REVIEW OF WESTERN AUSTRALIA’S GEODE蒂C FRAMEWORK AND PRIORITIES FOR SURVEY AND POSITIONING INFORMATION

SCOPING PAPER

Prepared by

H. J. Houghton
Land Consultant

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EXECUTIVE SUMMARY

The Department of Land Information (DLI) is to conduct a strategic review of Western Australia’s geodetic control framework during 2005. This report identifies the issues that should be addressed during that review, and the relative priority of those issues. It also identifies broader issues concerning surveying and positional information, including the interface between government and the surveying industry.

Western Australia’s existing geodetic framework is a reflection of the development needs of the State and the available technology at the time. It is a passive framework used predominately by surveyors for control of a diversity of projects covering the State. These mapping, engineering and infrastructure projects depend on the availability of an accessible, homogeneous statewide geodetic framework with consistent and accurate horizontal and vertical coordinates.

The advent of sub-metre positioning from the GPS satellite constellation has provided real time, active and accurate positioning information to the surveying industry and the wider community. Surveyors still need to relate their GPS position to the existing geodetic framework, while general users calibrate their measurements against the current framework coordinates. Calibration is essential to ensure measurements are on the correct datum and relate to the existing datasets which are based on the Australian Geodetic Datum.

GPS technology has advanced to the stage where horizontal and vertical position can be determined to a high accuracy (centimetre level) through a network of Continuously Operating Reference Stations (CORS). Future satellite systems to be launched over the next decade offer continuity of services and improved real-time positional information. The USA, Canada, Great Britain, Europe and New Zealand have operational CORS networks, while the Commonwealth and several Australian states are establishing CORS networks to meet the community’s wider needs for position. These countries are maintaining a core framework of ground survey marks from their existing geodetic infrastructure to support survey needs and allow calibration. Uses include asset management, machine control, tectonic plate monitoring, mapping and GIS applications. Western Australia does not have a strategy for how it will take advantage of this developing technology, and despite some isolated GPS applications, is a considerable way behind most states in the use of CORS technology.

While the ownership and responsibility for managing and maintaining the existing geodetic framework is clearly acknowledged as resting with State government, the role of government in facilitating the uptake of CORS technology is not as clear given the wider community need for positioning information. The role of government in facilitating the uptake of CORS needs to be clarified. Is it one of policy development, or of active involvement with industry to provide the base CORS network from which value added services can be developed? If government is to take a leadership role in the provision and use of positional information by the wider community, new skills and dedicated resources will be necessary.

In Western Australia, surveyors use GPS methods where conditions allow for a variety of tasks, more recently for cadastral surveys in rural areas and to connect their surveys to the geodetic framework. These connections are fundamental to the government’s aims for building a survey accurate Spatial Cadastral Data Base (SCDB).

The SCDB must have geodetic integrity and accurate coordinates to support surveys and to underpin the management and administration of land. The geodetic framework provides a homogeneous base through which the SCDB and all spatial datasets can be related.
Western Australia has been slower than other States to adopt Global Navigation Satellite Systems (GNSS) technology into its geodetic infrastructure. This may be to its advantage, given the potentially high capital costs, the rapidly occurring changes in technology and the introduction of a wider range of satellites via the GALILEO system in 2008. Equally however, it is clear that Western Australia should not postpone consideration of these issues, given the lead-times that may be required to introduce CORS networks or other technologies.

Should CORS technology prove to be required, then to take advantage of GNSS developments so they complement and enhance the existing geodetic framework, a transition strategy would be required. The existing framework would need to be retained to an agreed density to support current applications, while a CORS network was researched and established. This is particularly true for engineering projects where accurate height is necessary and for all projects requiring high accuracy positioning, as well as to support connection of cadastral surveys to the geodetic framework.

Issues to be considered relate to the uses and demand for new services, the appropriate role of government to facilitate the adoption of CORS, identification of benefits and costs and an appropriate funding model. Alternatively, if the review shows such a network is not a concern of government, how should the existing geodetic framework be managed and developed to continue to meet the needs of government and the community?

**Broader strategic survey and positional information issues** were also identified during interviews with key stakeholders and discussions with DLI clients. They are predominantly linked to the interface between government and the survey industry and the relationship that has resulted from that interface. There is a strong view that surveyors are key contributors to the cadastral system and provide additional information to maintain the integrity of both the cadastral system and geodetic framework. Better mechanisms are necessary to develop this cooperation and improve the total survey infrastructure for the State. Legislation for the protection of the geodetic framework and cadastral surveying requires modernising to support current and future demands on the survey system. Issues concerning survey data quality, service standards and improved communication of changes to DLI services to clients were also raised by many stakeholders.

From this, three areas of focus have been identified during this scoping study:

- issues concerning the State’s existing geodetic network;
- the potential uptake of GNSS technologies into the geodetic network; and
- broader issues concerning survey and positioning information.

A range of issues have been identified within these groupings, some of which overlap. In summary, these issues concern:

- The legislative and policy framework for the geodetic network, positioning information and survey matters
- The outcomes sought by government, industry and the community from the geodetic framework and the cadastre
- The appropriate maintenance and density of the existing geodetic network
Upgrade of the SCDB and use of survey accurate coordinates

Benefits, costs, risks and demand for a CORS network to support a geodetic framework and secondary use for real time positioning and decision making

Implementation and transition issues if a CORS network was integrated into the State’s geodetic framework

The respective roles of the State government and the private sector in providing a geodetic framework and introducing GNSS technology to it.

These issues are set out in some detail in Parts 3 and 4 of this report.

DLI had originally proposed that it would undertake a staged process to address issues raised in this scoping paper. This approach has been retained but with some modification. In summary, it is proposed that the Department address the issues in the following priority:

2005: reach agreement on existing geodetic network (strategic objectives, density and maintenance required)

2005–06: investigate use of GNSS technologies for geodetic network and real-time positioning; determine role of State government

2006-07: resolve broader issues concerning survey and positioning information.

The relative priority of the issues raised in this paper, and a process for how they should be addressed, are set out in Part 5.

Part 5 also identifies some other issues that would be more effectively addressed through DLI’s survey and customer service operations during 2005.

Before accepting this report and acting on its findings, the Department of Land Information seeks final comment from interested parties. Feedback is sought on the issues raised, their priority and the process for addressing them.

Please submit your feedback by 8 April 2005 to:

Duncan Mackay, Principal Policy Officer, Strategic Planning and Development, Department of Land Information, PO Box 2222, Midland, WA 6936

Phone 08 9273 7028  Fax 08 9273 7216  Email: duncan.mackay@dli.wa.gov.au

DLI will continue to consult industry groups and stakeholders during the detailed examination of the issues raised in this paper during 2005 and beyond.
1. INTRODUCTION

1.1 Purpose

The Department of Land Information (DLI) is to conduct a strategic review of the State’s geodetic control framework during 2005. The framework is a critical infrastructure for land registration and land development and supports the operations of a range of industries such as surveying, mapping, spatial information, engineering and construction.

Positioning technology is undergoing rapid and continuous development. Geodetic agencies internationally and in other Australian States are exploring the capabilities of GPS continuously operating reference stations (CORS) that broadcast corrections to enable accurate real-time positioning.

The review will consider the impact and use of technology such as satellite positioning systems and the capacity of the existing geodetic framework to meet the future needs of government, industry and the community.

This initiative arises from departmental reviews during 2003, in which the survey industry’s peak bodies identified a need for high-level policy development and a strategic focus on the relationship between the industry and government.

1.2 Terms of Reference

This scoping report is intended to assist DLI to determine the issues and priorities to be addressed during the full review, and the review process.

More specifically this report:

- identifies issues that should be addressed during a Departmental review of the State’s geodetic control framework during 2005, and the relative priority of those issues;
- recommends a process to the Department for conducting the review during 2005 and identifies groups and persons that should be consulted;
- identifies broader issues concerning survey and positioning information in which government has (or may have) a legitimate role, with particular reference to the interface between government and industry; and
- prioritises the order in which those broader issues should be addressed.

1.3 Background to the Review

In 2004 DLI commenced a process to better use its resources to deliver outputs. This process addressed the strategic alignment of DLI’s survey functions against the agency’s future direction. Key outcomes included a need for a strategy to develop the geodetic framework and formulate a more efficient mark maintenance regime.
These assessments indicated that a wider review of geodetic and related survey issues was needed for inclusion in DLI's forward planning. This report was commissioned to assist in scoping the issues for review during 2005. The 2005 review will result in an implementation plan for the development of the geodetic framework and identify survey reform items for inclusion in DLI’s policy and legislative program for 2006-2010.

1.4 Reference Group

DLI’s chief executive established and chaired an external reference group to provide advice to the Department and its consultant during the scoping phase of the review. The group comprised:

- Australian Spatial Information Business Association (Ray Watson)
- Dept of Spatial Sciences, Curtin University (Will Featherstone)
- Land Surveyors Licensing Board (Neil Browne)
- Spatial Sciences Institute (Peter Byrne)

The group met twice while members individually met several times with DLI’s consultant. The group reviewed the consultant’s draft report prior to its finalisation.

1.5 Scoping Study – Methodology

DLI appointed an independent consultant (Henry Houghton) to prepare a scoping paper prior to the main review. The consultant’s work was addressed in three phases:

- Initial meetings with key DLI staff and the external reference group. An assessment of the existing geodetic program; a review of the situation and strategic directions in other jurisdictions, and to formulate interview questions.
- Conduct and analyse interviews, and consult with the reference group members.
- Identify issues; develop options and priorities for consideration during the DLI 2005 Review of the Geodetic Control Network.

A background paper (refer Appendix 2) was prepared describing the current geodetic framework, trends which are impacting the framework including the relationship with the cadastre and CORS technology; and a questionnaire designed to identify demand, roles, costs, benefits and transitional issues relevant to a future geodetic framework.

A cross section of some 22 DLI clients was interviewed (Appendix 3). Interviews were biased to surveyors who are the main users of the existing framework but users of positional information, GPS service providers and equipment suppliers were included to gain a better appreciation of potential uses of CORS technology and future technology trends. A summary of issues raised during the interviews is at Appendix 4.
### 1.6 Acronyms

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AFN</td>
<td>Australian Fiducial Network</td>
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<tr>
<td>ANN</td>
<td>Australian National Network</td>
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<td>AGCC</td>
<td>Australian GNSS Coordinating Committee</td>
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<td>AMSA</td>
<td>Australian Maritime Safety Authority</td>
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<td>BM</td>
<td>Bench Mark</td>
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<tr>
<td>CORS</td>
<td>Continuously Operating Reference Station</td>
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<tr>
<td>CRC-SI</td>
<td>Cooperative Research Centre – Spatial Information</td>
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<tr>
<td>GDA94</td>
<td>Geocentric Datum of Australia 1994</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite Systems</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>ITRF</td>
<td>International Terrestrial Reference Framework</td>
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<td>RTK</td>
<td>Real Time Kinematic GPS</td>
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<td>SCDB</td>
<td>Spatial Cadastral Data Base</td>
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<td>SSM</td>
<td>Standard Survey Mark</td>
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2. BACKGROUND

This section provides information and definitions to support the discussion of issues later in this paper.

2.1 Geodetic Framework

_The Geodetic Framework_ consists primarily of 54,000 ground marks covering the State. The marks consist of:

- 29,000 Standard Survey Marks (SSMs) that have accurate horizontal positions and usually an accurate vertical component. (In urban areas SSMs have spirit-leveled height and are extensively used for height purposes).
- 25,000 Bench Marks (BMs) that have accurate vertical position but only approximate horizontal position. BMs are generally located along roads at 5 to 10 kilometre intervals.

These ground marks are supported and made useable by a reference framework comprising geodetic and vertical datums, and datasets of survey data and computations.

The height network of bench marks is separate from the horizontal framework over the State, and together they form the geodetic framework. The marks are connected nationally to the Australian Geodetic Network to form a homogeneous framework of measured and coordinated marks that provide a position relative to the Earth’s centre.

Due to adjustment and observation accuracy, the absolute horizontal accuracy of WA’s geodetic marks is about 300mm. The absolute error of height control is harder to quantify. Anomalies exist because height is derived from a series of tide gauges around the coast and long level networks across the country.

Relative accuracy is also variable, but generally adequate to support most applications:

- **urban** areas, 70% of SSMs are within +/-0.03m (horizontal) and 95% of SSMs and BMs are within +/-0.03m (vertical);
- **rural** areas, 80% of SSMs are within +/-0.20m (horizontal) and 90% of SSMs and BMs are within +/-0.03m (vertical); and
- **remote** areas, 90% of SSMs are within +/-0.30m (horizontal) and 70% of SSMs and BMs are within +/- 0.03m (vertical).

WA’s geodetic network has grown as the State has developed, and the location of marks often reflects the technology and systems available at the time. Many marks were sited on hill tops for inter-visibility. However, this can make them difficult to access and use for positional information. This has been particularly evident since the advent of GPS technology and the flexibility and accuracy it offers. The hierarchy of orders has also determined network design.
2.2 Use and Users

The geodetic framework was first established in the 1850s and was developed and maintained primarily for geodetic control of mapping. Since the 1960s the framework has been extended and maintained primarily to provide geodetic control to support infrastructure development, with particular reference to:

- high population areas (esp. Perth metropolitan);
- environmentally sensitive areas;
- areas of high economic value (e.g. natural resources); and
- communication routes.

The geodetic network is also integral for the State’s strategy to improve the integrity of the cadastre by linking land boundaries to geodetic coordinates (see next section).

Surveys originating from the geodetic framework are essential to locate, map and construct infrastructure such as roads, dams, pipelines, pastoral properties, farms and town sites. Surveyors use the network to provide accurate positional control for infrastructure programs, engineering activities and for cadastral survey connections.

Surveyors are the primary users of the geodetic framework. The framework is a “passive” system that requires users to physically occupy the survey mark in order to use the system’s inherent integrity and accuracy for transferring position. This requires specialised equipment and procedures for survey control.

However, the geodetic framework is also used by a number of para-professionals for referencing assets, preparing “as constructed” surveys of services and maintaining databases of spatially related information. Local government and utilities use the framework to locate assets, while many are particularly interested in height for engineering and coastal applications where height is critical. The framework is essential to engineering planning, design and implementation.

The bench marks (Australian Height Datum height only) and standard survey marks (position and AHD height) are used by a wider group of professionals who require accurate, consistent height (e.g. for construction of water pipes and roads). Generally, AHD marks are more accessible and the technology for height transfer is simpler and cheaper.

Several government agencies depend directly on the framework for their asset management (Main Roads, Water Corporation) and require a maintained, homogeneous, State-wide framework to ensure integrity.

The framework is also used to support scientific studies such as monitoring the Meckering Earthquake zone and measuring variations in sea level due to the “greenhouse” effect.
All government agencies interviewed have varying reliance on the framework for asset management, but all use the SCDB as their source of cadastral information. Users also commented that the use of the SCDB combined with the information readily available through Landgate is giving improved productivity for work planning and survey. Therefore the integrity of the SCDB (provided by connection of all cadastral surveys to the geodetic framework) is critical to maintain user confidence in this dataset.

DLI’s Strategic Market Survey (2004) identified users of geodetic services comprised 53% private survey firms, all levels of government 26% with the remaining 21% being mining companies, engineering firms and other consultants.

2.3 The Geodetic Framework and the Cadastre

In simple terms, the cadastre is the collective ‘map’ of all parcels of land and shows the boundaries between each parcel as defined by an authorised survey. The cadastre has traditionally existed and functioned without geodetic references, as cadastral boundaries were primarily defined by dimension (length and angle) and relationship to local monuments.

Since 2000, the State has required all cadastral surveys to be connected to the geodetic framework (as defined in regulations and guidelines made under the Licensed Surveyors Act 1909). This requirement was implemented to strengthen the future positioning and re-establishment of cadastral surveys because boundary marks were being destroyed at a rapid rate, causing the reliability and cost of survey to be adversely affected. Uncertainty in boundary position has the potential to undermine public confidence in the land title system and therefore alternative boundary identification methods were required.

By connecting cadastral surveys to the geodetic framework, fewer boundary reference marks are needed and geodetic coordinates can be used to reliably relocate boundaries and efficiently locate any evidence of an original boundary. Most importantly the public’s confidence in the land title system is maintained.

Connections are by direct radiation if there is a clear line of sight, or by traverse (if it is not directly visible), between the cadastral boundary mark (generally a corner) and a SSM. This is normally done using ground survey methods, predominately traversing with Total Station equipment (a combined distance, leveling and angle measuring device). There is a growing use of GPS technology (see below) to effect connection; however despite offering some efficiency (potentially time savings of over 50%) it is not useable in all situations. Obstructions (such as buildings, powers lines, trees or the general terrain) can interfere with the GPS satellite signals or communication link between GPS receivers located on the geodetic SSM and the cadastral mark, limiting the effectiveness of GPS methods.

Cadastral connections are used to improve the accuracy of the Spatial Cadastral Data Base (SCDB). The SCDB is the fundamental administrative base used by the State to manage and administer all land. It also allows all other information such as heights, assets (pipelines, telecommunications, power, gas, etc.), roads, vegetation and soils to be accurately and unambiguously related and aligned.

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1 WALIS Publication at www.walis.wa.gov.au
Over many areas where survey accurate SCDB coordinates exist, the SCDB supports the efficient re-establishment of property boundaries and the design and location of new surveys. It is inevitable that the SCDB coordinates will eventually come to be regarded as strong evidence in the property boundary definition process.

Coordinates of land parcel boundaries in the SCDB were originally digitized from maps but have been progressively upgraded to survey accuracy. Currently about 70 per cent of the land parcels in the SCDB have been upgraded to survey accuracy. Substantial completion of this upgrade within the near future will require a priority and additional resourcing. Following this phase, the SCDB could move to maintenance mode, i.e. all new cadastral surveys will be added as lodged at DLI and their integrity retained.

### 2.4 Global Positioning System

Global Positioning System technology has been available for about 20 years. While the technology has popular applications such as boat and vehicle navigation, it is also revolutionising the work of surveyors and other professionals who need high-accuracy positioning information.

GPS is based on a satellite constellation owned by the United States federal government, which broadcasts precise time signals and orbit parameters. These signals are acquired by GPS receivers which in turn calculate position with respect to the earth’s centre. GPS operates world wide, and the coordinates of any position can be calculated on an earth centered datum (e.g. ITRF) or converted to a specific datum such as that adopted for Australia; the Geodetic Datum of Australia (as determined from GPS observations in 1994, hence GDA94).

While GPS was originally established for military purposes, the growing civil use of GPS and, more generally, Global Navigation Satellite Systems (GNSS) has resulted in a new USA Spaced-based Navigation and Timing Policy, which (among other aims):

> “recognises the growth in civil use of GNSS as a global utility whose multi-use services are integral to US national security, economic growth, transportation safety, and homeland security and an essential element of the worldwide economic infrastructure.”

Other GNSSs operated by Russia (GLONASS) and Europe (GALILEO) provide redundancy and reduce the risk of system failure. This is becoming increasingly important as the number of users, the extent of global reliance and the range of applications increase.

The use of GPS for accurate positioning by surveyors is increasing as the cost of receivers comes down and industry competition increases. Several WA firms use GPS extensively for cadastral surveys, particularly in rural and remote areas where the geodetic control framework is sparse or inaccessible. GPS is not effective in forested areas or in the “urban canyons” of the city as it needs a clear horizon to receive signals from the satellite constellations. Horizontal accuracy is dependant on the method used, and can range from 10 metre to 10 millimetres, while height is more variable and influenced by satellite geometry, receiver quality and local gravity variations.

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2. www.dli.wa.gov.au Metadata for the SCDB
3. www.agcc.gov.au
2.5 GPS Positioning Methods

There are several methods used to obtain different orders of positional accuracy from GPS:

- **Point Positioning:** Receivers use broadcast information from the satellite constellation (normally four satellites) to give instant position. Errors due to satellite orbit errors, atmospheric effects, clock errors, etc. limit accuracy to about 10 metres. Because of these errors, results from either cheap navigation (single frequency) or expensive survey accurate (dual frequency) receivers are similarly affected.

- **Wide Area Differential GPS:** To improve the accuracy of positions obtained from GPS, differential corrections can be applied to the observed position at the remote site. These corrections are calculated at one or more base stations by comparing the observed position with the known position at these base stations. Normally, these base stations are a permanent service, such as AMSA. The accuracy of differential GPS is about 0.5 metre to 5.0 metre and generally degrades with increasing distance from the nearest base station. The user needs one GPS receiver and a communications link for correction data. The service provider operates base stations on known locations (linked to the existing geodetic framework).

- **Classic Static Differential:** If accurate survey position is required, two or more geodetic (high precision) receivers are used, with at least one operating from a known position (usually on a geodetic mark). By using the phase of the GPS signal rather than the satellite-receiver distance (the pseudo-range) a magnitude increase in accuracy compared with Differential GPS methods is possible. Simultaneous observations for several hours are required and with appropriate post-processing of the data, this technique can be used over several hundred kilometers to produce relative accuracy of about one part per million (e.g. 10 millimetres over 10 kilometres).

- **Rapid Static Differential:** A similar method to Classic Static Differential, but only applicable to short lines (less than 5 kilometres). Observation times can be reduced to less than 30 minutes.

- **Real Time Kinematic (RTK):** A minimum of two geodetic receivers are required, one at a known base station (normally a geodetic mark) and a rover collecting data at unknown stations. Additional rovers can be used where corrections are transmitted on open channel radio. Depending on conditions, terrain, vegetation, radio strength, etc. RTK can be used over distances of up to 10 km with an accuracy of between 2 and 10cm. Corrections are applied in real-time and no post processing is required. This method is used extensively for land sub-division and cadastral connections.
2.6 GPS Positioning Services Available Over Western Australia

There are several “active” GPS base station systems covering part or all of the State:

- The Australian Maritime Safety Authority (AMSA) Beacon system developed to provide national off-shore navigation services and coastal regions, providing near real-time position to about 2.5 metre.

- AUSPOS (Geoscience Australia) is a Classic Static Differential system which requires a minimum of six hours of data and using a free post-processing service can give positional accuracy of 5 to 10 centimetre anywhere in the State.

- OMNISTAR, is a commercial service for subscriber-based positioning anywhere in the State in near real time (0.1 to 1.0 metre), and uses wide area differential GPS techniques.

None of these services provides sufficient coverage and accuracy to support urban cadastral survey or engineering surveys. In remote areas, results from post-processed data from the AUSPOS system (at least six hours of observations) can give acceptable position to locate a survey. Where practical and economic, surveyors use RTK GPS survey methods to carry out cadastral surveys. This requires two survey quality GPS receivers, one as a base located on an existing geodetic framework SSM and one as a rover.

2.7 Continuously Operating Reference Stations (CORS)

An active CORS system provides corrections in real time to support real time positioning. A CORS system can also transmit signals to a central computer from which data are accessed by expert users online or on demand for post processing of position (e.g. the AUSPOS system). This distinction needs to be understood, as it provides potential for significant gains without significant cost. Active CORS requires sophisticated communications technology and a denser network of stations.

CORS is the general term given to an active network of RTK GPS stations. It consists of a network of GPS receivers located on known points (position and height), feeding data from GPS satellites within range to a central computer. This data is processed, corrected and re-transmitted to the GPS stations in real-time. Subscribers to the service can operate a rover GPS and receive corrections broadcast from the GPS stations to accurately compute their position in real-time. To achieve high accuracy, CORS sites are generally located between 20 and 50 kilometres apart to avoid atmospheric uncertainties which impact accuracy.

CORS technology is changing rapidly, and methods are being tested in Victoria (GPSnet), Queensland (SunPoz) and Sydney (SydNET), to optimise the services and provide a level of redundancy45.

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4 Implications of Incorporating Digital GPS Networks into Traditional Geodetic Infrastructures. ICSM Geodesy Technical Sub-Committee Draft Paper, December 2004
5 Proceedings of the 2004 International Symposium on GNSS/GPS, Sydney, Australia, 6-8 December 2004
There are variations to these configurations offered by equipment manufacturers. For example Trimble’s Virtual Reference Station (VRS) technology is designed to improve accuracy to the centimetre level. In the case of a VRS system, a user’s GPS rover dials the computer via mobile phone and sends its approximate position. The computer then generates a Virtual Reference Station at that approximate position and sends corrections. The rover is then positioned in real-time with centimetre accuracy relative to that Virtual Reference Station. However, these positioning methods are not always available due to terrain, building and vegetation obstructions.

Australia operates a “Zero” Order network on the eight Australian Fiducial Network (AFN) sites, continuously monitoring the position of the stations for integrity purposes and to assist global monitoring of the GPS system. It is these stations which act as base stations for the AUSPOS service. Corrections from the AFN sites (collectively the AUSPOS system) are retrospectively applied to observations recorded at any rover sites occupied by users across Australia. The Australian National Network (ANN) of some eighty geodetic stations across the country has been adjusted with the AFN stations and the values adopted to support the new GDA94 datum.

The AFN positions were used to realise the Geocentric Datum of Australia (GDA94), and to define position (in terms of a group of three coordinates) as a recognised value standard for legal traceability purposes.

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6 Guidelines under the National Measurement Act 1960
3. GEODE蒂C FRAMEWORK AND CADASTRE – GENERAL ISSUES

This chapter sets out issues concerning the management of the geodetic framework and planning for its future. These issues relate to, and overlap with wider issues for survey and positional information and the cadastre. The uptake of global navigation satellite systems technology into the geodetic network is discussed in chapter four.

3.1 General Demand

Most surveyors commented that they could not see major change in demand for geodetic control. Because projects occurred throughout the State demand was variable, but well coordinated geodetic marks were required to be available on demand. There is an expectation that government will provide appropriate framework density as needed to support such development. This was particularly the case for cadastral connections, viewed as a regulatory requirement of government.

Concern was expressed by several users that there was a risk of long-term degradation of the integrity of geodetic coordinates through the loss of survey marks. While some users extracted information for all marks over a project area for planning purposes, they indicated this was done to ensure sufficient information on marks in an area was available in case some marks were missing and alternative marks had to be used, i.e. to provide redundancy. Quantity should not be seen as a measure of demand, i.e. volume is not relevant, quality of the coordinates used and the value-add is a better measure.

The capacity of the existing geodetic framework to meet current demand is therefore linked to DLI’s ability to respond to densification needs over new development areas and the maintenance strategy adopted. There are no major changes in demand expected in the future, provided the integrity of the state-wide framework is maintained.

3.2 Maximising Value of Geodetic Connection and SCDB

The requirement for surveyors to connect a cadastral survey to the geodetic network is expected to yield long-term benefits for government, the survey industry and the public. These benefits need to be identified, harnessed and capitalised upon.

As a result of geodetic connection, the State will amass a survey accurate spatial infrastructure that can function as an authoritative dataset for all government land administration and asset management. Surveyors will be able to use survey accurate geodetic coordinates from the SCDB to quickly locate cadastral points, reducing the level of work required in re-establishing survey boundaries and for surveying new subdivisions (where cadastral marks are regularly destroyed during development).

An increasing number of cadastral surveyors are using the SCDB coordinates (derived from cadastral connection to the geodetic network) to assist in new survey design and asset location. Users commented that the use of the SCDB, combined with information available via Landgate, is improving productivity for work planning and survey.
Nevertheless, users were not necessarily clear on the government’s objectives for the development of the SCDB or the rationale for connecting cadastral surveys to the geodetic network. Previous studies and a cadastral survey industry workshop identified key elements of a cadastral strategy to support the demands of a modern society, which included the need for a reliable geodetic coordinate base for assisting in boundary definition. Despite these activities, there is still some industry debate on the requirement to connect cadastral surveys to the geodetic framework, and clarification of Government’s objectives for this requirement is needed.

Government and industry need to develop a shared and common vision for cadastral and geodetic infrastructure and assess ways to capitalise on the value and investment made through geodetic connection and the development of survey accurate coordinates, and consider how to identify and maximise the benefits of the dataset. Issues that could be addressed through this process might include: what standards are required for cadastral surveying, the status of the SCDB, traceability of measurements, role/legality of coordinates for survey, etc.

<table>
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<tr>
<th>ISSUE</th>
<th>A shared vision to realise the benefits of the geodetic infrastructure and cadastre is required from government and industry.</th>
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<tbody>
<tr>
<td>ISSUE</td>
<td>Increasing reliance on the geodetic framework and the SCDB coordinates by surveyors is raising questions on the integrity and traceability of the SCDB coordinates, their legal status and use for both re-establishments of survey boundaries and in new subdivisions.</td>
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### 3.3 Geodetic and Survey Legislation

A related issue is the legislative framework to support the geodetic network, the SCDB and cadastral connection to the geodetic network.

The requirement for surveyors to connect a cadastral survey to the geodetic network has increased the importance of the network in respect to legal boundary (cadastral) surveys and thus land ownership.

The *Standard Survey Marks Act 1924* has been adopted in Western Australia as the legislative basis for the establishment and maintenance of both the horizontal and vertical components of the State’s geodetic framework. Despite the Act being somewhat dated it remains as the principal enabling legislation and is used to protect survey marks. There has never been a prosecution under this legislation and its effectiveness in protecting the geodetic framework is questioned.

DLI’s Business Improvement Report 2003 commented that the Act needs updating and a possible “Survey Coordination Act” may be necessary. Legislation in Queensland and Victoria would provide a model that could be adapted.

| ISSUE | Legislation for the definition and protection of the geodetic framework is outdated, ineffective and in need of modernisation. |

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7 Discussion Paper on Cadastral Infrastructure: Strategies for meeting Community Needs, DOLA, 1999
8 A workshop on the Cadastre of Western Australia, Institution of Surveyors Inc. W.A. 1998
A related question is which government body should in future take lead responsibility for making regulations and guidelines for survey practice. The Land Surveyors Licensing Board has traditionally played this role and was instrumental in driving the strategy to connect cadastral surveys to the geodetic network. The Board has historically been closely associated to DLI and predecessor departments through its membership and administrative location. The Board, under the ex officio chairmanship of the Surveyor General, has been primarily responsible for making regulations for survey practice in WA.

It should also be noted that parties other than the Board are able to make regulations governing survey practice under various Acts of Parliament, including the Registrar of Titles, Commissioner of Titles, Minister for Land Information and the Governor.9

As a result of competition policy changes made to the composition of the Board, and administrative changes to be made to the Board’s relationship with DLI, it may be appropriate for the Board to focus increasingly on the occupational licensing of cadastral surveyors. In this respect, there is potential for the Board to gradually move to a model where it functions as the self-regulatory arm of the profession rather than serves as a government body for regulation of industry practice.

This approach would be consistent with other jurisdictions in Australia and New Zealand, notably in Victoria and Queensland.

**ISSUE:** A new legislative or policy model may be required for the long-term regulation of cadastral surveyors and surveying in WA.

### 3.4 Geodetic Marks – Density and Maintenance

The Department of Land Information, as the custodian of the geodetic framework is responsible for maintenance of SSMs and data management and information access in conformity with national and international standards for geodetic control frameworks.

Through legislation, the Government has indicated its requirement for connection of cadastral surveys to the geodetic framework to underpin the State’s land titling system and administrative responsibilities. In fact, since the 1900s the State has required surveyors to maintain the cadastral survey system to provide certainty for cadastral boundaries (Licensed Surveyors Act 1909). Cadastral connections are an essential part of retaining certainty and public confidence in location and re-location of cadastral boundaries. Maintenance of the geodetic framework is important to support these objectives.

Statistics indicate that some 500 geodetic marks are reported as destroyed each year, with DLI selectively replacing about 300 marks. Donated marks bring the replacement rate up to 500 marks per year; however the majority of these are from Main Roads WA associated with remote area road casement surveys. New ground marks are placed where development projects require control. The destruction rate equates to about 1% of marks, and, while comparable with international and national experience, is misleading as attrition is occurring in the more volatile areas where SSMs are required.

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9 The Registrar, Commissioner and Minister are able to make regulations under the *Transfer of Land Act* while the Governor may make regulations under the *Land Administration Act* and *Strata Titles Act*. 

Prepared by HJ Houghton for the Department of Land Information
Appendix 1 shows the trends in destruction and replacement/extension of marks since 1998-99 and the inspection rate. The statistics indicate that the rate of mark destruction remains fairly constant annually. Appendix 1 also shows that the density and maintenance program in WA compares very favorably with other Australian jurisdictions.

In developing urban areas, there is a general industry view that the framework is not meeting demand due to a lack of marks and mark maintenance. As the framework is used to provide control for land sub-division and to allow cadastral connection to support the development of a survey accurate spatial cadastral database (SCDB), user demand is for early densification of the framework over urban development areas. Many surveyors require these marks and their geodetic coordinates at an early stage in the land development process for initial sub-divisional design, to control servicing (drainage, water, and sewerage) and final cadastral connection.

While DLI undertakes targeted maintenance, there are a number of survey firms who do report on mark condition, although this is not mandatory. Reporting is therefore ad hoc, and due to cost and time constraints private surveyors do not replace damaged or missing marks. While surveyors have a legislated responsibility to maintain the cadastre, their contribution to the geodetic framework is voluntary, and not formally recognised or compensated for by government.

If the user-driven mark inspection trial proposed by DLI\(^\text{10}\) is to be successful, a partnering arrangement with industry will be essential. The requirement to connect cadastral surveys to the geodetic framework is for the long-term benefit of the community, government and surveyors, therefore the additional cost of geodetic mark inspection and maintenance should not be disproportionately placed onto the surveyor or their client.

Due to a lack of SSMs some surveyors are using alternative methods (e.g. height from existing sewerage manhole lids) to position services. These practices, while understandable, are highly undesirable, as they destroy the integrity of the framework and could lead to serious and costly mistakes in the placement of utility services.

Permanent Survey Marks (PSMs) placed in sub-divisions within Special Survey Areas (SSAs) as required by Regulations and guidelines under the Licensed Surveyors Act, are connected to at least two Geodetic Control Framework marks by private surveyors. However, there is no requirement for these marks to be leveled to provide AHD height, limiting their future value as control for survey. Height is becoming an important issue in cadastral surveys for height control in large complexes and definition in multi-level strata developments. As PSMs are part of the densified Geodetic Framework should height be mandatory to support subsequent surveys? A reasonably dense, maintained framework of SSMs is required to support this activity.

The existing density of SSMs was developed to support varying accuracy requirements over urban, peri-urban, rural and remote regions of the state. When established, line-of-sight was necessary to permit the original measurements, and to allow easy connection. Its configuration is a reflection of the measuring technology available at the time of establishment. The industry has an expectation that the existing density of SSMs will be available to allow cadastral connections to be done economically using available technology, generally Total Station (measures distance and angles electronically).

\(^{10}\) Business Re-alignment Report, Geographic Services-Survey Services, Business Improvement, 2003
One of the key tasks in the forthcoming review of the geodetic network will be to establish the density and maintenance requirements of the network. Improved survey technology now available for cadastral connections to the geodetic framework (Total Station and GPS) may allow for the density of the network to be relaxed, at least in certain areas.11 Matters that will have to be taken into consideration include:

- potential cost increases for surveyors if longer traverses were required;
- the accuracy of survey connection; and
- the accuracy of the ultimate SCDB coordinates derived from the survey.

Accuracy of height is also a critical consideration for network density. A number of users stressed the importance of SSMs and BMs used for height (Australian Height Datum elevations) and the inconsistencies within the framework. This was a particular concern for coastal zone developments and monitoring projects. The density and ongoing maintenance of BMs and SSMs used as height control for engineering purposes is important to minimise height discrepancies and to discourage substandard survey practices.

Future development of the geodetic framework raises the issue of “height modernisation”, where a new height model as defined by GPS observations (the ellipsoidal height) is used. This ellipsoidal height can be related to the AHD (a geoidal height, which is approximated by mean sea level), however the issue is complex and given the high dependence of many users on the existing AHD any change will require robust discussion. In Australia, the Intergovernmental Committee on Survey and Mapping (ICSM) and Geoscience Australia are investigating the technical implications of height modernisation but the impact on users of a change in height datum needs to be better understood.

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**ISSUE:** Agreement is required between government and users of the geodetic network on the appropriate density and level of maintenance for the geodetic framework. A related issue is the need for AHD heights for cadastral surveys and the accuracy required.

**ISSUE:** There is uncertainty over the accuracy and use of GPS derived height and its relationship to the existing AHD datum. The implications of an Australian “height modernisation” project (through ICSM) need to be better understood by stakeholders.

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11 DLI Geographic Services-Survey Services Business Improvement Report, 2003
3.5 Upgrading the Spatial Cadastral Data Base

Surveyors are using the coordinates from the SCDB to plan new cadastral surveys at the design stage, and to support sub-division development. They are also using the survey accurate coordinates to locate existing survey marks and to establish original land boundaries. Unless SCDB coordinates are survey accurate they are of little value. Many SCDB coordinates have been digitised from best available mapping (e.g. rural 1:25 000 scale, with potential for errors of up to 25 metres), and until cadastral surveys are connected to the geodetic framework and the survey accuracy reflected in the SCDB coordinates, these coordinates are not useful for cadastral surveys.

The SCDB has metadata (information about coordinates; source, accuracy, etc.) for each point, so the user can decide if the coordinates are suitable for their purpose. Survey accurate coordinates can be easily used with GPS and Total Station technology and are therefore in high demand. A survey accurate SCDB will provide the base information that surveyors of the future will use to establish and re-establish land boundaries.

Rural users in particular, are concerned about the density of the geodetic framework and the quality of the SCDB. More relevantly, some indicate a willingness to provide new information to support both the geodetic framework (through the placement of extra SSMs) and the upgrade of the SCDB to survey accuracy. However their perception is that DLI is unable to use the donated information in a timely manner to produce survey accurate coordinates for the benefit of all users. Some country surveyors report that it can be months or years before DLI uses a survey lodged with a cadastral connection to upgrade the SCDB in that area. One respondent stated that DLI had focused on developing a high quality title system and information access platform (Landgate), but had yet to seriously address deficiencies in the State’s survey system.

All surveyors commented on the increasing reliance placed on SCDB coordinates (of cadastral corners) to assist in the efficient re-establishment of cadastral boundaries. DLI has an ongoing work program for the spatial upgrade of the SCDB and plans to accelerate this work over the next four years. Subject to government funding, substantial capital funding will be made available to complete the upgrade.

| ISSUE: | A survey accurate SCDB supports the efficient use of modern survey technology (such as GPS and CORS) for cadastral surveys and asset location. DLI needs to communicate its plan to complete the spatial upgrade of the SCDB and the relevant annual work programs. |
| ISSUE: | Surveyors’ cadastral connections in rural town areas are not being used in a timely manner to upgrade the SCDB due to DLI’s upgrade methods and other program priorities. |
4. UPTAKE OF GNSS TECHNOLOGY INTO GEODE蒂C FRAMEWORK

4.1 The Need

This paper so far has focused on issues that should be addressed to develop and improve the existing model of the geodetic framework – that is, a network of ground marks that support engineering, infrastructure projects, cadastral surveying and other positioning uses such as asset management.

There is little evidence that the demand by users other than surveyors for the existing geodetic framework will change into the future. This is primarily because the existing framework is passive and requires specialist survey skills and time to derive and transfer accurate position. Accuracy and consistency will remain as the principle reasons for using the framework. Users have a high degree of confidence in the framework and mistakes are rare.

The existing geodetic framework would continue to support most survey needs, provided that it was modified to provide more accessible SSMs and that agreement was reached on the density and maintenance required.

However, it is appropriate and timely for State government to consider what role it should play in facilitating and driving the uptake of GNSS technology into the State’s geodetic framework. Surveyors are using GPS methods more routinely and understand its strengths and limitations; therefore a future framework which builds on this awareness and complements the existing framework is desirable. It must also be accessible and have high integrity to ensure positioning standards and the resultant data sets do not degrade.

A network of continuously operating reference stations (CORS) that actively provided positional information to a high accuracy over the most developed areas of the State could complement the current framework of ground marks and service wider real time positional information needs. Alternatively, a CORS network with post processing services (similar to AUSPOS or the original Victorian GPSnet service) could provide a simpler and cheaper solution to a number of users who do not require accurate (better than 0.10 metre) real time positioning.

CORS networks have been established nation-wide by geodetic agencies in USA (National Geodetic Survey), Canada, Great Britain (Ordnance Survey), New Zealand (Land Information, NZ), Sweden (Lantmateriet), Germany (Federal Agency for Cartography and Geodesy) and Hungary (Institute of Geodesy, Cartography and Remote Sensing). The Australian Fiducial Network (operated by the National Mapping Division of Geoscience Australia) provides a GPS post-processing service, while Victoria (Department of Sustainability and Environment) and Queensland are implementing real-time coverage at centimetre accuracy12.

In all cases these CORS networks have been established by government (while the private sector has developed value-added services based on the networks). In these jurisdictions high accuracy survey use of CORS, while important, does not appear to be a major driver, although the introduction of CORS has impacted the nature of geodetic frameworks.

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12 Implications of Incorporating Digital GPS Networks into Traditional Geodetic Infrastructures. ICSM Geodesy Technical Sub-Committee Draft Paper, December 2004
In general, the development of active CORS networks in other countries and within Australia has been driven by the wider positional requirements of the community, and not by the specific needs of existing geodetic framework users or cadastral surveying. In New Zealand and parts on the United States, for example, the key drivers for establishing a CORS network have been scientific and public safety issues, i.e. where the monitoring of the movement of the earth’s crust is critical.

In other jurisdictions the objectives for establishing CORS networks are less clear but seem to be linked to asset management, machine guidance, economic development and the opportunity to take advantage of new technology. Another driver for governments to implement CORS networks is the desire to avoid unnecessary duplication of services between competing private suppliers and potential confusion from overlapping services.

In summary, the key drivers for the establishment of CORS networks by governments appear to be:

- Monitoring earth crustal movements (plate tectonics, geoidal measurements) and other scientific studies. This driver is not directly relevant to Western Australia, although active measurement of the geoid in WA is done by Geoscience Australia.

- Providing reliable and definitive positional information for all forms of asset management and emergency services. This driver is relevant to Western Australia, but would require quantification of demand, accuracy, coverage and raises issues of State government’s role.

- Establishing a framework for continuous supply of positional information, at a consistent standard (e.g. common datum GDA94) in partnership with the private sector, from which value-added applications can develop. This is relevant to WA, but would require a cost-benefit assessment.

In WA, a CORS network over the more populated areas of the State would improve positional certainty for all users if it delivered homogeneous, quality assured centimetre positional accuracy, anywhere, anytime. However a strong demand for this level of service was not identified by those users interviewed. Demand appears to be satisfied by existing services, although experience suggests that demand for improved real time accuracy will grow as GPS positional technology improves. This has been the case in the USA, United Kingdom and Victoria.

### 4.2 Role of Government

Unlike the existing geodetic infrastructure, users’ views on the role of the State government in facilitating the uptake of a CORS network are mixed. Users acknowledge the government is the owner of the existing geodetic framework and therefore responsible for its integrity, completeness and maintenance. Because of the potential of a CORS network to service not only the survey industry but a wider range of users the role of State government in developing such a network needs to be examined.

DLI has committed to maintaining the existing geodetic network and will continue this when it becomes a statutory authority. If the authority were to develop or contribute to a government-owned CORS network, this would most likely be for reasons of public benefit rather than for commercial return.
Interviewees commented that State government’s role should not be as a competitor, but as a leader in establishing a CORS framework as a basis for industry to develop value added services. The role should be one of coordination to avoid unnecessary duplication and to prevent confusion which could result in safety issues, or undermine the economic competitiveness of the State. Others felt the government was responsible for a CORS but its ownership and operation could be a shared responsibility with both the private sector and Commonwealth government.

Several responses indicated a public-private partnership was appropriate, supported by a structured research and development program to complement the activities of the national Cooperative Research Centre (Spatial Information) of which DLI, other government agencies and a number of local survey firms are participants. Because government has not developed or communicated a policy on the implementation of a CORS network for the State, there is a lack of coordination and direction. It is possible that several CORS networks could be established over the South West of the State in the near future by private operators.

Many users stated that they were unaware of the State government’s strategic plan for the future provision of positional data, but felt it should take a lead role in the introduction of better positioning services for the State. Questions were raised over the government’s (and particularly DLI’s) capacity to effectively manage this role. Most believed there were limited opportunities for their views and input to be considered.

The role of the Commonwealth government was viewed as one of national coordination, international collaboration for continued involvement in satellite programs such as GPS and more specifically through Geoscience Australia, the operation of reference stations throughout Australia (a national CORS-AusPos, supporting the Australian Fiducial Network for international integrity monitoring of the GPS satellite network), and development of national standards through committees such as the Inter-government Committee on Surveying and Mapping (ICSM) and the Australian Global Navigation Satellite System Coordinating Committee (AGCC). There was limited appreciation by WA users of the respective responsibilities of these committees. Victoria has indicated that it had worked closely with the Commonwealth to ensure its GPSnet (statewide coverage) was compatible with the national framework.

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**ISSUE:**
State government’s role in developing positional infrastructure including and beyond the existing geodetic infrastructure needs to be defined and communicated. This will involve looking forward at real time positioning technologies and applications, and the roles to be played by State agencies including DLI.

**ISSUE:**
DLI will need to ensure it has appropriate skills and resources if it is to take a lead role within State government in determining and delivering positional certainty through CORS technology.

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4.3 CORS and a Future Geodetic Framework

Continuously operating reference stations have been established to support very high accuracy geodetic applications since the 1980s. Geodetic techniques are by their very nature ‘multi-station’, taking advantage of the geometric strength, reference datum stability (and redundancy) afforded by network-based positioning. Such CORS networks have been set up globally, as well as in geodynamic ‘hot spots’ such as Japan, Southern California and New Zealand where there is significant tectonic motion.

In Europe, as in many other countries, countrywide ‘active control stations’ have been established, consisting of CORS that collect data specifically for survey and mapping applications. In small, highly populated countries such as Germany and Denmark, the CORS systems provide high accuracy, real-time positioning services across the entire country. In Great Britain, traditional survey mark infrastructure has been modified by evolving GPS technology. The original framework of survey marks coordinated by the Ordnance Survey of Great Britain in 1936 (OSGB36) has gradually become less usable. It has now largely been replaced by a network of 30 active CORS stations and about 900 passive control marks, many of which were the original survey marks.

In Australia, Victoria’s GPSnet provides a State-wide service which is being upgraded to support centimetre accuracy in real-time. As a small densely populated state, Victoria’s strategy is appropriate, however, the existing geodetic framework will be maintained indefinitely to support survey activities. Queensland has a mix of CORS over developed regions, and accessible passive GPS stations at selected densities across the rest of the State, a similar strategy to the United Kingdom.

In Western Australia, a future geodetic framework was discussed with a cross section of existing users during the preparation of this scoping report. Most respondents acknowledged that a future framework would include a CORS component, although they saw risks in moving to total dependency on an internationally owned and operated positioning system. There were mixed views on the density required of CORS stations, but most believed State coverage (in some form) was necessary. Even with a CORS, users stated they required ground marks to provide redundancy (risk management), reference for re-establishment of position, and calibration of CORS and GPS equipment. Survey users foreshadowed demand for higher positional accuracy and certainty will continue as urban density increases and asset location/management within service corridors becomes more critical. Therefore, the consensus was that marks must be maintained at an agreed density and location for the foreseeable future; especially for height, and until satisfactory and repeatable accuracy can be generated from CORS positioning. As part of a transition plan, it would be necessary to continue to maintain and upgrade the existing framework until the paradigm shift in positioning has been realised and accepted by all users of the geodetic framework.

The ICSM Geodesy Technical Sub-Committee also concluded that the “introduction of GNSS has allowed a more targeted approach to the maintenance of the physical geodetic infrastructure. The network of survey marks is rapidly changing shape to target areas of high activity and significance” (Appendix 5).

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15 The Future of Geodetic Networks, a Report for DOLA by Spatial Sciences, Curtin University of Technology 2000
Consequently, because Western Australia is a large sparsely populated State, a future modified geodetic framework could include a CORS network over the more populous South West and a more accessible passive framework in rural and remote areas, using the existing framework wherever practical. The passive framework would consist of accessible survey marks at an agreed density, established by GPS and connected to the existing geodetic framework. This approach has been used in the United Kingdom and Queensland. Depending on the coverage of an active CORS network, a future framework is likely to support not only survey and mapping activities but real-time position-related information to a wider range of users.

A comparison of the existing and a possible modified future geodetic framework is helpful in identifying the relative strengths and weaknesses of each alternative. This comparison while not exhaustive summarises the main issues around each strategy.

### 4.3.1 Maintaining the Existing Geodetic Framework

**Advantages**

- Retains and continues the existing integrity of the framework
- Cost is maintenance only (no capital expenditure)
- It is a static asset and is “technology proof”
- It is usable by all surveying technologies
- State-wide coverage integrated with the national framework
- Could be made more user-friendly by siting some SSMs in more accessible locations

**Disadvantages**

- Marks are being destroyed more rapidly as urban development increases
- Many SSMs are difficult to access, thus adding to the time required for surveying
- Specialist survey knowledge and equipment is required to use effectively
- Normally be used in daylight only
- Mark maintenance is laborious and infrequent without a regular inspection program
- Occupation of two or more marks is generally necessary and thus time consuming
- The vertical control framework has inherent inconsistencies

### 4.3.2 Modified Passive Geodetic Framework Complemented by CORS

**Advantages**

- 24x7 access to centimetre accuracy in real time over CORS areas
- A rural-remote passive GPS framework which is easily accessible
- Integrity monitoring is continuous
- Accessible positioning to a wider user base
Disadvantages

- Establishment and maintenance cost of CORS are not known
- Changing technology could outdate CORS in less than ten years
- Not useable in all areas due to terrain and building obstructions
- Sophisticated communications required for real time positioning
- Risk of system failure (satellite, communications, CORS)

4.4 Secondary Uses of a CORS Network

A geodetic framework incorporating CORS technology would relay position-related information and attract a wider range of users than the current framework. At present, requirements for (non-survey) positional information are being met through existing positioning systems (including the geodetic framework).

These systems include:

- public free-to-air systems provided by AMSA (coastal beacon network, real-time, low accuracy, coastal areas) and Geoscience Australia (AusPos, statewide, post processed, moderate accuracy);
- direct GPS signals used by low cost hand held receivers (real time, State-wide, low accuracy); and
- subscriber-based services (OmniStar, real-time, statewide, medium accuracy).

The information from these services is used for asset management, engineering and construction, off-shore positioning, precision farming and general navigation. These applications have different accuracy needs but most operate in real-time mode.

Many users believe that the market for positioning services from CORS networks would increase rapidly in applications such as:

- machine control (earth moving equipment, construction);
- asset tracking and management;
- environmental monitoring;
- mining and mineral exploration;
- agricultural uses;
- geotechnical services;
- expanded survey services;
- all real time positioning applications;
- all forms of mapping for GIS purposes; and
- most importantly, where high accuracy real-time positioning is needed (monitoring, engineering and construction applications)\(^\text{16}\).

Current service and equipment suppliers believe growth will also occur as the number of GNSS increases later this decade with the advent of the European Galileo system. Nonetheless, there was limited feedback from interviewees on future use indicating a need for better market knowledge on possible applications.

Government (State and local) is also a significant user of geodetic survey and GPS positional information for many applications including vehicle tracking, vegetation mapping and monitoring and asset management. There are occasional reports of projects that use positional information and GIS (Refer WALIS News, Issue 23, Agriculture WA’s GIS goes mobile) which indicate the growing applied use of the technology. The extent of use and potential demand for positional information has not yet been formally raised through the WALIS Council. A more detailed understanding of this need is required to determine if a CORS network is needed.

Current and future applications will rely on the ready availability and quality of the government’s base datasets. Experienced users noted that because CORS allows real time position to support real time decisions, the base data used must be highly reliable. Data such as the SCDB, topographic and elevation models, roads detail and associated textural information is provided by government and must be compatible in accuracy to CORS-derived position, and accurate in content. Real time accurate positional information from CORS networks would test the integrity of government’s spatial databases and place pressure on the need to tag all spatial data with uniform and meaningful accuracy standards (metadata issues).

Irrespective of questions of a State CORS network, better communication is required between government agencies that use GPS to understand needs, avoid duplication and encourage cooperation. Communication is required with suppliers of positioning technology for the same reasons. WALIS may be an appropriate forum for these activities to occur.

The capability of DLI’s spatial datasets to synchronise with real time positioning provided by a CORS network would require examination and planning.

4.5 Benefits, Costs and Funding

Anecdotal evidence from Victoria\(^\text{17}\) shows that considerable investment is required to establish a CORS network, and develop a sufficiently reliable service to convince users to subscribe on a regular basis. The Victorian GPSnet experience commenced a decade ago and was built over time in collaboration with the private sector and academia to minimise direct cost. GPSnet has recently committed to an upgrade to provide real time GPS signal corrections to support high accuracy Location Based Services throughout the state\(^\text{18}\). The key driver (and benefit) of the Victorian strategy was to provide an authoritative CORS network over the state to service the diverse community needs for asset management and positional information. This initiative has avoided the costly duplication of resources and infrastructure which may have occurred if other groups had established ad hoc base stations over Victoria. Nonetheless, Victoria has committed to maintain the existing geodetic infrastructure in accordance with a formal risk management plan which concentrates maintenance on key areas.

\(^{17}\) Descriptions of the existing VicPosition (GPSnet) system, Ramm & Hale, 2003 and 2004, Personal communications

The situation in Western Australia is similar, with several interviewees (from the private sector) indicating their desire to establish CORS-type networks over the most densely populated areas of the State. Because the existing market for positioning information is diverse and is being serviced by a variety of GPS facilities, information on benefits is poor. There is a need for better market information to assist the evaluation of the benefits of a CORS network. Establishment costs approximate $40,000 per CORS station plus communication costs and ongoing operating costs.

Total investment would be conditional on the density and extent of CORS coverage, and the strategy adopted over rural areas of the State. For example, a CORS in every major regional town and a network over the Perth region and South West could require over 50 CORS stations.

Those interviewed were mainly users of GPS technology, and had accrued benefit from their individual experiences. They were generally uncertain on the additional benefits a CORS strategy may provide. Most users commented that it was undesirable to have duplicated systems providing basic positioning services, several remarked that the government should provide a basic network on which industry could innovate and value-add. Several views were expressed on the risks associated with monopoly services in a State which is large but with a small population.

Surveyors agreed that the obvious benefit of a CORS would be savings in equipment, (given that only one receiver, not two, would be necessary) and substantial time savings in not having to establish a base station for high accuracy position (1cm). Others believed there would be a cost to those surveyors who do not already have GPS equipment as they would need to invest to remain competitive. Some firms who do not have GPS equipment currently contract specialists to provide that service. Users indicated that current equipment would normally be replaced within five years but also to be compatible with the new satellite constellations planned from 2008 onwards. Most stated that the cost was not a barrier if it provided a competitive advantage.

Views were mixed on the appropriate funding model because it was not clear whether a CORS network was required to support and integrate with the existing geodetic framework, or whether it might be established for commercial activities. Those users who believed the government was responsible for positional certainty, standards and integrity monitoring felt government should pay; however, there were other views (based on the wider application of CORS) that funding should be a shared responsibility between state and federal government and the private industry.

Some users stated a user-pay principle should apply for access to CORS data (similar to the subscriber-based approach in Victoria and Queensland). The consensus view was that a public-private sector partnership was the best model given the mixed applications a CORS network would support. This model is used in Victoria and Queensland and is consistent with developments in the USA which has national and state-level networks. National networks (such as Australia’s AFN) are operated by federal governments, while state networks are generally a partnership.

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19 CORS networks in the USA
Some concerns were voiced over the risks associated with being solely dependent on CORS, with comments that a maintained (reduced) geodetic framework of ground marks was essential. Views on the risks of reliance on foreign owned and operated satellite services for position were balanced by the benefits accrued from the free-to-air service available, and the redundancy provided by having access to several satellite systems (American GPS, Russian GLONASS and the European Galileo system).

ISSUE: Better information is needed on the costs, benefits, risks and demand for the State government to establish a CORS network.

4.6 Implementation and Transition to Future Geodetic Framework

There are many users dependent on the existing geodetic framework, and national and international studies\(^{20}\) conclude that regardless of when a CORS network is established, there would continue to be a need for a geodetic reference framework of ground marks to support the activities of current users. This will be the case until an active CORS is in place (or any system which purports to provide accurate positional information), fully operational and completely accepted by all users.

All countries and Australian States establishing CORS networks are in a transition stage and none has moved to complete reliance on a CORS network. The United Kingdom strategy includes a number of passive geodetic ground marks (established by GPS observations) to cover less densely populated areas. A transition period of ten years was suggested by some users of WA’s existing geodetic framework, qualified by the need for uninterrupted coverage of all areas within a CORS network. Given the reliance of Australia’s spatial information infrastructure on accurate and homogeneous position, it is critical that the geodetic framework is never allowed to degenerate\(^{21}\).

There was limited comment on this issue, perhaps indicating a level of uncertainty on the potential of CORS technology and positioning methods which are still emerging. While the Australia CRC-SI\(^{22}\) consortium (of which DLI and several local survey firms are contributors) has a research objective over the next seven years to provide quality assured, homogeneous centimeter position, anywhere, anytime; the indicative timeframe illustrates the research and development complexities involved in producing reliable, accurate position information are formidable.

In summary, comments on implementation were mainly grouped around technological issues:

- Transition period of up to 10 years to allow CORS establishment, user exposure and technology take-up.
- Total reliance on CORS raises “black box” issues, where the user no longer has control or full understanding of the process.
- Strong local R&D commitment in close collaboration with users would be required to ensure users’ needs are addressed.

\(^{20}\) [www.geod.nr.ca.gc.ca](http://www.geod.nr.ca.gc.ca) (Passive networks, Traditional Reference Networks, Canada)

\(^{21}\) The Future of Geodetic Networks, Department of Spatial Sciences, Curtin University of Technology, 2000

\(^{22}\) CRC-SI Projects 1.1 (Enhancing Australia’s Core Geodetic Infrastructure) and 1.2 (Quality Control Issues for Real-Time Positioning) [www.crcsi.com.au](http://www.crcsi.com.au)
The impact of changing technology with the next generation of satellites and associated investment is unknown.

Potential geodetic datum change (possibly a dynamic datum as is the case in New Zealand) and the related traceability of coordinates.

Doubts over the completeness of CORS coverage due to “terrain shadows” affecting communications (similar to mobile phone “dead zones”).

Real-time positioning will require base datasets with high integrity, and at a comparable accuracy.

Users also commented on the need for legal traceability of position through the existing geodetic framework to the national standard (the AFN stations), the risk management associated with a less dense physical mark framework, and the lead times for technology uptake. Finally, views were expressed on the clarification of role and time required to concurrently undertake R&D and to establish responsibilities for ownership of the CORS, its ongoing, continuous operation and integrity monitoring of the framework.

<table>
<thead>
<tr>
<th>ISSUE</th>
<th>Agreement on the density and maintenance of marks would be required if a CORS network was integrated into the State’s geodetic infrastructure.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISSUE</td>
<td>The proclamation of position as a standard under the Commonwealth National Standards Act 1960 requires traceability where GPS position is used for legal purposes (cadastral surveying) and for prosecution of offences that involve legal position (e.g. fishing limits). The legal traceability of position to the standard requires definition in WA.</td>
</tr>
</tbody>
</table>
5. PRIORITY AND PROCESS FOR ISSUES IDENTIFIED

5.1 General Considerations

Based on interviews and an assessment of national and international trends, a number of key issues have been identified. The pivotal issues concern the strategic development of the State’s geodetic infrastructure, its relationship to the cadastre, and the ability to meet the long-term needs of government, industry and the community for accurate survey and positional information.

There are several options possible, ranging from “the status quo” (e.g. continue to maintain the current geodetic framework ‘as is’) to “do everything” (e.g. establish an active network of continuously operating reference stations across the State). The benefits, costs and risks of such options need to be better understood.

The role of State government in this process needs to be defined, both in protecting the public interest and in aiding Western Australia to maintain its competitive edge in the global economy. As a minimum, it is likely that State government would monitor framework integrity and set standards for CORS networks to ensure the State’s spatial information infrastructure is not degraded, and the community’s confidence in positional information is maintained. The role of the private sector needs to be defined too.

Western Australia has been slower than other States to adopt GNSS technology into its geodetic infrastructure. This may be to its advantage, given the potentially high capital costs, the rapidly occurring changes in technology and the forthcoming introduction of a wider range of satellites via the GALILEO system. Equally however, it is clear that Western Australia should not postpone consideration of these issues, given the lead-times that may be required to introduce CORS networks or other technologies.

Leadership is required in coordinating and developing a State strategy. This is an appropriate role for State government and for the Department of Land Information as the custodian of the existing geodetic network. DLI’s ability to engage with industry, academia and present and future users of the geodetic network will be pivotal to the development of a successful strategy.

A range of issues concerning survey and positional information were raised during the development of this scoping paper, and these indicate some level of dissatisfaction with the relationship between State government and the survey industry. Conversely, many participants indicated that the survey industry is willing to contribute to the integrity of the cadastral and geodetic systems, provided their contribution is recognised and used for the benefit of other surveyors.

Concerns were expressed that many issues have been debated over many years with little or no outcome, and a more focused methodology is required to achieve results. The process for accreditation of surveyors that was implemented in the 1990s was given as an example of a successful method used to address and resolve an issue.
5.2 Review Process

DLI had originally proposed that it would undertake a staged process to address the issues raised in this scoping paper. This process would comprise:

- Review of geodetic network and uptake of GNSS technology (2005)
- Implement geodetic review recommendations (2006)
- Review other strategic issues for survey and positioning information (2006 –2008)

This approach may not be suitable to tackle the issues raised in this scoping paper and their relative priority. Alternatively, it is proposed that DLI focus on three streams:

- priorities for existing geodetic network;
- potential uptake of GNSS technologies into geodetic network; and
- broader issues concerning survey and positioning information.

This work would be done concurrently and take place during 2005 – 2007. It is proposed that the issues raised in this scoping paper be addressed in the priority outlined below. Some related matters should be addressed directly through DLI’s survey and customer service operations.

5.3 Priority Issues for Review During 2005

| ISSUE: | A shared vision to realise the benefits of the geodetic infrastructure and cadastre is required from government and industry. |
| Timeframe: | Complete during 2005 |

The review should focus on a strategic vision and desired outcomes for government, industry and the community, irrespective of what kinds of technologies are used for geodetic infrastructure. DLI should lead this process by preparing a consultation paper and consulting with a wide community of users of the geodetic infrastructure and the cadastre, including the surveying industry.

| ISSUE: | Agreement is required between government and users of the geodetic network on the appropriate density and level of maintenance for the geodetic framework. A related issue is the need for AHD heights for cadastral surveys and the accuracy required. |
| Timeframe: | Complete during 2005 |

DLI should seek to build agreement on the required density and level of maintenance for the existing network of ground marks in the next five years for horizontal and vertical marks and irrespective of whether a CORS network might be introduced after that time. Agreement should incorporate the widest community of users of the network.
ISSUE: Better information is needed on the costs, benefits, risks and demand for the State government to establish a CORS network.

Timeframe: Commence 2005, complete 2006

There is insufficient information available for State government to make a decision on whether to develop a CORS network. Closer examination of the experience of other governments in establishing CORS networks, especially in Australia is required. However, experience in other jurisdictions is only of limited relevance in decision making for Western Australia, given the differences in population density, urbanisation, terrain, industry practice and the legislative and policy framework.

It is recommended that DLI commission a trial in the Perth metropolitan area of a limited CORS network, in order to gather better information on the costs, benefits, risks, uses and potential uses of such technology. The trial should involve Curtin University and other strategic partners and be designed to service a wide range of users.

ISSUE: Irrespective of questions of a State CORS network, better communication is required between government agencies that use GPS to understand needs, avoid duplication and encourage cooperation. Communication is required with suppliers of positioning technology for the same reasons. WALIS may be an appropriate forum for these activities to occur.

Timeframe: Commence 2005, ongoing work

5.4 Priority Issues for Review During 2006

The following issues should be addressed once agreement is reached on a vision for the geodetic infrastructure and better information is available as to the benefits, costs and risks of implementing a CORS network.

ISSUE: State government’s role in developing positional infrastructure including and beyond the existing geodetic framework needs to be defined and communicated. This will involve looking forward at real time positioning technologies and the roles to be played by State agencies, including DLI.

Timeframe: Commence late 2006, complete 2007

ISSUE: DLI will need to ensure it has appropriate skills and resources if it is to take a lead role in determining and delivering positional certainty through CORS technology.

Timeframe: Commence late 2006, ongoing
ISSUE: The capability of DLI’s spatial datasets to synchronise with real time positioning and decision making provided by a CORS network would require examination and planning.

Timeframe: Commence 2006

Examination of the above issue would be subject to the outcomes of the trial to be undertaken in 2005 and decision making as to State government’s role in developing positional infrastructure.

ISSUE: Increasing reliance on the geodetic framework and the SCDB coordinates by surveyors is raising questions on the integrity and traceability of the SCDB coordinates, their legal status and their use for both re-establishments of survey boundaries and in new subdivisions.

Timeframe: Commence 2006, ongoing

ISSUE: Legislation for the definition and protection of the geodetic framework is outdated, ineffective and in need of modernisation.

Timeframe: Commence 2006

ISSUE: The proclamation of position as a standard under the Commonwealth National Standards Act 1960 requires traceability where GPS position is used for legal purposes (cadastral surveying) and for prosecution of offences that involve legal position (e.g. fishing limits). The legal traceability of position to the standard requires definition in WA.

Timeframe: Commence 2006, ongoing

This issue is not unique to Western Australia. It is appropriate for DLI as the State’s land information agency to work on this issue with national organisations such as ANZLIC and ICSM and counterpart agencies in other States and Territories. DLI will need to also work closely with local stakeholders who may be affected.

5.5 Priority Issues for Review During 2007

ISSUE: Agreement on the density and maintenance of marks would be required if a CORS network was integrated into the State’s geodetic infrastructure.

Timeframe: Commence 2007

Examination of the above issue would be subject to the outcomes of the trial to be undertaken in 2005 and decision making as to State government’s role in developing positional infrastructure.
ISSUE: A new legislative or policy model may be required for the long-term regulation of cadastral surveyors and surveying in WA.

Timeframe: Commence 2007

Addressing this issue in 2007 will provide time for agreement on objectives, the development of a policy framework and for consultation with users and stakeholders.

ISSUE: There is uncertainty over the accuracy and use of GPS derived height and its relationship to the existing AHD datum. The implications of an Australian “height modernisation” project (through ICSM) need to be better understood by stakeholders.

Timeframe: Commence 2007, ongoing

5.5.1 Matters to be Addressed by DLI’s Survey Operations

The following issues were raised during scoping but fall outside the review process proposed. They are best addressed as operational matters by DLI during 2005.

ISSUE: A survey accurate SCDB supports the efficient use of modern survey technology (such as GPS and CORS) for cadastral surveys and asset location. DLI needs to communicate its plan to complete the spatial upgrade of the SCDB and the relevant annual work programs.

ISSUE: Surveyors’ cadastral connections in rural town areas are not being used in a timely manner to upgrade the SCDB cadastral areas due to DLI’s upgrade methods and other program priorities.

5.5.2 Matters to be Addressed by DLI’s Customer Service Operations

The following issues were raised during scoping but fall outside the review process proposed. They are best addressed as operational matters by DLI during 2005.

- While quality of survey information was raised (field books as microfiche copies), it was recognised DLI had partly addressed the issue by scanning all survey plans. More importantly the quality of customer service is causing concern, particularly the experience and responsiveness of staff.

- There were particular issues concerning Landgate which reflect a general lack of responsiveness and communication of service standards by DLI to customers. However, all interviewees were complimentary of the value added by access to datasets provided through Landgate. Users are accessing the system from the field and report favorably on its value.

- DLI’s future status as a statutory authority is not well understood, particularly with respect to its roles of delivering government services and commercial services.
5.6 User Groups to be Consulted

Government (state and local) is a significant user of geodetic survey and GPS positional information for many applications including vehicle tracking, vegetation mapping and monitoring and asset management. Agencies should be consulted on their current and future positional requirements; WALIS may be a suitable forum.

In addition to groups already identified (refer Appendix 2), there are several sectors who should be consulted during further review of the geodetic network and the uptake of GNSS technologies. They include:

- GPS (and related technology) suppliers, who have national and international experience and resources;
- CRC-SI interstate participants;
- operators of the Victorian, Queensland and New Zealand CORS networks;
- operators of the AMSA network and Omnistar system; and
- scientific organisations (including CSIRO and Geoscience Australia).

Suggestions were made that recreational users of GPS may have input, but no representative body was identified.
## 6. APPENDICES

### 6.1 Appendix 1 – Total Number of Geodetic Marks Maintained by Inspection Program and Other Surveys

<table>
<thead>
<tr>
<th>Activity</th>
<th>Geoscience Australia</th>
<th>New Zealand</th>
<th>TAS</th>
<th>ACT</th>
<th>S.A.</th>
<th>N.T.</th>
<th>Victoria</th>
<th>W.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Survey Staff</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>23</td>
<td>8</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>Office Staff</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1.5</td>
<td>6</td>
</tr>
<tr>
<td>Active GPS Support</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Work Outsourced (%)</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td>95%</td>
<td>0</td>
<td>0</td>
<td>0 (some contract maintenance funding)</td>
<td>0</td>
</tr>
<tr>
<td>Mark Inspection?</td>
<td>ARGN</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Frequency?</td>
<td>2 yearly</td>
<td>5 yr</td>
<td>Ad hoc</td>
<td>Ad hoc</td>
<td>N/A</td>
<td>Ad hoc</td>
<td>Ad hoc, opportunity basis</td>
<td></td>
</tr>
<tr>
<td>Rely on Industry Feedback?</td>
<td>N/A</td>
<td>No</td>
<td>Not reliable</td>
<td>LGAs, survey firms</td>
<td>yes</td>
<td>partly</td>
<td>mostly</td>
<td></td>
</tr>
<tr>
<td>No. Marks Maintained</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Over 80,000 in total</td>
<td></td>
</tr>
<tr>
<td>Horizontal and Vertical</td>
<td>100</td>
<td>54,800</td>
<td>2,500</td>
<td>2,100</td>
<td>2,100</td>
<td>7,000</td>
<td>29,000</td>
<td></td>
</tr>
<tr>
<td>Vertical only</td>
<td>40,000</td>
<td>40,000</td>
<td>6,500</td>
<td>6,500</td>
<td>6,000</td>
<td>25,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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23 Includes geodetic and cadastral survey functions.
24 Coordinated cadastre requires combined activity with geodetic
25 Supports GPSnet and existing geodetic infrastructure.
Total No. of Geodetic Marks Maintained by Inspection Program and Other Surveys

Financial Year

No. of Marks Maintained


Other Rural Towns Metro City

Prepared by HJ Houghton for the Department of Land Information
6.2 Appendix 2 – Strategic Review of Geodetic Network and Other Priorities for Survey and Positioning Information

Project Overview

This initiative arises from departmental reviews during 2003, in which the survey industry’s peak bodies identified a need for high-level policy development and a strategic focus on the relationship between the industry and government.

The Department of Land Information (DLI) is to conduct a strategic review of the State’s geodetic control network during 2005. The network is a critical infrastructure for land registration and land development and supports the operations of a range of industries such as surveying, mapping, spatial information, engineering and construction.

Positioning technology is undergoing rapid and continuous development. Geodetic agencies in other States are exploring the capabilities of GPS continuous tracking base stations that broadcast corrections to enable accurate real-time positioning.

The review will consider the impact and use of new technology such as satellite positioning systems and the capacity of the network to meet the future needs of government, industry and the community.

A consultant, in conjunction with a reference group of industry professionals, will assist DLI to determine the issues and priorities to be addressed during the review, and the review process.

The consultant and reference group will assist DLI also to identify broader strategic issues concerning survey and positioning information in which government has a legitimate role, and with particular reference to the interface between government and the survey industry. These issues may be broad-ranging and not necessarily linked to the geodetic network review. DLI will use this advice to prioritise a work program for policy and legislative review during 2006 - 2010.

Consultancy Brief

The consultant’s principal task will be to prepare for DLI a strategic report that:

a) identifies issues that should be addressed during a Departmental review of the State’s geodetic control network, and the relative priority of those issues;

b) recommends a process to the Department for conducting the review during 2005 and identifies groups and persons that should be consulted;

c) identifies broader issues concerning survey and positioning information in which government has (or may have) a legitimate role, with particular reference to the interface between government and industry; and

d) prioritises the order in which those issues should be addressed during an ongoing process of review during the period 2006 - 2010.
BACKGROUND DISCUSSION

The Western Australian Geodetic Network Status

- Was established over the past 150 years in response to the development needs of the State. Primarily, it was developed to provide positional reference for surveys and for both cadastral and topographic base mapping.

- Reflects the development needs of the State and the constraints of the available technology and topography, in that geodetic stations needed to be intervisible and no more than 50-60km apart.

- Has been used to support economic development (mining and agricultural), various infrastructure projects (dams, pipelines and other services) and the coordination of cadastral surveys.

- Consists of 29,000 Standard survey Marks (SSMs) with accurate horizontal position and usually accurate vertical heights; and 25,000 Bench Marks (BMs) with accurate height and only approximate horizontal position.

- Complies with national and international standards for geodetic control networks.

- Data maintenance and management (including physical maintenance) is the responsibility of DLI (within national parameters).

- Is routinely intensified in areas of urban land subdivision.

- Has an absolute accuracy in the order of 100mm. The absolute error of the height control is harder to quantify. There remain anomalies in the network.

- The relative accuracy is variable:
  - urban areas, 70% of SSMs are within +/-0.03m (horizontal) and 95% of SSMs and BMs are within +/-0.03m (vertical)
  - rural areas, 80% of SSMs are within +/-0.20m (horizontal) and 90% of SSMs and BMs are within +/-0.03m (vertical)
  - remote areas, 90% of SSMs are within +/-0.30m (horizontal) and 70% of SSMs and BMs are within +/- 0.03m (vertical)

- Information on these marks is freely available through the Geodetic On-Line Access (GOLA) system, and includes accuracy statements, site access information, mark status and when the mark was last visited.

- Principal users are concerned with surveying, mapping and asset management; engineering, mining, geological and environmental monitoring.

- The annual direct cost of management and maintenance is approximately $800,000, while revenue from sales of data is minimal.
Current Trends Impacting the Geodetic Network

- The demand for reliable spatial information increases as the population grows and the use of land becomes more intense and complex. The locations of services and of land interests become increasingly more important as the intensity of occupation and development grows. This applies in urban and regional areas.

- Access to accurate and reliable spatial information is critical. Users of spatial information expect it to be complete, accurate, up to date and affordable. They also expect it to be made available without delay. Many applications, particularly in transport and engineering demand spatial data in real time.

- Modern positioning and surveying technology provides the ability for any citizen to accurately locate an object. Technology has made it easier than ever to have spatial information in a homogeneous form. This is achieved by orienting the data with the geodetic framework.

- The spacing of control points is determined by the propagation of errors in contemporaneous surveying technologies and the objective accuracy of the derived data sets.

- Modern spatial data – accurate, comprehensive and available – provides users with the means of making sound decisions about land and land related issues. It also provides a boost to productivity by allowing decisions to be made quickly and confidently using all relevant information.

- The users of spatial data typically have no interest in the geodetic framework, other than as a definition of the reference datum. The makers of the data are reliant on the geodetic framework as the primary reference data source.

The Geodetic Framework and the Cadastre

- The Spatial Cadastral Data Base (SCDB) is a continuous cadastral map of the State. It is the most used map of all. There is an ongoing effort to combine the measurements of the physical cadastral boundaries and the coordinates of the geodetic framework to build a survey accurate SCDB.

- There is no direct relationship between the SCDB and the land title register. The SCDB coordinates are currently used by licensed surveyors to more efficiently locate cadastral marks to position boundaries. They are not used to define boundaries.

- It is inevitable, as the spatial accuracy of the SCDB improves, along with the quality of the geodetic framework and the measurements of the licensed surveyors, that the SCDB will become an increasingly important source of evidence of the spatial definition of property boundaries.
In the future, the SCDB will be recognised as an integral part of the geodetic framework – a network of many measurements – and that the common law will embrace the use of the geodetic framework for surveying of property boundaries. So the two systems will become integrated, not only spatially but administratively and in law (this should not be confused with the concept of a legally coordinated cadastre).

Given this, any consideration of the geodetic framework must take into careful account the needs of those entrusted with the property boundary definition – the surveyors.

Current and Emerging Technologies and Opportunities

GPS is the technology which has most impacted the spatial community.

Many developed countries are implementing continuously operating reference station (CORS) networks based on the existing and planned new generation of GPS satellite constellations, linked to a conventional, sparser network of passive geodetic marks.

There are code-based wide area differential GPS systems operating over Western Australia, supporting a variety of low precision (about 0.5m) position and navigation applications.

To support users with high precision (1 cm) requirements and to continue to provide positional data for the spatial data infrastructure of the State, a future geodetic network might be characterised by an array of permanent, continuously operating reference stations (CORS) that relay position related information in real time to a wide range of users.

New trends indicate that the future GPS modernisation program (post 2008) may offer more flexible positional solutions at a high and repeatable accuracy independent of a ground CORS network.

Issues Arising

Historical Perspective and Current Trends

- Who owns the network?
- Who is responsible for the integrity of the network?
- What are the options for its service delivery?
- Who will pay for this in future?
- Are there any risks emerging?
- Is there political support?

The Cadastre and the Geodetic Network

- What spatial tolerances required by users and the community?
- Are rural areas to be considered different from urban?
- What is the time required to start any new regime of less dense control?
- Will the surveying community support this?
- What currently holds back the take up of geodetic coordinates as evidence?
  - What will be the cost and/or benefit to surveyors?
  - Are the capital and maintenance costs to be saved offset by these benefits?
  - Is there any opportunity for a partnership between surveyors and the government?

➢ Emerging Opportunities

- What are the industries and users that have not yet been considered?
- How can the future network operation be most effectively managed?
- How will the existing homogeneity, standard and quality of positional information be maintained?

QUESTIONNAIRE

The background information on the current status of the Geodetic Network, its relationship with the cadastre, current and emerging technologies and issues arising was developed to prompt discussion. A number of questions follow which explore these issues in more detail. They are not exhaustive, and respondees are encouraged to raise any issue which may be relevant to the broader scope of the Review.

Demands, Users, Needs

What demand is there, present and future, for a traditional geodetic network (consisting of permanent ground monuments whose positions have been determined in a well-defined coordinate system)? Who are the users? What are their needs (e.g., network density)?

What demand is there, present and future, for the uptake of a CORS network into the geodetic infrastructure? Who are the users? What are their needs? What set up would be preferable for WA (metro, regional, industry sectors, e.g., mining)?

How does all this fit within national and international context (e.g., compatibility and integration with other States, Australian spatial data infrastructure, dependencies on other nations' satellite systems)?

Role of Government

What is the role of government in facilitating the uptake of a CORS network? What are government’s broad and specific responsibilities in this area (e.g., legislative, public interest, state development, economic competitiveness)?

What are the responsibilities of government to provide a geodetic network to support the State’s land titling system and legal certainty for cadastral boundaries?

What, if any, is the role of the Commonwealth government?
Benefits, Costs, Funding

What would be the benefits of implementing a CORS based geodetic network in WA? Who would benefit, how and why? To what extent are the benefits measurable?

Who should fund a CORS network, and why?

What economic model can/ should be used to fund a CORS network?

- Provided by State and fully funded by taxpayers
- Funded by State and operated on cost recovery or commercial basis
- Consortium between State and private sector with costs and revenues shared

Implications of economic model for:

- Ongoing management of network
- Future development
- Governance and accountability (eg. accuracy, legal basis of measurement)

Implementation Issues

When should the implementation of a digital GPS network begin? Why? How do we manage the transition? How do we meet the needs of all users?

To what extent will the State be required to maintain a traditional monument-based network in the future (over the next 5, 10, 20 years and beyond)? How would this be funded and managed?

User Groups to be Consulted (Either During Scoping Phase or During Main Review)

Utilities and infrastructure providers:

- Main Roads
- Water Corp
- Western Power
- Alinta Gas
- Railways
- Telecom

State government agencies:

- Dept Industry and Resources (mineral titling)
- DPI (planning, land development, infrastructure corridors)
- Dept of Agriculture
- CALM (resource management)
- Transport
- FESA
Local government authorities, eg.:

- Stirling
- Melville
- Bayswater
- Cockburn

Industry sectors:

- Land developers
- Engineering
- Mining
- Surveying (including offshore)
- Spatial information

**General Comments**

General comments on broader strategic issues concerning surveying and positional information in which government has a legitimate role, including the interface between government and the survey industry are invited.
6.3 Appendix 3 – List of Interviewees

*Whelans Survey and Mapping Group* (21/12/04) Ed McKinnon, Ken McKinnon, Ian Gardner (Survey and Mapping)

*Fugro* (22/12/04) Ray Watson (ASIBA, Survey)

*Spatial Sciences Institute* (22/12/04) Richard Browne, Executive Officer (Survey)

*City of Stirling* (23/12/04) Ashley Hams (Local Government)

*John Bullock & Associates* (24/12/04) Geoff Lockhart (Survey)

*Main Roads, WA* (4/01/05) Greg Myers, Peter Ward (engineering)

*McMullen Nolan* (5/01/05) John McMullen, Gerry Nolan, Nick Mariano (Survey, Mapping, GIS)

*DLI Internal Reference Group Members* (6/01/05) Bob McCarthy, Linda Morgan, Ken Alexander, Eric Horlin, Barry Cribb. (Survey)

*McMahons Construction* (7/01/05) Max Milne (engineering survey and construction)

*Victoria Dept Sustainability and Environment (Spatial Group)* (8/01/05) Martin Hale, GPSnet Project Manager (Asset management)

*Department of Transport (Marine)* (10/01/05) John Mullally (marine survey)

*Kennedy Instruments (Leica)* (11/01/05) Alf Stretton (equipment supplier)

*AAM Hatch Pty Ltd* (11/01/05) Don Abbey (survey and mapping)

*GHD Surveys Pty Ltd* (12/01/05) Alex Jolly, Peter French (Survey, engineering)

*Public Transport Authority* (12/01/05) Colin Shipp, Robert Holloway (Survey, asset management)

*Stadia Instruments (Topcon)* (12/01/05) Garry MacPhail (equipment supplier)

*Haefeli-Lysnar (Trimble)* (13/01/05) David Evans (equipment supplier)

*Omnistar International* (13/01/05) Geoff Glazier (GPS services, precision farming)

*Harley Hedderwick (Surveyors, Bunbury)* (14/01/05 and 18/01/05) Sebastian Bolhuis (surveying)

*Water Corporation WA* (construction) (14/01/05 telephone) Stephen Pickford (engineering, surveying)
Geoscience Australia (National Mapping Division) (14/01/05 telephone) Gary Johnson (GTSC/ICSM Chairman) (Commonwealth, geodesy, GPS services)

Scanlan Surveys (21/01/05) Bill Scanlan (surveying).

TOTAL: 22 interviews; 10 surveying, 4 engineering surveying, 1 Local Government, 1 asset management (Government), 3 equipment suppliers, 2 GPS service providers, 2 mapping, GIS.
6.4 Appendix 4 – Interview Summaries

Preamble

(Need to draw the distinction between government’s current role with the geodetic network to underpin state development and cadastral use (specialised, narrow but critical, high accuracy need statewide, height demand, cadastral integration with geodetic, integrity and homogeneous need, datum and standards, legislation, clear responsibility of government) and future role with a CORS which has a broad, diverse potential user base (why? Safety? Unnecessary duplication and confusion of supply need for coordination specs and standards, legal traceability). How to establish? DLI as a leader/ facilitator, active involvement in network management? As a partner with industry and Commonwealth government….no other sector will develop a state-wide facility to centimeter accuracy…without subsidy).

Once there is agreement on the role then other issues can be addressed. R&D, user group coordination, the type of future physical geodetic network (marks, etc.).

To determine the key issues surrounding the current and possible future geodetic network, interviews were held with a cross section of the existing geodetic network user base (major users), and other organisations who could be potential users of a future CORS network. An important distinction between the existing and potential user groups is that future users of positioning information will have more diverse needs than the current predominantly survey focused users.

In total, structured interviews were held with 22 organisations, representing survey (cadastral and control), engineering and mining, utilities, local government, transport, marine and technology suppliers. Additional input was provided by members of the DLI External Reference Group and relevant DLI staff members.

Each interviewee was provided with a background paper, describing the consultancy brief, current status and future trends, and a questionnaire prior to interview. To encourage discussion on the geodetic network, the background paper presented a possible future infrastructure based on a CORS network which could deliver quality assured, homogeneous coordinates to 10mm accuracy, anywhere and at any time.

A list of organisations interviewed and the background paper is at Appendix 3 and 2.

An analysis of responses to the questions raised has been grouped under the following main headings to determine the key themes. The key issues have been determined from these themes.
Current Status, Demand, Users, Needs (Existing Geodetic Network)

The network is predominately used by surveyors for cadastral connections and as control for various infrastructure programs and engineering activities. It is a passive network, and specialist skills and equipment are needed to transfer and compute accurate position. Most users believe it is adequately maintained (attrition rate about 1% per annum, maintenance at about the same rate; refer Appendix 1 for details on mark maintenance and network densification) and coordinate integrity is good, but are concerned at the lack of bench marks or standard survey marks for height control in some areas of the State.

There were mixed views on the density and maintenance requirements for the network, particularly the density required to support cadastral connections, partly due to the cost/time required and partly because of the technology constraints. For example; if a connection was up to 5km distant, obstructions such as buildings, cause problems for real time GPS measurement. Others argued that a 3-5km passive GPS network over urban areas would be an alternative, given that many existing SSMs are not GPS-friendly (obstructions, not safe to occupy, etc.).

Rural and remote users commented on the difficulty in accessing marks (on hills, or restricted for environmental reasons) and generally used other methods to ascertain position (eg. using AusPos and long GPS observation periods to get post-processed position). Some suggested that the integrity of the marks on hills (Trignometrical Stations) should be transferred to more accessible locations (along roads where most rural/remote BMs are located).

Maintenance was viewed as a government responsibility, and although a number of survey firms do report on mark condition, it is not mandatory. Reporting is therefore ad hoc, and due to cost and time constraints private surveyors do not replace damaged or missing marks. One user commented that while surveyors contributed to the geodetic network and the cadastral system, it was not recognised or compensated for by government. There was a belief that the relationship between government and the survey industry was a partnership, however this was not acknowledged.

As the network is used to provide control for land sub-division and to allow cadastral connection to support the development of a survey accurate spatial cadastral database (SCDB), user demand is for densification over urban development areas. Many surveyors use GPS methods for cadastral survey, and are not inconvenienced by a less dense network, although some did comment on the cost of the cadastral connection being disproportionately borne by the client.

Several government agencies are directly dependent on the network for their asset management (Main Roads, Water Corporation) and require a maintained homogeneous State-wide network to ensure integrity. All other agencies interviewed have varying reliance on the network for asset management, but all use the SCDB as their source of cadastral information.
Most users commented that they could not see major change in demand for geodetic control. Because projects occurred throughout the State demand was variable, but well coordinated geodetic marks were required to be available on demand. There is an expectation that government will provide appropriate network density as needed to support such development. This was particularly the case for cadastral connections, viewed as a regulatory requirement of government. Concern was expressed by several users that there was a risk of long-term degradation of the integrity of geodetic coordinates through the loss of survey marks. While some users extracted information for all marks over a project area for planning purposes, they indicated this was done to provide redundancy, and should not be seen as a measure of demand, i.e. volume is not relevant, quality of the coordinates used and the value-add is a better measure.

A number of users stressed the importance of the marks used for height (Australian Height Datum elevations) and the inconsistencies within the network. This was a particular concern for coastal zone developments and monitoring, where alternate datums were preferred to avoid problems (eg. hydrographic chart datum, Lowest Astronomical Tide). This was not a concern for cadastral surveys.

An increasing number of cadastral surveyors are using the SCDB coordinates (derived from cadastral connections to the geodetic network) to assist in new survey design and asset location. Users commented that the use of the SCDB combined with the information readily available through Landgate is giving improved productivity for work planning and survey. Rural users in particular, are concerned about the density of the network and the quality of the SCDB. More relevantly, some indicate a willingness to provide new information to support both the geodetic network (extra SSMs placed) and the upgrade of the SCDB to survey accuracy; however their perception was that DLI was unable to use the donated information in a timely manner for the benefit of all users. One respondent stated that DLI had focused on developing a high quality title system and information access platform (Landgate), but had yet to seriously address the deficiencies in the State’s survey system.

**Future Demand, Users and Needs of a CORS Network**

As part of the Background paper (Appendix 2), a possible future network of Continuously Operating Reference Stations (CORS) is described. This network could complement the existing geodetic network, and service the positional information needs of a wider user community. The current providers of similar services over Western Australia include direct GPS positioning (about 10m accuracy), Omnistar (commercial provider, 1.0m to 0.1m accuracy, differential GPS, real time, subscriber service), Australian Marine Safety Authority (AMSA Beacon system, coastal coverage, real time about 2.5m, free-to-air) and AusPos (greater than 6 hour GPS observations and post processing of results by Geoscience Australia who operate the AusPos system throughout Australia, 0.05m horizontal and 0.08m vertical, free-to-air). Collectively, these existing GPS based services meet the known needs of a broad range of users. These include: precision farming, off-shore positioning, asset management, environmental monitoring, exploration and remote project positioning needs.

The technology provides real time positional information continuously to the wider community, without the need for detailed knowledge of surveying or geodesy. In effect, the surveyor is a small (but significant) high accuracy end user of GPS technology.
Internationally, the drive to establish a CORS network is primarily scientific (monitoring earth crustal movement) and more recently to support machine control applications. Such networks are extensively used in the United States, Canada, United Kingdom, New Zealand and Europe (particularly Germany). Value-added use is evident in all countries that have established such systems.

In Australia, all States except Tasmania, South Australia and Western Australia are planning or have, partial or complete CORS networks. Victoria has a GPSnet system covering the State and is progressively improving the service to centimeter accuracy. Queensland has a mix of CORS over developed regions, and accessible passive GPS stations at selected densities across the rest of the State.

It was with this background that interviewees provided comment on a possible CORS network over Western Australia.

Most respondents acknowledged that a future network would be based on a CORS strategy, although they saw risks moving to total dependency on an internationally owned and operated system. There were mixed views on the density required, but most believed State coverage (in some form) was necessary. Even with a CORS, users stated they required ground marks to provide redundancy (risk management), reference for re-establishment of position, and calibration of CORS and GPS equipment. Users of the existing network commented that marks must be maintained at an agreed density and location for the foreseeable future; especially for height, and until satisfactory and repeatable accuracy can be generated from CORS positioning.

Interviewees believe that the market for CORS services would increase rapidly in applications such as machine control (earth moving equipment, construction), asset tracking and management, environmental monitoring, mining and mineral exploration, agricultural uses, geotechnical services, expanded survey services, all real time positioning applications, all forms of mapping and for GIS purposes. Survey users foreshadowed demand for higher positional accuracy and certainty will grow as urban density increases, and asset location/ management within service corridors becomes more critical.

These uses have varying accuracy requirements and the market may be substantially satisfied by current GPS services. Current service and equipment providers believe growth will occur as the number of GPS satellites increase (Galileo in Europe, 2008 on) and new frequencies (and hence quality, accuracy) are included. Nonetheless, there was limited feedback on future use, indicating a lack of market knowledge in this State.

Technically, users believed that the data management issues will be complex given the datum (GDA94) is active and constantly changing, albeit slowly. The development of a stronger and more accurate relationship between the AHD height (determined by spirit leveling from tide gauge networks) and geoidal height (from GPS/ CORS) would result in more applications. Traceability of coordinates and integrity monitoring of the CORS were viewed as critical risk management issues, and all users commented that these were the responsibility of government.
Role of Government

Unlike the existing geodetic infrastructure, the user views on the government’s role in facilitating the uptake of a CORS network are mixed. Users of the current geodetic network understand it is the result of over 100 years of development, reflecting various measuring methods at a density designed to meet many uses. All acknowledge the government is the owner and therefore responsible for its integrity, completeness and maintenance.

Interviewees commented government’s role should not be as a competitor, but as a leader in establishing a CORS framework as a basis for industry to value add. The role should be one of coordination to avoid unnecessary duplication and to prevent confusion which could result in safety issues, or undermine the economic competitiveness of the State. Others felt the government was responsible was for a CORS but its ownership and operation could be a shared responsibility with both the private sector and Commonwealth government. Several responses indicated a public private partnership was appropriate, supported by a structured research and development program to complement the activities of the national Cooperative Research Centre (Spatial Information) of which DLI, other government agencies and a number of local survey firms are participants. Comments were also made on the government’s role in integrity monitoring and accreditation of CORS, relevant standards (including the datum) and for legal purposes (including cadastral surveys), traceability of CORS positioning to the national standard for position (as gazetted under the National Measurement Act).

A related issue concerning the quality of base datasets used in conjunction with GPS position was raised by several interviewees. AS CORS allows real time position to support real time decisions, the base data used must be highly reliable. Data such as the SCDB, topographic and elevation models, roads detail and associated textural information is provided by government and must be compatible in accuracy to CORS-derived position, and accurate in content. Users commented that real time accurate positional information from CORS networks will test the integrity of government’s spatial databases.

Many users stated that they were unaware of the government’s strategic plan for the provision of positional data, and felt it should take a lead role in the introduction of better positioning services for the State. Questions were raised over the government’s (and particularly DLI’s) capacity to effectively manage this role. Most believed there were limited opportunities for their views and input to be considered.

The role of the Commonwealth was viewed as that of national coordination, international collaboration for continued involvement in satellite programs such as GPS and more specifically through Geoscience Australia, the operation of reference stations throughout Australia (a national CORS (AusPos), supporting the Australian Fiducial Network for international integrity monitoring of the GPS satellite network), and development of national standards through committees such as the Inter-government Committee on Surveying and Mapping (ICSM) and the Australian Global Navigation Satellite System Coordinating Committee (AGCC). There was limited appreciation by users of the respective responsibilities of these committees. Victoria indicated they had worked closely with the Commonwealth to ensure their GPSnet (statewide coverage) was compatible with the national network.
On the specific issue of the government’s role in providing a geodetic network to support the State’s land titling system and legal certainty for cadastral boundaries, surveyors interviewed believed it was a government regulated requirement and therefore the responsibility was clearly government. Most stated that geodetic mark maintenance was adequate to support connection of cadastral surveys; however because many cadastral marks are disappearing (thus increasing the cost of survey), the geodetic infrastructure is becoming critical to the re-establishment of boundaries, hence maintenance and mark density are also vital. Surveyors indicated they required extensions and a denser geodetic network over urban development corridors prior to subdivision, and to support design, mapping and utility projects. Most were satisfied with the current DLI response times to this activity.

One rural surveyor stressed the need for country towns to be adequately covered, because the present density is not adequate to support spatial upgrade of the SCDB. He had particular problems with the lack of spatial upgrade, despite lodging cadastral connections, believing DLI were not processing the work in a timely manner (due to the methods used for spatial upgrading and other priorities). All surveyors commented on the increasing reliance placed on the SCDB coordinates (of cadastral points) to assist in the re-establishment of cadastral boundaries.

Benefits, Costs, Funding

Anecdotal evidence from Victoria shows that considerable investment is required to establish a CORS network, and develop a sufficiently reliable service to convince users to subscribe on a regular basis. The Victorian experience commenced a decade ago, and has recently committed to an upgrade to provide real time GPS signal corrections to support high accuracy Location Based Services throughout the state. The key driver (and benefit) of the Victorian strategy was to provide an authoritative CORS network over the state to service the diverse community needs for asset management and positional information. This initiative has avoided the costly duplication of resources and infrastructure which would have occurred if other groups had established ad hoc base stations over Victoria.

The situation in Western Australia is similar, with several interviewees indicating their desire to establish CORS-type networks over the most densely populated areas of the State. Because the existing market for positioning information is diverse and is being serviced by a variety of GPS facilities, information on benefits is poor. There is a need for better market information to assist the evaluation of the benefits of a CORS network.

Interviewees were mainly users of GPS technology, and had accrued benefit from their individual experiences, they generally were uncertain on the additional benefits a CORS strategy may provide. Most users commented that it was undesirable to have duplicated systems providing basic positioning services, several remarked that the government should provide a basic network on which industry could innovate and value-add. Several views were expressed on the risks associated with monopoly services in a State which is large but with a small population.
Survey users agreed that the obvious benefit would be savings in equipment, given only one receiver (not two) would be necessary, and there would be time savings in not having to establish a base station for high accuracy position (1cm). Others believed there would be a cost to these surveyors who did not have GPS equipment, but would need to invest to remain competitive. Some firms who do not have GPS equipment currently contract specialists to provide that service. Users indicated that current equipment would normally be replaced within five years but also to be compatible with the new satellite constellations planned from 2008 onwards. Most stated that the cost was not a barrier if it provided a competitive advantage.

Because it was not clear whether a CORSSS network was required to support and ultimately replace the existing geodetic network, or was for commercial activities, views were mixed on the appropriate funding model. Those users who believed the government were responsible for positional certainty, standards and integrity monitoring felt government should pay; however, there were other views (based on the wider application of CORS) that funding should be a shared responsibility between state and federal government and the private industry. Some users stated a user-pay principle should apply for access to CORS data (similar to the subscriber-based approach in Victoria and Queensland). They also commented that a number of current users of the geodetic network neither pay for access nor contribute to its maintenance.

Some concerns were voiced over the risks associated with being solely dependent on CORS commenting that a maintained (reduced) geodetic network of ground marks was essential. Views on the risks of reliance on foreign owned and operated satellite services for position were balance by the benefits accrued from the free-to-air service available, and the redundancy provided through several satellite systems (American GPS, Russian GLONASS and European Galileo).

**Implementation Issues**

There are users dependent on the existing geodetic network, and national and international studies conclude that regardless of when a CORS network is established, there will continue to be a need for a geodetic reference network of ground marks to support the activities of current users. This will be the case until an active CORS is in place, fully operational and completely accepted by all users (Featherstone, 2000; ICSM 2004; Canada?; NZ (Zero Order and fifth Generation)). All countries and Australian states involved in establishing CORS networks are in the transition stage none have moved to complete reliance on a CORS network. Even the United Kingdom strategy includes a number of passive GPS ground marks to cover less densely populated areas. The transition period is expected to be greater than ten years. Given the reliance of Australia’s spatial information infrastructure on accurate and homogeneous position, the new geodetic network must never allow this infrastructure to degenerate (Featherstone, 2000).

There was limited comment on this issue, perhaps indicating a level of uncertainty on the potential of CORS technology. While the Australia CRC-SI consortium (of which DLI and several local survey firms are contributors) has an objective over the next seven years to provide quality assured, homogeneous centimeter position, anywhere, anytime; the indicative timeframe illustrates the research and development complexities involved in producing reliable, accurate position information.
Comments were mainly grouped around the technological issues including:

- Transition period of over ten years to allow CORS establishment, user exposure and technology take-up.
- Total reliance on CORS raises “black box” issues, where the user no longer has control or full understanding of the process.
- Strong local R&D commitment in close collaboration with users to ensure their needs are addressed.
- The impact of changing technology with the next generation of satellites and associated investment.
- Potential geodetic datum change (possibly a dynamic datum as is the case in New Zealand) and the related traceability of coordinates.
- Doubts over the completeness of CORS coverage due to “terrain shadows” affecting communications (similar to mobile phone “dead zones”).
- Real-time positioning will require base datasets with high integrity, and at a comparable accuracy.

Users also commented on the need for legal traceability of position through the existing geodetic network to the national standard (the Australian Fiducial Network stations), the risk management associated with a less dense physical mark network, and the lead times for technology uptake. Finally, views were expressed on the clarification of role and time required to concurrently undertake R&D and to establish responsibilities for ownership of the CORS, its ongoing, continuous operation and integrity monitoring of the network.

**User Groups to be Consulted**

In addition to those groups already identified (refer Appendix 3), there are several sectors who should be consulted. They include GPS (and related technology) suppliers, who generally have national and international experience and resources to refer to; CRC-SI interstate participants; operators of the Victorian, Queensland and New Zealand CORS networks; scientific organisations (including CSIRO and Geoscience Australia). Suggestions were made that recreational users may have input, but no representative body was identified. Operators of the AMSA network and Omnistar system should also be consulted.

Government (state and local) is currently a significant user of geodetic survey and GPS positional information for many applications including vehicle tracking, vegetation mapping and monitoring and asset management. There are occasional reports of projects that use positional information and GIS, (Refer WALIS News, Issue 23, AGWA’s GIS goes mobile) which indicate the pervasiveness of the technology. WALIS have not yet raised the subject of positional need for formal discussion, however contact with users through the DLI WALIS Councilor is also recommended.
Broader Strategic Issues

A number of issues concerning survey and positional information were raised by interviewees, and indicate a level of dissatisfaction with the relationship between government and the survey industry. Many also indicate willingness by the industry to contribute to the integrity of the cadastral and geodetic systems, provided their contribution is recognised and used for the benefit of other surveyors. A view was expressed that this relationship should be acknowledged as a partnership arrangement, rather than the surveyor being treated only as a customer. Concerns were expressed that many issues have been debated over many years with little or no outcome, and a more focused methodology is required to achieve results. The accreditation of surveyors’ process implemented in the 1990s was given as an example of a successful method used to address and resolve an issue.

Issues requiring attention included:

- A clear policy on the future development of the cadastre; addressing such matters as the status and legality of SCDB coordinates for use in cadastral surveys, the increasing importance of the geodetic network and how the geodetic cadastre will be developed and the role of boundary definition in defining property rights and interests.

- A stronger legal basis is required for the geodetic network, the coordinates derived from it and the protection of ground marks placed.

- As the cadastral and geodetic networks combine, there is a need to clarify how surveys are coordinated and how relevant surveying regulations will be developed. The regulation of surveyors and surveying needs to be separated as has been done in other jurisdictions (Queensland: Survey and Mapping Infrastructure Act and a Registration of Surveyors Act; Victoria are developing a new Survey Coordination Act), to allow government in consultation with industry to define its business requirements (through surveying regulations, etc.). This issue was raised and partly implemented following the 1987 Functional Review of the then Department of Lands and Surveys.

- Surveyors are currently required by regulation to maintain the cadastre, while there is an assumed responsibility for reporting or replacing geodetic marks with little recompense. Many surveyors do voluntarily provide valuable additional survey information; however there is no “quid pro quo”. The belief is that because no partnership exists, issues such as copyright claims over survey plans reflect that perceived imbalance.

- DLI’s statutory authority status is not well understood, particularly as DLI becomes a competitor in the market (for example aerial photographs). This concern was also reported in the 2004 DLI Customer Satisfaction Survey results.

- While quality of survey information was raised (field books as microfiche copies), it was recognised DLI had partly addressed the issue by scanning all survey plans. More importantly the quality of customer service is causing concern, particularly the experience and responsiveness of staff.
There were particular issues concerning Landgate which reflect a general lack of responsiveness and communication of service standards by DLI to customers. However, all interviewees were complimentary of the value added by access to datasets provided through Landgate. Users are accessing the system from the field and report favorably on its value.

GEODETIC INFRASTRUCTURE (GROUPING OF KEY ISSUES ARISING FROM INTERVIEWS)

SUMMARY

Broader Strategic Issues:

- Recognition of surveyors “partnership” arrangement with Government:
  1. legislated cooperation in cadastral survey (maintenance, etc.);
  2. assumed cooperation in geodetic (limited recompense) and street address assignment; and
  3. copyright in survey claims are a reaction to this situation.

- Quality of some survey information and customer service (experience/responsiveness).

- Traceability of coordinates used from SCDB – needs legislative base? (Queensland model) and SCDB integrity.

- Policy/strategy for development of the cadastre is not clear (spatial interests – no vision or enunciated plan).

- No coordination of Surveys Act – separated from registration of surveyors (Queensland/Victoria models).

- Access to information online needs better user input/consultation/response (eg. Landgate).

- DLI statutory authority role – not well understood – particularly as a “competitor” in land information market (refer Customer Satisfaction Survey Report).

- Transfer of Land Act is a “transmission of interests” Act and does not recognise spatial issues.

GEODETIC INFRASTRUCTURE – ISSUES

EXISTING NETWORK

Interview Responses:

- Many Standard Survey Marks not suitable for GPS use, or unsafe to occupy.

- Maintenance viewed as adequate (loss rate 1% per annum) but Bench Marks (height) density a concern in some areas.
Scoping Paper for 2005 Review of Western Australia’s Geodetic Framework
and Priorities for Survey and Positioning Information

- Coordinate integrity is good – but inconsistencies exist (particularly vertical).
- Mark maintenance is government responsibility, some surveyors do advise missing, endangered or damaged marks – not mandatory (but) mark replacement not done due to cost/ time issue.
- Rural/ remote Standard Survey Marks (Trig points) not easily accessible (hilltops) – surveyors may use local datum or establish position on a Bench Mark (accessible – on roads) using “AUSPOS” service.
- No legislative protection of network (Standard Survey Marks Act 1924 dubious).
- Densification of control (Standard Survey Marks) necessary in urban development areas.
- Connection of cadastral surveys to geodetic (regulatory requirement) requires maintained network (although some survey firms use GPS to connect marks up to 5km distance).
- Lack of reliable Bench Marks (height) metropolitan causes user to use alternate/ de facto datum.
- Geodetic connection costs (of cadastral surveys) are borne by client – disproportionate – should be custodial responsibility.
- Several government agencies directly dependent on geodetic for their asset development/ maintenance (Main Roads, WAWC).
- All agencies that use the SCDB Spatial Cadastral Database (cadastral layer for admin, asset location, GIS) are indirectly dependent on the geodetic infrastructure.
- Government is viewed as custodian – responsible for integrity, database and maintenance.
- Volume of data accessed is not best indicator of value or use – quality of coordinates and mark availability are critical.
- Main Roads contribute significantly to maintenance – with marks placed along road easements prior to construction (contractual requirement).
- Used almost exclusively by surveyors – as a passive network, specialist skills are needed to compute position.
- Network reflects technology available when established – not necessarily current needs.
- Density in country townsites not sufficient to support cadastral upgrade (SCDB coordinates not reliable/ accurate).
- Many discrepancies between Australian Height Datum (AHD) heights and coastal datum (chart datum – lowest astronomical tide) used by transport/ marine, developers use AHD – causing issues.
Essential – while cadastral upgrade program continues (cadastral then has geodetic integrity).

Network supports traceability (under National Measurement Act) for position (i.e. GPS use).

Lack of control is causing added cost/time to several infrastructure projects.

Risk of long term degradation of geodetic integrity through loss of marks.

**GEODETIC INFRASTRUCTURE – ISSUES**

**FUTURE NETWORK**

**Interview Responses:**

- Will require ground marks for reference/calibration at an agreed density and location.

- Ground marks for AHD height will need to be maintained until satisfactory GPS/geoidal heights can be derived to an appropriate repeatable accuracy.

- Future (10 – 15 years) network will be based on “CORS Continuously Operating Reference Stations GPS” strategy (national/international best practice).

- CORS is an active system, positional information will be more easily obtained by a wide range of users. Surveyors, as high end users (10mm) will be in the minority but significant.

- Datum for coordinates (GDA) will need active management as it changes over time (Epoch linked) and traceability will be critical.

- Will need to be state wide and have redundancy (risk management issues).

- Concerns over ownership, integrity and monopoly problems.

- Reliance on foreign infrastructure (satellites and processing services) – risk management.

- Increasing reliance on SCDB raises integrity issues and may inhibit the full adoption of coordinates (and associated efficiencies).

- Is not generally understood by users nor discussed at forums such as WALIS – GPS is not generally discussed at WALIS.

- Surveyors should have free access to the SCDB in return for anomaly resolution and cadastral integration.

- Cost to industry to upgrade equipment technology (five year life?) – some savings in reduced cost of ‘rover’ technology.
Needs a level of Commonwealth coordination of augmentation systems (CORS) to avoid - datum, standards, confusion, unnecessary duplication, integrity.

Government role should not be as a competitor (i.e. framework CORS is a base for value-added by industry).

Better user needs assessment (no single driver: New Zealand – Tectonic plate monitoring; United Kingdom – better positioning; United States – monitoring, asset management; machine control, navigation; Victoria – asset management and belief in growing demand for position; Vic and Queensland – commercial but not yet delivered).

Integrity of SCDB is an inhibitor to adopting coordinates.

Positional certainty, cadastre: metro=0.025m, Rural >0.1m, Remote <0.3m.

Potential duplicated CORS networks = unnecessary duplication, gives a redundancy, not a monopoly, integrity-continuity issues.

Risk of sole dependency on GPS (need physical network).

Surveyors are only small users of high quality – accuracy positional data.

Height model needs resolution (geoid – spheroid) to better use GPS for height.

Traceability of coordinates and legal barriers to use of coordinates.

Cost of GPS – not a barrier if it provides a competitive advantage.

Essential for asset location/management within corridors as urban density increases (accuracy real-time).

User pay principle for access to CORS (subscriber – based), users of current geodetic network do not contribute to maintenance, eg. utilities.

Ownership of CORS: Government, operation: private sector – for base network CORS – must include collaboration with Commonwealth.

Increase will be in real-time users – speed, accuracy, repeatability (Local Governments – large users).

Transition – less than ten years to allow CORS setup and testing, user exposure and technology transfer.

Retain agreed density of physical network for redundancy, calibration and transition.

SCDB is used extensively to cadastral survey, GPS used to do cadastral surveys and connections.

Growth of use of GPS in construction (roads, etc.) and project management.
Concerns on total reliance on CORS – “black box” issues.

Government responsible for integrity, standards, regulatory issues, traceability, datum.

Strategy must be State-wide and include coastal zone.

Expectation of a “user pay” system.

Benefits include users not having to establish their own base stations (security) and time efficiencies.

Changing technology with GPS/ GALILEO (around 2010) – extra frequencies/ compatibilities – Government should not over-invest in technology.

Must have active local research and development and industry liaison to ensure needs are addressed.

GPS (United States) now under civil mandate.

GDA (Geocentric Datum of Australia) Datum is time-based (at an epoch in 1994) – movement of 7cm per year will cause datum changes, or move to a dynamic datum (time-based).

Issues of communications for CORS (shadows) impacting real-time users.

Research and development for GPS plus inertial navigation systems to overcome communication issues, eg. of need for ongoing research and development at Curtin and CRC.

Government to provide CORS at a framework level – industry to value add and innovate.

Value-add relies on a secure CORS (high accuracy but watch terrain effects on signal, etc.).

Project in remote areas show good agreement between AHD and GPS height (using AUSGEOID).

Growth in use for monitoring and geotechnical surveys.

Multiple CORS to be avoided.

Transition – lead times for less dense network to allow technology uptake.

Need to focus on SCDB integrity (completeness) and traceability.

CORS to be framework only to minimise risk and encourage value adding/ innovation.

Homogeneous network is essential to support infrastructure projects state-wide.
Expanding use of CORS or asset management (accuracy approximately 0.1m) and machine control (approximately 10mm).

Government role based on public need, safety – integrity monitoring, standards, continuity, access, zero level (with Commonwealth).


Key risk – managing loss of marks/ degradation of network.

Use of coordinates (SCDB) for cadastral is impeded due to integrity/ traceability in SCDB.

Uptake of technology will vary throughout survey industry (technical competency, funding issues).

Commonwealth role: high level coordination, maintenance of national CORS, relevant standards and input to Australian Global Navigation Satellite System Coordination Committee (AGCC) – standards, privacy and spectrum management).

Implementation role of government for CORS – coordination, needs identification, Public Private Partnership (PPP) to establish, research and development.

Legal traceability needs clarification (Victorian model).

GPS suppliers have “turn-key” CORS and are anxious to establish networks over South West WA (commercially focused).

GPS suppliers want a Public Private Partnership (PPP) and will contribute to research and development.

Technology will change over next 10 – 15 years (new generation of satellites) offering new positioning solutions (therefore infrastructure must be flexible and minimal).

Government role has resource and skill base implications.

Growth areas are mapping and GIS applications.

“Niche” markets have already been developed (eg. precision farming, 0.1m accuracy – 2000 of 37,000 farms in Australia – OMNISTAR).

CORS offers real-time solutions, base data used must be highly reliable (eg. SCDB, topographic, etc.).

WALIS has not actively considered whole-of-government positioning needs.

Rural/ remote/ country towns have variable SCDB, coordinate quality impeding survey and technical application (perception DLI has modernised title system and access, eg. Landgate, SmartRegister, but survey has been neglected).
Potential use of CORS in rural areas if height accuracy improved.

Commonwealth manages 45 GPS receivers for geodesy, AUSPOS, international monitoring and coordination via ICSM (Intergovernmental Committee on Survey and Mapping) and AGCC (Australian Global Navigation Satellite System Coordination Committee).

Commonwealth role seen as national coordinator (ICSM, AGCC) various national projects (height modernisation, new gravimetric geoid, sea level monitoring, tectonic plate monitoring, etc.) ensuring compatibility of State augmentation networks with national (eg. Victoria).

CORS will not work everywhere – needs a modified physical network.
6.5 Appendix 5 – Implications of Incorporating Digital GPS Networks into Traditional Geodetic Infrastructures

Executive Summary

The ICSM Geodesy Technical Sub-Committee (GTSC) has identified two fundamental drivers for the uptake of digital GPS networks into the geodetic infrastructure. They are:

1. improved positioning efficiency from new Global Navigation Satellite Systems (GNSS) technology, including the ease with which the geodetic infrastructure can be upgraded or densified; and

2. the need to facilitate and manage the inevitable uptake of GNSS technology by a wide group of users, ranging from cadastral surveyors to non-specialist indirect users, ensuring it is compatible with the existing infrastructure and works effectively with it.

The GTSC also identified a list of issues that need to be considered. Clearly the context of particular issues may vary with local conditions and requirements, but all must be considered when integrating new technology with the old. The following list introduces these issues:

- Keeping the geodetic infrastructure relevant to the user base
- Cost effective use of existing GPS equipment
- Improved efficiency for mark maintenance
- Global geodesy supporting national geodetic infrastructure
- Broader (non-survey) spatial community
- The need to maintain homogeneous geodetic infrastructure
- GNSS is not suitable in all circumstances
- GNSS is not well suited to the propagation of the vertical datum
- GNSS is useful for AHD benchmark maintenance
- Monuments provide positional integrity
- Monuments enable integrity of the datum to be monitored
- Risk management in a project may restrict GNSS use
- GNSS is global and dynamic

When considering these issues several additional factors also need to be considered. Firstly, integration of GNSS in the geodetic infrastructure serves a far broader “positioning” community then ever before. As such the fiscal implications should be seen as an extension to business and an opportunity, rather than a refocus.

Secondly the introduction of GNSS has allowed a more targeted approach to the maintenance of the existing physical geodetic infrastructure. The network of survey marks is rapidly changing shape to target areas of high activity and significance.

Finally jurisdictions have different requirements and policies. For instance, an infrastructure that suits remote Western Australia is quite clearly going to have different requirements to that of central Victoria. The choice of the style and extent of integration of GNSS networks into the existing infrastructure is jurisdictionally dependant.
Introduction

In May 2000, the GTSC prepared a report on “The Australian Geodetic Infrastructure–10 Years & Beyond” (GTSC, 2000) which predicted that there would be an explosion in the use of positioning, with a rapidly expanding user base and a broad range of applications. It stressed that all users need convenient access to the physical realisation of the geodetic infrastructure and that although in the long run the need for ground marks will decline as the trend to real time positioning continues, initially there would be an increase in the number of ground marks as new useable 3-dimensional marks are established. In summary it stated that “at the very least a relatively smaller number of marks will always be required to define the datum”.

In a subsequent report the GTSC noted that in Australia by 2008 the ITRF-GDA94 difference will exceed a metre and that high accuracy users were already able to see the difference (GTSC, 2002). However, this report also noted that transformation parameters were available to remedy this situation and a further report confirmed this option (GTSC, 2003). ICSM subsequently agreed to retain GDA94 and reassess the situation in five years. Similarly it was agreed to retain AHD71, but proceed to develop a system to accurately convert ellipsoidal heights to AHD. In 2000, NZGD2000 was introduced in New Zealand incorporating a deformation model to account for the effects of crustal deformation to enable the currency of the datum to be maintained over a period of time. New Zealand chose to retain its 13 separate orthometric vertical datums and develop a new national ellipsoidal-based vertical datum and geoid model to accurately convert between the two systems.

The predictions of the GTSC reports are rapidly becoming evident and the use of GNSS is becoming far more prevalent in the maintenance and densification of the geodetic infrastructure both in Australia and New Zealand. It is also playing an increasing part in the wider spatial industry. For this reason, at its meeting in May 2004, ICSM asked the GTSC to examine this issue and eventually the following request was proposed.

“To prepare an issues paper on the technical and fiscal implications of incorporating digital GPS networks into traditional geodetic infrastructures.”

A modern integrated geodetic infrastructure is the fundamental reference frame for all spatial datasets and is the means for all users to gain access to the datum. It consists of a number of elements including:

- Terrestrial networks of physical marks with horizontal coordinates and/ or heights.
- Passive GPS sites where suitably accurate GPS observations have been used to establish datum connection on physical marks.
- Continuously operating reference stations (CORS) (eg. Australian Regional GPS Network (ARGN), GPSnet in Victoria, SYDNet, PositioNZ).
- Active or Real Time (RT) GPS systems (eg. VRS, Omnistar, etc.).
- Data, observations and intellectual property (eg. datums, transformation parameters, standards, etc.).
For the purposes of this paper the GTSC interprets the phrase “Digital GPS network” to mean CORS and Active or Real Time networks. These inherently include both post-processed data and real time coordinate solutions. While, based on the current situation, this paper refers to GPS, in the future it should be taken to include other evolving GNSS systems such as Galileo.

Drivers

There are two generic drivers for the uptake of digital GPS networks into the geodetic infrastructure. They are:

1. improved positioning efficiency from new GNSS technology, including the ease with which the geodetic infrastructure can be upgraded or densified; and

2. The need to facilitate and manage the inevitable uptake of GNSS technology by a wide group of users, ranging from cadastral surveyors to non-specialist indirect users, ensuring it is compatible with the existing infrastructure and works effectively with it.

Issues/Implications

The inclusion of digital GPS networks into the geodetic infrastructure and the growing use of such positioning systems in a wide range of non-specialist areas present a number of issues for the custodians of the geodetic infrastructure. The particular issues may vary with local conditions and requirements, but all must be considered when integrating new technology with the old.

Keeping the Geodetic Infrastructure Relevant to the User Base

Development and maintenance of the geodetic infrastructure is a fundamental component of the spatial data infrastructure. While the overriding influence has always been to continually maintain and improve the accuracy and density of the geodetic infrastructure so that it serves a broader section of the spatial industry, the recent development of GNSS positioning technologies has resulted in a change of emphasis. Now we are tasked with keeping the geodetic infrastructure relevant to the user base, which may involve much more than improved accuracy and geometric density of marks.

The number, quality and location of marks can now be more easily targeted directly to user “hot spots” or for specific applications. Depending on the application, users of digital GPS systems could also have specific requirements. The method of access to the real time signal (eg. Mobile Phone, Radio, etc.); the format of the data (RTCM, etc.); and the required level of accuracy, integrity and security may vary for different user applications.
Cost Effective Use of Existing GPS Equipment

The trend with GNSS applications is to utilise costly GPS units more effectively by establishing shared Continuously Operating Reference Stations (CORS) in secure locations. For example in the New Zealand situation Land Information New Zealand has established a partnership with Geological and Nuclear Sciences to develop their PositioNZ network which controls and monitors the geodetic infrastructure as well as providing information for geophysical studies and hazard mitigation. The next logical step is the augmentation of the system resulting in significant cost and time efficiency improvements for the user. Working cooperatively with government (national, state and local), commercial and academic organisations to reduce overlap and share costs can produce combined solutions that may provide benefit to more than the originally intended market.

CORS have additional setup and maintenance costs, but various models are available for their installation and maintenance. These could range from purely commercial services; through commercial systems owned and operated by government, where real time corrections are sold to industry, as in the Queensland VRS network; wholly government owned systems that provide access to data for post processing and enable commercial enterprises to value add for real time capability; and consortium infrastructures where costs, maintenance and benefits are shared with industry partners, as in Victoria’s GPSnet.

Improved Efficiency for Mark Maintenance

GNSS techniques allow datum transfer with high accuracy and reduced logistics and planning. Survey control can be directly established exactly where it is required and marks can be placed and maintained very effectively and efficiently. Intervisibility between the placed marks may need to be considered so they can then be used for exclusively terrestrial applications such as the cadastre.

Global Geodesy Supporting National Geodetic Infrastructure

The data from the Continuously Operating Reference Stations, providing they are suitably monumented, can be used for a variety of globally based geodetic applications such as tectonics and geophysics as well as broader science disciplines (eg. climate change). At the highest level they contribute directly to datum definition through the International Terrestrial Reference Frame (ITRF) and datum infill elsewhere. The benefits of a consistent global reference frame then flow back to Australia’s and New Zealand’s national framework and onto the jurisdiction infrastructure. Improved CORS networks in Australasia could increase this contribution for infrastructure and science.
Broader (Non-Survey) Positioning Community

Australia and New Zealand have a history of rapidly adopting new technology and GNSS is no exception. In-car navigation systems, geo-referenced communication systems, precision agriculture, machine guidance, Location Based Services (LBS) and many more, are resulting in the range of users of positioning technology growing significantly. Positioning technology through GNSS is penetrating the broader community far deeper than any previous positioning system. The vast majority of new users are non-survey based and have little understanding of issues like accuracy and datums. Yet the accuracy requirement for these users frequently exceeds that achievable without taking proper account of datum issues. It is therefore sensible that GNSS infrastructure should be setup for the benefit of all possible users.

Need to Maintain Homogeneous Geodetic Infrastructure

The proliferation of accurate, active GPS services in the spatial industry is largely satisfying the requirements of users, with appropriately accurate services (eg. SunPos, GPSNet, SYDNet, PositioNZ) available over zones of high development, and wide area services (eg. Omnistar) with generally lower accuracy available elsewhere in Australasia and worldwide. It does however place the onus on ICSM to ensure that the positioning information obtainable from these systems is compatible with the nationally adopted datums (i.e. GDA94, NZGD2000 and AHD71). The risk of datum fragmentation is serious and potentially economically damaging if a homogeneous geodetic infrastructure is not maintained. In all the examples of overseas active GPS systems examined an accurate and accessible method of providing the local coordinates and height is a prerequisite to success (see attached information). In addition, consistent standards for GNSS infrastructure are increasingly required to maximise their application.

GNSS is Not Suitable in all Circumstances

While GNSS applications are expanding rapidly a number of circumstances and applications still exist where the physical environment is not suitable or friendly to GNSS observations (or the project specifications do not warrant the use of GNSS or it is financially more viable to do it via other survey means). Clearly GNSS positioning requires good satellite geometry and sky visibility. This may never be achievable under some circumstances such as heavily vegetated areas and urban canyons, which are usually Central Business Districts where the accuracy requirements are generally paramount due to high land values. In these cases even the addition of extra satellites will not improve accuracy because of the inherent bad geometry caused by the restricted sky view and potential multipath. Similarly, some applications, such as cadastral definition, require connection to survey monuments in the vicinity of the survey. The integration of digital GPS networks thus may require legislative changes for some applications.
GNSS is Not Well Suited to the Propagation of the Vertical Datum

For a number of reasons GNSS techniques are still inherently weak at realising the vertical component. The first is the geometric uncertainty caused to GNSS heights by satellite constellation and antenna factors. The second is that orthometric based vertical datums such as AHD71 cannot be replicated geometrically by GNSS because of the geoid-ellipsoid separation and the variation between the geoid and mean sea level as evident in Australia in the case of AHD.

In Australia, despite significant improvements in geoid determination, and the current Height Modernisation project, the fact remains that the only rigorous method of propagation of the AHD at accuracies of third order or better is by conventional leveling techniques from existing benchmarks. A large proportion of users of survey marks are those primarily concerned with orthometric heights. This limitation will remain while an orthometric height datum is adopted, but in Australia and New Zealand it will be mitigated by accurate geoid models including the modeling of the AHD71 – geoid offset.

Although in Australia the Height Modernisation project is expected to produce in 2005 a first version of the combined gravimetric and geometric geoid to reduce GNSS derived heights directly to AHD, it will take many revisions over many years before this system, together with GNSS positioning, would replace benchmarks. Even then a sparse network of physical benchmarks would still be required for some applications.

It is interesting to note that, in contrast to Australia, New Zealand is moving towards the adoption of a new national vertical datum that will be based on GPS derived ellipsoidal heights.

GNSS is Useful for AHD Benchmark Maintenance

GNSS does however provide another tool for AHD71 benchmark maintenance. Once an accurate GNSS ellipsoidal height has been observed for an AHD benchmark, then that benchmark becomes recoverable by GNSS techniques. This can assist in safeguarding the significant investment involved in its original establishment.

Monuments Provide Positional Integrity

Generally, where integrity or confidence in position is needed, survey monumentation is still very important. This includes marks by which digital GPS network positions can be checked, or when redundant methods are required for verification of data or to minimise risk and prove quality. Marks provide access to the datum in the local area for both GNSS and non-GNSS users. Significant levels of survey projects (eg. cadastral surveys and engineering projects where relative accuracy is paramount) are still completed using terrestrial techniques, and maintenance of survey marks allows a continuity of this service, which for many may still be the most economic technique. The integrity of the monuments themselves is of course also important, but this is usually provided by their relativity with adjacent marks.
Monuments Enable Integrity of the Datum to be Monitored

In a country like New Zealand, subject to non-uniform deformation, the density at which active control stations can be economically placed is insufficient to monitor accurately the effects of non-uniform crustal deformation. Additional high quality marks are required at a density to monitor crustal deformation over more localised areas and at times following a deformation event such as an earthquake, so as to enable the datum to be monitored and upgraded following that event. Such networks have also been installed in WA and SA over seismic zones.

Risk Management in a Project May Prohibit GNSS Use

Applications may exist where risk management dictates that the positioning methodology should avoid the use of systems outside the control of the project. Sovereignty can become an issue when exclusive reliance is placed upon a system owned by a foreign nation, to complete activities related to national security or economic activity. A hypothetical example would be maintenance of the Cadastre if survey marks were not maintained and then GNSS accuracies were heavily degraded for some reason by the system owners. For this reason alone, it is sensible to maintain a suitable density of horizontal and vertically coordinated ground marks.

GNSS is Global and Dynamic

GDA94 and AHD71 are static – they do not change with time – and this is not only satisfactory, but essential for most users. GNSS augmentation which provides GDA94 and AHD position is an effective addition to the geodetic infrastructure. However, augmented GNSS systems which provide global positions (ITRF) will differ from GDA94 and this difference will continue to change with time due to plate tectonics. Ideally these systems must provide GDA94 positions automatically and seamlessly for the users as many of them will not have an understanding of the problems involved.

NZGD2000 is a semi-dynamic datum that includes a deformation model that attempts to model the effects of ongoing crustal deformation across New Zealand. However it will also need to consider moves to newer realisations of the ITRF in the future to maintain accuracy and currency.

Conclusion

Integration of digital GPS networks into the traditional geodetic infrastructure serves a far broader positioning community than was previously thought possible. While the “marks based” geodetic infrastructure is primarily used by professionals with survey skills, a GNSS enhanced geodetic infrastructure also serves many segments of the spatial community who have little or no survey training. This places the onus back onto ICSM to ensure that the geodetic infrastructure is homogenous, sufficiently accurate and accessible to suit the requirements of the broader spatial community.
It should be noted that concurrent with the introduction of GNSS techniques to the geodetic infrastructure has come the changing shape of the traditional mark based networks. Visibility for triangulation or trilateration is no longer a prerequisite for mark placement (though it may still be an important consideration for some users of the geodetic network). This has resulted in “hill top” marks being no longer maintained while denser, more accurate networks of marks are being established in “hotspots” or areas of high demand. Generally GNSS techniques play a strong role in placing these new marks. This relationship and interdependence between traditional physical networks and GNSS will continue with both requiring maintenance and resources.

Apart from the requirements of specific “hotspots”, the location and density of both digital GNSS base stations and required physical marks will vary with the particular geography, demography and user applications in each jurisdiction. Network extension and maintenance strategies are assessed individually, taking into account specific needs including availability, location and quality of existing geodetic infrastructure, future development prospects/requirements and regulatory requirements relating to cadastral datasets and land registration processes.

Generally there is a need for improved relative accuracies in urban areas. This may dictate denser networks of survey control. However, there are some rural areas that may have the same requirement. (eg. mapping projects, environmental impact studies, mining and engineering works and seismic activities which will have particular requirements). If in the near future there is a full uptake of GNSS techniques by industry, the trend for physical marks is likely to be for a broad spacing of perhaps 100s of km in very remote areas; 20-100km in rural/pastoral areas; 5-20 km in peri-urban areas and street corner level to 5km in urban areas.

Currently, the distribution and density of GNSS base stations also depends on their application. AUSPos uses are satisfied by the broad distribution of the ARGN (typically a thousand kilometre or more); GPS base stations for post-processed survey data may have spacing of the order of 100 kilometre; VRS networks need to have a 50-70 kilometre density; and RTK base stations have a useful range of about 20 kilometre. This may change with future technological developments.

The fiscal implications of incorporating digital GPS networks into traditional geodetic infrastructures are complex and beyond the expertise of the GTSC. However, while there are costs associated with the introduction of digital networks, there are also enormous benefits from a much wider user base than was previously served. The allocation of resources needs to be viewed in the context of an additional service provided to the spatial industry, rather than a reallocation away from the existing infrastructure. The cost benefits to the users needs to be examined as well as the cost burden to the government.

Ultimately jurisdictions need to consider all of these issues to decide which mix best satisfies the drivers in their area. Some jurisdictions may have their own additional drivers and issues to those discussed here.
AUSTRALASIAN CASE STUDIES

Victoria

Victoria has an extensive network of nineteen active GPS base stations covering most of the state (GPSnet, 2004). The network allows registered users working within range to download survey quality GPS data for their projects, providing an efficient means of establishing positions. Seven other base stations are subject to negotiation to provide services to users such as precision agriculture and machine guidance. A pilot study to provide Differential GPS for Location Based Services (LBS) is also planned. Martin Hale (2004) states that most users of GPSnet are not surveyors, but spatial data professionals or para-professionals, while the primary users of the ground marked networks are surveyors. He also maintains that “for the foreseeable future GPS/GNSS will not and cannot entirely replace ground mark networks for all forms of geodetic and other spatial positioning requirements.”

Five personnel employed in support of Victoria’s 15,000 survey marks only establish new marks in response to specific requests for control. Maintenance too is in response to specific requests for replacement of any marks destroyed or damaged. The GDA94 coordinates of the GPSnet base station have been derived from this network of marks and in a few instances there are differences of the order of 10 cm between these coordinates and the GDA94 derived from the ITRF positions converted to GDA94 using a national model.

This discrepancy will be resolved by a suitable readjustment of the network which includes ITRF-derived positions for selected GPS base stations, AHD junction points, subsidence monitoring points and common jurisdiction border points. In addition, a 50 kilometre passive GPS network incorporating the above points will also be included. The observation of this network has already commenced and the improved network will resolve the above issue and also contribute significantly to the development of the GPS-AHD correction surface.

Northern Territory

The NT Government is investigating the establishment of a pilot study with local authorities for the establishment of permanent GPS base-stations in the greater Darwin region. The objective of this GPS-based network will be to enhance the existing geodetic infrastructure and to facilitate the evolvement of a coordinated cadastre. It will also provide surveyors and other spatial users with the opportunity to utilise modern positioning technology efficiently and effectively to meet their business needs.

Queensland

The Queensland Department of Natural resources and Mines operates a Real Time Kinematic Virtual Reference System (VRS) over a large part of Brisbane (Higgins, 2002). This system allows suitably equipped and registered users to obtain centimetre accurate GDA94 positions in real time. However Queensland also maintains a dense network of marks that have been accurately tied to the national geodetic network. With its widely varying population density and varying growth patterns the preference is for VRS style solutions in larger urban areas, while AUSPos will be more influential in the most remote areas, and in between there will be continued reliance on ground marks on a case by case basis.
New South Wales

As well as the extensive conventional survey network, New South Wales is developing an active GPS system network (SydNet) consisting of seven base stations covering the Sydney metropolitan area (three already in place). The system will use the existing communications infrastructure of the railway network and will provide RTK positioning.

New Zealand

Three years ago Land Information New Zealand (LINZ) embarked on a four year program to implement an active control station network, known as PositioNZ, consisting of approximately thirty stations. To date fifteen stations are operating in the North Island, ten in the South Islands and one on the Chatham Islands. Over the next year a further five stations will be established in the South Island and one at Scott Base in Antarctica. Consideration is being given to several additional sites in the North and South Islands.

Future plans include developing an online post-processing service like AUSPos and investigating the development of a real time network using the 1-second data.

The business case developed to obtain support and funding for this project was on the premise that the active control network would enable geodetic control surveys to be undertaken more efficiently, and that the dynamics of New Zealand could be monitored and the results used to update the NZGD2000 deformation model which forms an integral part of NZGD2000. The business case was NOT built on the premise that such a network would reduce the need for conventional geodetic survey and control marks.

When NZGD2000 was developed, predominantly using GPS technology in the late 1990s, it was proposed that the geodetic infrastructure consist of six orders of marks Zero – five. Zero order marks were high accuracy GPS permanent tracking stations and fifth order geodetic marks used to support cadastral surveys and other users. The density of the fifth order marks was approximately 300m in urban areas, 1km in peri-urban areas, and 3km in rural areas. The intervening orders provided a breakdown from the high (Zero) to the low (fifth) order network, much in the same way as had been developed under the old NZGD49 when conventional survey technology was used.

The development of LandOnline and Survey Accurate Digital Control (SDC) areas led to the development of a dense fifth order network in urban and peri-urban areas. It also led to the concept of a geodetic cadastre with cadastral survey and boundary marks having geodetic coordinates. In SDC areas cadastral surveyors are required to tie their surveys to NZGD2000 control marks, and outside SDC areas, where NZGD2000 are close to the survey, surveyors are also required to tie to the NZGD2000 control network. The number of NZGD2000 geodetic marks rapidly increased during this period of development. In fact over 50,000 marks were added to the geodetic database.
As the PositioNZ network has been rolled out across the country geodetic contractors have been required to tie to the PositioNZ network. In the future this will enable geodetic control to be placed much more efficiently as it can be surveyed directly from the PositioNZ stations (zero order stations). This has meant that for most requirements there is no longer the need for the breakdown in control from the zero to the fifth order network, i.e. the first, second, third, and fourth order networks are largely becoming redundant. Often these (first – fourth) order marks are in areas where they are little used and hence in the future they need not be maintained, at least to their high order of accuracy, nor these networks extended. Where they are being used they are being resurveyed to fifth order standards instead of third or fourth, etc.

The development of the PositioNZ network has seen a simplification of the geodetic infrastructure to two orders of marks, zero order (PositioNZ stations) and fifth order. The small numbers of zero order marks (about 30) are costly and expensive to maintain and run, and the large numbers of fifth order marks are cheap and easy to place and survey. This has meant that many more geodetic marks are being placed to satisfy user needs in locations where they are required, particularly to satisfy cadastral surveyors’ needs. The development of the PositioNZ network has therefore seen a rapid increase in the number of fifth order marks and reduction to two main orders of mark, zero and fifth order.

INTERNATIONAL CASE STUDIES

Great Britain

Great Britain is an example of where traditional survey marks infrastructure has been modified by evolving GPS technology. The original network of survey marks coordinated by the Ordnance Survey of Great Britain in 1936 (OSGB36) has gradually become less usable, and few of the OSGB36 marks “have been checked more recently than the 1960s” (Ordnance Survey, 2004). This traditional network has largely been replaced by a network of thirty Active GPS stations and about nine hundred Passive GPS marks.

The network of Active GPS stations allows users to download data for post processing with their own GPS data. The density means that most locations are within about 100km of an active GPS station. “Typically, the Ordnance Survey active network would be used to position a small number of primary survey stations with a dual-frequency survey-grade GPS receiver and processing software, and surveying would then proceed from those primary stations using short-distance relative GPS methods (for example, Real-Time Kinematic, or a DGPS base station) or an optical survey instrument (for example, total station)” (ibid).

A Passive GPS network consisting of about 900 marks whose 3-dimensional ETRS89 positions have been accurately determined by GPS survey (ETRS89 is a 1989 precursor to ITRF). Many of these are new, purpose-built marks, while others are upgraded existing survey or bench marks that are physically annotated to indicate this. The precise ITRF positions of this passive network are monitored by the Ordnance Survey on a five year cycle and they recommend that “all GPS surveys should be based on control stations with accurate and recent ETRS89 coordinates” (ibid).
The Active and Passive networks are only able to replace the original OSGB36 network because Ordnance Survey have in place unique and accurate processes to transform between ETRS89 and OSGB36 positions and orthometric heights. With regard to height determination, Ordnance Survey recognises that “GPS observation times must be longer to obtain precise heights" and advises the use of several GPS coordinated marks on a project and leveling between them to check the consistency of the orthometric heights.

Although Great Britain has taken steps to modernise their geodetic infrastructure by introducing Active GPS systems, they have not dispensed with survey marks, but have rationalised them and made them more accessible. The maintenance of the 900 Passive GPS marks, in an area similar to Victoria Australia (approximately 230,000 km²), remains a significant task.

Canada

Canada has transferred responsibility for the maintenance of the classical networks of survey marks to the provinces. At the national level, a network of forty three active GPS stations, which make up the Canadian Active Control System (ACS), is operated along with a passive network of about 200 stations known as the Canadian Base Network (CBN). The CBN is re-surveyed on a five year cycle. These provide the fundamental framework upon which provincial and other federal agencies densify and establish their own control networks. Most Provinces are moving toward high precision networks with a combination of Active and Passive control points at various densities down to 30 km (Legree, 2004).

Canada continues to use the Canadian Geodetic Vertical Datum 1928 (CGVD28) and between 1972 and 2000 nearly the entire network of 124,000 km of leveling was re-surveyed. Canada is working towards a new geoid-based vertical datum compatible with GPS, but doesn’t expect a suitable geoid model to be available until at least 2006. It also recognises that the “transition from CGVD28 to a new datum will span several years or even decades”. Although the introduction of a new, GPS-compatible height datum would decrease reliance on the dense monumented ground network, it would require a set of transformation “shifts” to support the conversion of CGVD28 data. The existing benchmark networks would continue to remain during the transition period, which could last for decades. (CGRSC, 2004)

Germany

The German National Survey Satellite Service Positioning (SAPOS) provides centimetre accurate positioning services for a range of users and connection to the ETRS89 datum. However, it still requires the Berlin State software products for transformation to the still-valid Soldner-Berlin plane coordinate system and into the uniform nationwide DHHN 92 height reference system. “SAPOS will not be able to replace entirely the terrestrial measurement procedures for detail surveys. However the economic and technical advantages will lead to ever wider use of this modern technique” (Senate Dept of Urban Environment, 2004).
United States

The United States National Geodetic Survey (NGS) has around 16,000 geodetic control stations in three categories, with shared establishment and maintenance (NGS, 2004a):

1. The high accuracy network known as the Federal Base Network (FBN) that consists of about 1400 passive GPS stations at about 100 km spacing. This FBN is managed by NGS.

2. The Cooperative Base Network (CBN) of some 14,600 stations at about 25 to 30 kilometre spacing, which is maintained through cooperative agreements with other Federal agencies, state and local governments.

3. The User Densification Network (UDN) of additional monumented stations connected to FBN or CBN and surveyed by the private sector with no cooperative agreement.

In addition, NGS coordinates two networks of continuously operating reference stations (CORS): the National CORS network and the Cooperative CORS network. Around 300 CORS sites provide Global Positioning System (GPS) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout the United States and its territories (NGS, 2004). The Cooperative CORS network provides access to GPS data that are disseminated by organisations other than NGS.

NGS’s OPUS on-line GPS processing system is similar to Australia’s AUSPos system in that it provides both ITRF and locally adopted NAD83 positions (NGS 2004c).

NGS is coordinating Height Modernisation activities to facilitate an upgrade to the National Vertical Datum and geoid determination and the use of GPS in the accurate determination of height. The current vertical datum for United States is the North American Vertical Datum 1988 (NAVD88) which was adopted in 1993, but the existing network of marks is inadequate to meet the needs modern users as a result of many marks being disturbed or destroyed. Business cases for this funding have been based on the need for accurate and consistent height information to serve as the foundation for improved transportation systems, subsidence monitoring, sea level rise estimation, floodplain mapping, urban planning, storm surge modeling, habitat restoration, emergency preparedness, resource management, site-specific farming, construction, mineral extraction, and seismic and infrastructure monitoring.

Two examples demonstrate the breadth of initiatives being undertaken to augment the National Geodetic Network.

In Washington State (75% the size of Victoria) it is proposed to integrate 80 GPS Base Stations and re-measure around 5,000km of leveling traverses using Federal funding and a consortium of government and private industry representatives (NGS, 2004).
In Wisconsin (60% the size of Victoria), a Height Modernisation and Network Densification Project has been underway for three years and is due for completion in 2006. The key outcomes from this project are the densification of the existing GPS network at three different levels (primary base stations at 25 km spacing; secondary base stations at 12-14 km spacing; and local network stations at 6-8 km spacing); locating new bench marks at 2 km spacing along level lines; performing conventional leveling on bench marks, HARNs, and primary base stations; and performing GPS on all levels of GPS stations to transfer elevations (NGS, 2004e).

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