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Marine Imprint: the crucial impact of 33 years of AIMS research in the public interest

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EXECUTIVE SUMMARY

The role of the Australian Institute of Marine Science

The Australian Institute of Marine Science (AIMS) is a leader in marine research and is largely publicly funded. The core focus of AIMS is, through innovative, world class scientific and technological research, to generate and disseminate the knowledge required to inform the sustainable use and protection of the marine environment. AIMS is recognised worldwide for its expertise and the quality of its research into complex large-scale problems in tropical marine environments. It has unique capacity to investigate molecular to whole-of-system questions to help provide solutions for the conservation and sustainable use of Australia's marine estate. This is largely research in the national interest, often referred to as public good research.

AIMS provides independent advice based on the best available science to help ensure that Australia's marine resources are well managed, used sustainably and available for future generations. Government funding provides essential support for this research since, in general, private industry does not conduct marine research for public benefit. Public support for marine research is particularly critical since property rights in the marine environment are not owned in the same way as terrestrial resources.

Specifically, AIMS research plays an important role in supporting:

- the conservation and management of the Great Barrier Reef;
- Great Barrier Reef World Heritage Area catchment management;
- management of the Northern and Western Australian tropical marine environment;
- management of the international tropical marine environment; and
- environmentally sustainable development for tourism, off-shore oil and gas, aquaculture, on-shore mining and other industries.

Through the discussions held with AIMS external stakeholders in this study, it is clear that industry, government and other stakeholders have very high regard for AIMS scientific research.

The impact of AIMS

The fundamental impacts of AIMS research are its contribution to the preservation of Australia's iconic tropical marine ecosystems, most significantly (to date) the Great Barrier Reef World Heritage Area (GBRWHA). These iconic ecosystems are not just important for the economic value generated by associated marine industries, but also from their "non market" environmental, cultural and social significance.

Notwithstanding the fundamentally public good oriented nature of much of AIMS research, AIMS does generate direct economic impacts through a number of channels. The key channels identified in this study are:

- expenditure effects associated with AIMS operations;
- benefits from better informed GBRWHA management policy;
- contribution to the future of the tourism sector in the GBRWHA;
- contribution to the development of the Western Australian offshore gas industry;
- contribution to fisheries and aquaculture industry development;
- contribution to mining sector performance;
- biomolecular research sector development; and
- direct commercialisation of AIMS technology.

In this study, two economic modelling scenarios were developed to help assess the economic impacts associated with AIMS since its inception. The Centre of Policy Studies MONASH Multi-Regional Forecasting (MMRF) model of the Australian economy was used to calculate these impacts. The methodology underpinning the development of the modelling scenarios is conceptually similar to that being used in the current Department of Education, Science and Training study into the impacts of the Co-operative Research Centres Programme.

The first scenario is designed to capture only the expenditure effects associated with AIMS to date. The modelling scenario presents what Northern Queensland, Queensland and Australian economic performance would have been if AIMS had not been created and then received the inputs that it has received since its inception. The time horizon for this first scenario ends at 2005.

The second economic impact scenario extends the time horizon for AIMS impacts out to 2020 and has a different purpose to the basic expenditure effect tracking conducted through scenario one. In addition to capturing expenditure effects it represents an attempt to capture a small set of the potential "investment" effects associated with AIMS.

What the scenario one modelling shows is that when just accounting for expenditure effects, at the regional and State level the net economic impact of provision of taxpayer funding for AIMS is clearly positive. At the national level, however, the expenditure effects of AIMS are marginally negative. The results indicate that even in the highly unlikely situation that AIMS generates no economic impacts beyond simple expenditure effects, the true net cost to taxpayers of investing in AIMS is only around $1 per taxpayer per year.

Under scenario two, when the expenditure effects associated with AIMS and just one potential "investment" type effect are taken into account, at the regional and state level AIMS is shown to generate significant net economic benefits, both cumulatively and on a per annum basis. For instance, the projected 2.68% fall in the Far North region's annual gross value added due to the absence of AIMS would represent more than a halving of economic growth in the region. The net economic impacts of AIMS at the Australia wide level, however, remain relatively small. Nevertheless, it should be noted that by 2020 AIMS is generating higher Australian real private consumption of $53 million per annum with the effects of AIMS on the tourism industry more than offsetting the simple expenditure effects associated with the $26 million in taxpayer funding provided for AIMS. **Under this scenario, by 2020 AIMS is generating increased real private consumption in Australia of more than twice the level of taxpayer funding that it receives.**

While the true value of AIMS research cannot be fully captured in purely economic terms, the economic impact analysis in this study shows that public good focused research such as that conducted by AIMS has the potential to generate dramatic regional economic benefits and, at the national level, economic benefits for Australia well in excess of its costs. The findings from this study demonstrate the value of marine research to the nation and the importance of continued public funding to support this effort. Diversion of public funding away from mission-driven marine research in the national interest towards short term commercially focused research would be counterproductive, hindering the achievement of longer-term, higher-value objectives.

Implications for the future of AIMS

Four major conclusions, that have important implications for its future activities, can be drawn from this study into the impacts of AIMS, namely:

1. Given the tremendously high regard in which AIMS scientific research is held by its external industry, government and other stakeholders, the economic significance of the ecosystems that its research informs the management of, and the role AIMS research plays in supporting environmentally sustainable marine industries (tourism, off-shore oil and gas, on-shore mining developments, aquaculture and other industries), AIMS is highly likely to deliver strong net economic benefits for Australia for a small investment by taxpayers. Effective environmental management also provides insurance against the high economic costs associated with ecological restoration.

2. The true value of AIMS research can never be fully captured in purely economic terms. Investment in AIMS research is primarily an investment in better understanding of the marine environment to enable conservation and sustainable use of Australia's marine natural heritage. Information generated though AIMS research minimises the risk associated with decision making by managers and users of marine resources and provides a preparedness to respond to future/emerging issues.

3. While opportunities for the direct commercialisation of AIMS research should not be ignored, given the relatively small economic impacts available in this area when compared to the significant economic impacts associated with better marine environment management (for instance), the pursuit of commercialisation opportunities should not be allowed to displace activity away from AIMS core focus on conducting research that informs sustainable use and protection of the marine environment.

4. Based on the assessment of expenditure effects alone, AIMS represents a very small cost to the Australian taxpayer – $1 per taxpayer per year– compared to the benefits that its research generates.

The implication of these findings is that public support for AIMS provides economic, social and environmental impacts that deliver significant current and longer term benefits to Australia.

CHAPTER 1
Introduction

1.1 Project objectives

The primary objectives for this project were to:

- provide a clear picture of AIMS inputs and major outputs over its 33 years of operation and place this performance within the context of the broader Australian R&D System;
- establish the verified and quantified economic impact and other benefits of AIMS since its inception; and
- consider the future prospects for AIMS to contribute to Australia's economic, social and environmental development goals.

In effect, the central task in this study was to consider the type of impacts a highly public good focused research organisation such as AIMS generates and to quantify to the extent possible the effect of AIMS on economic welfare in Australia.

1.2 Project methodology

To this end, the following key information inputs were utilised in the conduct of this study:

- Information on AIMS inputs and key outputs was collated from AIMS annual reports for the years since its inception in order to build a comprehensive picture of AIMS operations over the past 33 years.
- Existing scientific reviews of relevance to AIMS, such as the Chief Scientist's 2001 *Review of Marine Research in Tropical Australia*, were collected and reviewed.

- Existing literature, such as the Productivity Commission 2003 study *Industries in the GBR Catchment and Water Quality*, surrounding the economic value of industries within the GBRWHA was gathered and assessed.
- Interviews were conducted with key AIMS research and management staff to map out what activities AIMS has been and currently is involved in and to identify potential impacts from AIMS work.
- Interviews were conducted with a range of AIMS external stakeholders, including marine park management policy makers such as the GBR Marine Park Authority and the Commonwealth Department of Environment and Heritage, industry end users of AIMS research such as Alcan, Woodside Energy, BHP Billiton Petroleum, Queensland Nickel, and the Association of Marine Park Tourism Operators. The purpose of these interviews was to gather independent end-user views on the extent of application of AIMS research outputs that is occurring and also to gather their overall views on the effectiveness of AIMS in delivery outputs that meet end-user needs.

On the basis of analysis of the information gathered from these sources, the Centre of Policy Studies MMRF Monash Computable General Equilibrium model of the Australian economy was then used to quantify the economic impacts of AIMS on the Northern Queensland, Queensland and overall Australian economies[1]. This was done using two different assessment time horizons and sets of impact assumptions.

The first level of modelling was used primarily to establish the expenditure effects associated with all of the funding, which has come from a range of sources that has been directed into AIMS since its establishment. This level of modelling also included a small number of clearly quantified and end user verified impacts that have already resulted from the application of AIMS research. This modelling level covers only the period from AIMS establishment up until the end of 2005.

The second level of modelling extends the first level of modelling to project outwards until 2020 in assessing some of the *potential* economic impacts that AIMS may generate. This level of modelling includes *estimated* impacts on the Tourism and Commercial Fisheries sectors in Northern Queensland that may be attributable to the activities of AIMS. The purpose of this level of modelling is not to definitively project the expected future impacts of AIMS, but rather to provide a reasonable quantification of just a few of the types of economic impacts that a highly public good oriented research organisation such as AIMS may be expected to deliver.

[1] The CoPS MMRF model has been used in a conceptually similar fashion within a number of recent studies investigating the economic impacts of research. These studies include: the 2005 study for the CRC Association into the impacts of the CRC Programme; the 2003 review of the economic impacts of the Australian Research Council; the 2005 review of the delivered and potential impacts of the Institute for Molecular Bioscience; the 2003 and 2005 reviews of the Victorian Government's Science, Technology and Innovation Initiative; the current review being conducted for the Department of Communications, IT and the Arts of the impacts of publicly funded ICT R&D; and, the current review of the CRC Programme being conducted for the Department of Education, Science and Training.

1.3 Structure of this report

This report is structured into six chapters and one appendix as follows:

Chapter 1 – Sets out project objectives and methodology.

Chapter 2 – Provides an accounting of inputs into AIMS since its inception and an overview of its key activities and outputs.

Chapter 3 – Sets out the framework used for assessment of AIMS economic impacts and some of the key methodological challenges involved in conducting such an assessment.

Chapter 4 – Describes the major identified impacts that AIMS activities have generated or contributed to.

Chapter 5 – Details the inputs into, and outcomes from, the two economic impact modelling scenarios developed in this study to quantify the economic impacts of AIMS.

Chapter 6 – Considers the implications of the findings from this study for future AIMS activities, funding and evaluation.

Appendix A – Provides the detailed outputs from the economic impact modelling conducted by the Centre of Policy Studies.

CHAPTER 2
Overview of AIMS operations

2.1 Inputs into AIMS

Since its establishment in 1972-73, AIMS has generated earnings from the Australian public and private sectors as well as from the public and private sectors overseas. When its revenue is adjusted into constant 2005-06 dollar terms (using the long term ABS inflation index), over its 33 years of operation AIMS inputs have been:

- $658 million in annual appropriation funding from the Commonwealth Government;
- $32 million in other revenue from the Australian public sector;
- $33 million in revenue jointly from the Australian public and private sectors;
- $19 million in revenue exclusively from Australian private sector sources;
- $21 million from overseas funding sources; and
- $26 million from other sources such as interest, publication sales and revenue from related entities.

AIMS revenue to date from all sources totals $789 million in 2005-06 dollar terms. In 2005-06, AIMS total revenue was $31.4 million, comprising:

- $23.1 million in appropriation funding from the Commonwealth Government;
- $0.3 million in other revenue from the Australian public sector;
- $4.8 million in revenue jointly from the Australian public and private sectors;
- $0.8 million in revenue exclusively from Australian private sector sources;
- $1.3 million from overseas funding sources; and

- $1.1 million from other sources such as interest, publication sales and revenue from related entities.

To put the current level of resourcing for AIMS into context within the broader innovation system in Australia, it should be noted that in 2005-06 the Commonwealth Government's appropriation funding for AIMS of $23.1 million represented less than 1 percent of the total Commonwealth Government science and innovation funding for that year of $5,951 million[2].

Over AIMS lifetime, the proportion of earnings (in 2005-06 dollars) generated from sources other than its annual appropriation funding, "external earnings", has increased considerably. Over the period 1972-73 to 1983-84 external earnings contributed on average 1.2 percent of AIMS revenue, from 1984-85 (when the first significant increase occurred) to 1993-94 external earnings contributed on average 14.5 percent of AIMS revenue and the for the 1994-95 to 2005-06 period external earnings has contributed on average 21.7% of AIMS revenues.

Another shift in the sources of AIMS inputs has been generated by the Institute's expansion into western and northern Australia. In addition to its offices in Perth and Darwin, AIMS has in recent years been actively seeking joint ventures and collaboration with other research providers to enhance research capability to meet the research needs of these regions. In 2005, the WA Government announced funding of $21m over 4 years for the WA Marine Science Institution (WAMSI) under the WA Major Research Facility Program. AIMS was invited to be a key partner in this group, which was established with Curtin, Edith Cowan & Murdoch Universities, UWA, CSIRO, Bureau of Meteorology, Western Australian Global Ocean Observing System and the WA Government represented by its agencies in the fisheries, environment, industry and resources, and heritage portfolios. WAMSI is expected to be one of the platforms for increasing investment by AIMS in WA.

In 2004, AIMS formally affiliated with James Cook University (JCU) in a joint venture, AIMS@JCU. This formalised the collaborative research relationship between the two organisations, through investment in infrastructure and research staff. AIMS and JCU received additional funding of $3.9m in the 2003-04 Federal Budget to support this collaboration, further emphasising Townsville as the leading international centre for Tropical Marine Science. This funding was utilised for actions such as the commissioning of a fibre-optic communication link between the two facilities to

[2] Analysis of DEST, *Science and Innovation Budget Tables 2006-07*

enable virtual in-lab collaboration, for example through the transfer of field data in real time, enhanced training of PhD students and collaborative research.

In June 2005, AIMS also increased its capacity in the north with the opening of the Arafura Timor Research Facility (ATRF), a joint venture between AIMS and the Australian National University (ANU) to provide a well equipped specialist marine science research precinct for marine and social scientists to conduct world-class research in the Arafura and Timor seas. The ATRF has facilitated close collaboration and cooperation with other Northern Territory research bodies, in particular Charles Darwin University (CDU), and to facilitate the effective and efficient use of all local marine research resources to benefit the Northern Territory, Australia and our regional neighbours. The ATRF was the result of a successful bid by AIMS and ANU for an Australian Government Major National Research Facility (MNRF) grant of $3.25 million.

2.2 Overview of AIMS activities

AIMS now has three sites, Perth, Darwin, and its headquarters at Cape Ferguson near Townsville which is at the geographical centre of the Great Barrier Reef. While core research is conducted throughout Australia's ocean territory, AIMS research effort is concentrated on northern Australia from the Great Barrier Reef to Ningaloo Reef in the West. AIMS expertise is also enlisted throughout tropical waters worldwide.

Building and disseminating basic understanding of tropical marine ecosystems

The core of AIMS activities is the development and dissemination of fundamental marine science knowledge. The Institute's scientific research has included the gathering of marine data, analysis of this data to develop understanding of the functions of ecosystems and the assessment of land and water activity impacts on the marine environment.

Following its establishment through the *Australian Institute of Marine Science Act* 1972, AIMS began its research programs in 1974-75. These initially comprised three program areas:

- Coral reefs and reef-building organisms – this program was intended to provide a taxonomic basis for future studies of the ecology, morphology and geology of the GBR. Projects organised over 8,000 specimens of the hard corals which dominate the reef into systematic groupings, and these were published as monographs. Additional studies concerned the physiography of the reef area, and of mechanisms and environmental factors in coral calcification in the reefs.

- Tropical marine webs – this program initially undertook a surface survey and documentation of the aquatic and atmospheric environment of the mangroves of Hinchinbrook Island, including systematic collections of herbarium material, and statistical analysis of the ecological character of this eco-system. Other projects included research into the behaviour, distribution and density patterns of planktonic animals, the basic feedstock of marine ecosystems, and the impacts of water currents and biological factors (including environmental stress, competition and predation) on population size.
- Marine pollution – this program was established with the goal of collecting and analysing preliminary baseline data relating to trace metals in representative organisms in the GBR area. This led to studies into the importance of river run-off in the distribution of pesticides in reef organisms. By 1979-80, AIMS had increased its focus on human impacts on catchment and reef ecology, emphasising that these impacts on tropical coastal ecosystems must be understood to be efficiently managed.

In recent years, AIMS has continued this program of research, building understanding of tropical marine ecosystems in support of good stewardship of marine resources. The Institute's research has evolved and broadened and effort now falls into six areas of focus:

- Biodiversity assessment and trends with a particular focus on coral reefs, coasts and continental shelf ecosystems;
- Environmental change and impacts including climate change and climate variability;
- Water quality and ecosystem health to understand the link between the land and the sea;
- Biodiversity sustainable use to ensure wealth generation from Australia's marine estate;
- Microbiology and biodiscovery. Microbes constitute the vast majority of marine biomass and are the primary engines of Earth's biosphere.
- Knowledge integration and synthesis and prediction.

AIMS work includes the dissemination of scientific knowledge; long-term monitoring of the GBRWHA and the reefs of northern and north-western Australia; monitoring the impact of land/water management; continued research on the implications of climate change (coral bleaching and ocean acidification); collaboration with the tourism, oil and gas, fisheries and aquaculture industries; and most recently, significant strategic alliances with overseas researchers and pharmaceutical firms to exploit the potential for developing therapeutic substances found in marine organisms. Strong links with users of its research has enabled AIMS to effectively transfer new knowledge to them.

Based on interviews conducted in this study with both key external marine management stakeholders such as the Great Barrier Reef Marine Park Authority (GBRMPA) and the Australian Government Department of Environment and Heritage (DEH) and major industry stakeholders such as Woodside Energy Ltd, BHP Billiton Petroleum Pty Ltd and Alcan Inc., it is clear that the quality and relevance of AIMS research into tropical marine ecosystems is held in very high regard.

AIMS and its researchers have featured highly in an ISI Essential Science report that analysed contribution to the field of coral reef ecology over the past 10 years. The analysis was based on more than 3,400 papers, more than 5,000 authors, and more than 1,600 institutions. AIMS was the second ranked institution in terms of citations, and two AIMS staff were in the top twenty cited researchers. AIMS staff were also authors on three of the four most highly cited papers during this period[3]. AIMS is ranked in the top 1% of institutions in the field of *Environment & Ecology* based on its total citations in that field[4].

AIMS long-term monitoring of coral health has meant that researchers have become expert in the extraction of climatic records from corals, using these as a measure of the extent and pace of past environmental change. Researchers have found that Australian coral reefs have 'bleached' when exposed to water that is hotter than the historical average, suggesting that coral may be an indicator of climate changes, with the possibility that these weather data may be used to predict how reefs might respond to climate change in the future. AIMS also studies the impacts of sea level change and increased carbon dioxide on tropical mangrove systems.

In 2003-04, AIMS monitoring in WA, Palau and Micronesia added to understanding of coral bleaching, providing more detailed knowledge of how hydrodynamics control variability in the heat stress associated with coral bleaching. AIMS collection of satellite temperature data on coral reef health has also resulted in the Sea Surface Temperature Atlas for the GBR, launched July 2002. These products are now used to support the national ocean modelling work of CSIRO, the Bureau of Meteorology, and the Australian Navy, as well as forming the basis of a prototype application developed by the GBRMPA to monitor temperatures associated with coral bleaching on the GBR.

[3] www.esi-topics.com/coralreef/inst/c1a.html

[4] www.in-cites.com/institutions/Australian_Ins_Mar_Sci.html

While AIMS research programs have evolved and broadened over its years of operation, its core focus has remained firmly on building up the basic understanding of tropical marine ecosystems.

Research supporting longer term GBR management

The importance of research and monitoring in the development of land and water management strategies for the GBRWHA was affirmed by the 1994 *25 Year Strategic Plan for the GBRWHA*, for which AIMS was one of the consulting stakeholders.[5]

One of the most important roles played by AIMS research in supporting longer term GBRWHA management is its collection, collation and release of data as part of its GBR Long-term Monitoring Programme. Broad-scale surveys of coral, algae, reef fish and crown-of-thorns starfish (COTS) populations have been conducted by AIMS since 1985, covering the perimeters of approximately 100 in- and off-shore reefs. The data are released in status reports to the GBRMPA and the general public via the internet and in CD-ROM form. AIMS also produces summary reports of longer term trends, particularly about issues of concern such as COTS populations and coral bleaching. For example, in 2003-04, this database underpinned a longitudinal comparison of COTS outbreaks, suggesting that successive outbreaks are not becoming more intense.

AIMS expertise is also able to be applied in response to discrete events that threaten environmental quality. For instance, AIMS staff played a role in informing GBRMPA's response to the 2000-01 grounding of a container ship near Cairns. Sediment contaminated by TBT antifoulant was shown to be highly toxic to coral larvae and to inhibit settlement at very low concentrations. This information was used by GBRMPA to determine the dimensions of the subsequent clean up operations.

One of the key factors in developing good ecological management policies is the communication of scientific research to non-scientific stakeholders. In recent years AIMS has become more active in the dissemination of its research findings to a wider audience than the peer academic community. The Reef Futures Knowledge Management system is the product of a collaboration between AIMS, JCU, and the CRC Reef. It is designed to increase access to highly technical research, using a range of media including text search engines and interactive mapping technologies to allow broader understanding of these complex issues.[6]

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5 GBRMPA, *The Great Barrier Reef: Keeping it Great: a 25 Year Strategic Plan for the GBRWHA 1994-2019*, 1994.

6 <www.reeffutures.org>

In 2002-03, AIMS launched its new research tool Coral ID, which enhances the identification of coral species and allows access to taxonomic and biogeographic information. Sold as a CD-ROM, this tool is intended as a resource for a range of users, including resource managers and researchers, tourism operators and recreational divers. AIMS is developing version 2, as well as Coral Geographic, a web-based product designed to capture all current knowledge of corals. This is expected to contribute to access to information about coral reefs both in Australia and globally.

Data provided by AIMS has provided the fundamental scientific basis for the development in recent years of several key management plans for the GBRWHA. For example, AIMS data and scientific advice has been an important input into the development of both the *GBRMP Zoning Plan* and the *Reef Water Quality Protection Plan*.

GBRMP Zoning and the Representative Areas Program

AIMS knowledge base of the distributions of plants and animals, environments and habitats in the GBRWHA was used by the GBRMPA as a framework for its Representative Areas Program (RAP). These data were stored in large public geographical information systems which were important resources guiding the selection of candidate sites for a network of marine protected areas to conserve the diversity of the World Heritage Area. The RAP initiative used AIMS scientific data as well as analyses and decision support tools developed at AIMS.

The *GBRMP Zoning Plan* 2003 provided increased protection through representative areas of the major habitats. The new plan provided zoning for 28 new coastal sections added to the marine park between 2000-02, development of a single Zoning Plan for the entire park, and a coordinate based zoning system intended to assist public understanding and compliance. In March 2004, new zoning of the GBRMP was passed through parliament. This integrated scientific advice from AIMS, and the updated RAP increased protection for all bioregions in the park.[7]

Reef Water Quality Protection Plan

AIMS role in informing management policy has included both direct marine management, and land management in the catchment area which flows into the GBRWHA. The Great Barrier Reef catchment covers 22% of the state of Queensland, comprising 35 major drainage basins on the mainland and large islands. The major

[7] GBRMPA, *The Representative Areas Programme* fact sheet

land use of this area is cattle grazing on native and cleared pasture, which occurs on over 75% of the catchment. The Productivity Commission in 2003 identified the most significant sources of diffuse pollution as soil erosion from grazing, and the over or inappropriate use of fertilizers and other chemicals by cropping industries.[8] In their summary, the interdepartmental Reef Science Panel (including the principal research scientist at AIMS) recommended in 2003 that there was clear evidence that the water quality in rivers entering the GBR lagoon has declined because of diffuse pollutants, especially nutrients and chemicals running off from cropping and grazing land, threatening the health of reef ecosystems.[9] Research from AIMS and other marine science organisations underpins these conclusions. From early programs collecting and analysing baseline levels of trace metals and organochloride pesticides in reef organisms, AIMS research has involved data collection and monitoring of the health of the GBR lagoon ecosystem. Expertise in marine life monitoring has allowed AIMS scientists to develop sophisticated bioindicator tests, seabed mapping technologies, and methods for observing and sampling reef life. In 2003-04, AIMS developed pioneering application of epidemiological methods to environmental issues, enhancing ability to establish causal links between terrestrial run-off, inshore water quality, and the health of adjacent coral reefs.

Alongside the findings that nutrient, pesticide and herbicide run-off from agriculture appears to have significant impacts on the health of surrounding reef ecosystems, AIMS scientists have also sought ways of managing these impacts in order to create sustainable outcomes for all stakeholders, including agricultural and aquaculture industries and conservationists. The Productivity Commission report notes that existing water quality policy measures largely focus on prescriptive end-of-pipe controls; instead, the authors suggest that combinations of land management measures tailored to local uses are necessary to improving downstream water quality.[10]

The 2003 Commonwealth/State *Reef Water Quality Protection Plan* (RWQPP) was introduced to address the issue of diffuse pollution into reef environments from broad scale land use, through consultative and collaborative strategies involving all parties to management of the land and water systems involved. AIMS has been a significant contributor of scientific input into implementation of the RWQPP, with survey data

8 Productivity Commission 2003, *Industries Land Use and Water Quality in the Great Barrier Reef Catchment*, Research Report, Canberra.

9 DEH, *Summary Statement of the Reef Science Panel Regarding Water Quality in and Adjacent to the Great Barrier Reef*, 2003

10 Productivity Commission 2003, *Industries Land Use and Water Quality in the Great Barrier Reef Catchment*, Research Report, Canberra.

of inshore reefs of the GBR providing a benchmark for assessing changes in the status of reefs. The programme is a collaborative effort between reef communities, industry, scientists and managers, and is initially running for two years but is expected to form the basis of a decade-long assessment of GBR catchment management. The RWQPP objectives of reduction of diffusely sourced pollutants and the rehabilitation and conservation of significant areas are addressed through strategies promoting better land use decisions and practices, including self-management approaches, education, economic incentives, and regulatory monitoring and evaluation. The role of research in this program of planning for sustainable natural resource management is substantial. The GBRMPA's Marine Monitoring Programme for the RWQPP is coordinated through CRC Reef on behalf of a consortium of research partners, amongst whom AIMS is the major science provider. This consortium won the multi-million dollar bid in 2004-05.

Research supporting management of Northern and Western Australian tropical marine environment

In 2001-02, AIMS established new bases in Darwin and Perth, extending and expanding respectively its research into these regions. In 2003-04, AIMS began a survey of the oceanic shoals bioregion in north Australian waters. This environment had previously received almost no scientific attention. AIMS documented physical, chemical and biological aspects of this region, revealing many new species. The geographical focus of the research is the region stretching from the reefs of northern WA to Darwin which has been targeted on the basis of demand from marine management agencies and industry. The generation of baseline scientific data about these environments is expected to feed into the development of effective environmental management strategies, including improved assessments of marine resources.

In 2005 AIMS researchers collaborated with industry and research groups to track whale sharks beyond Ningaloo Reef, providing valuable data to enhance fisheries management. Participants included CSIRO, US National Oceanic & Atmospheric Administration, Pacific Islands Fisheries Science Centre, Hubbs-SeaWorld Research Institute, WA Department of Conservation & Land Management, DEH, BHP Billiton, Woodside Energy, and Chevron. The use of satellite technology with improved 'SPLASH' tags suggested that there are significantly fewer individuals than expected, and that the whale shark population is more vulnerable than anticipated. The improved knowledge of movement patterns of whale sharks will aid in the development of species management plans, as well as enabling ecotourism operators to better predict seasonal movements of the whale sharks. The recently developed snorkelling with sharks industry contributes over $12m annually to the local Ningaloo economy.

In 2002-03, reflecting its new geographical reach, AIMS began a collaborative project with the NT Department of Infrastructure, Planning and Environment. The aim of this project was to monitor and compare water quality across the Darwin Harbour, and, through a website, to communicate this knowledge to all stakeholders. The NT government intends to explore the conversion of pastoral leases, particularly near the Daly River estuary, to agriculture. This study will help inform stakeholders of the potential impacts of such a policy, as well as underpinning management strategies for sustainable development in the region.

Research supporting management of the international tropical marine environment

AIMS expertise in survey method and communication has been applied beyond AIMS original GBR focus. The Institute is closely associated with the Global Coral Reef Monitoring Network (GCRMN), a global network of governments, NGOs and research organizations in over 80 countries under the aegis of the International Coral Reef Initiative which was launched by the UN in 1994. As well as monitoring Australian reefs, AIMS produces the bi-annual *Status of Coral Reefs of the World* publication, which reviews global reef status and management.

AIMS expertise in mangrove and coral reef assessment was used to provide advice to management agencies of reefs in Maldives and Thailand following the 2004 tsunami. AIMS researchers assessed the health of reefs, and the impact of tsunami on island geology and bait fisheries. Recommendations on rehabilitation focused on tourism and fishing. This came under the umbrella of the Global Coral Reef Monitoring Network, of which AIMS is a major member.

With industry partners including Western High (Aust.), Greenfields Resources Holdings (Japan) and Pennington Seeds Inc. (US), researchers from AIMS began a project in 2002-03 in the Fujian province of China. This project is looking at the possibility of using efficient coastal water recycling and minimising fertilizer use to reduce downstream estuarine pollution in the region.

Role in supporting environmentally sustainable industry development

One of the crucial stakeholder groups in the GBRMP and other marine environments is made up of industries whose agricultural, pastoral, commercial, and recreational use of the land areas in the catchment adjacent to the marine environment must be a part of any management policy.

> *"AIMS is engaged by the QDPI 'as a source of independent professional advice on potential impacts of proposed coastal land use.'"*
>
> Chief Scientist, 2001, *Review of Marine Research in Tropical Australia*, pg. 106

Marine science research provides knowledge of ecosystems and biological processes which are essential to developing guidelines for sustainable use of coastal and reef environments. In addition, this understanding may be used by industries such as mining, off-shore oil and gas, fisheries, aquaculture and tourism to improve commercial practices.

> *"AIMS is (also) providing the region with a strong research capability to support existing and emerging marine industries such as tourism, aquaculture and biomolecular discovery"*
>
> Chief Scientist, 2001, *Review of Marine Research in Tropical Australia*, pg. 108

As well as the long term 'public good' benefits of collaboration in managing marine resources, AIMS inputs to industry have also included the development of innovative aquaculture stocks and processes and most recently, research into potentially therapeutic uses of marine organisms.

CHAPTER 3
Framework for assessing the economic impacts of AIMS

3.1 Issues in assessing the economic impacts of AIMS

There are significant measurement challenges associated with assessing the impacts, both economic and non-economic, of AIMS. Valuation of economic impacts is especially complex for an organisation such as AIMS which largely deals with benefits which are not easily quantifiable, such as environmental or heritage values. The core mission of AIMS is to generate and transfer knowledge to support the sustainable use and protection of Australia's marine environment. While sustainable use and protection of natural environments may incidentally result in economic benefit, such a goal is largely in the public good sphere, and as such is largely external to markets. In many respects, the impacts of AIMS research in increasing scientific understanding cannot be fully quantified and attributed, as outcomes are not embodied in market transactions.

The economics of attaching "value" to the environment is still an evolving discipline. Internationally, however, the significant importance placed on research into the environment can be seen in the European Union's commitment of 2.1 billion Euros between 2002 and 2006 to its *sustainable development, global change and ecosystems* thematic priority.

Approaches to comprehensively "value" non-market goods such as ecosystem quality entail using methods such as contingent valuation and contingent choice valuations

which are open to debate. However, what is clear and economically quantifiable is that the direct costs associated with fixing environmental damage can be very high and that research that mitigates against environmental damage can therefore deliver high value. For instance, the United States government is slated to spend almost $8 billion restoring parts of the Florida Everglades as wetlands between 2000 and 2030. The Army Corps of Engineers also had a plan to spend $14 billion to restore New Orleans' barrier islands before Hurricane Katrina arrived[11].

In addition to the difficulties associated with "valuing" environmental outcomes, a number of other challenges exist in relation to the measurement of AIMS economic impacts. Chief amongst these challenges are "attribution" issues and the "contingent" nature of some of AIMS key impacts.

Attribution issues

Many of AIMS activities are one component of multi-party long-term endeavours. Even if the value of particular outcomes can be approximated or modelled, there remains the challenge of linking specific AIMS research efforts to these results. This involves determining the extent to which AIMS research has been necessary to the outcome.

To demonstrate the difficulty of the "attribution" issue, it is helpful to consider the two extreme options. At one extreme, you could assume that if AIMS research has been necessary (even if not sufficient) to a given outcome, 100% of the impact should be "credited" to AIMS. At the other extreme, unless AIMS activity has been both necessary and sufficient to generate an outcome, none of the impact should be "credited" to AIMS.

In a real world situation, it would be unlikely to find many impacts that can be solely attributed to one organisation or factor. This suggests that the first approach would risk over-estimation of the impact of AIMS by discounting the role of other factors in the generation of an outcome. On the other hand, the second approach would result in an unrealistically stringent exclusion of many benefits at least in part attributable to AIMS. For that reason, in this study we have attempted to strike a middle ground, considering each of the main contributors to a particular outcome and assigning "credit" for an outcome in proportion to the relative role of AIMS in generating the outcome.

[11] Woodworth (2006) The Scientist Volume 20, Issue 4

The contingent nature of some impacts

The core focus of AIMS is on building greater understanding of tropical marine ecosystems and in particular the impacts of human activity on these ecosystems. This knowledge is utilised in the formation of management policies for such ecosystems. The major potential impact of AIMS is therefore on the future wellbeing of these ecosystems, which in turn may flow through to measurable economic effects on industries such as tourism and fisheries.

The purpose of management policies for marine ecosystems such as the GBRWHA is to mitigate risks of environmental degradation occurring. However, even the most stringent environmental management policies can not guarantee that environmental degradation will not occur. Natural events such as cyclones, earthquakes, tsunamis, etc have the potential to inflict enormous damage to delicate reef environments and it can not be known if such natural events will occur in the future. Similarly, fish stocks could be dramatically depleted in the future due to the natural outbreak of disease. Therefore, any future estimation of the effect of environmental management policies and practices on the quality of the GBR or the health of fish stocks is contingent on what "natural" events may or may not occur to impact upon them. For instance, it may be determined that in the absence of a natural catastrophic event occurring well founded management policies would be expected to improve the quality of the environment by some measurable amount. However, this forecast outcome is *contingent* on no catastrophic natural event occurring. The actual future outcome could be that despite best practice management policy the ecosystem is severely damaged by a natural event. In this case the actual impact of good management policies on the ecosystem may be nil, as the ecosystem would be similarly damaged with or without good management practice being in place. However, the fact that the benefits from good management policy are contingent on certain natural events not occurring does not mean that good management policy should not be attributed some expected future value.

3.2 The approach to economic impact assessment adopted in this study

Construction of "with AIMS" and "without AIMS" scenarios

In order to assess the economic impact of AIMS since its inception, we must consider how economic outcomes in Northern Queensland, Queensland and Australia would have been different in the absence of AIMS and its activities. To create such a "without AIMS" scenario for economic performance, it is firstly necessary to

reallocate the resources that have gone into AIMS to some other use. In this way the "expenditure" effects of AIMS can be accounted for. Secondly, it is necessary to identify any discrete measurable economic outcomes that are attributable to the application of AIMS research by end users and to remove these effects from the economy within the "without AIMS" scenario for economic performance. In this way the "investment" effects of applying resources to AIMS can be accounted for.

Once the without AIMS scenario(s) have been developed, the Centre of Policy Studies' MMRF Computable General Equilibrium model of the Australian economy can be used to calculate the difference in economic performance that would have resulted from *not* establishing and resourcing AIMS since its inception.

Establishment of expenditure effects of AIMS

The true "cost" to taxpayers of the investment in AIMS should not be regarded as simply equivalent to the Government funding for AIMS. This is because the money invested in AIMS is not removed from the economy, but rather is spent within the economy. The true "cost" of the investment in AIMS is more usefully modelled by comparing the difference in economic performance between two scenarios:

1. The with AIMS case – a scenario where the government uses taxpayer funds (thus reducing to some extent real consumption which is considered the best indicator of economic welfare) to invest in AIMS which then spends this funding in the public services sector of the economy (which brings about some positive effects on real consumption); and
2. The without AIMS case – in this scenario, the assumption is that the government reduces taxation by an amount equivalent to AIMS funding (generating some positive effects on real consumption). As it no longer provides funding to AIMS, this is no longer expended in the public services sector of the North Queensland economy (resulting in some negative effects on real consumption).

Using the Centre of Policy Studies' MMRF model, the with and without AIMS cases can be compared in order to see the true "cost" to taxpayers of Government investment in AIMS in terms of higher or lower levels of real consumption.

Establishment of the investment effects of AIMS

If AIMS only impacts on Australian economic welfare were simple expenditure effects, its overall influence would be negative due to the dead weight loss involved in the collection and spending of taxation revenue.[12] However unlike transfer payments, such as pensions or unemployment benefits, government expenditure on AIMS funding would be expected to have flow on effects. That is, the generation of knowledge through AIMS funding has the potential to result in improved sustainability of existing industries, the development of new industries, and lead to better environmental outcomes. Impacts such as these would flow through to higher levels of economic welfare. Therefore, the effects of AIMS can be regarded as having some "investment" effects, as well as having the simple expenditure effects associated with any form of government spending within the economy.

In this study, by considering specific instances of where AIMS has generated knowledge that has been applied by end users, we have sought to identify some of the key "investment" effects of support for AIMS in addition to the simple expenditure effects associated with Government funding for AIMS.

3.3 A caveat regarding economic valuation of AIMS impacts

The fundamental impacts of AIMS – namely its contribution to the preservation of iconic tropical marine ecosystems – which in turn provide the primary rationale for its existence, are not able to be described in economic terms. The reason why ecosystems such as the GBRWHA are so important to Australia is not simply a function of the economic value associated with industries in the area such as tourism or fisheries. The iconic status of such an ecosystem comes from its "non market" environmental, cultural and social significance.

The GBRWHA, with its diversity of fish, corals, molluscs, birds, sponges, dugongs, whales and turtles is a unique ecosystem in which there are not just a few species which are valuable, but the entire ecology. The biodiversity of the GBR environment is one of the reasons why it has historically been important in human society.

[12] This would be the case at the national level. However, at the state and regional levels the expenditure effects in Queensland and Northern Queensland (where the majority of AIMS spending occurs) of AIMS funding outweigh the tax reduction effects.

For indigenous residents, an important means of maintaining culture is through ties to place, which are intrinsically connected to the biodiversity of the flora and fauna. The Aboriginal and Torres Straits traditional owners of the GBR area come from over forty groups, for whom the land is a site of history, and of contemporary identity. For non-indigenous Australians, too, the Reef is a symbol of Australian identity. It is an icon, a source of common values. That it is an ecosystem is apt; Australia is a nation of great natural beauty, and this has been central to the emergence of a national community.

Designating an ecological area 'heritage' highlights the long time scales which must be considered. In designating an area a 'heritage' place, we as a society are acknowledging that it is going to be of importance to generations in the future, and that we have a duty to preserve and pass down such a place to future generations. The GBRWHA is part of Queenslanders' heritage, as it is part of Australia's; indeed, it can be regarded as part of world heritage.

As UNESCO describes the sites included on its list of valuable world heritage places,

> *"Heritage is our legacy from the past, what we live with today, and what we pass on to future generations. Our cultural and natural heritage are both irreplaceable sources of life and inspiration. Places as unique and diverse as the wilds of East Africa's Serengeti, the Pyramids of Egypt, the Great Barrier Reef in Australia and the Baroque cathedrals of Latin America make up our world's heritage."*
>
> www.whc.unesco.org

When considering the measurable economic impacts of AIMS and its research, that are set out in Chapter 5, it must be remembered that these impacts represent just a secondary dimension of the true "value" of AIMS research.

CHAPTER 4
Identified impacts from AIMS

4.1 Expenditure effects generated by AIMS

As noted in Chapter 3, a clear measurable economic impact of AIMS is associated with the expenditure by AIMS, primarily within Northern Queensland, of Australian Government funding.

A second measurable impact of AIMS is associated with the private sector expenditure that it has attracted into (primarily) Northern Queensland and Western Australia that otherwise would not have occurred.

A third measurable impact of AIMS is associated with the fact that it has attracted international expenditure into (primarily) Northern Queensland that otherwise would not have occurred.

There is of course an opportunity cost to Australia associated with the first and second of these outcomes. The Australian Government funding expended primarily within Northern Queensland could have been left in the hands of Australian taxpayers, while the private sector expenditure could have been elsewhere directed within the Australian economy. The CoPS CGE MMRF Model allows the *net* effect of such impacts on the Northern Queensland, Queensland and Australian economies to be accurately assessed.

4.2 Benefits from better informed GBRWHA management policy

The major mechanism for AIMS delivering an end impact for the Australian community is through the application of AIMS generated knowledge and intellectual assets to improve the management of Australia's most iconic marine environment – the GBRWHA.

Since commencing operations in the early 1970s, AIMS has undertaken research to build understanding of tropical marine ecosystems with a view to providing the information necessary to underpin good stewardship of marine resources.

The scientific understanding of marine ecosystems generated by AIMS is crucial to the development of environmental management practices and policies. AIMS research has played a significant role in shaping management policies in the GBRWHA. For example, the GBRMPA used AIMS data on water quality in rivers and coastal seas to recommend new standards for the acceptable levels of sediments and nutrients carried by terrestrial run-off entering the GBRWHA. Fifteen years of AIMS data up to 2001-02 formed the basis of GBRMPA's 2001 *GBR Catchment Water Quality Action Plan*, which recommended specific water quality targets for individual river systems flowing to the GBR. This comprehensive body of river runoff research also stimulated the development of the joint Australian Government - Queensland Government *Reef Water Quality Protection Plan* (2003).

> *"GBRMPA uses research results to determine appropriate zoning regimes, and to formulate management plans for the various regions and resources of the Park"*
>
> Chief Scientist, 2001, *Review of Marine Research in Tropical Australia*, pg. 95

AIMS knowledge base of the distributions of plants and animals, environments and habitats in the GBRWHA was also used by the GBRMPA as a framework for its Representative Areas Program (RAP). These data were stored in large public geographical information systems which were important resources guiding the selection of candidate sites for a network of marine protected areas to conserve the diversity of the World Heritage Area. The RAP initiative used AIMS scientific data as well as analyses and decision support tools developed at AIMS. The *GBRMP Zoning Plan* 2003 provided increased protection through representative areas of the major habitats. The new plan provided zoning for 28 new coastal sections added to the marine park between 2000-02, development of a single Zoning Plan for the entire park, and a coordinate based zoning system intended to assist public understanding and compliance. In March 2004, new zoning of the GBRMP was passed through

parliament. The AIMS GBR long term monitoring program is currently being used to help assess the performance of the Plan.

One of the key factors in the translation of scientific understanding of an ecosystem into the development of good ecological management policies is the effective communication of scientific research to non-scientific stakeholders and users. To enhance such communication, the Reef Futures Knowledge Management System has now been established through collaboration between AIMS, JCU, and the CRC Reef. Its intent is to provide ready access to highly technical research in easily usable forms, using a range of media including text search engines and interactive mapping technologies to allow broader understanding of these complex issues.

Although it is not possible to put a precise dollar value on the contribution made by AIMS to GBRWHA management, it is possible to provide information in relation to the potential scale of economic value associated with AIMS work in this area through consideration of the impact of GBRWHA management on the tourism sector.

4.3 Contribution to the reef tourism sector

Results of a study into the link between GBR quality and recreational demand suggest that 35 per cent of tourists who visit the GBRWHA would not do so if the quality of the GBR significantly declined[13]. The recent introduction of a new zoning plan and a comprehensive water quality protection plan for the GBRWHA are specifically targeted at preventing such environmental degradation of the GBR occurring.

> *"The implementation of a Reef Water Quality Protection Plan will reduce the amount of nutrients and sediments from land-based sources that are impacting the inner reefs and seagrass areas. This will improve the sustainability of tourism business in these areas. The Great Barrier Reef Marine Park Authority, in consultation with all industries, has proposed a new zoning plan that aims to provide greater protection of the biodiversity of the Reef while maintaining its range of activities and uses. This Representative Areas Program seeks to protect the reef environment and preserve the commercial value of the reef underpinning the long term sustainability of the reef tourism industry."*
>
> Australian Government Tourism White Paper, *A Medium to Long Term Strategy for Tourism*, pg 42,43

[13] Kragt, M.E., et al, (2006), *Effects of GBR degradation on recreational demand: A contingent behaviour approach*, Fondazione Eni Enrico Mattei

If these plans act to prevent environmental damage that otherwise would have become apparent from say 2010 onwards, the flow on effect to tourism revenues would be significant. Between 2010 and 2020, tourism revenue for in the GBR catchment area is estimated to total more than $60 billion (and as an industry tourism is second only to mining in terms of total value of production in the region)[14]. Hence, even a 10 per cent decline in tourism due to environmental degradation (let alone a 35 per cent decline) would lead to a loss of more than $6 billion in revenue for the tourism sector in Northern Queensland. Given the necessary role of scientific information in the formulation of effective resource management policy and practice, and the central role of AIMS in generating this scientific information, it is clear that the work of AIMS has the potential to generate very real economic benefits.

4.4 Contribution to the development of the Western Australian offshore gas industry

Since 1994 AIMS has been collecting data on the marine ecosystem off the coast of Western Australia. In particular, AIMS has focused on building up understanding of the Ningaloo Reef, Exmouth Gulf region and remote coral reefs off North West Australia and the Timor Sea. Research at Scott Reef off North West Australia was initially co-funded by Woodside Energy. The company wanted to understand natural variation of marine conditions, particularly in their development lease areas around the reef. At the conclusion of the initial five year funding agreement in 1999, Woodside Energy and AIMS negotiated a series of additional one year agreements to continue and expand AIMS scientific work in Western Australia. While AIMS was interested in conducting this work from a scientific interest perspective to improve its understanding of the Timor and Arafura Seas, Woodside Energy saw this work as a valuable source of information that they required to properly meet lease retention requirements and to plan for the future development of gas fields in their lease areas. Hence a mutually beneficial co-funding arrangement for this scientific research has now continued for over 11 years.

More recently, three years ago AIMS also entered into a relationship with BHP Billiton Petroleum Pty Ltd (BHPBP) to conduct marine science research 30 to 50 km off the Western Australian coast in areas surrounding two large prospective BHPBP gas field development projects. AIMS specialised deep water environmental analysis expertise has provided critical information on environmental risk required for

[14] Based on industry projections in Productivity Commission, (2003), *Industries in the GBR Catchment and Water Quality*

BHPBP's Environmental Impact Statements for the two prospective developments, each of which would entail an investment by BHPBP of around $1 billion. As part of the agreement that AIMS has with BHPBP, AIMS is able to conduct strategic research of interest to AIMS as part of the expeditions they are undertaking for BHPBP. In this way, the relationship is not a simple fee-for-service arrangement, but rather a mutually beneficial partnership whereby BHPBP gains access to critical scientific data that it needs to progress its projects, while AIMS is able to leverage off the BHPBP funded projects to conduct a range of public good / national interest scientific research.

Both Woodside Energy and BHPBP see a number of benefits resulting from their relationship with AIMS. Most directly, independent scientific advice and high quality scientific data collection conducted by AIMS provides a necessary input to the completion of environmental impact statements relating to a number of proposed major gas field developments off the Western Australian coast. Woodside attests that without the long-term data sets that AIMS has developed, prospects for securing regulatory approval for their proposed gas field developments would be diminished. Also, because AIMS conducts this work on a co-funding basis, reflecting the fact that AIMS has an interest in conducting this work from a broader national scientific interest perspective, Woodside Energy has also benefited from some direct cost savings in accessing the scientific data they require.

Beyond such direct benefits however, the relationship with AIMS is seen to provide a number of less quantifiable benefits for Woodside Energy and BHPBP. These include:

- Reputational benefits – by funding the work of a highly credible independent, public scientific agency such as AIMS, the companies enhance their corporate reputation. In addition to funding the data gathering work relevant to their lease areas, BHPBP is now entering into a funding agreement with AIMS to undertake "national interest" research as part of their community support programme. Woodside Energy has also contributed funding to AIMS national interest research into better understanding of the Whale Shark population in the region.
- Credibility with regulators – AIMS is rightly seen as a highly credible and unbiased source of scientific information and the companies see this as raising the credibility of their environmental impact statement submissions to regulatory agencies. Science conducted by private consulting firms would not necessarily be seen by regulators as "credible and unbiased" information in the way that AIMS work is.
- Shaping of future work programs – AIMS plays an important independent role in guiding the companies as to what environmental analysis they need to undertake and, just as importantly, what analysis they do not need to undertake.

This helps the companies avoid undertaking unnecessary costly data collection projects.

- Shaping of development plans – AIMS, through its sea floor mapping work for Woodside Energy, identified potential viable sites to consider in the planning phase for gas platform locations in shallower water that will be far more cost effective than alternative deep water locations. While the company may have independently located such options, without AIMS work this would have taken longer and involved the company undertaking its own costly mapping exercise.

Overall, while it is not possible to put a precise dollar value of the contribution of AIMS work in Western Australia, it is clear that through building better regional understanding of the marine environment they are increasing the prospects for the environmentally acceptable development of major gas fields occurring. Given the multi-billion dollar nature of these potential developments, even if AIMS only increased the chances for development by a small percentage such an impact would translate to many millions of dollars in expected additional investment in the region and subsequent revenue generation from gas sales.

4.5 Contribution to fisheries and aquaculture industry development

A significant body of AIMS research conducted in conjunction with relevant industry stakeholders has led to improved management of fisheries and/or aquaculture production. AIMS 1998 national review of Australian fisheries habitat synthesised knowledge on the subject, and was used by the Fisheries Research and Development Corporation to guide its Ecosystem Protection Program. In 1998-99, AIMS research showed that mangrove-lined creeks efficiently capture excess nutrients in prawn farm effluent, quickly converting it into potential fish food.

AIMS role in prawn aquaculture industry development

Prawn aquaculture became tagged as a potentially sustainable use of land which was associated with fewer risks of ecological damage than traditional agriculture. AIMS research intended to improve prawn farming included the isolation of genes regulating fertility to improve the control of reproduction. In 2002-03 AIMS scientists demonstrated the potential to select for black tiger prawn (*Penaeus monodon*) stock with an enhanced ability to survive and reproduce in captivity. Animals spawned at AIMS could grow to reproductive size in less than 12 months, which could make the farming of high-value prawn species more profitable and sustainable. Other research outputs from AIMS include the development of improved egg-washing processes and tools to identify stress/viral infection relationships. These outputs have been

transferred to industry through AIMS collaboration with the Australian Prawn Farmers Association (APFA).

Another species identified as potentially profitable and sustainable has been the tropical rock lobster (*Panulirus ornatus*). Currently, there are significant limits to profitable farming of this species, and AIMS research has been working on domestication. In 2002-03, AIMS instituted a new collaborative project, receiving funding and other inputs from commercial partners, to domesticate the rock lobster. By 2004-05, the technologies for inducing out of season breeding of rock lobster larvae had been transferred to the industrial partner The MG Kailis Group. This enabled the work on domesticating the species to continue year round, thanks to a reliable supply of larvae which enabled The MG Kailis Group to achieve a world first in aquaculture by producing hatchery-reared juvenile tropical rock lobsters (*Panulirus ornatus*) in July 2006.

AIMS role in sponge aquaculture industry development

Sometimes research can lead to unexpected outcomes. AIMS researchers have used sponges as natural laboratories to enhance production of the bioactive chemicals produced by sponges. While the focus of this research effort was to increase the amounts of these chemicals available for potential application as new drugs and other products – a possibly lucrative but completely novel and therefore high risk new market – research trials demonstrated the potential for applying the low technology aquaculture methods used in this research to grow bath sponges.

Sponges can be simply grown from cuttings, with minimal overheads and infrastructure, and after straightforward processing, the product is non-perishable and light, and hence cheap to transport. In combination, these features make sponge culture a potentially ideal enterprise for remote, coastal Indigenous communities. Sponge aquaculture presented an opportunity for culturally appropriate enterprise within Indigenous communities which could provide employment, and a significant opportunity for socio-economic recovery and independence.

In early 2001, a collaboration between AIMS, the Queensland Department of State Development and Innovation, and the Palm Island based labour and training provider Coolgaree CDEP, was formed to explore the potential for this new opportunity for uptake within the indigenous community at Palm Island.

AIMS research commenced with a sponge survey, which identified two ideal and abundant local species. Since then, a comprehensive research program has addressed a range of issues including development of culture methods for commercially viable

growth and survival and an understanding of factors that promote sponge growth and survival, as well as knowledge about the wild populations, their dynamics and the potential impacts of sponge farming, to ensure that a new sponge industry can be sustainably managed. The results of this research and detailed market analysis have been compiled into a major report and provided to agencies responsible for regulation of this potential new industry, in support of Coolgaree's application for relevant permits.

A critical feature of this project has been engagement with and hands-on involvement of indigenous stakeholders from the outset. Central to this approach is the partnership with Coolgaree CDEP as the community based proponent for the work. Coolgaree personnel have been involved in all aspects of the research, including participating on research cruises and deployment of experiments. Extensive briefings have also been held on several occasions with the Palm Island Council, the Manbarra Traditional Owners, and the Indigenous Coordinating Centre (and its predecessors, ATSIC, ATSIS etc). Native Title issues were resolved through the negotiation, over an 18 month period, of an Indigenous Land Use Agreement, which was facilitated by and is now registered with the National Native Title Tribunal. This agreement is between Coolgaree and the Manbarra Traditional Owners. It lays out the conditions under which sponge farming may proceed in Manbarra sea country, including the resolution that a not-for-profit trust will operate the enterprise, with any profits available for community development projects. An extensive site clearance was conducted, and this formed the basis for site selection for the research. Two separate public displays in the Palm Island mall as well as fun and colourful sponge activity days at both schools on Palm Island, have ensured wide understanding and awareness of the project in the community.

Currently, the Palm Island project is poised at the interface between experiment and enterprise. Market assessment and business planning indicates that it will be economically viable and will employ over 30 people from Palm Island, although fund-raising to amass the required capital has only just begun. Most recently, 5 full time traineeship positions have been funded, to be recruited from the Palm Island community. These trainees will initially be an integral part of the research team, and will have the responsibility of deploying Coolgaree's first demonstration farm. Besides on-the-job skills development and technology transfer, these trainees will be formally trained as commercial divers. They will be skilled and well positioned to become the first employees of Australia's first sponge farm. The Palm Island experience is now

being transferred to two Torres Strait communities in collaboration with the Torres Strait Regional Authority.

AIMS role in aquaculture in the Asian region

AIMS aquaculture expertise has also been applied in the Asian region, with cost-effective aquaculture techniques introduced in Vietnam in 2000-01 expected to generate improved living standards in coastal communities in the Mekong Delta. The 5-year joint project between AIMS, the Vietnam Ministry of Fisheries, the Australian Centre for Agricultural Research, the Network of Aquaculture Centres in the Asia Pacific, and the University of Tasmania resulted in survival of black tiger prawns increasing from 5% to 40%, resulting in higher harvests and farm income.

4.6 Contribution to mining sector performance

AIMS role in the Alcan Gove Alumina Development

In much the same way that AIMS is contributing to the offshore gas industry in Western Australia, AIMS is now playing an important role within the mining sector through the provision of environmental monitoring and environmental management planning services to a major industry partner.

Over the past year AIMS has been working with Alcan on a range of projects relating to their $2 billion expansion of the Alcan Gove alumina refinery. The expansion of the Alcan Gove alumina refinery presents major economic, social and environmental benefits for Nhulunbuy, the Northern Territory and Australia. The project is located approximately 650km east of Darwin at the western end of the Gove Peninsula in the north-east of Arnhem Land. The Gove Peninsula juts into the southern end of Melville Bay in the Northern Territory. The AIMS projects include environmental monitoring and the development of environmental remediation technologies.

The NT Office of Environment and Heritage (OEH), in granting approval for the development, concluded that:

> *"the environmental issues associated with the proposed project have been adequately identified. Appropriate environmental management of some of these issues has been resolved through the assessment process, while the remainder will be addressed through monitoring and management actions detailed in a comprehensive Environmental Management Plan (EMP), included as part of the Mining Management Plan."*
>
> Alcan Gove Alumina Refinery Expansion, *Assessment Report 42*, July 2004

In granting approval for the development, a requirement was placed on Alcan to:

- report monitoring data on a regular basis;
- undertake an annual review of monitoring data and to submit an annual report on the interpretation of the monitoring data and the company's performance against stated environmental objectives or targets; and
- in interpreting monitoring data, also analyse developing trends so that potential issues can be identified and addressed well before they reach trigger values and become environmental issues.

Provision of improved knowledge about the marine ecosystems of marine environment near this development assists Alcan (and regulators) monitor and manage environmental risks. It should also be noted that Alcan, in establishing its relationship with AIMS, has been motivated by more than its need to meet minimum mandated environmental monitoring standards. Alcan has a strong commitment to be a leader in environmental best practice. This commitment to sustainability was recognised recently with Fortune magazine ranking Alcan No.1 in the metals industry and in the top 10 companies overall in its 2004 list of the *World's Most Admired Companies for Social Responsibility*. Alcan was also selected two years in a row as a component of the Dow Jones *Sustainability World Index*, which tracks the performance of sustainability-driven organisations worldwide.

Alcan sees its partnership with AIMS as important for a number of reasons[15], including:

- Most obviously, it helps Alcan to meet its obligations under its development license. Alcan sees AIMS as being a high quality independent provider of scientific data that is well regarded by regulators. The credibility of AIMS science is key to regulators having confidence that Alcan is meeting its environmental obligations.
- The partnership with AIMS also helps Alcan to enhance its reputation within the community. As part of its partnership with AIMS, it is intended that AIMS will make regular presentation of its reports to both regulators and the wider community.
- AIMS work is expected to help Alcan identify the most cost effective approaches to environmental management at the Gove development.

The expansion of the Alcan Gove alumina refinery presents major economic, social and environmental benefits for Nhulunbuy, the Northern Territory and Australia.

[15] Based on discussions with Alcan management staff.

The economic benefits associated with the development have been quantified as including[16]:

- Increased exports from about $560 million to $980 million per annum.
- Additional Gross State Product (GSP) to the Northern Territory economy of $90 million per annum during construction and $200 million per annum during the operational phase.
- Direct employment for an average of 750 people, with approximately 1,700 people during peak construction and up to 120 when fully operational.
- Approximately $60 million per annum in additional government payments through taxes.
- Ongoing royalty payments to traditional landowners of around $9 million per annum.

In addition to these direct economic impacts, the development will deliver social and environmental benefits such as:

- It will secure the long term future of Nhulunbuy as a regional service centre, providing improved power supply, infrastructure and service to the local community and create new opportunities for local Indigenous enterprises.
- The waste water inventory reduction project being undertaken as part of the development will reduce the amount of stored water in the residue disposal area and enable safe runoff to the marine environment.
- The conversion of power supply from fuel oil to gas will deliver air quality and greenhouse gas improvements.

While it is not possible to assign a particular share of "credit" for the economic and other impacts associated with the Gove development to AIMS, or to place a certain economic value on the fact that AIMS will contribute to environmental best practice at the development, this does not mean that AIMS has not made a real and valuable contribution to both these outcomes. As is the case in relation to the offshore gas industry in Western Australia, due to the large size of the economic impacts associated with the development, even a very small share of such impacts would dwarf the level of public funding that has gone into supporting AIMS capability to enter into such partnerships with industry.

AIMS role in improving efficiency of QNI ship scheduling

On a much smaller scale than its role in the Alcan Gove Alumina development, AIMS has also made a contribution to the mining sector through its recent work with Queensland Nickel (QNI) to improve the efficiency of its ship scheduling into and out of the Port of Townsville.

16 www.alcangove.com.au

The QNI Yabulu Refinery is located 25 kilometres north of Townsville. QNI is part of BHP Billiton's international nickel business, involved in the exploration, mining, processing and marketing of high-quality nickel and cobalt. QNI's Yabulu Refinery is a lateritic nickel and cobalt processing plant. It processes ore from third party mines in New Caledonia, Indonesia and the Philippines, and produces high-purity nickel and cobalt products that are used in the manufacture of stainless steel, specialty steels, alloys and chemicals. The nickel production capacity is currently 32 000 tonnes per annum, and the cobalt production capacity is approximately 1900 tonnes per annum. However, two new extension projects being undertaken will by 2008 more than double the production output at the Yabulu Refinery, from the current 32 000 tonnes per annum of nickel, to nearly 76 000 tonnes and over 3500 tonnes of cobalt.

QNI engaged AIMS to undertake a project to link AIMS tide data forecasting capability to the QNI ship scheduling system. This project allows QNI to improve the accuracy of its ship scheduling which allows them to better schedule stevedoring services and to provide better information to clients on delivery times[17].

4.7 Biomolecular research impacts

In 2004-05, AIMS reorganised its effort in biotechnology, recognising a change in industry priorities from agrichemical biodiscovery to a focus on anti-tumour agents and microbes.

Current estimates[18] identify that over a third of the world's marine-based anti-cancer drug leads come from, or have affinity with, species in Australasia, in spite of the low level of exploration and development effort in the region. Research at AIMS is ideally positioned to develop expertise and infrastructure leading to the identification of usable compounds. Its collection of marine samples has been stored in a database which captures details such as abundance and location, symbiotic microbiology and natural products chemistry. This knowledge is the basis for access to these potential social and economic benefits arising from biodiversity in Australasian marine ecosystems. The harvest of wild populations is unlikely to provide an ecologically sustainable source of bioactive compounds for development. The culture of micro-organisms and molecular biological approaches may be an alternative to chemical synthesis.

17 Based on discussion with QNI ship scheduling department

18 Newman DJ and Cragg GM (2004) *Marine natural products in clinical or advanced preclinical trials*. J Natural Products 67:1216-1238.

While the delivery of final impacts from AIMS biomolecular research are still to come, an example of the ways marine science may potentially lead to drug discovery, and of the ways a biomolecular approach may aid understanding of marine ecology, was the AIMS discovery in 1999-2000 of a substance isolated from a common marine sponge, *Rhopaloeides odorabile*, that was shown to be capable of killing human leukaemia cells. Studies of the bacterium's symbiotic relationship with the sponge led researchers to conclude that the active compound appears to be a product of this symbiosis. AIMS scientists have continued to develop techniques which increase understanding of active chemicals in marine organisms, including means of converting these into usable drug forms. In collaboration with scientists from the University of Aberdeen and the University of London's School of Pharmacy, AIMS researchers have replicated a cancer-fighting DNA from a sea squirt. This has been placed into an easily cultured bacterium, so that the therapeutic benefits of this agent can be utilised without the environmental consequences of harvesting large amounts of the original marine specimen.

AIMS biotechnology innovations also have the potential to improve food quality and optimise farm production management processes. The active chemicals found in marine organisms potentially have other applications than human pharmaceuticals. In 2002-03, research yielded 30 new lead compounds exhibiting specific C4 plant herbicidal activity. C4 class plants include most of the world's worst weed species but are harmless to major food crops which are C3 class plants. AIMS now have IP arrangements with Nufarm agricultural producers for commercialisation of the lead compounds.

AIMS role in shaping the biodiscovery legislative environment

At the 1992 Earth Summit in Rio de Janeiro, world leaders agreed on a comprehensive strategy for "sustainable development" - meeting our needs while ensuring that we leave a healthy and viable world for future generations. One of the key agreements adopted at Rio was the Convention on Biological Diversity (CBD). The CBD was negotiated under the auspices of the United Nations Environment Programme (UNEP) and came into force in December 1993. This pact among the vast majority of the world's governments, including Australia, sets out commitments for maintaining the world's ecological underpinnings as we go about the business of economic development. The CBD establishes three main goals: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources. It is much more than an environmental treaty - it is a hybrid that also addresses environmental, trade, development and

intellectual property rights issues. Perhaps not surprisingly, practical implementation of the third objective has proven a struggle, and due to the resulting ambiguities and commercial uncertainties, the CBD had a significant global negative impact on the viability of biodiscovery, including at AIMS.

In the post-CBD era, AIMS experienced great difficulty obtaining collection permits from some marine jurisdictions in Australia, the rights to existing collections were cast into legal doubt, and significant projects were stalled. In response to the lack of process and legislative basis for benefit sharing and the ambiguity on beneficiaries and benefits themselves, AIMS consulted widely and developed a Policy and Procedure for Access and Benefit Sharing (ABS) for Biodiscovery. The breakthrough was to procedurally separate the process of seeking a collection permit (based purely on environmental grounds, and for which there was already plenty of process and law), from that of negotiating benefit sharing, as well as acknowledging a wide range of non-monetary benefits of biodiscovery, including documentation of biodiversity to support better conservation and management, capacity building, and the ability to attract industry investment. AIMS put its new benefit sharing policy into practice for the first time in 2000, when it executed Australia's first benefit sharing agreement, with the State of Queensland.

AIMS practical approach and unique perspective, as both a user and preserver of biodiversity, has been widely acknowledged and consulted in a range of national and international forums. These include regular invitations to speak at international conferences, and appointment of AIMS staff to expert committees such as the CBD's panel of experts on access and benefit sharing, the Australian Government delegation to CBD negotiating meetings, the national inquiry into access to genetic resources in Commonwealth areas, the Commonwealth interdepartmental committee for access and benefit sharing and the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) biodiscovery working group. The biodiscovery potential of Australia's mega biodiversity is now recognised at the highest levels, as are the key impediments including anything that increases the cost, risk, and timeframe, such as lengthy, ambiguous process. In 2002, all governments entered into an inter-governmental agreement to develop a nationally consistent approach to access and benefit sharing. A new emerging legislative framework to deliver this includes the *Biodiscovery Act (Qld)* 2004, and the *Environment Protection and Biodiversity Conservation Regulation Amendment* 2005 (which both incorporate a procedural separation of access and benefit sharing), and other jurisdictions have indicated their intention to draft new laws. As a Commonwealth Government statutory authority,

AIMS will continue to play an important role in the provision of independent advice, based on practical experience from the biodiscovery coalface.

4.8 Direct commercialisation of AIMS technology

AIMS has in recent years pursued the commercialisation of technology it has created where the opportunity has arisen.

The Kord® hand held computing device and software is a technology developed at AIMS that has subsequently been directly commercialised by its spin-off company WetPC P/L. The underwater computer was first developed to assist data collection by providing a capacity for researchers to record observations while still underwater. WetPC P/L has produced a related product, the SeaSlate®. This unit is allows divers to search and map underwater landscapes, and in 2005 prototypes were produced for the Royal Australian Navy. This mapping capability could be adapted to many purposes, for example use by salvage divers, divers supporting offshore oil well operations, or marine archaeologists.

AIMS signed exclusive commercialisation rights to WetPC in 1998. The Kord® IT was sublicensed by WetPC P/L to a West Australian company, Nautronix, in 2000. WetPC P/L clients have included the Royal Australian Navy, the Australian Army, Australian Special Forces, DSTO, and the Royal Netherlands Army.

Another example of the direct commercialisation of AIMS research has been the creation of fast, sensitive and cost-effective biosensor tools, which combine natural chemistry and computer chip detector systems. Cleveland Biosensors P/L (formerly ToxiTech P/L), a spin-off company of AIMS and JCU, has built on the platform technology of AIMS and JCU to develop a test kit with the potential to detect paralytic shellfish toxins in seafood and water. This is expected to be used by shellfish farmers and restaurants in order to check the safety of seafood products. The company is currently developing other applications of the platform technology including the detection of algal toxins in drinking water for national and overseas markets.

The direct commercialisation of AIMS technology has not been, and is unlikely to be in the future, a major channel for the delivery of economic impacts from AIMS when compared to scale of impacts that AIMS can generate within major industry sectors such as tourism, mining and offshore gas development.

It is likely that the direct commercialisation of the research produced by an organisation such as AIMS will remain a small component of the benefits that the organisation generates. Nevertheless, this does not imply that opportunities for commercialisation should be ignored. However, given the relatively low economic impacts available in this area when compared to the significant economic impacts that are associated with better marine environment management (for instance), the pursuit of commercialisation opportunities should not be allowed to displace activity away from AIMS core focus on conducting national interest research that informs marine environment management.

CHAPTER 5

Quantification of AIMS impacts and implications for the future

5.1 Overview of economic modelling scenarios developed

Two economic modelling scenarios were developed to help assess the economic impacts associated with AIMS since its inception.

The first scenario is designed to capture only the expenditure effects associated with AIMS to date. The modelling scenario presents what Northern Queensland, Queensland and Australian economic performance would have been if AIMS had not been created and then received the inputs that it has received since its inception. The time horizon for this first scenario ends at 2005.

The second economic scenario extends the time horizon for AIMS impacts out to 2020 and has a different purpose to the basic expenditure effect tracking conducted through scenario one. In addition to capturing expenditure effects (AIMS Government funding is held steady at real 2005 levels out to 2020), it represents an attempt to capture a small set of the potential "investment" effects associated with AIMS. This modelling is of course based on assumptions whose accuracy can be neither "proved" nor "disproved". This is necessarily the case when dealing with projections of possible future outcomes. However, it is judged that the two investment effects included in the scenario clearly meet the test of being "reasonable".

The results of this second scenario should not be regarded as a definitive or comprehensive calculation of the future economic impacts of AIMS. For instance, no attempt has been made to "value" AIMS contribution to the expansion of the Western Australian offshore gas industry output or of AIMS contribution to the highly economically significant Alcan Gove Alumina development. Issues of attribution in such cases are simply too difficult to resolve, thereby preventing such valuation attempts from being worthwhile. Rather, the second modelling scenario is undertaken simply to highlight, through inclusion of just the potential economic impacts on the tourism and commercial fisheries industries in the GBR catchment area that are associated with AIMS contribution to GBRWHA management policy, the scale of economic impact that such "public good" focused research may deliver.

5.2 Scenario One

Modelling inputs

As indicated in Table 5.1, the dominant input into the "without AIMS" case for scenario one was to reallocate Australian Government funding for AIMS out of the public R&D sector in (primarily) Northern Queensland, but also to a small extent Western Australia and Darwin, to income tax reductions. The assumption is therefore that if AIMS had not received government funding, this money would have instead been returned to taxpayers as income tax reductions.

The other, much smaller, expenditure change inputs into the "without AIMS" modelling scenario were:

- To remove the international investment that has gone into AIMS from the Northern Queensland public R&D sector. This is because without the presence of AIMS such funding would have been unlikely to have been directed to that sector.
- To remove the Australian business expenditure that has gone into AIMS from, as appropriate, the Northern Queensland and WA public research sectors. This funding is returned to the private sector and reallocated to other activity as per its overall expenditure pattern.
- To marginally increase costs in the gas/mining sectors to reflect the expenditure that these sectors would have incurred, in the absence of their relationships with AIMS, employing private environmental consultancy firms to conduct environmental data collection.

Table 5.1 Inputs into "without AIMS" case scenario one

	1990*	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Change in Commonwealth Government expenditure into R&D in Northern Queensland	-205	-16	-16	-18	-18	-17	-17	-17	-17	-19	-19	-20	-21	-23	-22	-24
Change in Commonwealth Government expenditure into R&D in WA						-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Change in Commonwealth Government expenditure into R&D in Darwin															-1	-1
Change in Commonwealth Government income tax collected	-205	-16	-16	-18	-18	-18	-18	-18	-18	-20	-20	-21	-22	-24	-24	-26
Change in foreign investment into R&D in Northern Queensland	-2	-1	-0.3	-0.3	-1.4	-0.8	-0.7	-0.6	-1	-1	-0.9	-0.8	-1.8	-1.4	-1.5	-1.3
Change in Australian busines expenditure into public R&D in Northern Queensland	-0.8	-0.2	-0.2	-1	-2	-1.2	-1.8	-1.6	-1	-1.3	-0.6	-1.2	-1.4	-1.3	-1.1	-2.2
Change in Australian busines expenditure into public R&D in WA						-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Change in costs incurred in mining sector																1
Change in costs incurred in WA gas sector						1	1	1	1	1	1	1	1	1	1	1

* The CoPS MMRF CGE model is configured to deal most effectively with post 1990 economic performance. Therefore, all pre-1990 resourcing into AIMS was converted to 1990 dollar terms and applied as a one year "shock" in 1990 rather than being inputted into the model annually over the 1973 to 1990 period. While this results in a slight distortion in modelling results relating to the early 1990s, it does allow for a fair overall accounting for AIMS expenditure effects since its inception in the early 1970s. Notwithstanding the slight distortions created, it was felt that this approach was far superior to the alternative of simply not accounting for pre 1990 AIMS resourcing.

Modelling outcomes

The modelling outcomes (see Appendix A for full outcomes tables) for scenario one simply account for the various expenditure effects associated with the measured inputs to date into AIMS. Scenario one does not account for any of the flow on economic impacts of the research outputs of AIMS and as such the results of this scenario do not measure the actual overall impacts of AIMS on the regional, state or national economy. Rather, they establish a base line for the "costs" of investing in AIMS for the Australian economy as well as the "benefits" accruing to the Northern Queensland and Queensland economies that would result if AIMS research delivered no economic impacts other than the simple expenditure effects associated with its activities.

Bearing the limited aims of the scenario one modelling in mind, what the CoPS MMRF Model shows is that if AIMS had not existed and resources had been otherwise allocated as described above, in terms of Gross Value Added (in 2005 dollars):

- The Far North region (Division 34) would have had Gross Value Added cumulatively $781 million *lower* than has been the case with AIMS. In 2005 Gross Value Added would have been $20 million *lower* than was the case with AIMS.

- Queensland would have had Gross Value Added cumulatively $1,127 million *lower* than has been the case with AIMS. In 2005 Gross Value Added would have been $34 million *lower* than was the case with AIMS.
- Australia would have had Gross Value Added cumulatively $322 million *higher* than has been the case with AIMS. In 2005 Gross Value Added would have been $14 million *higher* than was the case with AIMS.

In terms of Real Private Consumption (in 2005 dollars):

- Queensland would have had Real Private Consumption cumulatively $699 million *lower* than has been the case with AIMS. In 2005 Real Private Consumption would have been $24 million *lower* than was the case with AIMS.
- Australia would have had Real Private Consumption cumulatively $408 million *higher* than has been the case with AIMS. In 2005 Real Private Consumption would have been $11 million *higher* than was the case with AIMS.

In terms of Real Government Consumption (in 2005 dollars):

- Queensland would have had Real Government Consumption cumulatively $923 million *lower* than has been the case with AIMS. In 2005 Real Government Consumption would have been $22 million *lower* than was the case with AIMS.
- Australia would have had Real Government Consumption cumulatively $904 million *lower* than has been the case with AIMS. In 2005 Real Government Consumption would have been $22 million *lower* than was the case with AIMS.

What these results indicate is that when only the expenditure effects associated with AIMS are taken into account, the net result is that on an Australia wide basis the economy has suffered very slightly due to the resourcing of AIMS – without AIMS Australian Gross Value Add would have been 0.001% higher in 2005 – while the Queensland economy has gained somewhat – without AIMS Queensland Gross Value Add would have been 0.027% lower in 2005. At the Regional level, the Far North region has gained significantly from AIMS – without AIMS Far North region Gross Value Add would have been 0.464% lower in 2005.

The story is similar in relation to Real Private Consumption, with Australia wide Real Private Consumption very slightly reduced – without AIMS Australian Real Private Consumption would have been 0.002% higher in 2005 – while in Queensland Real Private Consumption has been somewhat raised – without AIMS Queensland Real Private Consumption would have been 0.033% lower in 2005.

Given the moderate falls in Real Government Consumption, at both the Queensland and Australia wide level – in 2005 Real Government Consumption in Queensland is 0.298% lower without AIMS and is 0.048% lower Australia wide – total real consumption is lowered at both the state and national level in the absence of AIMS.

What the scenario one modelling shows is that when just accounting for expenditure effects, the net economic impact of provision of taxpayer funding for AIMS, while clearly positive at the regional and State level, is negligible at the national level.

The overarching conclusion from the scenario one modelling is that even in the highly unlikely situation that AIMS generates no economic impacts beyond simple expenditure effects, the true net cost to taxpayers of investing in AIMS is only around $1 per taxpayer per year[19].

5.3 Scenario Two

Modelling inputs

In the second "without AIMS" modelling scenario all inputs for the period up to 2005 are the same as those included in the first "without AIMS" modelling scenario. For each of these inputs, for the period 2006 to 2020, the level of inputs observed for 2005 were assumed to continue at the same level in constant 2005 dollar terms out to 2020. While this may or may not prove to accurately project such expenditure patterns out to 2020, in the absence of any evidence to the contrary it was the only reasonable approach to adopt in estimating necessarily uncertain future events.

As indicated in Table 5.2, two new "investment" effects from AIMS have been included in the modelling over the 2006 to 2020 period. These are changes in output in the Northern Queensland tourism sector and changes in output in the Northern Queensland commercial fisheries industry that are forecast to be potential outcomes associated with AIMS role in informing key recent GBRWHA management policies. In the "without AIMS" case it is assumed that gross output in these two sectors would have differed in the ways presented from the "business as usual" forecasts for the future output of these industries.

This, of course, introduces several levels of uncertainty into the modelling scenario. Firstly, the business as usual projections for the two industry sectors in Northern Queensland, which we have taken from projections set out in the Productivity Commission's 2003 study *Industries in the GBR Catchment and Water Quality*, are, as was cautioned by the Productivity Commission, not certain to be accurate base case performance projections. Secondly, the impacts that we assume AIMS to have on

[19] Based on the $11 million annual decrease in private real consumption in 2005 shown by the CoPS modeling to be the net result of the presence of AIMS and a figure of 10.9 million taxpayers in 2005/06 that is based on Department of the Parliamentary Library 2004 data as interpreted in Macdonald and Kippen, 2005, Working Paper in Demography No. 95, *Reform of income tax in Australia: A long-term Agenda*.

shifting future output in these industries away from the business as usual projected output for the industries are also uncertain. Both the projected performance of the industry with or without AIMS is contingent on a range of unpredictable economic and environmental event factors. For instance, a catastrophic natural event could severely affect either industry or a major economic downturn or upturn could also dramatically alter the prospects for either industry.

Notwithstanding the inherent uncertainty associated with forecast future with or without AIMS outcomes, we have attempted to reasonably project, based on current knowledge, the potential future change in output in these industries that would result from AIMS not continuing to operate in the future.

The forecast changes in future performance in the Northern Queensland tourism sector attributed to the removal of AIMS activities since its inception are derived as follows:

- The tourism industry's output in the GBR catchment is projected under a business as usual case to increase over the 2001 to 2020 period from a base level of $4,228 million per annum in 2001 to $4,878 million per annum in 2010 and to $6,367 million per annum in 2020. These projections are based on an assumption that the GBR does not suffer significant environmental quality decline.
- Results of a study into the link between GBR quality and recreational demand suggest that 35 per cent of tourists who visit the GBRWHA would not do so if the quality of the GBR significantly declined[20]. The recent introduction of a new zoning plan and a comprehensive water quality protection plan for the GBRWHA are specifically targeted at preventing such environmental degradation of the GBR occurring.
- In the absence of such best practice environmental management policies, we assume that from 2010 GBR quality may in fact have started to suffer significant environmental quality decline and that from 2010 to 2020 tourism output in the GBR catchment region would therefore suffer a steady decline when compared to the "no significant environmental decline" projections. We assume that in the absence of best practice management policies tourism output in 2010 would be 3% lower than the base case projection, in 2011 it would be 6% lower, in 2012 it would be 9% lower and so on until by 2020 tourism output in the region is 33% lower than the level forecast in the "no significant environmental degradation" base case.

[20] Kragt, M.E., et al., (2006), *Effects of GBR degradation on recreational demand: A contingent behaviour approach*, Fondazione Eni Enrico Mattei

- This still leaves the issue of how much of this "avoided tourism output decline" can be attributed to AIMS. While there is no objectively "right" answer to this issue, what is clear is that scientific information has played a necessary but not sufficient role in the formation of management policy. The other necessary contributor to the formation of best practice management policy has of course been the management policy makers themselves. In the modelling scenario we have assumed that half of the attribution for the policy changes should go to the underpinning scientific information and half should go to management policy makers. This admittedly arbitrary apportionment of responsibility for management policy outcomes is an attempt to reflect the fact that while scientific information is not fully responsible for management policy outcomes it is still a very important input to those outcomes.
- AIMS is not the only scientific organisation to have contributed to the formation of management policy. James Cook University and the CRC Reef (of which AIMS and James Cook University are core members) in particular have also played a role in providing scientific research to underpin management policy and practice. The CSIRO, Universities of Sydney and Queensland and the Queensland Department of Primary Industries and Fisheries also have involvement in research into the GBR. However, in terms of staff numbers, provision of infrastructure (AIMS has the two research vessels operating on the GBR) and the duration of involvement with GBR research, AIMS clearly represents at least half of the scientific endeavour into the study of the GBR ecosystem. Therefore, in the modelling we assign AIMS half of attribution for the impact of scientific information onto tourism output.

Under these assumptions, AIMS is assigned 25 percent of the "credit" for avoiding the potential decline in tourism output in the region between 2010 and 2020 that may have occurred in the absence of well informed and effective marine ecosystem management policies being adopted.

The forecast changes in future performance in the Northern Queensland commercial fisheries industry attributed to the removal of AIMS activities since its inception are derived as follows:

- The commercial fishing industry's output in the GBR catchment is projected to decline over the 2001 to 2020 period from a base level of $117 million per annum in 2001 to $111 million per annum in 2010 and to $93 million per annum in 2020.
- We assume that this decline is primarily driven by changes to marine zoning policy which have restricted some fisheries activities and hence reduce output.
- As in the case with the tourism industry outputs, we have assumed that half of the attribution for the policy changes goes to the underpinning scientific information and that AIMS accounts for around half of that underpinning scientific information.

Under these assumptions, AIMS is assigned 25 percent of the "responsibility" for the forecast decline in fisheries output in the region between 2006 and 2020.

Table 5.2 sets out the resulting inputs into the "without AIMS" case for scenario two.

Table 5.2 Inputs into "without AIMS" case scenario two

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Change in Commonwealth Government expenditure into R&D in Northern Queensland	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24
Change in Commonwealth Government expenditure into R&D in WA	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Change in Commonwealth Government expenditure into R&D in Darwin	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Change in Commonwealth Government income tax collected	-26	-26	-26	-26	-26	-26	-26	-26	-26	-26	-26	-26	-26	-26	-26
Change in foreign investment into R&D in Northern Queensland	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3	-1.3
Change in Australian busines expenditure into public R&D in Northern Queensland	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2
Change in Australian busines expenditure into public R&D in WA	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Change in costs incurred in mining sector															
Change in costs incurred in WA gas sector	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Change in output in Northern Queensland tourism industry (2001 dollars)					-37	-75	-116	-160	-205	-253	-303	-355	-410	-466	-525
Change in output in Northern Queensland commercial fishing industry (2001 dollars)		1	1	1	1	2	2	2	3	3	3	4	4	4	5

Modelling outcomes

Scenario two (see Appendix A for full outcome tables) sets out one possible scenario for the economic impact of AIMS out to 2020. It assumes that in addition to simple expenditure effects, AIMS also has impacts on the future gross output of the tourism and commercial fisheries industries in Northern Queensland through the role AIMS has played in key recent GBRWHA management policy changes.

The modelling should not be viewed as a definitive accounting for the full future impacts of AIMS, but rather as a means of illustrating the type of economic impacts that public good focused research into marine ecosystems may generate at a regional, state and national level.

The CoPS MMRF Model shows is that if AIMS had not existed and resources had been otherwise allocated as described above, and tourism and fisheries output altered as described above, in terms of Gross Value Added (in 2005 dollars):

- The Far North region (Division 34) would have Gross Value Added cumulatively $2,788 million *lower* out to 2020 than would be the case with AIMS. In 2005 Gross Value Added would be $309 million *lower* than would be the case with AIMS. **This represents a fall in regional Gross Value Add in 2020 of 2.68% when compared to what would be expected with AIMS.**

- Queensland would have Gross Value Added cumulatively $3,094 million *lower* out to 2020 than would be the case with AIMS. In 2020 Gross Value Added would be $264 million *lower* than would be the case with AIMS. **This represents a fall in Queensland Gross Value Add in 2020 of 0.21% when compared to what would be expected with AIMS.**
- Australia would have Gross Value Added cumulatively $387 million *higher* out to 2020 than would be the case with AIMS. In 2020, however, Gross Value Added would be $1 million *lower* than would be the case with AIMS. **This represents a fall in Australian Gross Value Add in 2020 of 0.003% when compared to what would be expected with AIMS.**

In terms of Real Private Consumption (in 2005 dollars):

- Queensland would have Real Private Consumption cumulatively $1,764 million *lower* out to 2020 than would be the case with AIMS. In 2020 Real Private Consumption would be $144 million *lower* than would be the case with AIMS. **This represents a fall in Queensland Real Private Consumption in 2020 of 0.20% when compared to what would be expected with AIMS.**
- Australia would have Real Private Consumption cumulatively $140 million *higher* out to 2020 than would be the case with AIMS. However, in 2020, Real Private Consumption would be $53 million *lower* than would be the case with AIMS. **This represents a fall in Australian Real Private Consumption in 2020 of 0.015% when compared to what would be expected with AIMS.**

In terms of Real Government Consumption (in 2005 dollars):

- Queensland would have Real Government Consumption cumulatively $1,126 million *lower* out to 2020 than would be the case with AIMS. In 2020 Real Government Consumption would be $7.7 million *lower* than would be the case with AIMS. **This represents a fall in Queensland Real Government Consumption in 2020 of 0.11% when compared to what would be expected with AIMS.**
- Australia would have Real Government Consumption cumulatively $1,096 million *lower* out to 2020 than would be the case with AIMS. In 2020 Real Government Consumption would be $6.6 million *lower* than would be the case with AIMS. **This represents a fall in Australian Real Government Consumption in 2020 of 0.02% when compared to what would be expected with AIMS.**

What these results indicate is that when the expenditure effects associated with AIMS and just one potential "investment" type effect are taken into account, the net result is that at the Australia wide level the impacts of AIMS remain relatively small. However, it should be noted that by 2020 AIMS is generating *higher* Australian real private consumption of $53 million with the effects of AIMS on the tourism industry more than offsetting the simple expenditure effects associated with $26 million in taxpayer funding for AIMS (that would have seen $11 million lower real private consumption

based on expenditure effects alone). Under this scenario, by 2020 AIMS is generating increased real private consumption in Australia of more than twice the level of taxpayer funding that it receives.

At the regional and state level, however, the results indicate that AIMS could generate significant net economic benefits, both cumulatively and on a per annum basis. When compared to the low level of taxpayer resources directed to AIMS, the potential impacts on the regional economy in particular are very large. A 2.68% fall in the Far North region's annual gross value added would represent more than a halving of economic growth in the region.

Overall, what the scenario two modelling indicates is that even when viewing the impacts of AIMS in purely economic terms, national interest focused research such as that conducted by AIMS has the potential to generate dramatic regional economic benefits and, at the national level, economic benefits for Australia well in excess of its costs.

CHAPTER 6

Implications for the future activity, funding and evaluation of AIMS

6.1 Implications for the future activities of AIMS

Four major conclusions, that have important implications for its future activities, can be drawn from this study into the impacts of AIMS, namely:

1. Given the high regard in which AIMS scientific research is held by its external industry, government and other stakeholders, the economic significance of the ecosystems that its research informs the management of, and the role AIMS research plays in supporting environmentally sustainable marine industries (tourism, off-shore oil and gas, on-shore mining developments, aquaculture and other industries), AIMS is highly likely to deliver strong net economic benefits for Australia for a small investment by taxpayers. Effective environmental management also provides insurance against the high economic costs associated with ecological restoration[21].

[21] Ecological restoration is expensive. The United States government is slated to spend almost $8 billion restoring parts of the Florida Everglades as wetlands between 2000 and 2030. The Army Corps of Engineers had a plan to spend $14 billion to restore New Orleans' barrier islands before Hurricane Katrina arrived. [Woodworth (2006) The Scientist Volume 20, Issue 4]. In Australia, the costs associated with restoration of the Murray-Darling reinforce these findings in the national context.

2. The true value of AIMS research can never be fully captured in purely economic terms. Investment in AIMS research is primarily an investment in better understanding of the marine environment to enable conservation and sustainable use of Australia's marine natural heritage. Information generated though AIMS research minimises the risk associated with decision making by managers and users of marine resources and provides a preparedness to respond to future/emerging issues.

3. While opportunities for the direct commercialisation of AIMS research should not be ignored, given the relatively low economic impacts available in this area when compared to the significant economic impacts that are associated with better marine environment management (for instance), the pursuit of commercialisation opportunities should not be allowed to displace activity away from AIMS core focus on conducting research that informs sustainable use and protection of the marine environment.

4. Based on assessment of expenditure effects alone, AIMS represents a very small cost to the Australian taxpayer – $1 per taxpayer per year – compared to the benefits that its research generates.

The implication of these findings is that public support for AIMS provides economic, social and environmental impacts that deliver significant current and longer term benefits to Australia. In noting the value of AIMS research in relation to marine resources and existing areas of iconic value, it is important to recognise the extent of Australia's marine jurisdiction and that little is known about the marine ecosystems of Northern Australia. Continued investment into basic strategic marine science and marine research capability is necessary to fully understand and benefit from Australia's Marine estate.

> *"Strengthened marine research capability and effort in tropical regions is needed to grow the knowledge base, to describe organisms and resources, to implement ecosystem approaches to improved understanding marine processes, and to support the Regional Marine Planning process of Australia's Ocean Policy . In so doing, tropical marine research can continue to provide a context for developing skills that will be increasingly important to the national economy and to sustainable resource development and management, as marine industries, already one of our fastest growing sectors of the economy, continue to expand."*
>
> Chief Scientist, 2001, *Review of Marine Research in Tropical Australia*, pg. 16

The impacts from AIMS research also show that investment in environmental research provides an informed, and essential, base needed to manage uncertainty in the marine environment – being prepared and planning for the future. Ongoing public support for marine science is an investment in Australia's future wellbeing and is particularly important given that private industry does not conduct environmental research for the public benefit – in the marine environment this public funding is particularly important since marine resources are not owned in the same way as terrestrial resources.

6.2 Implications for the future evaluation of AIMS

To be deserving of taxpayer support, any publicly funded research – irrespective of whether it is oriented to commercial or national interest outcomes – should be of high quality. A number of well established and reasonably well accepted measures are available for the evaluation of the quality of research being produced. Quality metrics such as publications in referred journals, publication citation rates, membership of learned academies, awards received and so on can be used to build an understanding of the academic quality of the research being produced by a research group or organisation. For an Institution such as AIMS to continue to receive funding, it is therefore necessary that AIMS should be able to convincingly demonstrate, using such generally accepted metrics, that it consistently produces high quality research. This performance expectation is entirely appropriate and is integrated into the Institute's funding process through the inclusion of performance indicators in the AIMS Triennium Funding Agreement. The indicators include measures of quality and AIMS reports against these indicators each year in its Annual Report. More recently, AIMS has implemented a regular program of external expert review of its research consistent with the approach likely to be adopted in the Research Quality Framework[22].

[22] The Research Quality Framework (RQF) is currently being developed by the Australian Government with a view towards its implementation in 2007 or 2008. The RQF will involve assessment of a wide range of publicly funded research and appears likely to be used to inform future research funding allocations within the public research sector. Indications from the 'RQF preferred model' paper released by the RQF Expert Advisory Group in early 2006 are that external expert panels will most likely be involved in the assessment of research quality.

In relation to the need to demonstrate the impact of research, the situation is more complex. There is always a temptation to base evaluations of research impact on what can be easily measured rather than on what is important but difficult to measure. For instance, measures such as patents held, licences executed and spin-off companies formed are sometimes used as proxies for the economic "impact" of research. The use of such measures, or even the use of more sophisticated measures for commercialisation performance such as the turnover of spin-off companies or the value of licensing revenue, while perhaps appropriate for research that is highly targeted at commercial outcomes, are entirely inappropriate as measures of the economic impact of national interest oriented research.

As this study demonstrates, such "commercial" outcomes represent only a very small part of the economic impacts that national interest oriented research can generate. Rather than reliance on inappropriate metrics for impact evaluation, it is therefore necessary to evaluate the impact of research organisations such as AIMS by actually looking at what the organisation does, how its research outcomes are applied by end users, and what the results of such research application are. It should be stressed that not all such results will be able to be expressed in purely economic terms.

Such a detailed impact evaluation process is time consuming and costly, and hence is not something that can or should be done on an annual basis. However, it would be reasonable to expect that national interest oriented research groups or organisations undertake a detailed review of their impacts every five years or so and that the results of such a review should influence future funding outcomes.

The timelines upon which impact should be assessed, should be tied to the timelines upon which funding is awarded. The arrangement between the Institute for Molecular Bioscience (IMB) and the Queensland Government provides a best practice example of such alignment of research funding and research evaluation.

The IMB was initially awarded ten years of funding but on the proviso that the extent to which its agreed Key Performance Indicators (in relation to research quality, organisational efficiency, and research impact) had been met must be independently assessed after five years of operation. Only once the results of this review of performance had been evaluated by the Government, was the second tranch of five year funding released. Such an arrangement strikes an appropriate balance between providing the funding certainty needed to facilitate the proper planning and undertaking of long-term research projects on the one hand and ensuring

performance accountability and focus on delivery of end value to the community on the other hand[23].

The adoption of such a funding and evaluation model by the Commonwealth Government in relation to AIMS would be a very positive step in improving how long-term national interest focused research organisations such as AIMS are funded and evaluated.

[23] It is interesting to note that a similar long term funding and evaluation model has been adopted by the Swiss National Science Foundation in relation to its flagship National Centre of Competence in Research program. Under this program major national research centres receive are awarded funding with an eight year time horizon. However, centres must provide annual reports on progress and after four years undergo a comprehensive external review as part of the funding renewal proposal process. If the review outcomes are positive, the next four years of centre funding is then approved.

APPENDIX A
Detailed modelling output tables

A.1 The CoPS Model

The Centre of Policy Studies (CoPS) has been commissioned by Insight Economics to simulate the economic impacts of AIMS. The analysis reported here is undertaken using the MONASH Multi-Regional Forecasting (MMRF) model. MMRF is a bottom-up model of Australia's six states and two territories.

This report contains a brief overview of the model and simulation results are then reported.

Model overview

MMRF is a very detailed dynamic, multi-sectoral, multi-regional model of Australia. The current version of the model distinguishes 49 industries, 54 products, 8 states/territories and 56 sub-state regions.

MMRF is founded on the Monash Multi-Regional (MMR) model, and was built in three stages. In the first stage, MMR was transformed into a dynamic system by the inclusion of dynamic mechanisms. These were added as self-contained blocks, allowing MMRF to include MMR as a special case. The second stage involved a range of developments designed to enhance the model's capacity for environmental analysis. In the third stage, a regional disaggregation facility was added, which allows state-level results to be disaggregated down to sub-state regions.

MMR

MMR divides Australia into the six states and two territories. There are five types of agents in the model: industries, capital creators, households, governments, and foreigners. The number of industries is limited by computational constraints. For each industry in each region there is an associated capital creator. The sectors each produce a single commodity and the capital creators each produce units of capital that are specific to the associated sector. Each region in MMR has a single household and a regional government. There is also a federal government. Finally, there are foreigners, whose behaviour is summarised by export demand curves for the products of each region and by supply curves for international imports to each region.

MMR determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders so that each region's stock of productive resources reflects regional employment opportunities and relative rates of return.

The specifications of supply and demand behaviour co-ordinated through market clearing equations comprise the general equilibrium (GE) core of the model. There are two blocks of equations in addition to the core. They describe regional and federal government finances and regional labour markets.

From MMR to MMRF: dynamics

There are two main types of inter-temporal links incorporated into MMRF: physical capital accumulation and lagged adjustment processes.

Physical capital accumulation

It is assumed that investment undertaken in year t becomes operational at the start of year t+1. Thus, given a starting point value for capital in t=0, and with a mechanism for explaining investment through time, the model can be used to trace out the time paths of industry capital stocks.

Investment in industry i in state/territory s in year t is explained via a mechanism that relates investment to expected rates of return. The expected rate of return in year t can be specified in a variety of ways. In MMRF two possibilities are allowed for, static expectations and forward-looking model-consistent expectations. Under static expectations, it is assumed that investors take account only of current rentals and asset prices when forming current expectations about rates of return. Under rational

expectations the expected rate of return is set equal to the present value in year t of investing $1 in industry i in region r, taking account of both the rental earnings and depreciated asset value of this investment in year t+1 as calculated in the model.

Lagged adjustment processes

One lagged adjustment process is included in MMRF. This relates to the operation of the labour market in year-to-year policy simulations.

In comparative static analysis, one of the following two assumptions is made about the national real wage rate and national employment:

1. the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or
2. the national real wage rate is unaffected by the shock and employment adjusts.

MMRF's treatment of the labour market allows for a third, intermediate position, in which real wages can be sticky in the short run but flexible in the long-run and employment can be flexible in the short-run but sticky in the long-run. For year-to-year policy simulations, it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in aggregate employment from its basecase-forecast level. The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years. This is consistent with macroeconomic modelling in which the NAIRU is exogenous.

MMRF: Disaggregation to sub-state regions

Few multi-regional models of the Australian economy have the level of sectoral detail supported by MMRF. This detail is usually more than adequate for contributions to public discussions on the effects of changes in policies concerning taxes, trade and the environment. However, people wanting to use MMRF in business and public sector planning are often frustrated by the lack of relevant regional detail. This applies especially to people interested in regional adjustment issues.

It is with these people in mind that we have incorporated into MMRF a tops-down method that enables disaggregation of state-level results for output, employment and greenhouse-gas emissions down to projections for 56 sub-state regions.

These regions are based on the Statistical divisions defined in the Australian Standard Geographical Classification (ABS catalogue number 1216.0). Our division structure differs slightly from that of the ABS. We combine the ABS's Darwin and Northern Territory - balance divisions into one division, Northern Territory. Similarly, Canberra and ACT - balance are combined into one division, Australian Capital

Territory. Note that both territories are distinguished as separate regions in MMRF. Hence, the tops-down disaggregation facility provides no additional detail for them. We also adopt a slightly different regional classification for WA than that defined by the ABS. Our WA regions are based on the classification used by the WA Department of Commerce. Finally, we identify the energy intensive La Trobe Valley in Victoria as a separate region (region 24), with 23 Gippsland defined to include all areas in the ABS statistical division Gippsland other than the La Trobe Valley.

The region capturing the Great Barrier Reef World Heritage Area and its surrounds is division number 34, the Far North region

A.2 Modelling scenario inputs

Inputs to the two modelling scenarios are as described in Tables 5.1 and 5.2.

A.3 Output tables for Scenario One

Table A.1 Dollar value outcomes from the scenario one modelling: Australia, Queensland, rest of Australia

Abs deviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Real gross value added ($'000, constant 2005 prices)																
Australia	61.4	22.3	20.5	19.9	19.1	18.3	17.7	17.2	16.7	16.7	16.3	15.9	15.6	15.4	14.6	14.5
QLD	-512.8	-50.9	-47.7	-50.5	-48.0	-44.2	-42.1	-40.0	-38.1	-39.3	-37.5	-36.8	-36.0	-36.1	-33.7	-33.7
ROA	574.2	73.2	68.2	70.4	67.1	62.5	59.8	57.2	54.8	56.0	53.8	52.7	51.6	51.5	48.3	48.2
Real private consumption ($'000, constant 2005 prices)																
Australia	153.2	26.3	23.3	22.5	20.7	19.9	18.4	17.1	15.8	14.9	13.7	13.5	12.8	12.3	12.0	11.5
QLD	-276.4	-36.0	-33.2	-33.9	-32.2	-29.7	-28.4	-27.2	-26.1	-26.7	-25.9	-25.4	-25.0	-25.0	-23.8	-23.7
ROA	429.6	62.2	56.5	56.5	52.9	49.6	46.8	44.3	41.9	41.6	39.6	38.9	37.8	37.3	35.7	35.2
Real government consumption ($m, constant 2005 prices)																
Australia	-486.8	-36.1	-33.6	-36.4	-33.9	-31.5	-29.3	-27.3	-25.3	-26.4	-24.6	-23.8	-23.0	-23.0	-21.5	-21.5
QLD	-487.4	-38.2	-35.6	-38.5	-36.0	-32.5	-30.3	-28.3	-26.4	-27.5	-25.7	-24.9	-24.1	-24.1	-21.9	-21.9
ROA	0.5	2.1	2.1	2.1	2.1	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.4	0.4

Table A.2 Percentage deviation outcomes from the scenario one modelling: Australia, Queensland, rest of Australia

Abs deviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Real gross value added (%))																
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QLD	-0.41	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
ROA	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Real private consumption (%)																
Australia	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QLD	-0.39	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03
ROA	0.13	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Real government consumption (%)																
Australia	-1.00	-0.08	-0.07	-0.08	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
QLD	-6.48	-0.52	-0.49	-0.52	-0.49	-0.44	-0.41	-0.39	-0.36	-0.38	-0.35	-0.34	-0.33	-0.33	-0.30	-0.30
ROA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table A.3 Outcomes from the scenario one modelling: Far North region.

Abs deviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Far North - Division 34																
Real gross value added ($'000, constant 2005 prices)																
	-399.9	-33.1	-30.7	-33.1	-31.0	-27.9	-26.1	-24.4	-22.7	-24.1	-22.6	-22.1	-21.5	-21.9	-19.6	-19.9
Real gross value added (%)																
	-6.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.6	-0.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5

A.4 Output tables for Scenario Two

Table A.4 Dollar value outcomes from the scenario two modelling: Australia, Queensland, rest of Australia

Abs deviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Real gross value added ($'000, constant 2005 prices)																
Australia	61.4	22.3	20.5	19.9	19.1	18.3	17.7	17.2	16.7	16.7	16.3	15.9	15.6	15.4	14.6	14.5
QLD	-512.8	-50.9	-47.7	-50.5	-48.0	-44.2	-42.1	-40.0	-38.1	-39.3	-37.5	-36.8	-36.0	-36.1	-33.7	-33.7
ROA	574.2	73.2	68.2	70.4	67.1	62.5	59.8	57.2	54.8	56.0	53.8	52.7	51.6	51.5	48.3	48.2
Real private consumption ($'000, constant 2005 prices)																
Australia	153.2	26.3	23.3	22.5	20.7	19.9	18.4	17.1	15.8	14.9	13.7	13.5	12.8	12.3	12.0	11.5
QLD	-276.4	-36.0	-33.2	-33.9	-32.2	-29.7	-28.4	-27.2	-26.1	-26.7	-25.9	-25.4	-25.0	-25.0	-23.8	-23.7
ROA	429.6	62.2	56.5	56.5	52.9	49.6	46.8	44.3	41.9	41.6	39.6	38.9	37.8	37.3	35.7	35.2
Real government consumption ($m, constant 2005 prices)																
Australia	-486.8	-36.1	-33.6	-36.4	-33.9	-31.5	-29.3	-27.3	-25.3	-26.4	-24.6	-23.8	-23.0	-23.0	-21.5	-21.5
QLD	-487.4	-38.2	-35.6	-38.5	-36.0	-32.5	-30.3	-28.3	-26.4	-27.5	-25.7	-24.9	-24.1	-24.1	-21.9	-21.9
ROA	0.5	2.1	2.1	2.1	2.1	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.4	0.4
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Real gross value added ($'000, constant 2005 prices)																
Australia	14.1	13.7	13.3	12.8	9.9	7.0	4.3	1.9	0.1	-1.3	-2.2	-2.7	-2.6	-2.0	-1.0	
QLD	-32.2	-30.8	-29.4	-28.1	-52.9	-77.9	-102.6	-126.7	-150.0	-172.4	-193.9	-214.3	-233.8	-252.3	-269.7	
ROA	46.3	44.5	42.7	40.9	62.9	84.9	106.8	128.6	150.0	171.0	191.6	211.7	231.2	250.3	268.7	
Real private consumption ($'000, constant 2005 prices)																
Australia	10.8	10.0	9.2	8.4	3.3	-3.2	-10.1	-17.1	-23.8	-30.1	-35.9	-41.2	-45.8	-49.8	-53.2	
QLD	-23.0	-22.3	-21.6	-20.9	-30.9	-42.2	-54.1	-66.1	-78.2	-90.0	-101.6	-112.8	-123.6	-134.0	-143.9	
ROA	33.8	32.3	30.8	29.3	34.2	39.0	43.9	49.1	54.4	59.9	65.6	71.6	77.8	84.2	90.7	
Real government consumption ($m, constant 2005 prices)																
Australia	-20.1	-18.8	-17.7	-16.6	-15.5	-14.5	-13.6	-12.6	-11.7	-10.8	-9.9	-9.0	-8.1	-7.2	-6.3	
QLD	-20.6	-19.3	-18.1	-17.0	-16.0	-15.0	-14.0	-13.1	-12.2	-11.4	-10.6	-9.8	-9.1	-8.4	-7.7	
ROA	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.7	0.8	1.0	1.2	1.4	

Table A.5 Percentage deviation outcomes from the scenario two modelling: Australia, Queensland, rest of Australia

Abs deviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Real gross value added (%))																
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QLD	-0.41	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
ROA	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Real private consumption (%)																
Australia	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QLD	-0.39	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03
ROA	0.13	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Real government consumption (%)																
Australia	-1.00	-0.08	-0.07	-0.08	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
QLD	-6.48	-0.52	-0.49	-0.52	-0.49	-0.44	-0.41	-0.39	-0.36	-0.38	-0.35	-0.34	-0.33	-0.33	-0.30	-0.30
ROA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Real gross value added (%))																
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
QLD	-0.03	-0.02	-0.02	-0.02	-0.04	-0.06	-0.08	-0.10	-0.12	-0.13	-0.15	-0.16	-0.18	-0.19	-0.20	
ROA	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	
Real private consumption (%)																
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	
QLD	-0.03	-0.03	-0.03	-0.03	-0.04	-0.06	-0.07	-0.09	-0.11	-0.12	-0.14	-0.15	-0.17	-0.18	-0.20	
ROA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	
Real government consumption (%)																
Australia	-0.05	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	
QLD	-0.28	-0.26	-0.25	-0.23	-0.22	-0.21	-0.19	-0.18	-0.17	-0.16	-0.15	-0.14	-0.13	-0.12	-0.11	
ROA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table A.6 Outcomes from the scenario two modelling: Far North region.

Abs deviation	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Real gross value added ($'000, constant 2005 prices)																
Far North - Division 34	-399.9	-33.1	-30.7	-33.1	-31.0	-27.9	-26.1	-24.4	-22.7	-24.1	-22.6	-22.1	-21.5	-21.9	-19.6	-19.9
Real gross value added (%)																
Far North - Division 34	-6.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.6	-0.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Real gross value added ($'000, constant 2005 prices)																
Far North - Division 34	-18.6	-17.4	-16.1	-14.9	-41.4	-68.4	-95.6	-123.0	-150.3	-177.5	-204.4	-231.1	-257.3	-283.2	-308.5	
Real gross value added (%)																
Far North - Division 34	-0.4	-0.4	-0.4	-0.4	-0.6	-0.9	-1.1	-1.4	-1.6	-1.8	-2.0	-2.2	-2.4	-2.5	-2.7	