University of Southern Queensland

Faculty of Health, Engineering and Sciences

Quantify and Explain the Differences in Horizontal Accuracies Between Commercial CORS Networks

A dissertation submitted by

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Abstract

Real Time Kinematic (RTK) surveying found its roots in the mid 1990's, giving surveyors the opportunity to carry out real time measurements using GPS signals with low ranges of accuracy. With single base RTK limiting accuracy at longer ranges network RTK has been implemented to provide precise corrections via cellular networks.

Increased reliable network RTK and satellite coverage has given more opportunities for surveyors to use this technology. Commercial network RTK providers now have means to be able to provide corrections to surveyors in most urbanised areas in Australia. From conducting a thorough literature review, a noticeable lack of field testing has been carried out to see if any of the commercial CORS networks that are available throughout Australia deliver different horizontal accuracies, and where the sources of these differences originate from.

Methodology is formulated in this report so that field testing can be carried out to substantiate these theories. Appreciation of the similar studies that have been undertaken in the past have helped shape measurement procedures, site selection and the equipment to be used for this research project. Two permanent marks that are linked to the cadastral network in South East Queensland will be measured by network RTK with corrections supplied by three private CORS networks. From the analysis of the data captured in the field a series of conclusions and recommendations will be presented in the final dissertation.

Results obtained from field data indicates that small differences seen between networks. This has been determined to originate from variances in CORS networks and baseline lengths used to perform measurements. However, the differences observed are at a smaller magnitude than the accuracy specifications of the equipment used to perform fieldwork.

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Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

M. Venaglia

[redacted]

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Table of Contents

Abstract ... ii

Acknowledgements ... v

Table of Contents ... vi

Table of Figures ... ix

List of Tables ... x

Glossary of Terms ... xi

Chapter 1 - Introduction ... 1

1.1 Background ... 1

1.2 Network RTK ... 1

1.3 Aim ... 2

1.4 Objectives ... 2

Chapter 2 - Literature Review ... 4

2.1 ICSM Guidelines ... 4

2.2 Network RTK Corrections ... 5

2.2.1 VRS ... 5

2.2.2 I-MAX ... 5

2.2.3 FKP ... 6

2.2.4 MAC ... 6

2.3 Network Comparison Studies and Methodologies ... 7

2.3.1 Research in Great Britain ... 7

2.3.2 Research in United States ... 8

2.3.3 Research in Spain ... 9

2.3.4 Other Research ... 10

2.4 Conclusion ... 10

Chapter 3 - Methodology ... 11

3.1 Introduction ... 11

3.2 Project Development ... 11

3.3 Site Selection ... 11

3.3.1 Mark Type ... 11

3.3.2 Baseline Length ... 11

3.3.3 Location ... 12

3.3.4 Site Analysis Tools ... 12

3.3.5 Test Site 1 ... 12

3.3.6 Test Site 2 ... 15

3.4 Equipment 20
3.4.1 Static GNSS Equipment 20
3.4.2 NRTK GNSS Equipment 20
3.5 Field Work 21
3.5.1 Static Data 21
3.5.2 NRTK Data 21
3.5.3 Measurement Settings 23
3.6 Data Collection 23
3.7 Conclusion 24
Chapter 4 - Results 25
4.1 Introduction 25
4.2 PM180957 27
4.2.1 VRS 60 epochs 27
4.2.2 VRS 120 epochs 28
4.2.3 Nearest Base 60 epochs 30
4.2.4 Nearest Base 120 epochs 31
4.2.5 IMAX 60 epochs 32
4.2.6 IMAX 120 epochs 34
4.2.7 MAC 60 epochs 36
4.2.8 MAC 120 epochs 38
4.3 PM206731 40
4.3.1 IMAX & VRS 60 epochs 40
4.3.2 MAC & VRS 60 epochs 41
4.3.3 IMAX & VRS 120 epochs 42
4.3.4 MAC & VRS 120 epochs 43
4.3.5 IMAX & Nearest Base 60 epochs 44
4.3.6 MAC & Nearest Base 60 epochs 45
4.3.7 IMAX & Nearest Base 120 epochs 46
4.3.8 MAC & Nearest Base 120 epochs 47
Chapter 5 - Analysis 48
5.1 Calculation of Uncertainties 48
5.2 PM180957 51
5.3 PM206731 55
Chapter 6 - Discussion 60
6.1 Further Study 61
6.2 Conclusion 62

Chapter 7 - List of References 64
Appendix A – Project Specification V1.5 66
Appendix B – Survey Mark Reports 67
Appendix C – Trimble R2 Manufacturer Specification 72
Appendix D - Leica GS18 Manufacturer Specification 74
Appendix E – Field Observation Record 76
Appendix F – Test Case List 77
Appendix G – Raw observation data for PM180957 78
Appendix H – Raw observation data for PM206731 82
Appendix I – Regulation 13 Cetrificates 87
Appendix J – Risk Management Plan 95

Table of Figures

Figure 3.1: Location of test site 1 relative to local trees. 13
Figure 3.2: Map of local area of test site 1, depicting red network CORS configuration 14
Figure 3.3: Map of local area of test site 1, depicting blue network CORS configuration 14
Figure 3.4: Map of local area of test site 1, depicting purple network CORS configuration 15
Figure 3.5: Site depiction of test site 2 16
Figure 3.6: Map of local area of test site 2, depicting the red network CORS configuration 17
Figure 3.7: Map of local area of test site 2, depicting the blue network CORS configuration 18
Figure 3.8: Map of local area of test site 2, depicting the purple network CORS configuration 19
Figure 3.9: Trimble R2 antenna and TSC3 controller 20
Figure 3.10: Leica GS18 and CS20 controller 21
Figure 4.1: Scatter plot of VRS NOW and SmartNet observations 26
Figure 4.2: Scatter graph displaying VRS corrections and 60 epochs of data 27
Figure 4.3: Scatter graph displaying VRS corrections and 120 epochs of data 28
Figure 4.4: Scatter graph displaying the new red network VRS corrections and 120 epochs 29
Figure 4.5: Scatter graph displaying nearest base corrections and 60 epochs 30
Figure 4.6: Scatter graph displaying nearest base corrections and 120 epochs 31
Figure 4.7: Scatter graph displaying IMAX / VRS corrections, sampled with 60 epochs 32
Figure 4.8: Scatter graph displaying IMAX / Nearest Base corrections, sampled with 60 epochs 33
Figure 4.9: Scatter graph displaying IMAX / VRS corrections, sampled with 120 epochs 34
Figure 4.10: Scatter graph displaying IMAX / Nearest Base corrections, sampled with 120 epochs 35
Figure 4.11: Scatter graph displaying MAC / VRS corrections, sampled with 60 epochs 36
Figure 4.12: Scatter graph displaying MAC / Nearest Base corrections,sampled with 60 epochs 37
Figure 4.13: Scatter graph displaying MAC / VRS corrections, sampled with 120 epochs 38
Figure 4.14: Scatter graph displaying MAC / Nearest Base corrections, sampled with 120 epochs 39
Figure 4.15: Scatter graph displaying IMAX / VRS corrections, sampled with 60 epochs 40
Figure 4.16: Scatter graph displaying MAC / VRS corrections, sampled with 60 epochs 41
Figure 4.17: Scatter graph displaying IMAX / VRS corrections, all sampled with 60 epochs 42
Figure 4.18: Scatter graph displaying IMAX / VRS corrections, all sampled with 60 epochs 43
Figure 4.19: Scatter graph displaying IMAX / Nearest Base corrections, sampled with 60 epochs 44
Figure 4.20: Scatter graph displaying MAC / Nearest Base corrections, sampled with 60 epochs 45
Figure 4.21: Scatter graph displaying IMAX / Nearest Base corrections, sampled with 120 epochs 46
Figure 4.22: Scatter graph displaying IMAX / Nearest Base corrections, sampled with 120 epochs 47
Figure 5.1: PU and mean coordinate of PM180957, Nearest Base, IMAX and MAC 60 epochs 51
Figure 5.2: PU and mean coordinate of PM180957, Nearest Base, IMAX and MAC 120 epochs 52
Figure 5.3: PU and mean coordinate of PM180957 and VRS correction for 60 epochs 53

Figure 5.4: PU and mean coordinate of PM180957 and VRS correction for 120 epochs 54
Figure 5.5: PU and mean coordinate of PM206731, Nearest Base, IMAX and MAC 60 epochs. 55
Figure 5.6: Static observation, PM206731 Nearest Base, IMAX and MAC corrections 60 epochs 56
Figure 5.7: Static observation, PM206731Nearest Base, IMAX and MAC corrections 120 epochs. ..57
Figure 5.8: PU and mean coordinate of PM206731 and VRS correction for 60 epochs. 58
Figure 5.9: PU and mean coordinate of PM206731 and VRS correction for 120 epochs 59

List of Tables

Table 4.1: Table represents 1 round of the 16 test cases observed in the field. 25
Table 5.1: Table of coordinates and uncertainties for each data set observed at PM206731. 50
Table 5.2: Table of coordinates and uncertainties for each data set observed at PM206731. 50

Glossary of Terms

BDS - BeiDou Navigation satellite system

CORS - Continuous Observation Reference Stations

DNRME - Department of Natural Resources, Mines and Energy

FKP - Flächen Korrektur Parameter = Area Correction Parameters

GDA94 - Geocentric Datum of Australia 1994

GNSS - Global Navigation Satellite System

GLONASS - Globalnaya Navigazionnaya Sputnikovaya Sistema

GPS - Global Positioning System

ICSM - Intergovernmental Committee on Surveying and Mapping

IMAX - Individualised MAX (MAC)

MAC - Master Auxiliary Concept

NRTK - Network RTK

PM - Permanent Mark

PU - Positional Uncertainty

RINEX - Receiver Independent Exchange

RTCM - Radio Technical Commission for Maritime Services

RTK - Real Time Kinematic

RU - Relative Uncertainty

SP1 - Special Publication 1 (Version 2.1)

SU - Survey Uncertainty

VTEC - Vertical Total Electron Content

VRS - Virtual Reference Station

Chapter 1 - Introduction

1.1 Background

Real Time Kinematic (RTK) Global Navigation Satellite System (GNSS) surveying has gained momentum of its widespread use to the consumer since its introduction during the mid 1990's (Rizos, cited in Janssen 2009, p. 1). The RTK process requires the use of at least two receivers, which are both observing satellite signals. One receiver is set up as base, which remains stationary over a known position, whilst the other receiver acts as a rover, and is able to move and measure positions of interest. A wireless communication link is established between the two receivers, via radio, cellular or wi-fi which serves to update the rover's receiver with baseline corrections for broadcast orbits and atmospheric conditions (Janssen & Haasdyk 2011, p.3).

RTK has the ability to give survey accurate positioning in real time and has seen it be a popular tool for construction surveying, earthworks set out and machine guidance amongst many other survey tasks. However, limitations lie in distance the rover can travel from the base station, the quality of the radio link and the time it takes to resolve phase ambiguities (European Space Agency 2011, para. 12). Accuracy begins to be degraded when the rover moves further than 10 km away from the base station (Berber & Arslan 2013, p. 2798; Janssen 2009, p. 1; Lejeune & Warnant 2008, p. 890; Yeh et al. 2012, p. 3). This restricts its flexibility when servicing wide local areas seen throughout Australia. A base can be setup temporarily to service a rover in a localised area, but can be costly, time consuming and additionally a potential source of error if not setup and configured correctly (Allahyari et al. 2018, p.1).

1.2 Network RTK

Network RTK (NRTK) has emerged as a solution for this problem, creating a so called 'network' of reference stations that are continuously observing GNSS satellites. The reference stations send their observed data to a central processing server in real time, which creates corrections which are sent to an autonomous rover via mobile internet. This then gives the rover the ability to measure with sub-decimetre level precision without the need to be connected to a traditional RTK base station (Allahyari et al. 2018, p.2; Berber & Arslan 2013, p. 2798). The added advantage of NRTK is the rover is able to extend its useable distance, only being restricted by the coverage of the network it is receiving the corrections from.

The strength of NRTK emanates from the processing server's ability to correct for localised conditions over a large area.

> [The server] 'makes use of known coordinates of permanent GNSS receivers and fixed carrier phase ambiguities and then computes the corrections for atmospheric and orbital errors' (Berber & Arslan 2013, p. 2798).

The number of satellite constellations have recently increased, with Russia's Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) now joining the United States' Global Positioning System (GPS) in having global coverage (Allahyari et al. 2018, p.1). China's BeiDou Navigation satellite system (BDS) is also contributing a large amount of satellites with full global coverage expected to operational by 2020. In addition, the European Space Agency's Galileo satellite system is also forecasting to be fully operational in the same year (European Space Agency 2019, para. 3). These GNSS are giving increased solution reliability and better satellite coverage to network RTK users (Paziewski & Sieradzki 2017, p. 2562). These factors are contributing to better accuracies for surveyors in the field and giving more opportunities for NRTK to be used in day to day survey activities. In the past, points of interest may have had partial obstructions to the sky, reducing the number of satellites from which the rover can use to gain a reliable signal. Supplementary satellites will now be able to contribute to reliable survey data (Paziewski & Wielgosz 2017, p. 12).

Australia has a vast network of Continuous Observation Reference Stations (CORS) located throughout the continent, with the capital cities and main regional hubs having the most concentrated coverage. Both public and private organisations have contributed to the reference station network in Australia. Three main national survey grade commercial network subscription providers consist of Leica Geosystems Smartnet Aus, Trimble's VRS Now and Topcon's All Day RTK. Combining the increased satellite numbers and the choice of NRTK coverage, the repeatability of GNSS measurement has many factors for the average surveyor to consider if it is going to be a reliable measurement method going forward into the future.

1.3 Aim

The aim of this research project is to firstly test the horizontal accuracy of GNSS measurements with corrections provided from three of the main private Network RTK providers available in the South East Queensland region. Secondly, quantify the results investigating whether there are any differences between each and explain why the differences occur.

1.4 Objectives

The objectives of this research project are:

- Perform a literature review to analyse preceding work that has been carried out in a similar field. Gain insight into project development and methodology from existing studies that could be relevant to be modified or built upon for this research project. Find information gaps in current research that this project can fill.

- Produce a project plan that encompasses the project problem in a manner that it can offer a potential solution.
- Carry out field work in a professional manner to avoid the inclusion possible errors or blunders that could hinder analysis of results.
- Analyse data comprehensively to be able to make informed considerations.
- Perform a summary from results and make recommendations.

Version 1.5 of the project specification is attached to Appendix A.

Chapter 2 - Literature Review

2.1 ICSM Guidelines

The Intergovernmental Committee on Surveying and Mapping (ICSM) offer guidelines when performing control surveys by GNSS. Important information is included for performing surveys using NRTK. Site selection is important as both internal and external factors can influence measurement. These guidelines provide the main considerations for these factors (ICSM 2014b, p.6):

- GNSS system effects such as ephemeris error and satellite availability and geometry at each survey site;
- atmospheric effects due to the ionosphere and troposphere;
- site-dependent effects such as obstructions, multipath and interference from non-GNSS radio sources; and
- instrumental effects, most noticeably un-modelled antenna phase centre offsets.

Additional comments to minimise blunders for positioning involve incorporating procedures to reduce the effects of antenna centring and orientation errors and checking mark identifiers. ICSM also give reverence to observation techniques when performing NRTK control surveys.

The guidelines suggest the following (ICSM 2014b, p. 9):

- Rover should only work within the Network RTK coverage area recommended by the service provider.
- All rover marks occupied twice, ideally with 30 minutes between occupations.
- Record and average positions for at least 1 minute after the rover has successfully initialised (i.e. after ambiguity resolution).
- 1 second logging of the raw GNSS data is recommended to enable post-processing if checks are required at a later date.
- Elevation mask at reference station and rover: 15 degrees

Both the guidelines for control surveys by GNSS and the guideline for adjustment of survey control specifies procedures for evaluating the quality of measurements performed by GNSS. This method is also applicable for NRTK measurements. The evaluation of Survey Uncertainty (SU), Relative Uncertainty (RU) and Positional Uncertainty (PU) at a 95% confidence level gives a method of analysing the accuracy of measurements (ICSM 2014a p. 4; ICSM 2014b, p. 12).

2.2 Network RTK Corrections

An important part of NRTK is the way the central processing server handles the observation data it obtains from its network of reference stations and how that is applied to the rover which is relied upon by the surveyor. Berber and Arslan (2013) performed a case study to evaluate the performance of four NRTK corrections - Virtual Reference Station (VRS), a correction service which utilizes the master auxiliary concept (MAC), Individualised MAX (I-MAX) and Flächen Korrektur Parameter = Area Correction Parameters (FKP). From this research a better understanding of how different network corrections affect survey accuracy can be determined. A breakdown of the method each network correction is structured is an important indicator of how possible differences in positioning accuracy can occur and be further explored.

2.2.1 VRS

This correction method requires the rover to communicate back to the server from where corrections are made. The position of the rover is relayed back to the server so that it can get an approximate location to establish a unique virtual reference station for the rover to get corrections from. The virtual reference station is then established within a few metres of the location the rover fist begins communication back to the server. This then sets the VRS location for network corrections. Due to the close proximity of the new base to the rover, all distance related errors associated with the atmosphere and satellite orbit are directly minimised. However, if the rover moves a considerable distance from where the VRS was created, corresponding distance differences could begin to be introduced, resulting in unreliable corrections. To avoid this a new VRS should be established if the rover travels longer distances from its original position (Berber & Arslan 2013, p. 2799).

2.2.2 I-MAX

In a similar fashion to VRS, I-MAX corrections require the rover to relay position information back to the server. The difference lies in where the server makes the corrections with surrounding network stations, receiving corrections from the server and having the nearest master station transmit its corrections to the rover. This gives the rover actual base station information as opposed to a generated model as supplied from a VRS which might not exactly resemble the ionospheric conditions at its created location. With the real distance to base the rover may then be able to use settings in software to be able to further calculate any residual ionospheric delay. In addition, the actual baseline generated in I-MAX corrections provides a source of legal traceability, in that reference information can be linked back to the base station corrections originated from (Janssen 2009, p. 7). The downside to I-MAX corrections is that the rover may end up accessing settings more than necessary, as the server does resolve some ionospheric disturbances. The I-MAX corrections are able to continuously update regardless of the distance the rover moves without needing to reconfigure (Berber & Arslan 2013, p. 2799).

2.2.3 FKP

In this network correction method, the rover does not need to supply its location to the server, as corrections are determined in a north-south and east-west direction and are available around a limited distance from each reference station. A model of distance reliant errors is created by the server and transferred from the closest reference station to the rover alongside other RTK corrections. This process is not as ideal as the rover is not getting optimised corrections for its actual position and the server assumes a linear change between stations, despite the possibility of non-linear changes occurring, hence the possibility of the rover inducing interpolation errors (Berber & Arslan 2013, p. 2799).

2.2.4 MAC

This method uses all of the reference station data to make corrections, supplying raw observation and coordinate data from the master reference station to the rover. The network of auxiliary reference stations also supplies raw data to the master, allowing the rover to obtain corrections from one base such as the FKP method, or to access multiple reference stations to gain a more rigours calculation of distance dependant error corrections. This gives the advantage of the rover being able to observe and adapt to existing atmospheric conditions, providing a reliable RTK solution during work performed (Berber & Arslan 2013, pp. 2799-2800).

This evaluation gives a good baseline of information to understand how network corrections a developed. Allahyari et al. (2018) give further explanation towards the Master Auxiliary Concept (MAC). The authors describe the MAC method in a similar fashion to how Berber and Arslan (2013) presented their description of MAC and I-MAX. However, Allahyari et al. add that MAX corrections are a similar version of MAC but use a proprietary Radio Technical Commission for Maritime Services (RTCM) transmission format that is developed for Leica Geosystems hardware. MAC and I-MAX rely on an outdated RTCM format which is open source, and acceptable to use on other manufacturers hardware.

Janssen (2009) confirms this explanation of how MAC, MAX and I-MAX operate with research done on VRS and MAC principals. The author gives further description to the MAC as having ambiguity levelled observations for all reference stations in the network, showing the dispersive and nondispersive correction data for each satellite and receiver pair. The master station transmits its full station data to the rover, including coordinate information and corrections, however for the auxiliary stations only the differences are transmitted. Further breaking down of auxiliary information is done to separate the dispersive and nondispersive parts due to the fact of the slow nature in which tropospheric and orbit errors change. This is intended to reduce the amount of data that is constantly sent to the rover (Janssen 2009, pp.3-4). The network is distributed into clusters and cells of reference stations. The cluster level of references stations exists as a group of at stations that have been processed to have their ambiguity observations levelled together. Groups of these clusters exist to create the network. A cell consists of at least three reference stations from a single cluster, which acts as the master and auxiliary stations from which the corrections are generated to the rover (Brown and Keenan, cited in Janssen 2009, p. 4).

Janssen (2009) further describes MAX as master auxiliary corrections based from the RTCM version 3.1 transmission format, and I-MAX corrections intended for use with rovers that do not translate RTCM 3.1 NRTK messages. The author compares I-MAX alike to the VRS style of corrections, with the main notable difference being the use of a physical reference station unlike VRS which assigns a virtual one. The author expresses this fact to be important as it shows the consistency and traceability of the corrections provided to the rover.

2.3 Network Comparison Studies and Methodologies

Many international research projects have been conducted to test NRTK performance, providing real world data to examine expected accuracy of NRTK measurements, recommended guidelines for using NRTK and the combination of satellite constellation pairings. These offer insight as to how field work can be carried out and data reduced and analysed. Each nation has varying levels of NRTK infrastructure in place and has its own geographical, environmental and technological considerations for delivering network corrections.

2.3.1 Research in Great Britain

Edwards et. al. (2010) have carried out a study on the performance of two Network RTK providers - Leica’s SmartNet and Trimble’s VRS Now. Achievable accuracy and best practice guidelines for Network RTK solutions were the primary goals of the research project. They cited the developing commercial usage of the emerging Network RTK technology in Great Britain as a reason for investigating these goals.

Eight test locations were chosen with a few key considerations involving distance to the nearest four reference stations, elevation differences and open nature of each site. Field equipment comprised of a tripod and tribrach arrangement, but with a unique inline bracket that was able to accept three antennas. The central antenna was centrally mounted over the mark being measured, with the other antennas equally spaced 250 millimetres either side of the central antenna. The central reference antenna was orientated to magnetic north using a compass to ensure repeatable equipment setups and antennas from both manufacturers were set to have a 10° elevation mask. This arrangement has the ability for the central antenna to be recording reference data, whilst the auxiliary antennas record the

Network RTK data all at the same time. Six hours of data was collected from each antenna for each observation, giving enough time for satellite constellation changes to take place. The authors explained that these steps in equipment setup and measurement duration was in order to reduce the chance that measurements could be affected by any biases from satellite configurations between each location (Edwards et. al. 2010, pp. 11-2).

Reference data was collected for the test sites and was processed using the closest five ordnance survey CORS, with coordinates from the best four held fixed, together with a number of other processes and settings to ensure the best quality position information could be determined for each location (Edwards et. al. 2010, pp. 13).

2.3.2 Research in United States

The case study by Berber & Arslan (2013) that investigated the four network correction methods previously described in Chapter 2.2 offers interesting methods for consideration in this project.

Berber & Arslan (2013, p. 2083) used a triple frequency GNSS rover, specifically a Leica GX1230, to perform test measurements along with a two metre pole, stabilised by a bipod. Whilst the use of a pole and bipod is a common field practice, there is a potential to induce centring errors into measured points therefore creating unnecessary differences between each measurement session. Each of the seven test sites were measured for two minutes, giving a total of 120 epochs of data. Whilst the authors describe the test site area to be flat and free from obstruction giving the receiver a clear view of the sky, they did attribute some undesirable variations of their results to short observation times (Berber & Arslan 2013, p. 2085).

A further consideration examined by the authors concentrated on ionospheric conditions before, during and after the test date. Data obtained from the code stored in IONEX format was used to map the Vertical Total Electron Content (VTEC). This was displayed against the Universal Coordinated Time to provide a pattern of atmospheric conditions around and during the time measures were to be taken. This allowed the authors to observe if there were any ionospheric anomalies that could influence data during the measurement process. Alongside the VTEC data, the Planetary K index was also monitored, showing no disturbance at the time of measurement (Berber & Arslan 2013, p. 2804).

A static survey was used to provide reference coordinates for NRTK data in this study. This was performed by the authors, collecting 2.5 hours of data on each test point using 5 second epochs of data. The results showed little variation between each network correction style, with one to two centimetres of difference between all Eastings and Northings to the reference data. No consistent pattern of accuracy was present however, the FKP network corrections appeared to be in the higher end of the measurement scale throughout the seven test sites (Berber & Arslan 2013, p. 2805).

2.3.3 Research in Spain

Garrido et. al. (2011) investigated three local GNSS networks MERISTEMUM, REGAM and ERVA. Whilst Spain was quickly adopting GNSS networks throughout the country, smaller privately-run networks are being developed instead of densifying the national network, due to economic and proximity reasons. This approach has led to a fragmented but widespread network coverage over two thirds of Spain. Issues arise when coordinates are obtained in areas on the fringe of differing networks resulting in conflicting final results when corrections have been applied. Garrido et. Al. (2011) conducted their research into obtaining repeatable centimetre positioning accuracy regardless of which RTK network is being used.

The study location was chosen for its remote proximity and the overlapping network coverage of the aforementioned networks. The control points to be surveyed were also part of REGENTE, the national 3d network in Spain. The three networks used were:

1. REGAM Network – Uses MAC corrections and had a total of 9 observation stations, however at the time of the study 2 were undergoing calculations and not of use. The network uses a combination of GPS and GLONASS satellites to achieve a constant 9 satellite coverage 24 hours a day. Leica equipment is used for reference stations.

2. MERISTEMUM Network – operates in the same region as the REGAM network. It had 5 operational observation stations and 3 borrowed stations from a neighbouring ERVA network for corrections in that part of the region. The network uses VRS based solutions. Trimble equipment is used for reference stations.

3. ERVA Network – Had a network of 8 observation stations and unlike the other two networks, uses a mixture of Leica and Trimble equipment for observations. The ERVA network supplies VRS solutions.

A total of 6 control points are used in the study with 3 observation sessions completed. For each session, 15 positions were recorded in real time, with each position representing a new ambiguity solution. After each position the NTRIP caster was disconnected until the phase solution was lost instead of turning off the receiver.

A single receiver was used for all tests. One frequency was used for longer duration observations, whilst the other was connected to a mobile phone to receive corrections from the three network providers but both getting their observations from a single antenna. “Thus, two dual-frequency GPS receivers (LEICA GRX1230) were connected to the same receiving antenna (LEICA AX1202) via a double-output amplified GPS source splitter at each control point” (Garrido et. Al. 2011, p259).

The REGAM network was found to have the closest results to those of the control coordinates from the national network, with the author reasoning that the REGAM network had more observation stations closer to the surveyed points resulting in more accurate corrections supplied for that location rather that how the network solution was obtained. The authors noted also a homogeneity in Easting and Northing between the different network solutions.

The study was state sponsored with little manufacturer or network provider input which gives confidence that no bias has been applied in any instance. The methodology of using a single antenna for dual receivers is an interesting choice for data collection. This study is now dated with many more satellites and constellations available to the end user, as well as the coverage and number of networks that could potentially be available.

2.3.4 Other Research

An extensive list of high quality research materials were examined in carrying out the literature review process however, they had little substance to add in forming the methodology or analysis of this project.

The depth of research information available also focused on the vertical component of NRTK measurement in addition to the horizontal, but is considered to be out of the scope of this project,

2.4 Conclusion

Previous research trends to focus on the accuracy of NRTK, generally looking to see how a network performs when to measuring to a set benchmark or truth coordinate. Whilst some studies compare different NRTK for accuracy they offered little to describe how differences between networks can be explained and why they exist. With NRTK shown to be become more accurate and widespread, and the need for traceability in measurements surveyors perform, the question of being able to quantify and explain the differences in horizontal accuracies between NRTK providers remains.

Chapter 3 - Methodology

3.1 Introduction

The following section will explain the procedures and methodology for carrying out the site planning, equipment, field work procedures and the analysis of data captured for this project. Additionally, a risk assessment and project schedule will be included.

3.2 Project Development

The aim of this research project is to firstly test the horizontal accuracy of GNSS measurements with corrections provided three the main commercial Network RTK providers available in the South East Queensland region, then quantify the results investigating whether there are any differences between each and explain why the differences occur.

Previous studies that have been conducted have concentrated on the accuracy aspect for NRTK surveying. Berber & Arslan (2013) used their study to identify the best correction type for land based surveying tasks, while Edwards et. al. (2010) performed a series of tests in Great Britain to find 3 dimensional accuracy of the national network when introducing extreme conditions such as significant height differences to base station network and network performance at the edge of coverage. These studies provide basis for the following methodology in the investigation of NRTK difference.

3.3 Site Selection

From conducting a literature review, considerations have risen and been applied from previous research for selecting an appropriate location for carrying out necessary tests. As outlined in ICSM guidelines, test locations will have implications on the quality of data that can be collected and analysed in this study and will be considered in the following sections (ICSM 2014b, p.6).

3.3.1 Mark Type

Berber & Arslan (2013) and Edwards et. al. (2010) studies selected existing marks in the cadastral network in their respective location. This has added benefit of already having a stable, easy to define physical survey mark from which to repeatably measure to. In addition, coordinates of the survey mark will already be in place and linked to the local datum. In Queensland a permanent survey mark network exists providing many stable potential locations to use as a test location.

3.3.2 Baseline Length

An important consideration for site selection is the distance of the closest reference station to the selected survey mark. This will indicate where network corrections will be developed and from previous studies could have the largest impact on positional accuracy between private NRTK providers. Edwards et. al. (2010) selected test sites that had the nearest base station ranging from 10 to 45 kilometres. This proved to give a sufficient range of distances for analysis. Ideally a site will be selected with 10 km from a reference station between networks and another site that is roughly 50 km from a common reference station. These distances have been shown though prior studies to either reduce or increase ionospheric effects on GNSS NRTK positioning.

3.3.3 Location

General location of the site important, as local issues may affect the suitability of the site for GNSS purposes. The presence of any overhead or surrounding obstructions that could interrupt and interfere with satellite signal and have the potential to induce multipath errors needs to be considered (ICSM 2014b, p.6). In addition, the safety and stability of the surrounding area the survey mark is located in needs to be take into account in order for the safety of the surveyor and the general public are ensured as well as the equipment.

3.3.4 Site Analysis Tools

The Queensland Globe, a website run by the Queensland Government, hosts a catalogue of permanent marks, providing location and data about each mark. This is a valuable tool for selecting an appropriate location, providing many layers of useful map data. In addition, each commercial NRTK provider has a network coverage map which provides location and coordinates of its respective reference station network as well as displaying its online status. A combination of these tools was used to select survey marks for measurement.

3.3.5 Test Site 1

Two CORS sites are located within the Department of Natural Resources, Mines and Energy (DNRME) grounds in Toowoomba, Queensland. These reference stations are used within 2 of the commercial networks, and have two permanent marks within 100 m. The permanent marks are suitable to be measured by GNSS and have GDA94 coordinates that have good horizontal uncertainty. PM180957 was selected as test location number 1. It has a mostly uninterrupted view of the sky, with only a small number of larger trees within 20 metres, posing the only close by interruption to the site as depicted in Figure 3.1.

Figure 3.1: Location of test site 1 relative to local trees.

Test site 1 was chosen to provide a location that has the nearest base station within 10 kilometres. 2 commercial networks use base stations located under 100 metres, while the third has its nearest base within 8 kilometres. More detail is supplied in the Survey Control Mark Report attached in Appendix B. Test site 1 is chosen to give contrasting baseline distances to CORS and changes of CORS configurations between commercial providers in relation to the site. Figures 3.2, 3.3 and 3.4 provide context of the distribution of CORS (depicted by coloured markers) in each network in relation to test site 1 (depicted by black marker). Each network has a different density and range of CORS at this location.

This site has restricted public access and is in an unused section of the site, ensuring that the equipment to be used for test measurements will be free from disturbance.

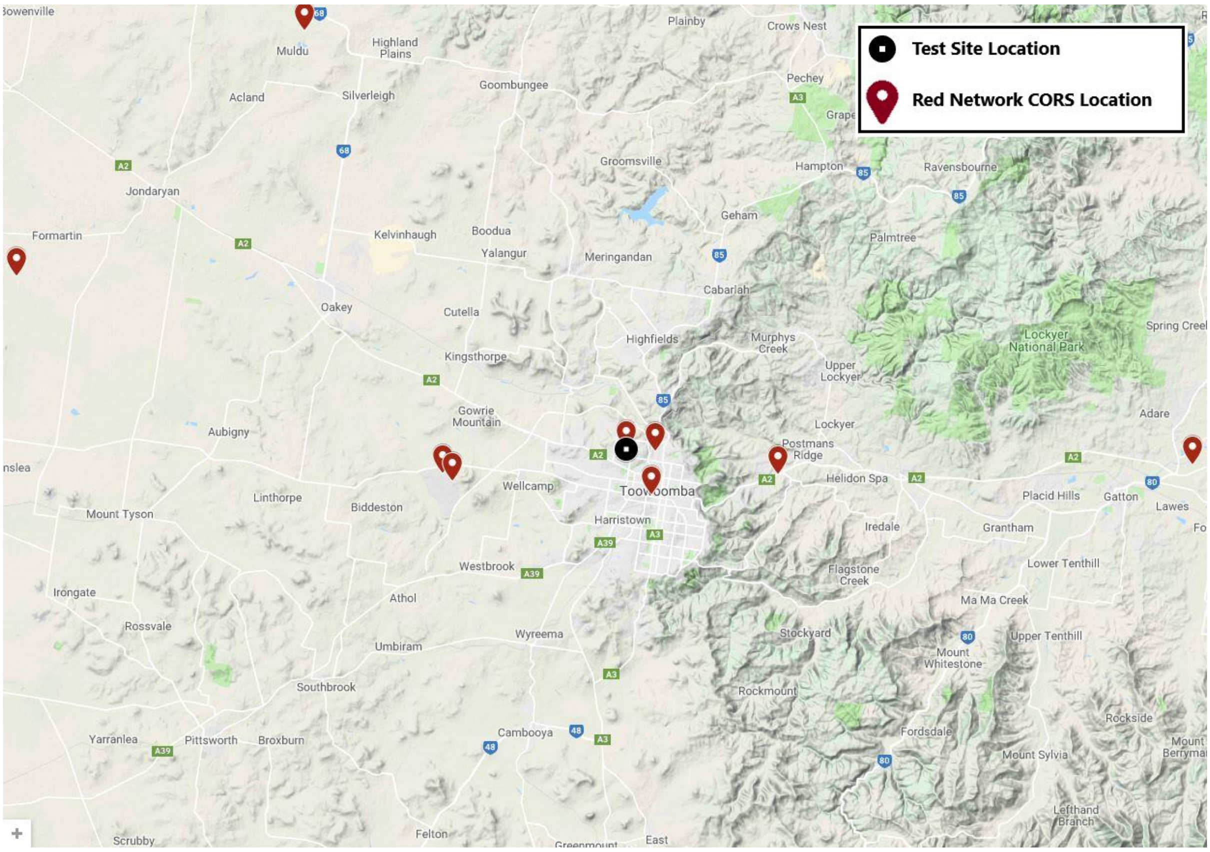

Figure 3.2: Map of local area of test site 1, depicting red network CORS configuration (Google Maps 2019).

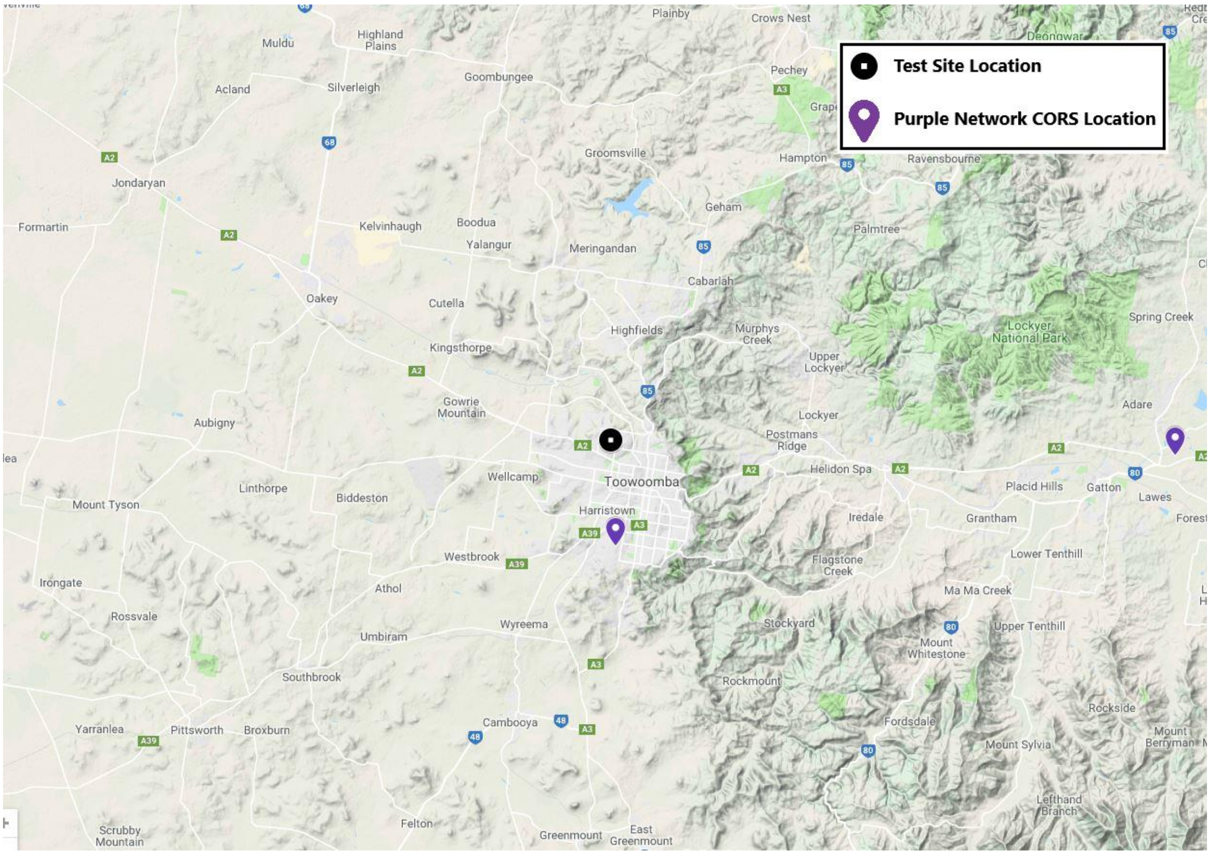

Figure 3.3: Map of local area of test site 1, depicting blue network CORS configuration (Google Maps 2019).

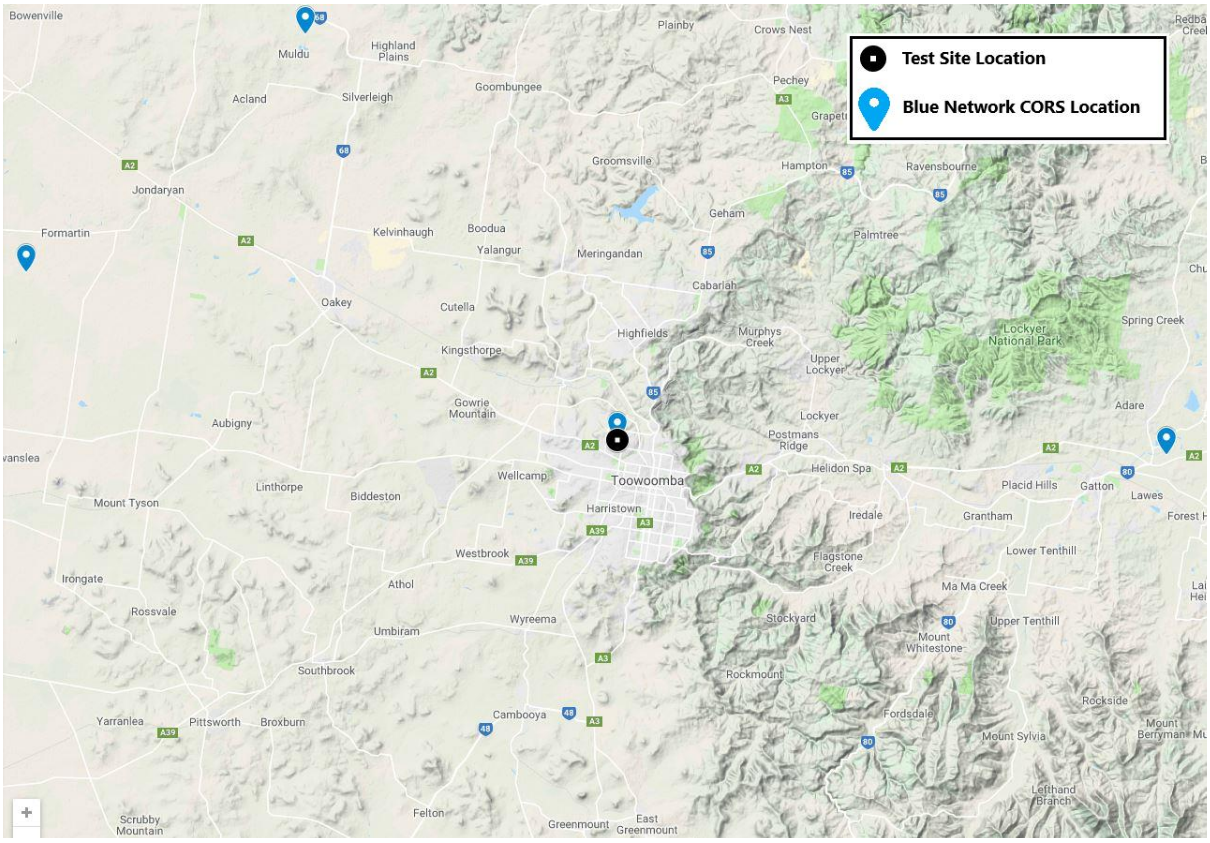

Figure 3.4: Map of local area of test site 1, depicting purple network CORS configuration (Google Maps 2019).

3.3.6 Test Site 2

A PM located on the road reserve of the New England Highway was selected for test site 2. PM206731 has little obstruction to the sky, suitable to be measured by GNSS and has GDA94 coordinates that have good horizontal uncertainty. Figure 3.5 depicts the typical terrain present at the site. A significant buffer from the road way was also present.

Figure 3.5: Site depiction of test site 2.

Test site 2 was selected to provide a larger distance between reference stations and to the PM, with nearest base locations ranging from 28 to 48 kilometres. Geometry of CORS in the networks are different for each provider. This configuration will be used to test each networks ability to provide corrections at longer distances and how these differences affect measurements. More of this mark is supplied in the Survey Control Mark Report attached in Appendix B. Figures 3.6, 3.7 and 3.8 show the relationships of each network to the test site.

Figure 3.6: Map of local area of test site 2, depicting the red network CORS configuration and test site 1 in Toowoomba (Google Maps 2019).

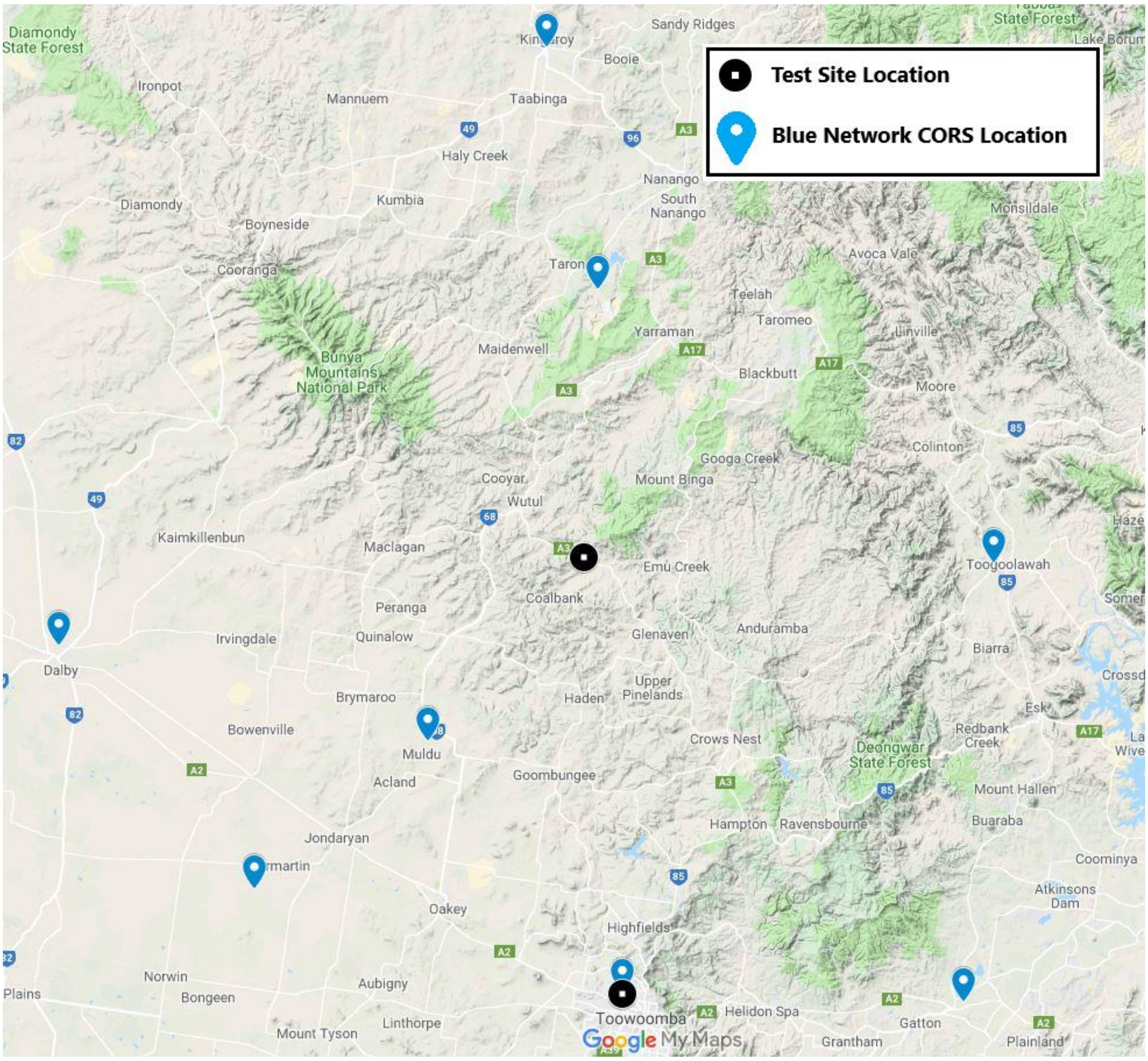

Figure 3.7: Map of local area of test site 2, depicting the blue network CORS configuration and test site 1 in Toowoomba for reference (Google Maps 2019).

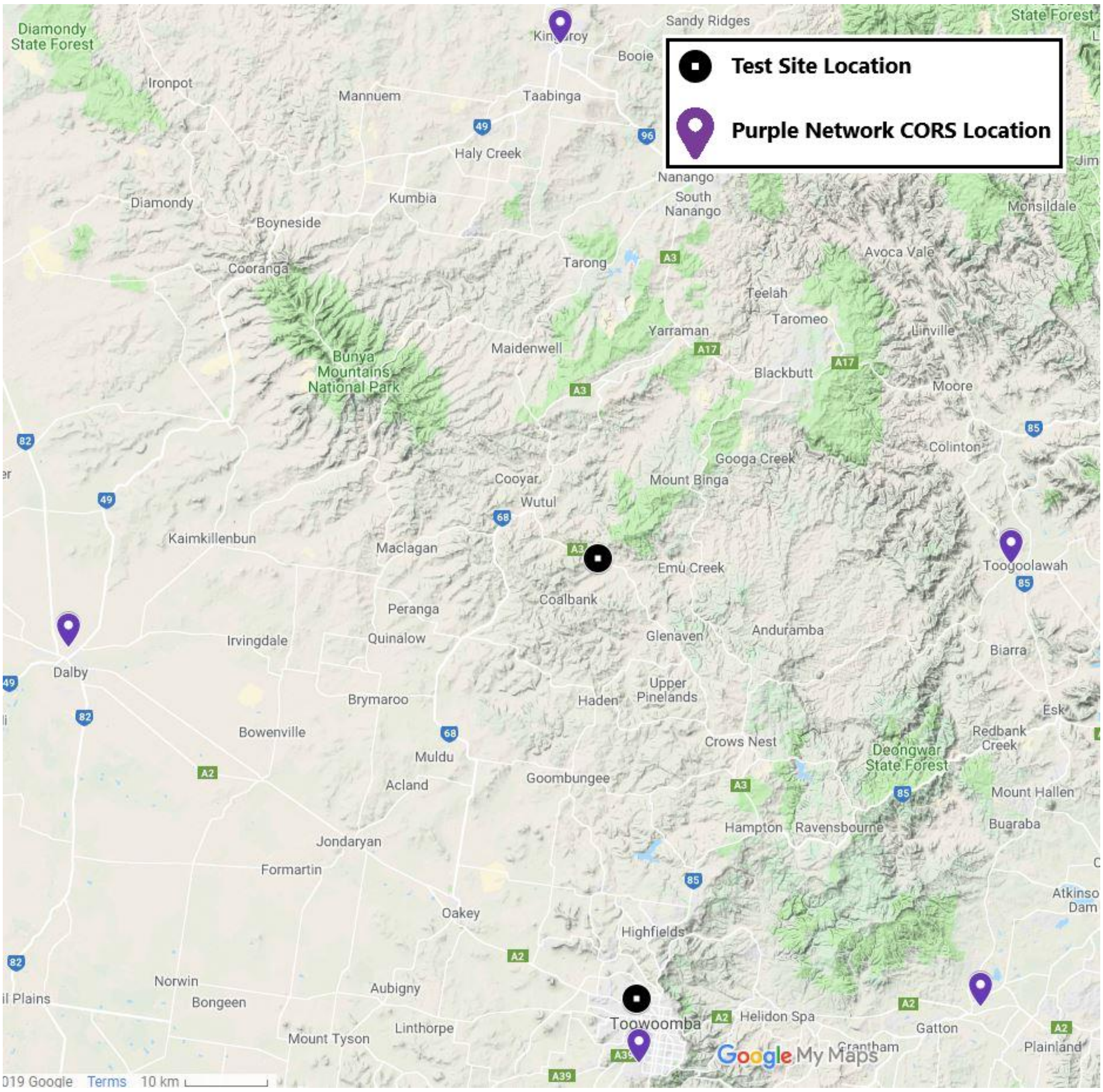

Figure 3.8: Map of local area of test site 2, depicting the purple network CORS configuration and test site 1 in Toowoomba for reference (Google Maps 2019).

3.4 Equipment

3.4.1 Static GNSS Equipment

For static GNSS measurements a Trimble R2 receiver and TSC3 controller was used. The Trimble R2 antenna and TSC3 controller, refer to Figure 3.9. The R2 is specified to have a horizontal accuracy of 3mm + 0.5 ppm RMS. The antenna is capable of connecting to controllers via wireless Bluetooth connection. Further details are included on the data sheet for the R8 found in Appendix C

Figure 3.9: Trimble R2 antenna and TSC3 controller (Trimble 2019).

3.4.2 NRTK GNSS Equipment

Many manufacturers each have GNSS equipment that is capable of accepting the required survey grade network corrections for, however a Leica GS18 GNSS receiver was chosen due to familiarity (seen in Figure 3.10).

The GS18 receiver connects to a Leica CS20 controller via Bluetooth connection which supplies the network corrections via a 3.5G internet connection. The GS18 receiver has 4G internet capability, however 4G reception was not available at test site 2 and was not used at either site 1 or 2. The GS18 is specified to have a horizontal accuracy of 8mm + 1 ppm. The CS20 controller runs Leica Captivate software which has the ability to configure separate NRTK settings which was used to provide a separate profile for each correction service and correction type. Further details are included on the data sheet for the GS18 and CS20 found in Appendix D. SmartNet Aus, VRS now and AllDayRTK provided each respective network correction and will the main focus of the analysis. To perform field work a tripod, tribrach and GNSS antenna adaptor was required.

Figure 3.10: Leica GS18 and CS20 controller(Leica Geosystems 2019).

3.5 Field Work

3.5.1 Static Data

To begin data acquisition, each permanent mark was measured by static post processed observations to confirm the supplied coordinates, and act as a check measurement for the test data set. Berber & Arslan (2013) and Edwards et. al. (2010) used a similar process with static data to provide a truth coordinate to substantiate test measurements in each respective study.

AUSPOS is a free online post processing service that is provide by Geoscience Australia. RINEX data is needed for processing by AUSPOS, with a minimum of one hour of raw GPS observations (Geoscience Australia 2019). Access to site and travel times dictated the length of static observations to six hours providing more than the minimum amount Geoscience Australia requires. At each location a Trimble R2 receiver and TSC3 controller was used to record the static data and what set up on a tripod over each mark. A DNRME field observation record sheet was used to ensure critical information including station information, time of observation, receiver height and weather information was recorded for future reference and analysis (see Appendix E).

3.5.2 NRTK Data

Once static measurements were complete, NRTK test measurements commenced on each chosen permanent mark. A series of test cases was established to test each correction provider and correction type. 16 separate test cases were identified to provide data for analysis. Point numbers have been assigned using the variables outlined in the test case list. Colours have been assigned to avoid bias in service providers. Chapter 4 will further list and explain the test cases A 4 digit number system was used to uniquely identify each point measured in each round, as follows:

- Fist digit represents the round number the point is measured in. These ranged from 1 to 6.
- Second digit represented the correction type. These ranged from 1 to 4.
  - VRS = 1, Nearest Base = 2, IMAX = 3, MAC = 4
- Third digit represents the test length. These included 1 & 2.
  - 1 = 60 epochs, 2 = 120 epochs
- Fourth digit represents the service provider. These ranged from 1 to 3.
  - Blue = 1, Red = 2, Purple = 3

For example, the decoding point number 3321 would result in:

3rd Round – IMAX – 120 epochs – Blue

As a minimum benchmark, 60 epochs of data were recorded, with this timeframe being the minimum stated by the ICSM guidelines (2014b, p.9). A maximum of 300 epochs of data has been determined to be the upper limit of time needed for NRTK data, with the law of diminishing returns reducing the need to observe for any longer (Allahyari et al. 2018, p. 12). Due to site specific time constraints, 120 epochs of data was established to be the maximum duration for NRTK measurements.

The following series of tests were performed on both locations:

- 60 epochs observation using VRS, Nearest Base, IMAX & MAC corrections
- 120 epochs observation using VRS, Nearest Base, IMAX & MAC corrections

Each measurement round consisted of the 16 test cases. Each correction type was measured in series to get similar satellite configurations for each NRTK provider. This has been seen by Edwards et. al. (2010, p. 12) to avoid any bias that could occur with changing number of satellites in view over longer periods of time.

Multiple rounds of measurements will be required, with ICSM guidelines specifying a gap of 30 minutes between rounds. Edwards et. al. (2010, p. 34) found that 20 minutes between rounds provided improvements to accuracy and reduces the effects of multipath on observation sets, with above 45 minutes showing little improvement. Due to the time taken to complete a measurement round an average of 50 minutes elapsed between measurement sessions.

The minimum specified by ICSM guidelines is set to two. Additional rounds will add to the quality of the data and potentially offer clearer analysis. Available battery storage limited field sessions to 6 measurement rounds.

Whilst there are many methods surveyors employ to configure an NRTK rover for field survey, it has been shown in previous studies such as Garrido et. Al. (2011) and Edwards et. al. (2010) that a solid platform such as a pillar or tripod is required to ensure there are not setup induced errors when mounting a GNSS receiver for field testing. Berber & Arslan (2013) used a pole and bipod method for conducting filed work. While this is a commonly accepted method for using a NRTK rover in the field, setup repeatability could become an issue over long observation periods such as what was experienced in this study. From these considerations, a tripod and tribrach was used to setup the GNSS receiver over the permanent marks being measured.

A single receiver setup was also employed. This ability of the GS18 to be able to connect to multiple NRTK providers avoided the need to have separate sets of equipment that would require frequent set ups to perform respective NRTK measurements. It will remain in service for each correction service and will be restarted at the end of each measurement so that a new set of ambiguities are solved to achieve independent observations. Other methods have included multi antenna setups as employed by Edwards et. al. (2010, pp. 11-2) and antenna signal splitting by Garrido et. Al. (2011, p259). These methods did not instil confidence that a replicated methodology would yield reliable results in this instance. Both authors then employed software algorithms to split large data samples of NRTK observations. This broke up the data into varying sample sizes of epoch data for further analysis. Whilst these are valid methods they have been deemed beyond the scope of this project.

A test case list field sheet was used to create a field procedure list for accurate point information and data collection. The test case list kept a separate record of each measurement providing a record of date, time, duration, settings and the equipment used, so that further analysis of factors outside of the raw data can be analysed at a later date. This list was checked when settings were selected, point number was entered into the controller and when the point was stored. Additional comments provided room for any anomalies that were experienced during measurement rounds such as long initialisation times or incorrect point information was stored. An example test case list can be found in Appendix F.

3.5.3 Measurement Settings

Before entering the field, network settings were entered into the Leica CS20 controller for quick access during observation times. RTCM 3 was used as the transmission format for all connections. Garrido et. Al. (2011, p258) used this transmission method in their study as it is a widely used publicly available format that is compatible with MAC and VRS based network corrections.

To further avoid any positional bias between measurement positions, the changing of network connection types disconnected the receiver from the NTRIP caster, losing the phase solution between storing the next position. Garrido et. Al. (2011, p258) found this to be a valid methodology was this best solution for this study.

3.6 Data Collection

At the end of field measurement field checklists were completed noting exported file name on the respective field sheet.

Static files were downloaded straight from the R2 receiver connected via USB cable to a laptop. The raw data files were then uploaded to cloud storage in addition to the laptop hard drive. This ensures data redundancy in the event of data corruption on one of these storage mediums. Trimble Convert to RINEX version 3.12 software changed the raw data file downloaded from the receiver to RINEX file format, which was then forwarded to AUSPOS for postprocessing. Results from AUSPOS were checked against permanent mark information obtained from the Queensland Globe and stored for further analysis.

NRTK files were downloaded from the CS20 controller to an SD card in a .csv file format. Similarly to the raw static files, the .csv files were stored on a laptop and cloud storage via transfer from the SD card to ensure data redundancy. No additional processing of the .csv file was required for analysis. A copy of raw data for PM180957 and PM206731 is attached in Appendix G & H.

3.7 Conclusion

The methodology outlined in this section was formulated from previous literature review, which was critically analysed to ensure suitability for this study. The following steps were taken to successfully complete field data acquisition:

- Site analysis and selection
- Equipment selection and justification
- Establish test cases for analysis
- Establish field procedures
- Undertake static check measurements
- Carry out field work
- Download and prepare data for analysis

Chapter 4 - Results

4.1 Introduction

It is important to display data in unbiased fashion so that impartiality can be maintained throughout the analysis and not effect conclusions and recommendations. This can be achieved by keeping a number and colour system when referring to hardware manufacturers and network providers. Each commercial network provider has been assigned a colour and shape to display coordinate information on the scatter graph. This has been done to avoid identifying each provider and to aid in visual analysis. Table 4.1 defines the 16 test cases that were used to obtain the following data in this chapter.

Table 4.1: Table represents 1 round of the 16 test cases observed in the field.

Test Case	Procedure	Solution type	Test length	Service	Point number
1	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	VRS	1 min test	Blue	1111
2		VRS	1 min test	Red	1112
3		VRS	1 min test	Purple	1113
4	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	VRS	2 min	Blue	1121
5		VRS	2 min	Red	1122
6		VRS	2 min	Purple	1123
7	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	Nearest Base	1 min test	Blue	1211
8		Nearest Base	1 min test	Red	1212
9		Nearest Base	1 min test	Purple	1213
10	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	Nearest Base	2 min	Blue	1221
11		Nearest Base	2 min	Red	1222
12		Nearest Base	2 min	Purple	1223
13	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	IMAX	1 min test	Blue	1311
		-		Red	
		-		Purple	
14	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	IMAX	2 min	Blue	1321
		-		Red	
		-		Purple	
15	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	MAC	1 min test	Blue	1411
		-		Red	
		-		Purple	
16	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	MAC	2 min	Blue	1521
		-		Red	
		-		Purple	

The colours that have been implemented in the following analysis and results sections are as follows:

- Purple – Network 1, VRS and Nearest Base
- Red – Network 2, VRS and Nearest Base
- Blue – Network 3, VRS and Nearest Base
- Black/Red (Orange for Black Background) – Network correction type IMAX
- Black (White for Black Background) – Network correction type MAC

From literature examined in Chapter 2, colour coded scatter plots like the sample provided in Figure 4.1 was shown to be an ideal visual tool when performing analysis of observations. Plots consists of Easting and Northings obtained in tests against the Easting and Northing set to 0,0 for the benchmark. This can show trends in movement from the benchmark of each individual private network (Edwards et. al. 2010, p. 22).

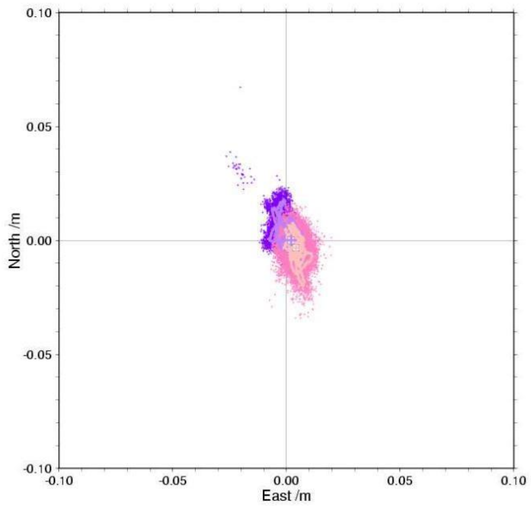

Figure 4.1: Scatter plot of VRS NOW and SmartNet observations (Edwards et. al. 2010, p. 22).

Each data file containing project measurements exported from Leica software has been uploaded and analysed in Microsoft Excel providing a slight variation of the previously mentioned method. Easting and Northing coordinates from test cases have been plotted on a X,Y scatter graph. A total of 96 points have been recorded for each PM. Reference station information, quality indicators and number of tracked satellites for each point is also included in the original export. This addition information provides quantifiable evidence for additional analysis beyond original point coordinates. Each test case has also been reduced to find a mean value for the 6 rounds of data at each site. This is calculated by adding the Easting or Northing values for each test case and dividing the result by the number of rounds.

4.2 PM180957

4.2.1 VRS 60 epochs

Each group of points obtained with VRS corrections and 60 epochs are displayed in Figure 4.2.

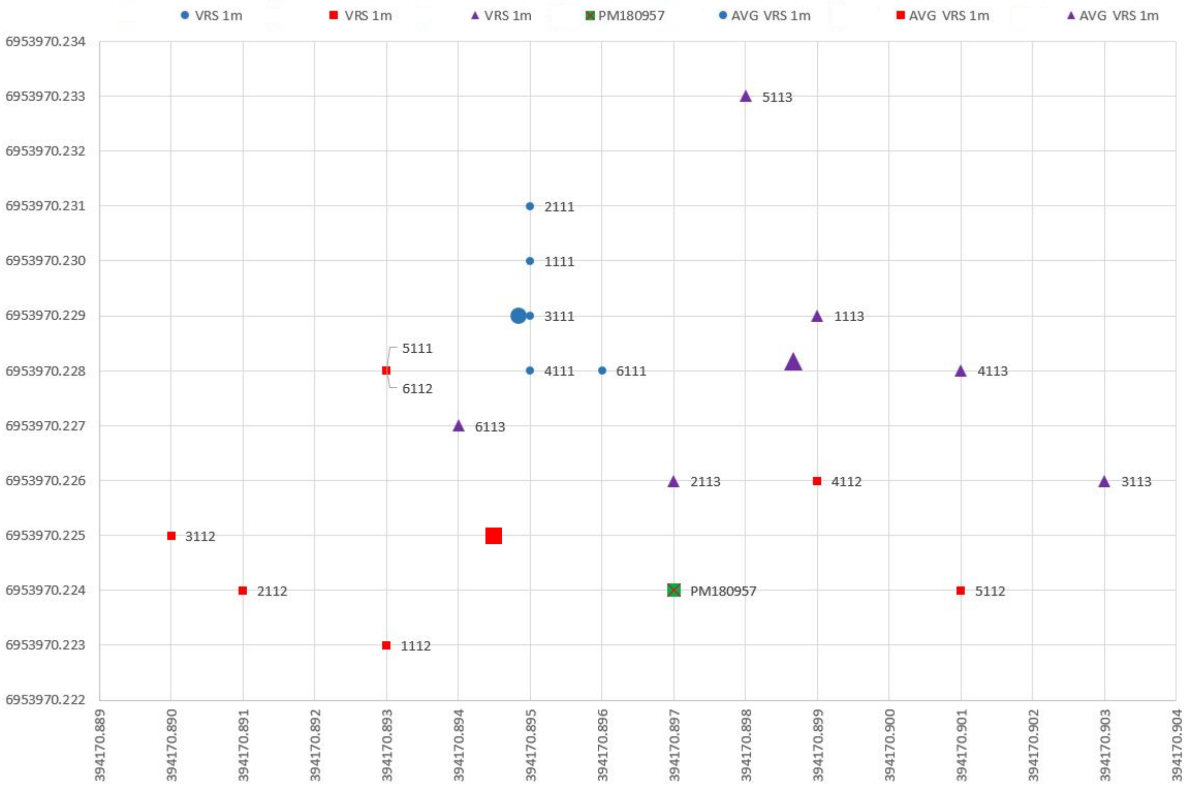

Figure 4.2: Scatter graph displaying VRS corrections and 60 epochs of data displayed with coordinates of PM180957 for reference. Larger icon represents the average of the 6 rounds of observations.

There are no discernible differences in point positions for this correction type between correction providers. Blue positions 1111 to 4111 share Easting coordinates of 394170.895 and form a structured pattern to their positions which is dissimilar to the 2 other correction providers point groupings. Further inspection of reference station coordinates for points 1111 to 4111 shows no similar pattern in point positions.

4.2.2 VRS 120 epochs

Each group of points obtained with VRS corrections and 120 epochs are displayed in Figure 4.3.

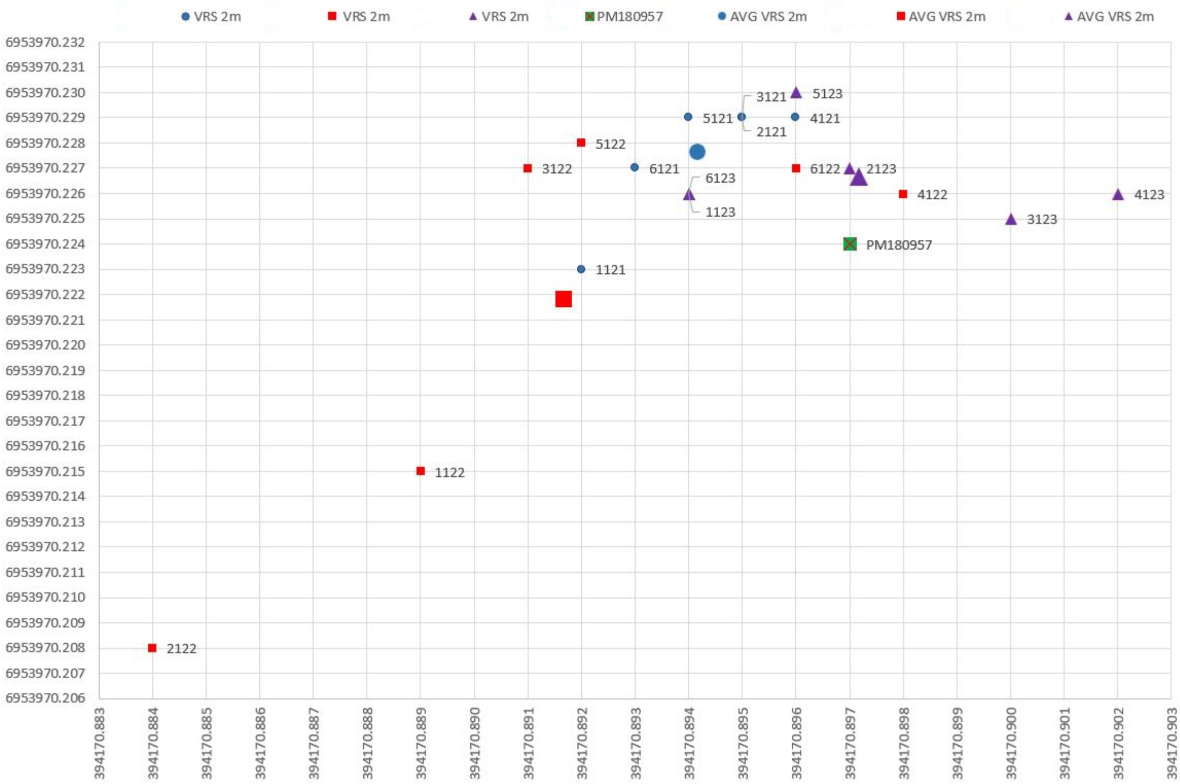

Figure 4.3: Scatter graph displaying VRS corrections and 120 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

The red network displayed similar positions to the blue network with the exception of 2 points 1122 & 2122. These points have shifted the mean of the 6 points collected in a south westerly direction away from the other point distributions. No other attributes behind these points stand out from the others observed in this series and would point to being outliers. Figure 4.4 shows the new set with the removal of points 1122 & 2122 and the new average coordinate.

Figure 4.4: Scatter graph displaying the new red network VRS corrections and 120 epochs of data displayed with original blue and purple data sets and coordinates of PM180957 for reference.

The longer observation times of the blue network do not repeat the previous formation of similar Easting coordinates seen in points 1111 to 4111.

With the exception of 4 points from the 60 & 120 epoch VRS sets of data, all positions are north of the reference PM180957 coordinate.

4.2.3 Nearest Base 60 epochs

Each group of points obtained with nearest base corrections and 60 epochs are displayed in Figure 4.5.

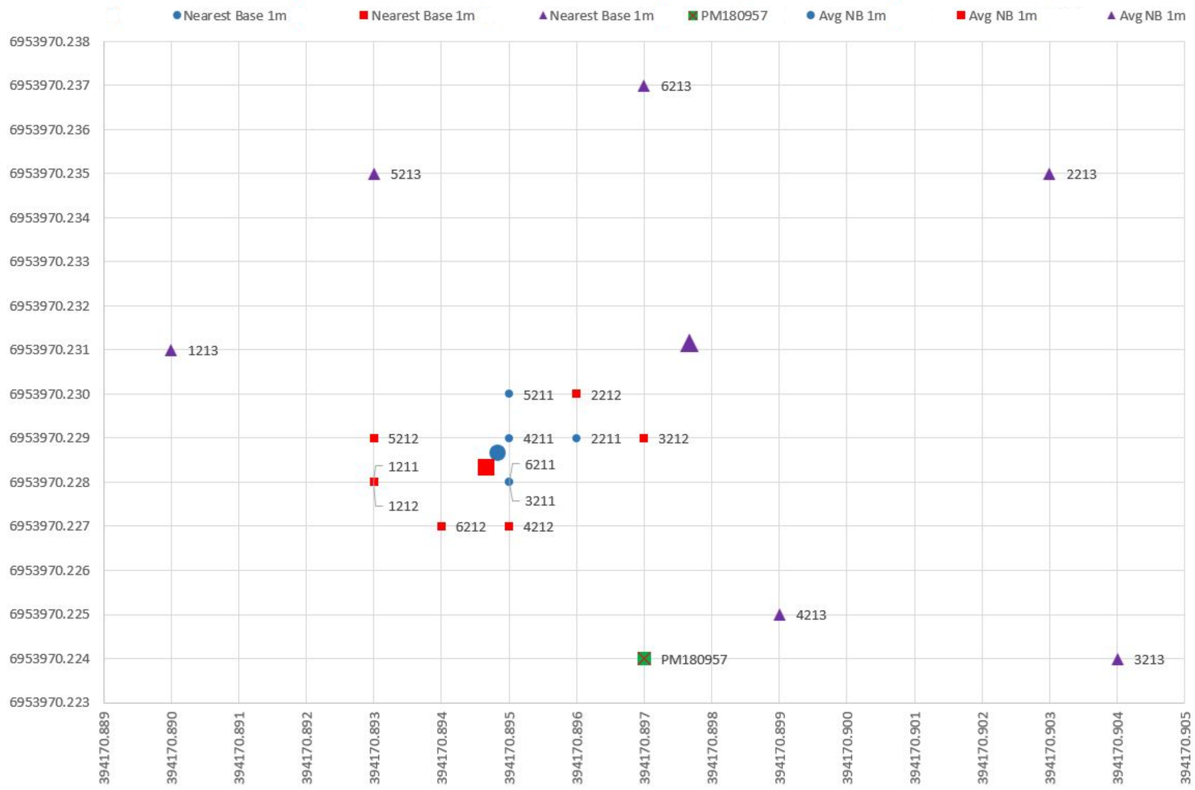

Figure 4.5: Scatter graph displaying nearest base corrections and 60 epochsof data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

Initial visual analysis shows that both red and blue corrections have a similar dispersed grouping. The purple corrections show a larger spread around the permanent mark coordinate, however 2 points - 4313 and 3213, both share similar Northing coordinates to the reference PM coordinate.

Further inspection of reference station coordinates for these positions shows that both red and blue points are linked to the nearest CORS at a distance of 63 metres. The nearest CORS for purple corrections is 7.5 kilometres away from the test location.

Each point observed has a similar amount of satellites between correction services. It is noted that the amount of satellites tracked reduces as the day progresses. Initial observations show 11 to 12 GPS satellites and 5 or 6 GLONAS satellites, with the number at the end of the day reducing to 8 and 5 satellites respectively.

4.2.4 Nearest Base 120 epochs

Each group of points obtained with nearest base corrections and 120 epochs are displayed in Figure 4.6.

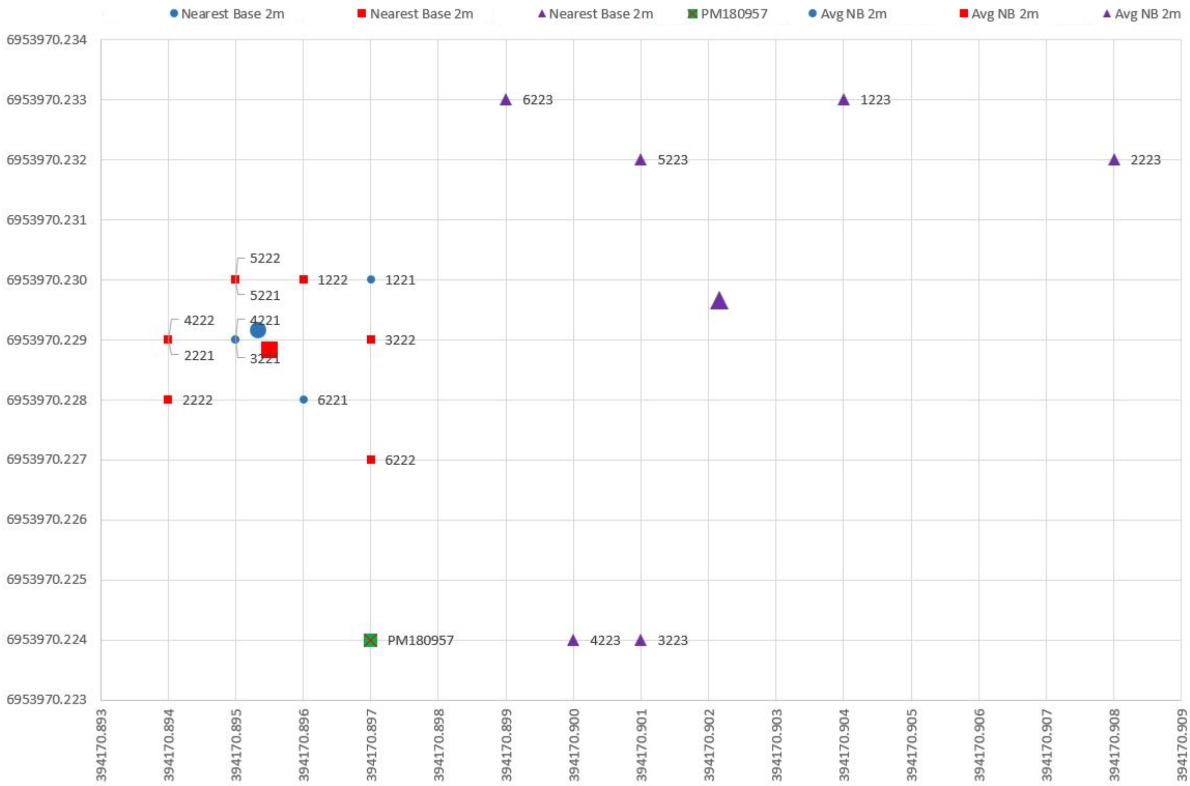

Figure 4.6: Scatter graph displaying nearest base corrections and 120 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

The longer observation times of the red and blue networks repeat the similarities seen from the shorter observation times. Additionally, the same 2 rounds (3 & 4) of observations from the purple data set display a similar Northing coordinate to the reference PM coordinate, whilst the remainder of points are in a much different Northing position.

All points observed in the VRS data set are north of the reference PM coordinate.

4.2.5 IMAX 60 epochs

Only one network provider offers an IMAX correction service at the time of testing. For analysis purposes this correction type was overlayed with VRS and nearest base correction types with observation lengths of the same time.

Figure 4.7 depicts the IMAX correction type with the VRS corrections, all using 60 epochs of data.

Figure 4.7: Scatter graph displaying IMAX and VRS corrections, all sampled with 60 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

IMAX points are close to the blue correction service mean point coordinate, with both point groups sharing a similar position from the reference coordinate.

Additionally, the IMAX 60 epoch data is shown in Figure 4.8 with the nearest base 60 epoch data set.

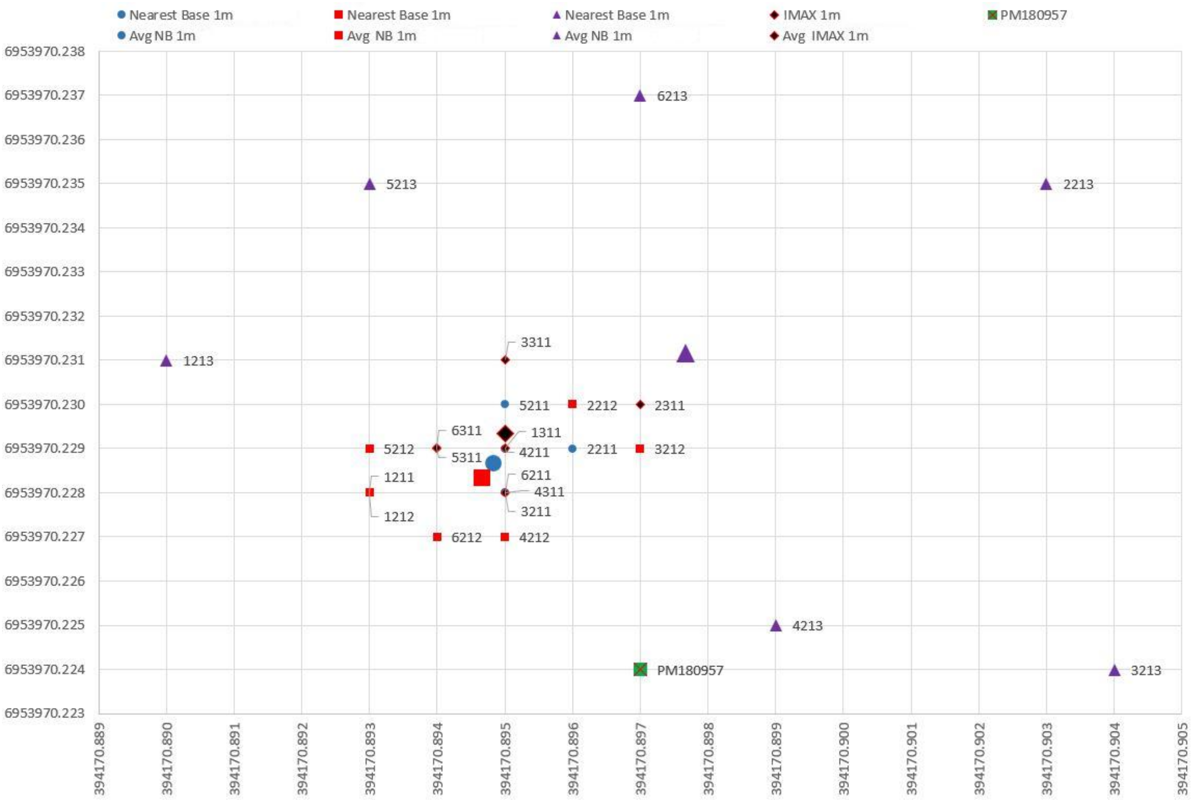

Figure 4.8: Scatter graph displaying IMAX and Nearest Base corrections, all sampled with 60 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

The mean coordinate of IMAX corrections are very similar to the red and blue networks mean coordinates. The IMAX reference coordinate is traced to the same point as seen with the blue and red networks nearest base reference station.

4.2.6 IMAX 120 epochs

Figure 4.9 depicts the 120 epoch results of IMAX and VRS correction types.

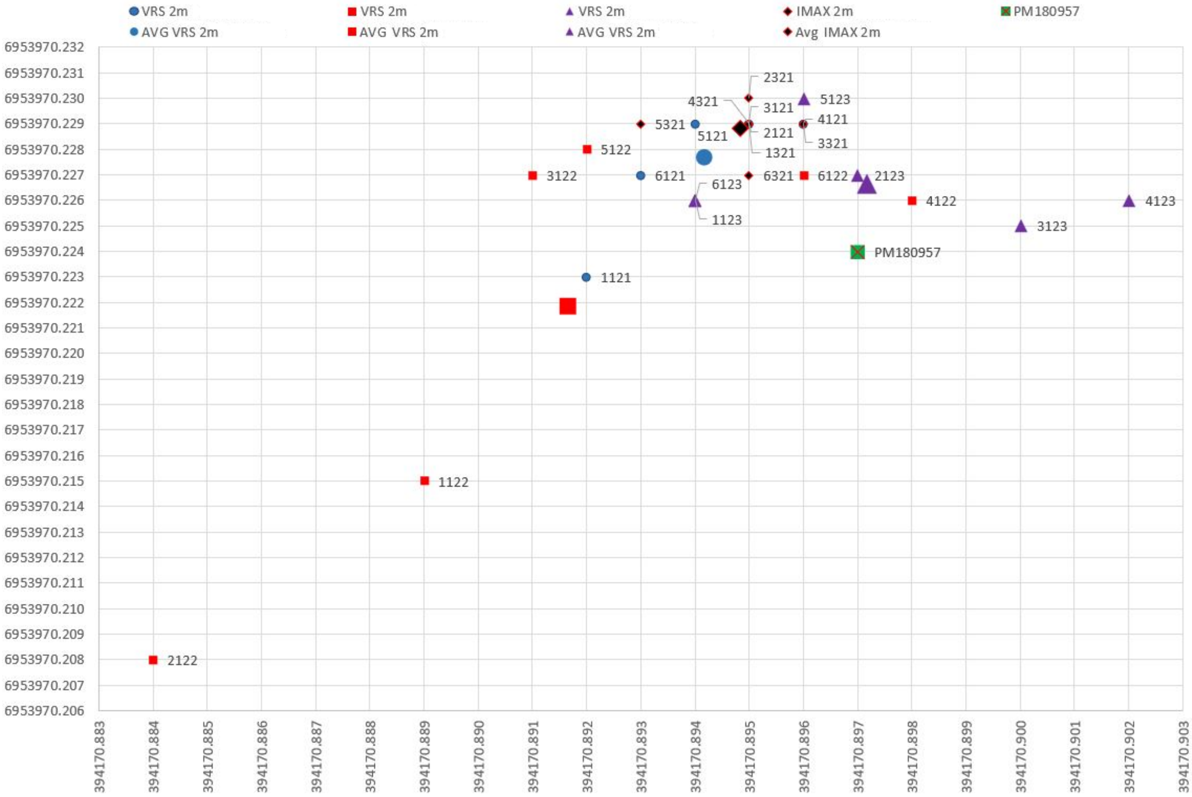

Figure 4.9: Scatter graph displaying IMAX and VRS corrections, all sampled with 120 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

IMAX point distribution is very small, with density ranging in a 3 millimetre square area. In a similar way to the 60 epoch data set, the mean of IMAX point coordinates is similar to the blue network. Figure 4.10 shows the 120 epoch results of IMAX and Nearest Base correction types.

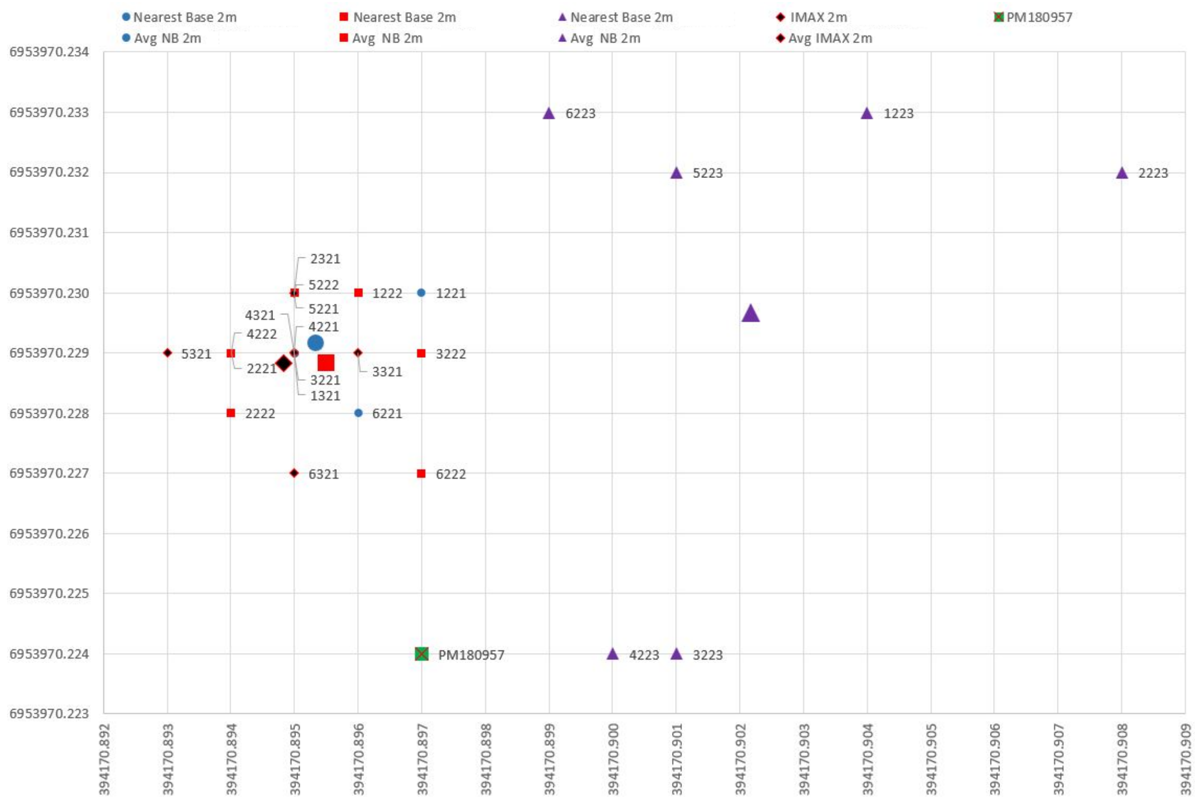

Figure 4.10: Scatter graph displaying IMAX and Nearest Base corrections, all sampled with 120 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

Clear separation can be seen between the IMAX, blue and red network data sets and the purple data set. Each average coordinate of IMAX, blue and red networks are very closely aligned falling within 1 mm of each other.

4.2.7 MAC 60 epochs

As with the IMAX correction type, MAC corrections are only supported with 1 network provider, and will be analysed with the nearest base and VRS correction types.

Figure 4.11 depicts the MAC correction type with the VRS corrections, displaying 60 epochs of data.

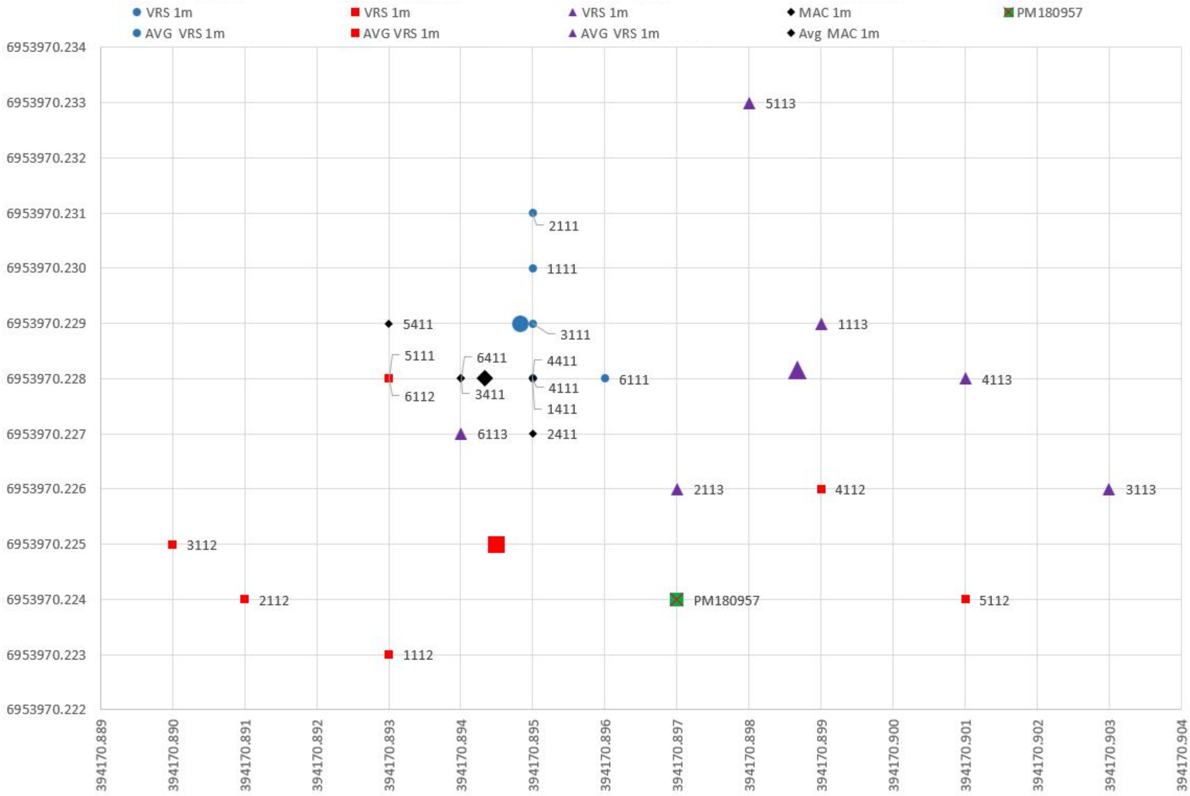

Figure 4.11: Scatter graph displaying MAC and VRS corrections, all sampled with 60 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

The MAC corrections show a very small grouping in comparison to the other 3 networks but have a similar average coordinate to the blue network. As with the IMAX corrections, the reference station coordinate is in line with the red and blue networks.

Figure 4.12 depicts the MAC correction type with the Nearest base corrections, displaying 60 epochs of data.

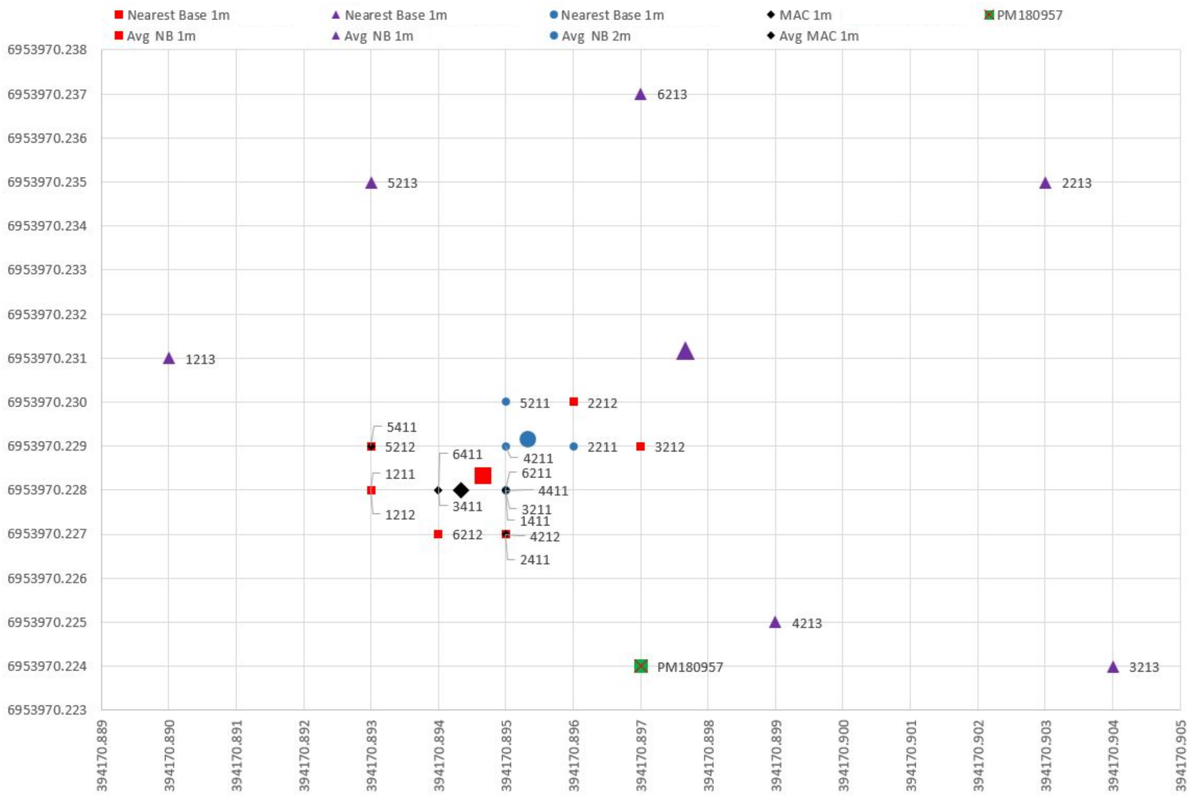

Figure 4.12: Scatter graph displaying MAC and Nearest Base corrections, all sampled with 60 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

As with the similar comparison with IMAX corrections, the MAC & Nearest Base corrections from the red and blue networks are quite similar and share the same reference station coordinate. The purple network has a larger grouping but presents a similar average coordinate.

4.2.8 MAC 120 epochs

Figure 4.13 depicts the 120 epoch results of MAC and VRS correction types.

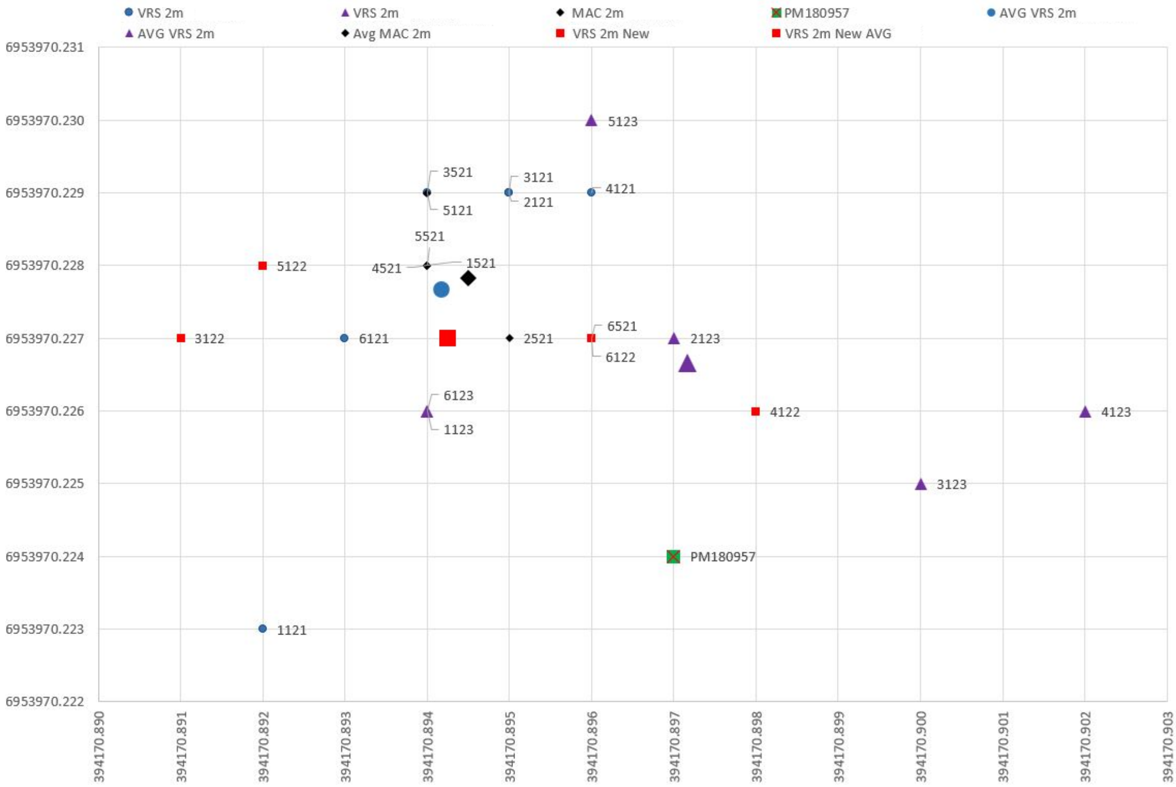

Figure 4.13: Scatter graph displaying MAC and VRS corrections, all sampled with 120 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

The MAC blue and red corrections have close average coordinates, and smaller groupings of points, however the purple network's average coordinate is closer to the PM coordinate.

Figure 4.14 shows the 2 minute Nearest Base corrections with the MAC data set. As per the similar dataset relating to the IMAX correction types, the MAC series has a close relationship with the red and blue data sets.

Figure 4.14: Scatter graph displaying MAC and Nearest Base corrections, all sampled with 120 epochs of data displayed with coordinates of PM180957 for reference. Larger icons represent the average of the 6 rounds of observations.

4.3 PM206731

4.3.1 IMAX & VRS 60 epochs

All VRS and IMAX corrections with 60 epochs are displayed in Figure 4.15

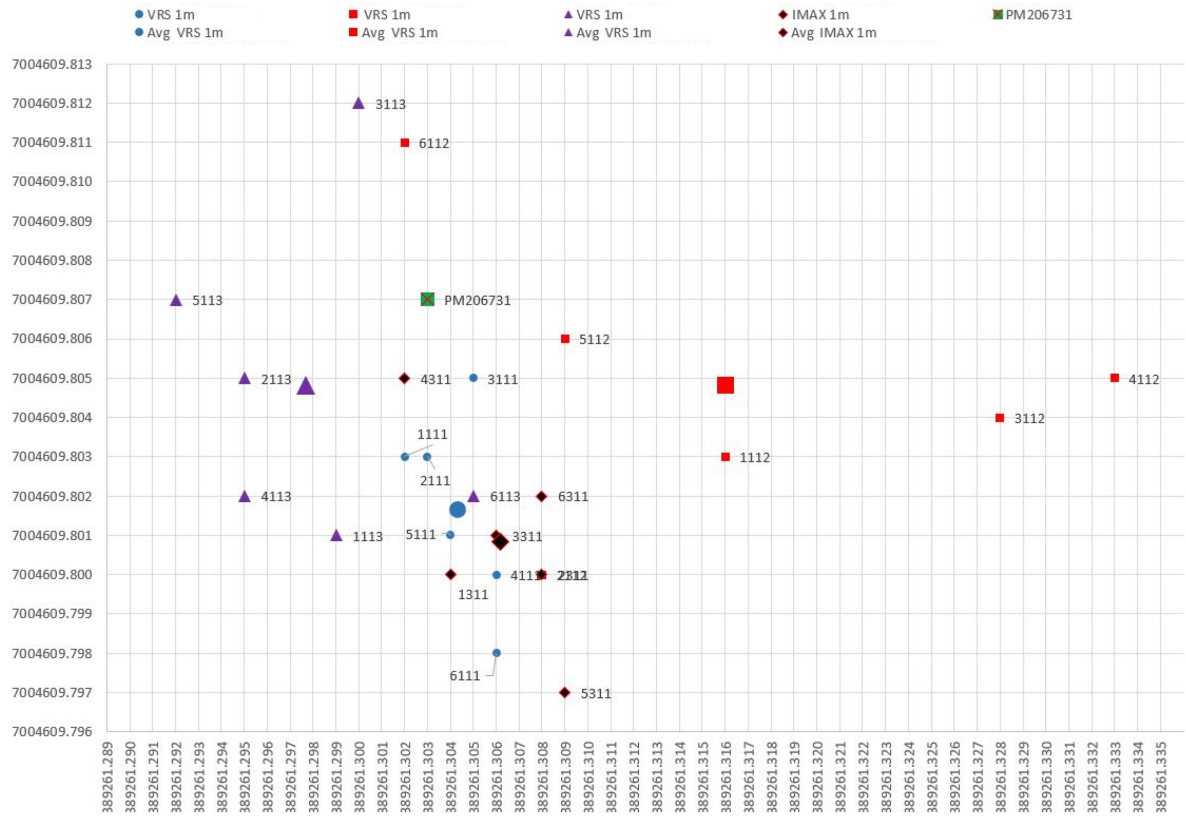

Figure 4.15: Scatter graph displaying IMAX and VRS corrections, all sampled with 60 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

The majority of the points lie to the south of the PM coordinate, with only 3113 and 6112 to the north. Groups have formed from each network provider, with a small amount of overlap between each network. The purple network group has fallen to the west and the red network group to the east. The blue network and IMAX points share a general similarity between the groups, having a similar Easting value to the PM while having a greater variation in nothing coordinates.

4.3.2 MAC & VRS 60 epochs

Figure 4.16 shows the 60 epoch data set of VRS and IMAX corrections.

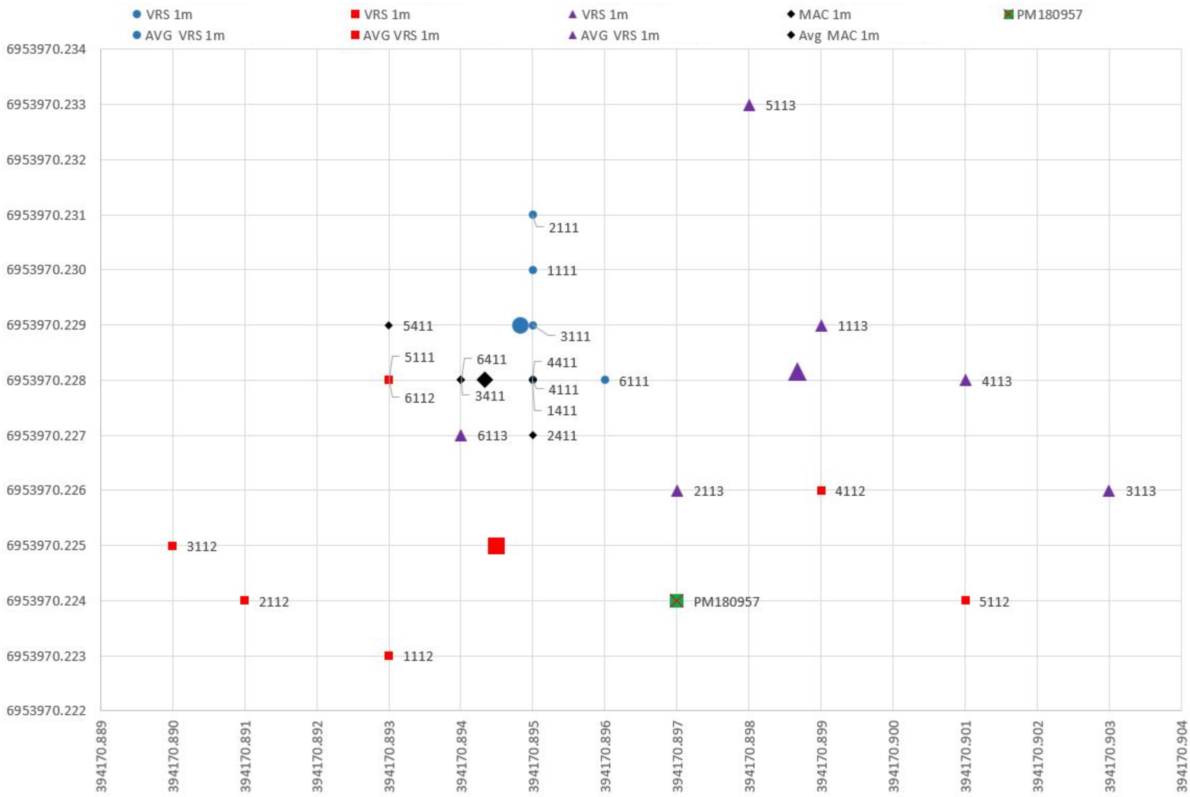

Figure 4.16: Scatter graph displaying MAC and VRS corrections, all sampled with 60 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

In addition to the IMAX data in Figure 4.16, the MAC data set shows less resemblance to the blue network, with the group having an average coordinate further away from that of the PM.

4.3.3 IMAX & VRS 120 epochs

Figure 4.17 shows the 120 epoch data set of VRS and IMAX corrections.

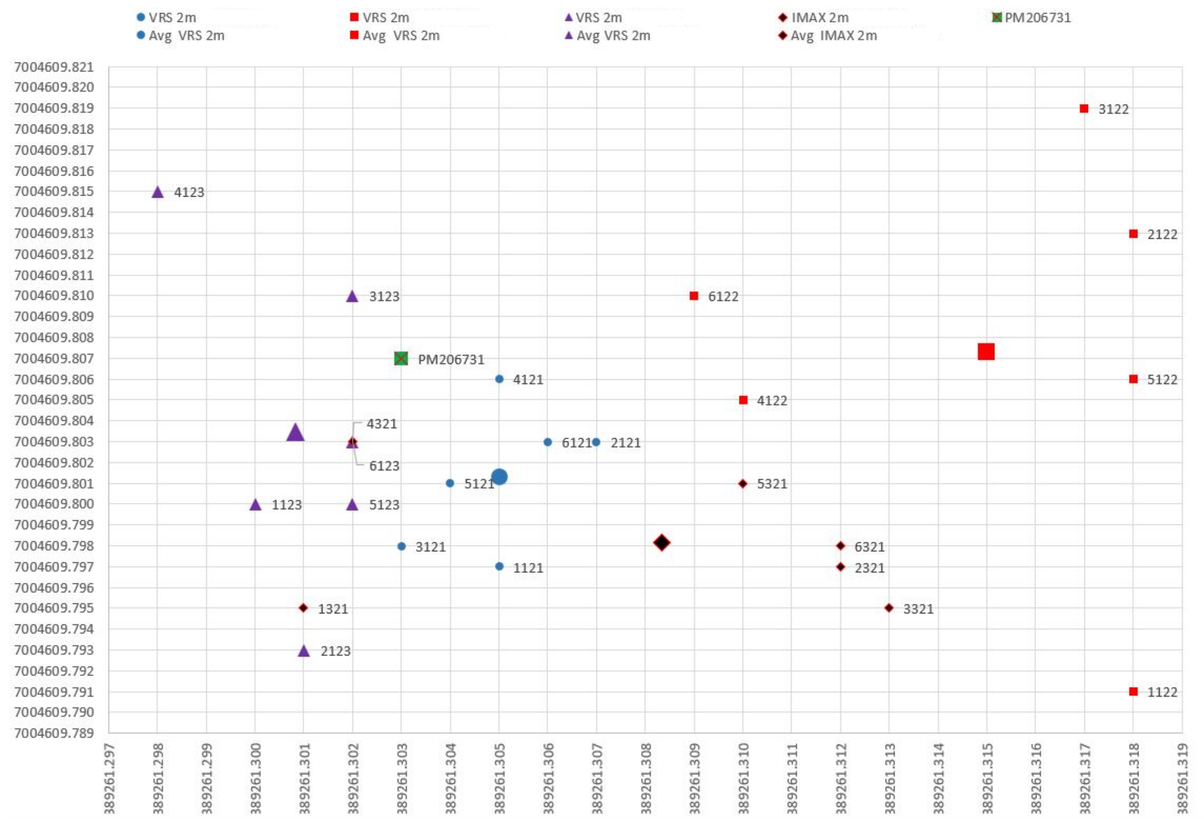

Figure 4.17: Scatter graph displaying IMAX and VRS corrections, all sampled with 60 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

The longer data sample shows a shift of each group to the north east when compared to the 60 epoch set. The groupings have as similar layout to the shorter set, with each network provider having a similar location in respect to the others with the exception of the IMAX data moving further to the east from the blue data. The blue network shows the smallest grouping while the purple network's average coordinate is the closest to that of the PM.

4.3.4 MAC & VRS 120 epochs

Figure 4.18 shows the 120 epoch data set of VRS and MAC corrections.

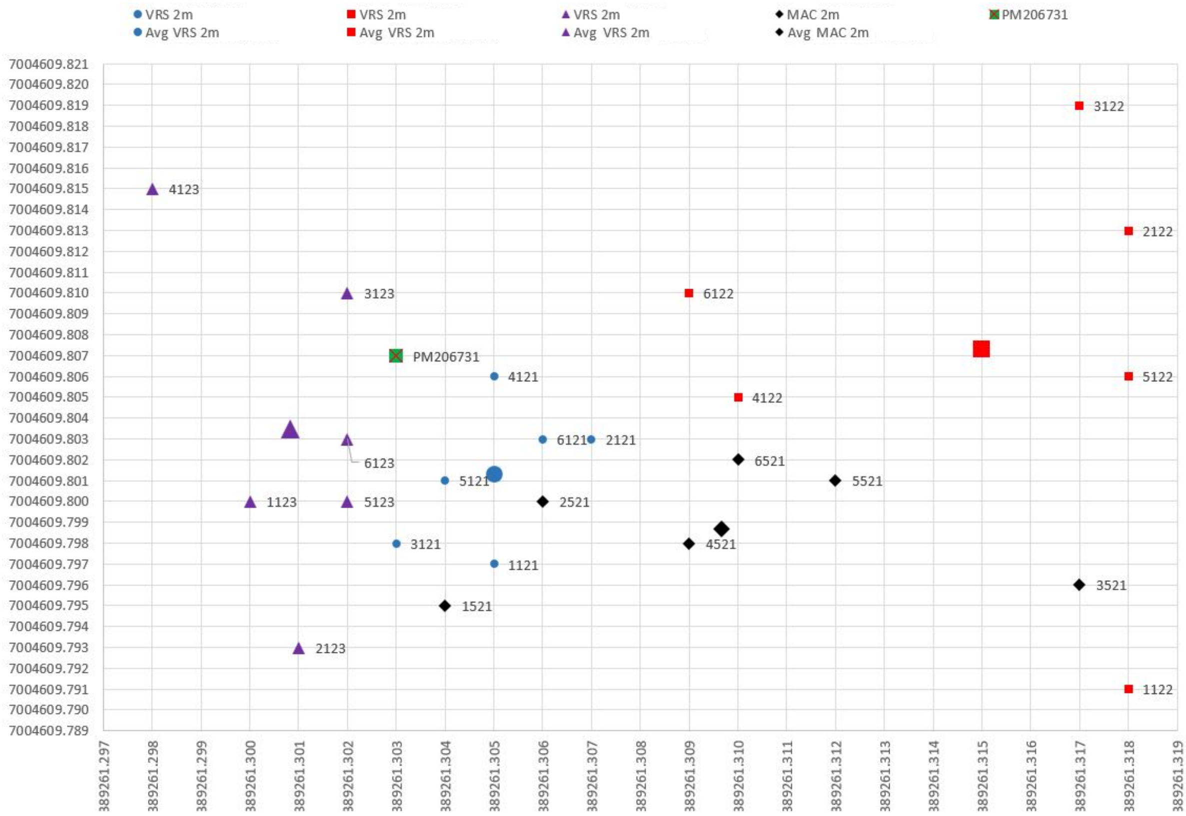

Figure 4.18: Scatter graph displaying IMAX and VRS corrections, all sampled with 60 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

The MAC corrections have changed in a similar fashion to the other data sets, moving to the east, while the average coordinate has shifted north. The MAC 120 epoch grouping is larger than the 60 epoch set.

4.3.5 IMAX & Nearest Base 60 epochs

Figure 4.19 shows the 120 epoch data set of VRS and IMAX corrections.

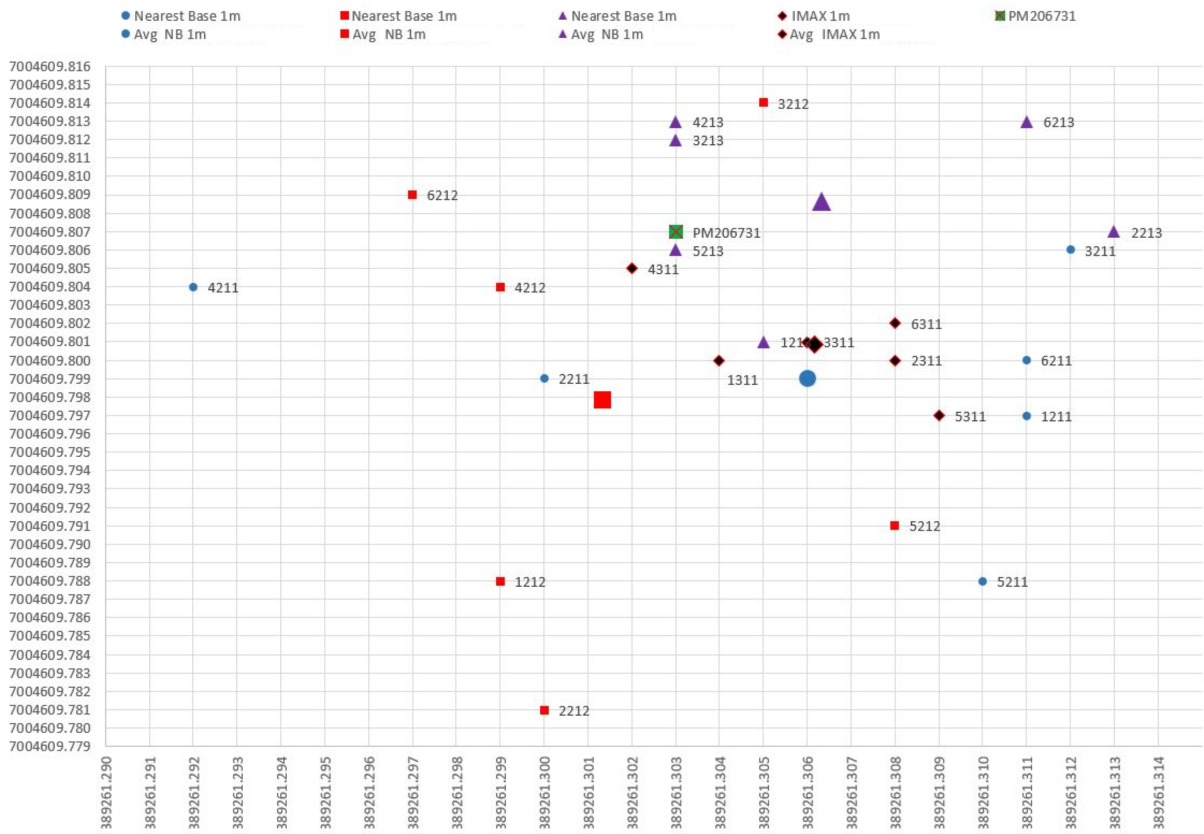

Figure 4.19: Scatter graph displaying IMAX and Nearest Base corrections, all sampled with 60 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

This data set shows less defined groups that the VRS data of the same duration. Networks show much more overlap in individual points. The IMAX corrections have a similar average coordinate to the blue network group but has a tighter group. The purple network has a different reference station to the other 3 correction types which share the same station.

4.3.6 MAC & Nearest Base 60 epochs

Figure 4.20 shows the 120 epoch data set of VRS and IMAX corrections.

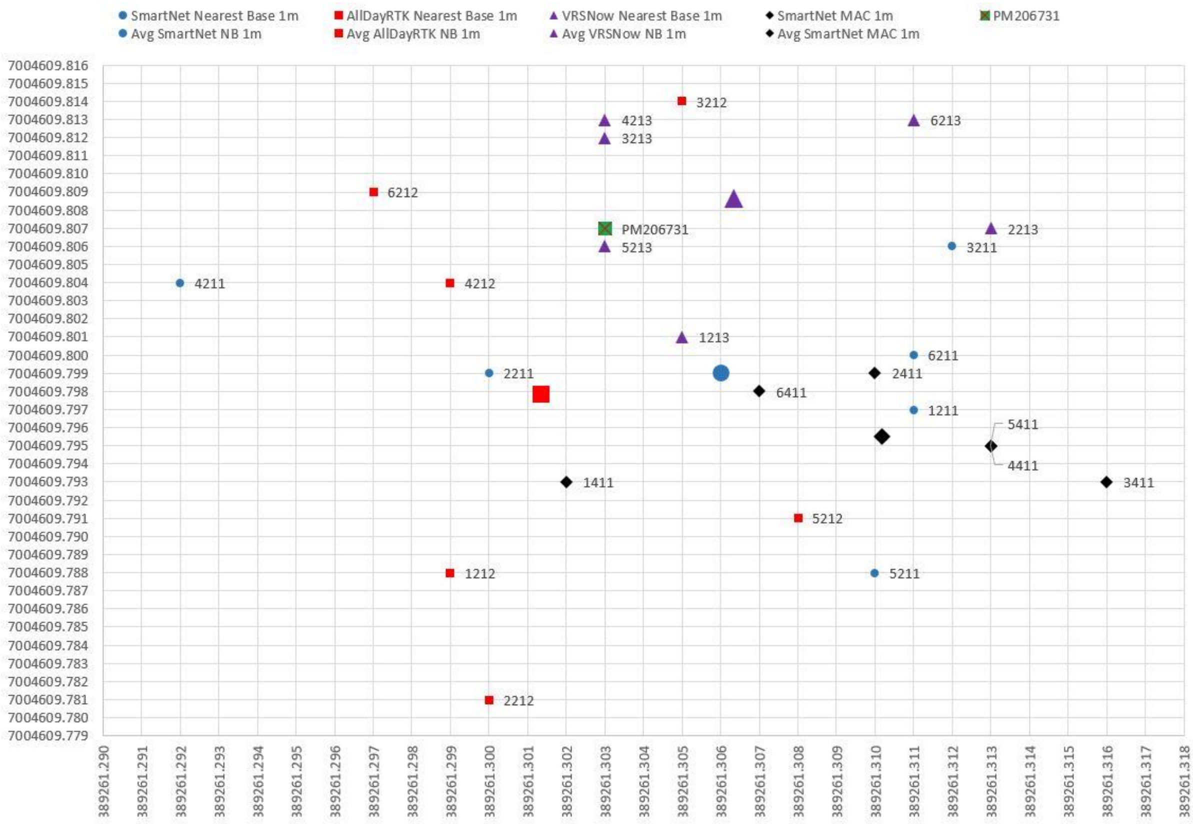

Figure 4.20: Scatter graph displaying MAC and Nearest Base corrections, all sampled with 60 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

The MAC 60 epoch corrections have similar Northing coordinates, with a greater variance in Easting coordinates. The average MAC coordinate is further away from the other 3 network corrections to the PM coordinate.

4.3.7 IMAX & Nearest Base 120 epochs

Figure 4.21 shows the 120 epoch data set of Nearest Base and IMAX corrections.

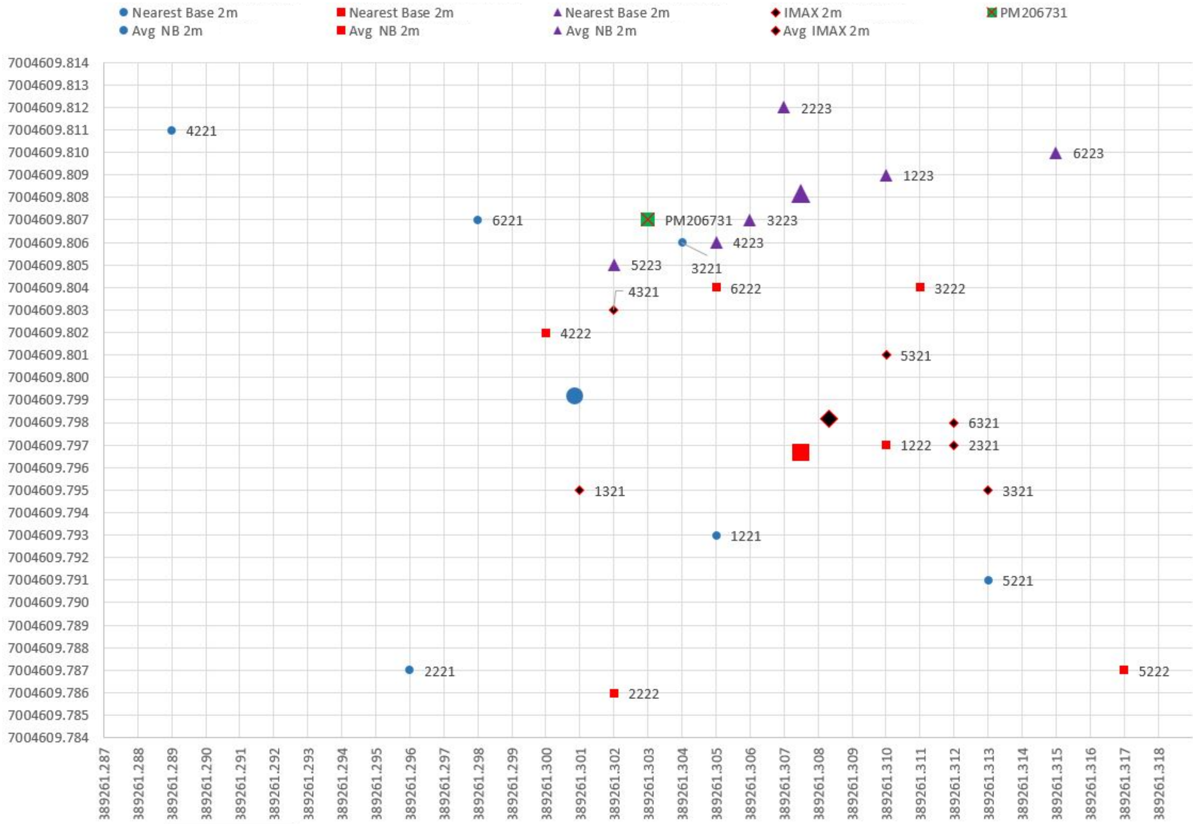

Figure 4.21: Scatter graph displaying IMAX and Nearest Base corrections, all sampled with 120 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

The purple network points have a similar group and spread as the 60 epochs set, however the blue and red networks have changed, pointing towards a larger spread of points in comparison to the 60 epoch set. IMAX corrections share a similar grouping location to the red network, with average coordinates that are close together.

4.3.8 MAC & Nearest Base 120 epochs

Figure 4.22 shows the 120 epoch data set of Nearest Base and MAC corrections.

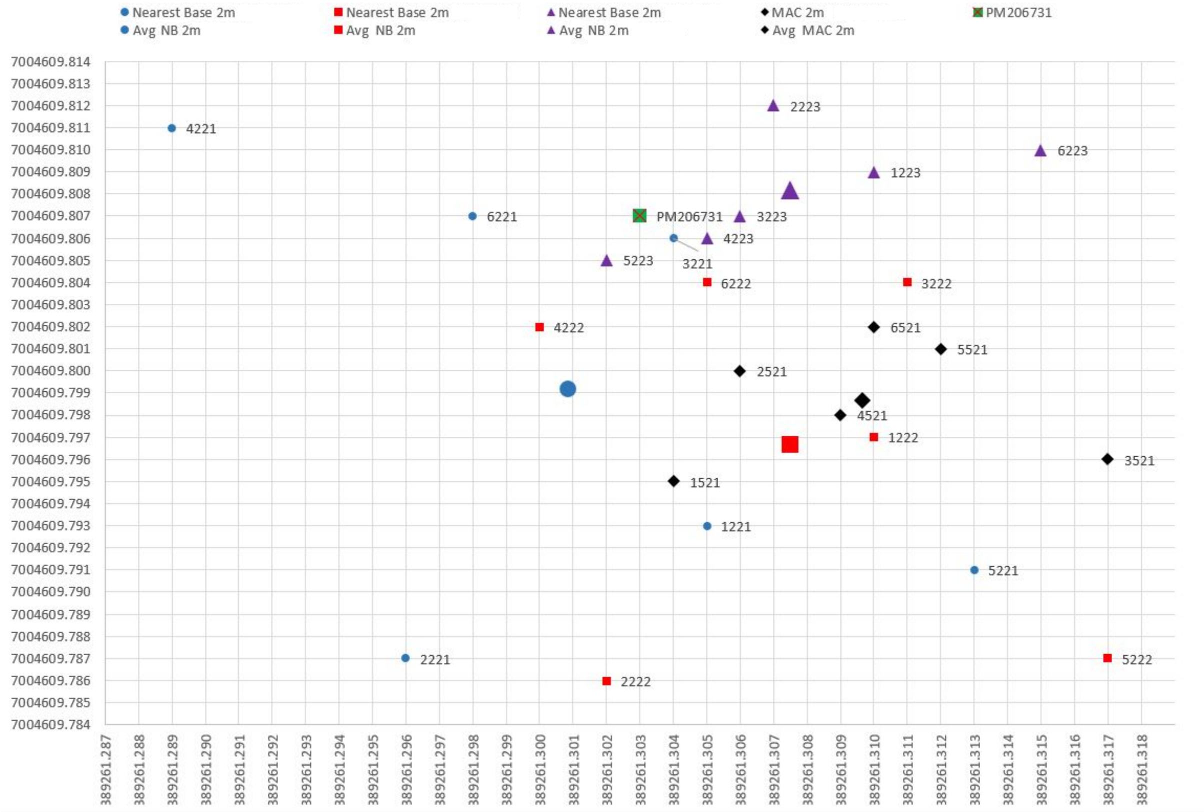

Figure 4.22: Scatter graph displaying IMAX and Nearest Base corrections, all sampled with 120 epochs of data displayed with coordinates of PM206731 for reference. Larger icons represent the average of the 6 rounds of observations.

The IMAX and MAC corrections from figures 4.21 & 4.22 are very similar, in both size, location and average coordinate. These correction types in this duration share a similar average coordinate to the red network. All points with the same reference station show a preference to the south of the PM coordinate, while the purple network receiving corrections from a separate reference station trends towards the north east.

Chapter 5 - Analysis

5.1 Calculation of Uncertainties

The horizontal accuracy specification of the Leica GS18 Rover is described as 8 mm + 0.5 ppm for a network RTK solution, which is shown in manufacturers specifications in Appendix D. These accuracy figures are quoted in 1 sigma levels and need to be multiplied by 2.448 to show these in terms of 95% confidence level as required by SP1 (ICSM 2014a p. 4).

SP1 guidelines for real-time GNSS surveys recognise the need to evaluate the quality of measurements obtained by RTK methods and provide the basis for the following methods for analysing NRTK field measurements (ICSM 2014b, p.12). It is however noted that the method described in SP1 requires an independent observation from another known reference station. In the instance of this project, the availability of nearby reference stations to carry out this redundant measurement observation was not available to all networks. The validity of data obtained from a reference station with a baseline potentially 60km + longer than that of the original observation would be questionable.

Additionally, due to the nature of network RTK outlined through the literature review in chapter 2, corrections are obtained via a network of CORS indicating that a number of reference stations are providing basis for the corrections provided. While no 'check measurement' is being carried out for the NRTK observations in this data set, the use of a datum PM provides high quality reference coordinate and could be considered to be a check in its own right.

Survey Uncertainty (SU), Relative Uncertainty (RU) and Positional Uncertainty (PU) for the survey data obtained through fieldwork in this report is determined by the following equations.

(Equation 1)

Survey Uncertainty = (0.008m + 0.5ppm * baseline dist.) * 2.448

Where Survey Uncertainty @ 95% = Manufacturer Specifications * 2.448

(Equation 2)

$$\text{Relative Uncertainty} = \sqrt{SU^2 + PM^2}$$

Relative Uncertainty = square root of survey uncertainty squared plus PM horizontal uncertainty squared

Where SU = Survey Uncertainty @ 95% in metres

PM = Permanent Mark Horizontal Uncertainty in metres

(Equation 3)

$$\text{Positional Uncertainty} = \sqrt{SU^2 + Ref^2}$$

Positional Uncertainty = square root of survey uncertainty squared plus Reference Station horizontal uncertainty squared

PM horizontal uncertainty is determined from the Survey Control Mark Reports supplied by the DNRME and can be found in Appendix B. Reference station horizontal uncertainty is determined from the Regulation 13 Certificate from Geoscience Australia and can be found in Appendix I, with a 4 character id assigned to each station. The CORS that were used for observations at PM180957 consist of TOOW and USQA and the CORS used at PM206731 consist of ACL2 and TOOG. It is to be noted that the Regulation 13 certificate for ACL2 expired on the 3rd of November 2018, with no new certificate being issued. Uncertainties have been used in this section based upon the expired certificate. Latitude and longitude stated by the regulation 13 certificate have been converted to coordinates by using the Redfern spreadsheet supplied by Geoscience Australia and checked against the reference station coordinates downloaded from the controller.

The limitation with the uncertainty figures in regard to VRS become apparent due to the virtual reference station that is created to supply corrections for measurements. As this is a localised virtual only reference taken from an initial uncorrected position obtained from the rover, no physical baseline exists to provide a basis for expected uncertainties (Spall, J 2019, pers. comm., 31 July). Therefore, survey uncertainty and horizontal positional uncertainty cannot be obtained for VRS corrected measurements using manufacturer specifications. For the purposes of this analysis, the baseline for the commercial providers nearest base reference station will be used for determining SU, RU and PU, but it should be noted that this data is only used for a comparison purposes and cannot be included in overall results.

The expected uncertainties for the data set at PM180957 and PM206731 are displayed as follows in Tables 5.1 & 5.2 noting that VRS Uncertainty is obtained from baselines from nearest base reference station coordinates.

To give some perspective towards the PU for each data set, each mean coordinate was plotted against the PM coordinate with circles depicting the diameter of the PU value determined from applying the equations 1 and 3. Colours are representative of each network type, with IMAX corrections using an orange colour and MAC corrections shown with white in order to differentiate their appearance over a black background. The PM coordinate and PU value are displayed in green.

Table 5.1: Table of coordinates and uncertainties for each data set observed at PM206731.

PM180957 - Toowoomba			Uncertainty Table				
Provider	Correction	Obs. Length	Mean Easting	Mean Northing	SU (m)	RU (m)	PU (m)
Blue	N.B.	60	394170.895	6953970.229	0.020	0.022	0.023
Red	N.B.	60	394170.895	6953970.228	0.020	0.022	0.023
Purple	N.B.	60	394170.898	6953970.231	0.029	0.030	0.031
Blue	N.B.	120	394170.895	6953970.229	0.020	0.022	0.023
Red	N.B.	120	394170.896	6953970.229	0.020	0.022	0.023
Purple	N.B.	120	394170.902	6953970.230	0.029	0.030	0.031
Blue	VRS*	60	394170.895	6953970.229	0.020	0.022	0.023
Red	VRS*	60	394170.895	6953970.225	0.020	0.022	0.023
Purple	VRS*	60	394170.899	6953970.228	0.029	0.030	0.031
Blue	VRS*	120	394170.894	6953970.228	0.020	0.022	0.023
Red	VRS*	120	394170.892	6953970.222	0.020	0.022	0.023
Purple	VRS*	120	394170.897	6953970.227	0.029	0.030	0.031
Black-Red	IMAX	60	394170.895	6953970.229	0.020	0.022	0.023
Black-Red	IMAX	120	394170.895	6953970.229	0.020	0.022	0.023
Black	MAC	60	394170.894	6953970.228	0.020	0.022	0.023
Black	MAC	120	394170.895	6953970.228	0.020	0.022	0.023

Table 5.2: Table of coordinates and uncertainties for each data set observed at PM206731.

PM206731 - Cooyar			Uncertainty Table				
Provider	Correction	Obs. Length	Mean Easting	Mean Northing	SU (m)	RU (m)	PU (m)
Blue	N.B.	60	389261.306	7004609.799	0.054	0.055	0.055
Red	N.B.	60	389261.301	7004609.798	0.054	0.055	0.055
Purple	N.B.	60	389261.306	7004609.809	0.078	0.079	0.079
Blue	N.B.	120	389261.301	7004609.799	0.054	0.055	0.055
Red	N.B.	120	389261.308	7004609.797	0.054	0.055	0.055
Purple	N.B.	120	389261.308	7004609.808	0.078	0.079	0.079
Blue	VRS*	60	389261.304	7004609.802	0.054	0.055	0.055
Red	VRS*	60	389261.316	7004609.805	0.054	0.055	0.055
Purple	VRS*	60	389261.298	7004609.805	0.078	0.079	0.079
Blue	VRS*	120	389261.305	7004609.801	0.054	0.055	0.055
Red	VRS*	120	389261.315	7004609.807	0.054	0.055	0.055
Purple	VRS*	120	389261.301	7004609.804	0.078	0.079	0.079
Black-Red	IMAX	60	389261.306	7004609.801	0.054	0.055	0.055
Black-Red	IMAX	120	389261.308	7004609.798	0.054	0.055	0.055
Black	MAC	60	389261.310	7004609.796	0.054	0.055	0.055
Black	MAC	120	389261.310	7004609.799	0.054	0.055	0.055

5.2 PM180957

The colours that have been implemented in the following analysis and results sections are as follows:

- Purple – Network 1, VRS and Nearest Base
- Red – Network 2, VRS and Nearest Base
- Blue – Network 3, VRS and Nearest Base
- Orange on Black Background – Network correction type IMAX
- White on Black Background – Network correction type MAC

Figure 5.1 shows 60 epoch data sets and provides visual confirmation that all 5 correction types with quantifiable PU values are capable of measuring the PM at 95% confidence.

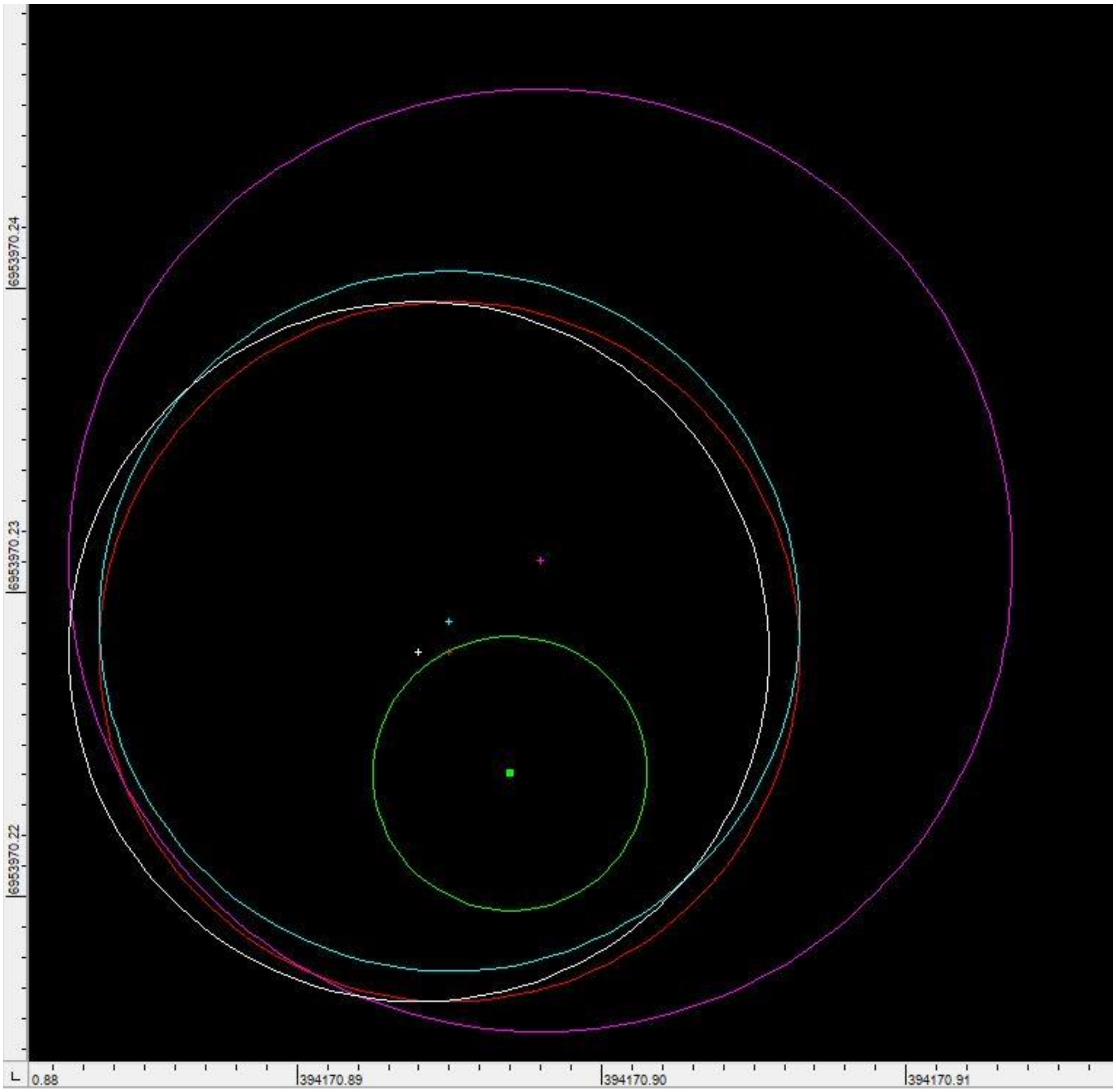

Figure 5.1: PU and mean coordinate of PM180957, Nearest Base, IMAX and MAC corrections for 60 epochs (Note: Blue and IMAX corrections have identical mean coordinate and PU – IMAX corrections hidden from view for clarity).

It is noted the purple network nearest base mean has a larger PU due to the longer baseline to its reference station. All corrections shown here wholly overlap the PM and its PU. IMAX and the blue nearest base network corrections have identical mean coordinates and PU values, while the red nearest base network and MAC corrections are within 1 mm of those mean values and a maximum of 5 mm from the PM coordinate. It is interesting to note that these 4 correction types have been referenced back to the CORS that is 63 metres away. The purple mean coordinate however is only 4 mm away from the other 4 networks, and 7 mm to the PM coordinate.

The small differences between each of these correction types and the PU agreement with the PM coordinate and its PU would suggest that as per the manufacture's specifications of the equipment, each correction type show no discernible difference for measuring this PM at this location.

Figure 5.2 shows 120 epoch data sets with the PU overlayed.

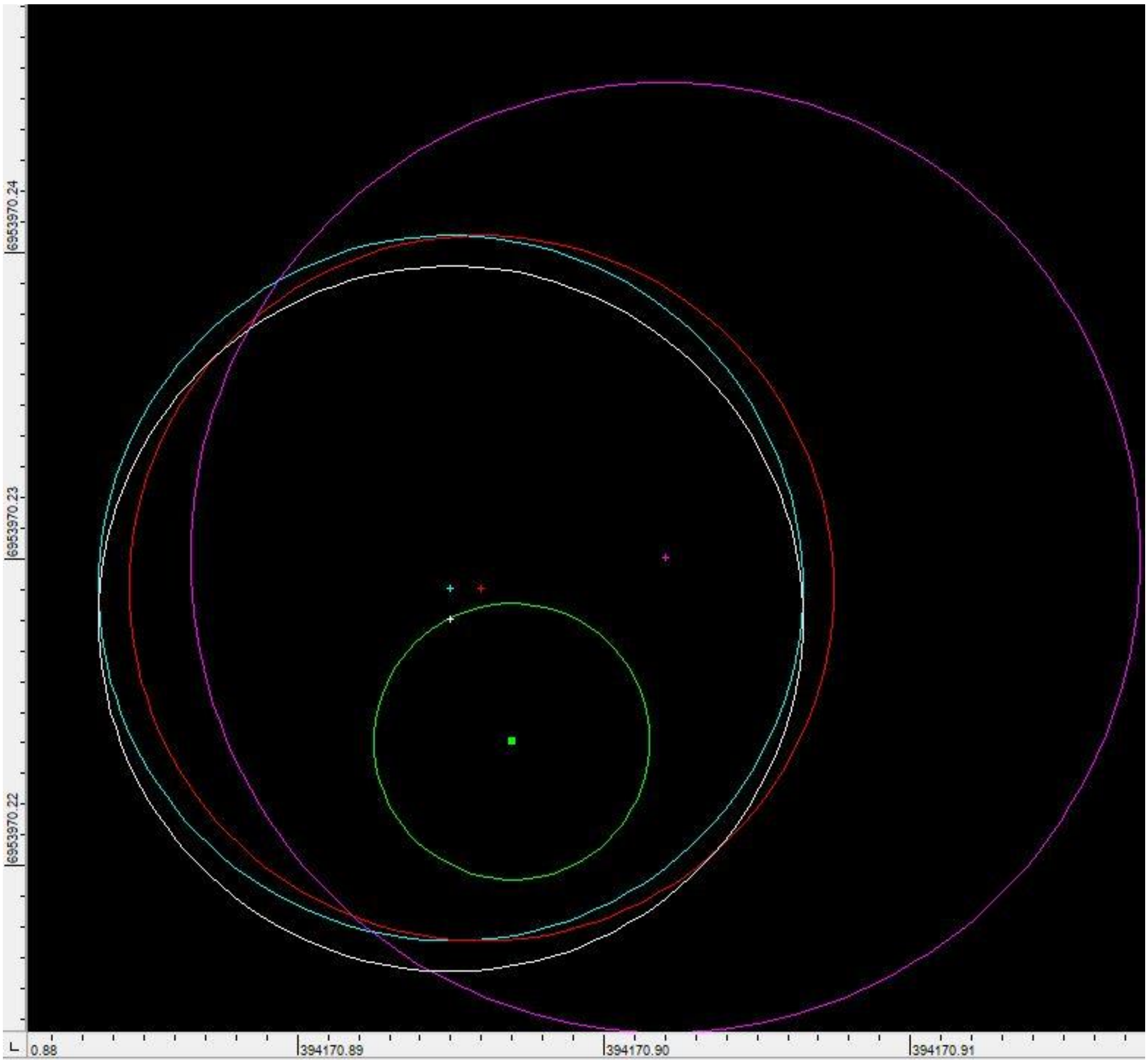

Figure 5.2: PU and mean coordinate of PM180957, Nearest Base, IMAX and MAC corrections for 120 epochs (Note: Blue and IMAX corrections have identical mean coordinate and PU – IMAX corrections hidden from view for clarity).

Little difference can be seen between the 60 and 120 epoch data sets, with all mean coordinate PU overlapping the PM coordinate PU. As with the 60 epoch data set the blue nearest base and IMAX mean coordinates are identical, with red nearest base network corrections and MAC corrections within 1 mm of them, and 5 mm to the PM coordinate. The purple nearest base network corrections are 7 mm to the other 4 correction types, and 8 mm to the PM coordinate. Again, while the purple mean coordinate shows a difference to the other networks, as per the manufacturer specifications for the equipment, the PU is overlapping the PM coordinate performing as per its expectations.

Figure 5.3 is included for completeness, as PU's for VRS corrections have been determined from baselines to reference stations from the comparative networks nearest base corrections.

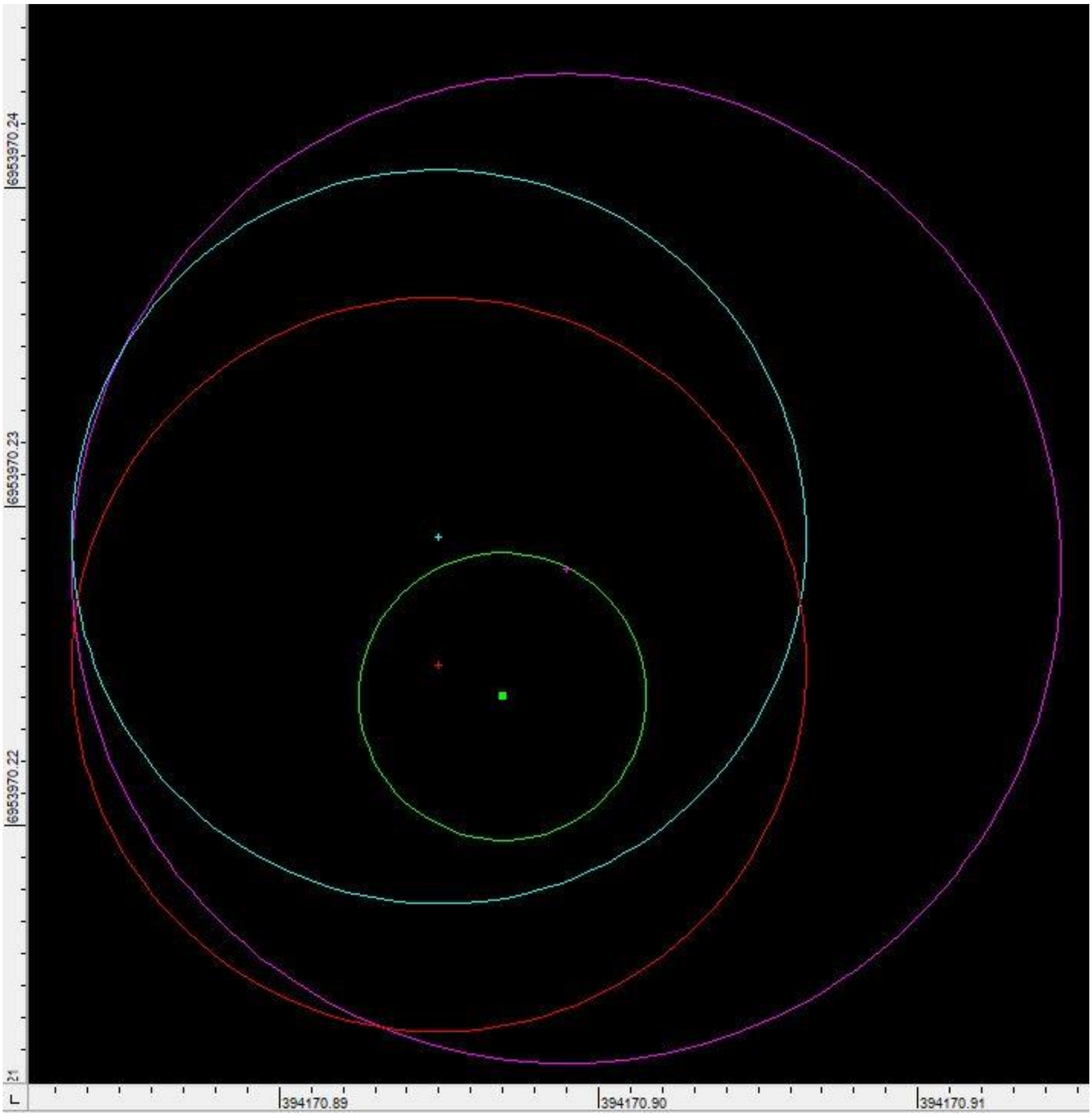

Figure 5.3: PU and mean coordinate of PM180957 and VRS correction for 60 epochs, noting that PU's have been modelled from nearest base correction baselines and not a direct representation of PU for VRS correction data sets.

The red networks mean coordinate is 2 mm to the PM coordinate while the purple and blue mean coordinate is 4 mm and 5 mm respectively. All theoretical PU for VRS corrections overlaps the PM coordinate and its PU. When comparing these values to the ones in Figure 5.1 no significant differences are presented, again suggesting that all network providers are performing to the expectations of the equipment that is being used to measure the PM.

Figure 5.4 shows the theoretical 120 epoch PU for VRS corrections.

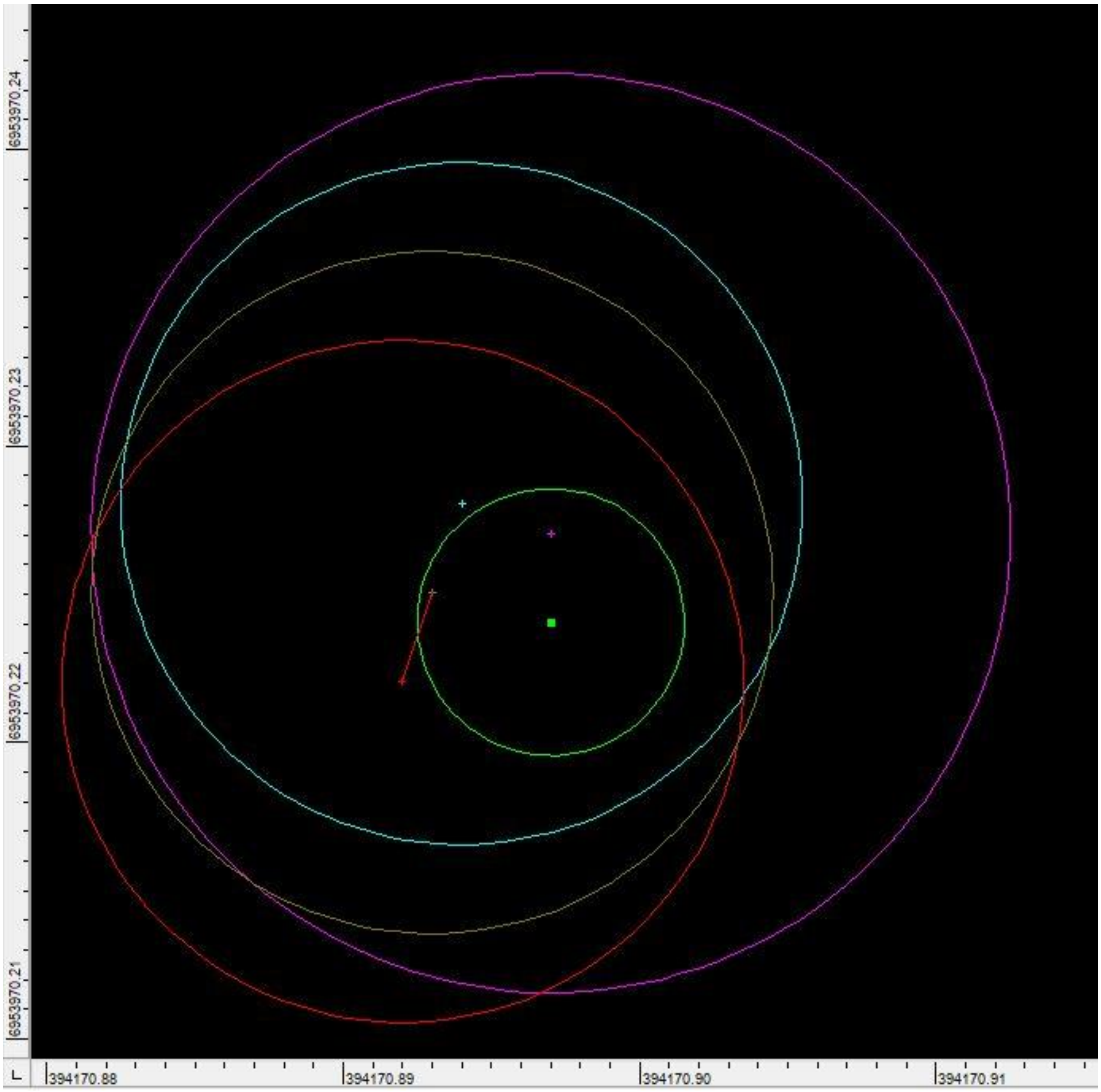

Figure 5.4: PU and mean coordinate of PM180957 and VRS correction for 120 epochs, noting that PU's have been modelled from nearest base correction baselines and not a direct representation of PU for VRS correction data sets.

Point 2122 was deemed to be an outlier due to its proximity to the other points recorded in that set, in addition to no other indicator to contribute to its location. The red line in Figure 5.4 represents the shift in mean coordinate when re calculated point 2122 is excluded. The gold colour is the new mean coordinate and PU of the remaining red points in that set. This improves the mean coordinate to 4 mm to the PM coordinate for the red network while blue and purple are 5 mm and 3 mm respectively. It is interesting to note that the red network VRS 60 epoch data set mean is closer to the PM coordinate than the new mean of the 120 epoch set.

5.3 PM206731

Figure 5.5 refers to PM206731 outside of Cooyar. The PU of these mean coordinates are much larger than the PU's seen at PM180957, attributing the differences to the larger baselines of the reference stations due to the sparse network density seen at this location.

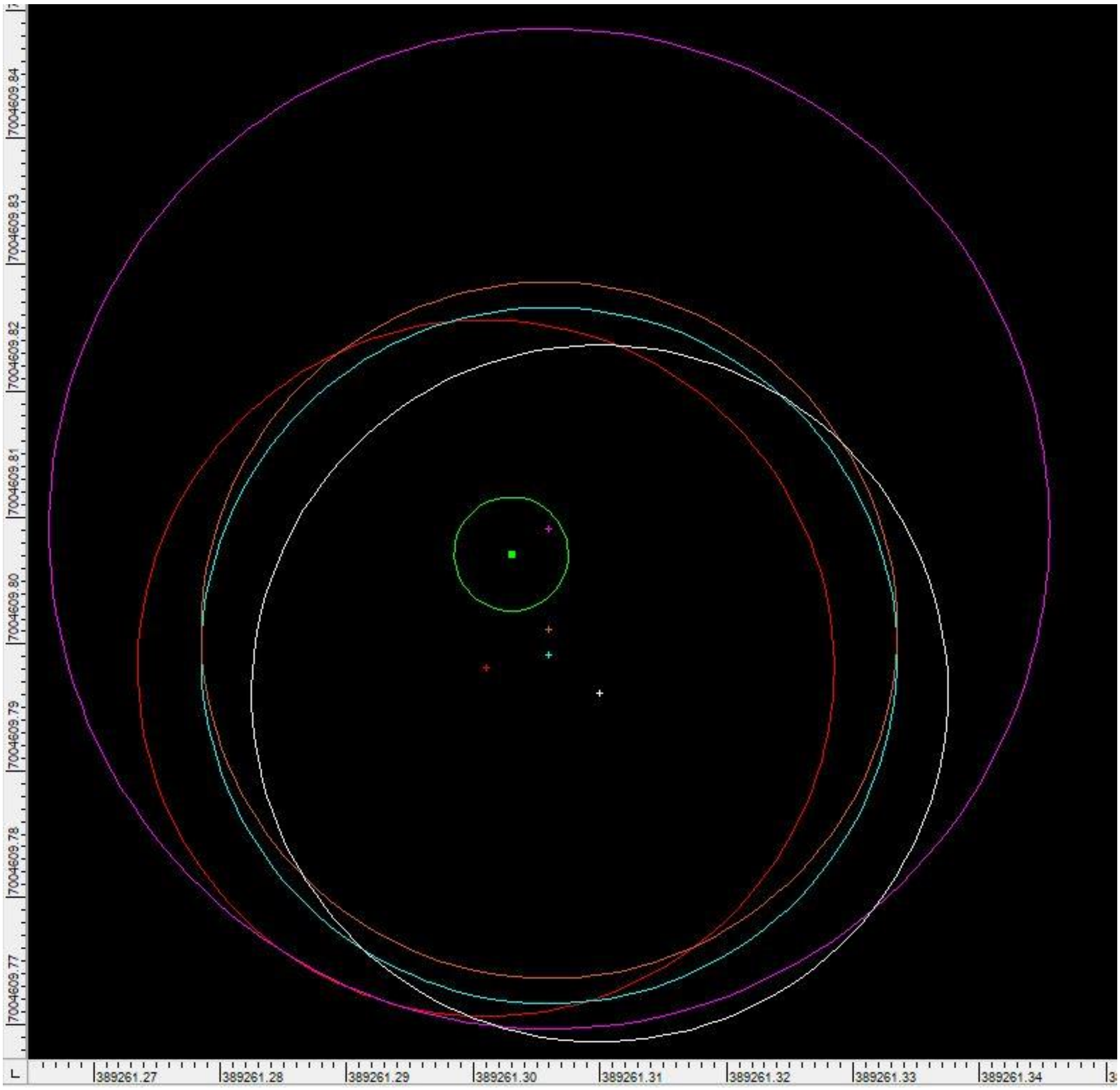

Figure 5.5: PU and mean coordinate of PM206731, Nearest Base, IMAX and MAC corrections for 60 epochs.

PU of the 5 network corrections all overlap the PM and its PU indicating that, as per the manufacturer specifications for the equipment used, meet the required purpose.

In closer inspection 4 correction types are within 9 mm of the PM coordinate, however the MAC corrections mean coordinate is 13 mm away, outside of the horizontal PU of the PM. The mean coordinates of 4 of the 5 correction types are grouped together to the south with the red, blue, IMAX and MAC corrections mean coordinate showing a distinct bias together, with each correction type tracing its reference coordinate back to the same source. The purple nearest base mean coordinate has its baseline distance 20 km longer than the other 4 results but is much closer to the PM coordinate. The inclusion of the static observation with its PU in figure 5.6 gives reference to the possibility that the true position could lie further south within the area that the PU's of the static and PM coordinates overlap. This would allow a better fit with all correction types.

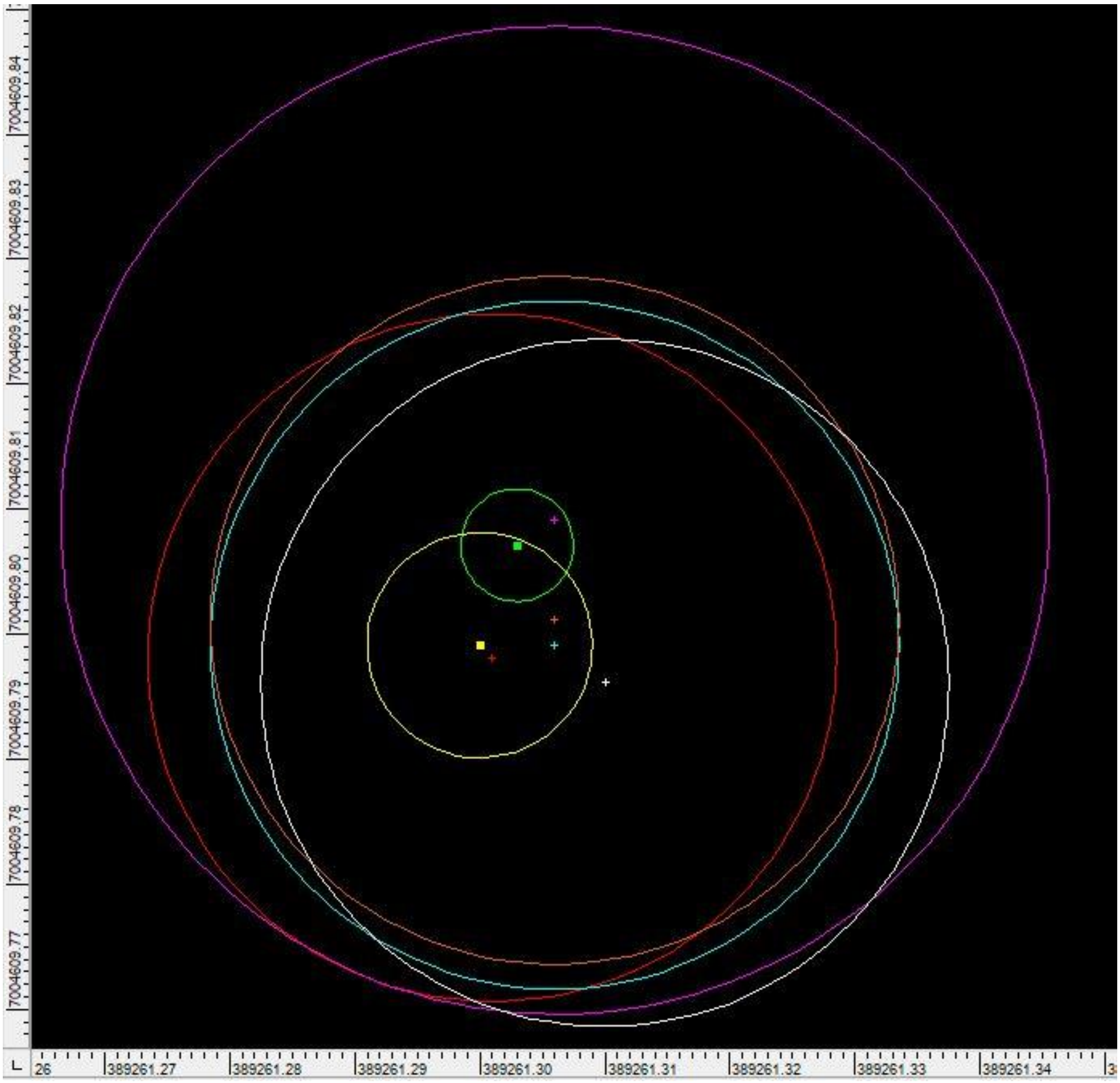

Figure 5.6: Static observation of PM206731 and PU shown in yellow with PU and mean coordinate of PM206731, Nearest Base, IMAX and MAC corrections for 60 epochs.

Figure 5.7 is a continuance of the 5 applicable data sets showing 120 epochs of mean data. The static observation is also included for reference, noting that the longer observation times do not change the overall pattern of the mean data sets indicating that the true coordinate could lie in the overlapping area between the static and PM PU. No mean coordinate is greater than 7 mm from the overlapping PU area.

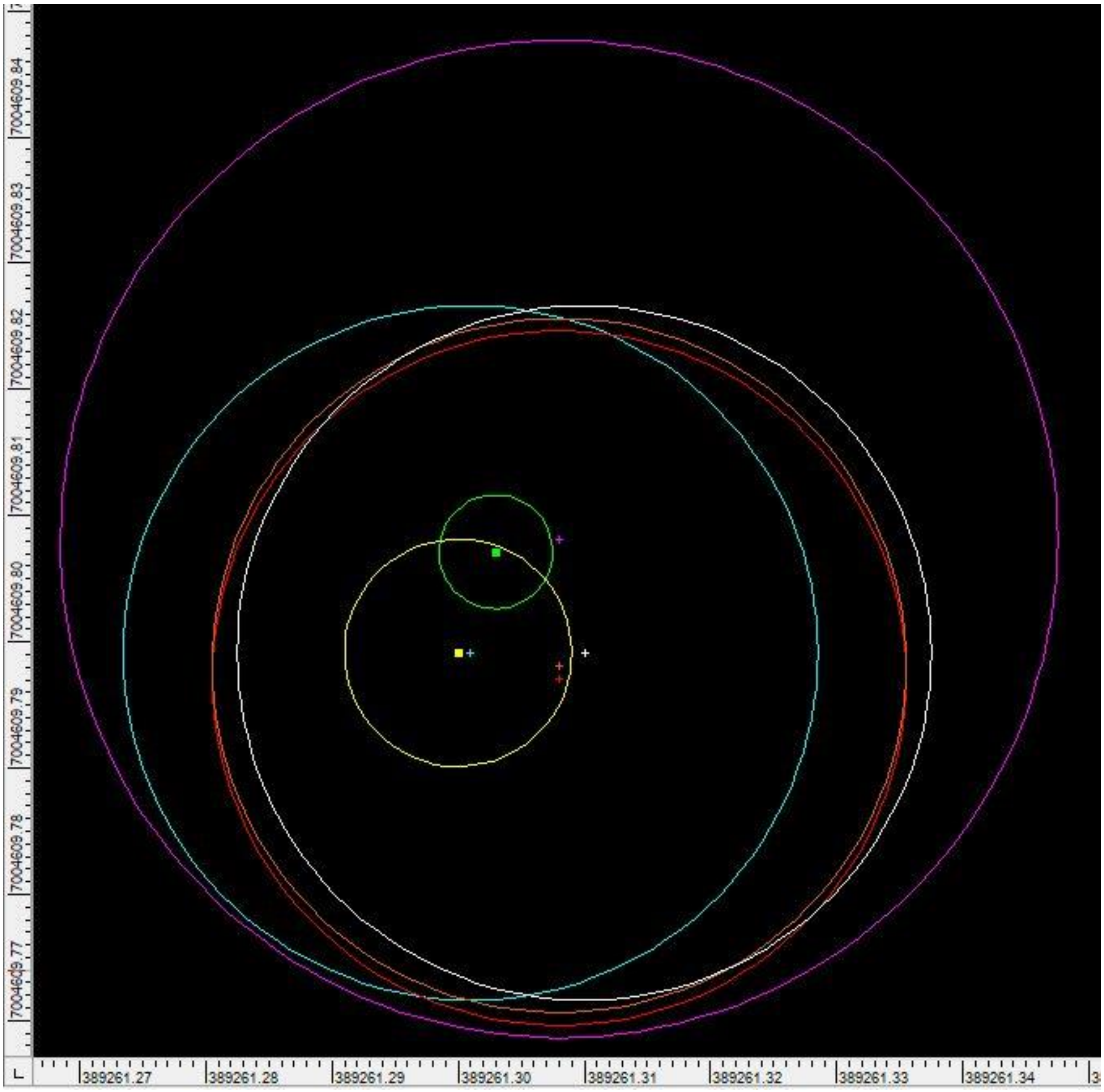

Figure 5.7: Static observation of PM206731 and PU shown in yellow with PU and mean coordinate of PM206731, Nearest Base, IMAX and MAC corrections for 120 epochs.

As with observations obtained at PM180957, the data observed at PM206731 show a general agreeance and no distinct differences outside of expected tolerances from equipment.

As with the results of VRS corrections taken at PM180957, the results in Figure 5.8 have been determined by applying the nearest base baselines from the corresponding network and cannot be considered a true representation of PU for these mean coordinates.

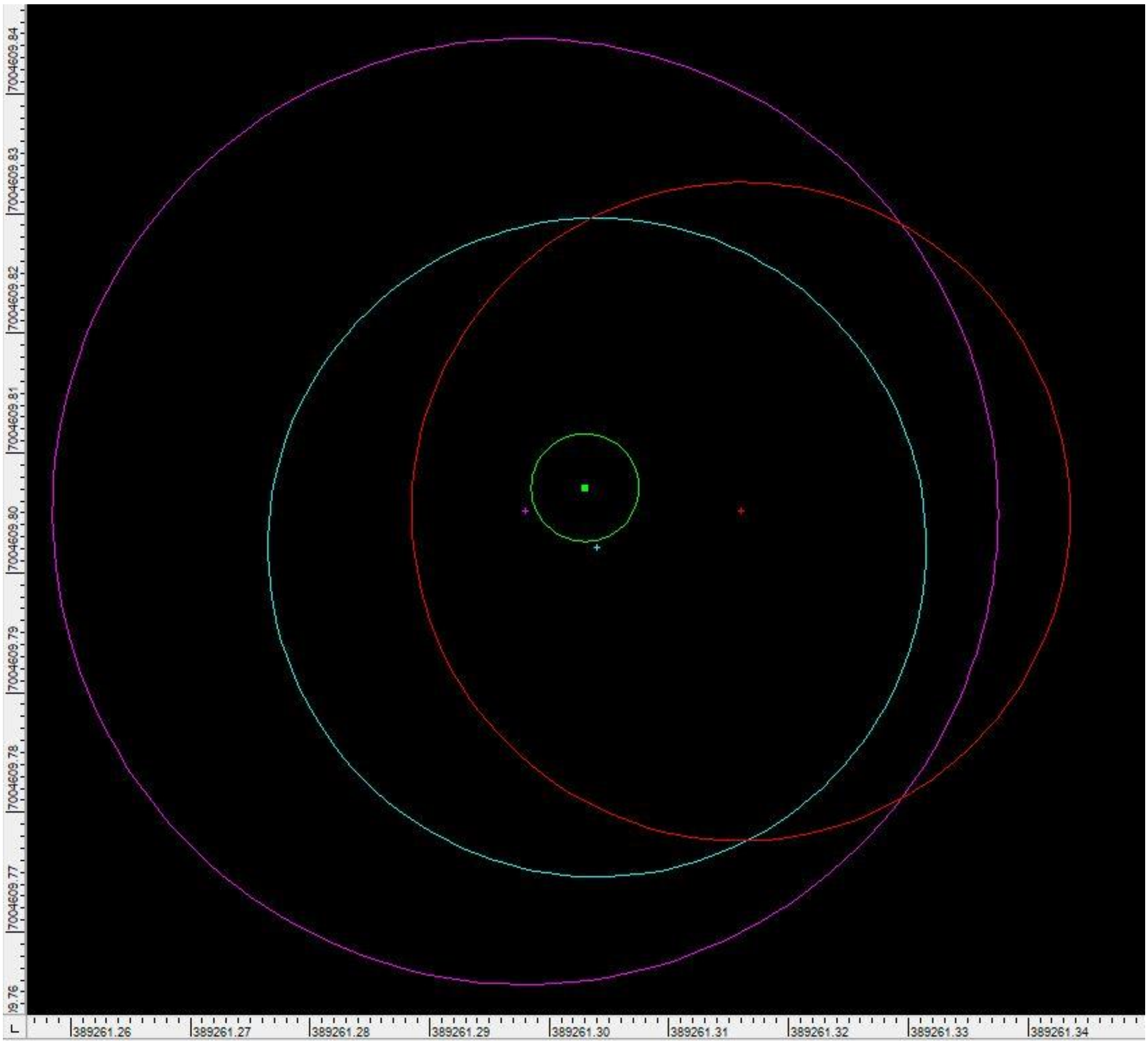

Figure 5.8: PU and mean coordinate of PM206731 and VRS correction for 60 epochs, noting that PU's have been modelled from nearest base correction baselines and not a direct representation of PU for VRS correction data sets.

As shown in figures 5.6 and 5.7, the mean coordinates of the purple and blue networks are shown to be 5 mm south of the PM coordinate. It was noted that the initialisation times for the red network were quite considerable, needing in most instances to be restarted for the initialisation to be fixed and begin observations. This site was on the edge of mobile reception, however there were no problems encountered by the other correction types. The difference shown by the red mean coordinate could be attributed to these difficulties experienced in observing this correction type at this location.

Figure 5.9 is of the longer 120 epoch VRS mean data sets, depicting a similar outcome to the 60 epoch observations.

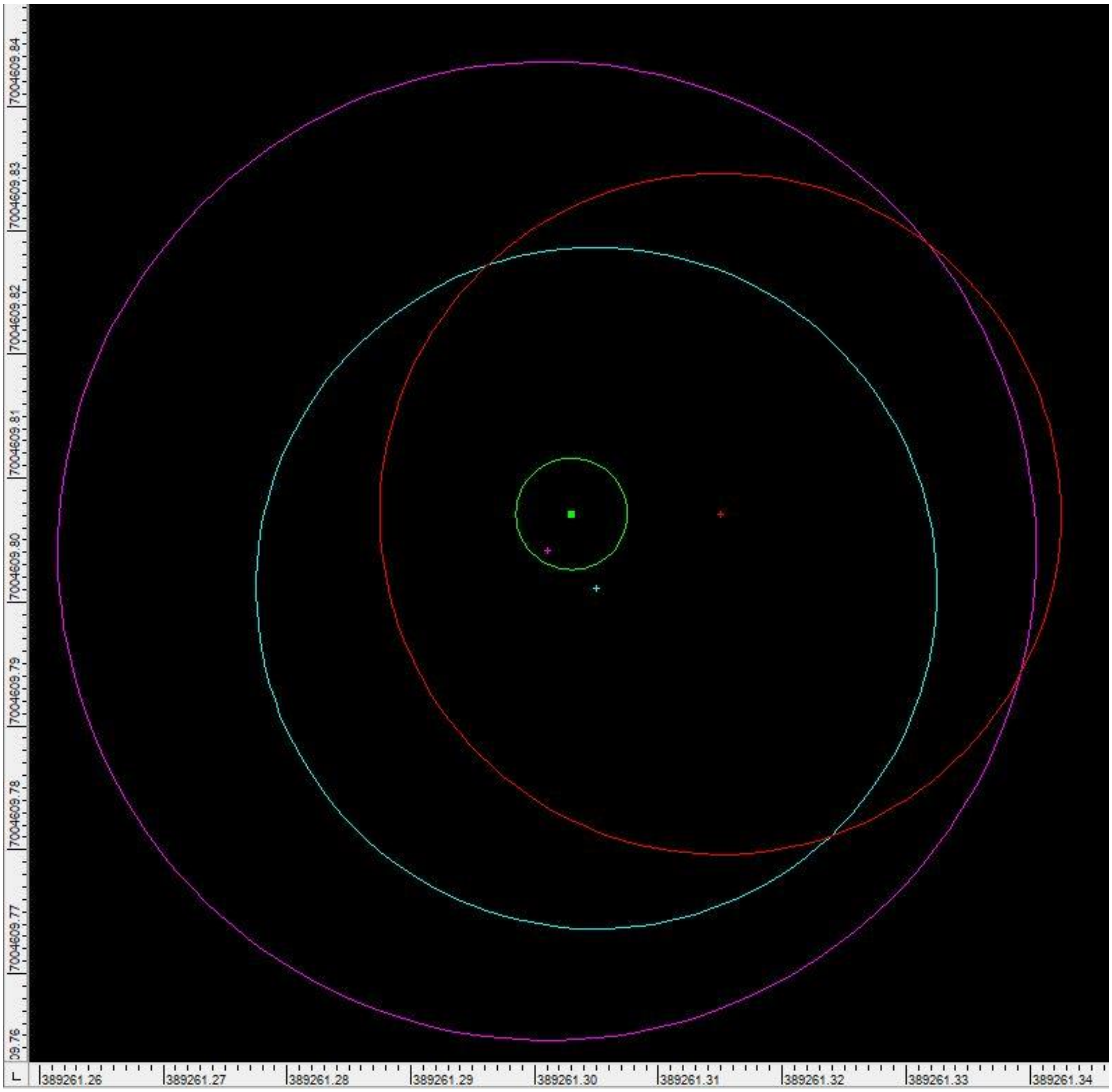

Figure 5.9: PU and mean coordinate of PM206731 and VRS correction for 120 epochs, noting that PU's have been modelled from nearest base correction baselines and not a direct representation of PU for VRS correction data sets.

The longer observation times showed 4 mm and 6 mm for the purple and blue network. As with the previous red network VRS observations, similar difficulties were experienced when initialising VRS corrections for that provider.

Chapter 6 - Discussion

From the results seen in this chapter, the distance to the nearest CORS has an effect on the overall performance of the data in both a physical and analytical sense. The difference in baseline lengths can be seen over the 2 sites selected. PM180957 has relatively short baselines between 60 metres and 8 kilometres while baselines from PM206731 are 28 kilometres to 48 kilometres.

However, it has been determined through the results that these slight variances in mean measurements are an expected function of the manufacturer's specifications. The method of determining the SU, RU and PU of the observations provided loose tolerances for the differences of the observations to still be meeting the expected accuracies of the equipment and procedures.

From the analysis of both the single observations and mean coordinates of observation sets, it is clear that when more observations are performed a better estimate of the known coordinate is acquired. This is seen at PM206731, where the range configuration of the CORS networks are tested and a single observation from each data set could provide a vastly different overall result. Again, baseline distance would appear to have a direct relationship with position quality. This is inferred that as a rover moves further away from the master reference station or from an area that has a better mathematical model of the atmospheric errors that affects the rover, the less effective the network correction will be.

Careful consideration of the SP1 guidelines will be required when determining field methodology for implementing NRTK equipment for field surveys. An estimate of the network providers CORS coverage is required to ensure that PU of the intended survey will meet the tolerance required. As results show from the PM180957 and PM206731 test sites, SU of 20 mm to 80 mm may change what field equipment could be required for surveys as specified by general guideline in SP1 (ICSM 2014b, p.5).

VRS corrections have shown to perform at a comparable rate to the other correction types however the issue remains of being able to calculate valid SU, RU and PU without having a physical baseline to draw back to as per SP1 guidelines. Legal traceability is an important issue for NRTK, with much of the correction data make available by commercial providers are sourced from proprietary algorithms not shared with the consumer (Janssen 2009, pp. 6-7). The reference station coordinate provided when data is exported is a simple way of checking that what has been used for field correction is the same as stated on Regulation 13 certificate supplied by Geoscience Australia.

Further analysis of the transmission protocols may also lead to better understanding and analysis of data obtained from VRS corrections. Janssen (2009, p. 7). discusses the idea that RTCM message 1032 contains information regarding the position of the closest reference station. This could lead to a reliable method of determining uncertainty for VRS corrections and result in a better understanding of VRS positions which could be applied to the ICSM SP1 Evaluation of real-time GNSS surveys guidelines (ICSM 2014b). Changes to network and hardware settings could provide some further differences between NRTK providers. The trial of different data transmission protocols such as RTCM 3.1 and CMR+ could be explored, repeating the previous rounds of measurements at both PM180957 and PM206731.

6.1 Further Study

The field work performed has provided a comprehensive data set for analysis. This study was solely based upon the comparison of horizontal positions obtained from 3 commercial NRTK providers. All vertical data is still yet to be analysed and could provide the basis for further study.

- The vertical component of observations could be separated from the horizontal and be analysed as a separate data set of its own.
- This study only assesses the data in 2 dimensions. Adding the elevation data would give an additional 3D analysis to the data set. This could further explain what effect baseline distance and CORS network configuration has between commercial NRTK providers.

In addition, the data could be broken down further to see if smaller sample sizes of the existing points change the dispersion of points overall. This could be seen to simulate the minimum of 2 observations as specified by SP1 guidelines.

Studies outlined in Chapter 2.3 provided many data sets and observations to base the authors conclusions from. To continue the research aim outlined in this report, further analysis of new data sets would be beneficial to gauge an idea of the amount of variance that is experienced between commercial providers. The site at PM180957 offered patterns of correction types as shown in section 4 of this report. A companion data set for that site could be obtained by observing similar patterns of correction types but reversing the baseline lengths for the purple, red and blue network corrections and analysing the effect of the opposite baseline length has on the new data. This would build on the data obtained at PM180957, which could be reused and expanded on.

Network geometry in this study was restricted to low numbers of CORS over a wide area in South East Queensland. Baseline length and the ability of the server to model the correction parameters is based upon the short distances seen at PM180957 and longer baselines seen at PM206731. Selecting a site that has a closer network of equally spaced CORS that are common to each network could provide a data set that has unbiased network geometry. A number of PMs or equally stable established marks could be then be measured suing a similar methodology to this study in comparison of the data obtained with unequal CORS locations that were present at PM180957 and PM206731.

6.2 Conclusion

In conclusion, this project has researched, field tested and analysed a surveying technology, NRTK.

RTK equipment has increased the capacity of the surveyor to provide reliable, accurate positing information using GNSS observations. NRTK been developed to address the limitations of RTK. NRTK has removed the need of a user requiring their own base and radio link to provide corrections to the rover. NRTK technology has increased the distances the rover can reliably work beyond what RTK equipment is capable of. NRTK is reliant on a server, coordinated with a network of CORS, to correct the position the rover is acquiring from GNSS observations.

New satellite constellations are increasing the number of satellites that are available to the consumer providing improved solution reliability. This is leading to better signals from obstructions and leading to increasing capacities of NRTK to be used for daily measurement activities. This has provided a focus for this study, noting that repeatable horizontal measurements are a basic need of the survey industry.

A comprehensive literature review has provided a collection of relevant information regarding NRTK surveying. ICSM guidelines have provided a reference frame for the minimum standards for carrying out observations. These guidelines have covered equipment settings in addition to observation times, techniques for avoiding sources of error and methods for conducting detailed analysis.

Investigation into the corrections aspect of NRTK from prior research provided a deeper understanding of how the network corrections are established and implemented to provide this service to the consumer. VRS, IMAX, FKP and MAC were identified as correction methods available to commercial network providers. The way corrections developed and applied has identified a potential source of difference between the correction types.

Recent studies into NRTK has also been carried out by many other researches, providing a foundation for the development of the methodology and analysis carried out in this research project. Site selection, equipment specification and data analysis were determined through applying critical analysis to methodologies seen from prior studies. This study has aimed to remove some variables shown in research materials that affect NRTK. Similar principals were applied to hardware, software, and station setup used to carry out field observations in an attempt to recreate consistent horizontal differences.

Careful consideration was given to selecting relevant test sites to conduct this project. 2 sites in the Toowoomba region have provided survey marks that have known coordinates of high quality. The locations of the test sites have been selected to test variables in the 3 commercial NRTK services that were selected for comparison.

A Leica GS18 GNSS receiver was used in the field to carry out observations at both test locations. In total, 192 individual horizontal observations were stored and downloaded for analysis. Data was downloaded and displayed for visual analysis using Microsoft Excel. Analysis of point information showed that groups of points did display some tendencies to disperse in patterns depending on correction type and baseline distance from where corrections originate from.

However, from determining the SU and PU of mean coordinates of the separate data sets, results showed that the differences seen from the visual analysis of the data were too small to be seen as quantifiable evidence of a distinct difference between the commercial providers.

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Appendix A – Project Specification V1.5

For: Michael Venaglia

Title: Quantify and explain the differences in horizontal accuracies between commercial CORS networks.

Major: Surveying

Supervisors: Chris McAlister

Enrolment: ENG4111 – ONC S1, 2019

ENG4112 – ONC S2, 2019

Project Aim: Record network GNSS data in the Toowoomba and surrounding area to identify differences in horizontal accuracies between VRS Now, SmartNet Aus and AllDayRTK, and analyse the differences to explain why they occur.

Programme: Version 1.5 20th March 2019

1. Review existing literature regarding GNSS network solutions which are generated and transmitted to the rover (IMAX, VRS and MAC)
2. Review methods for obtaining network GNSS data and an effective number of stations to provide a sufficient amount of data to give a successful analysis.
3. Formulate plan for field work.
4. Research each GNSS manufacturer's controller software, settings and processes for data recording, to ensure each GNSS rover is recording data correctly for analysis.
5. Coordinate with USQ and equipment supplier to arrange for GNSS equipment to perform field work. This will also need to include network RTK subscription access.
6. Carry out field work.
7. Download and reduce data captured by GNSS rover to be reviewed in Microsoft Excel
8. Analyse data and ensure that potential horizontal differences between manufacturers have been identified, explaining why these differences have occurred.

If time and resources permit:

9. Find possible solutions to network differences between manufacturers so that similar positions can be achieved with each network.

Appendix B – Survey Mark Reports

Survey Control Mark Report

ADMINISTRATIVE

Mark Number	180957		
Alternate Names	BORE 4223 1657	Town	TOOWOOMBA
	NRW TWB TOR WEST	Local Authority	TOOWOOMBA REGIONAL
	TOR NRW WEST		
Locality Description	NRW DPI COMPLEX TOOWOOMBA		
Related Information			

DETAILS

Mark Type	MINI MARK		
Installed By	GJ	Connections	
Installed Date	05-Jan-2009		
Mark Condition	GOOD		
Last Visited	10-Feb-2009		
Sketch Available	Yes		

GDA94 COORDINATES

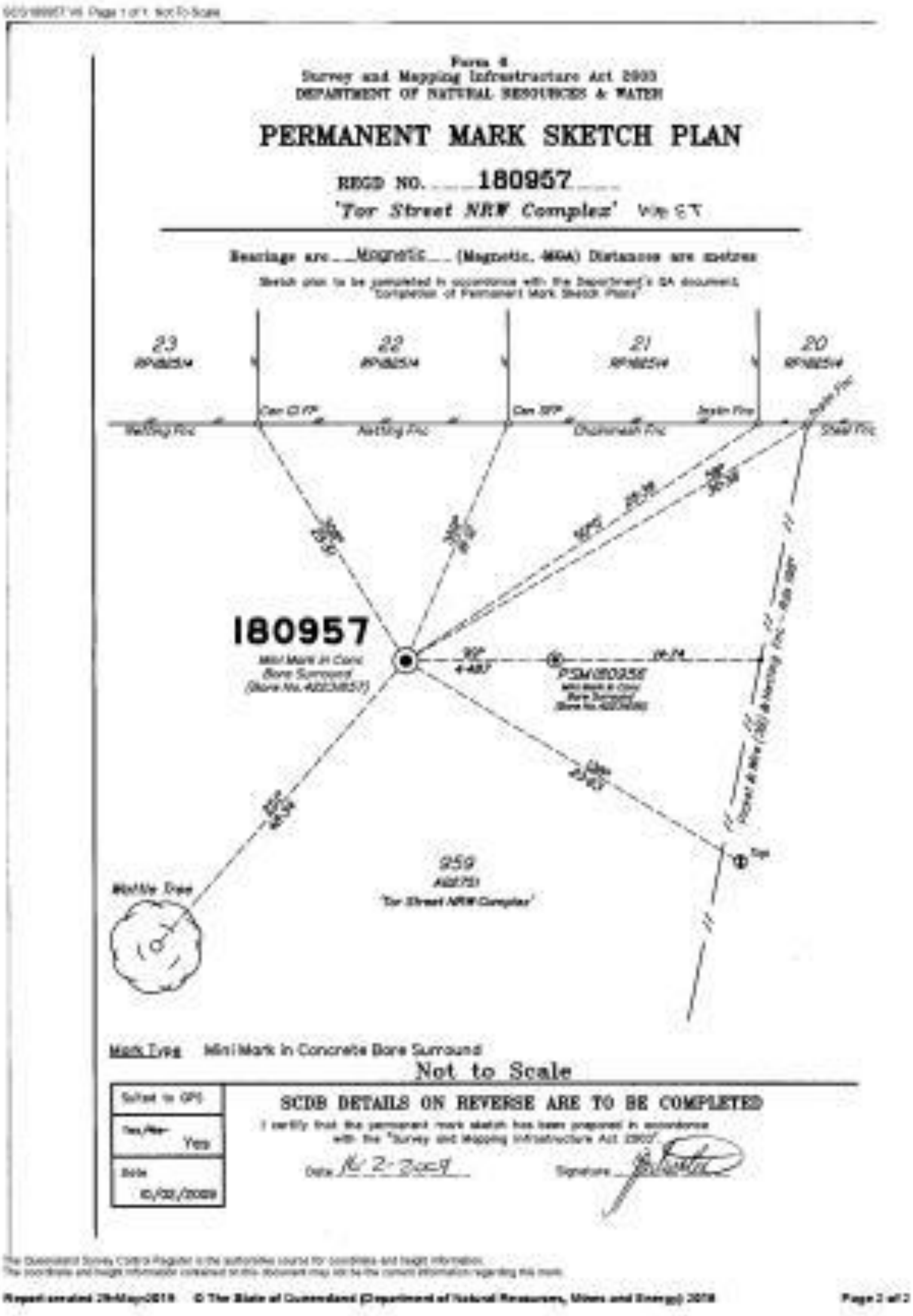
Lineage	Datum		
Latitude	27° 32' 02.05172" S	Horizontal Uncertainty	0.009m
Longitude	151° 55' 41.75649" E		
Ellipsoidal Height	682.785m	Vertical Uncertainty	0.022m
MGA94 Easting	394170.897m	MGA94 Point Scale	0.99973825
MGA94 Northing	6953970.224m	MGA94 Grid Conv	-0° 29' 43.73"
MGA94 Zone	56		
Published	20-Nov-2018	Fixed By	GPS
Adjustment	QLD ANJ 18.11		

AHD HEIGHT

Lineage	Derived		
Height	640.259m	Vertical Uncertainty	Class A / 4th ORDER
Published	10-Feb-2009	Fixed By	GPS
Origin Mark		NLN Section	
Source	TOOWOOMBA CITY BORES JAN2009		

Report created 29-May-2019

Page 1 of 2


Form 6
Survey and Mapping Infrastructure Act 2003
DEPARTMENT OF NATURAL RESOURCES & WATER
PERMANENT MARK SKETCH PLAN
REGD NO. 180957
'Tor Street NRW Complex'
180957
PSM180958
959
'Tor Street NRW Complex'
Wattle Tree
Mark Type Mini Mark in Concrete Bore Surround
Not to Scale
SCDB DETAILS ON REVERSE ARE TO BE COMPLETED
Yes

Survey Control Mark Report

ADMINISTRATIVE

Mark Number	206731		
Alternate Names		Town	COOYAR
		Local Authority	TOOWOOMBA REGIONAL
Locality Description	THORNVILLE		
Related Information	new england hwy - 0.3k north of st aubyn road. suitable for gnss. horz pu = 0.015 wide skeleton.		

DETAILS

Mark Type	S/PIC		
Installed By	DTMR	Connections	
Installed Date	18-Sep-2017		
Mark Condition	GOOD		
Last Visited	15-Dec-2017		
Sketch Available	Yes		

GDA94 COORDINATES

Lineage	Datum		
Latitude	27° 04' 35.08146" S	Horizontal Uncertainty	0.008m
Longitude	151° 52' 58.30089" E		
Ellipsoidal Height	481.358m	Vertical Uncertainty	0.024m
MGA94 Easting	388281.303m	MGA94 Point Scale	0.99975138
MGA94 Northing	7004808.807m	MGA94 Grid Conv	-0° 30' 30.32"
MGA94 Zone	56		
Published	08-Jul-2018	Fixed By	GPS
Adjustment	QLD ANJ 18.06		

AHD HEIGHT

Lineage	Derived		
Height	437.648m	Vertical Uncertainty	Class D / 4th ORDER
Published	15-Dec-2017	Fixed By	2 WAY LEVELLING
Origin Mark	35816	HLH Section	
Source			

SC5206731 V0 Page 1 of 2 Not To Scale

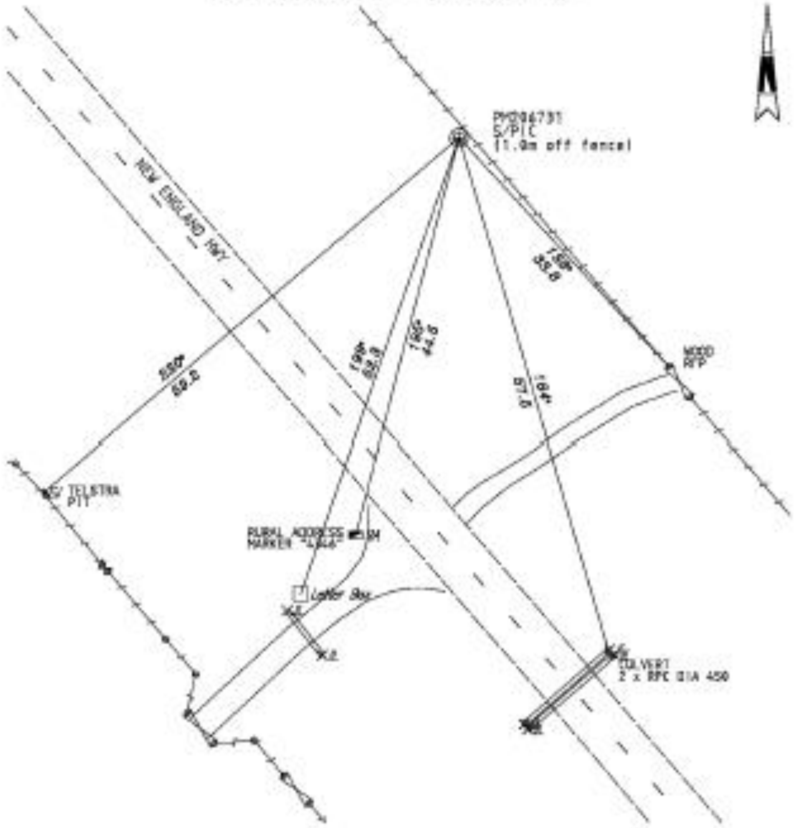
Form 6 – Version 5

Survey and Mapping Infrastructure Act 2003

PERMANENT SURVEY MARK PLAN

REGISTERED NO. 206731

Bearings are MGA Distances are metres



Mark Type: S/PIC

Suited to GNSS?	DETAILS ON REVERSE COMPLETED: ☐
YES	Prepared by: P.Lindenmayer (registered person or public authority) Date: 30/01/2018

This form is to be completed in accordance with the Department's Specification *Compilation of Permanent Survey Mark Plans*

The Queensland Survey Control Register is the authoritative source for coordinate and height information.
The coordinate and height information contained on this document may not be the current information regarding this mark.

Survey Control Register - Permanent Survey Mark Data Sheet

REGISTERED NO. 206731

Administrative Data

Alternative Name 1:	....	*Installed by:	DTMR
Alternative Name 2:	....	*Date installed:	19/09/2017
Alternative Name 3:	....	Date last visited:	15/12/2017
*Mark type:	Star picket	*Locality:	Thornville
	....	City or Town:	Cooyar
*Mark condition:	Good	*Local government:	Toowoomba Regional
Location description:	New England Hwy – 0.3k North of St Aubyn Rd		

Note: The Survey Control Register is the authoritative source for coordinate and height information. The vertical and horizontal data below **may not be** the current information regarding this mark.

Vertical Control Data

*Height: 437.648   *Datum: AHD D   Vertical Accuracy - *Order: 4   *Class: D

Vertical Origin - *Regd No: 35816   *Height: 483.495   *Datum: AHD D

Geo-Sphd N: .... Datum: .... Model: ....

*Fixed By: 2 way levelling   *Date: 15/12/2017

Horizontal Control Data

*Latitude: 27° 04' 35.09159"   *Longitude: 151° 52' 59.30114"   *Datum: GDA94

*Easting: 389261.307   *Northing: 7004609.803   *Zone: 56

*Horiz Positional Uncertainty: 0.015   *Fixed By: GNSS static   *Date: 15/12/2017

#Horiz Origin Regd No: 46572

#Latitude: 27° 08' 29.05821"   #Longitude: 151° 57' 04.38152"   #Datum: GDA94

Cadastral Connection Data

*Connected on Cadastral Plan No.: ....

Comments

....

Details completed by: **Name:** PHIL LINDENMAYER   **Date:** 30/01/2018

Organisation: DTMR

* Items marked thus are mandatory items for the section

Items marked thus are mandatory items if the coordinates are determined by connection to an existing mark (i.e. not Network RTK or AUSPOS)

The Queensland Survey Control Register is the authoritative source for coordinate and height information.
The coordinate and height information contained on this document may not be the current information regarding this mark.

Appendix C – Trimble R2 Manufacturer Specification

DATASHEET

Trimble R2

GNSS RECEIVER

VERSATILITY IN THE FIELD. FLEXIBILITY FOR YOUR WORKFLOW.

Work the way you want with the Trimble® R2 GNSS receiver. Using trusted Trimble technology the R2 receiver gives you the freedom to configure a solution by simply selecting the accuracy and GNSS performance to suit your application. Capable of achieving submeter to centimeter level positioning accuracy the Trimble R2 is the answer to keep you working productively in a wide range of geospatial applications, no matter what your workflow requirements are.

Whether you are performing pole-based stakeouts, surveying on roads, in mines or on construction sites, locating buried assets such as pipes and cables, capturing GIS field assets, or carrying out precision survey measurements, the versatile Trimble R2 is purpose-built for surveyors and mapping and GIS professionals alike.

Simple to setup and easy-to-use, the Trimble R2 pairs with any Trimble handheld, Trimble Access™ controller, or consumer-grade smart device across a variety of operating systems and platforms, to deliver reliable, high quality real-time data every time.

A Simple, Rugged System for Everyday Needs

Built to withstand the rigors in the field, the rugged IP65-rated Trimble R2 receiver will work as hard as you do in tough outdoor conditions. Its one-button start up and compact, streamlined form factor makes it fast to set up and can be operated either mounted on a pole, on a backpack or on a vehicle. The field-swappable battery means all day productivity with no interruptions, keeping you focused on the job at hand.

Technology to Keep you Productive

The Trimble R2 is capable of tracking the full range of GNSS satellite constellations and augmentation systems, and comes with an integrated Trimble Maxwell™ 6 chip and 220 channels to provide you with reliable accuracy and positioning performance. Achieve higher accuracy in real-time with the flexibility to choose correction sources from traditional RTK, VRS networks, to Trimble RTX™ correction services delivered by both satellite and Internet/cellular.

Trimble has evolved its Floodlight™ satellite shadow reduction technology to ensure the R2 receiver is able to provide reliable, accurate data even in difficult GNSS environments. Equipped with this advanced GNSS technology, you can achieve remarkable improvements to position availability and accuracy when heavy overhead cover, such as tree canopy and buildings, obstruct satellite signals, making even tough GIS workflows easier.

A Complete Solution

Connect the Trimble R2 receiver to your preferred controller or mobile device via a wireless Bluetooth® connection and add proven Trimble field and office software workflows to complete the solution. Data can be collected with the customizable workflows of Trimble field software such as Trimble Access or Trimble TerraFlex™ software that allow your teams to easily collect and communicate information between the field and office in real-time. Collected data can then be processed with Trimble office software, including Trimble Business Center or TerraFlex, providing you with data rich, high-quality deliverables for your organization.

For a simple, configurable, field-to-office solution, the innovative and flexible Trimble R2 GNSS receiver enables you to work accurately and productively your way.

Key Features

- A professional solution for geospatial applications ranging from sub-meter to centimeter accuracies to support any GIS or survey-grade workflow
- Easily collect data by pairing with devices such as smartphones, tablets or Trimble handhelds using Trimble Survey and GIS software
- Fast to setup, easy to use, keeping you productive and focused at your task at hand
- Supports multiple satellite constellations and correction sources for accurate data at any location
- Trimble Maxwell 6 chip with 220 channels and leading GNSS technology maximizes data quality

TRANSFORMING THE WAY THE WORLD WORKS

Trimble.

Trimble R2 GNSS RECEIVER

CONFIGURATION OPTION

Type	Smart antenna
Base operation	Yes. Logging only.
Rover operation	Yes
Rover position update rate	1 Hz, 2 Hz, 5 Hz
Rover operation within a VRS Now™ network	Yes

MEASUREMENTS

- Advanced Trimble Maxwell 6 custom GNSS chip
- High-precision multiple correlator for L1/L2 pseudo-range measurements
- Unfiltered, unsmoothed pseudo-range measurements data for low noise, low multipath error, low-time domain correlation, and high-dynamic response
- Very low noise carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Signal-to-noise ratios reported in dB-Hz
- Trimble EVEREST™ multipath signal rejection
- Proven Trimble low elevation tracking technology
- 220-channel GNSS
- 4-channel SBAS (WAAS/EGNOS/MSAS/GAGAN)

POSITIONING PERFORMANCE

SBAS (WAAS/EGNOS/MSAS/GAGAN) Positioning[1]

Horizontal accuracy	±0.50 m (1.6 ft)
Vertical accuracy	±0.85 m (2.8 ft)

Code Differential GPS Positioning[2]

Correction type	DGPS RTCM 2.x
Correction source	IBSS
Horizontal accuracy	±(0.25 m + 1 ppm) RMS ±(0.8 ft + 1 ppm)
Vertical accuracy	±(0.50 m + 1 ppm) RMS ±(1.6 ft + 1 ppm)

Static GNSS Positioning

Static and Fast Static	
Horizontal	3 mm + 0.5 ppm RMS
Vertical	5 mm + 0.5 ppm RMS

Post-Processed Kinematic (PPK)[2]

Horizontal accuracy	10 mm + 1 ppm RMS (0.033 ft + 1 ppm RMS)
Vertical accuracy	20 mm + 1 ppm RMS (0.065 ft + 1 ppm RMS)

Trimble RTX Positioning[3,4]

CenterPoint® RTX	
Horizontal accuracy	2 cm RMS
Vertical accuracy	5 cm RMS
FieldPoint RTX™	10 cm Horizontal RMS
RangePoint® RTX	30 cm Horizontal RMS
ViewPoint RTX™	50 cm Horizontal RMS

RTK Positioning[2]

Horizontal accuracy	10 mm + 1 ppm RMS (0.033 ft + 1 ppm RMS)
Vertical accuracy	20 mm + 1 ppm RMS (0.065 ft + 1 ppm RMS)

Network RTK[2]

Horizontal accuracy	10 mm + 0.5 ppm RMS (0.033 ft + 0.5 ppm RMS)
Vertical accuracy	20 mm + 0.5 ppm RMS (0.065 ft + 0.5 ppm RMS)

BATTERY AND POWER

Internal	Replaceable internal battery 7.4 V, 2800 mA-hr, Lithium-ion
External	Power input on the Mini-B USB connector, non-charging as per the USB standard 10 W USB adapter
Power consumption	4.95 W (VFD 100%), 3.7 W (VFD 12.5%) at 18 V, in rover mode
Operation time on internal battery	
Rover	5 hours; varies with temperature

MECHANICAL

User interface	LED indicators for receiver status On/Off key for one-button startup
Dimensions	14.0 cm (5.5 in) diameter x 11.4 cm (4.5 in) height
Weight	1.08 kg (2.38 lb) receiver only

ENVIRONMENTAL

Temperature	
Operating	−20 °C to +55 °C (−4 °F to +131 °F)
Storage	−40 °C to +75 °C (−40 °F to +167 °F)
Humidity	100% condensing
Waterproof	IP65
Pole drop	Designed to survive a 2 m (6.6 ft) drop onto all faces and corners onto concrete (25C)
Shock	
Non-operating	To 75 g, 6 ms, saw-tooth
Operating	To 40 g, 10 ms, saw-tooth 100 shock events at 2 Hz rate
Vibration	MIL-STD-810G (Operating), Method 514.6, Procedure I, Category 4, Figure 514.6C-1 (Common Carrier, US Highway Truck Vibration Exposure) Total Grms levels applied are 1.95 g

INTERNAL ANTENNA

Frequency Range	L1/L2 (GPS, GLONASS, Galileo, BeiDou, QZSS), MSS (RTX), L1 SBAS

COMMUNICATIONS

USB	1 USB 2.0 (Type B) device
Wi-Fi	Simultaneous client and access point (AP) modes
Bluetooth wireless technology	Fully-integrated, fully-sealed 2.4 GHz Bluetooth module[5]
Network protocols	HTTP (web browser GUI); NTP Server, TCP/IP or UDP; NTRIP v1 and v2, Client mode; mDNS/uPnP service discovery; dynamic DNS; eMail alerts; network link to Google Earth; PPP and PPPoE
Supported data formats	
Correction inputs	CMR, CMR+™, CMRx, RTCM 2.x, RTCM 3.0, RTCM 3.1, RTCM 3.2
Correction outputs	None
Data outputs	NMEA, GSOF
External GSM/GPRS modem, cell phone support	
Integrated receiving radio (optional)	Integrated 450 MHz UHF Radio
Channel spacing (450 MHz)	12.5 and 25 kHz
Sensitivity (450 MHz)	-103 dBm, GMSK 9600 baud 25kHz channel spacing
Data storage	48 MB internal memory[6]

CERTIFICATIONS

IEC 60950-1 (Electrical Safety); FCC OET Bulletin 65 (RF Exposure Safety); FCC Part 15.105 (Class B), Part 15.247, Part 90; Bluetooth SIG; IC ES-003 (Class B); Radio Equipment Directive 2014/53/EU, RoHS, WEEE; Australia & New Zealand RCM; Japan Radio and Telecom MIC

1 Depends on SBAS system performance.
2 Accuracy and reliability may be subject to anomalies such as multipath, obstructions, satellite geometry, interference and atmospheric conditions. Always follow recommended practices.
3 CenterPoint RTX accuracy is typically achieved within 5 minutes in select regions, and within 30 minutes worldwide. FieldPoint RTX accuracy is typically achieved within 5 minutes in select regions, and within 15 minutes worldwide. RangePoint RTX and ViewPoint RTX accuracy is typically achieved within 5 minutes worldwide.
4 Receiver accuracy and convergence time varies based on GNSS constellation health, level of multipath, and proximity to obstructions such as large trees and buildings.
5 Bluetooth type approvals are country-specific. For more information, contact your local Trimble office or representative.
6 The actual available capacity of the internal memory is less than the specified capacity because the firmware occupies part of the memory. The available capacity may change when you upgrade receiver firmware.

Specifications subject to change without notice.

Contact your local Trimble Authorized Distribution Partner for more information

NORTH AMERICA
Trimble Inc.
10368 Westmoor Drive
Westminster CO 80021
USA

EUROPE
Trimble Germany GmbH
Am Prime Parc 11
65479 Raunheim
GERMANY

ASIA-PACIFIC
Trimble Navigation
Singapore PTE Limited
3 HarbourFront Place
#13-02 HarbourFront Tower Two
Singapore 099254
SINGAPORE

Appendix D - Leica GS18 Manufacturer Specification

Leica GS18 T
Data sheet

Engaging software

The Leica GS18 T is accompanied with the revolutionary Captivate software, turning complex data into the most realistic and workable 3D models. With easy-to-use apps and familiar touch technology, all forms of measured and design data can be viewed in all dimensions. Leica Captivate spans industries and applications with little more than a simple swipe, regardless of whether you work with GNSS, total stations or both.

Seamlessly share data among all your instruments

Leica Infinity imports and combines data from your GNSS RTK rover, total station and level instruments for one final and accurate result. Processing has never been made easier when all your instruments work in tandem to produce precise and actionable information.

ACC»

Customer care only a click away

Through Active Customer Care (ACC), a global network of experienced professionals is only a click away to expertly guide you through any challenge. Eliminate delays with superior technical service, finish jobs faster and avoid costly site revisits with excellent consultancy support. Control your costs with a tailored Customer Care Package (CCP), giving you peace of mind you are covered anywhere, anytime.

PART OF HEXAGON

leica-geosystems.com

- when it has to be **right**

Leica Geosystems

Leica GS18 T

GNSS TECHNOLOGY		
Self-learning GNSS	Leica RTKplus SmartLink (worldwide correction service) SmartLink fill (worldwide correction service)	Adaptive on-the-fly satellite selection Remote precise point positioning (3 cm 2D)[1] Initial convergence to full accuracy typically 18 min, Re-convergence < 1 min Bridging of RTK outages up to 10 min (3 cm 2D)[1]
Leica SmartCheck	Continuous check of RTK solution	Reliability 99.99%
Signal tracking		GPS (L1, L2, L2C, L5), Glonass (L1, L2, L2C, L3[2]), BeiDou (B1, B2, B3[2]), Galileo (E1, E5a, E5b, Alt-BOC, E6[2]), QZSS (L1, L2C, L5, L6[2]), NavIC L5[3], SBAS (WAAS, EGNOS, MSAS, GAGAN), L-band
Number of channels		555 (more signals, fast acquisition, high sensitivity)
Tilt compensation	Increased measurement productivity and traceability	Calibration-free Immune to magnetic disturbances
MEASUREMENT PERFORMANCE & ACCURACY[1]		
Time for initialisation		Typically 4 s
Real-time kinematic (Compliant to ISO17123-8 standard)	Single baseline Network RTK	Hz 8 mm + 1 ppm / V 15 mm + 1 ppm Hz 8 mm + 0.5 ppm / V 15 mm + 0.5 ppm
Real-time kinematic tilt compensated	Topographic points (not for static control points)	Additional Hz pole tip uncertainty typically less than 8 mm + 0.4 mm/° tilt down to 30° tilt
Post processing	Static (phase) with long observations Static and rapid static (phase)	Hz 3 mm + 0.1 ppm / V 3.5 mm + 0.4 ppm Hz 3 mm + 0.5 ppm / V 5 mm + 0.5 ppm
Code differential	DGPS / RTCM	Typically 25 cm
COMMUNICATIONS		
Communication ports	Lemo Bluetooth®	USB and RS232 serial Bluetooth® v2.1 + EDR, class 1.5
Communication protocols	RTK data protocols NMEA output Network RTK	Leica, Leica 4G, CMR, CMR+, RTCM 2.2, 2.3, 3.0, 3.1, 3.2 MSM NMEA 0183 v4.00 and Leica proprietary VRS, FKP, iMAX, MAC (RTCM SC 104)
Built-in data links	GSM / UMTS / LTE phone modem Radio modem	Fully integrated, external antenna Fully integrated, receive and transmit, external antenna 403 - 473 MHz, 1 W output power, up to 28800 bps over air
External data links		GSM / GPRS / UMTS / LTE / CDMA and UHF / VHF modem
GENERAL		
Field controller and software	Leica Captivate software	Leica CS20 field controller, Leica CS35 tablet
User interface	Buttons and LEDs Web server	On / Off and Function button, 8 status LEDs Full status information and configuration options
Data recording	Storage Data type and recording rate	Removable SD card, 8 GB Leica GNSS raw data and RINEX data at up to 20 Hz
Power management	Internal power supply External power supply Operation time[4]	Exchangeable Li-Ion battery (2.8 Ah / 11.1 V) Nominal 12 V DC, range 10.5 - 26.4 V DC 7h receiving (Rx) data with internal radio, 5 h transmitting (Tx) data with internal radio, 6 h Rx/Tx data with internal phone modem
Weight and dimensions	Weight Dimensions	1.20 kg / 3.50 kg standard RTK rover setup on pole 173 mm x 173 mm x 108 mm
Environmental	Temperature Drop Proof against water, sand and dust Vibration Humidity Functional shock	-40 to 65°C operating, -40 to 85°C storage Withstands topple over from a 2 m survey pole onto hard surfaces IP66 / IP68 (IEC60529 / MIL STD 810G CHG-1 510.6 I / MIL STD 810G CHG-1 506.6 II / MIL STD 810G CHG-1 512.6 I) Withstands strong vibration (ISO9022-36-08 / MIL STD 810G 514.6 Cat.24) 95% (ISO9022-13-06 / ISO9022-12-04 / MIL STD 810G CHG-1 507.6 II) 40 g / 15 to 23 msec (MIL STD 810G 516.6 I)

LEICA GS18 T GNSS RTK ROVER	PERFORMANCE	UNLIMITED
SUPPORTED GNSS SYSTEMS		
Multi-frequency	✔	✔
GPS / GLONASS / Galileo / BeiDou / QZSS	✔ / • / • / • / •	✔ / ✔ / ✔ / ✔ / ✔
SUPPORTED GNSS SYSTEMS		
DGPS/RTCM, RTK Unlimited, Network RTK	✔	✔
SmartLink fill / SmartLink	• / •	✔ / •
POSITION UPDATE & DATA RECORDING		
5 Hz / 20 Hz positioning	✔ / ✔	✔ / ✔
Raw data / RINEX data logging / NMEA out	✔ / • / •	✔ / ✔ / ✔
ADDITIONAL FEATURES		
Tilt compensation	✔	✔
RTK reference station functionality	✔	✔
LTE Phone / UHF Radio (receive & transmit) modem	✔ / •	✔ / •

✔ Standard • Optional

[1] Measurement precision, accuracy, reliability and time for initialisation are dependent upon various factors including number of satellites, observation time, atmospheric conditions, multipath etc. Figures quoted assume normal to favourable conditions. A full BeiDou and Galileo constellation will further increase measurement performance and accuracy.

[2] Glonass L3, BeiDou B3, QZSS L6 and Galileo E6 will be provided through future firmware upgrade.

[3] Support of NavIC L5 is incorporated and will be provided through future firmware upgrade.

[4] Might vary with temperature, age of battery, transmit power of data link device.

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- when it has to be **right**

Appendix E – Field Observation Record

Department of Natural Resources and Mines

GNSS Single Static Session Field Observation Record				Project	
Mark ID (PSM#)	Alternate Name	Station Description		GA 4 Character ID	
206731				QLD 4 Character ID	
Region/Location	Observer/s	Agency		UT Day of Year at Start	
COOYAR	M. VENAGLIA	DNRME		Date Start	22/07/19
Receiver (if not a combined ant/rec)	Antenna	Set		Time Start	08 : 40
Type: R2 -1	Type:	NGS Antenna ID:		Date Stop	22/07/19
S/N: 5611503531	S/N:			Time Stop	15 : 09

Electronic Data Filenames		Weather Information (circle appropriate)			Local Time ■ OR UTC ☐	
~~35312020.190~~	Raw	Temperature	Sky	Wind	UT -> Local	+ 10 hrs
~~35311980.190~~	RINEX	Hot >30ºC	Fine/(Clear)	(Calm)	Elevation Mask	10 °
	Quality Control	Warm 15-30ºC	Shower/O'cast	Moderate	Epoch Rate (Seconds)	~~30 sec~~ 1 sec
	Booking Sheet	(Cold <15ºC)	Rain/Storms	Strong	GPS only ☐	GNSS ■

Antenna Height Details

Measure height to top of adaptor before attaching antenna if sighting to bottom of antenna mount is difficult. Measure "slant height" to bottom of ground plane, centre of bumper (R8), or the centre of bottom ring (LEI1203/Viva) at 3 points. For geodetic antennas, measure to inside of notch and book notch number. **"Height Entered into Receiver/Controller" should be ARP as calculated below.**

	Height to Bottom Antenna Mount / Top of Adaptor		
	Height Entered into Receiver/Controller		
1.635	Slant Height 1 <- Before	Notch # After ->	
1.635	Slant Height 2 <- Before	Notch # After ->	
1.635	Slant Height 3 <- Before	Notch # After ->	
1.635	MEAN SLANT HEIGHT <- Before	After ->	1.635

Station Setup Checks	Before	After
Antenna Height Checks OK	☑	☑
Levelled & Centred	☑	☑
Antenna Oriented North	☒	☒
Logging Data	☑	☑
On-site tracking confirmed	☑	☑
External Power Connected	☒	☒
Power Still on at End	☑	
PSM number physically confirmed	☑	
Photos/Proof of Occupation	☑	

Antenna Height Checks:

BAM = Bottom of Antenna Mount
ARP = Antenna Reference Point

ARP = √ (Mean Slant Height² - Radius²) - Ground Plane Offset

Height Check Parameters: - 0.005 m < ARP - BAM < 0.005 m

ARP (Before) = √(² - ²) -
= √ -
ARP (Before) =
ARP - BAM = 0. m (+/- 0.005m to BAM)

Height Check Before OK ? Y ☐ N ☐

ARP (After) = √(² - ²) -
= √ -
ARP (After) =
ARP - BAM = 0. m (+/- 0.005m to BAM)

Height Check After OK ? Y ☐ N ☐

Problems Encountered	Solved?
	Y☐ N☐
	Y☐ N☐
	Y☐ N☐

Comments: 7% BATTERY
NO ISSUES.

Antenna Offsets	TRM R8 (M1, 2 & 3), 5800 & MC L1/L2	TRM Zephyr	TRM Zephyr Geodetic 1&2	TPS Hiper_SR + NONE	LEI AS10	LEI GS15 (Viva)	JAV Triumph 1
Radius	0.091	0.0937	0.1698	0.0950	0.085	0.0980	0.0888
Ground Plane Offset	0.0552	0.0387	0.0444	0.0300	0.033	0.1580	0.0550

Queensland Government

GNSS_SingleStatic_Form.xls Last Modified: 25/10/2012 Page 1 of 2

Appendix F – Test Case List

Test Case List

Site	PM 206731 - COOYAR		Date			Round number	1 - ~~8:59~~ 9:08 (START) 9:59. (FINISH)
Test Case	Procedure	Solution type	Test length	Service		Point number	Complete/Comments
1	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	VRS	1 min test	SmartNet		1111	✓ / WRONG FIRST POINT SOLUTION TYPE.
2		VRS	1 min test	ADRTK		1112	✓
3		VRS	1 min test	VRSNow		1113	✓
4	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	VRS	2 min	SmartNet		1121	✓
5		VRS	2 min	ADRTK		1122	✓
6		VRS	2 min	VRSNow		1123	✓
7	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	Nearest Base	1 min test	SmartNet		1211	✓
8		Nearest Base	1 min test	ADRTK		1212	✓
9		Nearest Base	1 min test	VRSNow		1213	✓
10	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	Nearest Base	2 min	SmartNet		1221	✓
11		Nearest Base	2 min	ADRTK		1222	✓
12		Nearest Base	2 min	VRSNow		1223	✓
13	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	IMAX	1 min test	SmartNet		1311	✓
		-		ADRTK			
		-		VRSNow			
14	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	IMAX	2 min	SmartNet		1321	✓ / STOPPED + RESTARTED RTK
		-		ADRTK			
		-		VRSNow			
15	Set network soultion type. Initialisation complete. Set to store 60 epocs. Start logging.	MAC	1 min test	SmartNet		1411	✓ / "
		-		ADRTK			
		-		VRSNow			
16	Set network soultion type. Initialisation complete. Set to store 120 epocs. Start logging.	MAC	2 min	SmartNet		1521	✓ / "
		-		ADRTK			
		-		VRSNow			

Appendix G – Raw observation data for PM180957

Point ID	Easting	Northing	RTCM Ref	Network Type	Network Solution	Inside RTK Network	Ref Stations Used	Num RTK Positions
1111	394170.895	6953970.23	RTCM-Ref 0714	VRS	TRUE	Inside	1	60
2111	394170.895	6953970.231	RTCM-Ref 0774	VRS	TRUE	Inside	1	60
3111	394170.895	6953970.229	RTCM-Ref 0829	VRS	TRUE	Inside	1	60
4111	394170.895	6953970.228	RTCM-Ref 0889	VRS	TRUE	Inside	1	60
5111	394170.893	6953970.228	RTCM-Ref 0949	VRS	TRUE	Inside	1	60
6111	394170.896	6953970.228	RTCM-Ref 1006	VRS	TRUE	Inside	1	60
1211	394170.893	6953970.228	RTCM-Ref 0121	None	TRUE	Outside	1	60
2211	394170.896	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	60
3211	394170.895	6953970.228	RTCM-Ref 0121	None	TRUE	Outside	1	60
4211	394170.895	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	60
5211	394170.895	6953970.23	RTCM-Ref 0121	None	TRUE	Outside	1	60
6211	394170.895	6953970.228	RTCM-Ref 0121	None	TRUE	Outside	1	60
1311	394170.895	6953970.229	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	60
2311	394170.897	6953970.23	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	60
3311	394170.895	6953970.231	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	60
4311	394170.895	6953970.228	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	60
5311	394170.894	6953970.229	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	60
6311	394170.894	6953970.229	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	60
1411	394170.895	6953970.228	RTCM-Ref 0121	MAC	TRUE	Inside	6	60
2411	394170.895	6953970.227	RTCM-Ref 0121	MAC	TRUE	Inside	6	60
3411	394170.894	6953970.228	RTCM-Ref 0121	MAC	TRUE	Inside	6	60
4411	394170.895	6953970.228	RTCM-Ref 0121	MAC	TRUE	Inside	6	60
5411	394170.893	6953970.229	RTCM-Ref 0121	MAC	TRUE	Inside	6	60
6411	394170.894	6953970.228	RTCM-Ref 0121	MAC	TRUE	Inside	6	60
1121	394170.892	6953970.223	RTCM-Ref 0727	VRS	TRUE	Inside	1	120
2121	394170.895	6953970.229	RTCM-Ref 0784	VRS	TRUE	Inside	1	120
3121	394170.895	6953970.229	RTCM-Ref 0843	VRS	TRUE	Inside	1	120
4121	394170.896	6953970.229	RTCM-Ref 0903	VRS	TRUE	Inside	1	120
5121	394170.894	6953970.229	RTCM-Ref 0959	VRS	TRUE	Inside	1	120
6121	394170.893	6953970.227	RTCM-Ref 1017	VRS	TRUE	Inside	1	120
1221	394170.897	6953970.23	RTCM-Ref 0121	None	TRUE	Outside	1	120
2221	394170.894	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	120
3221	394170.895	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	120
4221	394170.895	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	120
5221	394170.895	6953970.23	RTCM-Ref 0121	None	TRUE	Outside	1	120

6221	394170.896	6953970.228	RTCM-Ref 0121	None	TRUE	Outside	1	120
1321	394170.895	6953970.229	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	120
2321	394170.895	6953970.23	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	120
3321	394170.896	6953970.229	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	120
4321	394170.895	6953970.229	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	120
5321	394170.893	6953970.229	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	120
6321	394170.895	6953970.227	RTCM-Ref 0121	i-MAX	TRUE	Inside	1	120
1521	394170.894	6953970.228	RTCM-Ref 0121	MAC	TRUE	Inside	6	120
2521	394170.895	6953970.227	RTCM-Ref 0121	MAC	TRUE	Inside	6	120
3521	394170.894	6953970.229	RTCM-Ref 0121	MAC	TRUE	Inside	6	120
4521	394170.894	6953970.228	RTCM-Ref 0121	MAC	TRUE	Inside	6	120
5521	394170.894	6953970.228	RTCM-Ref 0121	MAC	TRUE	Inside	6	120
6521	394170.896	6953970.227	RTCM-Ref 0121	MAC	TRUE	Inside	6	120
1112	394170.893	6953970.223	RTCM-Ref 1845	VRS	TRUE	Inside	1	60
2112	394170.891	6953970.224	RTCM-Ref 1883	VRS	TRUE	Inside	1	60
3112	394170.89	6953970.225	RTCM-Ref 2867	VRS	TRUE	Inside	1	60
4112	394170.899	6953970.226	RTCM-Ref 1963	VRS	TRUE	Inside	1	60
5112	394170.901	6953970.224	RTCM-Ref 1999	VRS	TRUE	Inside	1	60
6112	394170.893	6953970.228	RTCM-Ref 2033	VRS	TRUE	Inside	1	60
1212	394170.893	6953970.228	RTCM-Ref 0121	None	TRUE	Outside	1	60
2212	394170.896	6953970.23	RTCM-Ref 0121	None	TRUE	Outside	1	60
3212	394170.897	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	60
4212	394170.895	6953970.227	RTCM-Ref 0121	None	TRUE	Outside	1	60
5212	394170.893	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	60
6212	394170.894	6953970.227	RTCM-Ref 0121	None	TRUE	Outside	1	60
1122	394170.889	6953970.215	RTCM-Ref 1853	VRS	TRUE	Inside	1	120
2122	394170.884	6953970.208	RTCM-Ref 1893	VRS	TRUE	Inside	1	120
3122	394170.891	6953970.227	RTCM-Ref 1935	VRS	TRUE	Inside	1	120
4122	394170.898	6953970.226	RTCM-Ref 1975	VRS	TRUE	Inside	1	120
5122	394170.892	6953970.228	RTCM-Ref 2005	VRS	TRUE	Inside	1	120
6122	394170.896	6953970.227	RTCM-Ref 2043	VRS	TRUE	Inside	1	120
1222	394170.896	6953970.23	RTCM-Ref 0121	None	TRUE	Outside	1	120
2222	394170.894	6953970.228	RTCM-Ref 0121	None	TRUE	Outside	1	120
3222	394170.897	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	120
4222	394170.894	6953970.229	RTCM-Ref 0121	None	TRUE	Outside	1	120
5222	394170.895	6953970.23	RTCM-Ref 0121	None	TRUE	Outside	1	120
6222	394170.897	6953970.227	RTCM-Ref 0121	None	TRUE	Outside	1	120
1113	394170.899	6953970.229	RTCM-Ref 2841	VRS	TRUE	Inside	1	60
2113	394170.897	6953970.226	RTCM-Ref 2861	VRS	TRUE	Inside	1	60
3113	394170.903	6953970.226	RTCM-Ref 2867	VRS	TRUE	Inside	1	60

4113	394170.901	6953970.228	RTCM-Ref 2878	VRS	TRUE	Inside	1	60
5113	394170.898	6953970.233	RTCM-Ref 2891	VRS	TRUE	Inside	1	60
6113	394170.894	6953970.227	RTCM-Ref 2911	VRS	TRUE	Inside	1	60
1213	394170.89	6953970.231	RTCM-Ref 0161	None	TRUE	Outside	1	60
2213	394170.903	6953970.235	RTCM-Ref 0161	None	TRUE	Outside	1	60
3213	394170.904	6953970.224	RTCM-Ref 0161	None	TRUE	Outside	1	60
4213	394170.899	6953970.225	RTCM-Ref 0161	None	TRUE	Outside	1	60
5213	394170.893	6953970.235	RTCM-Ref 0161	None	TRUE	Outside	1	60
6213	394170.897	6953970.237	RTCM-Ref 0161	None	TRUE	Outside	1	60
1123	394170.894	6953970.226	RTCM-Ref 2846	VRS	TRUE	Inside	1	120
2123	394170.897	6953970.227	RTCM-Ref 2863	VRS	TRUE	Inside	1	120
3123	394170.9	6953970.225	RTCM-Ref 2871	VRS	TRUE	Inside	1	120
4123	394170.902	6953970.226	RTCM-Ref 2879	VRS	TRUE	Inside	1	120
5123	394170.896	6953970.23	RTCM-Ref 2896	VRS	TRUE	Inside	1	120
6123	394170.894	6953970.226	RTCM-Ref 2915	VRS	TRUE	Inside	1	120
1223	394170.904	6953970.233	RTCM-Ref 0161	None	TRUE	Outside	1	120
2223	394170.908	6953970.232	RTCM-Ref 0161	None	TRUE	Outside	1	120
3223	394170.901	6953970.224	RTCM-Ref 0161	None	TRUE	Outside	1	120
4223	394170.9	6953970.224	RTCM-Ref 0161	None	TRUE	Outside	1	120
5223	394170.901	6953970.232	RTCM-Ref 0161	None	TRUE	Outside	1	120
6223	394170.899	6953970.233	RTCM-Ref 0161	None	TRUE	Outside	1	120
RTCM-Ref 0121	394189.971	6953910.335						
RTCM-Ref 0161	394586.988	6946490.599						
RTCM-Ref 0714	394171.771	6953970.584						
RTCM-Ref 0727	394171.85	6953971.057						
RTCM-Ref 0774	394171.419	6953970.522						
RTCM-Ref 0784	394171.359	6953970.646						
RTCM-Ref 0829	394171.569	6953971.026						
RTCM-Ref 0843	394171.63	6953971.058						
RTCM-Ref 0889	394171.987	6953970.83						
RTCM-Ref 0903	394172.041	6953970.703						
RTCM-Ref 0949	394171.59	6953970.398						
RTCM-Ref 0959	394171.622	6953970.298						
RTCM-Ref 1006	394170.977	6953970.655						
RTCM-Ref 1017	394170.83	6953970.709						
RTCM-Ref 1845	394171.786	6953970.575						
RTCM-Ref 1853	394171.8	6953970.922						
RTCM-Ref 1883	394171.425	6953970.504						
RTCM-Ref 1893	394171.33	6953970.648						

RTCM-Ref 1935	394171.457	6953970.985						
RTCM-Ref 1963	394171.966	6953970.801						
RTCM-Ref 1975	394172.057	6953970.703						
RTCM-Ref 1999	394171.541	6953970.336						
RTCM-Ref 2005	394171.636	6953970.35						
RTCM-Ref 2033	394170.909	6953970.664						
RTCM-Ref 2043	394170.824	6953970.731						
RTCM-Ref 2841	394171.799	6953970.978						
RTCM-Ref 2846	394171.747	6953970.669						
RTCM-Ref 2861	394171.383	6953970.552						
RTCM-Ref 2863	394171.326	6953970.703						
RTCM-Ref 2867	394171.588	6953971.086						
RTCM-Ref 2871	394171.534	6953970.948						
RTCM-Ref 2878	394172.027	6953970.718						
RTCM-Ref 2879	394171.601	6953970.346						
RTCM-Ref 2891	394171.48	6953970.308						
RTCM-Ref 2896	394171.54	6953970.394						
RTCM-Ref 2911	394171.067	6953970.869						
RTCM-Ref 2915	394170.85	6953970.765						

Appendix H – Raw observation data for PM206731

Point ID	Easting	Northing	RTCM Ref	Data Format	Network Type	Network Solution	Inside RTK Network	Ref Stations Used	Num RTK Positions
1111	389261.302	7004609.803	RTCM-Ref 3201	RTCM v3	VRS	TRUE	Inside	1	60
2111	389261.303	7004609.803	RTCM-Ref 3259	RTCM v3	VRS	TRUE	Inside	1	60
3111	389261.305	7004609.805	RTCM-Ref 3331	RTCM v3	VRS	TRUE	Inside	1	60
4111	389261.306	7004609.800	RTCM-Ref 3381	RTCM v3	VRS	TRUE	Inside	1	60
5111	389261.304	7004609.801	RTCM-Ref 3439	RTCM v3	VRS	TRUE	Inside	1	60
6111	389261.306	7004609.798	RTCM-Ref 3501	RTCM v3	VRS	TRUE	Inside	1	60
1112	389261.316	7004609.803	RTCM-Ref 1111	RTCM v3	VRS	TRUE	Inside	1	60
2112	389261.308	7004609.800	RTCM-Ref 1177	RTCM v3	VRS	TRUE	Inside	1	60
3112	389261.328	7004609.804	RTCM-Ref 1197	RTCM v3	VRS	TRUE	Inside	1	60
4112	389261.333	7004609.805	RTCM-Ref 1229	RTCM v3	VRS	TRUE	Inside	1	60
5112	389261.309	7004609.806	RTCM-Ref 1261	RTCM v3	VRS	TRUE	Inside	1	60
6112	389261.302	7004609.811	RTCM-Ref 1295	RTCM v3	VRS	TRUE	Inside	1	60
1113	389261.299	7004609.801	RTCM-Ref 2808	RTCM v3	VRS	TRUE	Inside	1	60
2113	389261.295	7004609.805	RTCM-Ref 2812	RTCM v3	VRS	TRUE	Inside	1	60
3113	389261.300	7004609.812	RTCM-Ref 2816	RTCM v3	VRS	TRUE	Inside	1	60
4113	389261.295	7004609.802	RTCM-Ref 2818	RTCM v3	VRS	TRUE	Inside	1	60
5113	389261.292	7004609.807	RTCM-Ref 2820	RTCM v3	VRS	TRUE	Inside	1	60
6113	389261.305	7004609.802	RTCM-Ref 2822	RTCM v3	VRS	TRUE	Inside	1	60
1121	389261.305	7004609.797	RTCM-Ref 3213	RTCM v3	VRS	TRUE	Inside	1	120
2121	389261.307	7004609.803	RTCM-Ref 3286	RTCM v3	VRS	TRUE	Inside	1	120
3121	389261.303	7004609.798	RTCM-Ref 3340	RTCM v3	VRS	TRUE	Inside	1	120
4121	389261.305	7004609.806	RTCM-Ref 3398	RTCM v3	VRS	TRUE	Inside	1	120
5121	389261.304	7004609.801	RTCM-Ref 3453	RTCM v3	VRS	TRUE	Inside	1	120
6121	389261.306	7004609.803	RTCM-Ref 3513	RTCM v3	VRS	TRUE	Inside	1	120
1122	389261.318	7004609.791	RTCM-Ref 1119	RTCM v3	VRS	TRUE	Inside	1	120
2122	389261.318	7004609.813	RTCM-Ref 1171	RTCM v3	VRS	TRUE	Inside	1	120
3122	389261.317	7004609.819	RTCM-Ref 1203	RTCM v3	VRS	TRUE	Inside	1	120
4122	389261.310	7004609.805	RTCM-Ref 1237	RTCM v3	VRS	TRUE	Inside	1	120
5122	389261.318	7004609.806	RTCM-Ref 1273	RTCM v3	VRS	TRUE	Inside	1	120
6122	389261.309	7004609.810	RTCM-Ref 1305	RTCM v3	VRS	TRUE	Inside	1	120
1123	389261.300	7004609.800	RTCM-Ref 2809	RTCM v3	VRS	TRUE	Inside	1	120
2123	389261.301	7004609.793	RTCM-Ref 2815	RTCM v3	VRS	TRUE	Inside	1	120

3123	389261.302	7004609.810	RTCM-Ref 2817	RTCM v3	VRS	TRUE	Inside	1	120
4123	389261.298	7004609.815	RTCM-Ref 2819	RTCM v3	VRS	TRUE	Inside	1	120
5123	389261.302	7004609.800	RTCM-Ref 2821	RTCM v3	VRS	TRUE	Inside	1	120
6123	389261.302	7004609.803	RTCM-Ref 2823	RTCM v3	VRS	TRUE	Inside	1	120
1211	389261.311	7004609.797	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
2211	389261.300	7004609.799	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
3211	389261.312	7004609.806	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
4211	389261.292	7004609.804	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
5211	389261.310	7004609.788	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
6211	389261.311	7004609.800	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
1212	389261.299	7004609.788	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
2212	389261.300	7004609.781	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
3212	389261.305	7004609.814	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
4212	389261.299	7004609.804	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
5212	389261.308	7004609.791	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
6212	389261.297	7004609.809	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	60
1213	389261.305	7004609.801	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	60
2213	389261.313	7004609.807	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	60
3213	389261.303	7004609.812	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	60
4213	389261.303	7004609.813	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	60
5213	389261.303	7004609.806	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	60
6213	389261.311	7004609.813	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	60
1221	389261.305	7004609.793	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
2221	389261.296	7004609.787	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
3221	389261.304	7004609.806	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
4221	389261.289	7004609.811	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
5221	389261.313	7004609.791	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
6221	389261.298	7004609.807	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
1222	389261.310	7004609.797	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
2222	389261.302	7004609.786	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
3222	389261.311	7004609.804	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
4222	389261.300	7004609.802	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
5222	389261.317	7004609.787	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
6222	389261.305	7004609.804	RTCM-Ref 0119	RTCM v3	None	TRUE	Outside	1	120
1223	389261.310	7004609.809	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	120
2223	389261.307	7004609.812	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	120
3223	389261.306	7004609.807	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	120

4223	389261.305	7004609.806	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	120
5223	389261.302	7004609.805	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	120
6223	389261.315	7004609.810	RTCM-Ref 0121	RTCM v3	None	TRUE	Outside	1	120
1311	389261.304	7004609.800	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	60
2311	389261.308	7004609.800	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	60
3311	389261.306	7004609.801	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	60
4311	389261.302	7004609.805	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	60
5311	389261.309	7004609.797	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	60
6311	389261.308	7004609.802	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	60
1321	389261.301	7004609.795	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	120
2321	389261.312	7004609.797	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	120
3321	389261.313	7004609.795	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	120
4321	389261.302	7004609.803	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	120
5321	389261.310	7004609.801	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	120
6321	389261.312	7004609.798	RTCM-Ref 0119	RTCM v3	i-MAX	TRUE	Inside	1	120
1411	389261.302	7004609.793	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	60
2411	389261.310	7004609.799	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	60
3411	389261.316	7004609.793	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	60
4411	389261.313	7004609.795	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	60
5411	389261.313	7004609.795	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	60
6411	389261.307	7004609.798	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	60
1521	389261.304	7004609.795	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	120
2521	389261.306	7004609.800	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	120
3521	389261.317	7004609.796	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	120
4521	389261.309	7004609.798	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	120
5521	389261.312	7004609.801	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	120
6521	389261.310	7004609.802	RTCM-Ref 0119	RTCM v3	MAC	TRUE	Inside	6	120
RTCM-Ref 0066	390590.622	7035748.430							
RTCM-Ref 0119	371285.677	6982956.592							
RTCM-Ref 0121	437184.082	7004176.421							
RTCM-Ref 1111	389261.322	7004610.306							
RTCM-Ref 1119	389261.654	7004609.725							

RTCM-Ref 1145	389261.765	7004609.677							
RTCM-Ref 1147	389261.357	7004609.741							
RTCM-Ref 1151	389261.743	7004609.437							
RTCM-Ref 1157	389261.465	7004609.647							
RTCM-Ref 1161	389261.283	7004609.640							
RTCM-Ref 1163	389261.330	7004609.519							
RTCM-Ref 1167	389261.362	7004609.659							
RTCM-Ref 1171	389262.120	7004609.815							
RTCM-Ref 1177	389262.114	7004609.696							
RTCM-Ref 1197	389262.552	7004610.625							
RTCM-Ref 1203	389262.572	7004610.778							
RTCM-Ref 1223	389262.395	7004611.138							
RTCM-Ref 1225	389261.519	7004609.958							
RTCM-Ref 1229	389261.220	7004609.823							
RTCM-Ref 1237	389262.301	7004610.975							
RTCM-Ref 1261	389262.001	7004611.238							
RTCM-Ref 1269	389261.710	7004610.845							
RTCM-Ref 1273	389261.329	7004609.729							
RTCM-Ref 1293	389261.279	7004611.246							
RTCM-Ref 1295	389261.112	7004609.684							
RTCM-Ref 1303	389261.296	7004611.165							
RTCM-Ref 1305	389261.278	7004609.735							
RTCM-Ref 2807	389261.129	7004610.411							
RTCM-Ref 2808	389261.411	7004609.736							

RTCM-Ref 2809	389261.703	7004609.628							
RTCM-Ref 2812	389261.489	7004609.687							
RTCM-Ref 2815	389262.106	7004609.789							
RTCM-Ref 2816	389262.620	7004610.660							
RTCM-Ref 2817	389262.343	7004610.733							
RTCM-Ref 2818	389262.323	7004611.038							
RTCM-Ref 2819	389262.342	7004611.083							
RTCM-Ref 2820	389261.992	7004611.102							
RTCM-Ref 2821	389261.625	7004610.886							
RTCM-Ref 2822	389261.294	7004611.186							
RTCM-Ref 2823	389261.558	7004610.982							
RTCM-Ref 3201	389261.302	7004610.316							
RTCM-Ref 3213	389261.563	7004609.740							
RTCM-Ref 3259	389261.737	7004609.245							
RTCM-Ref 3286	389261.731	7004609.675							
RTCM-Ref 3331	389262.528	7004610.548							
RTCM-Ref 3340	389262.609	7004610.706							
RTCM-Ref 3381	389262.456	7004611.126							
RTCM-Ref 3398	389262.275	7004610.974							
RTCM-Ref 3439	389262.012	7004611.174							
RTCM-Ref 3453	389261.863	7004611.050							
RTCM-Ref 3501	389261.273	7004611.346							
RTCM-Ref 3513	389261.267	7004611.223							

Appendix I – Regulation 13 Cetrificates

Australian Government

Geoscience Australia

Certificate of Verification of a Reference Standard of a Position-Measurement in Accordance with Regulation 13 of the National Measurement Regulations 1999 and the National Measurement Act 1960

Name of Verifying Authority:

Name: National Positioning Infrastructure Branch
Organisation: Geoscience Australia
Address: Corner Jerrabomberra Ave and Hindmarsh Drive, Symonston ACT 2609 Australia
Telephone: (02) 6249 9111
Email: geodesy@ga.gov.au

Client detail:

Name: Matej Cerny
Organisation: Trimble Navigation Australia Pty Ltd
Address: 1 Puccini Court Stirling WA 6021
Telephone: (08) 6189 7405
Email: Matej_Cerny@Trimble.com
Date of request: 28 June 2019

Description and denomination of standard of measurement:

The measurement was undertaken using an antenna TRM115000.00 NONE (International GNSS Service antenna naming convention) with the serial number 2312107215 and refers to a point located 3.2350 m below the antenna reference point. The antenna is attached to a pole on a roof via a ground permanent marker. The station (4 character ID: USQA) is located at Toowoomba, Queensland. The certificate was determined using data from 02 June 2019 to 08 June 2019 inclusive. Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position issue 2.2. The reference number of this certificate is USQA28062019.

Permanent distinguishing marks:

Exempt under Regulation 16 (4)

Date of verification: 28 June 2019

Date of expiry of certificate: 27 June 2024

NATA

Accredited for compliance with ISO/IEC 17025 - Calibration. Accreditation No. 15002.

Value of standard of measurement:

Station (4 character ID): `USQA`

South Latitude and its uncertainty of value:

$$27^\circ\ 36'\ 5.17050'' \pm 0.00026''\ (0.008\ \text{m})$$

East Longitude and its uncertainty of value:

$$151^\circ\ 55'\ 54.59323'' \pm 0.00026''\ (0.008\ \text{m})$$

Elevation above Ellipsoid and its uncertainty of value:

$$760.874 \pm 0.020\ \text{m}$$

Geocentric Datum of Australia (GDA2020) coordinates referred to the GRS80 ellipsoid being in the ITRF2014 reference frame at the epoch 2020. The uncertainties are calculated in accordance with the principles of the ISO/IEC 98-3 Uncertainty of Measurement - Part 3: Guide to the Expression of Uncertainty in Measurement (2008), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, k, of 2. Measurement traceability is ensured against the recognised value standard for position of the Australian Fiducial Network.

Details of any relevant environmental or other influence factor(s) at the time of verification:

Uncertainty of the coordinates of the recognized-value standard of measurement of position (i.e. GDA2020); and Uncertainty due to instability of the GPS antenna mounting and modelling of the antenna phase centre variations.

Signature:
28 June 2019
Mr Gary Johnston
Geoscience Australia approved signatory

Branch Head
National Positioning Infrastructure Branch
Geoscience Australia

Being a person, or a person representing a body, appointed as a verifying authority under Regulations 71 and 73 of the National Measurement Regulations 1999 in accordance with the National Measurement Act 1960, I hereby certify that the above standard is verified as a reference standard of measurement in accordance with the Regulations, by the above-named authority.

Australian Government

Geoscience Australia

Certificate of Verification of a Reference Standard of a Position-Measurement in Accordance with Regulation 13 of the National Measurement Regulations 1999 and the National Measurement Act 1960

Name of Verifying Authority:

Name: Geodesy Section
Organisation: Geoscience Australia
Address: Corner Jerrabomberra Ave and Hindmarsh Drive, Symonston ACT 2609 Australia
Telephone: (02) 6249 9111
Email: geodesy@ga.gov.au

Client detail:

Name: Darren Burns
Organisation: Department of Natural Resources and Mines
Address: GPO Box 2454, Brisbane, Queensland 4001 Australia
Telephone: (07) 3896 3349
Email: darren.burns@dnrm.qld.gov.au
Date of request: 12 December 2017

Description and denomination of standard of measurement:

The measurement was undertaken using an antenna `LEIAT504GG NONE` (International GNSS Service antenna naming convention) with the serial number 103231 and refers to a point located 0.0000 m below the antenna reference point. This antenna is attached to a threaded spigot on stainless steel plate on pillar. The station (4 character ID: TOOW) is located at the Department of Natural Resources and Mines Business Centre, Lot 959 AG2751, 203 Tor Street, Toowoomba, QLD. The certificate was determined using data from 03 September 2017 to 09 September 2017 inclusive. Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position issue 2.1. The reference number of this certificate is TOOW12122017.

Permanent distinguishing marks:

Exempt under Regulation 16 (4)

Date of verification: 12 December 2017

Date of expiry of certificate: 12 December 2022

NATA

Accredited for compliance with ISO/IEC 17025. Accreditation No. 15002.

Value of standard of measurement:

Station (4 character ID): `TOOW`

South Latitude and its uncertainty of value:

$$27^\circ\ 32'\ 3.95764'' \pm 0.00029''\ (0.009\ m)$$

East Longitude and its uncertainty of value:

$$151^\circ\ 55'\ 42.45501'' \pm 0.00029''\ (0.009\ m)$$

Elevation above Ellipsoid and its uncertainty of value:

$$685.657 \pm 0.026\ m$$

Geocentric Datum of Australia (GDA2020) coordinates referred to the GRS80 ellipsoid being in the ITRF2014 reference frame at the epoch 2020. The uncertainties are calculated in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement (1995), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, k, of 2.

Details of any relevant environmental or other influence factor(s) at the time of verification:

Uncertainty of the coordinates of the recognized-value standard of measurement of position (i.e. GDA2020); and Uncertainty due to instability of the GPS antenna mounting and modelling of the antenna phase centre variations.

Signature:

12 December 2017

Dr John Dawson
NATA approved signatory

Section Leader
Geodesy and Seismic Monitoring Branch
Geoscience Australia

Signature:

12 December 2017

Mr Gary Johnston
Geoscience Australia approved signatory

Branch Head
Geodesy and Seismic Monitoring Branch
Geoscience Australia

Being a person, or a person representing a body, appointed as a verifying authority under Regulations 71 and 73 of the National Measurement Regulations 1999 in accordance with the National Measurement Act 1960, I hereby certify that the above standard is verified as a reference standard of measurement in accordance with the Regulations, by the above-named authority.

Australian Government
Geoscience Australia

Certificate of Verification of a Reference Standard of a Position-Measurement in Accordance with Regulation 13 of the National Measurement Regulations 1999 and the National Measurement Act 1960

Name of Verifying Authority:

Name: Geodesy Section
Organisation: Geoscience Australia
Address: Corner Jerrabomberra Ave and Hindmarsh Drive, Symonston ACT 2609 Australia
Telephone: (02) 6249 9111
Email: geodesy@ga.gov.au

Client detail:

Name: Darren Burns
Organisation: Department of Natural Resources and Mines
Address: GPO Box 2454, Brisbane, Queensland 4001 Australia
Telephone: (07) 3896 3349
Email: darren.burns@dnrm.qld.gov.au
Date of request: 12 December 2017

Description and denomination of standard of measurement:

The measurement was undertaken using an antenna `TRM55971.00 NONE` (International GNSS Service antenna naming convention) with the serial number 30473612 and refers to a point located 0.0000 m below the antenna reference point. This antenna is attached to threaded bolt in stainless steel bracket on the wall of a concrete water reservoir. The station (4 character ID: TOOG) is located on the Toogoolawah Water Reservoir, Lot 3 RP909760, Annette St, Toogoolwah, QLD. The certificate was determined using data from 03 September 2017 to 09 September 2017 inclusive. Analysis was undertaken following the procedures detailed in Geoscience Australia's GPS Analysis Manual for the Verification of Position issue 2.1. The reference number of this certificate is TOOG12122017.

Permanent distinguishing marks:

Exempt under Regulation 16 (4)

Date of verification: 12 December 2017

Date of expiry of certificate: 12 December 2022

NATA

Accredited for compliance with ISO/IEC 17025. Accreditation No. 15002.

Value of standard of measurement:

Station (4 character ID): TOOG

South Latitude and its uncertainty of value:

27° 4' 59.96156" ± 0.00026" (0.008 m)

East Longitude and its uncertainty of value:

152° 21' 59.10469" ± 0.00026" (0.008 m)

Elevation above Ellipsoid and its uncertainty of value:

193.494 ± 0.020 m

Geocentric Datum of Australia (GDA2020) coordinates referred to the GRS80 ellipsoid being in the ITRF2014 reference frame at the epoch 2020. The uncertainties are calculated in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement (1995), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, k, of 2.

Details of any relevant environmental or other influence factor(s) at the time of verification:

Uncertainty of the coordinates of the recognized-value standard of measurement of position (i.e. GDA2020); and Uncertainty due to instability of the GPS antenna mounting and modelling of the antenna phase centre variations.

Signature:	**Signature:**
12 December 2017	12 December 2017
Dr John Dawson NATA approved signatory	Mr Gary Johnston Geoscience Australia approved signatory
Section Leader Geodesy and Seismic Monitoring Branch Geoscience Australia	Branch Head Geodesy and Seismic Monitoring Branch Geoscience Australia

Being a person, or a person representing a body, appointed as a verifying authority under Regulations 71 and 73 of the National Measurement Regulations 1999 in accordance with the National Measurement Act 1960, I hereby certify that the above standard is verified as a reference standard of measurement in accordance with the Regulations, by the above-named authority.

Australian Government
Geoscience Australia

Certificate of Verification of a Reference Standard of a Position-Measurement in Accordance with Regulation 13 of the National Measurement Regulations 1999 and the National Measurement Act 1960

Name of Verifying Authority:

Name: National Geospatial Reference Systems
Organisation: Geoscience Australia
Address: Corner Jerrabomberra Ave and Hindmarsh Drive, Symonston ACT 2609 Australia
Telephone: (02) 6249 9111
Facsimile: (02) 6249 9969
Email: geodesy@ga.gov.au

Client detail:

Name: Jason Spall
Organisation: C.R. Kennedy Survey Solutions
Address: National Tech Support and Training Survey, 80 Kingsford-Smith Drv, Albion, QLD 4010
Telephone: (07) 3962 6210
Facsimile: (07) 3862 6212
Email: jspall@crkennedy.com.au
Date of request: 21 August 2013

Description and denomination of standard of measurement:

The measurement was undertaken using an antenna `LEIAX1202GG NONE` (International GNSS Service antenna naming convention) with the serial number 07160051 and refers to a point located 0.0000 m below the antenna reference point. This antenna is attached to a galvinised mast with a 5/8 inch thread. The station (4 character ID: ACL2) is located on the New Hope Coal Acland administration building, Cherrys Rd, Acland, QLD.

Permanent distinguishing marks:

Exempt under Regulation 16 (4)

Date of verification:

04 November 2013

Date of expiry of certificate:

03 November 2018

NATA

Accredited for compliance with ISO/IEC 17025. Accreditation No. 15002.

Value of standard of measurement:

Station (4 character ID): ACL2

South Latitude and its uncertainty of value:

27° 16' 13.08162" ± 0.008 m

East Longitude and its uncertainty of value:

151° 41' 58.62005" ± 0.008 m

Elevation above Ellipsoid and its uncertainty of value:

509.4526 ± 0.020 m

Geocentric Datum of Australia (GDA94) coordinates referred to the GRS80 ellipsoid being in the ITRF92 reference frame at the epoch 1994. The uncertainties are calculated in accordance with the principles of the ISO Guide to the Expression of Uncertainty in Measurement (1995), with an interval estimated to have a confidence level of 95% at the time of verification. The combined standard uncertainty was converted to an expanded uncertainty using a coverage factor, k, of 2.

Details of any relevant environmental or other influence factor(s) at the time of verification:

Uncertainty of the coordinates of the recognized-value standard of measurement of position (i.e. GDA94); and Uncertainty due to instability of the GPS antenna mounting and modelling of the antenna phase centre variations.

Signature: ______________________

04 November 2013

Dr John Dawson
NATA approved signatory

Section Leader
National Geospatial Reference Systems Section
Geoscience Australia

Signature: ______________________

04 November 2013

Mr Gary Johnston
Geoscience Australia approved signatory

Group Leader
Earth Monitoring and Hazards Group
Geoscience Australia

Being a person, or a person representing a body, appointed as a verifying authority under Regulations 71 and 73 of the National Measurement Regulations 1999 in accordance with the National Measurement Act 1960, I hereby certify that the above standard is verified as a reference standard of measurement in accordance with the Regulations, by the above-named authority.

Appendix J – Risk Management Plan

University of Southern Queensland **Offline Version**

USQ Safety Risk Management System

Note: This is the offline version of the Safety Risk Management System (SRMS) Risk Management Plan (RMP) and is only to be used for planning and drafting sessions, and when working in remote areas or on field activities. It must be transferred to the online SRMS at the first opportunity.

Safety Risk Management Plan – Offline Version			
Assessment Title:	Final year Project Risk Management Plan	Assessment Date:	29/05/2019
Workplace (Division/Faculty/Section):	Spatial Science/Surveying	Review Date:(5 Years Max)	31/07/2019
Context			
Description:			
What is the task/event/purchase/project/procedure?	Research Project		
Why is it being conducted?	Honours		
Where is it being conducted?	Toowoomba		
Course code (if applicable)	ENG 4111/4112	Chemical name (if applicable)	
What other nominal conditions?			
Personnel involved	Michael Venaglia		

Equipment	GNSS Survey Equipment
Environment	Public Road
Other	
Briefly explain the procedure/process	
Assessment Team - who is conducting the assessment?	
Assessor(s)	Michael Venaglia
Others consulted:	Chris McAlister

Eg 1. Enter Consequence

Eg 2. Enter Probability

Eg 3. Find Action

	Consequence				
Probability	**Insignificant** No Injury 0-$5K	**Minor** First Aid $5K-$50K	**Moderate** Med Treatment $50K-$100K	**Major** Serious Injuries $100K-$250K	**Catastrophic** Death More than $250K
Almost Certain 1 in 2	M	H	E	E	E
Likely 1 in 100	M	H	H	E	E
Possible 1 in 1000	L	M	H	H	H
Unlikely 1 in 10 000	L	L	M	M	M
Rare 1 in 1 000 000	L	L	L	L	L
Recommended Action Guide					
E=Extreme Risk – Task ***MUST NOT*** proceed					
H=High Risk – Special Procedures Required (See USQSafe)					
M=Moderate Risk – Risk Management Plan/Work Method Statement Required					
L=Low Risk – Use Routine Procedures					

Step 1 (cont)	Step 2	Step 2a	Step 3				Step 4				
***Hazards*:** From step 1 or more if identified	***The Risk:*** What can happen if exposed to the hazard with existing controls in place?	***Existing Controls:*** What are the existing controls that are already in place?	***Risk Assessment:*** Consequence x Probability = Risk Level				***Additional controls:*** Enter additional controls if required to reduce the risk level	***Risk assessment with additional controls:***			
			Consequence	**Probability**	**Risk Level**	**ALARP? Yes/no**		**Consequence**	**Probability**	**Risk Level**	**ALARP? Yes/no**
Example											
Working in temperatures over 35^0 C	Heat stress/heat stroke/exhaustion leading to serious personal injury/death	Regular breaks, chilled water available, loose clothing, fatigue management policy.	catastrophic	possible	high	No	temporary shade shelters, essential tasks only, close supervision, buddy system	catastrophic	unlikely	mod	Yes
Working on kerbing/road	Traffic accident leading to serious personal injury/death	High visability clothing	Catastrophic	Possible	High	Yes or No	set up traffic cones/bariiers,	Catastrophic	Unlikely	Moderate	Yes or No
Exposure to Sun	Sunburn/heat stress/long term cancer	Sunscreen, longsleeve clothing, widebrim hat	Catastrophic	Rare	Low	Yes or No	choose shadey position, move to shade when waiting for position	Minor	Rare	Low	Yes or No
Pedestrian traffic	trip over equipment/ bump equipment	bright colours of survey equipment	Moderate	Likely	High	Yes or No	set up barriers to restrict access	Minor	Rare	Low	Yes or No
Snakes	Snake Bite	low grass areas for survey	Catastrophic	Unlikely	Moderate	Yes or No	Snake garders, survey at cooler times when snakes not active	Catastrophic	Rare	Low	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No

Step 1 (cont)	Step 2	Step 2a	Step 3				Step 4				
***Hazards*:** From step 1 or more if identified	***The Risk:*** What can happen if exposed to the hazard with existing controls in place?	***Existing Controls:*** What are the existing controls that are already in place?	***Risk Assessment:*** Consequence x Probability = Risk Level				***Additional controls:*** Enter additional controls if required to reduce the risk level	***Risk assessment with additional controls:***			
			Consequence	**Probability**	**Risk Level**	**ALARP? Yes/no**		**Consequence**	**Probability**	**Risk Level**	**ALARP? Yes/no**
Example											
Working in temperatures over 35⁰ C	Heat stress/heat stroke/exhaustion leading to serious personal injury/death	Regular breaks, chilled water available, loose clothing, fatigue management policy.	catastrophic	possible	high	No	temporary shade shelters, essential tasks only, close supervision, buddy system	catastrophic	unlikely	mod	Yes
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No
			Select a consequence	Select a probability	Select a Risk Level	Yes or No		Select a consequence	Select a probability	Select a Risk Level	Yes or No

Step 5 - Action Plan (for controls not already in place)			
Additional controls:	*Resources:*	*Persons responsible:*	*Proposed implementation date:*
set up traffic cones/bariiers,	Traffic Cones/Barrier Tape	Michael Venaglia	31/07/2019
choose shadey position, move to shade when waiting for position	Trees/Umbrella/Quickshade	Michael Venaglia	31/07/2019
set up barriers to restrict access	Traffic Cones/Barrier Tape	Michael Venaglia	31/07/2019
Snake garders, survey at cooler times when snakes not active	Snake garders	Michael Venaglia	31/07/2019
			Click here to enter a date.
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Step 6 - Approval			
Drafter's name:	Michael Venaglia	Draft date:	29/05/2019
Drafter's comments:	Initial progress report draft		

Approver's name:	Chris McAlister		Approver's title/position:	Project Superviser	
Approver's comments:					
I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.					
Approver's signature:				Approval date:	Click here to enter a date.