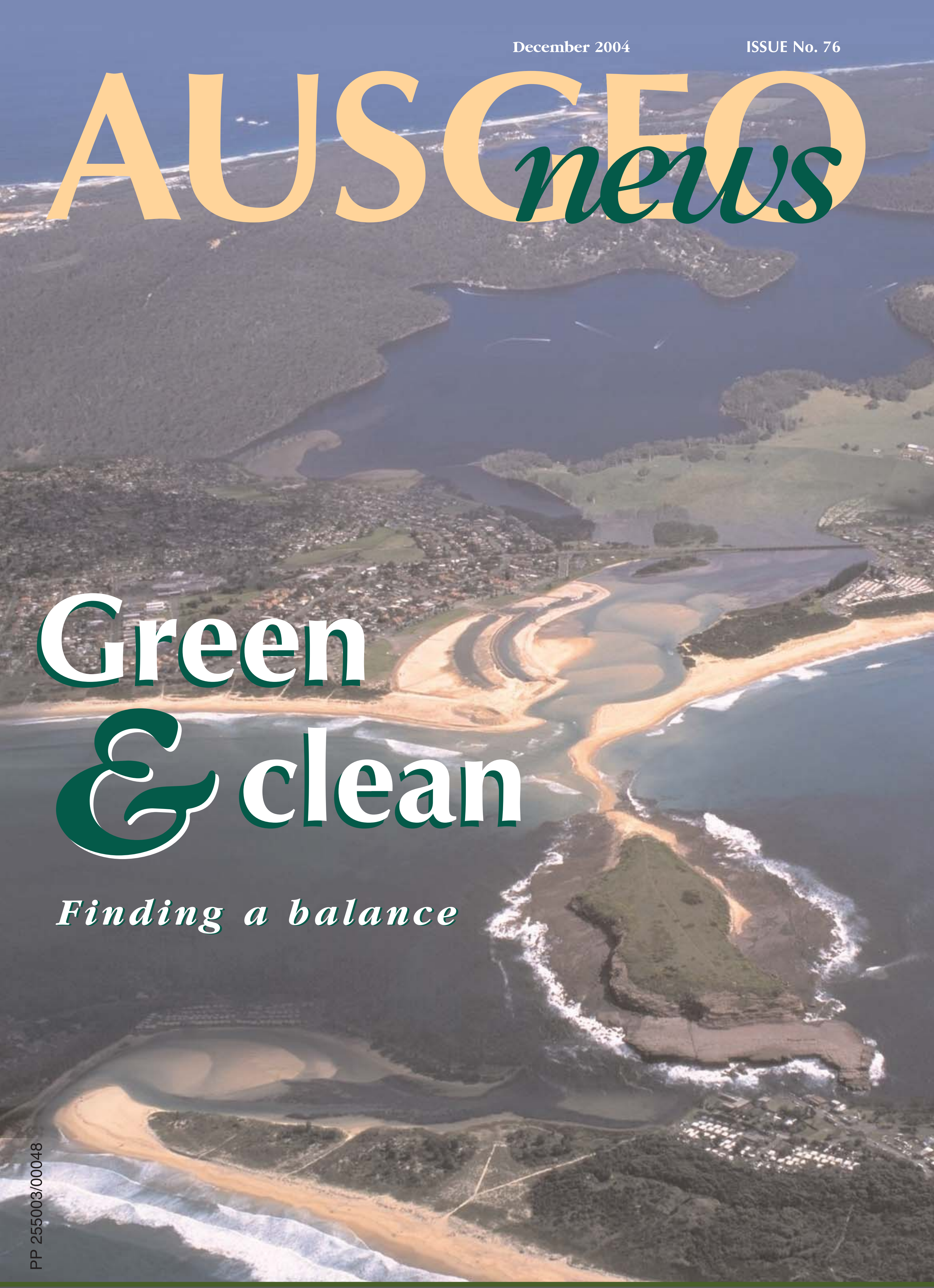
December 2004 ISSUE No. 76

# AUSGEO news



# Green & clean

***Finding a balance***

PP 255003/00048

***Also: Salinity management, geosequestration explained, Gawler seismic study..***

AUSGEO News
December 2004 Issue no. 76

# CONTENTS

Australian Government
Geoscience Australia

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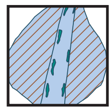
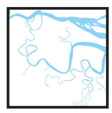
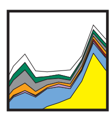




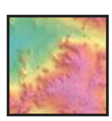






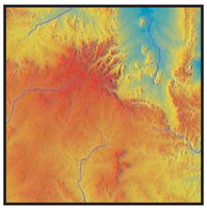








The cover image is a composite of estuaries in southern New South Wales. In many Australian coastal waterways plant growth is stimulated by nutrients that come from the catchment. Something is happening at the bottom of these water-ways or in their water that allows them to handle big sediment-nutrient loads without threatening ecosystem health. These factors are discussed in this issue of AusGeo News.



As Australia's national agency for geoscience research and geospatial information, Geoscience Australia holds historical and near real-time satellite imagery that helps Government and industry monitor and manage deforestation, salinity, erosion, urban sprawl, agricultural productivity and natural disaster damage resulting from droughts, floods and bushfires. Our national coverage of topographic information ensures that reliable data is available to support a broad range of Government programs. Geoscience Australia's advice on Australia's maritime boundaries assists in the environmental management and surveillance of Australia's vast ocean territory, especially with respect to oil spills and illegal bilge dumping. A recent internal review of Geoscience Australia's national mapping and remote sensing activities recommends enhancing access to 'public good' high quality satellite and other spatial data to support the increasingly diverse needs of government and the private sector. A significant step forward in this direction is the recent agreement to make the Japanese ASTER satellite data available through ACRES.

This issue of *AusGeo News*, the first in the electronic-only format, contains articles illustrating the important role geoscience is playing in contributing to a number of environmental issues of national importance. As usual it also contains announcements of new results and products of interest to a wide range of users in the minerals, petroleum, and spatial information sectors as well as the land and marine environments. The first results from the 2003 seismic reflection survey of the Gawler Craton in the vicinity of the giant Olympic Dam copper-gold-uranium deposit will be of interest to mineral exploration companies as it provides the first 3-dimensional image of this major mineral system.

Of particular concern to the minerals sector is the continued decline in Australia's share of global mineral exploration budgets despite an increase in activity.

The salinisation of Australia's waterways and land is a major challenge as recognised by the National Action Plan for Salinity and Water Quality. Geoscience Australia, through the CRC for Landscape Environments and Mineral Exploration (CRC LEME), in collaboration with a number of state agencies and CSIRO, has recently completed a number of projects that demonstrate the value to regional natural resource management of airborne geophysics. Airborne electromagnetic surveys, in particular, can be integrated with other geoscientific data in groundwater and salinity mapping and in determining controls on groundwater and salt movement.

Rising levels of greenhouse gas in the Earth's atmosphere is an issue of both national and international concern. Geosequestration of carbon dioxide is one proposed method to manage emissions from energy production. Geoscience Australia, through the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC), is engaged in geological studies to evaluate potential sites for the long-term storage of carbon dioxide.

Managing highly sensitive parts of Australia's marine environment is also a national priority. Estuaries and the coastal waterways in temperate Australia contain important habitats but are especially at risk because they are heavily used by coastal communities. The interplay of geomorphology and sedimentology controls the shape of estuaries and governs their vulnerability to human interference. The exchange of nutrients between estuarine water and sediments also influences the health of their ecosystems. The OzEstuaries data-base, developed by Geoscience Australia and now available on-line, contains new maps of sedimentary habitats for 73 near-pristine estuaries. It will assist in monitoring the health of the habitats in these ever-changing but important systems.

I hope you enjoy reading the December issue and wish you all the very best for the 2004 festive season.

# Comment


Neil Williams

**NEIL WILLIAMS**
CEO Geoscience Australia

# GEOSCIENCE ESSENTIAL IN *salinity management*

Recently completed projects in South Australia and Queensland have demonstrated the value of using airborne geophysics within an integrated geoscience approach to mitigating salinity in Australia.

The salinisation of Australia's waterways, groundwater resources and land is recognised at all levels of government and by rural and regional stakeholders as a major national challenge with profound economic, social and policy implications.

It is also recognised that large-scale revegetation of catchments to tackle this issue is in many cases impracticable, and that salinity management will need to be targeted to protect assets and maximise the return on investments.

To assist with these objectives, the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC LEME), in collaboration with a number of state agencies and CSIRO, has recently finalised a number of projects in South Australia and Queensland. The aim of these projects was to assess the effectiveness of airborne geophysics and integrated geoscience approaches for salinity mapping and management in a range of landscape, climate zone and land use settings. These priority strategic projects were identified under the Salinity Mapping and Management Support Program (SMMSP), and were funded under the auspices of the National Action Plan for Salinity and Water Quality (NAPSWQ).

These projects differed in approach from previous studies, as they were set up specifically to evaluate the use of airborne geophysics and integrated geoscience to address specific land management questions, as part of broader regional natural resource management strategies. The projects involved a staged and targeted approach, working within natural resource management policy frameworks, in close collaboration with local stakeholders.

Generally, previous salinity investigations involving airborne geophysics have been effective at knowledge generation, but ineffective in delivering outcomes for salinity management. This is partly because a better understanding of the sub-surface is only a first step in delivering outcomes, and because geophysics is only adding value to some of the knowledge already acquired.

Most of the SMMSP projects involved an integrated geoscience approach which combined regolith landscape and bedrock geological studies with airborne and/or ground and borehole geophysics, hydrogeology and hydrogeochemistry, to underpin outputs largely at sub-catchment scale. A common theme linking the projects was that they were not restricted to 'mapping salt' but were more concerned with gaining an understanding of the groundwater and salinity systems that prescribe water and salinity management practices. CRC LEME's contribution to these projects included mapping and understanding the nature and distribution of regolith materials through which groundwater and salt move, and hydrogeochemical studies to better understand the processes and rates of salt mobilisation.

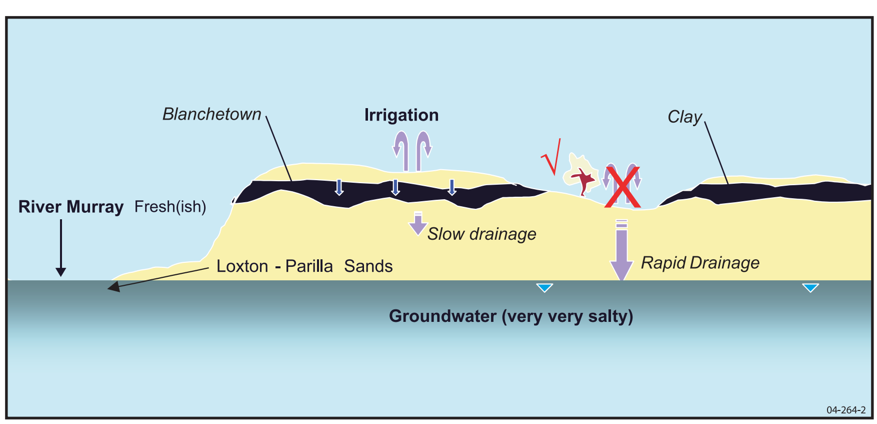



**Figure 1.** Schematic cross-section through the Riverland project area showing the relationship between the aquitard (Blanchetown Clay) and underlying groundwater in the Loxton-Parilla Sands aquifer.

## South Australian projects

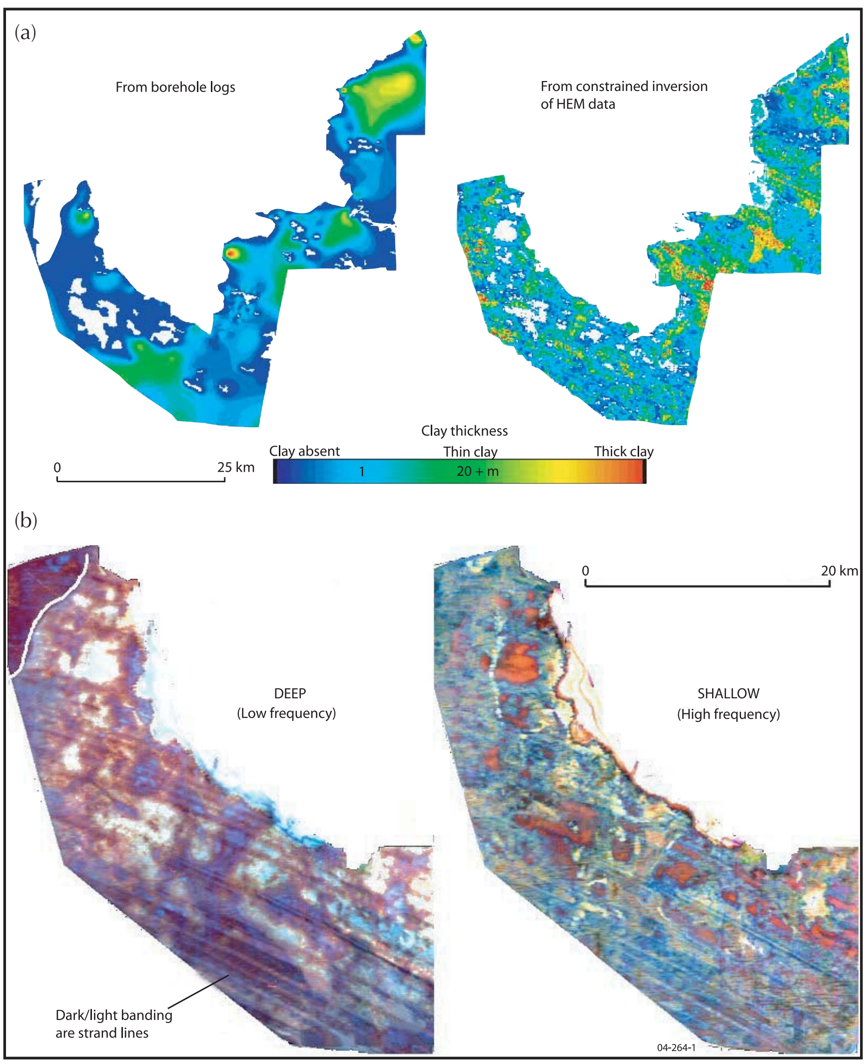
Projects were completed in five geographic areas: Riverland, Tintinara, Angas Bremer Hills, Angas Bremer Plains, and Jamestown. The salinity issues in each of these areas differed significantly, and the project areas range over complex erosional and depositional regolith landscapes. The projects involved collaboration with the South Australian Department for Land, Water and Biodiversity Conservation, CSIRO Land and Water, and the Bureau of Rural Sciences (BRS).

In the Riverland project, CRC LEME produced maps of near-surface clay materials and the underlying aquifer. An important component of the project entailed the calibration and inversion of Helicopter Frequency Domain Electromagnetic (HEM) data to derive datasets which are being used to identify areas of groundwater recharge in the Riverland area of the lower Murray. One of the factors considered in predicting rates of increase in Murray River salinity is increases in aquifer recharge in the Riverland area as a consequence of land clearing. Specifically, the near-surface fine textured unit known as Blanchetown Clay, an aquitard which reduces recharge to the lower aquifer, was mapped (figure 1). The Blanchetown Clay is characterised by elevated conductivities relative to the overlying and underlying sedimentary units (figure 2a). The derived maps of clay thickness were used, in conjunction with other critical data, as a basis for estimating rates of drainage through the unsaturated zone and for predicting groundwater recharge. The map of clay thickness was used as an input into a groundwater modelling exercise to determine the effects of proposed recharge reduction options in mitigating River Murray salinity. Outputs from this project are contributing to improved regional planning tools including:

- Improved recharge maps for underlying groundwater systems up to 100 years into the future, using the Blanchetown Clay map and recent developments in soil hydrology
- A floodplain attenuation model that simulates the impact on salt loads to the River Murray, and impact of irrigation development on the floodplain
- Improvements to models commonly used in land-use and salt assessments (SIMPACT irrigation planning model) and Border-to-Lock 3 MODFLOW (recharge and floodplain attenuation model).

Even for data-rich areas, the constrained inversion of the HEM data was essential for accurately mapping the clay layer. Without spatial constraints on depth to groundwater, groundwater salinity, and petrophysical (electrical) responses of the principal sedimentary units, we would have been unable to successfully generate a useful product. Principal outcomes of the project were:

- Development of new sedimentological models for the Blanchetown Clay and underlying Loxton-Parilla Sand.
- Successful staged use of airborne and ground geophysics for salinity management.
- Development of a new constrained inversion technique to map clay distribution.




▲ **Figure 2.** Riverland project **(a)** Comparison of clay thickness estimates from widely spaced boreholes (left) with thickness estimated from HEM (right). **(b)** HEM apparent conductivity composite images showing a plan view of strand lines in the Loxton-Parilla sand aquifer (left) and complexity in distribution of clays (right).

- Geophysical interpretations which contribute to salinity management plans and recharge reduction schemes. Clay thickness maps allow new estimates of aquifer recharge for dryland agriculture for present and future years (2023, 2053 and 2103). New hydrogeological models (MODFLOW and SIMPACT) were developed by CSIRO and the South Australian departments for Land, Water and Biodiversity Conservation, and Environment and Heritage using these data. They provide the necessary spatial information to achieve the greatest impact on river salinity through revegetation.
- Salinity inputs to the Murray River can be reduced.

Also in the Riverland area, salt interception schemes (SIS) being developed at Loxton and Bookpurnong on the Murray River, employ borefields in the Loxton Sands aquifer (figure 2b). Their purpose is to remove saline groundwater that rises in mounds beneath irrigated areas. CRC LEME contributed significantly to the design of the schemes through development of a new sedimentological model at Bookpurnong that defines lateral and vertical facies in the main aquifer systems. This model is based on borehole geology, ground and airborne geophysics, and sedimentological analysis of Loxton Sands and underlying Bookpurnong Sands. This is a precursor to a predictive groundwater hydraulic model.

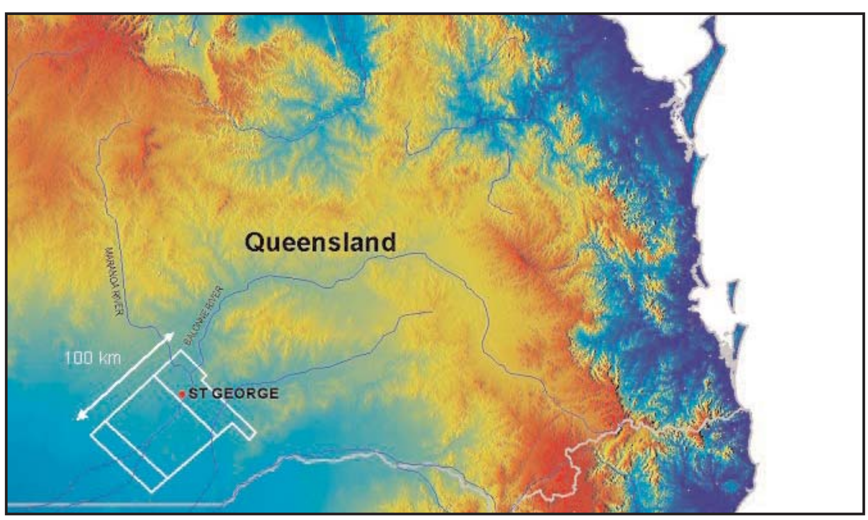
Definition of the sedimentological characteristics of the principal aquifer system—the Loxton Sands, has been problematic. Narrow zones of high transmissivity, characterized by reduced electrical conductivity at the watertable, are the target for ground TEM geophysical traverses. These are elements of a beach-barrier strandline sequence across the basin that developed in the Pliocene. Constrained inversions from helicopter electromagnetic data have helped to better define the geometry of this sedimentary system, and together with a hydrogeological interpretation allow an informed development and operation of the Loxton Sands salt interception scheme.

## Lower Balonne (Queensland)

This project, in southern Queensland (figure 3), involved acquisition of 8,000 square kilometres of airborne electromagnetic (AEM) data, the largest survey in Australia acquired for salinity investigations. The area is an important cotton irrigation district where there is debate over land cropping practices, water allocation and salinity risks. The project was undertaken in conjunction with the Queensland Department of Natural Resource Management (QDNRM), the Bureau of Resource Sciences (BRS), local catchment managers and cotton irrigators, and was funded under the National Action Plan for Salinity and Water Quality (NAPSWQ). The project evaluated the use of airborne geophysics (principally gamma radiometrics and time-domain AEM), for mapping surficial floodplain deposits and groundwater systems. The project is novel in its application of AEM technology to large inland fluvial floodplains, in an area where the salt distribution is unknown, and the hydrogeology is dominated by regional groundwater flow systems.

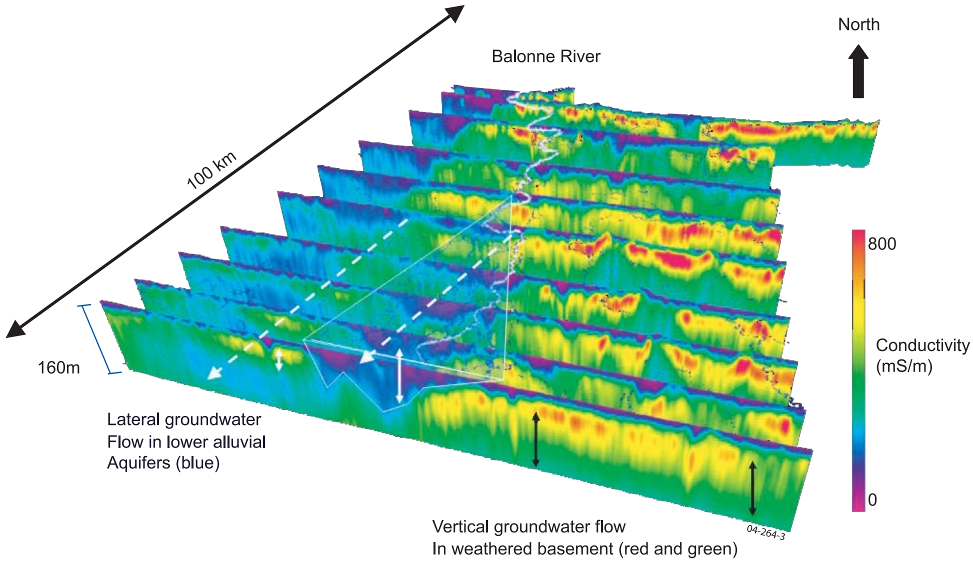
**Highlights of the project included:**

- A new method for constrained inversions of time-domain AEM data in areas of conductive basement lithologies (this had only been possible beforehand in areas with electrically resistive basement).
- A new model of landscape evolution was developed by integrating geophysics and biophysical datasets. The area is characterised by complex regolith architecture, a fault-controlled palaeo-valley at depth that hosts a fresh water aquifer, and saline aquifers near the surface. The compartmentalised sub-surface architecture is not evident from the surface landscape.
- The three-dimensional (3D) regolith model, when integrated with hydrogeochemical data, allows surface-groundwater interactions and groundwater movements to be modelled (figure 4). The integrated geoscience approach reveals apparently disconnected aquifers in nested groundwater flow systems concealed beneath the low relief landscape. Groundwater flow paths are different in each of the three major landscape zones.
- Integrated datasets that map near-surface groundwater tables, and detect water gain and loss points in the Lower Balonne river system.




▲ **Figure 3.** Lower Balonne airborne geophysics evaluation project location map (superimposed on digital elevation model).

**Figure 4.** Oblique-view AEM cross-sections through the Lower Balonne project area. Borehole data is used to assist with interpretation of AEM data to inform on salinity and groundwater distribution and movements.




**The main findings of the project include:**

- Airborne geophysics, particularly AEM, significantly improves the understanding of salinity risk and water security, in areas where there is a lack of data. Such datasets must be integrated with biophysical data (including bedrock geology and regolith data), and hydrogeological and hydrogeochemical data, in order to provide the best information on rates of movement for groundwater and salt.
- Integrated geoscience datasets provide a better understanding of the distribution of soil and regolith properties, salt stores and groundwater quality. This knowledge highlights areas in danger of salinisation if current practices are maintained.
- Newly identified land and groundwater management zones will enable modification of land practices to reduce salinity risks. This knowledge should also lead to more efficient water management.
- An enhanced understanding of dynamic water balance for the catchment.

## Conclusions

Preliminary external assessments of outputs from these projects have been very positive. Overall, these projects have demonstrated the value of an integrated geoscience approach for salinity management that incorporates airborne geophysics. Particular importance was attached to ensuring that geophysical data could provide a product of value, and how that product could be incorporated into the implementation of an existing management strategy.

**Specific lessons from the South Australian and Queensland projects include:**

- AEM is an important aid in salinity management, particularly where there are well defined targets and applications for the derived products. It is also of great value in areas where there is limited understanding of groundwater and salinity systems.
- While focus on a specific management objective or target is important, the design of geophysical surveys should also consider other targets that may be useful in salinity management. We need to be prepared for the unexpected benefit, but this should not be the driver of the survey.
- AEM is not limited to mapping of salt, but can provide invaluable insights into mapping groundwater and the regolith and bedrock materials that influence and/or control groundwater and salt movement.
- The success of constrained inversion of AEM data in both the Riverland and Lower Balonne projects is dependent on data availability and the scale of regolith landscape elements and the scale of hydrogeological variability—this approach is facilitated by a wealth of existing hydrogeological information—the more data, the more accurate the product.
- The assertion that where a large pool of land-management data exists at an appropriate scale, airborne geophysics is unlikely to add value, is incorrect. On the contrary, AEM data should always be examined, where the means exist, to translate derived information into something of value.
- The value of airborne geophysical (particularly AEM) data increases with the value of the asset. In lower-value areas serious consideration must be given to geophysical inputs in order to minimise costs. In areas with limited hydrogeological information, there may need to be more investment in ground programs, to get full value from AEM datasets.
- In the planning of a project, it is important to ensure that all relevant data are used in developing salinity management plans.
- Products derived from airborne geophysics only have value if they contribute to the planning of economic activities.

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# THE CHANGING FACE OF *temperate coastal waterways*

## HABITATS AND WATER QUALITY

When glaciers and ice sheets melted, sea level rose and flooded river valleys and low lying areas of the continental margin. About 7,000 years ago the waterways we now see around the coastline began to take shape. Australia's coastline is about 37,000 km in length with more than 1000 waterways identified and classified as a part of the National Land and Water Resources Audit.[1,2]

These waterways have been shaped by the erosion of our continent and waves and tides—two very powerful coastal forces. The shapes and biophysical characteristics of our tropical waterways such as habitat size, and water quality (flushing and turbidity/brown water) are controlled primarily by the rates of sediment and nutrient inputs and dominant tidal energies. Tropical coastal waterways tend to be well-flushed with high turbidities, and are dominated by very large intertidal mudflat areas and mangrove forests. In contrast, the changing shapes and biophysical characteristics of waterways in temperate Australia are controlled primarily by the different rates of sediment and nutrient discharges and interactions with high wave energies at the coastline. The classifications and conditions of Australia's coastal waterways are shown at www.OzEstuaries.org

### Evolution in temperate coastal waterways

The wave dominated systems of temperate Australia have been classified into several different types such as immature and partially-filled estuaries (and coastal lakes), river dominated estuaries (deltas), strand plains and lagoons. These systems comprise a variety of habitats and biophysical properties which continually evolve and change shape as they infill with sediments.

### Immature and partially filled estuaries

Immature and partially-filled wave-dominated estuaries are characterised by a large central basin and a constricted entrance, limiting flushing and exchange with the sea. Tidal excursion is inhibited and these systems have small intertidal areas. The effects of infilling and changing tidal ranges on habitats during the evolution of temperate wave-dominated waterways are shown in figure 1.

Analysis of data from the OzEsturies database reveals that the central basin comprises about 40 per cent, the intertidal flats and salt-marsh about 10 per cent, with mangroves representing about three per cent of the total areas of these systems.[3] Diatomaceous phytoplankton grow throughout and are dominant in the central basin and channels, while seagrass communities and other benthic algae inhabit the shallow margins. The relative areas of these different habitats and ecosystems are illustrated in figure 2 and immature estuaries are shown to the left of this figure.

With increasing sediment discharge, immature estuaries become partially filled, the depth shallows and a large proportion of the sediments within the central basin emerge into the photic zone where light penetrates. As a result the abundance of seagrass and other benthic plant communities increase as more surface area of bottom sediments are exposed to light (figures 1 & 2).

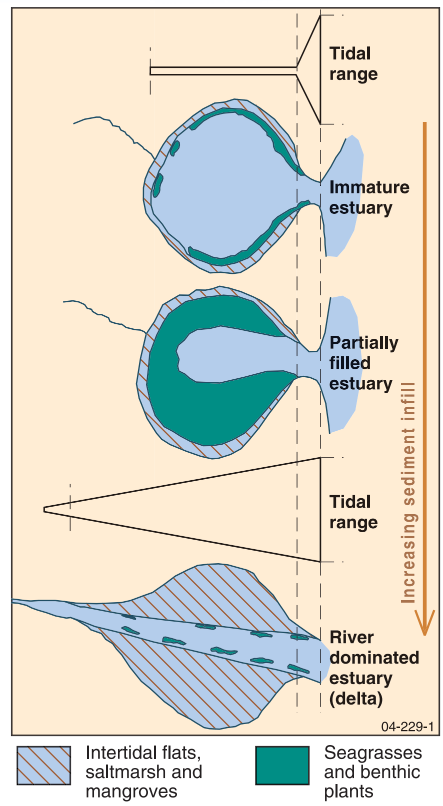



**Figure 1.** Conceptualization of estuarine shape, tidal penetration and ecosystem change during estuarine infilling.

The habitats in partially filled systems may change easily in response to external perturbations such as increased sediment inputs from the catchment (figure 2). Figure 3 shows a satellite image of immature-to-partially filled estuaries; the large central basin and the restricted entrances are key physical features.

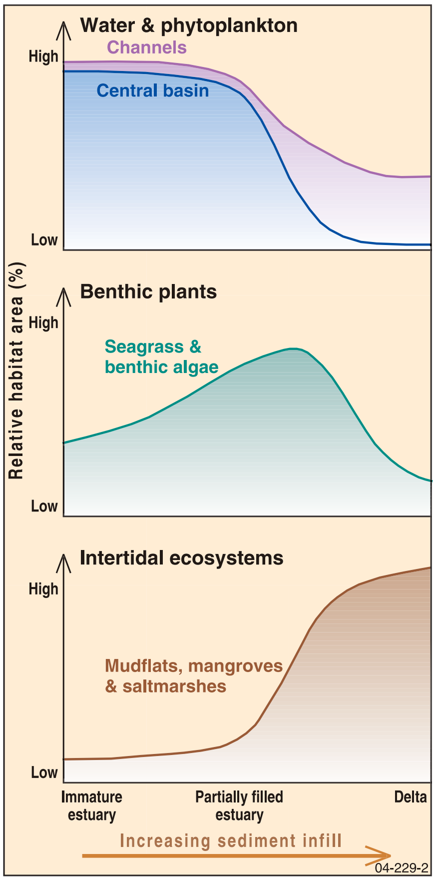



**Figure 2.** Changes in relative habitat abundances (water areas and phytoplankton, benthic plants and intertidal ecosystems) during estuarine infilling and evolution: immature estuaries to the left and river dominated estuaries (deltas) to the right.

## River-dominated estuaries (deltas)

Continual erosion of the catchment sediments will cause the central basin to fill. During this process (known as increasing maturity) channels increase, the entrance widens, and there is a greater connectivity with the sea and the tides penetrate further into the estuary (figure 1).

Because of the increasing tidal excursion the areas of intertidal mudflats, salt-marsh and mangrove habitats increase (figure 2). Analysis of the habitat areas of river-dominated estuaries show that the central basin comprised only <1 per cent, the intertidal mudflats and salt-marsh areas each comprised about 20 per cent, and the mangrove forests about 30 per cent of the areas of these systems.[3] . Therefore, with sediment infilling, estuaries mature into deltas and during this transition the mangrove areas increase about tenfold, while the intertidal flats and salt-marsh areas nearly double. Eventually, seagrasses (and other shallow-water benthic communities) are replaced by mangroves. These features are summarised in figures 1 & 2, with the characteristics of the deltas shown on the right of figure 2.

Figure 4 is an image of a river dominated estuary and the key physical features are the elongate nature of the system with channel development and an increased connectivity to the sea.

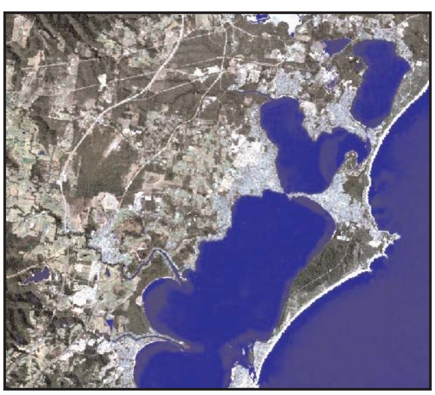


**Figure 3.** Satellite image of an immature-to-partially filled estuary.

## Water quality

Water quality deteriorates when estuaries become eutrophied. Eutrophication is the process of nutrient enrichment which can manifest itself in several ways including increased incidences of nuisance and toxic algal blooms (which can sometimes be harmful to human health), epiphytic growth on seagrass leaves (which result in the die-back of seagrass meadows), and prolific macro-algal growth which can sometimes clog waterways. In addition, when this plant material dies and accumulates on the sediments, its degradation can result in oxygen depletion from the water, fish-kills and sometimes the production of foul-smelling hydrogen sulphide or rotten egg gas.

Nitrogen, phosphorus and silicon are essential nutrients which stimulate plant growth, but nitrogen (N) is thought to be the most important nutrient controlling the potential eutrophication of temperate waterways. Sediments and nutrients from the catchment are the greatest threat to coastal water quality.[4] Eutrophication results when nutrient concentrations in the estuarine waters become too high. Several processes can remove nutrients from estuaries to maintain low nutrient concentrations and limit eutrophication. These include flushing to the sea, burial in the sediments and denitrification, a microbial reaction (unique to nitrogen) found at the sediment-water interface.

Denitrification occurs in low-oxygen environments, usually just below the sediment surface in the top mm-to-cm of sediments. This is part of the process of degradation of organic matter in sediments where N fixed into plants is converted into nitrogen gas. The gas escapes from the surficial sediments through the water column to the atmosphere and this process is a very important N-sink that reduces the concentrations of bio-available N in coastal waterways. Denitrification was responsible for removing N from Port Phillip Bay and controlling and limiting phytoplankton productivity.[5]

**Figure 4.** Satellite image of a river-dominated estuary.

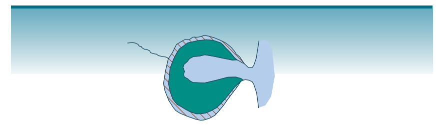
## Diatoms and denitrification in immature and partially filled estuaries

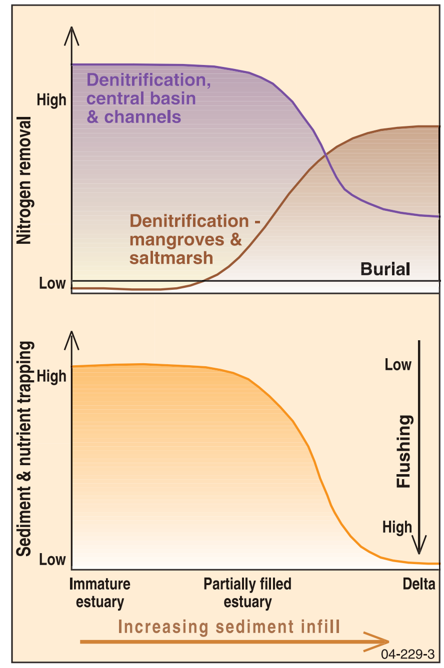
Immature and partially filled estuaries, strand plains and ICOLLS (intermittently closed and open lakes and lagoons) with restricted entrances are very efficient traps of sediment-bound and dissolved nutrients (figure 5). The most important process controlling bio-available nutrient concentrations in these systems is denitrification. These features of immature-to-partially filled estuaries are shown in figure 5.

Recent research has found that most of the nutrients are taken up into diatomaceous phytoplankton—despite an apparent visual abundance of macro-algal growth. Diatoms are small microscopic single-celled organisms which are formed during photosynthesis and require carbon, nitrogen, phosphorus and silicate to grow. They are most abundant in temperate climates; an organic sheath surrounds a silicate frustule (hard part). Diatoms sink rapidly to the sediments where they degrade. The degradation of this organic matter is enhanced by bioturbation and bio-irrigation—the burrowing and foraging activities of animals living in the sediments.

These processes facilitate denitrification and can limit the build-up of bio-available N and thus maintain good water quality in these systems. If diatom production is impeded significantly by limiting silicate supply to estuaries (such as by building dams and other impoundments on rivers and streams), then the amount of N lost by denitrification in the sediments will be reduced. The reason for this is because macroalgae thrive (displacing diatoms) recycling N through the water column rather then the sediments thus avoiding the denitrification reaction. Bio-available-N, added from the catchment, under these conditions, will accumulate in the water and result in an increased risk of eutrophication.

These processes are shown schematically in figure 6. Sensible management practices should maintain a healthy benthos and efficient denitrification.






▲ **Figure 5.** Changes in relative sediment and nutrient trapping and flushing characteristics and nitrogen removal processes such as burial, and denitrification in central basin, mangrove, salt-marsh and mudflat sediments.

## Denitrification, mangroves, salt marshes and flushing in river-dominated estuaries

With increasing sediment-infilling, immature and partially filled estuaries become river-dominated (deltas) (see figure 1). Connectivity to the sea is increased and flushing of sediments and water are enhanced and the sediment-nutrient trapping capacity reduced (figure 5). In time, the large water areas and low energy environments of a central basin are replaced by channels with a more vigorous circulation. Flushing is more important in mature estuaries than in immature estuaries (figure 5) helping to maintain low concentrations of bio-available N which inhibits prolific plant growth.

Denitrification remains an important process but in river-dominated estuaries, it is more important in channel-sediments, mangroves, intertidal flats and salt-marsh environments (figure 5).

Diatoms (even in mangrove sediments) remain an important vector to transport N to the sediments where it is lost because of denitrification. Research has shown that the denitrification process is very efficient in mangrove and intertidal flat sediments. Crabs and burrowing organisms are very common and abundant in mangroves and mud-flats. These activities facilitate the denitrification process by constantly turning over sediments, ventilating them with dissolved oxygen (which is rapidly consumed), and constantly renewing surfaces facilitating the break down of organic matter.

When mangroves and intertidal habitats are lost (through dredging and infilling to create housing and industrial estates), the natural cleansing capacity of these systems is drastically reduced and most probably lost forever.

As a result they become more prone to eutrophication. Mangroves and intertidal habitats have long been highly valued, as they are known to accommodate the nurseries of many of our common and popular recreational fish-catches and crustacean hauls. Similarly, their capacity to support and sustain good water quality should also be recognised.

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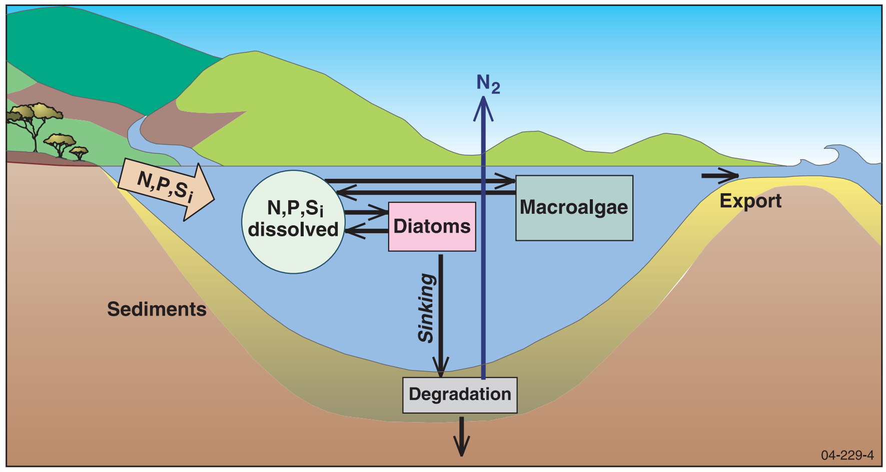


**Figure 6.** A schematic representation of the link between diatom formation in the water, degradation in the sediments and the important N-processes, including denitrification in the sediments.


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# Call for **RESEARCH PROPOSALS** for **ANSIR** experiments in 2005 & beyond

The Australian National Seismic Imaging Resource (ANSIR), a Major National Research Facility, is seeking bids for research projects for experiments in 2005 and beyond.

ANSIR operates a pool of state-of-the-art seismic equipment suitable for experiments designed to investigate geological structure. ANSIR is operated jointly by The Australian National University and Geoscience Australia.

The equipment is available to all researchers on the basis of merit, as judged by an Access Committee. Please note demand for the broad-band equipment is very high and this should be taken into consideration in the design of experiments. ANSIR provides training in the use of its portable equipment and a field crew to operate its seismic reflection profiling systems. Researchers have to meet project operating costs.

Applicants should consult the web site, www.rses.anu.edu.au/seismology/ANSIR/ansir.html for details of the equipment available, access costs, likely field project costs and the procedure for submitting bids. This site includes an indicative schedule of equipment for projects that arose from previous calls for proposals.

Researchers seeking to use ANSIR equipment from the beginning of 2005 should contact the ANSIR Director with regard to the formation of research proposals.


**Enquires should be directed to:**
**Prof. Brian Kennett**
**ANSIR Director**
**Research School of Earth Sciences**
**Australian National University**
**Canberra ACT 0200**
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**e-Email ANSIR@anu.edu.au**


# Geosequestration of carbon dioxide —*some frequently asked questions*

Recently there has been considerable interest from the media and the public about geological sequestration of carbon dioxide. However this increase in public awareness has also shown that some concepts that geoscientists take for granted are not always fully understood.

▲ **Figure 1.** Almost half of Australia's carbon dioxide emissions come from stationary sources and could potentially be stored. Three-quarters of these sequesterable emissions come from power stations.

Geoscience Australia is contributing to this research as one of the leading agencies in the Cooperative Research Centre for Greenhouse Gas Technologies(CO2CRC). The CRC draws on the expertise of research organisations and universities around Australia, and participants from the private sector include petroleum, coal and power companies.

So in an attempt to clarify the subject some frequently asked questions are explained below:

## What is geological sequestration?

Geological sequestration is the process of capturing carbon dioxide from industrial processes such as power generation and injecting it deep underground for long term storage in geological formations, thus preventing it entering the atmosphere and adding to the potential for climate change caused by greenhouse gases.

Among the options being considered for storage of carbon dioxide are injecting it into depleted oil and gas fields, deep saline reservoirs or deep unmineable coal deposits.

## Why do we need to store carbon dioxide?

In the modern world we rely on electrical power to provide the quality of life that we enjoy and that the developing world is aiming to achieve. Most of the power used to meet our needs is derived from burning fossil fuels in power stations. As renewable sources of energy are unlikely to be able to meet that demand, the dependence on fossil fuels as our major energy source is unlikely to change in the near future.

The burning of fossil fuels releases carbon dioxide, which is the gas that has contributed most to the greenhouse gas effect. Capturing the carbon dioxide before it is emitted and storing it in the deep subsurface will help to reduce the impact of our use of energy.

The development of this technology in Australia will not only reduce our emissions but also provide a lead to help the countries of the developing world reduce their greenhouse gas output.

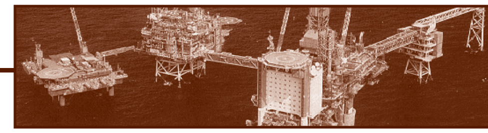
## How can you store anything in solid rock?

Many sedimentary rocks, particularly sandstones, contain large volumes of fluids held in microscopic voids or pores between the rock grains. These pores can be up to 30 per cent of the volume of the rock (figure 2). Where the pores are interconnected the rock has permeability, that is, fluids can move through it.

Rocks of this type form the underground reservoirs. Under normal conditions the pores in the rocks are filled with water, but under special conditions they may contain oil, natural gas (methane) or naturally occurring carbon dioxide.

Many finer grained rocks such as clays also have high porosity, however the pores are not interconnected and fluids cannot move through them, that is, they are impermeable. These rocks act as seals or caps to the reservoir rocks

Over geological time, the weight of the overlying sediments gradually reduces the porosity of both sandstones and shales until they are effectively impermeable. Often, however, sandstones may still retain significant porosity and permeability at depths in excess of four kilometres.



## What are 'deep saline reservoirs'?

Under normal conditions the pore space in rocks close to the surface are filled with fresh or brackish water. Rocks which contain water that is fresh enough to be used for humans or stock are called aquifers. Where the rock is exposed at the surface it is able to be recharged by rainfall. This causes a flow of water through the aquifer.

However, deeper in the geological section below the shallow aquifers, the pores are filled with highly saline waters that have only moved slowly, if at all, over millions of years. This length of time together with pressure of deep burial has resulted in these waters dissolving minerals from the rocks and reaching salinities sometimes many times that of seawater. Rock formations which contain these highly saline waters are called deep saline reservoirs.

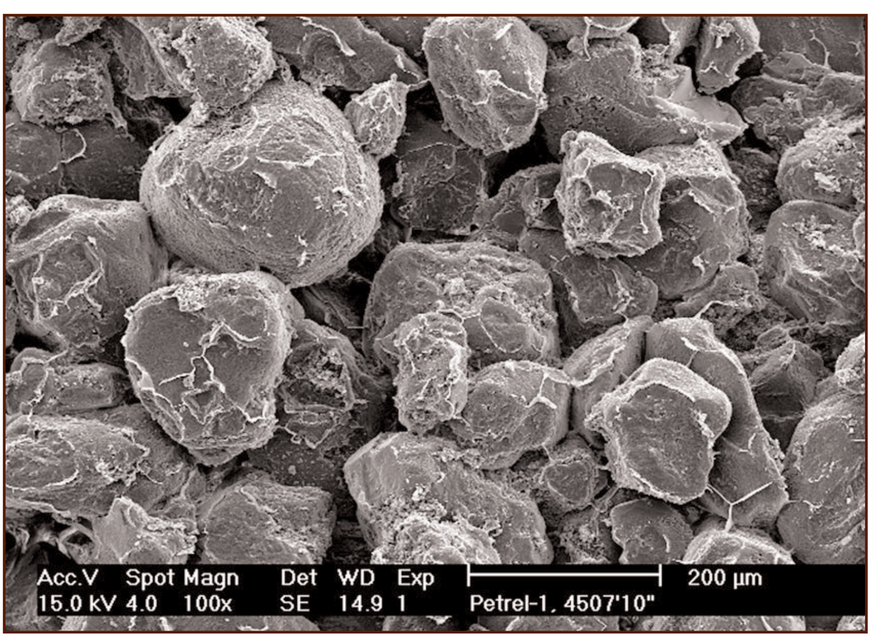
These highly saline waters do not rise to the surface and are only found during the search for oil and gas in the deep subsurface. They are too deep and too saline for any practical use and it is it is proposed to store the carbon dioxide in these reservoirs.

## How will the carbon dioxide be stored in the rock?

Carbon dioxide behaves in the subsurface in the same way as naturally occurring oil and gas. Oil and gas are more buoyant than water, and when they are generated in the subsurface by the action of the earth's heat, they enter the water filled pores of the rock and rise until they encounter a permeability barrier such as a shale bed. If the shape of the barrier is such that they cannot escape sideways, the fluids will remain trapped there as hydrocarbon accumulations for millions of years. It is these traps that oil companies explore for.

In geosequestration, carbon dioxide will be injected into the rock as a supercritical fluid, which means it is as dense as a fluid but behaves in many ways like a gas. This carbon dioxide will act like the naturally occurring gases and gradually rise from where it is injected until it reaches a barrier that will stop it from rising further. Careful selection of the injection site will ensure that such a barrier exists in the path of the rising carbon dioxide.

Over time, much of the carbon dioxide will dissolve into the ground water and be held permanently in solution. Some will react with minerals in the rock and be precipitated out as new minerals leaving only a small amount to remain trapped as a supercritical fluid.




▲ **Figure 2.** Under high magnification the pores between the grains in this sandstone can be seen.

## Could the carbon dioxide contaminate the fresh water supply?

The selection of the injection site is one of the most important issues in the underground storage of carbon dioxide. Because the aim of the process is long term storage, any injection site where there is not an adequate barrier between the deep reservoir and the shallow aquifer would be unsuitable for geosequestration.

From studies of oil and gas fields, scientists have a clear idea of which seals or barriers work best in each area. Often these seals are the same ones that already seal subsurface oil and gas accumulations

The identification of suitable storage sites is a critical part of the research that Geoscience Australia is currently undertaking for the CO2CRC.

## How long will it will be trapped there?

The petroleum industry is over a hundred years old and during this time geologists and other scientists have been studying the conditions under which oil and gas are generated and trapped in the subsurface. The importance of oil to the world economy since the middle of the twentieth century has meant considerable resources have been directed at understanding the environment in which hydrocarbon accumulations occur and how they are preserved.

Research in hydrocarbon-bearing basins worldwide has shown that it is possible to determine the time that the source rocks started to generate oil and gas, and show how long these fluids have been held securely in the adjacent traps. In almost all cases this is tens to hundreds of million years. The fact that the sealing rocks have held naturally generated oil and gas accumulations over such a period, often with naturally occurring carbon dioxide, demonstrates that they can contain carbon dioxide that is purposefully injected into them for a very long time.

## Where are the best sites for long term carbon dioxide storage?

Previous research carried out by Geoscience Australia has demonstrated that sedimentary basins, particularly those that are hydrocarbon producing, are the best geological provinces for the storage of carbon dioxide. This is because the conditions that allow for the trapping of oil and gas are also those required for the storage of carbon dioxide. These basins are also the ones we have the most information about because it was gathered whilst exploring for hydrocarbon resources.

However some basins that lack suitable source rocks for oil and gas could also make excellent storage sites, although less is known about them since they are less explored.

Gas fields from which almost all the gas has been extracted (depleted fields), are the prime candidates for successful storage. This is because they have already demonstrated they can trap and retain large volumes of gas. In the USA, fields of this type which are close to populated centres are often used to store natural gas produced from more remote locations.

In addition, some other structures that have never contained oil or gas could also provide suitable sites but these will need further research to demonstrate their potential.

## Could a hydrocarbon seal leak?

Under normal conditions the seal of a hydrocarbon trap may start to leak, and allow small quantities of gas to pass through and continue to move upwards through the rock column until it is trapped against barriers, or sometimes to be released at the surface as 'seeps'. This process reduces the pressure on the seal which then 'closes' again. In the natural world this process is uncontrolled.

However in a carbon dioxide injection project the capacity of the rock seals will have been measured in the laboratory and their limits known. In addition the injection wells and the storage site will be monitored by remote sensing devices that will enable the process to be slowed or halted if the pressure builds up faster than anticipated. This will allow excess pressure to be dissipated and when conditions are right, injection can re-commence.

This knowledge of the way the natural system works will enable the injection of the carbon dioxide to be controlled in such a way that it will not threaten the seal. If the seal is not perfect, there could be some potential for some gas to slowly leak out over time, and start to travel upwards through the overlying rock. However the complexity of the normal geological column is such that any escape pathway would be tortuous and the fluid movement slow, so that the time taken for even small amounts to reach the surface would be of the order of thousands of years.

## Do we have the technology to inject carbon dioxide underground?

The basic technology used to inject carbon dioxide deep underground has been used in the petroleum industry for some time to 'enhance' oil or gas recovery from depleting oil reservoirs. Currently there are several international pilot projects directly involving the injection of carbon dioxide into rock.

- In Saskatchewan, Canada, carbon dioxide is being used for enhanced oil recovery in the Weyburn Field.
- In Poland, carbon dioxide is being used to help extract methane from coal beds that are too deep to mine.
- In the Norwegian North Sea, in the first direct sequestration project, naturally occurring carbon dioxide is being stripped out of methane from the Sleipner Field and being reinjected into a deep saline formation 900 metres below the sea bed for storage (figure 3). Since this project started in 1996 over one million tons of carbon dioxide has been injected per year, and seismic techniques have monitored the successful dispersion and trapping of the gas within the formation.

▲ **Figure 3.** The Sleipner Project in the Norwegian North Sea has injected one million tonnes of carbon dioxide into a sandstone 900 metres below the seabed every year since 1996.

- In a similar project in Algeria which commenced in 2004, carbon dioxide is stripped from the natural gas produced at the In Salah Field and reinjected back into the gas reservoir for long term storage at the rate of one million tonnes per year.

These examples and a wide range of other enhanced oil and gas recovery projects from places as diverse as the USA, Turkey, Mexico and the Russian Federation demonstrate the maturity of the technology of carbon dioxide injection.

Geosequestration is a leading edge, proven technology that is an important part of the challenge to allow the benefits of plentiful energy to be enjoyed by both developing and developed countries whilst not continuing to add to the greenhouse gas load in the atmosphere.

The work of Geoscience Australia in researching and identifying suitable sites for geological storage of carbon dioxide will ensure Australia continues to be a leader in the development of this technology.

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# *New directions* for National Mapping Division

Geoscience Australia has recently undertaken an internal review of its national mapping and remote sensing activities to refine its strategic direction in the context of current government policies.

A significant influence on the review was the technological revolution that is sweeping through the spatial data world. This revolution encompasses the application of new digital mapping technologies, the integration of global positioning systems with digital spatial information and the evolution of second generation web technologies.

These technologies are revolutionising the way governments, companies and the public think about and use geographic information. Whilst Geoscience Australia distributed 136 740 paper maps during the 2002-03 financial year, digital products and distribution through the web constitutes a growing means of data transfer. Web downloads of Geoscience Australia's topographic information had increased to 6030 per month by October 2004, making a total of 49 422 downloads since January 2004. Increasingly users are demanding accurate and current data and information that is delivered faster with greater reliability and in ways that can be digitally integrated with their own information in real time—commonly referred to as interoperability.

In Australia, constitutional responsibility for land surveying and administration lies with the state and territory governments. Consequently the review has focussed on contemporary needs at the national level whilst taking into account the changing technological environment and the constitutional arrangements.

## National mapping role

The predecessor organisations to National Mapping Division (NMD) undertook the initial national mapping program at 1: 250 000 and 1:100 000 scales in partnership with the state and territory governments and Army Survey Corps in response to the needs of national development following World War II. Subsequent work has focussed on maintaining the map series whilst other parts of the government infrastructure built to support national development were restructured and privatised. As a result of this and the technological revolution, the 1:250 000 scale map series has been fully revised and is now available as both paper and digital products.

The new direction explicitly addresses the key policy drivers of the Australian Government and seeks to capitalise on developments in technology. The emphasis is on providing national geographic information for government purposes and in a form that makes it accessible and useable in a digital environment. The policy drivers originate from Geoscience Australia's parent department (Industry, Tourism and Resources), explicit roles that have been agreed for Geoscience Australia and determining where these responsibilities can be delivered more effectively through partnering. The policy drivers are emergency management, defence, marine zone management, Australian Government national mapping needs generally, public access and industry development.

- *Emergency management*—Following the Council of Australian Governments (COAG) agreement on emergency management arrangements in 2002 and mapping issues identified in the recent, parliamentary inquiry report 'A Nation Charred: Report on the inquiry into bushfires', NMD is implementing a project to meet emergency management needs for geographic information. This entails a pilot 1:100,000 scale mapping program comprising map sheets in priority areas in the ACT, New South Wales, Queensland, South Australia, Victoria, and Western Australia to support state emergency management requirements

* It will also provide geographic information to underpin a national natural hazard risk assessment program being undertaken by Geoscience Australia's Geohazards Division.

- *Defence*—Under a Service Level Agreement with the Defence Imagery and Geospatial Organisation, NMD will continue mapping priority areas of Australia to defence specifications using NMD's contractor panel. This partnership in mapping facilitates national coverage, improves the use and development of a consistent set of national topographic data and contributes to development of the spatial information industry through the contractor panel.

- *Marine zone management*—As part of the science program to support the Australian Government's Oceans Policy, NMD is commencing development of an Australian Marine Spatial Information System (AMSIS) to meet the needs of the National Oceans Office and other Australian Government marine agencies. NMD will also continue to work jointly with the parent department's Petroleum and Marine Division as well as the Departments of Foreign Affairs and Trade and Attorney-General on Law of the Sea and boundary delineation matters.
- *Other government priorities*—The 1:250 000 scale national seamless database of topographic information will be updated so the oldest information will be circa 2000 and then continuously updated. This will provide a current database of fundamental topographic information for access at 1:250 000 scale and will underpin the production of smaller scale products and reference maps. This database will be made available free through the web and will also be used to produce a series of 1:1 million aeronautical charts with Airservices Australia as well as thematic layers and maps on demand for emerging priorities.
- *Public access*—The relationship between NMD and its clients will change from one based on a 'Product or Service Offering' to one based more on 'Needs and Relationships' with its key clients. NMD will retain a product focus for meeting the mapping needs of the general public under the Spatial Data Access Policy. Products under the well known brand names like NATMAP, GEODATA and ACRES will continue to be made available to the public as paper, digital and web based products.
- *Technology and industry development*—The new model will enable NMD to function in smarter ways and to increase our value to key government clients whilst meeting the broader needs of the community. Technological innovation will be a key component of the new directions and NMD is participating in the Spatial Information Cooperative Research Centre to both develop and capture technological benefits. The benefits will include real-time application of remotely sensed data for emergency management and 2D and 3D visualisation of data sets.

The strategic development and application of GIS techniques and provision of high quality geospatial services across Geoscience Australia will continue. At the same time, maintenance of the existing seamless database and collection of new data will progressively switch from the 'map sheet' based system to a theme or layer-based system. AMSIS will be similarly developed as an authoritative source of marine spatial data with interoperability as a key strategic objective. Increased access to 'public good' data over the web and increased functionality including, eventually, web services will be a key focus of the new directions.

Consistent with Geoscience Australia's position as an agency of the Industry, Tourism and Resources Portfolio, NMD will continue to assist industry development through contracting out of services, improved access to information, and technology transfer. NMD's contributions to interoperability across government agencies and to the Spatial Information CRC, and its relationships with contractors, are ways in which Geoscience Australia can both achieve innovation in its National Mapping Program and develop industry capability. The utilisation of contractors for the development and delivery of Geoscience Australia products leads to technology transfer to and from the small business sector which in turn strengthens industry capacity. This approach aligns with the objectives of the Spatial Information Industry Action Agenda for development of industry capability, particularly in relation to improved data access and innovation through research and development.

## National remote sensing role

A detailed review of the Australian Centre for Remote Sensing (ACRES) has been undertaken in light of its nationally strategic position in receiving and distributing remotely sensed data for both scientific and operational applications. The review re-affirmed the importance of the national role carried out by ACRES and recommended that ACRES become more active in developing national approaches to remote sensing.

Although remotely sensed data is used extensively in Geoscience Australia's mapping program and to a lesser extent in other Geoscience Australia programs, the principal external uses include environmental monitoring, crop analysis and map production. Most of these applications are for Australian, state and territory governments' purposes. A key finding was the continuing need for and dependence on access to medium resolution multi-sensor data such as that represented by the Landsat series of satellites, an ongoing need for access to data from specialist sensors and with different levels of resolution.
The review found that satellite data provision across the world is a very complex mixture of public sector and private sector activity. Certain types of data and services are simply not available from the private sector at this time, although this could change with time. Similarly new sensors are being launched regularly by overseas government agencies and these create new opportunities for new remote sensing applications for the national benefit.

As a result of the review, Geoscience Australia will be strengthening its role to better strategically position ACRES to supply public-good satellite data into the future. It will work with its clients and stakeholders to better track emerging program needs and will establish a Technical Reference Group to assist development of a technical strategy to meet ongoing and emerging demands. It will actively engage with international satellite operators to plan access to new satellites and negotiate access to existing satellites to mitigate the failure of a crucial satellite or sensor. A key part of the strategy will be to ensure that ACRES's activities complement those of the private sector.

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# How estuaries cope with nutrients

Estuaries vary in shape and size, they support and sustain different ecosystems and are exposed to ever changing levels of nutrients from the catchment. Scientists can assess and predict the possibility of estuarine vulnerability to eutrophication by analysing the nutrient processing in sediments and in the water.

Nutrients such as nitrogen, phosphorous, and silica have a significant influence on the diversity and abundance of living resources in estuaries and elsewhere. Many interactions occur between organisms such as plants, fish, bacteria, and the nutrients in water and sediments.

Aquatic plants need dissolved nutrients from the water, which often limits their growth. Sea grass and algae, in turn, provide the essential habitat and food for higher organisms such as fish. In addition to nutrients entering the estuary from rivers and creeks, nutrients are added to estuarine water through the decay of biomass in the water and in sediments.

## The nutrient puzzle

Nutrients are present in various (chemical) forms and in various compartments of a waterway including the water itself, biomass and sediments. Nitrogen(N), for example, is present in the water as dissolved nitrate ($NO_3^-$), ammonia ($NH_4^+$), dissolved organic nitrogen (DON), and as di-nitrogen ($N_2$).

Plants make up a major proportion of the overall biomass. The plants can be free-floating (pelagic) and microscopically small (phytoplankton) or attached to the sediment (benthic). Benthic plants can be large such as sea grass (macrobenthic plants) or they can form a millimetre-thick film of microscopically-small algae (microbenthic algae).

The surface sediment underlying the water attracts most of the dead biomass and is highly reactive, moving and transferring nutrients to other estuarine compartments because bacteria causes the biomass to decompose. Below the reactive surface sediment layer, microbial breakdown of organic matter is much slower and the sediment serves as a storage compartment for nutrients ('refractive' sediment).

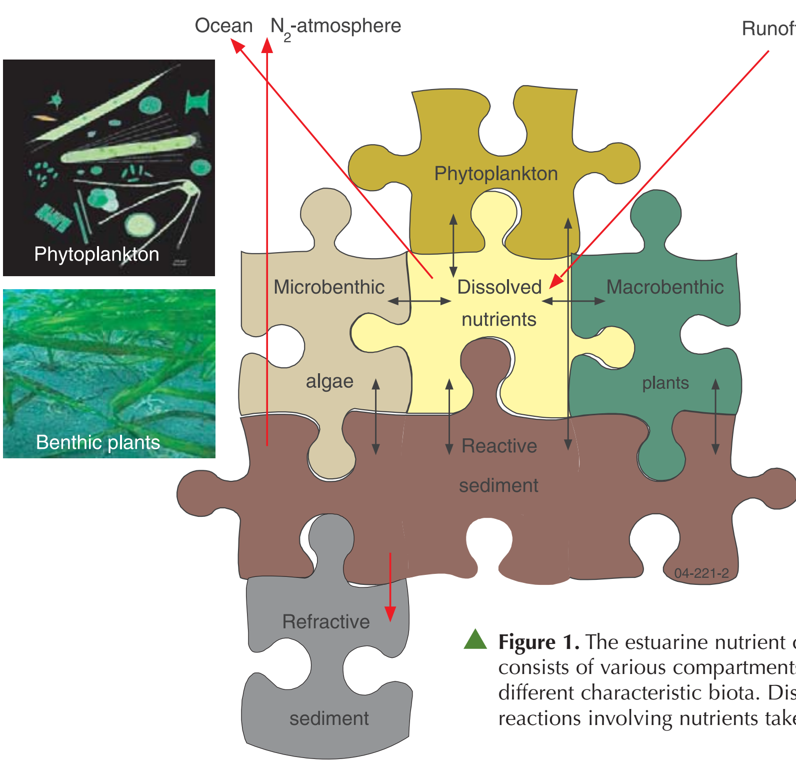


**Figure 1.** The estuarine nutrient cycle consists of various compartments with different characteristic biota. Distinctive reactions involving nutrients take place.

Various forms of nitrogen move freely between the different compartments, resulting in a complex network of biogeochemical processes (figure 1). These processes involve plant and bacterial activity and are mostly affected by the physical-chemical conditions such as light and nutrient availability, temperature, and sedimentation.

An estuary can be described as the transition between the river and the ocean with freshwater and associated nutrients entering the estuary and an exchange gateway at the ocean side. Depending on the proportion of freshwater entering and brackish-marine water exiting, estuaries have highly variable water residence times. Under high river water runoff conditions, the estuary is flushed, while the residence time in the same estuary can be very long under low runoff conditions or when the water exchange with the ocean is restricted. Nutrients are efficiently trapped and recycled within the various estuarine compartments when the water residence time is long, whereas flushing leads to significant nutrient outflow to the ocean.

Poor and deteriorating coastal water quality is associated with increased levels of dissolved nutrients ($NO_3^-$ and $NH_4^+$) and excessive plant growth, a trend in water quality referred to as eutrophication. Balancing the input and output of estuarine nutrients, such as nitrogen, allows scientists to estimate a sustainable nutrient load. While river runoff is the primary nutrient input, the output comprises the nutrient outflow to the ocean, the burial of nutrients in sediments, and the production of $N_2$ in sediments. $N_2$ is inert and eventually escapes to the atmosphere. The process producing $N_2$ is called denitrification and has the capacity to typically remove 50 to 90 per cent of all nitrogen entering the estuarine nutrient cycle.

## Eutrophication

This term refers to an increase in biomass production within an ecosystem over time. In order to compare the degree of eutrophication between different aquatic systems, a classification for (plant) biomass production was established ranging from oligotrophic (< 100 g C $m^{-2}$ $y^{-1}$) to hypertrophic (> 500 g C $m^{-2}$ $y^{-1}$) conditions.[1]

A common misconception is to think that high biomass production means that living resources within our coastal waterways are in a better condition. The implications of a high biomass production are dramatic for the health of an aquatic ecosystem and include the loss of habitat such as sea grass meadows, a decrease in biodiversity, and mass mortality induced by anoxic water or the release of toxins from certain groups of phytoplankton.

During eutrophication a cascade of physical—chemical effects lead to impacts on life in the water column and within the sediments (figure 2). As long as an estuary receives little nutrient loads from the catchment, slow-growing macro plants, (particularly sea grass) thrive, and provide shelter and support for a highly diverse range of life forms including young fish. Once nutrient loads increase, the fast-growing phytoplankton increases, reducing the light available for benthic plants. As a consequence, sea grass abundance declines and often fast-growing macro algae start dominating benthic plant communities. Plant growth will now become sporadic and follow pulses of nutrient-rich runoff. The sudden availability of nutrients together with the reduced salinity conditions promote new phytoplankton assemblages, which may contain a toxin-releasing species.

The phytoplankton bloom phase is then followed by enhanced oxygen consumption at the sediment surface where bacteria decompose organic matter. This enhanced oxygen demand often leads to anoxic bottom water conditions, particularly when the estuary is poorly flushed. Consequently, mass mortality becomes inevitable for benthic life under anoxic conditions.

## Case studies: St. Georges Basin (NSW), Wilson Inlet (WA), Fitzroy River Estuary (Qld)

St. Georges Basin and Wilson Inlet are very similar in size and shape, both are wave-dominated estuaries with a large surface area of 42 and 48 $km^2$, respectively. However, St. Georges Basin is significantly deeper and has therefore twice the water volume of Wilson Inlet. Secondly, the two estuaries are located in different rainfall zones and receive different volumes of water from the catchment. St. Georges Basin receives a fairly continuous river runoff which relates to a uniform rainfall throughout the year, while Wilson Inlet receives a few major pulses of river water, typically between August and December. These freshwater pulses add up to twice the total volume that St. Georges Basin receives during a year. Thirdly, the ocean gateway, or barrage, of Wilson Inlet is only open when the estuary receives major river runoff and about two months thereafter (August to February), while St. Georges Basin has a year round water exchange with the ocean.

These three physical differences in the estuarine environment have major implications for differences in the nutrient cycling, the biota, and the susceptibility to effects of eutrophication: The temporarily open barrage of Wilson Inlet leads to the accumulation of highly saline (marine) water at the bottom of the estuary, while the large volume of freshwater entering the estuary forms a layer on top. The estuary becomes stratified. This stratification restricts the vertical water exchange and oxygen re-supply to the estuary bed, where oxygen is rapidly consumed. Consequently, the bottom water becomes anoxic. At the same time, the surface water becomes enriched with nutrients such as nitrate, which then stimulates phytoplankton growth and leads to a major bloom (www.wrc.wa.gov.au/public/community/Wilson_Inlet_No5.pdf). On an annual basis, however, most of the dissolved nutrients are taken up by benthic plants including sea grass and benthic micro phytoplankton. The latter is only possible because large areas of Wilson Inlet are shallower than 3 metres and can receive light deep down on the estuary bed, a critical condition for benthic plant growth.

In contrast, St. Georges Basin is distinctively deep, which does not allow benthic plant growth in large areas (figure 3). This conclusion is numerically supported by the Simple Estuarine Response Model (SERM, www.per.marine.csiro.au/serm2), which predicts Wilson Inlet and St.

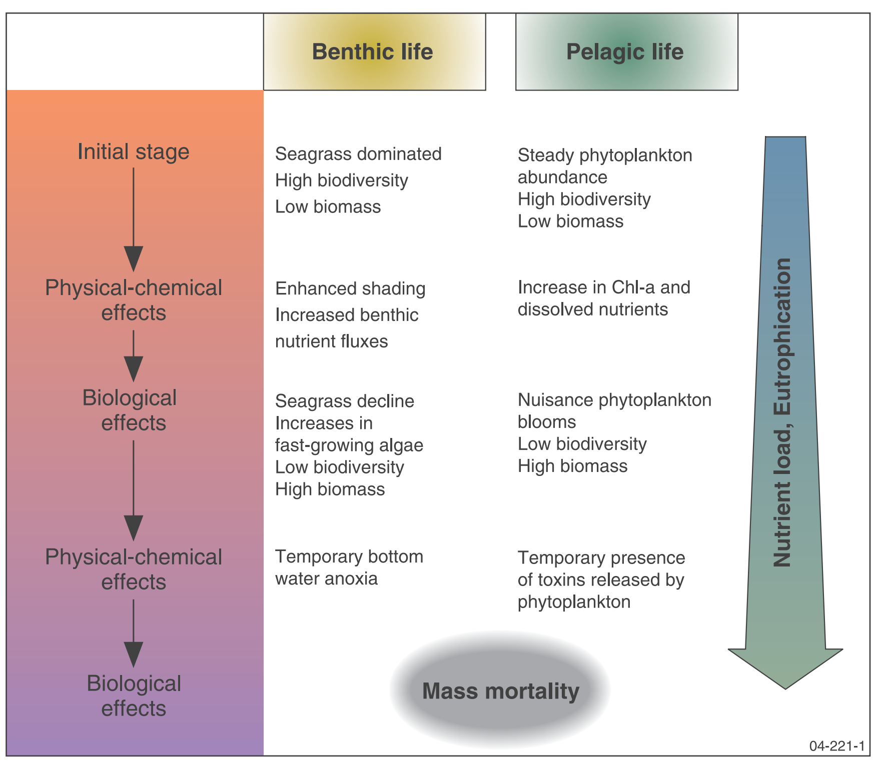


**Figure 2.** Increased nutrient loads from the catchments lead to an increase in the degree of eutrophication. A cascade of physical-chemical and biological effects lead to deteriorating water quality.

Georges Basin to have about the same rate of total plant growth (primary productivity), but distinctively different proportions in pelagic and benthic productivity. Benthic plant growth in Wilson Inlet is about 90 per cent, whereas it is only 10 per cent of the total primary productivity in St. Georges Basin. As a consequence, ongoing eutrophication in St. Georges Basin has probably increased phytoplankton growth and thereby reduced light penetration to the bottom. This is a typical effect of eutrophication and is likely to have contributed to the sea grass decline in St. Georges Basin, over the last 40 years.[2]

Similar to Wilson Inlet, the hydrology and nutrient cycling of the tide-dominated estuary of the Fitzroy River is strongly dependent on the season. Here, rainfall is predominant during the summer, and major floods occur usually between December to March. The Fitzroy River Estuary is also affected by the large tidal range of 4 metres. Water and its suspended matter moves rapidly back and forth in tidal creeks, and extensive (intertidal) areas are temporarily immersed during the tidal cycle. The intertidal areas in tropical north Australia consist predominantly of mangrove swamps and, to a lesser degree, intertidal mud flats. Mangrove swamps are highly productive and therefore constitute a major coastal ecosystem. Vegetated intertidal areas remove large amounts of carbon [3] and associated nutrients. In addition to the high nutrient burial, denitrification is highly efficient in mangrove sediments, so that these intertidal areas serve as a valuable filter for catchment derived nutrients. It has been shown that seagrass is effectively protected by fringing intertidal wetlands against excessive catchment N loads.[4] In the case of the Fitzroy River Estuary, the average width of a mangrove belt bordering both sides of the estuary channel is 1 km (figure 4). Here, nutrient levels in the estuary, plant productivity and nutrient flux are controlled predominantly by the combination of the biogeochemical functions of the mangrove swamps and their aerial extent, as well as the connection of these areas by intertidal creeks and the tidal flushing.

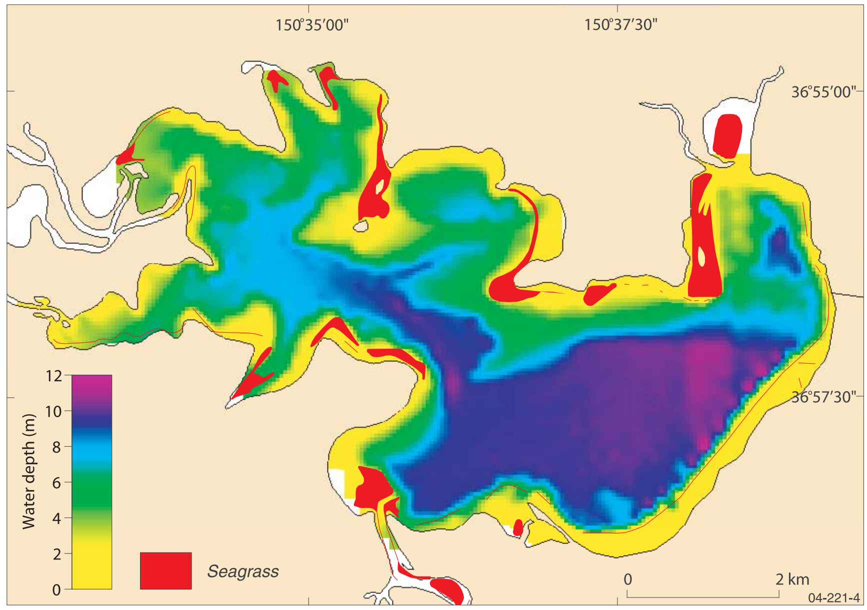


**Figure 3.** Large areas of St. Georges Basin (New South Wales) are too deep to allow light penetration to the estuarine bed. Consequently, benthic plants such as sea grass are restricted to a relatively small area, so that primary productivity in surface water is pre-dominant. Seagrass distribution according to Meehan.[2]

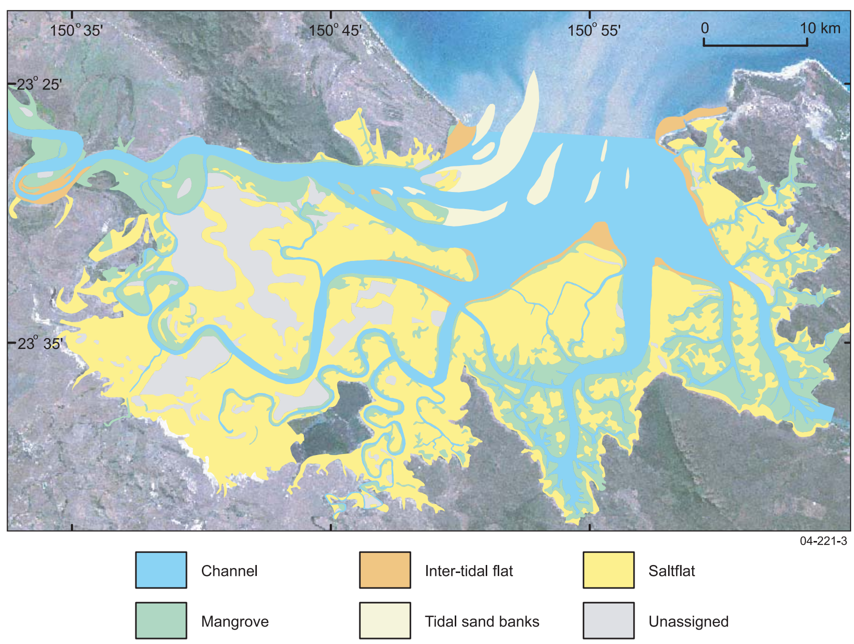


**Figure 4.** Water flow and nutrient reactions of the Fitzroy Estuary (Queensland) are strongly influenced by the high river water discharge during the summer and the large tidal range. Intertidal areas such mangrove swamps border the river channel and tidal creeks and serve as zones of significant nutrient processing.

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# COASTAL CRC project update

## Fitzroy Estuary and Keppel Bay Project

### *Water column survey*

In August this year, a team of scientists from Geoscience Australia and CSIRO Land and Water undertook a dry-season survey of the water column and bottom sediment properties in Queensland's Fitzroy Estuary and Keppel Bay.

They gathered in situ data, in particular time series measurements of water velocities and turbidity, together with physical and intrinsic optical properties of the water column and sampling of suspended sediment.

These data will:

- help parameterise and validate the mathematical models of hydrodynamics and sediment transport currently under development;
- facilitate the use of satellite measurements of surface water chlorophyll and suspended sediment concentrations to provide synoptic data for all of Keppel Bay; and
- allow further exploration of the temporal dynamics of sediment re-suspension and its impact on short term nutrient availability in Keppel Bay.

**Figure 1.** Scientists recover a submersible vibrocorer from the sea bed in Keppel Bay

### *Vibrocoring in Keppel Bay*

Scientists began work on a vibracoring project in Keppel Bay and the Fitzroy River estuary in September.

They aimed to obtain sediment cores, to a maximum depth of three metres below the seabed, at pre-selected sites within the study area in order to:

- 'ground-truth' the sub-bottom profiles for Keppel Bay and assist in the interpretation of the sedimentary sequences identified in these acoustic data; and
- obtain sediment samples of the various Holocene and Pleistocene subsurface units for analysis and characterisation.

Over a two day period, a total of 25 cores (19 aluminium and six PVC cores) were recovered from the 20 pre-determined sites (figure 1). One core at each site will be cut longitudinally and split to expose the core sample. The core will then be photographed and logged prior to sampling.

Logging includes visual estimates of colour, texture and composition of the various lithologic units, noting any major stratigraphic changes. Samples of the various units are collected from one of the core halves. The other half is run through a GeoTek logger to identify physical changes in the sediment and then archived for future reference.

The composition and texture of sediment samples from the vibrocores will be examined using various labratory intsruments such as XRD, XRF/ICP-MS and laser grainsize methods.

Examining these vibracores will allow deposits to be correlated and build a stratigraphic framework for Keppel Bay. Along with the sub-bottom profiles, these data will be used to reconstruct the Holocene and recent evolution of Keppel Bay. It will also help to quantify the volume of sediment in the bay derived from the Fitzroy River.

Additional cores at selected sites were collected to assess iron speciation within the sediments. Biomarker analysis will be completed by project partners, CSIRO Marine in Hobart (Dr Rhys Leeming) and Central Queensland University (Dr Viky Vicente-Beckett) who will measure pesticides within the estuary sediments.

### *Acoustic mapping of the estuary and seabed*

The Fitzroy Estuary is one of a number of tropical macrotidal estuaries in northern Australia. In this part of Australia there is an urgent need to assess the potential impacts of catchment land use on the estuarine system and coastal zone, including the Great Barrier Reef Marine Park.

The Coastal CRC Coastal Water Habitat Mapping project is assessing these impacts using sonar systems such as the multibeam Reson Seabat 8125 and Klein 5000 sidescan sonar.

Using these systems, scientists have acoustically mapped the bed of the Fitzroy Estuary, and sites in the adjacent Keppel Bay.

An added bonus of this project is the testing of the sonar equipment in highly turbid and muddy water, with tidal ranges of up to five metres. Adverse environmental conditions such as strong currents, zero water visibility and notorious sandbanks combine to make sonar surveys technically challenging. To date, these have been the most difficult environmental conditions in which the CRC has used this equipment.

The Reson 8125 used to capture a very high resolution bathymetric dataset in Keppel Bay, focused on a range of sediment bedforms. A repeat survey of these bedforms is being used to assess rates of movement, and quantities of sediment transported from the river to its final destination in Keppel Bay.

The Klein 5000 sidescan sonar has produced imagery of various sediment bedforms in the main estuarine reach of the Fitzroy River (figure 2). It shows the erosion of sediments from the river bank with large sandwave or 'slugs' moving down the river during flood periods only, and overlain by smaller bedforms which move during each tidal cycle.

Central Queensland's Fitzroy River and Keppel Bay, are examples of typical macro-tidal estuaries and inner shelf environments found in tropical northern Australia.

About the size of England, the Fitzroy River has one of the largest river catchments in Australia, at approximately 14 million hectares.

The Fitzroy is atypical of most Australian rivers because it has very high sediment yields. Further study of the acoustic data and sediment samples, including cores, grabs, and water column information, help to determine how catchment land-use practices affect the river and coast.

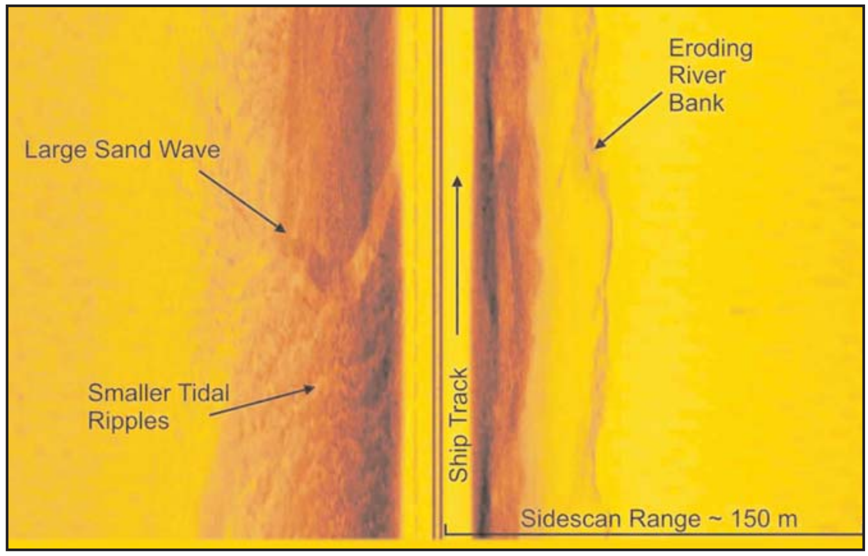
This collaborative field operation included scientists and technicians from Curtin University (WA), Defence Science and Technology Organisation (DSTO), and Geoscience Australia.

## Habitat maps of near-pristine estuaries

GIS maps of sedimentary habitats in 73 near-pristine estuaries in Queensland are now complete and available for download at www.ozestuaries.org. 'Near-pristine' estuaries are those with relatively little or no apparent human impacts (figure 3). Queensland has the greatest estuarine diversity as well as the largest number of estuaries in any state (305). It also has the highest number of 'near-pristine' estuaries (182).

Scientists plan to map 163 near-pristine estuaries from around Australia. The new maps will allow comparisons between regions and estuary types without the overprint of impacts related to post-European settlement.

They will also provide baselines from which to gauge changes that have occurred in estuaries in the more populated parts of Australia. These maps will also fill a gap in current knowledge, as predominantly modified estuaries were mapped as part of the National Land and Water Resources Audit. Using new methods, the latest maps are more accurate, detailed, and visually pleasing than the Audit maps.




▲ **Figure 2.** A sidescan sonar image of the bed of the Fitzroy Estuary main channel, collected using DSTO's Klein 5000 system.

## Further development of OzEstuaries database

OzEstuaries is entering a new phase of development. The web interface is undergoing a restructure, which will enable easier navigation and provide more functionality, including enhanced data query capabilities.

A significant amount of new coastal geoscientific data is being added, as well as images, data reports, additional online GIS layers, bathymetry data and 3D visualisations.

These data and information are derived from a range of current Coastal CRC projects, including the Coastal Water Habitat Mapping and Fitzroy Estuary projects. Upgrades will start coming online in the next few months.

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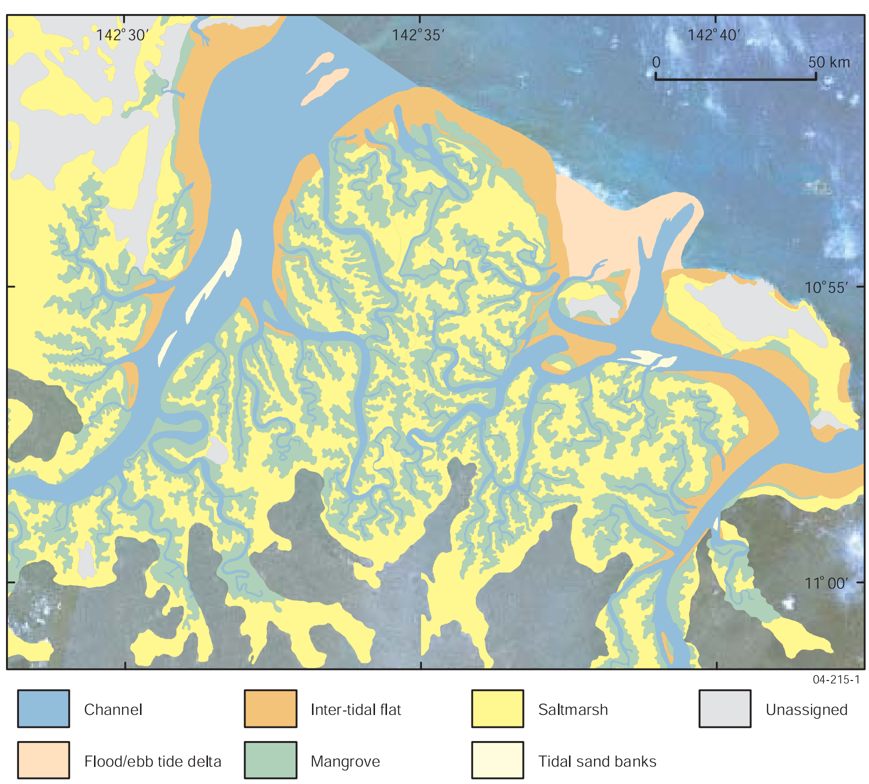


▶ **Figure 3.** Sedimentary habitat map for Kennedy Inlet (left) and Escape River (right), located near the tip of Cape York, Queensland.

# *Shifting sands* UPDATE

A clearer picture of the shifting sands and disappearing seagrass in Torres Strait is beginning to emerge. A second marine survey by Geoscience Australia scientists in October has revealed that seasonal winds are the principal cause of widespread sandwave movement in Torres Strait.

The survey was the second this year aboard James Cook University's research vessel *James Kirby* investigating the movement of sandwaves next to Turnagain Island. Two study sites, southwest and southeast of the island, were resurveyed with multi-beam swath sonar. The first survey completed in April fortuitously captured the moment when the sandwaves reversed their orientation from east to west, associated with the end of the monsoon and start of the trade-wind season (see *AusGeo News 75*). The second sonar survey completed in October showed that the crests of the sandwaves had moved up to several hundred metres further to the west over that time (figure 1).

Detailed measurements of wave and tide currents were also collected by six oceanographic moorings deployed in the vicinity of the sandwaves for the 21-day survey to provide insights into the main oceanographic processes causing sediment transport. While local waves and tides are responsible for resuspending the sand grains on the seabed, it appears that it is the longer-term net water movements driven by the prevailing winds that are responsible for the formation and migration of the sandwaves.

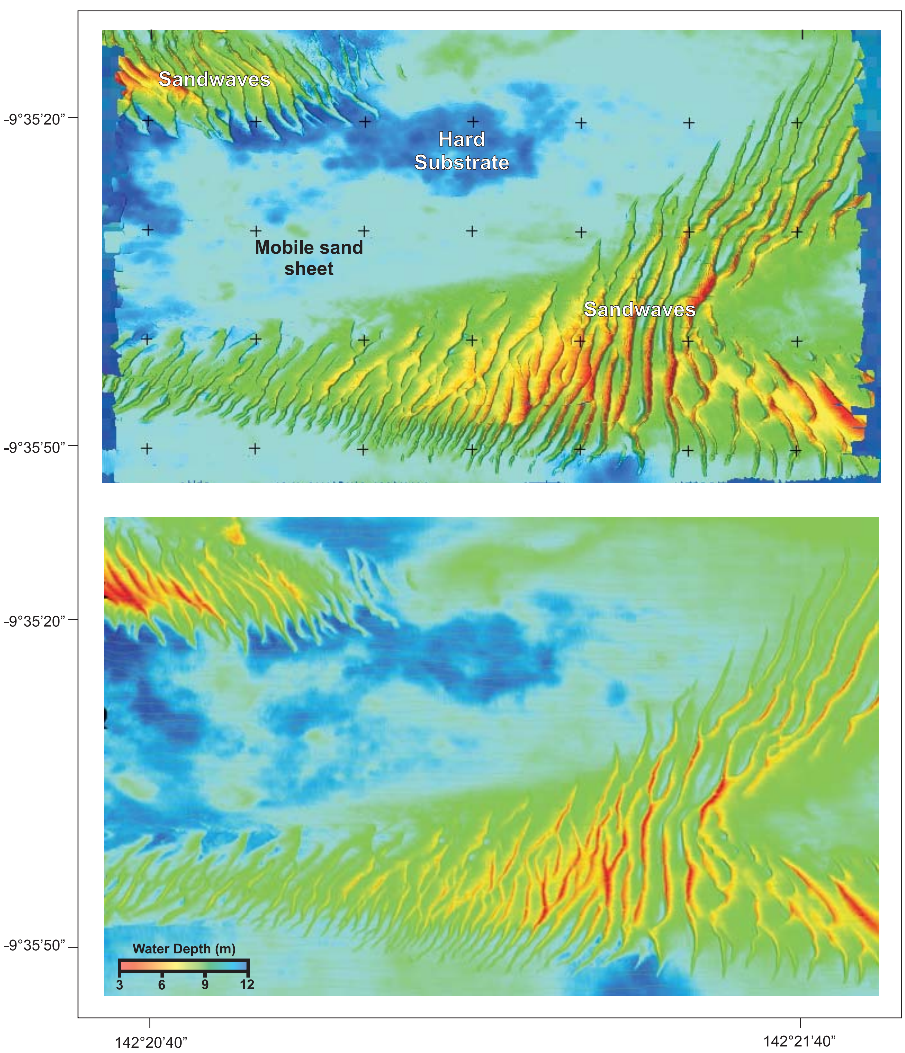


**Figure 1.** Swath sonar images showing the morphology of the sandwaves south-east of Turnagain Island in April (top) and October (bottom) 2004. Note that the sandwaves have changed from east to west under the influence of the trade winds.

The surveys have revealed for the first time, and in unprecedented detail, a picture of the dynamic nature of the seabed in Torres Strait. Further analysis of the sonar and sediment data from shallow cores collected from the sandwaves will be undertaken over the next few months to determine the amount of sand that has moved over the seabed during the 2004 trade wind season. This will be determined by calculating differences in the position of the crests of the sandwaves and estimates of the volume of sand. Comparison of the sonar data from the April and October surveys will be conducted to determine the extent of adjustments in seabed elevation. This can be translated into changes in the distribution of sand contained in the sandwaves over time.

The principal aim of the surveys is to increase our understanding of the processes causing the sandwaves to move, and their potential effects on the distribution, abundance and survival of seagrasses in Torres Strait. Because the sandwaves are extremely mobile, they have the capability to rapidly cover seagrass, which grows next to the sandwaves. Widespread smothering of seagrass beds will have consequences for dugong and green turtle populations which eat the seagrass. Traditional hunting of these creatures by the local Torres Strait Islanders will be affected.

The surveys are part of a larger program managed by the Reef Cooperative Research Centre (Torres Strait Program) investigating seabed ecosystems, and modelling of physical and biological processes occurring in Torres Strait. Results from Geoscience Australia's surveys will contribute directly to the development of management plans for the region.

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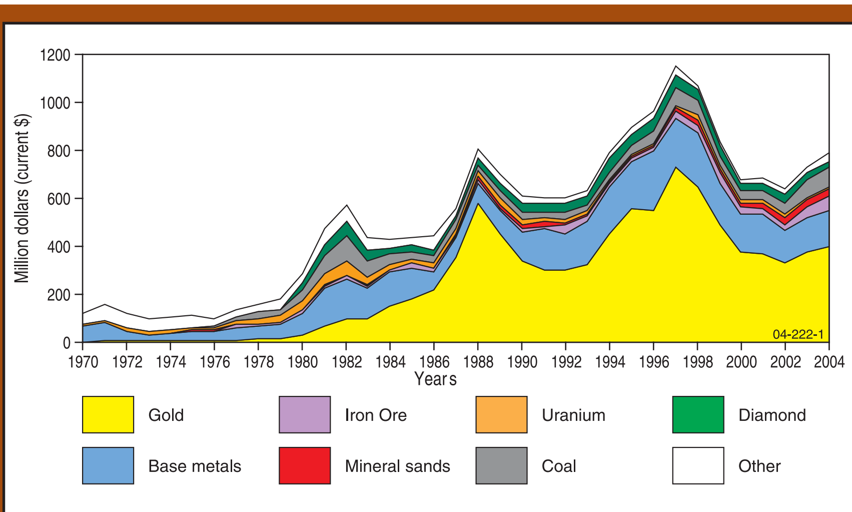
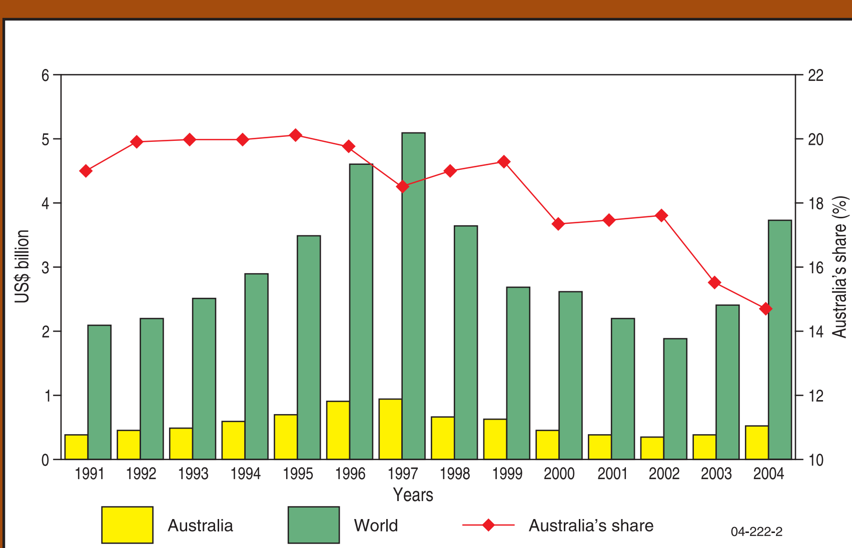
# Australia's mineral exploration ranking continues to slip

Recent surveys indicate that global exploration is re-bounding strongly from the major downturn of the last five years on the back of high gold prices and large increases in base metal prices driven by strong demand from China's industrialisation and urbanisation. Australian mineral exploration activity has also increased but its share of global exploration budgets continues to decline.

## Australian mineral exploration improves

Australian mineral exploration expenditure for the 2003-04 financial year, reported by the Australian Bureau of Statistics, was $786.7 million, an increase of 7.4% over 2002-03 figures (figure 1). Exploration increased in all jurisdictions except New South Wales and the Northern Territory. Western Australia dominated exploration expenditure with 59% of total spending followed by Queensland with 16%. Gold dominated exploration spending with 51% of total exploration, followed by base metals (19%), coal (10%) and iron ore (8%). Exploration spending was up for most commodities, except for mineral sands and diamonds, which each fell by approximately 13% (figure 1). The largest percentage increases in exploration expenditure were for uranium and iron ore.




## Global mineral exploration up strongly

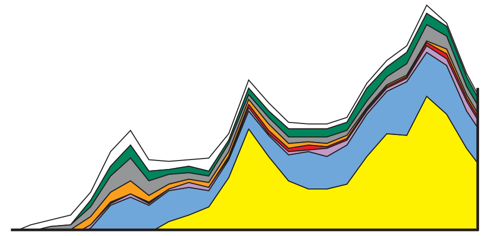
The recently released 2004 Metals Economics Group survey of global non-ferrous metal exploration budgets reports significant increases in global exploration budgets for the 2004 calendar year, an increase of more than 50% on the previous year to ~$US3.7 billion (figure 2). Exploration budgets were up substantially on last year's figures in all regions surveyed. Countries showing the largest increases were Mongolia (exploration at the Oyu Tolgoi copper-gold deposit) and the USA (increased gold exploration in the Carlin district).

Australian budgets also increased significantly in the 2004 survey but its share of global non-ferrous mineral exploration budgets fell to 14.7%, after Latin America (21.8%), Canada (19.6%), Africa (16.1%), and the rest of the world (15.4%). This was the first time Australia has not been in the top four regions for mineral exploration and its lowest recorded share of global mineral exploration (figure 2). (continued on page 24)

**Figure 1.** Australian mineral exploration expenditure 1970-2004 in constant 2003-04 dollars, based on Australian Bureau of Statistics data deflated by Consumer Price Index.

**Figure 2.** Global non-ferrous metal exploration budgets for 2004 together with Australian non-ferrous metal exploration budgets and Australia's share of global mineral exploration budgets for period 1991-2004. Source: Metals Economics Group Corporate Exploration Strategies 2004.

The Metals Economics Group survey figures are dominated by surging precious metals exploration with global gold exploration budgets up 68% in response to strong gold prices. The increase in gold exploration budgets (50% of total non-ferrous exploration budgets) in 2004 was accompanied by a small decrease in diamond exploration (13%); base metals exploration remained at 26% of total spending. Canada, particularly, showed a marked increase in gold exploration budgets with its share of global gold exploration more than trebling since 1997.



## Favourable outlook

Mineral exploration in Australia is recovering, but at a slower rate than in some other parts of the world. The increase in global mineral exploration is underpinned by high gold prices and strong demand from China for base metals and bulk mineral commodities such as iron ore, aluminium and coal. This trend seems likely to continue in the short term. Demand for base metals and the bulk commodities in the medium term will primarily depend on the rate and extent of economic growth in China and the impact of current high oil prices on the global economy.

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# GAWLER *seismic study*

In 2003, Geoscience Australia, in partnership with Primary Industry and Resources South Australia (PIRSA), conducted a deep crustal seismic survey across the eastern margin of the Gawler Craton to determine the crustal structure in the region of the giant Olympic Dam copper-gold-uranium deposit. Scientists recorded and processed over 250 line-kilometres of deep seismic reflection data from two lines centred on the Olympic Dam minesite.

The results provide new insights into the crustal architecture and the first regional-scale 3D image of this major mineral system.

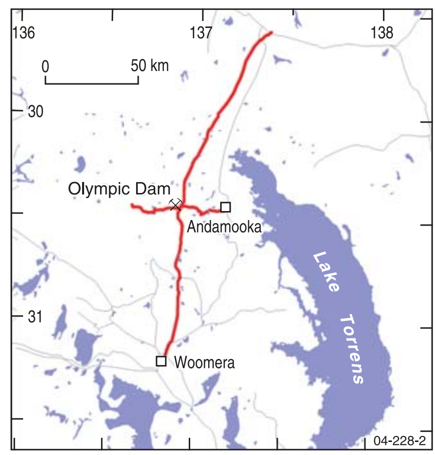
The Olympic Cu-Au-U province is host to the world's most outstanding example of an iron oxide-copper-gold deposit, Olympic Dam. However, the deposit and the entire eastern third of the Gawler Craton are covered by sedimentary sequences hundreds to thousands of metres thick.

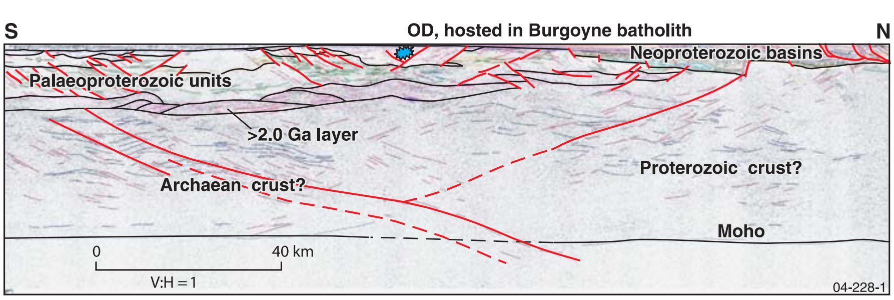
Before the seismic survey, the nature of the crystalline basement and its minerals systems could only be inferred from potential-field data and observations from relatively few drill holes.

Initial interpretations show that the Archaean–Proterozoic basement is typical of a fold-thrust belt. It displays thrusts and back-thrusts, related to known periods of orogenesis, in a comparatively layered crust with Palaeoproterozoic units to depths of 14 km overlying a mid-crustal reflective layer.

This layer, about five kilometres thick, displays ramp-flat geometries in contrast to the thrusts above it. Both the velocities and the style of deformation suggest it is possibly more mafic than the overlying units. This layer is older than the 2.0-1.85 Ga Hutchison Group, perhaps earliest Palaeoproterozoic to late Archaean.

Below the mid-crustal layer, a north-dipping transcrustal shear zone extends from the southern end of the profile to the Moho, possibly into the mantle. It does not appear to be a significant crustal boundary, despite its prominence. The deep crust of the northern part of the section, however, shows a different seismic character, which suggests that it may be a separate terrane.




The granite pluton hosting the world class Olympic Dam Cu-Au-U deposit is clearly imaged. About five kilometres thick, it is the only intrusive body associated with mineralisation apparent in the sections.

The cover rocks are up to six kilometres thick and show the structure of their basins and the influence of Cambrian inversion.

Interpretations of the Gawler Craton seismic sections are being incorporated into geophysical, geochemical, and geological models of the Olympic Cu-Au-U province so that a clear picture of its architecture and tectonic history can be developed.

In particular, the major basement geological units and structures identified in the seismic data will be integrated with potential-field data to develop a 3D geological model. This will allow scientists to assess the potential for more mineral deposits in the region, but also help them to understand how this province relates to other Archaean and Proterozoic terranes within the Australian continent.

Seamless

# SEAMLESS TOPOGRAPHIC DATABASE

## becoming a reality

For almost 50 years Geoscience Australia and its predecessor organisations have mapped Australia at scales from 1:100 000 to 1:20 million. For many years manual methods of cartography were used to produce paper maps, but in the last 15 years, since the introduction of digital cartography, a broader range of products, many now in digital format, have been produced.

Recent advances in database technology for managing geographic information systems (GIS) spatial data have been embraced by National Mapping Division (NMD) and promise to further revolutionise the way NMD fulfils its national mapping obligations. In embracing this technology, Geoscience Australia has created a seamless topographic database at 1:250 000 scale for the entire continent.

Geoscience Australia approached the technology by initially developing a functional specification that established the input and output requirements of the database. Among the issues considered were: what type of information do we want to store; what do we want to be able to do with the data in terms of maintenance, manipulation and output; and, what tools would be required to do these things?

After these and other issues were considered, various options were tested. Hardware and software were bench-marked and the performance of spatial data formats, such as Oracle Spatial, and SDE binary, compared. A method for populating and validating the database was formulated and a data model that adhered to national and international standards, maintained historic data, and allowed for future expansion into other themes and scales was constructed.

The data was modelled using point, line, polygon and multi-polygon spatial entity types and then categorised according to theme, class, subtype, and spatial entity type. Thematically-related and sometimes topologically-related features were grouped. The data model was documented, constructed in Unified Modelling Language (UML), and a pilot and a prototype database was developed.

Ten gigabytes of vector data, held in ARC/INFO coverages, was then reformatted and translated into the new data model. All 513 tiles of data were edge-matched and their 'bleed-edges', or overlaps, assimilated. The resulting database is seamless, continent wide, and arguably more significant than any other spatial dataset in Australia. It includes roads, streams, contours and all the other hydrographic, infrastructure, administration, vegetation and relief features appearing on the 1:250,000 scale topographic national map series. It is also fully attributed, down to feature level metadata.

Web pages and programs for delivering the data, and user-customised maps generated from the data, are currently being developed. Maintenance and validation of the database has commenced.

The seamless database has proved to be faster, more easily managed and maintained, and richer and more intelligent than the source coverages from which it was created. It better retains history and maintains data integrity.

Seamless topographic data at other scales are now being added to the database environment. It is envisaged that in the future a full range of both standard and on-demand paper and digital products will be derived directly from a single multi-scaled topographic database.

Creation of the seamless database has been a difficult, rewarding and significant step in building the Australian spatial data infrastructure.

## *Events* CALENDAR *2005*

**North American Prospects Exhibition**

American Association of Professional Landmen

26 & 27 January

Houston, Texas, USA

*Contact:* AAPL, 4100 Fossil Creek Boulevard, Fort Worth, Texas 76137 USA

phone +1 817 847 7700

fax +1 817 847 7704

e-mail nape@landman.org

www.napeonline.com

**PDAC International Convention & Trade Show**

Prospectors and Developers Association of Canada

6 to 9 March

Metro Toronto Convention Centre, Toronto, Canada

*Contact:* Prospectors and Developers Association of Canada, 34 King Street East Suite 900, Toronto, Ontario M5C 2X8

phone +1 416 362 1969

fax +1 416 362 0101

e-mail info@pdac.ca

www.pdac.ca

**APPEA Conference and Exhibition**

Australian Petroleum Production and Exploration Association

10 to 13 April

Perth Convention and Exhibition Centre

*Contact:* Julie Hood, APPEA Limited, GPO Box 2201, Canberra ACT 2601

Phone +61 2 6267 0907

fax: +61 2 6247 0548

e-mail: jhood@appea.com.au

www.appea.com.au

**AAPG Annual Meeting**

American Association of Petroleum Geologists Annual Meeting and Exhibition

19 to 22 June

Calgary, Canada

*Contact:* AAPG Convention Department, PO Box 979, Tulsa Oklahoma 74101-0979 USA

phone +1 918 560 2696

fax +1 918 560 2684

e-mail: sbenton@aapg.org

www.aapg.org

**AMSA 2005**

Australian Marine Sciences Association

11 to 13 July

Crowne Plaza, Darwin

*Contact:* PO Box 902, Toowong Qld 4066

e-mail: amsa2005@amsa.asn.au

www.amsa.asn.au

# *100K scale* mapping pilot to help emergency management

Disasters such as the bushfires in south eastern Australia in 2003 highlight the importance of up-to-date and appropriate spatial information in responding to and managing emergencies. This type of information is extremely valuable as it is used by emergency managers to prepare, plan, respond and recover from such disasters. To ensure the information can be used effectively, maps need to be current, relevant and accurate.

During the 2003 bushfire crisis, Geoscience Australia provided 3 400 topographic maps at 1:100 000 scale to support the fire fighting effort, despite almost two-thirds of the maps being more than twenty years old.

The currency of Geoscience Australia's 1:100 000 scale topographic map series ranges from 1961 to 1990, although a revision of 70 of the maps was completed in 2001. There are about 3 000 maps in the series and approximately half are available as published maps. However most of the data used to create the maps across the series are not available in a modern database environment.

In response to emergency management needs and the currency of the 1:100 000 scale topographic map series, Geoscience Australia is undertaking a 1:100 000 scale topographic mapping pilot project in several locations across Australia. The project is being undertaken in collaboration with State emergency management and mapping agencies and is piloting the use of the latest technology in satellite imagery and Geographic Information Systems (GIS), in generating 1:100 000 data and maps. The tangible outputs will include tailored GIS databases and digital and hardcopy maps for the following areas: Karijini National Park in Western Australia, the Gold Coast hinterland in Queensland, Barrington Tops in New South Wales, and the area around Benalla in Victoria.

In addition to providing key data and maps in the pilot areas, an important part of this project is to enhance Geoscience Australia's relationships with State emergency management and mapping agencies. Geoscience Australia is working closely with these agencies to develop tailored specifications for on-going mapping and to establish processes and arrangements that will maximise outcomes and production efficencies.

The spatial databases resulting from this project will be capable of supporting the ongoing development and maintenance of topographic information at a range of scales, particularly 1:100 000 scale. This not only benefits emergency management, but other key national requirements such as border protection, homeland security and natural resource management.

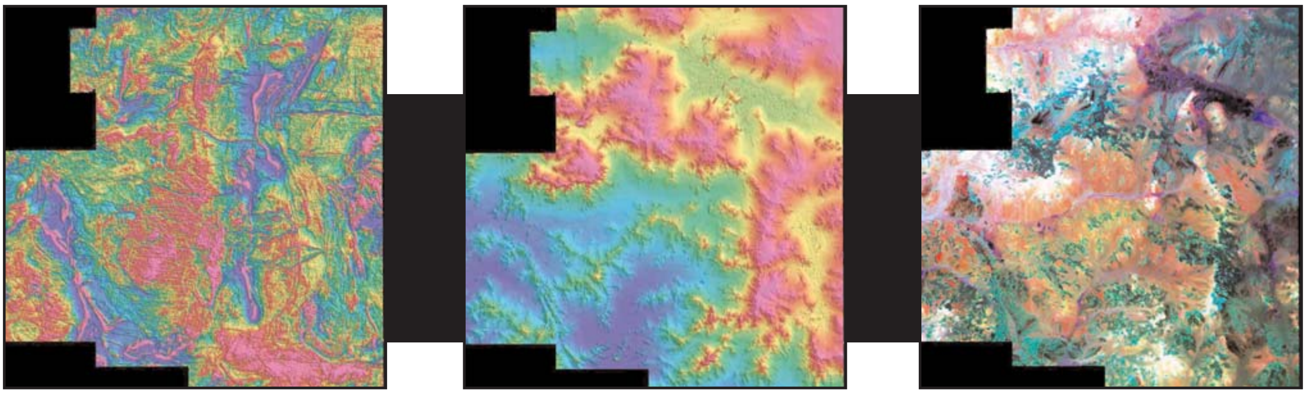
# Agreement signed between Australian Greenhouse Office and Geoscience Australia

Howard Bamsey, Chief Executive of AGO and Geoscience Australia's CEO, Neil Williams signing the agreement.

Geoscience Australia and the Australian Greenhouse Office (AGO) have agreed to cooperate closely on the supply, use and distribution of satellite imagery used to monitor changes in vegetation. Geoscience Australia's remote sensing unit, ACRES, has been downlinking Landsat imagery since 1979 and has built up an extensive national imagery archive. The AGO has used this imagery as one of the key information sources to construct the National Carbon Accounting System, used to track Australia's greenhouse gas emissions.

The satellite imagery shows that between our bicentenary in 1988 and 2001, 3.4 million hectares of forested land was cleared across Australia. However, more positively, the amount of carbon dioxide released due to land clearing has reduced between 1990 and 1999. Importantly, Landsat imagery is still being used today for many applications including environmental monitoring, crop analysis and map production. This rich digital information technology helps communities make informed decisions about where local and regional action will be most effective. As part of the agreement, ACRES will distribute the AGO image products including 12 epochs of processed imagery from 1972 to 2002. The products include a DVD containing three band compressed imagery in ECW format suitable for viewing by non-remote sensing users, as well as full resolution multi-spectral imagery mosaiced into 1:1 million map sheet tiles for use by spatial industry professionals. ACRES will be supplying 2004 Landsat imagery to enable the AGO to continue their monitoring work into the future.

# Geophysical data released for *key areas in WA*



Approximately 123 000 line kilometres of airborne geophysical data in the northern Yilgarn Block of Western Australia has recently been released. The area covered includes the entire Cue and Kirkalocka 1:250 000 sheet area and the 1:100 000 sheet areas of Yalgoo and Badja on the Yalgoo 1:250 000 sheet area.

The data shows a high potential for gold mineralisation but, as a result of the limited outcrop, mineral exploration has been hindered. It is expected that these new geophysical datasets will be a significant asset in mapping the region's Archaean geology as well as targeting exploration areas.

This dataset comprises magnetic, radiometric and elevation data from two surveys flown for the Commonwealth Government between April and August 2004. The data has been merged with two existing private company surveys, to provide continuous coverage over the northern Yilgarn region. As a result the magnetic, radiometric and elevation datasets have a variable line spacing of 200 to 400 metres, gridded using an 80-metre cell size.

These digital data (point-located and gridded) are available for free download from the web or on CD-ROM for $99 (includes GST) plus postage and handling.

**For more information about this dataset visit www.ga.gov.au/gadds. To order the CDs phone Freecall 1800 800 173 (in Australia) or +61 2 6249 9966, or e-mail mapsales@ga.gov.au**

# ASTER data available soon

Geoscience Australia's remote sensing unit (ACRES) recently signed an agreement with the Japanese Earth Remote Sensing Data Analysis Centre (ERSDAC) to distribute data from the ASTER sensor on board the TERRA satellite. ASTER is the Advanced Spaceborne Thermal Emission and Reflection Radiometer designed to obtain detailed maps of land surface temperature, emissivity, reflectance and elevation.

The ASTER sensor consists of three different subsystems—Visible and Near Infrared (VNIR), Shortwave Infrared (SWIR), and Thermal Infrared (TIR). Altogether, 14 discrete spectral bands are covered (see table1). Band 3 data from the VNIR system also has an additional backward looking telescope for the collection of stereo pairs.

The ASTER products will provide a useful addition to the ACRES product range, especially for applications involving geological studies or generation of digital elevation models.

**Table 1.** Characteristics of the three sensor systems of the ASTER instrument

| | VNIR | SWIR | TIR |
|---|---|---|---|
| Bands | 1–3 | 4–9 | 10–14 |
| Spatial resolution | 15m | 30m | 90m |
| Swath width | 60km | 60km | 60km |
| Cross track pointing | ± 318km | ± 116km | ± 116km |
| Quantisation (bits) | 8 | 8 | 12 |

▲ **Figure 1.** This 'decorrelation' image represents spectral variability in the short wave infrared region of the electromagnetic spectrum (EMS) captured by ASTER over the Century Copper / Zinc mine in Western Queensland.

Customers will soon be able to purchase archived Australian ASTER data and to place requests to ERSDAC for future acquisitions.

**For more information phone Jim Mollison on +61 2 6249 9221 or e-mail jim.mollison@ga.gov.au**

# *New edition* Magnetic Anomaly Map and Grids

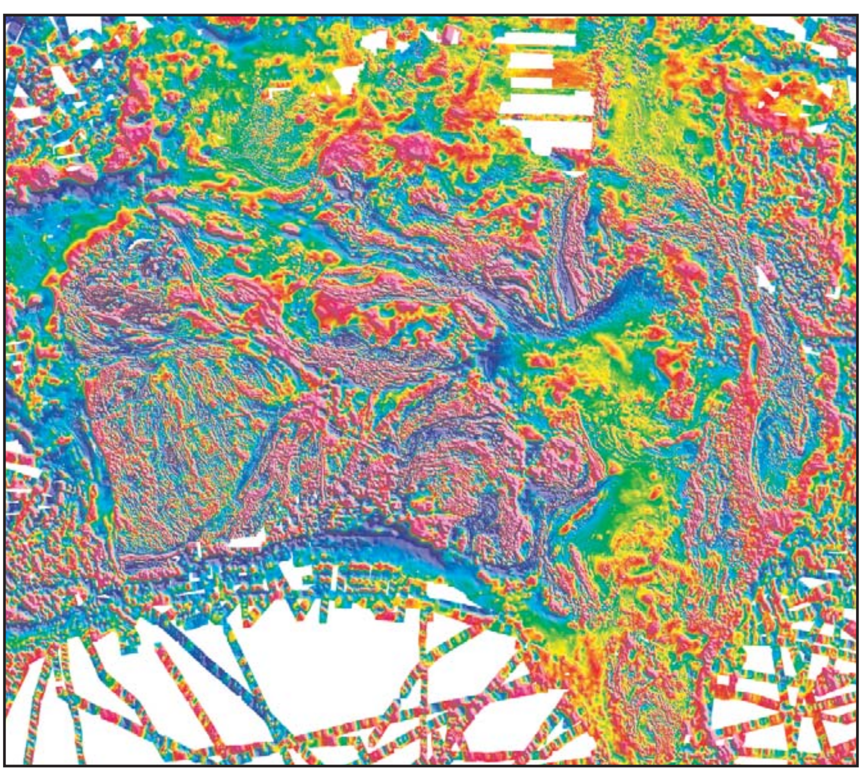
The new edition of the Magnetic Anomaly Map and Grid of Australia was produced from 19 million line kilometres of survey data from nearly 700 surveys. The new generation Magnetic Anomaly Grid Database (MAGDA) is the cornerstone of a completely new method of matching individual survey grids.

Developed using the concept of a database with matched Total Magnetic Intensity (TMI) grids, it is unlike previous editions, as it allows the extraction of composite grids of any resolution. Included in the release are hardcopy maps at 1:5 and 1:25 million scales, and composite grids with cell sizes of 7.2 and 15 seconds of arc (approximately 250 m and 400 m).

This edition was produced using a new compilation of TMI grid data, a new method that matches individual survey grids, and uses independent data to constrain long wavelengths. The resolution of each grid is optimal for the specifications of the source survey line data. Nearly 700 individual grids have been matched and merged into the composite grids, and used to produce images for the maps (figure 1).

Since the release of the third edition in 1999, new survey data has been acquired mainly by the state and territory Geological Surveys, and has been added to the database. It is estimated that around 19 000 000 line-kilometres of survey data were acquired to produce the grid data, over 10 000 000 line-kilometres more than for the previous edition. The index map (figure 2) shows the distribution of original survey line spacings from which the grids are derived.

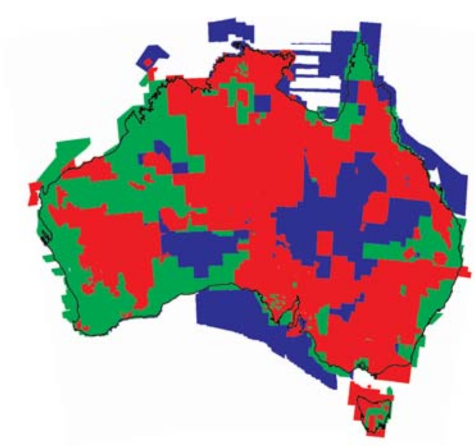
Matching the grids in the database was undertaken using a program called Gridmerge, originally developed at Geoscience Australia and now commercialised. It uses the statistics of the overlapping regions between adjacent surveys to globally minimise the differences in the base levels of all surveys. Provision has also been made to allow users to remove higher-order surfaces from grids. To constrain long wavelengths, an independent data set, the Australia Wide Array of Geomagnetic Stations (AWAGS) airborne magnetic data, was used to control the base levels of those survey grids which overlapped the AWAGS data. Using a convolution operator, the short-wavelength differences between the grids were smoothed.



▲ **Figure 1.** The 1:25 million scale version of the fourth edition of the Magnetic Anomaly Map of Australia.

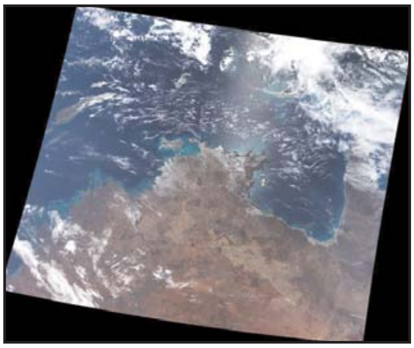
The TMI image used for the fourth edition map is an example of a range of products that can be easily generated from the new database. For example, the individual grids can convert to any desired map datum/projection and any selected areas of interest merged to the desired grid resolution. Databases of derivative grids can be automatically generated, such as reduced to the pole, vertical derivative and horizontal derivative products. Preliminary reduced to-the-pole and derivative grids of composites of the whole database have also been generated, using a tiling procedure.

Products derived from the magnetic database also provide insights into the distribution of magnetically susceptible minerals within the Earth's crust. They are of great value to mineral exploration companies and researchers of the solid earth. Magnetic minerals in small amounts are widespread in the crust, and become concentrated in zones which highlight the structures of the crust. This is particularly important for areas which have a significant thickness of surficial cover (regolith), which can mask the underlying crystalline basement rocks. The magnetic signatures of the basement, are measured through the cover and provide important interpretation to determine the nature and depth of the basement—significant information for mineral exploration.



▲ **Figure 2.** The distribution of survey line-spacings for data comprising the new database.

# MODIS *Update*



The Moderate Resolution Imaging Spectrometer (MODIS) instrument on board the TERRA and AQUA satellites provides multi-spectral remote sensing data in 36 bands at 250 metre, 500 metre and 1000 metre spatial resolution, with day and night coverage. Geoscience Australia's remote sensing unit (ACRES) has been providing MODIS products since 2001 (see AusGeo News 72).

ACRES provides on-line delivery of Near Real Time (NRT) Terra and Aqua MODIS satellite imagery. This MODIS data is available at no charge from the ACRES download site from the morning after acquisition and the following seven days. Older MODIS imagery is available from ACRES' archive. Details of the product specifications and the ordering procedure for the MODIS product are outlined at www.ga.gov.au/acres/prod_ser/modisprice.htm.

## MODIS data aids mapping of burnt areas

Burnt area maps are useful in developing appropriate mitigation strategies, by building fire history of a given area over a period of time, which is essential for planning and executing controlled burning to reduce fuel loads.

From September 2004, ACRES has offered MODIS data in Product Data Set (PDS) format. PDS files contain MODIS data in raw form with a minimal amount of processing such as Read Solomon correction, descrambling and packet recovery for various instruments streams. PDS data are useful to expert users who can implement their own algorithms to derive thematic products. A practical example is burnt area maps, which extends the current hot spot information provided daily by Sentinel at www.sentinel.csiro.au and Firewatch at www.firewatch.dli.wa.gov.au.

Geoscience Australia introduced PDS data in support of a project initiated by Western Australia's Department of Land Information (DLI) in collaboration with the Fire & Emergency Services Authority of Western Australia. The project was funded under the Natural Disaster Mitigation Program initiated by the Commonwealth Department of Transport and Regional Services.

This arrangement allows DLI to access continental coverage of MODIS data (via Geoscience Australia's Alice Springs downlink facility) for natural disaster mitigation and emergency management. It also provides vital backup for the Western Australian Satellite Technology and Applications Consortium receiver that DLI use to derive burnt area maps of Western Australia and the Northern Territory. This data is available free of cost to registered users from Geoscience Australia's MODIS web site acs.auslig.gov.au/modis_data. MODIS PDS data size ranges from 800 MB to one GB depending on the pass length.

# Landsat data *PRICES REDUCED*

Landsat data is now even more affordable and accessible to users as prices have recently been reduced following a review of the costs of transfer. The price reductions are primarily the result of efficiency gains at Geoscience Australia's remote sensing unit (ACRES) through reduced processing times, online ordering for distributors, and, automatic generation of ortho-corrected products. They are also in accord with the Commonwealth Government's Policy on Spatial Data Access and Pricing.

## Landsat 7 satellite SLC-Off/On composite products

Geoscience Australia has recently released Landsat 7 composite imagery which is a combination of two separate Landsat scenes acquired on different dates. One scene is the more recently acquired SLC-Off data that contains small gaps in the data due to a malfunction of the satellite's Scan Line Corrector on 31 May 2003 (see AusGeo News 74). The other scene is from data acquired before this date which contains no gaps (SLC-On data). The more recent SLC-Off data is used as the primary data source of the composite product, with the older SLC-On data used to fill any small gaps.

When ordering a Landsat 7 ETM+ SLC-Off/On composite product, customers will need to identify acquisition dates for both the SLC-Off data and SLC-On data. For the best result, dates need to be chosen from similar seasons and with minimal transient data such as clouds, fires, snow or other ground cover changes.

These SLC-Off/On composite products will only be available as ortho-corrected products in Fast L7A format. A full scene SLC-Off/On composite product has a recommended retail price of $900.

ACRES is currently looking into the development of composite products using data acquired from successive SLC-Off passes to minimise the temporal effects of using an older SLC-On scene. These products should be available in early 2005.

**For more information phone ACRES Customer Service on +61 2 6249 9779 or e-mail acres@ga.gov.au**