The Value of Spatial Information

The impact of modern spatial information technologies on the Australian economy

Prepared for the CRC for Spatial Information & ANZLIC – the Spatial Information Council

March 2008

ACIL Tasman

Economics Policy Strategy

ACIL Tasman Pty Ltd

ABN 68 102 652 148
Internet www.aciltasman.com.au

Melbourne (Head Office)

Level 6, 224-236 Queen Street
Melbourne VIC 3000

Telephone (+61 3) 9600 3144
Facsimile (+61 3) 9600 3155

Email melbourne@aciltasman.com.au

Darwin

Suite G1, Paspalis Centrepoint
48-50 Smith Street
Darwin NT 0800

GPO Box 908
Darwin NT 0801

Telephone (+61 8) 8943 0643
Facsimile (+61 8) 8941 0848

Email darwin@aciltasman.com.au

Brisbane

Level 15, 127 Creek Street
Brisbane QLD 4000
GPO Box 32
Brisbane QLD 4001

Telephone (+61 7) 3009 8700
Facsimile (+61 7) 3009 8799

Email brisbane@aciltasman.com.au

Perth

Centa Building C2, 118 Railway Street
West Perth WA 6005

Telephone (+61 8) 9449 9600
Facsimile (+61 8) 9322 3955

Email perth@aciltasman.com.au

Canberra

Level 1, 33 Ainslie Place
Canberra City ACT 2600

GPO Box 1322
Canberra ACT 2601

Telephone (+61 2) 6103 8200
Facsimile (+61 2) 6103 8233

Email canberra@aciltasman.com.au

Sydney

PO Box 1554
Double Bay NSW 1360

Telephone (+61 2) 9958 6644
Facsimile (+61 2) 8080 8142

Email sydney@aciltasman.com.au

For information on this report

Please contact:

Alan Smart
Telephone (02) 6103 8201
Mobile 0404 822 312
Email a.smart@aciltasman.com.au

Contents

Boxes, figures and tables

Executive summary

The Cooperative Research Centre for Spatial Information (CRC-SI) commissioned this study with the following terms of reference:

1. to establish the verified and quantified economic impact of spatial information to the Australian economy in 2006-7 year
2. to estimate the cost of inefficient access to data and identify the factors operating to create these inefficiencies
3. to consider the future prospects for spatial data to contribute to Australia's economic, social and environmental development goals.

We gratefully acknowledge the assistance of the Australian Government Department of Finance and Administration – Consultative Committee on Knowledge Capital – and the Queensland Department of Treasury – Office of Statistical Research – for reviewing the original brief.

Key findings

Aggregate economic impacts

The National Accounts do not capture the full extent of the spatial information industry.

- However it is conservatively estimated that industry revenue in 2006-07 could have been of the order of $1.37 billion annually and industry gross value added around $682 million.

The economic footprint of the spatial information industry is considered to be larger than this. Spatial information is increasingly being used in most sectors of the economy where it is having a direct impact on productivity.

This study found that in 2006-07 the accumulated impact of these direct impacts:

- contributed to a cumulative gain of between $6.43 billion and $12.57 billion in Gross Domestic Product (GDP)
  - equivalent to 0.6% and 1.2% of GDP respectively
- increased household consumption by between $3.57 billion and $6.87 billion on a cumulative basis
- increased investment by between $1.73 billion and $3.69 billion on a cumulative basis
- had a positive impact on the trade balance
  - exports were between $1.26 billion and $2.30 billion higher than they would otherwise have been

- imports were between \$1.18 billion and \$2.23 billion higher than they would otherwise have been
- real wages by were between 0.60% and 1.12% than they would otherwise have been.

Other impacts

Beyond these results the spatial information industry also contributes to a range of public impacts, including biosecurity, environment and social benefits.

The case studies undertaken for this report revealed that spatial information has an important and increasing role in biosecurity. A recent example was the role that spatial information played in managing the spread of equine influenza virus in Australia in 2007.

The Department of Agriculture Fisheries and Forestry has estimated that costs of control and reduced production from pests and diseases could be as high as \$8 billion per year. The Productivity Commission estimated that the impact of an outbreak of Foot and Mouth Disease on GDP could be between \$2 billion and \$13 billion in the first year. The contribution of spatial information to implementing biosecurity programs could be in the order of hundreds of millions of dollars in some years.

The current and potential value of spatial information systems in natural resources management, water and carbon markets was not assessed for this report. However it is likely that this value is large both in economic terms as well as in terms of sustainability of natural systems.

The transport case studies in this report suggest that the use of intelligent transport systems could reduce greenhouse emissions by between 0.5 percent and 1.5 per cent estimated to be worth between \$50 million and \$150 million per annum assuming a carbon price of \$15 per tonne CO_2-e. These systems are heavily reliant on spatial information.

The spatially enabled National Carbon Accounting Scheme will provide significant support towards reducing net emissions of greenhouse gases. In terms of overall reduction in greenhouse gas emissions, the value of reducing emissions to 108% of Australia's emission levels in 1990 (Australia's Kyoto target) would be valued at around \$1.4 billion at current carbon prices.

There is therefore a sufficient body of evidence to suggest that the spatial information industry is delivering significant environmental and social benefits in addition to the economic benefits identified above. These benefits can be expected to increase significantly as spatial information systems are further integrated into the operation of water markets, carbon markets, natural resources management and environmental management and monitoring programmes more generally.

Cost of inefficient access to data

Constraints on access to data are estimated to have reduced the direct productivity impacts in certain sectors by between 5% and 15%. It is estimated that this could have resulted in GDP and consumption being around 7% lower in 2006-07 (around $0.5 billion) than it might otherwise have been.

Future potential

The contribution of spatial information is likely to increase as spatial information becomes a mainstream enterprise resource in government and business organisations and as it penetrates mainstream consumer markets.

Increased adoption and new applications in existing sectors could increase the direct impacts in some sectors by up to 50% over the medium term. However a larger impact is likely to be in new applications in a wider range of industries.

The scale of the future contribution will be driven by the policy environment in respect of data access and skills development, further innovation in existing and new applications, increased awareness in government and industry and, most importantly, future application of new innovations in business systems.

The report

This report is based on research and case studies in twenty two sectors of the Australian economy augmented by a literature review of international and Australian studies. For each sector, the direct impact of spatial information has been estimated under two scenarios.

In each sector, care has been taken to develop a realistic "counterfactual" to ensure that the direct impacts of spatial information are not overstated. These direct impacts have been applied to a general equilibrium model to calculate the aggregate impact of spatial information on the Australian economy.

Literature review of past research

There is a growing body of literature, both Australian and international documenting how business and government use spatial information, and the impacts it has had in specific sectors. The literature recognises the need for a systematic assessment of its overall impacts (Alexander, 2003). ACIL Tasman is not aware of any studies that have assessed the aggregate impact of spatial information on national economies.

Case studies and reviews

In the case study analysis, ACIL Tasman explored the level of impacts and extent of adoption of spatial information in the private and public sectors. These indicators, together with evidence from literature reviews and industry interviews, contributed to the estimates of the accumulated direct impact in each sector under two scenarios:

- a quantifiable 'lower bound' scenario (scenario 1) which reflects the impacts we have been able to *confidently* and *verifiably* quantify through the use of reliable statistics, existing literature, expert opinion and through our case studies
- a 'realistic' estimated scenario (scenario 2) which comes closer to what we believe to be the reality (as distinct from that which we can confidently quantify).

Some of the sectors and the basis for the estimates of the direct impacts are discussed below. The accumulated direct impacts are summarised in Table 1 at the end of this discussion.

Agriculture

Increases in productivity in broad acre agriculture of 10% can be attributed to controlled traffic farming using geospatial information systems (GIS), augmented global navigation satellite systems (GNSS) and automated steering. Adoption in Australia is estimated to be around 10% in 2006-07. These parameters were used to estimate the impact of spatial information in agriculture for scenario 1.

Use of spatial information in variable rate application, yield monitoring, whole farm planning, natural resources management and pest and disease management were taken into account in scenario 2.

Forestry

Spatial information systems are increasingly being used in both public and private forestry. Applications include inventory management, remote assessment of forest attributes yield estimation, canopy health mapping and operations management.

The integration of a spatial information system developed by NGIS – ForMS- into Great Southern Plantations' corporate systems has created a centrally located system for capturing, storing and tracking plantation activities. This has increased the area that can be managed by each manager by 50%.

It was estimated that there is 100% adoption of these technologies in hardwood plantations and around 2.5% of the area managed by the public forestry sector in both scenarios.

Fisheries

Spatial information is used for recording fishing tracks, fisheries management and habitat mapping. A case study of the commercial fishing industry indicated that GPS plotters had improved productivity of commercial fishing operations by around 12%. Allowing for levels of adoption and limiting this to the fin fishing industry this is estimated to have produced a 4% improvement in total factor productivity in the fishing industry in scenario 1.

The additional benefits in improved fisheries management and productivity improvements in the non fin fish industry are taken into account in arriving at the estimate of 5.14% improvement in total factor productivity for scenario 2.

Mining and resources

The mining and petroleum sectors have been using spatial information in exploration and in planning, developing and managing operations for many years.

In the coal industry spatially enabled robotic mining is delivering around 37% improvements in productivity at around a 9 % adoption rate in 2006-07.

Use of the spatial information application "Millmapper" in precious metals mining is estimated to have improved milling operations and generated costs savings of around 2.4% with an adoption rate of around 11%.

Spatial information also assists in the operation and upgrade of mines with 3D techniques improving management of faulting problems in coal mines and off-site fabrication of new equipment and in bulk commodities handling.

In the upstream petroleum industry, spatial information is improving site selection and management of infrastructure, lowering environmental compliance costs and supporting deep water off-shore oil and gas operations.

The geoscience and exploration communities were early adopters of spatial information using techniques such as 3D seismic and later airborne geophysics to identify and characterise potential commercial resources. A significant proportion of the major new minerals and petroleum projects established since the late 1970s were discovered with the aid of spatially enabled exploration techniques.

The additional production from oil (mainly condensate), gas and minerals (excluding coal) realised as a result of these technologies is estimated to be 3%, 5% and 7% respectively for the general equilibrium modelling in this report.

Property and services

This sector includes a key part of the 'core' spatial industry i.e. the surveying industry. However, there are also many other businesses that use new spatial information systems including advertising and market research (which now routinely use GIS packages), property, planning, engineering, architecture, retail and trade.

Spatial information has the potential to significantly enhance the speed of urban land and infrastructure development.

A case study based on the production of the land industry in WA indicated a productivity increase of around 61% arising from the use of new spatial information technologies by the surveying profession. This was the basis for estimating the 0.5% impact in scenario 1.

The impact of other applications, including technologies such terrestrial laser scanning for 3D surveying and improvements in route and site selection, has been taken into account in the 0.7% impact estimate in scenario 2.

Construction

Spatial information technologies are routinely applied in the construction industry to accelerate planning and design, coordinate contractors and sub-contractors, manage projects over multiple sites, and aid architects, engineers, fabricators during construction and in the maintenance phase.

Several case studies demonstrated the power of spatial information. Spatial information is reported to have delivered savings of around 10% in the East Link road project in Melbourne with 50% faster map production and 80% faster access to information. In another example, GNSS-enabled surveying and design when combined with automated machine guidance delivered costs savings to the Forbes Shire Council road works. Maintenance is also assisted by GPS and GIS mapping systems for recording repair requirements and managing maintenance.

A 10% improvement in productivity is estimated in the construction sector with and adoption rate of the order of 2.5% in scenario 1 and 5% in scenario 2.

Transport and storage

The transport and storage sector was one of the earlier adopters of spatial information technologies. The use of GIS and GNSS technologies has been steadily growing for about a decade and it is now one of the fastest growing areas of GIS deployment.

Productivity gains in this sector are attributed to improvements in logistics, route selection and itinerary planning, transport planning, vehicle tracking, traffic and congestion management, transport operations in rail and air and intelligent transport systems.

The estimate of 1.4% productivity improvement in scenario 1 is based on the observed applications in intelligent transport systems, including route planning and GNSS enabled freight management. The estimate of 1.58% in scenario 2 is based on observations of applications in GNSS in taxi location services, lower congestion and road hazard management, improved supply chain transport planning and in air navigation.

Utilities

The utilities sector – electricity, gas and water – are significant users of spatial information. The main benefits to this sector are in improved asset management, better management of supply and demand and in the planning and construction of new pipelines, power lines, generators and storages. The case studies of Melbourne Water and Ergon Energy confirmed that savings in asset management and planning are being realised.

The case study of a Hazwatch application illustrated the potential for innovation in the use of spatial data to improve the management of natural hazards by utilities managers.

In scenario 1, the 0.73% impact is based on improved asset management in the electricity and water sectors. In scenario 2, the 1.25% impact takes account of wider applications in water, gas and electricity including asset and operations management, market planning and hazard management.

Communications

Spatial information is used in the communications sector for network planning, asset management and address management and route planning in the case of postal services.

The productivity improvements in scenario 1 are based on estimates of improvements in asset management and network planning in telecommunications and GIS use in address management (0.98%). In scenario

2, the impacts of improvements in GNSS use in postal and courier services, telecommunications market analysis and targeted marketing (1.32%) is taken into account.

Government

Government is a major user of spatial information. Areas of application include geoscience, bathymetry, natural resources and environmental management, biosecurity, defence and security, air and sea navigation safety, search and rescue, land development administration, development approvals, environment protection, program management and administration and policy formulation.

Spatial information is improving service delivery in all jurisdictions although there are only limited economic studies of the broader economic benefits. An economic assessment of the Western Australian Land Information System, demonstrated a benefit cost ratio of 9 to 1 to investment in coordination, capture and management of spatial data in Western Australia.

Case studies of the National Carbon Accounting Scheme and the National Water Audit undertaken for this report confirmed the importance of spatial information to policy formulation and management for climate change and water resources.

The case studies identify productivity improvements in administration of development approvals of around 7% in labour costs. The literature and case studies suggest that this is a conservative indicator of the improvement in administration in government services more broadly. A 50% adoption rate was assumed across all levels of government, leading to an estimate of a 0.34% productivity improvement in scenario 1.

In scenario 2, the 1.05% productivity improvement is based on observed – but not measured – improvements in asset management, service delivery more generally, infrastructure planning, defence, emergency services, risk management, biosecurity, compliance and regulation.

Other areas

ACIL Tasman's research also examined retail and trade, tourism and manufacturing. The take-up of spatial information in these areas is occurring but not as fast as in the sectors discussed above. No productivity shocks are included in scenario 1 while small productivity improvements are included in scenario 2.

Results

The accumulated direct impacts are summarised in Table 1.

Table 1 **Direct impact of spatial information on productivity and resource availability**

	Type of shock applied	Quantifiable scenario 1	Estimated scenario 2
Productivity shocks			
Grains (specialist growers)	Total productivity	0.93%	1.08%
Mixed (grain & sheep/cattle)	Total productivity	1.35%	1.50%
Sugar cane	Total productivity	0.11%	0.26%
Cotton	Total productivity	0.07%	0.22%
Other agriculture	Total productivity	0.00%	0.15%
Forestry	Total productivity	1.93%	1.93%
Fisheries	Total factor productivity	4.00%	5.14%
Construction	Total productivity	0.25%	0.50%
Business services	Labour productivity	0.50%	0.70%
Coal	Total factor productivity	0.21%	0.36%
Metal ores	Total factor productivity	0.16%	0.31%
Oil & Gas	Total factor productivity	0.15%	0.27%
Government	Labour productivity	0.34%	1.05%
Road Transport	Total productivity	1.40%	1.58%
Rail Transport	Total productivity	0.00%	0.45%
Air Transport	Total productivity	0.55%	1.04%
Other transport	Total productivity	0.00%	0.30%
Electricity/gas/water	Total productivity	0.73%	1.25%
Communications	Total productivity	0.98%	1.32%
Trade	Total productivity	0.00%	0.08%
Manufacturing	Total productivity	0.00%	0.02%
Other	Total productivity	0.00%	0.02%
Resource availability shocks			
Oil	Resource availability	3%	6%
Gas	Resource availability	5%	10%
Minerals nec	Resource availability	7%	14%

Data source: ACIL Tasman calculations and estimates

The aggregate model results are summarised in Table 2.

Table 2 **Aggregate impact of spatial information in 2006-07**

	Scenario 1				Scenario 2			
	Productivity only		Productivity plus resources		Productivity only		Productivity plus resources	
	%	$ billion	%	$ billion	%	$ billion	%	$ billion
GDP	0.51%	5.31	0.61%	6.43	0.99%	10.31	1.20%	12.57
Household consumption	0.50%	2.89	0.61%	3.57	0.93%	5.39	1.16%	6.78
Investment	0.51%	1.43	0.61%	1.73	0.98%	2.78	1.20%	3.39
Capital stock	0.56%	-	0.72%	-	1.05%	-	1.38%	-
Exports	0.45%	0.98	0.58%	1.26	0.80%	1.73	1.07%	2.30
Imports	0.39%	0.89	0.52%	1.18	0.72%	1.64	1.98%	2.23
Wages	0.50%	-	0.60%	-	0.92%	-	1.12%	-

Note: Scenario 1 is a 'lower bound' scenario which reflects the impacts ACIL Tasman has been able to confidently and verifiably quantify through the use of reliable statistics, existing literature, expert opinion and through case studies

Scenario 2 is considered a 'realistic' estimated scenario which is considered to be closer to the situation in 2006-07.

Data source: ACIL Tasman

Cost of inefficient access to data

In 2001, the Spatial Information Industry Action Agenda launched an ambitious program of policy reform for government and industry. The research undertaken for this report suggests that while progress has been made in some areas, success has been mixed.

Availability of fundamental data

Fundamental data includes data that is collected by agencies under public interest programmes and also data that is collected by agencies to meet specific agency purposes but may be made more widely available in the public interest (ANZLIC, 2001). Some fundamental data is created by the private sector (such as cadastral and some minerals exploration data) but captured by the public sector.

Some businesses consulted in the course of preparing this report, expressed a concern that Australia's competitiveness in this areas is being hampered by gaps in fundamental data relative to the quantity and quality of information available to some of their overseas competitors.

The consequences of gaps in fundamental data include:

- inefficiencies in planning for future infrastructure and redoing surveys to collect data that may have been captured previously at a low marginal cost

- less well informed policy formulation in natural resources management, environment and climate change adaptation
- lost opportunities for innovation and development of new products by the private sector
- less efficient planning and responses to emergencies such as bush fires and flooding
- lower efficiencies in developing faster development approvals and land management
- less opportunity for new approaches to asset management.

State governments are attempting to address fundamental data sets such as cadastre, topography, property, roads and geo-referenced imagery. Examples include the Shared Land Information Platform (SLIP) in Western Australia and the Spatial Information Exchange in NSW. However gaps in fundamental data remain.

Spatial data infrastructure

An essential component of a spatially enabled economy is the enabling infrastructure. With current technology, such infrastructure can be a virtual system that does not require the centralised storage of data. However, to work effectively, this requires interoperable architecture, based on distributed custodial spatial information management and open standards.

Consistent with this, one of the goals of the Spatial Information Action Agenda was the development of the Australian Spatial Date Infrastructure (ASDI). However many businesses, consulted in the course of preparing this report, consider that the ASDI – as it is currently implemented – falls short of providing ready and seamless access to spatial data. Although progress has been made in some important areas, spatial data collected, managed and disseminated at each level of government remains somewhat fragmented. For example, an independent study into the accuracy and currency of the metadata records of the Australian Spatial Data Dictionary (ASDD) found that the metadata was out of date and could not be used to convert to the new ANZLIC profile.

There are specific examples of world's best practice applications in spatial information management systems. The Queensland Spatial Industry Strategy (QSIIS), the Western Australian Land Information System (WALIS) and the Shared Land Information Platform (SLIP), the NSW Government Community Access to Natural Resources Information (CANRI) and the NSW Spatial Information Exchange (SIX), and the Victorian land and property information systems are good examples. However, overall progress towards whole-of-government approaches and engaging industry at state government levels has been mixed.

Australia's vision for the ASDI was built on the idea of multi-agency co-operation which in itself is difficult, as well as collaboration across different levels of government and between government and industry.

The lack of a consistent whole-of-government approach and the inadequate engagement between governments and industry has consequences for the growth of the spatial information industry.

Access to data

Consistency in access arrangement to fundamental data is crucial for its efficient use. ANZLIC has promulgated guidelines for best practice in enabling access to spatial information and hence spatially enabling the economy these guidelines are not being uniformly implemented across Australia.

Simple and effective access

An access arrangement should provide a simple, effective means of locating and obtaining spatial information.

For the widest possible access, custodians should offer a multi-faceted approach to delivery of information, catering for all types of users. This is not yet being achieved uniformly. On another front, digital rights management (DRM) is an area of interest, as the internet has become the centre of distribution for digital goods of all sorts, including spatial information.

Fitness for purpose

Users of spatial data must be able to easily ascertain the quality of their information and its ability to meet their requirements. In 2003 ANZLIC nominated the topic of 'data quality' as being one of five core issues still needing to be addressed as part of the ASDI development. In 2007, the study of NSW metadata found issues with the accuracy and currency of records surveyed. A major project is underway to update its records to comply with the ANZLIC modified implementation profile.

Spatial information quality has progressed considerably in recent decades in line with data transfer standards, with the introduction of international geographic data quality-related standards and the widespread adoption of metadata entry tools for the production of metadata for entry in searchable, web-based directories. However, the metadata remains in many formats and are currently not totally valid.

A national licensing framework

Custodians of spatial information must ensure that its distribution and use is in accordance with licences, agreements or other appropriate mechanisms that effectively manage the risks associated with the use of the information. The organisation acting as a data custodian is responsible for maintaining copyright provisions and ensuring that use of the information does not infringe any privacy or confidentiality requirements.

However current licensing practices have not kept up with the pace of technology.

An important development that is gaining widespread support in government is the development of a Government Information Licensing Framework (GILF). The GILF would be a standardised legal environment of terms and conditions within which all information transactions would occur.

A possible avenue of facilitating information sharing across jurisdictions is the Creative Commons licensing regime. Creative commons licenses are designed to facilitate and encourage more versatility and flexibility in copyright. The Queensland government, in consultation with other governments, has been developing a draft access regime based on this principle. An important feature of the proposed approach is its capability to enable licences to be executed at the time of data transfer. This will increase the efficiency of user access while at the same time achieving the above aims.

Pricing

Across and within levels of government there are differences in pricing and cost recovery policies. While governments adhere to the principles of cost recovery and competitive neutrality, individual agencies may interpret these principles in different ways.

Principles for pricing for fundamental data were set out by the Productivity Commission in a report released in 2001. The Australian Government implemented pricing principles in line with these recommendations in 2001. The impact on the dissemination of fundamental data from the Commonwealth was a dramatic increase over the following years.

However not all jurisdictions have implemented these policies and fundamental data is often issued at above the cost of its distribution. It is apparent that, in some cases, over-recovery of costs is occurring through the sale of value added spatial information by some government agencies.

Overall cost of inefficient access to data in 2006-07

Lack of completeness in policies relating to simple and effective access, fitness for purpose and development of a whole-of-government licensing framework are creating concern for spatial some information users.

The cost is in slower development of applications and less than optimal levels of application and innovation among users.

This is likely to have had an impact in the property and services, construction, government, transport and agricultural sectors. It is likely to have reduced the extension of spatial information into areas such as asset management in utilities, transport and storage applications and in emerging areas of consumer markets and applications in other industries.

The interviews and case studies in this report indicate that the biggest negative impact on productivity occurs in the areas of agriculture, transport, asset management and property and services. Productivity impacts in these sectors might have been between 5% and 15% lower as a result of these constraints.

This could have resulted in the impact on GDP and consumption being around 7% lower than it might otherwise have been under scenario 1 (Table 3).

Table 3 **Effect of constraints on Scenario 1 outcomes**

	Scenario 1 ex constraints		Scenario 1 with existing constraints		Effect of constraints on impacts
	%	**$ billion**	**%**	**$ billion**	**%**
GDP	0.61%	6.43	0.66%	6.91	7.5%
Household consumption	0.61%	3.57	0.66%	3.83	7.3%
Investment	0.61%	1.73	0.66%	1.87	7.8%
Exports	0.58%	1.26	0.62%	1.34	6.3%
Imports	0.52%	1.18	0.55%	1.25	6.3%
Real wages	0.6%		0.64%		7.1%

Note: Based on impacts adjusted by the estimate of the effect of constraints on increased productivity shocks.
Data source: ACIL Tasman modelling using Tasman Global

These are broad estimates of the economic welfare loss arising from inefficient access to data. Policy formulation may benefit from more specific estimates of welfare losses from current arrangements, particularly pricing policies. This would assist agencies when building the business case for funding of future maintenance and dissemination of fundamental data sets.

Future prospects

The future prospects for the spatial information industry are promising both in the medium term (five years) and the longer term (ten years).

Medium term

The contribution of spatial information to future economic activity will continue to grow as awareness of its potential grows. Medium term growth is expected to be driven by the following factors:

- increased adoption in existing applications
- introduction of new applications
- increased penetration into non traditional sectors and new markets
- increased use by government in delivery of services.

It would not be unreasonable to expect that the adoption levels in some sectors would increase by up to 50% over the next five years with current policies in place.

It is also certain that adoption in low using sectors will also increase over the next five years – although the level and nature of the applications is hard to predict.

The importance to Australia in managing the challenges of climate change, water, energy, natural resources management and biosecurity are outlined in this report. Maintenance of defence, security and emergency management services is also highly valued by the community.

While it is not possible to quantify the value of the contribution that spatial information make to areas, this report suggests that the value of the contribution is as significant in as the economic impacts discussed in this report.

Spatial information technology is crucial for effective and better management of these challenges. There are many examples cited in this report that show how spatial information is now crucial to many important government services. This report shows that that the application of spatial technologies in these areas is increasing.

Overall, it is possible that with the right policies the contribution of the spatial information sector to the economic aggregates over the medium term could be up to 50% higher than in 2006-07.

Longer term

Important future developments in spatial information that are likely to further enhance its economic impacts in the longer term are:

- the falling cost of acquiring data
- continuing developments of computing power making more applications and richer data analysis possible
- the arrival of spatial technologies into the consumer mainstream.

These developments are likely to lead to:

- a transition from spatial information as project based applications to mainstream enterprise systems
- The emergence of a new phase in the evolution of spatial information into mainstream consumer markets and business systems.

This will be a step up in the role that the spatial information plays in the Australian economy. It is likely to significantly increase in the value of its contribution to economic, social and environmental outcomes.

This evolution of the spatial information industry is likely to enhance the transformation from information based industries to knowledge based industries in Australia. This will be a crucial development for sustaining the international competitiveness of Australian industries.

The spatial information industry is creating valuable options for Australian society – in economic, environmental and social terms. The risk is that some of these options could be extinguished through non optimal policies and programs.

Implications for research priorities

The contribution of spatial information could be increased by addressing research priorities in the following categories:

- technologies to improve availability and access of data
  - fundamental data
  - data infrastructure
  - data access
- increasing the effectiveness of spatial technologies and addressing determinants of adoption rates in traditional areas including
  - agriculture
  - property and services
  - construction
  - utilities and asset management

  - transport
  - communications
  - biosecurity
  - environment
  - carbon and water trading
  - defence, security and emergency services
- developing technologies and techniques to support the move of spatial information into mainstream enterprise applications
  - integrating with management systems
  - exploring social and economic research applications
- developing technologies and techniques to support mainstream consumer applications
  - personal applications
  - locational systems
  - property and consumer information
  - public transport and infrastructure use.

These observations are a starting point for consideration of the research priorities.

1 Introduction

1.1 Terms of reference for this report

The Cooperative Research Centre for Spatial Information (CRC-SI) commissioned ACIL Tasman in July 2006 to conduct an independent quantifiable analysis of the value of spatial information to the Australian economy.

The study had three objectives:

1. to establish the verified and quantified economic impact of spatial information to the Australian economy in 2006-7 year
2. to estimate the cost of inefficient access to data and identify the factors operating to create these inefficiencies
3. to consider the future prospects for spatial data to contribute to Australia's economic, social and environmental development goals.

The terms of reference for this report are reproduced in full in Appendix A.

We gratefully acknowledge the assistance of the Australian Government Department of Finance and Administration – Consultative Committee on Knowledge Capital – and the Queensland Department of Treasury – Office of Statistical Research – for reviewing the original brief.

1.2 What is spatial information and what does this report cover?

Spatial information (SI) describes the physical location of objects and the metric relationships between objects.

Spatial information was originally recorded on paper maps and was the area of interest of surveyors, navigators, engineers and astronomers. This situation remained essentially unchanged until the advent of modern computers which has permitted maps to be produced, and therefore spatial information to be disseminated, in digitised form. The marginal cost of disseminating digitised spatial information is often close to zero.

Digital mapping, digital photography and remote sensing technologies fit easily into digital communications systems. When combined with in geographic information systems and accurate satellite positioning systems they provide an opportunity for layering data in ways that were not possible prior to say 1990.

The increase in processing power has also allowed capture and analysis of spatial data to move beyond 'surface description' to subsurface or three-dimensional data, and from static points to real time analysis of moving objects. Seismic mapping, photogrammetry, and many other areas of application have consequently emerged as specialties in their own right.

Modern technologies used to acquire and process spatial information include satellite based global positioning systems and imagery, geographical information systems, information and computing technology systems and a range of simulation and modelling software that enables a wide range of geospatial data to be layered onto digital maps.

This report is primarily concerned with what may be termed 'modern' spatial information technologies. As already indicated this typically involves spatial information in digitised form, whether it is based on transmissions from satellites or based on modern ways of mapping the earth.

1.2.1 Relative and absolute spatial information

There is a basic distinction between relative and absolute spatial information. Absolute spatial information requires geographical coordinates and delivery of these has in recent years been made possible at increasing levels of accuracy due to the advent of global positioning systems (GPS). Absolute spatial information, delivered in digitised form, is certainly included in this report.

Relative spatial information captures relationships of objects in space. A number of modern production techniques rely on very accurate relative spatial information. For example, underground mining machines are increasingly automated and use an array of high-tech sensors and tools to capture and process relative spatial information.

There is no 'hard-and-fast' or objective rule to decide whether new processes or products that rely on relative spatial information should be included in this economic assessment – for example modern computer assisted design (CAD) programs deal with relative spatial information. Basic CAD was however excluded from the scope of the present analysis as it was judged to fall within general ICT.

Inter-operability and layering was used several times as a criterion to help decide whether a process or application qualified as 'modern' spatial information technology.

For example, where absolute spatial information was integrated into CAD through layering of absolute spatial data over existing relative data this was accepted as being 'modern' spatial information technology.

1.3 Users of 'modern' spatial information

There are currently few, if any, sectors of the economy that have not begun to use modern spatial information technologies. Sectors such as property and business services (including surveying), mining, energy and agriculture are already reaping significant benefits from their use.

Government is also one of the biggest users. Spatial technologies support a wide range of activities including geoscience, bathymetry, biosecurity, emergency management, defence, environmental and natural resources management, development approvals and public administration.

2 The spatial information industry

This report uses the term 'industry' to refer to the private sector element of the (broader) spatial information 'sector'[1]. For the purposes of this study the spatial industry is defined as follows:

> The modern spatial information industry acquires, integrates, manages, analyses, maps, distributes, and uses geographic, temporal and spatial information and knowledge. The industry includes basic and applied research, technology development, education, and applications to address the planning, decision-making, and operational needs of people and organizations of all types.

Many of these activities are also carried out by members of the wider spatial information 'sector', which includes various government departments, public or semi-public agencies, universities and other not-for-profit institutions (such as the CRC for Spatial Information (CRC-SI) and some companies.

In the national accounting sense, all of these producers of spatial information and spatial information technology would be categorised as an industry. However, as already pointed out, this report reserves the term industry to the private sector only.

2.1.1 The Australian spatial information industry

Internationally, it is recognised that the spatial information sector is evolving rapidly. The (private sector) industry is expanding into a broad industry encompassing more than just surveying and cartographic activities.

Many of the technology enablers and value-adding organisations in the industry identify themselves as part of information and telecommunications services, or would classify their activities as services to areas such as transport, agriculture or mining. Their turnover and value-added contribution would accordingly be recorded in the national accounts as part of those service sectors. This makes it very difficult to get an accurate picture of the size of the industry.

As already noted, there is also a substantial amount of spatial activity in the public and not-for-profit sectors. This further complicates assessment of the spatial information sector as a whole.

---

1 Readers are warned that this terminology sometimes conflicts with the terminology used in national accounts, where an industry may include government activities. The ABS tourism satellite account is a good example of a measure of the tourism industry which includes a wide range of activities that may or may not be within the private sector.

The latest Australian and New Zealand Standard Industrial Classification (ANZSIC (2006)) does not define the spatial information industry as a separate industry. ANZSIC does capture quantitative data at a micro level classification called 'Surveying and Mapping Services – code 6922', which does include a number of 'core' participants in the spatial industry(see Box 1).

Box 1 **ABS Classification (ANZSIC) for 'core' spatial information industry activities**

The updated ABS 2006 industry classification (ANZSIC) sector 'Surveying and Mapping Services – code 6922' includes the following services:

- Aerial Surveying Service
- Cadastral Surveying Service
- Engineering Surveying Service
- Geodetic Surveying Service
- Gravimetric Surveying Service
- Hydrographic Surveying Service
- Land Surveying Service
- Map Preparation Service
- Mining Surveying Service
- Oceanographic Surveying Service
- Photogrammetry
- Seismic Surveying Service

Whilst industry code 6922 does include businesses that fall within the spatial information industry, it is unclear to what extent these businesses rely on 'modern' spatial information technologies. Many surveyors, for example, still use traditional techniques, although our interviews with a number of surveyors revealed that they are increasingly acquiring more modern systems which integrate GPS or other modern spatial technologies.

In the absence of more accurate information on the exact composition of activity undertaken, however, ANZSIC industry code 6922 provides the best gauge of the size of the spatial information industry.

Estimates of the size of the industry at the time of the Spatial Industry Action Agenda (2001) included an ABS estimate for the total operating income of the Surveying Services industry of $926 million in 1998-99.

More recently, the industry in Victoria together with the Victorian Government conducted in a census of the spatial information industry in Victoria (Fivenines Consulting, 2005). Using this data and extrapolating the results nationally ACIL Tasman estimates that the spatial information industry nationally consists of:

- 750 spatial information businesses with:
  - total revenue of $1.37 billion annually
  - industry gross value-added of $682 million.

The national industry footprint is thought to be much broader than illustrated in these figures. Recent research undertaken for the Spatial Education Advisory Committee (SEAC) suggests that:

- the number of people employed directly in the spatial information industry was around 31,400 people
  - with another 61,000 people engaged in using spatial information services in government and industry
- a total of around 93,000 people directly involved in spatial information services in industry and government (SEAC, 2007).

3 The industry's role in the economy

3.1.1 The "Where?" question

Expressed in the simplest terms, the spatial information industry seeks to provide better answers to "where?" questions such as:

- where are my assets?
- where are my customers?
- where should we plant, build, drill, or fish?

As indicated in Section 1.2, these questions have always occupied decision makers, and resources have always been devoted to answering these types of questions.

In the past, however, it was often impossible to collect specific spatial information, and even where it was possible, it was often too expensive to do so.

New spatial information technologies have made it possible to answer many of the "where?" questions that have previously gone unanswered. The technologies also permit us to ask new types of "where?" questions. However, as the economy has evolved and adapted to function in the absence of this type of information, some decision makers have simply forgotten to ask the "where?" question. Others are not aware that their fundamental questions could perhaps be answered using these new technologies.

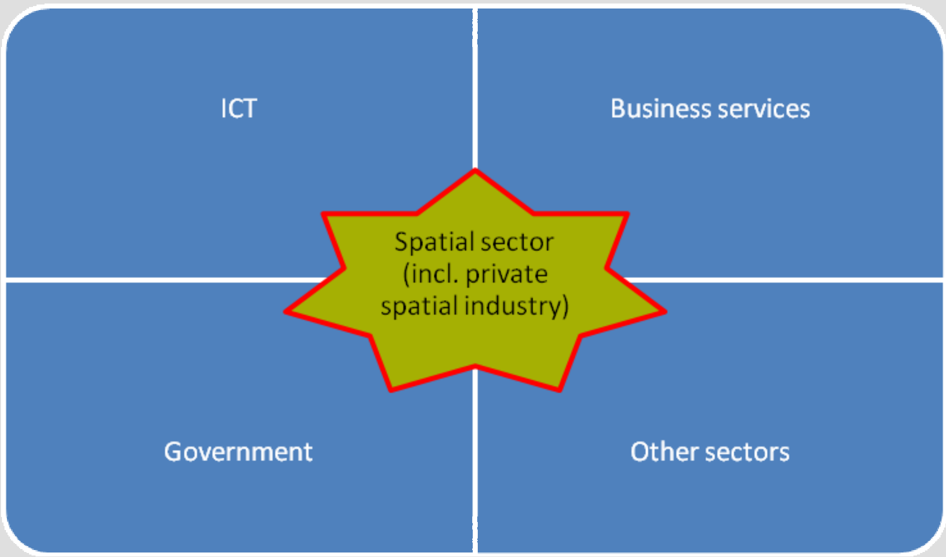
3.1.2 Footprint versus impact

In order to understand the role of any sector in the economy, several layers of analysis can be applied. For example, an estimate of the size of the sector (e.g., number of workers, turnover, value-added) might be presented as an indicator of the significance of that sector. Such types of measures capture what might be termed the direct 'footprint' of a sector on the economy.

Delineation of the economic footprint of spatial information technology on the economy involves a comprehensive overview of where activity is occurring and the extent of it. Footprint goes further than the estimates of the (private sector) industry presented in Section 2.1.1 above, because it would include all resources devoted to data capture and custodianship as well as R&D and other activities that do not occur in the private sector. Box 2 illustrates the scope of the footprint of spatial information.

Understanding the full footprint of spatial information activity will ultimately involve developing a better understanding and characterisation of many activities that are currently carried by government and non-profit organisations, including collaborative research undertakings such as those of the CRC-SI. Detailed surveys may therefore need to be carried out to identify the amount of spatial activity currently being undertaken in various sectors of the economy.

Box 2 **Footprint of the spatial information industry**



Data source: ACIL Tasman

It is also important to note that footprint measures can be misleading if applied inappropriately. For example, a subsidised industry might have a significant footprint only because it receives government support. Fledgling industries or industries with a concentration on R&D in the early stages of commercialisation tend to be more heavily dependent on direct and indirect government support. As a result, footprint measures do not always provide a good basis on which to draw inferences about long term or dynamic value to the economy.

Footprint measures also do not capture the value of the technology to users. Economic impact assessments should therefore be based on wider assessments of a sector – an assessment that would typically include and account for dynamic effects as well as non-financial linkages such as unpriced spillovers.

Such information might not ordinarily be reflected as a financial transaction between organisations. Also, to fully capture 'impact', firm, industry and economy-wide assessments must take into account what might have occurred in the absence of spatial technology (the 'counterfactual' scenario).

Box 3 illustrates how new spatial information technologies impact on the economy in complex ways. The example uses Millmapper (see case study in Section 6.3.3 of this report), but the illustration would apply to any application.

As the box shows, Millmapper has a direct impact on productivity in precious metals mining, a sub-sector of the mining industry. Millmapper also comprises a component of the spatial information industry and increases the value added in that sector.

The direct impact of Millmapper feeds through into the broader economy through these routes causing resource shifts in the economy ultimately resulting in higher economic activity – reported in terms of increases in Gross Domestic Product (GDP), consumption, investment and real wages.

Independent growth in other sectors of the economy can in turn impact on the spatial information sector (and industry) as well as other industries that have already been affected by the spatial information industry.

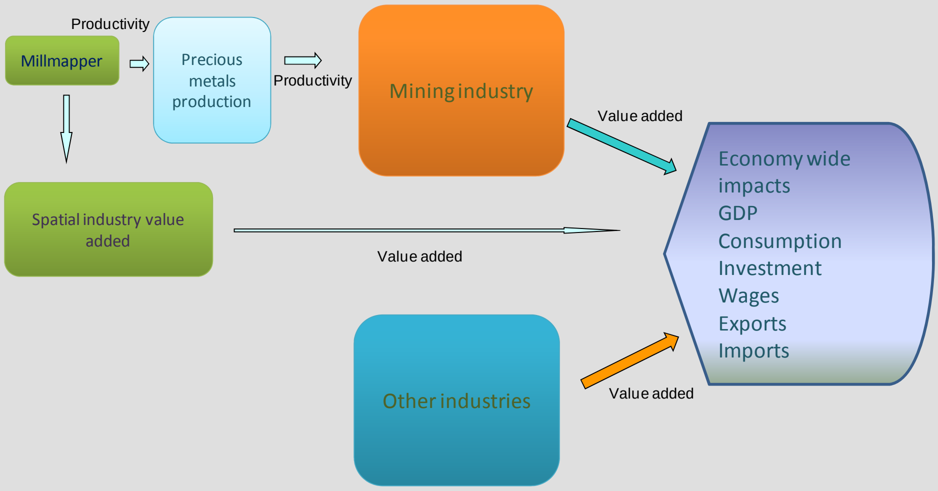
As a simple example, consider the fact that strong economic growth tends to increase the government tax base. Increased government revenues might then be spent on increasing funding for various projects that have a spatial information component.

Box 3 **Direct and indirect impacts**

Direct impacts are those that improve productivity or increase markets for an industry or sector such as might occur in the mining industry through improved mill maintenance.

Indirect impacts are the impacts on each sector that arise after the direct effects on each sector have worked their way through the economy.

Economy wide impacts are the cumulative net increase in economic activity that results.



Data source: ACIL Tasman

Advanced economic models such as computable general equilibrium (CGE) models, whilst abstracting from reality, do capture the way in which funds flow through the economy and resources shift between sectors as a consequence of productivity growth and other changes such as shifts in consumer demand or changing world prices for commodities.

Notice that advanced economic modelling recognises the role of *users* of technology, including intermediate users. Millmapper feeds into mining industry, but the mining industry does not itself sell to final household consumers. Other sectors further refine the product obtained from mining or utilise it to produce the products that households ultimately consume.

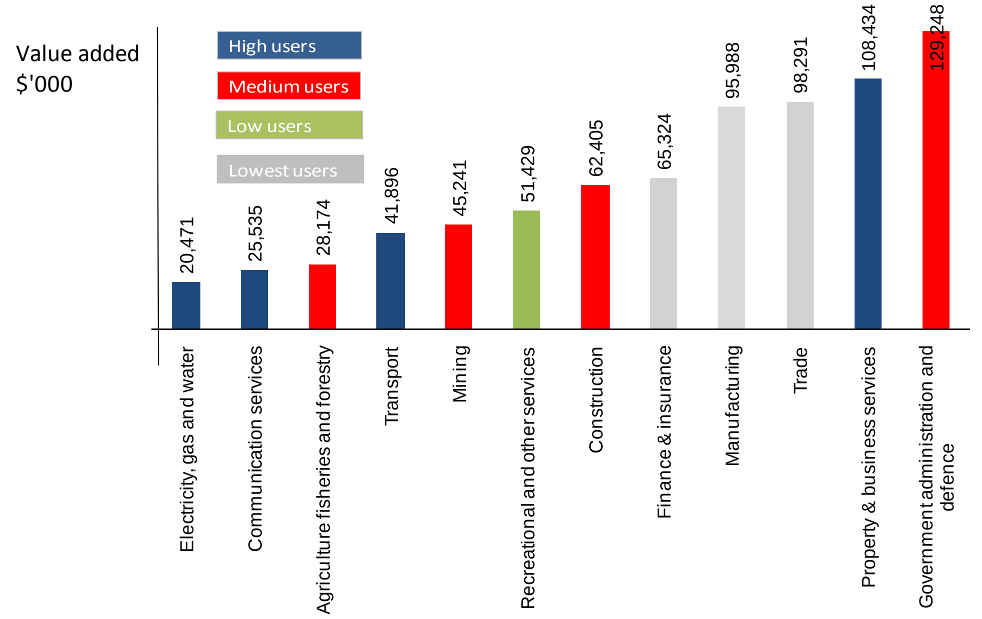
A good way of conceptualising the impact of the spatial information sector therefore recognises that the output of the sector is rarely targeted at 'final' household consumers, but usually *enables* other production processes. The sector produces 'platform' technologies which facilitate and assist in producing new solutions to existing problems.

In this sense it is clearly production-enhancing (along the lines shown with the Millmapper example), and it should therefore not be controversial to claim a role for spatial information technology in generating economic growth benefits.

The impact of spatial information on the economy is also a function of the size of each industry and its level of use. Figure 1 shows the value added for industry sectors by level of use of spatial information. High users include property and services, construction, mining, transport and agriculture. These areas are likely to be a major source of the national economic benefit from spatial information.

As spatial information penetrates other large sectors – such as retail and trade, recreation and other services and finance and insurance – further national gains might be expected.

Figure 1 **Industry value-add and intensity of use of spatial information**



Data source: ABS and ACIL Tasman

3.1.3 Spatial information and theories of economic growth

The idea that improvements in the production and use of spatial information will affect long term economic growth can also be firmly rooted in economic theory:

In the standard neoclassical models of economic growth based on the work of Robert Solow in the 1950s e.g., Solow 1956, 1957), the long run or stable equilibrium rate of growth is determined solely by the rate of technological progress (which is fixed *exogenously*, i.e., outside the model).

- Technological progress based on spatial information technologies can raise the long term rate of economic growth.

In more recent models of economic growth (e.g., Romer 1986, Aghion and Howitt 1992) the rate of technological progress is determined *within* the model (i.e., endogenous to the model), with key emphasis being placed on the roles of R&D and human capital in accelerating technological progress and thereby the rate of economic growth.

- The spatial information industry is clearly knowledge intensive, with many linkages to Australia's R&D capability and utilising a highly skilled labour force, making it a possible driver of sustained economic growth under the more recent economic growth models as well.

The claim that technological progress ultimately drives economic growth is therefore uncontroversial. However, growth models are too abstract to be able to throw light on the innovation system and how new technology successfully diffuses through the economy.

Many promising technologies never make an impact on the economy because the path from invention through to adoption and final impact is disrupted for one reason or another. There is a wide body on work on the causes of this type of innovation failure and many stories could be told: sometimes commercialisation processes are not suitable for the product or the staff involved in bringing new technology to market are not sufficiently skilled, at other times market dynamics or unforeseen events stall commercialisation.

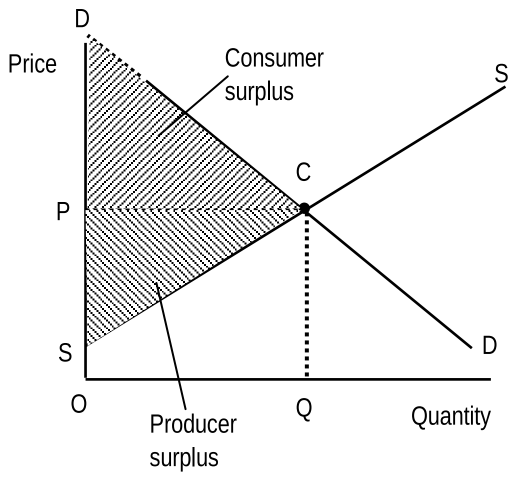
For these reasons, the methodology adopted for this report has been to focus on the existing demonstrable impacts of spatial information technologies. A number of other lessons drawn from experience with evaluations of previous technology waves have influenced the thinking behind this report, and these are summarised in the next section.

4 Assessing impacts

4.1 Theoretical underpinning

The economic values of market goods to the community are measured by consumer and producer surplus. The conceptual base for providing an understanding of consumer and producer surplus is the supply and demand, or market, model (Figure 1).

Figure 2 **Standard concepts of producer and consumer surplus**



ACIL Tasman chart

The interaction of demand and supply determines the market price for a good and the quantity that is produced in any given time period.

This market model provides the basis for identifying and estimating the net economic values to consumers and the net economic values to producers, referred to as consumer surplus and producer surplus, respectively.

Consumer surplus is the difference between what an individual would be willing to pay (demand) for a good or service (the total benefit to the consumer) and what they have to pay (the cost to the consumer i.e. consumer expenditure (price times quantity). In Figure 2 it is the area between the demand curve and the price line.

Producer surplus is the difference between the revenue (consumer expenditure) received for a good or service (total benefit to producer) and the costs (supply) of the inputs used in the provision of the good or service (economic cost to producer). In practical terms, it is the net revenue (before tax) that is earned by producer of goods and services. In Figure 2 it is the area between the price line and the supply curve.

While these concepts provide the economic framework for estimating economic value of spatial information they present difficulties when attempting to value the economic impact. Spatial information often delivers public goods and intangible benefits that are either unpriced or which may be intangible for which there is no monetary market.

4.2 Methods for assessing economic value

There are several methodologies that can be applied to assess the economic impact of goods and services. Those discussed below are practical approaches to the task consistent with the above theoretical underpinning.

4.2.1 Willingness to pay

Willingness to pay is a common approach to estimating the economic value of a good or service. This in effect attempts to infer a demand curve from which an estimate of the benefits can be made.

In many cases the geographic information services exhibit strong public good characteristics where price is difficult to determine or strong externalities where additional value is created but not reflected in price. Assessing willingness to pay can therefore require an estimate by proxy rather than an observation of a price determined in a market.

There are many credible techniques for estimating the willingness to pay. ACIL Tasman used survey techniques in a study of the economic benefits of the Western Australian Land Information System in 2004 (ACIL Tasman, 2004).

This approach requires the conduct of user surveys and is more suitable for assessment of a focussed product or service. In the case of this project however the number of sectors to be reviewed is likely to lead to unacceptable costs and time requirements. A willingness to pay approach was not suitable for this report.

4.2.2 Estimating value-added

An alternate approach to estimating the value of the economic contribution of a sector is to make high level estimates of its contribution to Gross Domestic Product (GDP) and other aggregates such as consumption, investment and real wages.

GDP is based on the concept of *value added*, which is the unduplicated value of goods and services produced in any given period. Gross value added is equal to a producer's value of outputs from the production process less the value of commodity inputs (intermediate consumption) plus taxes on products payable less subsidies receivable (ABS, 2000).

Estimates of value-added can be direct – that is the direct impact of the specific good or service – and indirect – that is for other industries that use the good or service. Direct value-added can be assessed from studies of the net benefits delivered by a sector compared with the counterfactual (the situation that would arise without the input from that sector). These are then used to estimate changes in outputs between the two scenarios which are then used to change assumptions in a Computable General Equilibrium (CGE) model of the economy.

CGE models provide the capability to model the economy wide impacts of changes in outputs on a national or regional level (the characteristics of ACIL Tasman's CGE model are discussed in Section 3.6).

General equilibrium models are an accepted means of estimating the direct and indirect impacts of changes in output of goods and services such as geographical information.

4.2.3 Valuing options

Another approach to valuing the impact of spatial information is in the options created for government and industry to realise higher levels of productivity, grow markets and move into higher value areas of economic activity. An options approach to valuation (referred to as real options in the non financial sector) can overcome weaknesses in traditional assessment approaches for activities subject to high levels of uncertainty. A note on the use of real options analysis is provided at Appendix C.

Such an approach may well apply to assessing the future economic, environmental and social benefits that are possible from spatial information. It is particularly useful for accounting for benefits of an environmental, security or social nature.

4.3 Literature review of previous impact studies

There is a growing body of literature, both Australian and international, which documents how business and government use spatial information, and the impacts it has had in specific contexts (see Appendix B). ACIL Tasman is unaware of any study that has employed a CGE model to calculate economy wide economic impacts of spatial information. There are, however, studies that have explored the impacts of spatial information in specific sectors or applications. The literature recognises the need for a systematic assessment of aggregate impacts (Alexander, 2003).

In reviewing these studies, it is important to appreciate that most have estimated the direct use values (such as those found in a cost benefits analysis), as distinct from those also capturing flow on values (as captured in a CGE model). Some of them capture impacts on an annual basis, while others report on cumulative impacts over times. Some of them also describe the impacts of a small subset of the spatial information (such as government spatial data infrastructure) rather than the whole spatial information industry.

Being a relatively new industry, and part of the rapidly growing information and communication sector, the spatial information industries of the world are growing at a rate far faster than that of general economic growth. Some estimates have the average annual growth rate of spatial information worldwide as high as 20 percent per annum (Spatial Information Action Agenda, 2000; Daratech, 2006). Some examples of the value of this investment in spatial information to developed economies include:

- OXERA estimated that the value of the geographic infrastructure to the Europe, as crudely measured by the amount invested, as ECU 10 billion per year (OXERA, 1999).
- A similar measurement of the amount invested in geographic infrastructure in Great Britain by NOP (1998) was £204 million in 1997. This equates to approximately .03 % of Great Britain GDP at the time.
- The total output value of China's geographic information industry was estimated to be over US$ 3 billion in 2005, and it is expected to grow to over $10 billion by 2010. The industry is expected to stimulate value in other related industries of around US $63 billion by 2010 (GIS Development News, 2006).
- In 2000, the Spatial Information Industry Action Agenda estimated that global expenditure on spatial information was $34 billion, and growing at the rate of 20% per annum.
- The value of the British Geological Survey alone to the United Kingdom economy alone was estimated to be well in excess of its annual turnover of £40 million (Roger Tym & Partners, 2003).
- The value of the GIS industry in Australia, as indicated by total GIS budgets across all industries, is estimated to be A$1 billion in 2006 (Corporate GIS Consultants, 2003).
- Halsing and Theissen (2004) estimated that the US Government's "The National Map" initiative had a net present value (NPV) over 30 years of US$2.05 billlion was found.
- ACIL Tasman (2004) used a combination of case study research and contingent valuation to estimate the direct use value of the Western

Australian Land Information System alone at approximately $14 to $15 million a year to the WA economy (ACIL Tasman, 2004).

- Price Waterhouse (1995) examined the economic aspects of establishing a more up to date digital mapping data base for use in NSW land information systems, and found that the benefit-cost ratios ranging from the updates to be significant; between 9:1 to 2:1 depending upon the reform options chosen. The major benefits from an accelerated program related to: additional sales of data by existing suppliers; those suppliers being able to provide data at a lower cost than if (relatively inexperienced) users attempted to digitise their own information; digital data substantially reducing the manpower needed in the longer term to produce and apply mapping output; and, new digital data.
- A Western Australian Government Taskforce (1990) found that substantial gains were likely from integrating land and geographic data held by State agencies. This integration would include steps to clarify data custodianship, the establishment of a land information directory, standard procedures for data collection, and improved marketing of data. The annual costs of integrating land information were estimated at $1.8 million and the potential annual benefits at $10.7 million – resulting in a benefit/cost ratio of 5.9:1 (Western Australian Department of Land Information, 1990).

More detail on these, and other studies, is provided in Appendix B.

5 Outline of the methodology

5.1 Approach

The initial literature review revealed very little data that would support a willingness to pay analysis and the cost of undertaking such a study would have been prohibitive. The review also revealed that there was little information available from past surveys or studies to provide a comprehensive analysis of direct impacts.

A value-added approach was therefore adopted using the Tasman Global CGE model of the economy to estimate the macroeconomic impact of spatial information in 2006-07.

To estimate the impact of spatial information on the economy in 2006-07 two case were considered:

- a reference case which assumed that the spatial information was not applied in the economy
- a "with spatial information" case which assumed that the spatial information was applied – effectively the situation in 2006-07.

Research therefore was undertaken into a series of case studies nominated by the CRC-SI, plus others identified by ACIL Tasman, to provide an estimate of the direct impacts of specific applications and use these as a guide to estimating direct impacts on selected sectors of the economy.

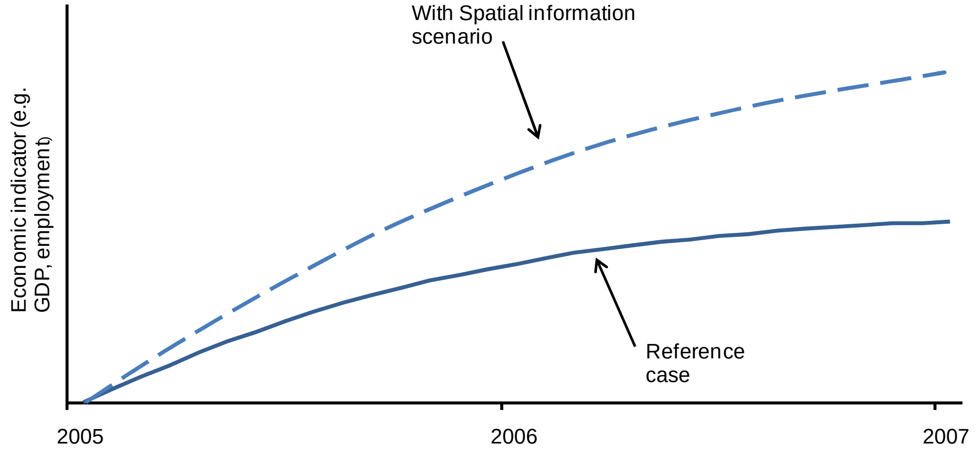
The results of the research and assessment are discussed in Sections 6 and 7 and the results of the modelling are discussed in Section 8. The following sections outline the details of the methodology.

The steps in the process were:

- research into case studies in each major sector to identify verified productivity improvements or resource increases attributable to spatial information
- using the results of cases studies and the literature review assess the levels of adoption and the impacts of spatial information in each sector
- estimate shocks to each sector attributable to spatial information for a lower bound and a more realistic scenario
- enter the shocks into Tasman Global to estimate the impact of spatial information on macroeconomic aggregates and on output in each sector.

The difference between the "with" and "without spatial information" represented the economic impact of spatial information in 2006-07 (see Figure 3).

Figure 3 **Economic indicators with and without spatial information**



In the course of this work broader economic, social and environmental impacts were noted and reported separately where appropriate.

5.2 Assessing the direct impacts

Spatial information can help business make better decisions, and thereby enhance productivity, across many industries. In addition, spatial information and the technologies by which it is created, used and disseminated, can be enabling, in that it can allow for some totally new business applications.

It is rare that spatial information is an end in itself. Rather, it is typically used to create useful information products that help organizations run better. This is most obviously so in industries where location and questions of 'where' are important, and hence where spatial intelligence is advantageous, but it's suspected that the value of spatial information now extends to many industries other than the traditional high intensity users.

This initial phase of research has been to explore the *direct* value of spatial information to a range of industries across the Australian economy, through a combination of a literature review and case study research.

By direct value, we mean the impacts upon businesses within each sector of the economy, typically in terms of cost savings, revenue gains or the facilitation of new applications (which are typically reflected in either revenue gains or cost savings). Regardless of whether the impact at the firm and industry level is a cost saving, a revenue gain or the facilitation of new applications, we quantify the impact in terms of a change in productivity.

Productivity is the efficiency with which inputs are converted into outputs. It is best considered as a ratio, a change in one unit relative to another unit. As such, changes to costs (inputs) or revenue (outputs) can both change productivity.

In determining which industries gain the most direct productivity gains from the use of spatial information, the general trend is that those industries that deal predominately in issues of geography and space as core business, such agriculture, fisheries, utilities, communications and transport, stand to gain the most through spatial technologies. For such industries, issues such of overcoming distances or appreciating complex links between spatial variables are core business.

Industries where business is performed largely within the confines of discreet and small boundaries, such as manufacturing, finance and retail trade, have relatively less to gain from the use of spatial information. In between are industries where parts of the industry deal in spatial issues, such as disease tracking and morbidity planning as part of health, but other parts are less spatial in nature.

In addition to the industry specific uses discussed in the following sections, there are a range of generic uses of spatial information that span many sectors. Most prominent of these are:

- market and infrastructure planning
  - building infrastructure and providing services where it is needed the most, by incorporating supply and demand side spatial variables
- asset management
  - managing existing infrastructure, identifying faults and sites needing attention quickly, and allowing for the site to be found quickly and the problem addressed faster
- appreciating spatial trends
  - spatial trends and issues that may not be apparent when data is presented in a tabular from are often clearly apparent in maps
  - any data that has a recognisable spatial dimension can be mapped and analysed in GIS, often shedding new light on problems and allowing for improved decision making and policy decisions.

It is important to note that, even though an industry may not stand to gain a great deal of direct benefit through spatial information, most will benefit in indirect ways. For example, even though sectors such as manufacturing and trade do not gain from direct productivity impacts, they do benefit indirectly through any impacts on the productivity of transport, such as access to as cheaper or quicker transport. These types of interactions, along with the overall stimulus to demand that a productivity gain in one area of the economy has upon another, are captured and explained in the CGE modelling.

In determining the direct impacts on industries, we have modelled two distinct scenarios. The first of which, called the 'verifiable and quantitative scenario', reflects the impacts for which we have been able to confidently quantify through reliable third party information or through our case studies.

In addition to the impacts we can confidently quantify, we are aware of a range of applications of spatial information across industries that we have been unable to find the necessary information to allow us to quantify the resulting productivity impacts. That is, we know that industries are benefiting in ways that we have been unable to capture in our quantitative scenario. To reflect this, and to model a scenario closer to what we believe to be the reality, we have developed a second scenario called the 'estimated scenario'.

The two scenarios therefore are:

- a quantifiable 'lower bound' scenario which reflects the impacts we have been able to *confidently* and *verifiably* quantify through the use of reliable statistics, existing literature, expert opinion and through our case studies
- a 'realistic' estimated scenario which comes closer to what we believe to be the reality (as distinct from that which we can confidently quantify).

The approach taken in this report has been to collect and analyse as much relevant information as possible to estimate the direct economic impacts. Interpreted widely, this approach involved learning lessons from impact assessments of past technology waves.

5.3 Lessons learnt from previous technology waves

ICT and biotechnology are two recent examples of emerging technologies which were seen to hold similar prospects for economic growth and in which similar issues arose for statistical collections as well as impact assessments in the Australian context (see ACIL Tasman 2003, 2005).

A number of key lessons from the experience with preceding technology waves have influenced the approach taken in this report. Key lessons include the following:

- Firm-level or case study data often show much greater (potential for) productivity gains or cost savings than are subsequently observed or can be confirmed at a sector- or economy-wide level.
  - The methodology adopted for the modelling exercise in this report ensures that sector-wide impacts of spatial information technologies are only a *small fraction* of what has been observed for individual economic agents (e.g., in case studies).

  - In turn, use of these sector-wide impacts as an input into computable general equilibrium (CGE) modelling ensures that the economy-wide impacts are not overstated.
- Against this must be set the fact that intra-firm resource shifting often occurs where new technologies free up resources (e.g., labour), which partly explains the shrouding of impacts at the aggregate level.
  - A thorough analysis of technology impacts therefore involves more detailed case studies such as are included in this report (see Chapters 6 and 7).
- Technologies can have generic as well as specific impacts; this is because some technologies are 'platform' or 'enabling' technologies and also because some activities are common to many firms or organisations across the economy (e.g., asset management, marketing, scheduling, etc.).
  - In the case of spatial information, for example, a GIS-based asset monitoring package can be used by almost any firm (generic impact of a platform technology) but a robotic total station with real time GPS would only have an impact in surveying (impact of a specific purpose technology).
    - … Our approach to the generic type impacts of spatial information technologies is described in further detail in Chapter 5.
- New technologies often build on existing technologies and care must be taken to isolate the *marginal* impacts of the new technology.
  - Spatial information technologies have evolved alongside general ICT (and may also have benefited from contemporaneous improvements in equipment design and manufacture, etc.) implying that care must be taken with attributing any observed productivity gains to spatial information technology as well as other contributing technologies.
- More broadly speaking, impacts tend to emerge incrementally over time as the technology diffuses through the economy (rather than as a one-off impact).
  - This is partly because real world economic agents operate in complex and dynamic market environments, where it can sometimes be advantageous to be a 'follower' rather than a 'leader' in technology adoption.
- A further issue to be considered for the evaluation of impacts of new technologies is the disruptive effect of innovation that in some cases can redefine the market in dramatic ways and kill of old markets (Christensen, 1997, 2000).
  - It is therefore important to consider the potential for wider adjustments in the economy that new technologies might indirectly delivered. This is a reason for using a CGE model to estimate the aggregate impacts. CGE models can take into account the wider impacts on all sectors, the

resource transfers and the impacts on the output of specific sectors resulting from changes in specific sectors.

- Finally it is important to consider the "counterfactual" when estimating direct impacts of changes in technology in a specific sector
  - Spatial information is an enabling technology that supports more efficient ways of doing work. Without the new spatial information technologies the work in question might still get done to some degree – but with lower efficiency, over a longer time frame or with less effectiveness.
  - In undertaking the case studies therefore careful consideration of the "counterfactual" was necessary to ensure that the "without" case was taken into account in estimating the direct benefit.

Given these key lessons, a conservative approach to estimating the overall impact of spatial information on the economy was adopted. As outlined in below this approach couples detailed technology or case study information and sectoral analysis with estimated technology adoption profiles and applies this in a computable general equilibrium (CGE) framework.

5.4 Assessment approach

Impact evaluations of emerging technologies are almost always complex and subject to varying degrees of uncertainty – at least until appropriate statistical reporting frameworks and measurement approaches have been developed and implemented by government agencies and industry. Given that the Queensland Spatial Information Office's efforts to identify the spatial information industry in Queensland are very much at the forefront of current statistical framework development in Australia but do not cover detailed economic impacts, it is unlikely that reliable *nationwide* indicators will become available in the near future(QSIO, 2007).

Perhaps even more importantly, there are currently no statistical collections that could throw light on the impacts of spatial information technology on *users* of that technology. This is to be expected given that the new spatial information technologies have only emerged over the past ten years or so and are just beginning to be incorporated more widely into working practices across the economy.

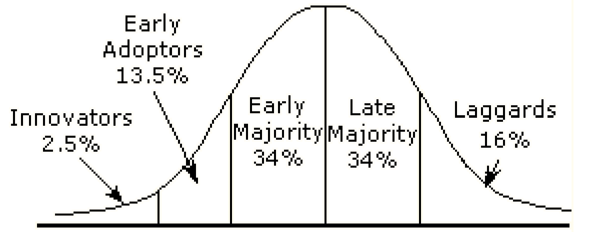
The absence of statistically reliable indicators on spatial technology uptake and impact from sector-wide and user-level surveys provides the overall context for the analysis and modelling undertaken during the preparation of this report.

5.4.1 Steps in the assessment

The following key steps were involved in building up the assumptions that underpin the modelling exercise:

1. identification and characterisation of modern spatial information technologies by economic sector
   - in some instances assisted by in-depth case studies
   - review of existing evidence on productivity growth in each sector
2. probing of specific applications and possible impacts in clearly identified areas
   - this step included literature surveys and discussions with various stakeholders (including technology adopters) and experts on the costs and benefits of adopting specific spatial information technology
   - impacts included quantitative impacts and qualitative impacts, but for the purpose of modelling only the quantifiable impacts were utilised
   - the discussions and analysis also took the 'counterfactual' scenario into account, i.e., what might have happened in the absence of the new technology
3. identification of current 'stage of adoption' following Rogers (Rogers, 2003) for each specific application in the sector it is used – as a proxy for the *actual* current rate of adoption (see Figure 4)
   - Where evidence on adoption patterns was available this was preferred over the proxy
4. verification of these current adoption rates as being plausible or reasonable through discussions with experts and/or by drawing on existing literature
5. recognition of possible generic productivity impacts
   - the methodology applies industry concentration as a proxy to identify sectors in which generic impacts are likely to have been largest to date (see Section 5.4.3)
6. synthesis of specific and generic impacts to arrive at reasonable *minimum* 'orders-of-magnitude' sector-wide annualised impacts at the level of disaggregation suitable for Tasman-Global, the CGE model employed for the final modelling exercise
   - involves concordances of Tasman-Global sector with ANZSIC sectors
7. finally, comparison of the situation *with* and *without* spatial information using Tasman-Global.

Figure 4 **Technology adopter categories**



Data source: Rogers (2003)

5.4.2 Generic impacts of spatial information technology

A number of spatial information platform technologies and products identified during the preparation of this report have generic impacts, i.e., these technologies or applications are not restricted to use in any one economic sector. Examples are asset mapping products, satellite imagery interpretation software such as Barista (see case study in Section 6.5.3), and GIS-based marketing tools.

Another example is the Spatial Information Exchange that has "channels" or spatial views to support decision making. The SIX channel approach uses the same foundation layers, cadastre, topography, imagery, standard searches which makes up 80% of the core data and then it is supplemented with role or function data. For instance, the Fire Channel has the core plus water-mains, fire-hydrants, administration boundaries, and the Planning Channel has core plus state, region, local and heritage environment controls. These emerging new service-oriented spatial applications take a fraction of the time to develop, run on shared platforms and only require a simple internet-browser to access spatial data.

Many organisations can potentially use or benefit from these types of products, including not only firms but also government at all levels (e.g., asset mapping by local councils), universities (e.g., in health research) and charitable organisations.

It is impossible to identify generic impacts by sector with the current statistical frameworks. However, during the preparation of this report it became clear that larger organisations appeared more likely to have invested in spatial information technologies with generic types of benefits.

5.4.3 Impact of organisation scale

Large organisations have always had to deal with the coordination problems that come with size – a small firm, for example, will have little problem identifying where its assets are. However, management of larger organisations involves scheduling complex rosters, assigning workloads by location, identifying assets in need of maintenance, and so on.

In terms of marketing, large organisations also have a bigger stake in knowing where their customers are. Investment decisions may similarly be affected by detailed knowledge of geographical and other variables that can be layered in a GIS environment (e.g., cable rollouts for telecoms, pipeline and other routes in energy).

Case studies and discussions with various parties also revealed that there are distinct advantages to some of the new geospatial technologies that relate to skill requirements and the tight labour market environment. Large firms have been able to shift less skilled employees into operations that would previously have been carried out by more skilled subcontractors (e.g., handheld GPS devices have greatly reduced the difficulty of some surveying tasks).

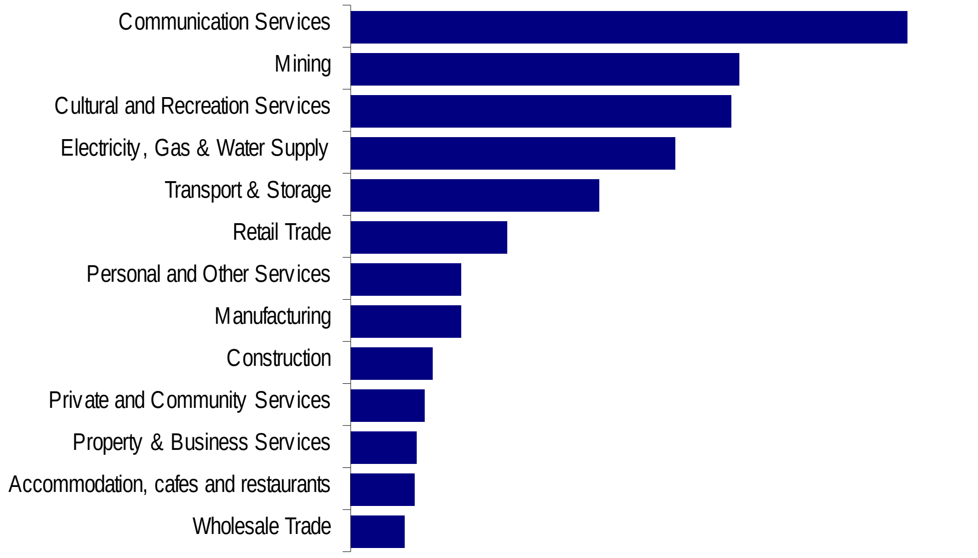
Also, many of the products are still priced at a level that can be prohibitive to small companies or sole traders (e.g., in construction).

To date, it is therefore the larger firms that appear to have had the greatest incentive to invest in the new spatial information technologies with generic type benefits.

In coming to a determination about the distribution of generic impacts of the new technologies across different sectors, the methodology employed in this report uses ABS statistics on industry concentration by sector to gauge how generic impacts might have been distributed across sectors.

Figure 5 illustrates that industry concentration varies significantly by economic sector – telecoms and mining, for example, are highly concentrated when compared to, say, construction or property and business services.

Figure 5 **Indicators of industry concentration**



Note: The figure is based on the share of industry value-added generated by the 20 largest groups in that industry.
Data source: Australian Bureau of Statistics, Industry Concentration Statistics, 2000-01 (latest available).

The above discussion demonstrates some of the theory and practical issues that informed our assessment of the impact of 'modern' spatial information technologies. As will be clear from the discussion, and due to the absence of more detailed statistical information, a number of assumptions had to be made to arrive at our economic impact estimates, which are discussed in further detail in Section 8 of this report.

Readers interested in the economic impact assessment may therefore proceed directly to Section 8 – it should be noted, however, that part and parcel of the methodology underpinning the results presented in Section 8 is the information contained in Sections 6 and 7.

6 Direct impacts on business sectors

6.1 Introduction

In the following sections we review some of the main applications of spatial information across the economy, and why some industries are gaining more directly from its use than others. Our conclusions on this are based upon:

- case studies
- broader literature from around the world
- use of spatial technologies by industry
- observed productivity impacts by industry of other related technologies such as ICT and computers
- observed whole of industry productivity growth over time
- our own experience and expertise in this field.

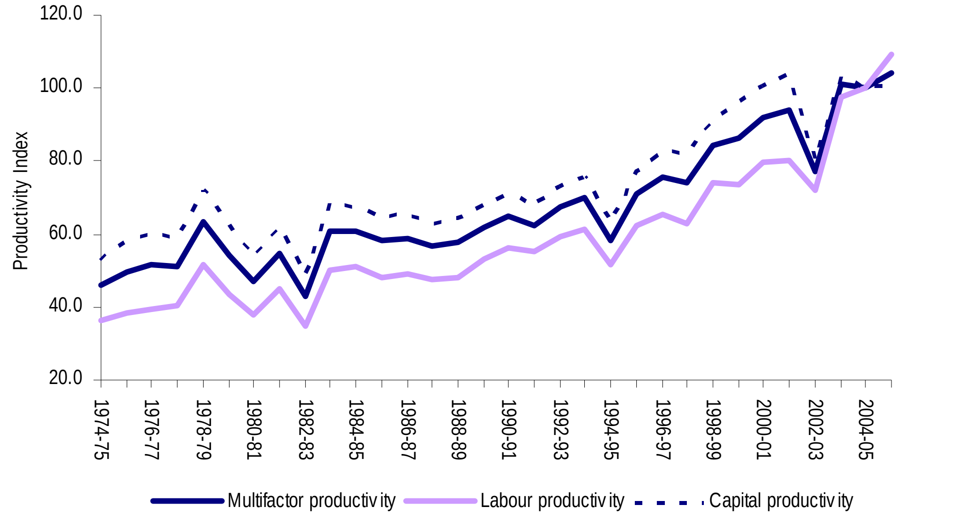
6.2 Agriculture, fisheries and forestry

Spatial information systems have already found an important role in helping Australia's agricultural fisheries and forestry industries maintain their competitive position in an environment where distorted global markets, climate variability and price pressures are constant challenges.

Agriculture is one of the economic sectors for which continued improvements in productivity has been crucial. The sector is highly dependent upon global trade in commodities and the observed long term trend declines in world market prices force farmers to continually seek cost saving innovations to stay competitive.

Australian agriculture has an admirable history of productivity improvement (see Figure 6). Continual increases in yield per acre have contributed significantly to this improvement. In addition agricultural producers face ongoing threats of pests and diseases attacking established cultivars.

Figure 6 **Productivity trends in agriculture, forestry and fishing, 1974-75 to 2005-06 (index, 2004-05 = 100)**



Data source: (Productivity Commission, 2006)

Spatial information has contributed to some of the productivity improvements, having been increasingly used in the agriculture, fisheries and forestry sectors since the early 1990s. Applications include those that improve production and lower costs for industry and those that assist governments to minimise the impacts of incursions of pests and diseases and monitor various environmental impacts.

Differential Global Position Systems (DGPS) were first applied in agriculture in the early 1990s for yield monitoring and farm planning. DGPS and GIS systems are now used in:

- yield monitoring and crop stress mapping
- controlled traffic farming (e.g. self-steering tractors)
- variable rate technologies (for applying fertilisers)
- soil condition mapping
- salinity mapping
- control of pests and disease outbreaks (by governments).

Spatial technologies have also assisted the fishing industry. The industry was an early adopter of GPS and GIS based mapping systems for location of fishing areas. Fisheries management authorities use spatial information for habitat mapping and monitoring of fish stocks. They are also used in delineating marine parks, to help ensure longer term sustainability of fish stocks in Australian waters and protect areas of conservation value.

Spatial information technologies are used in forestry for inventory management, developing yield harvesting plans, yield estimation and environmental compliance. As discussed in Section 7.4, they will also contribute to estimation of carbon sequestration by forests when carbon trading commences.

Spatial Information played an important role in managing the spread of Equine Influenza in NSW in 2007. GIS staff published maps daily showing restriction zones. The public had access to the latest information via the web through a portal. The Spatial Information Exchange (SIX), "EI" channel allowed the public to make inquiries on any property or parcel of land in NSW to determine its status, its relationship to restriction zones, transport routes and inspection stations. Call centre operators at the Menangle Control Centre used the same source of information, "EI" channel, to keep the public updated via the telephone channel.

The following case studies illustrate just how quickly spatial information technologies have been taken up in this industry and how quickly the applications are growing.

6.2.1 Case study – precision agriculture

During the past 15 years, spatial referencing has played a key role in what has become known as 'precision agriculture'. At a broad level the key developments in this area include:

- controlled traffic farming (CTF) or 'guidance'
- variable rate technology (VRT).

Other developments which have supported progress in these areas include advances in imagery and mapping which includes:

- soil condition mapping
- crop stress and yield mapping
- salinity mapping.

Advances in yield mapping have been combined with more accurate real-time positioning to enable experimentation with variable rate technology. Similarly, improved zone management is facilitated by more accurate spatial referencing and mapping. Another emerging area of research in precision agriculture is in the field of precision irrigation.

Some of the 'simpler' aspects of precision agriculture such as CTF have already made significant inroads in, for example, broad-acre farming (Robertson, Carberry, & Brennan, 2007); Price, GRDC, *pers comm*); other aspects are still under development and success in these areas is contingent upon advances being made in a number of related areas such as an improved understanding of temporal variation in yields for a field (McBratney, Whelan, Ancev, & Bouma, 2005).

Some of the key benefits from better use of spatial information in agriculture are not commercial but environmental. Reduced spraying of chemicals, reductions in the use of fertiliser, less burning of fuel, etc. all have direct and indirect environmental benefits (pollution, greenhouse gas emissions, etc).

Controlled traffic farming or 'guidance'

Controlled traffic farming refers to the use of real-time positioning technology for equipment guidance in agriculture. A number of private firms have emerged in the marketplace which can supply bespoke GPS equipment for use on agricultural machinery. The cost of installing these units has fallen significantly during recent years, which has encouraged adoption of the technology (Phil Price, GRDC, *pers comm.*).

One of the leaders in this field is Beeline Technologies, the first company to develop and commercialise hands-free steering (or 'auto-steer') technology, i.e. using GPS to assist motorised farm machinery to 'drive straight'. Farmscan is another leading provider of technology for precision agriculture applications (see Figure 7).

Figure 7 **Demonstration of auto-steering set-up**

Data source: PA Scanner – A newsletter on Precision Agriculture from FARMSCAN; Vol 2, August 2006.

An important commercial benefit of auto-steer is a reduction of overlaps – overlapping can occur with a number of mechanised tasks, such as planting, spraying and harvesting. Benefits due to reduced overlap of spraying alone are typically in the order of 10% savings on spraying costs (Robertson *et al* 2007). Beeline Technologies estimate that use of their products can reduce total farming cost by up to 15%.

Land and Water Australia cited studies from 1998 to 2003 citing yield increases for average years of between 10% and 30% with increases of up to 50% in above average years (Schofield, 2007). A report prepared for the Victoria Department of Sustainability and Environment by the Allens Consulting Group drawing on this and other research assumed that CTF would deliver a 10% gain in yield and a 15% reduction in costs (Allen's Consulting Group, 2007).

Recent evidence from broad-acre growers is that their investment in CTF pays back within 2-3 years – this is why adoption of this technology has "really taken off" during the last two years (Phil Price, GRDC, *pers comm.*).

Auto-steer technology also greatly reduces driver fatigue. Previously drivers had to continually correct for 'tram lining' – the tendency of tractors to follow longitudinal grooves in the field against the driver's steering input. The auto-steer facility allows less skilled drivers to operate tractors, thus increasing the potential workforce base, and may even prolong the driving careers of older staff/family members. It also allows operations to be done at night, in fog, etc. which improves timeliness and can have significant yield benefits (James Taylor, Australian Centre for Precision Agriculture, *pers comm.*).

Current adoption rates of CTF technology in Australia are estimated at "well over 10% and probably closer to 15% of growers" for broad-acre crops, including not only grains but also cotton and sugar (Price, GRDC, *pers comm.*).

Variable rate technology

Variable rate technology offers another productivity tool in addition to CTF. It uses detailed spatial information to enable matching of inputs with crop and soil requirements as they vary within a field. Spatial information must be coupled with other knowledge such as information on seasonal variation and other agronomic factors. Research on better understanding observed yield variations within fields is however still in progress, thus limiting the degree to which spatial information can currently make an impact in this area.

Nevertheless, research into VRT and differential management by the Australian Centre for Precision Agriculture suggests that a benefit of $10-50 per hectare can be achieved through variable rate fertilizer alone. As yet unpublished results based on more paddock years of data support this conclusion (James Taylor, *pers comm.*).

Current adoption of VRT in Australia is estimated at 3-4% for broad-acre crops (Price, 2004)(confirmed by Price, *pers comm.*).

Direct impacts for agriculture

This case study identifies a number of credible studies that confirm that improvements in productivity reflecting a reduction of at least 10% in input costs are being realised by adopters in broad acre agriculture in 2006-07. Adoption rates of between 10 to 15% are also reasonably confirmed in that year.

At the broadest level, a conservative assumption would be that the use of spatial information technologies has to date caused a fall in costs for broad acre farming as a whole of around 1% (see Table 4), after taking account of the cost of adoption. Whilst costs of adopting precision agriculture related spatial information technologies range from around $10,000 to $90,000 (CSIRO 2007), that for tramlining – which yields the benefits identified here – is at the bottom of that scale, i.e., around $10,000. This would have been 'paid back' within 1-2 years of using the technology on an average sized farm. Given that adoption has been gradually increasing over the past ten years, the assumption that a 1% cost saving which is net of adoption costs has occurred in 2006-07 is therefore justifiable.

The CSIRO (2007) report also estimated benefits per hectare from adopting the new technologies at $14 to $30. These figures were also taken into account in developing our shocks. Building on these two sets of information (i.e., the per hectare savings from CSIRO and the 1% cost saving from the literature), estimates were developed for grains, mixed enterprises (grains and sheep and cattle, sugar cane and cotton for Scenario 1. To arrive at the estimates, differences in average size of farms across these sectors were also taken into account, and the identified savings were then spread over each identified subsector of agriculture (Robertson M. , 2007).

Scenario 1 is considered to be a verifiable and quantifiable estimate but an estimate that is very much a lower bound number. The literature review and consultations undertaken for this research indicated that spatial information is also delivering benefits in terms of:

- pest and disease management (see Section 7.5)
- improved climate and weather forecasting
- whole farm planning
- yield gains.

Scenario 2 estimates were made on the basis of general observations of the impact of these additional gains.

The direct impacts for agriculture are summarised in Table 4.

Table 4 **Assumed direct impacts – agriculture**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Grains (specialist growers)	Impact of controlled traffic farming on savings in fuel and chemicals 10% savings 12.5% adoption	0.9%
	Mixed (grain and sheep/cattle	Fuel and chemical savings	1.4%
	Sugar cane	Fuel and chemical savings	0.1%
	Cotton	Fuel and chemical savings	0.1%
Scenario 2	Grains (specialist growers)	Additional impacts based on: • pests and disease management • improved climate forecasting • improved asset management and farm planning • natural resources management • increase in yield	1.08%
	Mixed (grain and sheep/cattle	As above	1.5%
	Sugar cane	As above	0.26%
	Cotton	As above	0.22%

Note: Based on case studies and literature review.
Data source: ACIL Tasman

6.2.2 Case studies – forestry

Spatial data is and has always been used by foresters in their day-to-day work. Foresters have been amongst the first to trial and adopt some of the new spatial information technologies. Forests NSW, for example, is making great progress in the use of new spatial technologies to assist in the management of forests.

Forests NSW

Forests NSW operates and uses four distinct GIS management systems[2]. The organisation uses an internal inventory management system called Total Forest Management System (TFM) which is linked to a number of GIS data management systems. Forests NSW uses a software product known as Atlas –

[2] Forests NSW are currently in the process of completing a cost-benefit analysis to quantify the value of some the new spatial information technologies.

a product in wide use across the forestry sector that enables management of large estates.

In the case of softwoods, inventory assessments are conducted once every 10 years. This requires inventory crews to go into the field to assess the state of the plantations. Crews are equipped with palm top GIS/GPS instruments which are used to locate plots the size of 1 hectare to conduct their assessment. According to discussions held with foresters, there has been a reduction in the crews required to complete these assessment tasks as a result of the spatial technology.

Spatial information is also used in yield estimation and in completing pre-harvesting plans to ensure that environmental requirements are met. The increased accuracy has resulted in a reduction in environmental transgressions (e.g. organisations may be fined if harvesting takes place in drainage areas). Prior to the use of spatial technologies, crews used paper maps to determine location.

A new and emerging area is the use of Light Detection and Ranging (LIDAR) (currently in the R&D phase). LIDAR is an optical remote sensing technology which finds range and other information about a distant object. It does this by measuring the properties of scattered light. Using LIDAR, the range of an object is determined by measuring the time delay between the transmission of a light pulse and the return of the deflected signal. LIDAR allows remote assessment of forest attributes like tree height and other structural attributes. This reduces the need to send crews into the forest for resource assessment. Currently this technology is costly, but is becoming more cost effective.

Other new areas include the increasing use of:

- digitised photogrammetry
- airborne cameras
- satellite imagery.

In another innovative use of spatial information to assess the forest resource, aerial sketch mapping of canopy health uses a PC tablet running GPS software and using GIS maps. The assessor can mark damage directly on the screen. This technology provides high accuracy as the assessor knows his location exactly at any point in time.

Great Southern Plantations

Great Southern Plantations is a major player in the commercial forestry sector. NGIS Australia built ***ForMS***, a spatially based forestry management system for Great Southern Plantations. ***ForMS*** has added a geographic dimension to Great Southern's operating systems. This integration of the company's operational business processes with GIS has resulted in multiple benefits. These are:

- All plantation management activities are tracked on a single centralised system.
- It has become easier to demonstrate compliance with environmental standards.
- Access to spatial information is not restricted to those with technical GIS skills.
- Work orders and jobs with spatial dimensions can be easily linked to corporate systems.

The development of ***ForMS*** took place over 3 phases. The first phase involved integrating existing data and developing the application. This was then integrated with the GIS. An NGIS product ***GeoSamba*** was used for this purpose, providing a GIS browser interface. The last phase involved integrating ***ForMS*** with Great Southern's other corporate systems.

ForMS greatly increased the ability to manage Great Southern's plantations by providing a centrally located system for inputting, storing and tracking plantation activities. Plantation managers are provided with sophisticated business intelligence on maintenance, planting fertilisation and harvesting. For example, if a plantation is due for insect control, the system identifies those properties that may be sensitive to the chemicals sprayed, such as vineyards and farms, and generates notices and reports of those who need to be informed.

Other gains have resulted through the automation of many previously paper based tasks, such as mobile ***ForMS*** out in the field for logging inspections and job recording.

The impact of the use of ***ForMS*** has been to increase the area that can be managed by each manager by around 50%.

Direct impacts for forestry

The Great Southern Plantations revealed a significant increase in labour productivity.

Consultations with the hardwood plantation industry suggest that there is close to 100% adoption of new spatial technology across the commercial plantation sector. Discussions with other government and industry participants revealed that use of the technologies is increasing in publicly managed forestry resources too, but that it is still in its 'early stages' of innovation. The assumption applied in this analysis was therefore to stipulate adoption of only 2.5% across publicly managed forestry.

Costs of adoption have been variable across firms as different technology platforms utilising spatial information have been developed by different users. The Great Southern Plantations case study revealed that the new technology platform represented a significant upgrade of the company's existing system, and estimated cost savings would in all likelihood have covered the cost of investment within 1-2 years of adoption. Given that general upgrading of ICT systems occurs in most companies, however, not all of the cost of switching to the new platform can be associated with the use of spatial information alone.

On the basis of this information, it was calculated that wage costs in the forestry sector were around $8.7 million lower in 2006-07 than they would have been without this application – equivalent to around 1.9% of compensation to employees in the sector. This was the productivity shock assumed for Scenario 1.

There are other benefits that were reported in the case studies. These included improvements in application of chemicals and general management and control. However given the relatively recent introduction of these technologies into this sector no additional assumptions were made for Scenario 2

Table 5 **Forestry impacts**

Scenario	Enterprise	Assumptions	Direct impact
Scenarios 1 and 2	Forestry	Impact of ForMS on labour productivity assuming • 100% adoption across plantation forestry • 2.5% adoption across native forest logging • 50% increase in area per manager	1.93%

Data source: Case studies, interviews and literature review

6.2.3 Case study – fisheries

Fishing is by its very nature an activity that relies on spatial information inputs. The introduction of GPS devices in commercial fishing, coupled with plotters, was a major development for the fishing industry. First experiments began in the mid-1980s and general technology rollout and adoption began in the late 1980s.

Fishers were quick to adopt the technology because it allowed them to track where the best fishing grounds were, which reduced search costs as well as saving fuel on operations. Some individual fishers stated that they saw their productivity rise by 50% or more as a result of this technology. Indeed, total industry output increased by around 50% since the late 1980s (from around 180,000 tonnes in 1988/89 to around 270,000 tonnes in 2003-04). However, the composition of output has changed markedly with a large increase in aquaculture.

The introduction of GPS technology in the late 1990s, followed by a range of other applications of spatial information (e.g. in habitat mapping) has also been beneficial to researchers and to the authorities that manage fish stocks, as discussed below.

Commercial fishing

In the case of a commercial fishing company, for example, a GPS unit attached to a plotter allows recording of tracks, which are a valuable resource in the fishing industry. Tracks increase productivity because vessels can be directed to the most productive fishing locations. For commercial fishing activity, with inputs including crew, fuel and gear, the less time vessels spend looking for the best fishing locations, the less costly is the fishing activity.

Discussions with commercial fishers suggest that they may now spend less time on the water than they used to ten or fifteen years ago. This difference can however not be solely attributed to GPS as other improvements in technology (e.g., boats, sonar scanning, nets, etc.) will also have contributed to this trend.

The best available scientific evidence indicates that the fishing power of the fleet increased by around 12% due to the uptake of GPS and plotters (Robins, 1988).

Fisheries management

GPS has increased the efficiency of fisheries management. The technology has allowed industry self-management of total allowable catch (TAC) as this is on a reef by reef basis. Fisheries Victoria and the industry developed a method of recording and reporting back actual catch at the place of landing via mobile. The information is recorded into the designated catch areas immediately and available within hours. Industry has access to this information through a secure Fisheries Victoria website. This allows industry to manage fishing effort between areas.

The Victorian Abalone Fisheries Association also has finer scale information for divers and provides reef code maps indicating voluntary size limits for each reef code. In 2001, the industry furthermore commenced and financed Length of First Maturity (LOFM) research to determine which reefs are fast, medium and slow growth areas. This type of spatial information therefore also helps to manage the fishery.

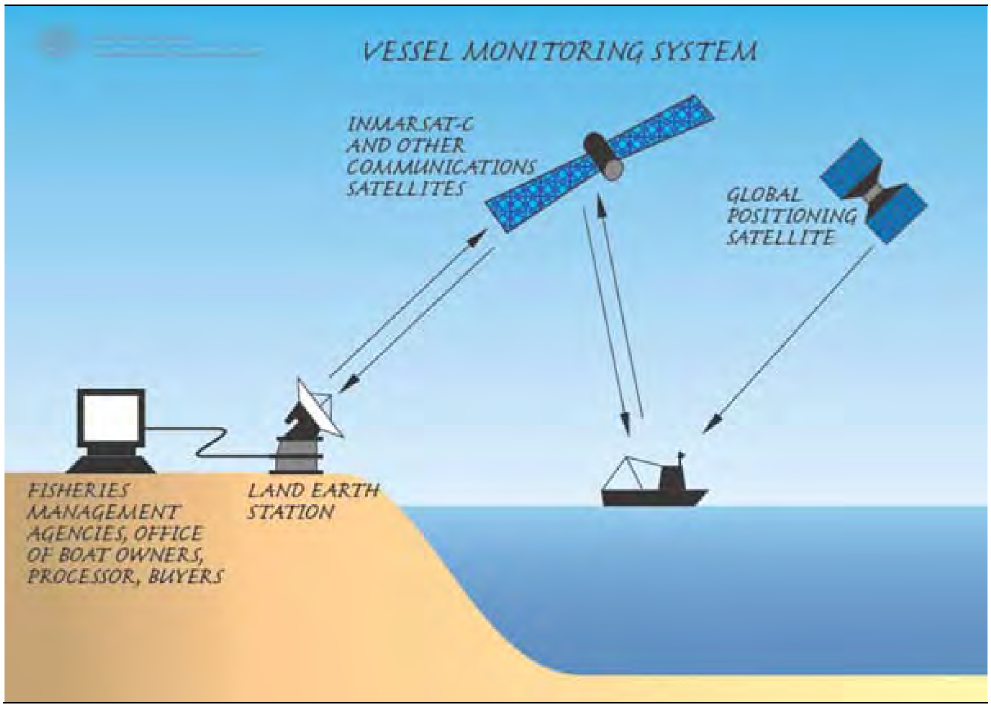
Australian Fisheries Management Authority's Vessel Monitoring System (VMS)

GPS is also used by AFMA as part of the Vessel Monitoring System (VMS) to monitor fishing activities in the Australian Fishing Zone. One of the functions of AFMA is to administer compliance monitoring programmes directed towards domestic and foreign fishing vessels and covering licensed and illegal fishing activities. The Vessel Monitoring System (VMS) is one of several programmes used to ensure compliance with AFMA's fishery management measures (see Figure 8).VMS is required on a fishery by fishery basis and consists of three main components:

- the tracking unit on the vessel i.e. the Automatic Locator Communicator (ALC) with built-in GPS
- the transmission medium – Inmarsat C satellite
- the base station.

VMS is used to prevent vessels from fishing in closures (areas with immature fish stock or protected species) and enables compliance with different quotas in different zones. In addition, the fishery itself has adopted the system to track their vessels, which has secondary benefits such as increased communication, safety and productivity.

Figure 8 **Vessel monitoring system**



Data source: AFMA

ALCs regularly transmit information on vessel position, course and speed via the Inmarsat-C satellite to the land earth station, located in Perth. Information is then sent by land line to a computer base station in Canberra. Automatic reports can be generated for any vessel at any time. In addition, compliance officers are alerted via short message service in the case of vessel non-compliance. ALCs are required on vessels which are:

- licensed to land orange roughy in the area of the Commonwealth Trawl Sector
- licensed in Western Deepwater Trawl fisheries
- all catcher, carrier and processor boats in the Northern Prawn Fishery
- licensed Bass Strait Central Zone Scallop Fishery boats
- All east and west coast tuna pelagic longline boats
- all foreign licensed vessels (AFMA, August 2007).

Mapping

Recent progress with spatial technology has also enabled the mapping of marine species and their habitats at a smaller spatial scale. There are various methods used to transform spatial data into meaningful information. For example, habitat mapping and biodiversity surveying.

Scientists in Western Australia are currently undertaking extensive mapping and surveying of the western coast in a project called 'Marine Futures'. Marine Futures is a partnership between the Natural Resource Management (NRM) regional councils, the Australian and West Australian governments and Fugro. The project aims to gain a detailed understanding of the different habitats found along the western coast. Activities undertaken by the Marine Futures team includes habitat mapping and biodiversity surveying. Habitat mapping involves three steps:

- hydro acoustic surveys, which provide contour and texture data of the sea floor using a multi-beam system mounted on the hull of a survey vessel
- towed video surveys, undertaken after hydro acoustic surveying, provide visual information for a more detailed definition of habitats
- synthesis or habitat classification, undertaken by the UWA spatial modelling team who use data from the video and acoustic surveys to develop fine scale habitat maps.

The habitat maps are an input to the biodiversity surveys. The biodiversity team comprises scientists from UWA, the WA Museum and the Department of Fisheries. From August 2007, they plan to undertake biodiversity surveys which supply information on the plants and animals that occupy a range of habitats. The surveys will be spatially referenced to the habitat maps. Key outputs of the biodiversity surveys will include the distribution and abundance of marine organisms in particular habitats.

Direct impact in fisheries

As discussed above the fisheries sector has benefited from spatial information in several ways:

- reduced operating costs attributable to use of GPS enabled plotting systems
- better fisheries management through vessel monitoring systems
- improved habitat mapping.

The case study identified a 12% improvement in productivity from GPS plotting systems (Robins et al 1998). This technology was adopted across the fishing industry in the early 1990s. Taking into account cost structure of the industry and applying this to fin fish only this is equivalent to a 4% productivity improvement. This has been adopted for Scenario 1.

The productivity improvement for Scenario 2 has been estimated at 5.14% and is based on an estimate of broader benefits also being realised in non fin fish (crustaceans), improvements in fisheries management and improved aquaculture planning.

Table 6 **Direct impacts for fisheries**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Fin fish industry	Impact of use of GPS plotters delivering 12% improvement in costs. Adoption rate 100%	4.00%
Scenario 2	Fin fish industry Crustacean industry Aquaculture	GPS plotters Improved fisheries management Improved weather forecasting and safer navigation Improved aquaculture planning	5.14%

Data source: Case studies, interviews and literature review

6.2.4 Impact summary for agriculture, fisheries and forestry

After taking account of the costs of adopting the new spatial technologies, the cost savings that have accrued to date under Scenario 1 have been estimated at around 1% for broad-acre agricultural input costs (fuel and chemicals) in 2007 and 2% for forestry (labour input costs) in 2007. This equates to a cost saving of around $71 million for these two sectors alone.

Further, the cumulative addition to fishing output over time that can be conservatively attributed to the use of GPS and plotters was estimated at 4.14% of output in 2007, equivalent to around $88 million at 2007 prices. Put together, the cost savings and output increases due to spatial technology across the three sectors are therefore in the region of $159 million.

It should be noted that these estimates are strongly verifiable and are very much lower bound estimates, as a range of the benefits associated with spatial technology – as discussed in preceding sections – have not been included here.

The benefits for Scenario 2, that are based on observed wider applications are estimated at about 1.25% for broad acre agriculture recognising increased yields, better management of pests and diseases, better farm planning and improved weather forecasting and natural resource management. Fisheries are also more likely to have benefited more broadly in better fisheries management, improved habitat mapping and wider applications in the non fin fish areas.

6.3 Mining and petroleum

Spatial information systems are integrated in many areas of the mining and petroleum sector from exploration, development, production and processing.

6.3.1 Exploration

Exploration for minerals and petroleum draws on a wide range of skills and technologies in geophysics, which have been made more effective in the past 30 years with the introduction of 3-D measurement and models combining layers of data to assist geologists in determining appropriate structures and targets for potential deposits.

Every geophysical and geochemical service is essentially spatially based. The services provided by companies in this sector depend on determining accurate location of data points to produce 3-D models of surface and subsurface geological features, anomalies and other features that provide clues to potential deposits. GIS systems augmented with accurate GPS systems and computer based modelling has produced capabilities that were not available in the past. They have led to new discoveries not possible before.

In the 1960s many of the minerals deposits discovered were in areas where *outcrops* led to evidence for discovery. Since that time however exploration has moved to *covered* areas where a better understanding of geological structures below the overburden became necessary to locate deposits. Geologists used measurements of gravity and magnetic anomalies to augment seismic mapping of subsurface structures.

A study by ABARE (2003) summarised a wide range of minerals discoveries directly attributable to, or substantially influenced by, mapping activities that were based on new spatial technologies. These include:

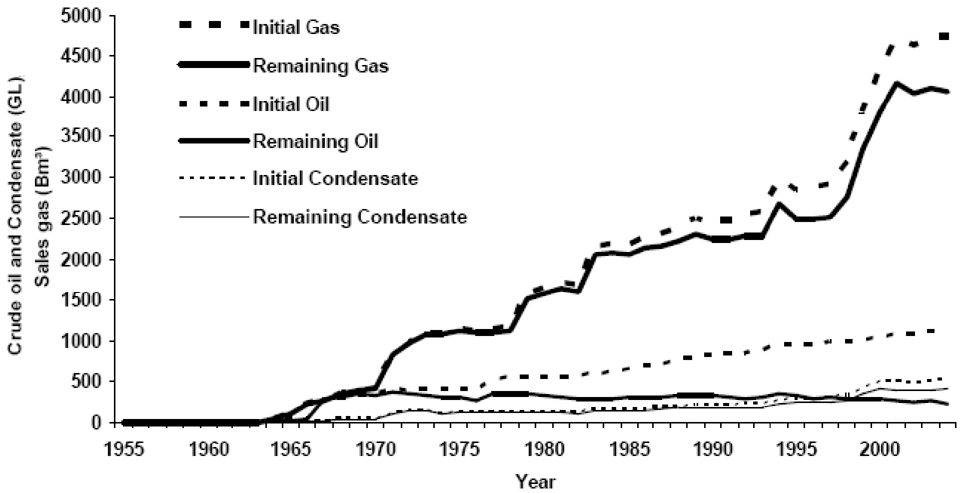
- Peko copper-gold mine
- Woodcutters lead-zinc-silver mine
- Olympic Dam copper-uranium-gold mine
- NW Queensland phosphate province, including the Duchess mine
- East Alligator uranium field, including Ranger
- Macarthur River lead-zinc mine
- Kambalda nickel area of WA
- Boddington, WA gold mine
- Gove bauxite mine.

Geosciences Australia (2006) also notes in their report on Australia's oil and gas resources that the:

> …reassessment of older gas discoveries has added a significant growth component to gas reserves along with important new discoveries…. recent gas discoveries have been the main contributor to the increase in condensate and gas reserves.

Figure 9, taken from Geoscience Australia (2006), reflects the jump in gas discoveries, showing that initial and remaining gas reserves have grown by at least 50% since the mid-1990s.

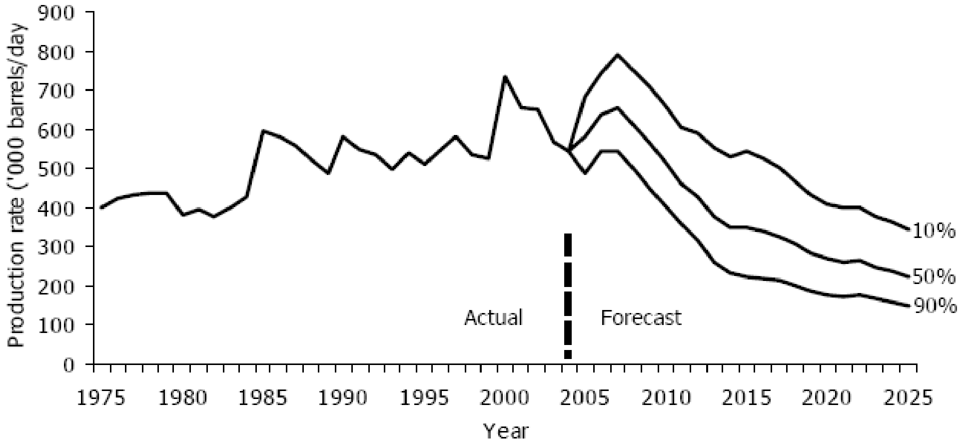
Figure 9 **Australia's initial and remaining commercial plus non-commercial reserves of crude oil, condensate and sales gas**



Data source: p. 30 in Geosciences Australia (2006), Oil and Gas Resources of Australia 2004, Department of Industry, Tourism and Resources: Canberra.

Figure 9 also shows the increase in condensate reserves which largely followed as a by-product of the new gas discoveries. Figure 10 illustrates how Australian output of crude oil and condensate has risen over recent years.

Figure 10 **Australia's annual production of crude oil and condensate 1975-2004 and forecast annual production at 90%, 50% and 10% cumulative probability 2005-2025**



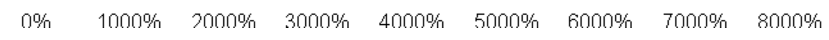
Data source: Geosciences Australia (2006), Oil and Gas Resources of Australia 2004, Department of Industry, Tourism and Resources: Canberra.

Data supplied by Geosciences Australia during the preparation of this report reveal that both Australia's total resource base of resources 'in the ground' as well as Australia's annual production of all the major minerals has increased significantly since 1975. According to Geosciences Australia, these increases can be attributed to spatial information:

> Virtually all of the additional resources were added as the result of use of spatial information, from regional geophysics and geology to 3D mine plans. (Ian Lambert, Group Leader, Onshore Energy & Minerals Division, Geoscience Australia, 19 September 2007, *pers comm.*)

Figure 11 illustrates that the amount of various 'in-ground resources' (Economic Demonstrated Resources + Paramarginal Demonstrated Resources + Inferred Resources) increased significantly since 1975. At the top of the list is the 'in-ground' gold resource which has increased from 156 tonnes in 1975 to 11,244 tonnes in 2006, i.e. by over 7000%. At the bottom of the range shown in Figure 11 is iron ore, for which the total 'in-ground' resource has risen from 17.8 Gt to 36.7 Gt, which nevertheless is a substantial increase of 106%.

Figure 11 **Increase of 'in-ground' resources since 1975, selected minerals, Australia**



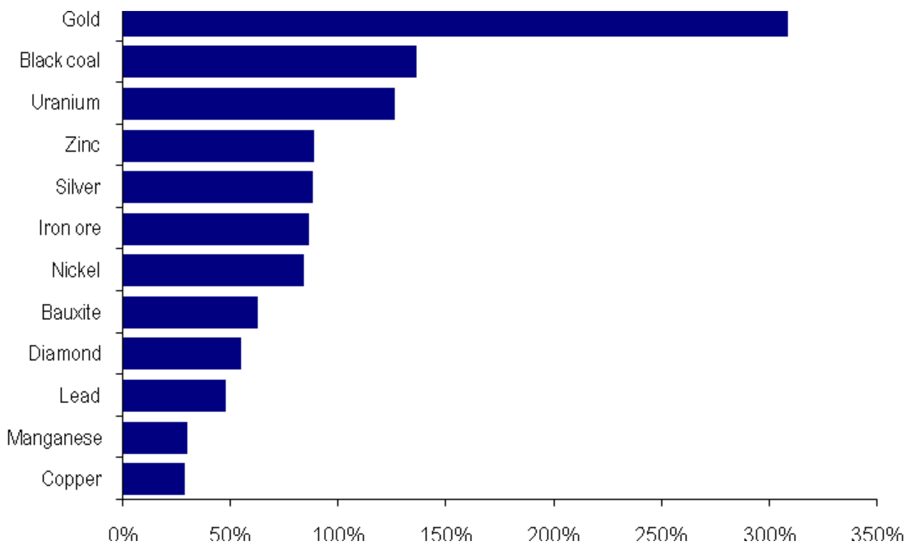
Data source: Data supplied by Geosciences Australia; compiled from national minerals inventory reports.

The large increase in discovery or knowledge of 'in-ground' resources has led to an increase in annual production of various minerals. Figure 12 compares average annual production levels for the period 1991-2006 with average annual production levels for 1975-1990. This shows that output has not increased quite as rapidly as the resource base itself, but, nevertheless increases in annual production levels have been substantial, ranging from 28% for copper to 308% for gold.

For the purposes of the analysis presented here, the decision to split the period 1975-2006 (for which data were supplied by Geosciences Australia) into two shorter periods was taken not only to facilitate longer term comparisons but also to make a simple linkage with 'modern' spatial information activity – as noted in the ABARE (2003) report:

> With the emergence of new exploration technologies, it was recognised in the mid to late 1980s that the first generation maps were becoming obsolete… Woods (1988) recommended a National Geoscience and Mapping Accord (NGMA) between federal, state and territory governments to accelerate a second generation geological mapping programme… The NGMA was established in 1990 to produce second generation geological maps, datasets and related information of Australia. NGMA mapping is underpinned by modern technologies, particularly airborne geophysics and seismic surveys. In particular, airborne geophysics was assessed to be a cost effective approach to rapidly increasing knowledge about Australia's surface and subsurface geology.

Figure 12 **Increase in annual production of major minerals, Australia (1991-2006 average compared with 1975-1990 average)**



Data source: Data supplied by Geosciences Australia; compiled from national minerals inventory reports.

As illustrated above, there has been a 'step-change' in discovery of gas, oil, coal and other minerals in Australia during the past thirty years. This coincides with the introduction of spatially enabled geoscience which has been a significant enabler in the discovery of these resources.

Whilst spatial information in some form or another impinges on various – if not all – activities in the mining sector (as further discussed below), it would not be appropriate to attribute all of the increase in the resource to spatial information alone – much like pollination in agriculture, spatial input is a necessary but not sufficient condition underpinning production.

In the case of the discovery of the Cadia gold deposits in NSW for example, , other key contributions apart from spatial information that led to the discovery of that particular mine came from having retained samples of previous rock drilling and from other geological research (ACIL Tasman, 2007).

In sum, there is no hard and fast rule to provide a guide to how much of the additional resource (or value of production) should be attributed to spatial information technology. In the estimate of economic impacts summarised at the end of this section it has been assumed that the contribution of spatial information ranged from a low attribution factor of 10% to a high attribution factor of 20%.

The role spatial information technology such as 3-D seismic mapping in the mining and resources industry has played over the past decade is further discussed in the following sections.

6.3.2 Development and production

Geospatial information systems also underpin development of mining and petroleum resources. Chevron Australia and Alinta Energy noted that environmental management of production and gas and oil pipelines has benefited from the new spatial information systems. It was estimated that these systems have reduced the cost of environmental management and compliance by around 5%. Information on endangered species, vegetation, route maps, elevation and engineering features can now be stored in three dimensions in one location enabling not only faster design and environmental approvals but also ongoing maintenance and management of facilities.

In offshore oil and gas production, spatial information systems, combined with technologies such as Laser Airborne Depth Sounding (LADS), Automated Remote Vehicle Technologies and dynamic positioning systems, have enabled deeper and more complex development of offshore oil and gas resources. These developments are now heavily dependent on spatial information systems.

Onshore minerals development and operation of mines is also enabled by spatial information systems. Spatial information systems using Terrestrial Laser Scanners can map mine areas so that machinery and installations can be manufactured and fabricated offsite using accurate three dimensional models of mine locations. This saves time, lowers costs and reduces interruption to mine operations.

Spatial technologies have also been used to improve processing of mine outputs. The case study below explains how Terrestrial Laser Scanning technologies have been developed into a product called 'Millmapper' which has reduced the costs of inspecting and maintaining milling equipment in precious metal mines. The application has considerable potential in Australia and overseas. The company that developed the system (Scanalyse Pty Ltd), with support from the CRC-SI, is looking now to potential significant exports based on the technology. The company has a strong competitive advantage over more traditional technologies and the prospect of a significant global market over the longer term.

6.3.3 Case study – Millmapper

Millmapper is used to perform precise measurement of mill liner properties and surface dimensions (such as thickness, wear rate, shape, size etc.) using high precision terrestrial laser scanning technology. The data from Millmapper is in a 3D format which allows detailed visual examination of all parts of the mill and improved monitoring of mill performance.

Mills are used in processing minerals (such as gold, copper, zinc, cadmium etc.) from their ores. This involves a cascading process of digging ores followed by crushing and milling, resulting in finer mineral particles. As milling is an important process in the mining value chain, every effort is made to regularly collect data on mill performance to reduce maintenance and prevent downtime.

Traditionally this has been done manually, with a worker having to stop the mill, prepare for a confined entry and then enter the mill to collect data using an ultrasonic thickness gauge. This process is time consuming, dangerous, inaccurate and less productive. Also, the measurements are based on a few fixed data points resulting in a less detailed status report.

Millmapper, on the other hand, provides a surface map with several million data points, which improves data accuracy, safety, production and productivity.

The main benefits of the Millmapper technology include the following:

- Reduced operating costs – Millmapper technology increases the life of the mill liner by 10% through better monitoring, reducing the cost of consumables in wear liners.
- Reduced downtime – due to an increase in mill wear liner life by 10% and reduced inspection downtime, a mill can operate for an extra 48 hours per inspection.

- Increased production – Millmapper provides detailed data which enables better design of components and improved levels of control over the operation of the mill.
- Less power consumption – using Millmapper technology would reduce power consumption compared to existing methods. It is expected that a mill's power consumption will fall by 5%.
- Enhanced safety – Millmapper technology allows workers to inspect the grinding mill without entering the inside of the mill. As the inside of the mill is dangerous it improves safety levels at the mine site.

6.3.4 Case study – robotic mining

Robotic mining has been an important innovation in the mining industry. Assisted by spatial information management systems, Robotic mining has become an important step along the way to automated mining.

The new generation employs various types of spatial information including millimetre radar, infra-red, laser, stereo vision data and uses accurate positioning, GIS and computing power to provide interpretation and operation systems. GIS systems are used to integrate mining rock and excavation data and to feed this into systems for operator interpretation.

The new generation of automated equipment is about 36% more efficient than the earlier technologies. Current levels of adoption in coal mining are around 50%. About 9% of the productivity savings are considered attributable to spatial information (*pers comm.* CSIRO).

6.3.5 Case study – QMASTOR Pit to Port

QMASTOR is a stockpile and supply chain management system. It uses spatially enabled technologies to track bulk commodity tonnages, their quality and value of bulk materials across the supply chain.

QMASTOR systems currently manage over 270 million tonnes of bulk commodity movements per annum in iron ore, coal and bauxite. The system has been adopted by resource companies such as BHP Billiton, OneSteel and Anglo Coal. QMASTOR was designed in response to a need for a stockpile management system at BHP Coal's Port Kembla stockpile area.

BHP Port Kembla required an automated, real time monitoring system for the accurate location of the heavy equipment used on the stockpiles, from which the location of coal parcels could be interpolated. This meant developing:

- a zonal stockpile model which collated coal position data, delivery tonnage and quality information, whilst retaining live reporting capabilities
- a reclamation system to meet shipping schedule quality requirements

- an economic optimisation routine to 'profit maximise' the blend
- a display of 'real time' stockpile and machinery status
- a reduction in the need for downstream sampling and analysis
- a tonnage reconciliation system to balance stockpile inputs and outputs.

QMASTOR developed a differential GPS configuration for locating the heavy equipment on the stockpiles. Accuracy requirements were achieved through the application of Differential GPS but, in addition, there was also a requirement for polling of multiple working vehicle positions. The solution was custom built using a radio telemetry system to transmit vehicle positions (coal parcel locations) to a central computer.

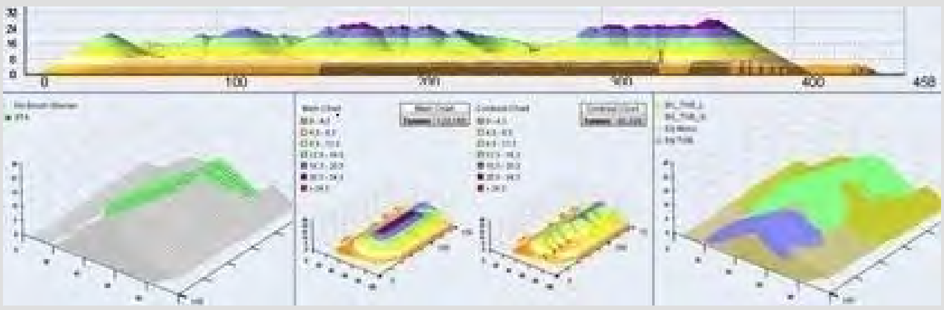
On May 30 2007, QMASTOR Limited announced the signing of a major contract with Rio Tinto Australia for the provision of its Pit to Port.net and SMS3D.net systems for installation throughout Rio Tinto's coal operations in Australia. This system will provide Rio Tinto with a complete end-to-end supply chain, quality management and logistic solution for their four large coal operations in Queensland and four operations in New South Wales.

At each site QMASTOR will install Pit to Port.net to provide:

- pit to vessel supply chain management
- inventory tracking, blending and grade control
- dispatch planning, forecasting and reconciliation.

SMS3D.net will be implemented to provide advanced three-dimensional stockpile management and modelling on plant feed and product stockpiles.

Box 4 **QMASTOR stockpile management system**



The stockpile management system uses GPS and GIS systems to track tonnages, quality and value of bulk commodities in stockpiles and along the supply chain.

Data source: QMASTOR

This system has potential applications in the mining industry, bulk terminals, power stations, metal smelters and refineries, commodity trading and in logistics. Economic data on the savings that are being generated are not publicly available. The main benefits that could arise from this application are:

- improvements in operational processes reducing costs
- increase in terminal throughput
- improved reporting standards
- improved vessel scheduling
- better management of coal quality in power stations leading to reduced emissions
- increase smelter and refinery efficiencies
- better management of value
- improved logistics
- reduced penalties for below quality standards.

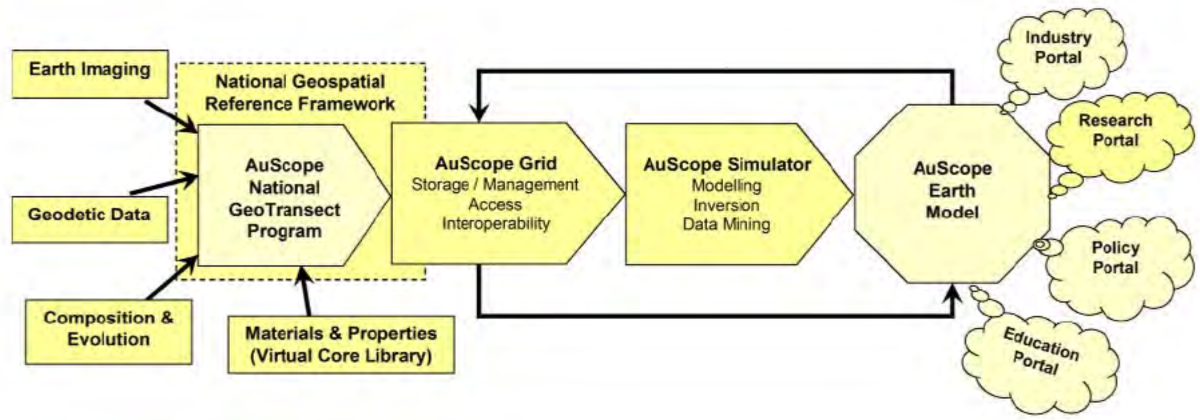
The level of application at the present time is limited to a small number of companies and no estimate has been made for productivity improvement in the 2006-07 financial year. However, this case study illustrates how important spatial technologies can be to Australia's mining and power industries in the future.

6.3.6 Case study – AuScope

Under the National Collaborative Research Infrastructure Strategy (NCRIS) funding was agreed in 2006 to develop a comprehensive research infrastructure for geoscience called AuScope.

The AuScope research infrastructure framework integrates geoscience data, processes the data and integrates the data into a model of the earth (see **Error! Reference source not found.**). Access is provided through a portal to industry, researchers, policy analysts and education institutions. It is an illustration of how data is integrated and delivered to users in many sectors.

Figure 13 **AuScope geoscience research infrastructure**



Data source: (Auscope, 2006)

AuScope is an example of integration of data, processing and access and interoperability necessary to maximise the benefit to society from appropriate access policies. It will address current problems with access to data held in geological surveys, research institutions and in government.

The information will create a wide range of options for researchers, industry and government to identify new commercial minerals prospects, monitor natural hazards and support education institutions in training and education in the earth sciences.

Having only been established in 2007 AuScope did not contribute an economic impact in 2006-07. Its impacts will arrive in future years. The system will create a geoscience data base with a common access portal that will give geoscientists an unprecedented access to a wide range of geophysical, drill core, geochemical and modelling data. It will also provide an Australia-wide mm accuracy differential GPS signal that will have value to more than just researchers.

6.3.7 Direct economic impacts

A most significant impact of spatial technologies has been in the further discovery of more difficult to find minerals and petroleum resources. The report shows that a significant increase in the discovery of reserves followed the emergence of spatially enabled 3D geoscience since the mid 1970s. This has had a most significant impact on the Australian economy as it positioned Australia to take advantage of the current surge in demand for commodities.

Improvements in the efficiency of mining and petroleum operations have also been realised. The direct impacts assumed for this report for Scenario's 1 and 2 are summarised in Table 7.

Verifiable savings to the industry (Scenario 1) were conservatively estimated at 0.2% of industry-wide input costs in 2007, or $66.8 million.

There are other benefits to the Australian economy which were not included in these estimates. These include reduced rates of injury and death, and improved working conditions and associated health benefits, which have come about due to increased automation of various processes (introduction of which involved significant contributions from new spatial information technologies).

Table 7 **Direct impacts – mining and petroleum**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Coal	Automated long wall mining and automated loaders using spatial information: • 36% increase in efficiency of identified tasks • Half of the benefit attributed to spatial information (conservative) • Identified the share of the activity in total costs of mining operations • Adoption rate of 9% (15% long wall; 5% loaders)	0.21%
	Metal ores	Based on Millmapper case study of savings in wear liners: • Mill operating cost savings of 2.4% achieved • Adoption rate of around 11% • Reconciled with sector wide statistics "Shock" = 0.16%	0.16%
	Oil and gas	Similar magnitude to Coal and Metal ores, supported by further case studies (e.g., Alinta) of applications in infrastructure, environmental management and spatially enabled production (dynamic positioning, remote operations offshore): "Shock" = 0.15%	0.15%
	Resource availability	Increased discoveries and production of oil (condensate) , gas and minerals as a result of spatially enabled exploration and development	Oil – 3% Gas-5% Minerals nec – 7%
Scenario 2	Coal	As above but assuming higher levels of adoption and including improved handling and supply chain management	0.36%
	Metal ores	As above but also including improvements in mine management through use of spatial in installation and operations	0.31%
	Oil and gas	As above but with higher assumptions on use of spatial in environmental management and in offshore operations	0.27%
	Resource availability	As above but assuming a high attribution of new discoveries to spatial information	Oil – 6% Gas-10% Minerals nec – 14%

Data source: Case studies, interviews and literature review.

6.4 Property and business services

This sector includes a key part of the 'core' spatial industry – i.e. the surveying and mapping industries. However, there are also many other types of businesses in the property and business services sector that have benefited from new spatial information technologies e.g. advertising and marketing services (which now routinely use GIS packages), scientific research, services to engineering, and so on. The current study focussed mainly on the 'core' industry.

6.4.1 Land development

Spatial technologies have had a major impact on surveying and mapping. This sector is critical to the delivery of land, infrastructure and buildings which at the present time are sources of bottle necks in some areas of the Australian industrial landscape. The provision of new blocks of land, for example, is critical in the longer term supply of housing. Faster provision of ports, railways and roads for mining and other large industrial projects is a key imperative of catching the current opportunities for export of minerals and energy commodities.

GPS units have been of major value in surveying where the site is such that one can't physically see some of the objects (e.g. in a forest). Traditionally, surveyors would have had to traverse the site to fix locations. With GPS a direct line of sight is not needed.

One surveyor stated that, as a result of modern spatial info-technology, there has been a 50-100% productivity improvement in their business over the last 5 years – they do nearly twice the work with the same or less staff. As an example, a job they did recently which would have taken 1.5 days by the traditional means only took 4 hours to complete with GPS (i.e. one-third of the time) (Raaen, B&P Surveys*, pers comm,* 2007). Another surveyor estimated that *very conservatively* the productivity improvement was at least 25% (Raneir Melick, Brazier Motti, *pers comm* 2007).

In NSW the Survey Services Portal, which is part of the Spatial Information Exchange (SIX), provides surveyors with online access to positional information of survey control marks and trig-stations. Tools to improve the productivity of surveyors in the field also assist with creating a high precision cadastre.

Remote sensing and airborne mapping systems are also able to significantly accelerate surveying efforts. Depending upon the level of detail required for the job at hand, aerial survey can be a much more efficient option.

6.4.2 Case study – Western Australia land development

The land development process in Western Australia has changed significantly during the past decade. According to Landgate, the State government's agency responsible for land and property information, there have been "vast" improvements with the use of technology from 1995 when the accreditation of surveyors was first introduced.

Significant milestones have been lodgement of digital data to accompany each survey plan lodged (to check the mathematics of the plan) and routine updating of the spatial cadastral database (SCDB). Landgate has continued to spatially upgrade the accuracy of the positioning of the SCDB data so that it is now 85% complete. The introduction of ePlan lodgement via email since 2005 has been another milestone – there is now 90% participation from the survey industry. Landgate WA claims that these initiatives as well as the SmartPlan spatial maintenance software have enabled it to efficiently process the continual increase of lots created over the period whilst maintaining an accurate spatial system.

As Table 8 shows, the total number of lots created in a given year has risen, on average, from around 20,000 lots in the mid-1990s to around 35,000 lots in the most recent years. The number of Practicing Surveyors in the State has however dropped from 276 in 2001 – the first year for which reliable data are available according to the Secretary of the WA Land Surveyors Licensing Board – to 245 today. The figures suggest that there has been a significant improvement in the productivity of surveyors since the turn of the decade.

Table 8 **Total lots created in WA, 1995-96 to 2006-07**

	Lots created	% change
1995/96	20,482	-
1996/97	18,930	-8%
1997/98	20,131	9%
1998/99	22,359	11%
1999/00	24,201	8%
2000/01	18,229	-25%
2001/02	24,081	32%
2002/03	24,921	3.5%
2003/04	28,309	14%
2004/05	30,648	8%
2005/06	34,255	12%
2006/07	35,639	4%

Data source: Land Surveyors Licensing Board

6.4.3 Engineering surveys

Improvements in technology have enabled surveyors to collect and process spatial data more easily. An example of the new technology is the robotic 'total' station (basically a theodolite with an inbuilt computer). It makes it easy to set out work and can automatically turn to chosen points. It can also track the surveyor around a site. The data that is captured can then be processed and extracted into a CAD model (see discussion in Section 6.5 below).

6.4.4 Case study – 3-D survey of Town Hall Station

The detailed 3D Survey of Sydney's Town Hall Station undertaken by Sinclair Knight Mertz (SKM) provided the Rail Corporation of New South Wales with the first complete picture of the station site as part of a planned major upgrade. The use of 3-D laser scanning technology allowed a rapid and very detailed data capture of the station infrastructure that facilitated the production of a complete 3-D CAD model of the entire station precinct. The model could then be used to produce an unlimited number of traditional 2-D drawings – far in excess of the original scope for twelve drawings as specified by RailCorp in the Request for Tender documents.

The detailed point cloud data gathered is now available for ongoing use, allowing for any future changes to the station infrastructure to be similarly captured and easily integrated maintaining a completely up-to-date 3-D CAD model of the facility. A full animated fly through of the 3-D model was also produced to give the client and associated stakeholders an unparalleled view and understanding of the resulting spatial data. The project was a first for RailCorp in terms of 3-D detailed survey being carried out and the quality of final deliverables far exceeded their original expectations and outputs anticipated from the survey brief.

SKM summarised the benefits as follows:

> Increasingly the emerging trend is seeing the innovative application of new technology from the Spatial Industry making a significant contribution to major engineering and other projects across many geographies. Excellence in Surveying and Spatial Information is often seen as the critical differentiator in major projects in facilitating the successful outcomes for ongoing works, as much of what comes afterwards is directly predicated on the spatial data supplied by Surveyors and Spatial professionals (SKM, 2007).

6.4.5 Route and site selection

This area of application is sometimes also referred to as corridor mapping. It can rely on various sources (e.g. aerial photography, satellite imagery, existing surveys) and models (e.g. digital elevation models, field data on hydrology or ecosystems), and combine these to map the best possible route for a proposed highway, pipeline, road, etc. This is a significant cost factor in the planning stages of major construction works and there are a number of examples where spatial information has already led to quicker delivery times and significant cost avoidance.

Lester Franks, for example, used GIS and GPS to support feasibility studies, route selection, design and construction of the natural gas distribution pipelines for Duke Energy in Tasmania in 2003. The systems greatly improved the planning and construction process, shortening the time for construction and providing more information for the management of the pipelines. Duke Energy originally engaged Lester Franks to produce maps of the route path to assist in detailed route selection during the pre-feasibility stage. They used a GIS to provide a detailed digital map that included:

- title
- geology
- threatened species.

These maps were placed on laptop computers which were used by field staff in the initial investigation. This greatly increased the productivity of field staff not highly trained but able to use the computer based GIS package very effectively. The system enabled the staff and planners to identify constraints immediately to the benefit of the route selection process.

At the design stage the spatial information was of great assistance. They used an ESRI GIS package to generate the alignment sheets. This reduced the time to produce the alignment sheets by "orders of magnitude". For example, when it was necessary to make a small change to one sheet, the consequential changes were automatically made to the other sheets. During construction the combination of GIS, GPS and laptop computers were instrumental in improving significantly the "as constructed" surveys. This enabled the surveys to accurately record:

- welds
- crossings
- valves
- cathodic protection points.

The system was able to produce a full 3D model of the installed pipe system along its entire route.

Spatial information is therefore beneficial to route selection, construction and subsequent operations and maintenance management.

6.4.6 Case study – Pacific Highway upgrade programme

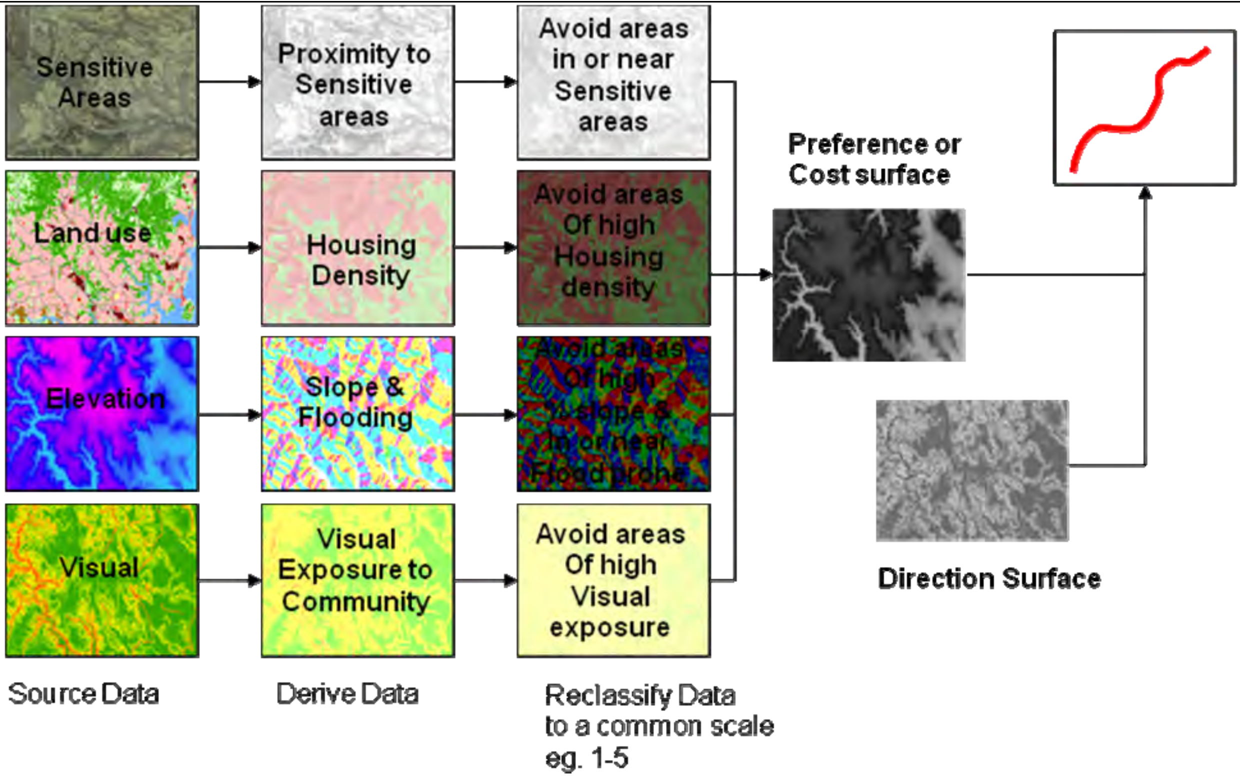
In a presentation to The Institute of Surveyors NSW made in February 2007, SKM reported on a route selection exercise that the company was involved in as part of the Pacific Highway Upgrading Programme (Wells Crossing to Iluka Road). In particular, SKM were engaged to undertake investigations leading to identification of feasible route options and to recommend a preferred route (SKM, 2007).

SKM used GIS to layer various data inputs in order to identify the best route for a highway that considers various criteria for minimising adverse impacts. The criteria included that the highway should:

- avoid areas of high housing density
- social impacts
- property impacts (high cost of property acquisition)
- avoid areas that are flood prone
- constructability
- safety
- avoid areas within or near sensitive areas
- ecological and heritage
- avoid areas of high visual exposure to houses
- visual amenity, air quality and noise.

Figure 14 shows SKM's spatial model for determining route selection. In summarizing optimal route selection, SKM notes that "The shortest path between two points…. may not be a straight line". This reflects the fact that routes are in practice optimised subject to various constraints. These include some of the constraints identified above, as well as physical limitations (slopes, substrates, etc.), considerations of cost, as well as political constraints.

Figure 14 **Route selection – spatial model**



Data source: SKM presentation on 'Route Selection' to *The Institute of Surveyors NSW*, 14 February 2007

Better route selection and planning will be very important for future highway upgrade programmes in Australia.

6.4.7 Design

Computer Assisted Design (CAD) programmes and packages have transformed working practices in the sector. Increasingly these incorporate geophysical information and support layering with spatial datasets. Architects and designers now routinely work with 3-D terrain models and look for spatial information in context, e.g. contours, features of sites and adjacent sites such as roads and waterways, etc. A significant part of this information comes from digital or digitized models, some directly from the internet. Nowadays they also produce digitized drawings. One benefit has been the ability to cast shadows from the sun for any time of year, permitting the design to better meet planning requirements and/or understand the impacts on adjacent sites.

Those interviewed noted that this technology had evolved over the years. However, it was noted that lately it has become much easier to obtain the information which means that architects use these models more.

A 25% improvement in productivity spread over the past ten years was not considered to be an unreasonable figure (architects/construction design). The respondents thought that when compared with ten years ago, they produce significantly higher levels of output. They also noted that the more information they can produce, the more the clients demand.

6.4.8 Direct economic impacts

As mentioned earlier, in addition to the specific benefits outlined for the 'core' spatial sector that is part of the Property and Business Services sector, many other firms and organizations will also have benefited from specific as well as generic benefits of using spatial information technologies. To put the sector into context, it had sales of $182 billion in 2004-05 – clearly a large sector of the Australian economy.

A major impact of spatial information technologies in the 'core' spatial sector has been more efficient, faster and more accurate provision of land and infrastructure. The benefits in terms of faster design and implementation and the potential in improved regulatory approvals is a very significant economic consequence of the technologies.

The benefits in terms of faster and more accurate planning and approvals, better route alignment of roads and infrastructure and better record keeping for maintenance and upgrades are recorded in the case studies. The productivity improvements included:

- a 50% to 100% productivity improvement in surveying
- a 25% improvement in engineering and architectural design
- significant improvement in environmental planning in route selection
- improvement in regulatory approvals processes.

A conservative approach has been taken to estimating the direct impact of these changes on the property and business services sector.

The cumulative impact of spatial information technology on the sector as a whole has been estimated as a 0.5% increase in (total) productivity for Scenario 1. Translation of such a total productivity shock into a nominal dollar figure is difficult; however, given the scale of the sector in 2004-05 a 'rough' estimate of the contribution would be in the region of $0.9 billion in 2006-07.

For Scenario 2 the increase was estimated to be 0.7% reflecting additional applications in engineering and science and in risk assessment.

Table 9 **Direct impacts – property and business services**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Surveying	A 61% increase in the productivity of land production Between 50% to 100% increase in productivity output by surveyors.	0.5%
Scenario 2	Surveying, engineering and science and the insurance industry	As above plus the use of GIS in engineering and science and the use of spatial data in risk assessment by the insurance industry.	0.7%

Data source: Case studies, literature review, interviews

6.5 Construction

Construction activity is in many ways spatial, as discussed in further detail below. Examples of where the use of spatial information has been incorporated into products or tools that have applications in construction include:

- ***Barista*** geo-positioning software used, for example, in building height determination
- Bentley View and other design and project management software tools that are increasingly approaching CAD/GIS/BIM interoperability
- BladePro 3D type GPS systems for graders used in road construction
- Leica SmartStation and other similar Total Stations with integrated GNSS/GPS for use in surveying.

Some companies operating in the construction sector will also have benefited from use of enterprise-wide business GIS such as the Tactician marketing platform (generic type benefits).

At the broadest level, the impact of integrating spatial information into existing practice in the construction and allied sectors can be analysed in terms of two questions:

- where to build (e.g., cadastral and engineering surveying; route selection and machine guidance in road and pipeline construction; feasibility studies; town planning; choice of site utilizing geospatial information on soil, topography, hydrography, etc.)
- how to build (notably building design; component fabrication; and coordination of construction activity)[3].

[3] We note that there are overlaps between some of these questions – in some instances a decision about where to build can clearly affect how to build, and vice versa.

Put slightly differently, the following economic (e.g., productivity) impacts of the use of spatial information can be identified for a broadly defined construction sector:

- land is being produced and made ready for construction more quickly (including quicker initial site or route selection, cadastral survey, land titling and land clearing, etc.)
- there is more efficient coordination of contractors and sub-contractor activity than in the past (within single construction projects as well as enabling improved oversight of a portfolio of projects, i.e., across a number of construction sites)
- specific cost savings have accrued to architects, designers, metal fabricators, engineering firms and sub-contractors, both during initial construction as well as in the maintenance of built assets.

Whilst these gains can be understood as flowing to construction in a broad sense, it is important to note that many of the activities involved in producing these gains do not fall under the ANZSIC Division which covers construction. The 'broad' impacts on the construction sector that have been identified during discussions with various stakeholders therefore need to be 'disentangled'.

This discussion therefore relates to those impacts that can reasonably be attributed to ANZSIC Division E (Construction). This includes residential and commercial building construction, non-building construction (e.g., roads, bridges, pipelines, electricity distribution lines, tunnels and jetties, etc.), site preparation services (land clearing, trench digging, leveling, earthmoving, etc.), as well as a number of ancillary services (includes construction of footpaths, structural steel erection services, etc.).

Box 5 **Statistical classification for construction**

This report has used the ANZSIC 1993 breakdown of industries because most existing statistics are still based on the 1993 classification. An example of the difficulty in assigning particular areas of production to the construction sector (or not) is given by ANZSIC Division L (Property and Business Services), Subdivision 78, which includes Consultant Engineering Services. The entry under this heading states that:

> Units mainly engaged in … managing or organizing construction projects as the prime contractor are included in the appropriate classes in Division E Construction (ANZSIC 1993, p. 208)

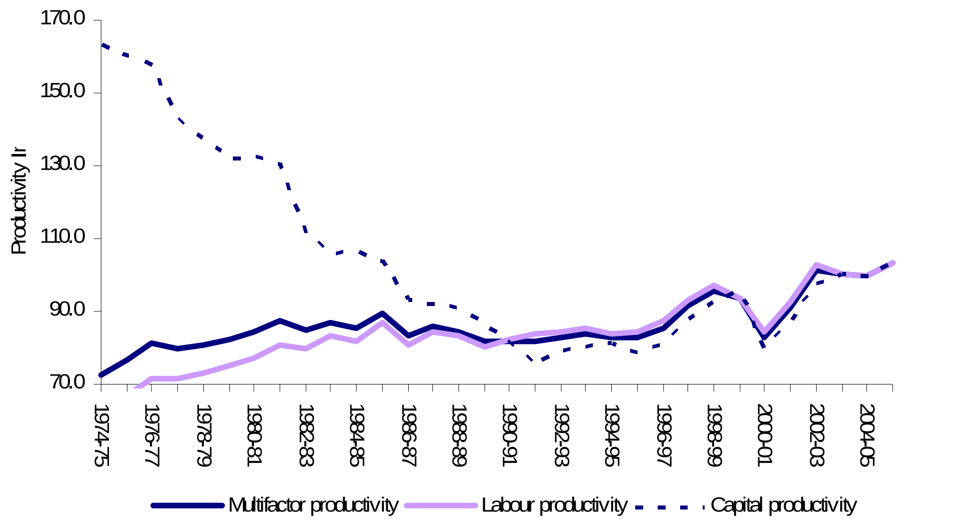
With the rise in subcontracting on Australian construction projects, it is possible that some large engineering firms could fall into this category. In some cases, savings associated with the use of spatial information would therefore be recorded in the 'Construction' sector rather than 'Property and Business Services', where they might otherwise have been expected to show up.

There is therefore invariably a 'grey area' in determining which sector to attribute given productivity gains to – however, we note that in the context of the overall exercise undertaken here that it is important not to 'double-count' productivity gains across different ANZSIC categories.

The new spatially enabled products have evolved alongside general ICT and have enhanced the impact that ICT has been able to make in the construction sector. As Figure 15 shows, capital productivity in the construction sector was declining until the early 1990s, but has risen since then.

The turnaround in capital productivity coincided with more widespread adoption and development of ICT applications in the sector in the early to mid-1990s.

Figure 15 **Productivity trends in the construction industry, 1974-75 to 2005-06 (index, 2004-05 = 100)**



Data source: Productivity Commission 2006, *Productivity Estimates to 2005-06*, December.

One benefit of the new spatial information technologies – especially in the light of increased subcontracting on Australian building sites (Masgood, 2003) – has been the ability to coordinate activities more smoothly. One example is where sub-contractors can use GIS to much more easily locate specific sites for fault correction or maintenance.

Similarly, digitized 3-D drawings are now routinely supplied by architects or engineers to subcontractors who may previously have had to produce their own plans and drawings. Errors are also much easier to rectify than in the past and costly change orders can therefore now often be avoided.

Spatially enabled Building Information Modeling (BIM) is used increasingly to ensure optimal management of construction projects. A recent example of a sophisticated application of BIM was in Heathrow's Terminal 5, with significant cost savings. In the US, the Open Geospatial Consortium's Interoperability Project on CAD/GIS/BIM interoperability is specifically targeting cost savings in the planning and construction of military housing infrastructure.

6.5.1 Construction machine guidance

During the past five years, GPS has had a significant impact in road construction. GPS systems are now routinely put on blades of graders and the geospatial information is used for machine guidance. GPS devices installed on the cutting head can, for example, automatically control the grade – with a

GPS device attached, an operator can sit back and let the GPS device lead the cutting drum to follow a predefined contour.

The cost is approximately $50,000 per GPS unit but once installed can be used for years on jobs that may otherwise have required significant input from road construction surveyors. The system simply requires an initial set up when contractors get to a site, in order to get the coordinates and download where the road is to be built. From then on the drivers can work independently as they get real-time readouts of their exact positions and how they are progressing along the planned route.

Traditionally, construction surveyors would have had to put stakes in the ground – these could get knocked over which then means that the workers on a site would not be certain of the exact location of the work to be undertaken. Surveyors would visit sites to ensure that construction was proceeding as planned – sometimes stopping work while checks and measurements were made. According to one interviewee, GPS has therefore produced a 'decent' cost savings in construction surveying and, ultimately, road construction.

6.5.2 Case study – The EastLink project

The EastLink project in Melbourne involves construction of a 45 km freeway-standard road connecting the city's eastern and south-eastern suburbs. Total project costs were estimated at $2.5 billion. The construction of the paved road, more than eighty bridges, seventeen interchanges and 1.6k three-lane twin tunnels was expected to be completed in three and a half years.

Major construction commenced in March 2005 with completion due in 2008. According to the key contractor's General Manager for Project Wide Delivery, smart technology was expected to be the key to achieve productivity gains in such a short time frame.

With 7.5 million cubic meters of soil to be moved, the traditional method of putting stakes in the ground to guide the machinery was never going to be satisfactory. Trimble technology has addressed that problem for us and has opened all sorts of opportunities on this project to increase productivity.

This is an example of where spatially enable technology has made a significant impact in road construction during the recent past in Australia. Discussion with distributors of Trimble GPS based products confirmed that an overall saving of 10% would be "reasonable". Savings would come from a combination of reduced number of workers and much more rapid completion of tasks.

One of the advantages of using spatially enabled equipment was that the sub grade of the road could be poured much more accurately – this is normally 2 inches thick and one of the steps of completing a road is to pour concrete to bring the road surface up to predetermined levels. It was suggested that in terms of concrete alone, 0.5 cm of extra paving over the length of the road has been avoided by using accurate spatial information.

Estimated at approximately $100 per square meter of 2-inch concrete, a reduction of 0.5 centimeters translates into a saving of about $20 per square metre. The EastLink involved laying 2 million square meters of paved road, so on this account alone a saving of $40 million can be estimated for this project.

6.5.3 Case study – Barista

Recently released, Barista is an affordable, easy-to-use photogrammetric software system for the generation of spatial information products from satellite imagery. Barista was developed from a CRC-SI research project.

The marketing plan for Barista identified a market niche at the 'low end' in the space borne remote sensing imagery market. The total size of the market is estimated to be in excess of $US 1 billion, leaving ample scope for Barista to make an impact in its designated niche. Competitors are unlikely to price down their software packages as they primarily target the top end of the market and incorporate more sophisticated functionality in their packages. The advantage of the Barista package is that little training is required to use this software, thus potentially opening the market to a range of new users.

Barista supports multi- and stereo-image networks and has been especially tailored for 3D geopositioning and feature extraction from single images via monoplotting.

Barista's main features are:

- high-accuracy geopositioning from high-resolution satellite imagery (HRSI) via bias-corrected RPCs (suited to IKONOS and QuickBird), a rigorous physical model (eg for SPOT5 and ALOS) and the affine projection model
- ortho-image generation
- pansharpening via IHS transformation and PCA
- monoplotting of points, lines and buildings to create 3D models from single images (requires an underlying DEM); affords building height determination.

As already indicated above, the package is $20,000 cheaper than existing 'high end' software available from competitors (mainly US players). The marketing plan for Barista identified a realistic target market of some 200 Australian users the medium term. If this is achieved, it could imply savings to users of $4 million. In the longer term, however, it is expected that the market scope (potential users) could be much wider than this, and if more sales are achieved then this will almost certainly imply a good payback on the cost to develop Barista at the CRCSI.

Barista is expected to find a wide range of applications in design and construction as well as surveying and mapping with its lower cost and broad three dimensional capabilities. This would include measuring the topography of the build environment for design purposes, tracking construction projects in 3 dimensions and monitoring building progress.

However, Barista was not released in sufficient time to have had a significant impact in 2006-07 (although one client is using the system in Europe). However, the above discussion provides an indication of the potential for this package – and similar technologies- to penetrate a wide range of markets in the future.

6.5.4 Case study – Forbes Shire Council

Located within the central western slopes of New South Wales, Forbes Shire Council is using global positioning system (GPS) technology to reduce the survey and set out time required for road construction. The Council has only one skilled survey and design person and were considering a road sealing project which would normally require hundreds of hours of this person’s time. Very early in the project development stage, it was identified that resources would be severely stretched and the use of contractors was considered but rejected, as the availability of the only local registered surveyor could not be guaranteed. Council therefore decided to investigate the use of GPS technology.

The Council’s construction plant was already fitted with Topcon laser systems, which are compatible with Laserquip’s GPS equipment. This meant the cost to use the GPS technology would be reduced. Laserquip could provide training and was prepared to spend time on the actual construction site with the plant operators to ensure that their skills in using the equipment were sufficient. As for quality assurance, the latest GPS technology can guarantee sub 20mm accuracy, which was more than sufficient for the project.

To collect the initial survey data required for the design work, a Survey Rover with GPS and satellite technology, and a field controller (handheld device) running Pocket 3D software was used. This unit was mounted on a motor vehicle and driven over the required survey area. It collected a data/survey point every two seconds, therefore allowing the survey to be done very efficiently. This method reduced the survey time to several hours, as opposed to days to complete.

The road design was then completed using standard design software and transferred to the Rover GPS receiver attached to the construction plant, by way of a Compact Flash Card. This resulted in real time images of the location and design being featured on the screen display unit in the cabin of the grader. The technology has an automatic mode, which allows the software to operate the plants hydraulics and automatically respond to the design requirements. This ensures correct pavement depth, super elevation, cross fall and formation width and eliminates the need for Council's surveyor to set out the works, including pegging the formation and the continuous requirement to undertake levels to ensure pavement thickness and project quality control (http://lgfocus.com.au/editions/2007/july/forbes.shtml).

6.5.5 Maintenance work

Asset survey and repair work can be carried out much more efficiently by using GPS followed up by GIS. Geospatial information can now be captured along with other data such as digital images taken on a handheld camera. An example comes from Logan Shire where the City Council has used the technology to improve footpath maintenance.

GPS enables association of pictures of cracks in footpaths with the location of where the picture was taken. The picture and information on the location is sent back to the office where treatment gradings are assigned, and then forwarded to subcontractors who use GIS to locate the site (within 1-3 meters), find the cracks and carry out repairs as instructed. It is also possible to run software to identify the worst footpaths or roads in an area and prioritize treatment for specific sections of footpath (OXERA, 1999).

Similar applications are likely to emerge across a range of assets, for example railway lines, electricity poles, etc. With further improvements in accuracy, it may also be possible that building and non-building repairs (e.g. bridges) and maintenance activities can be carried out more cheaply.

6.5.6 Direct economic impacts

Total expenses in the construction sector have been running at levels of around $130 billion per annum in recent years. It is difficult to estimate cost savings due to spatial technology across the full range of construction activity – the EastLink projects suggest that a one-off saving of 10% is plausible for large projects that adopt spatially enabled technology. Other improvements reported included:

- 50% faster map production
- 80% faster access to information.

The use of modern spatial technologies in the construction sector is constrained by the fact that a large (and increasing) proportion of construction services is provided by small, independent contractors (often sole traders). These small operators do not tend to bear the coordination costs for large construction projects, and do not have the resources to invest in major spatially enabled construction equipment, and have hence to date had limited incentive and/or ability to invest in these technologies. Developers, prime contractors, or equipment leasing firms, would thus have been most likely to invest in the new technologies.

On balance, given the relatively recent development and rollout of spatially enabled technologies in the construction sector, it was assumed that adoption is still at the innovation stage (i.e., 2.5% overall). This is by necessity a simplification, as adoption amongst the large firms may have been higher, but relevant statistical information is unavailable.

Using this conservative assumption about adoption of the new technologies, savings due to spatial information technology in the construction sector can be estimated at around $320 million per year in recent years. Costs of adoption do not affect the 'order of magnitude' of this assessment.

This implies a direct productivity improvement of 0.25% for the scenario 1 and 0.5% for scenario 2.

Table 10 **Direct impacts – construction**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Construction	10% saving arising from improved labour productivity and faster completion times 2.5% level of adoption	0.25%
Scenario 2		10% saving arising from improved labour productivity and faster completion times 5% level of adoption	0.50%

Data source: Case studies, literature review, interviews

6.6 Transport and storage

The transport industry comprises road, rail, air and sea transport and storage and involves the movement of both freight and people between two or more points. Hence, as an industry, it is focussed on spatial challenges, most notably the challenge of overcoming distance in the most efficient way possible.

Due to its spatial nature, the transport industry has always relied on maps and the industry was one of the earlier adopters of spatial technologies. The use of Geographic Information Systems (GIS) in transport has been steadily growing for at least a decade and is now one of the fastest growing areas of GIS deployment.

The benefits of spatial information are most evident in the road transport sector because in this sub-sector there are generally many routes and itineraries possible, whereas in a sub-sector such as rail the routes are less flexible. However, the benefits of spatial information are being experienced across all areas of the transport industry (ESRI, 2007).

6.6.1 Delivery routing, itinerary planning and vehicle tracking

The use of GIS to plan routes most efficiently, given constantly changing delivery requirements and likely traffic flow conditions can make the process of planning deliveries more efficient, save drivers time and cut costs on fuel. Evidence of the cost savings that such solutions can yield come from the USA, where one company has decreased fuel usage by 4.3%, reduced labour hours by 18% and cut drive time by an average of 7.4% (ESRI, 2007).

The transport industry was one of the first to employ GPS as means of tracking vehicles and freight movement. Tracking goods in transit utilises global positioning systems which increasingly utilise integrated systems of GPS and electronic mapping systems for total integrated systems (such as in car navigators). Many modern GPS units now have basic GIS functionality (hence they can function as mobile GIS units) while others allow for import/export options for use of data in GIS.

The ability to know where vehicles are at all times in relation to the demand for transport (with its two way locational dimensions) can enhance real time decision making, ensuring that the movement of freight or people occurs most efficiently given the availability of vehicles. Because the demand for transport and the availability of vehicles is often changing quickly, real time access and analysis of these variables can yield significant cost savings.

6.6.2 Case study – Austroads

Austroads is the association of Australian and New Zealand road transport and traffic authorities. These road transport authorities set road network access conditions for vehicles, taking into account such issues as vehicle type, dimension and mass.

The uses of Intelligent Transport Systems (ITS) in Australia are varied, diverse and far from matured. They range from providing guidance and assistance to drivers in a variety of conditions to specifically detecting and tracking vehicles.

Telematics is the specific technological capacity to locate vehicles in space and time. Australia has seen significant investment by the private sector in telematics services over the past several years. This has been more than matched by advances internationally. The range of services being provided or explored include both domestic and commercial vehicular operations including:

- in-vehicle navigation
- stolen vehicle recovery
- automatic crash notification and may-day services
- fleet management
- logistics/supply chain management
- hazardous goods management
- electronic toll collection.

The Intelligent Access Programme (IAP) objective is the implementation of a system that will remotely monitor freight vehicles to ensure they are complying with their agreed operating conditions; that is, ensuring they operate how, where and when they should.

Overall and assuming a take-up of 8,400 vehicles, IAP is estimated to generate a net present value (that is, present value of benefits less costs) of $264.2 million over seven years (allowing for two implementation years) and a benefit cost ratio of 5.4. Across all applications, the authorities' NPV is estimated to be $80.9 million and the operators' NPV $183.3 million. These results do not appear highly sensitive to assumptions about benefits and costs.

6.6.3 Rail use of GPS

Within the rail sub sector, the Rail CRC research team have developed a system with an in-cab GPS advice system to assist long haul trains to stay on time and minimise fuel consumption. According to the Rail CRC (2007), testing on industry trains showcased fuel savings of between five and 20%, without increases in journey times. Other benefits included reduced wear through reduced braking requirements and smoother train handling, via increased coasting and reduced powering.

Further to a Coronial Inquiry in the NSW Waterfall train disaster, a Rail Channel was developed within the Spatial Information Exchange (SIX). The Rail Channel is used by Rail Corporation and emergency services personnel to overlay rail assets and infrastructure on top of other foundation data such as roads, suburbs, properties, street directories, cadastre, topography, aerial imagery and other relevant spatial data. The SIX Rail Channel can identify with GPS accuracy any location or rail asset recorded in the system.

6.6.4 Road traffic management and congestion management

Geographic information systems also provide opportunities for analysing usage of infrastructure such as toll roads and road usage generally. Digitized aerial photography of real-time traffic conditions feeding into mobile GIS software and calculating preferred routes in real time, can save freight companies substantial time. Intelligent transportation systems to manage freeways, highways and major arterial routes are becoming increasingly popular.

6.6.5 Road and rail transport planning

An appreciation of existing transports hubs and networks in relation to expected population growth trends can identify areas of future bottlenecks in the absence of any forward planning. Spatial information is integral to transport modelling and managing congestion and freight.

An understanding of where people live compared to where they work can allow for optimal decisions on the most suitable transport type and transport routes. Such an application is covered in the road planning exercise by SKM in Section 6.4.6. To the extent that roads are placed in more optimal locations due to the use of spatial information in route planning, the savings are largely experienced in the transport sector.

6.6.6 Air traffic management

Member states of the International Civil Aviation Organisation (ICAO) have determined that aeronautical navigation services for the 21st century will be based on the global navigational satellite system (GNSS). This system, combined with spatially enabled technologies both on the ground and in aircraft will revolutionise air traffic management both en route and for takeoffs and landings.

In Australia this commenced with the development of non precision GPS. This provides improved navigation both at Airports and en route, reduces the number of terrestrial navaids needed and reduces fuel use and diversions because of the better tracking.

A newer and more accurate system is now being developed by Airservices in conjunction with Honeywell. This provides Approach with Vertical Guidance (APV) systems that can replace the current ILS (instrument landing systems.

The GNSS systems are augmented in accuracy with augmentation systems that may be:

- Aircraft Based Augmentation Systems (ABAS)
- Satellite Based Augmentation Systems (SBAS)

- Ground Based Augmentation Systems (GBAS)
- Ground Based Regional Augmentation Systems (GRAS).

GBAS will replace instrument landing systems at major airports while GRAS provides en route coverage and approaches with vertical guidance at regional airports. GBAS is a low risk system because it is designed from an aircraft perspective to look like ILS.

Safety is increased through increased signal stability and system design. Flexible approach paths facilitate minimal separation standards while the integrity, availability and continuity are an improvement on existing technology. GRAS will be a low cost en route and approach system product. Both systems use similar communications and message formats, so a single avionics unit is being developed for both products.

6.6.7 Case study – Airservices Australia

Airservices Australia is leading the world in the development of these systems in conjunction with Honeywell.

According to a cost benefit analysis undertaken in 1997, the most cost beneficial GNSS augmentation system, which was projected to meet the operational requirements whilst limiting risk of implementation, was one which utilises a combination of internationally standardised space and terrestrial based GNSS augmentation. Using existing space-based augmentation provided by the USA, Europe and Japan (with appropriate inter-governmental agreements) in combination with a supporting Australian infrastructure, it was expected that Australia would be able to reduce significantly its existing terrestrial navigation aids at great savings to users.

The analysis indicated that for an investment of approximately $40-60 million, leading to sole means implementation of GNSS within Australian airspace, projected annual savings for Airservices would be $20 million per year. Annual economic benefit to all Australian registered aviation operators (air carriers and general aviation) was projected at over $35 million.

The initial cost savings are to Airservices and the Airlines from non-precision GPS which provides global positioning for approaches at airports and for en route air traffic control. This offers benefits in the form of reduced fuel consumption, narrower flight corridors, better flight management and fewer diversions. Jet Star has done an evaluation of the investment in these technologies and estimates net benefits of around 2%-3% in lower operation costs. Aircraft and fuel operating costs comprise around 42% of Qantas total operating costs including depreciation (Airservices, 2007). Therefore a saving in productivity of 0.8% is possible for Jet Star regional services. The same would apply to Qantas city to city links.

The second is Approach with Vertical Guidance (APV) which uses GBAS for more accurate landing. The benefits are less diversions, fuel savings, narrower flight paths, flexible flight paths that allow aircraft to reduce environmental and noise impacts at curfew Airports. At the present time GBAS has only been installed at Sydney Airport and only Qantas is using it. Again the savings are around 2% of operating costs or 0.8% of operating costs at this airport. This represents possibly around 5% of all operating costs at Australian Airports.

These technologies also offer the following benefit:

- lower fuel costs
- more flexible flight paths to reduce noise and environmental pollution at curfews and highly populated areas
- narrower flight corridors
- less diversions due to weather problems which are increasing with climate change
- less terrestrial navigation aids with less local maintenance
- savings to consumers, industry and government.

6.6.8 Impact of intelligent transport systems

Sutton describes how, broadly, GIS has been implemented at three levels within transit organizations. At the first level, when the technology is first introduced into the organization, its application is project based in areas such as ridership analysis or bus stop inventory (Sutton, 2005). After a while, the GIS technology matures in the organization and becomes more widely used as a departmental resource, supporting a broader range of functions in business areas such as route planning. Finally, at the third level, it becomes a mainstream enterprise system that is part of the agency's information technology architecture.

It is at this third level that substantial productivity gains can be obtained. Intelligent transport systems integrate currently available and emerging information, computer, communications and vehicle-sensing technologies into transport infrastructure and vehicles in order to monitor and improve the safety, efficiency, management and operations of vehicles and transport systems. There is considerable evidence collected from within Australia and abroad that ITS can produce considerable reductions in accident rates and improvements in transport efficiencies.

There is also strong evidence that reductions in accidents and improvements in efficiency will produce significant financial savings to the community, largely through the more focused use of existing transport infrastructure and through reducing the need to build more and larger roads.

ITS Australia estimated that benefits would total, in net 1999 value terms to 2012, at least $14.5 billion. This was reported to be consistent with reducing the total costs of road accidents, congestion and vehicle emissions for the year 2012 by at least 12%, compared to the situation of not using ITS (ITS Australia, 1999). Specific savings were estimated as:

- $3.5 billion in efficiency savings
- $3.8 billion in savings from safety
- $7.5 billion in savings from reduced congestion and lost time.

By 2012, it is estimated that additional community and economic benefits of at least $3.8 billion per annum, excluding export income, will be produced if intelligent transport systems are implemented (Booz Allen & Hamilton, 1998).

Improvements to the efficiency of transport can also yield environmental benefits. For example, it is estimated that ITS will produce fuel savings of between 2% and 13% and reduce emissions by between 5% and 15% (Standing Committee on Transport and Regional Services, 2002).

Putting this in context, in 1998 Australia's transport sector contributed about 12% to the total of Australia's greenhouse gas emissions, with road transport accounting for 81% of these emissions. It is therefore estimated that a reduction of road transport related emissions could reduce Australia's total greenhouse gas emissions by between 0.5% and 1.5%.

This is equivalent to between $50 million per annum and $150 million per annum in the value of traded carbon in 2010 assuming a carbon price of $15 per tonne CO_2 -e.

Compared to other modes of transport, there are relatively fewer impacts of spatial information on rail transport. This is because the route is largely fixed with rail transport, unlike with other modes where there is more flexibility with routing. Nevertheless, even with rail there are benefits, once again relating to asset management and to the merging area of GPS in rail journey timing and schedule maintenance, as well as for fuel efficiency. For example, the Rail CRC research team have developed a system with an in-cab GPS advice system to assist long haul trains to stay on time and minimise fuel consumption.

In all areas of transport, businesses are adopting technologies to manage the transport task that will improve their bottom line performance, particularly in improvements in their financial performance and reductions in greenhouse gas emissions and usage of scarce resources, such as energy and water.

6.6.9 Direct economic impacts

The direct productivity impacts for transport used for economic modelling were based on estimates made from the case studies for road, rail an air transport:

For Scenario 1 these were on applications of spatial information in intelligent transport systems, traffic management and route planning and the use of GPS in freight management and air navigation.

For Scenario 2 estimates were based on additional applications observed in the use of spatial information for congestion and road hazard management, use of GPS in rail and in precision use of GNSS in flight path tracking and reduced airport costs and improvements in safety of navigation at sea.

The assumptions and productivity impacts for the modelling are summarised in Table 11.

Table 11 **Direct impacts – transport**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Road transport	Application of intelligent transport systems Route planning and GPS freight management	1.4%
	Rail transport	No estimate made	-
	Air transport	Non- precision GPS for traffic routing	0.55%
Scenario 2	Road transport	Estimated impacts of spatial information on GPS taxi services, better congestion and road hazard management and better supply chain transport planning	1.58%
	Rail	Estimated impacts of spatial information on asset management and fuel consumption.	0.45%
	Air transport	Improvements in tracking and flight paths, weather forecasting and lower airport navigation costs.	1.04%
	Other transport	Assumed extension of benefits to sea transport	0.3%

Data source: Case studies, interviews, literature review

6.7 Utilities (electricity, water and gas)

In much the same way as transport is involved in the movement of something between two points, the utilities sector (electricity, water and gas) is involved in the same fundamental challenge as part of what it does. In moving electricity, gas and water from source into customer premises, the utility industry benefits in similar ways to the transport industry.

Several commentators (e.g. OXERA 1999) have noted that the utilities sector, along with transport, stand to gain the most from spatial technologies. Utility infrastructure, equipment, facilities, crews, customers and even system events have an aspect that can be associated with a physical location. Major uses of spatial information in the utilities sector include:

- asset management of complex networks of powerlines, pipelines and channels
  - monitoring and maintenance of infrastructure, metering and management of systems utilise geographic information systems.
  - statistical control and data acquisition systems (SCADA) have realised significant economies in operation of natural gas pipelines and electricity transmission systems
- balancing supply and demand and ensuring optimal market performance
  - for example, the prices of National Electricity Market, sending signals to generators and distributors, are informed by GIS systems calculating supply and demand across different locations in real time
  - in water supply, hydrological modelling incorporates a range of spatial variables in managing river systems and water distribution, including rainfall, geology, topography, storage facilities and their capacities, and the location of demand at different points in time
- planning the optimal location of new pipelines, generators, powerlines or dams
  - for example, decisions over the location, size and cost of a new dam depend on information about spatial variables such as rainfall, topography, geology, number of people in the planned catchment area and urban and irrigation water demands, all which are potential GIS data sources
  - GIS is used in cost benefit analysis of new infrastructure projects, to better understand the magnitude and location of economic, environmental and social impacts.

6.7.1 Water supply authorities

Water supply authorities in Australia are under increasing pressure to more efficiently manage their asset infrastructure whilst meeting environmental and customer performance standards.

Across the country, water resources are managed by state and territory appointed water authorities ranging widely in the services provided, number of connected clients, geographic factors and service area. However, many authorities face common challenges in managing millions of dollars of assets and meeting the service demands of clients, government and other stakeholders.

Geographic Information Systems are widely used by the utilities sector to manage assets. These systems provide a range of functions needed by water authorities for their daily operations including the capture and recording of the extent of assets, scheduling their replacement, identifying the impacts of outages, planning works activities, managing customer queries and analysing environmental issues.

A recent survey by Spatial Vision found that of the 30 authorities surveyed, 29 (or 97%) operate a GIS (Spatial Vision, June 2007). Only one of the Small Urban Authorities did not have GIS software. The uptake of GIS has increased from the 2002 survey figure of 74% (across Victorian authorities only).

Where it exists, the GIS software was installed from as early as 1983 with the latest installation occurring in 2002. The Metropolitan Retail Authorities were the earliest group of authorities to first install GIS software. Of the authorities running GIS, 31% had their first installation in the 1980s, 41% in the 1990s and 24% since 2000. Since installing the first software, most authorities have updated their GIS with 69% stating that their latest system was installed after 2000.

The survey looked at business drivers for the use of GIS within water authorities. The greatest benefits from the implementation of GIS were considered to be:

- asset replacement planning
- capturing corporate knowledge
- recording the location of assets and features
- improved decision making.

6.7.2 Case study – Melbourne Water

An example of a water authority heavily using GIS is Melbourne Water. Melbourne Water is responsible for managing Melbourne's water supply catchments, its river and creeks and drainage systems, as well as removing and treating sewerage.

The business is owned by the Victorian government and manages over $8 billion in water supply, drainage and sewerage assets covering an area of about 7,800 square kilometres. The company generates revenues of over $500 million per annum predominantly from the supply of water, sewerage treatment and disposal and drainage rates. Melbourne Waters main customers are the 3 Melbourne retailers, South East water, City West Water and Yarra Valley Water.

Melbourne Water uses spatial information predominantly for asset management, asset maintenance (repairing and identifying faults), asset protection, hydrological modelling, map production, planning and spatial analysis

Melbourne water also provides the information generated by their systems to outside consultants for their assistance in asset management. Melbourne water also uses census data (CDATA 2001) from the ABS in planning future works and identifying future infrastructure needs.

Prior to the implementation of these systems Melbourne water relied on physical maps and the knowledge of field staff to locate assets. Melbourne Water first moved to GIS in 1997 in the drainage area. The process of adoption has been an incremental process with subsequent adoption by the water and sewerage teams.

Melbourne Water currently use MapInfo and are examining a web mapping service (WMS) which allows it to link into real time data of the web and pull it straight into their GIS system for analysis.

Another source of data for Melbourne Water is Sentinel fire data which is provided by Geosciences Australia. The integration of Sentinel fire data allows the mapping of the location of bush fires to the location of the catchment areas, allowing them to identify and respond to dangers at an early stage.

They are currently in the process of implementing a system that allows the retrieval of real time Bureau of Meteorology data. This will allow them to identify locations where there is a string likelihood of flooding and take precautionary or preventive action to protect assets.

As a result of the use of GIS systems, Melbourne Water noted that there had been substantial improvements in terms of speed and accuracy in planning and operations.

The main impediment faced by Melbourne Water to the optimal and efficient function of their spatial technologies lies in the sharing of data between utilities. While there are clear benefits from organisations having access to each other's data however, many organisations are reluctant to provide data for risk management reasons, specifically potential liability issues resulting from the provision of erroneous data.

In the future Melbourne Water is looking to move to greater in field or portable use of GIS (similar to the mobile computing technologies used in local government). They are more likely to focus on using GPS to locate assets, and consider developing a web based GIS application.

Another potential application Melbourne Water is considering is 3 dimensional modelling of underground flows to ensure adequate flow through their pipes. They are also contemplating the development of a spatial database to replace their current use of tab files. Melbourne water also envisages greater use of imagery in the future for quality assurance purposes, in particular geo-coded satellite imagery, aerial photography and infrared imagery.

6.7.3 Case study – Electricity distribution

Energex and Ergon Energy have both engaged spatial information systems in support of their electricity distribution operations. They are illustrative of applications that are gradually being adopted elsewhere in Australia.

Energex

Energex is an electricity distributor servicing about 2.7 million people in South East Queensland. It has $6.6 billion in assets and its distribution area covers 25,000 sq. kilometres. This includes 50,000 kilometres of electricity lines and cables and over half a million power poles, 43,000 transformers and 290,000 street lights.

Uses of spatial data

A significant issue for Energex has been compiling data bases that link their customers' location in relation to their networks. In the past there has been no dynamic link between the businesses customer database and their network maps, so that in managing their address systems assumptions, had to be made as to which part of the network serviced a specific address.

An indication of the extent of the mismatch was evident during storm events when the connection between customers addresses and the network was found to be only 38% accurate. As a result, service technicians were slower to respond to service calls, due to technicians going out to incorrect locations and failing to find the on-the-ground source of a problem quickly.

Error in the customer systems included wrong or badly managed addresses, missing or duplicated addresses.

With the assistance of CTG, Energex developed and address system linking the company's GIS and customer systems. Prior to the implementation of the solution, Energex operated a call centre with 10 people involved in handling emergency calls. The same load is currently handled by only 1 person. It is clear that there have been significant efficiencies in handling emergency calls.

Overall, efficiency improvements in Energex's business have come from improved integration of operations with spatial information. In the absence of GIS, it would be necessary to revert to the service standards of the 1980s.

Ergon energy

Ergon energy are an electricity distribution company that covers nearly the whole of Queensland. They have $6.7 billion in assets, revenues exceeding $2.2 billion per annum and employ about 4,000 people.

Ergon services about 600,000 customers across regional Queensland, over an area of 1.7 million square kilometres or 98% of Queensland. Their network consists of 150,000 kilometres of power lines and a million power poles.

Uses of spatial data

The main areas in which spatial information is used at Ergon are:

- asset management
- asset maintenance
- customer service
- service order fulfilment.

An example of where Ergon uses GIS is in organising resources for new connections or fixing faults. The system relays information on asset locations to crews via hand held devices to enable the location and tracking of faults etc. Ergon uses a GIS product called SmallWorld, which is popular with utilities.

The benefits of this system are likely to translate into lower average time to reconnect services as well as reduced time to rectify faults. By improving the ability to track and maintain assets, GIS also helps to minimise the occurrence of faults. However, these benefits are likely to be mixed in with other factors and it is difficult to split out the gains that can be directly attributed to GIS.

Currently, Ergon do not use GIS systems to spatially model and forecast demand as a future network planning tool. This analysis is done outside of such systems through visual interpretation of paper maps, however it is anticipated that such uses for GIS will be employed in the future.

Ergon Energy is considered to be one of the more innovative companies in the electricity distribution market. They recognise spatial data as key to all of their information management platforms.

6.7.4 Case study – *Hazwatch* and INDJI

The Hazwatch system was developed by the CRC-SI and draws on existing data such as maps of infrastructure and provides warnings in the event of fire or bad weather or other impending disasters. The recent Canberra bushfires perhaps provide an example of where the system could have been applied to assist the emergency services. Benefits of the system are largely derived through the avoidance of damage to costly infrastructure.

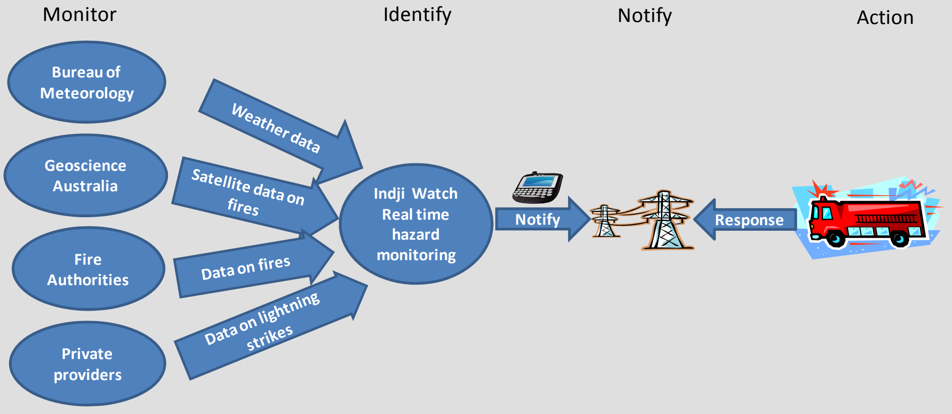
iintegrate Systems is a Perth based software developer whose product INDJI Watch is based on the Hazwatch technology. The system monitors natural and manmade hazards in real time and identifies threats to assets and people by matching the incidence of hazards against assets and people. The most common natural hazards it works with are bush fires, floods and lightning – though conceivably it could be anything.

iintegrate provides a single centralised control system for warnings. This is very important to emergency management organisations. It minimises the potential for communication problems particularly incorrect communication of warnings to utilities and infrastructure operators.

The system is a hosted solution with data stored at a large data centre. Warnings and alerts are delivered to clients via SMS and fax. Clients can then monitor the situation by going to a map viewer on the system website.

Data for the system is obtained from a number of sources, both private and public sector. Bushfire information is obtained from Geoscience Australia who download satellite data and run an algorithm to identify hot spots on the earth's surface. Information on lightning is obtained through private sector providers. Information on the incidence of bush fires is also obtained from various fire authorities. Weather information is sourced from the Bureau of Meteorology.

Box 6 *Indji*



*The **Indji** system integrates data on hazards from a range of sources and notifies clients when a hazard threatens a critical installation or infrastructure. The warnings may be transmitted by SMS or as a digital map warning on a PDA. The marginal cost of accessing and processing the data is small relative to the value of the damage avoided.*

Data source: iintegrate systems

The schematic in Box 6 shows the sequence chain for ***Indji***. The system accesses data from a number of sources, processes it and, when certain conditions are met (such as proximity of a hazard to infrastructure), it transmits a warning to the client.

This case study demonstrates the increasing value along the spatial data value chain. The marginal cost of capturing and accessing the data is small. Value is added as that data is processed and integrated into a warning system. The marginal cost of communicating the processed data is also low yet the value at this point in terms of average annual social and economic costs avoided is likely to be large.

The electricity sector clients are transmission companies operating the grid in Queensland, NSW and Victoria, comprising 70% of the transmission market. There is potential to service Tasmania, SA and WA in future. The most significant market for this technology is probably overseas. The product has only been on the market for 12 months and the potential markets in Australia and overseas offer the potential for significant growth in applications.

6.7.5 Direct economic impacts

The direct economic impacts lie in two areas

- more efficient asset management
- less interruptions to supplies.

The most significant impacts of spatial information systems have been in the more efficient management of assets and in customer service principally in water, electricity and gas. The ability to manage several layers of data in spatial information management systems has resulted in provision of information to management and staff in a faster and more comprehensive way.

Estimating the productivity benefit from the Energex and Ergon case studies is difficult partly because of the higher levels of service provision now required by the public and governments. The Energex example demonstrated how efficiency in the use of call out staff was achieved through the use of spatial systems. General enquiries suggested that an efficiency improvement of around 10% in asset planning and management was not unreasonable. Taking account of the proportion of expenditure made up by asset management in the total expenditure of these utilities it would not be unreasonable to conclude that a total productivity improvement of 5% in operating costs could be attributed to the use of modern spatial information systems.

There is also a contingent value on minimising interruptions to supply from utilities. The cost of the loss of gas supplies in Victoria in 1998 from the Longford explosion was estimated to be of the order of $1 billion. The impact of fire on Victorian transmission lines from fire in early 2007 has not been quantified but the loss in business revenue and social disruption is not insignificant. The value of lost load in the National Electricity Market is $10,000 per MWh. This represents the opportunity cost of interruptions to electricity supply which are often the consequence of damage to infrastructure resulting from fires and other natural hazards. This gives some indication of the cost of damage to electricity infrastructure.

For the purpose of economic modelling in Scenario 1 the estimates focussed only on the impact of more efficient asset management. Where adopted, this has resulted in productivity improvements. Scenario 2 includes estimates of the impacts of hazard management and market facilitation, such as the use of spatial information in the management and operation of electricity and water markets. The estimates are summarised in Table 12.

Table 12 **Direct impacts – utilities**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Electricity and water,	More efficient asset management	0.73%
Scenario 2	Electricity, gas, water, pipelines, cables.	More efficient asset management, market facilitation, hazard management	1.25%

Data source: Case studies, interviews, literature review.

6.8 Communications

The communications sector comprises two distinct sub sectors – postal services and telecommunications. Both of these sectors face the challenge of allowing communication between parties by overcoming the barrier of physical separation and space. That is, overcoming distance is the core business of communications and hence the industry can gain a great deal through the use of spatial technologies.

6.8.1 Network planning

By incorporating supply side (where services are available) and demand side (demographics, business data) market data, improved information network planning decisions becomes possible. This leads to more efficient layout of new broadband or mobile phone networks to most efficiently meet unmet demand.

For example, determining the expansion of a wireless broadband network requires identification of the best location for a base station. This depends upon a range of variables that a GIS can analyse, including measures of unmet demand, location of competition services, topography, and the range of a service under different demand conditions.

Through the use of spatial information communications professionals are able to integrate location-based data into analysis and management processes in network operations, marketing and sales, customer care, data management, and many other planning and problem-solving tasks.

In the area of network planning and where to deploy a service, a GIS optimised network can, for the same cost, result in more potential customers being covered by a network.

An example of such use is TransACT, a relatively new entrant into the Australia telecommunications market providing voice and data (internet) and Pay TV services throughout the ACT on a cable and wireless network. As all of their entire infrastructure is relatively new, compared to the copper wire network of their incumbent telecommunications companies, they have heavily employed GIS in their network planning and decisions over what to invest and where.

6.8.2 Asset management

In detecting faults or bottlenecks (i.e. the source of bandwidth congestion) quickly, problems can be identified quickly and disruptions to network performance minimised. The applications of spatial information in asset management in telecommunications is similar to the uses discussed in the utilities section, as both industries are involved in managing networked infrastructure.

6.8.3 Address management and route planning in postal

In the postal communications sector, the improvements to address management made possible through GIS enhance the speed and accuracy of postal communications. In Australia, the move towards a standard geocoded address database (G-NAF) is likely to yield significant cost savings, not just for the address management but also for users of address data (including postal delivery).

Evidence from New Zealand (ESRI, 2007), for example suggests that due to the adoption of a GIS server, New Zealand Post now save up to 10% on the processing cost of a standard letter item. This is due to staff being able add, change, and map postal addresses more easily and accurately. Postal and courier services are increasingly employing GPS navigator systems to assist in itinerary planning and in finding addresses quickly.

The impacts of these, and other, applications in the communication sector are substantial. It is in the area of telecommunications where many of the benefits of spatial information lie, particularly in the relatively new areas of broadband internet and mobile phone services. The infrastructure required to provide these services is new, and hence its provision has largely coincided with the emerging GIS applications that can be used to optimise network layout and development.

Therefore, perhaps more than in any other industry involving infrastructure deployment, the location of that infrastructure has been most influenced by spatial technologies in telecommunications.

6.8.4 Direct economic impacts

As discussed, the telecommunications sector has been uniquely placed to benefit from spatial information more than other industries, because so much of the industry had been transformed since the introduction of GIS. It has been used extensively in much of the network planning and infrastructure locational decisions that now provide of the mobile phone and broadband internet telecommunication services.

The use of GIS to optimise the location of, for example a wireless broadband tower, with a given radial coverage area and often restricted by line of sight requirements, results in more customers and therefore more revenue, for the same level of infrastructure investment, or the same number of customers for smaller level of investment. Either way, productivity to the telecommunications provider is enhanced.

The gains to the industry from spatial information for the two scenarios are summarised in Table 13. The estimates represent weighted average of gains to the postal and the telecommunications sectors.

Table 13 **Direct impacts – Communications**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Telecommunications and postal	Asset management and network planning in telecommunications, postal use of GIS in address management	0.98%
Scenario 2	Telecommunications and postal	As above, plus use of GPS in postal and courier services, telecommunications market analysis and targeted marketing	1.32%

Data source: Case studies, interviews, literature review

6.9 Retail and trade

Excluding the flow on benefits from other sectors (most notably transport and agriculture), the retail and trade sector does not appear to be experiencing great gains from spatial information use. In the United Kingdom (UK) as early as 1998, fifty-three percent of the major retailers had adopted GIS (Hernadez et al., 1999). Major areas spatial information is being used in trade are systems that help retail and trade businesses decide where to trade, what to stock and where to market. To some degree Australian retailers are thought to have utilised similar systems.

6.9.1 Where to trade

Businesses may use spatial information to gain a better understanding of the characteristics of a market area, knowledge of where potential customers may come from. An idea as to the likely size of a market in a given area can enhance decision making for businesses wishing to expand, introduce new products or services and improve the efficiency of marketing campaigns. Demand for goods or services can be spatially modelled and compared to supply side information, allowing for the accurate identification of areas of greatest unfulfilled demand for different goods and services.

6.9.2 What to stock and where to market

Through a better understanding of the nature of their customer catchment area, traders can carry stock most suitable to the nature of each stores' catchment area, and marketing can be better targeted to appeal to the demographics of their target audience.

Brick and mortar businesses can use GIS applications to compete with internet retailing by allowing shoppers to browse their store virtually. A retailer can develop a map of its store using GIS software to calculate the actual dimensions of a store. This can even handle multilevel stores and shelf location and depths. Consumers can view the map on a live website. While using the virtual map, the consumer can see how many items are in stock, detailed information about the product, and any associated items that are on sale or available for purchase.

6.9.3 Emerging applications

Customer smart cards are an emerging technology, especially in high-tech retail establishments, employing spatial technologies. The smart cart is a computer-enhanced shopping cart that can be found in some retailers today. This cart is designed with a map or database of the store in which a customer can query a specific item as they walk through the store.

The smart cart will locate the item within the store, direct the customer to that item using a map, provide additional information about the item, and offer supplementary items needed and their locations (GIS Frontiers, 2001). It is predicted in the future that the smart cart can also be used to check out consumers faster. The smart cart would run through an X-ray type machine that would identify and checkout all purchasers.

6.9.4 Impacts

While it is clear that the retail and trade sector are using and drawing benefits from spatial information, there is little credible information available in the public arena to base an assessment of the contribution it is making to productivity and market growth.

For the purpose of this study therefore no gains were claimed for the retail and trade sector for scenario 1. This would lead to an underestimate overall of the benefits delivered by spatial information and a small gain was assumed for Scenario 2 (Table 14).

Table 14 **Direct impacts – retail and trade**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Retail and trade	No gains assumed	-
Scenario 2	Retail and trade	Gains assumed in more efficient stocking and store location, targeted marketing	0.02%

Data source: Case studies, interviews, literature review

6.10 Tourism

Even though tourism development is a distinctly geographical activity with serious implications for destination areas, there appear few significant current applications in tourism. However, applications appear to be emerging in holiday planning, tourism management and facilities planning.

6.10.1 Holiday planning

Online hotel and holiday applications employ mapping technologies allowing users to specify, in broad terms, their preferences (including geographical variables and price) and the software recommends appropriate options. In addition to the online mapping search facilities, basic GIS applications and spatial information are backing up some of the search criteria. Electronic navigators and maps are often an important component of making travel plans, and are used while travelling.

6.10.2 Tourism management and provision of facilities

The relationship between geographic factors, marketing strategies, visitor behaviour, visitor perceptions of various attractions, and trip/traveller characteristics are also critical components for the managers and planners of tourism-related businesses (Chen, 2007).

Visitor flow management is one application, involving the use of GIS to identify principal tourist activity spaces within a destination and the flows among destinations.

Authorities may also draw on spatial data analysis to develop strategic plans for infrastructure and facilities (e.g., building public transportation systems linking various tourist activity spaces).

6.10.3 Facilities planning

GIS can be used to demonstrate tourism impacts on various industrial sectors in a time-series and spatial format (Chen, 2007). Within this category, analysts can use all or several of the previous categories by employing the "what-if" tool of GIS. This tool allows the development of scenarios for predicting what the effect of a change in a certain variable(s) will be in the destination.

Farsari and Prastacos suggest a future opportunity for GIS applications in tourism planning involving facility inventory and resource use (Farsari, 2004): This involves the use of GIS in connection with the issue of environmental justice (namely the fact that tourism may not benefit all segments of society equally). It also involves developing an inventory of resources in order to identify conflicting but also complementary land uses and activities, available infrastructure, and natural resources.

6.10.4 Impacts

While there was evidence in the literature that spatial information is bringing benefits to tourism there are no studies that would adequately inform this assessment for the year 2006-07. Therefore no benefits were included in the general equilibrium modelling for this sector for Scenario 1.

In recognition of evidence that spatial information is used in tourism as small productivity improvement of 0.02% was assumed for Scenario 2.

Direct impacts – retail and trade

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Tourism	No gains assumed	-
Scenario 2	Tourism planning and management	Gains assumed in more efficient planning and management in the tourism industry	0.02%

Data source: Case studies, interviews, literature review

6.11 Manufacturing

Of all major industries, manufacturing appears to one with little to gain from the use of spatial information. We are aware of some small applications, but the nature of businesses of the industry, being largely operations confined to the small boundaries of individual properties, limits their potential to use and benefit from spatial information.

Manufacturing clearly benefits a great deal indirectly, predominantly through productivity gains in construction, transport and trade, but these flow on benefits are not direct to the industry and instead are captured and explained in the GE modelling.

Small areas of productivity gains through the use of spatial information in agriculture are evident in:

- Minimising environmental impacts and complying with environmental regulations can be made more efficient by understanding spatial variables in a GIS environment, such as wind directions, microclimate, hydrological and groundwater modelling and controlling noise.
- Logistics planning, and cost savings can be realised through the establishment of clusters of manufacturing activity (where business save money and, in some cases, achieve economies of scale, through strategic proximity to related and supporting industries)

- Planning where facilities should be built. Considerations such as proximity to transports hubs (especially rail, road and port facilities), location of competing and complementary businesses and availability of suitable staff are all able to be informed by GIS systems.

6.11.1 Impacts

There was little information or evidence on which to base estimates of the productivity benefits of spatial information to manufacturing beyond the observation that there clearly are some applications in play as at 2006-07. For this reason no account was taken of the benefits from the use of spatial information in manufacturing for Scenario 1.

A small productivity improvement was assumed for Scenario 2 on the basis of the literature review and interviews that suggest some benefit to the manufacturing industry has occurred in logistics, planning and environmental management (see Table 15).

Table 15 **Direct impacts – manufacturing**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Manufacturing	No gains assumed	-
Scenario 2	Manufacturing	Gains assumed in more efficient logistics, planning and environmental management	0.02%

Data source: Case studies, interviews, literature review

7 Impact on government

7.1 Government in general

The diverse nature of what government does throughout its different levels and departments makes a complete review of its collective use of spatial information beyond the scope of this project. Yet there is little doubt that the provision of public services and infrastructure across entire jurisdictions, be they national, state or local, are benefiting from the use of spatial information. In Australia, governments of all levels have been leaders in the deployment and use of spatial technologies.

7.1.1 Australian Government

The Australian Government is a significant user of spatial information. The 2005-06 Annual Report of the Spatial Data Policy Executive reported that Australian Government agencies spent around $85 million on spatial data production and management in 2006-07. It identified 29 departments or agencies that employed spatial information in one form or another (OSDM, 2006). Significant users included:

- Geoscience Australia
- The Australian Hydrographic Service
- The Bureau of Resource Sciences
- The Defence Imagery and Geospatial Organisation
- The Department of Agriculture Fisheries and Forestry
- The Australian Fisheries Management Authority
- CSIRO
- Land and Water Australia
- The Department of Environment and Water
- The Murray Darling Basin Commission
- Centrelink.

However the adoption of spatial information is not uniform all across agencies. In 2006, AGIMO conducted a survey of the extent of spatial enablement in Australian Government agencies (AGIMO, 2007). The report found that use of spatial information technologies in the thirty organisations surveyed was infrequent although it tends to be used in a wide range of activities. Some of its conclusions were:

- Where it is being used, it is more likely to be in business processes for programme delivery and operations i.e. services and interface with the community.
- In a small number of cases the frequency of use was found to be high.
- Around a third of organisation business information contains locational components.
- There is a high value generated from the use of locational components found in business information.
- There would be a reasonable amount of additional value to organisations if business information not presently locationally useable were to become so.
- The most used spatial data were street addresses, streets and roads, postcodes boundaries, Australian Standard Geographical Classification boundaries and metadata. Most organisations accessed spatial data from another agency within the Australian Government.
- Most organisations report plans to implement or enhance their spatial information technology capability.

Research for this report confirmed that geospatial information has enhanced the way in which many Australian Government agencies plan and deliver services. Spatial information was also found to support decision making and policy formulation in areas such as natural resources management and program planning through its ability to present economic, environmental and social data by geographic area. Spatial information has a significant role to play in assisting governments in addressing triple bottom line outcomes at local, regional and national levels. There are some outstanding examples of its application in Australian Government agencies that have been well recognised.

Geoscience Australia (GA) was highly commended in the Pre-Disaster Category (National Significance) at the 2005 Australian Safer Communities Award for its contribution in three separate projects:

- collaborative 100K mapping pilot for emergency management
- Project Perth – a major hazard risk assessment
- scenario modelling for the assessment of national catastrophic disaster capability.

The Rainfall to Pasture Growth Outlook Tool, developed by the Department of Agriculture, Fisheries and Forestry, was recognised by the Business Review Weekly as one of Australia's top five innovations of 2005. The service supports pasture and grazing management. Farmers are provided historical, current and forecast weather information for their local area that allows them to estimate pasture growth in relation to rainfall, soil moisture and other climatic conditions. Information is based on data collected from over 3,300 weather stations across Southern Australia.

Management of a wide range of environmental problems or threats has been significantly enhanced with GIS. For example, understanding of the impact of land clearing in catchments is enhanced by spatial information on the hydrology of downstream land use, the range of nearby species, the distribution of different soil types and groundwater mapping.

GIS has already been applied to mapping and monitoring greenhouse emissions, salinity and water quality. Notable examples include:

- the National Land and Water Resources Audit (NLWRA) that utilises spatial information to record and analyse water quality and water use
- mapping of groundwater salinity with airborne electromagnetic geophysics produces data that is now incorporated in spatial information systems that support salinity management strategies.

Generally, Australian Government spatial initiatives are being pursued as part of a broader information, communications and technology strategy, often collectively referred to as e-government. The following are some wider examples:

- The Australian Government Online Services Project (AGOSP) was announced in July 2007, which will see australia.gov.au provide an interface to advanced spatial technologies. It will incorporate a National Government Services Directory with advanced search and mapping capabilities and 'smart' forms that will pre-populate user information where appropriate. It will all be part of the new online service point.
- Spatial data assists with the Department of Health and Ageing's (DOHA) objectives of supporting universal and affordable access to high quality medical, pharmaceutical and hospital services, while helping people to stay healthy through health promotion and disease prevention activities.
- The Department of Families and Community Services and Indigenous Affairs (FACSIA) is using the mapping intelligence to identify areas of need and make faster strategic decisions.
- Spatial information may have distinct benefits in preventing fraud; for example, identifying over servicing whether it is Medicare, pharmaceuticals or benefit payments. Spatial information enables administrators to review population characteristics at a local level and match these against the user population of services and visualise any discrepancies. These may then be followed up by investigation.
- Native TitleVision was developed by the National Native Title Tribunal. It won the 2005 Asia-Pacific Spatial Excellence Awards and was a finalist at the inaugural e-Award for Excellence in e-Government 2006. Created by the Tribunal's Geospatial Services unit it provides access to geospatial information on native title matters. Over 170 organisations access this service, which is used by case officers, lawyers, native title applicants,

judges, administrators and interested parties who are geographically distributed across rural, remote and urban Australian locations.

- The Shared Land Information Platform (SLIP) was developed in line with Western Australian Government's strategic planning framework, Better Planning, Better Services, which challenged Government agencies to provide more "citizen-centric" government. SLIP has demonstrated world's best practice in providing spatial information online, in a more efficient and seamless manner. SLIP has overcome the challenges of traditional Government models by promoting shared outcomes whilst maintaining Government agency accountability.

There are a number of agencies or institutions with a role in spatial policy and implementation at the national level. These include:

- Australian Government Information Management Office
- Geoscience Australia
- The Australian Spatial Data Policy Executive
- The Office of Spatial Data Management.

In addition the Australian Government participates in ANZLIC and the Public Sector Mapping Agency (an unlisted public company wholly owned by the Australian and State Governments).

The Australian Government has promoted policy development for the spatial industry through support for the Spatial Industry Action Agenda and its support for ANZLIC.

The Office of Spatial Data Management plays a central role in supporting the Spatial Data Policy Executive, promoting the efficient use of Australian Government data sets, representing the Australian Government's interests in coordination of access to spatial data and access arrangements and fostering the development of the spatial information industry.

The Australian Government introduced new pricing and access policies in 2001 and has been progressively pursuing reform at the national level.

7.1.2 Case study – Australian Government Information Management Office (AGIMO)

AGIMO is located in the Department of Finance and Administration. Its mission is to foster the efficient and effective use of information and communications technology (ICT) by Australian Government departments and agencies. It provides strategic advice, activities and representation relating to the application of ICT to government administration, information and services.

AGIMO includes spatial information in its portfolio of interests but does not have full policy responsibility for spatial information which is technically located within the Communications portfolio. Responsibility for strategic leadership rests more with the Spatial Data Policy Executive.

7.1.3 Impacts – Australian government

The AGIMO and OSDM reports show that there are significant if narrow applications of spatial information in Australian Government agencies; but agencies have only limited quantifiable assessments of their net economic benefits by the agencies.

In a 2002 study by the National Office for the Information Economy for AGIMO estimated agency benefits from e- government across 24 programmes, these agencies expected to reduce annual costs by $100 million (AGIMO, 2002) at a capital cost of around $108 million.

Of these agencies, 67% expected to reduce costs significantly due to improved business processes and a further 64% expected to reduce staff costs and other direct costs. This was assessing the broader online initiative, not spatial information alone, but it is an indication of the benefits that are being realised from e business systems that spatial information enriches.

The case studies and discussion in this report show that there are potentially very significant economic, social and environmental benefits already accruing in areas such as geoscience, biosecurity, defence and emergency services and in the efficiency of Australian Government administration and services generally.

7.2 State and territory government users of spatial information

Across Australia each state and territory government has established an information office with the role of leadership and advice on information and communication technologies, technology procurement, e-government and other initiatives.

Effective property markets are of fundamental and critical importance to economic development in Australia. Processes are required to manage land availability with trusted systems and spatial information services to ensure confidence and security in ownership, property boundaries and valuation.

State and territory governments are also using spatial information in the areas of natural resource management, including land, water and marine resources, while extending the use of spatial into areas such as e-services on line and services delivery and planning.

Key areas of use at state and territory level include the following:

- urban planning, which requires an appreciation of the spatial links between socio-economic trends (population growth, age of the population, location of unemployed people etc) and physical features (environmentally sensitive areas, existing infrastructure)
  - determining the appropriate location of a range of important urban planning boundaries is greatly facilitated by GIS, including land use zonal boundaries, designated activity centres, pedestrian routes, urban growth boundaries, future transport and green wedges
- service planning and delivery which is guided by spatial representation of trends across states and regions including
  - service delivery and access according to population distribution and movements
  - service outcomes based on demographics
  - performance monitoring
  - data repositories for taxation, land titling and infrastructure
- land management and planning
  - ANZLIC has formed the Standing Committee on Land Administration to partner with allied bodies, including Registrars of Title, Valuers-General and surveying and mapping, and align activities to obtain a coordinated response to land management reform
  - local government's capacity to efficiently manage its responsibilities for planning and land administration has improved through ICT and spatial information tools and processes
- crime prevention and response
  - spatial analysis of crime statistics can reveal patterns that assist in crime prevention through, for example, where to patrol or where to increase surveillance activities
  - the emerging use of satellite tracked transponders can result in the recovery of stolen property, and provide a disincentive for theft
- emergency management, for police, fire and ambulance services
  - spatial information and GIS assists in effectively planning for emergency response, determine mitigation priorities, analysing historical events, and predict future events
  - it is has been suggested that the use of global positioning systems alone have reduced emergency response times in transport related emergencies by 20% (House of Representatives Standing Committee on Transport and Regional Services, 2002).
  - in Western Australia spatial information is readily used by a number of key agencies through SLIP for emergency management purposes. SLIP assists cross-agency planning and communication by providing a platform that can provide customised information to support the

specific operational needs of Western Australia's emergency management sector as and when required.

7.2.1 State government strategies

State Governments have been actively investing in spatial information services with some states achieving considerable progress in developing whole-of-government approaches to the delivery of spatial information services.

Western Australia is a world leader in whole-of-government processes for managing spatial information. It developed the Western Australian Land Information System (WALIS), a successful model for collaboration on spatial information, which has been in operation since the 1980s. Building on WALIS, the Shared Land Information Platform (SLIP) is a key component of the state's e-Government agenda for improved service delivery. SLIP has transformed the way that government spatial information is used and shared. SLIP has assisted the Western Australian Government in achieving its' goal of providing more "citizen-centric" government, with land information now broadly accessible online, in real-time. This innovative approach has been the result of a collaborative effort by a number of Government agencies, led by Landgate. SLIP commenced development in early 2005 and was formally launched in late 2007 and is already demonstrating considerable benefits in terms of access to information, reduced duplication of data, and efficiencies in business system development.

Queensland has a well developed strategy for spatial information management across government through the Queensland Spatial Information Infrastructure Strategy (QSIIS). Although the strategy promotes uses and benefits to both government and the private sector, the private sector involvement to date has been somewhat limited. The Smart Service Queensland provides a framework for new initiatives in the delivery of spatial information and services such as through the Access Queensland and Information Queensland programs.

Victoria has been a world leader in land and property information systems, creating innovative products and services such as the Land Exchange.

New South Wales has led other jurisdictions in creating access to natural resource information held within agencies, departments and the community through the Community Access to Natural Resource Information (CANRI) project. A recent initiative through the Board of Surveying and Spatial Information (BOSSI) aims to establish a whole-of-government approach known as the Common Spatial Information Initiative (CS2I). In March 2006, the NSW Government launched the Spatial Information Exchange (SIX) government shared service. In January 2008, SIX was expanded and offers personalised or function based channels to various agencies such as Rail

Channel, Fire Channel, Planning Channel, Valuation Channels, and Government Property Register. SIX provides a single authoritative spatial information platform to the public (PeopleFirst Channel), businesses (Survey Mark Channel) and government.

7.2.2 Case study – Western Australian Land Information System

The Western Australian Land Information System (WALIS) is an alliance of diverse public and private sector organisations, as well as community groups. The mission of WALIS is to build networks of people and technology to share spatial information and to continually improve its usefulness and accessibility.

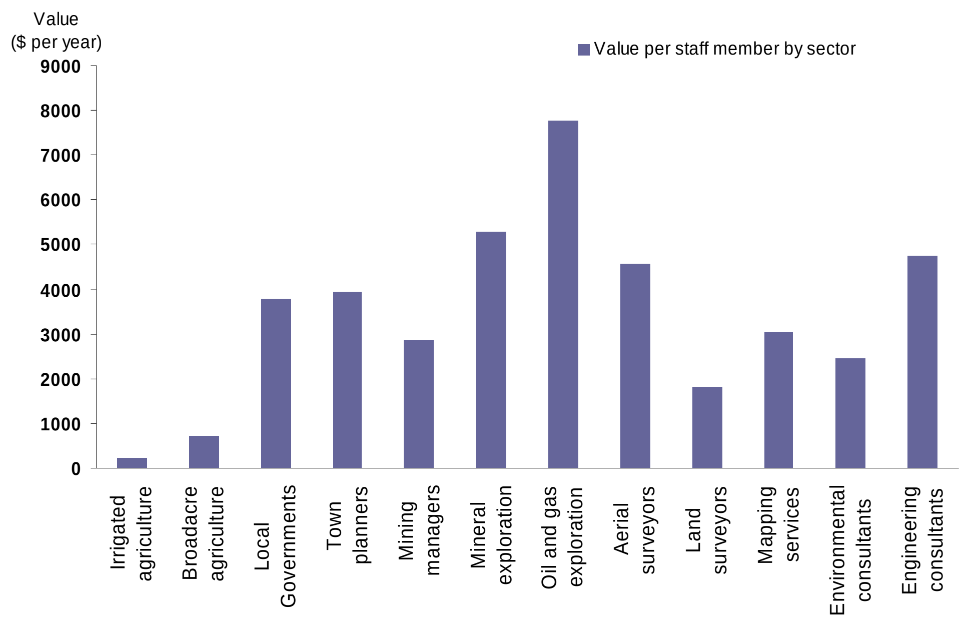
Established by the Western Australian Government in 1981, WALIS has served as the state's prime spatial information coordination body. It oversees the management of spatial information across the state community, and it coordinates capture of fundamental spatial data through the State Land Information Capture Programme.

Quantitative analyses yielded estimates of the value contributed by WALIS of $14 and $15 million a year, respectively, to the Western Australian economy. Most of the benefits accrue to local government. The benefit to cost ratio was estimated to be of the order of nine (ACIL Tasman, 2004).

WALIS also adds value because it enables a more efficient collection and production of spatial data. This is adjudged to have an annual value of at least one million dollars a year.

The cooperation that WALIS has achieved provided the foundations for the development of Shared Land Information Platform (SLIP). SLIP was delivered and continues to operate as a significant cross-government collaborative initiative that defines clear responsibilities and accountability for shared outcomes to be delivered by lead agencies. SLIP has simplified access to the government's spatial information by better utilising current infrastructure, and adopting a whole-of-government approach in its development. Services are now in place, delivering the most up to date spatial information to consumers, ensuring data integrity by maintaining agency accountability.

Figure 16 **Value contributed by WALIS, per staff member, by sector**



Data source: ACIL Tasman

7.2.3 Case study – QSIIS

In 2004, the Queensland Spatial Information Council (QSIC) released a strategic plan – the Queensland Spatial Information Infrastructure Strategy (QSIIS)- to set the direction and provide coordination for the development of spatial information infrastructure.

QSIIS strategic objectives are:

1. promote the value and importance of spatial information in decision-making to senior level management in governments
2. promote and market the value importance and application of spatial information to industry and the community
3. ensure spatial data is available and maintained to specified data quality and coverage standards to meet business needs
4. provide standards, guidelines and procedures that support efficient data access for users across government and other sectors
5. develop cooperative arrangements and remove barriers to collaboration between organisations
6. promote development of single point of discovery and access for spatial data resources (initially for Sate government resources)
7. support the development of skills and capacity building in the application and use of spatial information .

Smart Service Queensland is the model for new initiatives in the delivery of spatial information and services such as through the Access Queensland and Information Queensland Data Network. Unfortunately, due to lack of a national licensing framework it is not yet possible to extend the full features of such a portal nationally.

The strategy has placed Queensland at the forefront of policy development and industry/government collaboration.

There is no economic assessment of the value of QSIIS to the economy. The authors of a 2004 report, Study of Spatial Imagery Use and Management in the Queensland Government, commissioned under by QSIIS, concluded the following in respect of the economic benefits of spatial imagery:

- that it was not possible to estimate the extent and cost of duplication of purchases of spatial imagery within the Queensland Government but that if purchases (and indeed production) were coordinated the benefits would include:
  - reduction in the costs of agencies purchasing the same data
  - improved access enabling improved government decision making and processes
  - encouragement of agencies to share information(QSIIS, 2004).

7.2.4 Case study – vegetation monitoring in Queensland

The Department of Natural Resources, Mines and Energy administers the Land Act 1994, Vegetation Management Act 1999 and the new provisions under the Vegetation Management and Other Legislation Amendment Bill 2004. This responsibility includes monitoring vegetation clearing throughout the state to determine whether it has been legally undertaken or not. In the event that clearing is illegal then court proceedings may ensue.

Medium resolution satellite imagery as well as aerial photography and on-site investigations, are used in evidence at these proceedings. The initial clearing assessments of the Statewide Land and Trees Study (SLATS) of NRME (completed using satellite imagery) are used to target potential illegal clearing. Imagery is acquired for dates that represent the condition of the cleared area both before and after the clearing event.

Experienced interpreters of spatial imagery present this evidence to the court. Remotely sensed imagery provides invaluable historical evidence of the presence of vegetation where it has later been cleared. On-site investigations are carried out for these cases. The condition of the site prior to clearing is harder to determine by field observations than by using remote sensed imagery.

The courts have already accepted satellite imagery as evidence. Remote sensed imagery reduces the amount of time spent by the court in determining these cases by presenting physical evidence of the clearing event. Using spatial imagery considerably enhances the preliminary investigations to a potential court case by targeting and by providing support materials (QSIIS, 2004).

7.2.5 Case study – SIX

In 2006, the Spatial Information eXchange (SIX) was launched in NSW. SIX is a cross government shared service initiative that enables common e-business functions required to support front-line government services, businesses and citizens to access spatial and related information in an on-line environment. SIX offers:

- Search and discover of spatial (location based) information. This includes options to search and display data using specialised viewers or through direct access via web service channels.
- Real time access to up-to-date government information. Key base data include: addresses, cadastre, topography and high resolution imagery. Secure access to spatial information, government registers and land and property related searches.

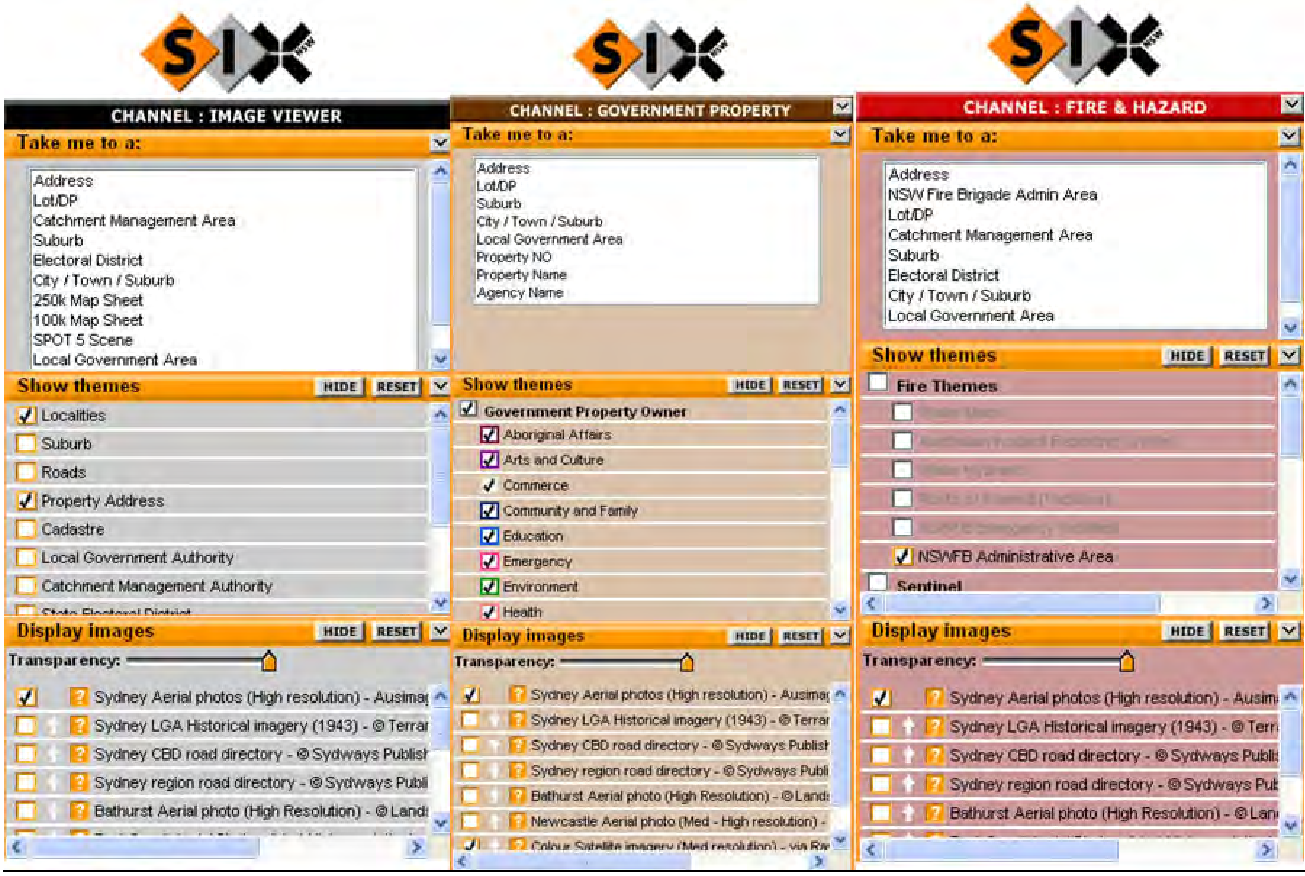
The Spatial Information eXchange provides fast and easy access to whole of government information including the latest land and property information, emergency services assets, maps, digital data and imagery across NSW.

SIX strategic objectives and benefits

The objectives and benefits of SIX are:

1. improved Information Access for agencies and citizens
2. improved Government Processes
3. better Socio-economic Outcomes through:
   - enhanced sharing and integration of spatial information across government, industry and the community
   - improved quality of decision-making and streamlined reaction times
   - improved management of community-supplied information
   - reduced government administrative effort and resources
   - improvement in data integrity, by accessing data directly
   - improved communication with the public and easier access for citizens to participate in government decision-making, and
   - increased inter-agency, agency to business and business to business collaboration.

Figure 17 **The SIX channels**



Data source: NSW Department of Lands

7.2.6 Impacts – State Governments

While there is no comprehensive assessment of the value of spatial data at the state level, the case studies and selected reports are evidence that spatial information is delivering significant benefits to the management and planning of government services at the State level.

7.3 Local government users

Spatial information is important and used widely throughout a council's operations to:

- develop asset registers
- collect income through rates and taxes
- create town-planning schemes
- assess development applications
- manage infrastructure such as roads and buildings
- coordinate council elections.

One of the prerequisites for spatial information management in local government involves the establishment and maintenance of a database of relevant information in digital format. Access to reliable and up-to-date information reduces the uncertainty in planning and management by helping identify, model and analyse situations and issues. The value of the information and the effectiveness of decision-making and planning processes are closely related to the quality and completeness of data and the manner in which it is made available.

Local governments are now making extensive use of mobile computing. Tablet personal computers have been used for many years in local government inspection applications. There is now an emerging use of personal digital assistants (PDA) to record data in the field.

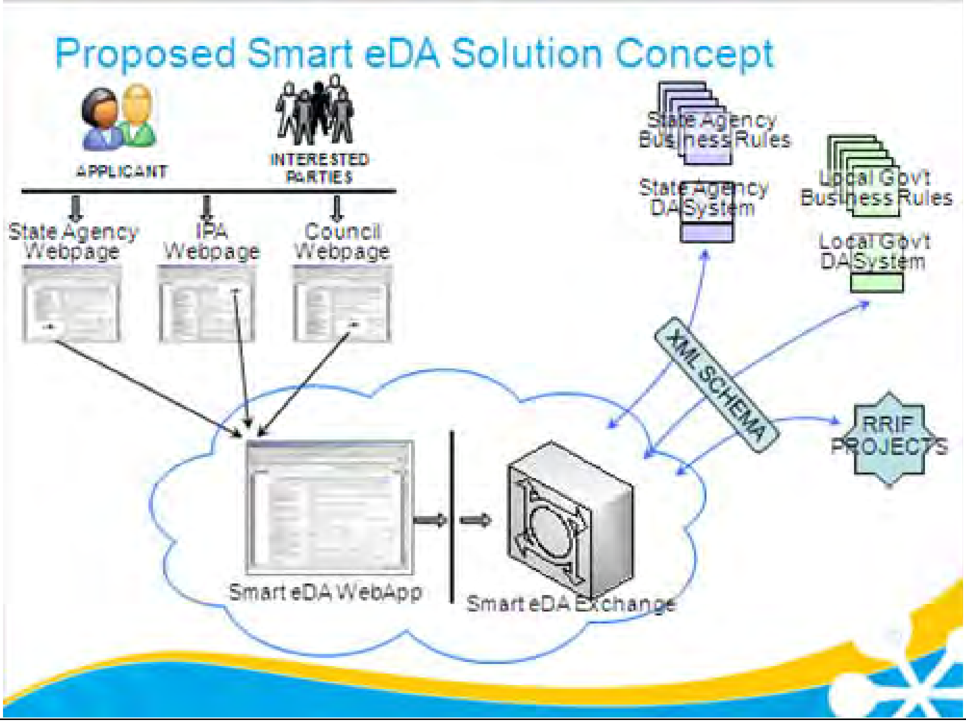
Electronic form filling and mapping software solutions enable the capture of field data directly into the computer, avoiding the need for double keying from paper forms and validating the data at the point of capture. Applications include highways maintenance, property inspection, tree and grounds inspection, environmental health and social services.

7.3.1 Case study – local government in Queensland

With the assistance of a grant provided by AusIndustry under the Regulation Reduction Incentive Fund, local governments in Queensland are implementing a spatially enabled development approval system. In essence, this project provides the online capability for small business to lodge their development applications across the internet and also to track the status of their application on a 24 hour by 7 day basis.

The structure of the system is illustrated in Figure 18.

Figure 18 **Spatially enabled development approvals in Queensland**



Data source: Local Government Association of Queensland

The electronic system is an example of the use of networked information systems using GIS, IT and communications technologies to reduce the time required and the staff needed for approvals.

A survey by the Local Government Association of Queensland, and information from other participating Queensland councils, indicates savings of around 10% from improved business processes. Ninety two councils are participating in the eDA programmes of which it is assumed that 50% are already generating cost savings.

The implementation of eDA programmes is taking place nationally, with take up high amongst the 160 or so larger and city councils, and it is expected to soon spread more widely across the total of 670 councils nationally.

7.3.2 Direct impacts – local government

The case studies undertaken for this report indicate that the largest benefits of spatial information systems is likely to be in local government of all the governments.

The Queensland local government case study revealed benefits in labour use efficiency, administration and process improvement and in asset management. It was estimated that for local government labour and process improvements had delivered a productivity improvement of 0.37% in one year based on the assessed savings in labour

This is a conservative estimate assuming 50% adoption across local government. If improvements in asset management and the use of mobile computing using spatial capabilities were included, a higher estimate of productivity improvement would be justified.

7.4 Natural resources management, environment and climate change

Management of our natural resources and environment are important to all governments in Australia. Responding and adapting to climate change is an increasingly important policy imperative. Spatial information plays an important role in monitoring, planning and regulating the sustainable use of natural resources.

7.4.1 Water resource management and markets

The National Water Initiative (NWI) is Australia's blueprint for national water reform. Central to the initiative is the development of water markets and trading. Water trading is one of the means by which available water resources will be reallocated amongst users, representing a fundamental shift away from the historic administered allocation arrangements. Trading may involve a reallocation of water within a sector, between sectors, or between communities. Just as governments have had responsibility for land title and property rights, so too will they now be administering water property.

For successful national water trading markets to develop, water registers and water accounting frameworks must be compatible across jurisdictions. Spatial information systems will play an important role in facilitating water accounting systems. There must be the potential to establish compatible registry systems to handle trade in entitlements within irrigation districts, between catchments and in some cases between jurisdictions.

Water accounting systems that support water trading will need to be updated frequently and include spatial information to record transfers between geographically dispersed sellers and buyers. These accounts will need to be reconciled periodically, with provision for independent auditing. Information will also be available to entitlement holders, who are also likely to want to reconcile it with their own spatially enabled data bases.

Similarly, spatial information will be crucial to managing government water purchases, including water procured for environmental purposes.

A recent high profile case in the Menindee Lakes area in NSW illustrated the significance of spatial information in monitoring and enforcing water property rights whether allocated to individual users or for environmental flows.

In the absence of being able to detect piping that was diverting water to adjoining properties, the authorities in NSW were unable to mount a successful prosecution. Using satellite imagery and other spatial information, the NSW Government can now act to prevent water theft.

7.4.2 Case study – National Land and Water Resources Audit

The Audit provides data, information and nationwide assessments of Australia's land, water, and biological resources to support sustainable development.

The sponsors of the Audit – ANZLIC and the National Heritage Trust – are developing a strategy for improving the Australian natural resources information infrastructure. As a result of this strategy, information will be easily accessed and integrated to support decision making for the sustainable management of Australia's water resources.

The Audit's key information delivery mechanisms are the:

- Australian Natural Resources Atlas
- Australian Natural Resources Data Library
- Australian Natural resources Atlas.

The Australian Natural Resources Atlas is an internet-based 'one-stop-shop' for data, maps, information and links to related sites. The Atlas is organised by subject and geography.

For example, the Australian Water Resources Assessment 2000 data and information are available in a hierarchy, from Australia-wide to drainage divisions to basins to individual stream gauging stations or bore monitoring sites. Further, the water resources assessment is linked to information collected as part of the other Audit assessments. These data can be combined to produce user defined maps.

The Audit plays an important role in working with the Australian Government, and all states and territories, to report on the condition of Australia's land, water and biological resources.

The Audit's strategy aims to maximise the return on the investment in natural resource management, including through promoting the development of linked natural resource management data and information systems.

The Audit hosts a number of activities to support and progress the implementation of an Australian Natural Resource Information Infrastructure (ANRII) including:

- discussion papers
- and workshops and meetings
- NRM community agreed application schemes.

A key component of achieving natural resource information systems interoperability will be the development of NRM community agreed application schemas. A small technical group is progressing this for a limited number of key natural resource information products.

The Audit provides free access to Atlas data which is downloaded from the internet. It support research and development and policy planning and formulation in relation to water resources, biodiversity, salinity, vegetation and a framework for monitoring Australia's water and land resources in a structured way. The benefits of the Audit are realised through better policy and planning and as a result improved economic, social and environmental outcomes.

It was not possible to quantify these values for this report. However the benefits are significant given the challenges of addressing the over-allocation of some of Australia's water resources, the challenges of drought and climate change and achieving sustainable natural resource management outcomes.

7.4.3 Climate change

Spatial information is being used in several contexts in formulating and implementing policy on climate change.

Spatial information is particularly important to the Australian Government's $126 million project to establish the Australian Centre for Climate Change Adaptation. The centre's work will assist those most affected by climate change, such as farmers, businesses and local governments to better understand climate change and its impact and how to develop responses to it.

It is also proposed to develop a national digital elevation model for Australia as part of the National Climate Change Adaptation Framework. This model will not only map the whole country but also provide a very high resolution imagery of those areas particularly at risk from climate change as well as for disaster mitigation and environmental monitoring.

Finally, spatial information is and will be used in emissions monitoring and in carbon trading. Spatial information technology has emerged in time for Australia to develop a national carbon accounting system. This system is to greenhouse gases and emissions trading what the national accounts are to the management of the national economy. Accurate emission data are needed to plan for optimal greenhouse and natural resource management outcomes.

7.4.4 Case study – National Carbon Accounting System

The NCAS combines satellite imagery with models and data to provide a 30-year dynamic account of greenhouse emissions across the continent. The system is used to:

- determine Australia's land-based sources and sinks
- track progress towards national emissions targets
- inform policies and programmes in vegetation and land management.

The system relies on spatial information systems to achieve its objectives.

- It tracks greenhouse gas sources and sinks from the land. Land-based sources and sinks are of key interest to Australia, forming around 30% of the national emissions profile from activities such as land clearing, cropping, grazing and forestry.
- The tools enable the recording of climate relevant surface data for assessing the net change in vegetation over time, the impact on vegetation of water flows and undertaking analysis for the purpose of making projections and reporting results.

The main thrust of the project is to optimally identify woody vegetation, defined as greater than 2 metres tall and 20% canopy cover and change to woody vegetation via land clearing and regrowth over the entire continent of Australia (i.e. identify woody versus non-woody cover). This is achieved through the use of Landsat imagery, which spans the era from 1972 to 2004 for this project.

Developed through extensive collaboration with scientists, policy makers and industry professionals, the NCAS combines satellite imagery with models and data to provide a 30-year dynamic account across the Australian continent.

- GEOIMAGE has been heavily involved in the technical aspects of this project from its inception in 2000, working closely with the AGO and CSIRO and a range of private sector groups.
- Landsat imagery covering the entire continent of Australia was chosen for each epoch. Landsat MSS imagery (with 80m pixels) was used for epochs before 1984 and Landsat TM and ETM+ imagery has been used for more recent epochs.
- Thirteen different years, or epochs, were identified for the mapping. These range from 1972, through 1977 to 2000, 2002 and 2004.
- Areas of cloud and fire scars were clipped out and the imagery ortho rectified to a base set, which was decided as the 2000 epoch. Accuracy was

very important when ortho rectifying because each pixel needed to be compared to its corresponding pixel from each different epoch. The imagery was then calibrated to a base year (2000) to ensure consistent pixel index values because images captured at different times, such as in different seasons would produce different pixel reflectance values.

CSIRO created a conditional probability method using Landsat imagery which predicts the probability of a set vegetation type occurring for each pixel. This is achieved by calculating the best Landsat band combination for a certain zone for a certain vegetation type. This is then plotted against the second best combination for each scene and a threshold value is calculated. These threshold values or indices for each vegetation type in each zone within Australia are the probability of each pixel of being classed as woody vegetation. Therefore, each pixel from each year is classed as a percentage of being either woody or non-woody vegetation. A computer interpolation programme predicts the probabilities for the years in between the epochs used.

For example, if a pixel has a high (90%) probability of being woody vegetation during the 1972, 1975 and 1977 epochs but, in 1979, the probability is classed as 10%, the interpretation is that clearing occurred between 1977 and 1979.

The results of the monitoring and projections can be presented in a GIS format to record data spatially. The system assembles the data in a single data base ensuring total duplication of data for different users and different reporting systems.

NCAS is fundamental to Australia's response to climate change. It is instrumental in ensuring that Australia can report that it is complying with the Kyoto Targets and meeting the requirements of Parts 3.3 and 3.7 of the Kyoto Protocol. It follows that it will be fundamental to a future carbon trading scheme.

7.4.5 Impacts

The challenges facing the nation – sustainable management of water, soils and addressing climate change- are significant factors in our future economic well-being. The impact on the economy and the environment if they are not managed well are likely to be significant.

Spatial information systems are fundamental to managing our natural resources. The value they offer lies in the value of the options they preserve for Australian society in sustainable use of our natural resources and in the economic benefit that will be drawn from them.

This has not been measured. However, the case studies reveal a potentially very high value that will be derived from spatial information in facilitating the efficient operation of water and carbon markets in future.

A study undertaken by the Water Services Association showed for example that water trading would make a major contribution to reducing the requirement for future water storages and infrastructure necessary to meet the demands that industries and urban centres would make on water resources (ACIL Tasman, 2007).

It is difficult to quantify the economic benefits delivered by the National Carbon Accounting Scheme. Benefits are both in meeting international obligations, better implementation of policies for sequestration of carbon and reduced environmental damage associated with emissions of carbon dioxide and other greenhouse gases.

In terms of overall reduction in greenhouse gas emissions, the value of reducing emissions to 108 per cent of Australia's 1990 emission levels by 2010 (Australia's Kyoto target) would be around $1.4 billion at a carbon price of $15 per tonne CO_2-e. NCAS will provide significant support towards monitoring and reducing net emissions of green house gases.

The value of the NCAS contribution to the Australian economy will rise exponentially as the world moves to greenhouse gas emissions trading and trends over time in the price per tonne of emissions rises.

7.5 Biosecurity

Protecting Australia's biosecurity is one of the nation's highest priorities. The costs of incursions of exotic diseases and invasive plants and species can be very high. Invasive species are costing Australia billions of dollars annually mainly in terms of costs of control and the value of lost production.

- Pests and diseases, such as the Asian Gypsy Moth and eucalyptus rust, would not only affect commercial enterprises but also have severe consequences for natural ecosystems.
- An outbreak of a new zoonotic disease, such as Nipah virus or highly virulent avian influenza, in Australia would have serious effects on the broader economy including health, education, hospitality, travel and tourism and business investment.
- An outbreak of Foot and Mouth Disease (FMD) or Bovine Spongiform Encephalopathy (BSE) would have devastating effects on trade in livestock products, with economic effects in excess of $10 billion (Productivity Commission, 2002).

- A study of the regional economic impact of a Karnal blunt wheat incursion in Western Australia estimated a reduction in GDP of 0.02% or around $0.2 billion (Wittwer, 2006).

According to the Department of Agriculture Fisheries and Forestry:

- Estimated costs of control and the value of production foregone for plant diseases and invertebrate pests of plants is at least $0.7 billion and as high as $2 billion per annum.
- For animal diseases and invertebrate pests of animals the estimate is at least $1.2 billion per annum.
- The economic impact of weeds and the main vertebrate pest animals already established in Australia has been calculated at approximately $4 billion and $0.7 billion per annum respectively. (These figures primarily represent production losses and control costs, as the cost of weeds to the environment and biodiversity is largely incalculable.)
- Invasive species are now identified as the greatest threat to Australian biodiversity after habitat loss.
- The total cost of control and the value of production is estimated to be around $8 billion per year (Agrtrans Research, 2005).

Australian Government and the State governments jointly manage monitoring and control programmes to protect Australia from incursions of exotic pests and diseases. There are many elements to these activities including quarantine inspections, monitoring, mitigation programmes and emergency response plans.

Agriculture emergency management involves well established coordination arrangements and pre prepared plans including AUSVETPLAN, PLANT PLAN, and AQUAVETPLAN. Increasingly coordination and planning arrangements draw on spatial information systems to research, plan, control and mitigate the impacts of incursions when they occur.

7.5.1 Case study – controlling foot and mouth disease

Foot and mouth disease (FMD) is a virus that attacks farm animals such as cattle, pigs, sheep etc. It kills young animals and reduces livestock productivity. Although it has been found to have no health impact on humans, an outbreak of FMD could have large trade effects, especially on Australia's meat export to FMD-free countries such as Japan and the United States of America.

In 2001, the UK experienced an outbreak of FMD, which affected more than 2000 farms and resulted in the culling of more than 6 million animals. The direct cost to the economy was estimated at more than £8 billion.

In 2002, the Productivity Commission estimated the impact of an FMD outbreak in Australia (Productivity Commission, 2002). The main impact (based on a 12 month outbreak scenario) included:

- revenue loss to the livestock industry (especially the beef industry) of about $12.8 billion (NPV based on a 10 year timeframe)
- the cumulative impact on Australian GDP in the first year of the outbreak alone would be between $2 billion to $13 billion depending on the length of the outbreak. Other effects included employment, tourism, social and environmental impacts.

Spatial models are used to prepare Australia for any impact of an FMD outbreak and to avoid a similar impact on the Australian economy. Such models incorporate spatial attributes, such as farm locations, into their computation and provide high quality outputs useful for disease control exercises.

The main benefits of spatial models over other non-spatial models in reducing the impact of an FMD outbreak include:

- retrospective analysis of past FMD outbreaks
- exploring strategies to reduce the impact of FMD in different outbreak scenarios
- assessing resource needs in different outbreak scenarios
- assessing high risk prone areas and production systems in the event of an outbreak
- evaluating effectiveness of monitoring and control strategies
- providing exercises and training before an actual outbreak.

An Australian example of a spatial model used for reducing the impact of an FMD outbreak is AusSpread which is a regional spatial simulation model, designed by the Department of Agriculture, Forestry and Fisheries (DAFF) in 2004, that operates within a GIS framework. The data sets include real farm boundary or point-location data based on agricultural census and land use information. It represents different species and production systems, which allow the Department to follow targeted mitigation strategies in the event of an FMD outbreak. Strategies in the model are based on the AUSVETPLAN[4] for FMD. Outputs include outbreak parameters/settings, outbreak maps and outbreak costs/statistics[5].

---

[4] http://www.animalhealthaustralia.com.au/programmes/eadp/ausvetplan_home.cfm

[5] http://www.epicentre.massey.ac.nz/acvsc/scwk_05/Beckett_FMD_modelling.pdf

Although there is no indication of the economic impact of using spatial models to reduce the impact of an FMD outbreak, it is clear from the Productivity Commission's estimates that reducing even 5% of the costs of an outbreak using effective mitigation strategies through spatial modelling could save several millions of dollars for the livestock industry and the wider Australian economy.

The Australian Biosecurity Collaborative Research Centre for Emerging Diseases has on its research agenda, plans to develop new decision support tools using spatial modelling to better manage an FMD outbreak under different scenarios.

7.5.2 Case study – Australian Plague Locust Commission

Locusts have the potential to inflict large economic losses on Australia's rural industries in the eastern states. A key element of locust control involves being able to identify the conditions under which locust swarms are likely to occur and then being able to track the movement of a swarm once it has formed, so that airborne response teams can locate the swarms and deposit pesticides in the right place. GIS systems form a vital component of such activity. GIS systems are also used in identifying landowners in the areas adjacent to where locust control activities are taking place so that any dangers or costs of locust control on third parties can be avoided.

The Australian Plague Locust Commission's (APLC) strategy for locust control is based on the ability to detect populations of locusts early. The APLC operates a GIS based decision support system (DSS) to assist in locust control operations. The system is used to co-ordinate the collection, processing and display of spatial information which is used to forecast locust populations. The detection of outbreaks is aided by the availability of environmental and weather data which allows the system to identify likely sources of outbreaks and allows for preventive action.

In November 2005, ABARE completed a cost-benefit analysis for the APLC. This found that whilst APLC expenditure on locust control operations amounted to $6.8 million in 2004-05, the value of potential crop losses avoided due to these control operations was $55.5 million. Over the 6 years to 2004-05, APLC expenditure averaged $4.5 million per annum, with average avoided losses of $29 million.

Given the importance of the spatial data component in the APLC locust control operations, it would appear reasonable to attribute some of these savings to spatial information technology. DAFF has estimated that the proportion of benefits that are due to the use of spatial technology as a result of the improvement in forecasting, early detection and planning might be about 20%.

However, if one considers that there are regulatory requirements to notify farmers of control activity and other requirements to forbidding control activity on or near organic farms or conservation reserves, it becomes clear that it would be now be virtually impossible for the APLC to conduct its current level of control activities without spatial information.

This simply illustrates the extent to which control of pests and diseases is now dependent on the use of spatial information systems to ensure that the threat to Australian agriculture from pests and diseases is properly managed.

7.5.3 Future developments – BioSIRT

In 2006 the Primary Industries Ministerial Council agreed to develop a spatially enabled Biosecurity, Surveillance, Incidence Response and Tracing application (BioSIRT). Elements of the program are already in application in some states but the total package not expected to be completed until the first half of 2008. A key objective of the program is to achieve consistency and inter-operability between jurisdictions (Spatial Vision, 2006).

BioSIRT will:

- reduce the time taken for incidence response
- support ongoing monitoring of disease status
- reduce duplication between jurisdictions in data management and response planning.

While there has been little public information on the expected impact of BioSIRT, the contribution of spatial information to the management of response plans is understood to be very significant in the light of the annual cost of control and reduced production referred to above and in the cost of disease outbreaks such as occurred with equine influenza in late 2007(*pers comm* DAFF).

7.5.4 Impact

There has been some research into the economics of plant and animal disease outbreaks but it is not sufficient to draw conclusions on the aggregate economic impact of biosecurity programs – and the likely contribution of spatial information.

The economic impact of spatial information is twofold:

- reducing the costs of managing the biosecurity programmes
- reducing duplication in data management

- contributing to reducing the average annual damage from disease incursions.

Both case studies showed how spatial systems support management programmes for monitoring and responding to threats. They are important elements of the operating systems. The benefits from biosecurity programmes are very high in terms of damage avoided and in maintaining the quantity and quality of Australia's agricultural production and exports.

The case studies showed, for example, that the 'net' annual value of the activities of the Australian Plague Locust Commission was in the region of $25 million and we estimated in this case study that the contribution of spatial information was worth at least $5 million each year.

There are up to 20 exotic diseases or major concern to Australian agriculture producers. There is no estimate of the annual value of biosecurity control programs in terms of reducing the expected annual damage of incursions of pests and diseases. However noting the magnitude of the potential damage, it is possible that this might be in the order of one or two billion dollars.

If this were the case, and using the case studies as an indicator of the role of spatial information in control strategies, it is possible that the contribution spatial information to reducing the expected damage could potentially be in the hundreds of millions of dollars (one estimate suggested an order of magnitude of around $400 million based on the expected the potential economic loss from disease outbreaks and in reduction in annual control costs and lost production). The implementation of BioSIRT will provide the framework to fully realise the potential of spatial information in disease control strategies.

7.6 Defence and national security

The Defence Imagery and Geospatial Organisation (DIGO) was established in November 2001 to provide geospatial intelligence in support of Australia's defence and national interests. This includes production of maps and charts, foundation data, integrated products, visualisation and simulation. Geographic information, including administrative boundaries, telecommunication facilities and radar visibility analysis and thematic subjects including illegal immigration, illegal fishing and maritime boundaries, are generated over a number of countries and regions.

A goal for the organisation is to transfer all mapping operations to digital technology. The aim of having a fully integrated, automated defence mapping capability is imperative to meet the ever-increasing needs for digital geospatial products. The weapon systems to be used in the field depend upon accurate and current digital data which will meet fast evolving standards being developed by the international defence geomatics community.

7.6.1 Counterterrorism

Counter terrorism is also relies heavily on spatial information systems. A National Spatial Information Management Working Group (NSIM) was established in March 2007 to enhance decision support capabilities through access and use of information, including spatial information.

NSIM released a strategic plan in September 2007 to support critical infrastructure protection (CIP), counter-terrorism (CT) and emergency management (EM) within and between the Australian Government, states and territories and local government. The plan encompasses prevention, preparedness, response and recovery (PPRR) and draws heavily on the use of spatial information for its implementation.

The goals for the strategy, to be achieved by 2010, are:

- national spatial capability to support decision making
- easy national access
- high awareness and demonstrated use
- interoperable and integrated systems and information
- agreed data standards and access protocols
- national all hazards governance process.

The Strategy also requires that in future, investments in spatial systems will require the preparation of a business case to assess the costs and benefits of each investment and identify the most optimal outcomes. Over time this will provide information about the economic and social impacts of such investments.

7.6.2 Emergency management

Changes in the geopolitical environment and increasing concern about critical infrastructure and continuity of supply of essential services have created increased pressure on governments to develop consistent policies and coordination mechanisms for emergency management. Spatial information systems and technologies are playing an increasingly important role in developing more effective response mechanisms at all levels of government.

The release of the 2002 Council of Australian Governments (COAG) Report *Natural Disasters in Australia: Reforming mitigation, relief and recovery arrangements*, coupled with the increasing emphasis on the development of emergency management plans and policy in relation to counter terrorism, has added to this impetus for greater cohesion across and within jurisdictions.

In emergency services, information about the location of an incident (e.g. an accident or a crime) is often critical in determining the manner and size of the response. Spatial information and GIS assists in effectively planning for emergency response, determining mitigation priorities, analysing historical events, and predicting future events. In Western Australia, SLIP provides one example, by enabling the development of the tools and services needed to better support the operational needs of WA's emergency management sector.

It is estimated that the use of global positioning systems alone has reduced emergency response times by 20% (House of Representatives Standing Committee on Transport and Regional Services, 2002).

This consideration also includes protecting critical infrastructure, national security, strategic defence and counter-terrorism and response planning and implementation for bushfires, floods and earthquakes, all activities which can be enhanced through the use of spatial information. Many of the benefits articulated in the discussion of other industries are also applicable to what different levels of government do.

The Australian Emergency Management Committee (see Box 7) comprises Australian Government and state departments and agencies who meet to coordinate emergency policy and programmes between the three levels of government.

Box 7 **Australian Emergency Management Committee**

Australian Emergency Management Committee (AEMC)

National agencies

Emergency Management Australia *(EMA)*

Geoscience Australia *(GA)*

Department of Transport and Regional Services *(DOTARS)*

Australian Bureau of Statistics (ABS)

Jurisdictional representatives

NSW Fire Brigades

Vic Office of the Emergency Services Commissioner

Qld Department of Emergency Services

Fire and Emergency Services Authority of WA (FESA)

SA Fire and Emergency Services Commission (SAFECOM)

ACT Emergency Services Authority

NT Department of Police, Fire and Emergency Services

Industry bodies or other groups

Australasian Fire Authorities Council (AFAC)

Australian Council of State Emergency Services (ACSES)

Emergency Management Working Group (EMWG) for the Steering Committee for the Review of Commonwealth/ State Service Provision (SCRCSSP)

Non-attending members

Australian Local Government Association *(ALGA)*

Council of Ambulance Authorities *(CAA)**

Wider emergency management community

Data source: Attorney General's Department

Emergency management is moving from a response only approach to one based on to disaster mitigation. Spatial information has a key role to play in implementing this change.

7.6.3 Impact

Spatial information technologies have become one of the cornerstones in responding to threats and terrorism.

The economic and social impacts of these technologies are in avoided costs of terrorism and natural disaster events and in the broader benefits of national security for the community at large.

It is evident that spatial information systems deliver significant productivity benefits to the administration and management of anti terrorism activities, emergency management and in the conduct of Australia's defence programs.

The value of safety and security is however likely to be significantly higher than the productivity impacts on administration and management. It was not possible to quantify these impacts for this report.

7.7 Maritime and air safety

Safety at sea and in the air is a high priority for Australians and for the marine environment. Air navigation safety is discussed in Section 6.6. This section discusses maritime safety and search and rescue.

The Australian Maritime Safety Authority is responsible for safety, marine environment protection and maritime and aviation search and rescue. As part of its charter it provides services and support to the marine industry for navigation aids and navigation safety, management of pollution from oil spills and search and rescue activities.

The International Convention for Safety of Life at Sea (SOLAS) includes a requirement for all ships to carry to up-to-date nautical charts and publications for the intended voyage. Under SOLAS, this carriage requirement may be satisfied fully or partly by electronic means.

The use of electronic chart systems (ECS) and electronic display information systems (ECDIS) is increasingly being adopted for navigation purposes. They provide higher levels of integration of bathymetric data, satellite positioning and other information for safer navigation at sea.

A recent review of carriage requirements stated:

> In December 2006 the Marine Safety Committee (MSC) of the International Maritime Organisation agreed amendments to the High Speed Craft (HSC) regulations requiring all HSC craft built after 2008 to be fitted with ECDIS and existing HSC to be retrofitted by 2010.
>
> At the same meeting MSC also accepted the findings of a Formal Safety Assessment (FSA) on ECDIS presented by Norway and other nations showing the positive benefit of fitting ECDIS. As a result of this study MSC has instructed the NAV sub-committee to discuss the extension of mandatory carriage of ECDIS to other classes of vessel and to report back to them in 2008 (Primar Stavenger, 2007).

By 2010 spatial information is likely to find more widespread applications in bridge and maritime navigation systems. GPS and DGPS have been part of this framework since around 1990, allowing the rationalisation of terrestrial navigation aids and more efficient ship operations and lower fuel use.

7.7.1 Case study – Australian Maritime Safety Authority

The Australian Maritime Safety Authority is an Australian Government agency responsible for the delivery of safety and navigation services to the Australian maritime industry and to the delivery of search and rescue services to marine and aviation industries.

AMSA has been a leader in the application of geographic information and global positioning systems to undertake its task. There are three activities that depend heavily on these systems:

- search and rescue (SAR)
- navigation aids and safety
- oil spill response plans.

These activities highlight the importance of spatial information systems to AMSA. These systems allow more rapid and accurate operational responses than were viable with paper-based practices and allow a greater capacity to accommodate high transient workloads within operational budgets. Improvements affect both efficiency and effectiveness.

Australia's Search and Rescue region is one of the largest in the world, covering approximately one tenth of the earth's surface. **AMSA** operates an Emergency Response Centre (ERC) which includes the globally recognised entity of "Rescue Coordination Centre Australia" (RCC). The centre is staffed 24-hours by search and rescue specialists with naval, merchant marine, air force, civil aviation or police service backgrounds. It is supplemented with additional staff for other emergency response operations as necessary.

AMSA requires spatial information systems that cover and manage all incidents from the ERC. The strategic vision of the system is to integrate operational practices, communications and statistical data collection for all types of emergency response operations into a single flexible and effective application. System development is based on requirements for search and rescue support.

This has been achieved through the implementation of a GIS comprising ArcGIS Desktop interface ArcMap and spatial database portal ArcSDE, enabling **AMSA** to manage incidents through the use of online maps and spatially based functions. A Common User Interface (CUI) forms the hub of all work processes within the system, allowing the operator to display information as required using ArcMap, access the specialist sub-systems and receive and send all messages from a single location.

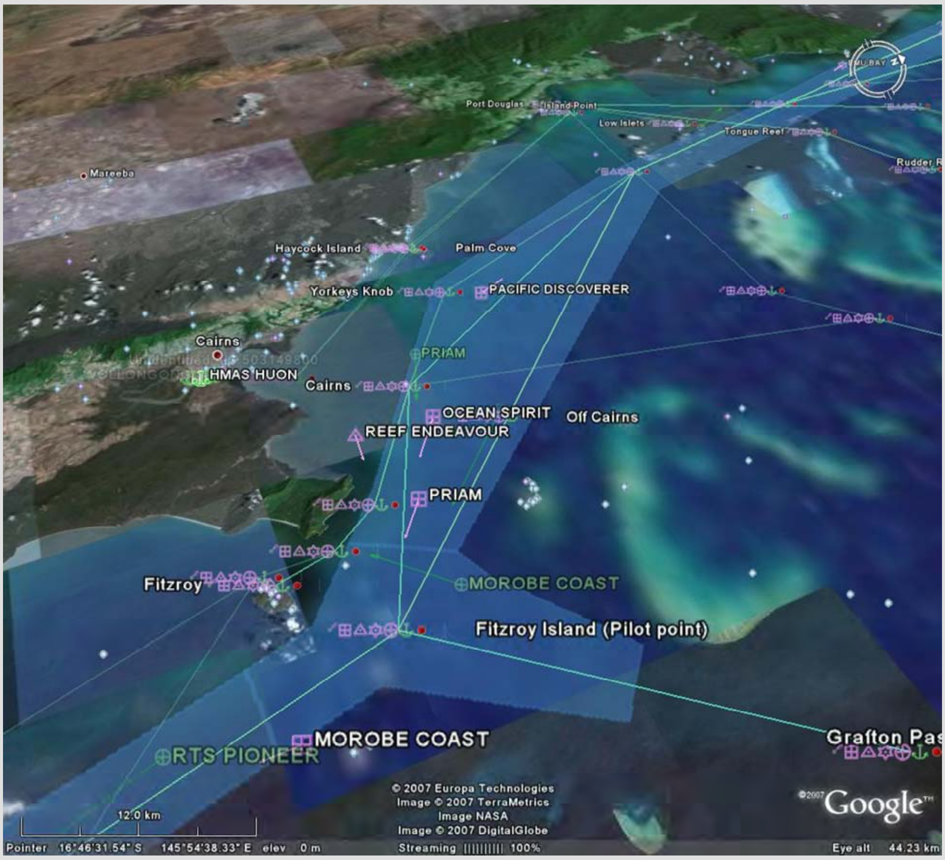
Improved data from corporate holdings is managed using ArcSDE and online links to the Bureau of Meteorology, Airservices Australia and CSIRO are now included. A framework of security, audit, incident tracking and information capture for reporting is also built into the system.

AMSA has paid particular attention to enabling common user access to the system and common displays of system-sourced operational information. This enables the RCC staff on duty to act as an effective team on the one incident and for all staff to access the common picture of events. Business continuity is assured through backup arrangements at a Disaster Recovery Facility.

The application includes the ability to cross reference incident events by location and time using an incident timeline display. This allows operational staff to better relate the large amount of intelligence reports received during an incident. "On-line incident" will see the delivery of incident information to other SAR units via the internet, improving the quality and timeliness of information sharing.

AMSA has also integrated its ship reporting system data with Google Earth to provide a flexible mapping tool to monitor ship movements in the Barrier Reef. This illustrates of how spatial information systems can be integrated into other applications and business systems (see Box 8).

Box 8 **Vessel tracking**



The combination of the Automatic Ship Identification with Google earth is an example of innovation in applications of spatial information.

Data source: AMSA

The integrated GIS have further enhanced AMSA's world-class search and rescue responsiveness to aviation and maritime incidents in and around Australia. This has been achieved through better management of peak workloads, coordinated dissemination of information to internal and external organisations, the reduction of risk through edit checks and visualisation, and a more effective audit trail.

AMSA staff noted that the time taken to brief six aircraft for a major search has reduced from around an hour to approximately fifteen minutes. This improvement allows for more rapid search initiation and also for greater flexibility in adapting search activity already in progress.

It has also provided a rich opportunity for developing other information to improve understanding of shipping routes, plan the placement of navigation aids and monitor movements of vessels in environmentally sensitive areas such as the Great Barrier Reef and Torres Strait.

7.7.2 Case study – Australian Hydrographic Service

The Australian Hydrographic Service (AHS) maintains the national hydrographic data collection. This collection has been created from the accumulation of charts, surveys and other related information used in providing the national navigation chart series:

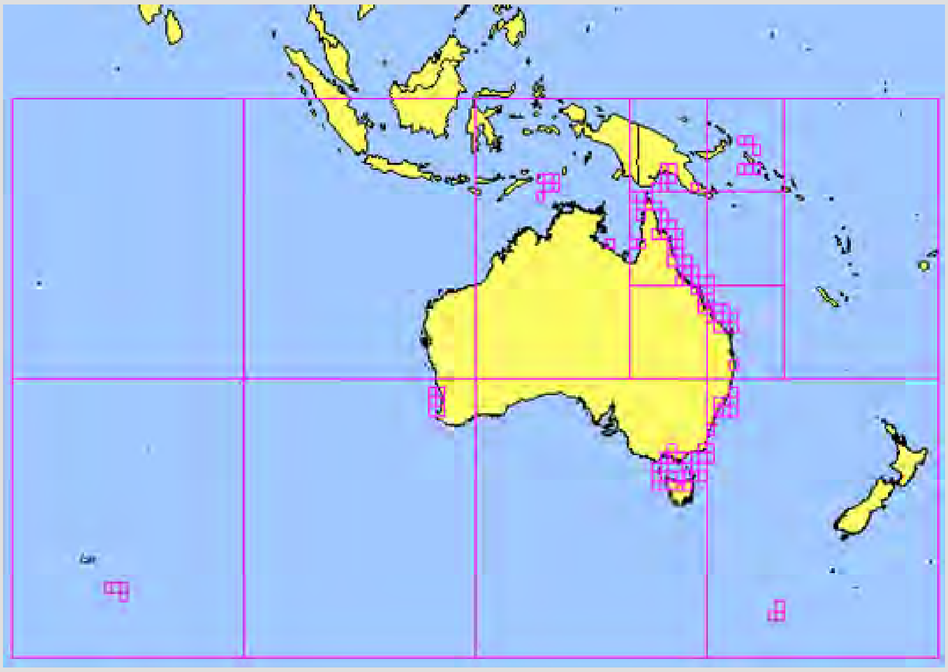
- depth data
- maritime boundaries
- names
- navigational marks, lights and buoyage
- tides and tidal streams
- wrecks.

Records include copies of original Admiralty surveys, some dating back to the 19th century, together with all RAN surveys and numerous other plans, reports and documents which have been used in the creation of Australian navigation charts.

The AHS is now developing electronic charts to meet these emerging requirements. Under the SEA 1430 programme, the service is building a digital hydrographic data base. The data base is spatially enabled and provides work and data control and military geospatial information.

There is no information publicly available to assess the impact on efficiency of the service or shipping. However it is evident that the system is providing a wider array of more accurate data for which updating charts and controlling the input of new data is far more efficient than with paper charts.

Box 9 **Electronic Navigation Charts in Australian Waters**



The coverage of electronic charts currently available in Australian waters and adjacent waters is expanding with work by the Australian Hydrological Service. Spatial information systems are supporting this work to build a digital hydrographic data base.

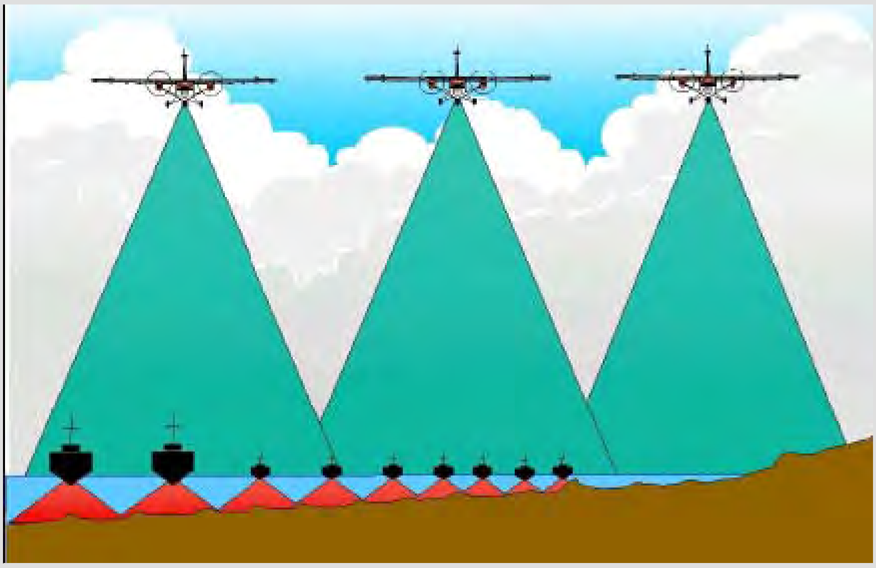
Data source*: Australian Hydrological Service*

7.7.3 Innovation in bathymetry

Significant advances have been achieved in the use of Airborne laser (LIDAR) bathymetry (ALB). ALB is a technique for measuring the depths of relatively shallow, coastal waters from the air using a scanning, pulsed laser beam. It is also referred to as airborne LIDAR hydrography (ALH) when used primarily for nautical charting

ALH provides significant productivity improvements for mapping coastal waters such as in the Great Barrier Reef. It significantly increases the scale and scope of bathymetric mapping with clear advantages in safer navigation and more effective management of navigation in marine parks and sensitive environmental areas.

Box 10 **Airborne LIDAR Hydrography**



Airborne LIDAR techniques are delivering productivity gains that increase the scale and scope of bathymetric mapping. Integration of such outputs with digital charts and satellite positioning is creating powerful new products for navigation safety and protection of the marine environment.

Data source: (Guenther, 2000)

7.7.4 Impact

There is strong evidence that spatial information is delivering benefits to the marine sector and to search and rescue areas of government. Improvements in productivity from electronic charts and accurate positioning are clearly providing productivity improvements to AMSA and the AHS although quantification of these impacts is not possible for this report.

There is little doubt that the value in reducing damage and loss from emergencies and search and rescue is significant. The reduction in time to brief search and rescue planes from 1 hour to between 3 and 15 minutes would have significant benefits in increasing the probability of finding those lost at sea and reducing search costs.

7.8 Health and ageing

Spatial information is important to a number of health research and policy questions. Spatial epidemiology is an emerging field of research in which spatial methods have enabled progress be made in the precision of exposure estimation. In epidemiological modelling, spatial information also helps control for confounding and modifying variables across various study populations. It should be noted that the impact of spatial information on ultimate health outcomes will come at a significant lag, as findings from R&D need to be validated and incorporated into health practice; and adoption and implementation of new types of health management regimes can often be fraught with difficulties and delays. The impact of spatial technology in this area is therefore best seen as an extremely long term impact.

A key area in which spatial information and new spatial technologies such as GIS have potential impact are better control of spread of disease. Medical entomology research focussing on mosquitoes in the Northern Territory may yield some longer term benefits in controlling disease outbreaks there. Spatial information is also central to more accurate research of the impact of air pollution across urban populations in particular. Some impact modelling has been carried out at the National Centre for Epidemiology and Population Health which shows anticipated changes in the regional distribution of disease, particularly as a consequence of climate change. Another area of research focuses on spatial correlation and clustering, although almost all instances in which disease clusters have previously been suspected have subsequently been attributed to chance.

Finally, there is some scope for using location information to improve health care administration, for example in predictive modelling of funding requirements by area; and health infrastructure requirements assessment and planning for future capital works such as new hospitals; and in operational matters in relation to asset management.

7.8.1 Case study – asthma

As a case in point one might take the costs of asthma, in which it may be possible that more accurate spatial information may help resolve some outstanding research questions (e.g. links with air pollution and other possible factors such as childhood exposure to swimming pools).

The Australian Institute of Health and Welfare's latest *Burden of Disease and Injury* report shows that 4,045 years of life (YLL) were lost to asthma in 2003 – this is due to premature deaths attributed to the disease – in addition to the 59,054 years of life with disability (YLD) attributable to asthma in 2003. Even a conservative valuation of $150,000 per YLL and $50,000 per YLD would put the total loss to Australia due to asthma alone at $3.6 billion in 2003.

Any intervention or measure that could claim, say, a 10% reduction in these figures would therefore be worth at least $370 million per year. Considering that asthma accounted for only 0.3% of YLLs and 4.4% of YLDs in 2003, the potential value of improving health outcomes in general is therefore very high.

7.8.2 Health incident monitoring

The Tropical Public Health Unit (TPHU) within Queensland Health has responsibility for implementing strategies to protect the public health of North Queensland from Sarina to the Torres Strait, in total covering just over 750,000 km^2.

The TPHU has used spatial technologies and imagery for the last 5 years and have been able to derive great efficiencies by altering existing practice to incorporate some of the products that are available in the spatial information marketplace. TPHU primarily use aerial photography to determine the likelihood of potential malarial mosquito breeding habitat near malaria cases. Another emerging use of spatial imagery has been with Environmental Health Officers administering Strychnine permit applications.

For malaria case notifications, the benefits of Queensland Health's application of spatial imagery are reductions in the numbers of field inspections and field studies. The reduction in case responses has meant that travel, dry ice and Octenol requirements have all been reduced significantly and this has also freed up time for dengue fever control efforts. Each response not required would save Queensland Health over $1,000 per response.

The benefits of using spatial imagery for the strychnine assessment process have been far more wide-reaching, as ground verification of applications was time consuming and arbitrary at best and, as such, frequently did not occur. Spatial imagery has been essential to demonstrate the dangers of strychnine use within the communities and assisted in preventing the misapplication of strychnine, which could lead to potentially fatal consequences (QSIIS, 2004).

7.8.3 Impacts

As with other areas, spatial information systems are increasing the efficiency of epidemiology with benefits in terms of reducing the incidence or impact of disease. This will reduce the social and economic costs of illness and reduce the demands on our medical facilities, including hospitals and clinics. As the Queensland Health study showed, it helped to produce savings in dengue fever control in northern Australia.

The economic impact lies in these reduced costs. It has not been systematically assessed across the health spectrum.

7.9 Direct impacts for Government

There is little doubt that spatial information systems have enabled governments to deliver services more cost effectively and efficiently than in the past. As was shown in earlier in this chapter, the economic value of these services can be significant.

There is significant potential for greater value to be realised from the use of spatial data in government. The case studies and examples reveal the potential for faster and more efficient regulatory approvals for land development, infrastructure and facilities construction and for planning of government services at all levels.

A key impact on government to date is in the more efficient delivery of services to business and the community. The 2002 study by the National Office for the Information Economy for AGIMO referred to in Section 7.1.1 showed that of the agencies surveyed, 67% expected to reduce costs significantly due to improved business processes through e- business and a further 64% expected to reduce staff costs and other direct costs. This provides some guide to what is likely to be emerging for spatial technologies which are associated with e government.

In estimating impact on government for the modelling we focussed only on productivity improvements that spatial information delivered in 2006-07. From our case studies it was estimated that the potential productivity improvement that could be attributed to spatial information was between 5% and 20% in the situations where it was applied. Taking into account the level and nature of adoption across government a lower bound productivity benefit of around 0.34% was assumed for Scenario 1 (using local government as a lower bound guide).

A productivity benefit of 1.05% was assumed for the realistic scenario based on observed impacts of spatial information on functions across whole of government, including asset management, resources management, reduced costs of service delivery, improved services, infrastructure planning, defence and emergency preparedness, risk management, compliance and regulation.

Table 16 **Direct impacts – government**

Scenario	Enterprise	Assumptions	Direct impact
Scenario 1	Government services	Increase in productivity in delivery of services across all levels of government.	0.34
Scenario 2	Government administration	On observed impacts of spatial information on functions across whole of government, including asset management, resources management, reduced costs of service delivery, improved services, infrastructure planning, defence and emergency preparedness, risk management, compliance and regulation	1.05%

Data source: Case studies, literature review, interviews

The above results do not include the impacts of spatial information on biosecurity, environment and social dimensions of the Australian economy.

8 Indicative national economic impact in 2007

The direct impacts by sector for Scenarios 1 and 2 provide the input "shocks" for the general equilibrium model. These are applied as productivity shocks in each sector. In addition, additional shocks are applied to account for the increase in resources facilitated in part by spatially enabled geoscience.

The results of the modelling are discussed in Section 8.9.1. A brief overview of the GE model is discussed first.

8.1 Overview of the Tasman Global model

Tasman Global is a large-scale, global, computable general equilibrium model. It is designed to account for all sectors within an economy and to account for the interactions between economies. The model is able to analyse issues at the sectoral, global, national and sub-national levels and to analyse the impacts of various policies on production, consumption and trade at the macroeconomic and sectoral levels.

For this report it was used to analyse the impact that spatial information induced productivity enhancements and increases in minerals and petroleum have had on the Australian economy

8.2 Comparative Statics versus Dynamics

Tasman Global is a model that can estimate relationships between variables at different points in time when run in dynamic mode, or can be used to compare two equilibriums (one before a change and one following) when run in comparative static mode.

Comparative static analysis has been used for this report. Spatial information has been in use for different lengths of times in different industries. Fishing, for example, was an early adopter, with first use dating back to the late 1980s. By using the comparative static approach, the modelling has been allowed to focus on the accumulated benefits in 2006-07 of the application of spatial information and related technology across a range of industries in the Australian economy.

8.3 The database

The database for Tasman Global has been developed from the Global Trade Analysis Project database (GTAP) that model was constructed at the Centre for Global Trade Analysis at Purdue University in the United States. It is the most up-to-date, detailed database of its type in the world.

The GTAP database contains a wealth of sectoral detail, with 57 industries specifically detailed. For practical purposes these industries are usually aggregated in some manner to reduce solution times and to match available data.

For the modelling in this report, the model was aggregated to the 32 industries shown in Table 17. The foundation of this information is the underlying input-output tables in the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands. Industry demands, so-called intermediate usage, are the demands from each industry for inputs. For example, electricity is an input into the production of telecommunications services. In other words, the Australian telecommunications sector uses electricity as an intermediate input.

Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households; their consumption of electricity is a final demand.

The other key feature of the input-output tables is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources described below) as well as paying taxes or receiving subsidies.

Table 17 **Sectors in the Tasman Global database**

	Number Sector		Number Sector
1	Cereal grains	17	Non-ferrous metals
2	Sugar cane, sugar beet	18	Other heavy manufacturing
3	Plant based fibres – cotton	19	Electricity
4	Bovine cattle, sheep and goats, horses	20	Water
5	Wool	21	Construction
6	Other agriculture	22	Trade
7	Forestry	23	Other Transport
8	Fishing	24	Water transport
9	Coal	25	Air transport
10	Oil	26	Communication

11	Gas	27	Finance and insurance
12	Minerals nec	28	Other business service
13	Processed foods	29	Recreational and other services
14	Other light manufacturing	30	Public admin. and defence, education, health
15	Petroleum, coal products	31	Rail transport
16	Iron and Steel	32	Road and pipeline transport

8.4 Factors of production

Capital, land, labour and natural resources are the four primary factors of production. The capital stock in each region (country or group of countries) accumulates by investment less depreciation in each period. Both capital and labour are mobile between industries and, to a lesser extent, across regions through international capital flows and labour migration. Land is used only in agriculture and is fixed in each region.

Tasman Global explicitly models natural resource inputs as a factor of production in resource based sectors (coal mining, oil and gas extraction, other minerals, forestry and fishing). For example, the coal mining industry uses three factors of production: labour, capital and a natural resource (reserves of coal). The natural resource is a factor solely in the production of resource based commodities and is not mobile between sectors or regions.

8.5 The labour market

It is assumed that the policy changes do not change unemployment from the so-called natural rate of unemployment for any economy. Any shifts in the demand for labour are assumed to be offset by changes in real wages sufficient to prevent the emergence of an unemployment rate different from the natural rate. This is the "full employment assumption".

8.6 National income, savings and consumption

In Tasman Global, a representative household in each region owns all factors of production and receives all payments made to the factors, all tax revenues and all net interregional income transfers. The representative household allocates its net income across private and public consumption and savings. National savings are assumed to move in the line with national income. Total consumption expenditure is calculated as the difference between current household income and savings, with the ratio of private consumption to government consumption assumed to be constant. Given total private consumption, the representative consumer maximises current period utility by choosing consumption levels for each consumption product.

8.7 Producer behaviour

Producers in Tasman Global are assumed to operate in perfectly competitive markets using constant returns to scale technologies. Under these assumptions prices will be set to cover costs and Tasman Global industries earn normal profits at all times, with all returns paid to primary factors of production. Thus, changes in output prices are determined by changes in input prices of materials and primary factors.

8.8 Nature of the direct impacts

As discussed in Section 2, the direct productivity impacts by industry have been determined for two scenarios:

- the quantifiable 'lower bound' scenario which reflects the impacts we have been able to *confidently* and *verifiably* quantify through the use of reliable statistics, existing literature, expert opinion and through our case studies
- the 'realistic' estimated scenario which comes closer to what we believe to be the reality (as distinct from that which we can confidently quantify).

The direct impacts discussed in Chapters 6 and 7 are summarised in Table 18 showing the size and type of shock applied in the model is identified. A total productivity shock indicates that the productivity improvement is applied across all inputs, including the use of goods and services and the use of factors of production. A total factor productivity shock is only applied to the use of factors of production: labour, capital, land and natural resources. A labour productivity shock is only applied to the use of labour. The resource availability shocks are applied to the stock of the natural resource used by the industry.

Table 18 **Direct impact of spatial information on productivity and resource availability**

	Type of shock applied	Quantifiable scenario	Estimated scenario
Productivity shocks			
Grains (specialist growers)	Total productivity	0.93%	1.08%
Mixed (grain & sheep/cattle)	Total productivity	1.35%	1.50%
Sugar cane	Total productivity	0.11%	0.26%
Cotton	Total productivity	0.07%	0.22%
Other agriculture	Total productivity	0.00%	0.15%
Forestry	Labour productivity	1.93%	1.93%
Fisheries	Total factor productivity	4.00%	5.14%
Construction	Total productivity	0.25%	0.50%
Business services	Labour productivity	0.50%	0.70%
Coal	Total factor productivity	0.21%	0.36%
Metal ores	Total factor productivity	0.16%	0.31%
Oil & Gas	Total factor productivity	0.15%	0.27%
Government	Labour productivity	0.34%	1.05%
Road Transport	Total productivity	1.40%	1.58%
Rail Transport	Total productivity	0.00%	0.45%
Air Transport	Total productivity	0.84%	1.04%
Other transport	Total productivity	0.00%	0.30%
Electricity/gas/water	Total productivity	0.73%	1.25%
Communications	Total productivity	0.98%	1.32%
Trade	Total productivity	0.00%	0.08%
Manufacturing	Total productivity	0.00%	0.02%
Other	Total productivity	0.00%	0.02%
Resource availability shocks			
Oil	Resource availability	3%	6%
Gas	Resource availability	5%	10%
Minerals nec	Resource availability	7%	14%
Coal	Resource availability	0.93%	1.08%

Data source: ACIL Tasman calculations and estimates

8.9 Results

The results of the modelling for both the quantifiable lower bound and the estimated realistic scenarios are summarised in Table 19.

Table 19 **Economic impacts of two scenarios**

	Scenario 1				Scenario 2			
	Productivity only		Productivity plus resources		Productivity only		Productivity plus resources	
	Per cent	A$ billion	Per cent	A$ billion	Per cent	A$ billion	Per cent	A$ billion
GDP	0.51	5.31	0.61	6.43	0.99	10.31	1.20	12.57
Household consumption	0.50	2.89	0.61	3.57	0.93	5.39	1.16	6.78
Investment	0.51	1.43	0.61	1.73	0.98	2.78	1.20	3.39
Capital stock	0.56	-	0.72	-	1.05	-	1.38	-
Exports	0.45	0.98	0.58	1.26	0.80	1.73	1.07	2.30
Imports	0.39	0.89	0.52	1.18	0.72	1.64	1.98	2.23
Wages	0.50	-	0.60	-	0.92	-	1.12	-

Data source: Tasman Global modelling

8.9.1 Quantifiable 'lower bound' results

The aggregate impact of spatial information in 2006-07 under the quantifiable 'lower bound' scenario was a gain of 0.79% or $6.4 billion.

- of this gain, $5.31 billion was attributable to increased productivity and the remainder to increased resources.

Other aggregate impacts of spatial information in 2006-07 for the lower bound scenario were:

- a gain of $3.57 billion in household consumption (0.61% increase)
- a gain of $1.73 billion in investment (0.61% increase).

Household consumption and investment increased by similar percentages, while capital stock was 0.98% higher as a result of the contribution of spatial information.

A notable result is that spatial information is seen to have contributed positively to Australia's trade balance, particularly when resource availability effects are included

- exports were higher by $1.26 billion
- imports were higher by $1.18 billion.

The modelling assumption that unemployment remains at its natural rate means that the modelling results show no employment gains. However, workers are clearly better off due to an estimated real wage increase of 0.60 per cent when resource availability effects are included.

8.10 Estimated 'realistic' results

Due to the larger productivity and resource availability gains under our 'estimated' scenario, the overall economic impact of this scenario was a gain of 1.2% or $12.57 billion.

- Of this gain, $10.31 billion was attributable to increased productivity and the remainder to increased resources.

Other aggregate impacts of spatial information in 2006-07 for the estimated realistic scenario were:

- a gain of $6.78 billion in household consumption (1.16% increase)
- a gain of $3.39 billion in investment (1.20% increase).

Capital stock was by 0.98% higher as a result of the contribution of spatial information.

As with the lower bound scenario. spatial information is seen to have contributed positively to Australia's trade balance, particularly when resource availability effects are included

- exports were higher by $2.30 billion
- imports were higher by $2.23 billion.

Real wages under this scenario are seen to have increased by up to 1.12% as a result of spatial information.

8.11 Impacts on industry output

Table 20 shows the impact of spatial information on the output from Australian industries under the two scenarios. Clearly, those industries receiving the larger productivity gains – grain growing, sheep and cattle farming, forestry, fisheries and road transport – perform well, as do those mining sectors – oil, gas and other minerals – that experience increases in their available resource stocks. But overall the industry gains are well spread, with falls in output from only five sectors: plant based fibres, wool, other agriculture, other light manufacturing and other heavy manufacturing. The sectors showing some decline received no benefit or only small benefits from spatial information, and their decline will have occurred do to competition for labour with the sectors that gained greater benefit and/or from export declines due the appreciation of the Australian currency that has resulted from the use of spatial information.

Table 20 **Industry impacts of two scenarios – increase in output attributable to spatial information**

	Scenario 1		Scenario 2	
	Productivity only	Productivity plus resources	Productivity only	Productivity plus resources
	%	%	%	%
Cereal grains	1.76	1.67	1.88	1.70
Sugar cane, sugar beet	0.36	0.28	0.54	0.37
Plant based fibres – cotton	-0.10	-0.19	0.07	-0.11
Bovine cattle, sheep and goats, horses	0.87	0.81	1.07	0.96
Wool	-0.32	-0.42	-0.15	-0.35
Other agriculture	0.01	-0.04	0.17	0.08
Forestry	0.41	0.37	0.51	0.43
Fishing	3.21	3.22	4.17	4.19
Coal	0.24	0.29	0.42	0.52
Oil	0.32	3.14	0.33	5.98
Gas	0.55	4.51	0.58	8.52
Minerals nec	0.30	0.46	0.65	0.98
Processed foods	0.39	0.30	0.58	0.41
Other light manufacturing	0.17	0.06	0.39	0.17
Petroleum, coal products	0.42	0.73	0.74	1.36
Iron and Steel	0.27	0.29	0.57	0.62
Non-ferrous metals	1.20	1.00	2.12	1.73
Other heavy manufacturing	0.14	0.00	0.35	0.05
Electricity	0.83	0.89	1.48	1.62
Water	0.74	0.83	1.33	1.52
Construction	0.50	0.61	0.97	1.19
Trade	0.40	0.47	0.77	0.92
Other Transport	0.27	0.27	0.74	0.74
Water transport	0.25	0.25	0.82	0.81
Air transport	1.01	1.02	1.94	1.97
Communication	0.79	0.84	1.26	1.34
Finance and insurance	0.34	0.40	0.64	0.75
Other business service	0.40	0.45	0.71	0.82
Recreational and other services	0.54	0.66	1.00	1.24
public admin. and defence, education, health	0.42	0.47	1.05	1.15
Rail transport	0.31	0.36	0.64	0.75
Road and pipeline transport	0.75	0.86	1.08	1.30

Data source: Tasman Global modelling

Clearly, those industries receiving the larger productivity gains – grain growing, sheep and cattle farming, forestry, fisheries and road transport – perform well, as do those mining sectors – oil, gas and other minerals – that experience increases in their available resource stocks. But overall the industry gains are well spread, with falls in output from only five sectors: plant based fibres, wool, other agriculture, other light manufacturing and other heavy manufacturing.

The sectors showing some decline received no benefit or only small benefits from spatial information, and their decline will have occurred do to competition for labour with the sectors that gained greater benefit and/or from export declines due the appreciation of the Australian currency that has resulted from the use of spatial information.

8.11.1 Biosecurity and environmental benefits and social benefits

The above results do not include the impacts of spatial information on biosecurity, environment and social dimensions of the Australian economy.

The case studies identified that spatial information has an important and increasing role in biosecurity. The national implementation of the BioSIRT application in 2006 will establish a nationally consistent spatially enabled surveillance, incident reporting and disease tracing system. The cost of control and lost production from pests and diseases has been estimated to be as high as $8 billion per year (Agrtrans Research, 2005). An outbreak of a disease such as foot and mouth disease could incur cumulative impact on GDP of up to $13 billion (Productivity Commission, 2002). The contribution that spatial information could make to reducing the cost of control and lost production and reducing the impact of incursions when they occur could be in the order of hundreds of millions of dollars.

The value of spatial information systems in natural resource management, water trading and climate trading markets has not been assessed. However, given the imperatives in these areas it is likely to be large both in economic as well as in terms of sustainable systems and conservation values.

The transport case studies suggested that the use of spatial information systems could reduce greenhouse emissions worth between $50 million and $150 million per annum at current carbon prices.

In terms of overall reduction in greenhouse gas emissions, the value of reducing emissions to 108% times Australia's emission levels in 1990 (Australia's Kyoto target) would be valued at around $1.4 billion at current carbon prices. The spatially enabled National Carbon Accounting Scheme will provide significant support towards reducing net emissions of greenhouse gases.

There is therefore a sufficient body of evidence to suggest that the spatial information industry is delivering significant environmental and social benefits. These benefits can be expected to increase significantly as spatial information systems are further integrated into the operation of water markets, carbon markets, natural resources management and environmental management and monitoring programmes more generally.

9 Impact of inefficient access to data

ACIL Tasman drew on evidence provided from the case studies, the literature review and from interviews with users to draw conclusions about the adequacy of data access. The findings, an estimate of the cost of constraints, are discussed in this section.

9.1 Overview

Issues associated with the access to spatial data were initially identified for the Spatial Information Industry Action Agenda. The reviews and case studies revealed that, while progress has been made in some areas, success has been mixed.

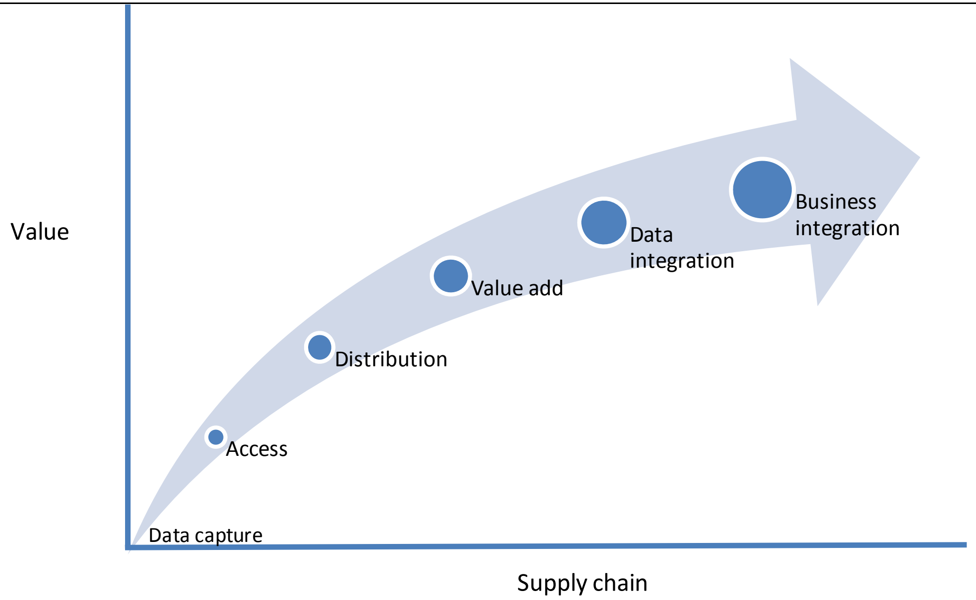
The areas of concern that were identified in the consultations included:

- Availability of fundamental data
- Adequacy of spatial data infrastructure
- Access to data
- Pricing for access

Each area of concern reduced the economic contribution of spatial information in different ways. To put this into perspective, it is useful to examine the spatial information supply chain. A schematic of the supply chain is shown in Figure 19.

As the supply of spatial information moves from data capture, access to distribution, value is added. Further along the supply chain, data integration and business integration add more value. The Hazwatch hazard warning system illustrates this relationship (see Section 6.7.4). Inefficiencies in access to fundamental data can have ramifications along the supply chain amplifying the impact and cost of these inefficiencies.

Figure 19 **Spatial information supply chain**



Data source: ASIBA

9.2 Fundamental data

Fundamental data includes data that is collected by agencies under public interest programmes and also data that is collected by agencies to meet specific agency purposes but may be made more widely available in the public interest (ANZLIC, 2001). Some fundamental data is created by the private sector (such as cadastral and some minerals exploration data) but captured by the public sector.

Each jurisdiction – federal, state and territory or local – is responsible for its own policies, and for funding the collection and custodianship (i.e. the management) of its spatial data holdings.

The concern expressed by business is that some applications are being constrained by availability and access to data. This is limiting opportunities for further applications.

In part, these gaps are understood to exist because the information is not needed for government purposes or decision making, yet only government has the capacity to commission and fund the type of information required. While governments may outsource the collection of data to business, only government has the institutional capacities to impose census and surveys across the economy.

There is a "market failure" because both business and/or the community may have needs for spatial information that would generate considerable net public benefit but, in some jurisdictions, government agencies do not have the appropriation or are unaware of the need to fund the capture of this information.

Two examples are the failure to update the national map series from 1:250,000 to the 1:100,000 and to develop a nationally coordinated digital elevation model (DEM).

9.2.1 National maps

GA lists the currency of this series of maps as ranging from 1961 to 2000. A 2003 feature article in an industry journal (Fairall, 2003) commented that:

> …the 1:100,000 map sheets are in much the worst shape. The majority date from the 1970s and 1980s, and are not useful for many purposes as a result. In many cases they remain the best available published maps and are still called on in large numbers, particularly in emergency situations such as the recent bushfires.

The House of Representatives Select Committee inquiry into the 2003 Canberra Bushfires was provided with information on the age distribution of maps distributed by. This information showed that a substantial majority of the 1:100,000 series maps distributed were over 20 years old, with some more than 30 years old. The Select Committee report recommended that:

> … the 1:100,000 national mapping programme be accelerated to achieve an average life of no greater than 10 years with priority given to those areas susceptible to national disasters.

The Committee was advised that it is expensive to update the 1:100,000 map series, which comprises more than 3000 maps. In contrast, the 1:250,000 scale series involves only 513 maps. GA reports that it is not currently funded to undertake an accelerated programme to update the 1:100,000 series, notwithstanding that there is in-principle support from COAG based on the review it commissioned into Australia’s approach in dealing with natural disasters.

9.2.2 National elevation data framework

ANZLIC is sponsoring development of a nationally coordinated DEM with the support of the Australian Greenhouse Office (AGO) and Geoscience Australia (GA). A project team comprising representatives of ANZLIC, AGO, GA and the CRC-SI has been set up to guide the process. This is expected to include the following steps:

- develop a business plan, setting out the intent and potential form of a nationally coordinated DEM, identifying key stakeholders and a preliminary review of existing usage of DEM in Australia
- develop a user needs analysis through direct contact with key stakeholders around Australia

- develop a science case to support the implementation of the project
- develop an implementation plan using the user needs analysis and feedback from stakeholders on issues such as governance arrangements, funding and technical standards
- develop and gain agreement on use of applicable data standards and access arrangements such as licensing.

A key challenge for the specification of a DEM will be contemporary requirements for high resolution data in areas such as climate change, water resources management, disaster mitigation and environmental monitoring.

9.2.3 Implications

The consequences of gaps in fundamental data include:

- inefficiencies in planning for future infrastructure and redoing surveys to collect data that may have been captured previously at a low marginal cost
- less well informed policy formulation in natural resources management, environment and climate change adaptation
- lost opportunities for innovation and development of new products by the private sector
- less efficient planning and responses to emergencies such as bush fires and flooding
- lower efficiencies in developing faster development approvals and land management
- less opportunity for new approaches to asset management.

It is not possible to make a precise estimate of the impact on productivity or on national output of these inefficiencies. The case studies suggest that some productivity has already been foregone. The sectors that appear to be most affected include:

- property and services
- utilities and asset management
- transport
- agriculture
- emergency services
- biosecurity.

These sectors comprise around 30% of Australia's GDP and are important in the provision of land and infrastructure, food and fibre and safety and security.

However the larger impact is likely to occur in the future. The opportunities forgone for the future are likely to be considerably larger.

9.3 Inadequacies in spatial data infrastructure

To progress from an information economy to a knowledge economy requires a spatially enabled society, one in which informed decisions are made on the basis of accessible, accurate, reliable and well maintained data.

An essential component of a spatially enabled economy is the supporting infrastructure. With current technology, such infrastructure can be a virtual system that does not require centralised, consolidated storage of data within a single agency, with all the costs that this entails. Instead, the infrastructure can be achieved through interoperability architecture, based on distributed custodial spatial information management and open standards.

This was the vision for the ASDI at the time of the Spatial Information Action Agenda in 2001. Since 2001 there has been some success, both at a national level and, subsequently, as state and territory governments have taken on key roles. In 2007, there has been a concerted effort lead by natural resource sectors to update its metadata. Most jurisdictions have adopted common metadata registry software from ESRI, Geoportal Tool Kit, which a commercial-of-the-shelf solution compliant with the ANZLIC 19115 metadata standard.

However, the ASDI – as it is currently realised – falls short of providing ready and seamless access to spatial data and information products and tools. Although progress has been made in some important areas, spatial data collected, managed and disseminated at each level of government is fragmented.

At the national level, the development of the ASDI has been led by ANZLIC. The current model sees ANZLIC decide on which guidelines and standards to use, while the key stakeholders independently build the ASDI components.

ANZLIC's strength is its inclusive structure. Its weakness is that because no one government has direct jurisdiction over mapping and spatial information, there has been duplication of effort and gaps in co-ordination.

Where state governments have defined roles, such as in cadastral mapping, ANZLIC has attempted to co-ordinate activity but it has no authority to enforce the adoption of the standards, policies and technical solutions necessary to a fully operational national spatial data infrastructure.

As a consequence, ANZLIC has tended to focus on those areas where it has a central role, such as counter terrorism, emergency management, natural resources management and water management. Even in these areas, the delivery of counter terrorism and emergency management operations is being progressed by various state government initiatives and has therefore often been uncoordinated.

The National Spatial and Information Management Working Group has now released the document “Spatial Strategic Plan 2007-2010”. This is a plan for a national spatial capability that can be used to support critical infrastructure protection, counter terrorism and emergency management activities at the national, state and local level s (National Spatial and Information Management Working Group, 2007).

As discussed in Section 7.2.1 above there are examples of world’s best practice in the state governments towards a whole-of-government approach. The achievements of SLIP (WA), QSIIS, CANRI in NSW and the Victorian land and property information systems are outstanding examples. However, with the exception of perhaps SLIP, overall progress towards whole-of-government approaches and engaging industry at state government levels has in reality been mixed.

One of the major imperatives for local government is not only improving its own level of spatial enablement but in mitigating the costs of the data that it captures and collects to transmit to state, territory and federal governments.

Industry in partnership with governments has made a contribution where there have been opportunities to do so.

- The Spatial Interoperability Demonstrator Project (SIDP) has been largely successful in demonstrating the potential of an open, standards-based architecture.
- The Shared Land Information Platform (SLIP) has delivered a distributed infrastructure, committed to open standards and partly based on open source software that greatly enhances the ability to discover, access and use spatial information and provides a proven mechanism for sharing information and reinforcing custodianship principles. SLIP is also proving to be an effective solution to address many of the issues of sharing spatial information across local governments
- The National Oceans Portal will provide an internet-based, customer-focused view into data and information of interest to users of the marine environment and will draw on resources from Australian oceans data centre agencies.

In summary, the first generation of spatial data infrastructure development in Australia has tended to be product based. While there have been attempts to break down silos and implement whole-of-government approaches, success has been at best partial.

A possible problem with the history of ASDI development to date has been lack of integration with the business outcome sought. In this context we note that the roadmap and framework for the NSW Spatial Information Strategy has been successful because it has defined the business outcomes of its ASDI development.

Significantly, development of the ASDI has yet to engage fully with the business and the broader community, who have a range of needs and uses to be met by accessible spatial information. While ANZLIC has seen basic standards such as metastandards adopted, the depth and breadth of application varies at state government level. There remains duplication of effort and expense in creating data, infrastructure and frameworks for data sharing. There remains a weak interaction between the traditionally strong land and property sector with the sectors concerned with management of natural resources, scientific information and socio-economic information.

Australia's vision for the ASDI was built on the idea of multi-agency co-operation which in itself is difficult, as well as collaboration across different levels of government and between government and industry. In the intervening period the roles of government and private sector participants in the supply chain have shifted somewhat and the capacity of the private sector has matured.

Hence, the Australian experience in developing a virtual spatial information infrastructure has meant that, rather than spatial data infrastructures being mechanisms for enhancing innovation and efficiencies in the supply chain, they have progressed only as far as being points at which spatial data that is discoverable can be accessed and retrieved.

What is not "shared" or communicated are needs, strategies, goals, value-added services and innovation, processes and operational objectives that are the context for the use of the spatial information.

9.3.1 Virtual Australia

The concept of Virtual Australia has been developed by the CRC-SI. It was intended to consist of governance mechanisms and interagency collaborative arrangements across government and across government and industry.

As an enabling platform, Virtual Australia was conceived to link the public and private organisations and business enterprises in the spatial information industry and facilitate the sharing of spatial data and services. It was to be structured and managed in such a way that it is seen by users as a single enterprise.

The value of the Virtual Australia concept is that it emphasised the interdependence of the producers and suppliers of spatial information and the orientation towards the needs of customers. This is consistent with the maturing of the industry and the rise in innovation and commercialisation.

Virtual Australia offers an ideal framework for consideration in the development of a fully realised, operational ASDI.

9.3.2 Positioning infrastructure

Australia has a great reliance on global navigational satellite positioning infrastructure. The case studies referred to in this report all indicate the significant value that accurate positioning adds to the application of spatial information systems.

Free to air GNSS generally requires augmentation to achieve the accuracies necessary for the new applications in agriculture, navigation and asset management. There are both government and commercial augmentation services provided in Australia at the present time. However the performance levels and range varies between the different systems.

Australia does not yet have a fully coordinated infrastructure of reference stations to provide the augmentation necessary for high level positioning accuracy many of the current and emerging applications require. There is a need to develop a fully integrated network of ground based reference stations involving collaboration between government and industry.

The proposed AuScope system of national reference stations will be an important extension to augmentation systems in Australia. At the present time however it is not clear how it will engage with the existing systems and what its uses will be. It is first and foremost research infrastructure.

9.3.3 Implications

The lack of a consistent whole-of-government approach and the inadequate engagement between governments and industry has consequences for the growth of the spatial information industry. The result of this has been reflected in a lower level of dissemination of spatial information beyond the traditional areas of property, geoscience, bathymetry mapping to areas such as asset management, natural resources management, socio economic services and the mainstream consumer markets.

Important also is the extent of application in government at all levels in areas such as defence and security at the national level and regulatory and approvals processes at the state and local level.

It is difficult to estimate the impact on growth in 2006-07 but given the size of the sectors that are missing out such as government, construction and asset management the impacts would be significant – of the order of between 5% and 15% on productivity outcomes varying from sector to sector.

9.4 Access to data

ANZLIC has promulgated guidelines for best practice in enabling access to spatial information and hence spatially enabling the economy (Box 11). Interviews and consultations undertaken in the course of research into the case studies indicated that these guidelines are not being uniformly achieved in Australia.

Box 11 **Guiding principles for access to spatial data – ANZLIC 2001**

All sectors of the community should have easy, efficient and equitable access to fundamental spatial data where technology, data formats, institutional arrangements, location, costs and conditions do not inhibit its use.

The fundamental spatial data needed by all sectors of the community should be available to support economic, environmental and social needs.

Governments should seek to maximise the net benefits to the community when developing their spatial data access policies and pricing regimes.

Fundamental spatial data should be made available online through customer-focused portals, as one of a number of ways to meet community needs for equity of access.

Access arrangements should be geared to maximise the use of spatial data resources in both public and private sectors and to encourage the development of an innovative and competitive value-adding industry.

Access arrangements should recognise confidentiality, privacy, security and intellectual property rights.

Data source: ANZLIC

There are three current areas concerning access to spatial information:

- simple and effective access, including the implications of digital management rights for access
- data information quality, based on fitness for purpose
- the development and implementation of a whole-of-government licensing framework.

Simple and effective access

An access arrangement should provide a simple, effective means of locating and obtaining spatial information.

While this includes non-digital information and physical forms of access and distribution, in most cases data custodians have adopted policies that place the internet as the primary means of locating and obtaining spatial information.

For the widest possible access, custodians should offer a multi-faceted approach to delivery of information, catering for all types of users. This is not yet being achieved uniformly.

Users range from the highly sophisticated (e.g. through advanced software and databases) to the non-technical (e.g. through browser applications, on-line delivery of mapping products, embedding mapping in desktop applications).

- Less than 1% of users can be classed as mapping/design/GIS ‘experts’. Typically, these users create and maintain data, have had a high level of training and use specialist GIS software as part of their day to day activities.
- Analysts make up fewer than 5% of users. These users make business decisions, have usually had application level training and use specialist GIS software as part of their day to day activities.
- The remaining 95% are typically non-technical users, who would access the data through the web or other mobile applications using browsers or standard desktop software.

In the past there has been a narrow focus on the access to and distribution of data, mainly towards mapping/GIS staff and, to a lesser extent, spatial analysts. New techniques and applications are now providing access to spatial information for the non-technical users.

Digital rights management (DRM) is an area of pressing interest, as the internet has become the centre of distribution for digital goods of all sorts, including spatial information.

DRM, as a technical interdisciplinary field, is at the heart of controlling the digital content and assuring authorised, user friendly, safe, well-managed, automated and fraud-free distribution.

The field of DRM combines cryptographic technology, software and systems research, information and signal processing methods, legal, social and policy aspects, as well as business analysis and economics.

In the spatial information area the Open Geospatial Consortium (OGC) is just one amongst others developing the digital rights management architecture that is appropriate for suppliers and users of spatial information.

Fitness for purpose

In 2003 ANZLIC nominated the topic of 'data quality' as being one of five core issues still needing to be addressed as part of the ASDI development (ANZLIC, 2003).

Specifically, ANZLIC determined the problem to be *"incomplete knowledge about the availability and quality of existing spatially referenced data*". As such, one of the priority areas for ASDI development in the future is the stated goal of enabling users to "*easily ascertain the quality of existing spatial data and its fitness to meet their needs."*

Spatial information quality has progressed considerably in recent decades as data quality information has been included in data transfer standards, with the introduction of international geographic data quality-related standards and the widespread adoption of metadata entry tools for the production of metadata for entry in searchable, web-based directories. A good example of such a tool is provided via SLIP, which has developed a web-based application that provides users with the ability to search metadata on all SLIP data services and data layers contained within these services.

Metadata is the starting point for access as it provides the means for 'discovery' of spatial information. For example, in the Australian Spatial Data Directory (ASDD), hosted by GA on behalf of ANZLIC, it is possible to search approximately 39,000 ANZLIC metadata records on 25 ASDD nodes located around Australia (www.asdd.ga.gov.au/asdd).

However, advice to ACIL Tasman from industry interviews suggests that the metadata remains in many formats and is currently not completely valid. For example, a recent study of 5,141 metadata records of NSW natural resource sectors confirmed that the records were out of date and could not be automatically upgraded to fit the ANZLIC 19115 profile. Metadata custodians in NSW are re-creating its metadata records and storing it in a NSW State SDI Node. The ASDD will be trained to harvest NSW metadata from the State Node.

Incomplete knowledge about the quality of data is a fundamental issue that has yet to be properly addressed.

Users of spatial data must be able to easily ascertain the quality of their information and its ability to meet their requirements. Users need to know:

- where quality varies throughout a dataset
- the degree of uncertainty that is associated with any of their derived information products

- for non-experts in particular, there needs to be an improved way of communicating data quality, especially in the context of web-based metadata.

Further, one of the key risks driving the need for data quality is litigation risk. For example:

- there is now a common expectation for data quality statements to be provided by providers when transferring data
- the need for individuals and agencies applying spatial data to protect their reputations and justify their decisions, especially when they may be subject to legal challenge
- the requirement by organisations to minimise the risks associated with claims of negligence and liability relating to the use of spatial information
- the maturing of the spatial information industry and user community to the point where new concerns such as quality, legal issues, pricing and custodianship are now recognised as having a major impact on the success of the creation and delivery of spatial data products and services
- recognition that spatial information is now considered to be a commercial product and that its provision is subject to consumer law in terms of warranties and guarantees that it will meet certain specifications and can satisfactorily be applied to given tasks.

To help address these 'next-generation' research issues, a project has been initiated by the CRC-SI which aims to design, develop and test new modelling and visualisation solutions for communicating spatial data quality and uncertainty to future users of spatial data.

9.4.1 Need for a national licensing framework

Custodians of spatial information must ensure that its distribution and use is in accordance with licences, agreements or other appropriate mechanisms that effectively manage the risks associated with the use of the information. The organisation acting as a data custodian will be responsible for maintaining copyright provisions and ensuring that use of the information does not infringe any privacy or confidentiality requirements.

Unlike the case with most other products and services, users do not purchase spatial information products and services. Rather they enter into licensing or other such agreements with the custodian to use that information.

These licences set out the terms and conditions that apply to such use and protect the intellectual property that results from the development and maintenance of the spatial information. The custodian of spatial information maintains intellectual property rights over that information.

At local government level, national funding of $45 million through the Networking the Nation programme and the partnership between ANZLIC and the Australian Local Government Association (ALGA) have facilitated both the take up and use of common spatial information standards at local government level.

An important development that is gaining widespread support in government is the development of a Government Information Licensing Framework (GILF). The GILF would be a standardised legal environment of terms and conditions within which all information transactions would occur.

The benefits of the GILF are to:

- facilitate improved access to and use of government held data and information within government
- establish a standard, single framework for access to all data for other jurisdictions, community and the private sector
- help manage governments' intellectual property
- reduce legal risks associated with potential unauthorised use of data and information products and services both in and outside of government.

Current licensing practices have meant:

- confusion and costs for clients, community and custodians
- near impossibility to design an architecture for an online portal solution such as the Information Queensland National Data Network
- difficulties for information users to know if they are fully complying with legal obligations
- a hindrance to innovation.

One avenue of facilitating information sharing across jurisdictions that will be looked at is the creative commons licensing regime.

Creative Commons defines the spectrum of possibilities between full copyright — *all rights reserved* — and the public domain — *no rights reserved.* This regime potentially provides a legally effective information licensing framework to enable all agencies to share information (Creative Commons, 2007).

Creative commons licenses are designed to facilitate and encourage more versatility and flexibility in copyright.

- The licences are designed to help content creators quickly and easily tell the world their work is available for sharing but only on certain terms.
- The scheme exists as a series of licences that are customised to the specific needs a content creator may have.

- Creative commons provides an alternative layer of copyright and a store of material that can be accessed and understood by almost anyone, with minimal effort.

The creative commons scheme potentially offers an innovative legal framework to recording, protecting and distributing information, across both government and non-government spheres.

The Queensland Government has been developing a business case for an open content licensing model based on the Creative Commons approach. The proposal is intended to provide a standard legal environment of terms and conditions within which all government information transactions can occur. It aims to reduce legal risks associated with the transfer of spatial information, improve the management regime for intellectual property and minimise the administrative burden on governments.

An important feature of the proposed approach is its capability to enable licences to be executed at the time of data transfer which will increase the efficiency of user access while at the same time achieving the above aims. It is aimed to apply across jurisdictions which, when implemented, will significantly increase the efficiency of data transfer. This will have benefits in current uses and in future innovation.

9.4.2 Implications

The lack of completeness in policies relating to simple and effective access, fitness for purpose and development of a whole-of-government licensing framework are were reported as creating concerns to those users who are not in the mainstream.

The cost is in slower development of applications and less than optimal levels of application and innovation among users.

In 2006-07 the cost has been in less penetration of spatial information into new areas and possibly a lower level of innovation in the industry to meet emerging demand beyond the more traditional areas of application.

This is likely to have had an impact in the property and services, construction, government, transport and agricultural sectors and reduced the extension of spatial information into areas such as asset management in utilities, transport and storage applications and in emerging areas of consumer markets and applications in other industries.

9.5 Pricing for access

Across and within levels of government and its various agencies there are differences in pricing and cost recovery policies.

Generally, pricing policies for accessing spatial information distinguish between fundamental data – a public good – and spatial information products and services. In charging for spatial information products and services, agency pricing is based on cost recovery.

When fundamental spatial information – that is a public good – is charged for on the basis of full cost recovery, it is inefficient and will lead to sub-optimal outcomes for the economy as a whole. Across and within levels of government and its various agencies there are differences in pricing and cost recovery policies. While all governments profess to adhere to the principles of cost recovery and competitive neutrality, individual agencies interpret these principles in different ways.

9.5.1 Productivity Commission Report

Principles for pricing were originally outlined in a Productivity Commission Report released in 2001 (Productivity Commission, 2001). The conceptual framework on which recommendations in this report were based was the existence of market failure associated with spatial data held by governments. Market failure relates to the public good characteristics of fundamental data, the existence of spillovers, information failures and natural monopoly.

The Productivity Commission set out the following principles.

- Cost recovery should be implemented for economic efficiency reasons, not merely to raise revenue.
- Information agencies and the Government together should define a basic product set according to public good characteristics, significant positive spillovers and other Government policy reasons.
- The basic product set should be funded from general taxation revenue.
- Additional information products should be classified into three broad categories and priced accordingly:
  - dissemination of existing products at marginal cost
  - incremental products (which may involve additional data collection or compilation) at incremental (avoidable) cost
  - commercial (contestable) products according to competitive neutrality principles.

9.5.2 Current policies

The Commonwealth Government adopted cost recovery policies broadly consistent with these principles. Following their implementation the use of fundamental data increased dramatically. The increase in distribution of fundamental data sets was reported in the annual report of the Spatial Data Policy Executive (OSDM) as follows:

- in the 2002-03 financial year:
  - OSDM distributed 90,438 copies of fundamental spatial datasets
- in the 2005-06 financial year:
  - OSDM distributed 1,524,206 datasets with the internet accounting for 60% of the means of distribution.

There would be a number of factors driving this increase, including growing demand in Australian Government agencies and the community for spatial data and further investment in new data sets. However, there seems to be a reasonable correlation between the increase in distribution of data sets and the lower pricing policy for fundamental data which was introduced in late 2001.

The state governments have not consistently followed the Australian Government's lead. It is evident that some are charging more than marginal cost for fundamental data either directly or through over recovery of costs for value-added services. There is some evidence that some state governments may be exercising monopoly leveraging in value-added markets leading to over-recovery of the cost of fundamental data.

9.5.3 Implications

Pricing policies that recover more than the marginal cost of supplying fundamental data are inefficient. It results in lower value creation along the supply chain, less opportunity for development of commercial and government applications and a net loss of economic welfare.

Research for this report identified at least one area where full cost recovery charging for fundamental data had resulted in one organization choosing not to use a fundamental data set in one of its spatial information applications. This is a sub-optimal outcome in terms of the Productivity Commission's findings.

Quantifying the economic welfare loss from inappropriate pricing was not possible for this report. However an indication of the opportunities forgone is perhaps illustrated by the dramatic increase in the distribution of fundamental data sets that following the pricing policy reforms introduced by the Commonwealth Government in 2001.

It would not be unreasonable to conclude that a more optimal (and higher) use of fundamental data would have resulted if more efficient pricing policies had been more universally applied. This would have resulted in higher productivity effects and higher national economic welfare in 2006-07.

As the contribution of spatial information to the national economy continues to grow, it may be timely to quantify the economic welfare loss from inappropriate pricing. This would help government agencies concerned build a stronger business case to fund future maintenance and dissemination of framework datasets.

9.6 Overall cost of inefficient access to data

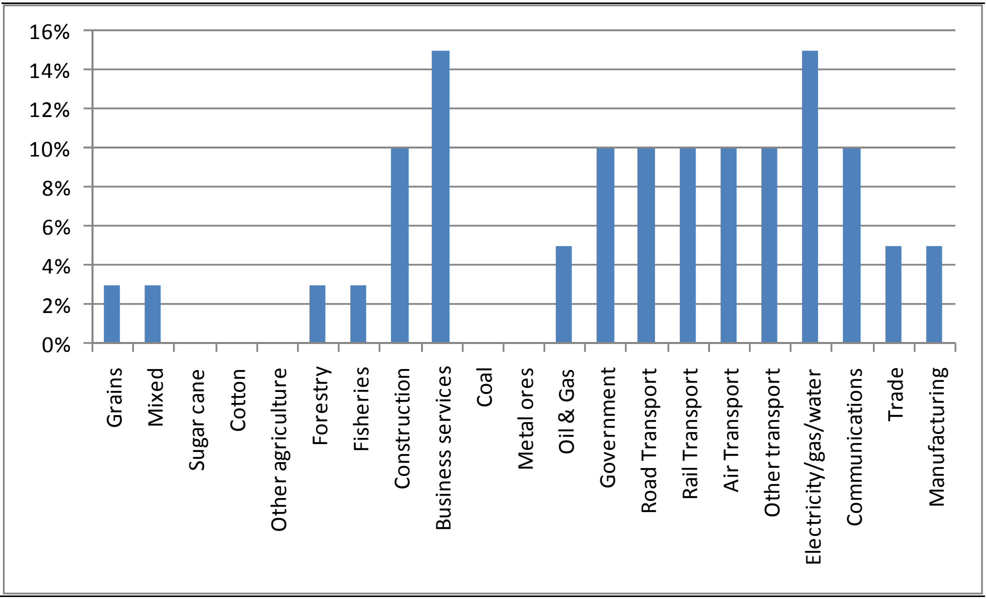
As the discussion in the previous section shows, it is difficult to draw precise conclusions about the cost of inefficient access to data across all of the sectors examined. The costs arise in three ways:

- lower levels of productivity and/or adoption in existing applications
  - this would apply particularly in agriculture, property and services, construction, transport and asset management of utilities and in certain areas of government such as in emergency services and biosecurity
- lower levels of adoption in new applications
  - as would apply in the above areas and in improved environmental and developmental regulation processes, consumer markets, tourism and new business applications
- lower levels of innovation
  - which depends on integration of new developments with existing platforms to build new products and services.

Those consulted in the course of the case studies were not able to be explicit about the impact of constraints on productivity. The distribution of constraints is not likely to be uniform. The interviews however suggested that the biggest impact on productivity occurred in the areas of agriculture, transport, asset management and property and services.

It is possible that productivity impacts in these sectors might have been between 5% and 15% higher in 2006-07 if the constraints had not existed. A possible distribution of these variations is shown in Figure 20

Figure 20 **Effect of constraints on productivity impacts**



Note: These percentages represent the extent to which the direct impacts in 2006-07 might have been higher if the constraints on access to data had not existed.

Data source: ACIL Tasman

The constraints are unlikely to have affected the rate of discovery of minerals and petroleum.

The impact of constraints on innovation cannot be estimated with certainty. However, applying these changes to the shocks showed that the aggregate economic impact for Scenario 1 could have been around 7% higher in 2006-07 (Table 21).

Table 21 **Effect of constraints on Scenario 1 outcomes**

	Scenario 2 ex constraints		Scenario 1		Percentage increase in impact
	Per cent	**$A billion**	**Per cent**	**$A billion**	
GDP	**0.61**	6.43	0.661	6.91	7.5%
Household consumption	0.61	3.57	0.659	3.83	7.3%
Investment	0.61	1.73	0.660	1.87	7.8%
Exports	0.58	1.26	0.620	1.34	6.3%
Imports	0.52	1.18	0.549	1.25	6.3%
Real wages	0.6		0.643		7.1%

Note: Based on impacts adjusted by the proportion of increased productivity shocks set out in Figure 20.

Data source: ACIL Tasman modelling using Tasman Global

10 Future prospects

The future prospects for the spatial information industry are promising both in the medium term (five years) and the longer term (ten years).

10.1 Medium term outlook

In the short term increased adoption of existing and emerging technologies is likely to see an increase in the contribution of spatial information to the currently spatially enabled sectors.

10.1.1 Future contribution of spatial information

Economic

The contribution of spatial information to future economic activity will continue to grow as awareness of its potential grows. Medium term growth can be expected to be driven by the following factors:

- increased adoption in existing applications
- introduction of new applications
- increased penetration into non traditional sectors and new markets
- increased use by government in delivery of services
- new services designed for traditionally non-spatial users (public and business).

There are well established spatial information applications in sectors such as mining, property and services, construction, transport and agriculture. There is nevertheless scope in many areas for increased adoption. Adoption of controlled tracking farming in agriculture was reported to be around 10% to 15% in the case study. Current trends suggest that this will increase as costs fall and demand for increased productivity in broad acre farming increases. Increases in adoption of existing applications are likely to occur in the other sectors as knowledge of the potential of spatial information is disseminated more widely in each industry.

Proactive policies of governments can also be expected to increase the adoption of existing applications in government.

Current trends also suggest that development of new applications will lead to increased use of spatial information in traditional sectors as well those sectors that are currently less intensive users. The latter would include tourism and recreation, retail and trade, communications and manufacturing.

Growth in mainstream consumer markets for spatial information is also likely to be a significant source of growth. This is highly likely to include markets and business models that don't currently exist. Introduction over the past five years of spatially enabled information applications such as in real estate, mapping and navigation systems had created new consumer markets. Lower costs and the innovative nature of the industry strongly suggest that this trend will continue and most likely accelerate.

The case study and research also provided a strong indication that applications by governments will also increase strongly over the next five to ten years.

It is difficult to model the economic impacts of these trends over the next five years because of the changing nature of the applications and uses. However, it would not be unreasonable to expect that the adoption levels in existing sectors would increase by up to 50% over the next five years with the right policies in place.

It is also certain that adoption in low using sectors will also increase over the next five years – although the level and nature of the applications is hard to predict.

Taking these considerations into account it is possible that, with the right policies in place, the contribution to national economic production and household consumption could be up to 50% higher than that calculated for 2006-07.

Environmental and social benefits

The importance to Australia in managing the challenges of climate change, water, energy, natural resources management and biosecurity were outlined in this report. Maintenance of defence, security and emergency management services is also highly valued by the community.

While it was not possible to quantify the value of the contribution that spatial information made to these areas, this report suggested that the value of the contribution has been significant in both economic and social terms.

Spatial information technology is crucial for effective and better management of these challenges. There are many examples cited in this report that show that some tasks could not be undertaken by governments without spatial information technologies. This report showed that that the application of spatial technologies in these areas is increasing.

There is little doubt that the social and environmental benefit that spatial information can deliver is very large. While many of the services are more public good in nature, they are very important to future national welfare broadly defined.

10.2 Longer term

In the longer term spatial information will move to a new level to become mainstream enterprise systems applied in consumer applications and more fully integrated into government and business systems.

Government shared spatial services can be expected to expand and enter the mainstream. Commercial value added spatial services can be expected to increase and expand. The potential exponential power of spatial information involves users being able to collaborate and combine local information with authoritative foundation information. The value proposition will be about turning information into knowledge and creating new industries and information.

Important future developments in spatial information that are likely to further enhance its economic impacts relate primarily to the falling cost of acquiring data, continuing developments of computing power making more applications and richer data analysis possible, and the arrival of spatial technologies into the consumer mainstream.

10.2.1 Falling costs of spatial data and systems

The falling cost of acquiring spatial data is being driven by:

- more widespread use of GPS, satellite imagery, aerial photography and remote and 3D sensing
- falling cost of analysing and transforming primary data into value-added forms, due to increasing computing power and accompanying arrival of more powerful spatial software
- falling cost of distributing that data to more and more users through an increasingly networked world
  - the increasing development and adoption of higher bandwidth next generation broadband solutions is expected to offer further opportunities for low cost (even free) data distribution, even for datasets previously too large for network dissemination.

The emergence of a geo referenced world is being made possible through falling costs in systems. According to industry sources:

- it now costs less than $US1 to install a GPS chip in a mobile phone
- radio frequency information tags now cost less than 5 cents.

Thus we are likely to see increased use of GPS in mobile phones and increased use of wireless applications in spatial systems.

All of these developments, collectively, act to reduce the cost of acquiring spatial data, potentially enhancing use and value.

10.2.2 More powerful applications

Increased access to cheaper data accompanied by more and more powerful applications has an important flow on effect, relating to what economists call the network effect.

In summary, this relates to the increasing marginal value that a user gains from use of a technology with each additional person that uses the technology. In other words the value of using spatial information over a GIS system increases as more users are using the same system, creating more data and more additional applications and more opportunities for data exchange.

Applied to a business' decision on whether to invest in a GIS system, for example, it is a far more attractive proposition when there is already a mass of existing data and applications that can be applied to the challenges facing the business, compared to if the data had to be generated and transformed totally by the one business.

More powerful applications are also likely to lead to new navigational interfaces where digital information will be overlayed with social and economic data in the real world. The AMSA case study showed that this is already occurring.

Non geographic mapping of economic and social trends will create new opportunities for networked social and economic research which is already finding applications in location of stores, investment in telecommunications facilities and analysis of urban and social planning.

Spatial capabilities will also support working in 3 and 4 dimensions. This will allow trends to be assessed both geographically and over time. ACIL Tasman has already developed a spatially enabled model of the global gas market which shows infrastructure requirements over time as well as over distance.

10.2.3 The consumer mainstream

Another important development that will increase the aggregate impact of spatial information is its imminent arrival into the consumer mainstream. Until recently spatial applications were largely the domain of specialist business application requiring trained personal with specialized geographical knowledge.

However, this has begun to change over recent years, as applications have become both more widespread and more user-friendly.

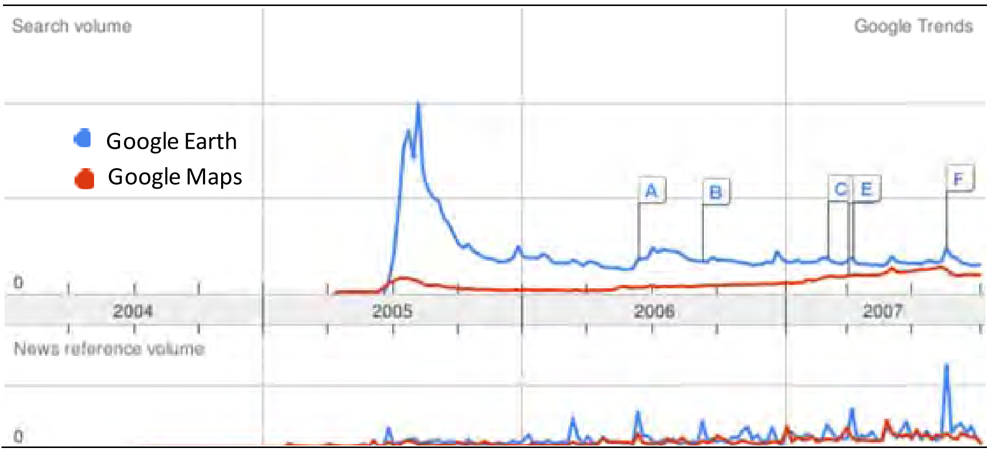
With the recent acceptance of spatial technologies such as GPS, in-car navigators and online mapping applications by households and personal consumers, spatial technologies are being adopted by mainstream society more than ever before. In particular, the mobility of portable GIS and GPS systems has revolutionized GIS use.

The incorporation GPS and, in some cases, basic GIS, into next generation mobile phone functionality is expected to further bring spatial technologies to the general population. The benefits of this are not just in the direct impacts of increased use.

The geographic literacy that the use of such applications is likely to drive further spatial opportunities, as geographically literate users from different industries come to recognise innovating new ways to apply the technology and data to their specific industries.

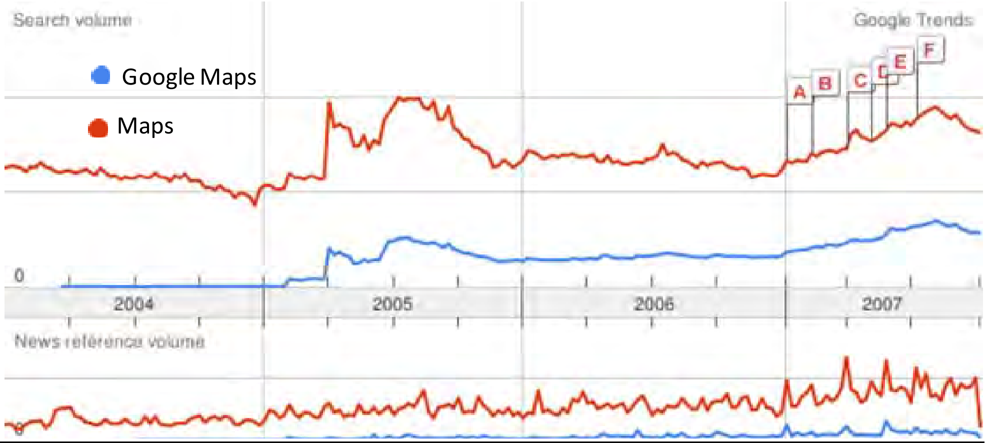
A search of Google trends shows how quickly new spatial applications can be taken up in the consumer market. Figure 21 compares the growth in enquires for its Google Earth and Google Maps applications and Figure 22 compares searches for Maps and Google Maps. While Google Earth enquiries peaked shortly after its introduction and then stabilised shortly thereafter at a lower but consistent level, search enquiries for the mapping application has been growing since 2005. Over the same period searches for Google Maps had been increasing as a proportion of general map enquiries. These trends are not necessarily definitive but do demonstrate how rapidly new applications can be adopted in Australian society but also how awareness of digitally supported mapping systems is growing.

Figure 21 **Search volumes for Google Earth and Google Maps**



Data source: Google trends

Figure 22 **Search volumes for Maps and Google Maps – Australia**



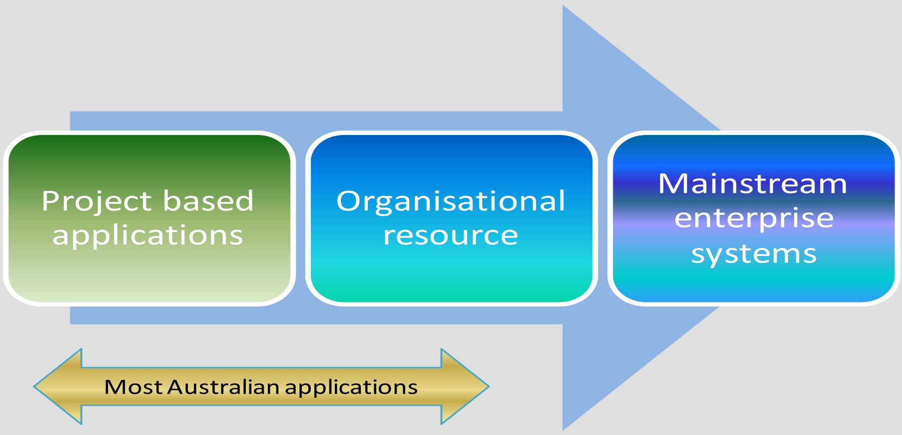
Data source: Google Trends

10.3 An evolving industry

Most spatial information applications in Australian government and industry to date are either ***project based*** or used as ***an organisational resource***.

Lower costs, higher analytical power and further business integration is likely to lead to spatial information systems becoming ***mainstream enterprise applications*** as has the internet and personal computing.

Box 12 **Phases of adoption in enterprises**



Data source:

While the future is always hard to predict, trends in the use of systems such as Google Earth, digital maps and GPS suggest that Australia along with much of the developed world is entering a new phase in spatial information systems.

10.3.1 The next phase

In very general terms, the development of spatial information systems has developed in three phases so far:

- a mapping and surveying phase up to 1970
  - characterised by paper maps
- a technical applications phase
  - introduction of digital co-ordinates between 1970 and 1990
- a service provider phase
  - characterised by the integration of GIS, GPS and IT
- including a move to 3D and 4D applications from around 2000.

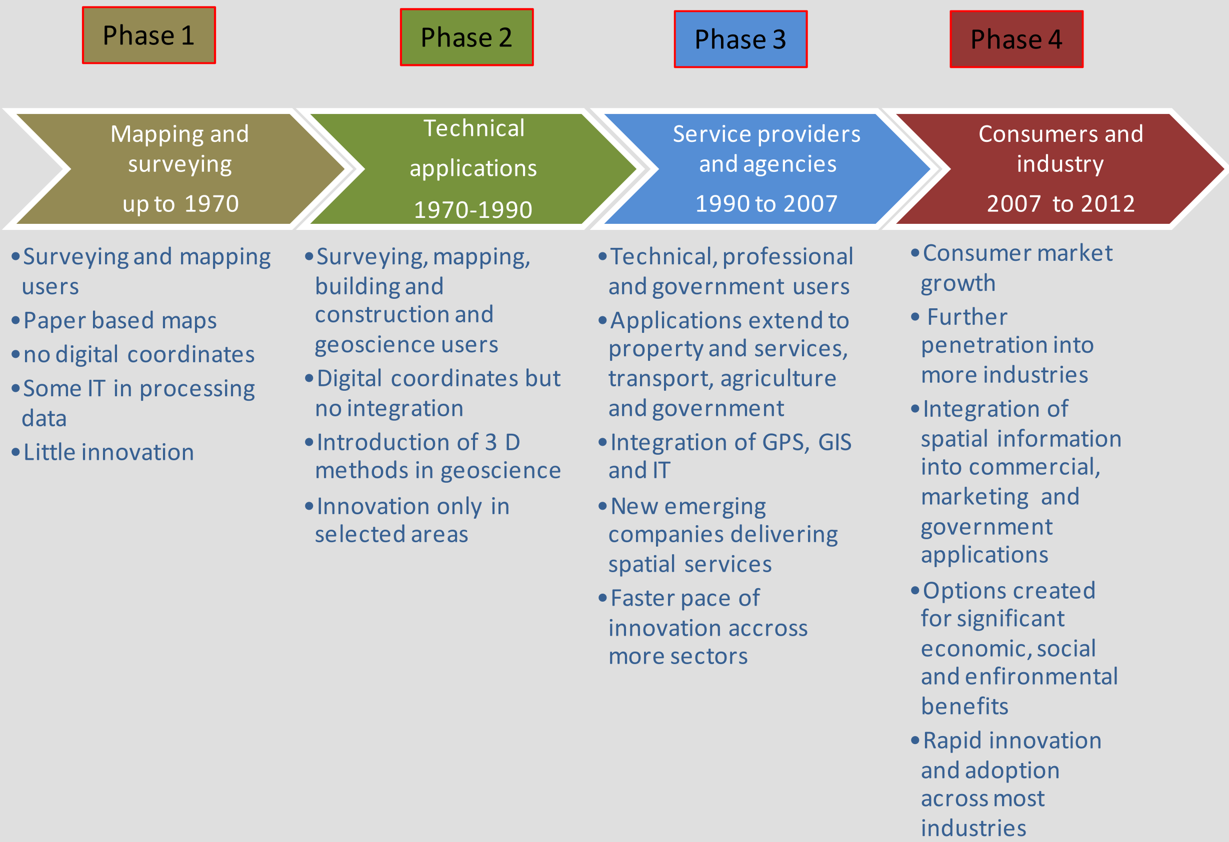
The current trends suggest that spatial information is entering a fourth phase of penetration into consumer markets and full integration into mainstream enterprise systems (see Box 13).

This phase has the potential to bring significantly higher benefits to government and businesses in Australia with implications for higher levels of economic growth and more effective management of the social and environmental challenges of the future. As the case studies revealed, spatial information is critical to management of water resources and adapting and responding to climate change.

It also offers significant opportunities for the growth of new industries based on spatial information. These industries are likely to find significant global opportunities as spatial information becomes more mainstream in the global economy supported by broad band access and new applications suitable to consumers and non GIS professionals.

Levels of innovation are likely to be higher for successful companies and research and development may also need to move to providing the science and knowledge to support innovation in mainstream consumer and business markets as well as to support the data infrastructure questions and the science to support environmental and natural resource management systems.

Box 13 **Four phases of spatial information development**



Data source: ACIL Tasman

The fourth stage is likely to offer significant opportunities for consolidation and expansion of existing applications but, more importantly, development of new industry models, higher levels of benefit and opportunities in global markets for innovative companies.

The options created for Australian companies to develop new products and applications from Australian research and development are likely to be very significant. However like all options, the exact path that the markets will take may be hard to predict.

It is likely to be a time that will require research and development, innovation and commercialisation to be directed towards global as well as national markets.

With the right policies and supporting research and development it would not be unreasonable to conclude that the impact of spatial information on economic growth could be significantly higher than the impact in 2006-07.

It will be essential to meet the environmental and climate change challenges that Australia will have to address over the next ten years and beyond.

The success of the spatial information industry is also likely to be critical to maintaining international competitiveness for Australian industries.

10.3.2 Knowledge based industries

The spatial information industry is a knowledge intensive industry which, having recently emerged is at the forefront of innovative activity in the Australian economy. The sector recruits and depends upon highly educated people and staff with advanced skills in ICT. The opportunities created in this sector help retain key human capital assets in the country and provide attractive career options for young Australians. For example, The CRC for Spatial Information currently has 24 PhD and Masters students developing spatial information expertise.

Where the sector differs from some other knowledge-intensive sectors is that it has already generated a suite of customised products which are selling at a profit. This is unlike some other fledgling innovative sectors (e.g., biotechnology) in which many spinoff companies launched during the last decade are yet to trade profitably.

Part of the explanation for this is that the core spatial industry has grown somewhat 'organically' out of the surveying and mapping sectors discussed in this report. Interaction with various publicly funded R&D programs and the general ICT sector also undoubtedly contributed to the growth of the industry, but the detail of these interactions has not been the subject of this report.

We note, however, that with the growth of the spatial industry, it is likely that a number of existing economic activities will in due course be either changed 'beyond recognition' or become obsolete. This is largely because the automation facilitated by various advances in software, hardware and machining, when combined with spatial information, makes many previously manual, labour intensive tasks, as discussed throughout this report obsolete.

Some of the wider economic and social impacts which will be a consequence of modern spatial information technologies have therefore not been covered in the current report, but could nevertheless be important.

10.3.3 International competitiveness

As this report reveals, spatial information is also highly important for the ongoing competitiveness of many of Australia's industries – mining, resources, property and services, construction and transport. It is also a crucial component of government administration – defence and security, biosecurity, geoscience, bathymetry and asset management.

However the international competitiveness of Australia's industries is also affected by the relative advancement compared with other countries. Canada, China and Europe are all moving relatively quickly down the path of more efficient spatial information systems.

To maintain the international competitiveness of Australia's spatial information applications and industry it is important not to fall behind the global leaders. Australia has many areas where it is world class. However constraints on data, among other things, are a threat to success in this area.

A healthy spatial information industry will be an important supporting industry for Australian business. The opportunity is there for the industry to develop in its own right. But importantly it will be an important supporting industry for the emerging economy that will be spatially enabled.

11 Implications for future research and development priorities

This project did not undertake an investigation of research and development priorities. However any assessment of the relative value of various research investment portfolios must take into account their potential contribution to the economic and social wellbeing of Australian society. Current and potential economic impacts provide some pointers to research and development priorities.

The following observations on possible implications of the findings of this report for research priorities are drawn from the case studies, literature review and interviews conducted in the course of analysis for this report.

11.1 Generic issues

The contribution of spatial information to the economic, social and environmental welfare of Australia could be increased if the constraints on access to data are addressed in the near term. Most of the issues are whole of government policy questions that require policy reform. However there may be research that addresses some of these issues including:

- fundamental data
  - research priority might be given to what fundamental data should comprise in terms of the needs of government, industry and society
  - including levels of currency, coverage and content
- data infrastructure
  - priority areas could include interoperability, standards and systems,
  - progressing the concept of Virtual Australia
- positioning infrastructure
  - to progress the goal of achieving centimetre level accuracies in near real time across most of the continent
- data Access
  - technologies and systems to provide simple and effective access
  - developing consistency between data access portals such as AuScope and the Integrated Marine Observing System
  - developing more efficient licensing and privacy arrangements.

11.2 Increasing as adoption of established technologies

Increased adoption of existing spatial information technologies in business and government operations will increase the economic and social contribution of spatial information to Australia.

The case studies indicated that greater contribution from spatial information may be achieved through further extension of spatial information in several economic sectors. Notable areas and possible research needs include:

- agriculture
  - providing farmers with simple, user-friendly, integrated information systems
  - researching factors that will increase the adoption of precision agriculture where it is economic to do so
- property and services
  - technologies to increase the more efficient supply of infrastructure and land
  - use of spatial technologies for faster and more efficient development approvals and environmental regulation
- construction
  - lower cost spatial technologies for measurement and management of the construction process
  - easier to use interfaces with spatial technologies
- transport and handling
  - technologies to improve congestion management, rail use of GNSS and consumer information on public transport
  - technologies to optimise fuel use and lower emissions
  - technologies to track vehicles, goods and commodities, especially in bulk handling at railheads and ports
- biosecurity
  - approaches to monitoring and capturing data including the use of interfaces
  - consistency between data sets
- natural resources and climate change
  - use of spatial information systems in monitoring greenhouse gas emissions and pollutants in the atmosphere, in water courses and the marine environment
  - interoperability between natural resource data portals
  - applications in carbon and water trading

  - spatial information in meteorology and weather predictions
  - Integration of spatial information with remote sensing and data capture
- defence, security and emergency services
  - integrating systems and applications for wider user groups.

11.3 New applications and mainstream enterprise systems

This report concluded that the next stage in the development of spatial information is likely to be through mainstream enterprise systems. This would lead to the broader application of spatial information into new areas of retail and trade, tourism and recreation, government administration as well as extending its use in traditional sectors.

Research priorities in this respect could include:

- development of user interfaces more suited to non spatial information specialists
  - including lap top computers, personal data organisers and widely used software and applications
- integration of spatial information systems into organisation wide ICT and communications
- development of spatially based strategy and economic models and management information systems more suited to general management
- use of spatial information in social and economic research
  - extending use beyond data capture to analysis, planning and decision support.

11.4 Mainstream consumer markets

Emergence of spatial information into mainstream consumer markets is likely to be economically and socially very significant in the next five years.

Anticipating the direction, scale and scope of such developments is difficult to predict.

Priority research issues could include:

- analysis of emerging consumer needs
  - individual spatial applications
  - applications for social networks
  - commerce
  - public transport
  - intelligent maps

  - property and commercial information
  - monitoring location of vehicles, possessions and people
- integration of spatial data and existing and emerging applications
  - to widen use by non-specialist consumers
  - to expand access to spatially relevant consumer relevant data bases.

11.5 Concluding comments

The above suggested areas of research priority are drawn from observations of the case studies and analysis for this report. They do not take into account prospects for certain technologies, risks or potential research findings that might provide further guidance to prioritisation. They should therefore be viewed as a starting point in consideration of future research priorities.

A Terms of Reference CRC-SI

The Cooperative Research Centre for Spatial Information (CRC-SI) commissioned ACIL Tasman in July 2006 to conduct an independent quantifiable analysis of the value of spatial information to the Australian economy in the 2006-07 financial year.

The study had three objectives:

1. to establish the verified and quantified economic impact of spatial information to the Australian economy in 2006-7 year
2. to estimate the cost of inefficient access to data and identify the factors operating to create these inefficiencies
3. to consider the future prospects for the spatial data to contribute to Australia's economic, social and environmental development goals.

Several issues were relevant to this study:

- The study was to provide a firm figure for the total value of spatial information to the Australian economy.
- The study aimed to identify the key factors that are operating to prevent SI making an even larger contribution to the Australian economy and will therefore help provide a fundamental basis for the programs of the CRCSI rebid in 2008.
- The study needed to be conducted with the full rigour of a federal treasury study.
- The study was supported by ANZLIC, and the ASIBA Board. Its conduct in all phases was coordinated with each of these organisations. At the same time ASIBA conducted a parallel study with ACIL Tasman to explore a range of sector-specific case studies to demonstrate the impact of spatial information and technology (SI&T) on the national economy. It also identified constraints on the industry, such as skills shortage, privacy, data pricing and property rights, as well as a general unawareness about SI&T's diverse potential. The ASIBA report has been published as "Spatially Enabling Australia." CRC-SI

B Literature review

A brief review of the available literature provides some indication of the value of spatial information to developed economies, including Australia

B.1 International studies

Numerous international reports and initiatives (eg OECD 2006, JT03206702, INSPIRE) suggest that there are enormous efficiency gains to be had for the economy by better integration of government and private spatial information operations.

Studies of the direct value of the spatial information industry have estimated that:

- The industry worldwide grew by 27% per annum from 2002 to 2004, Daratech (2006).
- (The Spatial Information Industry Action Agenda, 2000) global expenditure on spatial information was AUD34 billion and growing at the rate of 20% per annum.
- The total output value of China's geographic information industry was estimated to be over US$ 3 billion in 2005, and it is expected to grow to over $10 billion by 2010. The industry is expected to stimulate value in other related industries of around US $63 billion by 2010.
- (OXERA, 1999) the value of the geographic infrastructure to the Europe, as crudely measured by the amount invested, as ECU 10 billion per year.
- A similar measurement of the amount invested in geographic infrastructure in Great Britain by NOP (1998) was £204 million in 1997 (OS, 1998 out of OXERA, 1999).
- The value of the British Geological Survey alone to the United Kingdom economy alone was estimated to be well in excess of its annual turnover of £40 million (Roger Tym & Partners, 2003).

B.1.1 The National Map – a U.S. cost-benefit study conducted in 2003-04

"The National Map" (TNM) is a US Government initiative somewhat similar to the Western Australian Government's Land Information System (WALIS) in that it integrates geospatial data from a number of sources in consistent format and makes it available to the public. Its broad aim is "to assist effective decision making".

B.1.2 The study

A cost benefit study of The National Map (TNM) is described in a February 2004 journal article by Halsing and Theissen. This study by Halsing et al sought to evaluate the additional benefits that have accrued to past users from having access to the service. It involved large scale data modeling, but still appears to rely a great deal for its results on analysts' judgments (Halsing, 2004).

B.1.3 Methodology

In the study, the specific applications of TNM were identified and classified into three different "tiers".

- The first was the simplest and referred to paper mapping and simple overlay analysis.
- The second tier was more complex route planning or locational analysis.
- The third tier involved complex geospatial statistics and formal optimization modeling.

Users were also classified into tiers, with third tier users able to use first and second as well as third tier applications, and second tier users able to use first tier as well as second tier applications. Assumptions were made about the rates at which users of applications of the TNM data could make the transition from tier 1 to tier 2 or tier 3.

The proportion of each type of user in every county in the US at the start of the period was estimated on the basis of an earlier survey and the growth in each category of users was projected over 30 years. Applications by the Federal Government were recorded separately. A time series of the costs producing the service was similarly estimated.

The net benefits accruing from an application were taken to be the difference between the costs and benefits of the application using TNM and the costs and benefits of not using the TNM for the same application. These values were obtained from users at each tier through telephone surveys and literature review. The net benefit for each application is drawn randomly from a normal distribution of outcomes centered on a US$1,000 average, said to be a conservative figure in view of the survey information. For applications at Federal Government level, an average US$10,000 net benefit was assumed.

B.1.4 Model results

Using this mixture of synthetic and empirical information, a computational model was created to simulate the number of users, applications, innovation and diffusion and changes in net benefits.

Overall, a net present value (NPV) over 30 years for the project of US$2.05 billlion was found, with a standard deviation of US$490m (and 95% confidence limits of US$1.07 to US$3.03m). In the NPV calculations, a seemingly low 3.2% discount rate was used. Ancillary calculations, such as breakeven period, key variables identified in the sensitivity analysis are reported.

B.2 A review of earlier Australian studies

B.2.1 Introduction

A web-search reveals that over the last decade there have been several studies or reviews of the value of spatial information and infrastructure in Australia

Some are on related subjects such as:

- GDI pricing policy (for example Longhorn and Blakemore (Longhorne, 2003))
- contracting-out to the private sector of certain GDI functions (for example Brown and Brudney (Brown, 1998))
- funding options for GDI services (for example Fires and Warneke.)
- WALIS Valuation Project (ACIL Tasman 2005)

Some involve a limited discussion of the benefits and costs of such systems. Most do not attempt a quantitative assessment of the costs and benefits, although they may be valuable in other respects.

B.3 Quantitative studies

This section presents brief reviews of three earlier studies which have looked at the whole of spatial data infrastructure and services and have attempted some quantitative analysis of the value of the product.

B.3.1 ANZLIC study Feb 1995

In 1994 the Australia New Zealand Land Information Council (ANZLIC) commissioned Price Waterhouse (PW) to look (among other things) at the economic gains from the use of GDI services in Australia over the past 5 years (Price Waterhouse, 1995).

PW was also asked a few other questions such as what steps data supplying organisations in Australia should take to maximise potential infrastructure benefits, but its responses to these questions are not discussed here.

Surveys conducted as a part of PW's review indicated that the benefit cost ratio for GDI usage was approximately 4:1. That is, for every dollar of investment a return (gross benefit) of $4 on average was associated – estimated at about three quarters of a billion dollars a year. Significantly, this is the estimated benefit for all uses of the data, not just uses stemming from the existence of an integrated framework of the kind WALIS provides. PW found that if users had been forced to meet their data requirements from other sources, their costs would have been approximately 6 times higher, representing an annual cost of about $1 billion.

Analysis of costs

The major cost categories relating to the operation of land and geographic infrastructure were defined by PW as:

- feasibility studies
- hardware and software
- hardware and software maintenance
- data collection or purchase
- data base entry and transfers
- data base maintenance in the form of edits, updates and backups
- personnel training
- in house support for systems users
- operating expenses in relation to staff, paper, computer disks etc
- general overheads such as office space, air conditioning, access to library and reference facilities.

Such costs are pretty much clearly defined and thus estimating them was not difficult.

Analysis of benefits

Price Waterhouse outlines three broad categories of potential GDI benefits:

- to the supplying agencies – in the form of reduced costs and expanded product and service range through:
  - reduced man-hours needed to collect, check, process, analyse, and distribute data (through reduced duplication of effort across agencies)
  - replacement of dull or repetitive in-house tasks
  - improving system flexibility in terms of adjusting to individual user requirements
- to agencies and other users which purchase or order data – through reduced costs and expanded the product and service range
- to the broader community.

The report explains that user effects should be estimated by examining the contribution of land and geographic data to the ultimate impact of a project or program, relative to other project or program inputs which were relied upon. Of course, it is difficult to isolate the contribution of the one input when there are so many others.

The Price Waterhouse method was to evaluate the benefits flowing to data using agencies by simply referring to intra-agency efficiency gains derived from:

- data being delivered in a more timely manner
- data being able to be used without the need for elaborate transformation
- data being geared closely to individual user requirements
- higher levels of data accuracy
- improved data coverage.

The report also comments that it is difficult to measure community wide benefits, thus it does not attempt to capture such benefits in the analysis. Price Waterhouse explains community wide benefits by the use of an example that describes the use of GDI to alleviate waste-water pollution at metropolitan beaches. The community benefits in this example are described, PW says, by the benefits that accrue to owners of the beach-side hotels, patrons of the beach whose leisure activities are enhanced by swimming in cleaner water and so forth.

Survey methodology

For the purposes of this study, Price Waterhouse surveyed over 80 major suppliers of land and geographic data in Australia and over 350 major data users.

Suppliers

Suppliers were asked for information on:

- total costs of producing land and geographic data
- sales or distribution of data
- effort directed to capturing, processing and distributing data
- areas and levels of activities over the next 10 years
- recent and expected technological advances
- internal methods of performance monitoring.

The PW report's commentary on how it estimated the cost structure of the data supply industry is instructive about the generally pragmatic approach PW took throughout its study:

The supplier survey was distributed to 82 organisations which were estimated to cover around 85% of Australia's total supplier population. Forty-one organisations, representing 50% of the total sample, furnished returns. The survey respondents to arrive at an indicative aggregate supply cost. An adjustment was then made to account for the initial shortfall in the coverage of the total survey sample of some 15 percent. Stratification and extrapolation procedures yielded an indicative aggregate cost figure for suppliers of all land and geographic data throughout Australia.

Users

PW's user survey contained questions on the following:

- data products and services respondent had acquired over the past five years
- areas of industry activity in which data was applied
- major sources of data – internal, external and by supplier agency type
- major data forms – paper maps, text, digital vector, and imagery
- data costs over the past five years
- forms and costs of the next-best source of data supply
- internal efficiencies arising from the use of data
- contribution of data to the ultimate success of projects or programs undertaken by users
- external efficiency gains which flowed to other organisations or to individuals as a result of those projects or programs
- desired improvements in land and geographic data availability and coverage.

Of the 370 survey forms sent out to users, there were 57 responses. The coverage was considered inadequate statistically. The user survey was therefore abandoned and the value of usage was estimated as the cost of production and distribution using data from the supplier survey.

An observation that PW felt it could make from the user information it obtained was that nearly two thirds of all data was generated by firms for internal use – making many organisations both providers and consumers of their own data products. The remaining one third of data used was obtained from outside sources, of which 58% (by cost) came direct from State Government agencies, 19% from Commonwealth Government agencies, 9% from local government agencies, and 14% from the private sector.

The 4:1 ratio mentioned earlier was derived from the survey question regarding cost savings. It asked about the cost of the use of the GDI compared to the cost of using the next best alternative. The cost differential was calculated as the benefit.

Although the survey did not generate any sophisticated answers to the question of valuing the data infrastructure, it did provide some good qualitative information on the matter. For instance, 65% of respondents registered improvements in their internal efficiency as a result of using the infrastructure.

Case studies

In addition to conducting surveys, the PW report undertook a handful of short case studies. The case studies included:

- Local government – Shire of Melton (Victoria) where data is utilised for property identification and to validate existing land records
- Law enforcement – NSW police. Infrastructure is used to identify the accurate location of vehicle crash sites (assists in investigating hit and run incidents), tracking criminal activity by time and location, transfers of intelligence between policing units and the generation of statistics to inform the community and neighbourhood watch members about accidents in their vicinity
- Public utility management – Sydney electricity uses data infrastructure for information leading to environmental impact statements, asset replacement and maintenance schedules, cable network planning, monitoring asset performance such as street lighting and mapping sub-terrain structures to indicate optimal cable paths
- Health care – North Sydney area health service where data infrastructure is used to determining causal relationships between disease and environmental factors such as lead levels and toxic waste, establishing the most effective site for location of medical screening programs, monitoring demands placed on nursing homes, planning emergency services networks, and investigating food-borne disease outbreaks
- Natural resource management – tree mapping in Victoria
- Education – Victorian Department of School Education
- Mining – CRA exploration.

All the case studies generated useful insights.

B.4 Previous cost benefit studies

Cost-benefit studies indicate that substantial net benefits arise from spatial information infrastructure investment. The major studies are those by:

- ABARE (ABARE, 1994)
- KPMG Peat Marwick (KPMG Peat Marwick, 1991)
- Tomlinson, (Tomlinson Associates, 1993)
- Price Waterhouse Economic Studies and Strategies Unit (Price Waterhouse, 1992)

- Department of Defence (Department of Defence, 1992)
- EASAMS (Deparment of Mines and Energy, 1991)
- Western Australian Government Taskforce (ACIL Tasman, 2004)
- MWP Management Consultants (MWP, 1988)
- Bureau of Transport Economics (Bureau of Transport Economics, 1983).

ABARE 1994

ABARE examined the economic costs and benefits of two selected applications of land and geographic data – the use of satellite imagery to map tree cover in Victoria, and the use of remotely sensed information to monitor pasture fertiliser status throughout Australia.

Net gains of around $1.5 million were estimated to have flowed from the first application, where gains were measured in terms of the lower cost of satellite imagery relative to the next best alternatives of aerial photography and land surveys.

For the second application, a net gain of around $66 million was estimated. In this case, benefits were measured from the perspective of remote sensing allowing farmers to identify their most efficient fertiliser distribution patterns and to replicate these in other areas of their operations to produce higher overall crop/livestock yields.

KPMG study 1991

KPMG's study aimed to construct a business case for the development and co-ordination of spatial information systems within South Australia's public sector.

Final results were based on experience from three projects, namely:

- the establishment of a State asset management system
- the mapping of a storm water network
- the construction of a spatial information systems data directory.

In overall terms, costs of around $1.2 million were estimated, compared with between $3.5 million and $7.0 million in benefits. The gains from improved access to data were generated from a number of sources, perhaps the most important being higher internal productivity as higher quality data reduced manpower requirements within State Government agencies.

Tomlinson Associates 1993

Internal efficiencies were also the principal component of gains identified by Tomlinson Associates which examined, in considerable detail, the costs and benefits of land and geographic data use within the Victorian Government.

Tomlinson estimated that overall data costs of $56 million would yield benefits of around $312 million to the State, representing a benefit/cost ratio of 5.5:1.

The study covered the five key program areas of:

- demography
- land status and asset management
- community health and welfare
- resources and the environment
- State planning and infrastructure.

Sets of results were presented for each major Government agency. Gains were generated primarily through data increasing staff productivity within agencies and providing for improvements in the utilisation, pricing, maintenance or disposal of agency assets.

Price Waterhouse Economic Studies and Strategies Unit 1992

Price Waterhouse Economic Studies and Strategies Unit surveyed the Public Interest Program of the Australian Surveying and Land Information Group (AUSLIG).

The study estimated total program costs to be in the order of $27 million compared with Program benefits which were estimated conservatively at $103 million. This produced a benefit/cost ratio of around 3.8:1.

Net gains were measured mainly in terms of AUSLIG's low data supply costs relative to the costs of alternative sources of land information. Results were presented for each of AUSLIG's major product groups on an Australia-wide basis.

Department of Defence 1992

The study by Defence attempted to assess gains arising from the Royal Australian Navy's hydrographic program.

A number of major benefits were identified including a reduction of shipping costs through improved navigational information, and a reduction in risk associated with accidents at sea. These benefits were unable to be quantified and therefore compared with the program's costs.

EASAMS study 1991

The EASAMS study developed a strategic framework for a geoscientific information system in South Australia. While an overall figure for net gains was difficult to determine, the study was unequivocal in its support for a more "open systems architecture" for the State's Department of Mines and Energy. Important benefits from such a system would come through substantially lower systems operating costs as data collation times were reduced and professional staff were released to concentrate on the more effective analysis and presentation of data and to generate additional geoscientific information. Mineral exploration in South Australia was expected to grow as the State's geoscientific information improved.

Western Australian Government study

A Western Australian Government Taskforce found that substantial gains were likely from integrating land and geographic data held by State agencies. This integration would include steps to clarify data custodianship, the establishment of a land information directory, standard procedures for data collection, and improved marketing of data.

The annual costs of integrating land information were estimated at $1.8 million and the potential annual benefits at $10.7 million – resulting in a benefit/cost ratio of 5.9:1.

Benefits were likely to include an improved ability to respond to land management issues, undertake natural disaster planning, replace ageing infrastructure, avoid duplication in Government services, and improve labour productivity within data supplying agencies.

Price Waterhouse Urwick study

Price Waterhouse Urwick examined the economic aspects of establishing a more up to date digital mapping data base for use in NSW land information systems. In particular, the study looked at the costs and benefits of undertaking accelerated digitisation of the State's cadastral and topographic land information compared with the costs and benefits of producing the same output with established staffing and financial resources.

PWU found a substantial net gain was likely from reforms, with benefit-cost ratios ranging from 9:1 to 2:1 depending upon the reform options chosen. The major benefits from an accelerated program related to: additional sales of data by existing suppliers; those suppliers being able to provide data at a lower cost than if (relatively inexperienced) users attempted to digitise their own information; digital data substantially reducing the manpower needed in the longer term to produce and apply mapping output; and, new digital data allowing users to undertake additional tasks such as more extensive environmental control and more effective maintenance of assets.

MWP Management Consultants 1988

MWP Management Consultants found that substantial long-term benefits were likely from establishing an integrated land information system for the ACT. These would come mainly from staff savings in data-using agencies, the supply of data in a timelier manner to users, improved tax collection by Treasury, and lower costs of data transfer.

Bureau of Transport Economics 1983

Work by the Bureau of Transport Economics in 1983 provided an indication of how large the benefits might be.

The Bureau pointed out that the establishment a more efficient passage through the Great Barrier Reef (northeast of Mackay), in which the Naval Hydrographer played an important role, had provided a direct deep-sea route for naval and commercial shipping from Queensland to the Coral Sea. Based on savings in fuel costs alone, the benefit-cost ratio for the passage was around 2.7:1.

C Real options

Real options has, since the early 1990s, attracted growing international interest as an approach to investment planning and management that addresses serious limitations in more traditional discounted cash flow modelling methods. These limitations are most acute where there are high levels of uncertainty about future developments that would impact on the value of an investment or contract commitment, and where there is scope for adapting the strategy over time to emerging information about those future conditions. Many spatial applications exhibit these uncertainties.

ACIL Tasman has, for several years now, been drawing on key elements of this approach to enhance the services it can offer in respect of risk-based decision making where the value of different options must be estimated. The newness of the formal paradigm (though elements have been around for many years, as evidenced by the early risk modelling done by ACIL) warrants some specific discussion. Most of the elements were already in place, but these have been further adapted within a framework that is both intuitively appealing and powerful.

The real options approach has simultaneously addressed increasingly obvious problems with the older investment models — and explored the sometimes counterintuitive prospect that options can offer of allowing *value to be extracted from volatility* and uncertainty. This can be done by designing options that limit downside risk while retaining access to upside volatility or opportunity.

The real options approach is underpinned by 2 key concepts:

1. Every investment choice or strategy commitment can be viewed as changing the set of options available to the investor and/or the wider community — and its value should be judged in terms of the *change in the value of the associated sets of options.*
   a) Raising the possibility of bringing to bear on these physical asset management strategies the powerful tools that have emerged, and have been accepted, for valuing financial options; and
   b) Inviting the design of strategies that increase the value of the option set.
2. Where there are high levels of uncertainty, the value of a set of options is heavily dependent on both the robustness of those options in dealing with the likely range of possible futures, and the flexibility offered to adapt strategy in the light of emerging information — about markets, technologies, competitors, environmental threats etc.

Any sound comparison of alternative strategies must therefore take into account differences in flexibility and robustness — and these should be seen as fundamental parts of the value of an option, not simply as inputs to a risk analysis.

In some respects, the value of spatial information technologies lies in the options they create for businesses and governments to realise future economic and social benefits.

D List of organisations and individuals consulted

- Alinta (Chris Hamilton, GIS Manager; and Greg Donald, Environmental Manager)
- ASIBA (David Hocking, CEO)
- Association of Consulting Surveyors Victoria
- ANZLIC
- Australian Centre for Precision Agriculture (James Taylor, Research Fellow)
- AST (Don Hitchcock, Managing Director)
- Airservices Australia
- Australian Bureau of Statistics, Construction Survey Team
- Australian Construction Industry Forum (Graeme Taylor, Executive Director)
- Australian Institute of Quantity Surveyors (Terry Sanders, General Manager)
- Australian Maritime Safety Authority
- Australian Government Information Management Organisation
- Attorney General's Department
- B&P Surveys (Brian Raaen)
- Brazier Motti (John Butterhand and Raneir Melick)
- Chevron Texaco
- Construction Industry Institute, Queensland University of Technology (Denise Redfern)
- Cox Humphries Moss – Architects & Planners (Graham Humphries, Director)
- CRC for Spatial Information (Dr Peter Woodgate CEO, Dr Graeme Kernich, Business Manager)
- CSIRO (Michael Robertson, Sustainable Ecosystems, Stuart Minchen, Land and Water)
- Department of Agriculture Fisheries and Forestry
- Australian Government Department of Finance and Administration – Consultative Committee on Knowledge Capital – and the Queensland Department of Treasury – Office of Statistical Research
- Defence Imagery and Geospatial Organisation
- Department of Lands, NSW
- Department of Planning and Infrastructure NT

- Energex
- Ergon
- Engineers Australia (Leanne Hardwicke, Director)
- Fugro Spatial Solutions
- Geoscience Australia
- Geocomp Systems
- GRDC (Phil Price)
- GISjobs International (Dean Howell, Managing Director)
- Land Development Agency, ACT
- Land Development Corporation NT (John Dong)
- Land Surveyors Licensing Board, Western Australia (Richard Browne, Secretary)
- Landgate, Western Australia (Barry Cribb, Mgr Land Boundary Services; John Del Borello, Team Leader Plan Lodgment, and Mike Bradford, Executive Director-Information Access)
- Melbourne Water
- National Centre for Epidemiology and Population Health (Dr Keith Dear, Senior Fellow in Biostatistics; and Ivan Hanigan, Data Management Officer)
- NGIS (Paul Farrell, Managing Director)
- Omnistar
- Office of Spatial Data Management
- Queensland Department of Treasury – Office of Statistical Research
- Reeds Consulting
- Royal Australian Institute of Architects (David Parken, CEO)
- SKM (Tony Wheeler, Principal; and Tamara Dousse)
- Scanalyse Pty Ltd
- Spatial Sciences Institute
- Surveyors Registration Board of Victoria (Anita Davids, Executive Officer)
- TransACT (Mark Blake, Network Build Manager)
- Ultimate Positioning (distributors of Trimble Australia products)
- University of Melbourne (Dr Gary Hunter)
- Whelans (David Purnell, Manager GeoInfoSystems)

E References

ABARE. (1994). *Remote Sensing Use in Tree Cover Mapping and Pasture Management - An Economic Analysis*. Canberra.

ABS. (2000). *Australian National Accounts - Concepts, Sources and Methods.* Canberra: Australian Bureau of Statistics.

ACIL Tasman. (2003). *ICT and productivity – an economic analysis of Australian industry*. Canberra: National Office of the Information Economy.

ACIL Tasman. (2007). *The Impact of Water Reform on the Mining, Energy, Petroloeum and Pulp and Paper Industries.* Canberra: Department of Industry Tourism and Resources.

ACIL Tasman. (2004). *Value of the Western Australian Land Valuation System.* Perth: Western Australian Land Information System.

AFMA. (August 2007). *Vessel Monitoring Systems http://www.afma.gov.au/industry/vms/default.htm.* Canberra: AFMA.

Aghion, P. a. (1992). A model of growth thorugh creative destruction. *Econometrica* .

AGIMO. (2002). *E-government benefits study*. Canberra: Commonwealth of Australia.

AGIMO. (2007). *Results of a survey on Spatial Enablement of Australian Government.* Canberra: Commonwealth of Australia.

Agrtrans Research. (2005). *Review of progress of invasive species*. Brisbane: Agrtrans Research.

Airservices. (2007). *Annual Report.* Canberra: Australian Government.

Alexander, T. (2003). Measuring the Value of Geospatial Information: Critical need or fools errand. *Bienniel Coastal Geotools Conference.* Charleston SC.

Allen's Consulting Group. (2007). *The Economics of GPSnet to Agriculture.* Melbourne: Department of Sustainability and Environment.

Australian Greenhouse Office. (2007). *Emmissions Factors on www.ago.gov.au.* Canberra: Australain Greenhouse Office.

Booz Allen & Hamilton. (1998). *Intelligent transport systems for Australia.* Sydney.

Brown, M. B. (1998). A Smarter Better and Cheaper Government: Contracting and Geographic Information Systems. *Public Administratrion Review* .

Bureau of Transport Economics. (1983). *Evaluation of the Construction and Operation of Navigational Aids in Hydrographers Passage.* Canberra: AGPS.

Chen, R. J. (2007). Geographic information systems applications in retail, tourism and teaching curriculum. *Journal of Retailing and Consumer Services* , 289-295.

Christensen, C. M. (1997, 2000). *The Innovators Dilemma: When New Technologies cause great firms to fail.* Boston MA: Harvard Business School Press.

Corporate GIS Consultants. (2003). *Benchmarking the effectiveness of Geographic Information Systems to meet NSW Couincil Business Processes.* Sydney: Press Release.

Daratech. (2006). *GIS Markets and Opportunities.* Cambridge MA: Daratech Inc.

Deparment of Mines and Energy. (1991). *A Strategic Framework for the Development of a Geosceintific Informaiton System - Report of the Working Party.*

Department of Defence. (1992). *An Economic Analysis of the Benefits of the RAN Hydrographic Program.* CAnberra: AGPS.

ESRI. (2007). *Case studies on www.esri.com/showcase/case studies/index.html.*

ESRI. (2007). *ESRI Case studies on www.esri.com/showcase/case studies/index.html.*

Farsari, Y. P. (2004). GIS applications in teh planning and manageemnt of tourism: Blackwell companions to Goegraphy. In A. H. Lew, *A companion to tourism* (pp. 596-607). Oxford: Blackwell Pubishing.

Fivenines Consulting. (2005). *Victorian Spatial Industry Census.* Melbourne: Fivenines Consulting.

GIS Development News. (2006). *Annual total productino value of China's geographic informaiton industry.* GIS Development news.

Guenther, C. L. (2000). Meeting the Accuracy Challenge in Airborne LIDAR Bathymetry. *Proceedings of the EARLSig LIDAR Workshop, Dresden, FRG* , 2.

Halsing, D, Theissen, K, Bernknopf, R. (2004). National Maps: Benefits at what Costs? *Geospatial Solutions* .

Hemadez, T. B. (1999). Explaining REtail GIS: Thye Adoption, Use and Development of GIS witin Retailing in the Netherlands, the UK and Canada. *Netherlands Geographical Studies* .

ITS Australia. (1999). *e Transport: Thye national strategy for intelligent transport systems.*

KPMG Peat Marwick. (1991). *A Business Case for Development of Spatial Inforamation Systems Within the Public Sector.* Adelaide: Office of Information Technology, South Australia.

Longhorne, R. B. (2003). Revisiting and Valuing the Pricing of Digital Geographic Infomrmation.

Masgood, T. W. (2003). Investigating the Role of ICT in Impriving Priductivity in Construction Supply Chains in the Australian Construction Industry. *Second International Conference on Construction in the 21st Century.* Hong Kong.

McBratney, A., Whelan, B., Ancev, T., & Bouma, J. (2005). Future Directions of Precision Agriculture. *Precision Agriculture* , Vol 6, pp.7-23.

MWP. (1988). *Development of an integrated ACT land information system.* Canberra: ACT Administration.

OSDM. (2006). *Annual Report of the Spatial Data Policy Executive.* Canberra: Commonwealth of Australia.

OXERA. (1999). *The Economic Contribution of Ordinance Survey GB.* UK: Oxford Economic Research Associates Ltd.

Price. (2004). Spreading the PA Message. *Ground Cover, Issue 51* .

Price Waterhouse. (ANZLIC). *Australian Land and Geographic Data Infrastructure Benefits Study.*

Price Waterhouse. (1992). *The Economic and Social Benefits of AUSLIG's Public Interest Program.* Canberra: AUSLIG.

Primar Stavenger. (2007). *Facts about electronic charts and carriage requirements.* Helsinki.

Productivity Commission. (2002). *Impact of a Foot and Mouth Disease Outbreak on Australia, Research Report.* Canberra: AusInfo.

QSIIS. (2004). *Study of Spatial Imagery and Use in the Queensland Government.* Brisbane: Queensland Government.

QSIO. (2007). *Identifying the Queensland Spatial Information Industry.* Brisbane: Queensland Spatial Information Office.

Raaen, B. (2007). *pers comm.* Canberra: Raneir, Melick, Brazier, Motti.

Robertson, M., Carberry, P., & Brennan, L. (2007). *The economic benefits of precision agriculture: case studies from Australian grain farms.* Sustainable Ecosystems Division: CSIRO.

Robins, C. W. (1988). The impact of global positioning systems and plotters on fishing power in teh northern prawn fishery. *Journal of Fishing and Aquacultural Science* , 1945-1651.

Roger Tym & Partners. (2003). *The Economic Benefits of the British Geological Sevice.* London: Roger Tym & Partners.

Rogers. (2003). *Diffusion of Innovations.* New York: Free Press.

Romer, P. (1986). Increasing returns and long run growth. *Journal of Political Economy vol 94, no. 5* , 1002-1037.

Schofield, C. a. (2007). *Land and Water Australia's Portfolio Return on Investment* . Canberra: Land and Water Australia.

SEAC. (2007). *Spatial Information Industry in Australia.* Canberra: Australian Spatial Industry Business Association.

Senate Standing Committee on Rural and Regional Affairs and Transport. (7007). *Australia's future oil supply and alternative transport fuels.* Canberra: Parliament of Australia.

SIIAA. (2001). *Positioning for growth.* Canberra: Commonwealth of Australia.

SKM. (2007). *Presentation to the Institute of Surveyors.* Sydney.

SKM. (2006). *Three dimensional survey of Town Hall Station.* Sydney: APSA Spatial Awards.

Solow, R. (1956). A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics* , 65-94.

Solow, R. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics* , 39.

Spatial Vision. (2006). *Press release.* Melbourne: Spatial Vision.

Spatial Vision. (June 2007). *The Use of GIS by Australian Water Authorities.* Melbourne: Spatial Vision Innovations Pty Ltd.

Standing Committee on Transport and Regional Services. (2002). *Moving on intelligent transport systems - inquiry into variable speed limits - A case study of intelligent transport systems.* Commonwealth of Australia.

Sutton, C. J. (2005). GIS Applications in Transit Planning and Operations: A review of current practice, effective management and current callenges in the USA. *Transportation Planning and Technology Vol. 28, No. 4.* , 237-250.

Tomlinson Associates. (1993). *State Government of Victoria Strategic Framework for GIS Projects*. Melbourne: Office of Geographic Data Coordination.

Western Australian Department of Land Information. (1990). *An integrated land information program Phase 1*. Perth.

Wittwer, G. M. (2006). *Regional Economic Impacts of Plant Disease Incursions using a general equillibrium model*. Canberra: PLant Health Australia.

F Glossary

NLWRA	National Land and Water Resources Audit
43pl	A consortium of some 50 companies working with the CRC-SI to foster spatial information and learning.
AGIMO	Australian Government Information Management Office
AGO	Australian Greenhouse Office
ALGA	Australian Local Government Association
AMSA	Australian Maritime Safety Authority
ANZLIC	Australian and New Zealand Land information Council known as ANZLIC – the Spatial Information Council
ASDD	Australian Spatial Data Directory
ASDI	Australian Spatial Data Infrastructure
ASIBA	Australian Spatial Information Business Association
BOSSI	Board of Surveying and Spatial Information (NSW)
CANRI	Community Access to Natural Resource Information (NSW)
CGDI	Canadian Geospatial Data Infrastructure
CGE	Computable General Equilibrium Model
COAG	Council of Australian Governments
Competitive neutrality principles	Competitive neutrality principles ensure Government businesses face the same costs and commercial pressures that face their private sector competitors. National Competition Policy (NCP) competitive neutrality principles aim to remove the unfair advantage government agencies have when competing in the market place. The principles also remove the impediment to efficient resource allocation that had arisen from the regulatory advantage of government owned businesses.
CRC-SI	Co-operative Research Centre for Spatial information

Creative commons	Creative commons licenses are designed to facilitate and encourage more versatility and flexibility in copyright
CRIS	Client Resource Information System (WA)
DEM	Digital Elevation Model
DEST	Department of Education Science and Training
DGPS	Differential Global Position System (higher accuracy than CPS)
DIGO	Defence Intelligence and Geospatial Office
DITR	Department of Industry Tourism and Resources
DOHA	Department of Health and Ageing
DRM	Digital rights management
Fundamental data	Data that is collected by agencies under public interest programmes and also data that is collected by agencies to meet specific agency purposes but may be made more widely available in the public interest
GA	Geoscience Australia
GeoConnections	Canadian Spatial Data Infrastructure
GILF	Government Information Licensing Framework
GPS	Global positioning system
Interoperability	Interoperability describes the ability to work together to deliver services in a seamless, uniform and efficient manner across multiple organisations and information technology systems.
LADS	Laser Airborne Depth Sounding
Land Exchange	Land Exchange is part of Land Victoria, a division of the Victorian Government's Department of Sustainability and Environment (DSE). Land Exchange enable people to exchange land related information and conduct transactions via the Internet

LIDAR	Light Detecting and Ranging
Metadata	Metadata is structured data which describes the detailed characteristics of a data set.
NCAS	National Carbon Accounting Scheme
NWI	National Water Initiative
OCC	Online and Communications Council
OGC	Open Geospatial Consortium
OSDM	Office of Spatial Data Management
PSMA	Public Sector Mapping Agency
QSIIS	Queensland Spatial Information Industry Strategy
Satellite account	An ABS method for measuring the contribution of industries that are defined by the demand for a service, in particular tourism and information and communication technologies
SCOTS	Standards based off the shelf
SDAP	Spatial Data Access and Pricing policy
SDI	State and territory and local government spatial data infrastructure
SEAC	Spatial Education Advisory Council
SIAA	Spatial Information Action Agenda, 2001
SLIP	Shared land information Platform, Western Australia
SSI	Spatial Sciences Institute
WALIS	Western Australian Land Information System