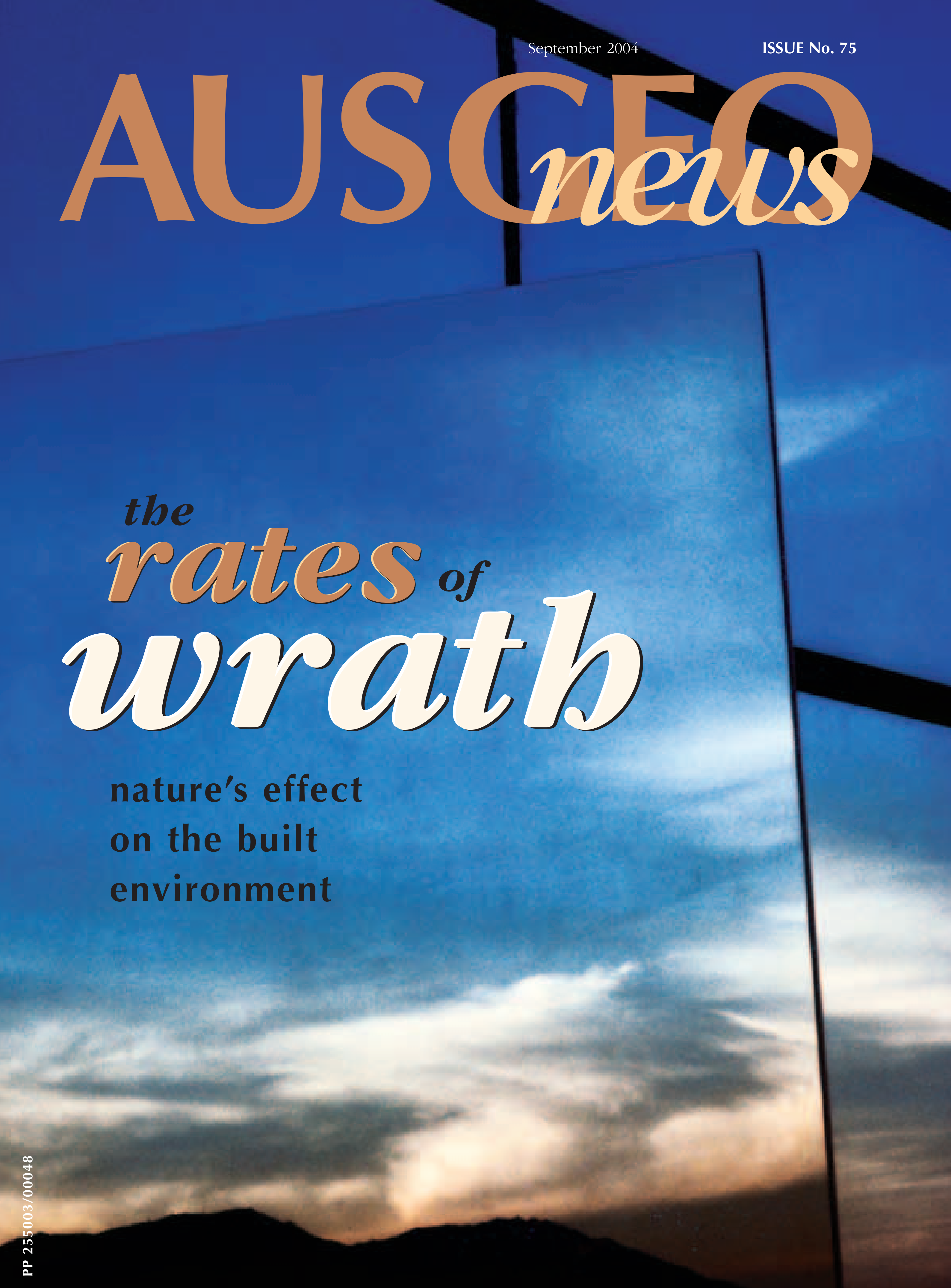
September 2004 ISSUE No. 75

AUSGEO *news*



the rates of wrath

nature's effect on the built environment

PP 255003/00048

Also: *Riddle of the shifting sands, oil province hunt begins, seep detection results promising...*

AUSGEO News
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Australian Government
Geoscience Australia

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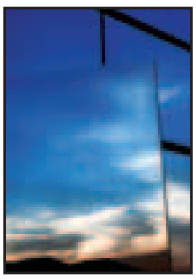

Nature, although beautiful, can unexpectedly change and wreak havoc on the built environment. In this issue we reflect on how Australia is preparing for the potential effects of natural hazards, by considering Geoscience Australia's risk modelling and the crucial monitoring networks it has been building.

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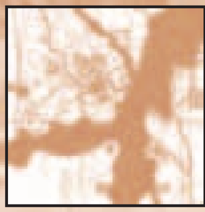
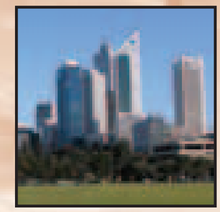




Summer approaches and with it, we hope some much-needed rain. Some of our readers overseas have been getting too much rain and with it floods that are exacting a heavy toll. We sympathise because Australian floods generally have a big price; in 1974 alone they cost Australia $2.9 billion.

Even though floods are the most costly natural disaster for us, there are many others that affect Australia. The Australian Government wants to reduce the social and economic impacts of natural disasters and has been considering how they can be better managed.

A review commissioned by the Council of Australian Governments, 'Natural Disaster Relief and Mitigation Arrangements in Australia' highlighted a desperate need to improve disaster mitigation. The review provides Geoscience Australia with a clearly defined role in helping the Australian Government to develop and implement a five-year national program of disaster risk assessments.

Geoscience Australia already had strong formal responsibilities for natural disaster monitoring and advice. Its activities include monitoring regional earthquake activity, global nuclear activity, and geomagnetic space weather, and providing alerts of geomagnetic activity that can affect communications and space craft. It also maintains the geodetic framework that supports all spatial information and associated applications in Australia and its offshore territories.

It was logical therefore to establish a new Geohazards Division that not only builds on this important work, but uses its know-how and tools to identify and apply innovative research to such national issues as security and critical infrastructure protection. This is an exciting direction for the organisation.

The Geohazards Division develops risk-assessment models and tools, and databases of the built environment, critical infrastructure and lifelines. The division is at the forefront in preparing advanced visualisation techniques to explore the data and models. It constantly highlights the crucial and expanding application of spatial information to broader and previously unimagined social, economic, environmental and security issues.

Information about some of these activities is published in this issue of *AusGeo News*.

The reform of natural hazard management in Australia presents significant challenges. It is a complex issue that requires a focused and strategic approach from all levels of government.

Geoscience Australia looks forward to working with other contributors in this initiative to develop a truly significant and worthwhile outcome that will ensure we better understand the relationship between our Earth and the built environment.

Comment

Neil Williams

NEIL WILLIAMS
CEO Geoscience Australia

Small threat, but WARNING SOUNDED for *tsunami research*

Mention 'tsunami' and fear washes through coastal settlements in many southern Pacific islands. Australia rarely thinks about tsunamis, yet it has an enormous mainland coastline that is rapidly being populated.

There is an international tsunami warning system for the Pacific Ocean, but none for the Indian Ocean. How vulnerable is Australia to the risk of tsunami, and are we leaving our western coastal communities exposed?

Geoscience Australia has been modelling open-ocean propagation of earthquake-related tsunamis that may affect our western coastline.

Tsunami is a Japanese term that means 'harbour wave'. It is used worldwide to describe a large sea wave generated by sea-floor disturbance. Some spectacular tsunamis such as the 1883 Krakatoa and 1998 Aitape tsunamis were generated by sea-floor disturbances associated with volcanic eruptions or landslides. Subduction zone earthquakes, though, are the most common source of destructive tsunamis.

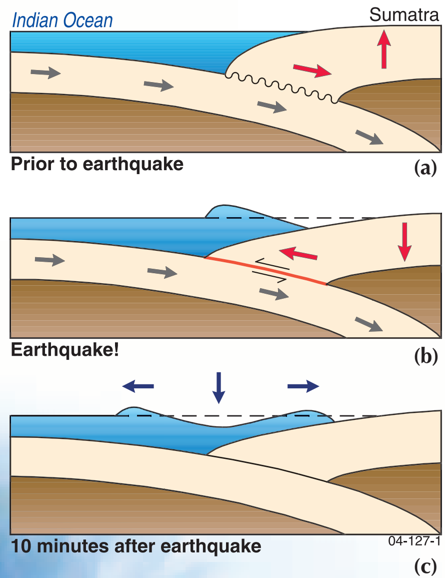


Figure 1. Subduction zone earthquakes are the most common source of destructive tsunamis. They are generated when **(a)** the lower subducting plate drags against the upper plate, causing flexure; **(b)** stress on the plate boundary causes the upper plate to rebound to its initial, un-flexed position, displacing the sea surface; **(c)** the displaced sea surface propagates outward as a tsunami.

The red arrows in **(a)** and **(b)** indicate the direction in which the upper plate is deformed due to drag and release of the lower plate.

Plate convergence

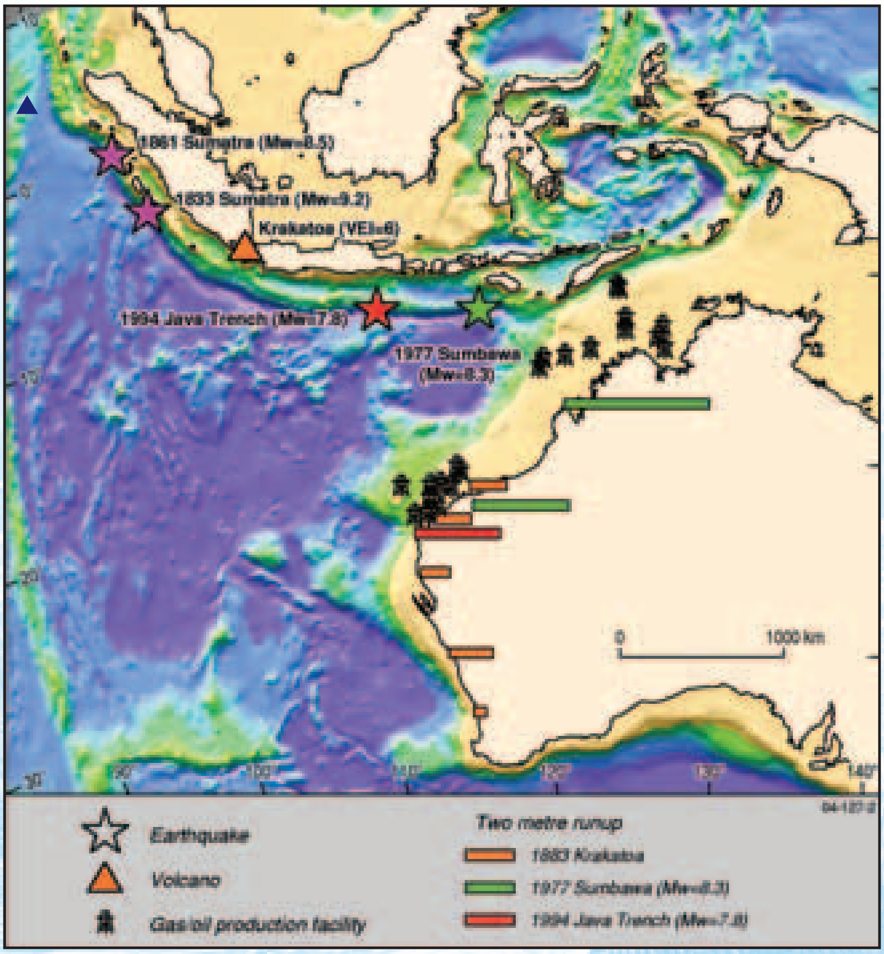
A subduction zone is where two of the Earth's rigid tectonic plates are converging towards one another; and one plate, usually composed of heavier oceanic material, dives beneath the other generally lighter plate of continental material (figure 1). At the boundary where these plates rub past each other, the lower plate drags upon the upper, flexing it slightly downward (figure 1a). When the flexing increases to the point where the stress on the plate boundary exceeds the frictional strength of the interplate contact, the upper plate rebounds to its initial, un-flexed position. This causes sea-floor displacement, which happens so quickly that it is initially reflected on the ocean's surface (figure 1b). This disturbance to the sea surface propagates outward as a tsunami (figure 1c).

In the deep ocean this wave travels at speeds of 300–500 kilometres/hour and may be only a few tens of centimetres to a metre or so in height. As it approaches shallow water, the wave speed slows dramatically and the height may increase to 10 metres or more.

Australian region

The Pacific Tsunami Warning Centre was established because several earthquake zones around the Pacific Rim generate earthquakes so massive that the associated tsunamis can affect the entire Pacific basin. Even the 1960 Chilean earthquake caused a one-metre high tsunami in Sydney. Australia, though, is not thought to be at high risk from tsunamis because most accounts relate to trans-Pacific tsunamis such as the Chilean event.

The most direct threat to Australia is to the north-west off Indonesia, where the Australian plate subducts beneath the Eurasian plate. This subduction zone is called the Sunda Arc.



Earthquakes off Java have caused large tsunamis which reached heights of four to six metres on Australia's north-west coast (the 1994 Java and 1977 Sumbawa earthquakes, respectively, see figure 2). These events caused little damage in Australia and no lives were lost. But population increases in north-western Australia and the substantial investment in oil and gas infrastructure along the Northwest Shelf (figure 2) suggest that the potential risk of tsunami merits further consideration.

Western Australia's economy would feel the impact if a tsunami affected Northwest Shelf oil and gas production.

Sunda Arc

There are two distinct zones for earthquake activity in the Sunda Arc. The 1977 and 1994 events mentioned above occurred in the eastern part of the arc, where relatively old (approximately 100 million years) oceanic lithosphere subducts offshore Java. Very few of the classical subduction zone earthquakes illustrated in figure 1 occur in this part of the arc—1994 being the only confirmed event of this type. The largest earthquake-generated tsunamis in the eastern Sunda Arc are actually normal faulting events in the Australian plate, in the 'outer rise' where the subducting plate bends prior to diving beneath Indonesia.

Figure 2. Tsunami-generated events off West Australia are colour-coded to match run-up observations. Mw is a logarithmic measure of earthquake size, similar to the Richter scale. VEI is the Volcanic Explosivity Index; Krakatoa with a score of six is one of the largest in recorded history. There are no recorded observations in Australia of the tsunami events of 1833 and 1861. Important areas of oil and gas production along the Northwest Shelf are shown.

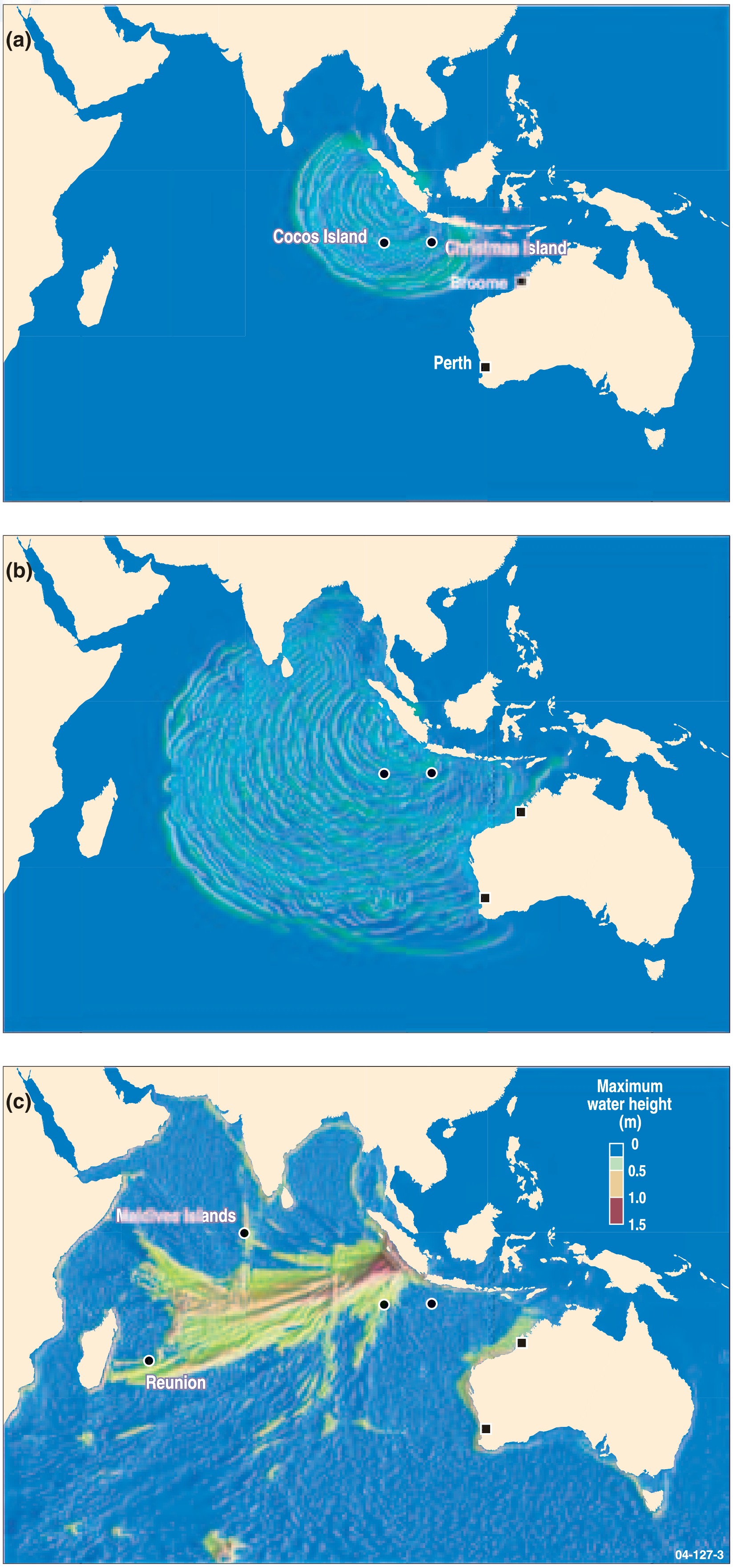


Figure 3. Results of numerical modelling of the open-ocean propagation of the tsunami associated with the 1833 Sumatra earthquake: **(a)** illustrates the tsunami's propagation in the Indian Ocean after two hours, and **(b)** after five hours; **(c)** shows the distribution of maximum tsunami wave height throughout the Indian Ocean.

Farther to the north-west in the Sunda Arc, relatively young (40 million years) oceanic lithosphere subducts offshore Sumatra. The subduction of such young oceanic lithosphere in the Pacific Ocean is associated with most of the massive earthquakes that generate the huge tsunamis that pose a threat to the entire Pacific basin. Although there are no Australian observations on record of tsunamis excited by earthquakes off Sumatra, great thrust earthquakes occurred there in historic times. The most recent occurred in 1833 before widespread European settlement in Western Australia.

The moment magnitude of the earthquake in 1833 is estimated to be 8.7–8.8, and 8.3–8.5 for the one in 1861.[1] However, the magnitude of the 1833 earthquake may have been as high as 9.2 based on a recent study that used the growth ring record of coral micro-atolls to estimate the uplift.[2] This massive earthquake would probably have affected the entire Indian Ocean basin, and the whole Western Australian coastline.

Tsunami modelling

Geoscience Australia has been modelling the open-ocean propagation of the tsunami associated with the 1833 Sumatra earthquake (figure 3). This modelling is accurate only for tsunami propagation in deep water, and does not account for shoreline run-up, where the amplitude will usually increase several fold.

The numerical simulation shows that although the waves are large enough to affect the entire Indian Ocean basin, most of the tsunami energy radiates out into the Indian Ocean and not towards Australia. Even though Western Australia is spared the largest tsunami waves generated by the earthquake, open-ocean tsunami wave heights all along the western coast are 15–25 centimetres, and the run-up from these may be one metre or more.

Tsunami alert

Geoscience Australia is involved in negotiations with the Bureau of Meteorology and Emergency Management Australia to establish an Australian Tsunami Alert Service.

One well-established method to warn the public about impending tsunamis is to rapidly locate and estimate the size of earthquakes which occur in a region, and estimate whether the detected event has the potential to produce a tsunami. However, the size of tsunamis often cannot be estimated with complete confidence based on earthquake data, because some of the details of the faulting mechanism are not easily resolved using seismic data alone.

Direct observations of the tsunami are necessary to establish with confidence whether or not a large tsunami has been excited by an earthquake or other event. This information is available from tide gauges.

In the Australian region, tide gauges on Cocos Island and Christmas Island will provide an early, direct indication of whether a tsunami has been excited off the Indonesian coast (figure 4). Tide gauges on these islands will record the tsunami just 15 and 40 minutes, respectively, after an earthquake. This could provide a tsunami warning three to four hours before it has an impact on the Australian coast (figure 4).

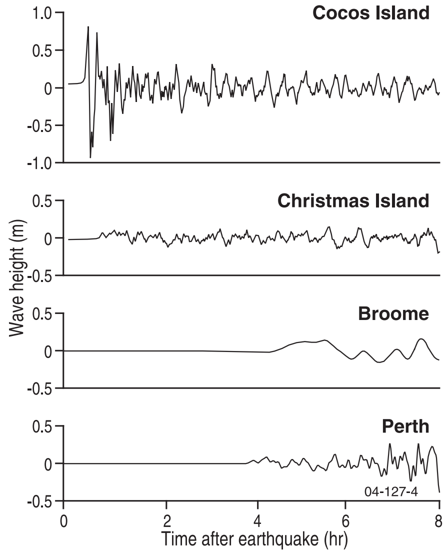


Figure 4. Waveforms computed at hypothetical tide gauges in deep water off Christmas Island, Cocos Island, Broome and Perth. The tsunami's early arrival at the two islands may provide a basis for warning more distant areas. The tsunami reaches Broome at almost the same time as that travelling a much longer path to Perth, due to the shallow ocean between Indonesia and north-west Australia.

Research needs

The tsunami hazard for Australia is probably highest along the north-west coast. But the tsunami hazard along the coast near Perth may be higher than historical experience suggests because there were very few settlers in Western Australia prior to 1840 to make observations.

Historical accounts of tsunamis in the region need to be collated. Although Australian accounts of the massive 1833 earthquake are lacking, there are many Indonesian ones, and there should be evidence in historical documents from elsewhere in the Indian Ocean. Further research into tsunami hazard for the Western Australian coast should also include a systematic study that distinguishes between tsunami and storm deposits.[3]

More accurate tsunami run-up calculations are also needed, to identify places along the coast where tsunami energy may be focused (this would also be useful to narrow down the search for tsunami deposits). Finally, a warning capability should be established, using tide gauges on Cocos Island and Christmas Island to provide several hours' advance warning of a tsunami generated off Sumatra.

Image courtesy of National Information Service for Earthquake Engineering, University of California, Berkeley. Engraving by Edouard Riou, 1833-1900

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1. Newcomb KR & McCann WR. 1987. Seismic history and seismotectonics of the Sunda Arc. Journal of Geophysical Research; 92:421–439.
2. Zachariasen M, Sieh K, Taylor FW, Edwards RL & Hantoro WS. 1999. Submergence and uplift associated with the giant 1833 Sumatran subduction earthquake: Evidence from coral micro-atolls. Journal of Geophysical Research; 104:895–919.
3. Nott J & Bryant E. Extreme marine inundations (Tsunamis?) of coastal Western Australia. Geology Journal; 11:691–706.

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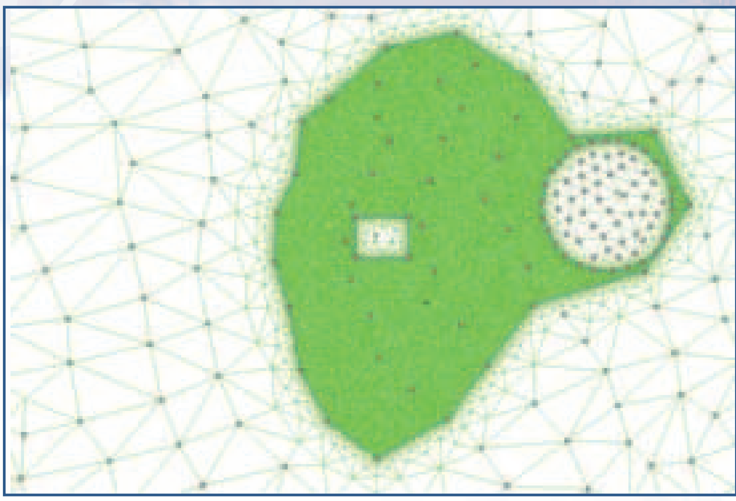
Water flow software, open to all

Geoscience Australia's Risk Research Group is developing open-source software that simulates the physics of water flow in rivers, estuaries and along a coastline. The software will provide decision makers with a tool capable of simulating hazard scenarios that cannot otherwise be studied feasibly.

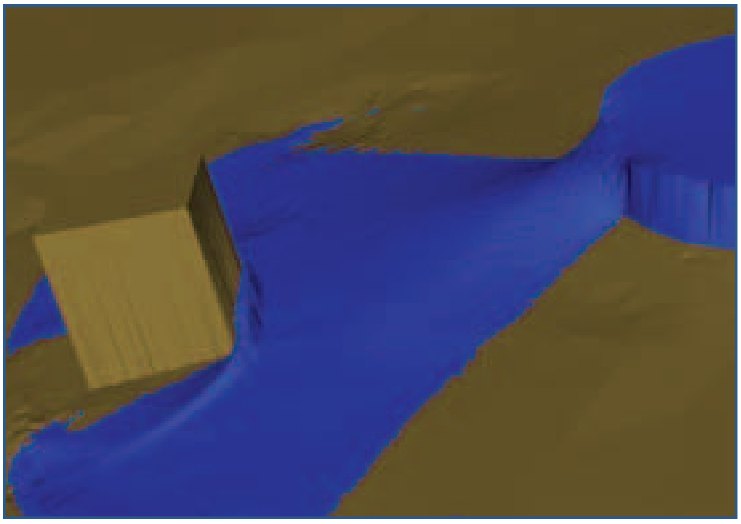


▲ **Figure 1.** An example of a geometry generated by Pmesh

Initially, the software is being used to simulate the impact of storm surges along the Australian coastline. This particular model is due for release in 2005.

Eventually the software will be used to model other hazards like floods. It will also be applicable in situations such as studying how a proposed rock and concrete break-water would protect a boat ramp from heavy swells.

The fluid dynamics simulations are based on sophisticated mathematical and numerical techniques developed by Geoscience Australia and the Australian National University. This mathematical modelling approach is capable of simulating other phenomena including tsunamis, landslides and bomb blasts.



▲ **Figure 2.** This visualisation of a dam break is a screenshot from an animation tool developed at Geoscience Australia in collaboration with Dr Darran Edmundson from the Australian National University Supercomputing Facility.

How it works

The fluid dynamics module, called Pyvolution, is based on mathematical equations governing the behaviour of flowing water. The study area is represented by a large number of triangular cells and water depths. Speeds are tracked over time by solving the governing equation within each cell.

To set up a particular scenario the user specifies the geometry (bathymetry and topography), the initial water level, what happens at the edge of the domain (called the boundary conditions) such as the tide and any wind field that drives the water, as well as frictional resistance from various terrains. The geometry could be, for example, a digital elevation model of an estuary.

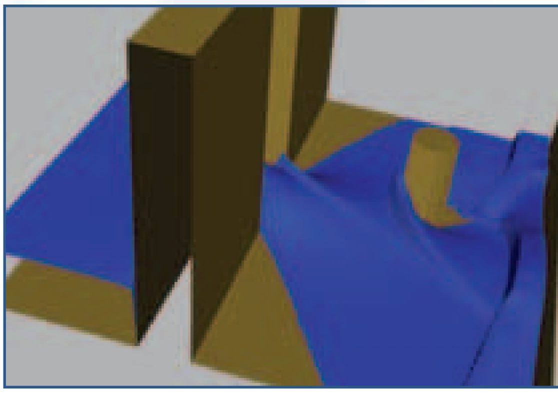
A tool called Pmesh has been developed to set up the geometry of the problem. It produces a triangular mesh of the study area and allows the user to specify the locations and types of boundary conditions that are going to be applied (figure 1).

For example, to simulate the consequences of a water supply reservoir breaking as the result of an earthquake (figure 2), the topography surrounding the reservoir is loaded into Pmesh. The reservoir wall is treated as a boundary condition. The nature of the reservoir collapse and the initial depth of water in the reservoir are specified. The generated mesh (106 185 triangular cells in this example) is passed to Pyvolution, which simulates the motion of the water as it moves from cell to cell. The water gushes out of the breach, and driven by gravity finds its natural path downhill except where it is diverted by an obstacle such as a simulated building.

Module capabilities

Pyvolution can model the process of wetting and drying as water enters and leaves an area. This means that it is suitable for simulating water flow onto a beach or dry land and around structures such as buildings. It is also capable of capturing surges, commonly referred to as shocks by mathematicians (figure 3).

Think, for example, of water from a tap splashing into a sink. There will typically be a flat area of water with very shallow depths and high speeds surrounded by a thicker layer of calmer water. The transition between the regions forms a shock. Shocks will be typically encountered in areas of rapid changes in speed or bathymetry.



▲ **Figure 3.** Some complex patterns are captured in this simulation of water flowing through a breach in a levee, down onto a flat surface and past an obstacle. These include a shock where water reflected off the wall (right-hand side) meets the main flow. Other physical features simulated are the standing waves and interference patterns.

Software used

Most components are written in Python which is an object-oriented programming language. Software written in Python can be produced quickly, and readily adapted to changing requirements throughout its lifetime. Python is an example of open-source software (OSS): it is freely available, developed and supported by many organisations, and all source code is available for scrutiny and modifications.

The animation tool used with the storm surge model is based on OpenSceneGraph which is another OSS component allowing high-level interaction.

Geoscience Australia's storm surge model will be released as OSS next year to encourage risk researchers to use, validate and contribute to the model's development.

For more details phone Ole Nielsen on +61 2 6249 9048 or e-mail ole.nielsen@ga.gov.au

OPEN-SOURCE software

Open-source software (OSS) can be freely used, redistributed, analysed and modified by anyone. These rights are backed by legally binding licenses such as the General Public License.[1] It is usually developed in projects involving several individuals, organisations and even countries. OSS products are generally not owned by any single company and therefore cannot be purchased on the market.[2,3]

The main advantages of OSS are:

- The costs of using existing OSS components are almost zero, and tools can be assessed and selected quickly.
- The software code is open and readable by anyone, and those with programming skills can add features. This allows organisations to leverage a large amount of software and use it for their own purposes.
- People improve, modify or customise programs and give them back to the open-source community so others benefit from their work. There is no notion of public liability with open source. Hence, releasing open-source code is low risk.

Prominent examples of OSS are the Linux operating system, the Apache web server (which serves on about 65% of all web servers worldwide), MapServer (which is a development environment for building spatially enabled internet applications), and MySQL (a widely used relational database).

Organisations that are using and contributing to OSS include IBM, Sun, Hewlett Packard, Apple, Novell, Lawrence Livermore National Laboratories, Google, Yahoo, and Industrial Light and Magic.

Governments have begun to use OSS to share software they create and to reduce costs. For example, the city of Munich recently switched all 14 000 of its computers to the Linux operating system. In Australia, the Australian Capital Territory Legislative Assembly passed a bill in December 2003, encouraging the use of OSS.[4]

For government, OSS offers a reliable and affordable avenue as it has for the storm surge modelling software developed by Geoscience Australia's Risk Research Group.

Further reading

1. GPL OSS license: www.gnu.org/philosophy/enforcing-gpl.html
2. Open source initiative: www.opensource.org
3. Open source industry Australia: www.osia.net.au/
4. Government Procurement Guideline Act, clause 6A, passed on 11 December 2003: www.legislation.act.gov.au/

Indirect costs of HAZARDS explored through LOSS MODELS

Between 1967 and 1999, the economic cost of natural disasters to Australia was estimated at $1.14 billion per year in 1999 dollars.[1] These estimates include the cost of casualties but exclude disruption costs to the wider community.

Geoscience Australia is developing economic loss models that estimate the potential losses to Australian society from natural hazards. Early models were direct-loss models that measured building and contents damage. These are being further developed to incorporate losses at a regional, state and national level that are beyond the initial impact of the event.

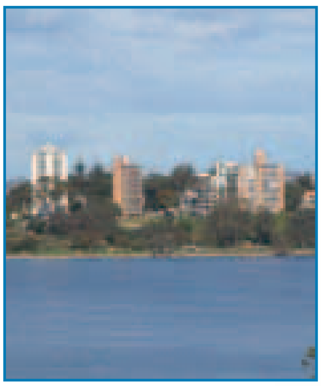
Geoscience Australia and the Centre of Policy Studies at Monash University are developing a modelling framework to estimate the indirect economic impacts of natural hazard events. The research draws on Monash University's Computable General Equilibrium (CGE) model, which can distinguish 166 industries and 58 regions in Australia.

The model accounts for hazard-induced supply shortages and reductions in the demand for goods and services. The recovery path of key economic variables such as output, employment, consumption and building and content stocks are compared to their forecast value (i.e. the expected value assuming the natural hazard event did not occur). This provides vital information on a specific region's ability to recover from a natural hazard event.

The CGE model is a key component of Geoscience Australia's national risk assessment framework. The detailed regional breakdown in the model allows the economic impact of natural hazards to be compared across regions and aggregated at a state and national level. The model can be used to simulate different levels of damage for a range of natural hazards (earthquake, flood, tropical cyclone, severe wind and landslide), for regional comparisons of economic vulnerability.

Geoscience Australia's framework will be a valuable tool for examining the policy implications of different levels of disaster relief and investment during recovery periods.

▲ **Figure 1.** Earthquake source zones in south-west Western Australia showing the epicentre of the earthquake used for the Perth case study.



Perth case study

The framework is being applied to the Perth metropolitan area to estimate the potential indirect economic impacts of a range of hypothetical catastrophic earthquakes. The study uses the direct-loss model to simulate the damage to buildings and their contents from earthquake scenarios in south-west Western Australia. These direct estimates of damage are inputs to the indirect economic model framework.

The first earthquake scenario is an earthquake of moment magnitude six located in the Perth metropolitan area (figure 1). The total damage to Perth's building and contents is almost $9.8 billion. Residential buildings represent about 70 per cent of the total building stock, so homes account for almost $5.5 billion of the total damage. Damage to buildings and contents associated with trade, manufacturing and the delivery of services account for the remainder of the total damage.

The consequences of an earthquake of this magnitude on Perth's economy are severe, particularly without government assistance. Preliminary results (figure 2) indicate that the estimated initial impact on employment is a fall of three per cent below forecast levels. After 10 years, employment is still expected to remain below forecast levels. Building and content stocks recover slowly, and after 10 years are expected to be five per cent below forecast levels.

Income earned in Perth (indicated by Real Gross Regional Product or GRP) is estimated to initially fall four per cent below forecast levels and is expected to remain about two per cent below baseline values after 10 years. This reflects the lower levels of building and content stock producing income. The loss in national welfare which reflects losses in consumption flows and future income-earning capacity is $6.4 billion.

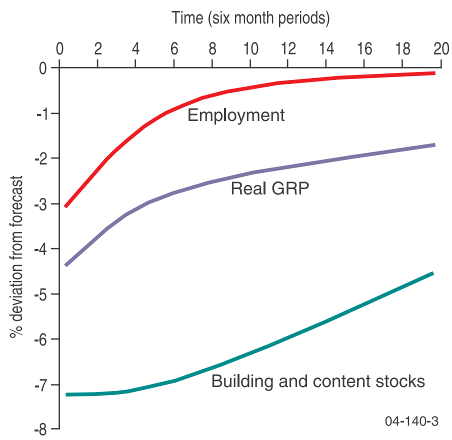


Figure 2. Employment, income and capital stocks in the Perth region would be severely affected by a magnitude six earthquake in the metropolitan area. It would take years to recover from the event.

Future work

The indirect economic loss model will be used to ascribe a uniform fall in building and content stocks to all regions in Australia. The work will identify regions that are slower to recover and have greater down-stream losses. It will provide policy makers with tools to assess economic vulnerability. The initial work should be completed by October.

The indirect economic loss model will also be applied in measuring the economic impact of lifeline failures such as power and water supply. The outputs of this component are expected in June 2005.

Reference

1. Bureau of Transport Economics. 2001. Economic costs of natural disasters in Australia. Canberra: Bureau of Transport Economics, report 103.

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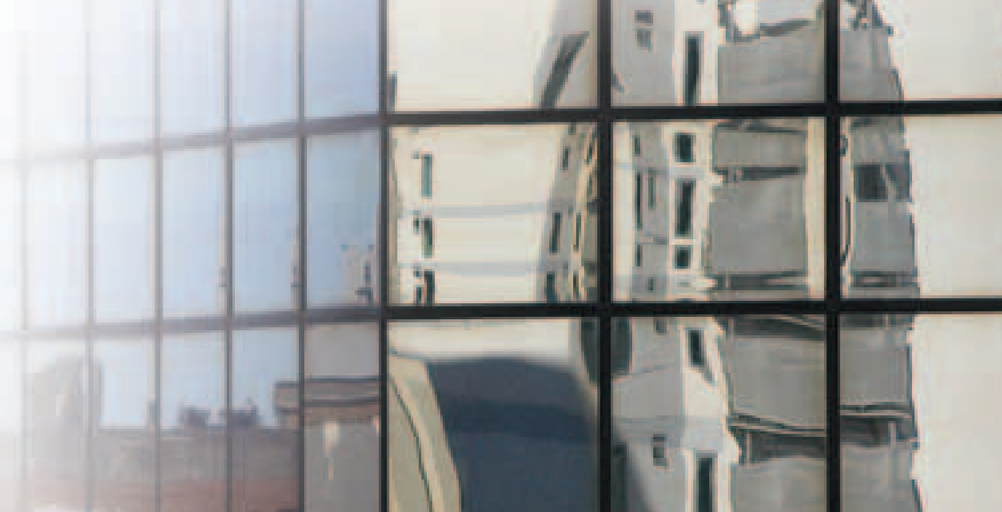
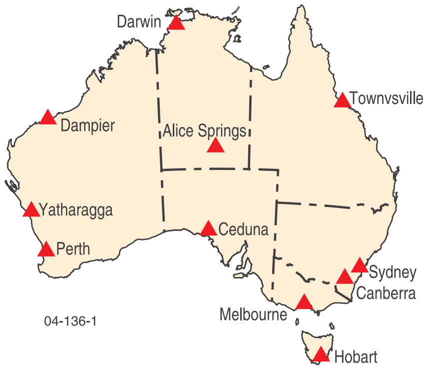


NETWORK SET FOR *precision gravity*

To take independent measurements, and more accurately determine vertical movement of the Earth's crust, Geoscience Australia has been collocating gravity with space geodetic measurement systems at various sites around Australia.



▲ **Figure 1.** Absolute gravity was observed at 11 sites on the Australian mainland and Tasmania in a survey conducted by Micro-g Solutions for Geoscience Australia in June 2003.

A combination of measurements is used to generate reference frames for scientific studies and mapping. Scientific studies into changes in Earth's systems caused by melting polar ice sheets, earthquakes, ground-surface subsidence, sea-level changes, and tides require an accurate measurement of gravity.

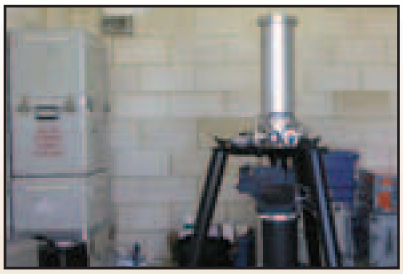
Gravity variation

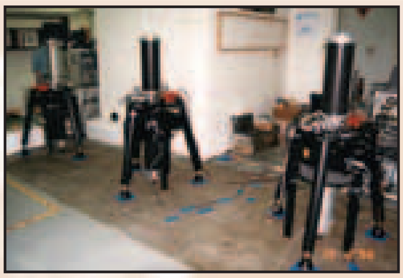
Near the Earth's surface an object falls with an acceleration of about 9.8 metres per second squared due to the force of gravity. But this value of acceleration varies with location, height and time.

The Moon's daily cycle is the largest influence on the time variation; its orbit distorts Earth's crust by causing it to bulge with the Moon's movement.

The unit of measure commonly used for the acceleration due to gravity is the Gal. One Gal equals an acceleration of one centimetre per second squared. Earth's normal gravity is 981 Gal.

The acceleration due to gravity can be measured with an accuracy of about two microGals with a precision absolute gravimeter. Two microGals equate to a height change of about six millimetres at the Earth's surface.





Measuring absolute gravity

The FG5 is the only precision absolute gravimeter currently in commercial production. It operates by dropping a test mass inside a vacuum chamber. The descent of the free-falling test mass is monitored accurately using a laser interferometer. One laser beam is reflected from a corner cube on the falling test mass and the second laser beam is reflected from a reference reflector. An active-spring system supports the reference reflector in seismic-isolation to improve noise performance.

The precision iodine stabilised laser system and a high-quality rubidium clock provide a very accurate distance measurement system. The computed accelerations are 'absolute' because they are based on primary standards of measurement for length and time.

A single software package drives the FG5 during data acquisition and processing. The software includes standard modelled corrections which are applied to all gravity measurements. These corrections include a change in gravity due to a variation in local barometric pressure, polar motion, earth tides, ocean tides, and vertical gravity gradient (the value of change in gravity from the instrument measurement point to the ground).

The final result from data processing is a mean value for the acceleration due to gravity at the observed site.

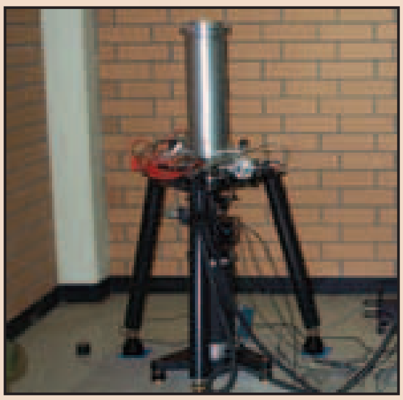


Table 1. Collocated measurement techniques at or near sites observed during the June 2003 absolute gravity survey

Survey site	GPS	GLONASS	SLR	DORIS	VLBI	Seaframe tide gauge	Existing FG5 sites	AFGN
Sydney								X
Canberra	X	X	X	X	X		X	
Melbourne	X							
Ceduna	X					X		
Alice Springs	X							X
Perth								X
Yatharagga	X	X	X	X			X	
Dampier	X							
Darwin	X	X				X		X
Townsville	X					X	X	
Hobart	X				X		X	

AFGN Australian Fundamental Gravity Network
GPS Global Positioning System
VLBI Very Long Baseline Interferometry
SLR Satellite Laser Ranging
GLONASS Global Navigation Satellite System
DORIS Doppler Orbitography and Radiopositioning Integrated by Satellite

Absolute gravity facilities

An absolute gravity observation facility that could run three absolute gravimeters concurrently was established at Mount Stromlo in the Australian Capital Territory in 1996. A year later, the Australian National University installed a superconducting gravimeter in the vicinity. Since 1996, several high-accuracy absolute gravimeters have occupied the site.

The Mount Stromlo absolute gravity facility was damaged by bushfires in January 2003 and will be re-established at Geoscience Australia's adjacent Satellite Laser Ranging facility later this year.

Absolute gravity survey

To establish a network of high-accuracy absolute gravity values, a survey was conducted at 11 sites on the Australian mainland and Tasmania for Geoscience Australia during June 2003 (figure 1). These sites were selected because they were at or near other measurement facilities (see table 1).

The survey was completed in 16 days by acquiring measurements overnight at the observation site, and flying between sites during daytime. The data acquisition specifications for the FG5 at each site were:

- a minimum data acquisition time of six hours
- measurement precision to be less than 1.5 microGals
- total uncertainty to be less than 3 microGals
- 12 or more complete 100 drop sets.

Absolute gravimeters do not need calibration or drift correction, but two sets of repeat measurements were made to check the FG5. The repeat measurement taken at Tidbinbilla, near Canberra, before and after the survey differed by 0.6 microGal. The other set of measurements taken at an observatory in Boulder, Colorado before and after the survey differed by 1.2 microGal, which is about the level of the environmental gravity noise at the observatory.

The measurement precision at all sites is below one microGal and in many cases below 0.5 microGal. The absolute uncertainty for all sites (including environmental and instrument errors, but not the gravity gradient) is about two microGals.

The gravity gradient was observed at each site by measuring gravity at two different heights about 1.2 metres apart. Except for the Townsville site, there are no anomalous signals in the results. The Townsville site is near the shoreline and so the anomaly (tidal amplitude ~5.2 microGals) may be due to ocean tides.

Network usefulness

The survey covered an impressive 15 000 kilometre linear distance with stations approximately equidistant over the entire continent. These sites will be used for future episodic measurements of gravity to develop a long-term time series as an independent measure for vertical crustal motion and sea-level change studies.

The absolute gravity sites are an important part of the Australian Fundamental Gravity Network and provide useful tie points for relative gravity surveys. The network upgrade will help improve the geoid model for Australia which is used by spaced-based positioning systems, such as GPS, to convert ellipsoidal heights in an Earth-centred reference frame to equivalent heights on the Australian Height Datum.

For more information phone Geoff Luton on +61 2 6249 9050 or e-mail geoff.luton@ga.gov.au

Continuous GPS boosts *Pacific sea-level monitoring*

Climate change is blamed for rising sea levels and frequent flooding and storms in many South Pacific nations, and for the long-term drought over southern Australia.

The Australian Government established the AusAID-funded South Pacific Sea Level and Climate Monitoring Project in the early 1990s to help governments and communities better manage the impacts of environment and climate changes in the Pacific region.

Geoscience Australia has been rolling out the project's third, five-year phase by establishing a continuous permanent GPS network (CGPS) at tide gauges around the southern Pacific.

Accurate short- and long-term records of sea level are usually collected by tide gauges, but these can be affected by vertical motion of the land. To accurately monitor vertical crustal motion, continuous GPS data are needed—and generally for more than five years for reliable velocity estimates.

South Pacific network

From July 2001, Geoscience Australia began setting up a CGPS network around the South Pacific, and has since been processing and analysing data as they come on-line.

The CGPS infrastructure comprises a network of permanent, continuously operating geodetic-quality GPS satellite receivers (and associated equipment), communication systems, and a high-level computation facility. To date, 10 of 12 CGPS stations are established. These CGPS stations are combined with existing monitoring stations in Australia and its offshore territories to form the regional scientific monitoring network (figure 1).

Figure 1. CGPS stations in the South Pacific and Australian region: a triangle denotes a tide gauge CGPS station in the South Pacific sea-level monitoring network, and a circle denotes a tide gauge CGPS station in the Australian region

The network is also attached to 13 core stations in the global International GPS Service (IGS) network and to some other tide-gauge stations in the region to enhance the network density and improve the accuracy of the data processing.

The network is used to discriminate sea-level change signals from vertical crustal motion. Geoscience Australia has developed software to extract vertical crustal motion signals from various other geophysical signals. Vertical crustal motion velocities and their uncertainties from some stations of the network are listed in table 1. For example, in Townsville, if sea-level rise estimated from tide gauge records is 1.0mm/yr, the true sea-level rise should be 2.1mm/yr due to 1.1mm/yr rise of the tide gauge at Townsville.

The estimated velocity for Australian and Antarctic CGPS stations is much more reliable than South Pacific stations because they have been operating for a longer time.

Table 1. Vertical crustal motion velocity and uncertainty

CGPS/TIDE GAUGE STATION	LENGTH OF TIME SERIES	VERTICAL VELOCITY (MM/YR)	UNCERTAINTY (± MM/YR)
Samoa–South Pacific	07/2001–03/2004	-2.8	1.0
Cook Islands–South Pacific	09/2001–03/2004	-2.4	1.0
Townsville–Australia	01/1995–03/2004	1.1	0.2
Cocos Island–Australia	01/1995–03/2004	-0.6	0.2
Hillary–Australia	06/1997–03/2004	-5.1	0.3
Burnie–Australia	11/1999–03/2004	4.8	0.3
Casey–Antarctica	01/1995–03/2004	2.8	0.2
Davis–Antarctica	01/1995–03/2004	0.7	0.2
Mawson–Antarctica	01/1995–03/2004	0.8	0.2

International resource

The daily observation files collected by GPS receivers at each station are archived by Geoscience Australia and distributed to local, regional and international communities through Geoscience Australia's web site.

Geoscience Australia is a Type 1 global analysis centre for the IGS GPS Tide Gauge Benchmark Project (http://op.gfz-potsdam.de/tiga), and so its GPS solutions are submitted to the IGS for further analysis. Geoscience Australia has provided 468 weekly solutions (from January 1995 to March 2004) from the CGPS network covering the South Pacific, Australia and Antarctica. The data and the high-quality analysis make an important international contribution towards determining and understanding the impacts of global climate change and sea-level rise.

The network is also useful in other research such as studies of relative crustal motion and boundary deformation among Pacific, Australian and Antarctic plates, and the likely deformation within these plates. Radio communication and navigation can benefit from ionospheric parameters derived from the CGPS data processing and the tropospheric parameters can be used to refine weather forecasts and climate-change models.

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coordinate asia-pacific

Campaign builds consistent coordinate framework for ASIA-PACIFIC region

Australia can build a road, railway line or pipeline starting at two ends of the country knowing that they will meet in the middle. Much of the developing Asia-Pacific region is not so fortunate.

Australia has a nationally consistent coordinate framework, the Geocentric Datum of Australia 1994 or GDA94 that allows all spatial measurements to be accurately related to each other.

The term 'geocentric' indicates that the coordinate system origin is the centre of the Earth. Geocentric datums are compatible with satellite navigation systems such as the Global Positioning System (GPS).

Many countries in the Asia-Pacific region don't have geocentric datums. They refer to different systems, including astronomic observations. Others use multiple coordinate datums in their country, and those that share land borders generally don't use the same datum (like Australian states until the first national datum in 1967). Many Pacific Island countries have numerous islands unconnected to a single national datum.

Consequently it can be hard to answer simple questions such as where is my property; where are forestry and water resources, or national boundaries; and how do I overlay data sets. Asset and resource management becomes difficult, inefficient and incompatible with modern spatial tools such as GPS and satellite remote sensing.

Linking the region

The United Nations Regional Cartographic Conference for Asia and the Pacific in Beijing in May 1994 resolved to establish a Permanent Committee for GIS infrastructure comprising national surveying and mapping agencies. Over the next three years, working groups were established and a project to maintain permanent geodetic observation sites and build a homogeneous Spatial Data Infrastructure for the Asia-Pacific region was approved by the UN.

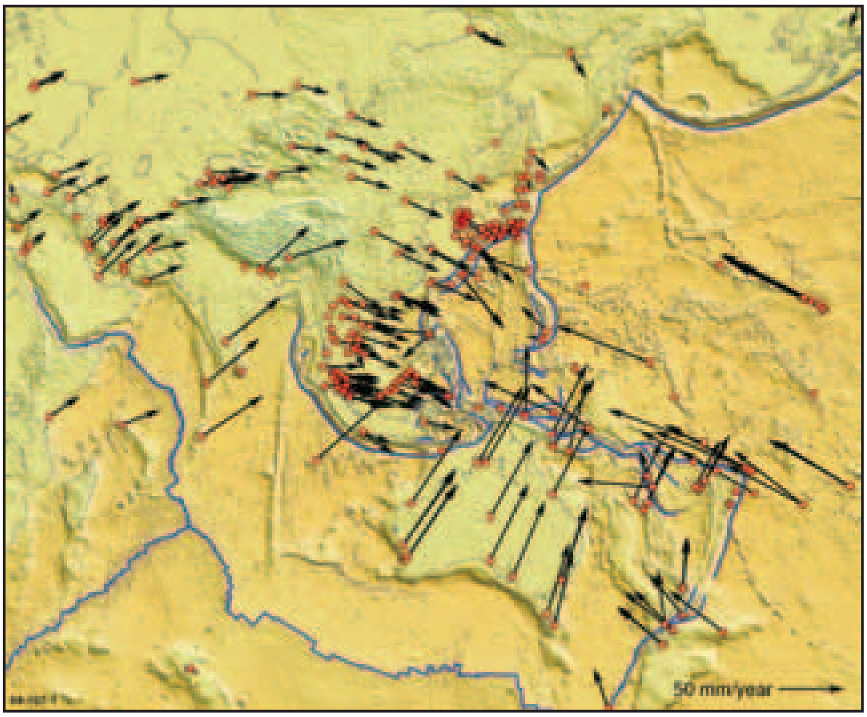


Figure 1. The Asia-Pacific Regional Geodetic Project GPS network with recognised plate boundaries shown in blue. All GPS sites used in computation are marked as red dots. Where sites have been observed in two or more campaigns a tectonic (displacement) vector has been computed and is shown as a black vector.

The project was also endorsed by the Asia-Pacific Space Geodynamics Program, and by the regional Very Long Baseline Interferometry network of the Asia-Pacific Telescope.

With this mandate, a multi-technique geodetic campaign has been observed each year since 1997 throughout the Asia-Pacific region. The Asia-Pacific Regional Geodetic Network (APRGN) generally incorporates at least a week of GPS observations, a month of Satellite Laser Ranging (SLR) observations to geodetic satellites (Lageos1, Lageos2, Stella, Starlette, Ajisai, Etalon1 and Etalon2), and a month of Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) observations. One or two 24-hour Very Long Baseline Interferometry observation sessions are also observed during the campaign.

GPS observations are coordinated by Geoscience Australia and acquired by national agencies throughout the region (table 1). Campaign data are analysed by Geoscience Australia, which has produced a multi-year, multi-technique computation of precise geodetic coordinates and velocities for the region.

Project plans

More than 300 stations have been positioned at the millimetre level throughout the Asia-Pacific region (figure 1)—an area which extends from Iran in the west, to Russia in the north, Cook Islands in the east, and Australia and New Zealand in the south. This has been possible through cooperation and mutual support among the region's space geodesy organisations.

The project will provide an accurate regional geodetic reference frame integrating all space geodetic techniques, and also assess existing data processing and analysis capabilities (for GPS, SLR, DORIS, VLBI). Where techniques are co-located it will verify the terrestrial connections.

Table 1. The participating countries and agencies in the Asia-Pacific Regional Geodetic Project

Country	Agency/Organisation
Australia	Geoscience Australia; Flinders University; Australian National University
Brunei	Survey Department
Cambodia	Ministry of Land Management, Urban Planning & Construction
China	Institute of Modern Geodesy; National Geomatics Centre of China; Changchun Artificial Satellite Observatory; Shanghai Astronomical Observatory
Cook Islands	Ministry of Works
Fiji	Department of Lands & Surveys
Germany	Geodynamics of South & South-east Asia Project
Hawaii	University of Hawaii Pacific GPS Facility
Hong Kong	Lands Department Geodetic Survey Section
Indonesia	Geodetic Division, National Coordination Agency for Surveys & Mapping
Iran	Geodynamics Department, National Cartographic Centre
Japan	Japan Coast Guard; Geographical Survey Institute; University of Tokyo Earthquake Prediction Research Centre
Kiribati	Land Management Division, Ministry of Home Affairs & Rural Development
Laos	National Geographic Department
Macau	Cartography & Cadastre Bureau
Malaysia	Department of Survey & Mapping
Maldives	Ministry of Construction & Public Works
Mongolia	State Administration of Geodesy & Cartography
Nepal	Topographical Survey Branch, Survey Department
New Zealand	Institute of Geological & Nuclear Sciences, Land Information New Zealand
New Caledonia	Laboratoire de Geosciences, Institut de Recherche pour le Developpement
Niue	Department of Justice, Lands & Survey
Philippines	Coast & Geodetic Survey Department, National Mapping & Resource Information Agency
Papua New Guinea	National Mapping Bureau; University of Technology Department of Surveying & Land Studies
Singapore	Land Survey Department
South Korea	Geodesy Division, National Geography Institute
Samoa	Department of Lands, Survey & Environment; Defence Mapping Unit
Sri Lanka	Institute of Surveying & Mapping
Thailand	Royal Thai Survey Department
Tonga	Geodesy & Surveying Division, Ministry of Lands, Survey & Natural Resources
Tuvalu	Lands & Survey Department
United States	UCAR UNAVCO Facility
Vanuatu	Department of Land Survey
Vietnam	Vietnam Research Institute of Land Administration
International	International GPS Service (IGS)

The current focus is on acquiring a vertical datum for the region by observing GPS at sea-level tide gauges and by coordinating absolute and relative gravity observations. This work will provide an infrastructure to better assess climate and sea-level changes in the region.

For more information phone John Dawson on +61 2 6249 9028 or e-mail john.dawson@ga.gov.au

Glossary

DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite) is a highly accurate French system for determining satellite orbit and station positioning. With DORIS there are no ground receivers because the satellite is the receiver.

Global Positioning System (GPS) is a constellation of satellites designed for global navigation that the geodesy community uses to very precisely position points on the Earth's surface.

Satellite Laser Ranging (SLR) is a geodetic technique that involves bouncing laser pulses off orbiting satellites to precisely compute orbits and determine the coordinates of the SLR system.

Very Long Baseline Interferometry (VLBI) is a technique that uses two antennas to measure the different arrival times of a radio wave front emitted by a young neutron star with a strong magnetic field. VLBI is used to compute precise coordinates on the Earth's surface and to establish the relationship between Earth-based coordinate datums and a star-based coordinate system.

GPS station Phuket, Thailand, longitude 98° 18′ 12″, latitude 7° 45′ 32″, height 24.0 metres above mean sea level. This station was observed by the Royal Thai Survey Department.

GPS station Hovd, Mongolia, located at the base of the Altai mountains, longitude 91° 37′ 28″, latitude 47° 57′ 46″, height 1454.1 metres above mean sea level. This station was observed by State Administration of Geodesy and Cartography, Ministry of Infrastructure, Mongolia.

Spatial data repository crucial to *quick response*

Emergency managers need fundamental data, especially in times of crisis. The 2001 September 11 event in New York demonstrated that serious emergencies require coordinated use of inter-state and inter-agency spatial information.

Agencies responsible for emergency management are aware of how spatial analysis can assist decision making. Emergency events can be modelled, and mitigation or response strategies can be implemented and tested in the virtual world.

Over the past 10 years, Geoscience Australia has used spatial modelling and analysis to examine the risks of various natural hazards to the built environment. It has published reports for Cairns, Mackay, Gladstone, south-east Queensland and Newcastle, and next year will release one for Perth.

The GeoInsight Spatial Awareness campaign in 2002 presented case studies of spatial information use to over 900 participants in 24 workshops around Australia. These case studies demonstrated how Geographic Information Systems (GIS) can be used to quickly visualise various scenarios and interrogate numerous sources of data.

There is an acute shortage of appropriate data to support emergency management GIS. The skills and resources of the public and private sectors therefore need to be pooled, and procedures must be established to ensure effective coordination during a national crisis.

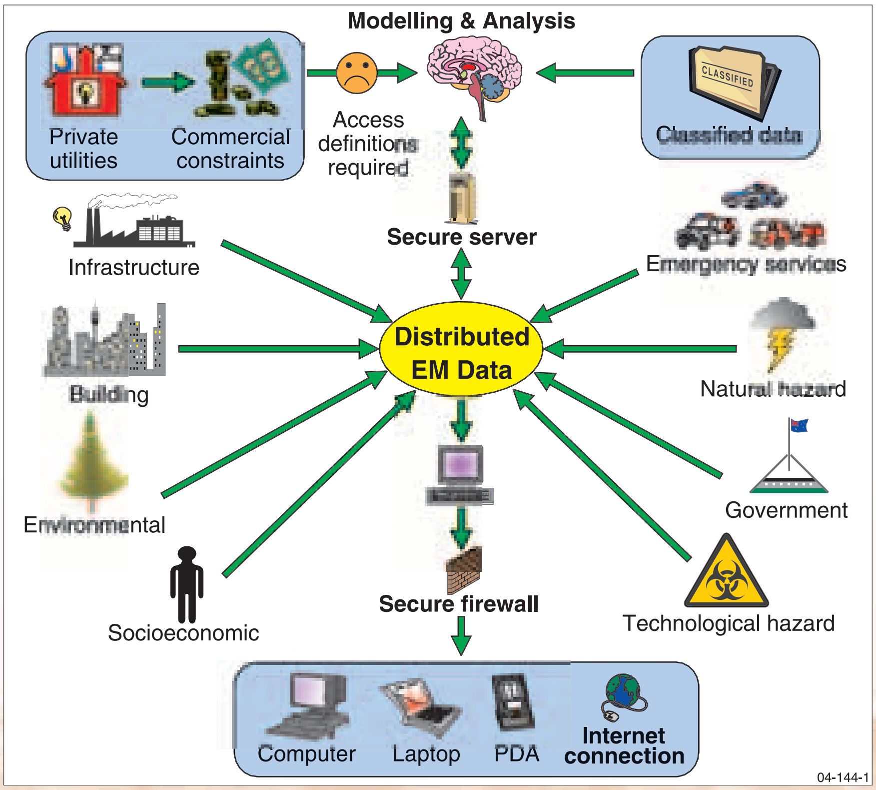


Figure 1. A conceptual model of the infrastructure required to support an emergency management spatial data library. Data grouped under themes can be accessed by emergency managers via secure web services. With stringent security, privately held critical infrastructure and classified intelligence data can be integrated with mainstream information from hosted data repositories.

Spatial data library

One way to improve data accessibility is to create a multi-agency, spatial data repository, or spatial data library, that offers unhindered access to a wide range of key datasets. This idea was proposed by ANZLIC (Australian and New Zealand Land Information Council) in 2003 to meet counter-terrorism needs.

The library would house all of Australia's relevant emergency management spatial datasets, from high-resolution satellite imagery to vectors depicting road centrelines.

Each government agency would be custodian of its spatial datasets, and update the datasets weekly or monthly to maintain the library's currency. Privacy issues attached to sensitive datasets would have to be addressed; but with care, appropriate personnel could have unrestricted access in emergencies.

Single portal

High-speed telecommunication cables and other technological advances make the concept of a nationwide data repository a reality. A virtual library could be accessed by emergency managers anywhere 24/7, through a fast and secure portal.

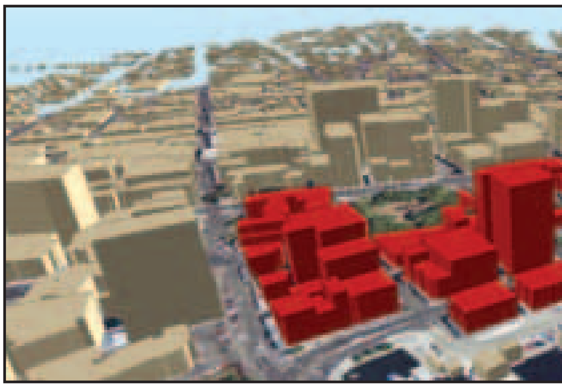
The virtual library could be coordinated by one organisation, with all tiers of government being responsible for implementing and maintaining their data. The coordinating organisation would ensure the datasets exhibit consistency (e.g. in format, scale, projection or datum, and currency) and are interoperable.

Such a structure would allow emergency managers to build in hours rather than days, a comprehensive GIS using remotely accessed data from many areas of government.

This system of distributing information through a single portal has been shown to work effectively in emergency situations at both regional and state level.

The Land Information Systems Tasmania (LIST) is a spatial library constructed, maintained and served by the Department of Primary Industries Water and Environment in Hobart. During 'Mercury04', a multi-jurisdictional counter-terrorism exercise in March this year, spatial data were extracted from LIST into a GIS to interrogate and visualise real-time data. The results from these accurate and current datasets allowed Tasmanian emergency managers to make many timely, critical decisions.

For more information phone Tony Hunter on +61 2 6249 9930 or e-mail tony.hunter@ga.gov.au



Landslide spotters needed

Geoscience Australia needs landslide spotters to report landslides that they see, hear about, or notice mentioned in electronic and print media.

The Australian Landslide Database has more than 700 entries detailing landslides and sets of landslides on the Australian mainland, Tasmania, Lord Howe Island and Norfolk Island. It includes landslides of all sizes, on natural and artificial slopes, some mine subsidence events, and a number of human-triggered 'failures'.

These 'failures' include cave-ins caused by excavation, boulders displaced during climbing, rock ledges breaking under people's weight, and vibration-triggered landslides.

A short version of the landslide database is available via Geoscience Australia's home page. In this version, locations of landslides on the Australian mainland and in Tasmania are displayed on a map. The web information includes descriptions of the landslide's location, the landslide type, date of occurrence, and a brief description of the event and its consequences.

The database is continually updated to keep it current and complete. Please help maintain the accuracy of this database by being a landslide spotter.

For more information phone Marion Leiba on +61 2 6249 9445 or Matt Hayne on +61 2 6249 9536, or e-mail landslides@ga.gov.au

Building BLAST trial

Five tonnes of hexolite

Five tonnes of hexolite high-explosive were detonated above ground during an international explosives trial in the Woomera Prohibited Area in South Australia on May 6 this year.

The blast test was an invaluable opportunity to validate the many theories and models about expected damage to buildings hit by explosives—in this case, the equivalent of six tonnes of TNT.

Test structures included industrial and residential buildings, bunker structures, general storage structures and fuel storage tanks. Isolated components subjected to the blast included blast doors, concrete panels and a number of different glazing targets.

Ranges to the targets varied from 17 to over 600 metres from ground zero (the centroid of the blast).

Woomera is one of a few places in the world that has the available space and support infrastructure for this type of blast trial.

The exercise was sponsored by the United Kingdom Ministry of Defence and managed by the Australian Department of Defence. There were also participants from the USA, Canada, Singapore, Germany, and the Netherlands, and Australian-based researchers from CSIRO and the University of Melbourne.

A number of commercial groups used the trial to assess their products' behaviour when exposed to blast loading.

Geoscience Australia was an observer because the trial results will help in its ongoing work in

Site response to *shaky ground*

Soils, sediments and weathered rock, referred to as the regolith, can modify earthquake ground-shaking, and hence influence the local earthquake hazard in a region.

Geoscience Australia is currently assessing earthquake risk in Perth, Western Australia, and a key part of the work involves developing site response models. Work to date indicates that Perth's regolith has the potential to significantly amplify earthquake ground-shaking.

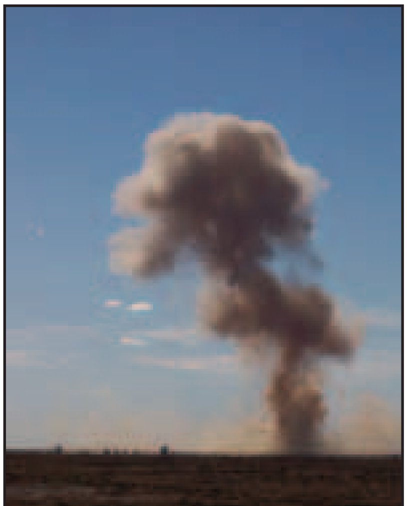
Perth's regolith has evolved through a series of depositional and erosional cycles. It comprises weathered and unweathered rock (laid down over 50 million years ago), which is buried beneath sediments that have generally been deposited over the past two million years.

Based on an analysis of records from over 2000 boreholes, the Perth region is divided into four regolith site-classes, as shown in figure 1. These classes define regions considered to have a 'comparable' response to earthquake ground-shaking.

Because Perth's regolith is complex, it is impossible to precisely delineate regions of specific materials. To account for such variability, multiple regolith profile types are being included. For models of certain site-classes (classes D & E) the ground-shaking effect involves calculating responses for 30 profiles of the dominant material (e.g. limestone) and 10 profiles of the less-common material (e.g. deep sand).

Amplification factors, which are a measure of how much the regolith will amplify ground-shaking, are calculated for each site-class based on statistically derived shear-wave velocity profiles.

The response of the regolith to earthquake ground-shaking is also influenced by the intensity of the ground motion, and the magnitude of the earthquake. Consequently,



Blast cloud from four kilometres away

Industrial buildings prior to the blast (~150 metres from ground zero)

counter-terrorism and critical infrastructure protection. A particular area of interest was the behaviour of glazed targets when subjected to blast loads.

Geoscience Australia is providing its summary of the trial in the Safeguarding Australia newsletter and the Engineers Australia civil engineering magazine.

For more information phone Ken Dale on +61 2 6249 9083 or e-mail ken.dale@ga.gov.au

Industrial buildings following the blast

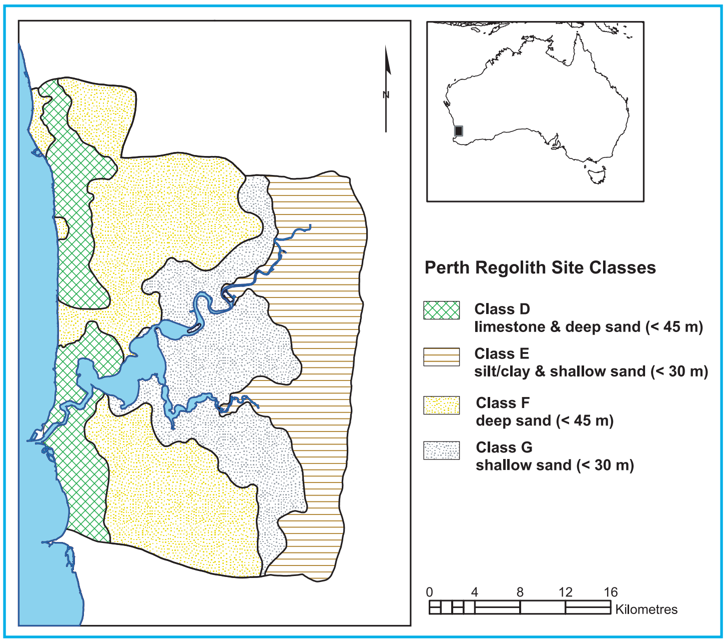
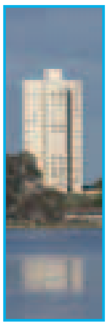
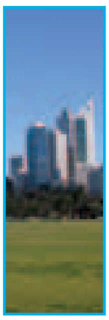


Figure 1. Regolith site-classes of the Perth region, Western Australia



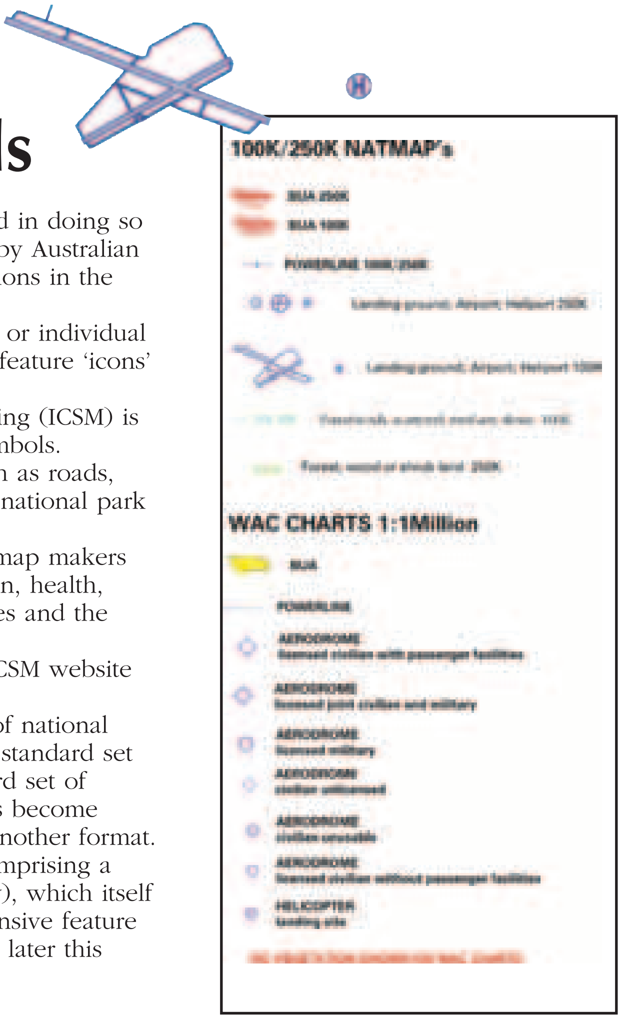


amplification factors are being calculated for a series of earthquakes with a moment magnitude of six, and a range of intensities.

Results of the site response modelling, which account for variability in both regolith materials and ground-motion parameters, will provide better estimates of earthquake hazard and risk in Perth. The information will help identify optimal sites or routes for infrastructure in the region, and enable emergency managers to more efficiently plan resource allocation and disaster management.

For more information phone Andrew McPherson on +61 2 6249 9315 or e-mail andrew.mcpherson@ga.gov.au

Consistent map symbols



Almost everyone has used a topographic map at some time and in doing so has interpreted symbols from the map's legend. Symbols used by Australian map makers are generally consistent, but there are some variations in the way features are presented.

For example, government organisations, private companies or individual map makers may use different aerial shading patterns or point-feature 'icons' to symbolise the same feature.

The Intergovernmental Committee on Surveying and Mapping (ICSM) is under charter to produce a nationally consistent set of map symbols. Standard topographic symbols will be adopted for features such as roads, railways, aircraft facilities, built-up areas, forests, watercourses, national park boundaries and contours.

These standard topographic symbols will be of interest to map makers and users across a wide range of disciplines including education, health, science, marine, tourism, defence, resources, emergency services and the environment.

Information on the agreed symbology is available on the ICSM website www.icsm.gov.au.

For digital map data ICSM plans to establish a generic set of national feature codes and domain names. National feature codes are a standard set of names for topographic features; domain names are a standard set of attributes associated with these features. Standard feature codes become important whenever a topographic database is translated into another format.

The feature codes are based on a three-tiered hierarchy comprising a theme (e.g. cultural) with a feature code (e.g. recreation facility), which itself has a set of associated terms such as 'picnic area'. A comprehensive feature code list is currently being reviewed by ICSM before its release later this year.

Topo field *verification*

Topographic maps, or NATMAPs, have been produced by Geoscience Australia's National Mapping Division for more than 40 years. The maps are used across Australia for emergency services, defence operations, land management, and recreational pursuits.

Because the maps reflect the geography at a particular point in time, features can change almost as soon as a map is produced—particularly the constructed features such as roads and buildings. Topographic maps therefore need to be re-assessed quite often.

As part of its verification program, Geoscience Australia conducts field reviews of its topographic maps. Information gleaned in the field is currently being used to update its 1:250 000 scale NATMAPs and companion digital data (GEODATA). Map production methods and revision processes are also evaluated as part of the verification program.

In 2003–04, almost twenty 1:250 000 scale NATMAPs were reviewed from three regions in Australia: New England and north-western New South Wales (October 2003), Kalgoorlie goldfields region in Western Australia (November 2003), and Sydney Basin and surrounds (April 2004). The field team comprised three mapping specialists who liaised with local stakeholders, and conducted aerial and on-ground field verification.

Before each trip, stakeholders such as land-management agencies, local councils and mining companies are sent relevant NATMAPs to critique. They are asked to comment on the representation of topographic features, point out errors, and assess the map quality.

When the field team visits the area under review, it meets with stakeholders and records their feedback. It also verifies many topographic features such as vertical obstructions, road alignment, and changes in reserve boundaries using GPS and GIS technology, and special software (OziExplorer with NATMAP Raster 250K).

OCTOBER *celebrations*

International Earth Science Week 2004 will be celebrated from October 10–16. The week is an opportunity for all involved in earth sciences to share the results and significance of their work with the community.

This year's theme 'Living on a Restless Earth' focuses on natural hazards and how to reduce their effects on society.

Geoscience Australia maintains the national Earth Science Week web site (www.ga.gov.au/about/event) and encourages the Australian community to get involved. Geoscience Australia's Earth Science Week poster has been distributed nationally.

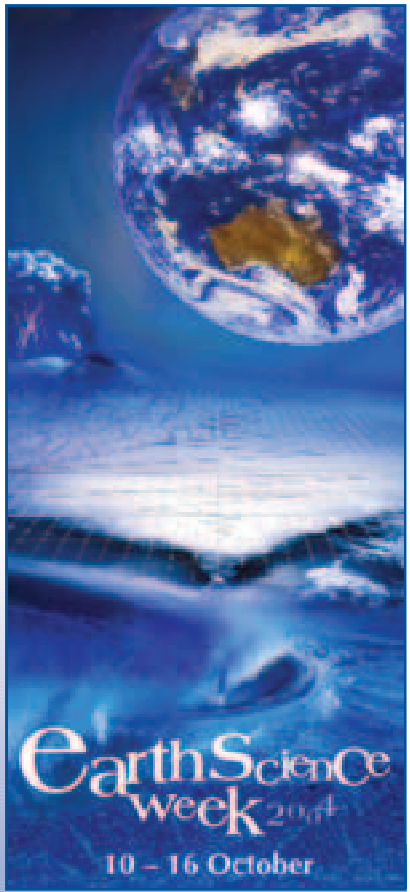
Preparations are also in hand for the October launch of a new reference database, AusGeoRef.

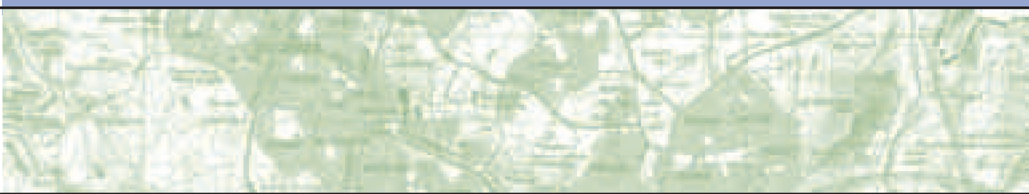
AusGeoRef promises to make the search for Australian geoscience publications quicker and easier. Its parent database GeoRef was established in 1966 by the American Geological Institute and contains over 2.4 million references to geoscience journals, books, maps, conference proceedings and reports, making it the world's best geoscience database. References can be found by searching for title, author, subject, or publication date.

Users will be able to subscribe to the complete GeoRef database, the Australian content only database AusGeoRef, or to a customised alert service via the web.

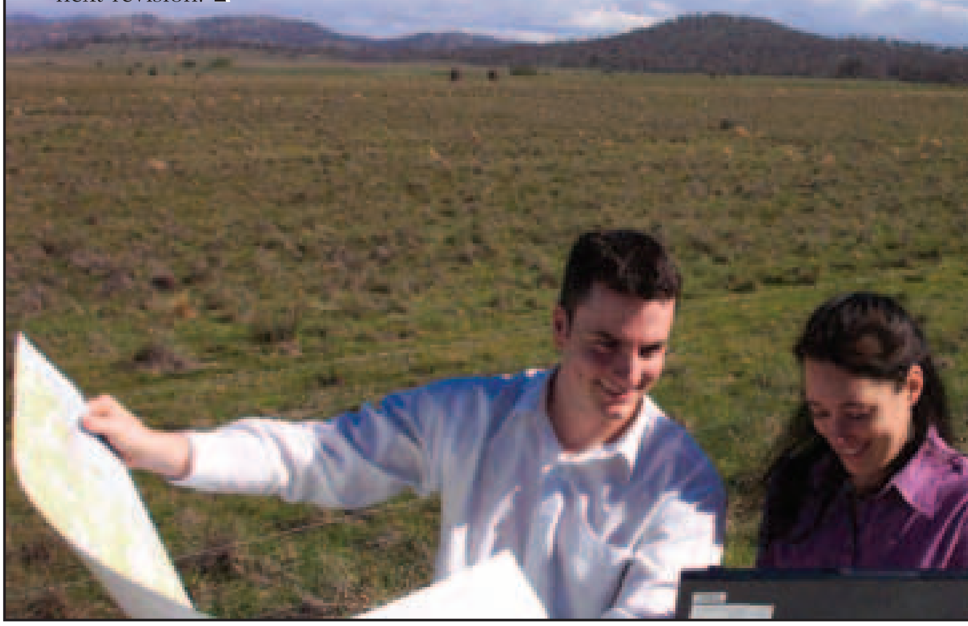
To subscribe please visit www.geoscience.gov.au

AusGeoRef
AUSTRALIAN GEOSCIENCE REFERENCES





Geoscience Australia also relies on observations from members of the public that use NATMAP and GEODATA products. The public can notify Geoscience Australia about changes to features or map errors via the web www.ga.gov.au/nmd/mapping/#Feedback. All feedback is recorded and if possible corrections are made to work-in-progress or else stored for the next revision.



MAJOR commitment to DMAP

Australia's approach to managing natural disasters changed radically with the Disaster Mitigation Australia Package (DMAP) launched in December last year. It heralded a shift in focus that will eventually give Australia a world-class national framework for natural disaster management.

DMAP grew out of a review commissioned by the Council of Australian Governments in 2001 regarding Australia's approach to natural disaster response and recovery.

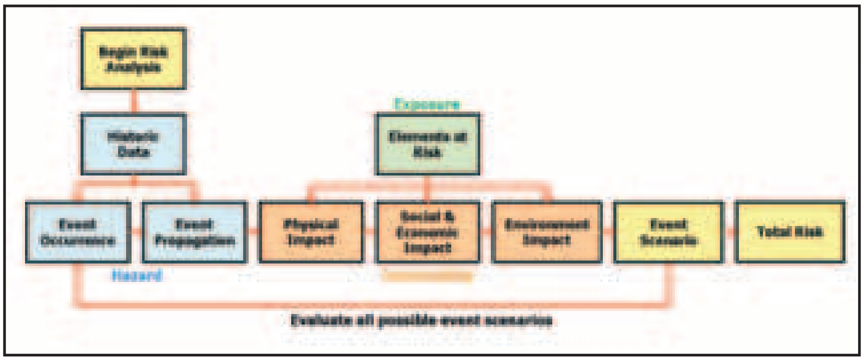


Figure 1. The national risk assessment framework

The review concluded that a new approach (one of anticipation and evidence-based disaster mitigation) was needed to create safer, more sustainable Australian communities and regions by reducing risk, damage and losses in economic, social and environmental terms.

DMAP is administered by the Department of Transport and Regional Services. A complete report of the review is posted on the department's web site.






Important partnership

Geoscience Australia has formed a partnership with the Department of Transport and Regional Services to help implement DMAP. Current work focuses on two important Reform Commitments specified under Recommendation 4 of the review report:

1. Develop and implement a five-year national program of systematic and rigorous disaster risk assessments.
2. Establish a nationally consistent system of data collection, research and analysis to ensure a sound knowledge base on natural disasters and disaster mitigation.

A successful outcome largely depends on effective collaboration among government and non-government groups across Australia, and a successful data-analysis and collection program.

The first step in developing national disaster risk assessments is generating national databases and standardised methods and models for assessing risk. These methods need to be applied across a number of natural hazards (earthquake, bushfire, flood, tropical cyclone, severe wind and landslide), and be sufficiently accurate to allow risk comparisons among different hazards and across regions.

National framework

A national risk assessment framework will bring together all the elements of natural hazard risk research (hazard, exposure and vulnerability) to define the national threat from a range of hazards. To do this requires a long-term commitment to data collection and the development of nationally consistent guidelines and capabilities for hazard and risk-modelling.

The risk models used should strive to better forecast future events and their impacts by using physical models as a base, particularly those where the total risk might be affected by a change in natural, built or social environment.

Most present-day models capture the risk in terms of the direct damage or cost of a future disaster. Research is needed to extend these estimates to include indirect effects (loss of income, quality of life) as well as other social, political and economic factors that can play a role in decisions about risk treatment.

Figure 1 illustrates the steps required to comprehensively analyse risk. This complex framework cannot be achieved or implemented quickly. But it will significantly decrease the level of uncertainty and provide more accurate and reliable risk assessments. As well, the framework will be applicable to other hazards and issues of national security.

Shared data

Since starting the Cities Project in 1996, Geoscience Australia has been developing models and conducting risk assessments in urban centres for many of the natural hazards integral to DMAP. In some of the preliminary work for DMAP, it is researching the social and economic impacts of natural hazard events on Australian communities. But to develop the essential databases and models on a national scale, Australia must capture complete and consistent data across all jurisdictions, which requires commitment from each level of government.

The collected data need to span all elements of risk (hazard, exposure and vulnerability) and encompass information about the direct costs, government expenditures, risk-assessment and mitigation measures, and post-disaster information.

Products of DMAP work will include an agreed national risk assessment framework, risk maps to compare risks across hazards and regions, and web-based loss assessment and visualisation tools for risk assessments.

Spatial data *forums*

A series of mapping and remote sensing forums was recently held in Canberra, Adelaide, Perth and Brisbane by Geoscience Australia to inform business partners and other stakeholders about its activities, and to discuss issues faced by the spatial information industry.

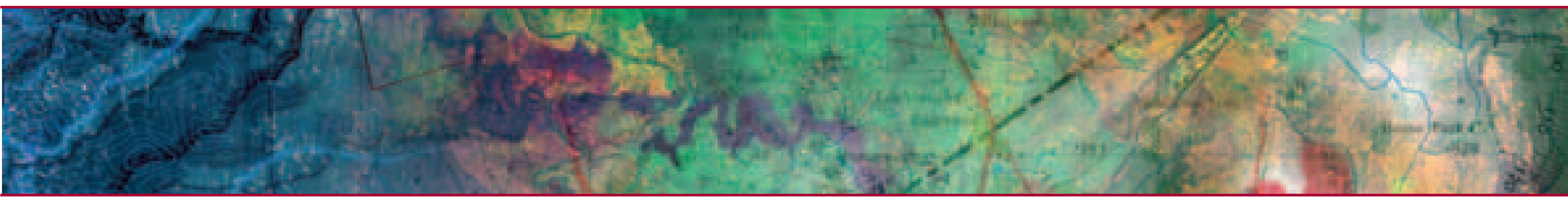
The Australian Government's Spatial Data Access and Pricing Policy was a major topic discussed. Most delegates applauded the policy, which was introduced in September 2001.

Other issues discussed included: an explanation of the drivers for national mapping activities; on-line data availability; market trends in mapping and remote sensing, including product consumption and accessibility; the status of satellites (particularly the Landsat missions); the mapping forward program (map and data sets revision); data delivery initiatives under development; and the practical application of products such as the NATMAP Raster Mosaic of Australia.

There was a lot of networking among industry participants, and an opportunity for local spatial industry experts to showcase innovative applications in using spatial data.

Participants were given insights into how remotely sensed data are assisting governments and other decision makers to maximise agricultural production and manage activities that impact upon the environment (e.g. tree clearing, salinity, and exploration).

Forums will be held in other cities in the near future.



Hope surfaces

with gas bubbles in seep detection trial

Searching for oil in a frontier province of Australia is like looking for a needle in a haystack when faced with a marine area 1.5 times the onshore area. The task, although challenging, can be much more targeted with some well-planned reconnaissance using the latest tools in oil-seep detection.

Geoscience Australia is involved in a four-year program to examine natural hydrocarbon seepage around Australia, using funding announced by Minister for Industry Tourism and Resources, Ian Macfarlane, in May 2003.

The aim is to ground truth various survey and remote-sensing techniques in a known petroleum area, and then use the knowledge gained to detect active petroleum systems elsewhere in frontier basins.

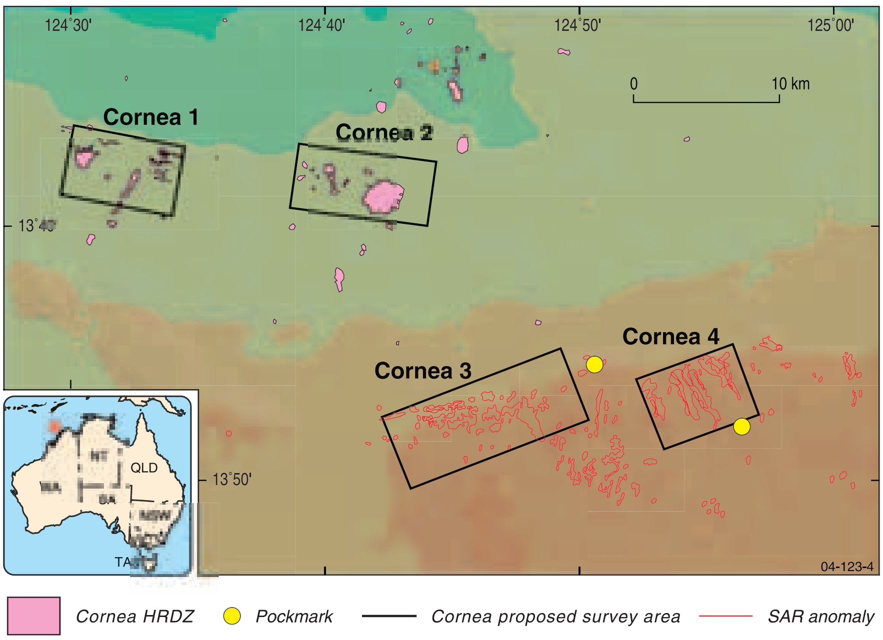
Yampi Shelf survey

In March, various techniques were tested over an area of natural hydrocarbon seepage off north-western Australia, in the Yampi Shelf and Cornea oil field area (figure 1), using a converted pearling mother-ship, the *Parmelia K*. Several areas of interest were selected before the survey using remote sensing data (e.g. Landsat and Synthetic Aperture Radar), 2-D and 3-D seismic, water column geochemical 'sniffer', and Airborne Laser Fluoresence.

Key survey sites were then mapped using side-scan and multi-beam sonar to highlight detailed seabed features. Once features of interest were found, sediment and biological and water samples were collected at the target sites.

Although the proposed survey program was cut short by tropical cyclones Evan and Fay, a lot of new information was collected about seepage and its expression on the Yampi Shelf. Survey data are being interpreted at Geoscience Australia and integrated with previous data to detect and characterise oil and gas seeps.

The preliminary results already provide key insights.



▲ **Figure 1.** Detailed work on the Yampi Shelf was carried out in the areas marked by the boxes. The Cornea oil field is located below box one.

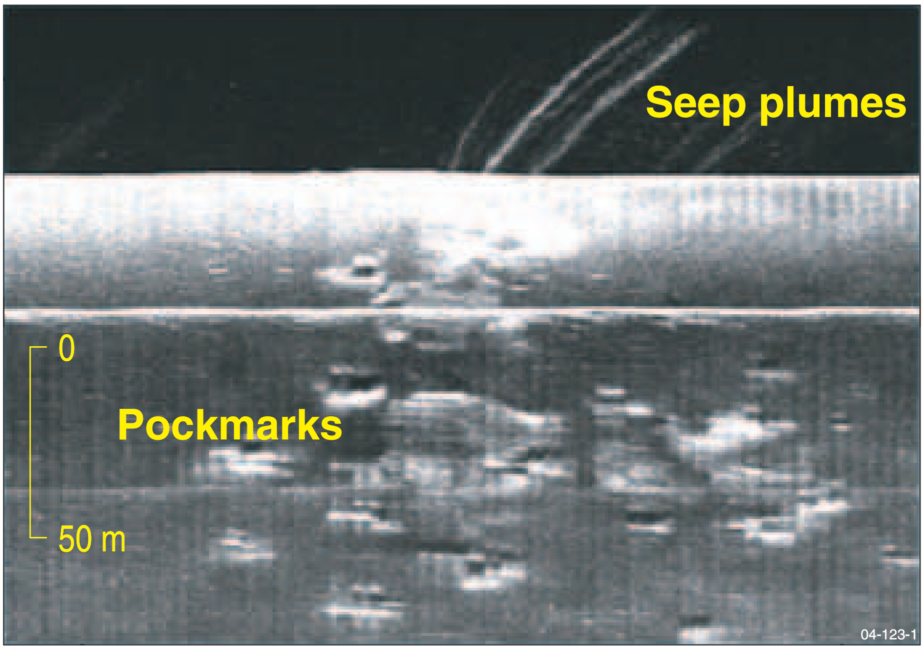


Figure 2. A side-scan sonar image acquired on the Yampi Shelf shows bubble plumes rising from a field of pockmarks.

Seepage bubbles

Active seepage was detected using side-scan sonar at 100 and 500 kHz frequencies. This consisted of plumes of gas bubbles rising from fields of pockmarks that were 5–10 metres in diameter, and hard-ground areas (figure 2). The bubble plumes reached tens of metres above the sea-floor in 90 metres water depth. Bubbles were also observed at the sea surface, where they burst, leaving wispy films of oil—indicating that they have a hydrocarbon source.

This active seepage was strongest around low tide and subsided as the tide height increased. At high tide the active sites exhibited low intensity plumes rarely rising more than two metres above the sea-floor.

Significantly, the active seep sites can be tied to seismic features, such as low-velocity zones, 'gas chimneys' and amplitude anomalies (figure 3, page 28).

A key tool used during the survey was the 200 kHz echo sounder which detected active gas plumes and was used to visualise the extent of the seep plumes through the water column. This tool also proved very useful during the sampling phase of the work.

The ship was positioned over active seep sites so that the echo sounder could observe the location of sediment and water sampling tools relative to the seepage plumes. This allowed accurate sampling of active seep sites.

Sediment samples

A range of sample types was collected for geochemical and biological analysis. Most of the sediments consisted of muddy carbonate sands. Course-grained sediment and carbonate cementation in some areas made gravity coring extremely difficult. However, grabs and dredges recovered sediment samples for analysis.

Biological communities of shelly fauna, which often included heavily encrusted worm tubes, were found close to active seeps. But very little shelly material was recovered and no worm tubes were found 30–50 metres away from seep sites.

Analysis of geochemical and biological material is under way at Geoscience Australia, in collaboration with CSIRO and the Australian Institute of Marine Sciences.

Other tests

An Acoustic Doppler Current Profiler was deployed to measure current directions and the velocity of currents over seabed features. To test for hydrocarbon slicks, a sea-surface skimmer was developed that samples water for on-board fluorometer analysis.

An extensive remote-sensing data set was also collected. An airborne hyperspectral survey was carried out over the survey region in collaboration with Hyvista Corporation, and Landsat and Synthetic Aperture Radar data were collected by satellite for correlation with the seabed survey and seismic data.

Initial results indicate that a detailed knowledge of bathymetry, tide and current velocities greatly enhances interpretation of remote-sensing data to detect hydrocarbon seeps in relatively shallow shelf waters.

Next stage

The Yampi Shelf survey has allowed Geoscience Australia to image active hydrocarbon seepage sites and to link these to seismic and remote-sensing evidence for the first time. The ground-truth work will benefit exploration in shallow water along the north-west shelf of Australia.

This integrated approach to oil-seep detection will be used in future surveys. The lessons learned during the Yampi Shelf survey will be applied to identify and sample evidence of active hydrocarbon seepage in a survey in the Arafura Sea in 2005.

Oil shows within wells in the Arafura Basin illustrate the presence of active petroleum systems; however, no proven accumulations have yet been drilled. Furthermore, the northern half of the basin is un-drilled and will provide an interesting target for the forthcoming survey.

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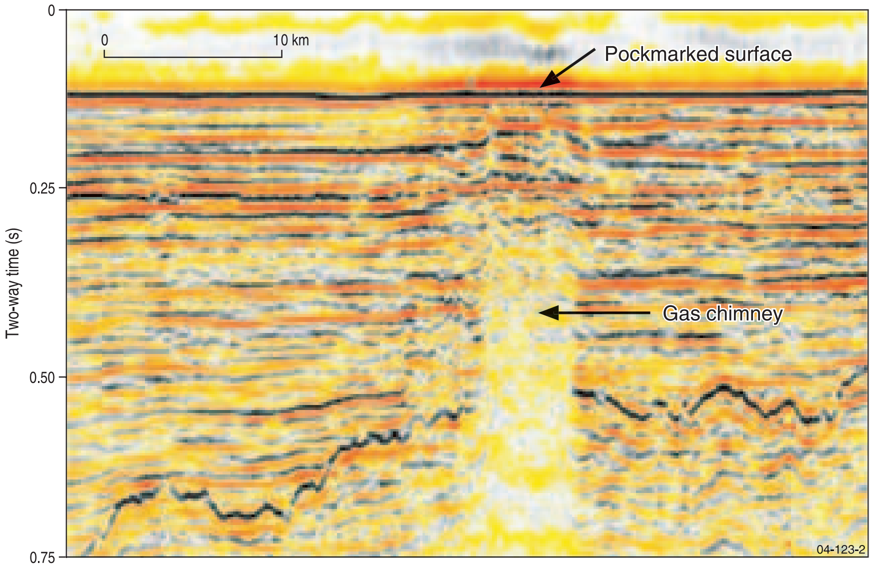
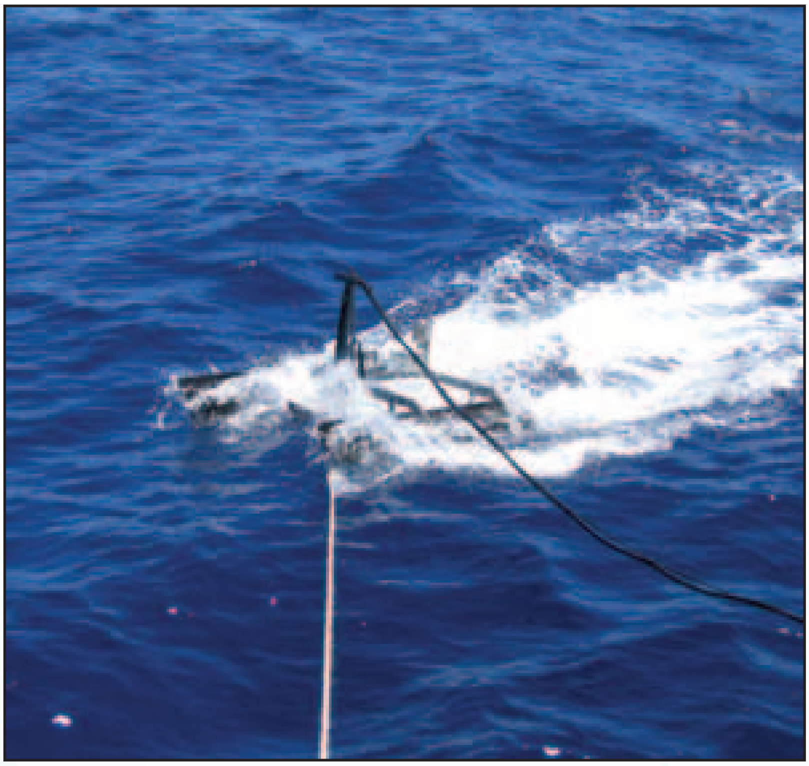


Figure 3. This seismic section was taken across the survey area. The associated pockmarked field is the image shown in figure 2, and is related to the larger Hydrocarbon Related Diagenetic Zone (HRDZ) in box two in figure 1.



Geoscience Australia developed this sea-surface skimmer to test for hydrocarbon slicks. The instrument collects water samples for on-board fluorometer analysis.