Research and Technology in Tropical Australia – Symposia

1992

Australian Science and Technology Council

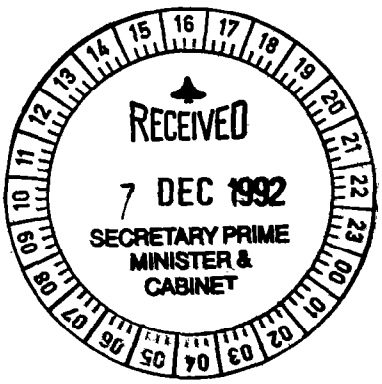
Research and Technology in Tropical Australia

Symposia

Review Papers Presented at:

Townsville - 16 November 1992

Darwin - 18 November 1992



Occasional Paper No. 23

November 1992

ISBN 0 646 12377 7
ISSN 1036-3319

ASTEC is the Commonwealth Government's principal source of independent advice on a wide range of policies and programs related to science and technology, and of concern to Commonwealth departments and agencies, higher education institutions and private enterprise.

Printed in Australia by Panther Publishing and Printing

Preface

In April this year the Prime Minister commissioned ASTEC to undertake a study of research and technology in tropical Australia and their application to the development of the region. ASTEC will be reporting to the Prime Minister in mid-1993.

ASTEC organised two symposia, in Townsville on 16 November 1992 and Darwin on 18 November 1992, as a key part of the public consultation process for the study. To inform and stimulate discussion at the symposia, ASTEC commissioned a number of papers which review research and technology in various fields.

These review papers examine issues in eight major sectors relevant to tropical Australia: the climate; the economy; social services and health; agriculture (including fisheries and aquaculture); the mining/energy industries; the tourism industry; natural biological systems; transport, communications and access issues; and education and research training. They reflect the views of the authors and are not necessarily those of the Australian Science and Technology Council.

The papers have been edited by Dr Richard Williams, with assistance from Dr Martin Wardrop and Ms Patricia Berman of the Office of ASTEC. Editorial support was provided by Mr Karl Brennan of the Office of ASTEC.

Thanks are due to the Office of Northern Development, James Cook University and the Northern Territory University for assisting in the organisation and administration of the symposia.

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1 WEATHER, CLIMATE AND RELATED RESEARCH IN TROPICAL AUSTRALIA

Dr J. Zillman

Director, Bureau of Meterology

1.1 INTRODUCTION

The weather and climate of tropical Australia impact critically on the economic performance of primary, secondary and tertiary industries and the social fabric of the region. Tropical cyclones, severe thunderstorms, flooding and drought can impact upon these industries, not only in any actual damage they may cause, but in the cost of precautionary measures taken to minimise these effects. To assist these industries and any future development, it is necessary to have an understanding of the nature of weather and climate in the region. The Bureau of Meteorology has monitored the weather and climate of tropical Australia and undertaken research into the underlying physical and dynamical processes since its establishment as a Commonwealth agency in 1908. In recent years the Bureau has collaborated with CSIRO, University and other research groups and overseas research organisations in a series of studies of the Australian monsoon regime.

1.2 THE GLOBAL CIRCULATION

To understand the mechanisms of weather and climate, it is necessary to consider the role of the atmosphere and oceans in balancing out the differential heating between equatorial and polar latitudes. The total earth-atmosphere system experiences net heating in the tropics where the short-wave energy absorption exceeds the long-wave emission and net cooling in the polar regions where the outgoing long-wave exceeds the incoming short-wave radiation. In order to maintain a balance, there is a net energy flow from low to high latitudes in the atmosphere and oceans. This balance is acheived through a thermally driven circulation which carries warm air poleward and cool air equatorward. But because the earth is rotating, the poleward moving air will tend to carry with it the angular momentum it acquired through frictional contact with the earth's surface. As it moves closer to the earth's axis in its poleward travel, it will accelerate rapidly eastward. On appproaching middle latitudes it reaches eastward speeds relative to the earth's surface which can no longer be maintained in balance with meridional pressure gradients and it breaks down into wave patterns and eddies.

In the tropics, this meridional overturning is known as the Hadley circulation, which, because of earth's rotation, gives rise to the trade winds in the lower tropsophere. Another feature of the tropics is the Walker ciculation. This is an equatorial east-west circulation

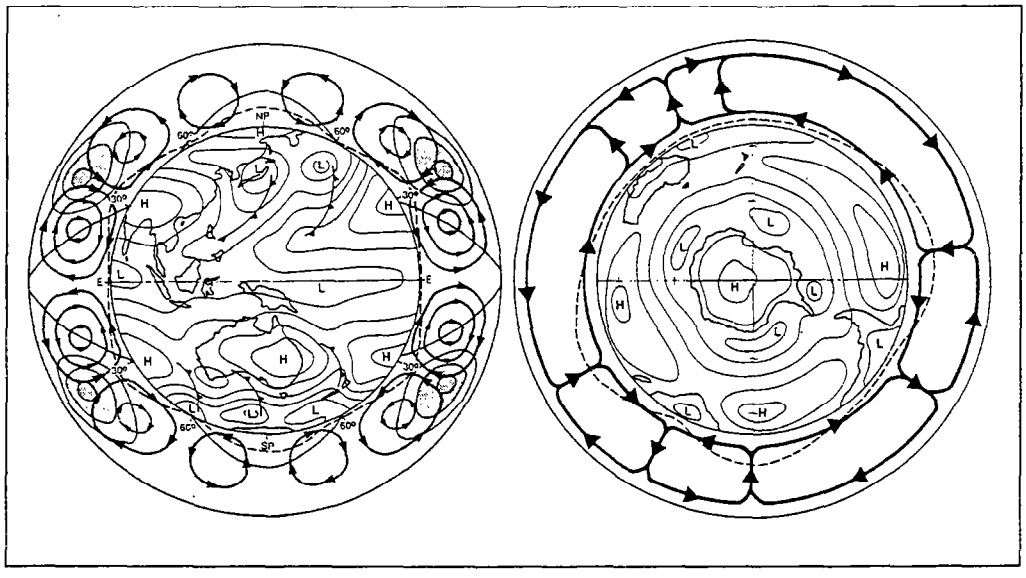

Figure 1: ***Broad features of the general circulation showing the mean meridional circulation (left) and the time averaged pattern of east-west circulation around the equatorial belt (right).***

pattern resulting from an east-west distribution of atmospheric heating and cooling brought about by the presence of land, sea and other geographical features through the tropics. These two features of the global circulation pattern can be seen in Figure 1.

The long term average patterns of surface pressure and wind direction for January and July are shown in Figure 2. The July map shows that tropical Australia is under the influence of the relatively dry and stable southeast trades. The January map depicts tropical Australia under the influence of the monsoon.

1.3 THE MONSOON

The annual north-south migration of the Hadley circulation is reflected in the migration of the region of tropical rainfall and in particular, over Australia, in the onset and retreat of the monsoon.

The monsoon moves over tropical Australia during the southern hemisphere summer, erratically and with frequent breaks, and is characterised by rainbands and monsoonal depressions. The monsoon rains vary greatly from year to year in their onset date, duration and intensity. On average the monsoon commences in late December and lasts for a couple of months.

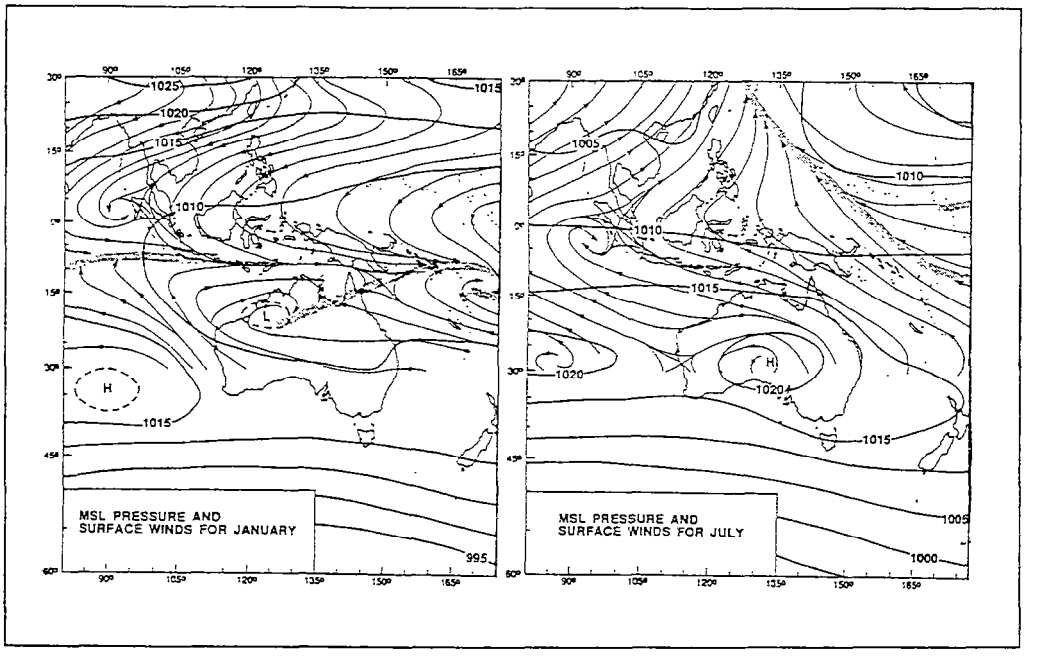

Figure 2:*The long term average patterns of Mean Sea Level pressure (hPa) and surface winds for January (left) and July (right).*

1.4 TROPICAL CYCLONES

Tropical cyclones are an important component of the monsoon, and about 95% form near the centre of monsoon activity. Figure 3 shows the observed frequency of formation of tropical cyclones over a twenty year period. In the Australian region, the tropical cyclones frequently track west-southwestwards before either encountering the Australian continent or recurving to the southeast. Many of these cyclones exhibit quite erratic movement, generally because they have low travel speed and are not embedded in a well developed middle tropospheric steering current.

Tropical cyclones can produce extreme values of wind speed, rainfall, atmospheric pressure, tide levels and sea height. High winds are directly related to the low central pressure of a cyclone. The combination of low pressure and high winds produces an increase in tide levels, called a storm surge, which can cause inundation of low-lying coastal areas. Torrential rains can produce flooding of river systems.

The maximum sustained wind in a tropical cyclone can exceed 150 km/h, with gusts above 200 km/h. The strongest tropical cyclone wind gust recorded over mainland Australia was 259 km/h at Mardie, Western Australia during cyclone **Trixie** in 1975.

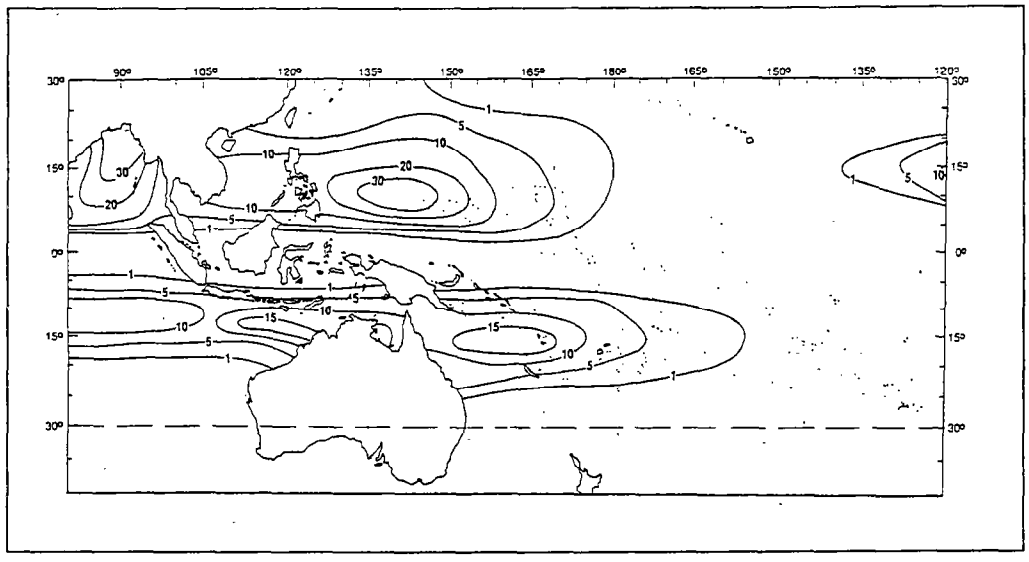

Figure 3: ***Observed frequency of tropical cyclone formation in terms of the number of occurrences per 5° latitude-longitude square per 20 years.***

A particularly destructive aspect of a tropical cyclone near the coast is the storm surge. This is a raised dome of water about 60 to 80 km across which can be 2 to 5 m higher than the normal tide level. That Australia has not suffered a major storm surge disaster has been due to both the relatively small number of people at risk and the fact that the biggest surges have not occurred at high astronomical tide. However, the rapid population increase in the tropics is exposing more people to danger each year.

Some of Australia's heaviest rainfalls have occurred in association with tropical cyclones and their decay over land. The 72 hour fall of 1715 mm at Mooloolah, Queensland, in February 1893, was the highest recorded, with three cyclones affecting southeast Queensland in quick succession, causing extensive damage in the Brisbane River valley. Approximately 52000 ha were flooded, some to a depth of 30 metres or more, and two of Brisbane's major bridges were washed away. Over 500 houses were swept down the Brisbane River. Other extreme rainfalls have been a 72 hour fall of 1260 mm at Finch Hatton, Queensland in February 1958 and a 24 hour fall of 1140 mm at Bellenden Ker, Queensland in January 1979

1.5 THUNDERSTORMS

Thunderstorms are another feature of tropical Australian weather, which develop when cold air overlies warm, moist air, resulting in the atmosphere being inherently unstable and supportive of strong convection. When the atmosphere is especially unstable and the windflow provides the most efficient input of energy to the cloud, a severe thunderstorm develops. Around the coastal areas of tropical Australia these severe thunderstorms tend to occur during the transition season between the dry and wet seasons. Severe storms are those which produce

either flash-flooding, damaging hailstones, destructive wind gusts or tornadoes. Thunderstorms not classified as severe may still cause damage or injury through lightning strikes.

Analysis of the geographical distribution of severe thunderstorms in Australia is hampered by the low population density and lack of observations over most of the continent. Existing records suggest that most of the damaging storms occur in a crescent from Brisbane, through coastal NSW and Victoria to Adelaide. The most damaging individual storms have hit southeastern Queensland and the central NSW coast. In January 1985 a severe hailstorm passed over Brisbane, breaking windows, lifting roofs and damaging cars, which, in 30 minutes, caused over $180 million of damage in the city.

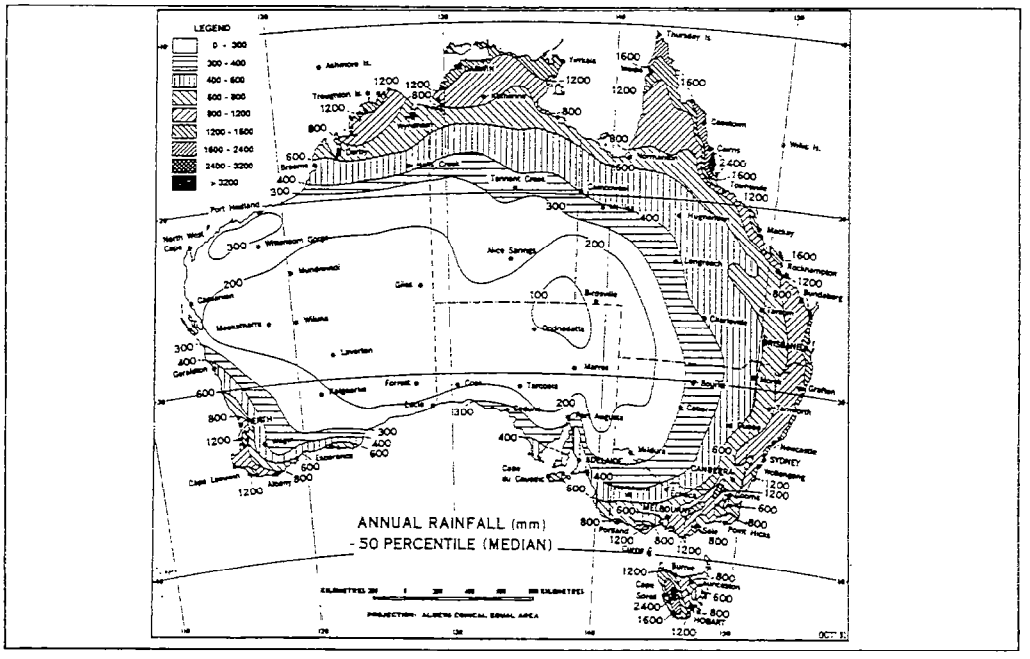

Figure 4: ***Median Annual Rainfall (mm) for Australia***

1.6 RAINFALL AND TEMPERATURE

The annual median rainfall for Australia is shown in Figure 4. In tropical Australia, the regions of higher rainfall are along the north and east coast with those of lowest rainfall in the centre and west of the continent. The spatial variations in temperature also follow a similar pattern. The diurnal variation of temperature is lower in coastal regions than in the interior of the continent. Figure 5, using Darwin as an example, shows mean monthly temperature, mean monthly relative humidity (measured at 3pm) and mean monthly rainfall for a coastal tropical station. This particularly highlights the marked "wet" (higher mean temperatures and relative humidity) and "dry" (lower mean temperature and relative humidity, and almost total lack of rainfall) seasons that are a major feature of the climate of tropical Australia.

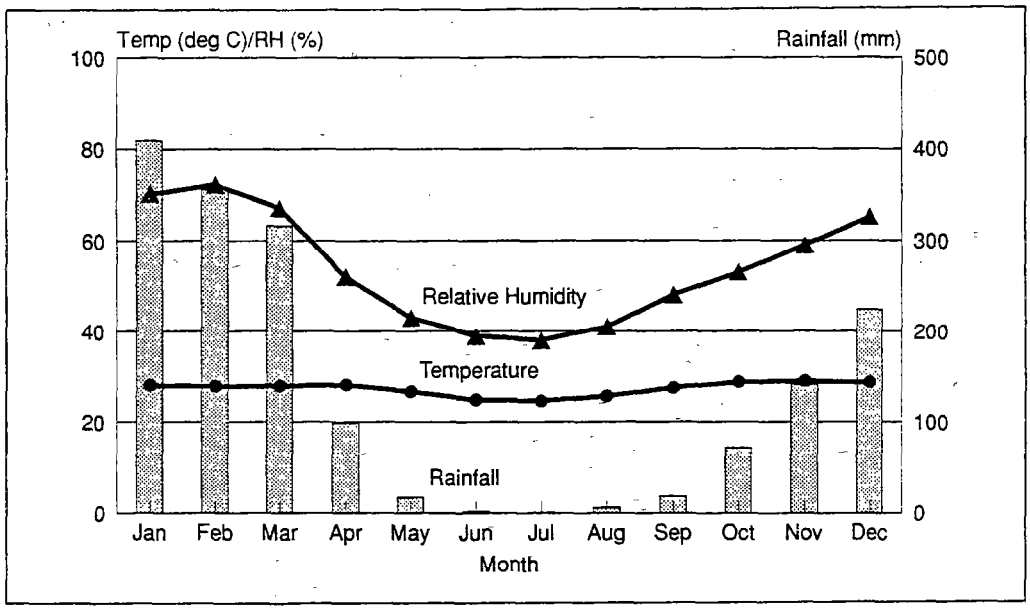

Figure 5: ***Mean monthly: Temperature, Relative Humidity (measured at 3pm) and Rainfall for Darwin***

1.7 TROPICAL CYCLONE WARNING SYSTEM

The Bureau of Meteorology is responsible for detecting, tracking and issuing warnings of tropical cyclones in the Australian region. The warning system is based on three Tropical Cyclone Warning Centres in Brisbane, Darwin and Perth. Each of these offices is equipped with sophisticated communications equipment and special facilities to enable quick response to the changing threat posed by a moving tropical cyclone. The centres receive data from radar-equipped weather stations at strategic locations around the coastline, a series of automatic weather stations on off-shore reefs, a network of several hundred cooperative observers and reports from ships, aircraft, off-shore oil rigs and satellites.

1.8 VARIABLILITY

The climate of Australia is affected by variations, not only in the Hadley circulation, but also in the Walker circulation, with its rising motion in the west Pacific and subsiding motion in the east. The west Pacific component is linked to the storm activity in the maritime continent. The Walker circulation is part of a coupled system involving the ocean and the atmosphere of the global tropics, with climatic impacts felt in many regions of the world. A measure of the intensity of the Walker circulation is the Southern Oscillation Index (SOI), which is the normalised difference in surface pressure between Tahiti and Darwin. There are significant statistical correlations between the SOI and a number of climate-related parameters for northern Australia. Such an example is shown in Figure 6 where the SOI (line) shows correlation with central Queensland rainfall.

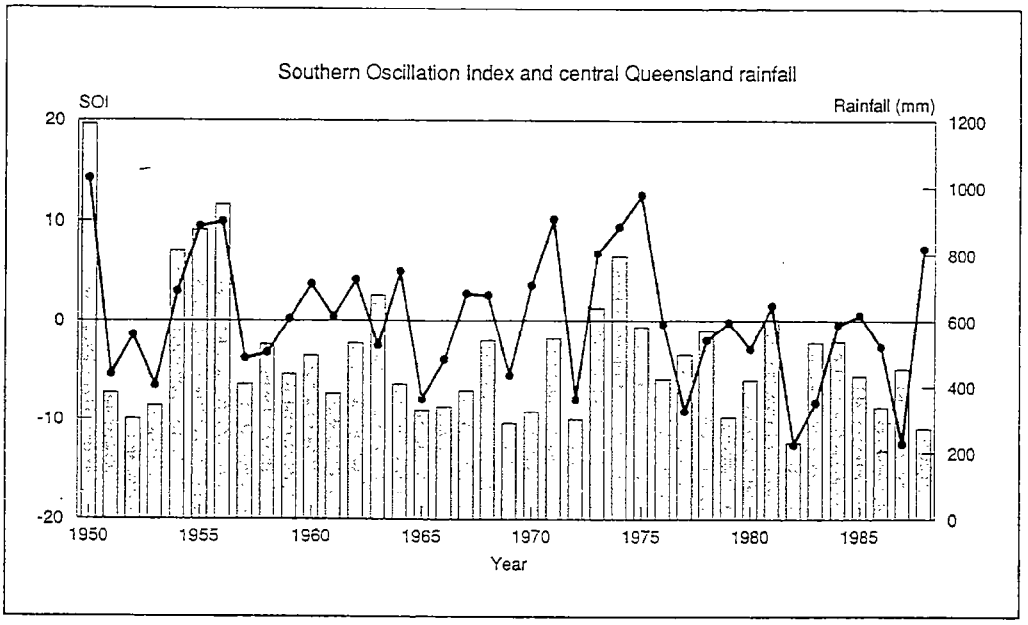

Figure 6: ***Correlation between the Southern Oscillation Index - SOI (line) and central Queensland rainfall (bars)***

Interannual variations in the location and intensity of the Walker circulation are associated with large year-to-year fluctuations in the climate of northern Australia. Thus El Niño events, when the sea-surface temperature of the eastern Pacific becomes anomalously warm, usually leads to widespread drought in northern Australia; for example, in 1982-83 and in 1991-92. Such events occur irregularly every 2 to 7 years, and they persist for about a year. The opposite of El Niño events (called La Niña) also arise when there is enhanced convection across the maritime continent, leading to very wet years in tropical Australia . As an example of this variability, Figure 7 shows tropical cyclone tracks over the southwest Pacific area for an El Niño year and a La Niña year.

1.9 RESEARCH ACHIEVEMENTS

Scientific research conducted by the Bureau of Meteorology has demonstrated the link between Australia's climate and global scale atmospheric phenomena such as the Southern Oscillation and El Niño. The large interannual variability associated with the Southern Oscillation has also been shown to impact directly on agriculture and the biosphere. Robust statistical relationships between descriptors of the Southern Oscillation and El Niño, and aspects of the climate of tropical Australia have been identified.

The climate of the tropics is sensitive to the global distribution of sea surface temperatures (SST). Recent research in the Bureau of Meteorology Research Centre (BMRC) has shown that the two dominant components of rainfall in the Australian tropics are linked to SST

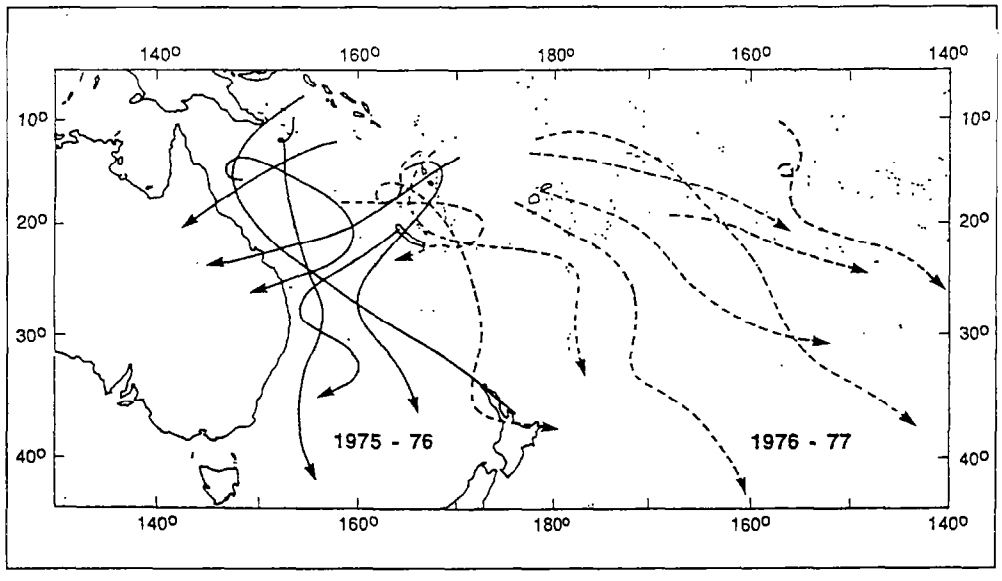

Figure 7: ***Tropical cyclone tracks for 1975-76, a non El Niño year (solid) and 1976-77, an El Niño year (dashed)***

distributions in the Pacific and Indian Oceans. Simulations conducted with the BMRC global climate model have confirmed the importance of SST distributions to tropical rainfall and are now directed at long term prediction of the behaviour of the El Niño and Southern Oscillation phenomena over the Pacific Ocean.

On smaller space and time scales, research conducted in tropical Regional Offices has been directed at improving forecasts of tropical cyclones in order to reduce cost to the community associated with over and under-warning.

Research in BMRC flowing from the Australian Monsoon Experiment (AMEX, see Table 1), which focused on the interaction between large scale monsoon flow and thunderstorm convection, has led to substantial improvements in tropical numerical weather prediction over the past five years. It has also shown that Darwin is of international significance both meteorologically and as a major logistical centre for international tropical research. Current and recent international programs in and around Darwin include the Equatorial Mesoscale Experiment (EMEX), the Stratosphere-Troposphere Exchange Project (STEP), the Tropical Rainfall Measuring Mission (TRMM) and the Tropical Ocean Global Atmosphere (TOGA) program of the World Climate Research Programme (WCRP). The focus of each of these programs is given in Table 1. An associated benefit of such international cooperative programs is access to advanced technologies which can be assessed for future operational applications in conjunction with the Bureau's Darwin Regional Forecasting Centre.

1.10 FUTURE RESEARCH

The WCRP will continue to be a major focus for tropical research in Australia. For four months from November 1992 the TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) field program will be conducted in the tropical western Pacific and based in Townsville. It is designed to clarify the physical processes associated with the exchange of heat, moisture and momentum across the air-sea interface. The Bureau of Meteorology, CSIRO and other organisations are also involved in extending the program of ocean observations and analyses for the Pacific and Indian Oceans under the World Ocean Circulation Experiment (WOCE) component of the WCRP.

Australian scientists will participate in the Global Energy and Water Cycle Experiment (GEWEX) under the WCRP. Contributions will include participation in projects designed to improve the representation of clouds in climate models (GCSS, see Table 1) and preparation of a ten-year rainfall climatology (GPCP, see Table 1). Continued involvement in TRMM, which is designed to measure the rainfall over all of the tropics, and coordination of MCTEX (Maritime Continent Thunderstorm Experiment), designed to study the interactions of tropical storms in the Darwin region, will also contribute to the objectives of GEWEX.

Critical to the ongoing development of climate research and operational climate analysis and prediction is the maintenance and enhancement of international observing and communications systems. To this end the Bureau of Meteorology, the Commonwealth Heads of Marine Agencies and the relevant national committees of the Academy of Science will be examining ways of furthering the objectives of the Global Climate Observing System (GCOS, see Table 1). There are also plans to participate in CLIVAR (Table 1), an international follow-up to TOGA, focusing on climate variability on interannual timescales. The results of this research will be channelled into improved operational long range forecasting through enhancements to the coupled ocean-atmosphere global numerical models now under development.

After consultation between a number of groups involved in the IGBP, plans have been developed for a proposed Global Change Regional Research Network. This proposal was recently considered of high merit in the ASTEC Major National Facilities Study.

Research findings will continue to be translated into improved short to medium range operational forecasting and warning performance through the ongoing development of improved numerical techniques combined with advances in observing technologies. Particular attention will be given to improved forecasting of severe weather events, particularly tropical cyclones.

Table 1: A summary of international research programs of relevance to tropical Australia in which the Australian meteorological community has participated or plans to participate in the near future.

Program	Acronym	Description
World Climate Research Programme	WCRP	Component of World Climate Program (WCP), jointly sponsored by the World Meteorological Organization (WMO), International Council of Scientific Unions (ICSU) and Intergovernmental Oceanographic Commission (IOC).
Tropical Ocean Global Atmosphere	TOGA	Ten year program of WCRP, from 1985, focused on El Nino, Southern Oscillation and monsoon phenomena.
International Geosphere-Biosphere Programme	IGBP	Implemented in 1986 by ICSU to focus on research into biological and geochemical aspects of global change; complementary to WCRP.
Australian Monsoon Experiment	AMEX	Australian program to investigate the interaction between large-scale monsoon flow and thunderstorm convection in Darwin region, held in conjunction with EMEX and STEP in 1986-87.
Equatorial Mesoscale Experiment	EMEX	USA-sponsored, focused on tropical diabatic heating processes.
Stratosphere-Troposphere Exchange Project	STEP	USA-sponsored, focused on vertical mass exchange in the tropics.
Tropical Rainfall Measuring Mission	TRMM	Sponsored by NASA, a program to launch a satellite in 1997 carrying a rain measuring radar; Darwin is a ground truth station (one of two) with Doppler radar operating over four wet seasons since AMEX in 1986-87.
TOGA Coupled Ocean-Atmosphere Response Experiment	TOGA COARE	Major international field program in the tropical western Pacific, for four months from November 1992; Bureau co-ordinating Australian involvement from Townsville.
World Ocean Circulation Experiment	WOCE	A component of the WCRP TOGA, observing and analysing data from global oceans; Australian involvement includes CSIRO, RAN and BMRC.
Global Energy and Water Cycle Experiment	GEWEX	A WCRP program focusing on shorter timescale aspects of the global water cycle, especially the role of clouds; supported in Australia by the Academy of Science's National Committee for Climate and Atmospheric Science (NCCAS).
GEWEX Cloud System Study	GCSS	Being established to improve capability to represent impacts of cloud systems in global climate models; BMRC involvement through Darwin monitoring facility.
Global Precipitation Climatology Project	GPCP	A GEWEX program, to produce a 10 year climatology on global rainfall; BMRC involvement through intercomparison of satellite data and direct rainfall measurement using TOGA COARE data.
Maritime Continent Thunderstorm Experiment	MCTEX	International program planned for 1994-95, to study mesoscale interactions of tropical storms over islands and continental areas near Darwin.
Global Climate Observing System	GCOS	Program to maintain global networks and communications systems for climate data to support operational climate analysis and prediction and research; being established by WMO, ICSU, IOC and United Nations Environment Programme (UNEP).
Climate Variability Project	CLIVAR	Proposed project of WCRP to follow TOGA in 1996, to focus on global climate variability on interannual timescales and due to interactions between atmosphere, ocean and land.

2 THE ECONOMY OF NORTHERN AUSTRALIA

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This paper presents an economic overview of Northern Australia in terms its contribution of Australia's gross domestic product and overseas exports. This analysis seeks answers to the question, "Where are we now?". Two other questions which must also be answered are, "Where can we be in the future?", and "What can we do to get there?", answers which are not discussed in depth in this paper.

To understand more fully the nature and extent of economic activity in Northern Australia the specific features of its three primary regions - Northern Queensland, the Northern Territory, and Northern Western Australia - must be separately analysed.

2.1 THE DELINEATION OF NORTHERN AUSTRALIA

For the purposes of this study, Northern Australia is defined as tropical Australia, subject to its southern boundary being delineated so as (i) to be based on the boundaries of relevant Statistical Divisions of Queensland and Western Australia, and (ii) to include all of the Northern Territory.

2.2 AREA AND POPULATION

The area of Northern Australia as delineated above is 3.516 million km^2, which is 46% of the area of Australia. Each of the three regions is also large in area, Northern Queensland 1.240 million km^2, the Northern Territory 1.346 million km^2, and Northern Western Australia 0.929 million km^2. However, Northern Australia has a relatively small population for such a large proportion of the area of Australia. Its current population is about 950,000 or 5.4% of the population of Australia. The approximate population of each of the three regions are Northern Queensland 715,000 (75% of the population of Northern Australia), the Northern Territory 160,000 (17%), and Northern Western Australia 75,000 (8%). However, about 665,000 people live on the coastal strip of Northern Queensland east of the Great Dividing Range.

2.3 GROSS REGIONAL PRODUCT

In order to document the contribution of Northern Australia to Australia's GDP, it has been necessary to compile regional product accounts for Northern Queensland and Northern

Western Australia to complement the account published by the ABS for the Northern Territory. The estimates made for this study have been based on the State Accounts for Gross Domestic Product at Factor Cost, by Industry and Principal Components, for the year 1989-90 (ABS, *Australian National Accounts: State Accounts, 1989-90*). Thus the estimates of GRP are estimates of labour income and gross operating surplus (gross factor income or value added at factor cost) for the 12 economic sectors which appear in the State Accounts. These sectors include the two notional sectors (with implicit gross operating surplus) of Ownership of Dwellings and General Government.

The estimates of GRP for 1989-90 are presented in Table 1, where Australia is divided into two regions, Northern Australia and the Rest of Australia. The data for the Rest of Australia is, of course, obtained by subtracting the estimates for the GRP of Northern Australia from the ABS statistics for GDP at factor cost for Australia. Table 1 indicates that in 1989-90 Northern Australia's GRP (at factor cost) was $20,405 million, which was 6.2% of Australia's GDP at factor cost. With only about 5.4% of the population, value added per head of $22,305 was therefore higher in Northern Australia, compared with value added per head of $19,174 in the Rest of Australia.

TABLE 1
Estimates of Gross Regional Product at Factor Cost 1989-90: Northern Australia and Rest of Australia

Industry	Northern Australia	Rest of Australia
agriculture etc.	1305	12691
mining	5273	9976
manufacturing	1631	51904
electricity etc.	962	9791
construction	1472	23022
wholesale & retail trade	2209	46745
transport & communication	1562	25915
finance & business services	1079	31372
public administration, defence & community services	2461	48697
recreation, accommodation & personal services	938	12833
ownership of dwellings	1218	28368
general government	295	6313
TOTAL	*20405*	*307627*

2.4 INDUSTRY PROFILES

The industry profiles, specified by the percentage of GRP from each economic sector, are clearly different in these two broad regions of Australia. These profiles are shown in Table 2, where the sectors are listed in descending order of percentage contribution to GRP in each region.

TABLE 2
Industry Profiles of Northern Australia and the Rest of Australia 1989-90
% of GRP

Northern Australia		Rest of Australia	
1. mining	25.8%	1. manufacturing	16.9%
2. public administration, defence & community services	12.1%	2. public administration, defence, & community services	15.8%
3. wholesale & retail trade	10.8%	3. wholesale & retail trade	15.2%
4. manufacturing	8.0%	4. finance & business services	10.2%
5. transport & communication	7.7%	5. ownership of dwellings	9.2%
6. construction	7.2%	6. transport & communication	8.4%
7. agriculture	6.4%	7. construction	7.5%
8. ownership of dwellings & personal services	6.0% 4.2%	8. recreation, accommodation	
9. finance & business services	5.3%	9. agriculture	4.1%
10. electricity etc.	4.7%	10. mining	3.2%
11. recreation, accommodation & personal services	4.6%	11. electricity etc.	3.2%
12. general government	1.4%	12. general government	2.1%

The most striking feature of Table 2 is the relatively large size of the mining sector in Northern Australia and its relatively small size in the Rest of Australia. In Northern Australia the mining sector contributed 26% of its GRP, compared with a contribution of 3% in the Rest of Australia. This also means that while Northern Australia contributed 6.2% of Australia's GDP at factor cost in 1989-90, it contributed 34.6% of value added in Australia's mining sector.

Other sectors of Northern Australia which contributed more than the mean 6.2% to Australia's GDP were agriculture 9.3%, electricity 8.9%, and recreation, accommodation & personal services 6.8%. With coal being the input for electricity generation, and the recreation, accommodation & personal services sector sometimes being related to tourism, we can say that the major industries which determine the economic performance of Northern Australia are mining, agriculture and tourism, which, in essence, are all natural resource based activities. Moreover, although the manufacturing is relatively small (8% of

GRP) the major activities are concerned with the processing of mining and agricultural products.

2.5 MERCHANDISE OVERSEAS EXPORTS FROM NORTHERN AUSTRALIA

Table 3 gives estimates for of merchandise exports from Northern Australia for the year 1990-91, the source of data being the ABS statistics on overseas trade from each Australian port (available on microfiche), supplemented by statistics in the annual reports of the various Port Authorities.

In 1990-91 merchandise exports to overseas countries from Northern Australia were valued at $14,817 million, and represented 28% of Australia's merchandise exports in that year, a proportion over 4 times larger that the region's contribution to Australia's GDP. On a relative population basis, overseas exports from Northern Australia in the year 1990-91 were valued at $15,900 per head, while exports from the Rest of Australia were valued at only $2300 per head.

In terms of broad commodity groups exports from Northern Australia were:

mineral fuels and other petroleum products	40.2%
mineral ores & concentrates excluding mineral fuels	36.8%
manufactured and semi-processed products	20.7%
agricultural products	2.4%

Most of the commodities in the manufactured exports group are intermediate goods (semi-processed products) from the mining sector and agricultural commodities. If these exports are allocated to the sources of origin, the mining sector accounted for 89% of merchandise exports from Northern Australia and the agricultural sector for 9%. These statistics reinforce the significance of the mining sector previously noted in analysing contributions to GRP.

The main minerals exported (as mineral fuels, concentrates or semi-processed products) are coal, crude oil, liquefied natural gas, petroleum condensate, iron ore, gold (as monetary gold), silver/lead/zinc (as crude lead and lead/zinc concentrates), copper (as cathodes, shapes, rod and wire), bauxite (as ore, alumina and unwrought aluminium products), manganese, uranium, diamonds, nickel (as nickel oxide and cobalt) and salt. The only minerals exported in processed form (beyond concentrates) are bauxite, copper, lead, and nickel.

The main agricultural commodities exported are raw sugar, meat, wool, wheat and grain sorghum.

The large proportion of overseas exports from Northern Australia compared with its much smaller proportion of GDP highlights two significant features of the economy of Northern

Australia, namely its dependence for its prosperity and growth on its export base, and the extent to which it is an open economy.

TABLE 3
Overseas Merchandise Exports from Northern Australia 1990-91

	$million	$million
1. AGRICULTURAL PRODUCTS		
wool	115	
wheat and other cereal grains	108	
all other commodities	127	
TOTAL (1)		350
2. MINERAL ORES AND CONCENTRATES EXCLUDING MINERAL FUELS		
iron ore	2516	
gold	1139	
uranium/manganese/bauxite	731	
copper/silver/lead/zinc ores and concentrates	449	
diamonds	430	
salt/silica/kaolin and other minerals	181	
TOTAL (2)		5446
3. MINERAL FUELS, LUBRICANTS AND OTHER PETROLEUM PRODUCTS		
coal	3495	
crude oil, condensate and other petroleum products	1648	
liquefied natural gas (LNG)	818	
TOTAL (3)		5961
4. MANUFACTURED AND SEMI-PROCESSED PRODUCTS		
processed mineral products (alumina, aluminium, refined copper, copper products, nickel oxide, crude lead)	1816	
raw sugar	775	
meat	246	
machinery and transport equipment	151	
other manufactures	72	
TOTAL (4)		3060
TOTAL MERCHANDISE EXPORTS NORTHERN AUSTRALIA		14817
TOTAL MERCHANDISE EXPORTS AUSTRALIA		54477
% OF EXPORTS FROM NORTHERN AUSTRALIA		28.3%

For example, if it is assumed that the GRP of Northern Australia increased at the same rate as GDP in 1990-91, then GRP would have been $20,800 million in that year, and overseas exports in this region would have constituted 71% of final expenditure on GRP at factor cost, compared with only 11% of final expenditure on GRP at factor cost for the Rest of Australia. If we also add intrastate and interstate exports, expenditure on exports rises to a ratio of 83% of final expenditure on GRP at factor cost in Northern Australia.

2.6 GRP FOR THE REGIONS OF NORTHERN AUSTRALIA

The estimates of the GRP for each of the three regions of Northern Australia for the year 1989-90 are given in Table 4.

TABLE 4
GRP of the Regions of Northern Australia
1989-90

Industry	Northern Queensland	Northern Territory	Northern Western Australia
agriculture etc.	1211	50	44
mining	2690	847	1736
manufacturing	1397	167	67
electricity etc.	806	100	56
construction	898	407	167
wholesale & retail trade	1629	461	119
transport & communication	1220	227	115
finance & business services	760	238	81
public administration, defence & community services	1436	854	171
recreation, accommodation, & personal services	650	230	58
ownership of dwellings	969	150	99
general government	213	68	14
TOTAL	13879	3799	2727

Not surprisingly, given the fact that Northern Queensland has 75% of the population of Northern Australia, it also has by far the largest GRP. However, the proportion of Northern Australia's GRP from Northern Queensland, 68%, is less than the population proportion. This is an outcome of the fact that Northern Queensland has a more diversified economy than the other two regions, with a larger proportion of its GRP coming from sectors where the capital/labour ratio is lower than in the mining sector.

The last statement refers to the greater importance of gross operating surplus in the mining sector than labour income. For Northern Australia as a whole gross operating surplus from

the mining sector represented 68% of value added at factor cost in this sector in 1989-90, compared with an average proportion for all sectors of 52%, or perhaps a better comparison, a proportion of 47% from the other 11 sectors.

In other words, the mining sector operates with a much smaller labour force per $1 of value added than do the other sectors, and hence it supports a much smaller population in a region. Where mining dominates a regional economy, the outcome will be a high GRP with a relatively small population, which does not support the establishment and growth of those industries which sell to regional inhabitants.

The extreme case in this regard is Northern Western Australia, where in 1989-90 64% of total value added came from the mining sector, compared with 19% for Northern Queensland and 22% for the Northern Territory. Thus GRP per head of population in Northern Western Australia in that year was $37,356 compared with $24,275 in the Northern Territory and $20,252 in Northern Queensland. Alternatively it can be said can that in Northern Western Australia $1 million of value added supported 27 people resident in the region, whereas in Northern Queensland it supported 49 people.

2.7 INDUSTRY PROFILES OF THE REGIONS OF NORTHERN AUSTRALIA

The differences among the regional economies of Northern Australia can be illustrated by noting the industry profile of each region in the form given above in Table 2. In this case, however, only the ten "normal" industries will be shown, omitting the two sectors with implicit valued added - ownership of dwellings and general government. Details are shown in Table 5.

(a) The industry profiles in Table 5 indicate the importance of mining in all three regions.

(b) Manufacturing is important only in Northern Queensland.

(c) Agriculture is important only in Northern Queensland, which is also the only region where crops are grown to any significant extent. Other activities are mainly the rearing of sheep and cattle.

(d) Public administration, defence and community services is the most important sector in the Northern Territory, indicating the extent to which government activity contributes to its GRP (although some community services are provided by the private sector). If general government is included with this sector, the contribution to the Territory's GRP is 24%, twice as large as the proportion in Northern Queensland, and nearly four times as large as the proportion in Northern Western Australia.

TABLE 5
Industry Profiles of the Regions of Northern Australia
% of GRP in 1989-90

Northern Queensland		NorthernTerritory		Northern Western Australia	
1. mining	19.4%	1. pub ad etc.	22.5%	1. mining	63.7%
2. wh & ret trade	11.7%	2. mining	22.3%	2. pub ad etc.	6.3%
3. pub ad etc.	10.3%	3. wh & ret trade	12.1%	3. construction	6.1%
4. manufacturing	10.1%	4. construction	10.7%	4. wh & ret trade	4.4%
5. tpt & comm	8.8%	5. fin & bus serv	6.3%	5. tpt & comm	4.2%
6. agriculture	8.7%	6. rec & accom	6.1%	6. fin & bus serv	3.0%
7. construction	6.5%	7. tpt & comm	6.0%	7. manufacturing	2.5%
8. electricity	5.8%	8. manufacturing	4.4%	8. electricity	2.1%
9. fin & bus serv	5.5%	9. electricity	2.6%	9. rec & accom	2.1%
10. rec & accom	4.7%	10. agriculture	1.3%	10. agriculture	1.6%

2.8 MERCHANDISE EXPORTS FROM THE REGIONS OF NORTHERN AUSTRALIA

Table 6 gives the values of merchandise exports from the three regions of Northern Australia for the year 1990-91. Of total exports from Northern Australia of $14,817 million, $7816 million (52%) came from Northern Queensland, $2092 million (14%) from the Northern Territory, and $4909 million (33%) from Northern Western Australia.

These export proportions can be compared with GRP proportions - Northern Queensland 68% of GRP and 52% of exports of Northern Australia; the Northern Territory 19% of GRP and 14% of exports, and Northern Western Australia 13% of GRP and 33% of exports. The relatively large disparities between the two proportions for Northern Western Australia further emphasises the dependence of the economy of this region on exports, which are almost entirely minerals (iron ore, crude oil, liquefied natural gas, diamonds, gold, salt).

2.9 SUMMARY

The preceding discussion has shown that Northern Australia encompasses 46% of the land area of Australia, contains 5.4% of the population, contributes 6.2% of GDP, and accounts for 28% of overseas merchandise exports.

The economy of Northern Australia is based firmly on the exploitation of its natural resources, with the mining sector being very large in all three regions. Crop farming is important only in Northern Queensland, with the pastoral industry being found generally

TABLE 6
Merchandise Exports from the Regions of Northern Australia 1990-91

1. Northern Queensland

	$ million
Agricultural Products	
wheat and other cereal grains	108
wool	105
other commodities	93
Mineral Ores and Concentrates	
coal	3495
gold	666
copper/lead/zinc ores and concentrates	373
bauxite	103
silica, kaolin and other minerals	89
Manufactured and Semi-Processed Products	
alumina and aluminium products	915
raw sugar	775
refined copper, copper products, crude lead	528
meat	211
nickel oxide and cobalt	179
machinery, transport equipment and other goods	176
TOTAL	7816

2. Northern Territory

Agricultural Products	
fish, livestock and other commodities	24
Mineral Ores and Concentrates	
crude and other petroleum products	889
uranium, manganese, and bauxite	606
gold and other minerals	334
Manufactured and Semi-Processed Products	
alumina	194
meat, machinery and equipment, and other goods	45
TOTAL	2092

3. Northern Western Australia

Agricultural Products	
wool, livestock, fish and other commodities	20
Mineral Ores and Concentrates and Mineral Fuels	
iron ore	2516
liquefied natural gas	818
crude oil, condensate and other petroleum products	729
diamonds	430
gold, lead/zinc, salt and manganese	359
Manufactured and Semi-Processed Goods	
meat, machinery and equipment	37

throughout Northern Australia. Manufacturing is significant only in Northern Queensland, where it is based mainly on the processing of minerals and agricultural commodities. Relatively few final goods are manufactured.

As a result the mining sector also provides most of the exports from Northern Australia, 77% for ores and concentrates in 1990-91, plus 12% of exports for processed mineral products, giving 89% of exports emanating from the mining sector. The main minerals exported as ores and concentrates are mineral fuels (coal, crude oil, liquefied natural gas), iron ore, gold, silver/lead/zinc, diamonds, bauxite, manganese, and uranium. For semi-processed minerals the major exports are alumina, refined copper and copper products, unwrought aluminium products, nickel oxide and cobalt, and crude lead.

The agricultural sector is also an important source of exports. The main (unprocessed) agricultural commodities exported are wool and wheat. From the manufacturing sector the (processed) agricultural products exported are raw sugar and meat. In 1990-91 9% of the overseas exports of Northern Australia emanated from the agriculture sector.

Finally a major feature of the economy of Northern Australia should be noted, which may be termed the high degree of location specific production, meaning that the output of major commodities tends to be concentrated in relatively small areas. The following summary outlines the situation for the main forms of economic activity in Northern Australia which constitute its export base.

2.9.1 *Agriculture*

The most ubiquitous industry in a spatial sense is beef cattle, which are found in most areas right across Northern Australia. In all there are over 8 million beef cattle, with 6 million in Northern Queensland, 1.4 million in the Northern Territory, and about 800,000 in Northern Western Australia.

Sheep are found mainly in the western parts of Northern Queensland (west of the Great Dividing Range), with 8 million sheep. The only other area with sheep is the Pilbara region of Northern Western Australia with just over 300,000 sheep.

Most crops are grown along the coastal strip of Northern Queensland. Sugar cane is the most widely distributed crop, and is grown from Mossman (Far North region) in the north to Sarina (Mackay region) in the south. Other crops tend to be concentrated in smaller areas. Wheat is grown in the Fitzroy and Mackay regions. Cotton is grown in the Fitzroy region. Tobacco is grown on the Atherton Tableland in the Far North region (Mareeba/Dimbula). Bananas come mainly from the Tully area of the Far North region, and tomatoes from the Bowen area of the Northern region. Other horticultural commodities are grown in these coastal regions of Queensland, with some also grown near Darwin in the Northern Territory and Kununurra in the Kimberley region.

2.9.2 *Mining*

Minerals tend to be found in specific areas. Of the mineral fuels, coal comes from the Bowen Basin in Northern Queensland (which runs through the Northern, Mackay and Fitzroy regions from Collinsville in the north to Moura in the south); natural gas is found off-shore from the Pilbara region on the north west shelf; crude oil is found off-shore in the same area as natural gas and also off-shore near Darwin.
Iron ore comes from several mines in the Pilbara region of Northern Western Australia, with a little from one mine in the Kimberley region (near depletion). Most of the copper produced come from the mine at Mt Isa. Similarly most silver/lead/zinc comes from two mines at Mt Isa, with smaller quantities from mines near Charters Towers (Northern Queensland), and at Cadjebut (Kimberley region). Gold is mined in isolated parts, with about 13 mines in Northern Queensland (mainly in the mountain areas of the east and near Mt Isa), 12 mines in the Northern Territory and 1 in Northern Western Australia.

Bauxite comes from two mines on the east and west sides of the Gulf of Carpentaria, from Weipa in Northern Queensland and Gove in the Northern Territory. Uranium is produced by two mines in the Northern Territory, and manganese by two mines, one in the Northern Territory at Groote Eylandt (in the Gulf of Carpentaria) and the second in Northern Western Australia at Woodie Woodie (Pilbara region). Salt is obtained from the evaporation of sea water at three "mines" on the coast of the Pilbara region. Diamonds come from the Argyle and Bow River deposits in the Kimberley region. Nickel is mined at Greenvale near Townsville, but the deposit will be depleted by the end of 1992.

2.9.3 *Manufacturing*

Manufacturing enterprises are almost exclusively located in Northern Queensland. In terms of numbers, sugar mills dominate, with 18 sugar mills in the coastal areas from Mossman to Sarina. There are six export meatworks with six export meatworks in Northern Queensland at Rockhampton, Mackay, Bowen, and Townsville. There is also a small export meatworks at Broome in Northern Western Australia. The only other major agricultural based manufacturing is dairy products, with Malanda on the Atherton Tableland being the main producer (and smaller plants at Rockhampton, Gladstone, and Kununurra).

Otherwise the main manufacturing enterprises are metal processing plants. The major ones are a copper smelter at Mt Isa; a copper refinery and a nickel refinery at Townsville; and an alumina refinery and an aluminium smelter at Gladstone. Several other relatively large metal manufacturing firms are also located at Gladstone, and there is one at Cairns.

2.9.4 *Tourism*

Tourism is also an export based economic activity, but it is necessary to distinguish between domestic and international tourism. Domestic tourism refers to Australian travellers and these come both from within a given region and from outside that region

(elsewhere in Australia). In that sense domestic tourism will be found, in varying stages of development, in most parts of Northern Australia. However, international tourism is more location specific, with the major areas being Cairns/Whitsunday/Mackay in Northern Queensland, and generally throughout the Northern Territory.

2.10 WHERE IN THE FUTURE?

The most striking features of Northern Australia which have a significant bearing on its future development are listed below.

(a) A small population of less than 1 million (less than in Adelaide, Perth, or Brisbane) spread over 46% of the area of Australia means that local markets are too small to support local production other than perishable goods and services.

(b) The growth of Northern Australia has therefore been based on the expansion of its export industries, especially those which utilise its natural resources - mining, agriculture, manufacturing based on mining and agriculture. A partial exception is the Northern Territory where public sector growth has been an important feature of recent development.

(c) With a high degree of dependence on overseas exports, the economy of Northern Australia is to a significant extent subject to international forces - exchange rates, world commodity prices, level of world economic activity, protection policies in overseas countries. In general the Northern Australian export industries operate with very little direct government support, although many mining and manufacturing ventures have connections with overseas corporations.

(d) Tourism appears to many people to be "the" growth industry of the future, but its impact on the economy of Northern Australia as a whole has been over-estimated, as has its future potential to stimulate growth. International tourism is important only in specific parts of Northern Australia, and while domestic tourism is more widespread, its impact on the economy is smaller than the impact of international tourism.

It is very difficult to see the economy of Northern Australia changing its structure and course dramatically over the next couple of decades. The population is too small, the area too large, minerals and agriculture too concentrated in specific locations, and manufacturing too dependent on mining and agriculture, to expect a great change. In addition technological changes and microeconomic reform may see a further rise in labour productivity (and increasing capital/labour ratios), inhibiting future population growth.

At best the population of Northern Australia over the next two decades may grow to about 1.25 million people, provided the exploitation of its natural resource base continues as it

has over the previous two decades, when the population increased from about 600,000 to 950,000. However, it should be noted, as further evidence of the impact of the huge area and scattered population of Northern Australia, that of this increase of 350,000 people in the 1970s and the 1980s, 250,000 occurred in Northern Queensland, 75,000 in the Northern Territory, and 25,000 in Northern Western Australia.

3 SOCIAL SERVICES AND HEALTH

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3.1 ABSTRACT

Marked inequities in social welfare and health persist in Northern Australia, for several reasons. Firstly, the large distances and the low population densities in the north lead to increased costs of transport and communication, increased costs of social and family support,and increased costs of service delivery. Secondly, the remoteness, the lack of social infrastructure and the climatic extremes of the north have until recently hindered the recruitment, retention and training of health professionals. Thirdly, the exotic diseases and health problems of the north have challenged the skills of even the best health professionals. Fourthly, the lingering frontier tradition and the lack of traditional family supports in the north are associated with increased risks of alcohol-related problems, including motor vehicle accidents and domestic violence.

Progress is being made because of the increasing commitment, from all levels of government, to the principle of equity in access to social and health services for all people living in Northern Australia. It is now widely accepted that the services needed in the north are more costly than equivalent services in other parts of Australia, and that the costs must be met by fiscal equalisation. Despite this acceptance, there has been an overall contraction since 1985 in relative levels of Commonwealth funding for the Northern Territory. Nevertheless, these years have seen the establishment of the Menzies School of Health Research, Batchelor College, and the Northern Territory University to assist with the education and training of health professionals in the north. Furthermore, great strides have been made in the efficiency and effectiveness of social and health service delivery. Except for problems related to alcohol use and violence, most health indicators for non-Aboriginal people in the Northern Territory are now comparable to those for other Australians.

Aboriginal people are still the most disadvantaged. They live in poverty and in poor housing, often in the most extreme environments, with low retention rates in the educational system, and limited prospects for employment. Aboriginal health continues to be poor because of poverty, poor living conditions and health infrastructure, poor nutrition, poor hygiene, use and abuse of alcohol, cigarettes, kava and petrol, and because of limited access to and uptake of appropriate health services. For example, the life expectancy of Aboriginal adults is some 20 years less than that of other Australians, while Aboriginal children continue to suffer from ear infections, skin sores, and other treatable conditions

which would not be tolerated in any other section of Australian society. Untreated ear infections in childhood can lead to deafness, educational impairment and social disability in adult life, untreated chest infections can lead to lung damage and premature death from bronchitis or bronchiectasis, while untreated skin infections in childhood may lead to rheumatic heart disease and to kidney failure, which is 20-100 times more frequent in some Aboriginal communities than in the general Australian community.

Improvement in Aboriginal health requires :

- a greater commitment to Aboriginal self-management
- more resources to improve the social conditions and health infrastructure for Aboriginal people;
- more resources to provide services that will really meet the current health needs of Aboriginal people;
- better access to health education for Aboriginal people;
- Aboriginal responsibility for the lifestyle, hygiene and social changes that will improve health; and
- more co-ordination and expert leadership in the planning and management of health services for Aboriginal people.

3.2 SCOPE OF THIS PAPER

For practical reasons, this paper mostly addresses social issues and health issues relevant to the Northern Territory. Nevertheless its major conclusions also have relevance for Northern Australia, which is defined (Harris, 1992) to include also the northern regions of Queensland and Western Australia. For the purpose of this paper, Northern and Tropical Australia are treated as synonymous.

3.3 HISTORICAL PERSPECTIVES

3.3.1 Social Influences Which Shaped the Northern Territory

The social development of Northern Australia has been dominated by its small and dispersed population, by its remoteness from other population centres, by the consequential difficulties with transport and communication, by diseconomies of scale in service provision, by the climatic extremes and exotic diseases, by the often fragile nature its economy, and by the ethnic mix and cultural diversity of its people.

The character of the Northern Territory population has been greatly influenced by its history and geography. Because of its extreme climate and its frontier traditions, the

historical importance of the pastoral industry, and the continuing importance of mining and government for employment, there was an historic trend for men without women to come to the north in search of work and adventure, or to escape from real or perceived problems down south. This trend was associated with strong personalities, a hard-drinking lifestyle, an often transient work-force, and a shortage of white women in the early years of the Territory. During the years of direct Commonwealth administration the mobility of the workforce was further enhanced by the view that a public service posting in the north was a hardship post, to be endured, but rarely enjoyed, as the price for a promotion.

The missions and churches had a great influence in leavening the frontier traditions of the north, and until the 1980s they were major providers of education and social welfare, particularly for Aboriginal people.

Northern society has also been greatly enriched by the diverse ethnic backgrounds of its immigrants. The gold-rushes of last century attracted Chinese immigrants and many stayed on to develop commercial enterprises. Immigrants from Europe and Asia have helped to develop fishing and pearling in the far north, mining and many other enterprises in the Territory. With the increase in Asian immigration, particularly since the 1970s, a larger proportion of such immigrants settled in the north than in other parts of Australia. As a result of these influences, Darwin, Broome and other northern towns had become successful as multiracial communities long before this concept was fashionable with southern policy-makers.

The problems arising from the lack of social and economic infrastructure in the Northern Territory were well recognised, but often ignored, during the years of administration from Canberra. Although World War II demonstrated the vulnerability of the sparsely populated north, little was done to promote economic and social development after the war. Nevertheless by the 1950s and early 1960s, communication and transport had improved to such an extent that it was no longer so easy for those in Canberra to ignore the far north. Furthermore, there was interest in new developments of bauxite, uranium and other mineral deposits, and the conscience of Australia was beginning to register the social problems and health problems of Aboriginal people, many of whom lived in Northern Australia. For all these reasons, by the 1970s there was a re-awakened interest in and a net increase in the flow of resources and people to the Northern Territory.

The devastation of Darwin by Cyclone Tracy in 1974 had a profound and permanent influence on the Northern Territory, because of the emotional impact on decision-makers down south, because the temporary evacuation and dispersion of the Darwin population led to increased understanding of the north in other parts of Australia, because of the economic benefits of the resources that were needed to rebuild the city, and particularly because the new Darwin had inputs of skills, values and technologies that had not previously been well represented in the north.

It also seems clear that another effect of Cylone Tracy was to hasten the granting of self-government to the Northern Territory in 1978 on financial terms that were generous when

compared with the preceding generations of neglect by the Commonwealth. With self-government, the Northern Territory was able to take major steps to improve the quality and stability of its work-force, to increase local opportunities for education and training, and to improve the social and economic infrastructure. This honeymoon period for the Northern Territory came to a painful end in 1985, with a substantial cut-back in the relative levels of Commonwealth funding (N.T. Budget paper No.3).

3.3.2 Historical Perspective on Health

In a recent history (Kettle, 1991), Ellen Kettle gives a fascinating and detailed account of the long and painful struggle to deliver adequate health and social services to the Northern Territory. From the first temporary white settlement at Fort Dundas in 1824 to the eve of the modern era in 1970, her story captures the problems caused by the remoteness, by the years of neglect and misunderstanding from down south, and by the lack of resources, infrastructure and expertise to deal with the special health problems of tropical and central Australia. For example, when the controversial Dr Cecil Cook arrived in 1927, there was only one other medical practitioner in the whole of the Territory. The heroes of her story are those who brought about change : Rev John Flynn and Dr Clyde Fenton who established wireless communication and the Flying Doctor Service to bring medical aid to pastoralists and miners who opened up northern and central Australia, Father Frank Flynn who was the first to treat trachoma in the Aboriginal population, Dr John Hargrave who played a key role in bringing leprosy under control, Dr Kerry Kirke, the first paediatrician in Central Australia, and the many others, including Sister Kettle herself, who rendered devoted service over many years as government employees, missionaries, or private practitioners.

3.3.3 Historical Perspective on Aboriginal Health and Welfare:

Before white settlement, Aboriginal Australians were well adapted to their hunter-gatherer life in northern Australia. Population densities were higher in the far north, where food was more plentiful because of heavier rainfall; in contrast, hunter-gatherer bands had to range over larger distances in the more arid regions towards Central Australia. These traditional lifestyles are believed to have been healthy because of the nutritious bush food, because of adequate exercise, and because the wide dispersion and nomadic movements of Aboriginal people did not favour cross-infection by diarrhoeal pathogens and other infectious agents.

With white contact, the health and social welfare of Aboriginal people was subject to catastrophic change. The reasons are discussed, for example, in Reid and Trompf (1991):

(1) An unknown number of Aboriginal people in Northern Australia were killed by explorers, pastoralists, miners and police;

(2) White exploration and settlement introduced many infectious diseases, previously unknown to Aboriginal people, which caused high rates of disease and death in the non-immune population;

(3) The pastoralists, settlers and miners forced or eased Aboriginal people from their traditional homelands, decreasing their access to water supplies, bush-foods and to their sacred sites. Over the same period, settlers and missionaries introduced Aboriginal people to unhealthy dependencies on sugar, flour, tea and tobacco, which continue to have adverse effects on health;

(4) Aboriginal people were encouraged to live in areas defined by pastoralists or missions, and later to live in fixed settlements defined by the bureauocracy, and to give up their nomadic lifestyle and their traditional ceremonies; these trends hastened the disruption of Aboriginal culture, favoured the spread of sexually transmitted disease and other infectious diseases, and added to the number of children of mixed parentage;

(5) Under the assimilationist policies which prevailed until well into the 1950s, most Aboriginal children of mixed parentage were forcibly removed from Aboriginal communities, and sent to institutions, often interstate, or given for adoption without the knowledge or consent of family; siblings were often separated and sent to different institutions, and in many instances such mixed race children would grow to adult life (and even die) without knowing who they were, where they had come from, and without knowing any of their relatives (Cumming, 1990). The best that can be said of this assimilationist child-welfare policy is that it helped to educate a cadre of Aboriginal people who are politically and socially active in Aboriginal affairs today. However, this policy has had two additional adverse effects, which are powerful and long-lasting: firstly it has deprived many Aboriginal people of their Aboriginal cultural heritage, secondly it has become the symbol of the alienation that many Aboriginal people feel towards the power-brokers in the white bureauocracy;

(6) By the late 1960s and early 1970s, with the introduction of comprehensive welfare benefits for Aboriginal people, the introduction of equal pay, and the more widespread access to alcohol, traditional Aboriginal culture in Northern Australia came under even greater stress. No longer was it necessary to hunt and forage to survive; people could use their wages or 'sit-down money' to buy (poor quality) food from community stores; if money was used for grog, there was drunkenness and domestic violence as well as the risk of malnutrition when there was no money left for food. This cruel and contemporary parody of Aboriginal culture reached its low-point in the town-camps around the major northern towns in the 1970s and the 1980s. To a lesser extent the pattern was repeated in rural Aboriginal communities, depending on their success in controlling local sources of supply of alcohol;

(7) Petrol-sniffing by Aboriginal children and young adults was first observed sporadically during World War II when the north was invaded by the motorised military. This dangerous habit, best interpreted as a rejection by children of the authority of traditional

elders, has spread subsequently with the greater availability of petrol as part of the Toyota culture in rural communities. Petrol-sniffing has tended to be episodic, and in some communities it has never become a problem. Petrol causes acute intoxication as well as long-term damage to the brain and nervous system. It is the most common cause of hospital admission and death for adolescents from some rural Aboriginal communities (Brady, 1991; Currie, 1991).

(8) Kava drinking was introduced into Aboriginal communities in Arnhemland in the early 1980s as an alternative to alcohol. The rationale was that kava would not trigger violent behaviour in the same way as alcohol. It was also believed that kava did not cause other harmful effects. However, subsequent research has shown that kava can cause toxic effects to the liver, and the blood and the kidney, and possibly to other parts of the body (Mathews et al, 1988). By causing passivity and euphoria, rather than violence, kava-drinking can lead people to neglect their family and social responsibilities. Kava drinking is expensive, and because of the profits to be made from its supply, and because of its addictive properties, there has been social conflict within communities over the steps taken to regulate kava use.

3.4 CONTEMPORARY SOCIAL FACTORS RELEVANT TO HEALTH

3.4.1 Northern Territory Population

The Northern Territory population was estimated to be 167,800 in December 1991 (Budget paper no. 6, 1992), an upward revision of earlier estimates . There is a natural increase of approximately 2500 per year, a net migration from overseas of approximately 500-1000 per year, and a net migration to interstate destinations of 500-2000 persons per year since 1986. Prior to 1986, there was a net migration into the Northern Territory of some 1000 persons per year. The Northern Territory population represents 1% of the Australian population, and about 17% of the population of Northern Australia as defined by Harris (1992).

Ethnic Mix: Almost 37,000 (22%) of Territory residents are Aboriginal, and approximately 32,000 (19%) were born outside Australia; these figures tend to under-estimate the ethnic diversity of the Northern Territory, as another 12% of the population have parents who were born overseas. The Northern Territory is now home to substantial numbers of immigrants from East Timor, Sri-lanka, Vietnam and other countries of south-east Asia and the Pacific, and to earlier immigrant groups from China, Greece and other European countries.

Age Distribution: The Northern Territory population also has an unusual and young age distribution. Approximately 28% of the population are under 15 years of age compared with 22% for Australia as a whole. Nevertheless the proportion in the age group 15-44, 56% in the Northern Territory, is much greater than might be expected from the number of children; this presumably reflects the continuing immigration of young adults into the Northern Territory. As a corollary, there is a relative deficit of elderly persons in the

Northern Territory; only 2-4% of the population are over the age of 64, compared with 11% for Australia as a whole (ABS, 1992; Budget paper no.6, 1992). Because of the high proportion of recent immigrants, and the high turnover which still pertains in some sections of the population, there are fewer three generation families and fewer extended families than would be seen in Australia as a whole.

Birth Rates: The Aboriginal birth rate was 29.6 per 1000 in 1990, compared with the birth rate for other Territorians of 19.1 per 1000, and an Australian birth rate of 14.9 per 1000. Because of the high birth rate and the high death rate, the age-distribution of the Aboriginal population is very skewed, with diminishing numbers in successive age groups; this age-distribution pattern is typical of that seen in third-world countries.

Location: Over 90% of the non-Aboriginal population lives in urban Darwin, Alice Springs, Katherine, Tennant Creek, Gove, Jabiru and Alyangula. Most Aboriginal people in the Northern Territory still live in rural communities, although substantial numbers live at least temporarily in transitional communities or camps close to the towns. Those Aboriginal people living permanently in urban areas are more likely to be of mixed descent.

Visitors: The demography of the Northern Territory is further complicated by the large numbers of interstate and overseas visitors. For example, in 1990/91 there were estimated to be 6 million visitor nights for the Northern Territory; possibly 70% were from outside the Territory, which means that there were an average of 11,500 external visitors on any one night. These numbers would be significantly greater in the dry (tourist) season than in the wet season. A significant proportion of visitors come to stay with their relatives in the Northern Territory; a typical example is that of the grandparents from down south coming to visit the nuclear family during the dry season. Other visitors come to the conventional tourist destinations (Uluru, Kakadu, Litchfield, Nitmiluk) on tour packages, as independent tourists or as backpackers, while others are attracted to the easy lifestyle of the north, or by the various alternative lifestyles that are well established, particularly in Darwin.

3.4.2 Employment In the Northern Territory

The labour force for the Northern Territory in 1991/2 averaged 81725 persons; the unemployment rate was slightly below the Australian average and the labour force participation rate of approximately 72% was significantly greater than the Australian average of 63% (Northern Territory Budget Paper No. 6); this apparently high participation rate may partly reflect the younger age structure of the NT population, and possibly the low rate of inclusion of rural Aboriginal people in the employment surveys (1% of NT households) carried out by ABS.

A more accurate reflection of the participation rates of Aboriginal people in the labour force can be obtained from census statistics. At the 1986 census (the latest available), the

participation rate of Aboriginal adults in the Northern Territory labour force was approximately 42%, and of those actually in the labour force, 35% were unemployed.

Because of limited employment opportunities for Aboriginal people living in rural communities in 1986, the participation rates and employment rates would be even lower than the overall averages for Aboriginal people in the 1986 census. Altman (1987A,B) has discussed the economic value of work in the subsistence economy of rural Aboriginal communities, as well as the options for subsidised production of art and artefacts, and the development of other services and industries. Since 1986, CDEP programs (Community Development Employment Programs) have been taken up by a larger proportion of Aboriginal rural communities. As CDEP participants are counted in the labour force, this helps to account for the apparently high current rate of labour force participation in the NT, despite the lack of conventional employment opportunities for Aboriginal people in rural communities.

3.4.3 Income Levels in the Northern Territory

In 1992, real average weekly earnings for full-time adults in the Northern Territory were approximately $650 per week, compared with some $620 per week for Australia as a whole (NT Budget paper No.6, 1992). Thus, for employed adults, income levels went some way towards meeting the higher costs of living in the Northern Territory. Corresponding figures for persons employed part-time, for unemployed persons and persons not in the labour force are less readily available.

Incomes of Aboriginal People: Official estimates of current weekly income are not available separately for Aboriginal people in the Northern Territory. From the 1986 Census data (ABS, 1990, Table 14.4) it is possible to derive an approximate estimate of average income for Aboriginal adults in the Northern Territory in 1986. The overall average was $155 per week in 1986 dollars. For employed Aboriginal adults, average weekly income was approximately $230, compared with only $120 for those who were unemployed or not in the labour force. These levels of income, predominantly derived from unemployment and social security benefits in the case of those not employed and not in the labour force, can be compared with the average full-time earnings in the Northern Territory of approximately $520 per week in 1986. After discounting for the effects of taxation, and the overall participation rates in the Northern Territory workforce, it seems clear that, on average, Aboriginal adults had only 50-60% of the per-capita income of other adults in the Northern Territory.

The poverty of Aboriginal people was also evident in earlier estimates of Aboriginal income. Fisk (1985) estimated that in 1981 the average money income in the Northern Territory was $74 per week per Aboriginal adult, and $43 per week per Aboriginal person, compared with national averages of $89 per Aboriginal adult, $50 per Aboriginal person, and $157 per adult and $119 per person for the whole of Australia. For August 1985, Altman estimated that the mean per capita weekly income for Aboriginal people at Mutitjulu in Central Australia was $78; income was extremely variable from household to

household, and the per capita mean varied from $12 to $142 over households. (Altman, 1987A).

The overall trend is clear: Aboriginal people in the Northern Territory have had average money incomes that were less than 50% of those of other Australians, and also less than the incomes of Aboriginal people in other states. Although Altman (1987A,B) has pointed out that rural Aborigines have greater access to non-money income through their ability to hunt and gather bush-food, it is now clear that the contribution of bush food to the Aboriginal diet is generally unimportant except in a few locations (Lee et al, 1992).

Aboriginal people in parts of the Northern Territory have access to royalty income from mining leases (Altman, 1983), and the opportunities to generate income by selling art and artefacts and through tourist developments are now increasing in some communities (Altman, 1987A,B, Altman and Taylor, 1987). However, in the majority of rural Aboriginal communities, full-time employment is available to only a small minority working for the council, school, health centre or store. More employment opportunities, particularly part-time ones, are now being developed through CDEP programs administered by community councils (Altman and Taylor, 1987). For Aboriginal people in towns and cities, as well as for those in rural communities, other employment opportunities are limited by lack of skills and expertise, which in turn reflect the limited educational opportunities of Aboriginal people.

Since 1986, CDEP programs, tourism and art have increased in importance as sources of income for Aboriginal people, but it is unlikely that their average income levels have improved in relation to incomes of other Territorians. More research is needed to estimate current income levels of Aboriginal people in the Northern Territory.

Aboriginal expenditure patterns follow the pay cycle, and money tends to run out, in many households, at the end of the fortnight; money is distributed in accordance with kinship obligations, and when men in the household are drinkers, it is difficult for the women to retain enough money to buy food for the family. Gambling in Aboriginal communities can play an important role in the redistribution of money, and in helping to generate larger sums for capital purchases.

3.4.4 Housing in the Northern Territory

At the 1986 census, the latest for which data are available, there were 42,556 dwellings identified in the Northern Territory, housing 140,636 persons with an average of 3.3 persons per dwelling. However, when the data are tabulated in more detail, the average occupancy was 5.8 persons per dwelling for Aborigines, and 2.9 per dwelling for other Territorians. More importantly, the quality of Aboriginal dwellings was much poorer, as 5266 Aboriginal people were still housed in 920 improvised dwellings. (ABS, 1990).

Independent observations, collected in ten rural Aboriginal communities in the Northern Territory in 1986-7 (Munoz et al 1991), showed much higher average occupancy rates,

with 3705 persons in 419 houses (8.8 per house), 269 in 44 sheds (6.1 per shed), and 426 in 83 humpies (5.1 per humpy). Furthermore, even in those houses where water supplies, toilets and showers were fitted, there was a high rate of malfunction. In some communities up to 32% of the showers and toilets were not working. Power was available in 61% of dwellings, washing machines in 27%, and refrigeration in 36%. The quality of housing and the availability of facilities was less in Central Australian than in Top End communities.

Munoz et al (1991) also discussed the problems encountered in maintaining Aboriginal housing, and the way that this can be influenced by traditional beliefs and customs. In particular, in Central Australia, it is usual for an Aboriginal house to be abandoned on the death of an occupant, and an unoccupied house it is at greater risk of damage by vandals. In contrast, in the Top End of the Northern Territory, Aboriginal beliefs allow for a house to be re-occupied after a short ritual of ceremonial cleansing. Thus, houses are less likely to be damaged by vandals in the Top End, which allows for easier maintenance and preservation of housing.

In the years since 1986-87, and with the development of the National Aboriginal Health Strategy in 1989 (DAA, 1989), more resources have been devoted to the provision of housing and services in Aboriginal communities.

3.4.5 Transport and Communication in the Northern Territory

Communication services in the Northern Territory have improved markedly over the last generation, with STD telephone dialling to and from all but a few remote locations. For example, almost all rural health centres now have telephone services, whereas only a few years ago they were still dependent on the radio-telephone for contact with regional centres and emergency services. Telephone and facsimile communication have greatly streamlined business contacts of the Northern Territory with other states and been of particular benefit in the administration and support of remote communities and homesteads. Although Telecom services to remote areas of the Northern Territory are subsidised, the end costs to the user add considerably to Northern Territory overheads.

Overnight courier services, privately operated, are available between northern and southern cities at costs which are competitive with the much slower postal service. It is not clear whether Northern Territory business is subsidised by the national courier operators.

Daily air services link Northern Territory cities with the south, but on most days there is little or no choice of departure time. Typically services leave the south in the early morning, and leave Darwin to return in the early afternoon. Air travel is expensive, and because tourist travel is more discretionary, there are more offers of concession fares to entice tourists north than there are for locals to fly south.

Road transport, typically 'road trains' deliver freight to northern cities, mostly from Adelaide, Brisbane or from the rail-head at Alice Springs. The Commmonwealth has yet to fulfil the commitment, made in 1913, to extend the railway line to Darwin.

Remote communities in central Australia and in parts of the Top End are serviced by road transport, at least for most of the year. Coastal communities inaccessible by road are serviced by barges operating out of Darwin. Almost all remote communities are serviced also by light aircraft to deliver passengers, mail, urgent freight, medical supplies and perishables. The Aerial Medical Service and the Royal Flying Doctor Service provide emergency services and evacuation from remote communities. The direct and indirect costs of air travel and freight add very considerably to the costs of business and service provision and costs of living in remote communities.

Aboriginal people in remote communities need to travel frequently for business or ceremonial reasons or to attend funerals; travel costs, whether by air or Toyota, can consume a large proportion of income.

3.4.6 Food Supplies in the Northern Territory

The majority of people in the Northern Territory now have access to good food supplies through well-stocked supermarkets in the cities and towns. As most of the food is brought to the Northern Territory by rail and or road transport, it is comparable in quality and variety to the food in southern cities. However, it is still difficult, particularly in the smaller towns, where supplies may come by sea or air, to obtain enough fresh fruit and vegetables at reasonable prices. In Darwin and other northern towns, southern food supplies are complemented by mangos, melons and other local produce, and by the ready availability of Asian and other cosmopolitan food.

Food supplies in the major towns of the Northern Territory are more expensive than in southern cities, although in recent years the price loadings have averaged only 10-30%. In the more remote communities in earlier years, prices were up to 50% greater than in Southern cities (Fisk, 1985).

3.4.7 Food Supplies in Rural Aboriginal Communities

Aboriginal people in remote communities in the Northern Territory have not had access to good food supplies. With the advent of the cash economy, they have ceased to rely on bush foods except on an occasional basis, and have instead become reliant on food from community stores, usually operated, on a monopoly basis, by store managers with little interest in food quality or Aboriginal welfare. Aboriginal food choices have been restricted by their "sugar, flour and tea" habits learnt from the pastoralists or missionaries, by limited access to good food in the stores, by a limited understanding of nutrition and of the techniques and facilities for cooking and preserving Western foods, and by the expense of any fresh fruit and vegetables and other nutritious foods that happen to be available in community stores.

These issues have been discussed in more detail in the proceedings of a 1991 Workshop on Aboriginal nutrition (Mathews, 1991), which gives recommendations on how to

improve the availability and use of good food in Aboriginal communities. Important advances have already been made. For example, the Arnhem Land Progress Association (ALPA), exemplifies what can be done when the community stores are operated by a co-operative, with Aboriginal directors, and with the implementation of a nutrition policy, to be adhered to by store managers (McMillan, 1991).

Lee, Bonson and Yarmirr (1991) report on how the Minjilang community has gone even further than this; in the course of a comprehensive good food campaign, the community succeeded in changing their eating habits over a 12 month period. The consumption of unhealthy foods such as sugar and fat was decreased significantly, and the consumption of healthy foods such as fresh fruit and vegetables, brown bread and lean meat was increased. The changes in eating habits resulted in the correction of vitamin deficiencies, and in the correction of other nutritional abnormalities. In the longer term, these changes, if sustained, would be expected to lead to substantial improvements in the health of Aboriginal people.

3.4.8 Alcohol in the Northern Territory

On average, adults in the Northern Territory consume almost twice as much alcohol per head as adults elsewhere in Australia, and there is a corresponding increase in the rates of family breakdown, motor vehicle accidents, alcohol related violence, domestic violence, drunkenness and civil disturbance, manslaughter and murder, alcoholic brain damage and psychosis, and alcoholic liver damage (Legislative Assembly, 1991).

It is clear that these adverse social outcomes are influenced by the frontier tradition, the macho lifestyle, the lack of extended families and family support, by the marginalisation of some Territorians from mainstream society, and by other social stresses which lead to alcoholic excess. However, it is also clear that while alcohol use can be a response to such social stress, the loss of control caused by alcohol is also the major cause of the associated accidents, violence and crime.

As with other frontier societies, the Northern Territory continues to be tolerant of alcohol use and abuse; this tolerance is related to personal attitudes and alcohol-related behaviours of many members of society, to the economic interests of the alcohol industry, which are relatively more important in the Northern Territory because of high consumption levels, and to the interests which the Liquor Commission and the government have in the excise income and in the contribution that alcohol makes to the overall Northern Territory economy.

Despite these influences, the Northern Territory government, through the Chief Minister, has introduced an ambitious program to reduce alcohol consumption and its adverse effects in the Northern Territory over the period 1991-2000 (Living With Alcohol, 1991).

3.4.9 Aboriginal People and Alcohol

When Aboriginal people drink, they are more likely to be binge-drinkers, and to drink to excess over short periods of time. This mode of drinking, in the frontier tradition of drovers and miners, is more harmful to physical health, more likely to cause drunkenness, violence and crime, and more likely to compete for money which would be more prudently applied to buy food and other necessities. This stereotype of an Aboriginal drinker, who drinks until the money runs out, applies to only a minority of Aboriginal people. In fact, Aboriginal people are more likely to be total abstainers (59%) than other Territorians (37%).

The tragedy of Aboriginal drinking has been reviewed by Marcia Langton (1991) in her report "Too Much Sorry Business", annexed to the Royal Commission Report into Aboriginal Deaths in Custody. The report argues that although alcohol (white man's poison) has been incorporated into contemporary Aboriginal culture, this has not been done in a way that allows for controlled social drinking. Langton emphasises the importance of Aboriginal people being empowered and resourced to take responsibility for their own drinking habits, and criticises the motivation of the Liquor Commission, the lack of consultation by the white bureaucracy, and the poor representation of Aboriginal people on mainstream bodies responsible for alcohol and social policy.

At community level, many Aboriginal people, who are now non-drinkers, have been able through their own efforts, to give up drinking at dangerous levels. Brady and others have begun to document the personal histories of Aboriginal ex-drinkers, with the aim of identifying the characteristics and strategies of those who have succeeded, so that this information might be used to help others to beat the grog in future.

There have been some enlightened aspects of alcohol policy in the Northern Territory, including the provision of restricted areas legislation to help Aboriginal communities to exclude alcohol if that is their wish, and the provision of sobering-up shelters, which have helped to keep Aboriginal people out of gaol. Enlightened policies have also helped to bring about the low rate of deaths in custody relative to the number of Aboriginal prisoners in the Northern Territory.

There are continuing problems associated with the regulation and provision of alcohol for Aborigines : too many liquor outlets (70 for 26,000 people in Alice Springs), exorbitant prices charged at some outlets, trafficking in grog by people such as some taxi-drivers, and community difficulties in implementing or achieving consensus on restricted areas legislation and other liquor control policies. Furthermore, the Liquor Commission and some proprietors of liquor outlets have been reluctant to co-operate with initiatives of Aboriginal community leaders to limit the availability of alcohol to their people.

Nevertheless, there are many successes, most notably when Aboriginal elders, by their leadership and example, have been able to convince the younger members of the community of the importance of controlling alcohol. A major new initiative has been

launched by Aboriginal people in central Australia to develop support services for Aboriginal people wishing to give up the grog, and to promote social policy changes to reduce the abuse of alcohol. One recommendation is to prevent the cashing of welfare cheques at alcohol outlets.

3.4.10 Crime and Custody

Drunkenness and crimes related to alcohol explain most of the custodies in the Northern Territory (Legislative Assembly, 1991). Protective custodies of intoxicated persons in 1990-91 numbered 28443 for Aboriginal people and 2646 for others (ABS, 1992), showing that Aboriginal people were 38 times more likely to be apprehended for intoxication than other Territorians; the overall rate of protective custodies in the Northern Territory was 8 times higher than in any other state or territory. Homicides in the Northern Territory are most often alcohol-related, and the rates are some sixfold greater than for Australia as a whole. Sexual abuse, domestic violence and child abuse are all alcohol-related, and all occur at much higher rates in the Territory. Road traffic fatalities are 2.5 times more frequent in the Northern Territory than in Australia as a whole, and at least 60% are alcohol-related (Legislative Assembly, 1991)

3.4.11 Petrol Sniffing

The control of petrol sniffing is made more difficult by the fact that it involves Aboriginal children who are questioning or rejecting traditional values; such children have few other distractions in remote communities, and their parents may be ambivalent because they were sniffers themselves in their younger days. Many sniffers give up the habit after weeks, months or years, sometimes without apparent long-term harm, but for others, sniffing can result in fatal asphyxiation, death or disfigurement from accidental burning, or permanent brain, neurological or heart damage from the effects of toxic lead, hydrocarbons or asphyxia (Brady, 1992; Currie, 1992).

Community programs to help control petrol sniffing have promoted sporting or cultural activities for children, or used traditional art-forms and Aboriginal leadership to promote traditional values and a healthy lifestyle, often based on a return to an outstation living (Lowe, 1991; Brady, 1992). More work is needed to assess the long-term outcome of petrol sniffing, and the effectiveness of interventions.

3.4.12 Kava Use

Kava use is still prevalent in Arnhem Land communities. Because of community concern about the health and social costs of kava, the Northern Territory government has acted to regulate its sale and to limit the supply to consumers on a daily per capita basis. These regulations have had poor compliance at the community level because of the trafficking in kava from non-drinkers to drinkers, and because a number of community leaders have themselves had both personal and economic interests in the kava sales; further consultations are in progress.

3.5 EDUCATION IN THE NORTHERN TERRITORY

3.5.1 Primary and Secondary Education in the Northern Territory

In 1990 there were 171 schools, 2376 teaching staff and 32,327 full time students at primary, secondary or special schools in the Northern Territory. The retention rate to year twelve for all students was about 48%, compared to the national average of 64% (ABS, 1992).

Official retention rates for Aboriginal students are not readily available. However there were 8010 Aboriginal children enrolled in primary schools compared with approximately 8500 from the eligible age-groups of 4-12 years (ABS, 1992; Budget paper no. 6). Although enrolments and retention rates for Aboriginal children in primary school thus appear to be adequate, this conclusion must be qualified for two reasons. Firstly, it is clear that the attendances of Aboriginal children at primary schools, particularly in rural communities, are intermittent and that the overall attendance rates are much lower than the enrolments would suggest. Secondly, because of the low attendance rates and because of hearing and health problems, Aboriginal children tend to make slow academic progress. Thus the primary school population tends to include Aboriginal children who are older than 12, and thus the apparent enrolment rates in primary school will tend to seriously overestimate the real rates.

The low retention rates of Aboriginal children are more clearly evident in the secondary school system. Compared with approximately 4560 students of eligible age (13-17 years), there were only 2199 enrolled on a full-time basis in secondary schools in 1990 (ABS, 1992); this average enrolment rate (48%), will seriously overestimate the enrolment rates in the later years of secondary school, which are extremely low for Aboriginal students.

If the retention rate to year 12 for non-Aboriginal students in the Northern Territory is similar to that for the rest of Australia (64 % in 1990), then the apparent retention rate for Aboriginal students in the Northern Territory would be about 15% in 1990. Because of such low retention rates, both now and in the past, there has been a welcome emphasis on adult education for Aboriginal people.

3.5.2 Tertiary Education and Training in the Northern Territory

In the discussion which follows, I have focussed attention on those matters that are of particular relevance to health.

The Menzies School of Health Research was established in Darwin in 1985, with support from the Northern Territory Government, the Menzies Foundation, and academic support from the University of Sydney, to carry out research and education of relevance for health in northern Australia. An annex of the School was commenced in Alice Springs in 1987.

The School has attracted financial support from the National Health and Medical Research Council and the Australian Research Council through the competitive granting system, and carried out important work of particular relevance to tropical disease and the health of Aboriginal people. The School has also trained 12 post-graduate research students, with approximately 20 post-graduate students currently enrolled.

The School is currently seeking support from the Department of Employment, Education and Training to develop course-work in public health relevant to the needs of northern Australia, and has sponsored an expression of interest to establish a Rural Health Unit in the Northern Territory. In collaboration with the Northern Territory Department of Health, the School has also begun to make plans to provide advice and educational support, and to carry out relevant health research in the eastern provinces of Indonesia.

Through the affiliation of the Menzies School with the University of Sydney and the Royal Darwin Hospital, the University of Sydney will rotate medical students through the Royal Darwin Hospital for clinical training from 1993; this will provide unique experience for the students, help to further enhance the quality of medicine in Northern Australia, and eventually lead to the establishment of an academic teaching department to specialise in the medical problems of tropical Australia, and the health problems of Aboriginal people.

The School of Nursing of the Northern Territory University, established in 1987, is now responsible for nursing education and research training in Darwin, and is involved in the co-operative development of core curriculum for rural health nurses.

Batchelor College is responsible for the training of Aboriginal Health Workers at Certificate level, and the course is presently being upgraded to Associate Diploma. The College specialises in the cross-cultural education of Aboriginal students, particularly those from traditional communities.

3.6 HEALTH IN THE NORTHERN TERRITORY

Except for the risk of exposure to tropical diseases, and high rates of alcohol- related problems, accidents and violence, the health indicators for non-Aboriginal Territorians are now comparable to those for other Australians.

3.6.1 Tropical Health Problems

There has been no local transmission of malaria in northern Australia since the 1960s, although the mosquito vectors are still present, albeit controlled by spraying programs near to Darwin. However, the Royal Darwin Hospital sees 20-50 cases of malaria each year in tourists or immigrants who have acquired the infection overseas, so there is a very real risk of re-introduction if the current control programs are not maintained.

Ross River virus infection is also transmitted by mosquito vectors, and in the very heavy wet season of 1990-91, an epidemic of epidemic polyarthritis due to the virus affected

many hundreds of people; fortunately, although the pain and disability can last for weeks or months, it is not fatal. The condition occurs in all of northern Australia and in parts of southern Australia. Dengue is another mosquito borne virus infection, common in North Queensland, which is debilitating and potentially dangerous; it has not been a problem in the Northern Territory in recent years.

Scrub typhus, a rickettsial disease, has been reported in tourists visiting Litchfield Park in the Top End; the disease is potentially fatal if not diagnosed and properly treated (Currie, 1991).

Leprosy has been almost eliminated from the Northern Territory, although a handful of cases are diagnosed each year in Aboriginal people.

Melioidosis, due to a bacteria found in tropical soils, can cause potentially fatal septicaemia, abscesses and pneumonia, particularly in persons who are susceptible because of associated alcoholism or diabetes. Although there can be a high rate of asymptomatic infection, the heavy wet season of 1990-91 was associated with high incidence of serious and fatal disease in the Top End.

Hepatitis B infection is frequent in northern Australia because of the high frequency of carriage of the virus in the blood of immigrants from Asia, the Pacific and southern Europe, and in some Aboriginal groups (Gardner et al 1992). The acute infection can be harmful in those infected as adults, whereas for those infected in infancy or childhood, there is a longer-term increase in the risk of cancer of the liver or cirrhosis. Protective immunisation is now routine for all Aboriginal infants, and is available for other infants in northern Australia.

HTLV-I virus infection is endemic in some Aboriginal communities in northern Australia; up to 14% are infected in Central Australia. The virus, probably transmitted in the breast milk from one generation to the next, is asymptomatic for many years, and causes a rare form of T-cell leukaemia in a small proportion of infected adults (Bastian 1992). Overseas studies show that the virus can also cause tropical spastic paraparesis, a form of paralysis, but this has not been described in Aboriginal people. No vaccine is yet available to prevent virus transmission, but the risk of transmission to non-infected populations is now very low, except for the possibility of blood-borne transmission from HTLV-I positive donors. It is likely that the blood donor population, at least in northern Australia, will be routinely screened, so that any virus positive donors are detected and withdrawn from the donor panel.

HIV (AIDS virus) infection is present in northern Australia in the usual risk groups (homosexual men, intravenous drug users, and recipients of contaminated blood or blood products); 63 infections were known in the Northern Territory in August 1991, a rate that is somewhat lower than the Australian average (NT Health, 1991). There is no evidence that the virus is spreading in the Aboriginal community in the Northern Territory, although

there has been great concern about the rapid spread of HIV in small Aboriginal communities in at least one other state.

3.6.2 Health Indicators in The Northern Territory

Mortality: The last period for which comprehensive data have been published is 1979-83 (NT Health, 1986). During this period, the age standardised all-cause mortality rates for non-Aboriginal people in the Northern Territory, were somewhat lower than expected for Australia as a whole. However, there was an excess mortality due to external causes of injury (accidents, suicide and homicide).

Aboriginal mortality: The situation is dramatically different for Aboriginal people . The "Standardised Mortality Ratio" is about 370 for both Aboriginal males and females, compared with a standard of 100 for the whole Australian population. This means that the average risk of death at any age for an Aboriginal person is increased by 3.7 times compared with the average Australian. For particular causes of death the excess risk for Aboriginal people is even greater. For example, the risk of death from infectious disease is increased by more than 30 times, and the risk of death from respiratory disease (lung disease) is increased 8 times in males and 14 times in females. Nervous and mental disorders, and nutritional disorders (including diabetes) were also greatly increased, and maternal mortality (complications of pregnancy) was increased 30 fold in Aboriginal women.

Infant Mortality: Infant mortality rates (deaths within one year of birth) are widely used as an index of health and health care services. The infant mortality rate for Aboriginal infants in the Northern Territory has fallen from over 100 per 1000 in the 1960s, to about 30 per 1000 in the late 1980s. In 1990, the rate was 31.8 per 100, and the risk of infant death was increased about 5-fold for an Aboriginal birth outside hospital. This supports the conclusion that the decline in infant mortality has been due to the increase in the proportion of Aboriginal infants born in hospital (90 % in 1990), as well as to improvements in antentala care and maternal and child health services. Nevertheless, the Aboriginal infant mortality rate is still much higher than that for Australian infants generally (8.2 per 1000 in 1990) and for non-Aboriginal infants in the Northern Territory (5-10 per 1000). This is partly due to the high incidence of low birth weight in Aboriginal infants, which may reflect poor maternal nutrition, smoking and other risk factors of Aboriginal women, but also to the lesser access to and utilisation of high quality antenatal and maternal and child health services by Aboriginal mothers.

Mortality due to Alcohol: In a recent study, Chalmers (1992) has shown that an alcohol problem predicts a five-fold increase in mortality rate over a 10 year follow-up period; the presence of an alcohol problem eliminated the mortality difference between Aboriginal and non-Aboriginal groups. Langton (1991) and Weeramanthri (unpublished) have reported that some 50% of Aboriginal deaths can be attributed to the effects of alcohol.

Overall Mortality in Northern Territory: In 1990, for the Northern Territory population as a whole, the age standardised death rates for males were increased by 47% and for females were increased by 55% compared with Australia as a whole; death rates for the NT were higher than in any other state (AIH, 1992). The major reason for these differences is the persistently raised mortality amongst Aboriginal people comprising 22% of population in the Northern Territory. If anything, these later data suggest that Aboriginal mortality has increased since 1983, probably because of the effects of alcohol-related deaths, accidents and heart disease.

3.6.3 Hospital Admissions in the Northern Territory

On a per capita basis, hospital admission rates in the Northern Territory are comparable to rates in other States (AIH, 1992). However, because of the young age of the Northern Territory population, it would be expected that admission rates would be lower than the national average. The discrepancy is explained by the high admission rates of Aboriginal people, most particularly by the very high rates of hospital admission of Aboriginal infants for diarrhoeal and nutritional problems (Munoz et al 1992A; NT Dept of Health). Although Aboriginal admission rates are high compared with those of non-Aboriginal people, they are low relative to the levels of excess morbidity and mortality in Aboriginal adults. This indicates that Aboriginal people are still under-using health services relative to their needs.

3.6.4 Morbidity in the Northern Territory

Surveys of health status in the Northern Territory have shown that the morbidity levels and risk behaviours for non-Aboriginal people are comparable to those elsewhere in Australia, except that alcohol consumption and cigarette smoking are more prevalent in the Northern Territory (AIH, 1992).

However, for Aboriginal people, particularly those in rural communities and town camps, morbidity rates are very high both for children and adults. Alcohol is the most important cause of social and physical morbidity in adults, and it has important indirect effects on the health and welfare of children.

Rates of gastro-enteritis, helminth infection, malnutrition, anaemia and acute respiratory infection in infants and young children continue to be high, and although hospital admission rates continue to be high (Munoz et al 1992A), these conditions increasingly are managed in the community.

Recent research at the Menzies School shows that all Aboriginal infants are colonised with pathogenic respiratory bacteria (Moraxella, Pneumococcus and Haemophilus) within 1-4 weeks of birth, and that this colonisation co-incides with the onset of middle ear infections in all infants, often without symptoms in the early stages, but eventually leading to persistent otitis media through childhood, hearing problems and educational difficulties in later life.

Impetigo (school sores) are present in about 15-20% of children of school age at any time, and most of the sores are infected with group A streptococci, which are known to be able to cause rheumatic heart disease and kidney disease (van Buynder et al, 1992).

In central Australia and in the cattle country there is still a high prevalence of chlamydial infection in the eye and the nasopharynx of infants and young children, together with signs of follicular trachoma in the eye.

The majority of Aboriginal children with otitis media, impetigo, and trachoma do not present for treatment, treatment is rarely offered and compliance is low; this neglect is contributing to high rates of childhood morbidity, and to serious complications in later life.

Adult Aboriginal people have high rates of chronic bronchitis and bronchiectasis, presumably because of the high rates of cigarette smoking, and the long-term effects of (poorly treated) chest infections in childhood; such chronic lung damage helps to explain the high rates of mortality from respiratory disease in adult Aborigines. They are also malnourished, with high rates of vitamin deficiency, obesity and diabetes mellitus (Lee et al, 1992; Mathews et al 1991) and high rates of high blood pressure, often associated with obesity and or alcohol use or proteinuria (van Buynder, 1990; Pugsley, 1991).

Sexually transmitted diseases are particularly prevalent in Aboriginal communities; at least in part, this reflects the low rates of treatment, which increases the rates of carriage and thus the risk of transmitting the infection to others. Sexually Transmitted Diseases due to gonorrhoea and chlamydia can be complicated by infertility or ectopic pregnancy.

The high rates of proteinuria are of grave concern. For example, in the Tiwi Islands, 30 to 50% of middle-aged adults have significant proteinuria. This is associated with a high incidence of end-stage kidney failure (up to 100 times the average rate for Australia as a whole). Without dialysis or transplantation, such kidney failure is fatal. It is likely, although unproven at present, that much of the proteinuria and kidney failure is a long term consequence of glomerulonephritis complicating untreated streptococcal skin sores in childhood.

In central Australian communities, proteinuria is more often a marker of diabetic renal disease. Proteinuria, smoking and hypertension increase the risk of diabetic vascular complications (requiring amputations), diabetic eye disease (causing blindness), and also of cardiovascular mortality in the absence of diabetes mellitus.

The majority of Aboriginal people with chronic infections, Sexually Transmitted Diseases, obesity, diabetes, hypertension, proteinuria and vascular complications do not present for treatment except at the latest stages of their disease. Furthermore compliance with behavioural interventions or medication, if it is offered, is often low and resources are inadequate to cope with these increasing health problems.

3.7 OVERVIEW OF CAUSES OF POOR HEALTH

Historical studies and international comparisons clearly identify the importance of social factors as determinants of health. For example, health indicators began to improve in the slums of industrial Europe with the introduction of clean water supplies, sewage disposal and hygiene education in the 19th century, when there were almost no effective medical interventions. In the modern world, countries with the poorest health have the lowest per capita incomes, and the lowest literacy rates for women (Caldwell, 1990). This corresponds to the common-sense understanding that financial resources are needed to provide health infrastructure and health services, and that knowledge is needed within the family to make effective use of the available infrastructure and services.

3.7.1 Health of Aboriginal People

The health of Aboriginal people in the Territory continues to be very poor because of their poverty, because they still have limited access to good housing and the other infrastructure necessary for health, and because they have limited access to culturally appropriate health services, and to the knowledge that is necessary to make effective use of the infrastructure and the services. More specifically, the following factors contribute to poor Aboriginal health:

- Overcrowded living conditions, poor washing facilities, and poor hygiene continue to cause infectious diarrhoea;
- Overcrowding, poor hygiene, and lack of adequate diagnosis and treatment lead to high rates of carriage and transmission of infectious bacteria causing trachoma, otitis media (infected ears), pneumonia, bronchiectasis and lung damage, tuberculosis, Sexually Transmitted Disease, skin sores, rheumatic heart disease and possibly kidney failure;
- Poor nutrition increases the damage caused by infections, and leads to obesity, diabetes, hypertension and heart disease.
- Smoking increases the risk of infections, lung damage, heart disease and cancer;
- Alcohol abuse leads to violence, accidents and social disruption and to hypertension, liver damage or brain damage;
- Petrol sniffing can cause brain damage and death, while kava drinking causes weight loss, skin rash and other problems.

It is a matter of grave concern that many Aboriginal children and adults suffer from treatable conditions such as otitis media, trachoma, impetigo (skin sores), Sexually Transmitted Diseases, diabetes and hypertension which are rarely diagnosed and treated.

3.8 CONCLUSIONS

3.8.1 Fiscal Equalisation

On the grounds of social equity in access to services, and the clear need for more equity in social outcomes and health outcomes, there is a clear rationale for enhanced fiscal equalisation, with increased funding for northern Australia.

3.8.2 Costs of Service Provision

There has never been an adequate investigation of the real costs of providing equivalent services in the north, and there is strong evidence that the social and health needs in the north, particularly for Aboriginal people, have not yet been adequately met. There is a need for detailed social and economic research to establish the real costs of service provision, not only for the services that are already being provided, but for the costs of the services that are needed but are not yet being provided.

For example, an assessment of the costs of service provision for Aboriginal people should start with the morbidity profiles, establish the services and interventions required to really meet the needs, and then calculate the costs. Such a process would require considerable data collection and economic input, as well as detailed consultation with Aboriginal people and their service providers, and with other experts.

3.8.3 Responsibilities

In Commonwealth and Territory dealings, and matters affecting Aboriginal people, there has been divided responsibility. This has tended to lead people to work to control the resources, rather than to concentrate on the content and effectiveness of programs. The lack of professional input into planning has been particularly evident in relation to health services at both the Commonwealth and Territory levels, partly because of the mistaken belief in some quarters that the necessary emphasis on social programs and on community consultation also implies that the medical component of health programs should be de-emphasised.

The recent establishment of the Tripartite Forum, involving ATSIC, Commonwealth and Territory representatives, provides a forum that could allow for creative planning and policy development, provided that it does not get diverted by struggles over the control of resources, and provided that the Forum does not institutionalise the division of responsibility, which carries the risk that there is no final responsibility for improvements in planning and service provision.

There is a clear need for more professional input into the planning and implementation of improved health and social policies in Northern Australia.

3.8.4 Community Consultation

The importance of community consultation cannot be over-emphasised, and Aboriginal people generally need to be empowered to take control of their own affairs; this means that community administration needs to be professionalised locally so that individual community councils can deal directly with professional administrators, ideally Aboriginal. These local government administrators can then deal, from a position of strength, with the remote bureauocrats concerned with the provision of advice or resources. This could only be achieved if there is a net flow in resources from the remote bureauocracies into the communities themselves.

3.8.5 Community Development and Employment

The present development of Community Development Employment Programs needs to be extended and integrated with the provision of services, education and training opportunities within individual communities.

More reserch is needed to identify the features of successful programs so that these can be replicated elsewhere.

There needs to be a detailed analysis of the income and resources flowing to Aboriginal people so that deficiencies can be corrected on a needs basis.

3.8.6 Health Infrastructure

More resources are needed for new and expanded programs while up-to-date information on existing housing, sanitation and water supplies is analysed. The results of earlier programs should be assessed so that the problems in implementation and maintenance of culturally appropriate facilities can be identified to help improve the efectiveness of new programs.

3.8.7 School Education

A number of issues need to be addressed to improve education, particularly for Aboriginal children in rural schools. The debate over whether to emphasise Aboriginal language and cultural education at the expense of mainstream educational values needs to be addressed creatively, so that Aboriginal children can be offered the best from both worlds, by Aboriginal and non-Aboriginal teachers who are committed and professionally trained. These teachers need to be aware of the high frequency of hearing impairment in Aboriginal children, and to be trained to recognise it and to teach appropriately. Teaching programs for Aboriginal children need to focussed towards education for healthy living, to the development of skills that will be useful in the community as well as in the workforce, and to the transmission of cross-cultural knowledge and understanding that will help them to deal with the complexities of life in the Northern Territory.

There needs to be a more detailed examination of the reasons for the low retention rates of Aboriginal children in secondary school, and for the low attendance rates in primary schools. Such an examination could draw upon earlier research and commission new research. The results would be used to help improve the educational opportunities for Aboriginal children in a way that would be of benefit to them, to their communities, and to the wider community in northern Australia.

3.8.8 Tertiary education for Aboriginal People

The most important priority is to increase the number of professionally competent Aboriginal people who can become agents of social change for their own people. Aboriginal people need to have access to mainstream courses, as well as courses that emphasise Aboriginal culture. Courses such as those at Batchelor College need to be articulated to courses in mainstream institutions, so that there can be no substance to the claim that Aboriginal professionals can only aspire to levels of professional competence which fit them to only work in Aboriginal communities.

3.8.9 Professional Training for Health Professionals

The training opportunities for health professionals in northern Australia need to be further enhanced, so that doctors, nurses, allied health professionals and other professionals have access to education to upgrade their competence, and to develop new skills that are needed for work in rural centres and in northern Australia generally. Towards this end, the Northern Territory has submitted an expression of interest for the national Rural Health Unit and for funds to support public health training at the Menzies School and clinical training at the Royal Darwin Hospital.

Wherever possible, the training of health professionals in northern Australia should emphasise multidisciplinary aspects, and the interdependence of public knowledge, health infrastructure, hospital, community and public health services in bringing about improvements in health.

3.8.10 Management Protocols

There needs to be a commitment to the development of standard management protocols (E.g. as introduced by the Central Australian Rural Practitioners Association) and for the evaluation of innovative policies and management protocols. For example, in the health area, because of the high levels of untreated infectious disease in Aboriginal infants and adults, because Aboriginal people rarely present for treatment, and because compliance with treatment is poor, a strong case can be made to trial programs of community based screening and treatment (for example for otitis media in infants and Sexually Transmitted Diseases in adults).

3.8.11 Ethical Issues

The over-riding ethic is to be able to deliver meet the health and social needs of people in northern Australia on an equitable basis. Because the needs of Aboriginal people are so great, it is clear that the flow of resources to Aboriginal people, on a per capita basis, needs to be greater than that to other Territorians, just as the flow to other Territorians needs to be greater on a per capita basis than the flow of resources to other Australians.

In the development of new and more effective programs in northern Australia, there needs to be wide consultation and co-operation between all levels of government, as well as input from academics and community representatives. New strategies need to be developed to give control to local communities while at the same time giving them access to the best available professional advice.

No new programs, whether they relate to service provision or research, should be introduced without full consultation and ethical review by representatives of the communities concerned.

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4 RURAL AND FISHERIES PRODUCTION (NT)

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4.1 AREA AND POPULATION

The Northern Territory (NT) covers 27% of tropical Australia (18% of the continent) with an area of 1.36 million km^2, and its population of 170,000 represents 17% of the region and 1% of Australia's total. Furthermore, half of the NT's population lives in the vicinity of Darwin which means that the demographic density of the rural area is about one person per 16 km^2.

4.2 NATURAL RESOURCES AND ENVIRONMENT

The Territory lies between the 11° and 26° latitudes and is divided into three climatic zones:

The northern humid zone	(rainfall > 800 mm).
The transitional semi-arid zone	(rainfall 300-800 mm).
The southern arid zone	(rainfall < 300 mm).

The humid zone is the area between Darwin and Katherine which is commonly referred to as the Top End of the NT. The semi-arid zone extends from Katherine in the north to Tennant Creek in the south, and from the Gulf Country and Barkly Tablelands in the east to the Victoria River District in the West. The arid zone stretches south of Tennant Creek and beyond Alice Springs which lies at its centre.

In all zones most of the rainfall occurs between November and April (the wet season). The rain in the north is associated with the monsoon whose effect of which progressively diminishes towards the arid zone. In the coastal regions of the north, mean annual temperatures range from 23-32°C and relative humidity varies from 54-73%. Further inland, mean minimal temperatures fall to 15°C in July. In the arid zone, temperatures may be in excess of 40°C during December and January before the onset of summer rains, and in winter minimum temperatures fall below zero. Relative humidity ranges from 38% in June to 18% in September and October.

The vegetation of the humid zone is characterised by swamp plants including wild rice and Hymenachne grass in coastal and river areas, by shrubs and perennial grasses on the inland flood plains, and by open eucalypt forest or savanna of tall annual grasses. The semi-arid

zone is predominantly of open eucalypt savanna type and acacia shrublands. Mitchell grass covers the Barkly Tablelands and Hummock grasslands of Spinifex are found in rugged country and desert regions. In the arid zone Hummock grasslands are predominantly featured together with large areas of central arid woodlands and smaller areas of Chenopod shrublands in the south.

The NT coastline, which extends approximately 10,600 km, is characterised by a wide range of tropical coastline ecosystems, including sheltered and exposed sandy beaches, mudflats, rock platforms, coral reefs, seagrass beds and some of the most extensive and diverse mangrove forests in Australia. Tides are diurnal and semi-diurnal, ranging from less than 1.5 m (Gulf of Carpentaria) to approximately 8 m (Darwin Harbour).

4.3 PRIMARY PRODUCTION

The total published value of the rural industries and fisheries of the NT are presented in Table 1 and represents 1.3% of GDP. The industry sectors are discussed in more detail below.

TABLE 1. TOTAL PRODUCTION VALUE OF RURAL AND FISHING INDUSTRIES IN THE NORTHERN TERRITORY FOR 1990/91.

Animal Industries		**$ million**
Cattle		102
Buffalo		4
Intensive		14
	SUBTOTAL	120
Plant Industries		
Horticulture		20
Crops		2
Nursery		3
	SUBTOTAL	25
Fisheries		
Crustaceans (mainly prawns)		25
Fish		6
[Molluscs (mainly pearl shell)		0.2]
	SUBTOTAL	31
	NT TOTAL	176

4.4 ANIMAL INDUSTRIES

4.4.1 *Cattle Industry*

The cattle industry was one of the earliest to be established in the NT more than 100 years ago with the granting of pastoral leases in the Alice Springs region and one near Katherine. By 1884, there were 96,500 cattle on more than thirty cattle stations, most of the livestock being driven mainly from Queensland. The old stock routes provided the basis for the development of the Territory's road network in the 1960's (The Beef Road Project).

Today, the cattle industry runs about 1.35 million head of cattle on 270 rural holdings with an average holding size of 2,550 km^2. With more than 50% of the area of the NT devoted to cattle production, the industry is the principal user of the Territory's large rangeland resource. The production system has traditionally relied on the low inputs of extensive grazing of rangeland native pasture with carrying capacities ranging from 2-5 beasts/km^2 giving 80-120 kg annual liveweight gain per head or 2-5 kg annual liveweight turnoff per ha. Cattle were turned off for slaughter mainly for manufacturing grade meat for export and for finishing in Queensland and South Australia.

Since the opening of major manufacturing meat markets in the early 1960s and the subsequent Brucellosis and Tuberculosis Campaign (BTEC), the industry has moved towards more intensive management and has become more focussed on sound herd and business management practices. New markets are also developing with an expanding live feeder steer trade with SE Asia. A total of 324,895 head of cattle were turned off in 1990/91, of which 51% were moved interstate, 14% were exported live overseas, 30% were slaughtered at export abattoirs and 5% slaughtered for domestic use. The gross value of production in 1990/91 was estimated to be $102M (cf. $109M in 1988/89), or 58% of the total published value of the primary industry production in the NT.

4.4.2 *Buffalo Industry*

The buffalo industry originated from a few small herds of swamp buffalo which were introduced from the East Indies by the early settlers, but were later abandoned. Feral herd numbers quickly increased as they were well adapted to the wetlands of coastal areas and northern rivers.

Buffaloes were first hunted for their hides, but by the late 1950s there was also a market for buffalo meat for pet food and for human consumption, and later for live export mainly to Asia. By the mid 1980s, turnoff averaged 35,000 head per annum, including live exports of 2,675 head annually. In 1987/88, the industry was worth $9M.

Over the last decade, large areas of the Top End that once supported herds of feral buffalo have been destocked both in the interest of conservation of the natural habitat (Kakadu National Park) and for disease control measures (the BTEC). Estimated buffalo numbers

have dropped from 300,000 (1982, 1989) to a total of 50,000 in 1991. This has had a profound impact on the industry which has had to try and make rapid adjustments in the transition from a feral harvesting operation to the establishment of domesticated herds controlled by fencing. The resultant high development costs and inadequate cash flow has hit the industry particularly hard despite the availability of assistance measures. In 1990/91, total turnoff was 14,257 buffalo valued at $4.4M.

There continues to be a steady demand for live export buffalo and there appears to be potential to supply the domestic market with table quality meat. Short term and long term strategies are being put in place to enable the restructuring of this industry.

4.4.3 *Intensive Animal Industries*

The dairy, pig and poultry industries at present supply the NT market with 25% of its milk, 10% of its pork, 5% of its chicken meat and 90% of its egg requirements. Together they are worth in excess of $10M and contribute substantially to the economy of the NT. In servicing a growing local market, these industries have the potential for further expansion with import replacement implications. They also have export capabilities if comparative economic advantages arise.

New or emerging industries include crocodiles, camels and deer. While the latter two are in their infancy, the crocodile industry is developing rapidly and has the potential to become a significant niche market in the Animal Industries. Production of crocodile skins, valued at $1.2M in 1990/91, is competing with lower cost producers from other countries, such as Papua New Guinea, Thailand and Indonesia, but has the financial advantage of accessing the high quality end of the international market. Crocodile meat which is a byproduct of industry is being promoted for human consumption and now represents 5% of the total value of the industry.

4.5 PLANT INDUSTRIES

The attempts by early settlers to grow crops and vegetables were often thwarted by pests and diseases and the extreme climatic conditions of the tropics. During the 2nd World War however the army successfully cultivated a range of food crops for their needs and laid the foundations for a plant industry in the NT. In 1990/91, nearly 5,500 tonnes of cereal and leguminous grain crops were produced in the Top End, and of the 13,000 tonnes of fruit and vegetables produced, 60% were from the Darwin region, 30% from the Katherine region and the remainder were from Alice Springs.

4.5.1 *Horticulture Industry*

This industry has grown from $0.5M 10 years ago to $23M in 1990/91 with considerable potential for further growth. Mangoes and melons worth $7M and $5.4M respectively were the dominant earners.

The production of table grapes in the Alice Springs region is valued at $2M and bananas in the Top End are worth $1.5M. There are also emerging industries in asparagus, exotic tropical fruits such rambutan, abiu and durian, and chinese vegetables, which together are already approaching $1M in value. A citrus industry is in the process of being established with 35,000 trees already planted.

A recent study estimated nursery production in the NT at $6M (cf. published value of $3M), with palms being the major item produced. Interstate markets for NT nursery products valued $1.5-2M. A cutflower industry is being developed in the Darwin and Alice Springs regions. The larger Darwin industry has around 300,000 orchids valued at $1M.

4.5.2 *Cropping Industry*

In the early 1980s, the NT Government supported the development of a grain industry in the Katherine and Douglas Daly regions of the Top End. The total value of grains, seeds and forage crops now produced in these regions has risen to $4.0M. Grain production peaked in the mid-1980's, but irregular rainfall reduced crop yields which have now stabilised at a lower level as farmers have diversified into mixed grain/beef enterprises. With the development of low risk agronomy techniques and pasture legume rotations, the mixed farming option is proving to be more efficient and sustainable, and very profitable, with the production of high value crops such as sesame and mung bean integrated with cattle fattening for the live export market.

4.6 FISHING INDUSTRY

The published value of landings in the NT by the commercial fishing industry in 1990/91 was $31M. This figure does not fully reflect its actual value to the local economy as it does not include pearl production nor does it take into account the value of recreational fishing and the associated tourism. The most valuable offshore fisheries are controlled by the Commonwealth.

Total landings of fish in 1990/91 was 2,600 tonnes valued at $6.1M. The most important species are barramundi, snapper and mackerel. About the same tonnage of crustaceans, but worth $24.9M, were landed with prawns comprising most of the catch and its value. The mollusc fishery, including pearl shell taken for pearl culture, makes up less than 1% of the total value of NT fishing industry.

Aquaculture is an emerging industry with significant potential for production of barramundi, prawn and red claw, but needs further development to bring it into full commercial viability. Although there are no specific figures for pearl production they are estimated to be significant.

4.7 DISTRIBUTION OF R&D IN THE RURAL AND FISHING INDUSTRIES

The major aim of this Department is to enhance the contribution that rural and fisheries production makes to the Territory while ensuring that utilisation of natural resources is sustainable. The Department carries this out through the provision of industry support and regulatory protection services, and through R & D and extension/advisory services.

The R & D programs are planned and managed within a framework of Corporate Strategic Objectives and focus specifically on the economic viability of industry in relation to available natural resources and their management.

In 1992/93, the Department will be committing $5.5M and 95 full time staff to specific R & D (including Extension) programs. This comprises of $4.5M provided directly by the NT Government and equates with 15% of a total budget of $30M and 26% of total manpower resources. An additional $1M has been accessed from external funding sources. The cost of research farms facilities, biometric services and libraries, are a further $3M. Thus total expenditure associated with R & D is estimated to be $8.5M or 28% of the Department's budget, if external funding sources are also included.

The distribution of R & D funding for industry programs in 1992/93 is presented in Table 2. Plant, Animal and Fishing Industries will receive 40%, 34% and 23% of R&D funding respectively. The remaining 3% is for socio-economic and marketing research. Funding in these latter areas is likely to increase in the future as the Department strives to use its resources more efficiently to achieve its goals, and more emphasis is placed on research programs that benefit those areas of greatest opportunities for sustained economic development.

TABLE 2. NT GOVERNMENT R & D RESOURCE ALLOCATION BY INDUSTRY FOR 1992/93.

	NT Government ($ million)	External Sources ($ million)	Total ($ million)
Animal Industries	1.5	0.4	1.9
Plant Industries	2.1	0.1	2.2
Fisheries	0.7	0.5	1.2
Industry Support	0.2	0.0	0.2
TOTAL	4.5	1.5	5.5
Research Stations	3.0		

4.8 HIGHER R&D NEEDS OF THE NT

The cost of R & D inputs into Territory primary industries represents about 10% of GDP of this sector compared with national inputs of about 3% of GNP of Australian agriculture. There are a number of extra-ordinary constraints to socio-economic growth in this region that necessitate this higher level of R & D input than the rest of Australia.

4.8.1 *Early Stage of Development*

The development of the rural and fishing industries in the NT (and also the rest of Tropical Australia) is at a very early stage in comparison with the rest of Australia. While considerable progress has been made, there are still fundamental problems hindering agricultural development. The capacity of this Department to service such wide ranging needs of industry at this early stage of development is stretched and often exacerbated by expectations similar to those of southern states where industries are more fully developed and in a better position to contribute financially to these services. With regard to the fishing industry, the enormous task of assessing stock resources has resulted in a number of unexploited fisheries.

4.8.2 *Technology Transfer*

The tropical monsoonal environment, which is unique to northern Australia and the NT, suits agricultural systems that are quite different to those found in temperate climates. Moreover, northern Australia is one of the few tropical regions of the world where agriculture is not subsistence farming. Production technology from the southern states and elsewhere in the world is often largely unsuited to the production systems of the north.

4.8.3 *High Demand for New Technology*

The lack of knowledge of appropriate primary production systems in the tropical environment of the NT creates a higher demand for R & D into new production technologies. For example, new cultivars to be trialled, previously unknown pests and diseases to be identified and combated, and new cultivation methods developed to minimise erosion.

4.8.4 *Market Constraints*

There are a number of marketing aspects which present special difficulties in the NT compared with the southern states:

- Dependence on export market. The small scale of the Territory's domestic markets means that new industries, and the producers themselves, must be orientated towards interstate and international markets, and have the capacity and skills to do this at the outset.

- Distance from markets.

- Variability of commodity prices due to high proportion of NT products exported.

- Marketing of non-traditional products. Many of the products of tropical agriculture and fisheries are new and require longer lead times for market development, eg goldband-snapper, abiu and mangosteen.

- Cooperative marketing arrangements. The pioneering nature of agricultural development in the NT tends to bring with it a commercial independence among producers, making it difficult to organise cooperative marketing groups.

4.8.5 *Natural Resource Management*

The long term sustainable productivity of the natural resource base on which primary industries are so reliant remains poorly understood. The husbandry of these resources require the development of management programs to minimise risk of over exploitation. This demands considerable industry and production monitoring to develop a comprehensive knowledge base for the long term management of these resources.

4.8.6 *Seasonal Variability*

Agricultural production is also dependent on the weather which can be extremely variable in the tropics. Rural industries in the marginal rainfall areas are particularly vulnerable. Research is required to develop options to manage production systems in a risky environment, eg the development of decision support systems for drought management.

4.8.7 *Remoteness*

The Territory has a sparse population with long distances between population centres and rural communities. The provision of research facilities, including its infrastructure, and an advisory service to primary producers under these circumstances is very costly.

4.8.8 *Implementation of National Policy*

Part of the function of this Department is to implement national policies relating to the primary industries of Australia. The NT Government also undertakes programs to protect its own interests. Some of these programs also have benefits for the rest of Australia. For example, the NT is frontline to exotic pest, disease and weed introductions into Australia and the Territory Government is a service agent for the Australian Quarantine Inspection Service. However, the Government is also obliged to fund its own R & D programs and monitoring services to assist with the control of noxious weeds such as *Mimosa pigra*, and to protect its interstate markets and prevent the consequences of a quarantine breakdown, witnessed by the recent outbreak of *Thrips palmi*. Another example is the Government

funding of one-third of an EXANDIS program on the application of advanced technology for diagnosis of diseases transmitted by insects (arboviruses).

Other aspects include the vigorous pursuit by the Commonwealth of new initiatives, particularly in sustainable development, greenhouse and related conservation strategies. While these issues are fundamental to future development, they usually require procurement of competing R & D resources. Furthermore, there are still significant gaps in fundamental information about the natural resource base of the NT, yet the Commonwealth insists on imposing natural resources policies based on the knowledge of conditions in SE Australia which often bear little relation to the situation in the north.

4.8.9 *Federal Assistance for R&D in the NT*

The substantial withdrawal of CSIRO from agricultural research in the NT has effectively reduced Commonwealth assistance for R & D in the NT. Moreover, it is becoming more difficult to access Commonwealth funding for R & D relevant to regional development as a result of the centralisation of R & D Corporations in the temperate zone where funding priorities are towards commercialisation. This has led to considerably less access to funding for research to resolve long term problems facing the NT. The disparity in stage of development between the north and the south is only now starting to be recognised by these funding agencies, an exception being the Meat Research Council's North Australian Program .

Against this background of physical, political and funding constraints, it is becoming more difficult for the NT Government to maintain the level of R & D needed to continue sustained growth of the agricultural and fishery sectors. A decline in funding and effort has led to available resources being tightly focussed on short term gains rather than long term benefits. Without long term research strategies, there is a real danger of losing development opportunities and eroding the comparative advantage of existing technologies of the tropics.

4.9 OPPORTUNITIES FOR THE NEXT DECADE

The development of the rural and fishing industries of the NT are at an early stage in relation to southern states. Sustained growth of these industries, which is highly dependent on increased R & D inputs, will bring considerable socio-economic benefits to the region and to Australia.

4.9.1 Agricultural and Fish Production

There is considerable potential to expand the economic value of primary production in the NT by improving productivity and quality of product lines, and opening up new areas to rural and fishery development.

A priority area for the Animal Industries is the expansion of the live cattle export trade to south-east Asia. This will require R & D into identifying more productive and cost effective systems to achieve market specifications and greater inputs to transfer the new technologies and market requirements to industry.

In the Horticulture Industry, there is a continuing trend towards perennial fruit crops, particularly mangoes, rambutans and citrus, with an emerging potential to supply south-east Asian markets. The industry needs to reduce the risk of investment and to attract experienced growers by identifying a wider range of enterprise options, by developing effective pest control measures and by improving market access.

The change to mixed farming of livestock, pasture and crops by the Cropping Industry is relatively recent and will require more work on developing sustainable integrated production systems based on lower risk agronomy, high value crops and value adding of livestock.

In the Fishing Industry, aquaculture is set to make a big commercial impact once the industry has developed beyond the pilot phase. The barramundi hatcheries and prawn farms have begun to market their products. In addition, it is anticipated that there will be increased production from the offshore demersal and shark fisheries and an expansion of the recreational fishery.

4.9.2 *International Collaboration*

The Territory's unique position in terms of development of production orientated primary industries in the tropics and semi-arid environments provides the basis for new international business opportunities associated with provision of technical advice on sustainable agricultural practices in similar climatic regions of the world. Demand for such a service is set to increase markedly in the future. The NT, with its formidable intellectual capacity in areas of tropical agriculture (ie resource management, production, protection and marketing) and fisheries (eg benevolent trawl technology and recreational fishing management) is in a good position to capitalise on this growing demand particularly from the Asian Pacific economic region which represents 25% of world GDP.

The current level of interaction between this Department and other research institutes in SE Asia is considerable and the NT is well placed to forge even closer scientific links with its northern neighbours. This Department is also keen to provide training for overseas participants and has taken steps to promote this area of opportunity - however such a program is dependant on continuing financial support.

4.9.3 *Socio-Economic Development*

Sustainable growth in the primary industries sector will assist growth in other sectors of the NT economy. These growth effects include increased Gross Regional Product, income, employment and regional development. For example, if the value of agriculture and

fisheries increase by $1M then estimated increases are: GRP by $0.74M per annum (p.a.); NT incomes by $0.4M p.a., and NT employment by 18 people (CAERA, 1992).
There is every chance that, in learning the lessons of the past, the primary industries of the Territory can strike a balance in the use of resource so that they are not over exploited, but are protected for future generations.

4.10 RECOMMENDATIONS FOR EFFECTIVE EXPLOITATION OF OPPORTUNITIES

4.10.1 *Production*

Greater effectiveness can be achieved if the R & D effort is focussed on the development of production technology for tropical agricultural and fish products. There is also a need to be aware of the comparative advantage of developing production systems for agricultural commodities produced elsewhere in Australia where this is feasible, eg melons and asparagus.

4.10.2 *Resource Management*

From a regional and national perspective, the benefits of increased R & D inputs into gathering baseline knowledge of the resources supporting the primary industries will lead to a better understanding of the natural resource of the country and the potential for their exploitation in terms of sustained economic growth.

4.10.3 *Markets*

Markets for tropical agricultural products are already well established in south-east Asia and exploitation of these markets will provide the greatest opportunity for expansion of the NT primary industries over the next decade. Furthermore, increased trade links with Asia could benefit the rest of Australia in terms of accessing markets for manufactured goods. The flow-on from this could warrant further development of the Territory's infrastructure.

4.10.4 *Cooperative Research Centres*

The establishment of centres of excellence in tropical agriculture and fisheries would assist the consolidation technical knowledge and expertise and provide a better scientific foundation on which to conduct R & D. Moreover, greater effectiveness of the R & D effort is achieved through cooperative and collaborative programs between the research centres themselves and industry organisations. The involvement of Universities ensures that training needs are also met. Already applications have been made from the Territory to set up Cooperative Research Centres in Tropical Horticulture, Tropical Landscape Management, and Aquaculture. These institutions would also provide a spring board for international collaboration.

4.10.5 *Coordination of R&D*

The efficiency and effectiveness of R & D activities among the research institutes in the NT and northern Australia would be greatly enhanced by the formal mechanism of R & D coordination across the region. Coordinated R & D would promote the agricultural and fishing industries in the tropics by;

- minimising R&D duplication,
- maximising the comprehensiveness of R & D programs,
- recognising common broad R & D goals aligned with agreed industry requirements, and
- sharing and extending the R & D findings

4.11 SUMMARY

Progress in the development of the rural and fishing industries in the Northern Territory has been slow because of inadequate resources to undertake R & D of the constraints and opportunities for agricultural development in the dry and dry/wet tropics.

From a national perspective, the benefits of fostering R & D in northern Australia are likely to be in terms of sustained economic growth, protection from threats and a better understanding of the natural resources of the country and the potential for their exploitation.

The development of sustainable agricultural systems in tropical Australia would lead to international recognition of its products and expertise in tropical agricultural development and management of its resources.

The establishment of cooperative research centres in the tropics and the effective coordination of their R & D activities would promote the interests of agriculture and fisheries in the tropics and better direct funds to appropriate areas in conjunction with the needs of end-users.

5 MINING AND ENERGY R&D IN TROPICAL AUSTRALIA

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5.1 INTRODUCTION

Australia's economy is resource dependent, and is based on its efficient minerals, petroleum, and rural industries. The minerals and petroleum industries are particularly important as they are the largest contributors to exports. For example, in 1990-91 they earned $27.5 billion, that is, some 42% of total exports. Domestically produced petroleum earned $1 billion in exports, and saved some $7 billion in import replacement[1].

The minerals and petroleum industries drive much of the investment in Australia, with between one fifth and one third of total new private capital expenditure being directed to these industries. These industries are also a major contributor to government revenues. For example, in 1989-90, total government revenues from the industries amounted to $13.29 billion[1].

Because minerals and petroleum are non-renewable resources, exploration is the life blood of the industries. Expenditure on private exploration in Australia is amongst the highest in the world and amounted to $601.7 million in 1990-91 for minerals, and $582.6 million for petroleum[1].

The centre of gravity of Australia's mining industry lies very much in tropical Australia where particular geological provinces host some of the world's largest known mineral deposits of various commodities. Australia is one of the world's leading producers of aluminium, iron ore, black coal, diamonds, manganese, gold, uranium, lead, and zinc. Production of aluminium is dominated by the Weipa (Queensland) and Gove (Northern Territory) deposits on the Gulf of Carpentaria; iron ore production is centred on the various mines of the Hamersley Range in the Pilbara of Western Australia; diamond production is predominantly from the giant Argyle deposit in the East Kimberleys of Western Australia; and the nation's manganese production comes from the world class Groote Eylandt deposit (Northern Territory) in the Gulf of Carpentaria.

Although the mining of coal, gold, uranium, lead and zinc is not focused in tropical Australia, major deposits north of the tropic nevertheless contribute significantly to the national output of these commodities. Almost half of the nation's coal production comes from the mines of the Bowen Basin in Queensland, most of which lie north of the tropics. Important sites of gold production in the tropics are Telfer in Western Australia, Tennant

Creek and the Granites-Tanami regions in the Northern Territory, and the Kidston and north Drummond Basin regions in Queensland. The Ranger Mine in the Alligator Rivers region of the Northern Territory is the second largest uranium producer in the western world, while the world-class base-metal deposits at Mt Isa and nearby Hilton have made their operator, MIM Holdings, the world's biggest single-mine producer of lead and silver and among the ten biggest producers of copper and zinc.

Although Australia is not a major petroleum producer by world standards it is 80% self sufficient in petroleum. It is increasing its exports of petroleum products and maintaining a high level of self sufficiency largely through recent gas, condensate and oil developments on the Northwest Continental Shelf off the coast of northern Western Australia. In the Carnarvon Basin of the offshore Northwest Shelf, recent oil discoveries have been made at Griffin, Roller, Sinbad and Yodel. Griffin-1 was a significant oil and gas discovery, larger than other discoveries in the area. Important developments in offshore northwest Australia include the NW Rankin Gas project, the Goodwyn gas development now imminent, the Barrow Island oil field and many medium to small oil fields in the Carnarvon and Bonaparte Basins.

In addition to the abovementioned current operations, there are a number of known world-class deposits that have yet to be fully developed in tropical Australia. These include the recently-discovered Century and Cannington lead-zinc deposits in north-west Queensland, the Kunwarara magnesite deposit near Rockhampton, Queensland, the Jabiluka uranium deposit in the Northern Territory, the Kintyre uranium deposit in Western Australia, the Osborne copper deposit in north-west Queensland, and Nifty copper deposit in the Throssell Ranges, Western Australia.

5.2 RESEARCH AND DEVELOPMENT (R&D) IN THE MINING AND PETROLEUM INDUSTRIES

Figure 1 illustrates the main steps in the development life of a mineral deposit or petroleum accumulation. The sequence begins with exploration and is followed by discovery, feasibility study, development and production, and finally, by closure and rehabilitation. Although the economic rewards for this sequence of activities can be great, each step is capital intensive and involves high degrees of risk. Research and development therefore play an important role in the mining and petroleum industries with every effort being made to improve the selection of areas to be explored, to have available the most effective and efficient exploration tools possible, to maximise mining and metallurgical performance and to implement the best available rehabilitation practices.

5.2.1 *Regional Geological Mapping*

Research aimed at improving area selection involves regional geological mapping and related studies. The geology and mineral prospectivity of tropical Australia are unique to tropical Australia and this kind of research is therefore area specific. Responsibility for

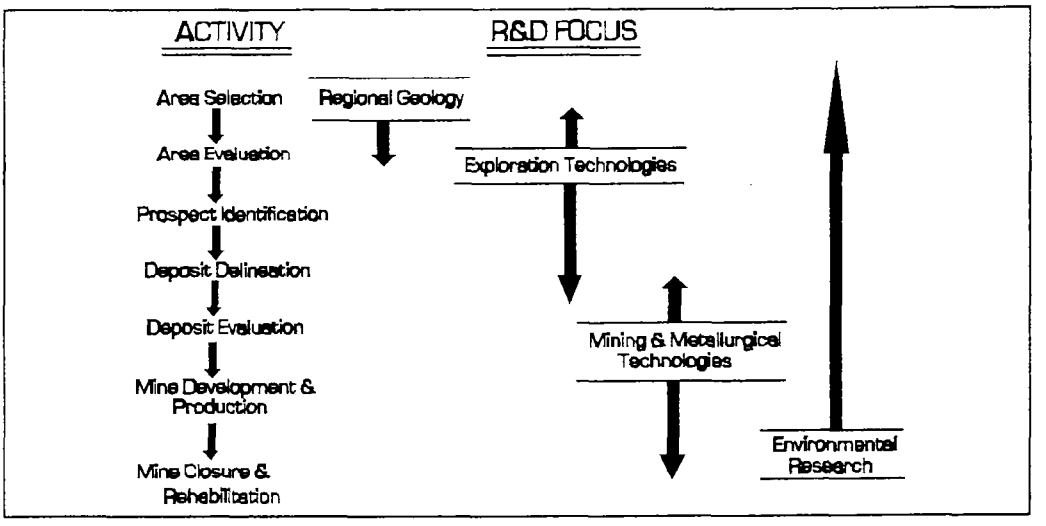

Figure 1: ***Research and Development in the Mineral and Petroleum Industries***

regional geological mapping in tropical Australia lies with the Commonwealth, through the Australian Geological Survey Organisation (AGSO), and the Western Australian, Northern Territory, and Queensland Governments through their respective Geological Surveys.

The main vehicle for the mapping is the National Geoscience Mapping Accord (NGMA), which is coordinated by the Chief Government Geologists Conference, a subcommittee of the ministerial council ANZMEC - the Australian and New Zealand Minerals and Energy Council. NGMA projects are providing new opportunities for government geoscientists to collaborate with university and industry geoscientists and the number of joint research projects in the area of regional mapping is increasing steadily.

In addition to a good understanding of regional geology, effective area selection also requires insights into the genesis of mineral deposits and petroleum accumulations, and into their relationships with the surrounding geology. In the case of minerals, this kind of research in Australia is undertaken mainly by universities and industry, with much of the work being funded through AMIRA - the Australian Mineral Industries Research Organisation. In the case of petroleum accumulations, this kind of research is also undertaken by universities, as well as by CSIRO, AGSO and the petroleum industry. The Continental Margins Program of AGSO, which utilises the Vessel Rig Seismic, has collected geoscientific data to provide information aimed at improving area selection for petroleum exploration of various offshore basins in the Australian Northwest Shelf. Like the mineral research, petroleum industry support is widespread and is frequently channelled through AMIRA's petroleum division.

5.2.2 *Exploration Technologies*

Research into exploration technologies is also area specific, but not to the same extent as regional geological mapping. Exploration tools, be they geochemically or geophysically based, can normally be applied successfully in a wide range of environments, provided area-specific research has been conducted to tune and adapt the tools to maximise their performance in that area.

In Australia, research into the development and local adaption of exploration tools is conducted by industry, often in collaboration with universities, and in particular, by CSIRO's Division of Exploration Geoscience. The recently formed Cooperative Research Centre (CRC) for Australian Mineral Exploration Technologies is building on CSIRO's activities in this area and is focusing on improved geophysical exploration tools. The object of the research is to develop more effective ways of finding ore bodies that are concealed by the regolith (weathered, *in situ* and transported material which covers bedrock) that overlays many of the more prospective parts of Australia including much of tropical Australia. Different challenges face the petroleum exploration industry in Australia and they are being addressed in another CRC, the Australian Petroleum CRC, which also embraces work on the genesis of oil and gas accumulations, as well as petroleum production problems.

Once new mineral and petroleum accumulations have been identified, the R&D focus shifts to problems associated with mining, metallurgy and oil production. Some of the research addressing these issues is of a fundamental nature and is generally conducted by the CSIRO and universities, often with support from industry that is channelled through AMIRA and APIRA. However, much of the research is focused entirely on specific mineral deposits and petroleum fields and is generally undertaken in-house by individual companies or under contract for these companies by universities, CSIRO, or private contract research organisations. Depending on the nature of the research it may be conducted on-site, or at the laboratories of the contracting organisations. Three new Cooperative Research Centres (CRC) were recently created to further expand Australia's research effort in downstream research areas: the Brisbane-based CRC for Mining Technology and Equipment, the Melbourne-based GK Williams CRC for Extractive Metallurgy, and the Perth-based AJ Parker CRC for Hydrometallurgy.

5.2.3 *Environmental R&D*

With heightened awareness of environmental issues surrounding mineral and petroleum resource development, environmental management is becoming an increasingly important aspect of Australia's mineral and petroleum industries. Growing attention is being paid to protection of the surrounding habitat during exploration and mining, and once production has ceased, to the rehabilitation of disturbed areas for long-term ecological stability[2].

Environmental research in the mining and petroleum industries is conducted by individual companies, universities and government agencies, with much of the work being directed

towards specific sites of development or potential development and towards various aspects of site rehabilitation. In the Ecologically Sustainable Development on Mining Working Group's Final Report[2], it was noted that serious gaps in the nation's R&D activity in relation to mining and the environment include deficiencies in baseline knowledge, both ecological and geological, in technical aspects of environmental practices, in management of the knowledge base and the R&D process, and in training, including through research, of both mining and environmental professionals[2].

5.3 SPECIFIC ISSUES

5.3.1 *The contribution that R&D might make in the future to mineral and petroleum resource development in tropical Australia*

In a recent assessment of the mineral prospectivity of Australia this reviewer[3] reviewed the nation's history of mineral discovery over the last 40 years and concluded that there are strong grounds to suggest that Australia's prospectiveness is higher today than it was forty years ago. The grounds for this conclusion include the fact that during the period several new mineral provinces were recognised, new deposits continue to be found at a steady rate, there have been major discoveries in provinces which have been explored actively for up to one hundred years, and there are large prospective areas under cover for which advances in technology now offer opportunities to prospect target zones below the regolith. While these conclusions were made for Australia as a whole, the already well-known mineral wealth of tropical Australia indicates that the conclusions are just as valid for this part of the continent. Therefore it is not unreasonable to assume that many new world class mineral deposits and petroleum accumulations remain to be found in tropical Australia, and that their discovery and development offer excellent potential for economic and social development.

There are several possible impediments to the realising of tropical Australia's full mineral and petroleum potential. Some of these are related to R&D, while others, beyond the scope of this review, are related to issues such as land access and the infrastructure necessary to support development.

Of the various impediments relating directly to R&D, the two most important issues both relate to deficiencies in baseline knowledge. The first is a deficiency in baseline geological knowledge and the second is a deficiency in ecological knowledge.

5.3.2 *Baseline Geological Knowledge*

As noted in the previous section, good regional geological maps are vital to successful exploration. In particular, maps and their associated geoscientific databases enable companies to identify areas likely to have the greatest potential. However, the mapping needs to be continuously updated to take into account new concepts and interpretations, as well as the additional insights provided by geophysics, remote sensing, regolith studies, and drill-hole data. Without the benefit of up-to-date maps, it cannot be expected that an

adequate level of mineral discoveries will continue, nor will data be available to resolve relevant environmental and land use problems1.

Table 1 summarises the age of the present generation of 1:250 000 scale regional geological maps available for tropical Australia. Mapping was allowed to decline dramatically after 1980 and tropical Australia is now in the position where 92% of the map sheets in Queensland and the Northern Territory are more than 12 years old, while in Western Australia the figure is 74%.

TABLE 1

1 250 000 Scale Geological Maps of Tropical Australia
Year of Most Recent Edition

	QLD	NT	WA
1955-60	1	0	0
1960-65	14	25	5
1965-70	20	18	17
1970-75	17	18	4
1975-80	16	11	27
1980-85	4	2	14
1985-90	1	2	4
1990-92	1	2	1
12 years or more since last revision	92%	92%	74%

The National Geoscience Mapping Accord is working towards rectifying this situation and in tropical Australia is presently working on Cape York Peninsula, Queensland, in Arnhem Land, Northern Territory, and in the East Kimberleys, Western Australia. While important new results are being produced in all three areas, the rate of progress is slow, because of limited resources. This problem can be resolved by either increased government spending on geological mapping, new collaborative arrangements between the public and private sectors, greater involvement by universities in the National Geoscience Mapping Accord, or by a combination of all three.

The AGSO Continental Margins Program is also aiming at the provision of framework knowledge relevant to petroleum exploration offshore tropical Australia. Conventional

framework seismic data have been collected in the Arafura Sea Basin and over the deep water margins of the Exmouth Plateau, both frontier areas for petroleum exploration. Rig Seismic has collected deep crustal seismic data to facilitate the understanding of gross basin architecture in the important Carnarvon and Bonaparte Basins. This information on basin architecture can provide a regional understanding within which petroleum explorers may more effectively carry out detailed and targeted exploration. The Continental Margin program has also collected geochemical and geological datasets offshore in tropical Australia to calibrate geochemical methods for possible exploration use and to provide geological ground-truthing for interpretation of seismic data where wells are unavailable. As is the case with the National Geoscience Mapping Accord, progress on the Continental Margins Program is slow because of limited resources.

5.3.3 *Baseline Ecological Knowledge*

Our understanding of tropical ecosystems is still imperfect. North Australia has a wide range of biotopes extending from savannahs to rain forests to mangrove forests. In all of these biotopes we know only the broad distribution of the major species and major survey efforts comparable to the National Geoscience Mapping Accord will be needed to bring the biological information base up to a level where it can be usefully employed in sound land use decision making and resource management.

5.4 ACKNOWLEDGEMENTS

I wish to thank my colleagues in the new Bureau of Resource Sciences for assisting me in the preparation of this brief review, in particular Gordon Battey, Roger Bradbury, and Paul Williamson.

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6 REVIEW OF TOURISM

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6.1 SUMMARY

- Tourism research should adopt a knowledge based platform rather than an advocacy or cautionary platform.

- Tourism research needs full and proper recognition as an area of study. In particular, tourism research fields warrant new classifications in the standardised descriptions of research fields. These classifications should be:

Field of Research:
1300 Tourism
1301 Tourism statistics
1302 Economic issues
1303 Tourist behaviour
1304 Tourism planning and development
1305 Tourism impacts (biophysical and sociocultural)
1306 Tourism marketing
1307 Tourism resource appraisal
1308 Tourism policy analysis

Socio-Economic Objective:

Economic Development
1200 Tourism, leisure and recreation
1201 Sport
1202 Entertainment industries
1203 Tourist attractions and tours
1204 Accommodation and tourism transport
1205 Leisure
1206 Recreation

National Welfare
1208 Environmental presentation and interpretation

Social Development and Community Services
1506 Holiday and tourism objectives

- The Australian Bureau of Statistics (ABS) coding and classification scheme for Australian industries should be re-organised to include tourism as a major contemporary economic system of national importance. The Canadian National Task Force on Tourism Data has provided a model and method for the more effective industrial classification of tourism.

- Recommendation 29(a) of the Ecologically Sustainable Development document on Tourism should be supported: viz. "additional funds be allocated to the Bureau of Tourism Research and other research organisation to strengthen strategic research".

  This is also consistent with the Commonwealth Department of Tourism's National Tourism Strategy (June, 1992) which recommends expanding "the scope and improving the co-ordination and funding of tourism research to provide for more effective policy development and industry planning".

- The 150% tax concession for Research and Development activities should be extended to tourism products and services as a special case where the "experience" of the visitor is validly recognised as the product. This expansion of the definition would permit market research and promotional evaluation to be conducted for tourism businesses.

- The Management Agencies and Authorities for World Heritage Areas in Northern Australia be approached with a view to funding Ph.D. tourism scholarships.

- Co-operative endeavours between tourism researchers, government agencies and tourism industry personnel such as currently constructed for the Cooperative Research Centres applications be reviewed as a mechanism for funding tourism research.

- The content of tourism research should be expanded beyond a narrowly conceived statistics base to include a set of research areas pertaining to quality tourism (including satisfaction studies, planning and resource appraisal models, ecotourism, market segmentation studies).

- National data bases be made more widely available at minimal cost to tourism researchers for detailed secondary analysis.

- ASTEC should recommend the creation of awards and incentives for quality tourism research publications or efforts. The incentives and the feedback such competitions engender could play a role in upgrading the amount and quality of research work on tropical Australia.

- ASTEC should support the internationalisation of tropical Australian tourism research. This requires tourism research in source countries as well as studies of international visitors in Australia.

- ASTEC should approach funding agencies (including the Australian International Development Assistance Bureau) to develop and host specialist tourism research training courses and programs in tropical Australia at Australian universities.

6.2 INTRODUCTION

Tourism the phenomenon is undoubtedly a glamorous human activity. The whole tourism system, which is effectively the integration of transport, accommodation, tourist attractions, and support services enables individuals to experience and luxuriate in the non-work world. In tropical Australia the glamour is enhanced as visitors experience a multisensory cornucopia of world heritage environments, sheer physical space and increasingly sophisticated tropical communities.

Tourism the research and development activity is a much more drab human activity. The whole tourism system, this integration of transport, accommodation, tourist attractions and community support services, demands research and development attention but the experience to date is that is can be a frustrating world in which to work. In tropical Australia the pressing volume of visitors to the Great Barrier Reef, to Uluru, Kakadu and the Daintree has seen some significant tourism research initiatives but the sheer volume of work needed is increasingly daunting.

Promotion and hype are the bylines for tourism the phenomenon. Our cognitive maps of the world, and increasingly of tropical Australia, are inscribed with the images of the tourism media - the Great Barrier Reef is Quicksilver, the Tully Gorge is Raging Thunder rafting, Cape Tribulation is the backpacker's world, Broome is Lord McAlpine's resort and Kakadu is Linda Kozlowski being rescued from *Crocydlus porosus* by Paul Hogan. Tourism promotion personnel are ubiquitous and the media title of tourism expert is easily earned in this field.

Promotion and hype bypass tourism research. The very necessary fundamental studies on resource appraisal, monitoring planning and impact assessment are too pedestrian for popular attention.

Additionally, our cognitive maps of the research world still struggle with how to classify tourism researchers. Like a newly formed football team, tourism scholars from diverse clubs and backgrounds are struggling together to perform and build a viable reputation and image. At best there are a few feral academics, some public service personnel and a growing number of cost conscious consultants.

Tourism, the glamorous phenomenon, attracts political and media attention chiefly through its role as an economic stimulant to local economics. Both separately and in combination with other industries tourism can be a major economic development tool (Gunn, 1988). Professor Harris' economic overview of Northern Australia recognises, in part, tourism's role in Northern Australia. His estimate of tourism's importance is, however, somewhat

understated as it did not include data from the Major Survey Research Program (now) the Queensland Visitor Survey or the Visiting Friends and Relatives sector. A conservative estimate of the importance of this domestic market sub-sector (up to 50% of visitors in key regions) even though they have lower daily expenditure than commercial visitors (one third of the value), would add 15% to the tourism sector. Irrespective of the total size of the tourism phenomenon, its central role in certain key areas of the North at present is undeniable and its future role in many more areas is attested to by the volume of building proposals sitting on the tables of Northern Australian local councils and shires.

In addition to the usual economic justification for considering tourism, there are significant social and environmental benefits from a well planned and managed tourism system. It has been argued with examples from the Antarctic to Addis Ababa that tourism can change visitor and host attitudes towards environmental conservation and protection since direct experience with environments is more convincing than endless save the planet campaigns. The positive efforts of the Cassowary Conservation Consultative Committee at Mission Beach is a community led response to human pressures including tourism. Controlled tourism activities have been demonstrated to have positive social benefits to host communities and visitors alike and the blending of social customs and traditions to deal with tourism can be enriching for both parties. The Kuranda based Japukai operation is a significant social tourism success story for Northern Australia.

6.3 TYPES OF TOURISM RESEARCH

Jafar Jafari, the editor of the world's most respected tourism journal, the *Annals of Tourism Research*, has a succinct category scheme for various types of tourism research. It is useful to review Jafari's scheme to assist in the process of evaluating current and predicting the future of Northern Australian tourism research.

Jafari (1990) defines four platforms of tourism research:

1. The Advocacy Platform
   - Writing in this mould preaches the economic good news of tourism. It is often the product of pro-tourism government lobby groups, development agencies or consultants.

2. The Cautionary Platform
   - Reacting against the hype of the advocate, writers in the cautionary platform point to the overestimates of tourism's economic effects, the difficulties of defining it as an industry, and the negative social and environmental impacts of tourism. Political scientists, geographers, pro-conservation groups, anthropologists and traditional economists have sometimes contributed to this platform. Consultants rarely adopt this platform.

3. The Adaptive Platform
   - A relatively slight body of work which attempts to marry advocacy and cautionary platforms in management or action oriented writing. A good Australian example would be the Ecologically Sustainable Development Working Groups Final Report on Tourism, Commonwealth Government of Australia, 1991.

4. The Knowledge Based Platform
   - Since 1980 the rapid development of tourism as a unique social and environmental science study area with its own questions, problems and methods has emerged. Writers in this group are concerned less with the politics of tourism and more with how the tourism system - markets, demand, tourism products, planning issues - can be studied and understood. Originality and contributions to knowledge are the hallmarks of the writings in this platform.

The Northern Australian tourism research contribution, largely through James Cook University has been strong in areas 3 and 4. To cite a few examples: University research has contributed to the Commonwealth Ecologically Sustainable Development (ESD) document on Tourism, to the Wet Tropics Strategic Directions, plus numerous management issues in North Queensland national parks and to the Port Douglas Planning Study in category 3 while in category 4 there is developing interest in planning models such as STAR (Structure of Tourist Activities for Regions), IMREST (a model to plan for and identify sustainable resources for regions), as well as the development of conceptual approaches such as mindfulness, travel motivation and scenic quality assessments. The concentration of attention in platforms 3 and 4 has not received wide distribution in the local tourism industry (which is usually more concerned with tourism politics and the advocacy platform) nor has it necessarily pleased conservation groups (which are usually more exclusively concerned with limiting the ravages of tourism in the cautionary platform). Nevertheless, strategically, the adaptancy and knowledge based platforms represent a critical long term future planning base for Northern Australian tourism and should be fully encouraged and supported.

It is the knowledge based platform which has and will give rise to planning, monitoring and assessment for tourist behaviour and tourism systems in our tropical environments. Whether it be reef or rainforest, rafting or rock collecting, knowledge based tourism research holds the future for viable mass and ecotourist management.

6.4 MAJOR AREAS OF TOURISM RESEARCH

Five key items are identified to encourage a knowledge based platform for Northern Australian tourism research.

6.4.1 *Recognition of tourism and tourism research*

It is rare that tourism research is properly recognised or identified in the Australian research context. It is ironic, for example, that the Compendium of Northern Australian Research which ASTEC has commissioned uses the Australian Bureau of Statistics system of research classification which has:

- fields of research classification which do not mention tourism
- socio-economic classifications (as used by ABS) which do not include tourism
- institution data derived from the first survey which classifies some of my own consumer behaviour research as "ecological".

It is highly desirable to recommend full and proper classification of tourism research - the Australian Research Council should take note of this point as well as ASTEC.

I propose the following classifications.

Field of Research: 1300 Tourism
- 1301 Tourism statistics
- 1302 Economic issues
- 1303 Tourist behaviour
- 1304 Tourism planning and development
- 1305 Tourism impacts (biophysical and sociocultural)
- 1306 Tourism marketing
- 1307 Tourism resource appraisal
- 1308 Tourism policy analysis

Socio-Economic Objective

Economic Development
- 1200 Tourism, leisure and recreation
- 1201 Sport
- 1202 Entertainment industries
- 1203 Tourist attractions and tours
- 1204 Accommodation and tourism transport
- 1205 Leisure
- 1206 Recreation

National Welfare
- 1208 Environmental presentation and interpretation

Social Development and Community Services
- 1506 Holiday and tourism objectives

Formal recognition that tourism exists as a scholarly area of study is a beginning.

A parallel classification problem exists with the collection of data relating to the tourism system. The phrase "the tourism industry" has been deliberately avoided in this presentation until this point. The delayed introduction of the term in this presentation serves to highlight the inadequate classification of tourism in the Australian Bureau of Statistics (ABS) data on industries. Indeed, in the Northern Australian Economic Study, tourism is forced into a curious kind of adjunct category because it is not classified in the 12 basic industrial codes.

A major recommendation from this review for the recognition of tourism is to shake up the moribund post World War II industrial classification still in use. It is time for the ABS to rethink its coding scheme for Australian industries, update the coding scheme and align it with contemporary industrial and economic activity. Such a scheme needs to take into account a proportional or fuzzy set theoretical approach to industry classification such that an activity may be proportionally counted as being involved in serving tourists. Much can be learned from international efforts to classify tourism and measure its effects. The Canadian National Task Force on tourism advocates a two tier system for tourism businesses. The Standard Industrial Classification used in Canada is sensitive to the percentage of revenue from tourism activity which forms a part of other business concerns.

It is not, however, the purpose of this paper to devise the details of the re-classification. Instead it is simply imperative to highlight the need for better category definition and to lay to rest the ghost that tourism is not a proper industry because it is not classified as such in the core statistics. This pedantic and semantic quibble is a little like the eighteenth century taxonomic dilemma of how to classify the platypus - it was not a duck or a fish but it was certainly alive, well and reproducing. Let us expand our research consciousness to give tourism the system a similar and proper taxonomic recognition.

6.4.2 *Funding of tourism research*

Finding resources to develop the study of tourism is a second major issue.

Traditional methods (like the Australian Research Council) are inadequate. Not only does a measure of prejudice exist towards a new area of inquiry but there are few established scholars to review research applications and to pursue the cause of tourism research. There is no industry equivalent of, say, the Meat and Livestock Corporation, to fund research.

The Commonwealth Government funds the Bureau of Tourism Research to collect the "big picture", that is, to provide a descriptive overview of tourism research. The Queensland and Northern Territory governments fund a survey of commercial accommodation visitors - formerly known as the Major Survey Research Project. This data collection exercise is now termed the Queensland Visitor Survey. It is currently conducted by the National Centre for Studies in Travel and Tourism (NCSTT) a commercial consultancy arm in

tourism of the James Cook University. The Queensland Tourist and Travel Corporation funds the Survey and owns it, but inquiries concerning the data are directed to staff of the NCSTT. The Queensland Tourist and Travel Corporation has funded occasional studies of special markets such as the visiting friends and relatives sector and backpackers. Some consulting agencies such as Howarth and Howarth produce their own accommodation occupancy statistics.

The general picture of tourism research funding is that almost all of the work conducted is oriented towards the collecting of broad statistical information and, with the exception of the Bureau of Tourism Research, the material is "owned" by consulting houses and dispersed for the commercial advantages of those organisations.

There is no tradition of a research organisation or body to fund non consultancy tourism research and no record of PhD scholarships, continuing professional society endowments or similar sources of funds. The Australian Tourism Industry Association together with the Queensland Tourist and Travel Corporation (QTTC) and the Australian Federation of Travel Agents did provide some start up money for a Chair of Tourism at James Cook University and remain involved through their other links. Such tourism industry initiatives do not, however, currently provide any research funding for fundamental or basic research which in tourism is the area of greatest need. Without a fundamental research network there can be no development of new models, methods and concepts. The consultancy process fails significantly to generate new approaches due to a recipe like formula for conducting specific studies as well as cost and time limitations on the development of ideas.

The 1991 Ecologically Sustainable Development (ESD) document recommends (Recommendation 29(a)):

> *that additional funds be allocated to the Bureau of Tourism Research and other research organisations to strengthen strategic research.*

Further, the ESD document proposes a "mechanism" for "opening up available research funds competitively" analogous to the Rural Industry and Development Corporation and their resources-based Land and Water Resources Resource and Development Corporation.

The view that government funds, at the Commonwealth level, be opened up for competitive research applications would benefit Northern Australia. There are significant tourism issues in Northern Australia (and some significant tourism researchers) and funds could be expected to flow to Northern Australia rather than simply expanding the operation of the Bureau of Tourism Research. Indeed the view that "additional funds" be allocated is perhaps clearest recognition in the ESD. document of the inadequate role of tourism research currently being conducted by the Bureau of Tourism Research.

This view is further strengthened in the Commonwealth Department of Tourism's *National Tourism Strategy*, June 1992, which recommends continuously reviewing the overall

structure and resourcing of tourism research and improving the scope and coordination of tourism research for policy and industry planning.

"Industry" funding of research is a more complicated issue. A major limiting factor for encouraging industry contribution to research is the fact that most tourism studies do not qualify for the 150% tax rebate for research and development. Social Science studies and consumer or market research are explicitly excluded from current taxation guidelines. Again, this legislation is misconceived and ill-directed when applied to tourism. For many businesses in tourism their "product" is the experience they offer to the visitor. In order to develop, enhance and provide quality to their consumers many such businesses would like to market test and evaluate their product. Yet, the present procedures disallow the tax rebate, presumably because the tourism product was not considered when the guidelines were constructed.

A change to the guidelines would substantially benefit tourism research throughout Australia. It would be of particular benefit to ecotourism companies using reef and rainforest settings which want to trial new interpretive and educational techniques for their guests. Additionally the testing of technological innovations (tourism radio, new diving or adventure tourism equipment) could be trialled more effectively if research was tax deductible.

The training and education of tourism researchers is now underway at the Northern Territory University and James Cook University. Regrettably there are no Ph.D. scholarships from industry or government with a special tourism emphasis. The World Heritage Areas and their management authorities or agencies could examine the partnership process for fostering such research now that explicit four year Honours graduates with research training are available to examine economic, social, environmental and community related tourism issues.

There are two major Co-operative Research Centre (CRC) applications involving the tourism industry and tourism research being processed at the time of writing this report. If successful, such university-industry-government agency co-operative research efforts would break new ground in Australian tourism research. The possibilities for such co-operative endeavours with tourism as a focus warrants ASTEC support. Irrespective of the success of the CRC initiatives in reef and rainforest research, the links and mechanisms for co-operation put in place to serve tourism understanding, business and management may be vehicles for other tourism funding attempts which ASTEC should support.

6.4.3 *The content of tourism research*

The tourism research areas which currently dominate the agenda in tropical Australia can be classified as 1301 Tourism statistics. The critical economic issues papers, including the document Economic Strategy for Northern Australia, rely solely on this material in their presentation of the importance and future of tourism. In addition to the issue of the quality of the existing tourism data, this reliance on broad tourism statistics alone to interpret

tropical Australia's tourism potential is very dangerous and limiting. It assumes that the past will neatly predict the future, and all the best forecasting models in tourism deny this neat temporal equation.

The Department of Tourism at James Cook University has a strategic plan which portrays a different research agenda and which may be used more generally to describe the needs for tourism research content in the North.

There are a number of organisations in Australia which conduct broad surveys of economic performance and tourism development. The Department of Tourism is more interested in developing hypothetico-deductive approaches to tourism studies - the systematic, theoretically driven and data tested approach to research. Accordingly it will focus on the more detailed innovative and less descriptive end of the tourism research spectrum. Particular areas of interest include community attitudes to tourism, boutique accommodation, physical impacts of tourism, visitor centres, the tourism-wildlife relationship, consumer relations to marketing, cultural tourism, ecotourism, specialist market segments, satisfaction studies, tourist motivation, aboriginal tourism strategies, the development and evaluation of interpretation for tourists and tourism planning and resource appraisal models.

There are very few researchers in Australia working on these issues which cumulatively amount to the development of a quality tourism emphasis. Much lip-service is paid to studies of satisfaction, motivation, interpretation, sensitive tourism and community considerations. Yet, there is little systematic Australian work in these areas. Recently the Great Barrier Reef Marine Park Authority have made some appointments in these areas but most management agencies, staffed largely by biological scientists, seem reluctant to deal with these pressing people issues. Such an orientation is consistent with the Australian Tourism Industry Association's goals for tourism research and reflects Commonwealth Government and Sustainable Tourism calls for research development. At the core of these approaches is the issue of assessing visitors and their experiences while retaining a focus on environmental protection and business profitability.

These perspectives are also in line with the Ecologically Sustainable Development document on tourism research, notably recommendation 29(b). The Working Group recommends

that the tourism industry provides funding to support additional work on the nature and structure of the industry beyond the collection and analysis of visitor data and to include the development of models which include economic linkages within the industry and between tourism and other industries.

This report recommends that ASTEC should support the spread of tourism research into the categories listed in Section 1, notably

1302 Economic issues
1303 Tourist behaviour
1304 Tourism planning and development
1305 Tourism impacts (biophysical and sociocultural)
1306 Tourism marketing
1307 Tourism resource appraisal.
1308 Tourism policy analysis

6.4.4 *Quality control of tourism research*

The standard of much of the work done by consultancy houses under the title of tourism research is poor. The prime task is to please the client and often this may mean meeting political agendas and providing supposedly "independent" assessments of tourism impacts and development opportunities. No formal qualifications are required of individuals setting themselves up as "tourism consultants" and until recently no University world of scholars existed who might critically evaluate the quality of the work in terms of its concepts, research design or statistical competence.

To a remarkable degree, consultants have retained the power and ownership over data submitted to organisations such as the Queensland Tourist and Travel Corporation (QTTC) which has no formal research section and few staff capable of checking the quality and reliability of research material.

The universities have much to contribute in the "quality control" of tourism research. Australia's only fully refereed tourism journal, *The Journal of Tourism Studies*, is produced by the Department of Tourism in Townsville.

ASTEC should support all attempts to upgrade the peer appraisal of consultancy research, academic research and promote the developing professionalism of tourism as a study area. Awards and incentives for quality tourism researchers should be created.

In particular the availability of data bases for Northern Australian tourism studies needs to be addressed. Currently there is no access to QTTC data bases or Bureau of Tourism (BTR) data bases for further analysis of tourism trends and issues. These public data bases should be more readily available at minimal cost to study centres and researchers to provide planning information for tourism.

Additionally tourism research by the BTR and the QTTC has not been conceived with the research community as a potential user. It is strongly recommended that research users, that is those who wish to conduct secondary or more refined analysis of existing data, be included in the research planning process. In effect this amounts to including members of Platform 4 in Jafari's terminology with members of Platform 1 in the tourism research generation process.

6.4.5 *International perspective on tourism research*

Too many documents on Northern Australian research lack an international perspective. Many lack a national perspective. Tourism development, management issues, marketing and the style of tourism developing internationally must be fully considered when planning and managing Northern Australian tourism. Realisation of the potential of Australia's North for the Japanese and other Asian markets as well as for other international visitors requires research in the source countries, not just in Australia. This research needs to take account of market trends and existing tourism products in those home communities to maintain the international competitiveness of Australian tourism. Much more effort should be spent on recruiting Asian students to Northern Australian Universities. James Cook University is the only Australasian university elected by the World Tourism Organisation to be a member of the "12" World Tourism Universities. This recognition stems from the publishing efforts of the Department and its successful South Pacific Fellowship program. A rich future of international collaboration could be achieved through ASTEC recommending specialist tourism research training programs to funding agencies (including the Australian International Development Assistance Bureau.

ASTEC should strongly support the internationalisation of Northern Australia tourism research both through student and staff research and through the executive development and training options for South Pacific/Asian tourism personnel.

6.5 CONCLUSION

There are many ambitious targets for tropical Australian tourism which are being set by the State and Commonwealth promotion bodies. Meanwhile local shires and councils and management agencies are struggling to preserve their tourism resources and the quality of community life.

Tourism, described by the Prime Minister as one of the glittering economic stars for contemporary Australia will be a self imploding star without the contribution of a well funded and sophisticated tourism research infrastructure.

7 TRANSPORT, COMMUNICATION AND ACCESS ISSUES IN TROPICAL AUSTRALIA

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7.1 INTRODUCTION

For the purposes of this paper the physical infrastructure is taken to mean the physical facilities required for the various modes of transport (road, rail, sea and air), communications, and water supply.

These infrastructure facilities are primarily provided as a support mechanism, for and arising from, other types of economic and social development. They typically provide support for the tourism, mining, defence and primary industry sectors. They also serve the commercial needs associated with an emerging manufacturing and trading sector and to the education, health and information service industries.

However, an important and sometimes unrecognised role of the physical infrastructure is to provide access and services to small and remote communities scattered throughout northern Australia. The infrastructure that supports these communities can rarely be justified on pure economic grounds. This leads us to the concept of community service obligations (CSO's) and of course, who should provide the funding to cover the associated costs.

While the broader issue of CSO's is outside the scope of this paper, recognition of the concept is necessary to understand the nature of the existing infrastructure and the role it plays in delivering the social justice and equity objectives of the various levels of government.

A further fundamental aspect of the physical infrastructure is that it is largely provided and funded initially by governments, although cost recovery is an objective which is pursued to different degrees by a number of government authorities. This situation generally reflects the "lumpy" nature of infrastructure investment and the long life of many infrastructure components means an investment is often made for future generations. The exceptions to this are usually found in large mining developments where whole towns, road, rail and power supplies are constructed to serve these projects which are

commercially viable in the short to medium term. The Pilbara region of Western Australia provides a clear example of this situation.

The cost of providing infrastructure to an individual development in remote areas can be a significant component of the final product cost and may lead to a conclusion to defer the project. This constraint has been recognised in the Carpentaria mineral region extending from Borroloola in the Northern Territory through to areas south of Mt Isa. As a result the Commonwealth, Queensland and Northern Territory governments together with the six major mining companies with interests in the area have combined to fund a study which may identify those issues where project synergy may lead to greater economies of scale and commercial viability. Clearly the physical infrastructure will be a significant component of this study which is due to be completed later this year.

To gain an appreciation of the role that research and development can play in the expansion of the physical infrastructure it is necessary to look in more detail at the various components.

7.2 THE ROAD NETWORK

The road network throughout northern Australia can generally be described at three levels which post 1993/94, will also correspond to the responsibility for funding and control. These are the National Highway System (NHS); State arterial roads; and local roads.

The NHS was established in 1974 for a number of purposes which are still largely relevant today. They include: encouraging and contributing to trade and commerce, overseas and among States; assisting industry located in major centres of population to be complementary to industry located in neighbouring major centres; reducing significantly transport costs of the products of rural and/or secondary industry, between points of production or points of export or consumption; providing for long distance movement associated with recreation and tourism; and improving movement between defence production centres, defence supply and storage locations, and defence establishments generally.

In northern Australia the NHS forms the spine of the network and provides for the interstate links connecting Australia's major cities as well as serving a role as the major inter-regional links. These highways are currently funded by the Commonwealth and this will continue in the foreseeable future. The construction and maintenance activities are however currently undertaken by the road authorities in Western Australia, Northern Territory and Queensland.

The State arterial roads provide regional access and in some cases secondary interstate links. These are largely funded by the State and Territory governments with some Commonwealth funding assistance which will cease in December 1993. This financial assistance will be replaced by the distribution of $350M pa as untied grants from January 1994.

Local roads are largely the responsibility of local government bodies which also receive some financial assistance from the State and Territory governments for this purpose. Unlike Queensland and Western Australia large areas of the Northern Territory are not incorporated in a local government body and the roads in these areas are managed by the Territory Government. These roads collect and feed local traffic from regional areas into the arterial and NHS network and often function as the sole road access for small (mainly Aboriginal) communities and individual properties throughout the vast interior of northern Australia.

The standard of the road network varies considerably both within the three categories described above and throughout northern Australia.

Obviously traffic volume is a major factor and this is reflected by the large proportion of gravelled and dirt roads. Of the 29,000 km of roads in the Northern Territory, about 23% are sealed, 40% gravelled/formed and the remaining 37% are unformed dirt. The replacement value of the Territory road network is estimated at approximately $1.6 billion. Expenditues requirements on Queensland declared road networks to the year 2001 are estimated to be about $10 billion. Current annual growth in vehicle kilometres travelled in the Queensland tropical zone is about 4.5%.

7.2.1 *Research and Technology*

To make the transport infrastructure safe, reliable and durable, requires considerable research and development to adopt technology to the tropical zone. Risks are involved in rectifying or constructing the transport infrastructure without the proper R&D support work.

The Commonwealth State and Territory governments are shareholders and financial supporters of the Australian Road Research Board (ARRB). Additionally AUSTROADS, an incorporated body consisting of the Commonwealth and State/ Territory road and traffic authorities undertakes various studies aimed at improving the efficiency of using, constructing and maintaining the road network in Australia. There is a close connection between AUSTROADS and ARRB and this ensures that road research and development efforts are co-ordinated and directed towards solving particular problems.

Through these organisations Australian researchers have access to international research efforts undertaken under the auspices of the Permanent International Association of Road Congress (PIARC) and the Road Engineering Association of Asia and Australasia (REAAA). While it is fair to say that small road authorities do not need to duplicate this effort there is a risk that problems affecting remote areas, where economic benefits may be small, will not be addressed.

It is important to give high attention to a number of factors in the Australian tropical zone within the next decade. They include the provision of new major transport infrastructures required in growing urban areas and future industrial areas; preserving existing transport

infrastructures; providing a better transport infrastructure for the transportation of goods; transport safety;greenhouse effects, traffic noise and air pollution is of continuing concern within the community.

The physical and economic benefits which flow from R&D investments in the transport industry to accrue through: reduced transport costs; a reduction in accidents and safer transport infrastructure; more durable structures;improved value for money spent on transport; operational efficiencies; the effective introduction of new technology; reduced travel time; the provision of environmentally friendly transport infrastructure.

In the 1991/92 financial year the Queensland Department of Transport Research conducted more than 56 projects under the R&D strategy and expenditure was about $3.4m. The majority of R&D resources was spent to achieve a safe, reliable and durable transport infrastructure. All these R&D activities are relevant to the tropical zone in Queensland. It has been shown that the benefit/cost ratio for the Queensland Department of Transport R&D projects is up to 80:1.

The R&D projects are aimed at achieving 13 strategic objectives, such as rehabilitation and maintenance technology; serviceability and durability of infrastructure; measurement and testing technology; economic structures; life cycle management and testing technology; efficient traffic management; sustainable environmental practices; new and improved materials; improved planning, design and construction; improved plant and its usage; training and development and technology transfer; and improved management systems.

To reduce development costs of transport infrastructure it is essential to carry out R&D works such as: finding low cost materials; effective construction and maintenance methods; increased durability of structures; the efficient use of low standard marginal local materials; marine technology in remote ports; effects of saturated road subgrade in tropical areas; reduction of traffic noise and air pollution; design of plant and equipment; and efficient and effective survey application.

The Northern Territory Government does not undertake any basic research on road engineering. Rather it seeks to identify those areas of research undertaken by others in Australia which have potential application in the Territory and experiments with applications which may in turn lead to further development and improvement of the original research. The same, but to a lesser extent, is probably true for Western Australia and Queensland.

A major effort in recent years has involved pavement research using the accelerated load facility which has examined the use and performance of various pavement materials including some of those which are used in northern Australia.

It is important to understand that roads in the north are primarily constructed using natural gravels and soils which by their very nature vary considerably in quality and durability. The high costs of construction and maintenance in remote areas suggest that if the use of

these materials could be improved then substantial upgrading of year round access would be achieved. A major problem in the outback is the level of dust on gravel and dirt roads. This not only produces adverse environmental and safety effects but also creates health problems for adjoining residents in many small communities.

Sealing of all these roads is not financially possible and research efforts to improve the performance and reduce the cost of dust suppressants would be a useful contribution to reducing these problems. It is not often understood that sealing a road without sufficient traffic will only increase long term maintenance costs and further reduce the ability of governments to provide a better road system.

A number of other products arising from previous research and development are now becoming more common in road construction.

Geotextile fabrics are now being used and tested in road construction in a number of climatic and soil conditions found throughout the north. They are used as a load spreader, where the gravel or fill is laid on top of the geotextile material and also as a sealant in black soil and expansive clays which are common throughout the north.

Polymer modified binders in bitumen are being used to increase the viscosity of binders and improve stone retention capability as well as to control cracking by allowing the binders to shrink and expand. These are now being used on all reseals throughout the Northern Territory.

Bitumen emulsion stabilisation of gravel pavement is also being undertaken in low plasticity gravels, to improve stone binding in the material and hence reduce the tendency to corrugate. It is used on gravel roads and on shoulders of sealed roads and should lead to improved and safer road surfaces.

It is apparent that research and development of road engineering in northern Australia largely relates to the application and further development of research conducted elsewhere in Australia and internationally.

7.3 AVIATION

Given the geography of the region, there is a great dependency on air transport in tropical Australia. For example, there are a number of island communities which have a need for a mainland connection; remote areas where road links are poor and possibly non existent in the wet season; and the distance factor itself - it is so much faster to go by air rather than by road or coastal barge.

For example, there is a minimum of 400 (probably closer to 500) aerodromes, in the Northern Territory alone. The Northern Territory Government has a maintenance responsibility for 177 of these aerodromes (licensed aerodromes and aircraft landing areas) and most of these are in the Top End. A major problem is the continuous maintenance of

these aerodromes whether they be on the mainland or island communities. The cost of establishment for any contractor undertaking major maintenance can be up to 30% of the total cost of the job. If materials have to be imported by barge or land transport this further increases the cost.

Most runway surfaces are gravel or natural surfaces. Many of these airstrips provide the only year round or available wet season access to the community and are an essential part of the community infrastructure. As with remote area road networks, the construction and maintenance technology has not substantially changed in decades and the inherent problems remain the same. The research and solutions required are in terms of materials and pavements able to withstand climatic extremes of wet and dry and the cost effectiveness of these materials.

To overcome problems of airstrips being too slick and/or eroded during the wet season or too eroded by wind in the dry, and because of the high cost of sealing airstrips, research into the use of binding agents is being undertaken. Paczyme (PZ1) is a multi-enzyme product which alters the soil's chemical and physical properties. It is used for stabilisation of clay soils and results in increased strength, durability and compaction densities. It is being trialed in the Northern Territory on a number of Aboriginal community airstrips. The longest has been at Peppimenarti airstrip which now has now been tested over two wet seasons. The main benefits are seen to be in terms of: cost (it is 10% of the cost of sealing the strip); environmental safety (it is non toxic and does not leach out); simplicity (it is just added to the water truck that waters down the strip and compacted); comparatively long life and maintenance (just rip up the strip, add more water and recompact).

It is now seen as an attractive alternative to sealing on low traffic density airstrips in remote areas, where only basic equipment is readily available. The extension of this application into rural roads is now being considered.

7.4 RAILWAYS

The current termination of rail links in the north at Mt Isa and Alice Springs is seen by many as a major omission in the north's physical infrastructure. The rail link between Alice Springs and Darwin is seen by the Northern Territory Government as an essential part of the infrastructure to substantially contribute to the development of northern Australia. As part of the national rail network it would allow for the development of Darwin as a nodal port and landbridge for connecting Australia to Asia and Europe. It would open opportunities for other economic developments and assist in shifting Australia's long term focus to the north.

In addition to the short term beneficial economic impact that construction of the railway would have on the national economy the long term benefits for the expanding defence role in the north are substantial.

Research and development activities which reduce the cost of constructing, maintaining and operating railways would further increase the possibility that the north-south rail link will be constructed.

7.5 PORTS AND SHIPPING

Australia's northern coastline is characterised by shallow waters, offshore reefs, tropical cyclones and in the north and west, by high tidal variations. Any of these is a disadvantage but in combination they represent a formidable challenge. These factors contribute to the high costs of constructing and maintaining port facilities and to the shipping companies which use them.

As an example, the proposed McArthur River Mine is based on export of its concentrates via shipping using the Gulf of Carpentaria. However, the shallow waters require that the product be barged out to ships at anchor in deep water and even that will require considerable inshore dredging. These cost problems with the provision of infrastructure are a further impediment to the development of our natural resources.

The application of material handling research and development may assist in reducing these disadvantages. Technological improvements in navigation systems and weather forecasting are already providing benefits and further research in these areas will no doubt be welcomed by the shipping industry.

7.6 WATER RESOURCE AND WATER SUPPLY SYSTEMS

The development and supply of water is a fundamental and often overlooked element of the physical infrastructure. Northern Australia experiences some of the heaviest rainfall in Australia and yet much of that runs off unused into the surrounding ocean. The highly seasonal nature of this rainfall requires the construction of major dams to store water and this can only be justified when warranted by continuous and large demands. As a result many communities in northern Australia are supplied solely or in part from groundwater sources.

In the Northern Territory the past few decades have seen extensive programs aimed at identifying surface and groundwater supplies. Considerable research and development of groundwater investigation techniques has resulted from this activity and may well have application in similar overseas environments.

While most Territory communities have an adequate quantity of water there are many where chemical quality does not meet international and national water quality goals. The construction of expensive and difficult to maintain water treatment plants is not an appropriate answer for remote areas where skilled technicians are few and far between. Efforts are now concentrated on ensuring that the water supply system is closed so that at least bacteriological contamination is eliminated. These systems have potential application throughout Asia.

Nonetheless, there remains the possibility that further research may provide an effective and simple means of achieving desirable chemical water quality standards. However, current efforts in this area of research are limited and overshadowed by the water quality needs of our major cities.

In any case, the adoption of idealistic national water quality goals must be tempered by the practicalities of living and working in remote areas and research into the long term health effects of using marginal water supplies needs to continue.

7.7 COMMUNICATION SYSTEMS

The application of research and development in these systems has had a dramatic impact not only on the economic development of northern Australia but also on the standard of living. People living throughout the north, even in the most remote of locations, now have access to television, radio and telephone services at a standard not contemplated a decade ago.

In setting up a telecommunications infrastructure in tropical Australia and successfully overcoming these testing conditions, Australia has gained considerable amounts of knowledge and expertise. In the process, we have also proved through everyday use that Australian technology works, and works well, in a tropical region. This is one of Australia's greatest assets, and is of major importance in developing our export trade. Over the years, because of the application of telecommunications technology, Telecom Australia (International) has successfully secured more than 200 overseas contracts, many involving expertise relating to remote area communications.

In particular Australia's research and experience in the application of solar photovoltaic systems has received considerable exposure in South East Asia. Notably, Australia has developed major training courses run by the United Nations Economic and Social Commission for Asia and the Pacific. These courses, about the application of solar technology to power communications equipment, were run in several South East Asian countries including Vietnam, Laos, Pakistan, Indonesia and China.

7.8 RESEARCH AND TECHNOLOGY ISSUES (COMMUNICATION)

7.8.1 *Reliability*

The reliability of equipment and materials used in telecommunications in tropical Australia is of prime importance for two reasons. Firstly, because of the remote locations of many of our installations, and secondly because of the harsh environmental conditions under which it must work.

There are several projects underway testing the reliability of equipment under such conditions. Of major importance is the powering of our installations in remote areas. Solar energy plays a key role in providing energy for remote area telecommunication

installations and Australia is the single largest commercial user of solar technology in the world. The need to develop photovoltaic technology in remote regions, and Australia's ideal testing grounds, have helped put Australia ahead of the world in the application of solar technology.

There are two test sites in Northern Queensland which have been in operation for more than a decade. These are evaluating the performance and reliability of solar modules in the harsh environment, with particular attention being paid to the effects of high temperatures and humidity.

Studies on batteries are also underway, which are an essential part of photovoltaic systems. They are used to store energy on sunny days for use at night and during inclement weather. Unfortunately, the high temperatures have a detrimental impact on the internal chemistry of the batteries. The range of battery technologies include valve regulated lead acid and nickel cadmium batteries for use in tropical environments. The level of solar radiation and its daily and seasonal variations is also obviously an integral part of an overall power system design. The optimum times to harness solar power has also been studied as the sun moves from the northern to southern sky in tropical areas.

7.8.2 *Lightning*

Another significant feature of tropical Australia is lightning. Many parts of tropical Australia experience frequent electrical storms. These can cause havoc to telecommunications services, damaging equipment, and occasionally, causing injury to users. Much successful research has already been channelled into this are, but as new technologies - such as the optical fibre network - develop, so must new practices and techniques must be invented to deal with these problems. The aim is to protect users and equipment, as well as maintaining service continuity, by finding ways to suppress the impact of lightning strikes on our telecommunications network.

A major research project is now underway in selected locations around Australia including Darwin and Cairns which will identify charges on the network due to lightning strikes. Measurements are being made of the parameters such as the frequency, peak voltages and currents, and duration surges.

7.8.3 *Materials*

The types of materials, used in the telecommunications network is another area requiring careful consideration and research. Temperature extremes and high levels of ultra-violet radiation can cause rapid degradation of plastics.

Insect damage is also significant, as they can attack the plastic jacketed cables. Experiments are now underway near Darwin at a site operated by the CSIRO to determine the resistance of various plastics to termites.

Paints also play a vital role in protecting many of the buildings and structures, such as antenna masts, in a corrosive tropical environment. Samples of plastics and paints are now undergoing exposure tests in Northern Queensland, as well as being subjected to laboratory tests at Research Laboratories in Melbourne.

7.8.4 *Electronics*

A fourth area of research focuses on the reliability of the electronics. Electronic equipment is susceptible to faltering under high levels of humidity. Connectors for example, which rely on metal to metal contact, may corrode and thereby introduce undesirable electrical resistance.

The high electrical insulation between components and printed tracks in circuit boards may be reduced by moisture on the board, leading to breakdown. Over a longer term, corrosion might also occur on these components and tracks.

Australia has extensive facilities for assessing components and equipment under simulated conditions of dry and damp heat, and corrosive atmospheres. This has led to the development of "tropicalised" versions of certain items of equipment.

7.8.5 *Thermal Design*

The final major area of research involving tropical Australia is in the thermal design of equipment housing. The region's high temperatures have challenged Australia to develop innovative techniques for cooling its may equipment shelters. Over the past decade, a number of shelters have been designed to use passive cooling, employing such methods as phase-change materials, thermal rock beds and air flow technologies.

Passive cooling has proved far superior to air conditioning plans, which are both energy inefficient and unreliable. Trials have been conducted evaluating a new active cooling equipment cabinet at Alice Springs and Innisfail. This uses a computer controlled heat exchanger and cooler system. Facilities at Pin Gin Hill, near Innisfail, have proved to be extremely valuable, not only in the testing of our new equipment cabinet, but in tests for our solar modules and samples of paints and plastics.

7.8.6 *International Research Collaboration*

Collaborative research on an international scale has proved invaluable. For example, the New Energy Development Organisation (or NEDO) of Japan has been a partner with Telecom Australia since the early 1980s. Australia's role has been to evaluate the performance of emerging solar photovoltaic technologies from Japan. The tests are being carried out in Australia because of the vast and extreme range of environments, something which Japan doesn't have. Of special interest, is the long term performance of the Japanese solar technologies under the harsh environmental conditions found in tropical Australia.

This means Australia gets initial access to the performance data of the world's latest innovations in solar technology.

7.9 ACCESS ISSUES

Australia has just completed a $550 million Rural and Remote Area Program (RRAP). It was one of the biggest civil engineering efforts ever undertaken in Australia. As a result, it is now possible for anyone, anywhere in tropical Australia to have a reliable telephone service. This includes expansive desert regions, outback rural Australia dotted only by remote sheep and cattle stations, and the dozens of isolated coastal towns that ring the coastline. This program did not only provide a telephone service. It provided people in rural and remote Australia access to the latest in modern day communications.

For example, the Northern Territory is connected to the rest of Australia through an optical fibre linking Darwin to Adelaide with a microwave link backup in event of optical fibre network failure. Telecom's digital microwave link is also used to connect the Northern Territory to South Australia and Queensland. These links rely on signal transmission between line-of-sight towers. Rural and remote areas are serviced by Telecom's Digital Radio Concentrator System (DRCS) which provides users with basic telephone services similar to those available throughout Australia. The DRCS is a solar power system, researched and designed by Telecom, which can reach up to 600 km from an automatic exchange and connect up to 127 consumers from a series of radio repeater towers spaced 30-50 km apart.

In high growth areas, High Capacity Radio Concentrator systems are being installed which reach up to 2000 km and connect up to 300 customers to a wider range of services. Telecom also now operates a mobile telephone service in Darwin and Alice Springs.

The establishment of Optus with its satellite technology will provide an alternative to land based technology. The satellite technology provides alternative telephone links in the Northern Territory, both in Darwin and to the more remote communities, where the costs of land based communication is uncompetitive and generally unaffordable.

Television and radio in the Northern Territory is via satellite with rebroadcasting taking place in regional centres but direct satellite to ground links in the more remote areas.

7.10 THE FUTURE

What does the future hold for the development of the physical infrastructure of northern Australia? What role will research and development activities play in this development?

The answers to these questions will be as diverse as the requirements that the infrastructure itself will have to serve and depends on where one sits in the economic, environmental and social debates.

Clearly the past achievements of research and their applications into the physical infrastructure have been substantial and there is no reason to doubt that the future will also see further advancements made. However, it is equally clear that research needs range from the highest level of communication technology through to such basic issues as improved dust suppressants.

In terms of the infrastructure most research has to date been carried out elsewhere and applied to appropriate situations in northern Australia with or without modification to suit tropical conditions. Given the range of issues to be addressed the establishment of a single major research facility in the north is unlikely.

There does appear to be a need, however, to more closely identify research needs for tropical Australia and encourage work at the national and international level to recognise these requirements. This may lead to redirection or modification of existing and future programs to provide solutions to problems constraining the economic and social development of northern Australia.

The next decade is likely to see a continuation of growth in the north. This growth is likely to occur against a background of environmental concern and an increasingly high awareness of Aboriginal issues.

Additionally, our northern neighbours are likely to continue their current strong growth rates and this should provide unprecedented opportunities for the application of research and development aimed at tropical Australia into areas of similar geography and climate. For example, opportunities for Australia arising from its telecommunications industry , and the wealth of knowledge and expertise gained in providing the tropics with a telecommunications infrastructure, are many. The international contacts already made with key people are invaluable, and this also enables Australia to keep informed of technological trends and indicators as to where Australia should be heading with future technologies.

In trade, a key opportunity for Australia in the export of renewable energy products that can survive tropical conditions. This includes photovoltaic modules. The opportunities for Australia in this area really are very significant. There is much evidence that equipment designed for European or North American markets has failed dismally in Asian and Pacific countries. Already more than half of the photovoltaic modules made in Australia are exported, but the scope to increase our market share is still considerable. Telecommunications products developed for use in tropical areas with local manufacturers could well find export markets.

In the area of economic development of the region, the manufacture of telecommunications equipment is likely to remain near major markets. But there are opportunities for other areas to produce more specialised products. At the University of the Northern Territory, in Darwin, there is work underway to develop amorphous silicon photovoltaic cells and modules which have great potential. There is also research being done on electronic units

to match the output of solar modules to storage batteries. There is no reason why these and similar items could not be manufactured in Darwin.

8 NATURAL BIOLOGICAL RESOURCES: RESEARCH IN TROPICAL AUSTRALIA

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8.1 INTRODUCTION

Tropical Australia is particularly rich in natural biological resources. It includes three very large World Heritage Areas, two in Queensland - the Great Barrier Reef Marine Park and the rainforests of the Wet Tropics - and one in the Northern Territory - Kakadu National Park. Outside the world heritage areas, there are also a range of large and small National Parks, as well as areas which, although lacking protected status, remain relatively unexploited. Throughout the world, tropical habitats tend to have higher biodiversity than elsewhere, and Australia conforms to this trend. The Australian region is one of the eight major centres of global biodiversity, and the majority of Australia's native plant and animal species, whether terrestrial, marine, or freshwater, are found north of the tropic of Capricorn. Although exploited and with some serious environmental problems, the Australian tropics remain relatively pristine compared to most of the tropical world. Unlike most of the Pacific and South-East Asia, they have never had to provide subsistence for high-density human populations. And, unlike much of southern Australia, where human populations are concentrated, there are few documented extinctions among the biota since European settlement. It is especially remarkable for a developed country like Australia to have such large areas in a relatively unmodified condition, and their existence is now a major attraction of tropical Australia's developing tourism industry. They are also a major attraction to American and European research workers with an interest in tropical ecosystem processes, since they allow tropical research to be undertaken in a developed, English-speaking and politically stable country. More importantly, from an Australian perspective, the existence of these areas also provides an opportunity to establish management regimens which minimize or avoid mistakes made elsewhere.

The need for ecological and environmental research to underpin both sustainable regional development and environmental management of the Australian tropics has not gone unrecognised. Much of the region's research effort is essentially biological, intended either to enhance primary production, or to help understand, protect and manage natural ecosystems and ecological processes. Research for primary production is discussed elsewhere; here we examine research into the region's natural biological resources.

8.2 WHO ARE THE PLAYERS?

For the purpose of this review, we recognize three classes of institutional "research players": those who actually undertake the research, those who fund it, and those who use the results. Institutions or agencies generally fall into more than one of these categories, although few cover all three.

8.2.1 *Research institutions and agencies*

There are a number of major research institutions and agencies undertaking significant levels of research into the biota, structure or functioning of natural ecosystems in tropical Australia. The largest of these groups of researchers (including the region's three Universities, the Australian Institute of Marine Science, several CSIRO laboratories, and several State and Territory agencies) are actually located in the tropics, but many institutions located outside the region undertake some tropical environmental research. Some of these operate field stations within the region to support their tropical programs (for example, the Universities of Queensland and Sydney run marine field stations at Heron Island and at One-Tree Island, as does the Australian Museum at Lizard Island). Research programs are supported from both external funds and by internal institutional resources (the latter normally appropriation funding from federal or state governments). Other groups with a research role (particularly the ANU and some federal government agencies), regard themselves, like CSIRO, as having a national rather than a regional charter and consequently undertake some research in the tropics.

Several characteristics of the institutional and disciplinary mix are worth noting, especially when compared to the situation prevailing in southern Australia:

- CSIRO, although present and important, is much less conspicuous than it would be in comparable listings for southern Australia. Less than 2% of CSIRO's total professional staff is based in tropical Australia even though the tropics comprise almost 40% of the land area, generate 16% of the nation's export income (Harris 1992), and include most of the nation's biodiversity. The proportion is higher for a few CSIRO Divisions with a strong biological/environmental orientation - perhaps the strongest tropical commitments are shown by the division of Wildlife and Ecology, which bases 20% of its total staff in its three tropical laboratories (at Darwin, Alice Springs, and Atherton) and by the Division of Tropical Crops and Pastures (which, despite its name, is nonetheless based in Brisbane and has recently substantially reduced its presence in tropical centres). With the financial stringencies faced by CSIRO in recent years, the organization's commitment to tropical research appears to have been shrinking. The net levels of CSIRO activity are matched by equally low or lower levels of activity from other agencies with a 'national' charter.

- most of the permanently-staffed research institutions and agencies within the region are concentrated at two major locations: Townsville in Queensland, and Darwin in

the Northern Territory. With the growth in size and research activity of the University of Central Queensland, the retention of a significant CSIRO presence, and increased activity by some Queensland agencies, Rockhampton is becoming a third such aggregation. Exceptions to this pattern are few: in the Northern Territory, the Office of the Supervising Scientist has a laboratory complex at Jabiru, and CSIRO maintains a laboratory at Alice Springs. In Queensland, CSIRO's rainforest research is based at Atherton, and there are a number of small research groupings (involving Queensland State agencies and a small campus of James Cook University) in Cairns. This does not mean that the research programs themselves are so restricted geographically: field sites and field stations are more widely dispersed.

- Because of the obvious need for research to underpin environmental management and the use of the region's biological resources, combined with the relatively low profile of CSIRO in most of tropical Australia, biological research undertaken by all three of the region's Universities has a more strongly applied and ecological flavour than is usual in a University context. Moreover, several of the older Universities and Museums outside the tropics have staff and resources committed to ecologically and environmentally-oriented tropical research projects and programs. In particular, the University of Queensland, Sydney University, the Australian National University, and the W.A. Museum have all been active in tropical Australia (indeed, staff of the Perth-based W.A. Museum appear to have provided the main impetus and effort devoted to inventory of the natural ecosystems of north-western Australia).

- there are several major special-purpose federal research agencies which are specifically targetted to tropical environments of particular importance, or to specific environmental problems. The most notable are the Australian Institute of Marine Sciences (AIMS), in Townsville, which targets tropical marine ecosystems, and the Office of the Supervising Scientist (OSS), established to undertake research and monitoring associated with uranium mining.

- the concentration of relevant research and management agencies in Townsville has resulted in a level of research activity and expertise in tropical marine science and technology which is unsurpassed anywhere else in the world.

- research on the natural ecosystems of tropical Western Australia is essentially expeditionary: there are no permanently-based research groups located there, although a western unit of AIMS is currently proposed to develop programs studying marine systems.

8.2.2 *Funding agencies*

Almost all the research agencies considered under 8.1.1 fund at least part of their own research programs from state or federal appropriations allocated for institutional support.

There are also, however, a variety of external agencies which support biological research in tropical Australia:

(i) Commonwealth competitive grants. The range of national research grant schemes available to researchers throughout Australia are, of course, also accessible on a competitive basis for work in the tropics. These are diverse, ranging from Australian Research Council grants and fellowships, for pure or applied research in any area, through to the various Rural Industry Research Funds (whose resources come from industry levies with matching Commonwealth funds), which promote research designed to support particular rural industry groupings. Some of the latter are geographically biased simply because the industries they assist are restricted to particular regions. There is no evidence to suggest that tropical researchers are any more or less successful *per capita* in acquiring support from sources of this kind than are researchers in the rest of Australia. But the absolute amounts of funding from these sources spent in the tropics are nonetheless relatively low, simply because there are so many more researchers working in southern Australia than in the north.

(ii) Environmental management agencies. Some agencies whose charter requires them to protect, manage or survey natural environments in tropical Australia undertake at least some research themselves. But these agencies also contract research by other groups. Examples include the Queensland Department of Environment and Heritage, the Northern Territory Conservation Commission, the Australian National Parks and Wildlife Service, and the Great Barrier Reef Marine Park Authority. We will argue later that these agencies can exert an influence on the direction of research undertaken in tropical Australia which is quite disproportionate to the research funds which they expend. We will also argue that arrangements which foster this kind of leverage should be vigorously encouraged.

(iii) Agencies or industries whose prime purpose is not environmental management, but which undertake environmental research, surveys, or monitoring of various kinds either as a prerequisite for development (eg, EIS requirements) or as a support for their primary purpose. Again, work funded from these sources is extremely diverse: examples include short-term surveys associated with the establishment of tourism developments; marine surveys and monitoring associated with harbour modifications; environmental evaluation and survey undertaken prior to the establishment of areas devoted to military training; longer-term research and monitoring of the biota associated with water impoundments, undertaken either as a way of monitoring water quality, environmental impact, or to examine potential public health risks.

(iv) Non-government organizations (NGO's) with an interest in conservation or environmental protection sometimes commission research to provide information they need. Large international organizations of this kind (eg, WWF, EarthWatch) often have well-developed systems of competitive research grants, but even smaller, single-issue organizations may need and commission research for specific projects of particular interest to them - a Queensland example involves the conservation of Cassowaries; a Northern Territory example, of Gouldian Finches.

(v) Some sources of funds for biological/environmental research in tropical Australia fall into none of the categories above. Research institutions based elsewhere occasionally subcontract tropical research to other agencies: for example, the CSIRO Division of Wildlife and Ecology is currently supporting research at JCU on the ecology and impact of cane toads in northern Australia.

With some notable exceptions, work funded under categories (ii) to (iv) above is generally published in the form of reports and seldom finds its way into the primary scientific literature. The quality and depth of the work described in such reports varies from eminently forgettable to extremely valuable. Public access to the reports is almost always possible, but locating them - or even learning of their existence - may involve some difficulty. This is, of course, true everywhere, not just in northern Australia. Given the scale of the region's biological resources and the problems and costs involved in their inventory, however, there is a good case for encouraging and supporting the region's major libraries (which, at this stage, means the libraries in the region's three Universities) to establish special collections covering reports and publications of this kind.

8.2.3 *Research Users*

The agencies or groups funding research (at least in categories (ii) to (v) above) are also, of course, users of the research which they commission. In many cases, they are also users of ecological or environmental research in the public domain which they do *not* directly fund or commission. Also, funds which they do provide may pay for only a part of the research costs, with the remainder coming from the internal resources of the research agency undertaking the work. (As in the rest of Australia, this is most strikingly true for research undertaken in Universities, where the costs of staff salaries and infrastructure are rarely included in the charges for research undertaken for government agencies - and sometimes not included or only partially included in charges to other groups.) Partial funding of this kind, if intelligently applied and monitored, means that user groups may drive a much greater proportion of the total ecological/environmental research effort than they actually pay for.

One other class of research use is normally influential in determining the emphasis of scientific research in any disciplinary area. That is, use by other researchers, whether within Australia or from overseas. Especially for scientists working in Universities and

research institutions such as CSIRO and AIMS, peer evaluation remains the primary source of professional credit. Performance criteria applied to professional scientists often include the extent to which their published work is cited by other scientists, and the opinion of other scientists as to the significance and value of their research. In biology and ecology, as in other disciplines, higher ratings from this source will accrue to work of general rather than local importance, and to work which involves significant theoretical content rather than being primarily descriptive. Again, this is true everywhere. The influence of theoretical considerations on the directions of ecological research in tropical Australia has, however, been surprisingly limited. In general, Australian tropical research has tended to have a very strong empirical and applied bias with a low - and relatively derivative - theoretical content. Given the current state of theoretical ecology as it relates to tropical systems, this is not necessarily a bad thing, since the discipline has been developed almost entirely by temperate-climate researchers and its conceptual models apply best to temperate systems. There are a number of long-standing theoretical issues within the overall disciplinary area which relate specifically to tropical systems. They are not wholly irrelevant to the Australian situation, but they tend to emphasize stable and relatively predictable environments which are certainly not the norm in Australian tropics. The need for a better theoretical basis for empirical work in high-variability, high-disturbance tropical systems like our own is becoming progressively more apparent. This is an area of pure science of global strategic significance in which Australia, should it make the effort, is potentially a world leader. Unless the field develops here, it is unlikely to develop at all in the foreseeable future.

8.3 WHAT RESEARCH IS GOING ON?

We cannot here provide a compendium of current research on natural biological resources within tropical Australia: such a compendium is presently being compiled under contract for the overall ASTEC study and will be reviewed in the final report. We can, however, outline major fields of research important to the analysis of biological resources in particular habitat types and indicate whether or not we are aware of significant activity in each.

8.3.1 *Inventory*

Inventory is here defined as all research intended to document the composition and distribution of biological resources, together with the technology (library resources, databases, geographic information systems, etc) intended to make the resulting information accessible and comprehensible to the user. It includes taxonomic and systematic studies of the flora and fauna, all forms of biological survey, documentation, characterisation and monitoring of biological communities, correlative distributional analysis, and a variety of data management and data presentation technologies. This is an area of considerable activity, involving institutions based both outside and inside the tropics, much of it driven by the needs of management agencies, who universally identify it as a research priority. It may be argued, however, that the current patterns of activity are somewhat unbalanced.

In recent years, there has been immense interest in computerised database systems which allow storage, retrieval, mapping, and analysis of location-specific biological data. Several of these are now being developed, by Universities, State agencies, and federal agencies such as ERIN, on both regional and on national scales. None of them are yet accessible to the average research or management user based in tropical Australia, but there is at least promise that these tools will become both available and relatively easily accessible within the next ten years. At the same time, biological distribution data useable in such databases is being collected: much of this is either commissioned by management agencies or required by them as part of environmental impact assessment processes. This data collection is not as comprehensive, geographically wide-ranging or as rapid as it needs to be, but data ***are*** becoming available for marine, terrestrial, and freshwater habitats. What is ***not*** happening on the same scale for most habitat types, however, is first, the basic taxonomic work of species characterisation and description which underpins analyses of this kind, and second, the training of biologists with well-developed skills in identification of plants and animals. Consequently, most surveys normally concentrate on the few major groups for which (a) the majority of species have already been described, (vertebrates, vascular plants, and the few well-characterised invertebrate groups such as butterflies, dragonflies, and corals), and either (b) species are easily identified by the non-specialist, or more commonly (c) there happens to be a specialist on the group available to those undertaking the surveys. (It is not accidental that the groups on which the most sophisticated tropical marine work has been undertaken - corals and fish - are also groups for which local taxonomic expertise is also available.)

The growing shortage of specialist taxonomists and the restricted opportunities for their training are national and increasingly, global problems. They are, however, particularly acute in the tropics for two reasons - first, that the tropics have many more species to characterise, and second, that most taxonomists, past and present, have lived and worked in temperate climates. Consequently a smaller proportion of the tropical biota has been described, identification is in any case a more difficult task, and for most groups, there are fewer people able reliably to undertake it. Nationally, most taxonomic expertise is concentrated in museums and in special collections such as CSIRO's Australian National Insect Collection, based in southern Australia. It may not be cost-effective or even feasible to establish major regional collections for most plant and animal groups, but facilities for maintaining good working collections need to be established, preferably based on the two regional museums in Darwin and Townsville, and the range of taxonomic expertise available in Northern Australia needs urgently to be upgraded. We comment further on this issue later.

8.3.2 *Population studies*

Under this heading we include research which focuses on the abundance and/or population dynamics of particular species or species groups. Outside the Universities (and increasingly, inside them) research of this kind has been primarily oriented toward species which may need some form of management. There are three major reasons for identifying species as in need of management:

- because they are perceived as vulnerable or threatened (eg dugongs, marine turtles, hairy-nosed wombats, Proserpine rock wallabies, rainforest frogs);

- because they themselves are perceived as a threat (introduced exotic weeds, introduced animals such as feral cats, foxes, cane toads, goats and wild pigs; some native species which pose problems to agriculture or animal production, such as insect pests, disease organisms, rabbits, or kangaroos; some native animal species which may have a large impact on natural ecosystems, such as the crown-of-thorns starfish; and some species which present problems for human or animal health, such as mosquitoes and marine stingers);

- because they are subject to harvesting (eg prawns, commercial finfish, and again, kangaroos).

Research of this kind has historically been, and still is, high on the list of priorities for environmental and natural resource management agencies (eg GBRWHA 1992, QDPI 1992, WTMA 1992). Considerable tropical research has been undertaken in some cases (eg on the crown-of-thorns starfish, on some exotic weeds, on prawn fisheries, on dugongs and turtles, and more recently, on cane toads). Management plans for threatened species in terrestrial systems can sometimes be developed quickly and at relatively low cost, but in general, research of this kind requires a long-term and expensive commitment to arrive at the stage of providing workable solutions and appropriate management plans. With a few exceptions (mostly for species in marine systems) that long-term commitment has not been there.

Species requiring management are an atypical subset of the biological world, so research not driven by an immediate need for management is strategically important to the development of an understanding of how tropical systems work. In tropical Australia, it is largely restricted to the Universities and to the Australian Institute of Marine Science. As noted earlier, the emphasis tends to be less in tropical Australian Universities than we would find in southern Universities, simply because the Universities have responded to the unfilled need for research on species with immediate management needs. This situation is unlikely to change in the foreseeable future.

8.3.3 *Impact Studies*

Here we consider research aimed at elucidating the direct or indirect effects of human activities. This includes studies of the effects of issues or practices such as fire management regimes on savannah-woodland habitats, habitat fragmentation on rainforest communities, nutrient inputs on coral reef communities, trawling and other fishing practices on non-target marine communities, and pollution effects of a variety of kinds on marine and freshwater systems.

Research of this kind may be both specific and generic - ie, it may be targeted at the effects of a particular, localised development or practice, with little application beyond the immediate local problem, or (like marine and freshwater nutrient studies of the effects of fishing) it may have very wide implications for communities and ecosystems throughout the entire region. Generic studies of this kind are of immensely greater value and of global significance both nationally and internationally, but they have several very obvious attributes:

- they are, almost by definition, large-scale, expensive, and relatively long-term.

- they need special targeted funding, since they are generally too large for competitive grant schemes, and although the need for them is often a consequence of economic activity, it is generally the activity of whole industries or classes of industries than of a few 'problem' operators.

- they are strongly interdisciplinary. Often, the range of expertise required to undertake them is well beyond the capacity of any single research agency, and require the development of complex collaborative arrangements. Consequently, they tend not to be 'owned' by particular research agencies.

An examination of the research priorities of environmental management agencies, at least in tropical Queensland (the Great Barrier Reef Marine Park Authority, the Queensland Department of Environment, the Wet Tropics Management Agency) suggests that generic "impact-oriented' research is close to the top priority of classes of problems needing a substantial increase in research effort. Mechanisms for funding research of this kind are profoundly unsatisfactory. With few exceptions, and despite their stronger than usual needs for continuity, they are painfully subject to the kinds of 'stop-start' support which is the normal fate of projects whose funding is dependent on their position on short-term political agendas. And because they are both expensive and not 'owned' by particular research agencies, they are unlikely to be carried over dry periods by the internal resources of those agencies.

8.3.4 *Community and ecosystem studies*

This includes all research on the structure and functioning of natural ecosystems and communities which goes beyond inventory to process and mechanism, and is not specifically targeted at evaluating, alleviating, or managing the impact of particular human activities. Like the population studies discussed earlier, research of this kind has strategic importance. Without an understanding of "normal" populations and ecosystems and the processes which drive them, we are restricted to an empirical 'case-by-case' approach to the management of biological resources, and moreover, one in which the critical variables which should be monitored in order to characterise and predict impact remain poorly defined. In tropical Australia, limited amounts of research of this kind are carried out by the Universities, the Australian Institute of Marine Science, and by CSIRO Division of

Wildlife and Ecology, with the most attention being given to freshwater and marine systems.

8.3.5 *Physiological, biochemical, ultrastructural, and genetic studies*

Applied to organisms in natural rather than cultivated systems, work of this kind on tropical species remains in its infancy, and most of it has been focussed on marine organisms on the one hand and (to a much smaller extent) native mammals and insects on the other. Some has clear and immediate application: eg. work by AIMS, searching for compounds with pharmacological activity in marine organisms, and on the chemicals used by corals to avoid sunburn. But much of it is directed at understanding how things work rather than at specific economic or management payoffs - eg. work undertaken at James Cook University to determine how tropical insects survive the dry season, the nutritional requirements of native marsupials, or how a pearl oyster makes pearlshell. Work of this kind is most often found in the Universities, both within the region and outside it.

8.4 PRIORITY-SETTING AND RESEARCH ORGANISATION

There are a number of significant issues related to the management of research on natural biological resources in tropical Australia.

8.4.1 *Disciplinary deficiencies*

An obvious and growing disciplinary shortfall, as noted earlier, is in taxonomic skills. Although many people need, use, and will pay for taxonomic services, few agencies other than museums wish to employ full-time taxonomic specialists. The poor employment prospects mean that few are trained. Part of the problem is that the primary interests of most taxonomic specialists are in phylogenetic reconstruction and biogeography, rather than in the tasks most in demand (routine identifications, species descriptions, and the production of identification keys). Especially for tropical systems, there may be a case for graduate training which aims to produce people who might act as taxonomic service providers. The taxonomic activities of those museums with a particular interest in tropical organisms (especially the Northern Territory Museum, the Townsville branch of the Queensland Museum, and the WA Museum) should expand to include much stronger elements of contract work providing identification services at a range of levels.

8.4.2 *Concentration, institutional mix, and critical mass*

Researchers rarely maintain their productivity in isolation, and in this field perhaps more than most, many problems need a 'critical mass' of workers covering a range of disciplines. This presents problems for tropical Australia, whose overall population density is relatively low. It is therefore probably a positive development that, perhaps more by accident than by design, research laboratories within tropical Australia have become concentrated in a few key locations, specifically Townsville, Darwin and now Rockhampton. Townsville provides an interesting model for the development of a major

research focus in the tropics, since, as noted earlier, its activity in tropical marine science is now of both national and international significance. What factors have been important in allowing this development? There are several:

- a unique, nationally and internationally recognised, and highly-valued biological resource - the great Barrier Reef - whose very existence is an incentive to marine research;

- the presence of a tertiary institution (James Cook University) committed to marine research, education, and research training. This means a steady supply of recruits to the region's marine research community, and problem-responsive research activity. (Universities, as a result of funding and graduate enrolment patterns, most often operate on a relatively short - 3 year or less - timescale for research projects. This makes them flexible and responsive, but may make the continuity needed by longer-term programs difficult to achieve if the programs are also costly.);

- the presence of the Australian Institute of Marine Science, which, like a CSIRO division, is better able than a University to achieve continuity in long-term and high-cost programs;

- a branch of the Queensland Museum whose taxonomic work focuses almost entirely on marine organisms, and a QDPI laboratory with interests in marine aquaculture.

This mix of research agencies provides complementarity in approach, disciplinary mix and timescale. With adequate cooperation, the region has a critical mass of researchers in marine science, and the ability to sustain ambitious and adventurous projects, including large collaborative interdisciplinary ventures. That potential also occurs in every capital city, in a wide range of research fields, but is only sometimes realised. For its realisation, a catalyst is needed. Often, this takes the form of a 'leading-edge consumer'; that is, an informed and sophisticated user of research results who provides a focus and an incentive for performance. That element is also present in Townsville, in the form of:

- an environmental management agency (the Great Barrier Reef Marine Park Authority) which uses research results and scientific advice as one of the inputs to its management decisions, and which has an unusually proactive and critical approach to the research community. GBRMPA obtains considerable leverage by contracting out most of the marine research which it funds, but the sophistication and impact of its dealings with researchers also have other sources. It obtains peer review and ratings, and may require revision, of the research reports it commissions. It runs open annual research meetings where its contractees describe and discuss their work, and which are attended by senior GBRMPA staff as well as those immediately responsible for research management. Its staff participate in other relevant scientific meetings. It has recruited staff from, and sometimes seconds staff to, research institutions in the region. It sets up scientific advisory committees to help design the largest of its contracts. It actively seeks major

special-purpose funding to tackle management-oriented research problems which are too expensive to support within its normal appropriations. It recruits beginning researchers into its network by offering small "augmentative grants" to research students. It actively seeks external scientific advice on a range of issues. It encourages institutional collaboration by inviting joint submissions for its contracts when the skills it needs cannot be found within a single institution. And it is almost obsessively communicative. As a result, it has an extraordinarily high profile within the scientific community, and exerts an immense degree of leverage. A significant part of the marine research effort in the region, quite apart from that which GBRMPA funds, is directed toward work which the research community thinks GBRMPA wants, ought to want, or might want in the future. Moreover, it has acted as a considerable force for integration and communication within the research community.

There are two new consequences of this integration. The first is the development of educational and consultancy arrangements involving JCU, AIMS, and GBRMPA, aimed at jointly marketing the tropical marine scientific and management expertise and educational programs of all three agencies both nationally and internationally. The second is a CRC proposal, again involving all three agencies as well as industry groups.

This is a model which might profitably be applied more widely. Australia can be a world leader in tropical environmental research and management, and it needs to develop appropriate and scientifically-based management strategies for its own biological resources. This is happening in tropical marine areas and could happen elsewhere. The key elements may be the presence of a sufficient number and diversity of researchers, plus an environmental management agency prepared to invest time and funds in its involvement with the research community. The wet tropics in Queensland, and the seasonal environments of the Northern Territory, both have the potential for these developments.

8.4.3 *Funding*

The most important issue here has been mentioned earlier: it concerns the funding of major collaborative programs and ensuring their continuity. The incentive for these programs will normally be the need to evaluate and manage the impact of human activities or other novel factors on our major natural ecosystems. This applies nationally, but esp ecially in tropical Australia where the areas to be covered are so large, natural biological resources are so valuable, and there are so few major research agencies present. Good examples are research into the effects of nutrient load and fishing activity on the Great Barrier Reef region, or work directed at the control of cane toads and other pest species. Problems like these require an expensive, long-term commitment of both funds and management effort for their solution. What they often get, however, is specially-allocated support following the expression of substantial public concern, followed by the withdrawal of support a year or so later, well before there is any possibility of a resolution, when they have (usually temporarily) slipped down the scale of public visibility. This approach is, to understate matters, seriously flawed. Australia needs to develop better mechanisms for funding

research of this kind and monitoring its progress, and for prioritising the problems needing research for their resolution. If such a funding and monitoring mechanism was also designed to ensure close interaction between research agencies and environmental management agencies, and to enhance the ability of the management agencies to use and commission research, the general benefit would be substantial.

8.4.4 *Numbers*

Biological and environmental researchers based in the tropics often have (sometimes well-justified) reservations about the value of "suitcase research" - that is, the work done and conclusions drawn by visiting researchers and consultants who do not interact with the resident research community, and do not stay long enough to appreciate the profound differences between real tropical systems, and the temperate systems they are accustomed to, and the tropical stereotypes often found in ecological textbooks. But tropical Australia is never going to have all the expertise it needs in residence. One solution to this problem may be to provide better means for visiting researchers to participate in collaborative programs. Tropical CRC applications with an environmental focus which are currently under consideration do provide for this.

8.5 CONCLUSIONS

One of Australia's major assets is the diversity, spectacular nature, and relatively intact condition of its tropical biological resources. In taking advantage of this asset, we need also provide for its protection and management. Research which allows us to do this has the potential to provide a reservoir of marketable expertise in tropical environmental management, technology, research and management training, and impact evaluation. The demand for expertise of this kind can only increase.

9 RESEARCH, EDUCATION AND TRAINING

Professor R M. Golding

Vice-Chancellor, James Cook University

Education and research training are key elements in the development of Northern Australia. Both activities depend primarily on a strong higher education presence. James Cook University of North Queensland, Australia's first University located in the tropics, has within its mission statement that the central purposes of the University are two-fold:

- to achieve and maintain excellence in the education of its students; and
- to achieve and maintain excellence in research, research training and the application of knowledge.

James Cook University (JCU) has accomplished a great deal over the years and certainly has played a significant part in assisting, where appropriate, in the development of North Queensland, and providing leadership in the region.

Since 1985 the University has grown from 3,400 students to just under 8,000 with some 80% from North Queensland. Next year enrolments will be well over the 8,000 mark. All our activities have grown: teaching, research, research training, and commercial activities.

Recent additions to the undergraduate programmes have included computer science, tourism, mechanical engineering, computer systems engineering, law, nursing, building, tropical marine and environmental chemistry, music and fine arts programmes.

Also, at the graduate level the University has introduced many new programmes such as in tropical health and medicine, law, and in management.

At the research and research training level the University has a high profile. In addition to maintaining research, research training and teaching programs across a range of basic disciplines, JCU has developed special research and research training strengths in the three following broad areas:

- Applied science and engineering;
- Life in the tropics;
- Marine Science & Technology.

To focus on specific areas relevant to the region some 16 centres or institutes have been established over the last few years, such as:

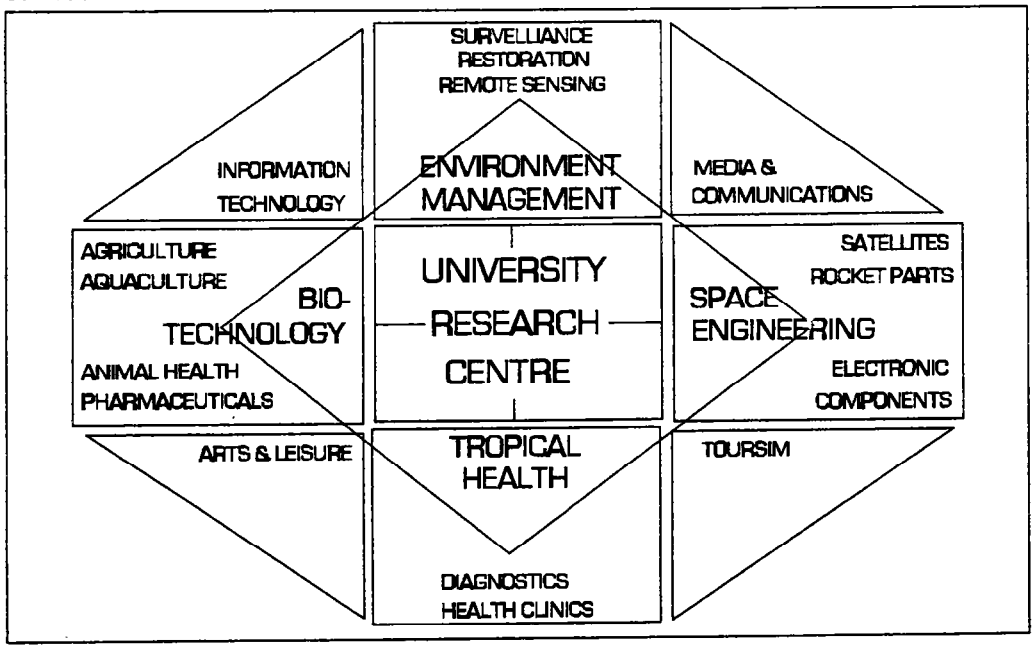
- the Anton Breinl Centre for Tropical Health and Medicine;
- the Australian Centre for Tropical Freshwater Research;
- the Institute for Tropical Rainforest Studies;
- the Sir George Fisher Centre for Tropical Marine Studies.

The University has moved significantly into several major commercial ventures with its present three companies JCU Uninet, the National Centre for Studies in Travel & Tourism Pty Ltd and JCU Tropical Biotechnology. Several other activities including joint ventures are being explored.

These activities have established a very solid base in North Queensland in education, research and research training. But much more needs to be achieved. The University is not, however, training enough of the population to support the potential of the region.

In Queensland and the Northern Territory the participation rates are well below the national average, and in North Queensland it is about one half the national average. If this is not addressed then it will become worse since the growth in Northern Australia is well above the national population growth rate.

Research and Research training should be relevant to the region and should be viewed as part of a research strategy focused on problems related to Northern Australia. Already James Cook University has a number of research-service centres which form a most important interface between the University and the real-world needs. This interface may be illustrated as below:



There is an excellent opportunity to build on these strengths by supporting, for example, an MFP-type development in North Queensland. Such a development will create the best possible opportunity for the North to meet the challenges of the future and at the same time tapping into the vast powerhouse of knowledge and activities of the University.

It is widely percieved that within Australia there is a lack of appreciation of the north's potential, namely, vast resources very close to huge markets within this tropical region of the north. Many of the Universities activities are severely limited due to the lack of adequate support from within Australia.

To pursue a number of developments the Universities has found it necessary to open several international links with overseas groups who share our vision. I am sure some of our present negotiations will result in some exciting developments here in North Queensland.

North Queensland has a great future. There is the opportunity to build significantly upon the considerable resources within the region. The University is strategically placed to interact around the pacific rim to develop new industries, at the same time achieving a balance between development and conservation of resources, and enhancing our attractive environment.

Finally, there are numerous activities with considerable potential and yet which would require a substantial education and research training input, such as:

- aircraft maintenance facilities;
- aquaculture;
- creative arts.
- economics of the region;
- extraction of methane gas from coal beds;
- management of our environment;
- medicine;
- tourism;
- tropical agriculture;
- tropical architecture;