University of Southern Queensland

Faculty of Engineering and Surveying

Virtual Reference Station (VRS)
In South Africa

A dissertation submitted by

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ABSTRACT

This project seeks to investigate and report on the performance of the South African Virtual Reference Station (VRS) concept as an extension of the Global Positioning System (GPS) Real-Time-Kinematic (RTK) survey technique. Using this investigation, it is hoped to provide reliable and valid information on the accuracy, precision and reliability of the VRS survey technique.

VRS addresses many of the limitations faced by the classic RTK technique. The past few years has seen many countries install permanent reference station networks to spatially model the biases for a given region. The Chief Directorate: Survey and Mapping has developed two permanent reference station networks called the Gauteng VRS network and Western Cape VRS network. Both these networks operate using Trimble's VRS hardware and software.

Classic RTK technique enables surveyors to carry out centimetre level positioning activities. The accuracy of classic RTK has been well documented. However, the accuracy, precision and reliability of the VRS network, here in South Africa, have yet to be proven.

The reliability of the Gauteng VRS network is assessed by carrying out detailed testing of determining the performance of the accuracy, precision, initialisation times and its coverage extent. Several test sites located within, on, and outside of, the network are selected and several measurements are collected, processed and collated at each test site.

The results indicate that the Gauteng VRS system is at least comparable to the classic RTK technique in the areas of accuracy, precision and initialisation times, and demonstrated greater robustness of the coverage extents of the system. The results of the test will be of interest to existing and potential users of GPS for positioning activities and will benefit them as an aid to making an informed decision.

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ENG4111 Research Project Part 1 & ENG4112 Research Project Part 2

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CERTIFICATION

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30 October 2008

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NOMENCLATURE AND ACRONYMS (OR ABBREVIATIONS)

CORS	Continuously Operating Reference Stations
GNSS	Global navigation Satellite System
GPS	Global Positioning System
GPRS	General Packet Radio System
GSM	Global System for Mobile Communication
HRMS	Horizontal Root Mean Square
OTF	On The Fly
RTK	Real Time Kinematic
TRIG	Trigonometrical Beacon
TTFF	Time To First Fix
USQ	University of Southern Queensland
VRMS	Vertical Root Mean Square
VRS	Virtual Reference Station

CHAPTER 1

INTRODUCTION

1.1 Background

At first Global Positioning Systems (GPS) was developed and used only for military purposes, for locating strategic points on the earth's surface. It was not long before the power and potential of the system was realized and it was introduced into different civilian applications such as the measurement of time, geodetic and cartographic uses, and in air, ship and car navigation (Razza 2005).

Surveyors who used GPS in the early 1980s endured long observation periods in the field and time-intensive post-processing back in the office. As a result, GPS was really only feasible for establishing survey control. To gain centimetre-level accuracy positioning in the field, surveyors in 1993 began using RTK GPS technology which also minimized data processing (Higgins 2001). For RTK positioning a reference receiver (base station) transmits its raw measurements or observation corrections to a rover (mobile) receiver via a data communications link, whether radio, modem or cell phone. With the introduction of RTK, GPS became a valuable tool for applications other than control work, including topographic mapping, cadastral surveys, high accuracy GIS and construction stakeout.

The most recent advancement in GPS technology, however, is scaleable GPS reference station infrastructure. GPS infrastructure consists of permanent or semi-permanent receivers operating continuously. Users no longer need to set up a separate base station to achieve RTK positioning; they simply use a GPS rover to connect to the established infrastructure. GPS infrastructure can range from a single reference station to a wide-area network.

The Chief Directorate: Surveys and Mapping is responsible for all South African networks and have therefore established this GPS Infrastructure and are making real-time VRS corrections available to users in the field.

The accuracy of classic RTK has been well researched and documented by several GPS manufacturers, for instance Trimble Navigation Limited. However, the accuracy, precision and reliability of the VRS network, here in South Africa, have yet to be proven. No published research papers with regards to the validation of the South African VRS and CORS networks could be obtained. As such the reliability of the VRS system must be assessed by carrying out detailed testing to determine the performance of its accuracy, precisions, initialization times and its coverage extents.

1.2 Research Aim

The aim of this research project is to investigate and report on the accuracy, precision, initialisation times and coverage extent of the South African (Gauteng) Virtual Reference Station (VRS) concept as an extension of the Global Positioning System (GPS) Real-Time-Kinematic (RTK) survey technique.

1.3 Justification

The use of the GPS technology by the surveying community has given rise to significant productivity benefits. The adoption of the Real-Time-Kinematic (classic-RTK) technique for centimeter level applications work has seen a revolution (Trimble VRS – Technical Brochure, 2001).

Works that usually required an entire survey team days to complete, now only requires a surveyor, with an additional crew member manning the base station and setting it up. With the classic-RTK techniques, survey works are completed in a very shorter period of time hence, increasing productivity.

However, classic-RTK technique has a number of factors that needed to be addressed and they are as follows:

- The requirement of having a local reference or base station, which in turn contributes to security issues (who would look after the reference station once it is set up), power supply (typically up to 8 hours per day), communications (radio telemetry link range) and the loss of productivity. This would also equate to the need of investing in a second unit of GPS receiver and the radio telemetry link via a radio modem.
- The limitation on the power of the output allowed for a radio modem to operate, limits the range of the base station's radio modem that is sending out RTK correction messages. The surveyor is able to work only within his radio telemetry link range. From personal experience, this is in the region of up to a range of between 5-10 kilometers, depending on environmental, weather and line of sight of the roving GPS receiver and the elevation at which the base broadcasting station was set-up.
- The propagation factor which arises when the distance between the rower and reference (or base) receivers increases. In certain instances, it gives rise to significant differences that exceeds tolerance levels set for a particular scope and specifications for a project.
- The reliance of a single reference station and the lack of redundancy factor and integrity monitoring (Ong 2003).

It was in the light of these limitations that the Virtual Reference Station (VRS) system was developed. The VRS has overcome all the limitations listed above and offers more for the potential user (Ong 2003).

Here are a few notable factors:

- Extended operating range that is supported under the VRS system network is easily 5 times more (up to 35km or more) than that of the normal radio telemetry means, via a radio modem.
- Increased productivity.

- Eliminates need to establish reference station. Instantly, the initial cost of using the GPS technology for survey works is halved. Thus, set-up, power, physical security of the reference station becomes a non-issue.
- Provides integrity monitoring.
- All users are in a common, and established coordinate reference frame.
- Eliminates dependency on single reference station.
- Uses established communications infrastructure of the GSM / GPRS mobile telecommunications network to support its telemetry links, because such network does not have a range limitation.
- The VRS makes use of each GPS observation data resultant positions are being corrected from a set of fixed reference stations. Part of the VRS system algorithm looks into having the processor perform integrity checks, and remove outliers from the solutions. Thus, having redundancy for all points surveyed.
- Effectively requires only one person to get the work done. Ideal in situations where area to be surveyed is large, as there isn't a need to change to another base station, as in the case of classic RTK technique (Ong 2003).

Currently, the Gauteng VRS coverage area comprises of four GPS base stations (see Figure 2.5 for map of existing Gauteng VRS coverage area). For legal traceability and professional integrity, it is important to provide information to aid in providing reliable predictions of the accuracy, precision, initialisation times and coverage of the VRS both within and outside of what is considered the 'normal' coverage area.

1.4 Research Method

The focus of this research project is on the reliability of the Gauteng VRS RTK network as a replacement for Single Base RTK and not on the influence of errors on the GPS.

To achieve the project aim, the following will be completed;

- Analyse the Virtual Reference Station concept as an extension of the Global Positioning System.

- Critically analyse any relevant prior research and literature regarding Virtual Reference Station networks.
- Develop and validate a method for testing the accuracy, precision, initialization times and coverage extents of the South African VRS-RTK GPS network.
- Collect data to allow measurement accuracy, precision, initialization times and coverage extents of the South African VRS-RTK GPS network.
- Analyse the collected data to quantify the accuracy, precision, initialization times and coverage extents of the South African VRS-RTK GPS network.

Chapter one introduced the reader to the problem and motivation of the VRS being implemented and the justification was listed. Chapter two will consist of the literature review, providing the background and information of what the VRS concept is and how it can benefit users in the positioning industry.

Chapter three will contain details of the testing plan and field execution. Chapter four will cover the data processing and collation of information. In chapter five, the results analysis and discussion will be carried out.

The project conclusion will be drawn in Chapter six and recommendations will be made for future and further research.

1.5 Summary: Chapter 1

The concept of Virtual Reference Stations dates back as far as 1999. Since then, different countries have undertaken a vast amount of research in this regard. Looking at results from various research papers, the VRS technique proved to be very reliable. However, in order to establish the VRS technique as a reliable and accurate method amongst professional GPS users, more research still needs to be carried out, especially in South Africa. In order for this research to be of value the results obtained must be compared with previous testing or standard industry specifications. This chapter will look at some of the test results from various projects undertaken in different countries.

This research project aim to investigate and report on the South African (Gauteng) Virtual Reference Station (VRS) concept vide detailed testing of the precision, accuracy, initialisation time and coverage extents. The justification and research method were also outlined.

In chapter two, the literature review will provide information of the VRS system as well as past testing results and the current status of the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order for this research to be of value the results obtained must be comparable with previous testing or standard industry specifications. Designing a testing procedure requires an in depth knowledge of the VRS concept and all issues surrounding previous testing. This will help develop a reliable test procedure that will be utilized in the completion of this project.

The aim of this chapter is to gather background information on CORS networks and characteristics of the systems, as well as the analyses of previous VRS RTK testing of networks in South Africa and overseas.

This chapter contains the background section that includes what the VRS concept is. This will be presented through a review of literature to establish a sound understanding of the VRS concept and provide an insight into various CORS networks and network testing.

2.2 Real-Time Kinematics (RTK) Surveying Technique

2.2.1 Overview

The RTK technique was first introduced during the mid 1990's. It became one of the preferred methods for surveying GPS control points. Users of this technique were able to obtain centimeter accuracies in real time without the need for long occupation setups and the need for the post processing of data. This technique makes use of carrier phase measurements. Carrier phase measurements is a technique whereby one will try to solve baselines between a base station (known control point) and a rover station by making use of a double differencing kinematic technique. The user needs two duel frequency instruments in order to carry out such a survey.

2.2.2 Real-Time Kinematics (RTK) Surveying

Investigations began in the mid 1990's to find the optimal way of processing reference receiver data, and then providing "correction" information to users, in real time. This practice is known as RTK Surveying (Rizos and Han 2003).

RTK positioning with GPS is a common survey technique used today. RTK GPS allows the use of a static base station at a known point and mobile rover unit for real time data collection. Computer processors within the roving receiver combine its measurements with the data broadcast from the reference station. With modern equipment only a few tens of seconds of data are typically required to fix the ambiguities associated with the GPS phase data observable and compute a baseline; the difference in latitude, longitude and height between the reference and rover positions (Higgins 2001).

2.2.3 Limitations of Real-Time Kinematics (RTK)

The limitations of RTK surveying will be summarized here to highlight the need to progress to a system containing a network of reference stations.

- Productivity, security and accuracy issues caused by establishing and running a GPS receiver and radio from their own reference station on all survey projects.

- Increase in distance dependant errors caused when the roving receiver is working farther than 10km from the reference station.
- Limitations caused from the range of telemetry communications.

2.2.4 Continuously Operating Reference Stations (CORS)

CORS is the general term given to an active network of GPS stations. Regional CORS networks have been created to support geodesy, surveying, mapping and high-end navigation. The use of a network of reference stations instead of a single reference station allows the modeling of systematic errors in the region and thus provides the possibility of error reduction (Landau et al. 2002). The reference stations transfer data from GPS satellites within range to a control centre. This data is processed, corrected and re-transmitted to the GPS stations in real time. The CORS sites are generally spaced between 20 to 70 kilometers to achieve the best accuracy. Mobile receivers operating within CORS network can receive corrections broadcast from the GPS reference stations to compute their corrections in real time. CORS technology is changing rapidly, with accuracy, reliability, station separation, atmospheric modeling and data processing strategies all being investigated. Current research hopes to minimize state CORS infrastructure duplication, maximize coverage and support a broader user base (Zhang et al. 2006).

2.3 Virtual Reference Stations (VRS)

2.3.1 Virtual Reference Stations (VRS) Concept

The VRS concept from Trimble is an extension of the RTK technique developed for GPS surveying and other forms of high precision positioning (Cislowski & Higgins 2006). The technique operates through CORS networks.

The VRS concept involves permanently operating Global Navigational Satellite System (GNSS) reference stations that are connected via data links such as modems to a control centre. The control centre continuously gathers the GPS data from the reference stations and a central processing computer models the spatial errors and produces a living database of regional area corrections (Landau et al. 2002). At the rover end, the GPS receiver makes a phone call giving its approximate location to the control centre. The central computer then generates corrections as if there was a reference station at the rover's approximate position. Algorithms are completed within the rover and it is positioned relative to this virtual reference station (Higgins 2001) Figure 2.1 display's the system architecture of the VRS concept.

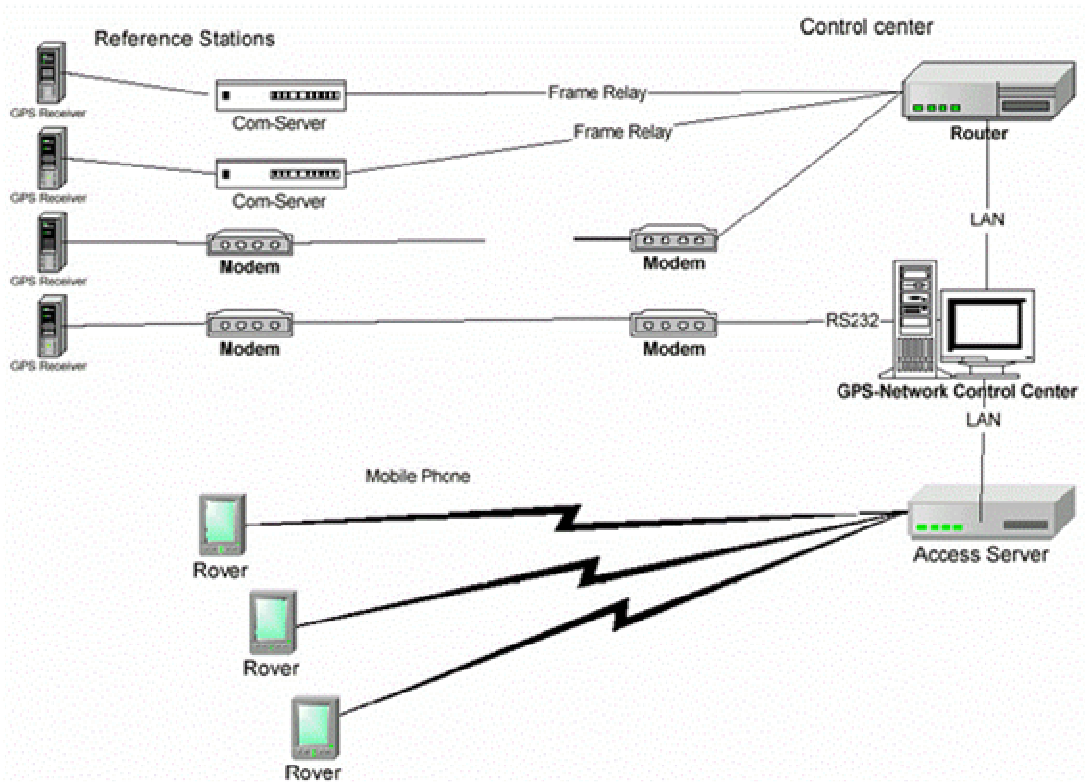


Figure 2.1: System Architecture of the VRS concept (Trimble 2003)

The improved performance of the VRS concept is due to the relatively short baselines between the virtual reference station and rover receiver, as opposed to the physical reference stations. As such the positional accuracy is not degraded by being too far from the physical reference stations. The fact that the corrections from the virtual reference station are interpolated from the surrounding physical reference stations contributes to the improved accuracy. Cislowski and Higgins (2006) state that even when the rover is 30 or 40 km from the nearest physical reference station it retains a positional accuracy of ± 20mm (horizontal) (Fritsch 2006).

2.3.2 How the VRS System Works

The VRS concept follows the principals listed below;

At least 3 reference stations are normally connected to the network server through communication links.

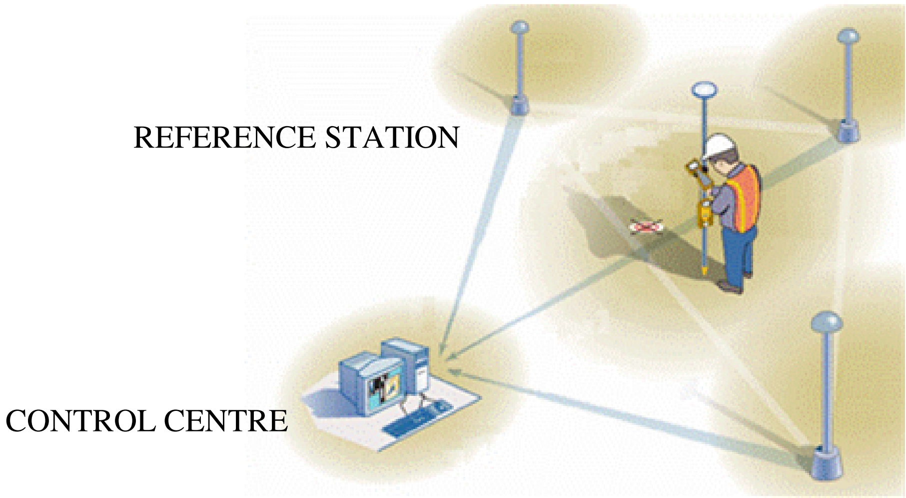


Figure 2.2: Network Sketch (Landau et al. 2002)

The approximate position of the rover is sent to the control centre running the GPS network. A mobile phone data link such as Global System for Mobile communication (GSM) is used to send the standard National Marine Electronics Association (NMEA) position called Global positioning system fixed data (GGA). GGA format is adopted because it is available on most receivers (Landau et al. 2002).

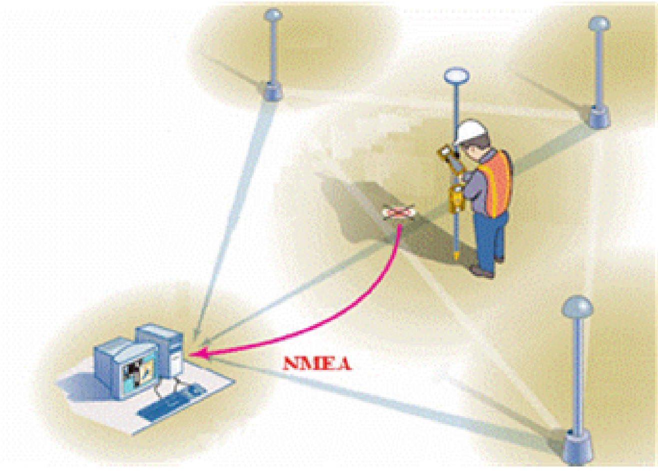


Figure 2.3: Rover transmits NMEA message to network server (Landau et al. 2002)

The control centre receives the approximate position and reacts by sending Radio Technical Commission for Maritime Services (RTCM) correction data to the rover. Once the rover obtains the data it computes a Differential GPS solution and updates its position. The position which is accurate ± 1 meter is sent to the control centre. New RTCM corrections will be calculated and returned back to the rover via the mobile phone data link. The corrections now appear to be coming from a station right next to the rover. It is possible using this technique to perform highly improved positioning within the GPS network (Landau et al. 2002).

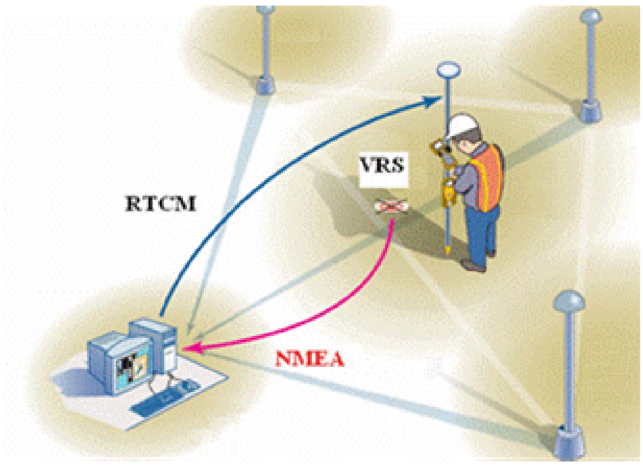


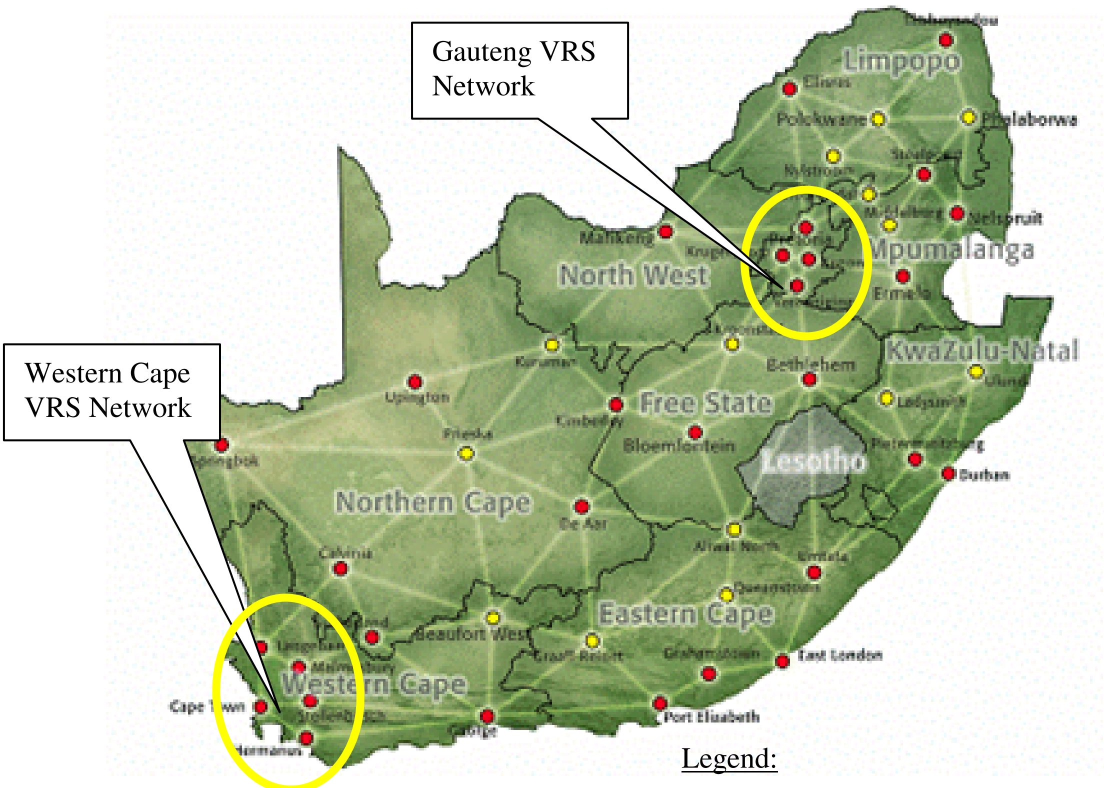
Figure 2.4: Network server transmits RTCM correction stream for VRS position (Landau et al. 2002)

2.4 The South African CORS Network

2.4.1 Overview

The Chief Directorate: Surveys and Mapping (CDSM), of the Department of Land Affairs of South Africa, established a network of active GPS base stations back in 1999. Since then GPS receiver design, active network management, and processing software have greatly improved. With this, and the age of current receivers and peripheral equipment, in mind, funding was made available by the Department of Land Affairs in the latter half of 2006 to upgrade and rebuild TrigNet.

The upgraded network uses Trimble's RTKNet software and 80 Trimble NetRS receivers to make network management and control more efficient and less complex, all to the benefit of TrigNet data users. A country-wide VRS DGPS using Trimble GPSNet software has also been implemented as well as two Trimble VRS RTK networks for Gauteng and the Western Cape.



Legend:

Red = Post Processing and Real Time data.

Yellow = Post Processing data only.

Figure 2.5: TrigNet Continues Operating Reference Stations.

3.4.2 Western Cape VRS Network

There are currently 5 reference stations in and around Cape Town making up the Western Cape VRS network. These reference stations are located in Mowbray, Langebaan, Malmesbury, Stellenbosch and Hermanus with a continuous connection to the control centre at the CDMS office in Mowbray.

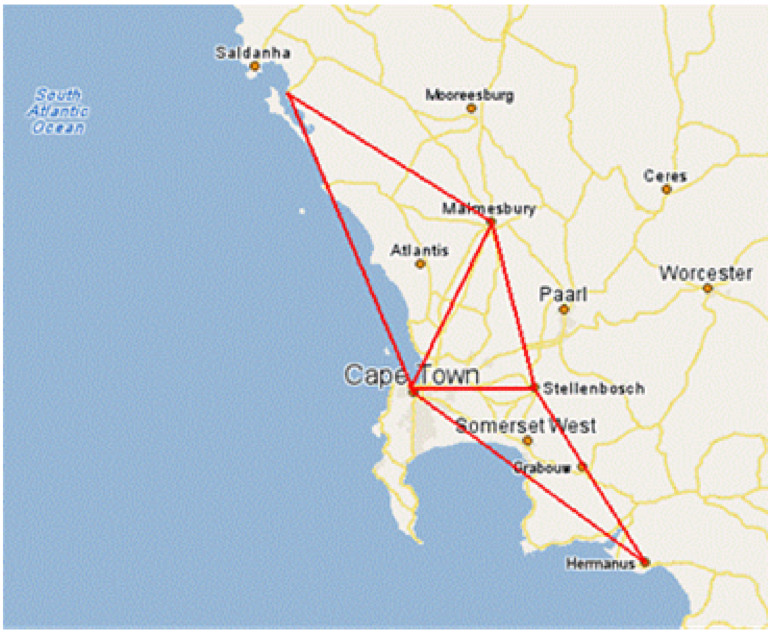


Figure 2.6: Western Cape VRS Network

In 2007 du Toit from Optron Geomatics investigated the Western Cape VRS network. His testing was to get a general idea of;

- The repeatability of the VRS solution,
- The initialization times and
- A comparison of the VRS solution versus a single base solution.

The testing was not meant to be an extensive or rigorous scientific test of the system, as that was past the scope of this investigation. It was structured more to give potential users an idea of accuracies and productivity improvements that can be expected.

The rover was set up over existing Town Survey Marks and the time taken to initialise was noted. The position of the point was then measured for 3 seconds and stored. After storing the point, the receiver was intentionally forced to loose the initialisation. This was repeated 10 times using a VRS solution, ten times using a single base solution from Cape Town, then Stellenbosch, and finally from Malmesbury. A Trimble R8 rover with an internal SIM card was used for the testing.

It was found that the repeatability of the VRS solution, as well as the single base solutions were excellent. All points fell within less than 1 cm of each another. The initialisation times were also astounding, with an average initialisation tome of 28 seconds. It was noticeable however, that for baselines longer than 30 kilometres the initialisation times were longer.

2.4.3 Gauteng VRS Network

The Gauteng VRS network consist of four reference stations in an around the Johannesburg area. These reference stations are located in Pretoria, Krugersdorp, Vereeniging and Benoni with a continuous connection to the control centre at the CDMS office in Mowbray. As this network only became fully operational during the end of 2007, no documented testing has been done on this network, hence the undertaking of this research project.

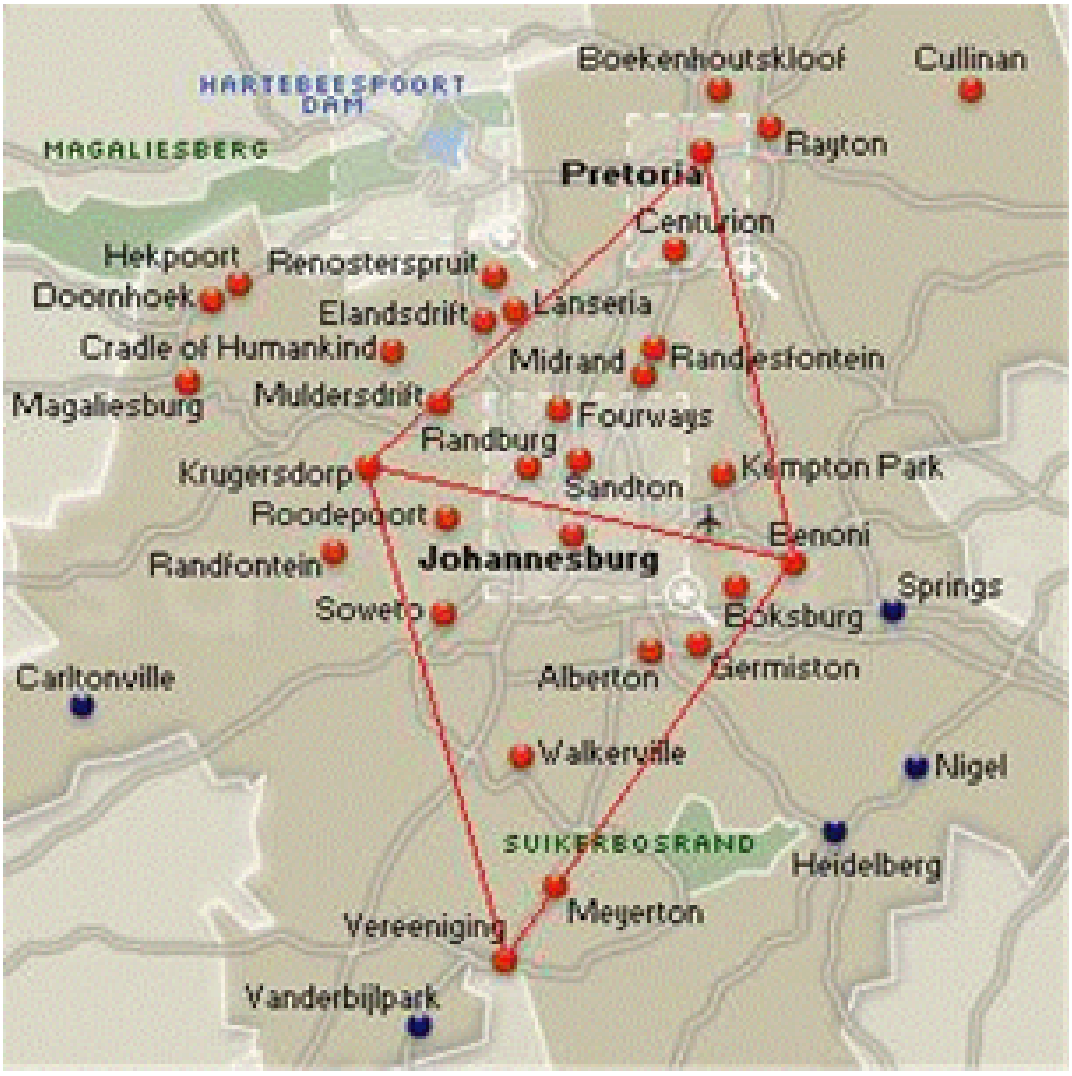


Figure 2.7: Gauteng VRS Network

2.5 Overseas RTK Networks

2.5.1 Overview

Over the last few years, the appealing nature of permanent reference stations has led to network installations in many countries. This section aims to give a brief description of two CORS networks in different countries and some VRS RTK testing completed within each network.

2.5.2 Singapore

Singapore Satellite Positioning Reference Network (SiReNT) is a new infrastructure replacing the Singapore Integrated Multiple Reference Station Network (SIMRSN). The VRS network, known as SiReNT is operated by the Singapore Land Authority (SLA). The network as shown in Figure 3.8 consists of five Trimble NetRS reference stations that are located at the extreme corners of the island and one in the middle to provide island wide coverage (SLA 2006).

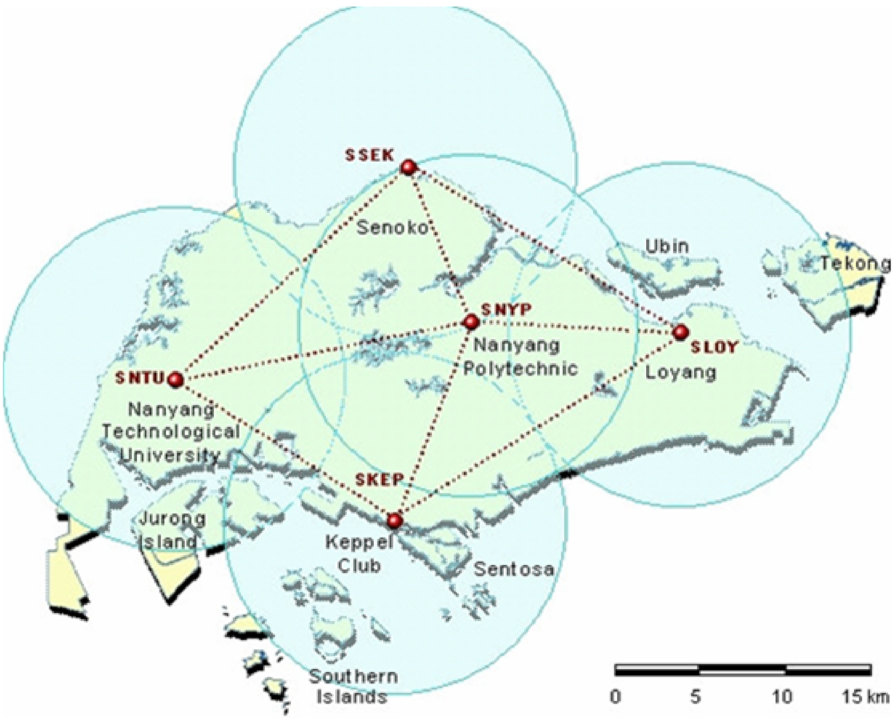


Figure 2.8: Singapore Satellite Positioning Reference Network (SiReNT) (SLA home 2006).

The former SIMRSN was a good test bed for network based positioning techniques as it operated, both as a research facility and an operational Network RTK service for the benefit of surveyors. In order to evaluate the above VRS RTK network infrastructure, tests were completed at two stations code-named NTU and GLC during 2002. Continuous data was recorded at NTU for a period of approximately 8.5 hours and 5.5 hours at GLC. The accuracy of VRS RTK positioning was examined by comparing a ground truth position computed from logged raw data against the VRS RTK position. The summary statistics for the two stations are listed in Table 3.1. The results indicate that the accuracy of VRS RTK positioning is generally better than 3cm in horizontal position, with the height accuracy being in the range of 1-5cm (Hu et al. 2003).

Table 2.1: Statistical results for NTU and GCL stations (Hu et al. 2003)

STN	STANDARD DEVIATION			CONFIDENCE LEVEL 99STN %		
	NORTHING	EASTING	HEIGHT	NORTHING	EASTING	HEIGHT
NTU	5mm	9mm	15mm	18mm	27mm	37mm
GLC	8mm	7mm	16mm	27mm	29mm	44mm

2.5.3 Finland

A VRS service has been available for surveyors in Finland since 2000. After a noticed increase in GPS use, the Finnish Geodetic Institute (FGI) decided to study the service. In the summer of 2003 FGI carried out testing on two existing and separate VRS networks in the area of Southern Finland (see Figure 3.9). A total of 33 benchmarks with known coordinates were selected as reference points in the study. Each of the test points where measured 3 to 4 times under different satellite geometry, and 20 observations in each session were collected (Häkli, P. 2004).

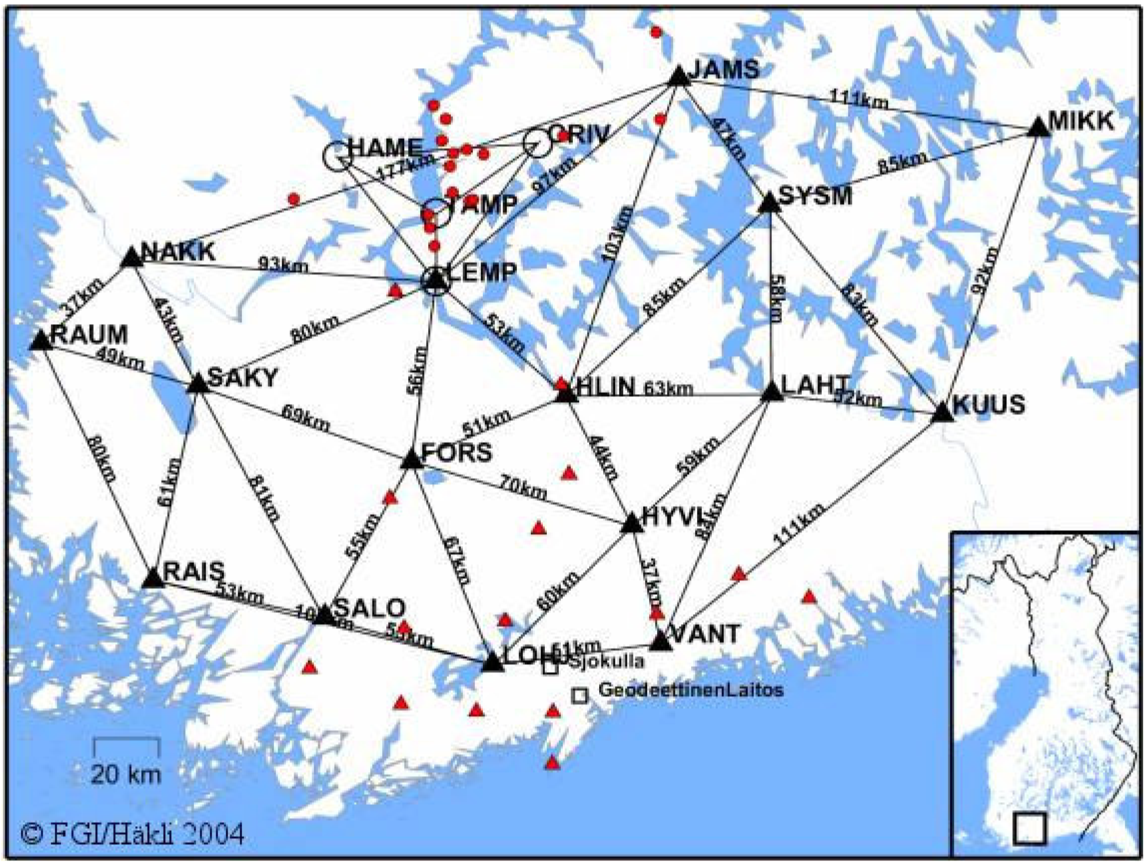


Figure 2.9: VRS networks during summer 2003 (FGI 2006).

Table 2.2 shows the results from the testing. The results indicate that centimeter-level positioning is possible and reliable using the VRS RTK technique.

Table 2.2: Accuracy and initialization times of VRS in Finland (Häkli, P. 2004).

n = 2152	NORTH	EAST	HEIGHT	PLANE	TTFF
AVERAGE	23mm	14mm	35mm	27mm	29s
95%	39mm	28mm	67mm	43mm	132s
99%	59mm	37mm	100mm	66mm	396s

2.5.4 Australia

The Department of Natural Resources and Water (NRW) of the Queensland Government is responsible for the surveying and geodetic infrastructure in the Australian state of Queensland (Higgins 2001). The NRW controls a CORS network situated in the South-East region which has been operating for several years. The network known as SunPOZ, (See Figure 2.10) uses a mixture of Trimble 4700, R7 and NetRS receivers as well as Leica GXR 1200 Pro receivers.

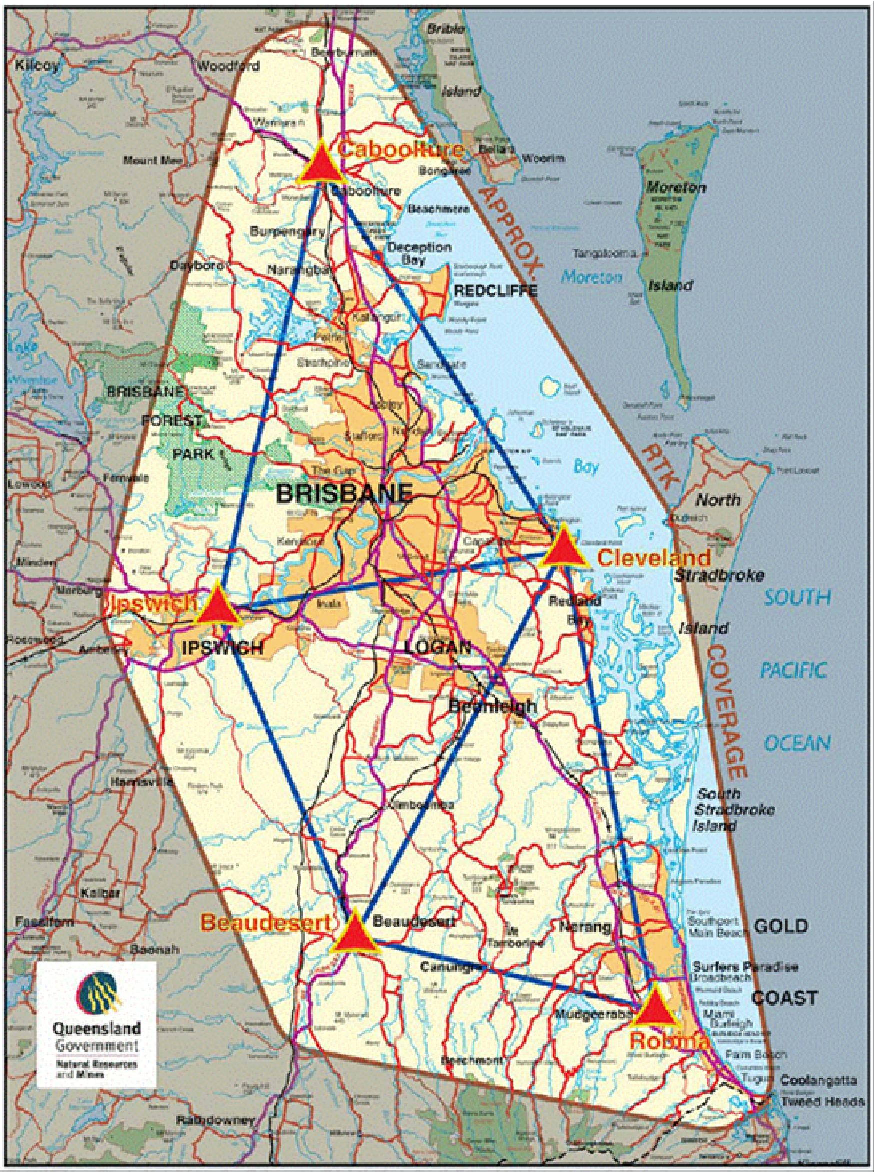


Figure 2.10: SunPOZ CORS Network in South East Queensland (NRW 2006).

The NRW completed initial testing of the network after its establishment as a pilot project. The testing concentrated on matters such as confirming that the VRS solution allowed the use of RTK positioning at all suitable locations within the network and establishing how the quality of results degraded as rovers moved outside the network coverage (Higgins 2001).

The project involved using Trimble's 5700 and 4700 GPS receivers to occupy 6 survey marks with known positions. Three of the survey marks were inside the network and three outside. A total of 115 occupations were completed over a two week period. A horizontal and vertical vector was calculated using the observed and known positions. Occupations having residuals greater than three standard deviations were removed during the analysis results. The removal of observations greater than three standard deviations lead to producing higher accuracy results than actually achieved in the field. Table 3.3 shows the results of the remaining 106 occupations.

Table 2.3: Results from Initial Testing with 6 Stations (Higgins 2001).

	HORIZONTAL 2D ACCURACY	ABSOLUTE HEIGHT ACCURACY
MEAN	32mm	40mm
STD DEVIATION	14mm	29mm

The VRS initialisation testing was completed using controlled conditions. A reference receiver was used in conjunction with special diagnostic software from Trimble to record 5 seconds of data before reinitialising. The test was conducted over a 15 hour period (See Higgins, 2001). The results were:

- For 510 initialisations with 5 or more satellites, the average initialisation time was 1.7 minutes.
- From the 510 initialisations there were 426 with 7 or more satellites and the average initialisation time of those was 1.3 minutes.

Further research was conducted by the University of Southern Queensland (Ong 2003) to test field applications. Ong's research on the SunPOZ CORS was completed using Trimble 5700 GPS receivers. The research and field testing compared the performance of the traditional RTK system with the VRS RTK system. During these tests, Classic RTK and VRS-RTK data were collected simultaneously to ensure that, as far was possible, the same physical conditions were experienced at the same time.

The test method consisted of selecting 15 sites both inside and out of the reference station network. The sites chosen were existing control stations with known coordinates published by the NRM&W. These control stations were accepted as error free.

At each test site 35-50 individual measurements comprising three epochs of data were recorded after an initialisation fix. The GPS data was received through a single antenna. An antenna splitter was used to simultaneously record real time positions of the VRS base station and traditional base station. The data recorders were triggered at the same time to start initialisation. The simultaneous recording of the GPS receivers provided a good method for reducing time bias errors.

A summary of the testing is listed below;

- An initialisation assessment consisting of comparisons between on-the-fly (OTF) initialisation times for VRS RTK and classic RTK techniques. The receivers were forced to lose lock and then re-initialise. The initialisation time or time to first fix (TTFF) was calculated at each site.

- An accuracy assessment consisting of horizontal and vertical comparisons against a known truth position. The residuals between the observed and known coordinates for each point were calculated.

The results from the RTK horizontal testing indicate that similar accuracies are obtainable. The average of all observations was 14mm for classic RTK mode and 13mm for VRS RTK mode. The results from the RTK height testing suggest that the VRS system achieves slightly better results than the classic RTK method. The VRS RTK mode performed consistently with the average of all points falling +5mm from the adopted known value compared to the result for the classic RTK height analysis which was -12mm form known value.

The accuracy and precision of the total results are listed in Table 2.4. The precision of results was calculated at the 95 percent confidence level.

Table 2.4: Precision of RTK Results (Ong 2003).

	HEIGHT AVERAGE	HEIGHT 95%	HORIZONTAL AVERAGE	HORIZONTAL 95%
CLASSIC RTK	-12mm	±75mm	±14mm	±30mm
VRS RTK	+5mm	±56mm	±13mm	±20mm

The results from the TTFF for all observations indicate good initialisation time with the classic RTK experiencing a fix within 112 seconds 95 percent of the time and an average TTFF of 40 seconds. The VRS RTK had an average TTFF of 32 seconds and initialised within 77 seconds 95 percent of the time.

2.6 Conclusion: Chapter 2

The literature review has introduced the RTK technique and the progression to network RTK through the establishment of CORS networks. The VRS concept was discussed along with the South African Gauteng and Western Cape networks which utilises the VRS technique.

This chapter has identified the increasing trend towards network RTK as an accurate form of point positioning. The information of previous testing has aided in the design of a testing regime for this project and has provided an indication of what values that can be expected during testing.

The following chapter will cover the test methodology and test program that was developed from the literature review.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction.

Chapter two provided a background into the VRS RTK mode of GPS surveying and the VRS networks in South Africa. Information was provided on some of the VRS system installed throughout the world including Singapore, Finland and Australia. Information was also provided on the limitations of various systems and why the VRS system was developed.

This chapter will thoroughly discuss the research design and methods and its relevance to this project. The proposed assessment of the reliability of the VRS system will take into consideration the precision levels achievable, time taken to achieve the stated precision levels, inclusive of the requirements associated with it and the coverage extent. The conditions affecting the techniques adopted while the survey was carried out were also important factors that were considered.

To meet the objectives of assessing the VRS system, the following aspects were considered: the site location, the field test design, data processing and the results analysis. In this chapter, the selection of feasible test sites, equipment selection and field test design aspects will be detailed. In chapter four the data processing and manipulation will be covered.

3.2 Selection of Feasible Test Sites

One of the main objectives of this research project was to consider the performance of the VRS system located in different geographical areas in relation to the network of VRS base stations. Land surveying takes place in all types of diverse locations from built up residential areas, rural farm land to mountainous regions. The sites selected for this research included most of the localities and operating conditions, representing situations found in everyday surveying. Some of the conditions included minimal to severe multipath and minimal to no overhead obstructions.

Suitable sites were selected within, on the perimeter of and outside the Gauteng VRS network. TrigNet and Trimble South Africa suggested during a telephonic interview that coverage for centimetre accuracy includes a 40 kilometre buffer around the outside perimeter of the VRS network. Therefore an additional site outside the 40 kilometre buffer area was selected to test the range limit of the network.

The relationship between test site locations and the Gauteng VRS network is shown in Figure 3.1. Table 3.1 also lists the distance from the individual test sites to the nearest base station and the distance to the VRS network perimeter. This information will be used when analysing the range limit of the network. The distance to the VRS network perimeter is measured perpendicular to the straight line between two reference stations.

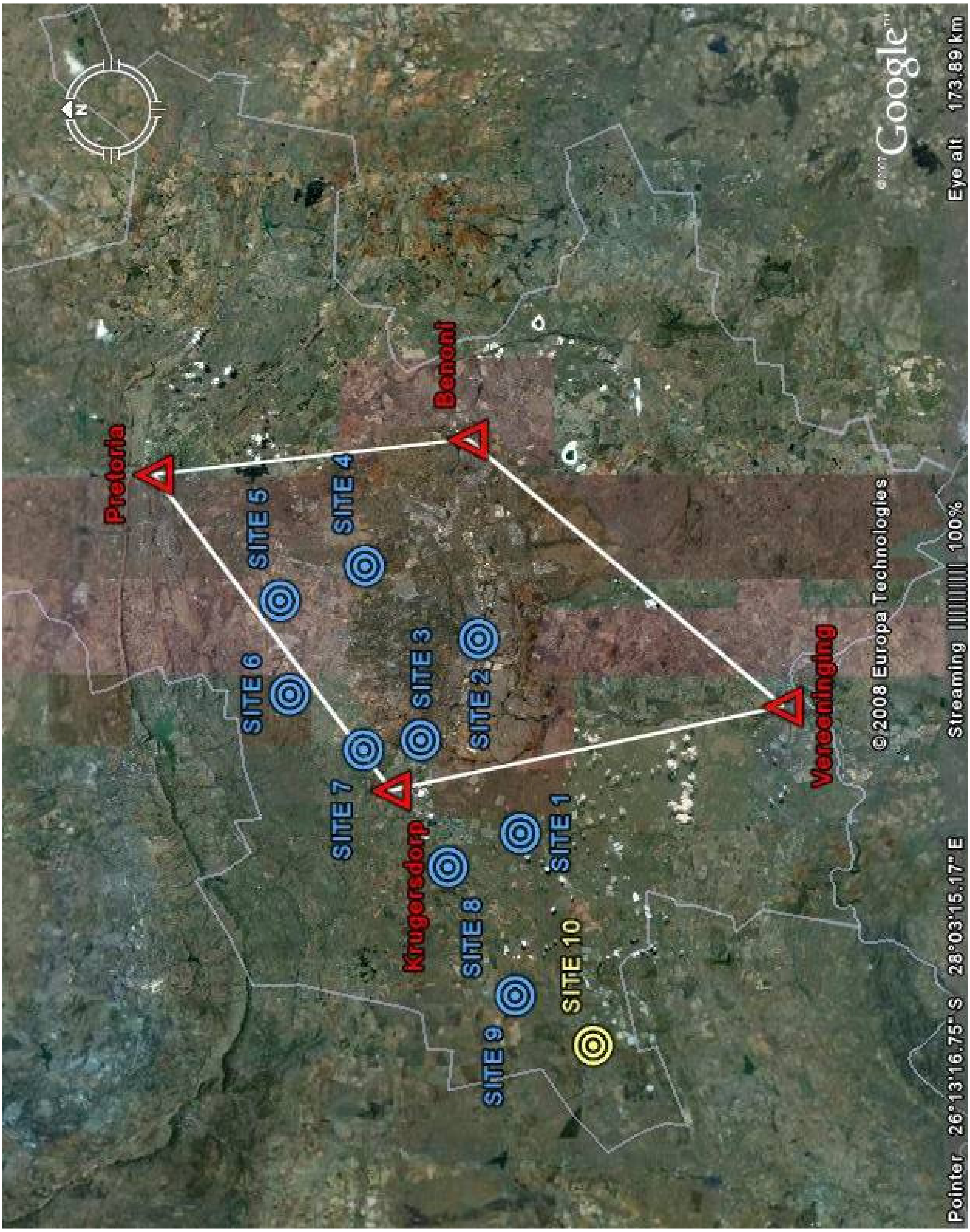


Figure 3.1: Test Site Locations and the Gauteng VRS Network.

Table 3.1: Test Site Locations in Relation to the VRS Network.

SITE	BEACON	DISTANCE TO VRS NETWORK	DISTANCE TO BASE STATIONS
SITE 1	Trig 135	Krugersdorp to Vereeniging = 11,29km Outside Network	Krugersdorp = 22,34km Vereeniging = 45,58km
SITE 2	Trig 620	Krugersdorp to Vereeniging = 15,85km Inside Network	Krugersdorp = 30,38km Vereeniging = 42,64km Benoni = 37,77km
SITE 3	Trig 416	Krugersdorp to Vereeniging = 7,08km Inside Network	Krugersdorp = 9,67km
SITE 4	Trig 187	Krugersdorp to Pretoria = 18,88km Pretoria to Benoni = 18,64km Inside Network	Krugersdorp = 37,13km Pretoria = 37,81km Benoni = 26,45km
SITE 5	Trig 148	Krugersdorp to Pretoria = 4,27km Inside Network	Krugersdorp = 35,92km Pretoria = 29,37km
SITE 6	Trig 103	Krugersdorp to Pretoria = 3,69km Outside Network	Krugersdorp = 22,83km Pretoria = 42,35km
SITE 7	Trig 478	Krugersdorp to Pretoria = 0,6km Inside Network	Krugersdorp = 8,0km
SITE 8	Trig 469	Krugersdorp to Pretoria = 12,93km Outside Network	Krugersdorp = 13,1km
SITE 9	Trig 219	Krugersdorp to Vereeniging = 37,21km Outside Network	Krugersdorp = 39,37km Vereeniging = 64,45km
SITE 10	Trig 242	Krugersdorp to Vereeniging = 47,92km Outside Network	Krugersdorp = 53,43km Vereeniging = 63,63km

An important factor when considering possible test site locations was the availability of Trigonometrical (Trig) Beacons.

The official coordinate reference system, used in South Africa as the foundation for most surveying, engineering and geo-referenced projects and programs, is known as the ‘Hartebeesthoek94 Datum’. The Hartebeesthoek94 Datum was based on the World Geodetic System 1984 ellipsoid, commonly known as WGS84, with the ITRF91 (epoch 1994.0) coordinates and with the Hartebeesthoek Radio Astronomy Telescope used as the origin of this system

The South African network of Trigonometrical Beacons is known as a passive network and consists of nearly 29 000 Trigonometrical beacons, coordinated on the Hartebeesthoek94 Datum. This network of passive beacons can be described as the backbone of most survey projects in South Africa.

On the other hand, the current Gauteng VRS Network is based on the ITRF2005 (Epoch 2008.002) Datum and therefore coordinates obtained by means of the VRS network are not comparable with the current published values of the Trigonometrical Beacons.

It was nevertheless decided to use trig beacons as test sites during this project to aid in future VRS research and to make test site locations easily identifiable for the South African Geomatics community.

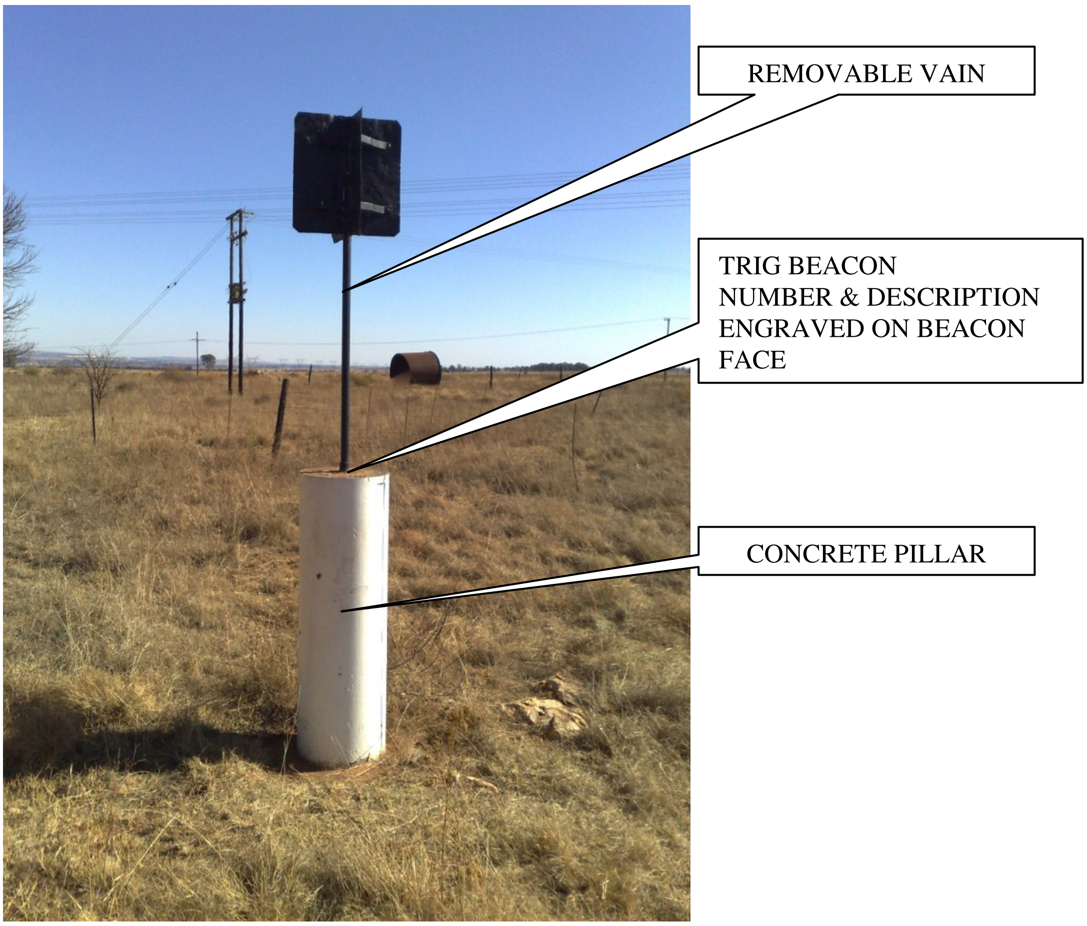


Figure 3.2: Standard Trigonometrical Beacon

3.3 Equipment Selection.

The following equipment was used during field data collection:

- Trimble R8 GNSS receiver (Firmware Version 3,64).
- Trimble TSC2 controller, data collector (Firmware Version 12,22).
- Enfora Compact Flash (CF) GSM/GPRS Modem Card – GSM/GPRS connection utilising the 'MTN' mobile network.
- Trigonometrical (Trig) Plate.
- Tribrach.
- Measuring Tape.

Figure 3.3: Typical Site Setup

3.4 Test Design.

3.4.1 Test Design for Initialisation Time

The time required by an RTK GPS receiver to solve integer ambiguities and achieve a ‘fixed’ solution is called initialisation time or time to first fix (TTFF). The TTFF is an important indication of RTK performance as the productivity of field crews in some situations can depend mainly on the availability of fixed ambiguities (Richter and Green, 2005).

The GPS receiver has to resolve or initialise the carrier phase ambiguities at power-up and every time the satellite signals are interrupted. A widely used technique for gaining automatic initialisation is termed ‘on-the-fly’ (OTF), which reflects that no restrictions is placed on the motion of the rover receiver throughout the initialisation process (Trimble 2001).

To time the initialisation time, it is thus necessary to loose lock or initialisation on the receiver, and this is done via user intervened action. The data logger (TSC2) had the ability to cause the fixed solution to be independent through the re-initialise hot key on the keypad. After the forced re-initialisation, the receiver automatically resolved the ambiguities OTF and provided a new fixed position. The position was logged for three seconds and stored. This process was repeated continuously for 40 measurements per control point.

It was possible to measure the TTFF using this method of losing and regaining initialisation as every action or command in the data logger (TSC2), the corresponding time is stamped. Therefore, with the time of every individual initialisation gained or lost being time stamped, it would be a simple matter to subtract the time initialisation gained from the preceding time of initialisation lost, to determine the TTFF. This information will be extracted from the raw Trimble DC file format using the Excel’s file open function. The process is detailed in chapter four.

3.4.2 Test Design for Accuracy and Precision

Accuracy can be thought of as ‘the tendency of values of a point position to come close to the quantity they are intending to represent’. It relates to the quality of the result. The precision of measurements must also be considered when discussing accuracy, as the ability to constantly reproduce similar results is equally important.

Accuracy and precision are essential issues in point positioning. Surveyors and professionals involved in the spatial science industry are required to accurately measure or position land boundaries, structures and various other features on a daily basis.

To test for the accuracy and precision level performance with the VRS system, a series of points were selected. As seen from previous testing procedures investigated in chapter two, at each of the selected points a classic post-processing coordinate would be compared to the three dimensional position values obtained from using the VRS technique.

A designed sample size of 40 measurements was taken at each site. This was also sufficient for statistical analysis of the results. As the sample size increases to 30, the distribution becomes normal (Stat Soft 2006). Therefore by collecting a sample size of greater than 30 point positions, the sample mean was able to approximate the population mean. When analysing normal distributions 95% of the observations fall within 2 standard deviations of the mean (Moore 1994).

The following test procedure was completed at each test site.

- A ‘Trig Plate’ and tribrach was first set up and levelled over the centre pipe of the Trigonometrical Beacon. This provided an accurate and reliable way of centring the equipment over the Trigonometrical beacon.
- The Trimble R8 GNSS receiver was placed in the tribrach. The receiver and data logger was switch on and the height of the antenna was measured. Any other relevant site information was also recorded in the field notes.

- The relevant post processing job was opened on the data logger. Specific site information was recorded on the data logger and a static survey was stated. The static survey was set to record at one epoch intervals for a total duration of one hour.
- After the post processing data was collected, the receiver was switched of.
- The relevant VRS job was opened on the data logger and the network was dialled into using the internal mobile modem.
- After the receiver had initialised and the ambiguities were solved the data collection period began. Data was collected for three epochs and stored. The receiver was forced to re-initialise and the process was repeated for 40 point measurements.

3.4.3 Test Design for Coverage Extent

To test for coverage extent one must examine and record data at different locations relevant to the VRS network. Some of the sites were incorporated into the test design to assess the receiver at the limits of its operating ability. This includes five test sites outside of the VRS network.

To assess the coverage area performance of the VRS system, test sites were selected:

- Inside the network.
- In areas near or on the boundary of the network.
- Outside of the network.

Test sites located outside of the network was necessary as it was desired to see what results could be achieved in these 'out of coverage' locations.

3.5 Conclusion: Chapter 3

This chapter outlined the test regimes of the accuracy, precision, initialisation time and coverage extent component. The associated field procedures to achieve the objective for the assessment of the VRS system were detailed.

The next chapter will explain how the data in this chapter was processed and manipulated. The various processing software used for the processing will be introduced, along with the comparison of the three-dimensional positional values derived from the measurement techniques.

CHAPTER 4

DATA PROCESSING & COLLATION

4.1 Introduction

In chapter three, we discussed the selection criteria of each test site where the design test regime and fieldwork aspects were carried out. With multiple measurements made to a single test site, significant amounts of data were captured. As a result a processing strategy is required to systematically process the captured data in order to facilitate the results analysis.

This chapter details the methods adopted for the processing of both the classic and the VRS technique for data captured in real-time mode and the post-processing mode. It will be followed by a discussion on the collation of the processed data.

This chapter thus comprises of two sections, the processing and the collation of collected data. The data processing has provided results relating to the accuracy, precision, initialisation time and coverage extent of the VRS system. Microsoft Excel was used to manipulate and present the processed data.

In chapter 5 the results from testing will been presented through the use of graphs and tables.

4.2 Data Processing

All data captured during field testing were downloaded to Trimble Geomatics Office (TGO) processing software at the end of the fieldwork phase. As outlined in chapter three, every control point was measured multiple times at each site. The point naming convention was facilitated by the auto-point increment function on the Trimble Survey Controller (TSC2).

Every downloaded file was in the Trimble DC file format, the proprietary file format for the TSC2. This format could by viewed using the Trimble DC Editor utility software, Microsoft Excel or any other text editor software. In order to extract the required strings of information from the DC file, a text or spreadsheet editor would be required.

4.2.1 Processing Software

Trimble Geomatics Office (TGO) is a software suite fully developed by GPS and Survey equipment manufacturers, Trimble Navigation Ltd. A particular helpful function was the reporting capability of TGO. This function allows a user to output only the required fields of information into a 'HTML' or Microsoft Excel 'CSV' format. This is useful for reporting purposes since the report submissions for each customer varies.

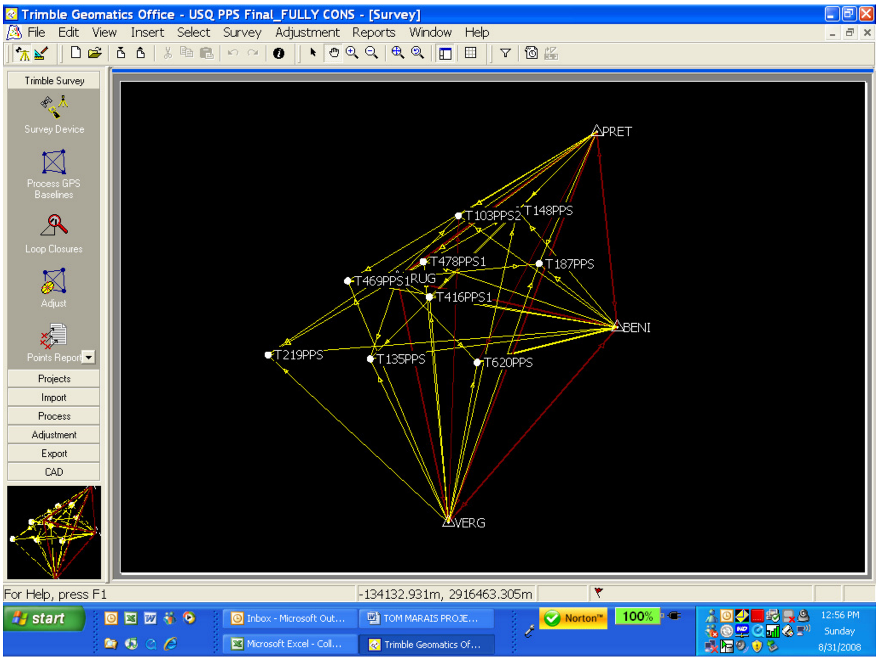


Figure 4.1: Trimble Geomatics Office Processing Software.

4.2.2 Processing of Static Data

All post-processing files gathered during site visits were imported into TGO. It was aimed to use all four VRS stations' rinex (Receiver Independent Exchange Format) files for post-processing purposes. The rinex files for each of the individual VRS stations were downloaded from the TrigNet website.

The TGO baseline processor outputs statistical indicators indicating the quality of each baseline. The criteria set for accepting a processed baseline are as follow:

- Reference Variance: ≈ 1.0. – The reference variance is a unit-less number that indicates how well the observed data fits the computer solution. Trimble recommends this figure to be as close to 1.0.
- Ratio: 2.5 times or more – The TGO baseline processor compares the two (2) solutions with the lowest variance. The ratio is the variance of the second best solution divided by the variance of the best solution.
- RMS: < 20.0 – The RMS (Root Mean Square) indicates the quality of the solution based solely on the measurement noise of the satellite ranging observations. It is independent of satellite geometry.

The accepted baselines were then used in the adjustment stage. At first a minimally constrained adjustment was employed. This adjustment serves to test the quality and integrity of the VRS reference stations input coordinates. This was then followed by a fully constrained adjustment, where all of the VRS reference station coordinates were held fixed.

The fully constrained adjustment gives rise to a single point coordinate, with statistics indicating its resultant quality, with respect to the VRS reference stations coordinates used to derive (or adjust) the 'new' point.

4.2.2 Processing of VRS RTK Data

The import utility of TGO brings the imported file into the TGO software. The processor then automatically captures the status of these points during the import stage and assesses (or interprets) the mode or technique of survey. As all RTK measured points have already had their positions corrected on site (through the VRS RTK technique) the TGO processor then display the points on the screen.

The multiple measurements made on a single point at each site, would number forty (40) measurements. The unique point number of each measurement allowed individual measurements to be exported as a single observed coordinate value.

All of the forty individual measurements at each control point were exported to Microsoft Excel. This was done to facilitate the analysis of each point precision and accuracy component.

4.3 Data Collation

4.3.1 Initialisation Time

A time stamp was inserted in the raw data every time the receiver lost or gained a fixed solution. The time taken for each initialisation was simply calculated via the subtraction of the GPS Time (measured in seconds) of the 'User Cancelled' or 'Initialization Loss' record in the DC file against that of the 'Initialisation Gained' record. No prior processing was required as only the timing information was needed.

4.3.2 Precision

The precision, or repeatability, of a point measured is important information required to ascertain the confidence that can be placed in the VRS system. The data set used for these comparisons were presented in the format shown in Table 4.3.

Precision describes the agreement of a set of results amongst themselves and is usually in terms of the deviation of results from the mean of a data set. A common used measure of precision is the standard deviation (Fritsch 2006).

For each set of results the standard deviation was calculated and recorded on the site statistics. The 95% confident interval was also calculated for each data set by the following formula:

95% CONFIDENCE INTERVAL = 2 x σ

Where: σ = Standard Deviation

2 is the value used when the distribution is normal.

For a meaningful comparison for the precision component to be carried out for the VRS RTK technique of survey, it was decided to compare the observations for the total number of points observed.

The following sub-section discusses the details of the manipulation and handling of the precision aspect for the horizontal (2D) and vertical (Height) component.

4.3.2.1 Horizontal Precision

As shown in Table 4.1 the easting and northing from the test results were subtracted from the mean value obtained from the whole data set. The resultant change in easting and northing was used to calculate a 2 dimensional (2D) vector that would represent the horizontal precision. The 2D vector is the distance between the observed point and the mean value of the data set. It was calculated using the following formula:

HORIZONTAL ACCURACY (Δ 2D) = $\sqrt{}$ (Δ E^2) + (Δ N^2).

The average change in easting and northing and 2D vector was calculated at each site and is included in the Appendix C.

4.3.2.2 Vertical Precision

The ∂ HT column in Table 4.3 reflects the residuals of each measurement's height component against the mean height of the data set.

4.3.3 Accuracy

The test for accuracy involved comparing the results obtained during field trials against coordinates derived from the processing of the classic post-processing technique. The resulting residuals of coordinates for each control point are shown in Table 4.4.

The deviation for the horizontal and vertical component for the accuracy is simular to that as stated in section 4.3.2.1 and 4.3.2.2 for the precision component.

4.3.4 Coverage Extent

Since the coverage extent component relies on information pertaining to the accuracy, precision and initialisation times, the manipulation of this data had to be prepared. Chapter five will discuss this aspect with regards to the location and proximity of the roving receiver to the VRS network boundaries.

4.3.1 Conclusion: Chapter 4

A huge amount of data was collected for this research. A strategy of collating the processed data was in place. TGO software was utilized to process the individual data sets. This was done to facilitate the collation and generation of graphs and to aid in the analysis and appreciation of the results.

The coordinate accuracy was calculated through the mean of each sites repeated measurements and subtracted from the classic post-processing value from residuals. The coordinate precision was calculated by subtracting the mean coordinate from each processed observation.

The initialisation time for each site were collated. No processing was required for the coverage extent as they relied on the processed and collated information for accuracy, precision and initialisation times.

In chapter five, the results will be analysed and discussed so that a conclusions can be drawn on the accuracy, precision, initialisation tomes and coverage extent of the VRS system.

CHAPTER 5

RESULTS AND ANALYSIS

5.1 Introduction

Chapter four explained the processes that were adopted to calculate and obtain final results of the field captured measurements. TGO was used to process the data and subsequently each of the processed files was exported to Microsoft Excel.

In this chapter, the results of those processed data will be presented and analysed. Through the analysis of the graphs generated for the accuracy, precision and initialisation time components, it would then give an indication of how good the reliability performance of the VRS system is. This will then lead into the final chapter where the conclusion and any recommendations will be made.

5.2 Results and Analysis

5.2.1 Initialisation Times

The results of points collected, with the exclusion of test site ten (10), as no VRS solution could be obtained, indicate fast and consistent initialisation times across all sites, as shown in Table 5.1 and Figure 5.1. The average initialisation time was under eight (8) seconds at all test sites. With several of the test sites being on the border or a considerable distance outside of the VRS network; it appears as if the distance to the VRS network had no influence on the fixing of ambiguities and the recorded initialisation times.

Table 5.1: Individual Site Initialisation Times Information.

GPS INITIALISATION TIME			
Name	Initialisation Time (s)	STD Dev	95% Conf Interval
SITE 1	7.2	1.8	3.6
SITE 2	7.1	2.1	4.1
SITE 3	6.8	1.5	3.0
SITE 4	7.1	1.7	3.4
SITE 5	6.9	2.5	5.0
SITE 6	7.0	2.5	4.9
SITE 7	7.9	4.1	8.2
SITE 8	6.9	1.8	3.7
SITE 9	7.5	2.0	4.1
Mean	**7.1**	**2.2**	**4.4**

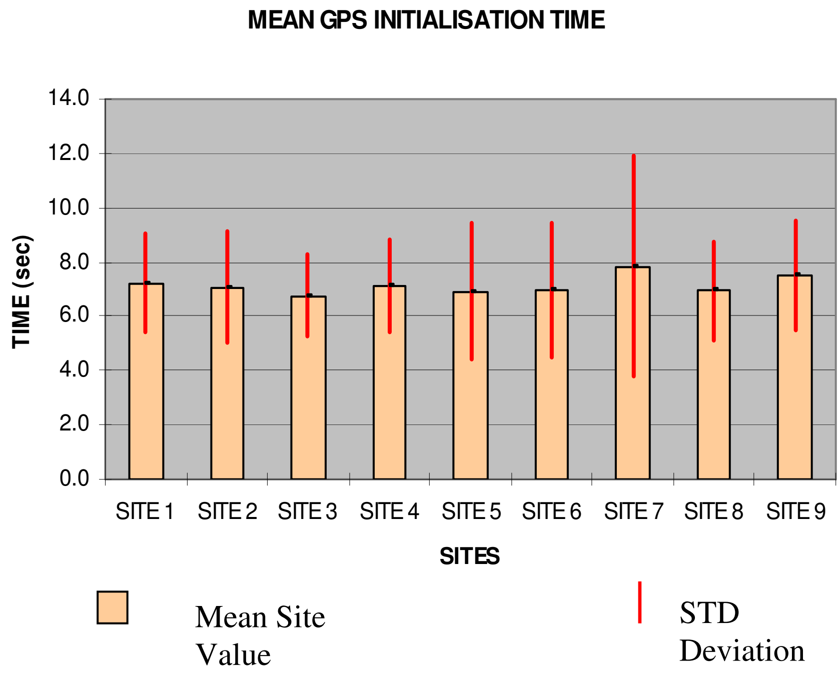


Figure 5.1: Initialisation Times.

The results obtained in this research indicate quicker initialisation times than previous research. Fritsch in 2006 reported an average initialisation time of 23, 24, 5 and 25, 5 seconds respectively, using a Leica, Thales and Topcon receiver. (Ong 2003; Ong & Gibbings 2005) reported an average initialisation time of 32 seconds using the VRS RTK mode of surveying. Higgins in 2001 recorded an average initialisation time of 1, 3 minutes.
Fritsch in 2006 suggest that improvements in the initialisation times when using the VRS RTK survey method may be due to the following:

- Updates to the VRS software that have improved modelling.
- Use of precise ephemeris.
- Improvements in the relative VRS reference station coordinates.

Perhaps the greatest factor responsible for improved initialisation times might be the constant upgrading of Trimble's receiver technology.

5.2.2 Precision

The precision component of this project yield excellent results, as shown in Table 5.2, Figure 5.2 and Figure 5.3. It was however noticed that there were height discrepancies on test site two, six and nine in relation to the rest of the test sites. After an in-depth investigation and several discussions with GPS experts at Optron Geomatics and TrigNet, no meaningful explanation could be found for these discrepancies.

An average horizontal precision of 6mm and a vertical precision of 13mm were obtained at a 95% confidence level. It was however expected that the precision levels for the height component to be between 2,0 and 2,5 times that of the corresponding horizontal component.

Table 5.2: Individual Site Precision Component Summary.

Name	Mean Values		STD Dev		95% Confidence Int	
	∂ 2D	∂ Ht	∂ 2D	∂ Ht	∂ 2D	∂ Ht
SITE 1	0.005	0.007	0.002	0.006	0.004	0.012
SITE 2	0.009	0.017	0.006	0.016	0.011	0.032
SITE 3	0.004	0.005	0.002	0.004	0.003	0.009
SITE 4	0.005	0.005	0.002	0.004	0.005	0.007
SITE 5	0.004	0.006	0.002	0.004	0.004	0.008
SITE 6	0.010	0.016	0.005	0.013	0.010	0.025
SITE 7	0.003	0.004	0.001	0.003	0.003	0.006
SITE 8	0.003	0.004	0.002	0.003	0.004	0.007
SITE 9	0.011	0.011	0.005	0.007	0.010	0.014
Mean	**0.006**	**0.008**	**0.003**	**0.007**	**0.006**	**0.013**

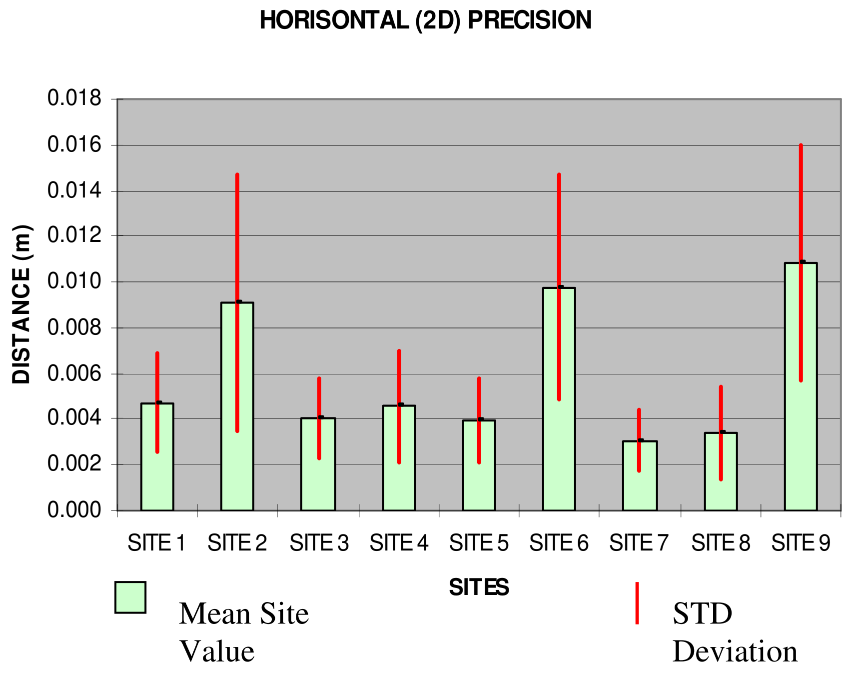


Figure 5.2: VRS Horizontal (2D) Precisions.

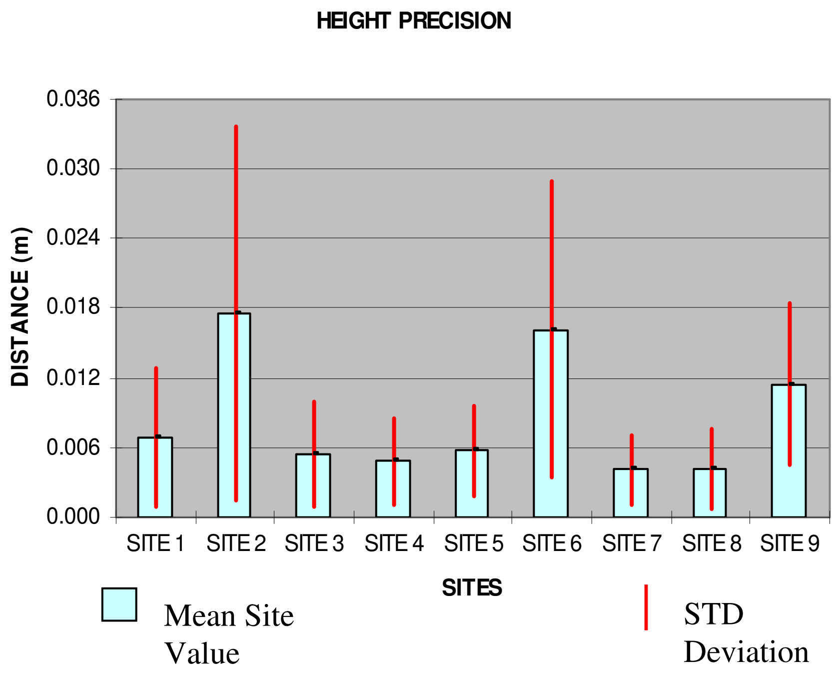


Figure 5.3: VRS Vertical (Height) Precisions.

These results showed an improvement over the horizontal precision of previous VRS testing. (Ong 2003; Ong & Gibbings 2005) reported a 22mm horizontal precision at a 95% confidence level. Fritsch in 2006 reported a horizontal precision of 20mm, 18mm and 16mm respectively, using a Leica, Thales and Topcon receiver.

The height precision obtained during this project also showed an improvement over previous VRS testing. (Ong 2003; Ong & Gibbings 2005) reported a 36mm vertical precision at a 95% confidence level.

5.2.3 Accuracy

The accuracy component of this research project also produced very good results as shown in Table 5.3, Figure 5.4 and Figure 5.5. As with the precision component of this project, several height discrepancies were noticed when comparing test sites two, six and nine with the rest of the test sites. Once again an in-depth investigation and several discussions with GPS experts at Optron Geomatics and TrigNet could not produce any meaningful explanation for these discrepancies.

An average horizontal accuracy of 8mm and a vertical accuracy of 22mm were obtained at a 95% confidence level. As with the precision component, it was expected that the accuracy levels for the height component would be 2,0 to 2,5 times that of the corresponding horizontal component.

The mean horizontal accuracy component was found to be 11mm with a standard deviation of 4mm and the mean vertical accuracy was found to be 22mm with a standard deviation of 11mm. The results showed a slight improvement over the horizontal accuracy of previous VRS testing.

Higgins in 2001 reported a mean horizontal accuracy of 32mm with a standard deviation of 14mm. Fritsch in 2006 reported a horizontal accuracy between 16mm and 33mm, 16mm and 34mm and 16mm and 43mm respectively using a Thales and Topcon and Leica receiver. Ong in 2003 obtained a mean horizontal accuracy of 17mm and individual point accuracies of between 0mm and 36mm.

The height accuracy obtained during this project showed a simular to slight improvement over previous VRS testing. Higgins in 2001 reported a mean vertical accuracy of 40mm with a standard deviation of 29mm.

Table 5.3: Individual Site Accuracy Component Summary.

ACCURACY

Name	Mean Values				STD Dev		95% Confidence Int	
	∂ Y (Easting)	∂ X (Northing)	∂ 2D	∂ Ht	∂ 2D	∂ Ht	∂ 2D	∂ Ht
SITE 1	-0.007	0.000	0.008	0.009	0.003	0.009	0.006	0.018
SITE 2	-0.010	-0.015	0.020	0.040	0.006	0.024	0.013	0.048
SITE 3	-0.004	-0.011	0.013	0.025	0.003	0.007	0.007	0.014
SITE 4	-0.010	-0.002	0.011	0.012	0.003	0.006	0.007	0.012
SITE 5	-0.002	-0.001	0.004	0.012	0.002	0.007	0.005	0.014
SITE 6	-0.002	-0.001	0.010	0.051	0.005	0.021	0.010	0.042
SITE 7	-0.001	-0.005	0.005	0.013	0.002	0.005	0.004	0.010
SITE 8	-0.003	-0.008	0.009	-0.006	0.003	0.005	0.005	0.011
SITE 9	0.012	0.009	0.017	0.039	0.009	0.014	0.019	0.027
Mean	**-0.003**	**-0.004**	**0.011**	**0.022**	**0.004**	**0.011**	**0.008**	**0.022**
STD Dev	**0.007**	**0.007**						

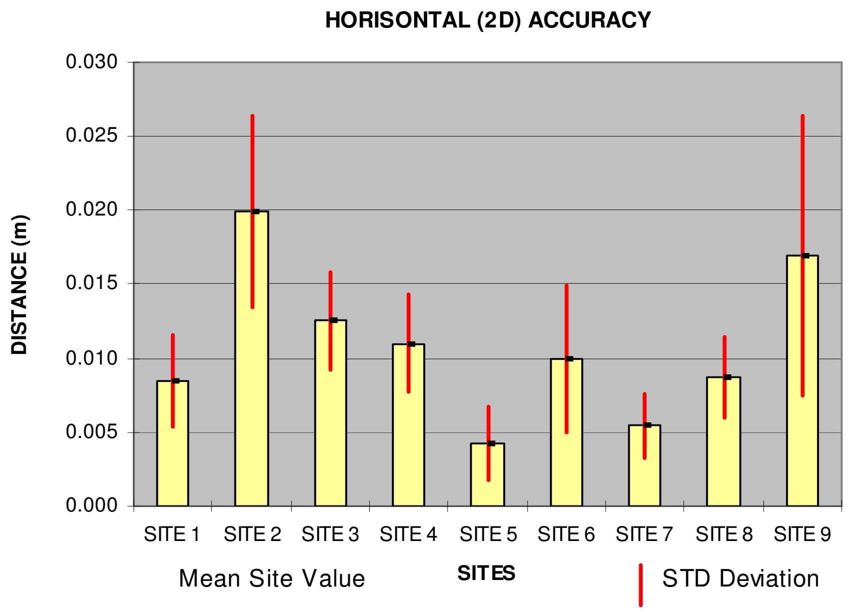


Figure 5.4: VRS Horizontal (2D) Accuracy.

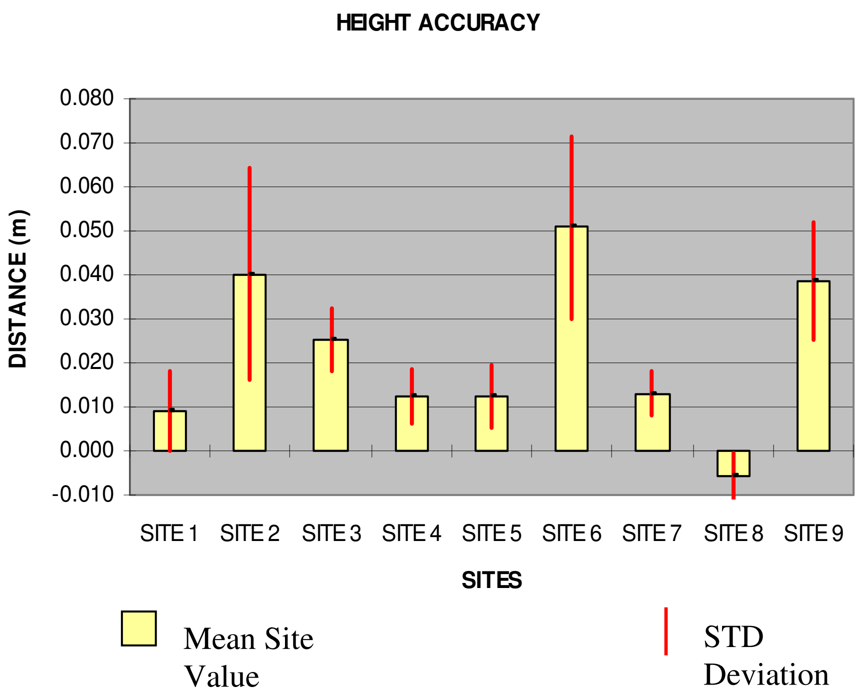


Figure 5.5: VRS Vertical (Height) Accuracy.

5.2.4 Coverage Extents

Of the ten (10) control sites identified and used during this research project, five (5) sites were located inside and five (5) site outside the VRS coverage network. As previously mentioned, Optron Geomatics and TrigNet suggested that there is a buffer area of 40km around the current VRS network and that good VRS results can be expected within the network and the 40km buffer area. For this reason test sites nine (9) and ten (10) were strategically chosen to “push-the-system” to its limits. It was also aimed to ascertain the reliable “extended” working range of the VRS network.

Test site nine and ten was located 37,21km and 47,92km, respectively outside the network. The closest base stations to test site nine being Krugersdorp at 39,37km and Vereeniging at 64,45km. For test site ten the closest base stations were Krugersdorp at 53,43km and Vereeniging at 63,63km. As expected test site ten rejected the VRS RTK survey method and no VRS initialisation or data collection could be done. Surprisingly, test site nine display results from the initialisation time, precision and accuracy simular to that of test sites one to eight.

Results from the initialisation time, precision and accuracy of test sites one to nine seems to indicate that the VRS system is able to perform to simular standards irrespectively if the points is located within or without the VRS network (keeping the 40km buffer area in mind).

We can see that by using the GSM mobile network for data transmission with VRS, the constraints of being within 10km of a base station, and radio communication as required by the conventional RTK survey technique are eliminated. All that is required for the VRS is to be within a GSM mobile coverage area. The algorithm and techniques employed by the VRS system to model the errors inflicted by atmospheric effects, and the process of providing a synthesized base station to the roving receiver at the remote end, seems to provide reliable results.

5.3 Conclusion – Chapter 5

This chapter has analysed and discussed the results obtained during comprehensive field testing of the Gauteng VRS network. The results indicate excellent results with regards to the performance of the VRS survey technique.

The average initialisation time was found to be less than eight seconds, even when venturing outside the VRS network by up to 37km.

The precision component of this project yield excellent results at all test sites. An average horizontal precision of 6mm and a vertical precision of 13mm were obtained at a 95% confidence level.

For the accuracy component this research project also produced very good results. An average horizontal accuracy of 8mm and a vertical accuracy of 22mm were obtained at a 95% confidence level. The average horizontal accuracy component was found to be 11mm with a standard deviation of 4mm and the mean vertical accuracy was found to be 22mm with a standard deviation of 11mm.

The coverage extent for the VRS network went beyond expectation. There were no indications that suggested any degradation to the performance of the system, within and outside of the coverage area (keeping the 40km buffer area around the network into consideration).

In chapter six, the conclusion and recommendations will be presented.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

The processed and manipulated results for the initialisation times, precision, accuracy and coverage extents of the Gauteng VRS system were analysed and discussed in chapter four and five.

From the information gathered in these chapters, final conclusions and recommendations will be drawn.

The aim and objectives as stated in the first chapter will be addressed in the conclusions and will be followed by the recommendations section.

6.2 Conclusions

Chapter one established the aim of this research project to assess the reliability and performance of the new Gauteng Virtual Reference Station (VRS) System of GPS Base Stations. To achieve this aim, the detailed testing and analysis of the initialisation times, accuracy, precision and coverage extents would be carried out.

6.2.1 Initialisation Times

The average initialisation time was under eight (8) seconds at all test sites, exclusive of test site ten (10) where no VRS data could be gathered. With several of the test sites being on the border and a considerable distance outside of the network, it appears as if the distance to the VRS network had no influence on the fixing of ambiguities and the recorded initialisation times.

6.2.2 Precision

Out of a sample size of 360 measurements utilising the VRS survey technique, an average horizontal precision of 6mm and a vertical precision of 13mm were obtained at a 95% confidence level. It was however expected that the precision levels for the height component to be between 2,0 and 2,5 times that of the corresponding horizontal component.

6.2.3 Accuracy

Simular results with regards to the accuracy testing were obtained as that of the previously mentioned precision results. An average horizontal accuracy of 8mm and a vertical accuracy of 22mm were obtained at a 95% confidence level. It was one again expected that the accuracy levels for the height component to be between 2,0 and 2,5 times that of the corresponding horizontal component.

6.2.4 Coverage Extents

The consistency of the VRS RTK techniques' results seen from the initialisation times, precision and accuracy of the four usable points outside the network suggests that it is able to perform to simular standards up to 37km outside of the network as points located within the VRS network. This factor may allow users to work outside the network coverage area of up to 37 km. Using the GSM mobile network for data transmission has rendered the working range factor as a 'non-issue' inside the existing test network.

6.3 Recommendations

As this was the first documented testing done on the Gauteng VRS network, further testing with regards to the current and future Gauteng network will be highly recommended. It is also recommended that extensive research and testing be undertaken with regards to the Wester Cape VRS Network.

6.4 Close

Through the detailed testing of the initialisation times, accuracy, precision and coverage extents, it was possible to give an assessment of the VRS system. The VRS system performed better than initially expected for the initialisation times, precision, accuracy as well as the coverage extents.

This project has therefore, achieved its aim of investigating and reporting on the South African (Gauteng) Virtual Reference Station (VRS) concept as an extension of the Global Positioning System (GPS) Real-Time-Kinematic (RTK) survey technique.

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APPENDIX A

PROJECT SPECIFICATION

Appendix A

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **Tom Marais**

TOPIC: Virtual Reference Station (VRS) in South Africa

SUPERVISOR: Peter Gibbings
Glenn Campbell

PROJECT AIM: This project seeks to investigate and report on the South African Virtual Reference Station (VRS) concept as an extension of the Global Positioning System (GPS) Real-Time-Kinematic (RTK) survey technique.

PROGRAMME: **(Issue B, 25 March 2008)**

1. Analyse the Virtual Reference Station concept as an extension of the Global Positioning System.
2. Critically analyse any relevant prior research and literature regarding Virtual Reference Station networks.
3. Develop and validate a method for testing the accuracy, precision, initialization times and coverage extents of the South African VRS-RTK GPS network.
4. Collect data to allow measurement accuracy, precision, initialization times and coverage extents of the South African VRS-RTK GPS network.
5. Analyse the collected data to quantify the accuracy, precision, initialization times and coverage extents of the South African VRS-RTK GPS network.
6. Submit an academic dissertation on the research.

As time permits:

7. Investigate any improvements that can be made to enhance the current Virtual Reference Station concept.
8. Design and comment on the possible expansion of the current Virtual Reference Station network.

AGREED ____________ (student) ____________ (supervisor)

Date: 25 / 03 / 2008 Date: 21 / 4 / 2008

Co-~~examiner~~ supervisor: P. Gibbings on ADL

EXAMINER:

APPENDIX B

TRIGNET TRIGONOMETRICAL BEACON SPECIFICATIONS

Monument Specifications

(a) TYPES 1 AND 2: STANDARD CONCRETE PILLARS WITH 1.26M AND 1.89M SIGNAL [8]:
A cylindrical concrete pillar that is 1.22 metre high and 38 centimetres in diameter, encased in a sheet-iron mould on a concrete foundation and surmounted by a removable iron signal that is either 1.22m or 1,89m high. The casing is painted white and the signal a dull black. The name and number of the beacon is impressed in the top of the concrete.

(b) TYPE 3: STANDARD BEACON ON PLATFORM [8]:
A concrete platform with a height of between 31 centimetres and 2.83 metres (up to 3.78 metres in exceptional cases) and 1.26 metres in diameter. Refer to paragraph B 4.2 (a) for pillar specification.

(c) TYPE 4: STANDARD UP-STATION [8]:
An iron pipe, that is 4.41 metre in length and 5 centimetres in diameter, is placed 63 centimetres into a ground excavation and concreted. The ground excavation has dimensions of 63 centimetres in depth and 79 centimetres in diameter and is concreted to 5 centimetres above the ground. The top of the pipe is fitted with a sleeve in which a standard 1.26 metre signal is inserted. The overall height of the vane, from ground to top, is 5 metres. The name and number of the beacon is impressed in the top of the concrete.

(d) TYPE 5: PIPE BEACON [8]:
An iron pipe that is 6.6 metres in length and 11 centimetres in diameter, is placed 1 metre into a ground excavation abd concreted.

(e) TYPE 6: 10-11 metre BLOCK BEACON [8]:
The block beacon consists of a platform built on a square concrete foundation. For hard ground conditions the concrete foundation dimensions are square in the horizontal, with sides of 3 metres, and 50 centimetres in the vertical. For soft ground the foundation dimensions remain the same but the entire foundation is sunk into the ground to a depth of at least 1 metre.

The concrete platform takes the form of a hollow tower, square in the horizontal, with sides of 1.44 metres, and walls that are 21 centimetres thick. The tower is constructed using concrete bricks with dimensions of 16 centimetres in the vertical, 21 centimetres wide and 47 centimetres long. The platform is built in sections of 3.06 metres (being 18 courses of brickwork), where each section is completed by the construction of a reinforced concrete slab, 16 centimetres thick. The total section height, including the reinforced concrete slab, is then 3.23 metres. The mortared spacing between the concrete bricks and courses of concrete bricks is 1 centimetre.

The completed platform may not exceed a height of 9.69 metres (3 sections). The construction of a standard 1.26 metre pillar on the platform will realise a maximum total height of 10.95 metres for the beacon.

Permanent steps, consisting of 20 millimetre round iron, are built into one side of the tower at 34 centimetre intervals (after every second course of concrete blocks), the lowest rung being no more than 63 centimetres above ground level. A railing, 95 centimetres high, constructed from 20 millimetre round iron or 16 millimetre square iron, is placed around the top of the platform.

(f) TYPE 7: BLOCK BEACON HIGHER THAN 10-11 metres [8]:

The block beacon consists of a platform built on a square concrete foundation. For hard ground conditions the concrete foundation dimensions are square in the horizontal, with sides of 4 metres, and 50 centimetres in the vertical. For soft ground the foundation dimensions remain the same but the entire foundation is sunk into the ground to a depth of at least 1 metre.

A foundation extension is required for platforms higher than 10 metres. A hollow tower is built with a wall of double thickness, square in the horizontal, with sides of 1.66 metres, and walls that are 43 centimetres thick (2 brick widths). The tower is constructed using concrete bricks with dimensions of 16 centimetres in the vertical, 21 centimetres wide and 47 centimetres long. The foundation extension is built in two sections of 2.38 metres (being 14 courses of brickwork), where each section is completed by the construction of a reinforced concrete slab, 16 centimetres thick. The total section height, including the reinforced concrete slab, is then 2.55 metres. The mortared spacing between the concrete bricks and courses of concrete bricks is 1 centimetre. The foundation extension may not exceed 5.10 metres.

The concrete platform is built on top of the foundation extension in the form of a hollow tower, square in the horizontal, with sides of 1.44 metres, and walls that are 21 centimetres thick. The tower is constructed using concrete bricks with dimensions of 16 centimetres in the vertical, 21 centimetres wide and 47 centimetres long. The platform is built in sections of 3.06 metres (being 18 courses of brickwork), where each section is completed by the construction of a reinforced concrete slab, 16 centimetres thick. The total section height, including the reinforced concrete slab, is then 3.23 metres. The mortared spacing between the concrete bricks and courses of concrete bricks is 1 centimetre.

The completed platform may not exceed a height of 9.69 metres (3 sections) above the foundation extension and 14.79 metres above ground level. The construction of a standard 1.26 metre pillar on the platform will realise a total height of 16.05 metres for the beacon.

Permanent steps, consisting of 20 millimetre round iron, are built into one side of the tower at 34 centimetre intervals (after every second course of concrete blocks), the lowest rung being no more than 63 centimetres above ground level. A railing, 95 centimetres high, constructed from 20 millimetre round iron or 16 millimetre square iron, is placed around the top of the platform.

(g) TYPE 8: 15 metre WINDMILL TOWER BEACON [8]:

A windmill tower beacon consists of two separate towers, an inner tower 12.59 metres in height which carries an 2.52 metre by 11 centimetre pipe extension at the top of the "beacon", and an outer tower 14.48 metres in height which carries an observer's platform.

(h) TYPE 9: 6.3 metre OR 8.82 metre WINDMILL TOWER BEACON [8]:

A standard 6.3 metre windmill tower is provided either with (A type) a tower cap and flange or (B type) a 11 centimetre by 2.52 metres pipe and flange. In both cases a pipe outer tower is erected round the windmill tower – in the case of the A type, 5.04 metres high and for the B type, 7.56 metres high. The outer tower is placed square to the diagonal of the inner windmill tower.

(i) TYPE 10: METAL TRIPOD BEACON [8]:

In built-up areas or where reservoirs, silos or water towers occupy the most suitable positions for a Trigonometrical beacon, a metal tripod beacon is used. The metal tripod beacon has a light structure, which can be erected with ease with minimum defacement to the building, or structure.

APPENDIX C

INDIVIDUAL TEST SITE DATA

SITE1 - T135 (KRUG 62)

Name	PPS Co-ordinates		
	Y (Eastings)	X (Northings)	Ellipsoidal HT
T135PPS	-69533.131	2907417.163	**1609.388**

Name	VRS RTK Co-ordinates			Accuracy			
	Y (Eastings)	X (Northings)	Ellipsoidal HT	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht
T135VRS1	-69533.120	2907417.163	1609.367	0.011	0.000	0.011	0.021
T135VRS2	-69533.116	2907417.164	1609.372	-0.015	-0.001	0.015	0.016
T135VRS3	-69533.116	2907417.167	1609.373	-0.015	-0.004	0.016	0.015
T135VRS4	-69533.120	2907417.162	1609.359	-0.011	0.001	0.011	0.029
T135VRS5	-69533.121	2907417.160	1609.356	-0.010	0.003	0.010	0.032
T135VRS6	-69533.124	2907417.163	1609.361	-0.007	0.000	0.007	0.027
T135VRS7	-69533.118	2907417.160	1609.350	-0.013	0.003	0.013	0.038
T135VRS8	-69533.123	2907417.159	1609.364	-0.008	0.004	0.009	0.024
T135VRS9	-69533.120	2907417.157	1609.358	-0.011	0.006	0.013	0.030
T135VRS10	-69533.127	2907417.160	1609.370	-0.004	0.003	0.005	0.018
T135VRS11	-69533.126	2907417.164	1609.368	-0.005	-0.001	0.005	0.020
T135VRS12	-69533.118	2907417.165	1609.362	-0.013	-0.002	0.013	0.026
T135VRS13	-69533.123	2907417.169	1609.359	-0.008	-0.006	0.010	0.029
T135VRS14	-69533.123	2907417.167	1609.356	-0.008	-0.004	0.009	0.032
T135VRS15	-69533.124	2907417.168	1609.357	-0.007	-0.005	0.009	0.031
T135VRS16	-69533.125	2907417.165	1609.346	-0.006	-0.002	0.006	0.042
T135VRS17	-69533.130	2907417.165	1609.342	-0.001	-0.002	0.002	0.046
T135VRS18	-69533.131	2907417.162	1609.348	0.000	0.001	0.001	0.040
T135VRS19	-69533.128	2907417.167	1609.355	-0.003	-0.004	0.005	0.033
T135VRS20	-69533.124	2907417.169	1609.355	-0.007	-0.006	0.009	0.033
T135VRS21	-69533.126	2907417.168	1609.356	-0.005	-0.005	0.007	0.032
T135VRS22	-69533.126	2907417.166	1609.358	-0.005	-0.003	0.006	0.030
T135VRS23	-69533.124	2907417.160	1609.344	-0.007	0.003	0.008	0.044
T135VRS24	-69533.124	2907417.167	1609.348	-0.007	-0.004	0.008	0.040
T135VRS25	-69533.126	2907417.167	1609.361	-0.005	-0.004	0.006	0.027
T135VRS26	-69533.123	2907417.164	1609.355	-0.008	-0.001	0.008	0.033
T135VRS27	-69533.124	2907417.163	1609.356	-0.007	0.000	0.007	0.032
T135VRS28	-69533.126	2907417.160	1609.348	-0.005	0.003	0.006	0.040
T135VRS29	-69533.126	2907417.155	1609.346	-0.005	0.008	0.009	0.042
T135VRS30	-69533.125	2907417.153	1609.338	-0.006	0.010	0.012	0.050
T135VRS31	-69533.124	2907417.159	1609.346	-0.007	0.004	0.008	0.042
T135VRS32	-69533.126	2907417.158	1609.357	-0.005	0.005	0.007	0.031
T135VRS33	-69533.125	2907417.158	1609.353	-0.006	0.005	0.008	0.035
T135VRS34	-69533.126	2907417.158	1609.356	-0.005	0.005	0.007	0.032
T135VRS35	-69533.126	2907417.159	1609.352	-0.005	0.004	0.006	0.036
T135VRS36	-69533.125	2907417.161	1609.355	-0.006	0.002	0.006	0.033
T135VRS37	-69533.120	2907417.166	1609.367	-0.011	-0.003	0.011	0.021
T135VRS38	-69533.121	2907417.167	1609.382	-0.010	-0.004	0.011	0.006
T135VRS39	-69533.122	2907417.163	1609.364	-0.009	0.000	0.009	0.024
T135VRS40	-69533.122	2907417.160	1609.362	-0.009	0.003	0.009	0.026
Mean	**-69533.124**	**2907417.163**	**1609.357**	**-0.007**	**0.000**	**0.008**	**0.031**
STD Dev				**0.004**	**0.004**	**0.003**	**0.009**

Name	Precision				Initialisation Time			Accuracy		HDOP	VDOP	SV's
	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Init Loss	Init Gain	TTFF	Hor	Vert	(Max)	(Max)	(Min)
T135VRS1	0.004	0.000	0.004	0.010	284955	284963	8	0.007	0.012	0.8	1.4	12
T135VRS2	0.008	0.001	0.008	0.015	284983	284989	6	0.007	0.012	0.8	1.4	12
T135VRS3	0.008	0.004	0.009	0.016	285011	285024	13	0.007	0.012	0.8	1.4	12
T135VRS4	0.004	-0.001	0.004	0.002	285034	285043	9	0.007	0.012	0.8	1.4	12
T135VRS5	0.003	-0.003	0.004	0.001	285066	285072	6	0.007	0.012	0.8	1.4	12
T135VRS6	0.000	0.000	0.001	0.004	285103	285107	4	0.007	0.012	0.8	1.4	12
T135VRS7	0.006	-0.003	0.006	0.007	285130	285137	7	0.007	0.012	0.8	1.4	12
T135VRS8	0.001	-0.004	0.004	0.007	285158	285164	6	0.007	0.012	0.8	1.4	12
T135VRS9	0.004	-0.006	0.007	0.001	285186	285193	7	0.007	0.012	0.8	1.4	12
T135VRS10	-0.003	-0.003	0.004	0.013	285215	285221	6	0.008	0.012	0.8	1.4	12
T135VRS11	-0.002	0.001	0.003	0.011	285253	285260	7	0.007	0.012	0.8	1.4	12
T135VRS12	0.006	0.002	0.006	0.005	285282	285288	6	0.008	0.012	0.8	1.4	12
T135VRS13	0.001	0.006	0.006	0.002	285308	285318	10	0.008	0.012	0.8	1.3	12
T135VRS14	0.001	0.004	0.004	0.001	285338	285345	7	0.008	0.012	0.8	1.3	12
T135VRS15	0.000	0.005	0.005	0.000	285365	285372	7	0.008	0.012	0.8	1.3	12
T135VRS16	-0.001	0.002	0.003	0.011	285392	285399	7	0.008	0.012	0.8	1.3	12
T135VRS17	-0.006	0.002	0.007	0.015	285422	285428	6	0.008	0.012	0.8	1.3	12
T135VRS18	-0.007	-0.001	0.007	0.009	285451	285463	12	0.008	0.012	0.8	1.3	12
T135VRS19	-0.004	0.004	0.006	0.002	285486	285492	6	0.008	0.012	0.8	1.3	12
T135VRS20	0.000	0.006	0.006	0.002	285513	285520	7	0.008	0.012	0.8	1.3	12
T135VRS21	-0.002	0.005	0.006	0.001	285543	285549	6	0.008	0.012	0.8	1.3	12
T135VRS22	-0.002	0.003	0.004	0.001	285571	285577	6	0.008	0.012	0.8	1.3	12
T135VRS23	0.000	-0.003	0.003	0.013	285598	285604	6	0.008	0.013	0.8	1.3	12
T135VRS24	0.000	0.004	0.004	0.009	285627	285632	5	0.008	0.012	0.8	1.3	12
T135VRS25	-0.002	0.004	0.005	0.004	285653	285659	6	0.008	0.013	0.8	1.3	12
T135VRS26	0.001	0.001	0.001	0.002	285680	285689	9	0.008	0.013	0.8	1.3	12
T135VRS27	0.000	0.000	0.001	0.001	285710	285717	7	0.008	0.013	0.8	1.3	12
T135VRS28	-0.002	-0.003	0.004	0.009	285741	285747	6	0.008	0.013	0.8	1.3	12
T135VRS29	-0.002	-0.008	0.008	0.011	285769	285776	7	0.009	0.013	0.8	1.2	11
T135VRS30	-0.001	-0.010	0.010	0.019	285797	285805	8	0.009	0.013	0.8	1.2	11
T135VRS31	0.000	-0.004	0.004	0.011	285827	285833	6	0.009	0.013	0.8	1.2	12
T135VRS32	-0.002	-0.005	0.005	0.000	285854	285863	9	0.009	0.013	0.8	1.2	12
T135VRS33	-0.001	-0.005	0.005	0.004	285885	285893	8	0.009	0.013	0.8	1.2	12
T135VRS34	-0.002	-0.005	0.005	0.001	285915	285921	6	0.009	0.013	0.8	1.2	12
T135VRS35	-0.002	-0.004	0.004	0.005	285942	285949	7	0.009	0.013	0.8	1.2	12
T135VRS36	-0.001	-0.002	0.002	0.002	285970	285980	10	0.009	0.013	0.8	1.2	12
T135VRS37	0.004	0.003	0.005	0.010	286186	286196	10	0.009	0.013	0.9	1.3	11
T135VRS38	0.003	0.004	0.005	0.025	286218	286224	6	0.009	0.013	0.9	1.3	11
T135VRS39	0.002	0.000	0.002	0.007	286247	286254	7	0.010	0.013	0.9	1.3	11
T135VRS40	0.002	-0.003	0.003	0.005	286277	286284	7	0.010	0.013	0.9	1.3	11
Mean			**0.005**	**0.007**			**7.2**	**0.008**	**0.012**	**0.8**	**1.3**	**12**
STD Dev			**0.002**	**0.006**			**1.8**					

SITE1 - T620 (MEREDALE RES)

Name	PPS Co-ordinates		
	Y (Eastings)	X (Northings)	Ellipsoidal HT
T620PPS	-97449.184	2908395.795	**1825.872**

Name	VRS RTK Co-ordinates			Accuracy				Precision				Initialisation Time			Accuracy		HDOP	VDOP	SV's
	Y (Eastings)	X (Northings)	Ellipsoidal HT	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Init Loss	Init Gain	TTFF	Hor	Vert	(Max)	(Max)	(Min)
T620VRS1	-97449.166	2908395.804	1825.844	0.018	-0.009	0.020	0.028	0.007	-0.006	0.009	0.012	125364	125373	9	0.010	0.022	1.0	2.1	9
T620VRS2	-97449.162	2908395.803	1825.765	-0.022	-0.008	0.023	0.107	0.011	-0.007	0.013	0.067	125395	125402	7	0.011	0.022	1.0	2.1	9
T620VRS3	-97449.161	2908395.802	1825.776	-0.023	-0.007	0.024	0.096	0.012	-0.008	0.014	0.056	125426	125433	7	0.011	0.022	1.0	2.1	9
T620VRS4	-97449.160	2908395.807	1825.779	-0.024	-0.012	0.027	0.093	0.013	-0.003	0.014	0.053	125455	125463	8	0.011	0.022	1.0	2.1	9
T620VRS5	-97449.156	2908395.805	1825.776	-0.028	-0.010	0.030	0.096	0.017	-0.005	0.018	0.056	125484	125490	6	0.011	0.022	1.0	2.1	9
T620VRS6	-97449.156	2908395.800	1825.793	-0.028	-0.005	0.028	0.079	0.017	-0.010	0.020	0.039	125518	125526	8	0.011	0.022	1.0	2.1	9
T620VRS7	-97449.153	2908395.803	1825.841	-0.031	-0.008	0.032	0.031	0.020	-0.007	0.021	0.009	125551	125557	6	0.011	0.022	1.0	2.1	9
T620VRS8	-97449.153	2908395.806	1825.834	-0.031	-0.011	0.033	0.038	0.020	-0.004	0.021	0.002	125807	125816	9	0.011	0.022	1.0	2.0	9
T620VRS9	-97449.166	2908395.803	1825.840	-0.018	-0.008	0.020	0.032	0.007	-0.007	0.010	0.008	125889	125897	8	0.013	0.022	1.1	1.9	9
T620VRS10	-97449.174	2908395.802	1825.861	-0.010	-0.007	0.012	0.011	-0.001	-0.008	0.008	0.029	125929	125937	8	0.011	0.019	0.9	1.6	10
T620VRS11	-97449.179	2908395.805	1825.855	-0.005	-0.010	0.011	0.017	-0.006	-0.005	0.007	0.023	125968	125975	7	0.011	0.019	0.9	1.6	10
T620VRS12	-97449.174	2908395.810	1825.839	-0.010	-0.015	0.018	0.033	-0.001	0.000	0.001	0.007	125997	126006	9	0.011	0.019	0.9	1.6	10
T620VRS13	-97449.172	2908395.811	1825.838	-0.012	-0.016	0.020	0.034	0.001	0.001	0.002	0.006	126031	126037	6	0.011	0.019	0.9	1.6	10
T620VRS14	-97449.176	2908395.813	1825.849	-0.008	-0.018	0.020	0.023	-0.003	0.003	0.004	0.017	126065	126072	7	0.011	0.019	0.9	1.6	10
T620VRS15	-97449.177	2908395.808	1825.854	-0.007	-0.013	0.015	0.018	-0.004	-0.002	0.004	0.022	126100	126106	6	0.011	0.019	0.9	1.6	10
T620VRS16	-97449.179	2908395.811	1825.846	-0.005	-0.016	0.017	0.026	-0.006	0.001	0.006	0.014	126132	126150	18	0.011	0.019	0.9	1.6	10
T620VRS17	-97449.170	2908395.810	1825.846	-0.014	-0.015	0.021	0.026	0.003	0.000	0.003	0.014	126175	126183	8	0.011	0.019	0.9	1.6	10
T620VRS18	-97449.174	2908395.809	1825.848	-0.010	-0.014	0.017	0.024	-0.001	-0.001	0.001	0.016	126206	126212	6	0.011	0.019	0.9	1.6	10
T620VRS19	-97449.178	2908395.815	1825.854	-0.006	-0.020	0.021	0.018	-0.005	0.005	0.007	0.022	126234	126241	7	0.011	0.019	0.9	1.6	10
T620VRS20	-97449.177	2908395.812	1825.855	-0.007	-0.017	0.018	0.017	-0.004	0.002	0.004	0.023	126263	126269	6	0.011	0.019	0.9	1.6	10
T620VRS21	-97449.177	2908395.809	1825.863	-0.007	-0.014	0.016	0.009	-0.004	-0.001	0.004	0.031	126291	126297	6	0.011	0.019	0.9	1.6	10
T620VRS22	-97449.179	2908395.814	1825.848	-0.005	-0.019	0.020	0.024	-0.006	0.004	0.007	0.016	126318	126326	8	0.011	0.019	0.9	1.6	10
T620VRS23	-97449.182	2908395.806	1825.849	-0.002	-0.011	0.011	0.023	-0.009	-0.004	0.009	0.017	126347	126352	5	0.011	0.019	0.9	1.6	10
T620VRS24	-97449.179	2908395.808	1825.831	-0.005	-0.013	0.014	0.041	-0.006	-0.002	0.006	0.001	126375	126381	6	0.011	0.019	0.9	1.6	10
T620VRS25	-97449.179	2908395.809	1825.841	-0.005	-0.014	0.015	0.031	-0.006	-0.001	0.006	0.009	126402	126408	6	0.011	0.019	0.9	1.6	10
T620VRS26	-97449.182	2908395.809	1825.837	-0.002	-0.014	0.014	0.035	-0.009	-0.001	0.009	0.005	126429	126435	6	0.011	0.019	0.9	1.6	10
T620VRS27	-97449.180	2908395.810	1825.823	-0.004	-0.015	0.016	0.049	-0.007	0.000	0.007	0.009	126456	126463	7	0.011	0.019	0.9	1.6	10
T620VRS28	-97449.182	2908395.819	1825.811	-0.002	-0.024	0.024	0.061	-0.009	0.009	0.013	0.021	126483	126489	6	0.011	0.019	0.9	1.6	10
T620VRS29	-97449.179	2908395.820	1825.820	-0.005	-0.025	0.025	0.052	-0.006	0.010	0.012	0.012	126511	126518	7	0.011	0.019	0.9	1.6	10
T620VRS30	-97449.185	2908395.819	1825.836	0.001	-0.024	0.024	0.036	-0.012	0.009	0.015	0.004	126539	126546	7	0.011	0.019	0.9	1.6	10
T620VRS31	-97449.181	2908395.823	1825.825	-0.003	-0.028	0.028	0.047	-0.008	0.013	0.015	0.007	126567	126573	6	0.011	0.019	0.9	1.6	10
T620VRS32	-97449.179	2908395.824	1825.821	-0.005	-0.029	0.029	0.051	-0.006	0.014	0.016	0.011	126598	126604	6	0.011	0.019	0.9	1.6	10
T620VRS33	-97449.179	2908395.824	1825.820	-0.005	-0.029	0.029	0.052	-0.006	0.014	0.016	0.012	126624	126630	6	0.011	0.019	0.9	1.6	10
T620VRS34	-97449.175	2908395.818	1825.824	-0.009	-0.023	0.025	0.048	-0.002	0.008	0.009	0.008	126652	126657	5	0.011	0.019	0.9	1.6	10
T620VRS35	-97449.176	2908395.811	1825.832	-0.008	-0.016	0.018	0.040	-0.003	0.001	0.003	0.000	126678	126685	7	0.011	0.019	0.9	1.6	10
T620VRS36	-97449.176	2908395.809	1825.834	-0.008	-0.014	0.016	0.038	-0.003	-0.001	0.003	0.002	126707	126713	6	0.011	0.019	0.9	1.6	10
T620VRS37	-97449.177	2908395.800	1825.844	-0.007	-0.005	0.009	0.028	-0.004	-0.010	0.010	0.012	126734	126740	6	0.011	0.019	0.9	1.6	10
T620VRS38	-97449.174	2908395.800	1825.844	-0.010	-0.005	0.011	0.028	-0.001	-0.010	0.010	0.012	126763	126770	7	0.011	0.019	0.9	1.6	10
T620VRS39	-97449.173	2908395.807	1825.836	-0.011	-0.012	0.016	0.036	0.000	-0.003	0.003	0.004	126791	126797	6	0.011	0.019	0.9	1.6	10
T620VRS40	-97449.178	2908395.803	1825.841	-0.006	-0.008	0.010	0.031	-0.005	-0.007	0.008	0.009	126821	126829	8	0.011	0.019	0.9	1.5	10
Mean	**-97449.173**	**2908395.810**	**1825.832**	**-0.010**	**-0.015**	**0.020**	**0.040**		**Mean**	**0.009**	**0.017**	**Mean**		**7.1**	**0.011**	**0.020**	**0.9**	**1.7**	**10**
STD Dev				**0.010**	**0.007**	**0.006**	**0.024**		**STD Dev**	**0.006**	**0.016**	**STD Dev**		**2.1**					

SITE1 - T416 (KRUG 113)

Name	PPS Co-ordinates Y (Eastings)	X (Northings)	Ellipsoidal HT
T416PPS	-84932.814	2891247.233	**1802.921**

Name	VRS RTK Co-ordinates Y (Eastings)	X (Northings)	Ellipsoidal HT	Accuracy ∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht
T416VRS1	-84932.809	2891247.241	1802.900	0.005	-0.008	0.009	0.021
T416VRS2	-84932.811	2891247.242	1802.900	-0.003	-0.009	0.009	0.021
T416VRS3	-84932.809	2891247.243	1802.908	-0.005	-0.010	0.011	0.013
T416VRS4	-84932.806	2891247.246	1802.906	-0.008	-0.013	0.015	0.015
T416VRS5	-84932.807	2891247.244	1802.900	-0.007	-0.011	0.013	0.021
T416VRS6	-84932.808	2891247.244	1802.897	-0.006	-0.011	0.013	0.024
T416VRS7	-84932.807	2891247.247	1802.896	-0.007	-0.014	0.016	0.025
T416VRS8	-84932.813	2891247.245	1802.897	-0.001	-0.012	0.012	0.024
T416VRS9	-84932.811	2891247.245	1802.894	-0.003	-0.012	0.012	0.027
T416VRS10	-84932.812	2891247.244	1802.891	-0.002	-0.011	0.011	0.030
T416VRS11	-84932.811	2891247.246	1802.898	-0.003	-0.013	0.013	0.023
T416VRS12	-84932.814	2891247.247	1802.897	0.000	-0.014	0.014	0.024
T416VRS13	-84932.810	2891247.249	1802.893	-0.004	-0.016	0.016	0.028
T416VRS14	-84932.811	2891247.245	1802.889	-0.003	-0.012	0.012	0.032
T416VRS15	-84932.809	2891247.244	1802.890	-0.005	-0.011	0.012	0.031
T416VRS16	-84932.811	2891247.242	1802.889	-0.003	-0.009	0.009	0.032
T416VRS17	-84932.812	2891247.242	1802.894	-0.002	-0.009	0.009	0.027
T416VRS18	-84932.815	2891247.243	1802.895	0.001	-0.010	0.010	0.026
T416VRS19	-84932.814	2891247.244	1802.904	0.000	-0.011	0.011	0.017
T416VRS20	-84932.815	2891247.243	1802.882	0.001	-0.010	0.010	0.039
T416VRS21	-84932.814	2891247.243	1802.881	0.000	-0.010	0.010	0.040
T416VRS22	-84932.810	2891247.240	1802.882	-0.004	-0.007	0.008	0.039
T416VRS23	-84932.811	2891247.239	1802.882	-0.003	-0.006	0.007	0.039
T416VRS24	-84932.811	2891247.240	1802.887	-0.003	-0.007	0.008	0.034
T416VRS25	-84932.813	2891247.241	1802.896	-0.001	-0.008	0.008	0.025
T416VRS26	-84932.812	2891247.240	1802.888	-0.002	-0.007	0.007	0.033
T416VRS27	-84932.811	2891247.243	1802.897	-0.003	-0.010	0.010	0.024
T416VRS28	-84932.808	2891247.243	1802.893	-0.006	-0.010	0.012	0.028
T416VRS29	-84932.807	2891247.244	1802.900	-0.007	-0.011	0.013	0.021
T416VRS30	-84932.804	2891247.240	1802.897	-0.010	-0.007	0.012	0.024
T416VRS31	-84932.803	2891247.242	1802.899	-0.011	-0.009	0.014	0.022
T416VRS32	-84932.804	2891247.244	1802.894	-0.010	-0.011	0.015	0.027
T416VRS33	-84932.806	2891247.244	1802.903	-0.008	-0.011	0.014	0.018
T416VRS34	-84932.806	2891247.249	1802.909	-0.008	-0.016	0.018	0.012
T416VRS35	-84932.807	2891247.249	1802.903	-0.007	-0.016	0.017	0.018
T416VRS36	-84932.804	2891247.248	1802.907	-0.010	-0.015	0.018	0.014
T416VRS37	-84932.807	2891247.248	1802.900	-0.007	-0.015	0.017	0.021
T416VRS38	-84932.807	2891247.249	1802.897	-0.007	-0.016	0.017	0.024
T416VRS39	-84932.809	2891247.250	1802.900	-0.005	-0.017	0.018	0.021
T416VRS40	-84932.809	2891247.251	1802.895	-0.005	-0.018	0.019	0.026
Mean	**-84932.809**	**2891247.244**	**1802.896**	**-0.004**	**-0.011**	**0.013**	**0.025**
STD Dev				**0.004**	**0.003**	**0.003**	**0.007**

Name	Precision ∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Initialisation Time Init Loss	Init Gain	TTFF	Accuracy Hor	Vert	HDOP (Max)	VDOP (Max)	SV's (Min)
T416VRS1	0.000	-0.003	0.003	0.004	133393	133402	9	0.005	0.011	0.6	1.2	10
T416VRS2	-0.002	-0.002	0.003	0.004	133425	133433	8	0.006	0.012	0.6	1.2	10
T416VRS3	0.000	-0.001	0.001	0.012	133455	133460	5	0.006	0.012	0.6	1.2	10
T416VRS4	0.003	0.002	0.004	0.010	133483	133488	5	0.007	0.013	0.6	1.2	10
T416VRS5	0.002	0.000	0.002	0.004	133517	133523	6	0.007	0.013	0.6	1.2	10
T416VRS6	0.001	0.000	0.001	0.001	133545	133552	7	0.008	0.014	0.6	1.2	10
T416VRS7	0.002	0.003	0.004	0.000	133574	133582	8	0.008	0.014	0.6	1.2	10
T416VRS8	-0.004	0.001	0.004	0.001	133607	133613	6	0.009	0.015	0.6	1.2	10
T416VRS9	-0.002	0.001	0.002	0.002	133635	133641	6	0.009	0.015	0.6	1.2	10
T416VRS10	-0.003	0.000	0.003	0.005	133662	133669	7	0.010	0.016	0.6	1.2	10
T416VRS11	-0.002	0.002	0.002	0.002	133692	133698	6	0.010	0.016	0.6	1.2	10
T416VRS12	-0.005	0.003	0.005	0.001	133722	133729	7	0.011	0.017	0.6	1.2	10
T416VRS13	-0.001	0.005	0.005	0.003	133753	133760	7	0.011	0.017	0.6	1.2	10
T416VRS14	-0.002	0.001	0.002	0.007	133784	133790	6	0.012	0.018	0.6	1.2	10
T416VRS15	0.000	0.000	0.001	0.006	133826	133833	7	0.012	0.018	0.6	1.2	10
T416VRS16	-0.002	-0.002	0.003	0.007	133857	133864	7	0.013	0.019	0.6	1.2	10
T416VRS17	-0.003	-0.002	0.003	0.002	133884	133891	7	0.013	0.019	0.6	1.2	10
T416VRS18	-0.006	-0.001	0.006	0.001	133913	133919	6	0.014	0.020	0.6	1.2	10
T416VRS19	-0.005	0.000	0.005	0.008	133941	133955	14	0.014	0.020	0.6	1.2	10
T416VRS20	-0.006	-0.001	0.006	0.014	134052	134060	8	0.015	0.021	0.6	1.2	10
T416VRS21	-0.005	-0.001	0.005	0.015	134080	134086	6	0.015	0.021	0.6	1.2	10
T416VRS22	-0.001	-0.004	0.004	0.014	134108	134114	6	0.016	0.022	0.6	1.2	10
T416VRS23	-0.002	-0.005	0.006	0.014	134136	134144	8	0.016	0.022	0.6	1.2	10
T416VRS24	-0.002	-0.004	0.005	0.009	134163	134169	6	0.017	0.023	0.6	1.2	10
T416VRS25	-0.004	-0.003	0.005	0.000	134189	134195	6	0.017	0.023	0.6	1.2	10
T416VRS26	-0.003	-0.004	0.005	0.008	134215	134221	6	0.018	0.024	0.6	1.2	10
T416VRS27	-0.002	-0.001	0.002	0.001	134240	134247	7	0.018	0.024	0.6	1.2	10
T416VRS28	0.001	-0.001	0.002	0.003	134267	134273	6	0.019	0.025	0.6	1.2	10
T416VRS29	0.002	0.000	0.002	0.004	134293	134301	8	0.019	0.025	0.6	1.2	10
T416VRS30	0.005	-0.004	0.007	0.001	134322	134328	6	0.006	0.012	0.7	1.2	10
T416VRS31	0.006	-0.002	0.007	0.003	134349	134356	7	0.007	0.012	0.7	1.2	10
T416VRS32	0.005	0.000	0.005	0.002	134376	134384	8	0.007	0.012	0.7	1.2	10
T416VRS33	0.003	0.000	0.003	0.007	134404	134409	5	0.005	0.010	0.7	1.3	10
T416VRS34	0.003	0.005	0.006	0.013	134431	134437	6	0.007	0.012	0.7	1.3	10
T416VRS35	0.002	0.005	0.005	0.007	134456	134462	6	0.005	0.010	0.7	1.3	10
T416VRS36	0.005	0.004	0.007	0.011	134484	134490	6	0.007	0.012	0.7	1.3	10
T416VRS37	0.002	0.004	0.004	0.004	134513	134519	6	0.006	0.012	0.7	1.3	10
T416VRS38	0.002	0.005	0.005	0.001	134540	134547	7	0.006	0.011	0.7	1.3	10
T416VRS39	0.000	0.006	0.006	0.004	134566	134572	6	0.006	0.012	0.7	1.3	10
T416VRS40	0.000	0.007	0.007	0.001	134593	134599	6	0.007	0.012	0.7	1.3	10
Mean			**0.004**	**0.005**			**6.8**	**0.011**	**0.016**	**0.6**	**1.2**	**10**
STD Dev			**0.002**	**0.004**			**1.5**					

SITE1 - T187 (PRE 11)

Name	PPS Co-ordinates		
	Y (Eastings)	X (Northings)	Ellipsoidal HT
T187PPS	-113592.277	2882429.187	**1600.070**

Name	VRS RTK Co-ordinates			Accuracy				Precision				Initialisation Time			Accuracy		HDOP	VDOP	SV's
	Y (Eastings)	X (Northings)	Ellipsoidal HT	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Init Loss	Init Gain	TTFF	Hor	Vert	(Max)	(Max)	(Min)
T187VRS1	-113592.269	2882429.185	1600.053	0.008	0.002	0.008	0.017	-0.002	-0.004	0.005	0.005	204980	204993	13	0.009	0.014	0.8	1.2	11
T187VRS2	-113592.275	2882429.188	1600.050	-0.002	-0.001	0.002	0.020	-0.008	-0.001	0.008	0.008	205074	205083	9	0.010	0.015	1.0	1.5	10
T187VRS3	-113592.272	2882429.188	1600.054	-0.005	-0.001	0.005	0.016	-0.005	-0.001	0.005	0.004	205106	205113	7	0.010	0.016	1.0	1.5	10
T187VRS4	-113592.269	2882429.189	1600.049	-0.008	-0.002	0.008	0.021	-0.002	0.000	0.002	0.009	205134	205142	8	0.010	0.016	1.0	1.5	10
T187VRS5	-113592.267	2882429.189	1600.056	-0.010	-0.002	0.010	0.014	0.000	0.000	0.000	0.002	205163	205171	8	0.010	0.016	1.0	1.5	10
T187VRS6	-113592.267	2882429.193	1600.050	-0.010	-0.006	0.012	0.020	0.000	0.004	0.004	0.008	205192	205199	7	0.010	0.016	1.0	1.5	10
T187VRS7	-113592.268	2882429.189	1600.064	-0.009	-0.002	0.009	0.006	-0.001	0.000	0.001	0.006	205219	205224	5	0.009	0.014	0.8	1.2	11
T187VRS8	-113592.266	2882429.188	1600.076	-0.011	-0.001	0.011	-0.006	0.001	-0.001	0.001	0.018	205245	205251	6	0.009	0.014	0.8	1.2	11
T187VRS9	-113592.268	2882429.196	1600.059	-0.009	-0.009	0.013	0.011	-0.001	0.007	0.007	0.001	205272	205278	6	0.009	0.014	0.8	1.2	11
T187VRS10	-113592.265	2882429.196	1600.060	-0.012	-0.009	0.015	0.010	0.002	0.007	0.007	0.002	205299	205306	7	0.009	0.014	0.8	1.2	11
T187VRS11	-113592.263	2882429.197	1600.064	-0.014	-0.010	0.017	0.006	0.004	0.008	0.009	0.006	205326	205333	7	0.009	0.014	0.8	1.2	11
T187VRS12	-113592.262	2882429.192	1600.062	-0.015	-0.005	0.016	0.008	0.005	0.003	0.006	0.004	205353	205359	6	0.009	0.014	0.8	1.2	11
T187VRS13	-113592.263	2882429.193	1600.059	-0.014	-0.006	0.015	0.011	0.004	0.004	0.006	0.001	205381	205387	6	0.009	0.014	0.8	1.2	11
T187VRS14	-113592.263	2882429.189	1600.061	-0.014	-0.002	0.014	0.009	0.004	0.000	0.004	0.003	205410	205417	7	0.009	0.014	0.8	1.2	11
T187VRS15	-113592.262	2882429.185	1600.055	-0.015	0.002	0.015	0.015	0.005	-0.004	0.006	0.003	205438	205445	7	0.009	0.014	0.8	1.2	11
T187VRS16	-113592.266	2882429.193	1600.058	-0.011	-0.006	0.013	0.012	0.001	0.004	0.004	0.000	205467	205474	7	0.009	0.014	0.8	1.2	11
T187VRS17	-113592.266	2882429.193	1600.056	-0.011	-0.006	0.013	0.014	0.001	0.004	0.004	0.002	205494	205501	7	0.009	0.014	0.8	1.2	11
T187VRS18	-113592.264	2882429.189	1600.065	-0.013	-0.002	0.013	0.005	0.003	0.000	0.003	0.007	205521	205528	7	0.009	0.014	0.8	1.2	11
T187VRS19	-113592.265	2882429.191	1600.067	-0.012	-0.004	0.013	0.003	0.002	0.002	0.003	0.009	205552	205558	6	0.009	0.014	0.8	1.2	11
T187VRS20	-113592.265	2882429.192	1600.064	-0.012	-0.005	0.013	0.006	0.002	0.003	0.004	0.006	205580	205587	7	0.009	0.014	0.8	1.2	11
T187VRS21	-113592.262	2882429.188	1600.065	-0.015	-0.001	0.015	0.005	0.005	-0.001	0.005	0.007	205608	205614	6	0.009	0.014	0.8	1.2	11
T187VRS22	-113592.262	2882429.187	1600.068	-0.015	0.000	0.015	0.002	0.005	-0.002	0.005	0.010	205633	205639	6	0.009	0.014	0.8	1.2	11
T187VRS23	-113592.267	2882429.191	1600.058	-0.010	-0.004	0.011	0.012	0.000	0.002	0.002	0.000	205737	205746	9	0.009	0.013	0.8	1.2	11
T187VRS24	-113592.269	2882429.191	1600.059	-0.008	-0.004	0.009	0.011	-0.002	0.002	0.003	0.001	205777	205782	5	0.009	0.013	0.8	1.2	11
T187VRS25	-113592.271	2882429.193	1600.058	-0.006	-0.006	0.008	0.012	-0.004	0.004	0.006	0.000	205803	205809	6	0.009	0.014	0.8	1.2	11
T187VRS26	-113592.270	2882429.190	1600.055	-0.007	-0.003	0.008	0.015	-0.003	0.001	0.003	0.003	205830	205836	6	0.009	0.014	0.8	1.2	11
T187VRS27	-113592.268	2882429.186	1600.053	-0.009	0.001	0.009	0.017	-0.001	-0.003	0.003	0.005	205857	205864	7	0.009	0.014	0.8	1.2	11
T187VRS28	-113592.269	2882429.193	1600.047	-0.008	-0.006	0.010	0.023	-0.002	0.004	0.004	0.011	205888	205895	7	0.009	0.014	0.8	1.2	11
T187VRS29	-113592.271	2882429.186	1600.056	-0.006	0.001	0.006	0.014	-0.004	-0.003	0.005	0.002	205916	205923	7	0.009	0.014	0.8	1.2	11
T187VRS30	-113592.266	2882429.185	1600.047	-0.011	0.002	0.011	0.023	0.001	-0.004	0.004	0.011	205948	205954	6	0.009	0.014	0.8	1.2	11
T187VRS31	-113592.272	2882429.190	1600.051	-0.005	-0.003	0.006	0.019	-0.005	0.001	0.005	0.007	205976	205982	6	0.009	0.014	0.8	1.2	11
T187VRS32	-113592.270	2882429.188	1600.053	-0.007	-0.001	0.007	0.017	-0.003	-0.001	0.003	0.005	206006	206014	8	0.009	0.014	0.8	1.2	11
T187VRS33	-113592.269	2882429.182	1600.061	-0.008	0.005	0.009	0.009	-0.002	-0.007	0.007	0.003	206035	206045	10	0.009	0.014	0.8	1.2	11
T187VRS34	-113592.270	2882429.184	1600.058	-0.007	0.003	0.008	0.012	-0.003	-0.005	0.006	0.000	206066	206077	11	0.009	0.014	0.8	1.2	11
T187VRS35	-113592.267	2882429.176	1600.061	-0.010	0.011	0.015	0.009	0.000	-0.013	0.013	0.003	206529	206538	9	0.009	0.014	0.8	1.3	11
T187VRS36	-113592.267	2882429.182	1600.062	-0.010	0.005	0.011	0.008	0.000	-0.007	0.007	0.004	206559	206568	9	0.009	0.014	0.8	1.3	11
T187VRS37	-113592.265	2882429.185	1600.055	-0.012	0.002	0.012	0.015	0.002	-0.004	0.005	0.003	206590	206595	5	0.009	0.014	0.8	1.3	11
T187VRS38	-113592.266	2882429.188	1600.052	-0.011	-0.001	0.011	0.018	0.001	-0.001	0.001	0.006	206618	206624	6	0.009	0.014	0.8	1.3	11
T187VRS39	-113592.267	2882429.192	1600.052	-0.010	-0.005	0.011	0.018	0.000	0.003	0.003	0.006	206642	206646	4	0.009	0.014	0.8	1.3	11
T187VRS40	-113592.265	2882429.191	1600.055	-0.012	-0.004	0.013	0.015	0.002	0.002	0.003	0.003	206781	206789	8	0.009	0.014	0.8	1.3	11
Mean	**-113592.267**	**2882429.189**	**1600.058**	**-0.010**	**-0.002**	**0.011**	**0.012**			**0.005**	**0.005**			**7.1**	**0.009**	**0.014**	**0.8**	**1.3**	**11**
STD Dev				**0.004**	**0.004**	**0.003**	**0.006**			**0.002**	**0.004**			**1.7**					

SITE1 - T148 (OL-CH)

Name	PPS Co-ordinates		
	Y (Eastings)	X (Northings)	Ellipsoidal HT
T148PPS	-107885.977	2868476.778	**1584.580**

Name	VRS RTK Co-ordinates			Accuracy			
	Y (Eastings)	X (Northings)	Ellipsoidal HT	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht
T148VRS1	-107885.978	2868476.781	1584.571	-0.001	-0.003	0.003	0.009
T148VRS2	-107885.975	2868476.779	1584.578	-0.002	-0.001	0.002	0.002
T148VRS3	-107885.974	2868476.786	1584.574	-0.003	-0.008	0.009	0.006
T148VRS4	-107885.977	2868476.781	1584.566	0.000	-0.003	0.003	0.014
T148VRS5	-107885.975	2868476.776	1584.565	-0.002	0.002	0.003	0.015
T148VRS6	-107885.979	2868476.774	1584.559	0.002	0.004	0.004	0.021
T148VRS7	-107885.975	2868476.773	1584.559	-0.002	0.005	0.005	0.021
T148VRS8	-107885.975	2868476.778	1584.557	-0.002	0.000	0.002	0.023
T148VRS9	-107885.973	2868476.782	1584.562	-0.004	-0.004	0.006	0.018
T148VRS10	-107885.974	2868476.788	1584.564	-0.003	-0.010	0.010	0.016
T148VRS11	-107885.974	2868476.783	1584.568	-0.003	-0.005	0.006	0.012
T148VRS12	-107885.972	2868476.783	1584.558	-0.005	-0.005	0.007	0.022
T148VRS13	-107885.971	2868476.781	1584.565	-0.006	-0.003	0.007	0.015
T148VRS14	-107885.971	2868476.782	1584.564	-0.006	-0.004	0.007	0.016
T148VRS15	-107885.970	2868476.781	1584.563	-0.007	-0.003	0.008	0.017
T148VRS16	-107885.971	2868476.782	1584.562	-0.006	-0.004	0.007	0.018
T148VRS17	-107885.971	2868476.785	1584.569	-0.006	-0.007	0.009	0.011
T148VRS18	-107885.972	2868476.780	1584.563	-0.005	-0.002	0.005	0.017
T148VRS19	-107885.973	2868476.777	1584.566	-0.004	0.001	0.004	0.014
T148VRS20	-107885.974	2868476.773	1584.563	-0.003	0.005	0.006	0.017
T148VRS21	-107885.979	2868476.774	1584.560	0.002	0.004	0.004	0.020
T148VRS22	-107885.979	2868476.779	1584.560	0.002	-0.001	0.002	0.020
T148VRS23	-107885.975	2868476.776	1584.561	-0.002	0.002	0.003	0.019
T148VRS24	-107885.973	2868476.781	1584.566	-0.004	-0.003	0.005	0.014
T148VRS25	-107885.973	2868476.780	1584.560	-0.004	-0.002	0.004	0.020
T148VRS26	-107885.971	2868476.780	1584.564	-0.006	-0.002	0.006	0.016
T148VRS27	-107885.973	2868476.779	1584.571	-0.004	-0.001	0.004	0.009
T148VRS28	-107885.975	2868476.776	1584.578	-0.002	0.002	0.003	0.002
T148VRS29	-107885.975	2868476.776	1584.577	-0.002	0.002	0.003	0.003
T148VRS30	-107885.977	2868476.776	1584.584	0.000	0.002	0.002	-0.004
T148VRS31	-107885.978	2868476.777	1584.583	0.001	0.001	0.001	-0.003
T148VRS32	-107885.976	2868476.778	1584.575	-0.001	0.000	0.001	0.005
T148VRS33	-107885.977	2868476.779	1584.574	0.000	-0.001	0.001	0.006
T148VRS34	-107885.978	2868476.777	1584.567	0.001	0.001	0.001	0.013
T148VRS35	-107885.976	2868476.774	1584.570	-0.001	0.004	0.004	0.010
T148VRS36	-107885.977	2868476.777	1584.567	0.000	0.001	0.001	0.013
T148VRS37	-107885.977	2868476.779	1584.576	0.000	-0.001	0.001	0.004
T148VRS38	-107885.979	2868476.779	1584.568	0.002	-0.001	0.002	0.012
T148VRS39	-107885.978	2868476.776	1584.573	0.001	0.002	0.002	0.007
T148VRS40	-107885.978	2868476.776	1584.575	0.001	0.002	0.002	0.005
Mean	**-107885.975**	**2868476.779**	**1584.568**	**Mean** **-0.002**	**-0.001**	**0.004**	**0.012**
			STD Dev	**0.003**	**0.003**	**0.002**	**0.007**

Name	Precision				Initialisation Time			Accuracy		HDOP	VDOP	SV's
	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Init Loss	Init Gain	TTFF	Hor	Vert	(Max)	(Max)	(Min)
T148VRS1	-0.003	0.002	0.004	0.003	197250	197258	8	0.007	0.015	0.8	1.8	11
T148VRS2	0.000	0.000	0.000	0.010	197281	197287	6	0.007	0.015	0.8	1.8	11
T148VRS3	0.001	0.007	0.007	0.006	197297	197305	8	0.007	0.015	0.8	1.8	11
T148VRS4	-0.002	0.002	0.003	0.002	197320	197326	6	0.007	0.015	0.8	1.7	11
T148VRS5	0.000	-0.003	0.003	0.003	197350	197356	6	0.010	0.014	1.3	2.1	10
T148VRS6	-0.004	-0.005	0.006	0.009	197377	197382	5	0.010	0.014	1.3	2.1	10
T148VRS7	0.000	-0.006	0.006	0.009	197408	197413	5	0.010	0.014	1.3	2.1	10
T148VRS8	0.000	-0.001	0.001	0.011	197434	197440	6	0.010	0.014	1.3	2.0	10
T148VRS9	0.002	0.003	0.004	0.006	197460	197467	7	0.010	0.014	1.3	2.0	10
T148VRS10	0.001	0.009	0.009	0.004	197487	197495	8	0.010	0.014	1.3	2.0	10
T148VRS11	0.001	0.004	0.004	0.000	197519	197525	6	0.010	0.014	1.3	2.0	10
T148VRS12	0.003	0.004	0.005	0.010	197546	197553	7	0.010	0.014	1.3	2.0	10
T148VRS13	0.004	0.002	0.004	0.003	197576	197582	6	0.010	0.014	1.3	2.0	10
T148VRS14	0.004	0.003	0.005	0.004	197605	197611	6	0.010	0.014	1.3	2.0	10
T148VRS15	0.005	0.002	0.005	0.005	197633	197639	6	0.010	0.014	1.3	2.0	10
T148VRS16	0.004	0.003	0.005	0.006	197659	197666	7	0.010	0.014	1.3	2.0	10
T148VRS17	0.004	0.006	0.007	0.001	197686	197694	8	0.007	0.015	0.9	2.0	10
T148VRS18	0.003	0.001	0.003	0.005	197714	197721	7	0.007	0.015	0.9	2.0	10
T148VRS19	0.002	-0.002	0.003	0.002	197742	197748	6	0.007	0.015	0.9	2.0	10
T148VRS20	0.001	-0.006	0.006	0.005	197770	197777	7	0.007	0.015	0.9	2.0	10
T148VRS21	-0.004	-0.005	0.006	0.008	197796	197803	7	0.007	0.015	0.9	2.0	10
T148VRS22	-0.004	0.000	0.004	0.008	197824	197830	6	0.007	0.015	0.9	1.9	11
T148VRS23	0.000	-0.003	0.003	0.007	197856	197862	6	0.007	0.015	0.9	1.9	11
T148VRS24	0.002	0.002	0.003	0.002	197882	197889	7	0.009	0.018	1.1	2.3	11
T148VRS25	0.002	0.001	0.002	0.008	198038	198059	21	0.007	0.015	1.1	2.3	10
T148VRS26	0.004	0.001	0.004	0.004	198132	198142	10	0.007	0.015	0.9	1.9	10
T148VRS27	0.002	0.000	0.002	0.003	198162	198170	8	0.007	0.015	0.9	1.9	10
T148VRS28	0.000	-0.003	0.003	0.010	198190	198196	6	0.007	0.015	0.9	1.9	10
T148VRS29	0.000	-0.003	0.003	0.009	198216	198223	7	0.007	0.015	0.9	1.9	10
T148VRS30	-0.002	-0.003	0.004	0.016	198246	198252	6	0.007	0.015	0.9	1.9	10
T148VRS31	-0.003	-0.002	0.004	0.015	198272	198278	6	0.007	0.015	0.9	1.9	10
T148VRS32	-0.001	-0.001	0.001	0.007	198298	198304	6	0.008	0.015	0.9	1.8	10
T148VRS33	-0.002	0.000	0.002	0.006	198330	198336	6	0.009	0.018	1.1	2.2	11
T148VRS34	-0.003	-0.002	0.004	0.001	198356	198363	7	0.008	0.015	0.9	1.8	10
T148VRS35	-0.001	-0.005	0.005	0.002	198384	198392	8	0.008	0.015	0.9	1.8	10
T148VRS36	-0.002	-0.002	0.003	0.001	198413	198418	5	0.008	0.015	0.9	1.8	10
T148VRS37	-0.002	0.000	0.002	0.008	198438	198444	6	0.007	0.015	0.9	1.8	11
T148VRS38	-0.004	0.000	0.004	0.000	198464	198470	6	0.008	0.015	0.9	1.8	11
T148VRS39	-0.003	-0.003	0.004	0.005	198494	198499	5	0.008	0.015	0.9	1.8	10
T148VRS40	-0.003	-0.003	0.004	0.007	198523	198529	6	0.008	0.015	0.9	1.8	10
		Mean	**0.004**	**0.006**	**Mean**		**6.9**	**Mean** **0.008**	**0.015**	**1.0**	**1.9**	**10**
		STD Dev	**0.002**	**0.004**	**STD Dev**		**2.5**					

SITE1 - T103 (PRE 95)

Name	PPS Co-ordinates		
	Y (Eastings)	X (Northings)	Ellipsoidal HT
T103PPS	-92585.501	2869883.091	**1401.876**

Name	VRS RTK Co-ordinates			Accuracy				Precision				Initialisation Time			Accuracy		HDOP	VDOP	SV's
	Y (Eastings)	X (Northings)	Ellipsoidal HT	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Init Loss	Init Gain	TTFF	Hor	Vert	(Max)	(Max)	(Min)
T103VRS1	-92585.496	2869883.097	1401.820	0.005	-0.006	0.008	0.056	0.003	0.005	0.006	0.005	213800	213821	21	0.009	0.017	0.9	1.7	10
T103VRS2	-92585.501	2869883.086	1401.840	0.000	0.005	0.005	0.036	-0.002	-0.006	0.006	0.015	213965	213971	6	0.020	0.026	0.6	1.2	10
T103VRS3	-92585.499	2869883.093	1401.821	-0.002	-0.002	0.003	0.055	0.000	0.001	0.001	0.004	213995	214002	7	0.020	0.026	0.6	1.2	10
T103VRS4	-92585.497	2869883.098	1401.800	-0.004	-0.007	0.008	0.076	0.002	0.006	0.006	0.025	214021	214026	5	0.021	0.027	0.6	1.2	10
T103VRS5	-92585.491	2869883.101	1401.773	-0.010	-0.010	0.014	0.103	0.008	0.009	0.012	0.052	214048	214054	6	0.021	0.027	0.6	1.2	10
T103VRS6	-92585.494	2869883.099	1401.777	-0.007	-0.008	0.011	0.099	0.005	0.007	0.009	0.048	214075	214081	6	0.022	0.028	0.6	1.2	10
T103VRS7	-92585.502	2869883.099	1401.793	0.001	-0.008	0.008	0.083	-0.003	0.007	0.007	0.032	214102	214109	7	0.022	0.028	0.6	1.2	10
T103VRS8	-92585.507	2869883.099	1401.809	0.006	-0.008	0.010	0.067	-0.008	0.007	0.010	0.016	214128	214136	8	0.010	0.019	0.9	1.7	10
T103VRS9	-92585.503	2869883.092	1401.822	0.002	-0.001	0.002	0.054	-0.004	0.000	0.004	0.003	214156	214163	7	0.010	0.019	0.9	1.7	10
T103VRS10	-92585.498	2869883.085	1401.828	-0.003	0.006	0.007	0.048	0.001	-0.007	0.007	0.003	214182	214188	6	0.010	0.019	0.9	1.7	10
T103VRS11	-92585.514	2869883.083	1401.844	0.013	0.008	0.015	0.032	-0.015	-0.009	0.017	0.019	214209	214216	7	0.010	0.019	0.9	1.7	10
T103VRS12	-92585.505	2869883.097	1401.819	0.004	-0.006	0.007	0.057	-0.006	0.005	0.008	0.006	214241	214249	8	0.010	0.019	0.9	1.7	10
T103VRS13	-92585.487	2869883.104	1401.802	-0.014	-0.013	0.019	0.074	0.012	0.012	0.017	0.023	214270	214276	6	0.010	0.019	0.9	1.6	10
T103VRS14	-92585.494	2869883.094	1401.817	-0.007	-0.003	0.008	0.059	0.005	0.002	0.005	0.008	214297	214305	8	0.010	0.019	0.9	1.6	10
T103VRS15	-92585.502	2869883.088	1401.809	0.001	0.003	0.003	0.067	-0.003	-0.004	0.005	0.016	214331	214338	7	0.010	0.019	0.9	1.6	10
T103VRS16	-92585.505	2869883.087	1401.817	0.004	0.004	0.006	0.059	-0.006	-0.005	0.008	0.008	214359	214365	6	0.010	0.019	0.9	1.6	10
T103VRS17	-92585.509	2869883.080	1401.836	0.008	0.011	0.014	0.040	-0.010	-0.012	0.016	0.011	214385	214391	6	0.011	0.019	0.9	1.6	10
T103VRS18	-92585.505	2869883.085	1401.843	0.004	0.006	0.007	0.033	-0.006	-0.007	0.009	0.018	214414	214420	6	0.010	0.019	0.9	1.6	10
T103VRS19	-92585.505	2869883.084	1401.850	0.004	0.007	0.008	0.026	-0.006	-0.008	0.010	0.025	214445	214451	6	0.011	0.019	0.9	1.6	10
T103VRS20	-92585.514	2869883.076	1401.853	0.013	0.015	0.020	0.023	-0.015	-0.016	0.022	0.028	214471	214478	7	0.011	0.019	0.9	1.6	10
T103VRS21	-92585.513	2869883.074	1401.853	0.012	0.017	0.021	0.023	-0.014	-0.018	0.023	0.028	214500	214506	6	0.011	0.019	0.9	1.6	10
T103VRS22	-92585.495	2869883.086	1401.822	-0.006	0.005	0.008	0.054	0.004	-0.006	0.007	0.003	214526	214533	7	0.011	0.019	0.9	1.6	10
T103VRS23	-92585.500	2869883.085	1401.842	-0.001	0.006	0.006	0.034	-0.001	-0.007	0.007	0.017	214553	214561	8	0.011	0.019	0.9	1.6	10
T103VRS24	-92585.498	2869883.085	1401.835	-0.003	0.006	0.007	0.041	0.001	-0.007	0.007	0.010	214582	214587	5	0.011	0.019	0.9	1.6	10
T103VRS25	-92585.506	2869883.079	1401.869	0.005	0.012	0.013	0.007	-0.007	-0.013	0.015	0.044	214606	214613	7	0.011	0.019	0.9	1.6	10
T103VRS26	-92585.503	2869883.084	1401.859	0.002	0.007	0.007	0.017	-0.004	-0.008	0.009	0.034	214632	214638	6	0.011	0.019	0.9	1.6	10
T103VRS27	-92585.505	2869883.087	1401.846	0.004	0.004	0.006	0.030	-0.006	-0.005	0.008	0.021	214660	214668	8	0.011	0.020	0.9	1.6	10
T103VRS28	-92585.501	2869883.090	1401.837	0.000	0.001	0.001	0.039	-0.002	-0.002	0.003	0.012	214691	214700	9	0.011	0.019	0.9	1.5	10
T103VRS29	-92585.492	2869883.096	1401.812	-0.009	-0.005	0.010	0.064	0.007	0.004	0.008	0.013	214721	214728	7	0.011	0.020	0.9	1.5	10
T103VRS30	-92585.500	2869883.104	1401.827	-0.001	-0.013	0.013	0.049	-0.001	0.012	0.012	0.002	214750	214756	6	0.010	0.016	0.7	1.3	11
T103VRS31	-92585.494	2869883.105	1401.804	-0.007	-0.014	0.016	0.072	0.005	0.013	0.014	0.021	214777	214783	6	0.010	0.016	0.7	1.3	11
T103VRS32	-92585.489	2869883.100	1401.805	-0.012	-0.009	0.015	0.071	0.010	0.008	0.013	0.020	214804	214810	6	0.010	0.016	0.7	1.3	11
T103VRS33	-92585.492	2869883.092	1401.813	-0.009	-0.001	0.009	0.063	0.007	0.000	0.007	0.012	214829	214835	6	0.010	0.016	0.7	1.3	11
T103VRS34	-92585.492	2869883.095	1401.837	-0.009	-0.004	0.010	0.039	0.007	0.003	0.008	0.012	215045	215053	8	0.010	0.016	0.7	1.3	11
T103VRS35	-92585.489	2869883.097	1401.830	-0.012	-0.006	0.013	0.046	0.010	0.005	0.011	0.005	215074	215082	8	0.010	0.016	0.7	1.3	11
T103VRS36	-92585.496	2869883.100	1401.826	-0.005	-0.009	0.010	0.050	0.003	0.008	0.008	0.001	215102	215108	6	0.010	0.016	0.7	1.3	11
T103VRS37	-92585.495	2869883.106	1401.829	-0.006	-0.015	0.016	0.047	0.004	0.014	0.014	0.004	215128	215134	6	0.010	0.016	0.7	1.3	11
T103VRS38	-92585.492	2869883.108	1401.820	-0.009	-0.017	0.019	0.056	0.007	0.016	0.017	0.005	215154	215160	6	0.010	0.018	0.8	1.5	10
T103VRS39	-92585.493	2869883.094	1401.838	-0.008	-0.003	0.009	0.038	0.006	0.002	0.006	0.013	215181	215187	6	0.010	0.018	0.8	1.5	10
T103VRS40	-92585.494	2869883.092	1401.831	-0.007	-0.001	0.007	0.045	0.005	0.000	0.005	0.006	215211	215217	6	0.010	0.018	0.8	1.5	10
Mean	**-92585.499**	**2869883.092**	**1401.825**	**-0.002**	**-0.001**	**0.010**	**0.051**			**0.010**	**0.016**			**7.0**	**0.012**	**0.020**	**0.8**	**1.5**	**10**
STD Dev				**0.007**	**0.009**	**0.005**	**0.021**			**0.005**	**0.013**			**2.5**					

SITE1 - T478 (PRE 93)

Name	PPS Co-ordinates Y (Eastings)	X (Northings)	Ellipsoidal HT
T478PPS	-83417.825	2881947.338	**1511.344**

Name	VRS RTK Co-ordinates Y (Eastings)	X (Northings)	Ellipsoidal HT	Accuracy ∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Precision ∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Initialisation Time Init Loss	Init Gain	TTFF	Accuracy Hor	Vert	HDOP (Max)	VDOP (Max)	SV's (Min)
T478VRS1	-83417.821	2881947.343	1511.343	0.004	-0.005	0.006	0.001	0.003	0.000	0.003	0.012	216716	216741	25	0.010	0.018	1.0	1.9	10
T478VRS2	-83417.825	2881947.347	1511.330	0.000	-0.009	0.009	0.014	-0.001	0.004	0.005	0.001	216765	216772	7	0.006	0.011	0.6	1.1	12
T478VRS3	-83417.824	2881947.347	1511.327	-0.001	-0.009	0.009	0.017	0.000	0.004	0.004	0.004	216801	216807	6	0.006	0.011	0.6	1.1	12
T478VRS4	-83417.825	2881947.343	1511.333	0.000	-0.005	0.005	0.011	-0.001	0.000	0.002	0.002	216828	216834	6	0.006	0.011	0.6	1.1	12
T478VRS5	-83417.824	2881947.343	1511.334	-0.001	-0.005	0.005	0.010	0.000	0.000	0.001	0.003	216880	216888	8	0.006	0.011	0.6	1.1	12
T478VRS6	-83417.822	2881947.344	1511.332	-0.003	-0.006	0.007	0.012	0.002	0.001	0.002	0.001	216907	216914	7	0.006	0.011	0.6	1.1	12
T478VRS7	-83417.824	2881947.340	1511.340	-0.001	-0.002	0.002	0.004	0.000	-0.003	0.003	0.009	216935	216944	9	0.006	0.011	0.6	1.1	12
T478VRS8	-83417.825	2881947.339	1511.340	0.000	-0.001	0.001	0.004	-0.001	-0.004	0.004	0.009	216967	216973	6	0.006	0.011	0.6	1.1	12
T478VRS9	-83417.822	2881947.339	1511.333	-0.003	-0.001	0.003	0.011	0.002	-0.004	0.004	0.002	216993	217007	14	0.006	0.010	0.6	1.1	12
T478VRS10	-83417.824	2881947.338	1511.336	-0.001	0.000	0.001	0.008	0.000	-0.005	0.005	0.005	217028	217035	7	0.006	0.010	0.6	1.1	12
T478VRS11	-83417.824	2881947.339	1511.336	-0.001	-0.001	0.001	0.008	0.000	-0.004	0.004	0.005	217055	217065	10	0.006	0.011	0.6	1.1	12
T478VRS12	-83417.823	2881947.339	1511.336	-0.002	-0.001	0.002	0.008	0.001	-0.004	0.004	0.005	217087	217100	13	0.006	0.011	0.6	1.1	12
T478VRS13	-83417.824	2881947.341	1511.318	-0.001	-0.003	0.003	0.026	0.000	-0.002	0.002	0.013	217120	217129	9	0.006	0.010	0.7	1.2	11
T478VRS14	-83417.824	2881947.343	1511.328	-0.001	-0.005	0.005	0.016	0.000	0.000	0.001	0.003	217150	217156	6	0.006	0.010	0.6	1.1	11
T478VRS15	-83417.826	2881947.344	1511.336	0.001	-0.006	0.006	0.008	-0.002	0.001	0.003	0.005	217176	217183	7	0.006	0.011	0.6	1.1	12
T478VRS16	-83417.825	2881947.344	1511.336	0.000	-0.006	0.006	0.008	-0.001	0.001	0.002	0.005	217206	217212	6	0.006	0.011	0.6	1.1	12
T478VRS17	-83417.825	2881947.346	1511.336	0.000	-0.008	0.008	0.008	-0.001	0.003	0.004	0.005	217234	217256	22	0.006	0.011	0.6	1.1	12
T478VRS18	-83417.826	2881947.346	1511.338	0.001	-0.008	0.008	0.006	-0.002	0.003	0.004	0.007	217277	217285	8	0.005	0.010	0.6	1.1	12
T478VRS19	-83417.827	2881947.345	1511.334	0.002	-0.007	0.007	0.010	-0.003	0.002	0.004	0.003	217308	217313	5	0.005	0.008	0.6	1.1	12
T478VRS20	-83417.828	2881947.346	1511.331	0.003	-0.008	0.009	0.013	-0.004	0.003	0.006	0.000	217334	217340	6	0.006	0.011	0.6	1.1	11
T478VRS21	-83417.827	2881947.346	1511.330	0.002	-0.008	0.008	0.014	-0.003	0.003	0.005	0.001	217363	217369	6	0.005	0.008	0.6	1.1	11
T478VRS22	-83417.825	2881947.346	1511.329	0.000	-0.008	0.008	0.015	-0.001	0.003	0.004	0.002	217390	217397	7	0.005	0.009	0.6	1.1	11
T478VRS23	-83417.828	2881947.343	1511.332	0.003	-0.005	0.006	0.012	-0.004	0.000	0.004	0.001	217418	217425	7	0.006	0.010	0.6	1.1	11
T478VRS24	-83417.826	2881947.343	1511.329	0.001	-0.005	0.005	0.015	-0.002	0.000	0.003	0.002	217445	217451	6	0.005	0.010	0.6	1.1	11
T478VRS25	-83417.826	2881947.344	1511.327	0.001	-0.006	0.006	0.017	-0.002	0.001	0.003	0.004	217471	217478	7	0.006	0.011	0.6	1.1	11
T478VRS26	-83417.822	2881947.342	1511.327	-0.003	-0.004	0.005	0.017	0.002	-0.001	0.002	0.004	217498	217504	6	0.005	0.009	0.6	1.1	11
T478VRS27	-83417.823	2881947.343	1511.325	-0.002	-0.005	0.005	0.019	0.001	0.000	0.001	0.006	217524	217531	7	0.005	0.010	0.6	1.1	11
T478VRS28	-83417.823	2881947.341	1511.328	-0.002	-0.003	0.004	0.016	0.001	-0.002	0.002	0.003	217551	217557	6	0.005	0.008	0.6	1.1	11
T478VRS29	-83417.821	2881947.341	1511.328	-0.004	-0.003	0.005	0.016	0.003	-0.002	0.003	0.003	217578	217584	6	0.006	0.011	0.6	1.1	11
T478VRS30	-83417.820	2881947.341	1511.330	-0.005	-0.003	0.006	0.014	0.004	-0.002	0.004	0.001	217604	217610	6	0.005	0.010	0.6	1.1	11
T478VRS31	-83417.819	2881947.340	1511.331	-0.006	-0.002	0.006	0.013	0.005	-0.003	0.005	0.000	217630	217637	7	0.006	0.011	0.6	1.1	11
T478VRS32	-83417.823	2881947.342	1511.328	-0.002	-0.004	0.004	0.016	0.001	-0.001	0.001	0.003	217658	217663	5	0.005	0.009	0.6	1.1	11
T478VRS33	-83417.821	2881947.342	1511.323	-0.004	-0.004	0.006	0.021	0.003	-0.001	0.003	0.008	217684	217689	5	0.005	0.010	0.6	1.1	11
T478VRS34	-83417.820	2881947.341	1511.327	-0.005	-0.003	0.006	0.017	0.004	-0.002	0.004	0.004	217709	217715	6	0.006	0.011	0.6	1.1	11
T478VRS35	-83417.821	2881947.342	1511.327	-0.004	-0.004	0.006	0.017	0.003	-0.001	0.003	0.004	217735	217742	7	0.006	0.011	0.6	1.1	11
T478VRS36	-83417.820	2881947.340	1511.329	-0.005	-0.002	0.005	0.015	0.004	-0.003	0.004	0.002	217763	217770	7	0.006	0.011	0.6	1.1	11
T478VRS37	-83417.821	2881947.344	1511.324	-0.004	-0.006	0.007	0.020	0.003	0.001	0.003	0.007	217793	217798	5	0.005	0.009	0.6	1.1	11
T478VRS38	-83417.822	2881947.344	1511.325	-0.003	-0.006	0.007	0.019	0.002	0.001	0.002	0.006	217816	217823	7	0.005	0.008	0.6	1.1	11
T478VRS39	-83417.821	2881947.342	1511.328	-0.004	-0.004	0.006	0.016	0.003	-0.001	0.003	0.003	217842	217849	7	0.005	0.008	0.6	1.1	11
T478VRS40	-83417.824	2881947.339	1511.333	-0.001	-0.001	0.001	0.011	0.000	-0.004	0.004	0.002	217870	217877	7	0.005	0.009	0.6	1.1	11
Mean	**-83417.824**	**2881947.343**	**1511.331**	**-0.001**	**-0.005**	**0.005**	**0.013**			**0.003**	**0.004**			**7.9**	**0.006**	**0.010**	**0.6**	**1.1**	**11**
STD Dev				**0.002**	**0.002**	**0.002**	**0.005**			**0.001**	**0.003**			**4.1**					

SITE1 - T469 (KRUG 13)

Name	PPS Co-ordinates		
	Y (Eastings)	X (Northings)	Ellipsoidal HT
T469PPS	-63620.542	2887013.450	**1607.869**

Name	VRS RTK Co-ordinates			Accuracy				Precision				Initialisation Time			Accuracy		HDOP	VDOP	SV's
	Y (Eastings)	X (Northings)	Ellipsoidal HT	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Init Loss	Init Gain	TTFF	Hor	Vert	(Max)	(Max)	(Min)
T469VRS1	-63620.537	2887013.460	1607.869	0.005	-0.010	0.011	0.000	0.002	0.002	0.003	0.006	220010	220022	12	0.006	0.011	0.8	1.4	10
T469VRS2	-63620.540	2887013.459	1607.875	-0.002	-0.009	0.009	-0.006	-0.001	0.001	0.002	0.000	220152	220162	10	0.006	0.012	0.8	1.4	10
T469VRS3	-63620.539	2887013.459	1607.874	-0.003	-0.009	0.009	-0.005	0.000	0.001	0.001	0.001	220181	220186	5	0.007	0.013	0.8	1.4	10
T469VRS4	-63620.537	2887013.457	1607.877	-0.005	-0.007	0.009	-0.008	0.002	-0.001	0.002	0.002	220207	220212	5	0.006	0.011	0.8	1.4	10
T469VRS5	-63620.536	2887013.454	1607.875	-0.006	-0.004	0.007	-0.006	0.003	-0.004	0.005	0.000	220232	220239	7	0.006	0.011	0.8	1.4	10
T469VRS6	-63620.541	2887013.456	1607.871	-0.001	-0.006	0.006	-0.002	-0.002	-0.002	0.003	0.004	220259	220268	9	0.008	0.014	0.8	1.4	10
T469VRS7	-63620.541	2887013.457	1607.867	-0.001	-0.007	0.007	0.002	-0.002	-0.001	0.002	0.008	220363	220371	8	0.006	0.011	0.8	1.4	10
T469VRS8	-63620.538	2887013.456	1607.868	-0.004	-0.006	0.007	0.001	0.001	-0.002	0.002	0.007	220391	220395	4	0.006	0.012	0.8	1.4	10
T469VRS9	-63620.540	2887013.455	1607.867	-0.002	-0.005	0.005	0.002	-0.001	-0.003	0.003	0.008	220414	220420	6	0.007	0.013	0.8	1.4	10
T469VRS10	-63620.540	2887013.456	1607.873	-0.002	-0.006	0.006	-0.004	-0.001	-0.002	0.002	0.002	220441	220447	6	0.006	0.012	0.8	1.4	10
T469VRS11	-63620.540	2887013.457	1607.877	-0.002	-0.007	0.007	-0.008	-0.001	-0.001	0.001	0.002	220467	220473	6	0.006	0.011	0.8	1.4	10
T469VRS12	-63620.540	2887013.458	1607.881	-0.002	-0.008	0.008	-0.012	-0.001	0.000	0.001	0.006	220493	220502	9	0.006	0.011	0.8	1.4	10
T469VRS13	-63620.539	2887013.458	1607.880	-0.003	-0.008	0.009	-0.011	0.000	0.000	0.000	0.005	220522	220528	6	0.006	0.011	0.8	1.4	10
T469VRS14	-63620.541	2887013.462	1607.885	-0.001	-0.012	0.012	-0.016	-0.002	0.004	0.005	0.010	220550	220555	5	0.007	0.013	0.8	1.4	10
T469VRS15	-63620.538	2887013.457	1607.874	-0.004	-0.007	0.008	-0.005	0.001	-0.001	0.001	0.001	220579	220585	6	0.007	0.013	0.8	1.4	10
T469VRS16	-63620.539	2887013.460	1607.886	-0.003	-0.010	0.010	-0.017	0.000	0.002	0.002	0.011	220603	220609	6	0.006	0.011	0.8	1.4	10
T469VRS17	-63620.539	2887013.457	1607.888	-0.003	-0.007	0.008	-0.019	0.000	-0.001	0.001	0.013	220630	220636	6	0.006	0.011	0.8	1.4	10
T469VRS18	-63620.539	2887013.457	1607.879	-0.003	-0.007	0.008	-0.010	0.000	-0.001	0.001	0.004	220658	220664	6	0.006	0.011	0.8	1.4	10
T469VRS19	-63620.539	2887013.459	1607.884	-0.003	-0.009	0.009	-0.015	0.000	0.001	0.001	0.009	220686	220692	6	0.007	0.012	0.8	1.4	10
T469VRS20	-63620.538	2887013.457	1607.873	-0.004	-0.007	0.008	-0.004	0.001	-0.001	0.001	0.002	220712	220719	7	0.006	0.011	0.8	1.4	10
T469VRS21	-63620.536	2887013.456	1607.876	-0.006	-0.006	0.008	-0.007	0.003	-0.002	0.004	0.001	220741	220747	6	0.006	0.011	0.8	1.4	10
T469VRS22	-63620.536	2887013.453	1607.873	-0.006	-0.003	0.007	-0.004	0.003	-0.005	0.006	0.002	220771	220777	6	0.007	0.012	0.8	1.4	10
T469VRS23	-63620.538	2887013.452	1607.873	-0.004	-0.002	0.004	-0.004	0.001	-0.006	0.006	0.002	220798	220805	7	0.006	0.011	0.8	1.4	10
T469VRS24	-63620.536	2887013.451	1607.871	-0.006	-0.001	0.006	-0.002	0.003	-0.007	0.007	0.004	220826	220833	7	0.006	0.011	0.8	1.4	10
T469VRS25	-63620.538	2887013.452	1607.871	-0.004	-0.002	0.004	-0.002	0.001	-0.006	0.006	0.004	220854	220861	7	0.006	0.011	0.8	1.4	10
T469VRS26	-63620.538	2887013.453	1607.876	-0.004	-0.003	0.005	-0.007	0.001	-0.005	0.005	0.001	220885	220891	6	0.006	0.011	0.8	1.4	10
T469VRS27	-63620.539	2887013.453	1607.871	-0.003	-0.003	0.004	-0.002	0.000	-0.005	0.005	0.004	220914	220921	7	0.006	0.011	0.8	1.4	10
T469VRS28	-63620.538	2887013.452	1607.864	-0.004	-0.002	0.004	0.005	0.001	-0.006	0.006	0.011	220947	220953	6	0.007	0.013	0.8	1.4	10
T469VRS29	-63620.542	2887013.459	1607.882	0.000	-0.009	0.009	-0.013	-0.003	0.001	0.003	0.007	220972	220982	10	0.007	0.013	0.8	1.4	10
T469VRS30	-63620.544	2887013.460	1607.875	0.002	-0.010	0.010	-0.006	-0.005	0.002	0.005	0.000	221106	221112	6	0.006	0.011	0.8	1.4	10
T469VRS31	-63620.542	2887013.461	1607.877	0.000	-0.011	0.011	-0.008	-0.003	0.003	0.004	0.002	221133	221138	5	0.006	0.011	0.8	1.4	10
T469VRS32	-63620.544	2887013.465	1607.879	0.002	-0.015	0.015	-0.010	-0.005	0.007	0.009	0.004	221159	221167	8	0.006	0.011	0.8	1.4	10
T469VRS33	-63620.541	2887013.463	1607.867	-0.001	-0.013	0.013	0.002	-0.002	0.005	0.006	0.008	221186	221198	12	0.006	0.011	0.8	1.4	10
T469VRS34	-63620.539	2887013.462	1607.871	-0.003	-0.012	0.012	-0.002	0.000	0.004	0.004	0.004	221285	221293	8	0.006	0.011	0.8	1.4	10
T469VRS35	-63620.542	2887013.463	1607.878	0.000	-0.013	0.013	-0.009	-0.003	0.005	0.006	0.003	221313	221320	7	0.006	0.011	0.8	1.4	10
T469VRS36	-63620.539	2887013.461	1607.876	-0.003	-0.011	0.011	-0.007	0.000	0.003	0.003	0.001	221341	221347	6	0.006	0.011	0.8	1.4	10
T469VRS37	-63620.539	2887013.460	1607.874	-0.003	-0.010	0.010	-0.005	0.000	0.002	0.002	0.001	221368	221374	6	0.006	0.011	0.8	1.4	10
T469VRS38	-63620.537	2887013.460	1607.871	-0.005	-0.010	0.011	-0.002	0.002	0.002	0.003	0.004	221393	221400	7	0.007	0.011	0.8	1.4	10
T469VRS39	-63620.538	2887013.460	1607.873	-0.004	-0.010	0.011	-0.004	0.001	0.002	0.003	0.002	221421	221431	10	0.006	0.011	0.8	1.4	10
T469VRS40	-63620.538	2887013.461	1607.875	-0.004	-0.011	0.012	-0.006	0.001	0.003	0.003	0.000	221450	221455	5	0.006	0.010	0.8	1.4	10
Mean	**-63620.539**	**2887013.458**	**1607.875**	**-0.003**	**-0.008**	**0.009**	**-0.006**		**Mean**	**0.003**	**0.004**	**Mean**		**6.9**	**0.006**	**0.011**	**0.8**	**1.4**	**10**
STD Dev				**0.002**	**0.003**	**0.003**	**0.005**		**STD Dev**	**0.002**	**0.003**	**STD Dev**		**1.8**					

SITE1 - T219 (KRUG 50)

Name	PPS Co-ordinates		
	Y (Eastings)	X (Northings)	Ellipsoidal HT
T219PPS	-42847.674	2906410.763	**1578.222**

Name	VRS RTK Co-ordinates			Accuracy				Precision				Initialisation Time			Accuracy		HDOP	VDOP	SV's
	Y (Eastings)	X (Northings)	Ellipsoidal HT	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	∂ Y (Eastings)	∂ X (Northings)	∂ 2D	∂ Ht	Init Loss	Init Gain	TTFF	Hor	Vert	(Max)	(Max)	(Min)
T219VRS1	-42847.669	2906410.765	1578.165	0.005	-0.002	0.005	0.057	0.017	0.011	0.020	0.018	300213	300226	13	0.012	0.020	1.0	1.7	8
T219VRS2	-42847.683	2906410.759	1578.168	0.009	0.004	0.010	0.054	0.003	0.005	0.006	0.015	300289	300301	12	0.012	0.020	1.0	1.7	8
T219VRS3	-42847.681	2906410.751	1578.176	0.007	0.012	0.014	0.046	0.005	-0.003	0.006	0.007	300340	300354	14	0.013	0.022	1.0	1.7	8
T219VRS4	-42847.683	2906410.750	1578.196	0.009	0.013	0.016	0.026	0.003	-0.004	0.005	0.013	300378	300387	9	0.014	0.023	1.0	1.7	8
T219VRS5	-42847.682	2906410.759	1578.174	0.008	0.004	0.009	0.048	0.004	0.005	0.007	0.009	300408	300414	6	0.014	0.024	1.0	1.7	8
T219VRS6	-42847.694	2906410.753	1578.214	0.020	0.010	0.022	0.008	-0.008	-0.001	0.008	0.031	300436	300445	9	0.014	0.024	1.0	1.7	8
T219VRS7	-42847.694	2906410.758	1578.195	0.020	0.005	0.021	0.027	-0.008	0.004	0.009	0.012	300485	300490	5	0.014	0.022	1.0	1.7	8
T219VRS8	-42847.688	2906410.759	1578.178	0.014	0.004	0.015	0.044	-0.002	0.005	0.006	0.005	300513	300519	6	0.015	0.024	1.0	1.7	8
T219VRS9	-42847.700	2906410.752	1578.198	0.026	0.011	0.028	0.024	-0.014	-0.002	0.014	0.015	300540	300549	9	0.015	0.024	1.0	1.7	8
T219VRS10	-42847.694	2906410.751	1578.201	0.020	0.012	0.023	0.021	-0.008	-0.003	0.008	0.018	300572	300580	8	0.015	0.024	1.0	1.6	8
T219VRS11	-42847.701	2906410.746	1578.200	0.027	0.017	0.032	0.022	-0.015	-0.008	0.017	0.017	300599	300605	6	0.015	0.024	1.0	1.6	8
T219VRS12	-42847.701	2906410.744	1578.192	0.027	0.019	0.033	0.030	-0.015	-0.010	0.018	0.009	300625	300632	7	0.015	0.024	1.0	1.6	8
T219VRS13	-42847.700	2906410.747	1578.181	0.026	0.016	0.031	0.041	-0.014	-0.007	0.016	0.002	300653	300660	7	0.015	0.024	1.0	1.6	8
T219VRS14	-42847.693	2906410.749	1578.179	0.019	0.014	0.024	0.043	-0.007	-0.005	0.008	0.004	300681	300689	8	0.015	0.024	1.0	1.6	8
T219VRS15	-42847.694	2906410.750	1578.180	0.020	0.013	0.024	0.042	-0.008	-0.004	0.009	0.003	300709	300715	6	0.015	0.024	1.0	1.6	8
T219VRS16	-42847.698	2906410.742	1578.189	0.024	0.021	0.032	0.033	-0.012	-0.012	0.017	0.006	300737	300746	9	0.015	0.024	1.0	1.6	8
T219VRS17	-42847.697	2906410.739	1578.214	0.023	0.024	0.033	0.008	-0.011	-0.015	0.018	0.031	300766	300773	7	0.015	0.024	1.0	1.6	8
T219VRS18	-42847.691	2906410.750	1578.190	0.017	0.013	0.021	0.032	-0.005	-0.004	0.006	0.007	300794	300800	6	0.015	0.024	1.0	1.6	8
T219VRS19	-42847.698	2906410.741	1578.199	0.024	0.022	0.033	0.023	-0.012	-0.013	0.018	0.016	300820	300826	6	0.013	0.020	0.8	1.3	9
T219VRS20	-42847.694	2906410.743	1578.195	0.020	0.020	0.028	0.027	-0.008	-0.011	0.013	0.012	300846	300852	6	0.013	0.020	0.8	1.3	9
T219VRS21	-42847.691	2906410.742	1578.189	0.017	0.021	0.027	0.033	-0.005	-0.012	0.013	0.006	300874	300881	7	0.012	0.020	0.8	1.3	9
T219VRS22	-42847.688	2906410.752	1578.178	0.014	0.011	0.018	0.044	-0.002	-0.002	0.003	0.005	300901	300907	6	0.012	0.020	0.8	1.3	9
T219VRS23	-42847.685	2906410.749	1578.179	0.011	0.014	0.018	0.043	0.001	-0.005	0.005	0.004	300929	300936	7	0.012	0.020	0.8	1.3	9
T219VRS24	-42847.682	2906410.754	1578.174	0.008	0.009	0.012	0.048	0.004	0.000	0.004	0.009	300957	300963	6	0.013	0.020	0.8	1.3	9
T219VRS25	-42847.680	2906410.759	1578.171	0.006	0.004	0.007	0.051	0.006	0.005	0.008	0.012	300984	300992	8	0.012	0.020	0.8	1.3	9
T219VRS26	-42847.675	2906410.765	1578.169	0.001	-0.002	0.002	0.053	0.011	0.011	0.016	0.014	301012	301017	5	0.012	0.020	0.8	1.3	9
T219VRS27	-42847.677	2906410.765	1578.170	0.003	-0.002	0.004	0.052	0.009	0.011	0.014	0.013	301040	301047	7	0.012	0.020	0.8	1.3	9
T219VRS28	-42847.679	2906410.766	1578.173	0.005	-0.003	0.006	0.049	0.007	0.012	0.014	0.010	301069	301080	11	0.012	0.020	0.8	1.3	9
T219VRS29	-42847.684	2906410.766	1578.175	0.010	-0.003	0.010	0.047	0.002	0.012	0.012	0.008	301100	301107	7	0.012	0.020	0.8	1.3	9
T219VRS30	-42847.682	2906410.769	1578.181	0.008	-0.006	0.010	0.041	0.004	0.015	0.016	0.002	301128	301134	6	0.012	0.020	0.8	1.3	9
T219VRS31	-42847.679	2906410.774	1578.162	0.005	-0.011	0.012	0.060	0.007	0.020	0.021	0.021	301156	301163	7	0.012	0.020	0.8	1.3	9
T219VRS32	-42847.674	2906410.764	1578.176	0.000	-0.001	0.001	0.046	0.012	0.010	0.016	0.007	301185	301194	9	0.012	0.020	0.8	1.3	9
T219VRS33	-42847.674	2906410.756	1578.191	0.000	0.007	0.007	0.031	0.012	0.002	0.012	0.008	301219	301226	7	0.012	0.020	0.8	1.3	9
T219VRS34	-42847.681	2906410.757	1578.192	0.007	0.006	0.009	0.030	0.005	0.003	0.006	0.009	301262	301269	7	0.012	0.019	0.8	1.3	9
T219VRS35	-42847.679	2906410.753	1578.195	0.005	0.010	0.011	0.027	0.007	-0.001	0.007	0.012	301289	301296	7	0.012	0.020	1.0	1.6	8
T219VRS36	-42847.677	2906410.746	1578.196	0.003	0.017	0.017	0.026	0.009	-0.008	0.012	0.013	301317	301323	6	0.013	0.022	1.0	1.6	8
T219VRS37	-42847.682	2906410.753	1578.172	0.008	0.010	0.013	0.050	0.004	-0.001	0.004	0.011	301345	301353	8	0.013	0.022	1.0	1.6	8
T219VRS38	-42847.682	2906410.752	1578.160	0.008	0.011	0.014	0.062	0.004	-0.002	0.004	0.023	301373	301380	7	0.013	0.022	1.0	1.6	8
T219VRS39	-42847.679	2906410.753	1578.165	0.005	0.010	0.011	0.057	0.007	-0.001	0.007	0.018	301401	301407	6	0.013	0.022	1.0	1.6	8
T219VRS40	-42847.676	2906410.750	1578.184	0.002	0.013	0.013	0.038	0.010	-0.004	0.011	0.001	301445	301453	8	0.013	0.022	1.0	1.6	8
Mean	**-42847.686**	**2906410.754**	**1578.183**	**0.012**	**0.009**	**0.017**	**0.039**			**0.011**	**0.011**			**7.5**	**0.013**	**0.022**	**0.9**	**1.5**	**8**
STD Dev				**0.008**	**0.008**	**0.009**	**0.014**			**0.005**	**0.007**			**2.0**					

APPENDIX C

TEST SITE DATA SUMMARY

SUMMARY

PUBLISHED VRS REFERENCE STATION CO-ORDINATES
TrigNet ITRF2005 EPOCH 2008-01-09

CLASSIC POST-PROCESSING COORDINATES

Site	Name	Y (Easting)	X (Northing)	Ellipsoidal HT	Code
SITE 1	T135PPS	-69533.131	2907417.163	1609.388	KRUG 62
SITE 2	T620PPS	-97449.184	2908395.795	1825.872	MEREDALE RES
SITE 3	T416PPS	-84932.814	2891247.233	1802.921	KRUG 113
SITE 4	T187PPS	-113592.277	2882429.187	1600.070	PRE 11
SITE 5	T148PPS	-107885.977	2868476.778	1584.580	OL-CH
SITE 6	T103PPS	-92585.501	2869883.091	1401.876	PRE 95
SITE 7	T478PPS	-83417.825	2881947.338	1511.344	PRE 93
SITE 8	T469PPS	-63620.542	2887013.450	1607.869	KRUG 13
SITE 9	T219PPS	-42847.674	2906410.763	1578.222	KRUG 50

MEAN ADOPTED VRS RTK COORDINATES

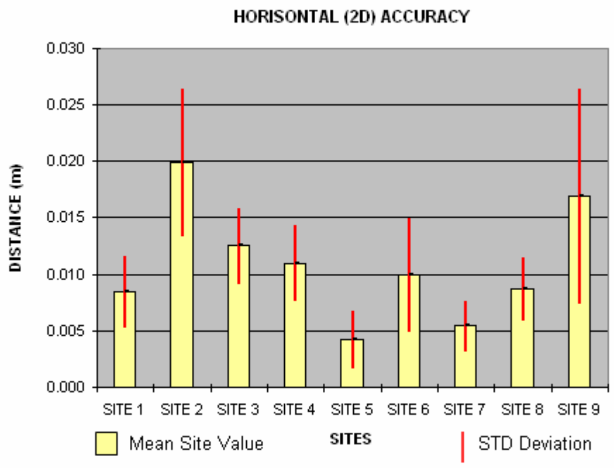
Site	Name	Y (Easting)	X (Northing)	Ellipsoidal HT	Code
SITE 1	T135VRS	-69533.124	2907417.163	1609.357	KRUG 62
SITE 2	T620VRS	-97449.173	2908395.810	1825.832	MEREDALE RES
SITE 3	T416VRS	-84932.809	2891247.244	1802.896	KRUG 113
SITE 4	T187VRS	-113592.267	2882429.189	1600.058	PRE 11
SITE 5	T148VRS	-107885.975	2868476.779	1584.568	OL-CH
SITE 6	T103VRS	-92585.499	2869883.092	1401.825	PRE 95
SITE 7	T478VRS	-83417.824	2881947.343	1511.331	PRE 93
SITE 8	T469VRS	-63620.539	2887013.458	1607.875	KRUG 13
SITE 9	T219VRS	-42847.686	2906410.754	1578.183	KRUG 50

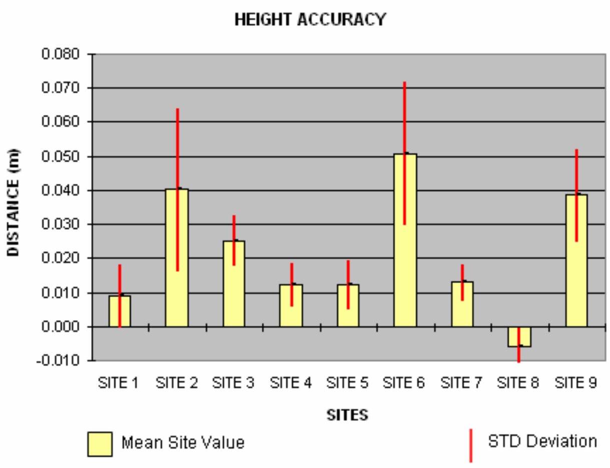
ACCURACY RESULTS

Name	Mean Values			
	∂Y (Easting)	∂X (Northing)	∂2D	∂Ht
SITE 1	-0.007	0.000	0.008	0.009
SITE 2	-0.010	-0.015	0.020	0.040
SITE 3	-0.004	-0.011	0.013	0.025
SITE 4	-0.010	-0.002	0.011	0.012
SITE 5	-0.002	-0.001	0.004	0.012
SITE 6	-0.002	-0.001	0.010	0.051
SITE 7	-0.001	-0.005	0.005	0.013
SITE 8	-0.003	-0.008	0.009	-0.006
SITE 9	0.012	0.009	0.017	0.039
Mean	**-0.003**	**-0.004**	**0.011**	**0.022**
STD Dev	**0.007**	**0.007**		

STD Dev		95% Confidence Int	
∂2D	∂Ht	∂2D	∂Ht
0.003	0.009	0.006	0.018
0.006	0.024	0.013	0.048
0.003	0.007	0.007	0.014
0.003	0.006	0.007	0.012
0.002	0.007	0.005	0.014
0.005	0.021	0.010	0.042
0.002	0.005	0.004	0.010
0.003	0.005	0.005	0.011
0.009	0.014	0.019	0.027
0.004	**0.011**	**0.008**	**0.022**

(Mean row: **Mean**)

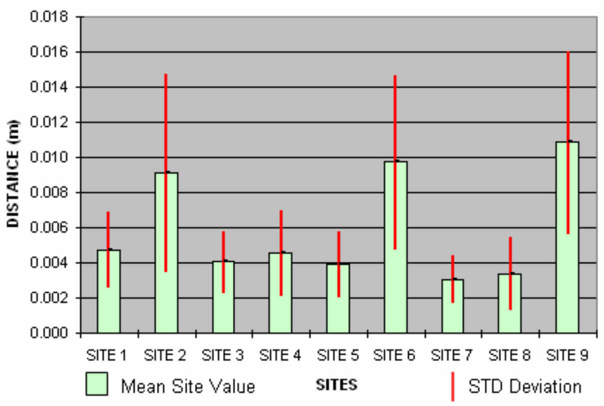




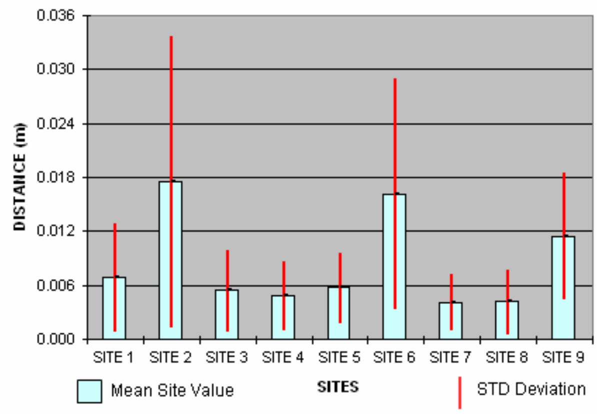
PRECISION RESULTS

Name	Mean Values		STD Dev		95% Confidence Int	
	∂ 2D	∂ Ht	∂ 2D	∂ Ht	∂ 2D	∂ Ht
SITE 1	0.005	0.007	0.002	0.006	0.004	0.012
SITE 2	0.009	0.017	0.006	0.016	0.011	0.032
SITE 3	0.004	0.005	0.002	0.004	0.003	0.009
SITE 4	0.005	0.005	0.002	0.004	0.005	0.007
SITE 5	0.004	0.006	0.002	0.004	0.004	0.008
SITE 6	0.010	0.016	0.005	0.013	0.010	0.025
SITE 7	0.003	0.004	0.001	0.003	0.003	0.006
SITE 8	0.003	0.004	0.002	0.003	0.004	0.007
SITE 9	0.011	0.011	0.005	0.007	0.010	0.014
Mean	**0.006**	**0.008**	**0.003**	**0.007**	**0.006**	**0.013**

HORISONTAL (2D) PRECISION



HEIGHT PRECISION



GPS INITIALISATION TIME

Name	Initialisation Time (s)	STD Dev	95% Conf Interval
SITE 1	7.2	1.8	3.6
SITE 2	7.1	2.1	4.1
SITE 3	6.8	1.5	3.0
SITE 4	7.1	1.7	3.4
SITE 5	6.9	2.5	5.0
SITE 6	7.0	2.5	4.9
SITE 7	7.9	4.1	8.2
SITE 8	6.9	1.8	3.7
SITE 9	7.5	2.0	4.1
Mean	**7.1**	**2.2**	**4.4**

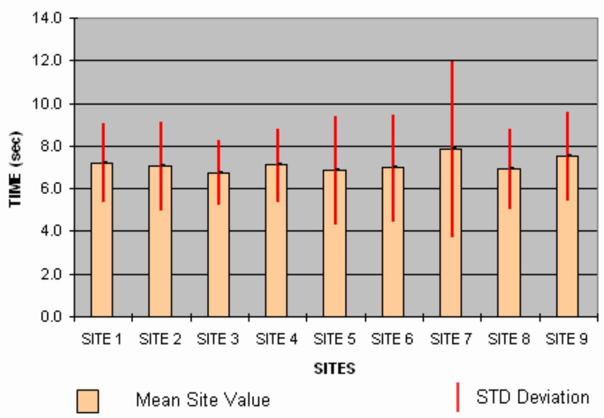
TRIMBLE QUALITY CONTROL

Accuracy		HDOP	VDOP	SV's
HOR	VERT	(Max)	(Max)	(Min)
0.008	0.012	0.8	1.3	12
0.011	0.020	0.9	1.7	10
0.011	0.016	0.6	1.2	10
0.009	0.014	0.8	1.3	11
0.008	0.015	1.0	1.9	10
0.012	0.020	0.8	1.5	10
0.006	0.010	0.6	1.1	11
0.006	0.011	0.8	1.4	10
0.013	0.022	0.9	1.5	8

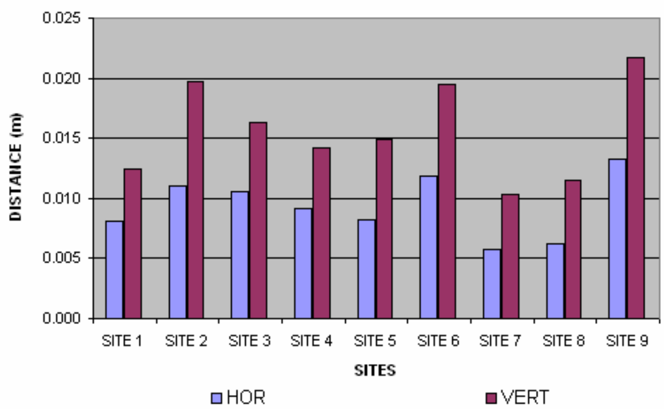
Mean

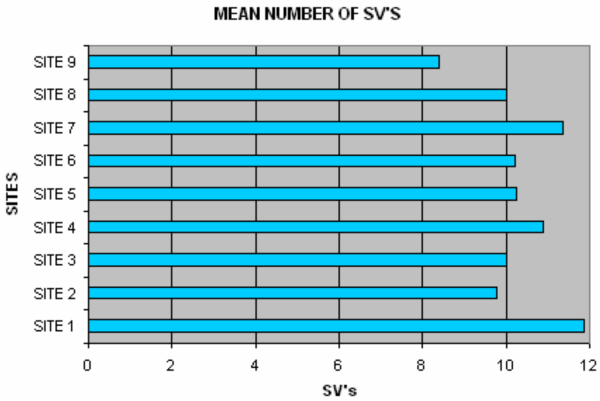
0.009	**0.016**	**0.8**	**1.4**	**10**

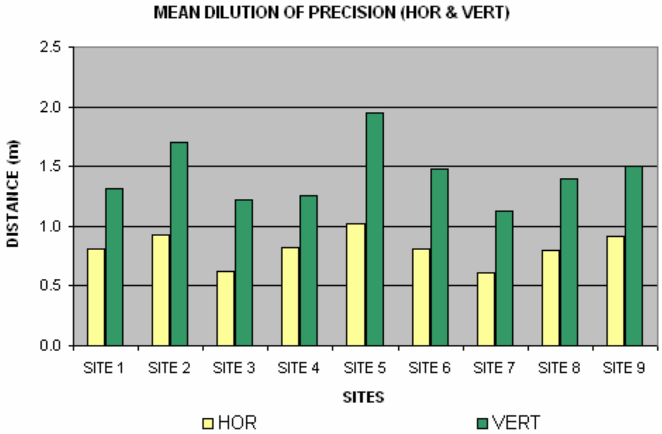
MEAN GPS INITIALISATION TIME



MEAN GPS ACCURACY (HOR & VERT)




MEAN NUMBER OF SV'S
SITE 9
SITE 8
SITE 7
SITE 6
SITE 5
SITE 4
SITE 3
SITE 2
SITE 1
SITES
0
2
4
6
8
10
12
SV's


MEAN DILUTION OF PRECISION (HOR & VERT)
2.5
2.0
1.5
1.0
0.5
0.0
DISTANCE (m)
SITE 1
SITE 2
SITE 3
SITE 4
SITE 5
SITE 6
SITE 7
SITE 8
SITE 9
SITES
HOR
VERT