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Landgate acknowledges Henry Houghton, Don Abbey and Ken Alexander, who assisted in development of this Strategy.

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For further information regarding WA’s geodetic framework, access www.landgate.wa.gov.au or contact Geodetic Data, Landgate on (08) 9273 7133.

Foreword

Although the way in which the geodetic framework impacts on the lives of all Australians is often unseen, its influence is felt daily. The framework provides a valuable spatial reference system with industrial and scientific applications. Without this infrastructure, Western Australia would not be in a position to support its land titling system, build roads or support land development with an assured level of accuracy.

Demand for Landgate's services continues to gather momentum under the steam of the State's housing and resources boom. The requirement for a wide variety of users to have up-to-date land information has created enormous pressure for an increasingly open, accurate and accessible geodetic framework, and Landgate's activities recognise these needs.

This document, the Geodetic Strategy for Western Australia, outlines the major issues, risks and opportunities associated with the geodetic framework. It also describes the related activities that Landgate will undertake over the next five years.

I acknowledge the contributions Landgate received during the consultation phase for this Strategy. Sixteen submissions were received from industry, the scientific and academic communities, government and the wider community of Western Australia. This feedback led to significant improvement of the Strategy, in terms of readability and content.

This Strategy sets a path for Western Australia's geodetic future. Landgate's planned initiatives are realistic strategies that will enhance, rationalise and sustain the geodetic framework. We can only achieve these goals through an innovative focus and strong collaboration with our stakeholders.

I look forward to the next five years and your ongoing support.



Grahame Searle
**CHIEF EXECUTIVE
LANDGATE**

2 November 2007

0 EXECUTIVE SUMMARY

The Geodetic Strategy for Western Australia includes programs and projects to connect with industry and science. Soundly implemented, these programs will provide ongoing enhancement of the value of this strategy into the future.

A shared vision for the geodetic framework between Landgate and the spatial community will flow into the objectives of all involved. Therefore, Landgate's search for ways to enhance the value of the strategy focuses on building the commercial and scientific relationships that will deliver the greatest benefit to the State.

The Strategy incorporates the views of its stakeholders; expressed through opportunities for feedback to the Geodetic Network Review; strategic market surveys and an industry questionnaire, and through research into Continuously Operating Reference Station (CORS) networks by Curtin University. This engagement with key stakeholders has helped Landgate to develop an understanding of the current and future needs for the State's Geodetic Framework.

A major impetus for the Strategy is the decision to implement a CORS network in WA as part of the Commonwealth Government's National Collaborative Research Infrastructure Strategy. This will be a major contributor to the way the geodetic framework is realised in Western Australia.

The Strategy will benefit society and the State by providing better, open access to the geodetic framework, especially through the proposed CORS network infrastructure. Access to that infrastructure will simplify the process of collecting quality spatial data, and will reduce the costs of doing so. Therefore spatial data will be shared more readily and serve a wider use than the single purpose for which it was collected. The commercial and community benefit of this is well documented through the WA Land Information System (WALIS).

Landgate, as custodian of the Western Australian geodetic framework, will lead its State and spatial community partners through a transitional period to 2012 when Western Australia will move to an open, accurate and accessible three-dimensional second-generation geodetic framework that is fully compatible with both Global Navigation Satellite System (GNSS) and terrestrial survey methods.

1 VISION

The Vision for Western Australia's Geodetic Framework is:

An open geodetic framework that provides users with the positioning solutions they need anywhere in WA at any time.

This Vision supports Landgate's Strategic Vision that looks forward to "a future where the use of land information knows no bounds."

2 OBJECTIVE

The objective of this Strategy is:

To deliver to all WA users an open, accurate and accessible geodetic framework.

Landgate, as custodian of the Western Australian geodetic framework, will lead its government and industry partners through a transitional period to 2012 when Western Australia will adopt an open, accurate and accessible three-dimensional second-generation geodetic framework that is fully compatible with both GNSS and terrestrial survey methods.

3 KEY PRIORITIES

The key priorities under this Strategy are:

1. **Setting standards and policy within an appropriate legislative framework.**
Landgate will continue its role of providing standards and guidelines, in conjunction with industry, State and national bodies;
2. **Establishment and operation of a CORS network;**
3. **Maintenance of the current geodetic framework;** and
4. **Engagement with industry,** via a dedicated Survey Networks Stakeholder Reference Group and comprehensive Communication & Consultation Strategy.

The nature of the Geodetic Strategy (and the CORS Network Establishment Project, in particular), the relative ease with which a CORS network can now be established, and the development opportunities that will flow from a unified CORS network all suggest that an enhanced relationship between Landgate and industry would produce significant benefits for the State [refer section 6: Benefits of the Strategy]. Open and formal cooperation will stimulate the development and extension to the CORS network by industry and promote the research and development required to develop GNSS-based products and services.

4 STRATEGIES

Landgate will deliver the leadership and long-term certainty required by all stakeholders and users who seek to benefit from the opportunities available from a modern geodetic framework.

The table below summarises Landgate’s strategies and proposed timeframes for achieving this (listed in no particular order):

Program/project	Activity timeframe				
	2007/08	2008/09	2009/10	2010/11	2011/12
4.1 Establish a State Wide CORS Network	[Bar from 2007/08 to mid-2011]				
4.2 Review and Maintain an Appropriate Network of Geodetic Survey Marks	[Bar from 2007/08 to end of 2011/12 with arrow]				
4.3 Deliver Geodetic Services	[Bar from 2007/08 to end of 2011/12 with arrow]				
4.4 Upgrade SCDB	[Bar from 2007/08 to mid-2011]				
4.5 Support Scientific Studies	[Bar from 2007/08 to end of 2011/12 with arrow]				
4.6 Provide Legal Traceability	[Bar from 2007/08 to end of 2011/12 with arrow]				
4.7 Update Regulatory Framework affecting Survey and Geodesy	[Bar from 2009/10 to end of 2011/12 with arrow]				

4.1 *Establish a State Wide CORS Network*

This project will establish and operate a Western Australian CORS network with the primary objective of expanding Australia's scientific capability in geodesy and geodynamic research for State and National benefit. This network will be part of a national CORS network being built by AuScope Ltd, an organisation for a National Earth Science Infrastructure Program. AuScope Ltd is funded under the National Collaborative Research Infrastructure Strategy (NCRIS) an Australian Commonwealth Government Programme. The WA CORS network will be jointly funded by AuScope and Landgate and will comprise about 26 CORS across Western Australia and will form the basis of a more openly accessible, second-generation geodetic framework for all users.

The network configuration will include sites at or near the Australian Baseline Sea Level Monitoring Project Tide Gauges of Broome and Esperance and an east west transect at about the latitude of Perth. The remainder of the sites will cover the most seismically active, populous and resource rich regions of the State at a density of approximately 200km. The rollout schedule will commence in 2007 and be completed by 2011.

At a time when GNSS technology has reached a watershed in useability and compatibility, Western Australia has an opportunity to enhance its scientific status in geodesy and geophysics. In parallel, this project will provide an impetus to upgrade the operational effectiveness of its public and private sector organisations involved with state development, infrastructure, land tenure and land management. WA can also provide the spatial infrastructure for future government, commercial and scientific services that are yet to be fully defined or understood.

Landgate will provide leadership by developing and publishing open standards for the design and operation of a publicly accessible CORS network, and will engage with public and private CORS operators to ensure a minimum overlap of redundant infrastructure and to maximise the benefits that an open CORS network can bring to the State and its citizens.

Landgate sees that the establishment of this base CORS network will provide opportunities for private industry to leverage off the facility to provide value added services to the wider community. In doing so, the State will benefit from additional network densification that may occur.

4.2 *Review and Maintain an Appropriate Network of Geodetic Survey Marks*

Landgate is responsible for the integrity of the geodetic framework, its density, maintenance, and distribution of quality data to all users in support of the development needs of the State. The Geodetic Survey Mark Maintenance Program continuously reviews key areas of land development and infrastructure projects to ensure reasonable access to a geodetic framework and its physical and mathematical integrity. New ground marks will be established on an “as required” basis in the short to medium term where the current density is deemed insufficient to cater for proposed development and/or where specific projects require local permanent monumentation. Landgate will continue to provide this valuable service to Western Australian society as custodian of the geodetic framework whilst it is still needed.

4.3 *Deliver Geodetic Services*

Consultancy and Project Management

Landgate provides consultancy and project management services to Government Agencies, including the Departments of Environment and Conservation, Agriculture and Food, and Water. Landgate provides control and mapping surveys in support of salinity and other environmental studies requiring detailed ground based surveys linked to National Datums.

Geodetic Support for Landgate Programs

Services include connections between the geodetic and cadastral networks to support the Spatial Cadastral Data Base (SCDB) upgrade program, validation and control for the topographic database. Landgate also has responsibility for all geodetic station (Trigonometric) reserves throughout Western Australia.

Geodetic Support for National Programs

Landgate provides representation on the Intergovernmental Committee on Surveying and Mapping (ICSM) Geodesy Technical Sub Committee (GTSC). The role of this committee is to implement national geodesy policies by coordinating geodetic activities between government agencies. Landgate also provides support for ICSM projects including Height Modernisation and Geodetic Support for Mean Sea Level Monitoring.

Education

Landgate will support education programs to improve the competence and understanding of WA users of all geodetic products and services, including GNSS.

4.4 Upgrade SCDB

The State has a digital database of all cadastral land parcels. To accommodate customer demand and to meet WALIS and Shared Land Information Platform (SLIP) objectives, a program of upgrading the dataset to full survey accuracy has commenced. To date, approximately 80% of the points in the database have been upgraded in the initial pass.

The Spatial upgrade process integrates boundary dimensions with surveyed connections to the geodetic framework. The result is improved spatial integrity and accurate coordinates with increased compatibility with many other spatial datasets. Being a survey accurate database, it provides for a range of opportunities for the use of new technologies and improving the efficiency of cadastral surveying.

4.5 Support Scientific Studies

This program will increase the visibility and influence of Western Australia's world-class academic resources in geodesy and geodynamics, as well as improving the access of our scientific community to resources that can be applied to research problems with local and worldwide application.

Data from the CORS infrastructure will support scientific studies and research programs in a number of fields, for example:

Discipline	Scientific Study
Geodesy and Surveying	<ul style="list-style-type: none"> • Datum definition • Establishment of a scientifically-based height datum derived from CORS GNSS and the high precision gravimetric geoid • Development and testing of advanced models and processing techniques for high precision, long baseline GNSS software

Discipline	Scientific Study
Geodynamics	<ul style="list-style-type: none"> Local deformation monitoring and geohazard studies Crustal motion and continental deformation monitoring
Oceanography and Atmospherics	<ul style="list-style-type: none"> Sea level monitoring Water vapour and atmospheric modelling

The results of such scientific studies could be significant, potentially providing practical application in the fields of surveying and geodesy. As well, this research will bear directly on decision making for hazard management including building codes, earthquake response planning, improved weather forecasting and tracking of intense storms and cyclones and the long-term potential for inundation of coastal areas.

4.6 *Provide Legal Traceability*

Landgate has, under legislation, the delegated role for verification of length standards within Western Australia. This involves a certification process every two years to ensure that the processes and facilities meet State and National standards. Certified facilities include two public access Electronic Distance Measuring Instrument (EDMI) Calibration Baselines – Curtin University (at Bentley) and Kalgoorlie – and a calibration laboratory at Midland for survey tapes, bands and spirit levelling staves. Landgate also maintains a GNSS system and methodology test network at Curtin University and an innovative testing facility for bar coded staves in Darlington.

The issue of legal traceability of Position and the responsibility for verification in Western Australia (indeed Australia) is under review. However, it is recognised that a well regulated, accurate and reliable geodetic framework is integral to this issue.

4.7 *Update Regulatory Framework affecting Survey and Geodesy*

The primary outcome of this strategy will be simplification of the existing outdated pieces of legislation that impact on geodetic matters and survey practices in Western Australia. This will be achieved by developing, in consultation with industry and the community, a modern regulatory framework of practical legislation supported by appropriate policies, standards and guidelines. A review of the current legislative framework to scope the required changes will be undertaken as part of this strategy in the lead-up to the development of new policies and legislation.

5 STAKEHOLDERS

The stakeholders for the Geodetic Strategy are:

- government** – Landgate, Commonwealth and State Government Agencies/Utilities, Local Government Authorities;
- industry groups** – survey, mining and engineering companies, agricultural industry, CORS operators;
- scientific and academic communities** – including environmental scientists, seismologists, meteorologists, academia; and
- the WA community** – eg. emergency services, tax payers.

The geodetic framework underpins all spatial data in Western Australia – either directly or indirectly.

Surveyors are the primary users of the geodetic framework. Their surveys locate, map and direct the construction of infrastructure such as roads, railways, mines, bridges, dams and pipelines. Further, the connections made by cadastral surveyors from the geodetic framework to the cadastre enable the accurate positioning of land parcels.

Others use the geodetic framework for positioning physical assets (eg. water and gas pipelines, telecommunication cables, sewerage and drainage infrastructure, power poles and bus stops) and maintaining databases of spatially related information. In particular, government agencies, local government and utility organisations use the framework to improve the integrity of the recorded locations for their assets. Engineering and mining companies, road, rail, electricity, water and gas utilities consider data derived from the geodetic framework as essential inputs for their design, construction and maintenance projects.

The geodetic framework also supports scientific studies for the benefit of the State. Examples include the ongoing monitoring of the South-West Seismic Zone, the measurement of variations in sea level related to climate change and the development of methods to track weather systems and improve the forecasting of intense storms and cyclones.

A 2004 Strategic Market Survey, conducted by the former Department of Land Information (DLI), identified that the users of geodetic services comprised 53% private survey firms and 26% all levels of government. The remaining 21% were mining companies, engineering firms and other consultants.

An independent scoping study for a review of WA's geodetic framework commissioned by DLI in 2005, and feedback to that study from interested spatial professionals, has provided many of the issues addressed by this strategy. Knowledge gained from research by Curtin University during 2006 (also commissioned by DLI) into CORS networks in the context of a future geodetic framework for WA has also been incorporated.

The March 2007 industry questionnaire revealed that users currently:

- perceive the current geodetic framework, realised through a network of geodetic survey marks (also referred to as ground marks, eg. Standard Survey Marks (SSMs), Benchmarks (BMs)), to be necessary.
- accept that new technology may potentially change the reliance on ground marks in the future, subject to:
 - a responsive positioning system, widely available throughout the State;
 - the system providing a reliable and practical realisation of AHD height; and
 - provision for situations where GNSS is unsuitable because of site limitations for satellite signal availability, or for projects that are not suitable for GNSS technology solutions
- expect horizontal position and AHD height accuracy to be better than 1 centimetre for many purposes, less than 5 centimetres for most purposes, and less than 1 metre for other purposes.

Since most respondents to the questionnaire (some 80%) believe they won't use the CORS infrastructure for their spatial project work, the Strategy caters for the distinction between providing the coordinates needed to spatially relate project work within the State, and the way stakeholders carry out that project work.

6 BENEFITS OF THE STRATEGY

The Strategy will benefit all stakeholders in a number of ways during the transition to a GNSS based CORS network infrastructure approach. It provides them with certainty in the support that will be provided by Landgate, and the future direction of that support for the geodetic framework.

Specifically, the Strategy will provide benefits through:

- realising and maintaining the current State and National (ANN, AFN) geodetic framework, both horizontally and vertically, to serve the spatial infrastructure needs of the State, using both statutory standards and guidelines to ensure quality;
- continuing Government support for the survey industry involved in the day-to-day development of the State and its infrastructure and resources;
- support for a process of continual and ongoing review of the Geodetic Survey Mark Maintenance program's priorities and potential for cost saving;
- strengthening the State's cadastral survey system, central to the reliability of land title in WA;
- support for legal traceability for position under the National Measurement Act 1960;
- encouraging the development and implementation of a three-dimensional datum for Australia that is fully GNSS compatible;
- providing Landgate a leadership role in building relationships with organisations that can add value to the CORS network;
- stimulation and support for WA companies and organisations to develop technology, products and services with a CORS focus;
- improving the State and Australia's ability to achieve major scientific advances in geodesy, geodynamics and atmospheric science;
- providing a significant opportunity for WA universities to increase their contribution to continental and global science;
- improved International GNSS Service products, such as precise satellite orbits, time transfer, and tropospheric and ionospheric modelling; and
- information sharing and education.

The Strategy provides both Landgate and stakeholders with a sound basis for developing relevant business models, planning investments in technology and implementation methodologies from 2007 to 2012. It provides the means of allowing stakeholders to continue operating under current systems whilst providing new infrastructure that can be introduced as benefits become available and are recognised by those stakeholders. That is, implementation strategies are user-driven, not imposed.

7 RISK FACTORS

To date, Landgate has not established a CORS network. It has relied on its existing ground marked geodetic network to deliver spatial control to users. This has reflected its concerns about the costs involved, the capability and robustness of GNSS, limited demand from users and significant uncertainties around the timing of major system upgrades and the advent of new systems.

In the past, Landgate has been a leader in the efficient application of GNSS technology to improve the state's geodetic infrastructure. However, the time is approaching when Western Australians will apply GNSS data in a wider range of products and services as part of their everyday work or recreation. This includes everyone from a water meter reader in Perth, to a haul-pack driver in a Pilbara iron-ore mine, from a family driving around looking for a restaurant, to an emergency services officer searching for a lost child. A risk to the State exists in being unprepared for this leap into CORS positioning by its users and the attendant legal and technical issues.

While it is recognised that modern technology is subject to continual change, it is now clear that GNSS technology is moving towards a universally accepted standard of operation. Receivers are now available that track both GPS (United States) and GLONASS (Russia) signals. They now also track the new GPS signals, first transmitted last year, and Europe's proposed Galileo system, even though Galileo may not be operational before 2012. Navigation satellite systems are also being developed in Japan, India and China.

The cost curve of GNSS receiver technology is also declining, similar to that of Personal Computer technology during the 1990s. Today, the cost of a CORS GNSS receiver is not prohibitive, particularly in comparison to the total cost of establishment and maintenance of a high quality base station site. Depending on design, future upgrades may have only a relatively small cost impact on an existing CORS network.

Specific risks that may affect consideration of the Geodetic Strategy include:

- *In the unlikely event that GNSS fails, how will WA maintain a geodetic framework?*
In the event of a natural disaster of global proportions, a major space storm that destroys the GNSS satellites, or a war that causes the countries operating GNSS to switch them off or restrict access, then the only realistic option in the short-term is to ensure that sufficient ground marks are maintained. Any of these events will cause significant uncertainty across society, possibly even threatening civil government. Maintaining a selected sub-set of the State's ground marks will ameliorate this effect by ensuring access to good spatial data for emergency planning and response and for national security.
- *How will Precise Point Positioning (PPP) impact on CORS?*
The proliferation of PPP, which is now being trialled in near-real time by Jet Propulsion Laboratory (JPL) and others, is a key risk factor for CORS. If successful, this could significantly reduce the need for a CORS network. Admittedly, CORS networks feed into these systems, so there is also a benefit if the WA CORS can feed into real-time PPP services. A similar threat may come from international GNSS data processing services such as AutoGIPSY.

- *What are the scientific risks involved in the Geodetic Strategy?*
Western Australia has global responsibilities to be engaged with world's best practice in science. Australian geodetic, geodynamic and atmospheric scientists are world leaders and the strategy will certainly improve their ability to provide new science and benefit to the State, Australia and the world community. Many scientists, including those in Western Australian universities, are already engaged in significant research programs that will benefit from this geodetic strategy. Therefore, there is seen to be little scientific risk in this geodetic strategy, other than the level of scientific risk associated with all research projects.
- *How do we manage the expectations of users of the Geodetic Framework?*
Many users of the geodetic framework have no need for either GNSS or a CORS network. Many other users of the framework are virtually GNSS users only, applying conventional methods only occasionally. There is a large distance between the two ends of the spectrum that is WA's GNSS expertise. At one end are some with world leading expertise; at the other end are users with very limited practical experience. This also implies that the level of understanding of GNSS technology and its application is similarly varied. Managing the expectations of this diverse group may be problematic. It will require the clear communication of the benefits and limitations of the Geodetic Strategy. It will also require an engagement with all users of the geodetic framework to ensure that their expectations are understood, addressed and supported by existing standards (eg. SP1).
- *What are the consequences of not achieving the Geodetic Strategy?*
 1. The lack of a proper integration of GNSS into Western Australian society may risk the general population moving to adopt GNSS technology in an ad-hoc manner and without the legal and geodetic frameworks in place to protect them from harm or from liability. If WA citizens suffer significant negative effects, this will translate into political action.
 2. The ad-hoc operation and delivery of CORS data to users is untested in law and may be exposed to significant liability. The development of legislative support and the adoption of open standards for the operation of CORS and the delivery and application of CORS data, that are part of this geodetic strategy will protect and inform both the supplier and user. It will provide a basis of certainty under law that government, industry and the community can rely on.
 3. Delay of the geodetic strategy will risk Landgate's leadership and functional role of custodian of the geodetic framework. Adoption of GNSS by industry and the community will accelerate over the next 5 years. Parts of industry, particularly the resource and development sectors, will adopt it as the fastest and cheapest method to deliver and propagate an accurate geodetic framework. This may lead to privately owned regional CORS networks operating independently and without common standards for data or accessibility to other users. These networks may adopt a height datum based on a geoid model, nominally equivalent to, but superseding, the physically marked AHD71.
- *What if we can not retain the expertise we need?*
With a nation-wide skills shortage, there is a real risk that Landgate will not be able to attract and retain the expertise needed to implement components of the Geodetic Strategy. Landgate is managing this risk via cadetship and trainee programs, innovative retention and reward programs, and succession planning.

8 APPENDICES

8.1 Acronyms and Glossary of Terms

Accuracy	Accuracy refers to the degree of certainty, conformity or closeness of a measurement or position to the "true" value. See also "precision".
AFN	Australian Fiducial Network A very high precision set of substantial SSM ground marks located at eight sites across Australia that continuously monitor their positions using GPS, and act as base stations for the AUSPOS service. The AFN positions are fundamental sites in the realisation of the Geocentric Datum of Australia (GDA94), and as a recognised value standard for the purpose of establishing legal traceability of position.
AHD / AHD71	Australian Height Datum (1971) The orthometric height system based primarily on spirit levelling, realised through a network of BMs across Australia.
ANN	Australian National Network Geodetic stations established using GPS at an interval of approximately 500 km across Australia.
AUSPOS	Australian Online GPS Processing Service Geoscience Australia's free automated web-based positioning service, providing users with the facility of submitting dual frequency geodetic quality GPS, static mode data, and receiving rapid turn-around precise coordinates through E-mail.
BM	Bench Mark A ground mark for which only the vertical height has been established.
CORS	Continuously Operating Reference Station A system of GNSS receivers tracking satellites continuously 24 hours a day. CORS sites are situated across a region, are permanent, and have very accurately pre-determined, known coordinates.
DLI	Department of Land Information Landgate's name prior to its establishment as a statutory authority on 1 January 2007.
EDMI	Electronic Distance Measuring Instrument Measurement of distances using the transmission and reflection of electromagnetic waves.
GDA94	Geocentric Datum of Australia 1994 The current geodetic datum used in Australia for all official spatial referencing systems, unless otherwise specified.

GLONASS	<p><u>Global Navigation Satellite System</u> The Russian global satellite positioning system equivalent to the US Department of Defense GPS.</p>
GNSS	<p>Global Navigation Satellite Systems A satellite navigation system (eg GPS) or combination of systems (GPS+GLONASS) that provide autonomous geo-spatial positioning with global coverage.</p>
GPS	<p>Global Positioning System A widely used satellite positioning and navigation system. The Satellite and ground-based Control Segments are maintained by the US Department of Defense.</p>
ITRF	<p>International Terrestrial Reference Framework A network of over 200 sites worldwide, and is based on the combination of sets of station coordinates of points on the surface of the earth and their crustal motion velocities, derived from observations of various space-geodetic techniques.</p>
JPL	<p>Jet Propulsion Laboratory A NASA laboratory established through the California Institute of Technology.</p>
PPP	<p>Precise Point Positioning A GPS positioning technique similar to a single point code pseudo-range position obtained from a hand held GPS receiver. The difference is that the technique utilises the more precise carrier phase data, improved orbits and satellite clock corrections. Under ideal conditions accuracies of 5-10cm can be achieved independent of baseline length.</p>
Precision	<p>Precision refers to the degree of certainty, conformity or closeness that repeated measurements of the same quantity are to each other; See also "accuracy".</p>
SCDB	<p>Spatial Cadastral Data Base Landgate's database system for storing and disseminating spatially defined cadastral boundaries, lodged cadastral boundaries, control marks, easements, topographic reference boundaries, surveyed mining tenement boundaries and administrative boundaries. All data is referenced to the common geographic framework based on GDA94.</p>
SLIP	<p>Shared Land Information Platform The Shared Land Information Platform is a shared information delivery service that is designed to provide fast and easy access to the state's land information. SLIP facilitates improvement of business processes and systems that use land information across government.</p>
SP1	<p>SP1 Special Publication 1 Standards and Practices for Control Surveys. An Inter-Governmental Advisory Committee on Surveying and Mapping (ICSM) publication.</p>
SSM	<p>Standard Survey Mark Physical ground mark for which accurate position has been established. Many also have accurate height.</p>

8.2 Supporting Information

What is a geodetic framework?

A geodetic framework is the documented system of all the physical and abstract elements required to fully realise a spatial reference system for practical use. It includes the mathematical models that define the datum for coordinate computation, the ground marks, the survey measurements and their coordinates and the document trail that provides traceability. A geodetic framework delivers a rigorous, complete and reliable realisation of position.

Australia's current geodetic framework includes two datums, the Geocentric Datum of Australia 1994 (GDA94) providing the horizontal datum, and the Australian Height Datum 1971 (AHD71) providing the vertical datum. It is a 'two-plus-one' dimensional framework: horizontal and height.

Western Australia's geodetic framework reflects the development of the State and the gradual improvement in technology experienced over a long period of time. It is used by surveyors for the spatial control of all major projects within the State. The extension and maintenance of the framework's ground marks is focussed on:

- populated and industrial areas (especially the Perth metropolitan area);
- other areas of high economic value or proposed development (such as for agriculture and the development of natural resource);
- communication and transport routes; and
- State responsibilities for land tenure, land management and national security.

Western Australia's geodetic framework has more than 54,000 ground marks. Their distribution across the state reflects the State's priorities and the survey methods used. There are:

- 25,000 Bench Marks (BMs). These have precise differentially-levelled heights but only approximate horizontal position; and
- 29,000 Standard Survey Marks (SSMs). These have a precise horizontal position and many have precise height.

Depending on the survey method and its adjustment, SSMs and BMs have various standards of Positional Uncertainty and Local Uncertainty. These correlate approximately with accuracy and precision [refer to the Glossary for definitions]. Local Uncertainty between ground marks in WA is low, ie. precision is high and supports most applications. Recognising the localised extent of most surveys, Local Uncertainty has the greatest effect – historically, surveyors have focused on precision and consistency across their survey area, not absolute positional accuracy.

Adopting a strategic view, the existing geodetic framework may be considered a first-generation model. Its use of an extensive network of ground marks, coordinated by conventional survey methods has been a slow, but robust, and very successful method for propagating geodetic infrastructure across the State. However, the cost of meeting the expectations of users for the distribution and accuracy of first-generation ground marks is

now prohibitive. Further, there is now a growing expectation in modern society for easy, accurate and cheap access to the geodetic framework.

Since the 1990's, the advent of Global Navigation Satellite Systems (GNSS) have changed the understanding on how best to deliver a geodetic framework. GNSS delivers a true three-dimensional survey system. Potentially, GNSS can deliver low positional uncertainty AND low local uncertainty. GNSS is revolutionising the way many surveyors work. It is also being used by many Western Australians with little, or no, understanding of geodetic principles. Therefore, a significant concern for government is the level at which GNSS is properly integrated with Western Australia's geodetic and legislative frameworks. In particular GNSS operate on different datums and due to their dynamic nature are not easily applied to Western Australia's static datum (GDA94) as would be hoped or believed.

Why do we need a geodetic framework?

A geodetic framework supports the sound management and development of land within the State. It provides the foundation on which the state's spatial data sets, such as mapping and GIS databases, may be built with confidence. It allows users of spatial information to compute distances, directions, heights, areas and volumes with a consistency and reliability that cannot be assumed for data that is not connected to the framework. It provides an open system of data and protocols that allow surveyors to mix data from different surveys with ease.

The existing first-generation framework requires users to physically occupy ground marks to be able to propagate the framework's integrity and accuracy into their work. This requires specialised equipment and techniques that are central to a surveyor's training and professional competence. A second-generation geodetic framework will not have the same requirement for occupation – a user will only need to compute a connection to the framework by obtaining GNSS data from the second generation marks. However, a surveyor's professional requirement for checks and redundant measurements means that physical ground marks will still be required for quality control in the short to medium term.

A second-generation geodetic framework will be a three dimensional datum. It will be fully compatible with GNSS and compatible with the first-generation framework. Backwards compatibility is required for two reasons: firstly, conventional survey is still the primary survey method used within the geodetic framework especially for BMs and urban SSMS; secondly, GNSS is not a replacement for existing survey technology, it is just another measurement tool. Further, into the next decade, the most significant limitations on survey-grade GNSS work will remain the range-from-base, connection to the local survey infrastructure and signal obstruction.

However, GNSS does need special attention if the State and all users of spatial data, not just surveyors, are to realise the benefits to productivity that GNSS offer in areas beyond conventional survey applications.

The State's geodetic framework also provides an open spatial infrastructure on which any creator of spatial data can build or add value. The infrastructure metaphor is valuable when considering the need for a geodetic framework; in the same way that electricity and roads are taken for granted within a modern society, a geodetic framework, almost invisibly, supports the confident, open and reliable management and development of land and the interests of landholders.

Recognising that the integrity of the cadastre is fundamental to the development and prosperity of the State and its citizens, the Government has implemented regulations that require Licensed Surveyors to connect their surveys to the geodetic framework. These connections are central to upgrading the SCDB to survey accuracy. A SCDB with geodetic integrity and accuracy will support re-establishment surveys, using either conventional survey methods or GNSS. Primarily though, it will improve the development, management and administration of land and the maintenance of built infrastructure. An accurate and precise geodetic framework will strengthen the SCDB and provide the State with a resource upon which a multiplicity of spatial applications and data sets may be built.

What are the geodetic issues facing Western Australia?

There are a number of geodetic issues currently facing Western Australia. They are not an immediate threat to the State's future but, if not properly addressed, will become a brake on its development. These include:

- The current horizontal datum in Australia, GDA94, is a static datum with coordinates fixed at the beginning of 1994 to the realisation of the ITRF at that time. GNSS use the ITRF and associated datum or a reference frame and datum closely aligned with it.

The ITRF is fixed at the centre of the earth's mass (including the oceans and atmosphere) and tied to the earth's polar axis. More than 200 well distributed tracking sites that contribute to the realisation of the ITRF monitor the movement of the earth's surface. The dynamic nature of ITRF with coordinates constantly changing in line with continental drift has resulted in an offset with GDA94 coordinates of approximately 0.9m as at 2007.

Using GNSS it is relatively easy to measure this difference. There are two practical solutions available for the transformation of ITRF coordinates into GDA94 coordinates. The current solutions include using a datum shift that is constantly being updated or a datum shift that can be calculated for a point in time using a rate of change factor. It however is not generally acceptable to stakeholders to impose a time varying coordinate system to account for the movement of the earth's crust;

- The current vertical datum, AHD71, has inconsistencies relative to GNSS derived ellipsoidal heights using the current geoid model, AusGeoid98. Other incompatibilities conflict with the free use of GNSS for major projects. These include slow trending biases and 'jumps' between adjacent AHD71 level traverses. The effect is regularly seen in GNSS surveys where many more connections are required to benchmarks than to horizontal control. The incompatibility between AHD71 and geoid heights has three possible solutions:
 - Develop a correction surface to minimise the impact of the bias and known anomalies;
 - Develop a new height datum based on ellipsoidal (GNSS derived) heights and the geoid; and
 - Wholesale readjustment of AHD71 to remove the known anomalies.

The current strategy is the first option and this is being developed as a national correction surface that will be released in conjunction with the next Geoid Model – expected early 2008. A by-product of the correction surface will be an ellipsoidal height datum, based on a subset of the geodetic network, that will be maintained for scientific and high accuracy height requirements. The need for this subset to be expanded to the entire network will be monitored;

- The use of the Precise Point Positioning (PPP) method highlights another potential issue with AHD71. The effects of ocean tide loading and earth tides create a vertical motion in the continental plate, particularly along the coast where most of the population and infrastructure exists. Potentially PPP will have the ability to measure this effect. The tidal effect is insignificant using differential methods such as spirit levelling or (short) GPS baselines;
- There is likely to be a relativity issue between the new CORS network and the existing ground mark network. The CORS network will be coordinated through highly accurate surveys not previously achievable for the ground mark network. This will inevitably lead to the readjustment of some marks to ensure compatibility and in the longer term a wholesale readjustment of the horizontal coordinates;
- Adoption of a second-generation geodetic framework will have implications for the maintenance of ground marks that must be worked through with industry. Maintenance of ground marks is required to support conventional survey methods and as a fail-safe infrastructure, but not all existing marks may need to be maintained; and
- Legal issues around GNSS need clarity. Legal Traceability of a GNSS solution is problematic as the statistical nature of positioning means it is not possible to be as certain of the result as, for example, a length measurement. This, and the multiplicity of possible uses for GNSS positions, may have implications for the liability of GNSS users, amongst both the survey industry and the public.

These issues need resolution and integration into WA's geodetic framework before the State, industry and the community can confidently obtain the highest accuracy and reliability from GNSS.