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ASSESSMENT OF THE IMPACT OF ELEVATION MASK ON THE GNSS POSITIONING

A Case of Dar es salaam around Ardhi University

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BSc Geomatics

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A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of Science in Geomatics (BSc. GM) of Ardhi University

CERTIFICATION

The undersigned certify that they have read and hereby recommended for acceptance by the Ardhi University a dissertation titled “**Assessment of the Impact of the Elevation Mask on the GNSS Positioning**” in partial fulfillment of the requirements for the award degree of Bachelor of Science in Geomatics oat Ardhi University.

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Date ………………………

DECLARATION AND COPYRIGHT

I **Kimweri Salehe H** declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

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22821/T.2019

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DEDICATION

I dedicate this dissertation work to my beloved parents Mr. and Mrs. HINJU KIMWERI, my friends and all relatives for their invaluable encouragement, prayers, unlimited love, patience, support and care throughout my studies. I really appreciate you for all you done to me. I love you, may God bless you all.

.

ABSTRACT

The global navigation satellite system (GNSS) has become an indispensable tool for precise positioning in various applications, including navigation, surveying, and geodetic monitoring. However, GNSS signals are susceptible to obstructions, such as buildings, terrain, and vegetation, which can lead to signal blockages and multipath effects, compromising the accuracy and reliability of GNSS positioning. This study investigates the impact of elevation mask settings on GNSS positioning accuracy. The elevation mask is a critical parameter that defines the minimum angle between the horizon and the satellites' line of sight that the receiver will consider for positioning computations. To assess the impact of elevation mask settings, LEICA GS15 GNSS receivers were used to collect field data over four monumented points PT01, PT03, MK09 and WTANK positioned under clear sky view. Static positioning technique was used in which the data collection was done in different observation time. Also, different elevation mask angles of 5˚, 10˚, 15˚ and 20˚ were tested and evaluated to understand its effect on positioning accuracy. The collected data were processed using Trimble Business Center in which data were categorized in 1 hours, 3 hours and 6 hours so as to obtain the uncertainties in Eastings and Northings for all established stations. The results reveal a direct correlation between the elevation mask angle and positioning accuracy. The maximum uncertainty obtained from processing is 0.003m from 20 ˚ elevation mask and the minimum uncertainty obtained is 0.000m from 5˚ elevation mask. This result shows lowering the elevation mask enhances the number of visible satellites, thus improving the availability of measurements. However, setting the elevation mask too low might lead to an increase in multipath and signal errors, adversely affecting the overall positioning accuracy. This research provides valuable insights into optimizing elevation mask settings for different GNSS applications considering satellite availability and positioning accuracy. The findings contribute to better-informed decisions when configuring GNSS receivers, enabling users to make more informed choices based on their specific application requirements. Ultimately, the study emphasizes the significance of considering elevation masks as a fundamental factor in optimizing GNSS positioning performance and enhancing the reliability of location-based services.

Keywords: Global Navigation Satellite System (GNSS), Elevation Mask.

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ACRONYMS AND ABBREVIATIONS

GNSS	Global Navigation Satellite System
GPS	Global Positioning System
TBC	Trimble Business Center
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistema
RINEX	Receiver Independent Exchange Format
TEQC	Translating Editing and Quality Check
DOP	Dilution of Precision
RMS	Root Mean Square
RTK	Real Time Kinematics
GDOP	Geometrical Dilution of Precision
WGS84	World Geodetic System of 1984

CHAPTER ONE

INTRODUCTION

This chapter describes the background of the research, the related studies that have been done by other scholars, statement of the problem that influences the study of the research, main and specific objectives of the research, significance of the research and Chapter summary of the report.

1.1 Background of the research.

Global Navigation Satellite Systems (GNSS) play a pivotal role in modern positioning and navigation applications. GNSS receivers utilize signals from a constellation of satellites to determine precise positions, velocities, and time information for a wide range of applications, including navigation, surveying, mapping, and precision agriculture. One critical parameter that affects GNSS positioning accuracy and reliability is the elevation mask angle. The elevation mask is the minimum angle between the satellite and the horizon that the GNSS receiver will use to track and calculate position (Ghilan & Wolf, 2015). Satellites below this angle are often obscured by buildings, trees, or terrain, leading to potential signal blockages and reduced signal quality. The elevation mask setting on GNSS receivers varies depending on the application and user requirements. In certain scenarios, such as urban environments with tall buildings or mountainous terrains, increasing the elevation mask may be necessary to mitigate multipath interference and improve positioning accuracy. Conversely, in open-sky environments, lowering the elevation mask can increase the number of satellites visible to the receiver, enhancing position availability and reliability (Hofmann-Wellenhof, 2008).

There is a significant increase in distance between a receiver and a satellite on the edge of the horizon as opposed to a satellite directly above the receiver. A receiver can be set to ignore any satellite signals that come from below a user definable angle above the horizon them out, the use of different mask angle is respectively to the specific area for example receiver is at the top of tall building where by there clear sky view with no obstruction, then low mask angle like 5 degree may be used. But usually in many surveys done in many areas that having obstruction like tall buildings, trees and other, mask angle used is 15 to 20 degrees which is allowable and acquire sufficient number of the satellites that having direct signal to the receiver (Juan, 2020).

Signals from satellites that are on the horizon of the observer must pass through considerably more atmosphere than signals coming from high above the horizon. Because of the difficulty in modeling the atmosphere at low altitudes, signals from satellites below a certain threshold angle, are typically omitted from the observations. The specific value for this angle (known as the satellite mask angle) is somewhat arbitrary. It can vary between 10° and 20° depending on the desired accuracy of the survey. Higher horizontal positioning accuracies will be obtained with satellites below 15° and thus mask angles between 10° and 15° are typically used in surveying (Ghilan & Wolf, 2015).

Although it may seem strange to want to get rid of a satellite that can help to determine your location more precisely, you should disregard satellites that appear close to the horizon since those at low angles are more likely to experience signal fading. Additionally, they are more sensitive to atmospheric noise than satellites that orbit higher in the sky. The majority of GPS applications let you increase an elevation mask but not decrease it. The purpose of an elevation mask is to improve the accuracy of the position solution by removing signals that may be subject to higher levels of atmospheric interference. There are several potential impacts of using an elevation mask on GNSS position

i. Improved accuracy: By excluding satellite signals that may be subject to higher levels of atmospheric interference, an elevation mask can improve the accuracy of the position solution.

ii. Reduced satellite visibility: An elevation mask can reduce the number of satellites that are visible to the GNSS receiver, which may result in a loss of coverage in certain areas.

iii. Increased acquisition time: If the elevation mask is set too high, it may take longer for the GNSS receiver to acquire satellite signals, which can increase the time required to calculate the position solution.

iv. Reduced reliability: In some cases, an elevation mask may exclude satellites that are the only ones available for a given location, which can reduce the reliability of the position solution (Teusnissen, 2019).

v. Less atmospheric interference: Signals travelling through the earth's atmosphere experience delays due to atmospheric refraction. Hence reducing the impact of these delay.

The value of the elevation mask used in GNSS systems varies depending on the specific application and the device. Typically, a value of 15-20 degrees is used as a default value for GPS, this value is chosen because it is high enough to reduce the likelihood of receiving blocked signals while still allowing the device to track a sufficient number of satellites for accurate and reliable position and navigation solutions.

However, depending on the specific use case and environment, different elevation mask values may be used. For example, in an urban environment where tall buildings can block signals from low-elevation satellites, a higher elevation mask value, such as 25-30 degrees, may be used to ensure that the device can track enough satellites to provide accurate and reliable position and navigation solutions. On the other hand, in an open environment such as a rural area with few tall buildings, a lower elevation mask value, such as 10-15 degrees, may be used to increase the number of visible satellites and improve the receiver's ability to lock onto a signal (Wu *et a*l., 2021).

Also, Elevation mask is a significant factor affects the accuracy of GNSS positioning. Satellite that are low on horizon, near the elevation mask angle, are more likely to be affected by atmospheric effects such as ionospheric and tropospheric delays and multipath errors. These atmospheric effects can cause significant errors in the calculated position, therefore limiting the number of satellites below the elevation mask angle can improve the positioning accuracy. Also, on the other hand setting the elevation mask too high can also limit the number of available satellites and decrease the accuracy of the calculated position (Wu *et al.*, 2021)

A study on impact of Elevation mask angle in Selangor, Malaysia. By using various mask angle setting for different GNSS positioning method based on established known points was conducted (Said, 2018). The study conducted by performing GNSS observation on two established reference points using multiple elevation mask setting for static and network RTK method with GPS and GLONASS satellite constellation. Then main outcomes were adjusted coordinates, PDOP, RMS, horizontal and vertical precision values, therefore analysis has been used to identify the ideal EMA setting could be used to achieve the best position accuracy.

A study on accuracy analysis of Multi-Mode Pseudo-Range SPP under different mask angle in Beijing, China was conducted (Deying *et al.*, 2021). The study based on the measured data under different mask angles, different combination modes of satellite navigation systems for multi-mode pseudo range SPP are calculated and analyzed. The results show that with the increase of the cut-off height angle, the number of visible satellites decreases gradually, with the PDOP becoming larger and fluctuating sharply. Meanwhile, the positioning deviation becomes larger and the stability becomes worse, and the epoch availability rate decreases gradually

Medina *et al*., (2020) conducted study on Impact of Satellite Elevation Mask in GPS and Galileo RTK positioning in German. Gives a comparative of the performance assessment for different high elevation masks of a multi-frequency multi-GNSS RTK method in a loose combination to avoid the case of the lack of coinciding frequencies. This study shows that even with a low elevation mask of 10˚, a GPS-only System offers a 52.61% of the mean ASR in comparative with a combined dual-System that offer 99.95% of the mean ASR. This performance is comparable even with an elevation mask of 45˚ when a combined GPS + Galileo System offers a benefit of 57.17% of the mean ASR with respect to GPS-only System.

Therefore, this study deals with determination of the optimal angle for the elevation mask between 5˚ up to 20˚ and to check the impacts of those elevation masks on the GNSS positioning with the different time of observation (i.e. 1 hour, 3 hours, and 6 hours) in order to achieve the best position accuracy.

1.2 Statement of the problem

Global Navigation Satellite Systems (GNSS) have become the keystone and main information supplier for Positioning, Navigation and Timing data. For the use of GPS positioning algorithms performance can be easily disturbed in signal-degraded environments due to space weather events, obstacles, urban areas, bridges, limited open sky view and/or low-elevation multipath effects (elevation mask). As we know that elevation mask has important in positioning, because it reduce the likelihood of receiving blocked signals while still allowing the device to track a sufficient number of satellites for accurate and reliable position. Also, the value of elevation mask that is usually used on the GPS observation is from 15 – 20 degrees so as to reduce/remove the degraded signals, but elevation mask from 0 - 15 mainly are not used in the GPS observation.

Therefore, due to that this study will check the impact of different low elevation masks from 5 – 20 degrees on how much they affect the GPS positioning of the point on the short and long period of observation.

1.3 Objectives of the Research

1.3.1 Main objective

To evaluate the impact of different elevation masks on the accuracy of GPS position measurements under different observation time, with the goal of identifying the optimal elevation mask setting that can provide the most accurate and reliable position estimates.

1.3.2 Specific objectives

- **i.** To Design and prepare a control points that can be useful in the GPS observation
- **ii.** To perform receiver's observation (Data collection) for short and long period of time with respect to the increasing of elevation mask from 5˚, 10˚, 15˚ and 20°.
- **iii.** To compare the position obtained after processing each observation with variation of elevation mask by TBC
- iv. To perform statistical analysis of the result obtained

1.4 Significance of the Research

This study provides the knowledge of the elevation mask, especially to know the rate of the effect of the low cutoff angle on the GNSS positioning on the short and long period of time observation. Also, this study is useful for GNSS receiver designers who are trying to optimize the performance of their systems under different conditions and applications. Help GNSS users in understanding the factors that affect the quality of GNSS position estimates and how to optimize their use of GNSS systems. Also, Researchers and academics; the study might advance knowledge of GNSS positioning and its limitations, which might guide and inform further studies/research and advancement in this area

1.5 Chapter Summary

The dissertation report consists of five chapters arranged in systematic order to fulfill the requirements, preparation and presentation of the study; "Assessment of the impact of the Elevation Mask on the GNSS Positioning".

Chapter one, introduces the background information of the study, previous and related study done by other researchers, statement of the problem, objectives, significance and beneficiaries of the study. Chapter two, presents the literature review of the study especially on the Elevation Mask effects on the GNSS positioning, the factors affecting the accuracy of the

GNSS positioning, the methods and theories done by previous study and how they differ to this study. Chapter three, explains on the methods done so as to meet the objectives of the study that involves the data collection and processing of the obtained data. Chapter four, presents the results, analysis and discussion of the obtained results. Chapter five, presents the conclusion led to the analysis and discussion of the results also provides the recommendations for the further researches.

CHAPTER TWO

LITERATURE REVIEW

This chapter explains the concepts of the GNSS and its positioning, techniques for positioning, accuracy of the point positioning and errors. It further explains the concept of elevation mask (cut-off angle) and its advantages and disadvantages on GNSS positioning.

2.1 GNSS

Global Navigation Satellite Systems (GNSS) are designed to provide position, velocity, and timing capabilities to users all over the world. The GNSS combine GPS, GLONASS, GALILEO, COMPASS, etc. It is originally designed that GPS consists of 24 satellites orbiting the earth at an altitude of about 20200 km. The satellites are distributed in six equally spaced orbit planes of inclination of 55 degrees with respect to the equator. Every satellite circulates the earth in a period of 12 hours sidereal time. The satellite sends timed signals at two L-band frequencies, 1.57 and 1.22 GHz, namely L1 and L2. The signals contain codes which can identify every satellite, satellite clock corrections of the satellite, time of the emitted signal, position, and other data related to ionosphere and satellite. The L1 signals are modulated by a Coarse/Acquisition (C/A) code, which is available for civilian use, and a more precise P(Y) code, which is available only for authorized users. The C/A code, which is for the civilian use, has a unique sequence of 1023 chips with a width of 300m and repeats every 1ms. The P code, which is for the military use, is extremely long (chips) but with a smaller chip width, 30m, and repeats itself every one week. Several techniques such as squaring and cross correlation were taken by high quality receivers in order to acquire the P code on L1 and L2 but with noise characteristics compared with the original codes (Hofmann, 2001).

One of the most important issues in GPS positioning is to observe the time difference between the satellites and users; therefore, GPS satellites use high quality redundant atomic clocks. The structure of GPS system is composed of three main segments which are customary for navigation satellites: space segment, control segment and user segment. The space segment consists of different generations of active satellites. The constellation was changed to a non-uniform arrangement with the increased number of satellites. The reliability and availability of the system have been improved in such an arrangement. The responsibility of control segment is to maintain the satellites in orbits, adjust satellite clocks, and upload navigation data. The control segment is composed of the master operational control center, six monitoring stations, four ground antenna upload stations and an alternate master control station. The user segment is to receive the GPS signals by different satellite receivers. 21 GPS has been used for the solution of geodetic problems since about 1983 (Seeber, 2003).

GPS is weather independence, capable of autonomous operation, and does not require a line of sight between target points. Because of the mentioned advantages, GPS can be used to continuously monitor deformations even during unfavorable weather conditions such as rain, snow and fog. The developments of GPS receivers, antennas, and data processing software have made GPS as a very effective tool for deformation monitoring with sub-centimeter accuracy. GPS receivers measure the satellite signals at a high sampling rate. GPS technique is widely used to monitor the deformations of all kinds of buildings and constructions. As any other developing technology, GPS technology has its own disadvantages when it is applied in the precise engineering applications. A major barrier is the achievable accuracy of GPS positioning solution, which is affected by many factors and restraints. In particular, multipath is one of the major limitations. Usually the systematic effects in the position results are amplified by weak satellite constellations. An effective solution is still elusive, although many efforts have been made in multipath mitigation (El-Rabbany, 2002)

2.2 GNSS positioning

GNSS positioning is a technology that uses signals from a network of orbiting satellites to determine the location of a device on the earth's surface, the most commonly used GNSS systems are the American GPS, the Russian GLONASS and the European Galileo.

To determine a location, the GNSS receiver on the device receives signals from multiple satellites and uses the information to calculate its precise position. The receiver determines the distance to each satellite by measuring the time it takes for the signals to travel from the satellite to the receiver. This information, along with the location and time of the satellite, is used to calculate the receiver's position. Also, the GNSS positioning is used in a wide range of applications, including navigation systems in vehicles and aircraft, surveying and mapping, tracking of the vehicles and assets and outdoor activities such as hiking and geocaching.

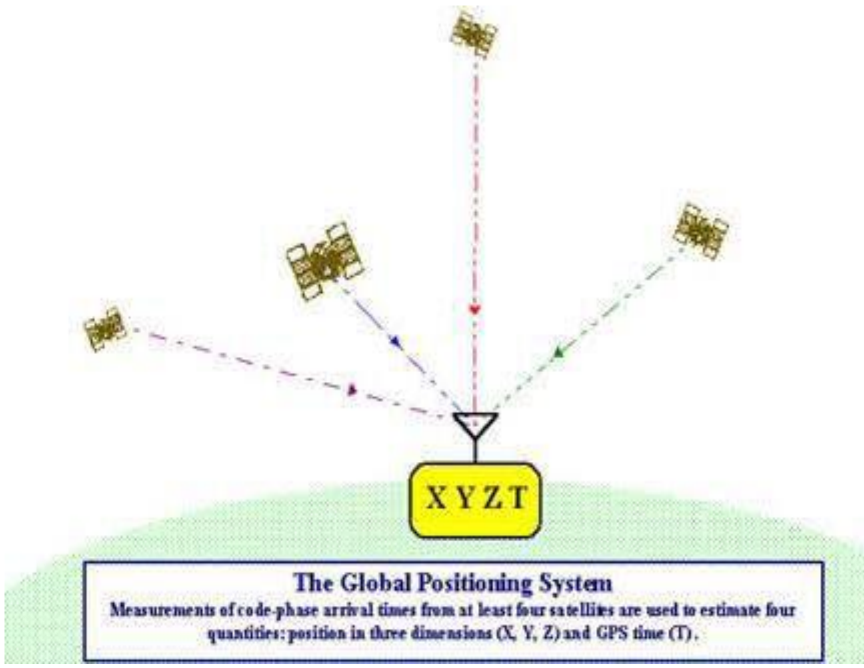

Figure 2. 1: Global Positioning System (Tallysman, 2019)

Only code measurements have been considered in the conceptual description of GNSS systems in figure 2.1. But in practice both code and carrier phase measurements are used to high-precision GNSS positioning. The code and phase measurement accuracy are affected by systematic errors, the local multipath environment, antenna and the GNSS receiver quality (Wellington, 2023).

2.3 GNSS point positioning Techniques

There are different methods that are used in GNSS point positioning with their uses, advantages and disadvantages as well as the choice of method depends on the specific application and the level of accuracy required, those techniques are

2.3.1 Single Point Positioning

This is the most basic form of GNSS positioning where a receiver uses signals from at least four satellites to determine its position without any correction from other sources. A single receiver with an internal GNSS antenna is used to calculate its position without the use of any additional reference station or correction data. The receiver uses the signals from the GNSS satellites to compute its position using trilateration, which involves measuring the time it takes for the signals to travel from the satellites to the receiver. The receiver then solves the equations to determine its position in three dimensions

In Single point positioning code measurements are used to compute receiver position directly where coordinates of a receiver at an unknown point are sought with respect to the earth's reference frame by using the known positions of the GPS satellites being tracked as shown in figure 2.2. Also referred to as absolute positioning, and often just as point positioning (Gosbert, 2015).

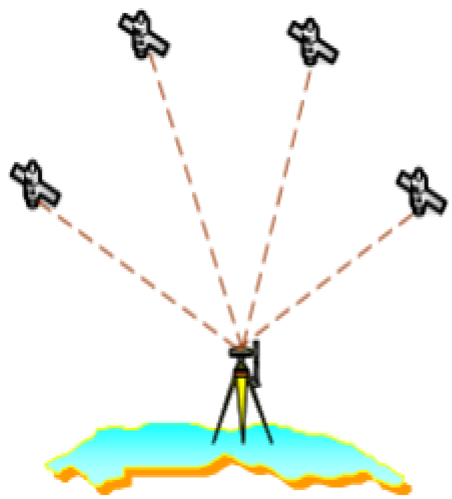

Figure 2. 2: Single Point Positioning (Tallysman, 2019)

2.3.2 Precise Point positioning (PPP)

This method involves processing data from a single receiver and using a network of global reference stations to provide corrections for atmospheric effects and other errors. PPP can achieve high levels of accuracy, but it requires a longer data collection time than other methods. Another method to increase the position accuracy in single-point positioning mode is to use accurate satellite clock information and accurate ephemerides data. This method is denoted as precise point positioning (PPP). This technique has been originally introduced for efficient analysis of GPS data from large networks (Zumberge *et al.*, 1997).

2.3.3 Real Time Kinematic (RTK)

This method involves using a base station with a known position to send correction signals to a rover receiver in real time or It transmits information to the rover via radio waves which is equipped with a compatible RTK receiver. The rover uses the data received from the base station to improve the accuracy of its position calculation, by comparing the signals received from GPS satellites with the correction information from the base station, the RTK system can determine the precise location of the rover. The main difference between static and kinematic surveying techniques is the length of time per session. In a kinematic survey, observations from a single epoch may be all that are used to determine position of the roving receiver. Establishment of control points using the static surveying method requires much longer sessions than are typically used in kinematic surveys (Ghilan & Wolf, 2015).

2.3.4 Static technique

The GPS observables are ranges which are deduced from measured time or phase differences based on a comparison between received signals and generated signals. Mainly, there are two types of GPS observables, namely the code pseudo ranges and carrier phase observables. In general, the pseudo range observations are used for coarse navigation, whereas the carrier phase observations are used in high-precision surveying applications. This is due to the fact that the accuracy of the carrier phase observations is higher than the accuracy of code observations. Beside the two GPS observables, the GPS satellite transmits a navigation message. The navigation message is a data stream added to both L1 and L2 carriers as binary bi-phase modulation at a low rate of 50 Kbps. It consists of 25 frames of 1500 bits each. The navigation message contains, along with other information, the coordinates of the GPS satellites as a function of time, the satellite health status, the satellite clock correction, the satellite almanac, and atmospheric data. Each satellite transmits its own navigation message with information on the other satellites, such as the approximate location and health status (Hofmann, 2001).

The general form of code pseudorange observation equation is:

$$P = \rho + c(dt - dT) + dion + dtrop + dorb + \varepsilon p \qquad (1)$$

And

The observation equation of the phase pseudorange is

$$\Phi = \rho + c(dt - dT) + \lambda N - dion + dtrop + dorb + \varepsilon\varphi \qquad (2)$$

where; P is the observed pseudorange,

ρ is the unknown geometric satellite to receiver range,

c is speed of light, which is equal to 299,792,458 m/s,

dt and dT are satellite and receiver clock errors respectively,

$dion$ and $dtrop$ are the errors due to ionospheric, tropospheric refractions respectively,

$dorb$ is the orbital error, and

εp is the code measurement noise.

the measured phase is indicated in meters by Φ;

λ is the carrier wavelength,

N is the phase ambiguity, and

$\varepsilon\varphi$ is the combined receiver and multipath noise.

The precision of a pseudo range derived from code measurement is about 1% of the chip length. Consequently, a precision of about 3m and 0.3m is achieved with *C/A*-code and *P*-code pseudoranges respectively.

There are different GPS techniques of observations. GPS Static technique is the common method for control networks, due to its high accuracy. Static technique positioning by carrier phase at present, is the most frequently used method by surveyors, as it is more accurate as compared to the code pseudorange measurements. The principle of static relative positioning, is based on determining the vector between two stationary receivers, this vector is often called baseline. According to this terminology, the process is called single or multipoint baseline determination. In static surveying 1 ppm to 0.1 ppm accuracies are achieved, which is equivalent to few centimeters and millimeter accuracy, for short baselines of some kilometers. The static surveying 10 is usually applied in high accuracy surveying projects, such as establishing new geodetic networks, densification of existing first order control networks or lower order network, crustal movements, and structural deformation (Hofmann & Moritz, 2005).

2.4 Factors affecting the accuracy of GNSS Positioning

GNSS positioning accuracy can be affected by various factors, following are some factors which are

i. **Satellite geometry**; the position of the GNSS satellites relative to the receiver affects the accuracy of the position calculated by the receiver. Better satellite geometry can result in more accurate positioning. When the satellites are located close together, the position calculated by the receiver can have higher errors, especially in vertical component. This is because the distance between the satellite signals received by the receiver is very small, and small changes in the satellite positions or the receiver position can cause significant changes in the calculated position.

On other hand, when the satellites are located far apart the position calculated by the receiver can have lower errors because the distances between the satellite signals received by the receiver are greater, and small changes in the satellite positions or the receiver position have a smaller effect on the calculated position (Seeber, 2003).

ii. **Atmospheric conditions**; The GNSS signal transmitted by the satellites must pass through the earth's atmosphere before reaching the receiver on the ground. The atmosphere can cause delays and distortions in the GNSS signals, which can result in errors in the calculated position. Two primary atmospheric effects that affect GNSS positioning accuracy are ionospheric delay and Tropospheric delays.

The ionospheric delay is the error in range and range rate due to the propagation of the GPS signal through the ionospheric medium. located 50-1000 km above the earth's surface. The lower 100 km of the ionosphere has negligible effect on the GPS signal. It is the upper part of ionosphere that has the highest variability causing potential problems to the GPS receiving systems

The troposphere affects the GPS L-band signal in terms of signal attenuation. scintillation and delay. The delay error is caused by wet (up to about 11km) and dry (up to about 40 km) components of the atmosphere and is a function of the satellite elevation and atmospheric conditions such as temperature pressure and relative humidity (Hofmann, 2001).

iii. Multipath; It occurs when the GNSS signal transmitted by the satellite reflects off nearby objects such as buildings, trees and other structures before reaching the receiver. When the reflected signal reaches the receiver, it interferes with the direct signal, causing errors in incorrect position calculations which can cause inaccuracies in the GNSS positioning.

Multipath errors can be particularly problematic in urban areas where buildings and other structures can reflect the GNSS signals (Satheesh, 2005).

iv. **Receiver clock errors;** To determine its position the receiver must synchronize its internal clock with clock used by the GNSS satellites. The receiver clock must be very accurate to calculate the time of flight of the signals accurately. However, even small errors in the receiver clock can cause significant errors in the calculated position.

The receiver clock error can be divided into two components, which are bias and drift. The bias represents a constant error in the receiver clock, while the drift represents a time-varying error.

v. **Signal interference;** The GNSS signals can be interfered with by other electronic devices such as radios and cellphones as well as high electronic wires that causing errors in the calculated position.

vi. **Elevation Mask;** It is a significant factor affects the accuracy of GNSS positioning. Satellite that are low on horizon, near the elevation mask angle, are more likely to be affected by atmospheric effects such as ionospheric and tropospheric delays and multipath errors. These atmospheric effects can cause significant errors in the calculated position, therefore limiting the number of satellites below the elevation mask angle can improve the positioning accuracy. Also, on the other hand setting the elevation mask too high can also limit the number of available satellites and decrease the accuracy of the calculated position (Wu *et al*., 2021).

2.5 Elevation Mask

It is the minimum GPS satellite elevation angle permitted by a particular receiver design where by satellites bellow this angle will not be used in position solution. It is the critical parameter that affects accuracy of GNSS positioning as shown in figure 2.4 (Board, 2010). Setting a higher elevation mask angle can improve the accuracy of GNSS positioning because satellites at a higher elevation have a more direct path to the receiver and are less likely to be affected by atmospheric errors and multipath. However, a higher elevation mask angle can also limit the number of available satellites and decrease accuracy of the calculated position. And if the elevation mask angle is set too low, the receiver may use satellites that are low on the horizon which are more likely to be affected by atmospheric errors and multipath. This can cause significant errors in the calculated position and decrease the accuracy of the GNSS positioning (Hofmann & Moritz, 2005).

Signals from satellites that are on the horizon of the observer must pass through considerably more atmosphere than signals coming from high above the horizon. Because of the difficulty in modeling the atmosphere at low altitudes, signals from satellites below a certain threshold angle, are typically omitted from the observations. The specific value for this angle (known as the satellite mask angle) is somewhat arbitrary. It can vary between 10° and 20° depending on the desired accuracy of the survey. Higher horizontal positioning accuracies will be obtained with satellites below 15° and thus mask angles between 10° and 15° are typically used in surveying (Ghilan & Wolf, 2015)

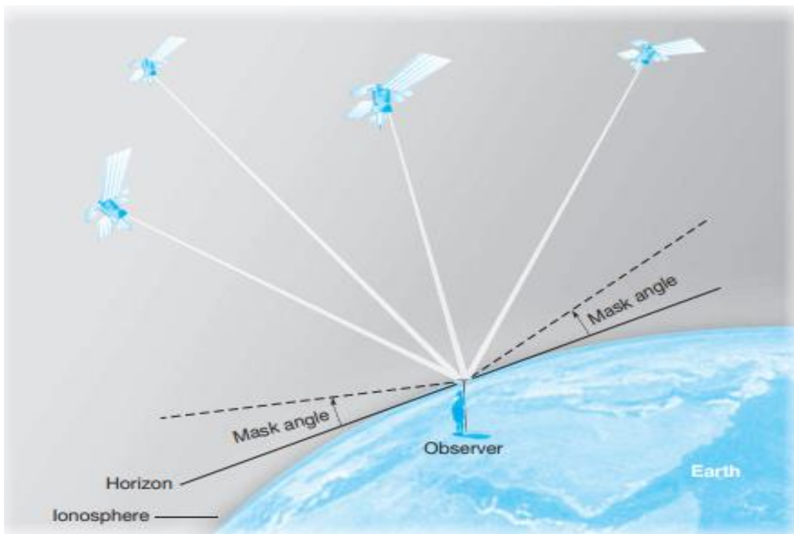

Figure 2. 3: Elevation mask (Cut-off angle) (Ghilan & Wolf, 2015)

2.5.1 Effects of the Elevation Mask on GNSS positioning

Significance of the Elevation Mask on GNSS positioning**.** By setting an elevation mask, a GNSS receiver can filter out satellite signals with low elevation angles which can have several positive effects on positioning accuracy and reliability, those significances including:

Reduction of multipath effects: Signals from satellites that are low on the horizon are more likely to be affected by multipath, which occurs when the signal bounces off nearby objects such as buildings or trees. By setting an elevation mask, the receiver can exclude these signals and improve the accuracy of the calculated position. The use of an elevation mask in GNSS receivers can help to reduce the impact of multipath on positioning accuracy. By setting a minimum elevation angle for the GNSS signals, an elevation mask can exclude signals that are more likely to be affected by multipath, such as those from satellites that are low on the horizon. This is because signals from satellites at low elevations are more likely to be reflected off nearby surfaces and arrive at the receiver from multiple directions, whereas signals from satellites at higher elevations are more likely to arrive at the receiver directly.

By excluding these signals, the receiver can improve the quality of the signals used in positioning calculations, which can lead to more accurate position estimates. This is especially true in urban or forested environments, where the number of surfaces that can reflect GNSS signal is higher. Overall, the reduction of multipath effects is one of the key positive effects of the excluding signals that are more likely to be affected by multipath (Adeleke & Idowu, 2022)

Reduction of interference: Signals from satellites with low elevation angles can also be more susceptible to interference from other sources such as radio towers, power lines, or other electronic devices. By filtering out these signals, the receiver can reduce the impact of interference on positioning accuracy. The use of an elevation mask in GNSS receivers can help to reduce the impact of interference on positioning accuracy.

By setting a minimum elevation angle for the GNSS signals, an elevation mask can exclude signals that are more likely to be affected by interference, such as those from satellites that are low on the horizon. This is because signals from satellites at low elevations are structures or vegetation, or to be affected by other sources of interference. By excluding these signals, the receiver can improve the quality of the signals used in positioning calculations, which can lead to more accurate position estimates. This is especially true in areas with high levels of interference, such as urban environments, where the number of sources of interference is higher. Overall, the reduction of interference is one of the key positive effects of the elevation mask on GNSS positioning (Rizos, 1997)

Improved reliability: The use of an elevation mask can also improve the reliability of GNSS positioning by excluding low-quality signals that may not meet the minimum requirements for positioning calculations. This can help to reduce the number of false fixes or incorrect position estimates. The use of an elevation mask in GNSS receivers can help to improve reliability by excluding signals that do not meet the minimum requirements for positioning calculations.

By setting a minimum elevation angle for the GNSS signals, an elevation mask can exclude signals that are weak or of poor quality, such as those from satellites that are low on the horizon or obscured by buildings or trees. This can help to ensure that only high-quality signals are used in positioning calculations, which can improve the reliability of the calculated position.

By excluding signals that do not meet the minimum requirements for positioning calculations, the receiver can also reduce the number of false fixes or incorrect position estimates. This can help to improve the confidence in the calculated position and reduce the likelihood of errors or inaccuracies. Overall, the improved reliability is one of the GNSS positioning. By excluding weak or poor-quality signals, the elevation mask can improve the quality of the signals used in positioning calculations and reduce errors in the calculated position, which can improve the reliability of the GNSS receiver (Hofmann-Wellenhof, 2008).

Negative effects of the Elevation Mask on GNSS positioning

While the use of an elevation mask in GNSS receivers can improve the accuracy and reliability of positioning, it can also have some negative effects. Some of the negative effects of the elevation mask on GNSS positioning are;

Reduced satellite availability: By setting a high elevation mask, fewer satellites may be available for positioning and exclude the signals from satellite that are low on the horizon, which can increase the time required to obtain a position fix, or even prevent the receiver from obtaining a fix altogether.

Increased susceptibility to interference: By excluding signals from satellites with low elevation angles, an elevation mask can make the receiver more susceptible to interference from sources that are close to the horizon, such as reflected signals, atmospheric effects which are tropospheric and ionospheric delays, or other electronic devices.

Reduced precision: While a high elevation mask can improve the accuracy of positioning, it can also reduce the precision of the calculated position, as it relies on fewer satellites. This can be especially true for receivers that have low-quality hardware or are located in challenging environments (Deying *et al.*, 2021)

2.5.2 Errors due to the Elevation Mask

Here are some common errors in GPS positioning that can occur due to elevation mask relative to specific situations or environments**:**

Multipath errors: This occurs when the GPS signal bounces off objects such as buildings, mountains, or other obstacles, and the reflected signal is received along with the direct signal. This can lead to errors in determining the actual location. It is a specific type of multipath error that occurs when the GPS signal reflects off a surface close to the receiver, such as the ground or water surface, before reaching the GPS antenna. The reflected signal arrives at the antenna with a time delay which can cause interference with determining the position.

The elevation mask error on GPS positioning can exacerbate multipath errors in certain situations. The elevation mask specifies the minimum angle of elevation that a satellite must have to be considered in elevation mask setting, it may track satellites more likely to cause multipath errors. For example, in a flat open area, if the receiver's elevation mask is set too low, it may track satellites that are close to the horizon and their signals may reflect off the ground, causing dip multipath errors. Similarly, in coastal areas if the receiver is close to the water surface and the elevation mask is set too low, the GPS signals may reflect off the water surface, leading to dip multipath errors. Therefore, it is important to set the elevation mask appropriately for the specific environment to minimize dip multipath errors and improve GPS positioning accuracy (Satheesh, 2005).

Signal attenuation: The GPS signal can be weakened by objects such as trees, hills or mountains and tall buildings. This can lead to a loss of signal strength, resulting in inaccurate location readings**.** Type of signal weakening that can occur when GPS signals are obstructed by terrain features, such as hills or mountains. When GPS signals travel through the atmosphere, they can be attenuated or weakened by various factors such as atmospheric conditions, foliage and terrain.

The elevation mask on GPS positioning can affect dipper signal attenuation in specific situations. The elevation mask specifies the minimum angle of elevation that a satellite must have to be considered in view of the receiver. If the elevation mask setting is too high, the receiver may not track satellites that are close to the horizon, which can be obstructed by terrain features. This can lead to a loss of signal strength, resulting in errors in determining the position.

For example, in mountainous areas if the receiver's elevation mask is set too high, it may not track satellites that are close to the horizon which can be obstructed by the mountains. This can lead to a loss of signal strength, resulting in a degraded GPS positioning accuracy. Similarly, in urban environments with tall buildings, if the receiver's elevation mask is set too high, it may not track satellites that are close to the horizon, which can be obstructed by the buildings. Therefore, it is important to set the elevation mask appropriately for the specific environment to minimize signal attenuation and improve GPS positioning accuracy (Rizos, 1997).

Interference: GPS signals can be interfered with by other signals, such as radio waves or electromagnetic waves from electronic devices. This can cause errors in GPS readings, or it is a type of GPS signal disturbance that can occur when other signals such as radio waves or electromagnetic waves from electronic devices, interfere with GPS signals. The elevation mask on GPS positioning can affect interference in specific situations. The elevation mask specifies the minimum angle of elevation that a satellite must have to be elevation mask setting is too low, the receiver may track satellites that are close to the horizon, which can be more susceptible to interference from other signals. For example, in an urban environment with high levels of electromagnetic interference if the receiver's elevation mask is set too low, it may track satellites that are close to the horizon, which can be more susceptible to interference from other signals. This can lead to errors in determining the position. On the other hand, if the elevation mask setting is too high the receiver may not track satellites that are visible above obstructions such as buildings or trees, which can lead to a loss of signal strength and reduced accuracy in GPS readings. Therefore, it is important to set the elevation mask appropriately for the specific environment to minimize interference and improve GPS positioning accuracy (Hofmann, 2001).

Satellite geometry: The geometry of the GPS satellites can also cause errors in positioning. This occurs when the GPS receiver cannot see enough satellites to get an accurate fix on its position. The geometry of the satellites in view of the receiver can affect the accuracy and precision of GPS positioning. The elevation mask on GPS positioning can affect satellite geometry in specific situations. The elevation mask specifies the minimum angle of elevation that a satellite must have to be considered in view of the receiver. If the elevation mask setting is too high, the receiver may not track satellites that are visible above obstructions such as buildings or trees, leading to a reduced number of visible satellites in the sky. This can result in poor satellite geometry, where the visible satellites are clustered in a particular area of the sky, leading to reduced accuracy and precision in GPS positioning.

Conversely, if the elevation mask setting is too low, the receiver may track satellites that are close to the horizon which can result in dip multipath errors, signal attenuation, and interference, as discussed above. These clustered in a particular area of the sky, leading to reduced accuracy and precision in GPS positioning. Therefore, it is important to set the elevation mask appropriately for the specific environment to achieve optimal satellite geometry, which can improve the accuracy and precision of GPS positioning. A good satellite geometry will ensure that there are enough visible satellites in the sky, spread across different areas to provide accurate and precise GPS readings (Rizos, 1997).

2.6 Software analysis

Software that will be useful on processing obtained data from the GPS receiver is Trimble Business Center (TBC). Trimble Business Center (TBC) is a complete software suite to accommodate both static and real time data, including the Russian GLONASS system. Planning provides a forecast of observation conditions, including satellite visibility Receiver Communication & Baseline Processing downloads field data, reduces raw GPS files to baseline vectors and provides statistical analysis (vector quality and basic loop closures with graphics). Network Adjustment & Data Output - allows inclusion of conventional survey data, geoid modeling, total network adjustments (GPS and terrestrial/geoid observations), and transformations to historic or local coordinate systems. RTK data handling, feature coding for automatic map generation, surface and corridor creation as well as terrestrial data management (total station data and limited scanning files) with many stock and custom ASCII and DXF output formats available (Trimble, 2015).

2.7 Review of Previous Works on Elevation mask

Said, (2018) conducted study on impact of Elevation mask angle in Selangor, Malaysia. By using various mask angle setting for different GNSS positioning method based on established known points. This study conducted by performing GNSS observation on two established reference points using multiple elevation mask setting for static and network RTK method with GPS and GLONASS satellite constellation. Then main outcomes were adjusted coordinates, PDOP, RMS, horizontal and vertical precision values, therefore analysis has been used to identify the ideal EMA setting could be used to achieve the best position accuracy.

Adeleke & Idowu, (2022) conducted study on mask angle and antenna height in Nigeria, aimed to reduce the arbitrary assignation of GPS mask angle and antenna angle to the minimum in order to optimize the accuracy of GPS positioning. They were using known control points; 76 coordinate observations were carried out for the determination of optimum antennal height while 23 coordinates were observed for the determination of optimum mask angle. were observed that 1.76m and 20˚ is the antenna height and mask angle with the least error level. Therefore, concluded that in a level terrain, 20˚ and 1.76m have proved to be the optimal mask angle and antenna height.

Deying *et al*., (2021) conducted study on accuracy analysis of Multi-Mode Pseudo-Range SPP under different mask angle in Beijing, China. Based on the measured data under different mask angles, different combination modes of satellite navigation systems for multi-mode pseudo range SPP are calculated and analyzed. The results show that with the increase of the cut-off height angle, the number of visible satellites decreases gradually, with the PDOP becoming larger and fluctuating sharply. Meanwhile, the positioning deviation becomes larger and the stability becomes worse, and the epoch availability rate decreases gradually.

Dyukov, (2016) conducted study on Mask angle effects on multipath and tree foliage environment in Melbourne, Australia. Aims to determine if the receivers with higher mask angle perform better in tree foliage environment. Results show that mask angle in GNSS receivers may not necessarily improve the speed accuracy parameter both in multipath and tree foliage related environments and determined that attenuation and scattering of GNSS signal in tree foliage environment may represent a higher threat for GNSS speed measurements compared to multipath related environment.

Medina *et al*., (2020) conducted study on Impact of Satellite Elevation Mask in GPS and Galileo RTK positioning in German. Gives a comparative of the performance assessment for different high elevation masks of a multi-frequency multi-GNSS RTK method in a loose combination to avoid the case of the lack of coinciding frequencies. This study shows that even with a low elevation mask of 10˚, a GPS-only System offers a 52.61% of the mean ASR in comparative with a combined dual-System that offer 99.95% of the mean ASR. This performance is comparable even with an elevation mask of 45˚ when a combined GPS + Galileo System offers a benefit of 57.17% of the mean ASR with respect to GPS-only System.

In contrast to the current research, Four Leica GS15 receivers used in static method where by surveyed area were visible to sky around Ardhi University. So as to meet objectives of the research, elevation mask was set 0˚ at the data observation so as to collect satellite signals comes from different elevation mask and the software used to process GPS data was Trimble Business Center (TBC) where by different elevation mask were set on the processing. Result from 0˚ elevation mask at 6 hours observation time are the base coordinate that used to compare the adjusted coordinate from other elevation mask so as to identify the optimal elevation mask setting that can provide the most accurate and reliable position estimates.

CHAPTER THREE

METHODOLOGY

This chapter described the procedures and method that were used in order to achieve both objectives. This chapter involve the description of field reconnaissance and network design was done, it also described how pre-analysis, data collection and data processing.

3.1 Field Reconnaissance and Network Design

3.1.1 Field Reconnaissance

This involves the visiting of the area to be surveyed which is within Ardhi University and to choose area for establishment of new points that were visible to sky. Also, in field reconnaissance there are two known control point identified that were used during GPS observation in Table 3.1, in which are stable and located area having visibility of the sky. Control points that were useful in GPS observation are;

Table 3. 1: Existing Control points

	EASTINGS (meter)	NORTHINGS (meter)	ELEVATION (meter)
W. TANK	523169.840	9252082.933	101.552
MKG09	523946.770	9252343.692	39.403

3.1.2 Network Design

Control Network is a network, often of triangles which are measured exactly by techniques of terrestrial surveying or by space techniques such as GNSS, VLBI, SLR and LLR. Control networks provide a reference framework of points for topographical mapping, Deformation surveys for all manner of structures**,** Construction works**,** extension and densification of existing control network**.**

There are two methods of establishment of control point, which are for conventional surveying and space or GNSS surveying. Convectional surveying is a surveying method that involves the use of traditional surveying equipment and techniques such as theodolites, levels, and chains or tapes. It is manual and time-consuming process that relies on the physical measurement of distances, angles, and elevations to determine the position and dimensions of a certain area or structure. This method requires intervisibility between adjacent stations. For horizontal control some of conventional techniques used are triangulation, trilateration, traverse and Resection. As well as for Vertical control Spirit levelling is used.

Space or GNSS surveying is the branch of surveying that involves using the space-based techniques and method to precisely measure and monitor the shape size and gravity field of the earth. For example, GNSS uses satellite to provide the precise positioning and timing information, and Satellite altimetry which uses radar or laser signals to measure the height of the earth's surface. For the GNSS some of the techniques used which are, Static and rapid static techniques for the horizontal and vertical control. In GNSS surveying relative technique mostly preferred and it needs visibility to sky.

Some criteria were followed when designing control network for this study, those criteria are; Network density: network should be designed with a sufficient number of control points to ensure that the required accuracy is achieved. The number and distribution of control points should be based on the size and complexity of the survey area. Control point selection, control points should be selected carefully, taking into consideration the location, accessibility, and stability of the ground. Points should be located on stable terrain and away from any areas that may be subject to significant movement or deformation. Observation methods, this used for establishing the control points should be appropriate for the level of accuracy required. Third-order control networks typically require high-precision geodetic surveying techniques, such as GPS (Global Positioning System). Minimum Included Angle, this should be greater than 30 degrees to ensure good geometric configuration and minimize the effects of observational errors and ill condition.

Some of the ill conditions that can affect the design of a geodetic control network include: Non-uniform distribution of control points, If the control points are not evenly distributed throughout the area of interest, the resulting mapping and surveying may be inaccurate. Therefore, it is important to carefully plan the location and spacing of control points to ensure proper coverage. Insufficient redundancy, redundancy refers to the number of control points used to determine the position of a point on the Earth's surface. Insufficient redundancy can lead to inaccuracies in the geodetic control network. Therefore, it is important to have enough control points to provide a high level of redundancy. Changes in the Earth's surface, earth's surface is constantly changing due to natural and human activities. These changes can affect the accuracy and reliability of a geodetic control network. Therefore, it is important to periodically update and adjust the network to account for these changes. Therefore, the network Figure 3.1 was designed based on selected controls which met all the aforementioned.

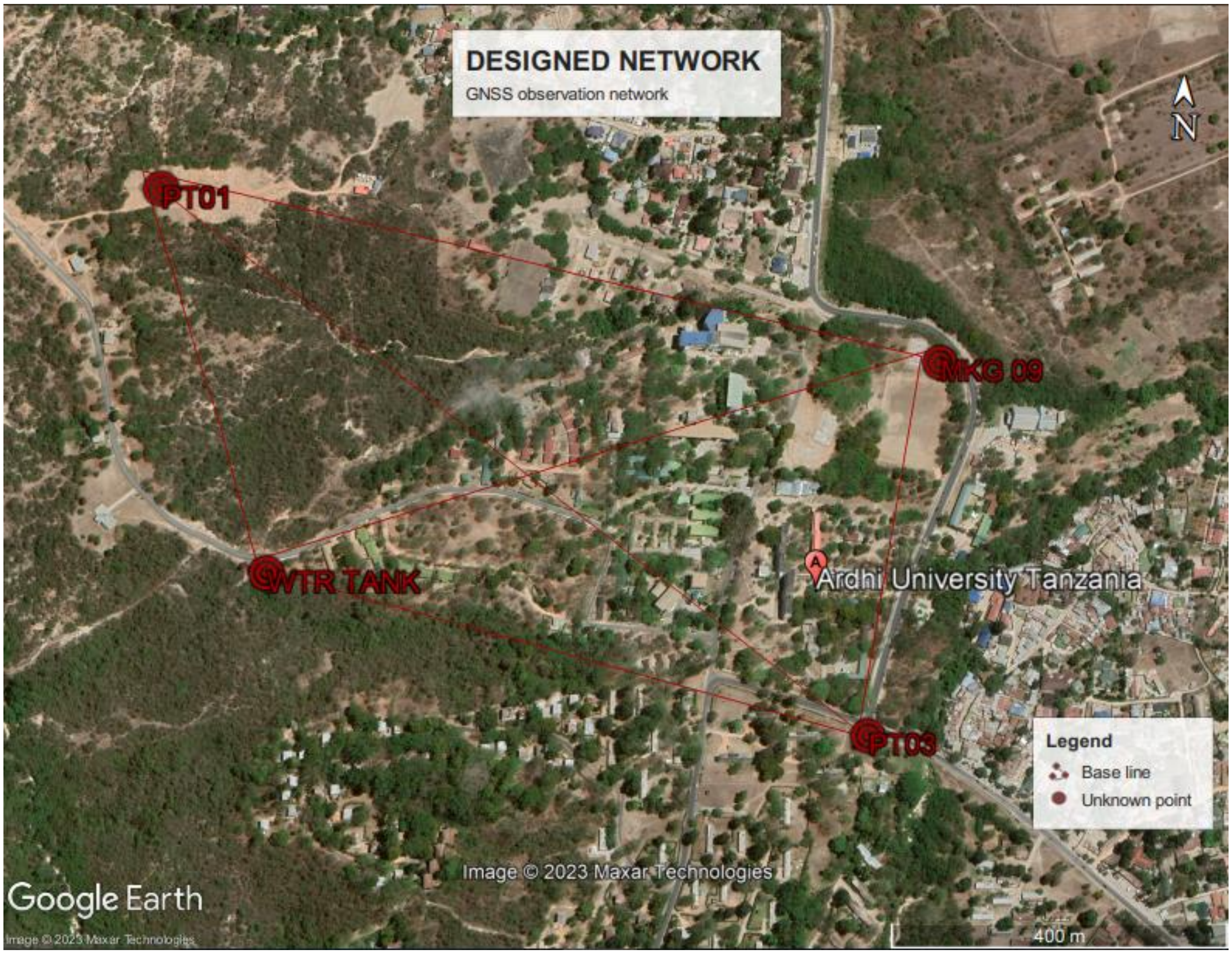

Figure 3. 1: Designed Network

3.2 Monumentation

During monumentation of the points some of criteria were considered as stability and durability, accessibility, satellite visibility, ground reference markers and others. In Figure 3.1, there are four points W. TANK, MKG09 which are known control point and PT1, PT3 which are the established points. In Figure 3.2, point PT1 was monumented as a single beacon for the research purpose as a temporary point, likewise to the PT3.

Figure 3. 2: Monumentation Process

3.3 Mission Planning

Before conducting the observation, mission planning was done by using TBC (Trimble Business Center) to check for the best day and time to conduct our survey basing on the Satellite visibility, satellite elevations, number of satellites available and the quality of their arrangement over any period of time. The choice of bad or good geometry of the satellite concentration is done by the help of Geometrical Dilution of Precision (GDOP). The combined effect for position and time is called GDOP. Low GDOP values indicate good geometry.

During planning the number of satellites that could be available at specific observation time was observed to be 13 satellites of GPS as shown in Figure 3.3 and the graphically the Dilution of Precision (DOP) for satellites on the day of observation shown in Figure 3.4.

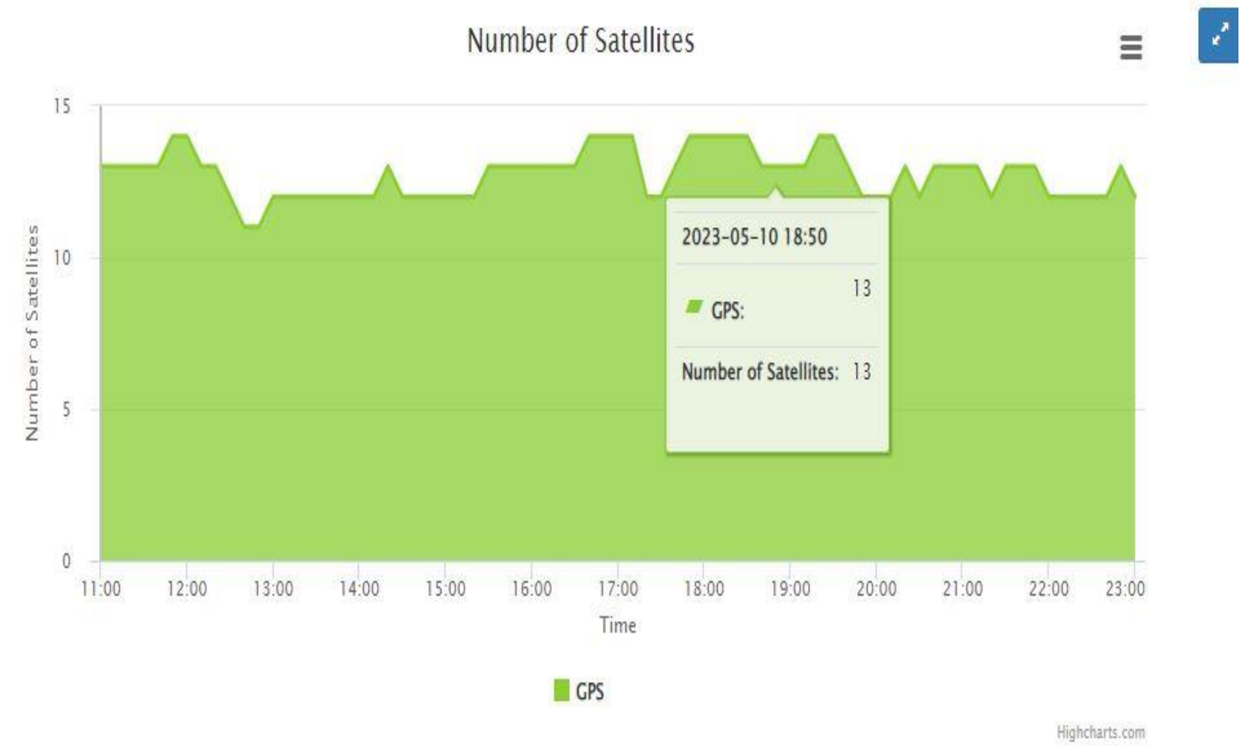

Figure 3. 3: Number of satellites available on observation date

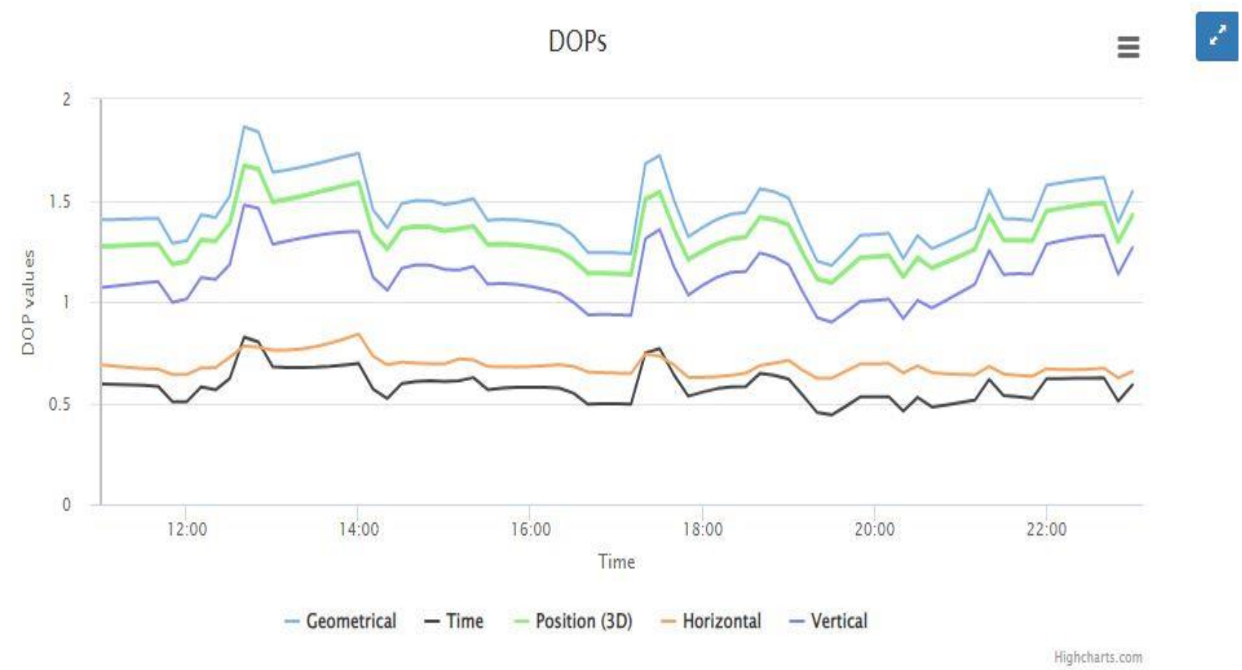

Figure 3. 4: Dilution of Precision (DOPs)

3.4 GPS Observation

Network consists of four points namely W. TANK, PT1, PT3 and MKG9. Four LEICA VIVA GS15 receivers were used in all stations with other tools like Tripod stand, batteries and tribraches. GNSS observation was done at a minimum of 6 hours for all stations. The receivers were set to observe the data in RINEX format. During configuration of the network, elevation mask or cut-off angle were set zero degree (0˚) so as to receive all observation signals from any cut-off angle since this study wants to know the accuracy assessment of the different elevation mask. Followed by other settings like, Maximum Geometric Dilution of Precision (GDOP) = 5, Data acquisition rate for static = 15sec, and others.

Figure 3. 5: Ongoing Static GPS Observation at station PT01

3.5 Quality check

Collected data from the field which is in RINEX format, has to be processed so as to obtain the coordinates of the points but data has to be checked before processing. In Figure 3.6 shows Quality check done by the e-office software so as to know the quality of the data. All data with respect to their points were pass the check by having data quality above 80% which is excellent to be used as shown in Figure 3.7.

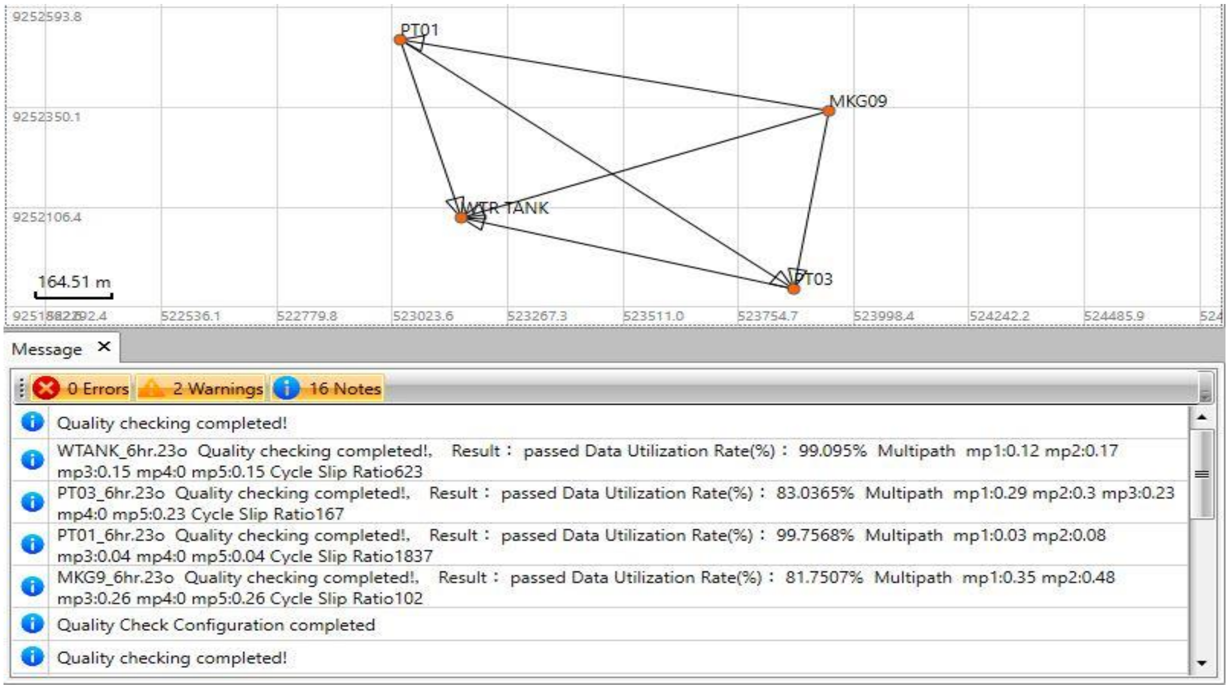

Figure 3. 6: Quality Check from e-office

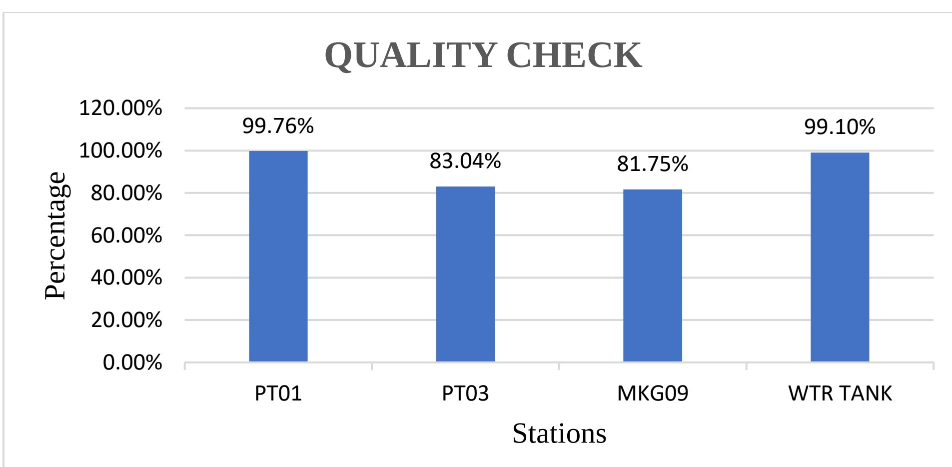

Figure 3. 7: Quality check for all stations in percentage

3.6 Data processing

Data were processed using Trimble Business Centre (TBC) software. Before processing, GPS data were arranged into different time of observation for example 1 hour, 3 hours and 6 hours by using window command program known as Translating Editing and Quality Check (TEQC) so as to check variation of the adjusted coordinates of the points respectively to the time of observation. Then data were imported into TBC and being processed for setting different elevation mask for example 5˚, 10˚, 15˚ and 20˚. At first was set elevation mask of 0˚, Baseline processing of the network were done for 6 hours data as shown in Figure 3.7 in which loop closure were allowable to continue with network adjustment. Free network adjustment was done because of the estimation of the surveyed points based solely on the observed data and calculates the adjusted coordinates of the points based on redundancy and statistical analysis of the measurements as shown in Figure 3.8. Adjusted coordinate obtained for 6 hours and 0˚ elevation mask becomes the base coordinates for comparison of other results from different elevation mask.

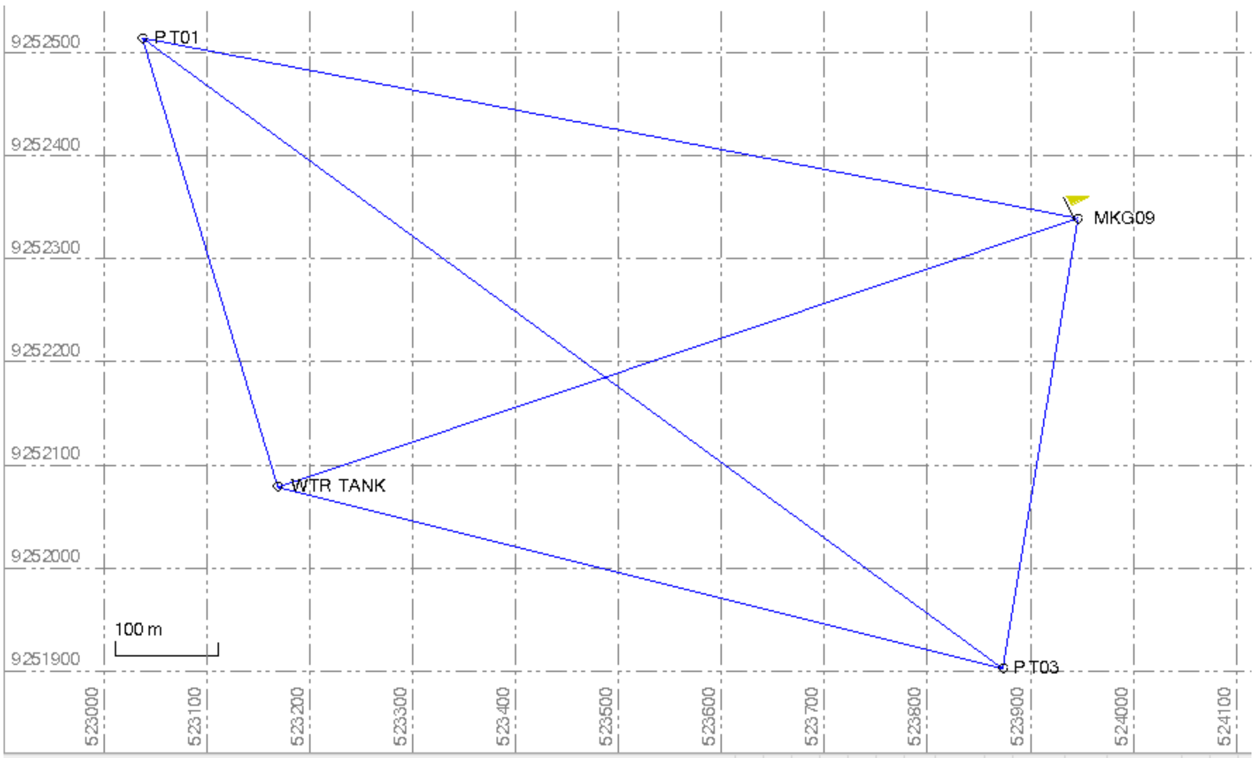

Figure 3. 8: Processed Baselines using TBC

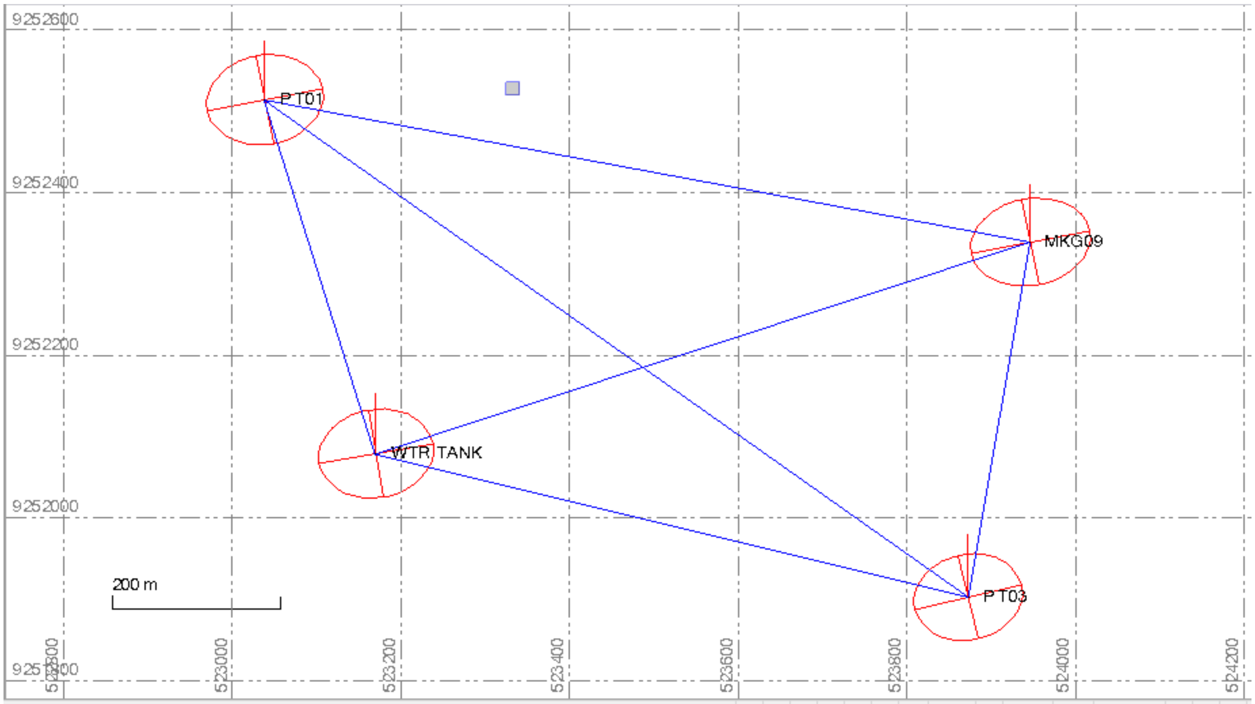

Figure 3. 9: Adjusted Network

CHAPTER FOUR

RESULTS AND ANALYSIS

This chapter presents the final results obtained after processing GNSS data by Trimble Business Center and analysis of the results were discussed including statistical analysis and graphical representation of the results.

4.1 Results

Data processed in TBC were result to the adjusted grid coordinates of the points in different time of observation (1hr, 3hrs and 6hrs) and elevation mask (5˚,10˚,15˚ and 20˚) with their eastings and northings uncertainties in WGS84 as the reference ellipsoid. Results differs in coordinates and uncertainties due to the time of observation and different elevation mask which are presented from Table 4.2 up to Table 4.13. Result in Table 4.1 are the base coordinate processed at 0˚ elevation mask with 6 hours of observation time that used for the comparison of other coordinates from different elevation mask.

Table 4. 1: Base adjusted coordinates in 6 hours observation time for 0 Elevation mask

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.734	0.001	9252513.867	0.001
PT03	523872.931	0.001	9251902.581	0.001
MKG09	523946.169	0.001	9252339.131	0.001
WTR TANK	523169.235	0.001	9252078.362	0.000

Table 4. 2: Adjusted grid coordinates in 1-hour observation time for 5 Elevation mask

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.724	0.001	9252513.870	0.001
PT03	523872.925	0.001	9251902.580	0.001
MKG09	523946.167	0.001	9252339.130	0.001
WTR TANK	523169.227	0.001	9252078.361	0.001

Table 4. 3: Adjusted grid coordinates in 1-hour observation time for 10 Elevation mask

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.725	0.000	9252513.870	0.001
PT03	523872.925	0.001	9251902.580	0.000
MKG09	523946.167	0.001	9252339.130	0.001
WTR TANK	523169.226	0.001	9252078.361	0.001

Table 4. 4: Adjusted grid coordinates in 1-hour observation time for 15 Elevation mask.

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.722	0.001	9252513.870	0.001
PT03	523872.923	0.001	9251902.581	0.001
MKG09	523946.168	0.001	9252339.132	0.001
WTR TANK	523169.222	0.001	9252078.361	0.001

Table 4. 5: Adjusted grid coordinates in 1-hour observation time for 20 Elevation mask.

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.721	0.002	9252513.871	0.002
PT03	523872.926	0.002	9251902.582	0.002
MKG09	523946.170	0.003	9252339.128	0.003
WTR TANK	523169.220	0.003	9252078.363	0.003

Table 4. 6: Adjusted grid coordinates in 3-hours observation time for 5 Elevation mask

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.727	0.001	9252513.869	0.001
PT03	523872.928	0.001	9251902.581	0.001
MKG09	523946.168	0.001	9252339.130	0.001
WTR TANK	523169.229	0.001	9252078.362	0.001

Table 4. 7: Adjusted grid coordinates in 3-hours observation time for 10 Elevation mask.

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.726	0.000	9252513.869	0.000
PT03	523872.927	0.000	9251902.580	0.000
MKG09	523946.168	0.000	9252339.131	0.000
WTR TANK	523169.229	0.000	9252078.362	0.000

Table 4. 8: Adjusted grid coordinates in 3-hours observation time for 15 Elevation mask.

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.728	0.002	9252513.867	0.002
PT03	523872.929	0.002	9251902.581	0.002
MKG09	523946.169	0.003	9252339.131	0.002
WTR TANK	523169.229	0.002	9252078.361	0.002

Table 4. 9: Adjusted grid coordinates in 3-hours observation time for 20 Elevation mask.

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.719	0.001	9252513.870	0.001
PT03	523872.926	0.001	9251902.582	0.001
MKG09	523946.169	0.001	9252339.129	0.001
WTR TANK	523169.221	0.001	9252078.365	0.001

Table 4. 10: Adjusted grid coordinates in 6-hours observation time for 5 Elevation mask

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.734	0.001	9252513.867	0.001
PT03	523872.931	0.001	9251902.581	0.001
MKG09	523946.169	0.001	9252339.131	0.001
WTR TANK	523169.235	0.001	9252078.362	0.000

Table 4. 11: Adjusted grid coordinates in 6-hours observation time for 10 Elevation mask.

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.733	0.001	9252513.867	0.000
PT03	523872.931	0.001	9251902.581	0.001
MKG09	523946.169	0.001	9252339.131	0.001
WTR TANK	523169.235	0.001	9252078.362	0.000

Table 4. 12: Adjusted grid coordinates in 6-hours observation time for 15 Elevation mask

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.734	0.001	9252513.866	0.001
PT03	523872.931	0.002	9251902.580	0.001
MKG09	523946.168	0.002	9252339.131	0.002
WTR TANK	523169.236	0.001	9252078.362	0.001

Table 4. 13: Adjusted grid coordinates in 6-hours observation time for 20 Elevation mask.

Point ID	Easting (meter)	Uncertainty	Northing (meter)	Uncertainty
PT01	523037.722	0.001	9252513.869	0.001
PT03	523872.926	0.001	9251902.583	0.001
MKG09	523946.169	0.001	9252339.129	0.001
WTR TANK	523169.223	0.001	9252078.364	0.001

4.2 Analysis of the Results

Analysis of the results was carried out in order to study the variation of coordinates and their uncertainties of points, obtained after processing GPS data using TBC. Comparison between coordinates from different elevation mask to the base coordinate are presented in Table 4.14 for 1 hour, Table 4.15 for 3 hours and Table 4.16 for 6 hours observation time.

Table 4. 14: Coordinates comparison for 1-hour observation time with the base coordinate

Stations	Base coordinate (0°)		Coordinates of the points for 1 hour							
			5°		10°		15°		20°	
	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)
PT01	523037.734	9252513.867	523037.724	9252513.870	523037.725	9252513.870	523037.722	9252513.870	523037.721	9252513.871
PT03	523872.931	9251902.581	523872.925	9251902.580	523872.925	9251902.580	523872.923	9251902.581	523872.926	9251902.582
MKG09	523946.169	9252339.131	523946.167	9252339.130	523946.167	9252339.130	523946.168	9252339.132	523946.170	9252339.128
WTR TANK	523169.235	9252078.362	523169.227	9252078.361	523169.226	9252078.361	523169.222	9252078.361	523169.22	9252078.363

Table 4. 15: Coordinates comparison for 3 hours observation time with the base coordinate

Stations	Base coordinate (0°)		Coordinates of the points for 3 hours							
			5°		10°		15°		20°	
	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)
PT01	523037.734	9252513.867	523037.727	9252513.869	523037.726	9252513.869	523037.728	9252513.867	523037.719	9252513.870
PT03	523872.931	9251902.581	523872.928	9251902.581	523872.927	9251902.58	523872.929	9251902.581	523872.926	9251902.582
MKG09	523946.169	9252339.131	523946.168	9252339.130	523946.168	9252339.131	523946.169	9252339.131	523946.169	9252339.129
WTR TANK	523169.235	9252078.362	523169.229	9252078.362	523169.229	9252078.362	523169.229	9252078.361	523169.221	9252078.365

Table 4. 16: Coordinates comparison for 6 hours observation time with the base coordinate

Stations	Base coordinate (0°)		Coordinates of the points for 6 hours							
			5°		10°		15°		20°	
	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)	Eastings (m)	Northings (m)
PT01	523037.734	9252513.867	523037.734	9252513.867	523037.733	9252513.867	523037.734	9252513.866	523037.722	9252513.869
PT03	523872.931	9251902.581	523872.931	9251902.581	523872.931	9251902.581	523872.931	9251902.58	523872.926	9251902.583
MKG09	523946.169	9252339.131	523946.169	9252339.131	523946.169	9252339.131	523946.168	9252339.131	523946.169	9252339.129
WTR TANK	523169.235	9252078.362	523169.235	9252078.362	523169.235	9252078.362	523169.236	9252078.362	523169.223	9252078.364

Since comparison of the coordinates from base coordinates shows that there is difference of 2mm to 3mm of the coordinate from 5, 10, 15 and 20 elevation masks for the different time of observation. Also, analysis performed on the trending of eastings and northings uncertainties against the elevation mask for different observation time of a specific point.

For PT01 in Figure 4.1, shows that there is rise of the eastings and northings uncertainties with respect to increase of elevation mask for 1-hour observation time. Also, for Figure 4.2 uncertainties increases as the increase of the elevation mask for both northings and eastings uncertainties has the same values so that graph overlay to each other for 3 hours observation time and for Figure 4.3 trending of the eastings uncertainties is similar to all elevation mask which is 0.001m and the general trend of the northings uncertainties is also similar to all elevation mask used which is 0.008m for 6 hours observation time

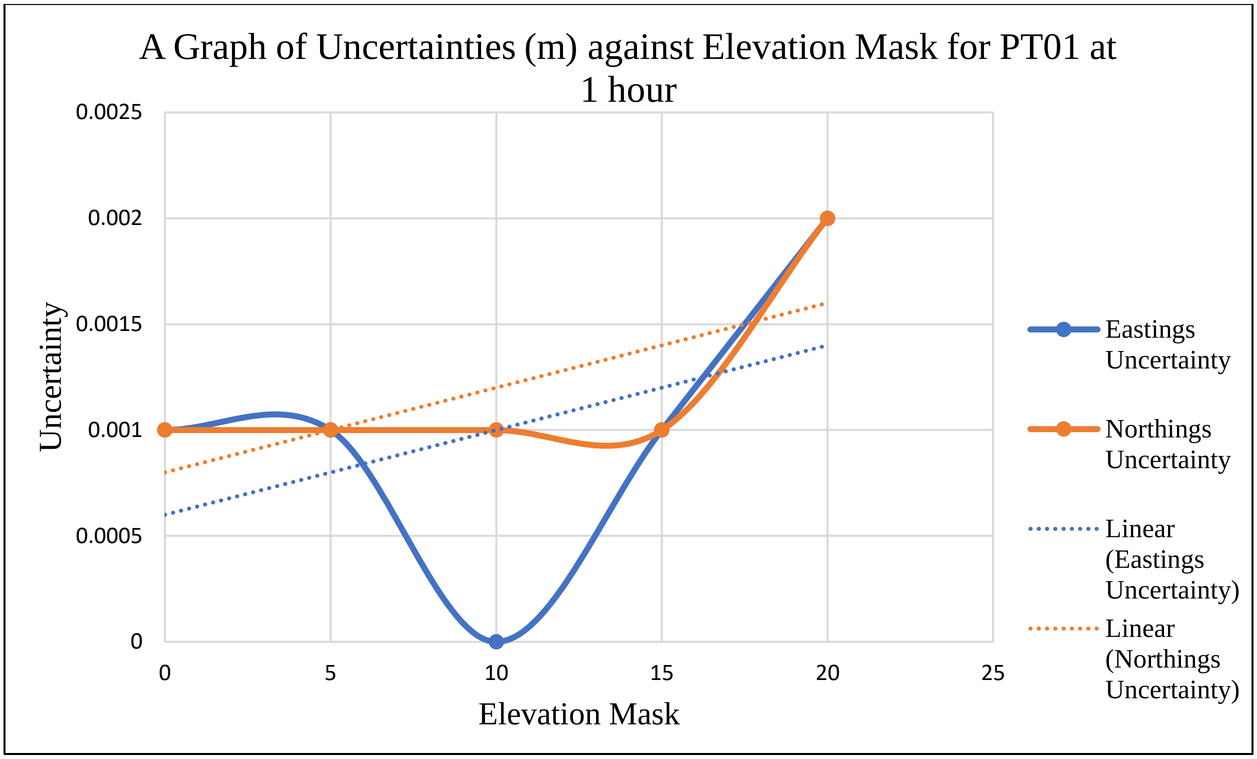

Figure 4. 1: Graph shows trend of Uncertainties for PT01 at 1 hour

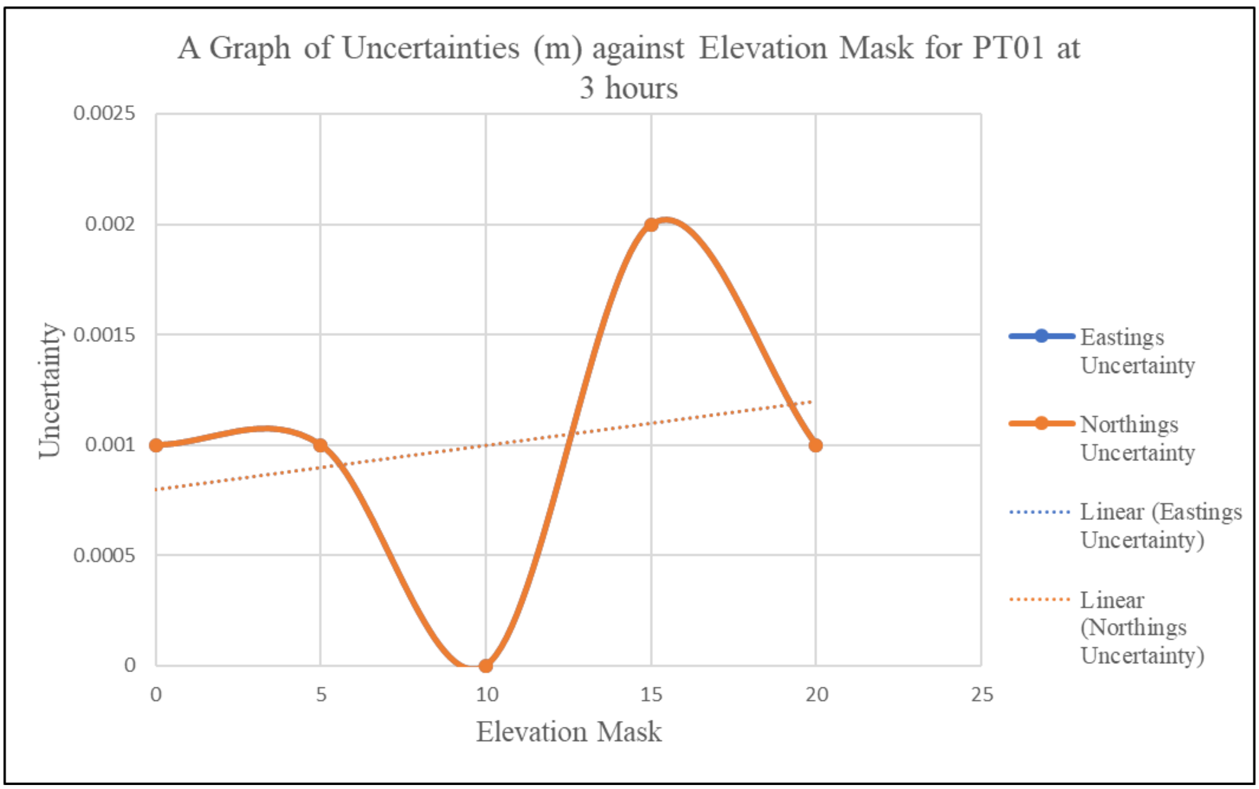

Figure 4. 2: Graph shows trend of Uncertainties for PT01 at 3 hours

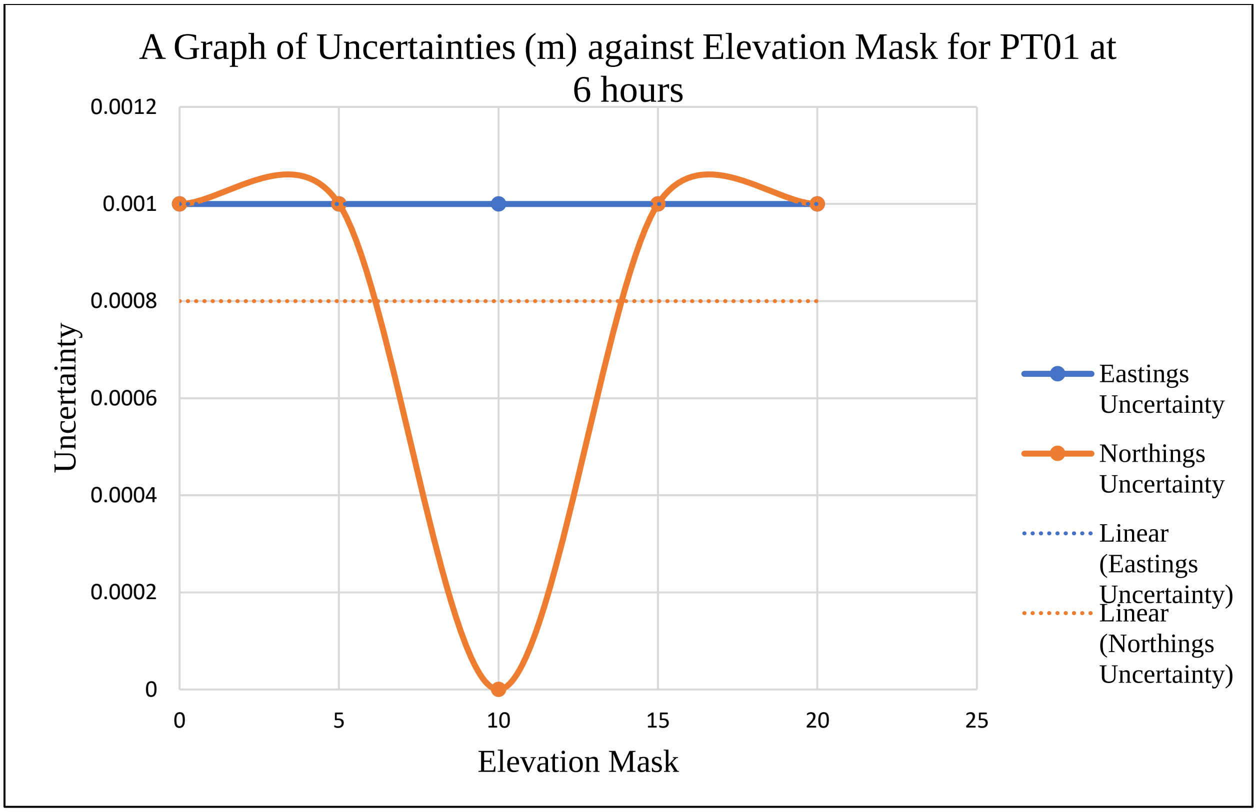

Figure 4. 3: Graph shows trend of Uncertainties for PT01 at 6 hours

For PT03 in Figure 4.4, shows that there is rise of the eastings and northings uncertainties with respect to increase of elevation mask for 1-hour observation time. Also, for Figure 4.5 uncertainties increases as the increase of the elevation mask for both northings and eastings uncertainties has the same values so that graph overlay to each other for 3 hours observation time and for Figure 4.6 trend of the northings uncertainties is similar to all elevation mask which is 0.001m and for the eastings uncertainties shows that there is rise with the increase of elevation mask for the 6 hours observation time.

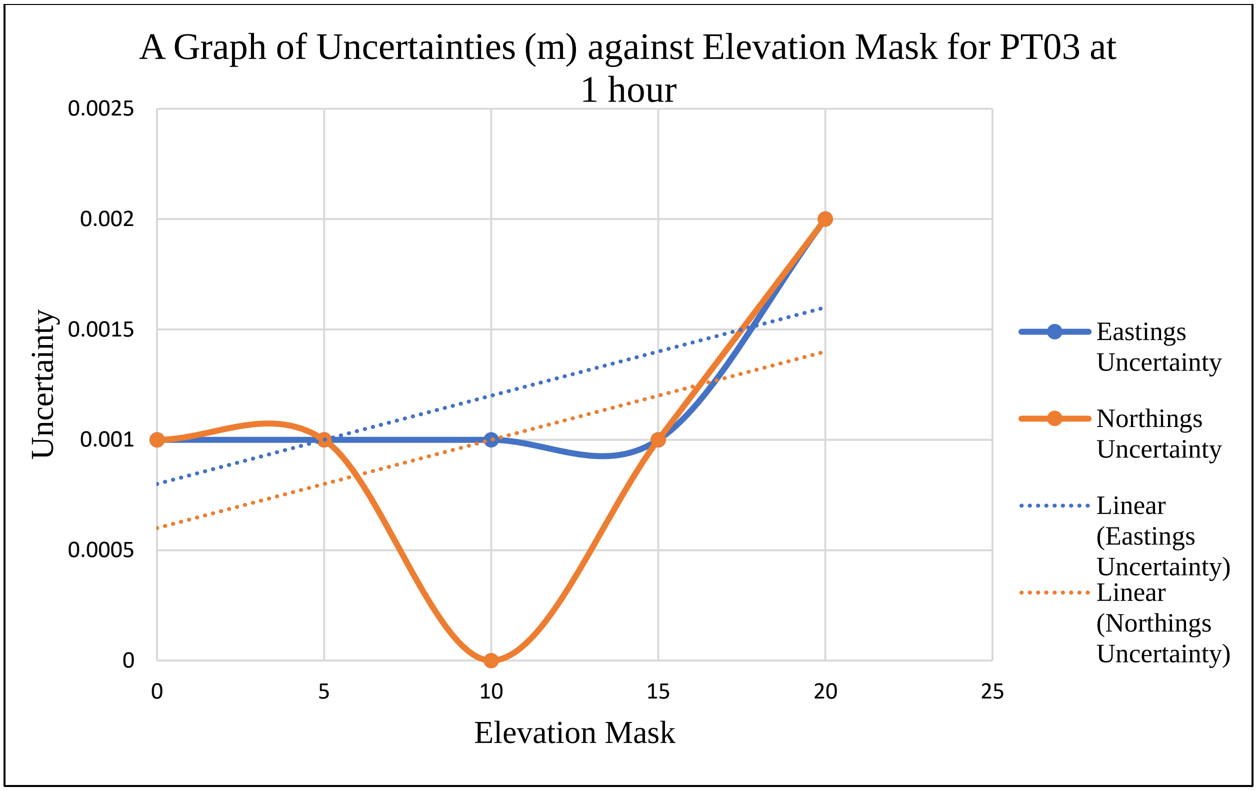

Figure 4. 4: Graph shows trend of Uncertainties for PT03 at 1 hour

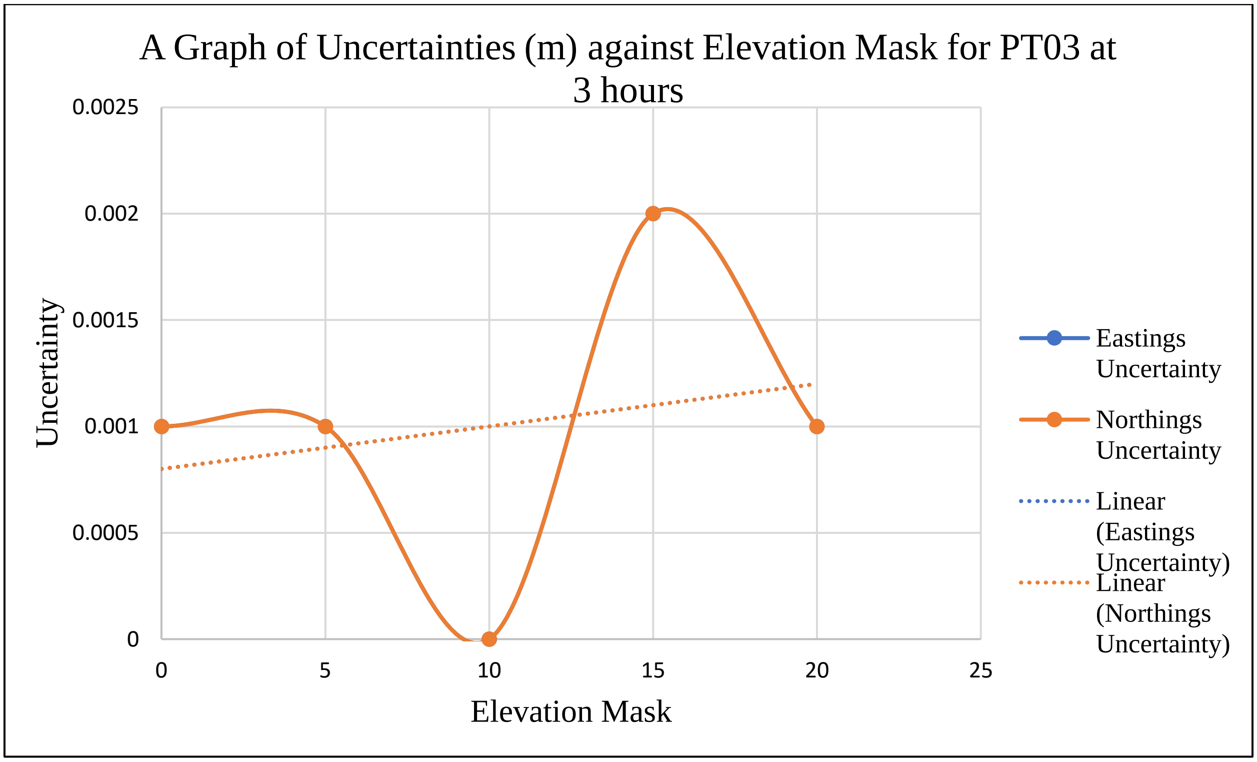

Figure 4. 5: Graph shows trend of Uncertainties for PT03 at 3 hours

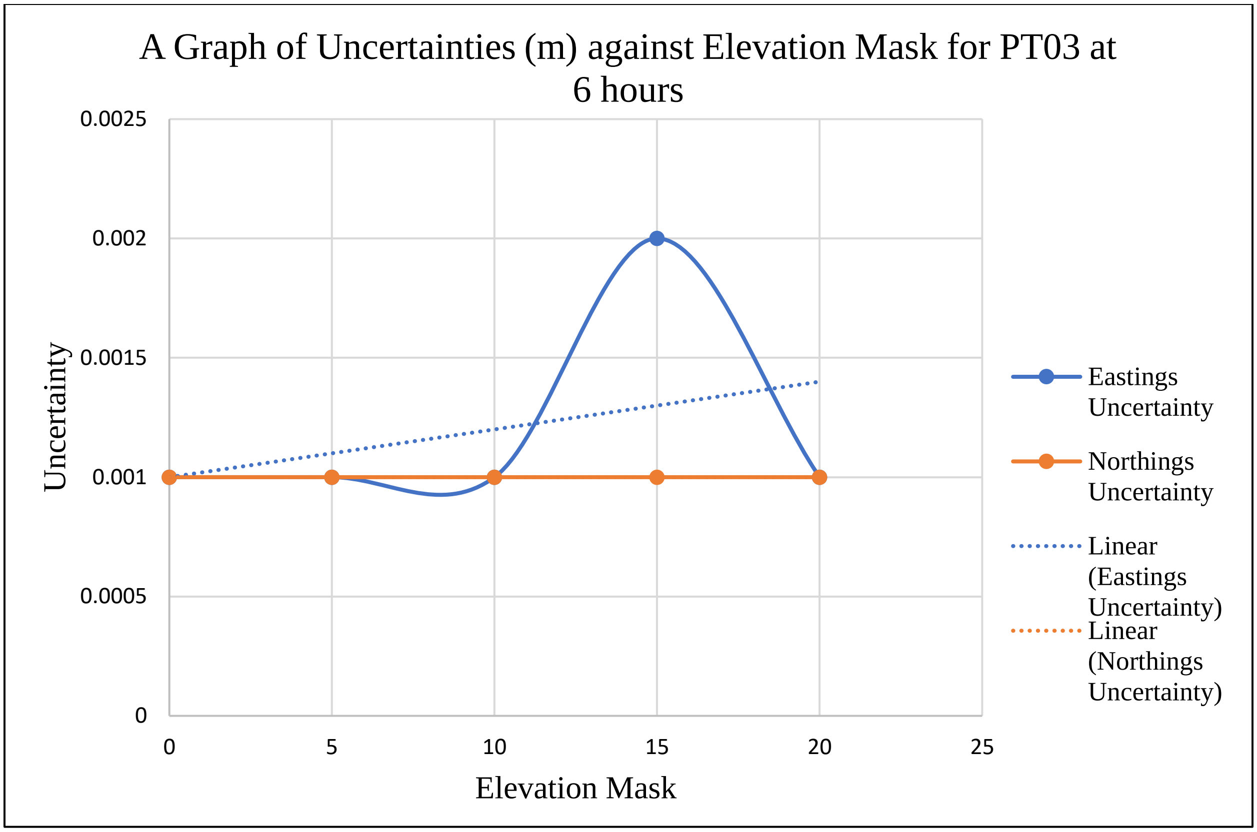

Figure 4. 6: Graph shows trend of Uncertainties for PT03 at 6 hours

For MKG09 in Figure 4.7, shows that there is rise of the eastings and northings uncertainties with respect to increase of elevation mask and has the same values so that graph overlay to each other for 1-hour observation time. Also, for Figure 4.8 uncertainties increases as the increase of the elevation mask for both northings and eastings uncertainties for 3 hours observation time and for Figure 4.9 northings and eastings uncertainties has similar trend as the increase of uncertainties with the increase of the elevation mask, since the values of the easting and northing uncertainties is similar hence the graph overlays to each other.

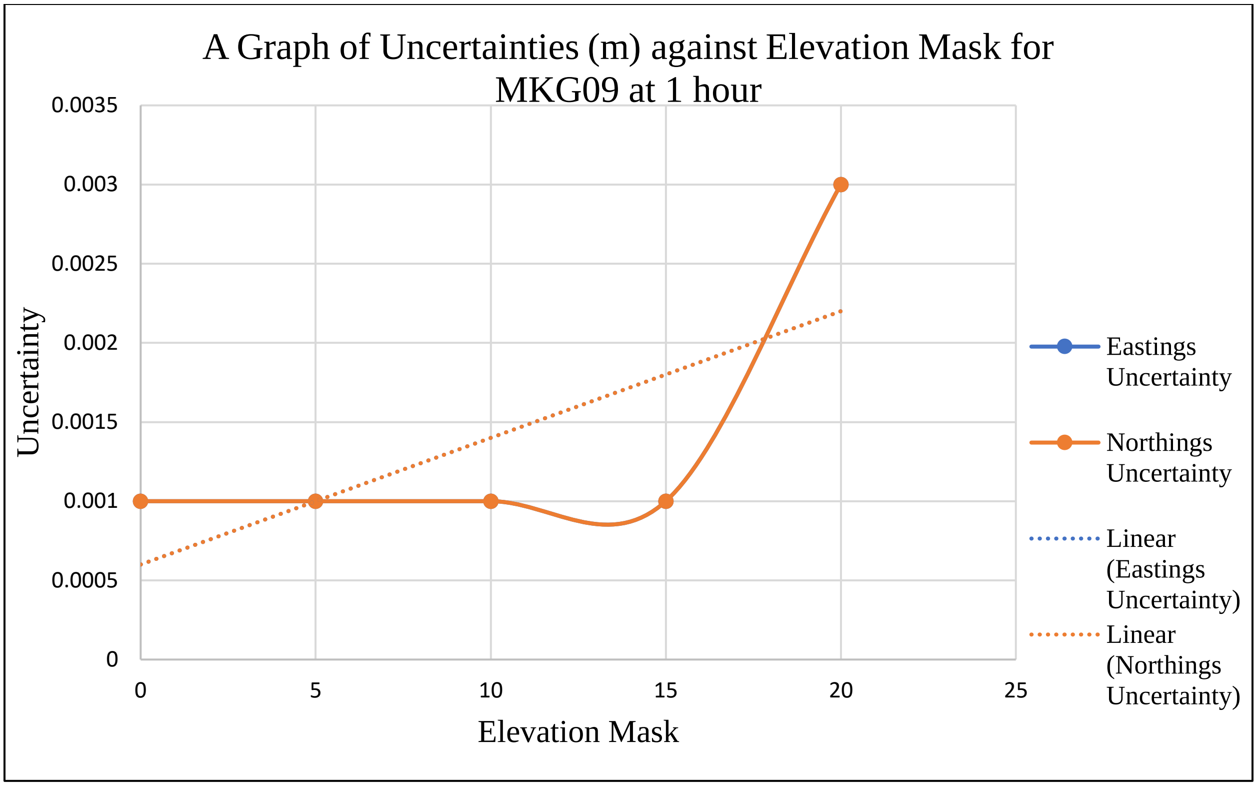

Figure 4. 7: Graph shows trend of Uncertainties for MKG09 at 1 hour

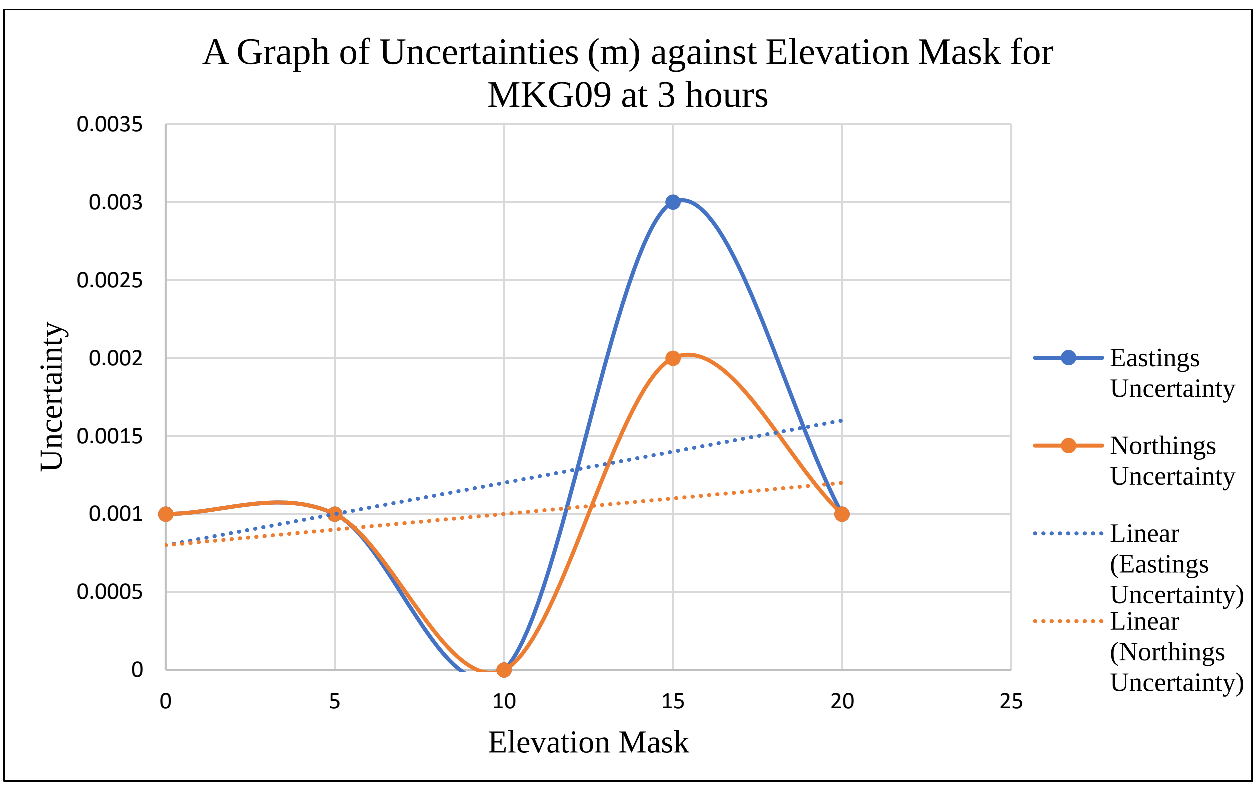

Figure 4. 8: Graph shows trend of Uncertainties for MKG09 at 3 hours

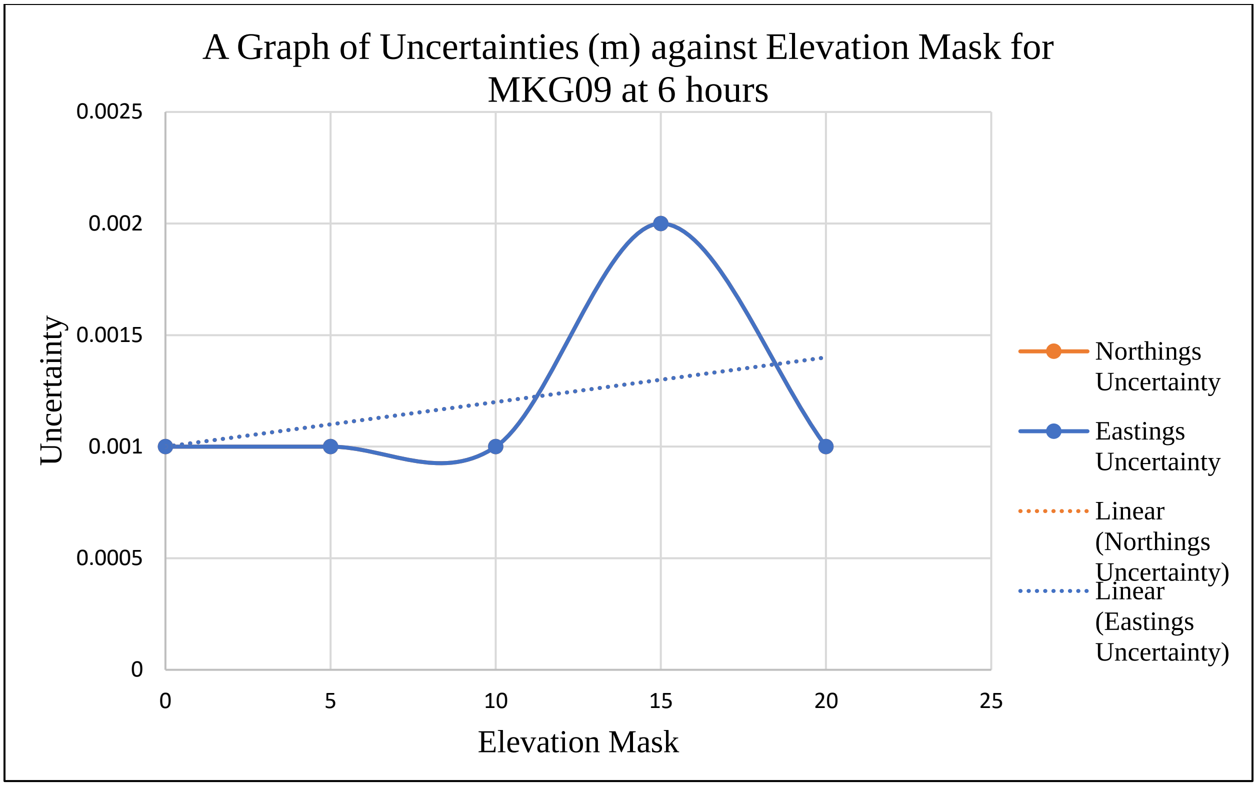

Figure 4. 9: Graph shows trend of Uncertainties for MKG09 at 6 hours

For WTR TANK in Figure 4.10, shows that there is rise of the eastings and northings uncertainties with respect to increase of elevation mask and has the same values so that graph overlay to each other for 1-hour observation time. Also, for Figure 4.11 uncertainties increases as the increase of the elevation mask for both northings and eastings uncertainties for 3 hours observation time and for Figure 4.12 northings uncertainties increases, as the increases of the elevation mask and for the eastings uncertainties shows that there is similar trend value for all elevation mask which is 0.001m for 6 hours observation time.

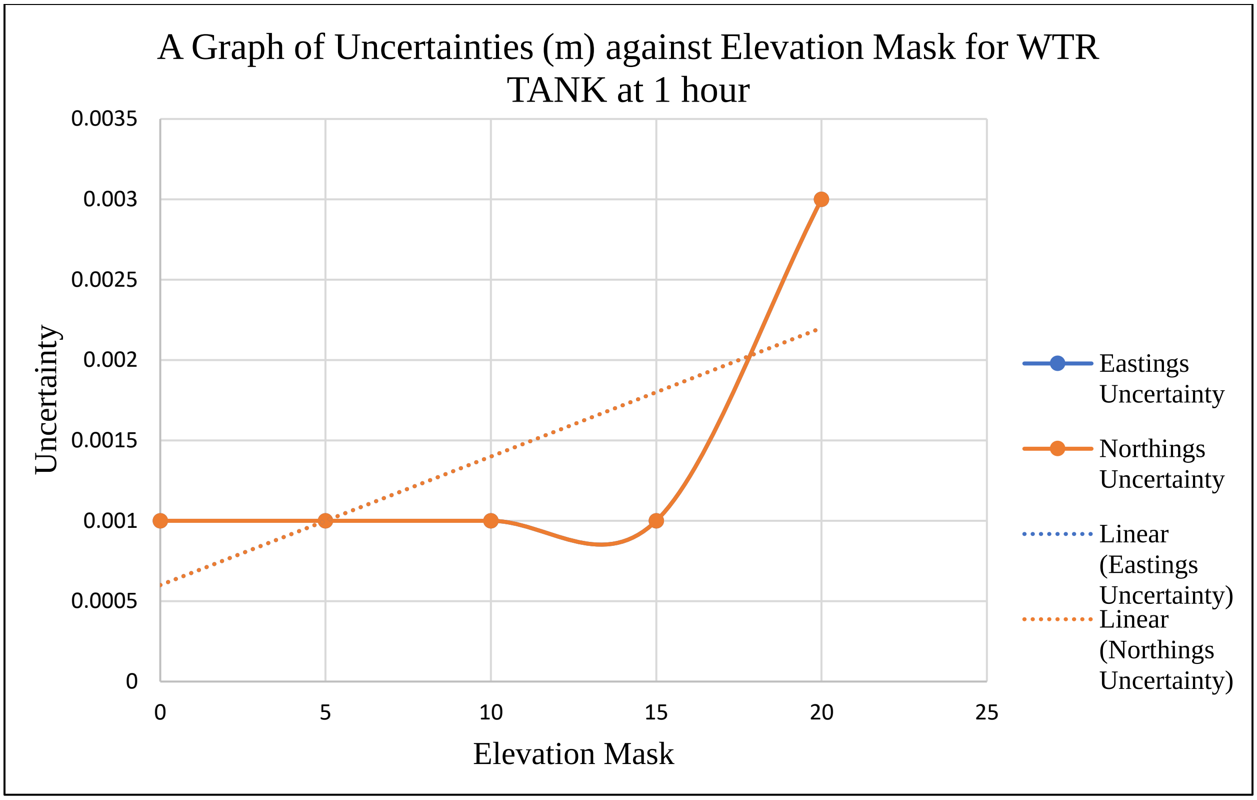

Figure 4. 10: Graph shows trend of Uncertainties for WTR TANK at 1 hour

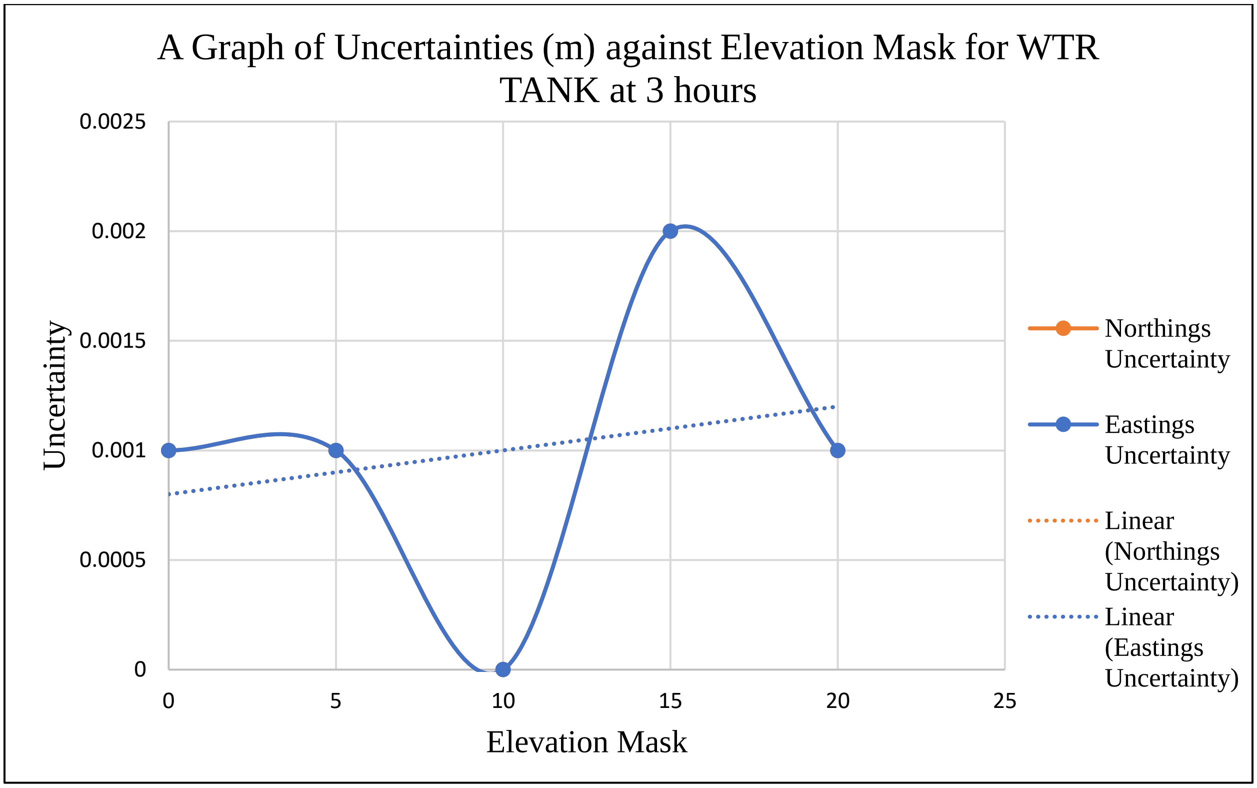

Figure 4. 11: Graph shows trend of Uncertainties for WTR TANK at 3 hours

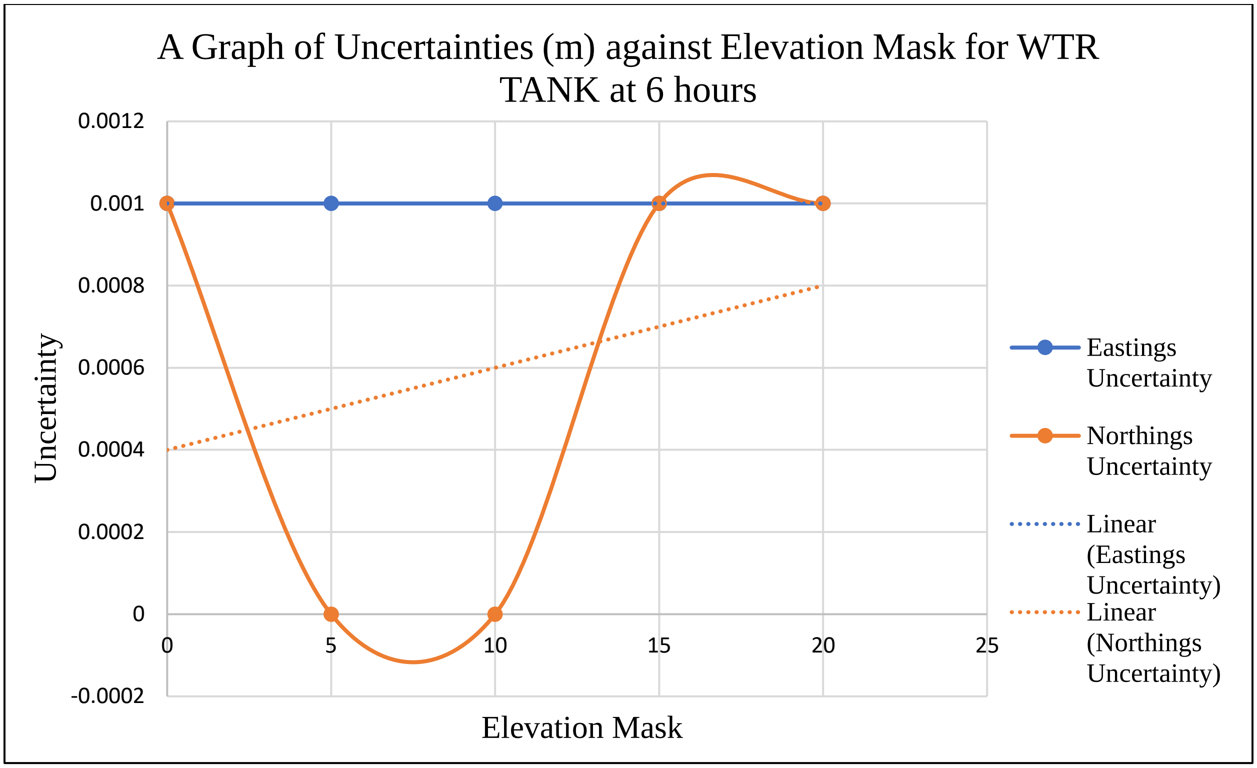

Figure 4. 12: Graph shows trend of Uncertainties for WTR TANK at 6 hours

4.3 Discussion of the Results

Aim of this study is to evaluate the impact of different elevation masks on the accuracy of GPS position measurements under different observation time, with the goal of identifying the optimal elevation mask setting that can provide the most accurate and reliable position estimates. Due to the analysis done using graph that shows the uncertainties against elevation mask in each station. Seems that for PT01 trend of uncertainties increases as the elevation mask increases except for 6 hours has similar trend for easting and northing uncertainties. For PT03, MKG09 and WTR TANK uncertainties increases as the elevation mask increases which is the common trend to each station. Generally, the results reveal a direct correlation between the elevation mask angle and positioning accuracy. Lowering the elevation mask enhances the number of visible satellites, thus improving the availability of measurements. However, setting the elevation mask too low might lead to an increase in multipath and signal errors, adversely affecting the overall positioning accuracy.

CHAPTER FIVE

CONCLUSION AND RECCOMENDATION

5.1 Conclusion

The findings of this study underscore the significance of the elevation mask angle as a crucial parameter in GNSS positioning. By setting an appropriate elevation mask, we can effectively mitigate the impact of multipath, signal interference, and ionospheric effects, leading to improved accuracy and robustness of GNSS positioning solutions. This study demonstrates that an elevation mask angle of a certain value proved to be optimal in balancing satellite visibility and signal quality, resulting in better positioning performance compared to either extremely low or excessively high elevation mask settings, as area with visibility to sky shows that as the elevation mask increases result to low accuracy of a point as the number of satellites decreases and for the area with multipath is required to use elevation mask that may mitigate the effect of the multipath on GNSS positioning.

5.2 Recommendation

For further research should be done on the impact of elevation mask on the GNSS position in the multipath and clear sky view area and compare difference rate on the both area with the base or known coordinates.

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APPENDICES

Network Adjustment Reports

6HRS FOR 0 ELEVATION MASK

Project File Data		Coordinate System	
Name:		Name:	World wide/UTM
Size:		Datum:	WGS 1984
Modified:	9/10/2018 11:10:55 AM (UTC:-6)	Zone:	37 South
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG 09	523946.169	0.001	9252339.131	0.001	48.374	0.004	
PT01	523037.734	0.001	9252513.867	0.001	102.094	0.003	
PT03	523872.931	0.001	9251902.581	0.001	51.625	0.004	
WTR TANK	523169.235	0.001	9252078.362	0.000	109.526	0.003	

Coordinates from a free adjustment should only be used for analysis of the inner accuracy of the network. They should not be distributed as final results.

1HR FOR 5 ELEVATION MASK

Project File Data		Coordinate System	
Name:		Name:	World wide/UTM
Size:		Datum:	WGS 1984
Modified:	9/10/2018 11:10:55 AM (UTC:-6)	Zone:	37 South
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG 09	523946.167	0.001	9252339.130	0.001	48.386	0.004	
PT01	523037.724	0.001	9252513.870	0.001	102.110	0.003	
PT03	523872.925	0.001	9251902.580	0.001	51.643	0.004	
WTR TANK	523169.227	0.001	9252078.361	0.001	109.528	0.003	

Coordinates from a free adjustment should only be used for analysis of the inner accuracy of the network. They should not be distributed as final results.

1HR FOR 10 ELEVATION MASK

Project File Data		Coordinate System	
Name:		Name:	World wide/UTM
Size:		Datum:	WGS 1984
Modified:	9/10/2018 11:10:55 AM (UTC:-6)	Zone:	37 South
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG 09	523946.167	0.001	9252339.130	0.001	48.378	0.003	
PT01	523037.725	0.000	9252513.870	0.000	102.117	0.002	
PT03	523872.925	0.001	9251902.580	0.001	51.643	0.003	
WTR TANK	523169.226	0.001	9252078.360	0.001	109.536	0.002	

Coordinates from a free adjustment should only be used for analysis of the inner accuracy of the network. They should not be distributed as final results.

3HRS FOR 15 ELEVATION MASK

Project File Data		Coordinate System	
Name:		Name:	World wide/UTM
Size:		Datum:	WGS 1984
Modified:	9/10/2018 11:10:55 AM (UTC:-6)	Zone:	37 South
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG 09	523946.169	0.003	9252339.131	0.002	48.347	0.022	
PT01	523037.728	0.002	9252513.867	0.002	102.178	0.020	
PT03	523872.929	0.002	9251902.581	0.002	51.607	0.021	
WTR TANK	523169.229	0.002	9252078.361	0.002	109.597	0.020	

Coordinates from a free adjustment should only be used for analysis of the inner accuracy of the network. They should not be distributed as final results

3HRS FOR 20 ELEVATION MASK

Project File Data		Coordinate System	
Name:		Name:	World wide/UTM
Size:		Datum:	WGS 1984
Modified:	9/10/2018 11:10:55 AM (UTC:-6)	Zone:	37 South
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG 09	523946.169	0.001	9252339.129	0.001	48.344	0.025	
PT01	523037.719	0.001	9252513.870	0.001	102.171	0.025	
PT03	523872.926	0.001	9251902.582	0.001	51.582	0.025	
WTR TANK	523169.221	0.001	9252078.365	0.001	109.604	0.025	

Coordinates from a free adjustment should only be used for analysis of the inner accuracy of the network. They should not be distributed as final results.

6HRS FOR 10 ELEVATION MASK

Project File Data		Coordinate System	
Name:		Name:	World wide/UTM
Size:		Datum:	WGS 1984
Modified:	9/10/2018 11:10:55 AM (UTC:-6)	Zone:	37 South
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG 09	523946.169	0.001	9252339.131	0.001	48.376	0.004	
PT01	523037.733	0.001	9252513.867	0.000	102.100	0.003	
PT03	523872.931	0.001	9251902.581	0.001	51.629	0.003	
WTR TANK	523169.235	0.001	9252078.362	0.000	109.531	0.003	

Coordinates from a free adjustment should only be used for analysis of the inner accuracy of the network. They should not be distributed as final results.

6HRS FOR 20 ELEVATION MASK

Project File Data		Coordinate System	
Name:		Name:	World wide/UTM
Size:		Datum:	WGS 1984
Modified:	9/10/2018 11:10:55 AM (UTC:-6)	Zone:	37 South
Time zone:	Mountain Standard Time	Geoid:	EGM96 (Global)
Reference number:		Vertical datum:	
Description:		Calibrated site:	
Comment 1:			
Comment 2:			
Comment 3:			

Network Adjustment Report

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG 09	523946.169	0.001	9252339.129	0.001	48.380	0.026	
PT01	523037.722	0.001	9252513.869	0.001	102.261	0.025	
PT03	523872.926	0.001	9251902.583	0.001	51.621	0.026	
WTR TANK	523169.223	0.001	9252078.364	0.001	109.676	0.024	

Coordinates from a free adjustment should only be used for analysis of the inner accuracy of the network. They should not be distributed as final results.