UNIVERSITY OF SOUTHERN QUEENSLAND

A COMPARISON OF DEPTH SOUNDER POSITIONING TECHNIQUES

FOR HYDROGRAPHIC/BATHYMETRIC SURVEYS

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ABSTRACT

Techniques used for Hydrographic surveys have significantly progressed from early Lead Line techniques to the utilisation of soundings for determining the depth of a submerged surface. To allow for the formation of the digital terrain model (DTM) of the submerged surface the XYZ position of a recorded sounding must be determined through remotely positioning a depth sounding device in order to achieve a relationship between each of the soundings. There are three common methods utilised in Hydrographic surveys to achieve this: GPS; Robotic Total Station; and GPS coupled with Tidal Height Datum methods. This dissertation provides an investigation of the use of different techniques of positioning a digital Echo sounder whilst undertaking Hydrographic or bathymetric surveys.

The methodology used for this project was based on framework established by International Federation of Surveyors (FIG). Such framework and standards covers the planning, execution and management of Hydrographic surveys. The methodology of this research involved completing a survey of an exposed tidal surface using Robotic Total Station. This surface was used as the standard of comparison. Once it became submerged, three additional surveys were completed utilising a depth sounder coupled with Robotic Total Station, RTK GPS and the Tidal Plane. For quality assurance, an additional survey using Robotic Total Station techniques was completed once the surface became exposed for a second time to ensure that the differences found between the methods and the base surface were not affected by topography changes due to tidal influences. Each of these terrain models determined from the sounding surveys were then related to the original survey, and their relationships evaluated.

Each of the methods utilising soundings created a representation of the submerged DTM surface; however, there is some uncertainty present over their height characteristics related to Australian Height Datum (AHD). Total Station methods provided the least difference from the base DTM model, with RTK GPS and Tidal/Water methods providing marginally greater difference.

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CHAPTER 1 – INTRODUCTION

1.1 Problem Statement

Increasing the knowledge of submerged surfaces, particularly those in navigation channels of both still and ocean waters, is a vital aspect of marine traffic management as it impacts the safety and efficiency of vessels operating on the water. The mapping of submerged surfaces can be classed as Hydrographic Surveying or Bathymetric Surveying. The former being for the purpose of mapping the coastline and ocean floor for navigation, engineering or for resources management, whilst the latter refers to surveying of the topography of the ocean's floor, lake, river or other water storage.

After the recent flood events throughout the state of Queensland the knowledge of what lies below the surface is vital knowledge for the benefit of both commercial and recreational vessels navigating the rivers, streams, bays and dams as there could be an amount of submerged debris or simply silt deposits which have changed significantly the floor of the water body.

Increasingly GPS technologies are being utilised for the mapping of submerged surfaces as this eliminates many of the errors associated with the positioning influences that affect the Echo soundings. However, the inherent nature of GPS heights introduces associated errors regarding ellipsoid–geoid correction values to relate the heights to the Australian Height Datum. Nevertheless with advances in geoid computation and the introduction of the latest version of the AUSGEOID09 system the effects on accuracy, precision and repeatability for surveys employing the Hydrographic technique are relatively unknown.

The problem is that it is unknown if using GPS is the most reliable and accurate methodology for positioning a echo sounder whilst completing Surveys using the hydrographic technique. Robotic Total Station methods and using Tidal/Water heights are also available for positioning a depth sounder whilst completing hydrographic/bathymetric surveys.

1.2 Research Aim

This project aims to assess the efficiency, effectiveness, accuracy and precision of various methods for determining the position of a depth sounder whilst completing Hydrographical Surveys. It will compare and contrast Total Station, RTK GPS and Tidal Plane methods of determining a submerged DTM surface.

This dissertation will employ both research and practical surveying techniques to achieve the following objectives:

- Define the limitations and applications of single frequency depth sounding equipment.
- Investigate the standards and methodology of Hydrographical Surveys, especially reliability and repeatability.
- Identify the Positional Techniques of Depth Sounding Operations.
- Conduct a Topographical Survey of an exposed tidal surface to provide a base DTM against which techniques will be compared.
- Complete three additional surveys of the base surface utilising a depth sounder coupled with Robotic Total Station, RTK GPS and the Tidal Plane respectively to produce a DTM surface for each technique.
- Evaluate and discuss the relationship between the initial base surface and each of the individual surfaces created from the three techniques being investigated.

It is becoming increasingly important for firms to understand the relationships between these techniques, technologies and their repeatability, accuracy and precision. This research will address the issues pertaining to each of the techniques and provide a direct comparison between these techniques utilising a tidal area which can be traditionally surveyed. Specifically via direct measurement using a Robotic Total Station, which has proven results, and then resurveyed using each of the three techniques coupled with a low cost single beam Echo sounder. The Echo sounder will require proper calibration to the water conditions and mounted on a small vessel.

1.3 Justification

Increasingly, surveying firms being tasked with the completion of Hydrographic and Bathymetric Surveys do not have access to the high budget systems of the professional Hydrographical services. Some of these surveys involve determining water volumes of flooded mine pits, calculating isolated dredging schemes, and determining obstructions submerged after the recent flood events in South East Queensland.

Many firms have access to Robotic Total Stations and RTK GPS systems which can be utilised with a digital transducer or Echo sounder. Another technique commonly utilised to complete Hydrographic Surveys is the use of the height of the water's surface as a datum for the measured depths to be related to. This is commonly referred to as the Tidal Datum and is generally coupled with a Transducer and Differential GPS to complete submerged surface mapping surveys (Blair 1983). There are inherent problems associated with using Tidal Datums in offshore situations. These include errors associated with Tide Measurement, Draft, Loading and Heave from Wave action (Kruimel 2011). However, many of these errors are eliminated through dialled in and observed corrections and remotely positioning the Echo sounder.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

In order to properly ascertain the extent and knowledge required for the completion of this project the content being examined was divided into components. This was required to properly understand all the factors relating to the Hydrographic technique in order to determine how to achieve accurate results and how to interpret them. By the end of this chapter it should be understood what is required to complete the comparison of Depth Sounder Positioning Techniques allowing the results presented in Chapter 4 to be properly understood.

This Literature review will explore the history and proven methodology behind the use of the Hydrographic technique and the factors which affect the results being produced including:

- Definition of Hydrographic/Bathymetric Survey
- Standards for Hydrographic Surveys in Queensland
- Data Acquisition Techniques
- Positional Techniques and Datum
- Errors in Hydrographical Surveys

2.2 Hydrographic/Bathymetric Surveying

Hydrographic techniques for mapping submerged surfaces is a widely proven technique originating from the 19^{th} century where Hydrographic offices were tasked with the provision of nautical charts for navigation and exploration.

Lead Line techniques were the first methods utilised by vessels such as the HMS "Challenger" and the US steamer "Blake" in the first surveys conducted on a large scale. Their innovative sounding technique of using Lead Line or wire rope was instrumental in the lifespan of the survey expeditions (Sigsbee). The first Echo sounding surveys, using sonar technologies, was completed by the German ship "Meteor" in the 1920s. A typical survey operation is shown in Figure 1.

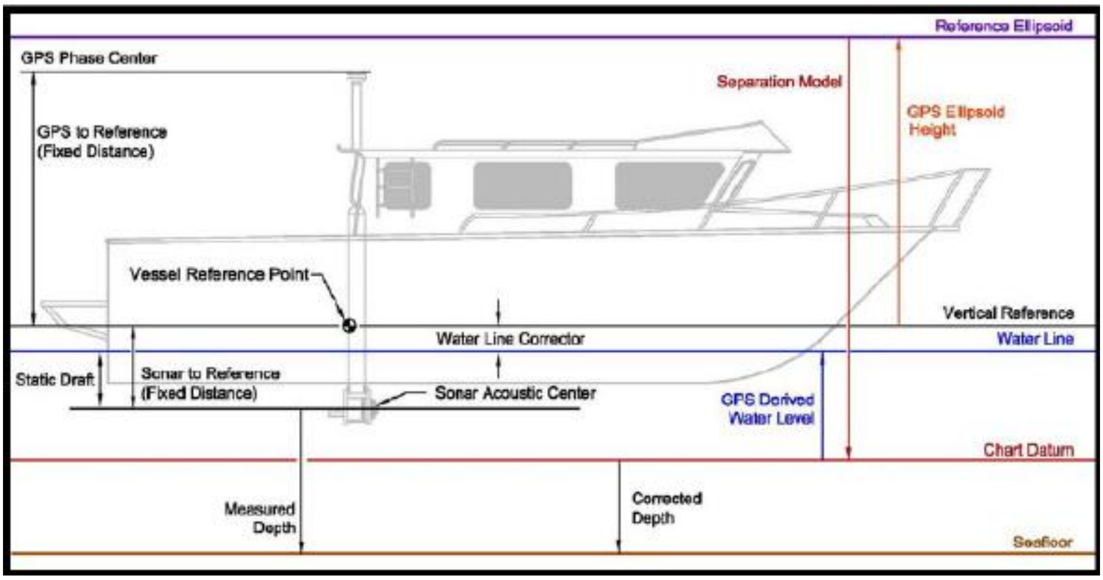


Figure 1 – Typical Hydrographic survey system (Kruimel 2011)

Figure 1 shows how a typical Echo sounding survey is completed using a vessel and transducer. The transducer has a known acoustic centre which is positioned by a GPS receiver mounted coincidently with the transducer. Distance from the vessel reference points are known to both the transducer and GPS receiver, allowing for the reduced position of the transducer to be determined from adjusted GPS positions (Gibbings 2004). When using GPS positioning techniques in offshore environments and Ports the correction from the GPS position and the Chart datum must be known in order to reduce the surveys to coincide with the local Hydrographic datum.

Hydrographic techniques have also been utilised to map water storages and flooded mine pits. Gibbings (2004) utilised a low cost transducer coupled with RTK GPS to determine the submerged terrain of a water storage with errors of less than 1% using the Hydrographic Technique. Surtees (2009) utilised the Hydrographic Technique coupled with RTK to map the sedimentation of the floor of a flooded mine operation with an average of less than 1% difference between water volumes mapped with varied transect lines.

2.3 Standards for Hydrographic Surveys in Queensland

The International Federation of Surveyors has developed a framework and standards for the planning, execution and management of Hydrographic surveys in order to handle the increased burden of responsibility on Port administrators and surveyors, to ensure that such surveys are undertaken to the appropriate standards by appropriately qualified personnel (FIG 2010).

Such standards are classified into three levels, with differing content and applications (FIG 2010). Overarching International Standards are those adopted by the International Hydrographic Organisation. These are intended to ensure a consistent quality of information contained in internationally distributed charts. Examples of the principles can be found in Appendix A.

National Standards pertain to the standards produced by individual national organisations, such as the Australian Hydrographic Service. Generally these are simply modified international standards to suit the environment. For instance, the United States Army Corp of Engineers publishes their own standards relating to pre and post dredging surveys (FIG 2010).

The third level of guidelines are produced by organisations at a regional or state level, an example are those produced by the Queensland Government Maritime Safety Organisation, that provides standards for Hydrographic Surveys within Queensland Waters which are documented and are readily available to the public. The document provides the framework for which Hydrographic surveys are undertaken in order for harbour masters and port authorities to complete the following (DERM 2011):

- Make management decisions with greater certainty and support
- Interpret the Hydrographic survey information received in terms of accuracy, reliability, validity and currency
- Identify the class of survey required for a particular purpose, based upon an assessment of risk to the safe movement of vessels
- Establish the level of competency required for the conduct of a particular class of Hydrographic survey
- Determine the interval required for that survey.

Classification Table for "Standards for Hydrographic Surveys within Queensland Waters"			
Survey Class[1]	*Depth tolerance* for Reduced Depths (2 standard deviation level)	Minimum Seabed Coverage (line spacing) [2, 3]	Minimum Qualification of Personnel Undertaking or Supervising a Hydrographic Survey
A	In the case of a declared port depth the *depth tolerance* is dependant on UKC[4]. In all other cases the *depth tolerance* is to be ±0.15m.	The method used shall ensure the minimum depth in the navigable waterway has been determined. (Refer to clause 5.1.2 on page 7 of these standards)	Certified Practitioner (Hydrography 1)
B[5]	In the case of a declared port depth the *depth tolerance* is dependant on UKC[4]. In all other cases the *depth tolerance* is to be ±0.15m.	20% (Refer to clause 5.2.2 on page 8 of these standards)	Certified Practitioner (Hydrography 1)
C	±0.2m	20% (Refer to clause 5.3.2 on page 8,of these standards)	Certified Practitioner (Hydrography 2)
D	±0.3m in depths less than 25 m	3 x average water depth or 25 metres whichever is greater. (Refer to clause 5.4.2 on page 9 of these standards)	Certified Practitioner (Hydrography 2)

Table 1 – Classification Table of Standards (DERM 2011)

Table 1 highlights the classifications for completing Hydrographic surveys within Queensland waters. From the table it can be observed the highest depth error tolerated by Queensland standards for surveying offshore is +/–0.3m found in class D surveys, whereas with class A surveys the depth tolerance required is /–0.15m. The table also highlight the minimum seabed coverage which determines the transect line spacing to be discussed further in later sections in addition to the expected XY coordinate accuracy as per the standards.

2.4 Data Acquisition Techniques

Hydrographic data can be acquired through a variety of methodology, ranging from traditional Lead Line direct measurement, more remote utilisation of depth sounding equipment in both single beam and multi beam forms through the use of LIDAR and advanced sonar systems (DERM 2011). For the purposes of this research, the technologies of mid–range depth sounding equipment (In terms of cost, accuracy and precision) and traditional Lead Line techniques were only considered as this is generally what is available due to budget restraints. Figure 2 gives a diagrammatical representation of the technologies to be addressed as part of this literature review.

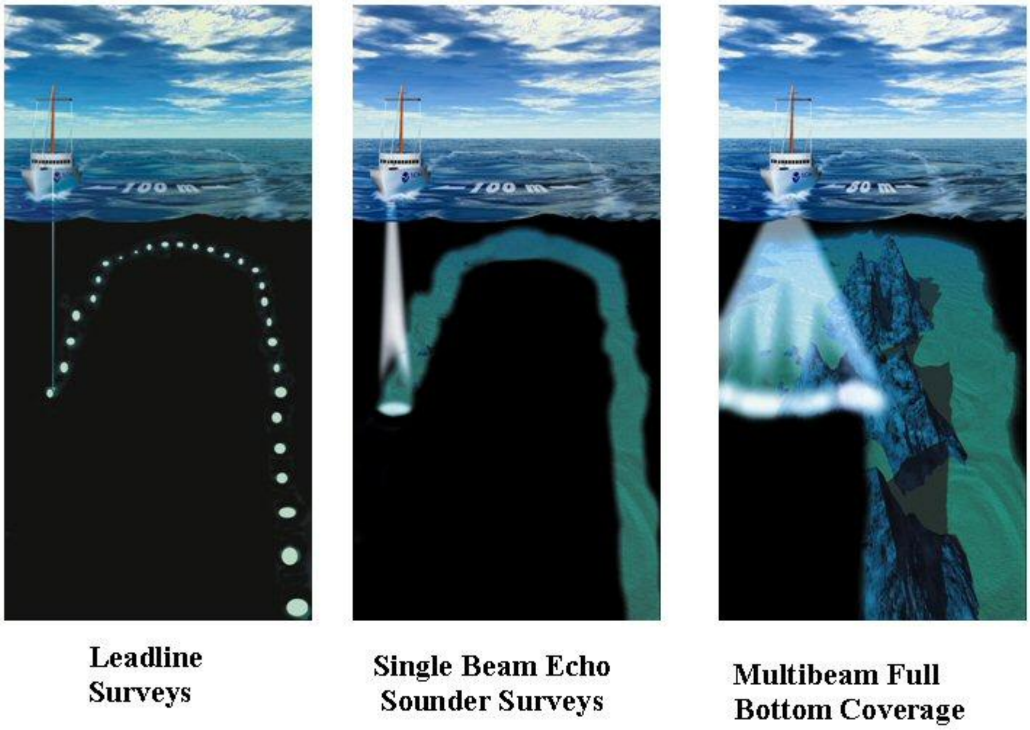


Figure 2 – Transducer Configurations (Force 1999)

Lead Line Surveys is the traditional technique utilised in early Hydrographic expeditions where a weighted, properly soaked, stretched and calibrated line (DERM 2011) is utilised to directly measure the depth from the surface to the sea floor. When the weight of the line needed to measure greater depths that exceeded the end weight, it made it difficult to ascertain if the weight hit the bottom or whether the line was simply coiling on the sea floor (Gardner, Dartnell et al. 2005)

Echo Soundings revolutionised the Hydrographic surveying world. Soundings are purely a sound pulse transmitted from a transducer at the surface which is then reflected off the submerged surface back to the transducer (Gardner, Dartnell et al. 2005). The time taken for the signal to be returned to the transducer is utilised to calculate the depth. These are accurate if the sounder is properly calibrated using a calibration plate or similar technique. This calibration is required due to the fact that different water types, salinity levels, temperature and similar factors affect the speed of the sound wave travelling through the water body (Gibbings and Raine 2004).

There are two common types of Echo sounders. Single Beam sounders are a data capture device with a single emitting component recording data in a single beam configuration. Multi Beam sounders utilise a number of single beam Echo sounders to allow for greater data capture and increased resolution. They are significantly more expensive than single beam sounders and also require extensively skilled operators. The number of beams and arc coverage of the transducer determines the swath width across which a multi beam sounder acquires depth measurements. (Surtees 2009)

2.5 Positioning Techniques and Datum

In order to properly determine the relationship between each of the sounding measurements, the position of the transducer must be determined at the time of each of the depth measurements. Traditionally, when using Lead Line sounding techniques, depths were fixed through the use of three point sextant fixes from mapped reference points. However, GPS revolutionised navigation in the 1990s, allowing for positions to be recorded using differential techniques.

Typically differential surveying techniques are utilised to position depth sounding techniques; however, smaller scale Hydrographic/Bathymetric surveys have been conducted utilising RTK GPS and Robotic Total Station technologies to determine the position of the Echo sounder during the survey (Gibbings and Raine 2004). RTK methods are also commonly used in port environments where onshore support is available for GPS radio corrections. Both GPS and Robotic Total Station presents as the most cost effective, reliable and repeatable means to position a depth sounder for surveying firms as these technologies are generally on hand, as opposed to the large scale systems utilised by professional Hydrographic services. For example, Nazaretian (2003) mapped 483 km of shoreline with a transducer costing approximately AUD$25000 with software valued at AUD$250000 (Gibbings and Raine 2004). These technologies are not economically viable for a survey operation which may only complete Hydrographic surveys incidentally throughout its financial year.

As part of the standards produced for the completion of Hydrographic surveys in Queensland waters, standards for horizontal positioning have been developed in order to ensure the integrity of data. From the standards, horizontal positioning shall be 1 metre +/– 1.5m at the 2 standard deviation. In terms of Datums, all

Hydrographic surveys carried out within Queensland waters are to be connected to GDA94 and traceable to the Australian National Network (DERM 2011).

Vertical Positioning of a depth sounder can be achieved through the use of trigonometric heights when using Robotic Total Stations, GPS Heights and finally sounding can be reduced to the Tidal Datum (Blair 1983), or height of the water's surface at the time of the survey.

Determining the relationship between Australian Height Datum (AHD) and the Ellipsoid when utilising GPS is achieved through using a Geoid model, or surface of equipotential, to approximate the mean sea level on which AHD is based. The most recent of these models is AUSGEOID09, which supersedes AUSGEOID98. AUSGEOID09 is a three–dimensional model which allows for the computation of ellipsoidal heights to AHD with a Height uncertainty of +/– 0.050m, improving on the AUSGEOID 98 model which only achieved an accuracy of +/–0.364m across 65% of Australia. (Brown, Featherstone et al. 2010)

Released in mid–2010, AUSGEOID09 no longer attempts to coincide with Mean Sea Level due to errors associated with topography and water density but directly to AHD. When AHD was established in the 1960s 32 tide gauges recorded what was believed to be mean sea level and adopted this observed value as RL 0.000 AHD. However, many of these gauges were affected by sea surface topography and were placed in sheltered areas, which failed to give a proper representation of the level being recorded. The most significant factor affecting the height being observed was that the warmer/less dense water off the Northern coast of Australia is approximately 1m higher than the water found off the Southern States. This difference was not addressed in the computation of the AUSGEOID98 model, which was mostly based on terrestial and satellite gravity, therefore it failed to account for the height error of AHD and provided only a "best fit" model for the calculation of AHD heights to within +/– 0.500m of AHD elevation.(Brown, Featherstone et al. 2010)

To overcome the factors affecting the accuracy of AUSGEOID98; AUSGEOID09 was calculated differently from the previous Geoid models. Instead of only utilising observed gravimetric data, AUSGEOID09 developers also included a geometric component developed from a combination of GPS and AHD data which describes the 1m offset trend between the AHD and the gravimetric geoid. Because of this, AUSGEOID09 is now no longer a true representation of the geoid as it is no longer a surface of equipotential as discussed previously.(Brown, Featherstone et al. 2010)

The gravimetric component of AUSGEOID09 was derived from the Earthgeopotential Model 2008, Land Gravity Data from Geoscience Australia, Geodata–DEN9S from an Australian Conglomoration and DNSC200GRA dataset developed by the Danish National Space Centre. EGM2008 was released by the National Geospatial–Intelligence Agency (NGA). Its predecessor was EGM96 which had 360 degree and order, utilising worldwide gravity data at 30 minute resolution. EGM2008 has a 5 minute mean resolution. The differences in gravity between AUSGEOID98 and AUSGEOID09 can be diagramically found in the Figure 3 below. Particular attention should be paid to the white areas depicted in the Gulf of Carpenteria and the 1m change visible.(Brown, Featherstone et al. 2010)

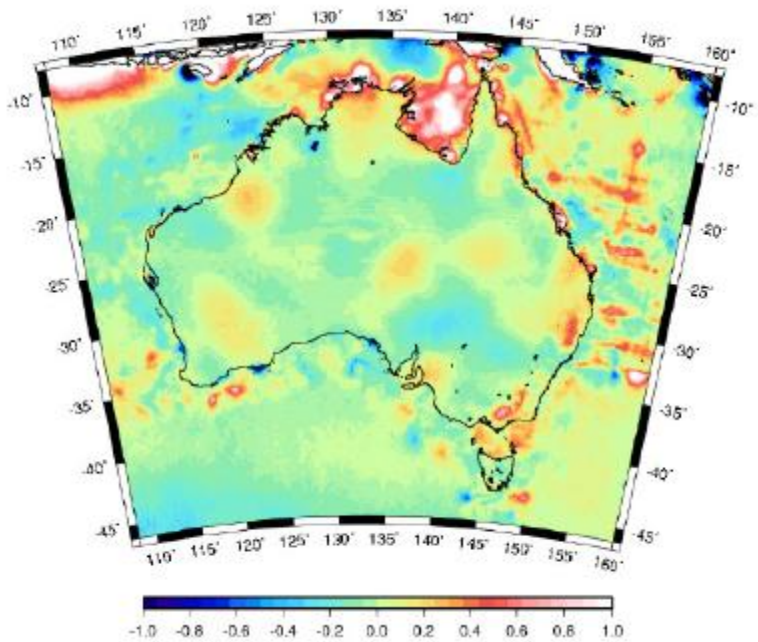


Figure 3 – AUSGEOID98 vs. AUSGEOID09 Gravimetric Methods (Brown, Featherstone et al. 2010)

Land Gravity data was released in July 2009 by Geoscience Australia. It comprised approximately 1.4 million observations for gravity, which is nearly twice as many as utilised by the developers of AUSGEOID98 due to a smaller grid size. In certain areas this ranged from 2 to 4 km down to 50m spacings. The Gridded Digital Elevation model of Australia or GEODATA was calculated from continent–wide topographic datasets containting Point Elevations, Streamlines, Water Body Boundaries and Cliff lines with a Grid spacing of 9 seconds or roughly 250m. This project was completed by a conglomoration of Geoscience Australia and the Australian National University. Finally, the Danish National Space centre provided Global marine Gravity Field Data based on Satellite Altimetry with a grid spacing of 2km, of 1 minute by 1 minute resolution.

Figure 4 below shows the 2638 coordinated locations (visualised in the Figure) by respective State and Territory surveying authorities and processed by Geoscience Australia to calculate the Geometric Component of AUSGEOID09. A secondary dataset of 4233 levelling junction points for the Australian National Levelling Network was also included to provide a higher resolution definition for the Geoid solution. The system was designed to provide a direct conversion to AHD values.

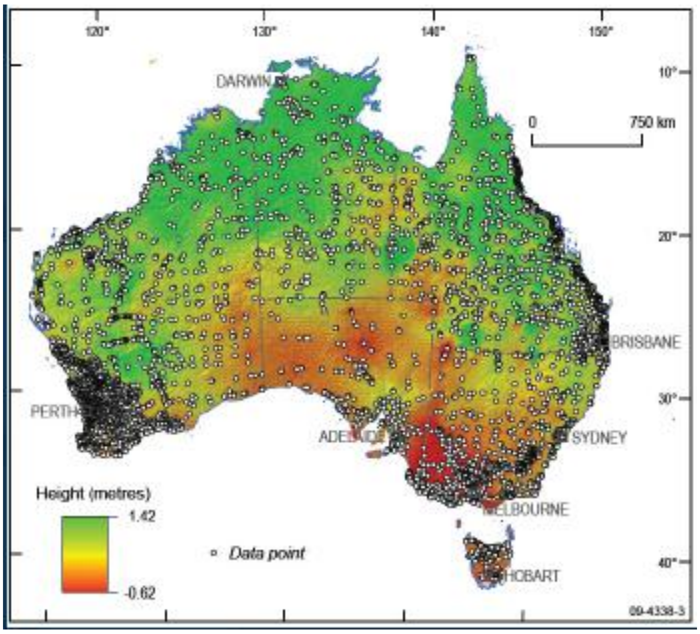


Figure 4 – AUSGEOI09 Data Points (Brown, Featherstone et al. 2010)

The actual computation of the AUSGEOID09 was completed in two stages. The gravimetric component was computed at 1’ x 1’ which is half the size of the 2’ x 2’ grid calculated for the 98 model. Over 7 million computation points were utilised with over 500 prototype Quasigeoid models calculated. The geometric component was then computed using least squares cross–validation, which removed one point from the prediction at a time and utilised that point for redundancy to check the calculated model. In total, 6871 points were utilised and computed to a node value for a 1’ x 1’ grid. These models were then combined to form the AUSGEOID09.

Even with all the re–computation of the model and the combined data, issues are still present in the model. These have been caused by errors in the levelling network, land subsidence, long wavelength geoid anomalies, GPS errors and a lack of data in a particular area. These areas are highlighted in the SSSI Figure 5 reproduced below showing absolute accuracy of the AUSGEOID09 system.

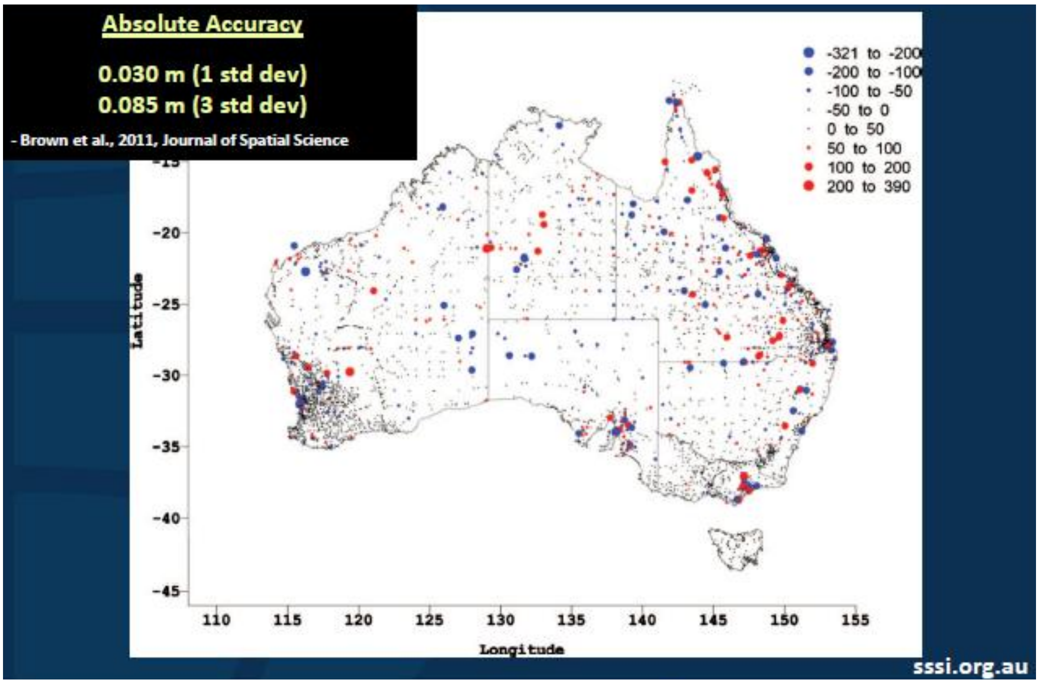


Figure 5 – AUSGEOID09 absolute accuracy (Brown, Featherstone et al. 2010)

2.6 Errors in Hydrographic Surveys

Errors in Hydrographic surveys can be attributed to two main sources. Kielland and Hagglund (1995) noted that these errors are attributed to the spread of the sounding measurements and errors in the distance and location of individual soundings (also noted in (Gibbings and Raine 2004)). Gibbings noted that Latency is directly related to the speed of the vessel undertaking the survey. That being at lower speeds, one to two knots, the effects of latency is minimal. The spread in the soundings can be directly attributed to uneven terrain characteristics being surveyed. The error in the actual location of the individual soundings can be attributed to inadequate calibration of the depth sounder as well as uncertainty in the actual XYZ position for the location of the sounder when the depth was recorded.

Gibbings and Raine (2004) noted that when calculating volumes of water storages, less than 1% error was found when utilising RTK GPS for Hydrographical techniques. Weyman–Jones (2010) found a maximum of 2mm and 3mm deflection when using the Robotic Total Station tracking technique on a 360 degree prism at a distance of 350 metres for vertical and horizontal position respectively. As previously discussed, this research will evaluate the relationship between using the GPS and Robotic Total Station techniques to determine the submerged terrain being surveyed.

Typically a user completing a Hydrographic survey will have to determine the height of the water from a tide gauge at the time of survey. In addition to this, vessel squat, settlement and draft must also be considered when completing Hydrographic surveys. However, when using direct measurement to the location of the sounder the effects of these errors are removed. If we know the relationship between the sounder and the datum, whether that be Ellipsoid, Chart Datum or AHD, we can eliminate the need for vessel squat, settlement, static and dynamic draft. Calculation tables for vessel squat and settlement are relative to speed over ground; despite this, in areas of high current, squat tables do not actually reflect any actual dynamic draft as dynamic draft is merely a function of speed through water, not of speed over ground. Utilising remote positioning of the sounder will also eliminate the errors associated with tide measurement at the actual gauge itself.

Method	Tide Measured	Tide Zoned Discrete	Delta Draft	Loading	Draft	Total Component
Traditional Ranges [1]	*0.01-0.05m*	*0.01-0.40m*	*0.01-0.03m*	*0.01-0.30m*	*0.01-0.20m*	*0.02-0.54m*
Project Values Zoned	0.01m	0.30m	0.01m	0.0m	0.01m	0.30m
Project Values GPS Water Levels	0.03m	0.00	0.00	0.00	0.00	0.03m

Values reported at 1 sigma

Table 2 – Water Uncertainty Levels (Kruimel 2011)

The reduction of errors by remotely positioning the Echo sounder can be seen in table 2 produced by the SSSI. Total uncertainty for Traditional ranges for Hydrographic surveys includes Tide measurement errors, discrete tide zone errors, delta draft, loading and draft giving traditional values of between 0.020 and 0.54m. By remotely positing the Echo sounder via GPS the total component of uncertainty falls to 0.030m.

2.7 Methodology and Resource Requirements

The methodology for the Hydrographic survey will be structured to enable for direct comparison between using RTK GPS, Tidal plane with GPS and Robotic Total Station in order to directly evaluate their appropriateness for surveying firms who are completing these surveys.

A Single Beam, low frequency Echo sounder, provided by Ultimate Positioning Brisbane, will be utilised for the depth surveying techniques. The Sea Floor Systems HydroLite TM Echo sounder is a portable, lightweight and ruggedised system with a depth range from 0.3m to 75m. This sounder can be linked directly via Bluetooth to data recorders to reduce the effects of latency (Raymond 2005), or misrepresentation of survey data due to delays in position and depth information. This sounder will be mounted on a small three metre aluminium boat in a transom position. The HydroLite operates on a frequency of 200KHz, working with a 4 degree beam and a ping rate of 6Hz. It can achieve a 1cm/0.1% depth accuracy. (Systems 2011)

Positioning using Robotic Total Station will be achieved using a Trimble S6, a 3" fully Robotic Total Station. Level control will be achieved through digital levelling from 1st order level control. GPS positioning will be achieved using a Trimble R8 RTK system and when utilising the Tidal plane the XY positions from this system will be utilised. GPS heights will referenced to AHD using AHD–ellipsoid corrections from AUSGEOID09. The Prism/GPS antenna will be mounted directly above the transducer to allow for ease of data collection. These will be the most cost effective methods and reflect the resources available to a mainstream surveying firm.

CHAPTER 3 – METHODOLOGY

3.1 Introduction

The purpose of this chapter is to define the methods to be utilised for the process of comparing Depth Sounder Positioning Techniques. It will cover a range of aspects including planning, equipment, error minimisation and the field observations and techniques employed.

The field methodology applied will allow for the direct comparison between Robotic Total Station, RTK GPS and GPS using Tidal/Water heights to directly compare the results to a base initial survey completed over the subject area. The survey will employ a predetermined 5m grid to be surveyed over the control area to provide a basis to which the sounding surveys will be compared. To ensure data cohesion the methods of Robotic Total Station, RTK GPS and GPS using Tidal/Water heights will be completed simultaneously over the subject whilst linked to an Echo sounder. This will ensure positions are recorded simultaneously and allow for direct comparison of each of the techniques.

Sounding Transect lines will be used, running over the entire site area. These will be based on the pre–calculated grid surveyed initially over the area to ensure data consistency. Equipment calibration will be essential to ensure reliable data is acquired. Sounder calibration, Draft calculation and Latency will all be addressed to ensure accuracy and repeatability of Echo soundings to determine the differences present in the sounder positioning techniques being utilised.

3.2 Planning

3.2.1 Site Location – Wellington Point

As with any practical research being completed, the site location is vital for the quality of the results being produced. This location also has a great effect on the methodology utilised for the data collection process. The site selected to complete this research was in Moreton Bay, referred to as Wellington Point (refer Figure 6).

Located around 15kms east from the Brisbane CBD district, this location was chosen for several specific reasons which would suit the methodology of the project.

Firstly, the location was chosen due to its ease of access for vehicles and its proximity to boat launching facilities, the closest one being a few hundred metres from the surveyed area. Also the need for on–shore support for both GPS and Robotic Total Station Methods could be easily accommodated by using this site. Secondly, the inundated areas surrounding the Point are shallow and tide–affected. Specifically the water at its peak tidal times has a depth of no greater than two (2) metres. Additionally, the seabed is exposed at low tides, allowing for an initial survey to be completed over the area to provide a control surface to which the surveying methods being addressed will be compared. Finally, the affects of tidal/wave action is quite limited due to the calm water conditions present in the area. Traditionally the effects of heave of the vessel would be required when in an offshore environment; however, the calm water conditions presented removed this factor and allowed for a bathymetric survey to be simulated. The calmer water conditions also allowed for the accurate measurement of tide/water level height to permit for the application of the water level to the observed depth soundings.

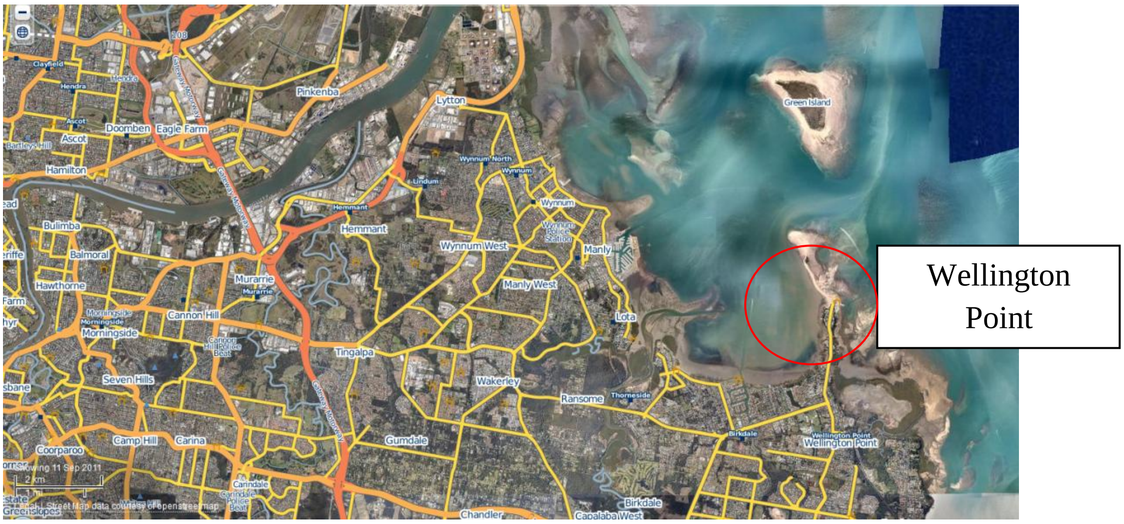


Figure 6 – Site Locality (Nearmaps 2011)

3.2.2 Survey Control

All surveys, either conventional, GPS or Hydrographic/Bathymetric, must relate measurements to an established datum. This is especially relevant when directly comparing methodology for surveys. Each of the control points utilised were digitally levelled with repeat sets of angles read between them to ensure limited uncertainty. For the purpose of height control, three (3) Permanent Surveying Marks with varying order were utilised which can be found in Table 3 below.

Point	**AHD VALUE**	**RL Order**
PSM 65719	2.223	3rd Order (Spirit Levelling)
PSM 753230	2.183	4th Order (Spirit Levelling)
PSM 172929	2.063	4th Order (Spirit Levelling)

Table 3 – Permanent Surveying Marks

Positioning control will be achieved through the use of MGA zone 56 coordinates for the GPS surveys and Arbitrary coordinates for Robotic Total Station Methods. The UTM based MGA Coordinates are a worldwide standard, widely used in many industries, and as discussed in Chapter 2, AUSGEOID09 represents the latest instalment of the Australian Geoid which can derive AHD height to +/–0.050m. The methodology behind this was to then scale, translate and rotate both the GPS surveys (that being Tidal and RTK GPS) onto the control used in the initial Robotic Total Station Survey, which was also coincident with the Robotic Total Station Sounding Survey to allow for Direct comparison of results produced. Whilst the GPS surveys were undertaken, multiple observed control point RTK observations will be recorded on the Terrestrial Control Stations of CP1000, CP1001 and PSM65719 (shown in figure 6) with the Base Station occupying PSM754230 to allow for the manipulation of the GPS data onto the terrestrial control. Robotic Total Station Surveys will be completed with the instrument established on CP1000 with a backsight station established on CP1001 with a check shot recorded to PSM65719.

Figure 6– Control Point Locations (Nearmaps 2011)

3.2.3 Transect Lines

The sounding surveys will use pre–calculated transect lines for the vessels to ensure proper guidance. These are determined from the 5m pre–calculated grid (mentioned in section 3.1) surveyed over the subject area and will be at ten (10) metre centres (skipping over every second 5m grid line) for the two hundred by three hundred metre subject area using the Stakeout Line function in Trimble Access to monitor the vessel's path. The density of the sample data will be reduced from 10m to 20m spacings and point density from 5m to 10m to evaluate any differences in DTM model production.

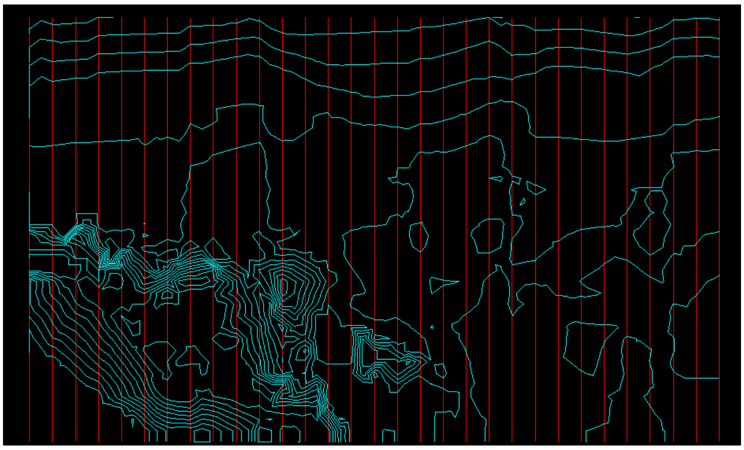


Figure 7 – Transect Lines

Each of these transect lines were staked out to provide offset from the line and distance along the line. These were calculated from the initial data in Civilcad and uploaded into the Trimble Access Software. The vessel was able to be navigated along each of these lines within +/– 1m for easting.

3.2.4 Software

In order to achieve synchronisation between datasets, soundings will be recorded directly into a TSC3 survey controller through a Bluetooth connection. Ideally a cable connection would be best to remove any cycle sign dropout. A Style sheet was then utilised to export various unprocessed and processed data files into CSV format depending on their purpose. For the Robotic Total Station Survey using the Echo Sounder a CSV with Depth and elevation was produced, for the RTK survey a CSV with XYZ was produced to allow for Post Processed depths to be applied, and finally a CSV with Time Stamp was used to determine the Tidal Plane/Water Height Dataset.

Software utilised onboard for the surveying equipment consisted of Trimble access and Trimble Survey Controller for the Trimble TSC3 and TSC2 respectively with CivilCad utilised for the data reduction and DTM production.

3.3 Equipment

After planning the Bathymetric survey the next integral part of this research was the equipment utilised for the comparison of Depth Sounder Positioning Techniques. The positioning of the digital Echo sounder for this research was achieved through the use of Trimble Equipment, a Robotic S6 Robotic Total Station and R8 RTK GPS systems. For each of the Survey Methods the 360 degree prism and the R8 receiver were mounted coincidently on the digital sounder prism pole to allow for positions to be relative to one another.

3.3.1 Robotic Total Station

Terrestrial positioning of the Echo sounder will be achieved through the use of Trimble S6 Robotic Total Station with Trimble survey controller 3 (TSC3). Through the use of Bluetooth technologies the TSC3 will be synchronised to the digital Echo sounder with an additional 2.4Ghz Radio connection to the Robotic Total Station.

Topographic positions will be recorded every 5 seconds with an associated depth being stored with the observation. These observations will be visualised on the screen of the TSC3 to allow for the vessel's position to be viewed relative to the transect lines.

Figure 8 – Trimble S6 Total Station

3.3.2 Real Time Kinematic Global Positioning System

A Trimble R8 GNSS system utilising a Trimble Survey Controller 2 (TSC2) with Survey Controller Software will fulfil the GPS requirements for the comparison of positioning techniques. Unfortunately, the digital Echo sounder can only be synchronised with a single data collection device at a time. Therefore the GPS will record positions at 5 second intervals in topographic mode, similar to the methodology to be applied for the Robotic Total Station techniques; however, because of the mounting of the receiver and prism coincidently, and with the positions recorded simultaneously, the depths provided by the Robotic Total Station Survey will be post–processed and applied to the GPS dataset to allow for the DTM models to be created.

The R8 system will be utilising UTM coordinates as discussed in the survey control section with AUSGEOID09 as the Geoid datum for heighting methods. Validation of the coordinates after scaling and rotation will be completed before the depths are applied to the GPS dataset.

Figure 9 – Trimble R8 GNSS

3.3.3 Digital Echo Sounder – Seafloor Systems HydroLite TM

In order to acquire the depths from the water's surface to the seafloor a single beam Echo sounder was utilised. A HydroLite TM system is a ruggerdised, wireless and user–friendly system developed to meet requirements of Tactical Dive Teams with full integration with other systems. This system was chosen because of its availability, repeatability and precision.

The system is adaptable to virtually any vessel type with wireless data transfer. The Echo sounder had a frequency of 200–kHz with a 9 degree beam with a 6Hz ping rate. Depth accuracy can be achieved at best of 1cm or 0.1% of depths, whichever is greatest. Interfaces are achieved through Bluetooth and serial connections.

For the production of data for DTM, the Echo sounder was linked with the TSC3 running Trimble access software logging simultaneously with a continuous topographic survey. The use of the Bluetooth connection coupled with a slow consistent vessel speed (as noted in section 2.6) will limit the effects of Latency error in the Robotic Total Station/RTK GPS positions relative to the soundings.

Figure 10 – HydroLite TM (SeaFloor Systems 2011)

3.3.4 Survey Vessel

A lightweight 3m Aluminium boat provided by Bennett and Bennett was utilised for this Hydrographic/Bathymetric Survey. The vessel is small, manoeuvrable and has limited draft which allows for operation in shallow waters and launching in the adverse terrain surrounding most shorelines and dams on which these surveys are completed.

The Echo sounder was mounted in the transom position with both survey controllers and the HydroLite system mounted securely in the vessel. The transducer was mounted below the water line with the 360 degree prism and GPS antenna mounted coincidently on the supplied mounting pole with corrections applied to each to determine the reduced level of the Transducer at the time of sounding recording.

Figure 11 – Survey Vessel and Vehicle

3.4 Echo Sounder Calibration

As discussed in Chapter 2, water salinity levels and water quality affect the depth produced by an Echo sounder. Temperature also has an effect on the beam. Therefore the HydroLite must be calibrated to the water conditions found at Wellington Point. This was achieved through the use of a calibration plate consisting of a metal plate one (1) metre square being lowered below the transducer and comparing the measured distance to the depth reported by the Echo sounder. A low–tensile metal chain was used to measure the reported depth, removing the need to measure the stretch value of the rope which is normally utilised when completing the calibration. (Surtees 2009)

As discussed in Chapter 2, errors in measurements of the soundings is primarily due to incorrect calibration of the Echo (Gibbings and Raine 2004). If significant differences are found between the measured value and reported value, a scale factor must be applied to the soundings prior to the reduction of the DTM models.

3.5 Latency

As discussed in Chapter Two the use of Bluetooth connections to data recorders reduces the effects of latency (Raymond and Han 2005), or misrepresentation of survey data due to delays in position and depth information. It must be noted that the positioning accuracy of +/–1.5m is the standard for Sounding positioning as per Queensland Standards as discussed in Chapter 2 – Literature Review.

In order to ascertain if there are any effects of latency in the data collection system, a survey will be completed over a rapidly changing grade, that being a boat launching ramp found at the survey site, with the Echo sounder (Gibbings and Raine 2004)

Transect lines defining the grade of the ramp will be utilised with any error in the grade definition between the different transect lines (forward and reverse) highlighting the effects of latency or misrepresentation of soundings in the system. Simply, if there is a difference between the grade plotted by the forward line to the reverse line, there is latency present in the data collection system.

3.6 Tidal Measurement

The measurement of the water height will provide a relevant height datum for the reduction of soundings to the tidal plane/water height to provide the basis for the third comparison DTM. The measurement of the tide will occur at 10 minute intervals throughout the survey to provide effective data coverage for the Echo Sounding reductions.

Measuring the tide will be achieved through direct measurement by a timber stake with a graduated steel tape mounted on the side. Two of these will be installed in the water close to shore to enable ease of access. The height of the top of the stake will be ascertained via Robotic Total Station in order to relate the measurement taken from the steel tape back to the site AHD datum. Even though the wave action was minimal at the project site, an average of 10 measurements will be taken to determine a mean height to be reduced to the AHD level in order to determine the water RL at each 10 minute interval.

The derived water height will then be utilised to reduce the measured Echo Soundings and the XY coordinates of the RTK survey to produce a DTM model to compare back to the base surface. A CSV with time stamp will be utilise to complete these reductions coupled with the measured depths derived from the Robotic Total Station Survey.

3.7 Vessel Draft

Vessel draft will need to be calculated in order to properly reduce the Echo soundings to the reduced water level when deriving the finalised data. This will be utilised for the Tidal/Water heighting methods to produce a comparison DTM.

Vessel draft is the derived distance from the bottom of the vessel to the water line. This value changes significantly when the vessel is under the influence of loading or forward motion as the position of the transducer will be affected by the draft of the vessel. The distance from the water line will increase when the draft of the vessel increases.

The methodology of the draft measurement for this project involves measurement of the distance from the transducer when the vessel is unloaded and stationary in the water. Once the vessel is loaded and a distance from the waterline to the transducer is measured once again. Finally, a third measurement whilst the vessel is underway will be completed. These measurements will allow for the unloaded, static and dynamic draft corrections to be measured and applied to the soundings and to be utilised in the DTM created from using the Water Datum. After this measurement technique was employed a correction of 230mm was established as a dynamic draft and loading correction.

3.8 Field Survey and Observations

The field component for data collection process for a comparison of Depth Sounder Positioning Techniques utilised the Trimble S6 and the Trimble R8 systems which were established on CP1000 and PSM 753230 respectively. A backsight was established on CP1001 for Robotic Total Station azimuth with check shots observed with both systems on PSM 65719. The internal radio was utilised for the Trimble R8 systems due to the range required being below 1km.

Once the setups for each of the data collection systems were established, the tide gauges were then setup to allow for water level determination throughout the survey period and the initial survey was carried out whilst the tide was at its lowest. This allowed for a base surface to be developed to compare the models produced by Robotic Total Station, RTK GPS and GPS with Tidal Datum. To complete this survey a pre–calculated 5m grid was observed over the base surface which was determined from initial observations utilising Robotic Total Station methods.

Whilst the tide was increasing in height to meet its peak to allow for the sounding surveys to be completed, the equipment calibrations and checks were completed to measure any uncertainties present in the data collection system for the sounding surveys. This involved addressing the issues of vessel draft, latency and Echo sounder calibration. As seen from Figure 12 the water conditions were calm and sheltered, which negated the need to measure the vessel heave during the survey.

Once the initial base survey and the measurement system calibration were completed, the receiver for the GPS system and the Robotic Total Station system were installed on the observation pole of the HydroLite Echo sounding system. This involved mounting the GPS receiver on top of the Robotic Total Station system, which was then mounted to the observation pole. A height was then input from both the Prism and the GPS receiver into the TSC3 and TSC2 respectively. Due to the installation of the measurement systems coincidently, the soundings recorded by the TSC3 and Robotic Total Station system could be post–processed and applied to the GPS datasets, overcoming the communication issues of the HydroLite only being able to synchronise with one Bluetooth device at time. A diagram of this system is illustrated in Appendix B.

Once the high tide had been reached the vessel was moved into position and each of the measurement systems were initialised. Both the TSC3 and TSC2 were placed in continuous topographic mode logging observations at 5 second intervals with the vessel operating at 1 to 2 knots (between 0.51 and 1.02 knots). The vessel was then navigated along the pre–calculated transect lines as discussed in section 3.2.3, established from the initial base survey grid to allow consistency in data collection. Water heights were measured by an additional party member throughout the field survey process. Points were logged simultaneously between each of the systems which will be validated before any post–processing is completed and DTMs produced.

Figure 12 – Survey Vessel Underway

Once the Simultaneous Sounding Surveys were completed, the vessel was removed from the water and final checks carried out for calibration. Checks were also made to control stations for both the GPS and Robotic Total Station systems to ensure data quality. Once the tide had receded, a final QA survey was completed over base surface to ascertain if any seafloor movement due to tidal influences was present that would affect the results of the soundings surveys. This was completed by setting out roughly twenty percent of the points originally surveyed with the Robotic Total Station to address any discrepancies which may be present between the original and present topographic locations.

3.9 Conclusions

The relationships between the DTMs of each of the surveyed methods will be directly compared to the base DTM surface in Chapter 4: Results and Data Analysis.

The surveys were completed using a HydroLite Echo sounder mounted on a 3m Aluminium vessel provided by Bennett and Bennett Surveyors.

The datasets will be edited in both Excel and CivilCad models to post–process and validate Echo sounding between each of the datasets and eliminate erroneous Echo soundings and positions. Direct height differences will be explored throughout the analysis process in addition to volume calculations at varying point densities between the base surface and each of the DTM models created for the methods being evaluated.

CHAPTER 4 – RESULTS AND ANALYSIS

4.1 Introduction

The aim of this chapter is to report on the data collected in the field survey component completed as defined in the methodology section of Chapter 3.

This analysis will involve the review of data relating to the checks undertaken for Survey Control, Calibration of the echo sounder, Tidal measurement, Satellite Availability in addition to the direct comparison of produced RLs and the DTM models produced. Data collected as part of a QA survey will also be addressed.

The data produced will be further discussed and recommendations made in chapter 5.

4.2 Control Evaluation

As with the inherent nature of GPS heighting, the errors associated with the Geoid separation values need to be evaluated to ensure the reliability of the network. In Chapter 3 – Methodology, the control network was of arbitrary origins with sets of angles read between stations that were also levelled to ensure vertical conformity with PSM65719 being utilised as the RL Datum.

The GPS vertical reliability was then evaluated to ensure the accuracy and repeatability of the N values. The results of this were downloaded into Excel and can be found below:

		OBSERVED GPS RL		Deltas	
LEVELLED FORM 6 VALUE		Single EPOC	3 Minute	Single EPOC	3 Minute
PSM 65719	**2.223**				
CP1001	**1.852**	1.867	1.856	0.015	0.004
CP1002	**1.762**	1.774	1.766	0.012	0.004
PSM 753230	**2.183**	2.195	2.189	0.012	0.006
PSM 172929	**2.063**	2.081	2.054	0.018	–0.009

Table 4 – Variance from AHD

The GPS base was established on PSM65719 with a series of check shots recorded on each of the major control stations, CP1000 and CP1001, and checks also recorded on neighbouring PSMs 753230 and 172929 to provide validity of the height datum. Single Epoch and 3 Minute observed control points were recorded on each of the Stations which gave varying results for RL values. Single epoch recordings ranged from 0.012m through to 0.018m each of the control stations. 3 Minute observations achieved results from 0.004m through to –0.009m. Each of these results provide a basis for the reliability and precision of the control network. Clearly the GPS N value calculations are quite high in accuracy and repeatability which provides credibility for the results being produced by the field survey for the comparison of depth sounder positing techniques.

4.3 Tidal Measurement

Figure 13 – Tidal Gauge Localities (Nearmaps 2011)

The accurate determination of the Tide/Water heights is an essential part of this evaluation of Positioning Techniques as it will provide the height datum to which the soundings will be related to for the use of Tidal datum techniques. For this methodology two gauges were established on site, comprising a Timber stake with a tape installed on the side as discussed in Chapter 3. The measurements taken for the tide determination can be found in Appendix C.

Tide Measurement was undertaken by an assistant at 10 minute intervals throughout the Hydrographical Survey and recorded. These were then input into Excel to determine the RL at the time of the measurement.

Each gauge measurement was correlated to the time at which the measurement was taken. The derived RLs were then averaged to acquire the Datum for the echo sounding and positions recorded in this time period. The RLs were then graphed to provide a visual trend of the tidal height throughout the survey timeframe. It can be seen that the tide heights fell steadily from 0.450m at 12:10 through to 0.11m at 13:40, a fall of 0.340m.

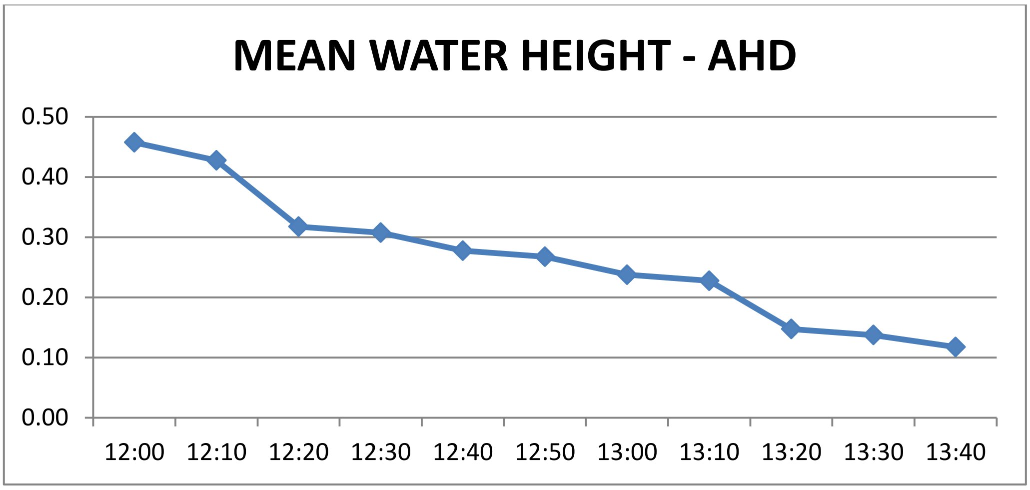


Figure 14 – Tide Measurement Graphed

4.4 Calibration

As part of the calibration process, a 1m x 1m steel plate was lowered below the transducer using a graduated steel chain in order for the known depth to be correlated with the echo sounding. A steel chain was utilised to remove the need for rope stretch calibrations to be determined with each (Surtees 2009). Each chain Link was fully extended and care taken to ensure no kinks were present in the chain during the measurement process. The results can be found in the table below.

Position Number	Measured Depth	Echo Sounding	Difference
1	0.360	0.370	0.010
2	0.450	0.462	0.012
3	0.480	0.472	–0.008
4	0.550	0.563	0.013
5	0.670	0.687	0.017

Table 5 – Calibration Distances

It was assumed that the salinity would affect the sounding depth significantly; however, from the results, we can see that error ranges from –8mm through to 17mm. The rated accuracy of the HydroLite TM is 0.010m or 1% of depth, whichever is larger. Clearly the depths being reported are close to the manufacturer's specifications, which can be attributed to the small depths being recorded as opposed to other studies where depths have been 10m or larger, which would have a greater effect on any calibrations required. As such, it was decided not to apply a correction to the soundings being recorded.

4.5 Latency

For the fieldwork component, the vessel motion was utilised to calculate a latency correction to be applied to the Trimble access software running on the TSC3 linked via Bluetooth to the HydroLite TM. Vessel motion was estimated at 1 to 1.5 knots (0.51m to 0.77m per second) which would be utilised to convert the distance observed between the plotted grades to a time correction to be applied.

The vessel was navigated at the desired speed of 0.51m – 0.77m per second over the desired grade, and a distance error of 0.019m was detected between the grades on average. This correction was deemed negligible as the sounder was in motion (Gibbings and Raine 2004); as such, the soundings are not exact values due to vessel movement.

4.6 GPS Satellite Availability

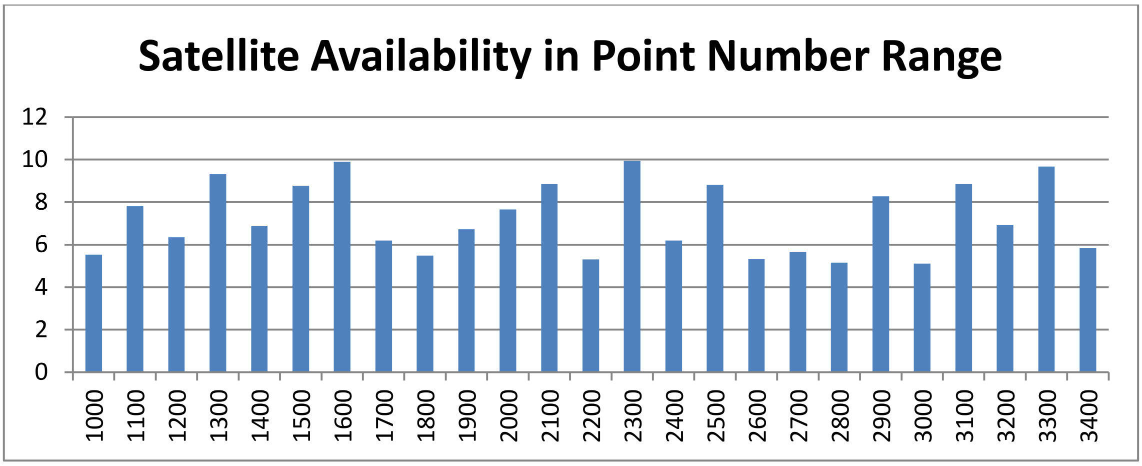


Figure 15 – Satellite Availability

The average number of Satellites tracked as part of the RTK GPS solution has been graphed above using Microsoft Excel after being extracted from the Raw data file from the TSC2 running Trimble Survey Controller. It is seen from the graph that the lowest number of satellites tracked as part of the GNSS solution is 5 Satellites throughout the Number ranges, with the highest being 10 satellites.

4.7 Data Files

In order to properly define the relationship between each of the positioning techniques, several datasets were utilised throughout the analysis process. Four surveys were primarily completed for DTM production with an additional QA survey completed as per Chapter 3 – Methodology. The datasets utilised for the analysis can be found below:

- Initial DTM Dataset
- Final QA Dataset
- Robotic Total Station Dataset
- GPS Dataset
- Tidal Dataset

The initial dataset comprised a pre–calculated DTM grid surveyed at 5m intervals over the site area. This dataset consisted of 3834 points located on the seafloor to provide data for the initial DTM. For the DTM production, 3321 (86%) points were utilised to provide sufficient overlap for the comparison of the positioning techniques

The final DTM dataset provided a Quality Assurance of the initial DTM surface to indicate if any seafloor movement was present from the tidal changes. If movement was present this data it would create doubt over the result being produced, whilst zero movement would provide data validation for the results. A total of 239 points were selected and resurveyed once the tide was at its lowest to provide data coverage over the site area.

The Robotic Total Station synchronised with the echo–sounding dataset comprised 1321 of raw data. 1216 points were utilised for the DTM production as 71 points (2%) were eliminated due to connectivity issues with the Bluetooth sounder. These were filtered initially by using the Export Style sheet from the TSC3, whereby points only with an associated sounding are exported, removing the need to manually edit points without a recorded depth. A further 34 points were removed from the dataset after initial DTM production as their reported depths were clearly in error. GPS and Tidal datasets were then tailored from the initial populations of 1472 positions to meet the 1216 points recorded by the Robotic Total Station population with soundings associated once position scaling and adjustments were made.

4.8 Initial DTM Survey

The initial DTM survey conducted to provide a base dataset for comparison was formulated using robotic total as discussed in Chapter 3 – Methodology. The pre–calculated DTM grid was “staked out” using Trimble Access software from which the data was exported from the TSC3 into comma delineated form to allow for importing into CivilCad 7, where the calculation of the DTM model was completed. Additional topographic locations were surveyed to provide grade determination and proper bank definition. Contours were then extracted over the dataset by using DTM triangulation to allow for the plotting of 0.100m contours over the site area. Little manipulation of the triangulation was required due to the level of data coverage over the site area.

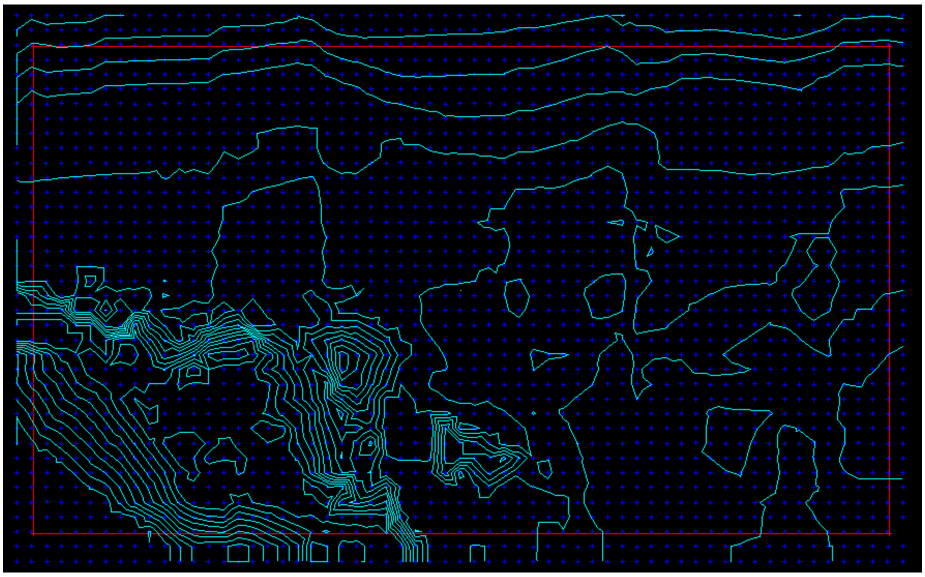


Figure 16 – Initial Survey Data

To allow for the later calculation of volumes, a boundary was established (shown in red in figure 16) to allow for volume area calculations to be coincident between all the DTM models, and to provide some control of the results being produced. If the areas were not coincident, the volumes reported would be in significant error and provide an incorrect illustration of the DTMs produced by each of the three techniques.

4.9 Final QA Survey

In order to provide validation of the results, a QA survey over the site area was completed over a selection of points in order to determine if any surface changes occurred due to Tidal Flow movement, as this would undermine any results produced. In simple terms this was completed to see if there had been any changes in the surveyed positions which would highlight any changes in the surface being surveyed.

A total of 239 points (20% of initial surveyed locations) were resurveyed over the site area using the Trimble S6 once the site was at low tide, in daylight. This occurred the following day after the Hydrographical Survey was completed. The results of the QA survey can be found in the figures following, which highlights the difference in the Surveyed positions. It must be noted that there are break lines present in the initial survey DTM which provides a better determination of the submerged surface

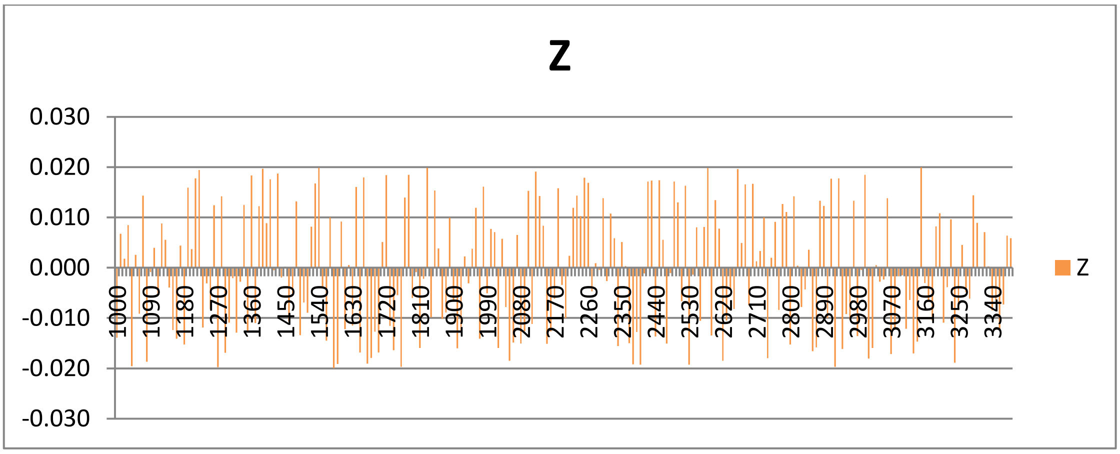


Figure 17 – Z Value Deltas

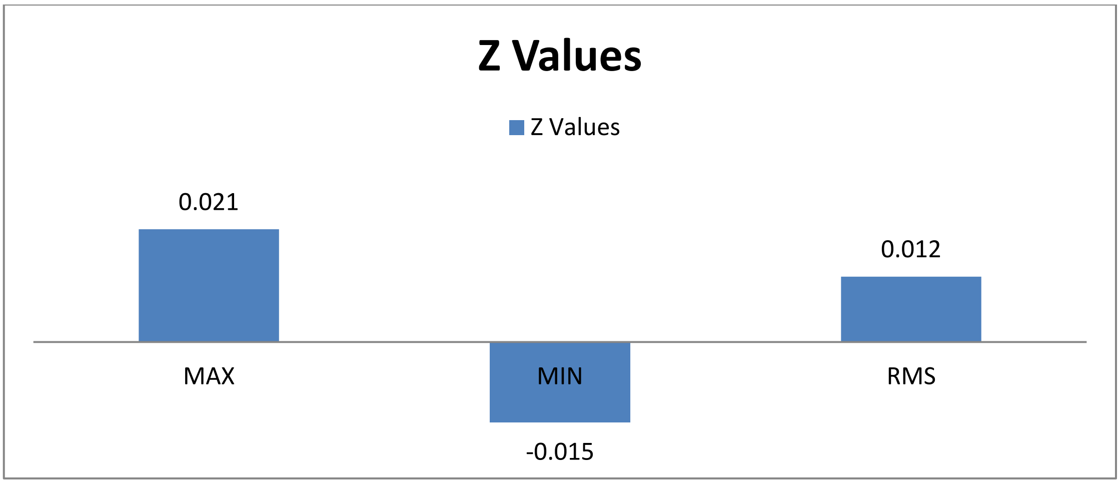


Figure 18 – Z Value Difference

Differences can be seen in the above figures where RL values appear to vary at random from the original position located in the initial survey. The maximum difference found in the surveyed position was 0.021m and the minimum difference at –0.015m. Importantly, the RMS value of the survey is +/– 0.012m, and given the nature of the soft surface being surveyed, this value can be considered negligible.

4.10 Echo Sounding DTM Production

So far issues of Survey Control, Tide Measurement, Calibration and Initial and Final DTM production have been addressed. The formation of the DTMs was established using the filtered 1216 points as discussed in the data section previously. For the data Analysis, 3 DTM types were investigated using different point and transect spacings for each method utilised. These can be viewed in the list below:

- 5m Spacing x 10m Transect
- 5m Spacing x 20m Transect
- 10m Spacing x 10m Transect
- 10m Spacing x 20m Transect

Comparisons between each of the DTM models will be completed by directly comparing the elevations produced at each position by each of the positioning methods with DTM elevations of the Base model at the 5m spacing x 10m Transect positions. In addition to this, Cut/Fill models will be completed over each of the Four Point/Transect Spacings for each of the methods, comparing the model back to the base DTM. Finally, volume calculations will be evaluated over the four DTMs for each method for an additional analysis of accuracy and precision.

As the data was collected, speed equating to a 5m point spacing was utilised whilst logging observations every 5 seconds (as discussed in Chapter 3 – Methodology). Filtering the data points to allow for the varied spacings and transect lines was achieved by deleting every second point to increase the point spacing to an average of 10m point spacing. The removal of every second transect line was the methodology to achieve greater transect spacing. The effect of changing Transect Spacing and Point Density will be highlighted by the volumes reported. Clearly the definition of the banks in the south west area of the job will be greatly affected by this increased data spacing.

To ensure data integrity, any suspect soundings which appeared to not agree with the base DTM model were removed to ensure proper calculation for comparison. The following figures, being the Robotic Total Station Survey with Echo Soundings, shows the effects of changes in the point and transect line spacings from 5m to 10m and 10m to 20m respectively. From these we can see that the elongation of triangles by adopting a larger transect line spacing whilst maintaining point spacing results in elongated triangles and incorrect DTM computation. Maintaining 5m and 10m point spacing and a 10m transect line creates a better triangulation solution. This will be further addressed in Chapter 5 – Discussion and Recommendations.

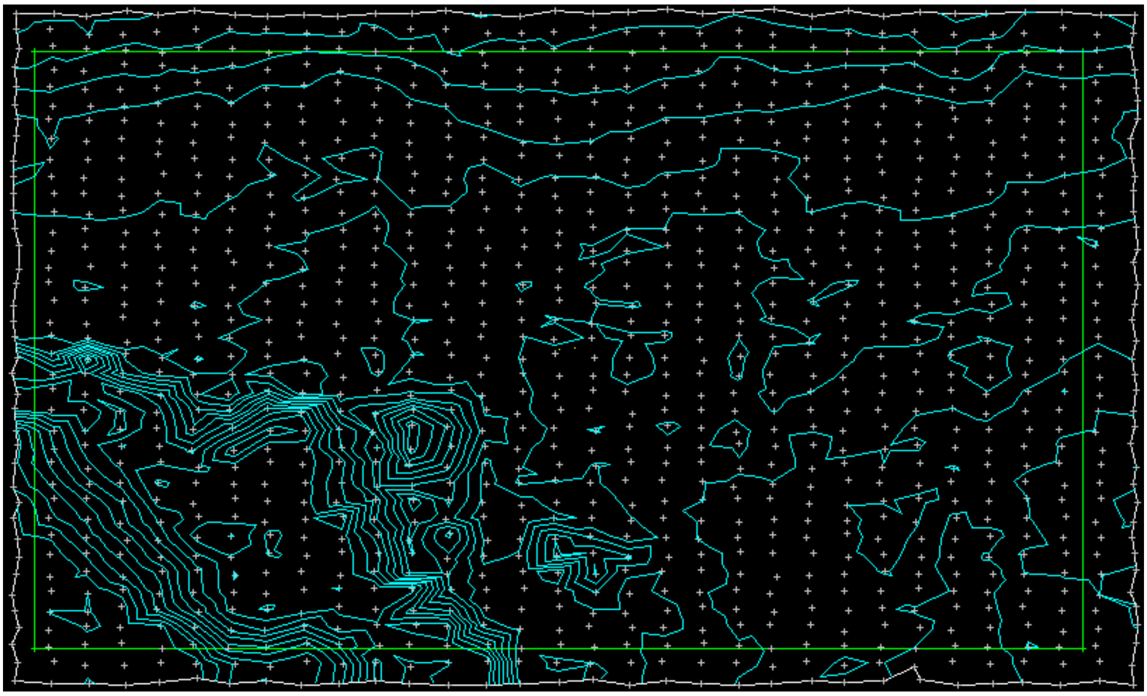


Figure 19 – Robotic Total Station 5m Spacing x 10m Transect Lines

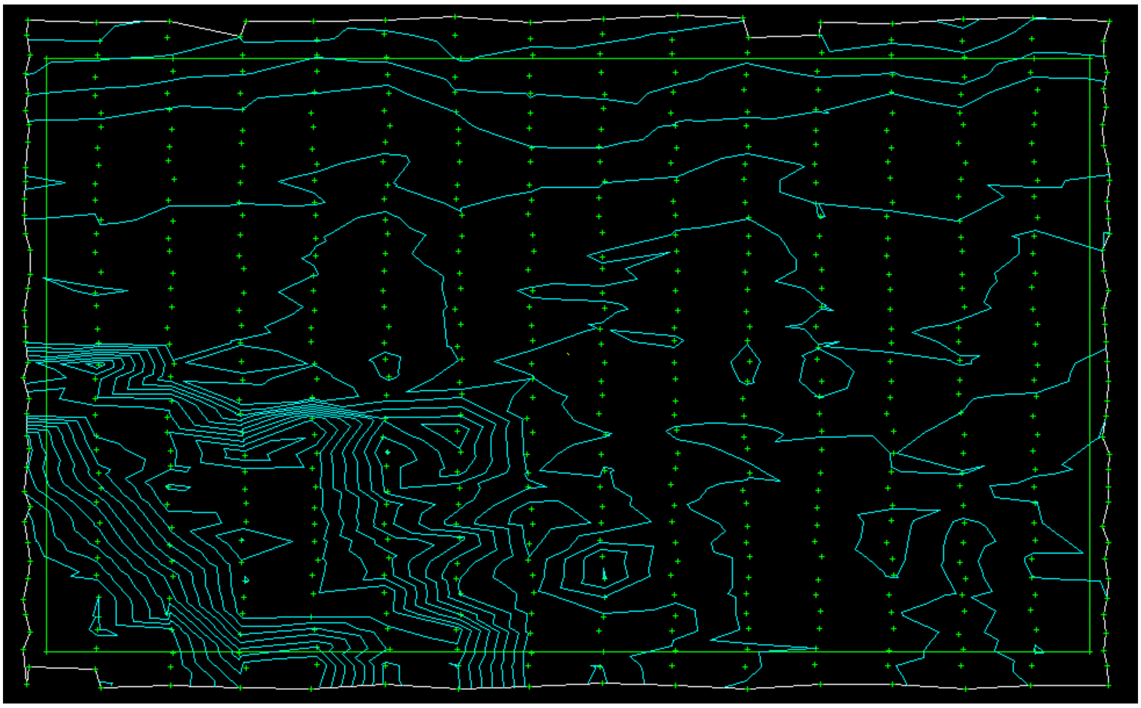


Figure 20 – Robotic Total Station 5m Spacing x 20m Transect Lines

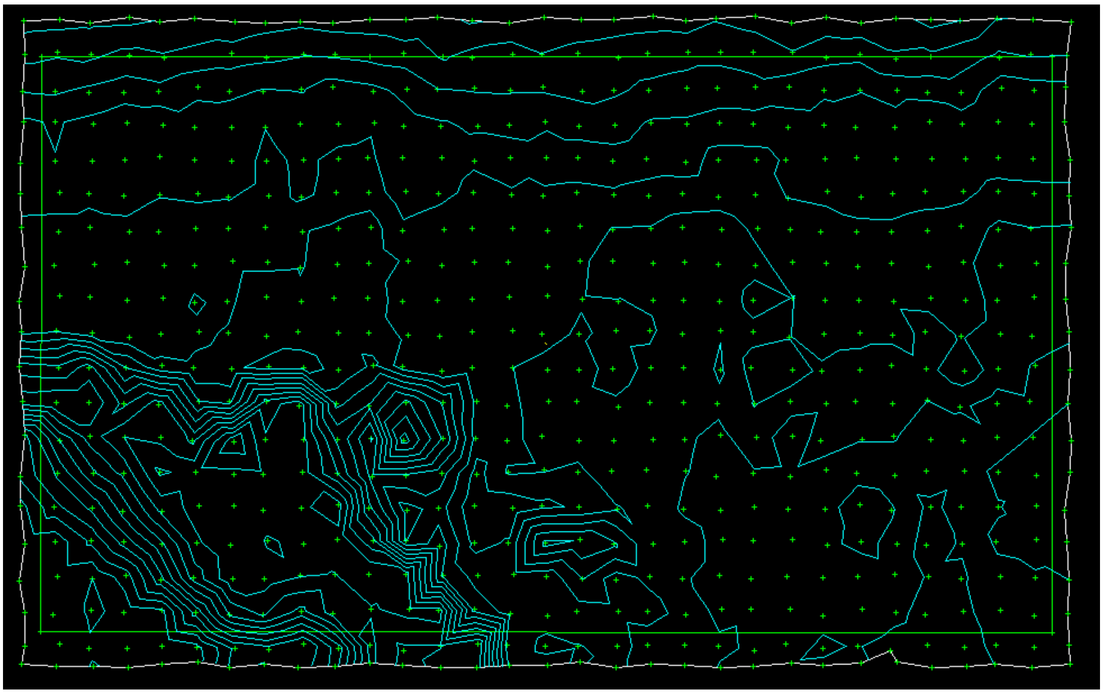


Figure 21 – Robotic Total Station 10m Spacing x 10m Transect Lines

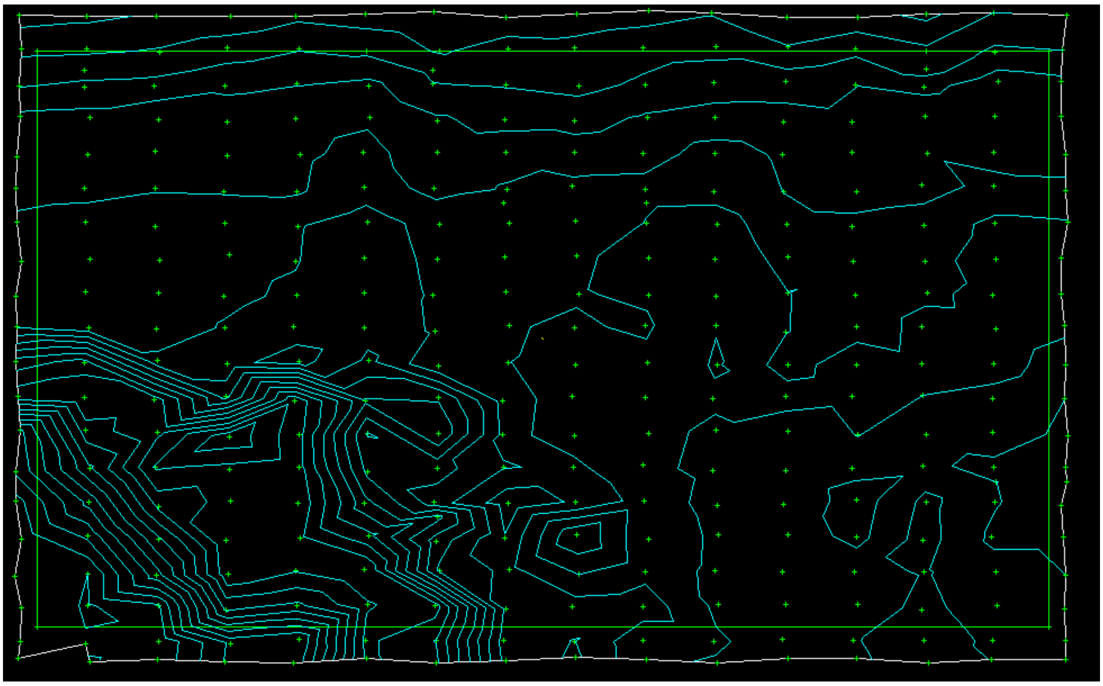


Figure 22 – Robotic Total Station 10m Spacing x 20m Transect Lines

DTMs produced for each of the point and transect spacings for the GPS and Tidal/Water Methods can be found in Appendix D and E found in the back of this document.

4.10.1 Establishing RTK GPS Dataset

As discussed in Chapter 3 – Methodology, the HydroLite was only able to maintain connectivity to one Data Collector at a time. Therefore it was established that the RTK GPS survey would only determine the position of the Transducer at the time of the survey, logging positions simultaneously with the Robotic Total Station Survey to allow for the echo soundings to be post–processed and applied to the position of the transducer at the time of survey.

In order to complete this validation, the position of the GPS at the time of the survey must be known in order to correlate the topographical position observed by the Robotic Total Station linked to the echo sounder, to provide confidence to apply the echo soundings. This was to be achieved by scaling and rotating the GPS dataset onto the coordinates of the Robotic Total Station dataset, from which the initial DTM survey was observed, thus allowing the four datasets to be compared as they are on the same coordinate system. The results of this can be seen in the Figure below which shows the Maximum and Minimum values for the 1216 points scaled, translated and rotated onto the Terrestrial control network.

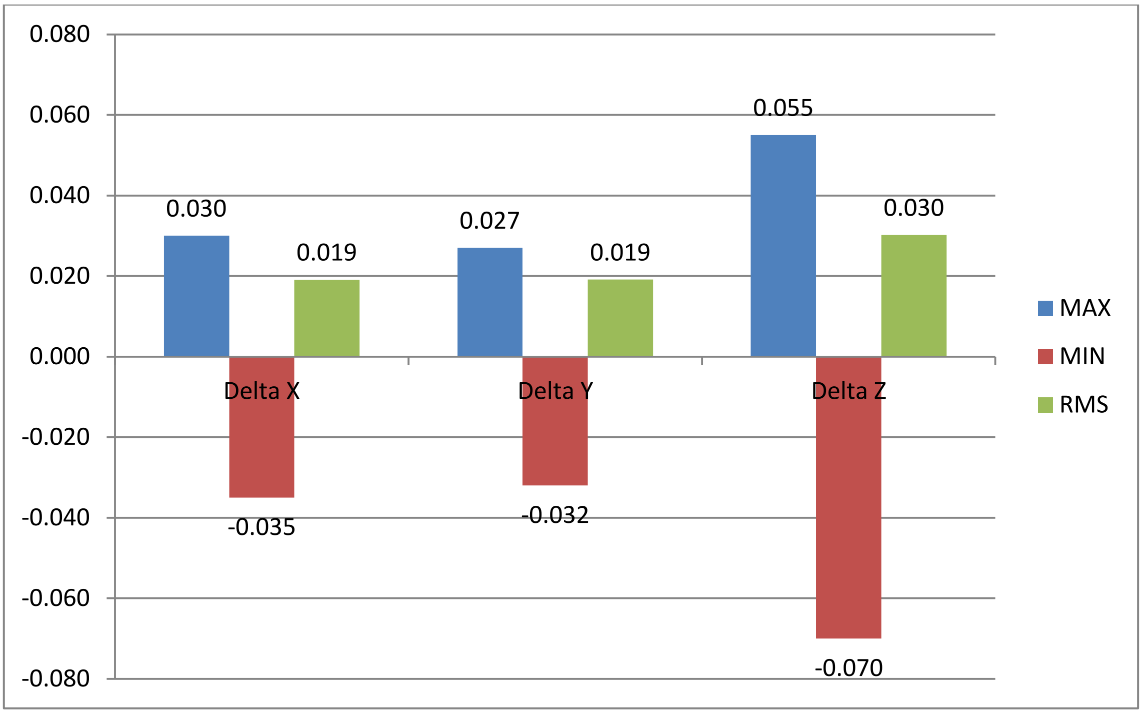


Figure 23 – Scaled Coordinate Residuals

From the graphed values it can be observed that the maximum difference between the Easting (X) coordinate is 0.030m and –0.035m with 0.027m and –0.032m being achieved for the Northing (Y) coordinate. The RL values range between 0.055m and –0.070m. RMS values for each of the coordinate value are 0.019m, 0.019m and 0.030m for Easting, Northing and Elevation Values respectively. As discussed in Chapter 2 – Literature Review the minimum accuracy of position for Hydrographic Surveys is +/– 1.5m with elevation of 0.2m being required. Clearly these specifications have been met.

4.10.2 Tidal/Water Height DTM

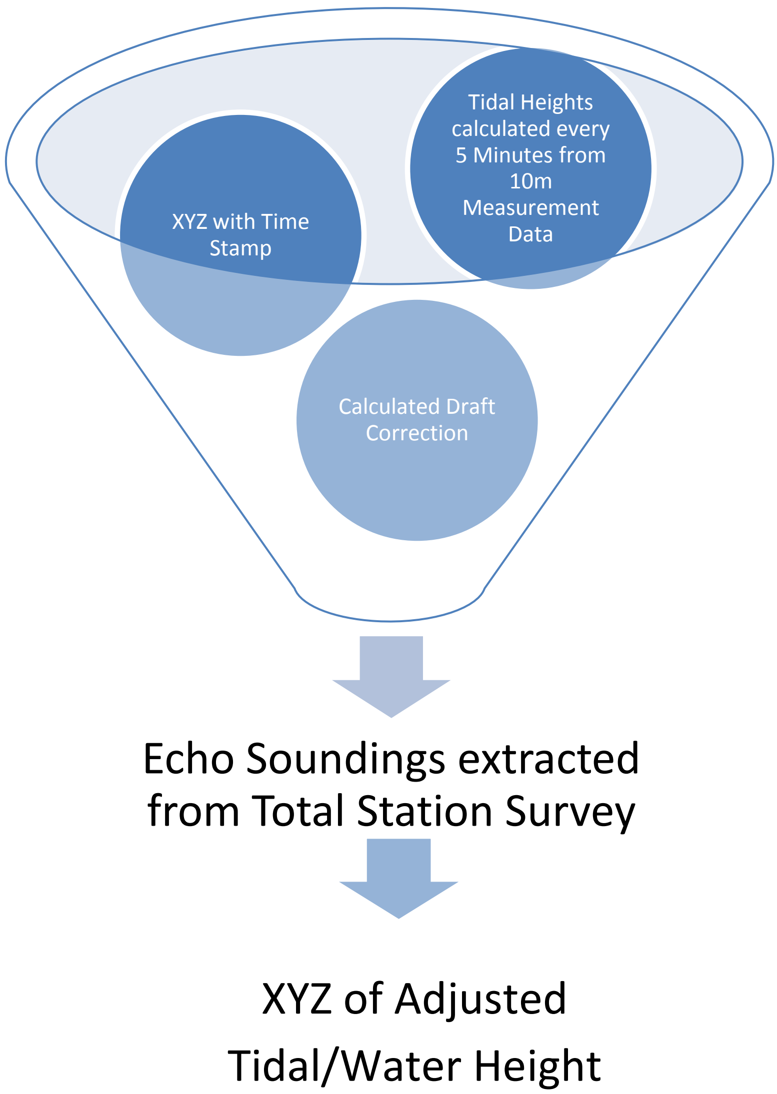


Figure 24 – Factors involved for Tidal/Water Height Datum

The calculation of the Tidal/Water Height DTM was significantly the most labour–intensive calculation process of the data reduction process. The above Figure demonstrates the various factors involved in the reduction of data for the computation of DTM surface for the Tidal/Water Height dataset.

There are 3 sets of data applied for the computation of the Tidal/Water Height DTM. These calculations were completed in Excel to form a comma delineated file to be read into CivilCad 7. From the TSC2 a XYZ with time stamp was exported from the TSC2 linked with the R8 GNSS system. Secondly, the dynamic draft correction was applied to the Echo sounding dataset, extracted and coordinated from the RTK GPS reductions. Finally the measured water heights, calculated from the measured 10 minute intervals to 5 minute graduations to allow for better application to the time stamped XYZ, were applied to each of the reduced echo soundings. The resulting DTM can be found below.

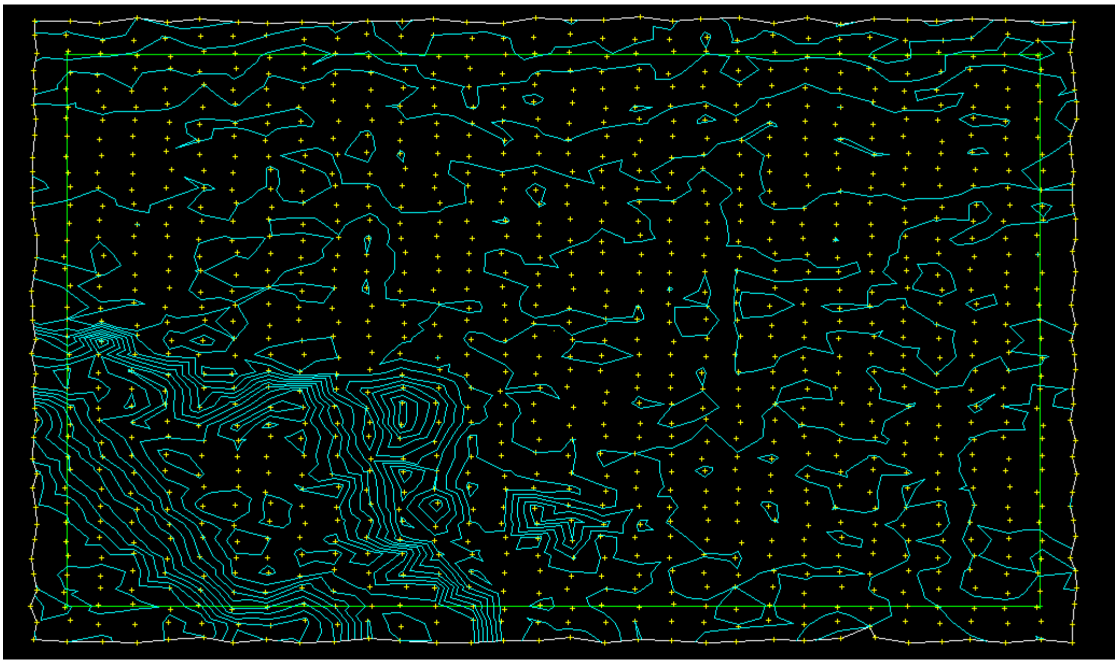


Figure 25 – Tidal/Water Height DTM

A comparison between the XYZ produced by the Tidal methods was completed against the RTK GPS dataset. This was completed over the entire dataset with the results being shown in Figure 26.

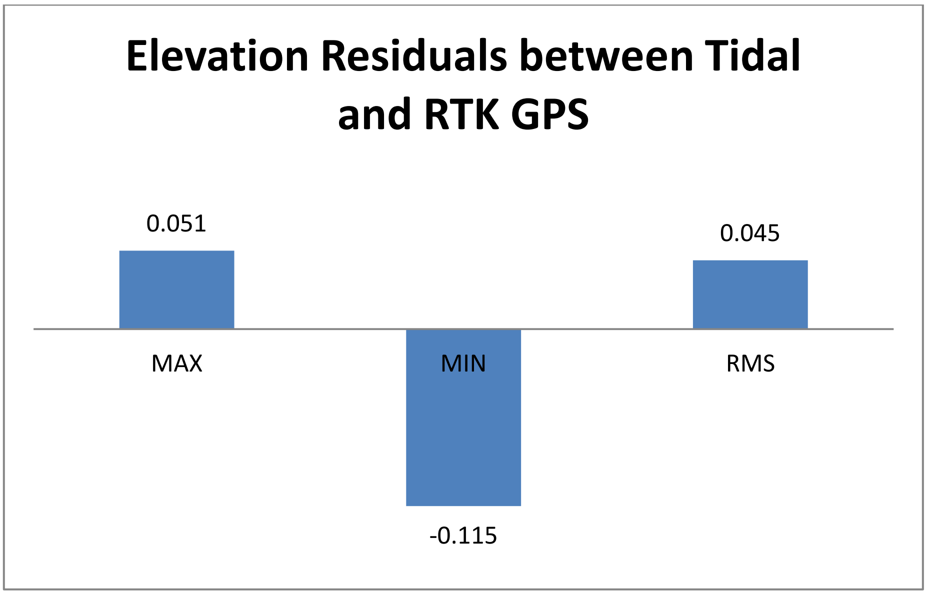


Figure 26 – Elevation Residuals

Maximum and Minimum differences are between 0.051m and –0.115 respectively with a RMS value between the datasets of +/–0.045m highlighting the RL difference at the Transducer.

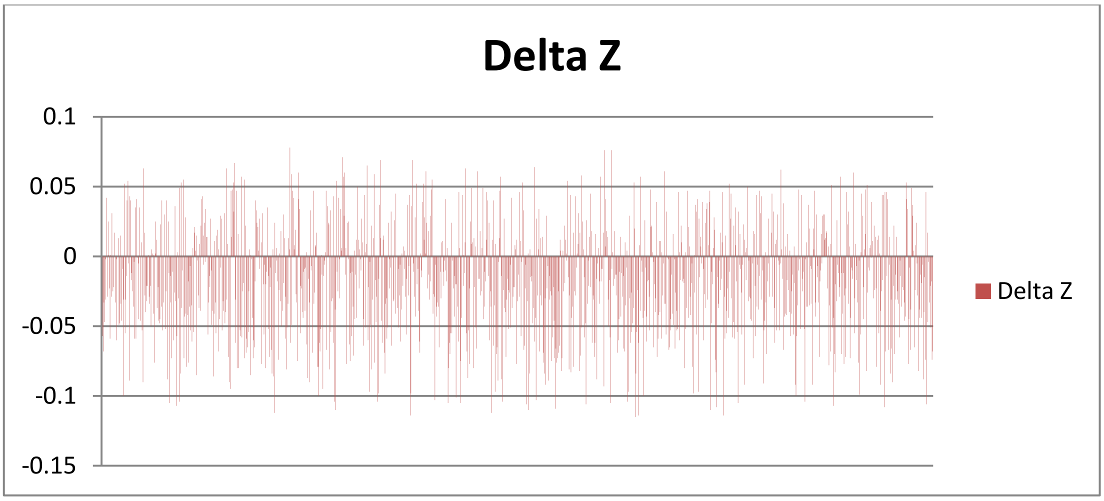


Figure 27 – Overall Delta Z

From the above Figure 27 the residuals between the RTK GPS position and the Tidal Plane/Water height elevation techniques can be viewed. Clearly the transducer is consistently lower 66% (799 observations of 1216) of the time. Naturally no XY comparisons were completed as the same XY coordinates were utilised for the reductions as the RTK GPS.

4.11 Direct Comparisons Between Methods

Once the DTM models were created using simultaneously logged positions the differences between the measured value and the corresponding Base DTM elevation were assessed for the entire dataset. This was completed in Microsoft Excel using CSV exports from CivilCad to directly correlate the measured values of each of the measurement systems and the corresponding Base DTM model. The reduced values were assessed for Minimum and Maximum values plus RMS values for the difference. The results of this analysis can be viewed in the following Figure.

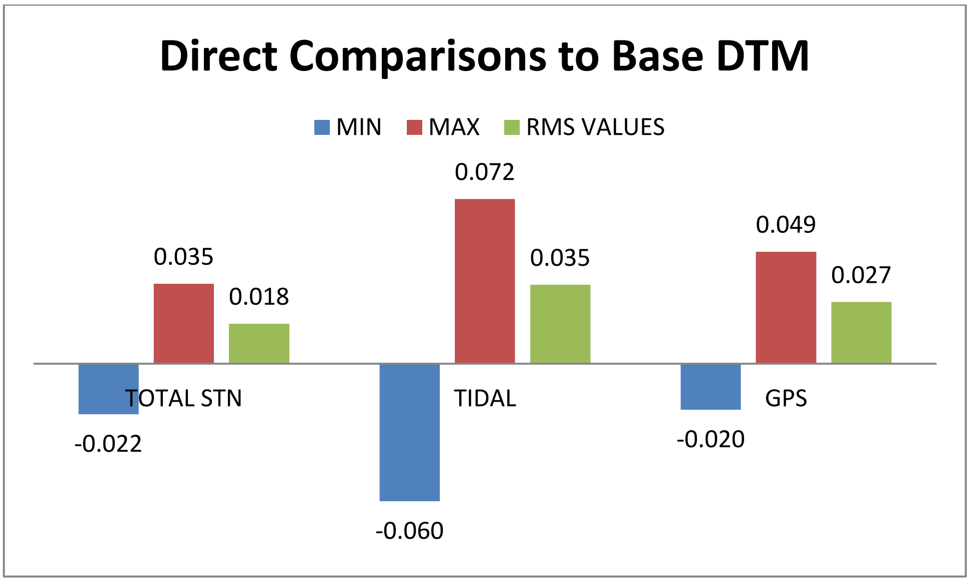


Figure 28 – Direct Comparisons

From this analysis we can visually determine that the Robotic Total Station provides greatest accuracy and precision of each of the depth sounder positioning techniques. Maximum, Minimum and RMS values are 0.035m, –0.22m and +/–0.018m respectively.

RTK GPS positioning represents the next most reliable positioning technique defined by this data. The technique has a variation of 0.049m and the lowest minimum value of –0.20m. RMS also represents significant repeatability at +/—.027m. Lastly, this data analysis shows greatest difference in the Tidal dataset with 0.072 and –0.060m for Maximum/Minimum values with the highest RMS of 0.035m

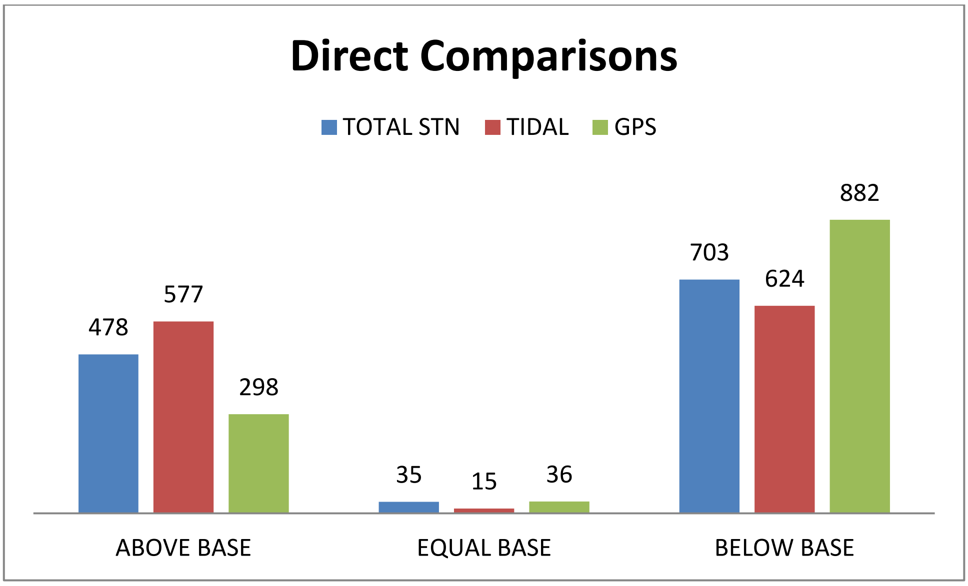


Figure 29 – Trend Comparisons

Further analysis of this data was completed to understand the direct relationship between the topographical position and the Base DTM. Specifically the populations of each dataset Lower, Equal or Higher in Elevation when compared to the base DTM position is shown using this bar chart. The above Figure provides a visual and quantitative analysis of this. A pattern is present in the residuals for each system whereby more than 50% of positions are higher, below the Elevation of the corresponding DTM position.

Further percentage analysis of each of the measurement techniques is shown in Figure 30.

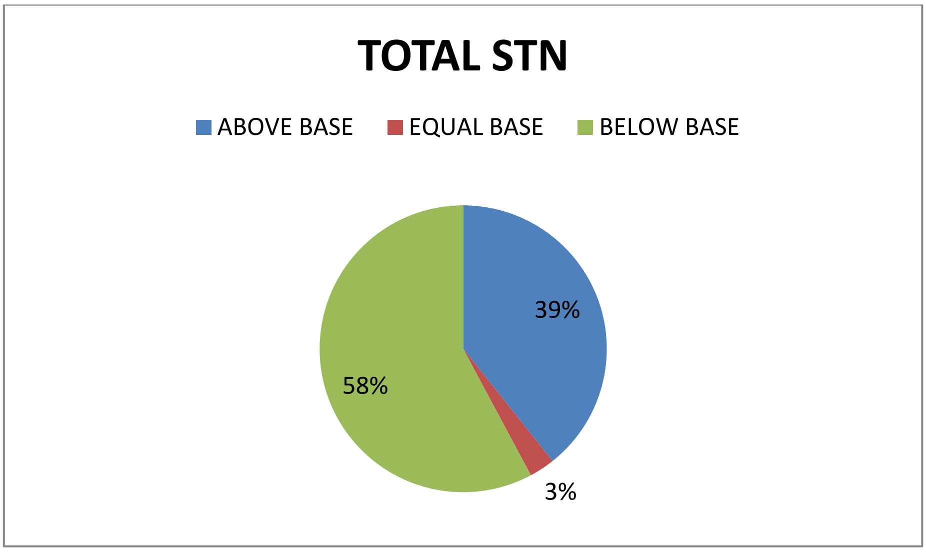


Figure 30 – Total Station Trend

Each of the Positioning Techniques have been plotted in Excel using pie graphs to represent percentage values of the positioning of each of the topographical locations. The Robotic Total Station data set provides 58% of observations below the base DTM surface, 39% above the base surface, with 3% of the positions agreeing with the initial base DTM surface.

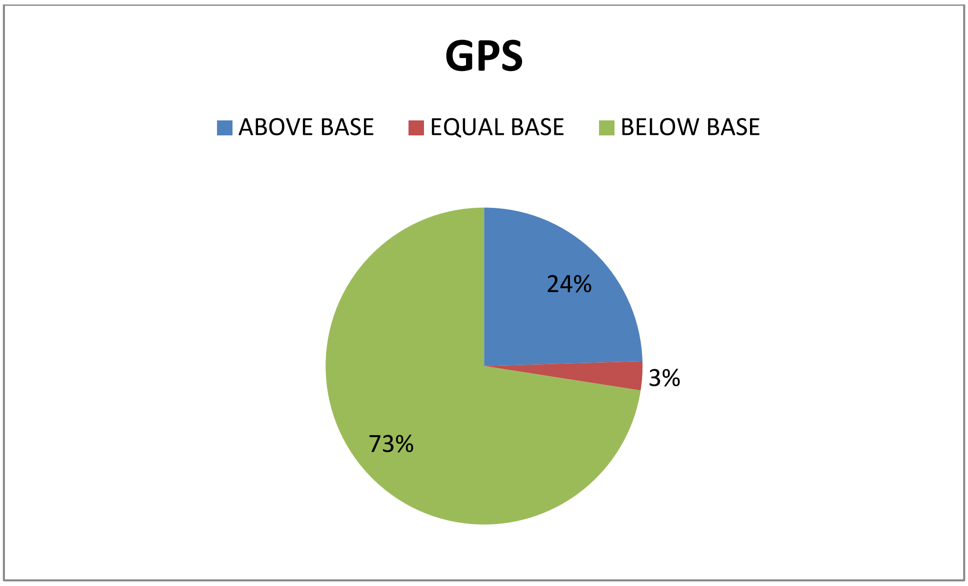


Figure 31 – RTK GPS Trend

An identical analysis of the RTK GPS dataset was completed. 73% of observations were below the position determined by the Base DTM surface, with 24% presenting residuals above the base, and a final 3% agreeing with the Base DTM surface.

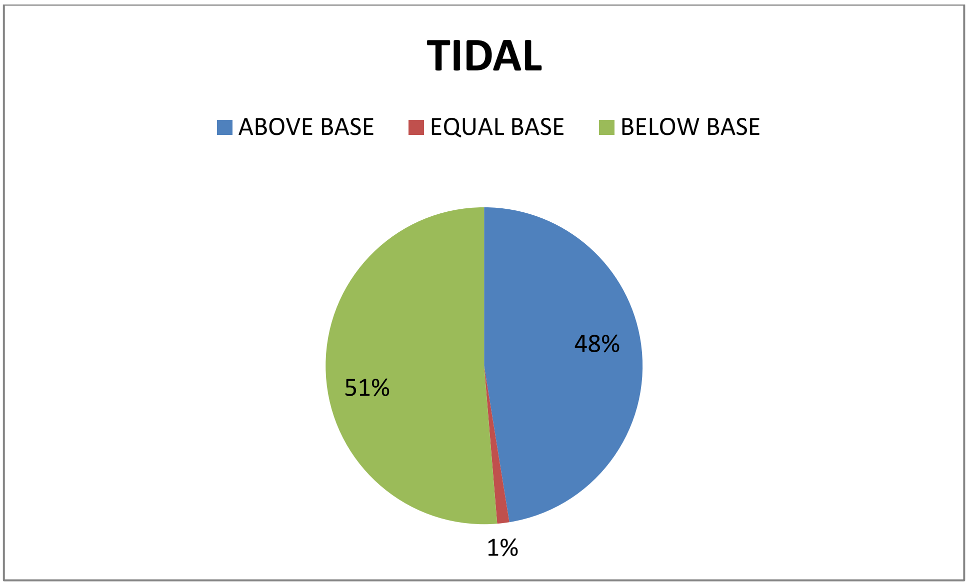


Figure 32 – Tidal Trends

Finally, the Tidal DTM residuals were assessed. They present an even spread of observation residuals above and below the base surface at 51% and 48% respectively. A negligible 1% of observations agreed with the base surface.

4.12 Cut/Fill DTM Analysis

Further data analysis has been completed using the development of Iso–patch Cut/Fill DTM models which provides definition of the visual difference between each of the positioning techniques and the base DTM model. This analysis was visualised for the 5m spacing at 10m transect lines for the Robotic Total Station, RTK GPS and the GPS Tidal plane DTMs. The graduations of the analysis technique can be seen in the image below where hue graduations were defined in the display setting of CivilCad. Variation up to 0.050m was defined to provide sufficient visualisation of the differences.

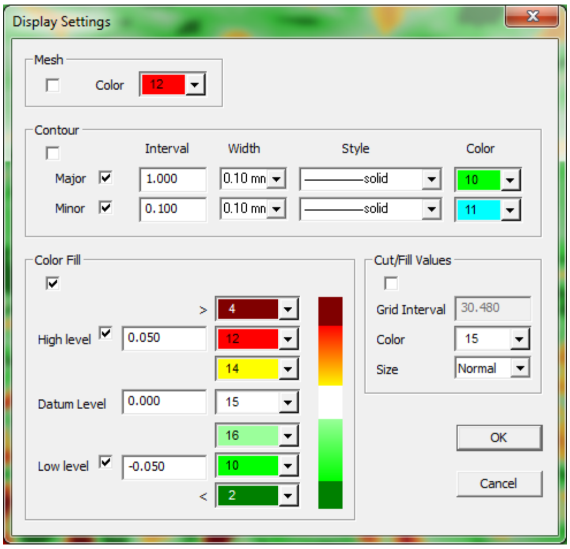


Figure 33 – Cut/Fill Model Legend

Each of the DTM cut fill models are visualised in the following 3 Figures:

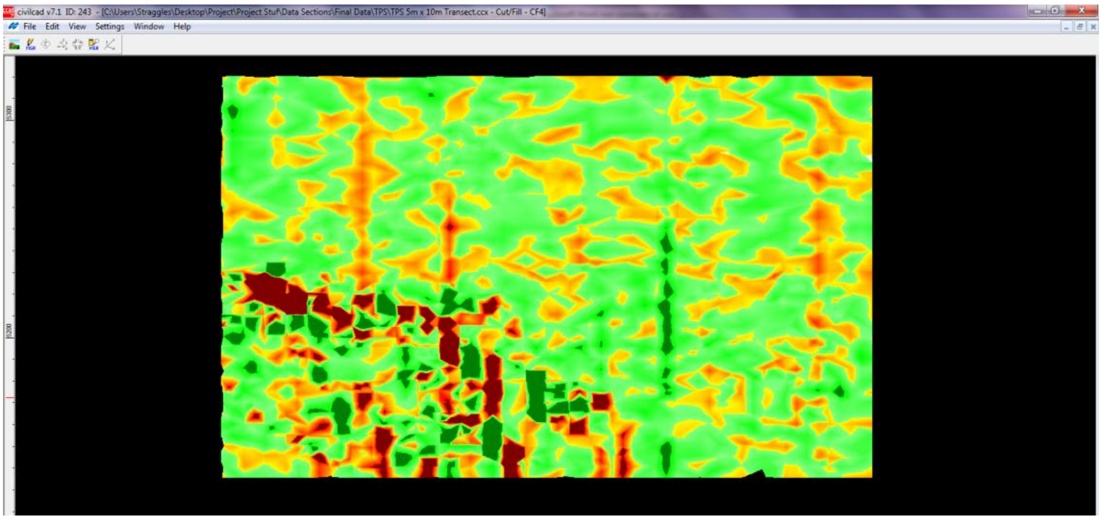


Figure 34 – Robotic Total Station 5m spacing x 10m transect analysis

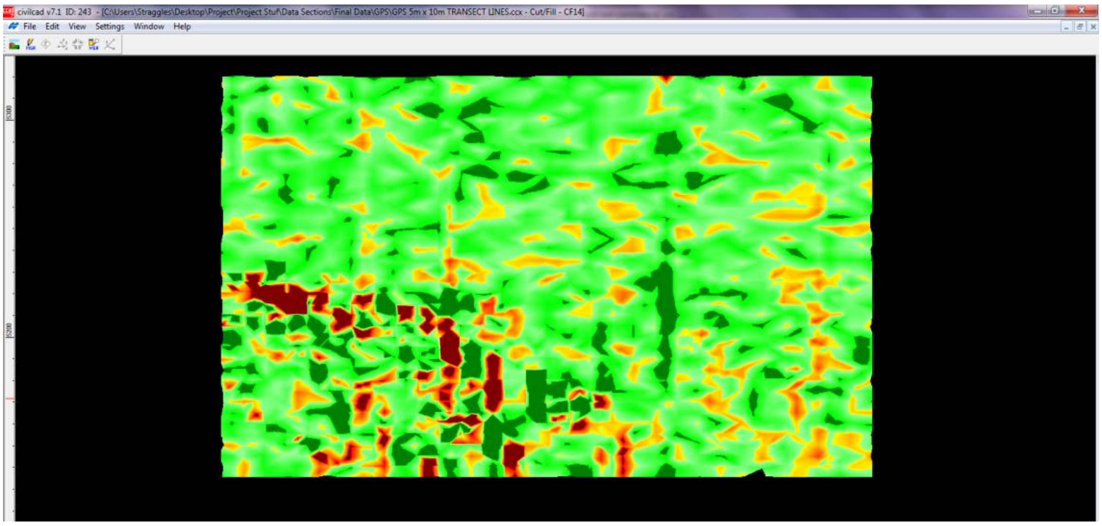


Figure 35 – GPS 5m spacing x 10m transect analysis

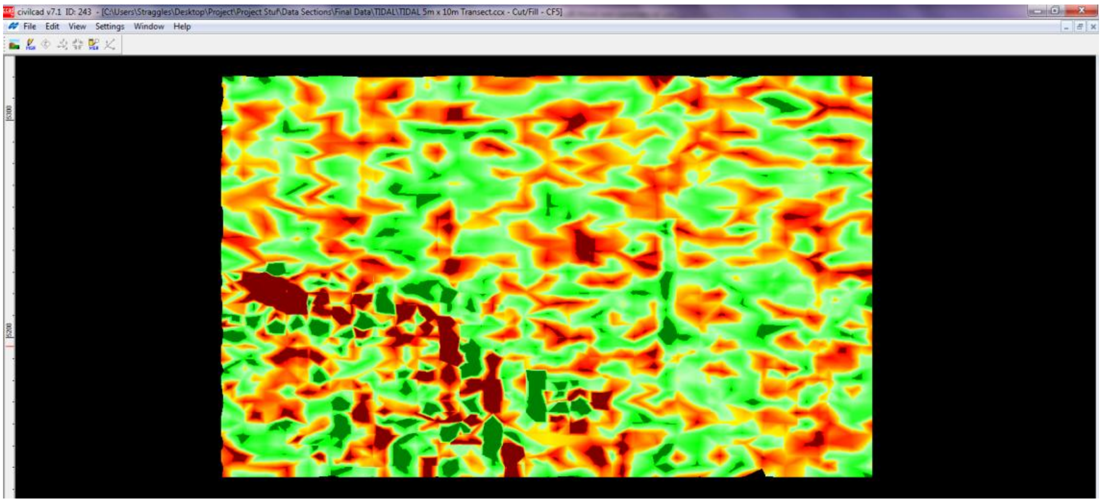


Figure 36 – Tidal 5m spacing x 10m transect analysis

Each of these models confirm the relationships shown in the position chart shown previously. That being an even spread of cut and fill values can be seen in the tidal plane comparison which agrees with the 50% split in the above/below values of the direct comparisons. The same observations can be made for the one–sided Hue catergorisation present in the RTK GPS and Robotic Total Station analysis where the comparison shows consisent vaiartion above the base DTM models.

It appears that the grade definition of the banked areas in the south west corner of the survey contains some error which is defined by the Hue variations. The variation is consistent between the three positioning techniques in nearly idential positions. Such observations will be further investigated in Chapter 5 – Discussion and Recommentations.

4.13 Volume Calculations

As discussed in earlier volumes between the base DTM 5m spacing x 10m Transect lines each of the defined point density/transect spacings were calculated as an additional analysis tool. The results of these volumes can be found tabulated below in Table 8 with full calculations found in Appendix F.

Comparison to Base						
Surface	**Point Density (m)**	**Transect Density (m)**	**Cut**	**Fill**	**Net**	**Ratio**
Robotic Total Station	5	10	323.4	605.4	282.0 (Fill)	0.534
	5	20	711.5	745.4	33.9 (Fill)	0.955
	10	10	466.9	692.2	225.3 (Fill)	0.675
	10	20	756.9	773.8	17.0 (Fill)	0.978
Tidal/Water	5	10	647.7	645.7	2.0 (Cut)	1.003
	5	20	1010.3	778.4	231.9 (Cut)	1.298
	10	10	771.4	743.5	27.9 (Cut)	1.037
	10	20	1069.3	769.5	299.8 (Cut)	1.390
RTK GPS	5	10	210.0	1136.3	926.3 (Fill)	0.185
	5	20	555.7	1258.0	702.3 (Fill)	0.442
	10	10	332.0	1172.5	840.5 (Fill)	0.283
	10	20	546.0	1290.8	744.8 (Fill)	0.423

Table 6 – Volume Comparisons

The volumes have produced varied and surprising results. Net fill values define the amount of fill to be applied to the dataset to meet the Base DTM surface with Cut values highlighting cutting volume required to meet the Base DTM surface.

It was expected that the data presented by the 5m spacings x 10m transect lines would present the most reliable data with the smallest volume differences. Secondly it was expected the Tidal dataset would provide the highest Net volume change. However, the smallest net volume was produced by the 5m x 10m Tidal DTM with the largest produced by the 5m x 10m dataset at 926.3 (Fill). This fill value can be attributed to the consistent 74% lower correlation of the direct comparison of the RTK GPS dataset to the Base DTM model.

The 50% spread of the Tidal/Water height DTM surface both above and below the Base DTM can provide basis for the relatively consistency cut and fill Ratios and the small relative net volume change represented in the volume analysis.

4.14 Conclusions: Chapter 4

The results of the survey control, calibration, Tide measurement, Satellite availability and the various DTM analysis techniques of the Initial/Base DTM, QA data and the DTMs produced by each of the positioning techniques have been analysed within this chapter.

The results have been varied, especially the calculated volumes. Such results will be further discussed in Chapter 5 – Discussion and Recommendations.

CHAPTER 5 – DISCUSSION AND RECOMMENDATIONS

5.1 Introduction

This chapter aims to discuss and make recommendations from the results produced by field survey for a comparison of depth sounder positioning techniques documented in Chapter 4 – Results and Data Analysis.

Transect Line and Point Spacing will be addressed for Volume Definition as part of this Chapter in addition to further investigation of the Direct Comparisons between the DTM models using the developed Cut/Fill models. Specifically the definition of submerged changes of grade has clearly affected the results produced. Finally, the suitability of equipment utilised and an Evaluation of AUSGEOID09 will be discussed.

5.2 Discussion

5.2.1 Transect Line and Point Spacing

In Chapter 4 – Results and Analysis, the effects of transect line and point spacing was clearly evident through the calculation of volumes. From Table 6 it can be observed that the volumes produced are affected clearly by the point spacings produced. However, no pattern is discernable in the produced volumes.

The net volumes produced agree with the direct comparisons completed over each of the datasets determined by the Positioning Techniques. The Robotic Total Station and RTK Datasets were consistently below the base DTM surface and as such their differences are Fill in value. The Tidal dataset appears to provide the most reliable definition of the DTM model in terms of its computed volume to the base model which is in direct contrast to its highest difference and MIN/MAX values calculated directly to the base DTM models.

The use of volumes to provide a determination of the reliability and accuracy should be taken with a grain of salt. As Figure 37 highlights, even with a 0.010m difference in the measured RL it correlates to a substantial error in the volume produced.

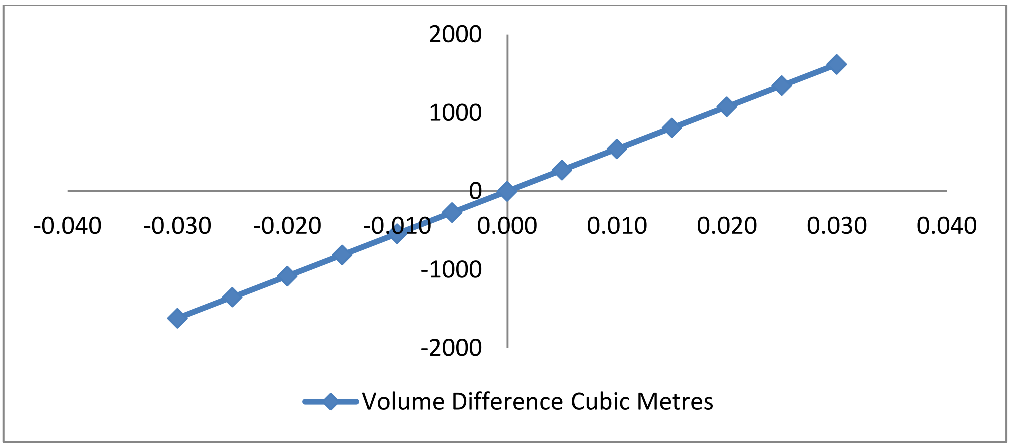


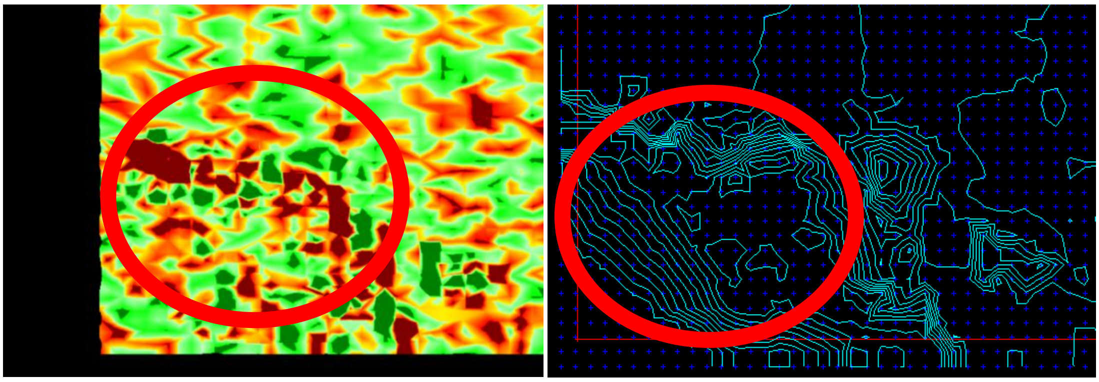
Figure 37 – Graphed Error Propagation

Coupled with the measurement accuracy of the echo sounder and the dynamic nature of the survey, the definition of the submerged model will not be an exact science as highs and lows would even out. As such, the definition of the model using the calculated volume should not be given higher weight than the direct comparison of the observed elevations to the Base DTM surface.

5.2.2 Cut/Fill Model Definition Evaluation

The use of Cut/Fill Iso–patch models provided an effective medium for the visual communication of the relationship between the Base DTM model and each DTM produced by each technique of Depth sounder remote positioning. The Figures present in Chapter 4 – Results provide a valid analysis of the relationships present between the models and agree with the trends presented in the direct data analysis of each technique.

However, some eccentricities are present in the data which are highlighted by the Iso–patch surfaces. From the data analysis completed the definition of the changes of grade in the south west section of the data are clearly not properly defined.



Tidal Plane DTM Model *Original DTM Base Model*

Figure 38 – Grade Misrepresentation

This lack of proper representation is present in each of the positioning techniques being explored as the observations were recorded in essentially identical positions.

As discovered by (Gibbings and Raine 2004) the use of a Zig Zag pattern between the water line and where the floor flattens out when defining changing grades in water storages would overcome this issue to properly define the changes in the grade of the sandbanks in this area.

5.2.3 Suitability of Technologies Utilised

The suitability of technologies utilised throughout this research in relation to its practicality for Hydrographic/Bathymetric Survey needs to be discussed. The methods evaluated via this research addressed small scale surveys of this nature in environments with calm water conditions to allow for a simplistic approach to the research without the need for expensive data management and capture systems.

Each of these methods utilised require the use of onshore support through either direct Robotic Total Station observation or RTK base support for real time GPS correction. The suitability of Robotic Total Station techniques is only valid for small scale localised surveys, both Hydrographic and Bathymetric, due to the need for line of sight and the practicality of MGA connections as required for Hydrographic surveys in Queensland waters when submitting to navigation and local authorities.

The use of RTK GPS allows for greater data capture capabilities, removing the need for line of sight, extending the range for the survey to the limits of radio connection without the need to provide MGA connections. However, the onshore support will continue to limit the GPS capabilities when completing Hydrographic surveys in further offshore environments.

The use of Water/Tidal heights required the use of expensive software and data collection systems but the use of GPS technologies provides remote positioning of the echo sounder, which removes much of the error associated with Hydrographic surveys as discussed in Chapter 2 – Literature Review.

5.2.4 AUSGEOID09 Reliability

The generation of AUSGEOID09 and the related accuracies were addressed as part of Chapter 2 – Literature Review, detailing the research completed. The Control Evaluation completed as part of the results Chapter further provided evidence of the reliability of the Geoid models relationship to AHD.

As discussed in Chapter 2 – Literature Review, the expected error of GPS heights being reduced using AUSGEOID09 in the range of +/–0.050m, was confirmed by the results presented in Chapter 4(Brown, Featherstone et al. 2010).

5.3 Recommendations

This section summarises the recommendations that can be ascertained from the data collected for a Comparison of Depth Sounder Positioning Techniques with respect to the desired accuracy and precision of the DTMs produced by each of the assessed methods.

The use of a Single Beam echo sounder has proven methodology in mapping submerged surfaces. Coupled with remote positioning, the echo sounder with GPS or Robotic Total Station technologies removed much of the error associated with the positioning of echo soundings.

Robotic Total Station methods for remotely positioning the echo sounder provides the highest accuracy and reliability for DTM productions. RTK GPS methods utilising AUSGEOID09 provides an accurate difference within tolerance of the

AUSGEOID09–expected errors, whilst the use of Tidal/Water heights in still water situations also provides a valid tool for data acquisition and QA purposes.

In order to properly define changing grades, a zigzag pattern should be adopted across the survey area at a uniform spacing, which will undoubtedly increase the accuracy of the DTMs produced.

5.4 Summary

The research completed as part of Chapter 2 – Literature Review allowed for background information to be acquired on the characteristics of each of the positioning techniques under investigation. The Hydrographic/Bathymetric technique, Data acquisition and Positioning techniques, errors in Hydrographic surveying, Standards for Hydrographic surveys and the resource requirements were all investigated as part of this research.

Chapter 3 – Methodology entered into detail the methods to be used to complete the research into the positioning techniques based on the research completed in Chapter 2. As discussed, each of the positioning techniques would log simultaneous positions at 5 second intervals. At a speed of 1.5 to 2 knots, points were logged at 5m spacings at 10m transect lines using a HydroLite TM single beam echo sounder synchronised with Bluetooth connection to a Trimble TSC2. The echo sounder was mounted in the transducer position on a small 3m aluminium vessel. As discussed in the Latency sections, the slow vessel speed negated any latency in the surveyed positions.

Chapter 4 detailed the results of each of the surveyed locations with respect to the base DTM surface. Calibration, Latency and Control evaluations were also undertaken as part of the data analysis. It was found that the depths reported by the echo sounder agreed with the manufacturer's specifications of 0.010m. Initial DTM surface, QA checks and the 3 DTMs produced by each of the positioning techniques were evaluated as part of this Chapter through direct comparison, Cut/Fill models and Volume differences through a variety of point density and transect spacings.

5.5 Conclusion – Chapter 5

Chapter 5 established parameters on which results should be given weight over other datasets. Transect line and Point spacings were explored and their effects on the volumes produced. Addition investigation was completed in the Cut/Fill model definition, the suitability of technology used as part of the research, and a discussion of AUSGEOID09 reliability.

Recommendations for areas of future research avenues will be explored in Chapter 6 – Conclusions in addition to a summary and discussion of the findings observed as part of this research.

CHAPTER 6 – CONCLUSIONS AND FURTHER RESEARCH

6.1 Introduction

The original aim of this project was to complete a Comparison of Depth Sounder Positioning Techniques for Hydrographic/Bathymetric Surveys. The methodology was to conduct a topographical survey of an exposed tidal surface to provide a base DTM against which techniques will be compared. Following this, three additional surveys of the base surface utilising a depth sounder coupled with Robotic Total Station, RTK GPS and the Tidal Plane respectively to produce a DTM surface for each technique were to be completed. Finally, an evaluation and discussion of the relationship between the initial base surface was to be completed for each of the individual surfaces created from the three techniques under investigation.

This Chapter will summarise this research by investigating the results produced, the analysis completed and the discussion of the results stated.

6.2 Conclusions

Robotic Total Station coupled with a HydroLite Single Beam echo sounder provides the most accurate and repeatable results for determining a submerged DTM surface. This method provided the smallest RMS values of +/–0.018m with maximum minimum values varying between –0.022m to 0.035m when completing comparisons to the initial DTM surface.

RTK GPS methods provided the next most reliable and accurate method of determining the submerged surface. Although consistently lower, the GPS point to point comparison provided Minimum and Maximum values of –0.020m and 0.049 with variation of +/–0.027m.

Finally the Tidal/Water Height dataset provided RMS values of +/–0.035m with Maximum/Minimum values of –0.060 and 0.072. The Tidal dataset had an even spread both above and below the base DTM surface, which affects the volumes between the models produced.

Point density and transect line spacings have also been addressed as part of this research. Previous studies have determined a relationship between the point spacing/transect line and the definition of the DTMs which have been produced; however, the data produced as part of this research reflects no correlation between the DTMs produced and the point spacings. This is an area for future research which will be discussed in the following section.

6.3 Further Research

These areas have been highlighted as topics within the project which will provide additional areas for future research and documentation.

6.3.1 Effects of Surface Density on Echo Soundings

The effects of the surface material and density on the returned echo sounding is something that needs to be further investigated. The degree of penetration and reflectance of varying frequencies at different Hertz values may provide a better indication of how Hydrographic surveys can be completed with better accuracy and precision.

6.3.2 Further Investigation of Latency

The effects of Latency in the measurement system has been understood as part of this research through recommendations by manufacturers and results produced by additional parties. However, a quantitative value for Latency through further investigation depending on the types connections utilised throughout the measurement system.

6.3.3 Further investigation of Surface Coverage

Several studies have been completed for investigations into the effects of varying point density and transect spacings. However, the difference of transect and point spacings in this project provided inconclusive results on the optimum data coverage level, therefore further research needs to be completed on this topic to provide better indication for the effects of changes in these variables.

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APPENDICIES

Appendix A – Survey Class Specifications

Class A Survey Classification

Application

Class A surveys are required for but not limited to:

- *Investigations of an area for a proposed new channel, anchorage, berth, swing basin, and so on, the outcome of which will be the gazetted declaration of a navigable depth.*
- *Increasing the declared depth in a channel, or berth area, or following maintenance, or development dredging, or bed levelling.*
- *Investigating a grounding or reported shoaling in an area.*

A survey is not a Class A survey unless it meets all of the requirements of this class.

Requirements

For survey information to satisfy this class the following shall be met:

- *The method or methods used to undertake the hydrographic survey within the waterway shall ensure that the minimum depth in the navigable waterway has been determined.*
- *The resultant reduced depths shall have a survey depth tolerance equal to or better than the survey tolerance in the port's UKC formula. In all other cases the survey depth tolerance shall be equal to or better than depth tolerance stated in the Classification Table.*

Class B Survey Classification

Application

Class B surveys are required for but not limited to:

- *Check or depth maintenance surveys. The information should be of sufficient quantity and quality that allows the relevant Regional Harbour Master to amend the declared depth if necessary.*
- *Initial investigations of any events that may have caused abnormal changes in the seabed. These are to be followed by class A surveys in areas where deemed necessary.*

A survey is not a Class B survey unless it meets all of the requirements of this class.

Requirements

For survey information to satisfy this class the following shall be met:

- *A class A survey has previously been carried out in the surveyed area and in the opinion of the Regional Harbour Master an obstruction to navigation is not expected.*
- *Depth data shall be collected from a minimum of 20 percent of the seabed in the navigable waterway. Spacing of sounding lines shall meet this requirement and may be of closer spacing in areas where siltation is known to occur. However the area coverage shall be negotiated between the Regional Harbour Master and the hydrographic surveyor and, where applicable, the Port Authority.*
- *The resultant depths shall have a survey depth tolerance equal to or better than the survey tolerance in the port's UKC formula. In all other cases the survey depth tolerance shall be equal to or better than depth tolerance stated in the Classification Table.*

Class C Survey Classification

Application

Class C surveys are required for but not limited to:

- *Navigation requirements for Small Craft Facilities such as boat harbours, channels, navigable rivers and creeks. In these instances UKC does not apply.*
- *Management of Aids to Navigation*

A survey is not a Class C survey unless it meets all of the requirements of this class.

Requirements

For survey information to satisfy this class the following shall be met:

- *Depth data shall be collected from a minimum of 20 percent of the seabed in the survey area. Spacing of sounding lines shall meet this requirement and may be of closer spacing in areas where siltation is* *known to occur. For surveys in less than 5 metres of water the nominal line spacing is to be 5 metres. Depending on the purpose of the hydrographic survey the area coverage can be negotiated between the client and the hydrographic surveyor.*

- *The resultant depths shall have a survey depth tolerance equal to or better than depth tolerance stated in the Classification Table.*
- *The information shall be of sufficient quantity and quality that enables the safe and effective management of Queensland Small Craft Facilities and Aids to Navigation.*

Class D Survey Classification

Application

Class D surveys are required for but not limited to:

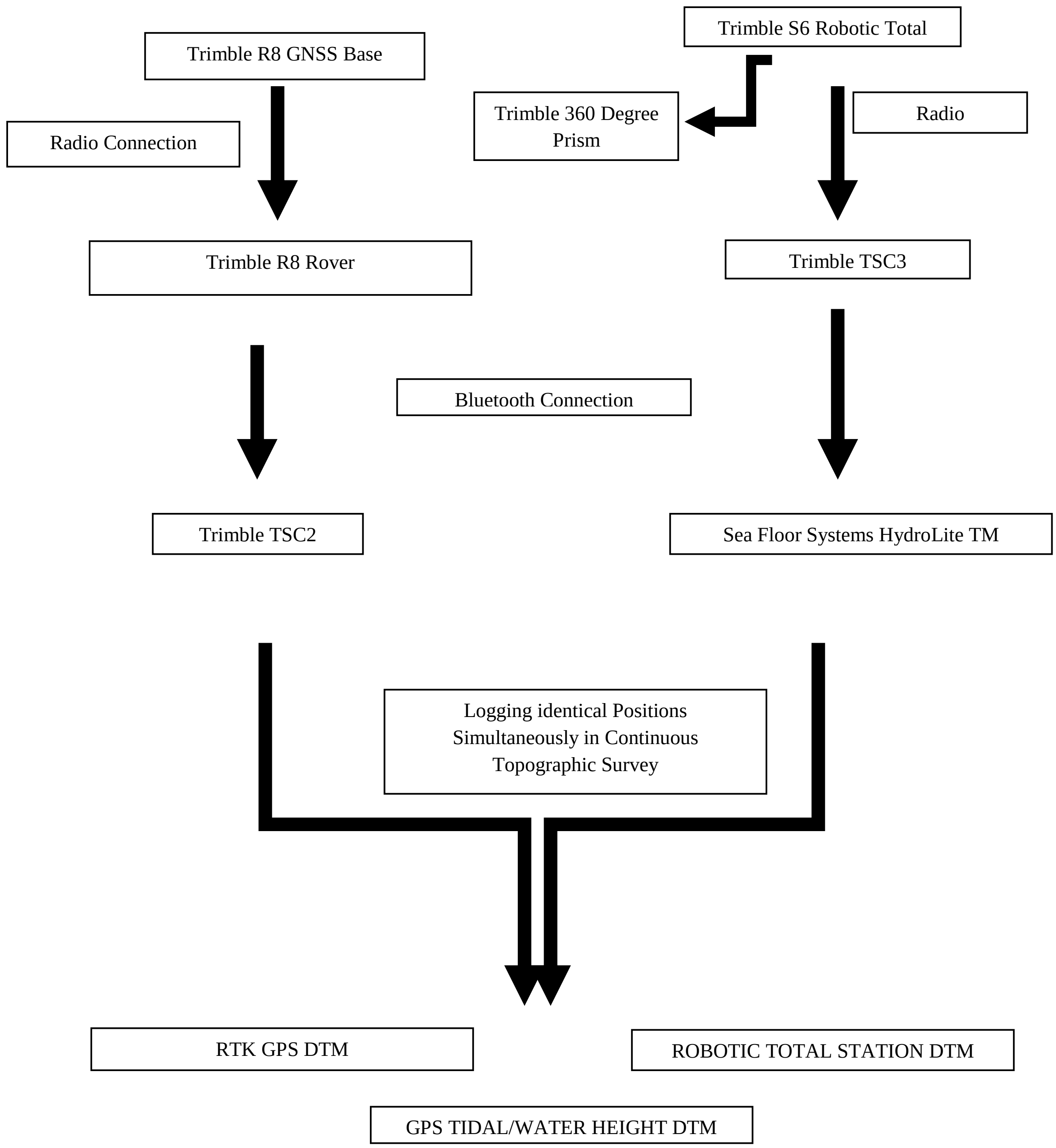
- *Surveys for small craft charts, boat ramps and coastal engineering requirements such as beach profiles of the Beach Protection Agency (BPA).*
- *A survey is not a Class D survey unless it meets all of the requirements of this class.*

Requirements

For survey information to satisfy this class the following shall be met:

- *The nominal spacing of survey lines is 3 x average water depth or 25 metres whichever is greater. Spacing of sounding lines shall meet this requirement and may be of closer spacing in areas where siltation is known to occur or closer spacing is required to adequately delineate a shoal, contour or seabed feature. Depending on the purpose of the hydrographic survey the area coverage can be negotiated between the client and the hydrographic surveyor. For example, for BPA profiles the line spacings have been pre–determined and are required to be resurveyed in the same positions.*
- *The resultant depths shall have a survey depth tolerance equal to or better than the depth tolerance stated in the Classification Table.*
- *The information shall be of sufficient quantity and quality that enables the safe and effective management of Queensland Waterways.*

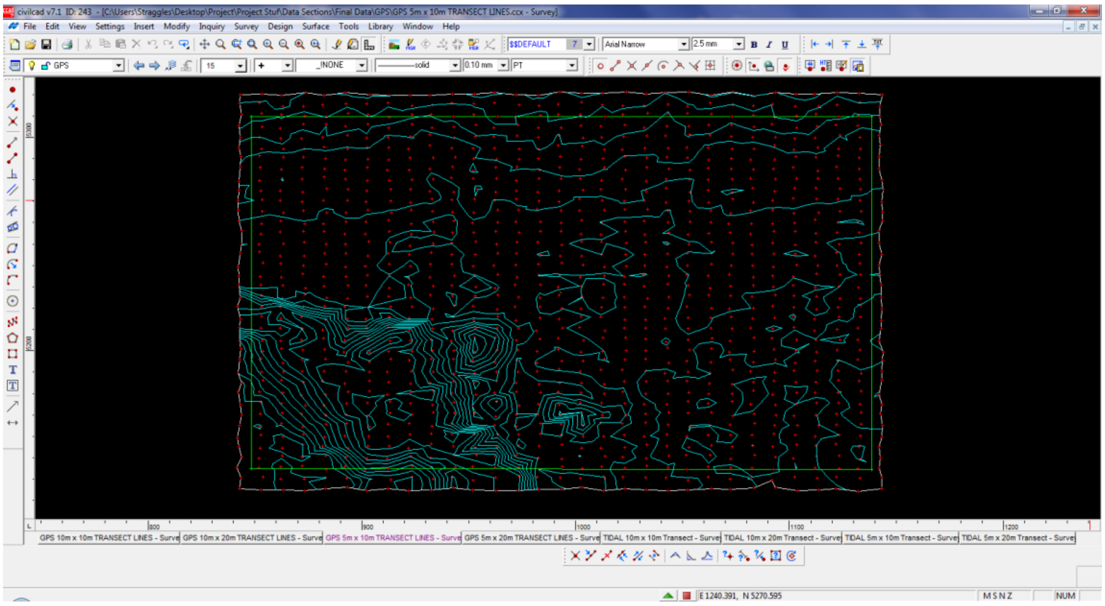
Appendix B – Measurement System



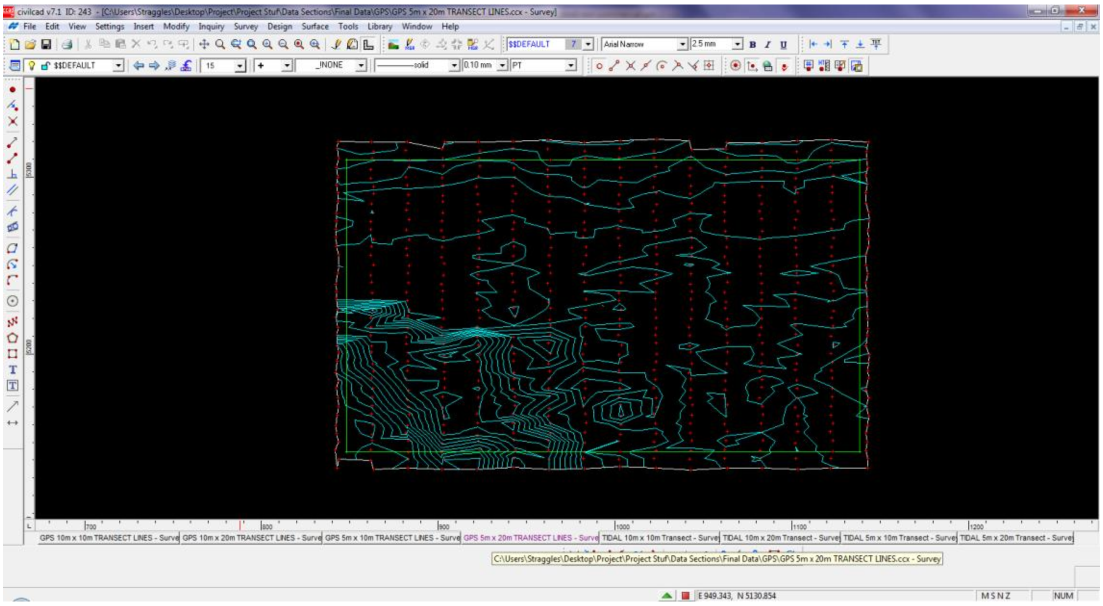
Appendix C – Tidal Measurement

Gauge 1	Measured Distance	Measured RL	Derived RL	Gauge 2	Measured Distance	Measured RL	Derived RL
12:00	0.40	0.85	0.45	**12:00**	0.26	0.72	0.47
12:10	0.43	0.85	0.42	**12:10**	0.29	0.72	0.44
12:20	0.54	0.85	0.31	**12:20**	0.40	0.72	0.33
12:30	0.55	0.85	0.30	**12:30**	0.41	0.72	0.32
12:40	0.58	0.85	0.27	**12:40**	0.44	0.72	0.29
12:50	0.59	0.85	0.26	**12:50**	0.45	0.72	0.28
13:00	0.62	0.85	0.23	**13:00**	0.48	0.72	0.25
13:10	0.63	0.85	0.22	**13:10**	0.49	0.72	0.24
13:20	0.71	0.85	0.14	**13:20**	0.57	0.72	0.16
13:30	0.72	0.85	0.13	**13:30**	0.58	0.72	0.15
13:40	0.74	0.85	0.11	**13:40**	0.60	0.72	0.13

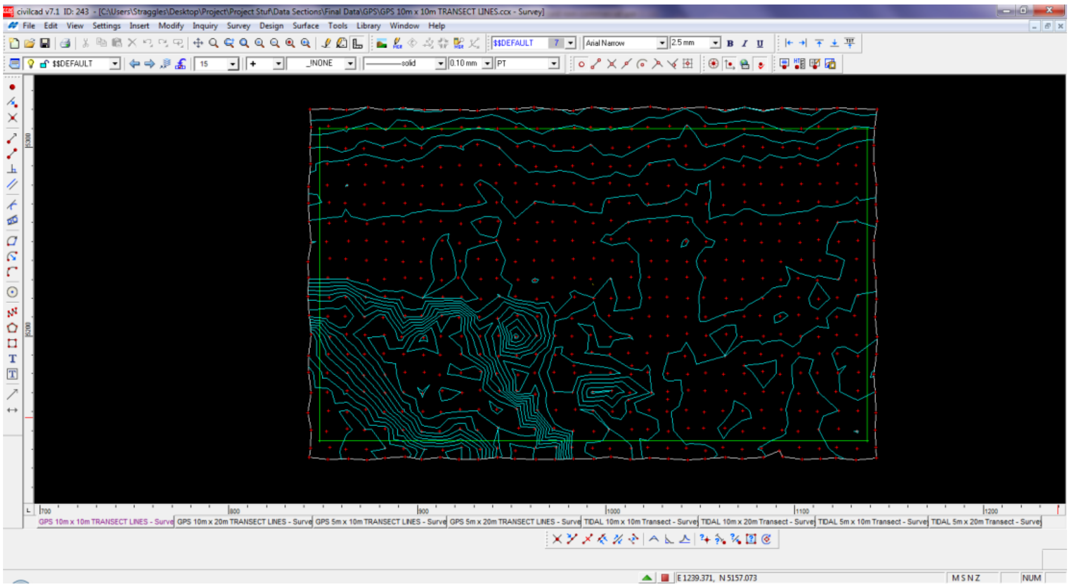
Appendix D – GPS Images



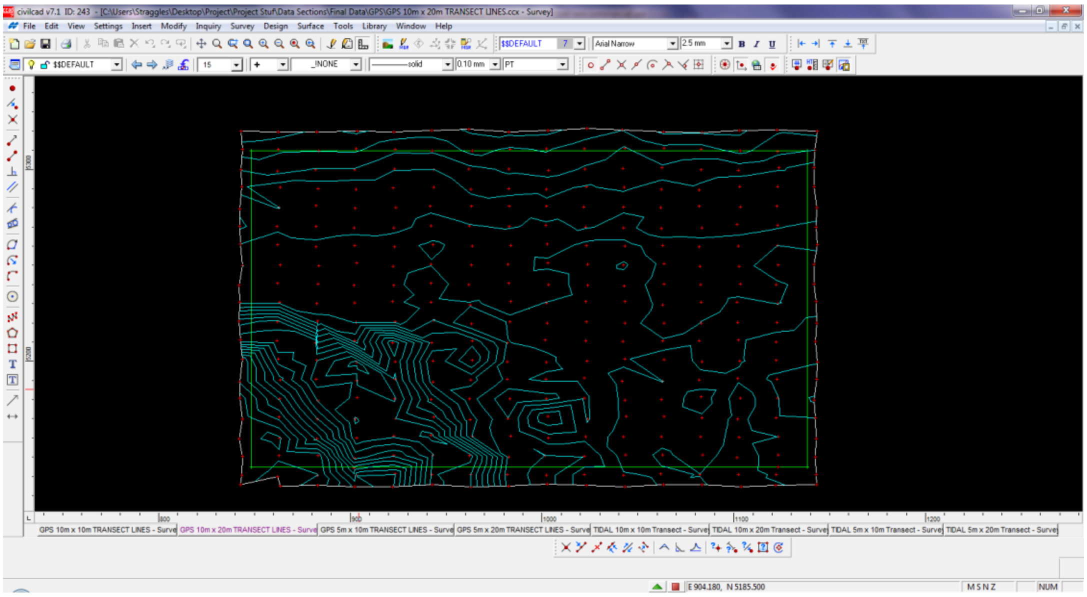
GPS 5m Spacing X 10m Transect



GPS 5m Spacing X 20m Transect

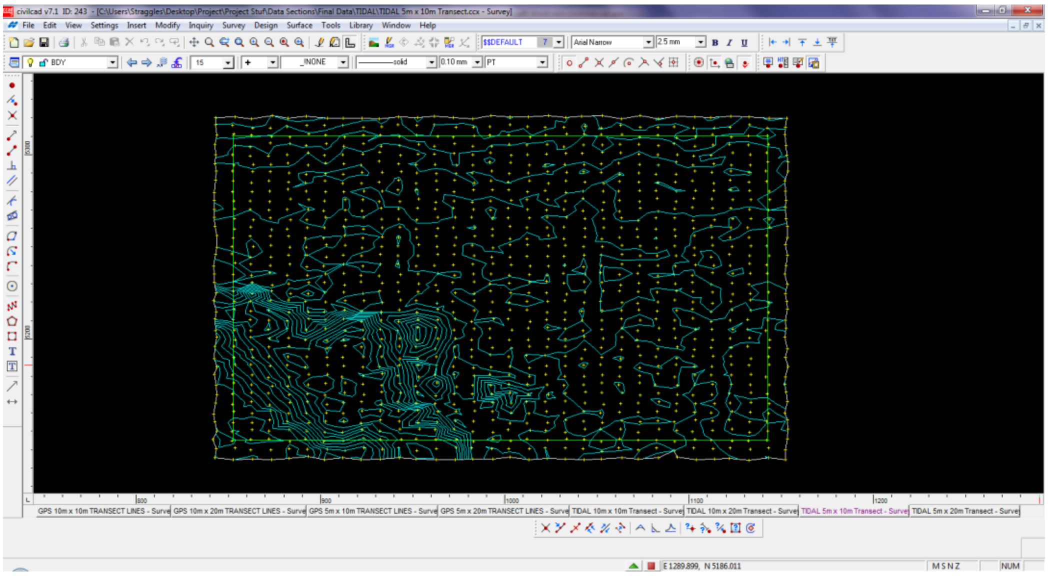


GPS 10m Spacing X 10m Transect

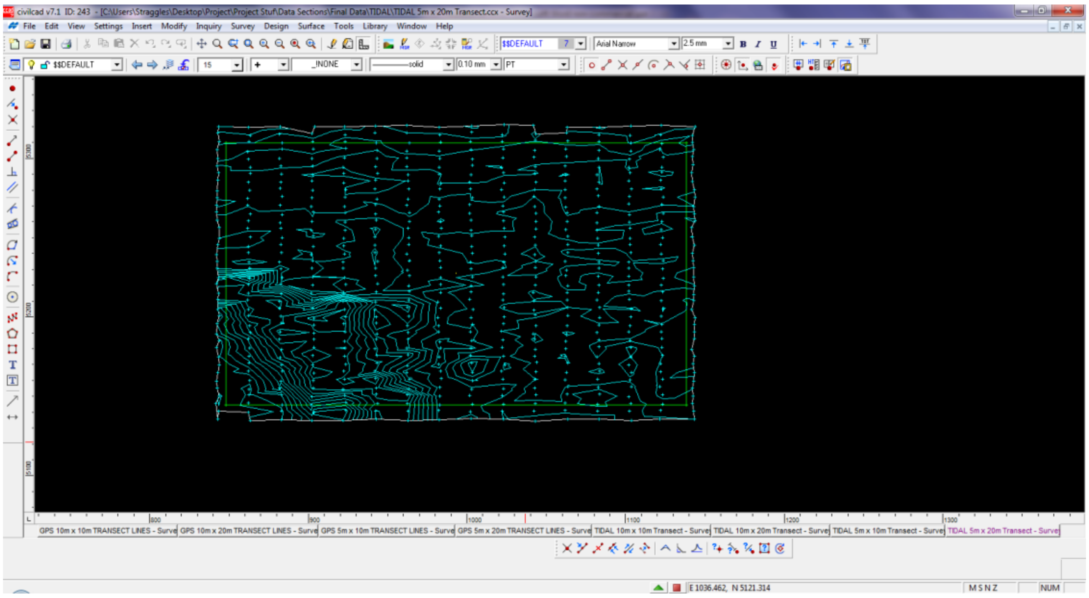


GPS 10m Spacing X 20m Transect

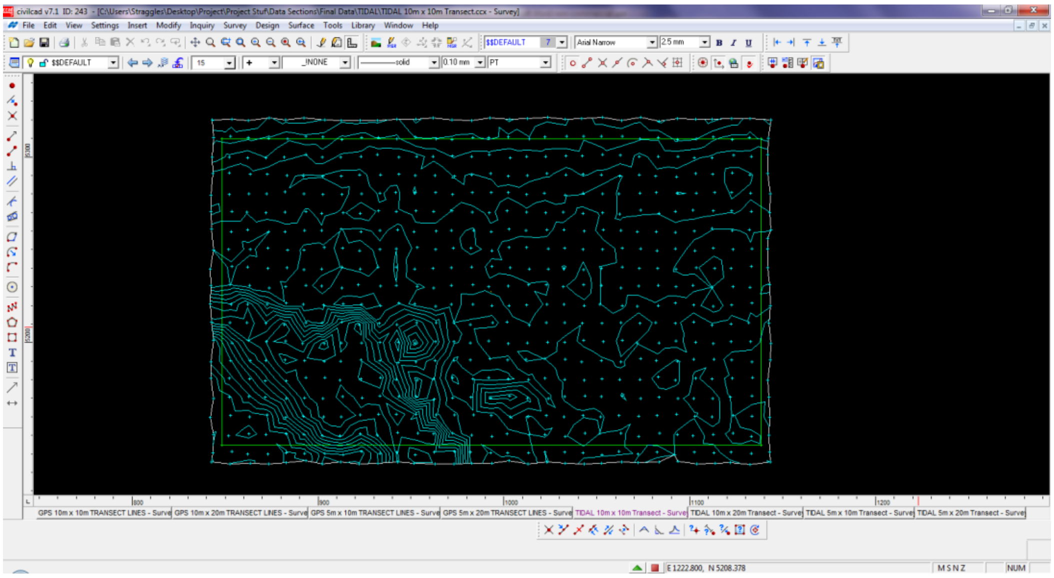
Appendix E – Tidal Images



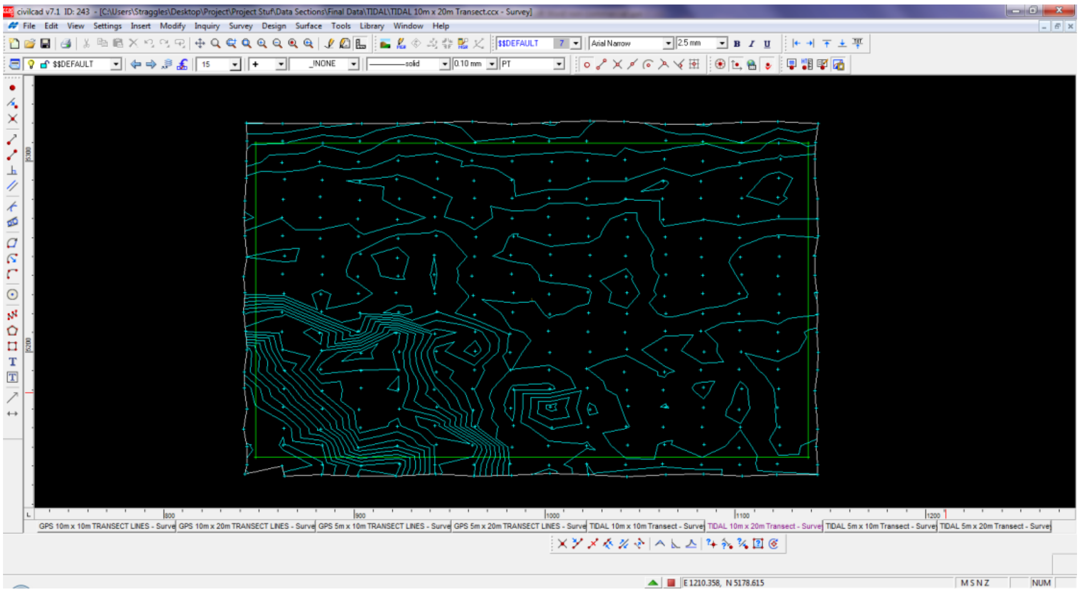
TIDAL 5m Spacing X 10m Transect



TIDAL 5m Spacing X 20m Transect



TIDAL 10m Spacing X 20m Transect



TIDAL 20m Spacing X 20m Transect

Appendix F – Volume Calculations

SURFACES:
=========
Design: TPS 5m x 10m Transect – tps 5 x 20
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47867.6 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 17571.0 (square metres)
Fill: 30283.9 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.534

Cut: 323.4 (cubic metres)
Fill: 605.4 (cubic metres)
Net: 282.0 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.7 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.4 (m)

SURFACES:
=========
Design: TPS 5m x 20m Transect – tps 5 x 20
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47865.5 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
=====================
Cut: 20371.6 (square metres)
Fill: 27483.3 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.955

Cut: 711.5 (cubic metres)
Fill: 745.4 (cubic metres)
Net: 33.9 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.7 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: TPS 10m x 20m Transect – tps 10 x 20
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47862.0 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 22127.7 (square metres)
Fill: 25727.2 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.978

Cut: 756.9 (cubic metres)
Fill: 773.8 (cubic metres)
Net: 17.0 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.5 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: TPS 10m x 10m Transect – tps 10x10
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47863.4 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 18301.9 (square metres)
Fill: 29553.0 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.675

Cut: 466.9 (cubic metres)
Fill: 692.2 (cubic metres)
Net: 225.3 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.5 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: GPS 5m x 10m TRANSECT LINES – gps 5 x 10
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47868.3 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 9283.5 (square metres)
Fill: 38571.4 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.185

Cut: 210.0 (cubic metres)
Fill: 1136.3 (cubic metres)
Net: 926.3 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.7 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: GPS 5m x 20m TRANSECT LINES – gps 5 x 20
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47866.3 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 12856.8 (square metres)
Fill: 34998.2 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.442

Cut: 555.7 (cubic metres)
Fill: 1258.0 (cubic metres)
Net: 702.3 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.7 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: GPS 10m x 10m TRANSECT LINES – GPS 10m x 10m
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47863.8 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 10991.3 (square metres)
Fill: 36863.6 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.283

Cut: 332.0 (cubic metres)
Fill: 1172.5 (cubic metres)
Net: 840.5 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.5 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: GPS 10m x 20m TRANSECT LINES – gps 10 x 20
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47862.2 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 13753.6 (square metres)
Fill: 34101.3 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 0.423

Cut: 546.0 (cubic metres)
Fill: 1290.8 (cubic metres)
Net: 744.8 (cubic metres) [fill]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.6 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.6 (m)

SURFACES:
=========
Design: TIDAL 5m x 10m Transect – tidal 5 x 10
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47869.7 (square metres)
Natural: 47867.1 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47852.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 23418.6 (square metres)
Fill: 24434.2 (square metres)
Matching: 0.0 (square metres)
Total Area: 47852.9 (square metres)

WARNING – There is a difference between volumes area and boundary area.

VOLUMES:
=========
Cut to Fill Ratio: 1.003

Cut: 647.7 (cubic metres)
Fill: 645.7 (cubic metres)
Net: 2.0 (cubic metres) [cut]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.7 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.4 (m)

SURFACES:
=========
Design: TIDAL 5m x 20m Transect – tidal 5 x 20
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47867.6 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 25466.5 (square metres)
Fill: 22388.4 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 1.298

Cut: 1010.3 (cubic metres)
Fill: 778.4 (cubic metres)
Net: 231.9 (cubic metres) [cut]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.7 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: TIDAL 10m x 10m Transect – tidal 10 x 10
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47864.4 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 23368.2 (square metres)
Fill: 24486.7 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 1.037

Cut: 771.4 (cubic metres)
Fill: 743.5 (cubic metres)
Net: 27.9 (cubic metres) [cut]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.6 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.5 (m)

SURFACES:
=========
Design: TIDAL 10m x 20m Transect – tidal 10 x 20
Natural: BASE edited final – base

REGION:
======
Boundary: test

SURFACE AREAS:
============
Design: 47862.8 (square metres)
Natural: 47869.5 (square metres)

PLAN AREAS:
=========
Boundary: 47854.9 (square metres) within the boundary
Design: 47854.9 (square metres) within the boundary and within design surface
Natural: 47854.9 (square metres)

CUT/FILL/MATCHING AREAS:
======================
Cut: 25981.8 (square metres)
Fill: 21873.1 (square metres)
Matching: 0.0 (square metres)
Total Area: 47854.9 (square metres)

VOLUMES:
=========
Cut to Fill Ratio: 1.390

Cut: 1069.3 (cubic metres)
Fill: 769.5 (cubic metres)
Net: 299.8 (cubic metres) [cut]

Cut: 0.0 (cubic metres) / (square metres)
Fill: 0.0 (cubic metres) / (square metres)

Average Cut Depth: 0.0 (m)
Maximum Cut Depth: 0.6 (m)
Average Fill Depth: 0.0 (m)
Maximum Fill Depth: 0.6 (m)

Appendix G – Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: **MATTHEW STRAHLEY**

TOPIC: COMPARING DEPTH SOUNDER POSITIONING TECHNIQUES FOR HYDROGRAPHICAL SURVEYS

SUPERVISOR: Dr Peter Gibbings

SPONSORSHIP: Bennett and Bennett Surveying and Ultimate Positioning

ENROLMENT: ENG 4111 – S1, X, 2011;
ENG 4112 – S2, X, 2011

PROJECT AIM: This project aims to assess the efficiency, effectiveness, accuracy and precision of various methods for determining the position of a depth sounder whilst completing Hydrographical Surveys. It will compare and contrast Total Station, RTK GPS and Tidal Plane methods of determining a submerged DTM surface.

PROGRAMME: (Issue B, 27th March 2011)

1) Research and define the limitations and applications of single frequency depth sounding equipment.

2) Investigate the standards and methodology of Hydrographical Surveys especially reliability and repeatability.

3) Identify the characteristics of Total Station Tracking, GPS Height Datums and the influences exerted on the Tidal Plane.

4) Conduct a Topographical Survey of an exposed tidal surface to provide a base DTM against which techniques will be compared.

5) Complete three additional surveys of the base surface utilising a depth sounder coupled with Total Station, RTK GPS and the Tidal Plane respectively to produce a DTM surface for each technique.

6) Evaluate and discuss the relationship between the initial base surface and each of the individual surfaces created from the three techniques being investigated.

AGREED ____________ (Student) ____________ (Supervisor)
Date: 08 / 04 / 2011 Date: / / 2011

Examiner/ Co-examiner: ____________