# Surveying Down Under:

# "3D" Location of Underground Pipe and Cable Networks

*WINNER:*
*1999 EXCELLENCE IN SURVEYING AWARDS*
*"Public Sector" Category*

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## ABSTRACT

This paper demonstrates the role of the government surveyor as a supplier of critical services in fields where the market is immature and the service is not available from private industry.

Notwithstanding that the role of the government surveyor is gradually changing from the traditional field survey role to one of project manager, there are parts of the geomatics industry which are critical to government organisations such as the Roads and Traffic Authority but which cannot be provided by the private sector. In such "immature" technologies, the RTA must remain integrally involved until maturity can be achieved by the industry.

"Immature" technologies provide the opportunity for the government surveyor to be a technology leader and to develop new and innovative methods of work. There are distinct and measurable benefits to be gained from this for the surveying profession as a whole. Such work has the potential to strengthen the role and reputation of the professional surveyor in the community with regard to the collection, manipulation and management of spatial data.

The detection and location of underground utility services is one such area which is critical to the Roads and Traffic Authority, particularly in terms of risk management, but where the Authority's needs are not yet reflected, and are not currently provided, by the private sector. The surveyors involved in this project have demonstrated that the role of government surveyors is not limited to demonstrating their skills above the surface of the earth but can be adapted to progress the discipline in mapping hidden structures and features that lie just below the surface.


## INTRODUCTION

Keeping the road network in good condition and managing a world class road system are two of the core functions of the Roads and Traffic Authority. The implementation of measures to achieve these goals quite often results in conflict with existing public utility services. The detection of these services prior to the design phase of roadworks can produce obvious savings in both time and money. Notwithstanding this, in past years the location of underground services was quite often left to the construction stage of a project, where services were literally "dug up". This has been at significant cost to the community.

A refreshing adoption of the principles of commercial awareness in government has resulted in the development of services which are purposefully aimed at reducing the total cost of a project to the community. The detection and surveying of underground public utilities is one such service that has been developed specifically for this purpose.

Whilst other organisations interested in the location of underground services are usually content with the knowledge of whether a service is present or not, the Roads and Traffic Authority needs to know the precise, three dimensional, position of the service so that this

can be incorporated into the new road design. The indirect benefit of this activity is that the records of the utility companies can also be updated with more highly accurate information. This, in turn, adds to the integrity of the State cadastre.

However, the Roads and Traffic Authority discovered that its requirements in regard to public utility detection were not able to be met by the private sector. Although detection companies did exist, they did not provide a precise location service: the technology was critical to the Authority but the market was immature. It therefore became necessary for surveyors in the Roads and Traffic Authority to find innovative ways of improving and enhancing the skills that they acquired in traditional surveying by expanding into less traditional survey practices.

Underground utility detection and location is a specialised field of spatial information management. The Authority's experience in this area has proven that you *can* measure what you *can't* see.

## BACKGROUND

Public utilities include gas, Telstra, Optus, electricity, high pressure fuel, water and sewerage services. Recommended space allocations exist for the placement of public utilities in footpaths. However, in practice, utility authorities do not strictly adhere to these allocations. Additionally, plans supplied by utility authorities contain a disclaimer that the plans only indicate either the *presence* or *absence* of a utility service and not its actual position. To limit their liability, public utility companies are also removing themselves from the physical detection of their own services.

Organisations that damage utility services are responsible for the damaged caused. As the Authority undertakes a large proportion of its work on existing roads, the risk of damage to utility services during construction works is high. Should a service be damaged, the total cost to the Authority comprises not only the down-time and repair of the service, but also the delay to the Authority's project as well. An additional community cost is the isolation of large sections of the community should a service be damaged and not immediately repaired. The reputation of the Authority is also compromised by any works which cause disruption to the community: especially when such adverse affects could have been avoided through proper planning and the utilisation of skills already existing within its workforce.

In the past the RTA has located underground services by using the presence of surface structures, such as hydrants, to indicate the possible location of the underground services, and then either "pothole" to try and find the service prior to the commencement of construction or find them using construction machinery. There is an inherent risk in damaging services using these methods.

Once the services had been found it then had to be determined if these services would have a detrimental effect on the proposed route of the road and the associated road drainage. In most circumstances the location of the services meant that a costly redesign had to be carried out or prolonged negotiations with the relevant service authorities was required to have the services relocated before construction could continue.

Through their work in road construction, RTA surveyors realised that there was a high risk to the Authority associated with not knowing the precise location of underground public utilities. They also realised that the accurate three dimensional location (including depth) of public utilities during the investigation stage of a project would permit the services to be incorporated into the design and hence avoid the possibility of significant costs in redesign during the construction phase.

The work now carried out by the Authority's Utility Locations Survey Unit is dependant on partnering between the Authority and service providers, as these utility authorities recognise that cooperation will assist them to update records which are either incomplete, outdated or inaccurate. In this respect, the service provided by the Roads and Traffic Authority is not only of benefit to itself but it also provides an immediate and measurable benefit to the community.

The service provided by the Authority's Utility Locations Survey Unit is highly valued by the Authority, utility companies and both public and private organisations, as it allows all organisations to make valuable and well informed decisions regarding the possible relocation of essential services and helps build and update the States cadastre.

## PROJECT SURVEYOR

Engineering Surveyor Paul Pemberton is the Unit Manager in charge of Utility Locations Surveys at the RTA's Sydney Technical Services Office at Parramatta. Paul's Utility Locations Survey team is comprised of Engineering Surveyors Peter Beaver, Jeffrey Best, Lindsay King and Survey Assistant Alistair Sheardown.

### Involvement of the Surveyor in the Project

The Utility Locations Survey Unit has located underground services for:

- major road and freeway concept and detailed design;
- intersection reconstruction;
- pavement rehabilitation surveys;
- drainage investigation on the approaches to the Sydney Harbour Bridge,
- the positioning of sound walls so that the supports for the wall can be placed so as not to impact on public utilities;
- *EnergyAustralia* to determine the best position for major jointing pits;
- work as executed ("as built") plans of the assets of other service providers such as Australian Water Technology and AGL.

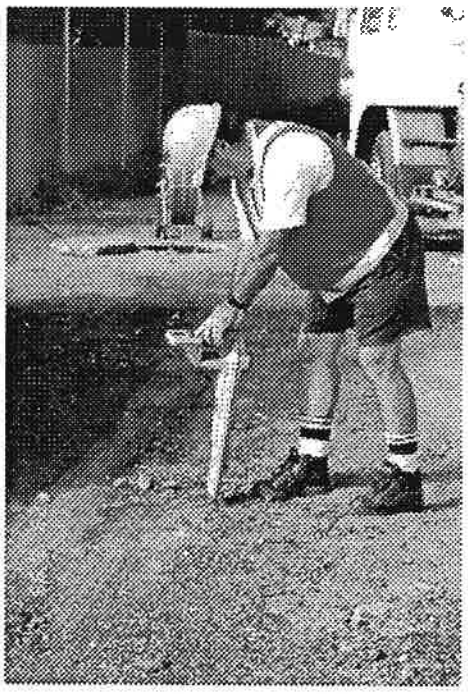
The process of surveying under the surface of the earth, or *surveying down under*, is one that can be time consuming, complicated, involved and is one aspect of surveying that presents its own variety of challenges. The tasks require of the project surveyor are to:

- determine the scope of the project through consultation with the design officer, project manager or through interpretation of construction plans;
- identify all those services that will have an impact on the project;

- collect and collate all available information from the various service providers;
- provide advice concerning services to the Authority, public utility authorities and the general public;
- manage the location survey of those services identified as having an affect on the project;
- determine innovative solutions to utility location problems which can have a real potential to affect the viability of the project, particularly in terms of cost and timeframe;
- determine the exact location of the services shown on the acquired utility plans;
- confirm that all utilities have been found even those that may not be shown on the acquired utility plans (that is, locate both charted and *uncharted* services);
- demonstrate that the surveyed position of the services is accurate;
- present the survey information in a format that can be easily used by the people requiring it: either in the form of a hard copy of a plan or in electronic format.

Surveyors involved in this type of activity require additional competencies to those expected of a surveyor involved in traditional work. These competencies include the successful completion of recognised studies such as:

- Gas Detector Course
- Senior First Aid Certificate
- Pipe & Cable Location Course
- Confined Space Management
- Working in Confined Spaces
- Traffic Control at Worksites
- Telstra Accreditation



*Surveyor Lindsay King receiving a transmission from a sonde attached to a flexicable. The flexicable has been fed into the stormwater pipe from the manhole in the middle distance.*

**Challenge to the Professional Surveyor**

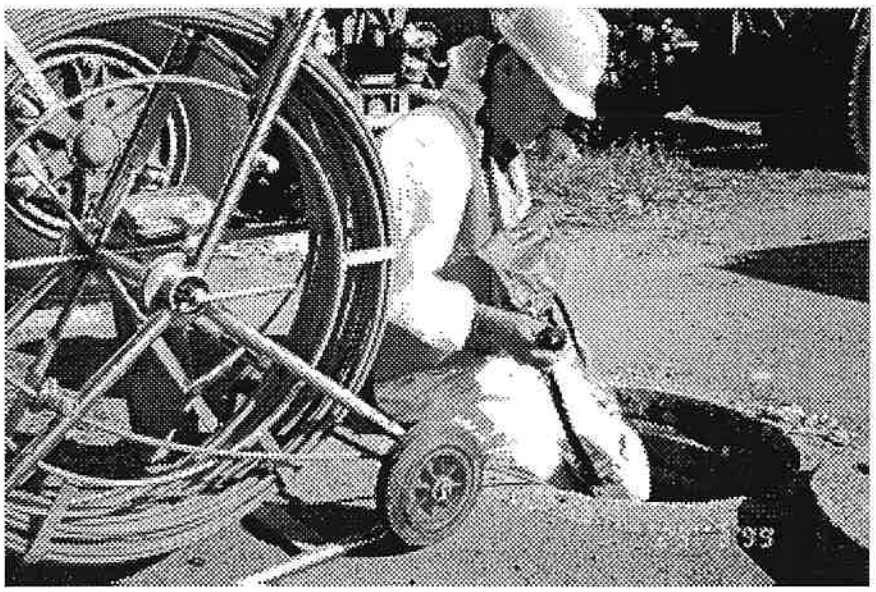
The challenge to the professional surveyor is to accurately fix the position of structures that can not be seen from the surface or easily accessed and still meet the client's time, cost and quality constraints. The surveyor needs to be able to:

- respond instantly to requests to determine the exact location of services;
- provide expert advice on utility location and the interpretation of utility plans;
- provide innovative solutions to problems in a limited time period;
- effectively communicate with all levels of management, other professionals, members of the public and representatives of the various service providers;
- provide accurate and competitive estimates for cost and time to carry out agreed work;
- engage professional service providers for tasks that are required to meet the project objectives;
- ensure that all work carried out complies with OH&S, Work Cover and public utility authority requirements for entering confined spaces.

The project surveyor must not only be experienced in the use of conventional surveying equipment, the surveyor must also be proficient in the use of:

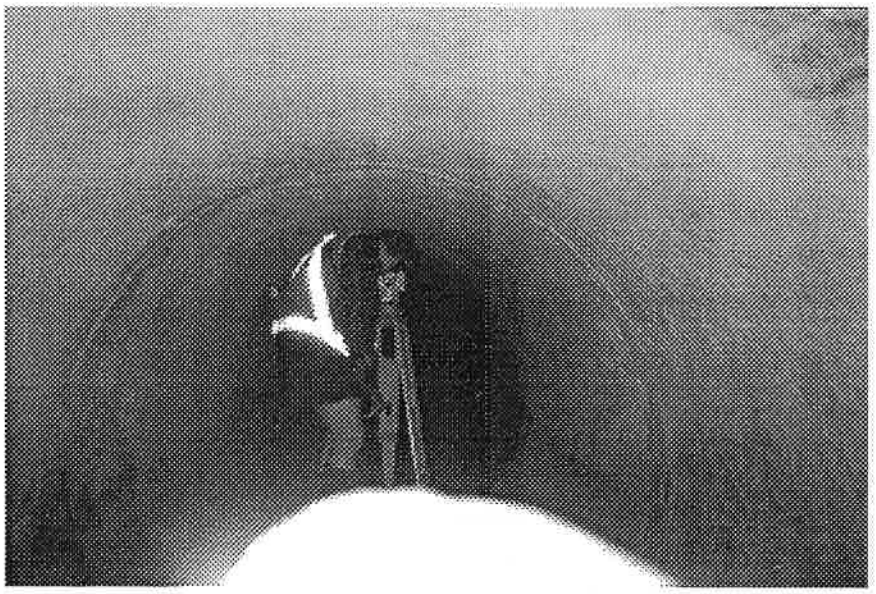
- Underground service locators such as the Radiodetection RD400 PXL2 and PDL2 receivers and the RD433 HCTX2 high powered transmitter;
- Gas testing equipment, such as the Gastech GX91 and 'Tox Alert' CGM-929, to detect upper and lower oxygen levels, carbon monoxide, hydrogen sulphide, methane and petrochemicals;
- Close Circuit Television cameras to determine the condition of stormwater pipes and to investigate utilities in areas of high environmental risk;
- 120 metre flexible rod and sonde (transmitter) for tracing the direction of pipes;
- 50 metre flextrace for tracing optical fibre or pipes of less than 20 mm diameter;
- GATIC lifting devices (for compliance with Occupational Health & Safety requirements);
- Quick response emergency breathing devices such as the CABA Emergency Response Device.

However, just as conventional survey instruments need to be utilised by an experienced and educated operator, the surveyor using underground utility detection equipment must be acutely aware of the capabilities of the instruments being used. It is perhaps more challenging for the underground utilities surveyor in that erroneous depths are not as easy to detect as a gross error in an above ground distance, which can be checked visually. The surveyor involved in this activity must be aware of hidden traps such as "shadowing", where a large utility may mask the position of a nearby smaller utility. The surveyor must also be aware of the need for quality checks on the work, through the use of a prod bar or pot-holing.



*Surveyor Paul Pemberton entering a confined space. Measuring equipment visible in the photograph are the 120 m flexible rod, Radiodetection receiver (behind reel) and the sonde. Safety equipment includes a hard hat, red vest, white overalls, gas detector, the CABA emergency breathing device and steel capped boots (latter not visible).*

The professional surveyor must also be aware of the unique and challenging occupational health and safety requirements associated with this type of work. Often the surveyor needs to hook onto live services or enter into confined spaces. If service ducts and pipes are sufficiently large, it may be necessary to traverse through these services, and this can result in additional concerns.



*Surveyor Jeff Best traversing through a 1500 mm diameter stormwater pipe between Wheat Road and Sussex Street, Sydney - four metres below the surface.*

## METHODOLOGY ADOPTED

Prior to the Authority becoming involved in this area of spatial information management, the public utility companies had removed themselves from the detection and location market. This meant that there was no set, safe, procedure for the detection of underground public utilities. The methodology developed by the Authority was as follows:

1. Receive project brief from client;
2. Issue utility inquiry to Sydney One Call services ("Dial Before You Dig"), which notifies utility companies of the area of interest;
3. Utility companies notify the Authority of the status of the services in the area of interest;
4. Collect relevant utility plans, confirm that a response has been made by all utility companies;
5. Locate all visible services on site (hydrants, Telstra pits etc) and compare surface features to the locations shown on the utility plans;
6. Commence location of water services using surface features;
7. Gas test Telstra and electrical pits prior to opening. Continue gas testing of open pits;
8. Use plans to compare cables shown on plans with those present in the pits;
9. Electronically locate all cables;
10. Locate gas services by pot-holing if a trace wire cannot be found;
11. Locate sewer and drainage pits and manholes. Gas test prior to opening and during survey activities. Obtain invert levels and direction of pipes by visual inspection, fluorescent dye or electronic location using sonde;
12. Carry out pot holing as a quality check or to resolve problems with electronic location. Reinstate pavement etc to Council's requirements following pot-holing;
13. Mark service location (position and depth) on the ground using coloured tags, paint etc;
14. Survey utility positions using conventional methods;
15. Download data and produce utilities model and plan;
16. Compare plan of survey with plans acquired from the utility companies to ensure all charted services have been found and identified;
17. Report on the location of utilities, highlighting problems experienced, services unable to be located, unidentified services located and review of pot holing results;
18. Independently check on plan and report, prior to forwarding to client.

*Electronic detection of a water service. The surveyor has exposed a stop valve and connected the transmitter to it. The transmitter has been earthed via the metal rod to complete the circuit. The surveyor is reading the depth of the service as detected by the receiver. Also included in this photograph is the small diameter prod bar used to confirm depths of pipes.*

## INNOVATION

### 1. Coding of Services

Because the Authority is interested in tracing all public utilities in an area, a system for identifying the located services needed to be developed. This is of primary importance where there is a delay between the electronic locating of the services and the commencement of the survey. There were basically two concerns: how to uniquely identify the wide variety of public utility services and how to differentiate between individual utility lines of the one service type.

To address this problem, the Utility Locations Survey Unit devised a method of colour coding using tags and alpha codes. The original adoption of alphanumeric codes was found to be unsuitable due to the possible confusion with the depth of the service, which is written on the tag after the code. Alpha codes have now been established as the method of identifying services, and these codes are shown on the table below. The Authority is currently holding discussions with the Queensland Department of Main Roads and VicRoads in Victoria with the object of obtaining interstate consistency in the labelling of underground utilities for survey purposes.

The NSW colour and code system devised by the Unit is as follows:

| Service | Colour | Alpha code |
|---|---|---|
| | | |
| Water | Blue | WMAA first watermain, WMAB second, to WMZZ |
| Stormwater | Blue | SWAA to SWZZ |
| Sewer | Orange | SMAA to SMZZ |
| Telstra/Optus | Red | TLAA, to TLZZ |
| Optical Fibre (Telstra/Optus) | Red | FUAA to FUZZ |
| Gas | Yellow | GMAA to GMZZ |
| High Pressure Gas | Yellow | HGAA to HGZZ |
| High Pressure Oil (Fuel) | Yellow | HOAA to HOZZ |
| Electricity | White | EUAA to EUZZ |

Although Australian Standard AS1345-1995 *Identification of the Contents of Pipes, Conduits and Ducts* is not intended to apply to buried or normally inaccessible services, the Unit chose the above colours to generally comply, wherever possible, with the Standard.

## 2. Closed Circuit Television

Often clients require to know the condition of pipes so that informed decisions can be made in regard to their replacement or repair. Utility services usually do not permit direct access by surveyors, and so a closed circuit television camera (CCTV) is used. The location of the camera within the pipe is very important and to determine this, the camera is attached to a sonde, which emits a signal to a receiver on the surface. This technique is able to record the condition and three dimensional position of the pipe and was used extensively on investigations on the status of the drainage structures within the abutments of the Sydney Harbour Bridge. The Unit also used ground penetrating (or impulse) radar on this survey to determine the positions of the abutment buttresses so that new drainage structures could be installed in positions which would not compromise the integrity of the structure. Ground penetrating radar determined that these buttresses were not in the positions shown on the 1920s design plans.

## 3. Plan format

The Utility Locations Survey Unit was required to develop a standard plan format, as underground utility plans had not been previously produced by the Authority. Information supplied by the utility companies was neither consistent nor sufficiently accurate to provide guidance in this task. The Unit was also required to manage the Authority's risk in this area of operation by the inclusion of an appropriate disclaimer on the plan.

The format of the plans used to convey information about the positions of underground public utilities needs to be readily understandable by those not familiar with plans of survey. Depths needed to be shown not only from the design model but from the existing natural surface. Long sections of services were also deemed to be necessary to provide a complete picture of the utilities for the designers. An example of plan formatting is included as Appendix 2 to this submission.

### 4. Detecting Uncharted Services

Surveyors are trained to examine all available evidence prior to providing professional advice. In terms of underground services, the client's interest is not restricted to services which have been charted by the public utility companies. The client needs to know the location of **all** services so that informed decisions can be made.

Experience in this field of operation has revealed that there are three scenarios:

1. a service exists in the location shown on the charting map supplied by the utility company;
2. a service shown on the charting map exists, but not in the position indicated on that map;
3. a service exists in the field which is not shown on any charting map.

The last of these presents a real and tangible risk which needs to be managed. The services involved in the first two scenarios can usually be located by reference to surface evidence such as manholes, hydrants and gas markers. Often such surface features will indicate the existence of an uncharted service which can then be traced. However, often surface information is not present and it is the experience of the surveyor which will detect if a signal appears to be reflected from an unknown utility and whether further investigation is warranted as a consequence of this. Procedures developed for high risk activities such as geotechnical core boring now include a scan of the whole area by the surveyor prior to the commencement of work.

## PROMOTION OF THE PROFESSION

The detection and location of underground services is a field in which there is an increasing demand for the services which a surveyor can provide. Notwithstanding this, it is also a high risk occupation in terms of both occupational health and safety for personnel and the business risk of an inaccurate or incomplete survey. Clients recognise the degree of expertise and professionalism which is inherent in those undertaking this task.

The Authority does not advertise that it has surveyors who specialise in underground utility detection. However, there are other organisations within the community which require this service. The reputation of the Authority's Utility Locations Survey Unit has lead to work being undertaken for other organisations, which include:

- EnergyAustralia
- Telstra
- Private design companies
- Sydney Water
- Private survey practices
- Department of Housing
- AGL
- Councils
- Rail Services Australia

Comments from clients in regard to one member of the team included the following:

Mr Walter Prolov of SWR Engineers Pty Limited writes *"I have always found Paul Pemberton to carry out the work in a professional manner within the time agreed and generally within his estimated costs. ... Paul Pemberton's work is accepted by Telstra to be of a high standard in terms of location of their services".*

Chris Osborne of the Authority's Road Design Services confirms that *"Normally nobody outside Telstra is allowed to carry out this (location) work without Telstra's supervision. Paul managed to carry out this survey work which involved exposing the cable in a number of locations, without Telstra's supervision. This was due to Telstra's recognition of his highly regarded expertise. This in turn saved us a lot of time and extra expense. Paul also had to carry out delicate negotiation with hostile and uncooperative property owners in order to enter private property to carry out his survey".*

## COMMUNITY

### Sensitivity to the Environment

The utilisation of underground service detection equipment means that the ground surface can remain comparatively undisturbed. This is particularly important in areas of high environmental significance or historical sensitivity. It also means that there is no unnecessary disruption to traffic as there is no need to use excavation to locate services between kerbs.

Techniques used in underground utility detection are now being expanded to the use of ground penetrating radar in the detection of contaminated sites. This radar can detect the extent of leakage from pipes or underground tanks. An accurate account of the extent of contamination can then be determined.

### Benefit to the Community

Damage to underground pipe and cable networks can isolate large numbers of people. The detection and location of underground services reduces the risk of "accidental" discovery of public utility services.

The opportunity to input accurate public utility locational information into the utilities layer of the Digital Cadastral Data Base is an additional benefit of the work being undertaken by the Authority's Utility Locations Survey Unit. The development of a survey accurate underground utilities database will assist in the prevention of accidents and reduce the associated costs to the community.

### Cost Effectiveness

The detection and location of underground services can be equated to "preventative medicine": for the relatively small outlay of the cost of a survey party, large repair bills can be avoided.

The detection of services during the design stage of a project can limit the extent of litigation caused by the accidental discovery of services, especially when this discovery results in personal injury.

The discovery of services during construction can halt works for a varying amount of time whilst new design is done or the service is removed. Either of these add significant variation costs to the project.

Where there are many options for the route of a project, the detection of underground services in the concept design phase can reduce the number of these options by eliminating those with high utility relocation costs. This, in turn, reduces the investigation costs into the determination of the new route.

## CONCLUSION

Improvements in positional technology such as GPS have reduced community perception of the value of the surveyor's work. The profession must extend itself into new areas of operation which require a level of skill not readily obtainable by members of the general community. Underground utility detection and location is one such area of operation.

The needs of the Roads and Traffic Authority to reduce the cost of its construction work and to minimise its risk in conflicts with existing public utility services opened a window of opportunity for its surveyors to demonstrate their unique contribution to the core business of the Authority. Expertise in surveying, combined with skills in public utility detection, has resulted in the timely delivery of a comprehensive service at a cost which is less than that which could be obtained through external agents.

The Authority's Utility Locations Survey Unit produces a complete service which combines underground utility *detection* with underground utility *location*. It is a service which directly addresses the needs of the Authority and indirectly addresses the broader requirements of the community. It is also a service that promotes the surveying profession to the community as the experts in spatial information data collection, manipulation and management.

**Surveying Down Under**: you *can* measure what you *can't* see.