Sudan University of Science & Technology
College of Graduate Studies

Interpolation of Spot Heights in Seloum Dry Port

استكمال نقاط الارتفاعات في ميناء سلوم الجاف

A Thesis Submitted as Partial Fulfillment of the Requirements for the Degree Master of Science in Geodesy and GIS

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الآية

قال تعالي :- (﴿ ولقد مكناكم في الأرض وجعلنا لكم فيها معايش قليلا ما تشكرون ﴾).*

(سورة الاعراف .. الاية رقم 10 .)

Dedication

To the spirit of my mother by the

Mercy of Allah. To my father

To my brothers and sisters

To my small family

ACKNOWLEDGMENT

All thanks and appreciation to those whom helped and encouraged the conduct of this research. I am also indebted to ***Dr. Elhadi Elnazir*** for his support, supervision and auspices beside his onus. Special and greatest gratitude goes to my brother and a confidant ***Dr. Imameldin Awad*** for his efforts and heedfulness to complete not only this thesis preparation but also during my M.Sc program as well as my family.

Special thanks to my colleagues in Sea Ports Corporation – Civil Engineering Department .Particularly the resident engineer in Seloum project Eng. ***Alwelied Hassan*** for his helping during the data collection phase. Finally my thanks to the Department of Surveying Engineering at the University of Sudan for Science and Technology.

My Regard

Researcher

Abstract

Leveling is a branch of surveying and one of its targets to find out the topography of earth surface, more over it is required in the setting out of all kinds of engineering works.

Creation of Dry ports are to help costal ports and they need to be interconnecting by road and rail infrastructure.

Planning and design of Dry ports as large area are looks like container ports at system and aspects.

Apprehensible of interpolation deals with knowing or telling what is going to happen, often but always, based upon experience or knowledge.

Explaining of some mathematical techniques (Inverse Weighting Distance and Polynomial) is for purpose of this research, besides explaining of Kriging method as one of the Geographical Information System (ArcGIS technique).

The main objective of this thesis is to interpolate spot heights of large area by using mathematical equation as geodesy technique and GIS and compare the results (contour maps) versus contour map created from the data observed from site with dual frequency GPS.

Interpolated data evaluated by Root Mean Square Error as statistical method.

The method used in this thesis proved the possibility prediction of spot heights in large area using mathematical techniques to interpolate from few points.

The result had shown good and converge interpolation using polynomial rank one and kriging from ArcGIS

المستخلص

تعتبر طريقة حساب الارتفاعات او تحديد طبوغرافية سطح الارض والمعروفة بالميزانية من احدي فروع علم المساحة . حيث تأتي أهميتها في مراحل دراسة وتطبيق المشاريع الهندسية .

تم استحداث وإنشاء الموانئ الجافة عموما لتقوم بمساعدة الموانئ الساحلية بالإضافة لخدمة المجتمع وهي ترتبط ارتباط وثيق بالبنية التحتية واستخدامات الأرض.

تخطيط وتصميم الموانئ الجافة يتشابه كتيرا مع تخطيط وتصميم موانئ الحاويات الساحلية منتصمي الساحات الكبيره وبعض خصائص الميناء الساحلي للحاويات .

لأغراض هذة الدراسة فقد تم شرح بعض الطرق الرياضية (طريقة معكوس وزن المسافة وطريقة كثيرة الحدود) بالإضافة لطريقتي الكريغن وأدوات الهايدرولوجي من نظم المعلومات الجغرافية .

الغرض الرئيس من هذة الدراسة استخدام المعادلات الرياضية في استخلاص مجموعة من نقاط الارتفاعات لمنطقة كبيرة نسبيا ومقارنة الطرق فيما بينها ومقارنتها بأحدي طرق نظم المعلومات الجغرافية ومن ثم إنتاج خرط كنتوريه للمقارنة النهائية مع الخرائط المنتجة من المعلومات التي تمت قرءتها من الحقل بواسطة الأجهزة الحديثة مثل أجهزة تحديد الموقع ثنائية التردد .

تم تقييم النتائج باستخدام طريقة متوسط الجذرالتربيعي للخطأ وهى احدي الطرق الإحصائية .

الطرق المستخدمة اكدت إمكانية استخدام المعادلات الرياضية لاستخلاص نقاط الارتفاعات من عدد قليل من النقاط التي تم جمعها من الحقل ؛ كما أظهرت نتائج جيدة ومتقاربة بين كثيرة الحدود من الرتبة الأولي وطريقة الكريغن .

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CHAPTER ONE

INTRODECTION

1.0 Overview

The main function of Sea Ports Corporations is to, logistically, serve the nation's needs for the transportation of goods and people using large available areas of water and land. Starting from its initial topographical studies, such areas need a special preparation and continuous follow-up. Information from the mid 2000s suggests that the Sea Ports Corporation Sudan (SPC) invested around $187 million in development projects. This resulted in the main areas being in good condition with a number of new berths added and infrastructure projects commissioned (World Bank, 2008). Yet, Port Sudan seaport remains one of the most inefficient ports in Africa. A steady increase in containers handled at Port Sudan has created serious port congestion problems, adding significant delays to the movement of freight. The port is already operating at 80 percent capacity at least, a level of intensity that creates problems in terms of congestion.

1.1 Statement of the Problem

In Port-Sudan seaport, some of the container areas for Customs Clearance are out of work during rainy seasons due to the separate planning and designing of container area as small parts instead of dealing with the entire area. This inattention of large areas in between the separately designed container areas always create serious problems as they may be of different topography. However, there is still some scope for easing capacity constraints by finding a solution this difference in topography, thus improving the efficiency of port performance. The present study therefore, attempts to apply certain simulation methods as a tool to get reduced levels and help predicting the spot heights of the topography of a certain region, Seloum Dry Port in particular. the present study will:

- Use mathematical techniques for prediction of spot heights.
- Use Arc GIS software for interpolation of spot heights, in addition to the use of Arc hydro tools for analysis .
- Comparing with observed heights.

1.2 Previous Studies

Johan, W.; Roso. V.; and Lumsden, K. (20) The Dry Port Concept – Connecting Seaports with their Hinterland by Rail

The hypothesis behind the article is that a consciously applied dry port concept can shift freight volumes from road to more energy efficient traffic modes that are less harmful to the environment, relieve seaport cities from some congestion, make goods handling more efficient and facilitate improved logistics solutions for shippers in the port’s hinterland. The main purpose of the article is to present the theory behind the dry port concept and to define three dry port categories; distant, mid-range and close. The article takes a logistic, technological, economic as well as environmental perspective, and is focused on how the new transport networks could be designed and also what can be learned from this by authorities and companies that plan to use or operate similar transport systems. The present study differs from this one in that it does not consider those theoretical issues; instead, it deals with surveying matters, which will definitely help achieving such dry ports' benefits . in the other side a global study were done using spatial interpolation techniques in the field of ports needs and that is; David L. Sterling, (2003). A Comparison of Spatial Interpolation Techniques for Determining Shoaling Rates of The Atlantic Ocean Channel, Nine interpolation techniques (inverse distance weighting, completely regularized spline, spline with tension, thin plate spline, multiquadratic spline, inverse multiquadratic spline, ordinary kriging, simple kriging, and universal kriging) were compared for their ability to accurately produce bathymetric surfaces of navigation channels..

At local level, two studies are found to be related to the present study,

Saif Mohamed Zeen Ahmed Mohamed, (2014) "The Using of Interpolation Methods of Leveling in Geodesy and Geographical System: a comparative study"

Bearing into account that elevations can be determined by various practical means, which is a tedious job and time and money consuming, the study took interpolation is one of the ways to mathematically estimate the height of a point using the heights of some neighboring points. The aim of the study is to perform methods of interpolation in both geodesy and GIS and to compare the results. The study concluded that the use of GIS in interpolations is better than using equations for interpolation as in geodesy. Despite the fact that the study meets with the current one in the use of interpolation to estimate the heights of a point, it differs in that it is a comparative study that mainly focuses on GIS. Moawia Mohammed Elamin, (2016) "Evaluation of Heights Interpolation Methods Using Geographical Information Systems"

The main objective of this study is to evaluate heights interpolation methods, and create a digital terrain models (DTMs) of base types of relief in two study areas (flatlands, hilly areas). This thesis focuses on the digital terrain modeling

(DTM) technique based on geometrical interpolation approach by fitting a surface that depends on the reference points that are chosen in the critical and characteristic locations of the field to represent the trend of the surface. Using the orthometric heights, all the points were computed, and multiple regression model was formulated as the required geometrical model to further adjust the derived (DTMS) from observation. Results have shown the interpolation using GIS techniques is effective and has a higher level of accuracy compared to conventional methods, especially in the areas with similar terrain. Results have also shown that Kriging methods enable to determine an appropriate estimated elevation in unknown altitude regions. This study differs in that it focuses on the application of three interpolation methods (Kriging, Natural Neighborand Inverse distance weights) in geographical information system (GIS).

1.3 Objectives of the Study

The present study at Seloum dry port aims at:

- Creating spot heights of a large area from the observations of some selected points with mathematical means.
- Using mathematical techniques to help reducing fieldwork.
- Create contour maps from data predicted.
- Create contour map from Arc hydro tools.

1.4 Thesis Layout

These study contents , chapter one is the introduction for this study , chapter two about leveling and some most common application , chapter three show the dry port , chapter four show the prediction techniques , chapter five about data collection and processing, chapter six is analysis and results according to testes done in the study, and conclusion and recommendation in chapter seven .Other pertinent information and analyses that are related to the study and may be interesting to a reader are included in appropriately labeled appendices at the end of the study.

CHAPTER TWO

LEVELLING AND APPLICATIONS

2.0 Introduction

This chapter discusses the theoretical issues of the study in relation to the research problem posed in chapter one. A general discussion about leveling is tackled. This includes some definitions related to the concept of leveling, a brief review about curvature and refraction, leveling methods, and famous (some of the most common) leveling application like contouring .

2.1 Leveling

Leveling is a general term applied to any of the various processes by which elevations of points or differences in elevation are determined. The object of leveling is therefore: i) to find the elevations of given points with respect to a given or assumed datum; and ii) to establish points at a given or assumed datum. The first operation is required to enable the works to be designed while the second operation is required in the setting out of all kinds of engineering works.

2.1.1 Definition

To expound the concept of leveling, some general definitions are to be presented first. This includes elevation, level surface, level line, horizontal line and vertical angle.

The elevation or height of a point near the surface of the earth is its vertical distance above or below an arbitrary assumed level surface or curved surface every element of which is normal to the plumb line. The level surface (real or imaginary) used for reference is called the datum. A level line is a line in a level surface.

The difference in elevation or height between two points is the vertical distance between the two level surfaces in which the points lie. Leveling is the operation of measuring vertical distance, either directly or indirectly, to determine differences in elevation (Anderson and Mikhail, 1998).

A horizontal line is a line, in surveying taken as straight, tangent to a level surface.

A vertical angle is an angle between two intersecting lines in a vertical plane. In surveying, it is commonly understood that one of these lines is horizontal.

2.1.2 Curvature and Refraction

In leveling, it is necessary to consider the effects of:

1. Curvature of the earth
2. The atmospheric refraction, which affects the line of sight.

Usually, these two effects are considered together**.** For more clarification see figure

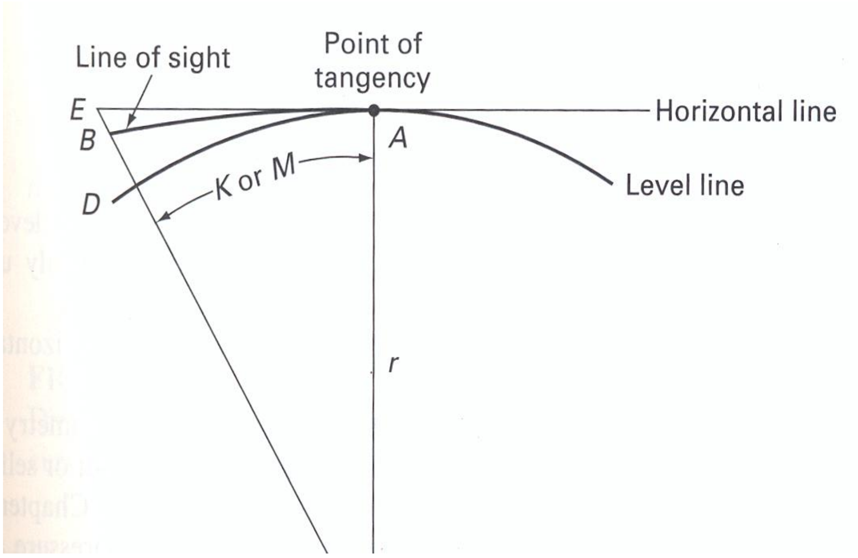


Fig. (2.1) Earth curvature and refraction

(Source : Surveying Theory and Practice , James M & Edward M)

Figure 1 shows a horizontal line tangent at (A) to a level line near the surface of the earth. The vertical distance between the horizontal line and the level line is a measure of the earth's curvature. It varies approximately as the square of the distance from the point of tangency.

In this Figure, let OA = r, the average radius of the earth. Also, let ED = c, the correction for earth curvature. Then (from above source)

$$r^2+AE^2 = (r + c)^2 = r^2 + 2\,rc + c^2 \qquad \text{…………..(2.1)}$$

$$AE^2 = c\,(2r + c) \qquad \text{……………(2.2)}$$

Because c is very small compared to r, a reasonable approximation for earth curvature is

Assuming a mean radius of the earth 6371 km, the curvature correction in meters is

$$C_m = 0.0785\ K^2 \qquad (2.3)$$

In which (K) is the distance from the point of tangency in kilometers. Thus, the curvature correction is 7.9 cm/km. For distances of 30 m the respective corrections would be 0.07 mm.

Owing to the phenomenon of atmospheric refraction, rays of light are refracted, or bent downward slightly. This bending of the rays of light towards the center of the earth tends to diminish the effect of earth curvature by approximately 14 percent. In Fig. (2.1), AB is the refracted line of sight and the distance BD represents the combined effect of curvature and refraction. Let (c & r) =BD be computed by the following equation:

$$(c\ \&\ r) = 0.0675\ K^2 \quad \text{meters} \qquad (2.4)$$

K in kilometers

In most ordinary spirit leveling operations, the line of sight is rarely approximately more than 2 m above the ground, where variations in temperature cause substantial uncertainties in the refractive index of air. Fortunately, most line of sights in leveling are relatively short (about 30 m) and back sight and foresight distances are balanced.

2.1.3 Methods

Difference in elevation may be measured by the following methods:

1. Direct or spirit leveling, by measuring vertical distances directly. Direct leveling is the most precise method of determining elevations and is the one commonly used

2. Indirect or trigonometric leveling, by measuring vertical angles and horizontal or slope distance.

3. Stadia leveling, in which vertical distances are determined by tachometry using the engineer's transit and level rod; plane table and alidade and level rod; or self-reducing tachometer and level rod; plane table and alidade and level rod; or self-reducing

4. Barometric leveling, by measuring the differences in atmospheric pressure at various stations by means of a barometer.

5. Gravimetric leveling, by measuring the differences in gravity at various stations by means of a gravimeter for geodetic purposes.

6. Inertial positioning system, in which an inertial platform has three mutually perpendicular axes, one of which is 'up' so that the system yields elevation as one of the outputs. Vertical accuracies of from 15 to 50 cm in distances of 60 to 100 km respectively, have been reported. The equipment cost extremely high and applications are restricted to very large projects where terrain, weather, time, and access impose special constrains on traditional methods.

7. GPS survey elevations are referenced to the ellipsoid but can be connected to the datum.

2.2 Levelling Applications

Of all the surveying operations used in construction, levelling is the most common. Practically every aspect of a construction project requires some application of the levelling process. The more general are as follows.

2.2.1 Sectional levelling

This type of levelling is used to produce ground profiles for use in the design of roads, railways and pipelines .

In the case of such projects, the route centre-line is set out using pegs at 10 m, 20 m or 30 m intervals. Levels are then taken at these peg positions and at critical points such as sudden changes in ground profiles, road crossings, ditches, bridges, culverts, etc. A plot of these elevations is called a longitudinal section . When plotting, the vertical scale is exaggerated compared with the horizontal, usually in the ratio of 10 : 1. The longitudinal section is then used in the vertical design process to produce formation levels for the proposed route design .

Whilst the above process produces information along a centre-line only, cross-sectional levelling extends that information at 90◦ to the centre-line for 20–30 m each side. At each centre-line peg the levels are taken to all points of interest on either side. Where the ground is featureless, levels at 5 m intervals or less are taken. In this way a ground profile at right angles to the centre-line is obtained. When the design template showing the road details and side slopes is plotted at formation level, a cross-sectional area is produced, which can later be used to compute volumes of earthwork. When plotting cross-sections the vertical and horizontal scales are the same, to permit easy scaling of the area and side slopes

2.3 Contouring

A contour is a horizontal curve connecting points of equal elevation. Contours graphically represent, in a two-dimensional format on a plan or map, the shape or morphology of the terrain. The vertical distance between contour lines is called the contour interval. Depending on the accuracy required, they may be plotted at 0.1 m to 0.5 m intervals in flat terrain and at 1 m to 10 m intervals in undulating terrain .According to (W.Schofield, 2007) the interval chosen depends on:

(1) The type of project involved; for instance, contouring an airstrip requires an extremely small contour interval.

(2) The type of terrain, flat or undulating.

(3) The cost, for the smaller the interval the greater the amount of field data required, resulting in greater expense.

Contours are generally well understood so only a few of their most important properties will be outlined here.

(1) Contours are perpendicular to the direction of maximum slope.

(2) The horizontal separation between contour lines indicates the steepness of the ground. Close spacing defines steep slopes, wide spacing gentle slopes.

(3) Highly irregular contours define rugged, often mountainous terrain.

(4) Delineate the limits of constructed dams, road, railways, tunnels, etc.

(5) Delineate and measure drainage areas.

If the ground is reasonably flat, the optical level can be used for contouring using either the ***direct or indirect*** methods .

2.3.1 Direct Method

In the direct method, the contour to be plotted is actually traced on the ground. Points which happen to fall on a desired contour are only surveyed, plotted and finally joined to obtain the particular contour. This method is slow and tedious and thus used for large scale maps, small contour interval and at high degree of precision. In this method, a benchmark is required in the project area. The level is set up on any commanding position and back sight is taken on the bench mark. Let the back sight reading on the bench mark be 1.485 m. If the reduced level of the bench mark is 100 m, the height of instrument would be 100 + 1.485 = 101.485 m.

To locate the contour of 100.5 m value, the staff man is directed to occupy the position on the ground where the staff reading is 101.485 -100.500 = 0.985 m. Mark all such positions on the ground where the staff reading would be 0.985 m by inserting pegs. Similarly locate the points where the staff reading would be 101.485 -101 = 0.485 m for 101m contour.

The contour of 101.5 m cannot be set from this setting of the instrument because the height of instrument for this setting of the instrument is only 101.485 m. Therefore, locating contours of higher value, the instrument has to be shifted to some other suitable position.

Establish a forward station on a firm ground and take fore sight on it. This point acts as a point of known elevation, for shifting the position of the instrument to another position, from where the work proceeds in the similar manner till the entire area is contoured.

2.3.2 Indirect method

In this method, the spot levels of selected guide points are taken with a level and their levels are computed. The horizontal positions of these points are measured or computed and the points are plotted on the plan. The contours are then drawn by a process called interpolation of contours from the levels of the guide points. The following are the indirect methods are commonly used for locating contours.

Squares or Grid method

Cross section method

2.3.2.1 Squares or Grid method

Squares or Grid method in this method, the area to be surveyed is divided into a grid or series of squares. The grid size may vary from 5 m x 5 m to 25 m x 25 m depending upon the nature of the terrain, the contour interval required and the scale of the map desired. Also, the grids may not be of the same size throughout but may vary depending upon the requirement and field conditions. The grid corners are marked on the ground and spot levels of these comers are determined by leveling. The grid is plotted to the scale of the map and the spot levels of the grid corners are entered. The contours of desired values are then located by interpolation. Special care should be taken to give the spot levels to the salient features of the ground such as hilltops, deepest points of the depressions, and their measurements from respective corners of the grids, for correct depiction of the features. The method is used for large scale mapping and at average precision.

2.3.3 Contour Interval:

The vertical distance between any two consecutive contours is known as a contour interval. For example, if the various consecutive contours are 100m, 98m, 96 m etc., then the contour interval is 2m. This interval depends upon,

- The nature of the ground
- The scale of the map and
- The purpose of survey

Contour interval for flat country are generally small, eg. 0.25m, 0.5m, 0.75 m etc, while For a steep slope in hilly area is greater, eg. 5m, 10m, 15 m etc.

Again ,for a small-scale map, the interval may be of 1m,2m,3m etc. and for large scale map, it may be of 0.25m,0.50m,0.75m etc.

It should be remembered that the contour interval for a particular map is constant.

CHAPTER THREE

DRY PORT

3.1 Dry ports concept

Dry port concept is a considerably novel concept that mainly aims at increasing cost-efficiency and environmental friendliness of transportation system especially seaports' inland access. The idea has theoretically been researched since the late last century, although the most practical dry port research is conducted during the last five or ten years.

The dry port concept is based on a seaport that is directly connected by rail to inland intermodal terminals, where shippers can leave and/or collect their goods in intermodal loading units as if directly at the seaport. In addition to the transshipment that a conventional inland intermodal terminal provides, services such as storage, consolidation, depot, maintenance of containers, customs clearance, and other additional services are also available at dry ports (Roso, 2009 b: 308). Hence, a whole range of administrative activities that could be moved inland with implementation of a dry port. Outsourcing activities from seaport to dry port relieves seaport, and hence seaport can concentrate in its core tasks and competencies.

The dry port concept is an inter-modal transportation system in which the maximum possible amount of freight transportation is accomplished by rail from a seaport or more to inland inter-modal terminals (dry ports) and vice versa. Only the final leg of the door-to-door transportation is carried out by road transport.

There is opinion say that :The dry port concept is still evolving and has not reached to its final shape yet. Besides depending upon its distance to the seaport, the role of the dry port may vary. As a result of this the related literature provides various definitions and point of views. However, by all the researchers it is accepted that a dry port must be directly connected to one or more seaports, must be capable of handling intermodal operations and must carry out the main functions of a port such as storage, consolidation and distribution of the goods.

3.2 Application

Advocates of dry ports concept believe that application of dry ports concept decreases external costs of the transport system such as costs for environmental processing since railroad is environmentally friendlier transport mode than road. This in terms to improve the capacity and cost-efficiency of a transport system; especially seaport's inland access. There are also other benefits of the dry port concept such as reduced congestion, noise and accidents at the whole transportation system.

In an optimal dry port implementation the whole freight transportation between seaport and dry port is carried out by rail. However, this sometimes faces some obstacles due to capacity of rail connection.

Based on most recent literature, dry ports are categorized into three different categories. These are close dry port, midrange dry port and distant dry port. This difference is due to their location from seaport. Close dry ports are located approximately 50 kilometers from seaport. Distant dry ports are located 500 km or over from seaport. Midrange dry ports are situated between close and distant dry ports. All the different dry port categories are presented in figure (3.1) below which also illustrates a comparison of a conventional hinterland transport and an implemented dry port concept.

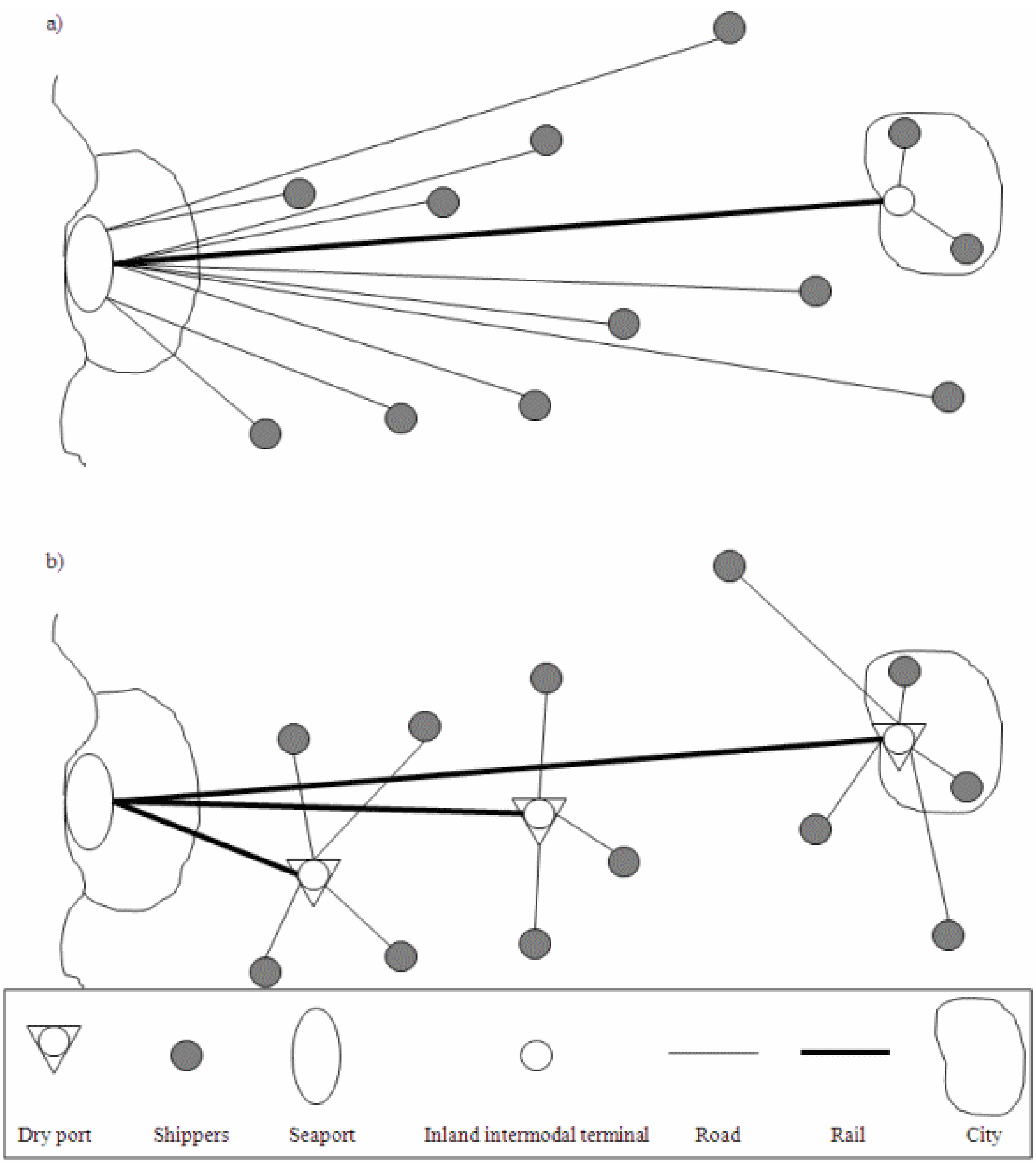


Figure (3.1) Comparison of a conventional hinterland transport and an implemented dry port concept.

Source :(Johan, W.; Roso. V.; and Lumsden, K, Dry Port Concept)

From figure (3.1) it can be seen that the distance traveled by road transport shortens, because shippers can use the nearest dry port instead of always carrying freight to seaport city. Moreover, the number of freight connections to seaports lessens. There are 10 road connections and one rail connection to and from seaport in the upper part of figure (3.1). With dry port solutions, there are only three rail connections to and from seaport. Dry ports relieve the transportation system.

3.3 Classification

Different benefits that dry ports create according to literature are summarized in table (3.1).

	Distance	Midrange	Close
Seaports	Less congestion Expanded hinterland Interface with hinterland	Less congestion Dedicated trains Depot Interface with hinterland	Less congestion Increased capacity Depot Direct loading ship-train
Seaport cities	Less road congestion Land use opportunities	Less road congestion Land use opportunities	Less road congestion Land use opportunities
Rail operators	Economies of scale Gain market share	Day trains Gain market share	Day trains Gain market share

Road operators	Less time in congested roads and terminals	Less time in congested roads and terminals	Less time in congested roads and terminals Avoiding environmental zones
Shippers	Improved seaports access " Environment marketing "	Improved seaports access " Environment marketing "	Improved seaports access
Society	Lower environmental impact Job opportunities Regional development	Lower environmental impact Job opportunities Regional development	Lower environmental impact

Table (3.1) Impacts generated by dry ports for the actors for the transportation system.

Source :(Johan, W.; Roso. V.; and Lumsden, K, Dry Port Concept)

CHAPTER FOUR

INTERPOLATION TECHNIQUES

4.1 Interpolation

The concept of prediction as synonym of interpolation deals with knowing or telling, usually correctly, beforehand what is going to happen. To predict, thus, is usually to foretell with precision of calculation, knowledge or shrewd inference from fact or experience.

Based on this principle, a prediction, or forecasting, is a statement about an uncertain event. It is often, but not always, based upon experience or knowledge.

In statistics, prediction is a part of statistical inference. One particular approach to such inference is known as predictive inference, but the prediction can be undertaken within any of the several approaches to statistics is that it provides a means of transferring knowledge about a sample of population to the whole population, and to other related populations, which is not necessarily the same as prediction over time. When the information is transferred across time, often to specific points in time, the process is known as forecasting.

Statistical techniques used for prediction include regression analysis and time series analysis and their various subcategories such as ordinary least square, logistic regression, autoregressive moving average models, and vector auto-regression models, when these and/or a related generalized set of regression or machine learning methods are deployed in commercial usage, the field is known as predictive analysis.

In many applications, such as time series analysis, it is possible to estimate the models that generate the observations. If models can be expressed as transfer function or in terms of state-space parameters, then smoothed, filtered and predicted data estimates can be calculated. If the underlying generating models are linear, the minimum-variance Kalman Filter and minimum-variance smoother may be used to recover data of interest from noisy measurements. Such techniques rely on one-step-a head predictors (which minimize the variance of the prediction error). When the generating models are nonlinear, then stepwise linearization may be applied with Extended Kalman Filter and smoother recursions. However, in nonlinear cases, optimum minimum-variance performance guarantees no longer apply.

4.2 Prediction Methods

Referring to the definition in the previous paragraph , prediction is usually to foretell with precision of calculation , knowledge or shrewd inference from fact or experience, so some calculated tests in geodesy and Arc GIS Software can be done .

4.2.1 Inverse Distance Weighting

This techniques estimates the "Z" value (Height , Gravity , … , etc) at point "P" by weighting the influence of nearby data points according to their distance from the prediction point and on the selection of the power value " gamma , γ ".

Using the following relation :

$$\mathbf{Z}\,p= \left(\sum (\mathbf{Z}i/\mathbf{d}\, ip^{\gamma}) \right) / \left(\sum (1/ \mathbf{d}\, ip^{\gamma}) \right) \qquad \ldots\ldots\ldots\ldots.. (4.1)$$

Where :

Z_p is the value to be estimated ,

Z_i is known value ,

d_{ip} plan metric distance between the data point,i , and the predicted point ,p, given by :

$$\mathbf{d}_{ip} = \sqrt{((\mathbf{x}_i - \mathbf{x}_p)^2 + (\mathbf{y}_i - \mathbf{y}_p)^2)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4.2)$$

γ is exponent depending on the nature of the field , and

$1/d_{ip}$ is known as the weight ***W*** . ***Excel*** program were used to solve mathematical problems in the classical method .

While in ***Arc GIS*** Software according to (***www.help.arcgis.com***) IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, IDW assumes that each measured point has a local influence that diminishes with distance. The IDW function should be used when the set of points is dense enough to capture the extent of local surface variation needed for analysis. IDW determines cell values using a linear-weighted combination set of sample points. It weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted .The IDW technique calculates a value for each grid node by examining surrounding data points that lie within a user-defined search radius. Some or all of the data points can be used in the interpolation process.

The node value is calculated by averaging the weighted sum of all the points. Data points that lie progressively farther from the node influence the computed value far less than those lying closer to the node show in Figure below

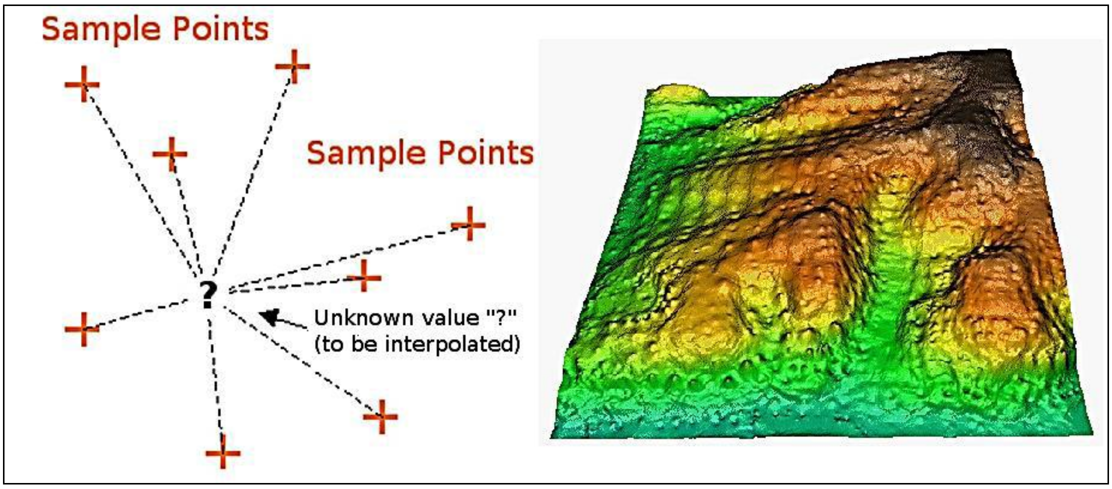


Figure (4.1) Calculating by average points.

4.2.2 Polynomial

This technique is the most widely used surface using this technique follows the assumption that, the height of a point (Z) is a function of its coordinates (x,y), (E.Enzir-2009). Or

$$\mathbf{Z} = f(x, y) \qquad \text{……………………..(4.3)}$$

A mathematical function has to be used . the general mathematical expression of surface with the nth order degree polynomial is

$$\mathbf{Z}i = a0 + a1\ X + a2\ Y + a3\ X\ Y + \ldots + an\ X\ Y \qquad \text{……….(4.4)}$$

Where :

a0 , a1, a3 , …etc are the polynomial coefficients . Each individual term of the general polynomial function has it own characteristics, to make a correct selection of the terms that represent the best model the surveyor must keep in mind the shape produced by each term . in order to determine quadratic and cubic surface equation, the minimum number of the reference points six and nine points respectively

Individual term	**Order of term**	**Description**
$a0$	Zero	Planer
$+ a1\ x + a2\ y$	First	liner
$+ a3\ x^2 + a4\ y^2 + a5\ xy$	Second	Quadratic
$+ a6\ x^3 + a7\ y^3 + a8\ x^2\ y + a9\ x\ y^2$	Third	Cubic
$+ a10\ x^4 + \ldots$etc	Fourth	Quadratic

Table (4.1): Expansion of Polynomial terms

Source : (Kennie and Peter, 1994)

For redundant reference points, the unknown polynomial coefficients ,x^ , can be determined by the least squares method according to the following equation

$$x\hat{}=(A^T A)^{-1} A^T b \qquad \ldots\ldots\ldots\ldots(4.5)$$

where:

A: is the coefficient matrix

B : is the vector of the observations, at reference points

For simplification, the four terms bilinear polynomial in the form of the following expression are current in use

$$\mathbf{Z}i = a0 + a1\mathbf{x} + a2\,\mathbf{y} \quad \ldots\ldots\ldots\ldots\ldots.. \quad (4.6)$$

$$Zi = a_0 + a_1\,x + a_2\,y + a_3\,xy \quad \ldots\ldots\ldots\ldots\ldots \quad (4.7)$$

4.2.3 Kriging

This one of the various techniques used in the Geographical Information System Software, (***Arc GIS***) , and it defined as geostatistical method based on statistical models that include autocorrelation ,(Arcmap,ESRI,2014) ,(http//help.arcgis.com) with considering both the distance and degree of variation between known data points when estimating values in unknown areas , (M .M.Alamin,2016) .

In Arc GIS the Kriging tools fits a mathematical function to specified function to specified number of points , or all points within a specified radius, to determine the output value for each location . Kriging is most appropriate when there is a spatially correlated distance or directional bias in the data ,the predicted values are derived from measure of relationship in samples using sophisticated weighted average technique . It uses a search radius that can be fixed or variable . the generated cell values can exceed value range of sample and the surface does not pass through samples .

Arc Hydro Tools

It is another technique in ***Arc GIS*** . The Hydrology tools are used to model the flow of water across a surface.

Information about the shape of the earth's surface is useful for many fields, such as regional planning, agriculture, and forestry. These fields require an understanding of how water flows across an area and how changes in that area may affect that flow.

When modeling the flow of water, you may want to know where the water came from and where it is going.

They are some steps according to the tools to explain how to use the hydrologic analysis functions to help model the movement of water across a surface, the concepts and key terms regarding drainage systems and surface processes, how the tools can be used to extract hydrologic information from a digital elevation model (DEM), and sample hydrologic analysis applications.

4.3 Statistic Evaluation (RMSE) :

To assessing the computed and created data the ***Root Mean Square Error*** **(RMSE),** as statistical method will be done, in form :

$$RMSE = \sqrt{\left(\sum \mathbf{v}^2 \right) / n(n-1)} \;\ldots\ldots \qquad (4.10)$$

Where v is the residual between observed Z value and computed Z value .

CHAPTER FIVE

DATA COLLECTION AND PROCESSING

5.0 Seloum Dry Port

Seloum dry port, an under-construction Sudanese dry port, is under Sea ports corporation authority and it was created after Seloum region (10) kilometers west of the Port Sudan figures (5.1) and (5.2) , to provide integrated logistic services to reduce the duration of the container port south court yards. Currently work in the activity of storage containers discarded , and the future support logistics for export and import . It is about 8000 km^2 is the whole area of the dry port . the maximum height is about 110 meter , while minimum height is about 69 meter , differentiate 41 meter , area (3250*2450)m^2 ,and location coordinates as table below (WGS84,UTM Projection , 37 North Zone):

	Easting Coordinate	**Northing Coordinate**
N.W Corner	306057.0606	2156965.5587
N.E Corner	308722.0243	2154934.8404
S.W Corner	304846.5329	2155373.4876
S.E Corner	307040.1387	2152726.3825

Table (5.1) **:** Location Coordinates of Seloum Dry Port

Source : Sea Ports Corporation Reports

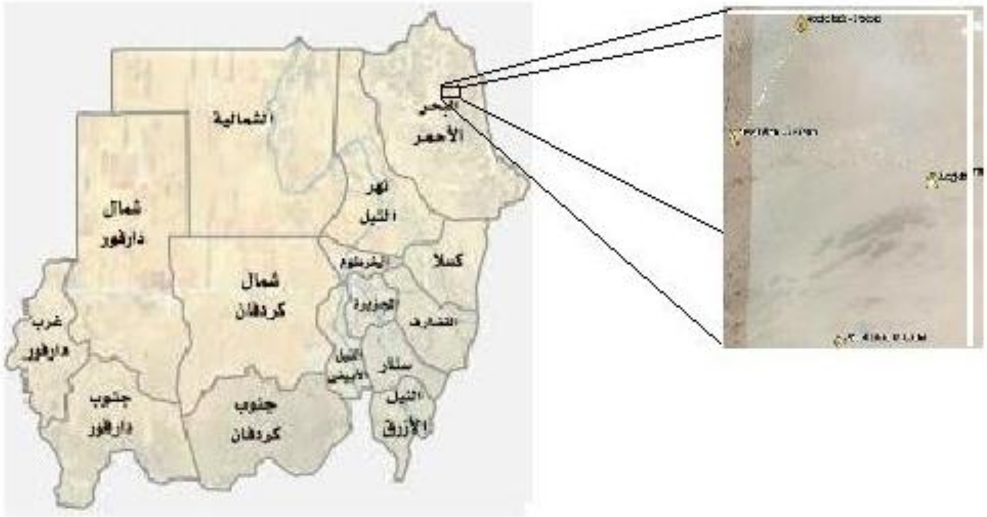


Figure (5.1): Study area of Seloum dry port

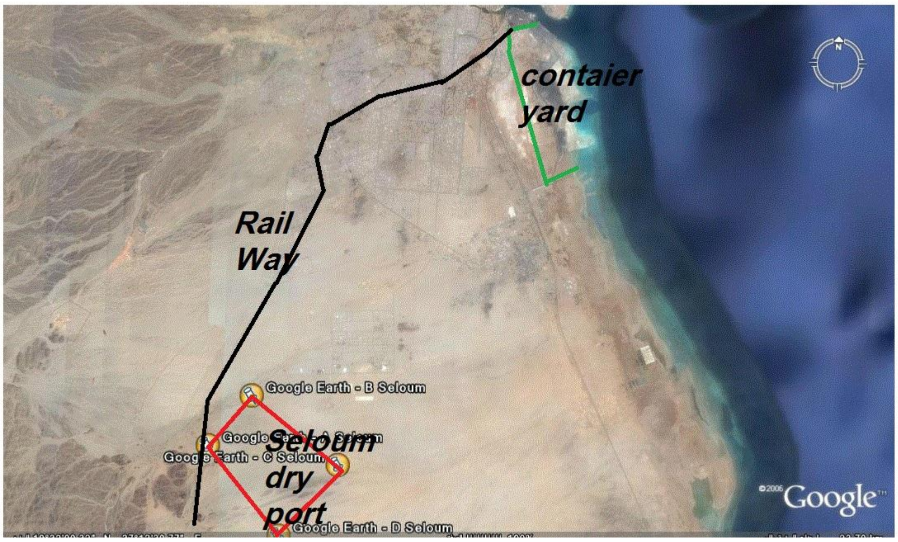


Figure (5.2) : Railway between container yard and dry port

5.1 **Data Collection**

Survey field work has especial procedures to be in mind like defining coordinates system and clicking old data in the site which well be as references .

5.1.1 Coordinates

For horizontal coordinates system, WGS 84 as ellipsoid reference was applied (UTM Projection, 37 North).while, for vertical coordinate, Coastal Datum of Inland Container Depot was applied, which created from Sudan railway Datum.

5.1.2 Existing Data

The horizontal control points (M01, M02, and SB9) which provided by FHDI Engineering Co, Ltd (Chinese Company). Where preserved in a good condition

There were 5 points in 3 Dimensions as control points were in state precision, (C2, C3, C5, C7, and C9) which provide FHDI.

5.2 Practical work

5.2.1 Instrument was used

Two sets of Leica 1200, dual frequency GPS were used. Navigators GPS was used to mention route accessed at site.

5.2.2 Inspections

With consideration of Real Time Kinematics Technique needs, the height of (C2,C3,C5, and C7) , points were checked from C9 as reference point .

Table(5.2) :Existing Data in Seloum

P.Id	EAST	NORTH	ELEVATION	CODE
1	308435.812	2154564.517	75.294	C2
2	307933.992	2153725.853	81.946	C3
3	306067.7	2153820.045	104.168	C5
4	305500.597	2155428.815	103.474	C7
5	306779.991	2156514.32	88.658	C9

Table (5.3):Checking of existing Data from C9

P.Id	EAST	NORTH	ELEVATION	CODE
1	308435.783	2154564.552	75.311	C2
2	307934.026	2153725.857	81.942	C3
3	306067.734	2153820.106	104.184	C5
4	305500.574	2155428.832	103.501	C7

5.2.3 Field method

Two parallel lines to North and South fences with approximately 250 meter interval distance between points , and two inner lines were observed covering whole area . 4 points for the corners and 55 points for the field .

5.3 Data collected

Table (5.4) in appendix presents the collected data as rover station sheet which content 60 points in three dimensions data and codes .(59 points + base station data C9) .

CHAPTER SIX

ANALYSIS AND RESULTS

6.1 Analysis

The necessary procedures were done as the requirement of tests hold to create best results for H values.

6.1.1 Geodesy Testing

In this research two main geodesy tests have been addressed, two sub testes in every one .General procedure is to select four points as control points to test four other points as testing points and then improve to eight control pints to test eight testing point beside all data points. The application of equations using the Excel package program.

6.1.1.1 Inverse Distance Weighting (IDW) Tests

The equations (4.1) and (4.2) mention in chapter four, the power gama (γ) was 1.85 in first test. Applying equation (4.2) using Office Excel program to get the distance between every chick point and all control points. While the selection and testing of the power gama(γ) was crucial and it is necessary for the application of the (4.2) equation .

First Test

In the first test power gama (γ) was 1.85 , table (6.1) show the eight control pointes, the eight testing points, H value (observed and computed) , and residual .while table (A-1) in Appendix show IWD first test H computed values .

Table (6.1) : IWD first test results for the eight control points

Control Points			**Testing Points**				
East	**North**	**H**	**East**	**North**	**Obs H**	**Com H**	**Residual**
308710.5	2154928	69.528	307724.6	2154846	80.07	79.636	0.434
307042.9	2152737	95.722	308154.9	2155359	74.79	74.837	-0.047
304856.5	2155378	109.99	307561.2	2154983	81.499	82.034	-0.535
306051.8	2156955	94.82	306094.7	2156122	96.68	96.772	-0.092
306984.4	2156253	87.29	305133.8	2155748	107.66	107.491	0.169
305520.3	2155490	103.26	304979.9	2155241	108.8	109.593	-0.793
305918.6	2154098	104.17	307046.4	2153852	91.84	91.961	-0.121
308150.3	2154489	76.87	306792.6	2154309	92.63	92.006	0.624

Second Test

Second test with this technique were done with two specific additional points and 2.9 power gama (γ) to investigate various in topography and power affection. Table (6.3) show the result of ten control points at the eight testing points. More over, table (A-2) in Appendix exposes the all points computed H value by the second test .

Table (6.2): IDW second test

Control Points			**Testing Points**				
East	**North**	**H**	**East**	**North**	**Obs H**	**Com H**	**Residual**
308710.5	2154928	69.528	307724.6	2154846	80.07	79.491	0.579
307042.9	2152737	95.722	308154.9	2155359	76.79	76.509	0.281

304856.5	2155378	109.99	307561.2	2154983	81.499	83.301	-1.802
306051.8	2156955	94.82	306094.7	2156122	96.68	95.715	0.965
306984.4	2156253	87.29	305133.8	2155748	107.66	105.912	1.748
305520.3	2155490	103.26	304979.9	2155241	108.8	109.37	-0.57
305918.6	2154098	104.17	307046.4	2153852	92.49	92.582	-0.092
308150.3	2154489	76.87	308388.1	2155178	72.93	71.747	1.183
305277.3	2154868	104.09					
307092.1	2155352	85.64					

6.1.1.2 Polynomial tests

In this technique two equations were tested to create computed H value which are derived from the mathematical function (4.6) in chapter four, give results in table (6.5) as applying four points at mention equation. Table (A-3) in the Appendix show all H values in this test.

Table (6.3): first polynomial test

Control Points				**Test Points**				
East	**North**	**Obs H**	**Com H**	**East**	**North**	**Obs H**	**Com H**	**Residual**
308710	2154928	69.527	69.528	306095	2156122	96.682	95.537	-1.145
307043	2152737	95.721	95.712	307561	2154983	81.499	82.7799	1.2809
304857	2155378	109.985	109.991	307725	2154846	80.073	81.3881	1.3151
306052	2156955	94.822	94.927	307046	2153852	91.842	91.6354	-0.2066
				306793	2154309	92.629	93.1006	0.4715
				305134	2155748	107.659	107.1	-0.5591
	POLY TEST1			304980	2155241	108.766	110.23	1.4643

				308155	2155359	74.79	75.2224	0.4324

and (4.7) in the fourth chapter also which create results shown in table (6.7) below, while table (A-4) in the appendix show the all H computed value for collected points

it is necessary to mention that all computation for matrixes need were done using ***Office Excel package program*** .

Table (6.4): Second polynomial test

Control Points				**Test Points**				
East	**North**	**Obs H**	**Com H**	**East**	**North**	**Obs H**	**Com H**	**Residual**
308710.5	2154928	69.527	69.671	306094.7	2156122	96.682	93.8247	-2.8573
307042.9	2152737	95.721	95.866	307561.2	2154983	81.499	81.9674	0.4684
304856.5	2155378	109.985	110.13	307724.6	2154846	80.073	80.6658	0.5928
306051.8	2156955	94.822	94.964	307046.4	2153852	91.842	91.6554	-0.1866
				306792.6	2154309	92.629	92.8047	0.1757
				305133.8	2155748	107.66	105.6428	-2.0162
	POLY TEST2			304979.9	2155241	108.77	109.2221	0.4561
				308154.9	2155359	74.79	74.1617	-0.6283

6.1.2 GIS Kriging Test :

This technique is one of the ***ArcGIS*** package program software tools. It done with ***arcgis 10.2*** software procedure and same selected points in geodesy testes. Table (6.5) below show H values computed by using this technique.

Table (6.5):Kriging test

ID	East	North	Obs H	Kriging	Residual
57	308710.5	2154928	69.5277	69.528	-0.0003
18	307042.9	2152737	95.7215	95.717	0.0045
15	304856.5	2155378	109.9851	109.99	-0.0049
8	306051.8	2156955	94.822	94.821	0.001
33	306984.4	2156253	87.2937	87.5252	-0.2315
28	305520.3	2155490	103.2658	103.2729	-0.0071
21	305918.6	2154098	104.1758	104.1476	0.0282
42	308150.3	2154489	76.8741	76.8771	-0.003

6.1.2 GIS Hydro Tools

This technique is one of the ***ArcGIS*** package program software tools . It done with ***arcgis 10.3*** . According to the need of the water flow direction in study area , so it deals with some specific tools in ***Spatial Analyst Tools\Hydrology*** like :

Fill

Fills sinks in a surface raster to remove small imperfections in the data.

Flow Direction

Creates a raster of flow direction from each cell to its steepest down slope neighbor.

Flow Accumulation

Creates a raster of accumulated flow into each cell. A weight factor can optionally be applied.

Stream Link

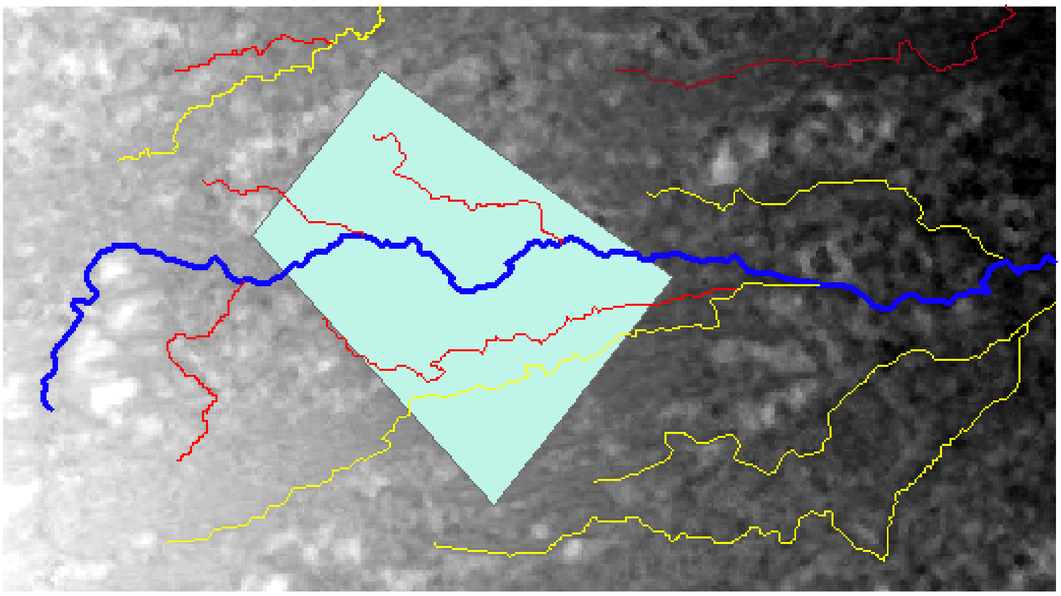
Assigns unique values to sections of a raster linear network between intersections.

Stream Order

Assigns a numeric order to segments of a raster representing branches of a linear network.

According to above procedure we get the figure (6.1) below and (A-2) (A-3) figures in appendix

Figure (6.1) show water direction at study area



6.1.3 Evaluation of the Predicting Data

To assessing the computed and created data the ***Root Mean Square Error*** **(RMSE)** (4.8) equation in chapter four were done, it was done for all data predicted as individual for every test . which shown as tables in the appendix an summarized in the table (6.6) below . More over , residuals between observed and computed H values in all testes which used to create RMSEs are shown as individual table in the appendix

6.2 Results

According to testes mentioned above, tables and figures were got

6.2.1 RMSE Evaluating

The evaluating using by applying the equation (4.5) which mention in chapter four, where residuals value between observed and computed data (v), while (n) is the numbers of field data.

The results were advert to possibility of reducing field work.

Predicting Method	***RMSE***
Geodesy IDW TEST 1	**0.35 m**
Geodesy IDW TEST 2	**0.27 m**
Geodesy Polynomial Test 1	**0.184 m**
Geodesy Polynomial Test 2	**0.248 m**
GIS Kriging Test	**0.16 m**

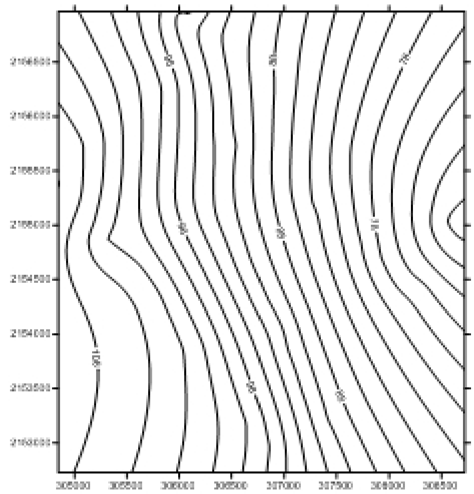
Table (6.6) : evaluating using the ***Root Mean Square Error*** **(RMSE)**

6.2.2 Contour Maps

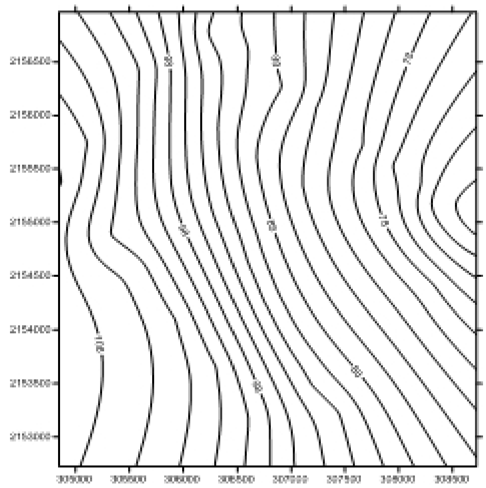
The comparing between techniques is one of the research targets, so a practical incident need so, use of the data predicted in creating contour maps helpful .

From the observed data a contour map was created with two meter interval contour line , while five contour maps were created from the computed data with same interval contour line.

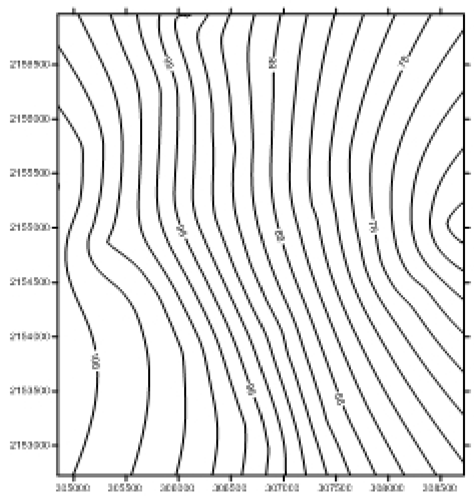
The figures (6.1) and (6.2) below are shown contour maps of observed data and predicted data



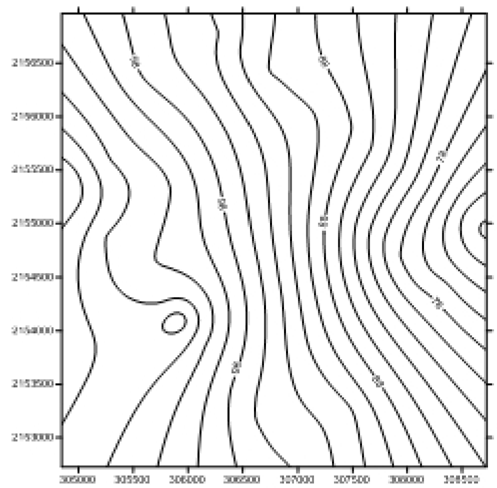
Observed Data Contour



Predicted ploynomial 1 Contour

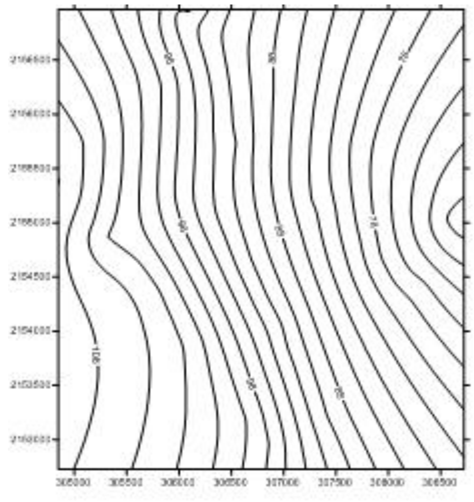


Observed Data Contour

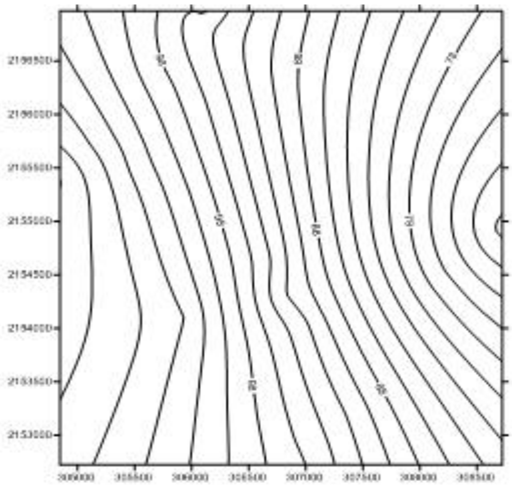


Predicted IWD 2 Contour

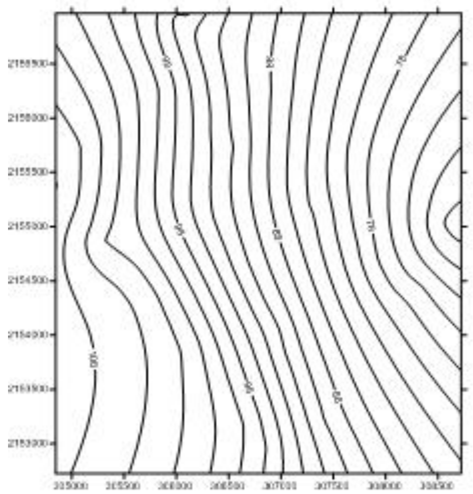
Figure (6.1) Observed contour map verses Geodesy contour maps



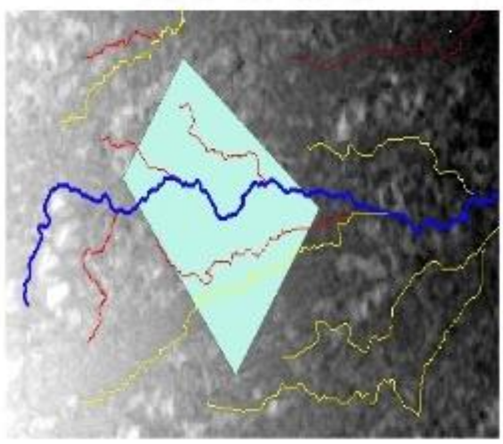
Observed Data Contour



GIS Kringing Contour



Observed Data Contour



GIS Hydrogy Contour

Figure (6.2) Observed contour map verses GIS contour maps

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion:

According to the Processing, analysis, and result in this study it can concluded that:

1- The mathematical method creates ±0.184 m result of spot heights.
2- The GIS (Kriging) create ±0.16 m result of spot height.
3- The integrated polynomial equation is a prove technique as well as Software.
4- Predicting using various methods can reduce field work in surveying works.
5- The surface can guide to select the compatible interpolation method.

7.2 Recommendations:

1- Site investigation is very important for site work and output techniques.
2- The strategic projects must be from whole to the part, not from part to the whole.
3- Decision maker prospect have to balance between budget and accuracy aim.
4- Inspect of Artificial Neural Networks of deterministic quantities.

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APPENDIX

Point ID	***Easting***	***Northing***	***Elevation***	***Point Code***
1	304846.533	2155373.49	110.0802	SCOR SW
2	307040.139	2152726.38	95.7844	SCOR SE
3	306057.061	2156965.56	97.4991	SCOR NW
4	308722.024	2154934.84	69.5064	SCOR NE
5	305666.292	2156442.78	101.1529	MSP55
6	305887.892	2156277.49	99.388	MSP54
7	306094.686	2156122.13	96.6816	MSP53
8	306257.856	2155995.14	94.8364	MSP52
9	306395.422	2155880.18	93.1407	MSP51
10	306569.089	2155734.92	91.7773	MSP50
11	306744.833	2155617.87	89.4918	MSP49
12	307092.103	2155352.36	85.6351	MSP48
13	307263.485	2155213.02	84.017	MSP47
14	307389.291	2155114.57	83.3013	MSP46
15	307561.211	2154982.76	81.4987	MSP45
16	307724.566	2154845.62	80.0732	MSP44
17	307925.077	2154690.61	78.0323	MSP43

18	308150.259	2154488.99	76.8741	MSP42
19	308294.517	2154397.34	76.9173	MSP41
20	307415.291	2153221.35	89.9545	MSP40
21	307202.606	2153492.71	91.4604	MSP39
22	307046.368	2153851.94	92.4924	MSP38
23	306942.741	2154041.36	92.595	MSP37
24	306792.558	2154308.89	92.6289	MSP36
25	306640.309	2154633.95	92.6784	MSP35
26	306576.168	2154856.98	92.5323	MSP34
27	306280.004	2155087.05	94.6973	MSP33
28	306047.732	2155231.86	96.9343	MSP32
29	305873.497	2155323.54	99.0338	MSP31
30	305695.493	2155402.95	101.1845	MSP30
31	305520.316	2155489.69	103.2658	MSP29
32	305317.084	2155616.5	105.5703	MSP28
33	305133.763	2155748.14	107.6595	MSP27
34	304856.513	2155378.09	109.9851	MSP26
35	304979.876	2155241.01	108.7657	MSP25
36	305165.887	2155014.59	106.229	MSP24
37	305277.275	2154868.01	104.0877	MSP23
38	305544.69	2154560.63	105.0867	MSP22
39	305731.749	2154332.43	104.9678	MSP21
40	305918.564	2154097.93	104.1758	MSP20

41	306111.289	2153878.66	103.4217	MSP19
42	306298.946	2153653.19	101.8768	MSP18
43	306488.128	2153426.62	100.6604	MSP17
44	306674.639	2153196.64	99.6715	MSP16
45	306855.06	2152959.91	98.049	MSP15
46	307042.86	2152737.42	95.7215	MSP14
47	308710.452	2154928.21	69.5277	MSP13
48	308584.877	2155035.94	69.6805	MSP12
49	308388.117	2155178.23	72.3049	MSP11
50	308154.871	2155358.58	74.7903	MSP10
51	307921.442	2155536.66	77.1319	MSP9
52	307684.888	2155715.97	79.4776	MSP8
53	307450.875	2155894.28	82.2298	MSP7
54	307218.262	2156071	84.6844	MSP6
55	306984.418	2156252.97	87.2937	MSP5
56	306745.112	2156429.04	89.3139	MSP4
57	306516.477	2156603.39	91.1903	MSP3
58	306289.101	2156778.11	92.8078	MSP2
59	306051.842	2156955.21	94.822	MSP1
60	306779.991	2156514.32	88.658	C9

Table (5.4) : the collected data form field

Point Code	Easting(m)	Northing(m)	Observed H(m)	Computed H(m)
SCOR SW	304846.533	2155373.488	*110.08*	109.98
SCOR SE	307040.139	2152726.383	*95.784*	95.72
SCOR NW	306057.06	2156965.559	*97.499*	94.82
SCOR NE	308722.024	2154934.84	*69.506*	69.54
MSP55	305666.292	2156442.78	*101.153*	96.97
MSP54	305887.892	2156277.493	*99.388*	96.92
MSP53	306094.686	2156122.132	*96.681*	96.71
MSP52	306257.856	2155995.142	*94.836*	96.1
MSP51	306395.422	2155880.183	*93.14*	95.55
MSP50	306569.089	2155734.921	*91.777*	94.6
MSP49	306744.833	2155617.87	*89.492*	93.49
MSP48	307092.103	2155352.364	*85.635*	90.38
MSP47	307263.485	2155213.021	*84.017*	88.18
MSP46	307389.291	2155114.572	*83.301*	86.3
MSP45	307561.211	2154982.764	*81.499*	83.5
MSP44	307724.566	2154845.622	*80.073*	80.77

MSP43	307925.077	2154690.61	*78.032*	78.09
MSP42	308150.259	2154488.994	*76.874*	76.87
MSP41	308294.517	2154397.341	*76.917*	77.04
MSP40	307415.291	2153221.348	*89.954*	92.97
MSP39	307202.606	2153492.712	*91.46*	92.62
MSP38	307046.368	2153851.935	*91.842*	92.47
MSP37	306942.741	2154041.355	*92.595*	93.25
MSP36	306792.558	2154308.892	*92.629*	94.79
MSP35	306640.309	2154633.947	*92.678*	95.97
MSP34	306576.168	2154856.982	*92.532*	96.14
MSP33	306280.004	2155087.046	*94.697*	98.5
MSP32	306047.732	2155231.856	*96.934*	100.37
MSP31	305873.497	2155323.544	*99.034*	101.78
MSP30	305695.493	2155402.953	*101.184*	102.9
MSP29	305520.316	2155489.692	*103.265*	103.26
MSP28	305317.084	2155616.504	*105.57*	103.64
MSP27	305133.763	2155748.136	*107.66*	104.68
MSP26	304856.513	2155378.086	*109.985*	109.99
MSP25	304979.876	2155241.013	*108.765*	108.58
MSP24	305165.887	2155014.586	*106.229*	105.58
MSP23	305277.275	2154868.006	*104.087*	103.69
MSP22	305544.69	2154560.628	*105.086*	102.18
MSP21	305731.749	2154332.434	*104.968*	102.99

MSP20	305918.564	2154097.931	*104.176*	107.17
MSP19	306111.289	2153878.659	*103.422*	102.61
MSP18	306298.946	2153653.189	*101.876*	99.6
MSP17	306488.128	2153426.616	*100.66*	96.93
MSP16	306674.639	2153196.64	*99.671*	95.51
MSP15	306855.06	2152959.914	*98.049*	95.43
MSP14	307042.86	2152737.417	*95.722*	95.72
MSP13	308710.452	2154928.205	*69.528*	69.53
MSP12	308584.877	2155035.937	*69.68*	70.75
MSP11	308388.117	2155178.225	*72.304*	74.44
MSP10	308154.871	2155358.577	*74.79*	78.69
MSP9	307921.442	2155536.664	*77.132*	82.54
MSP8	307684.888	2155715.973	*79.478*	85.9
MSP7	307450.875	2155894.283	*82.23*	88.38
MSP6	307218.262	2156071.001	*84.684*	89.62
MSP5	306984.418	2156252.969	*87.294*	89.75
MSP4	306745.112	2156429.044	*89.314*	89.89
MSP3	306516.477	2156603.386	*91.19*	91.57
MSP2	306289.101	2156778.109	*92.808*	93.98
MSP1	306051.842	2156955.208	*94.822*	94.81

Table (6.2) : IWD first test result for H value

Point Code	Easting	Northing	Observed H	Computed H
SCOR SW	304846.533	2155373.49	*110.0802*	110.17
SCOR SE	307040.139	2152726.38	*95.7844*	95.858
SCOR NW	306057.061	2156965.56	*97.4991*	100.178
SCOR NE	308722.024	2154934.84	*69.5064*	69.483
MSP55	305666.292	2156442.78	*101.1529*	105365
MSP54	305887.892	2156277.49	*99.388*	101.986
MSP53	306094.686	2156122.13	*96.6816*	97.413
MSP52	306257.856	2155995.14	*94.8364*	96.862
MSP51	306395.422	2155880.18	*93.1407*	94.391
MSP50	306569.089	2155734.92	*91.7773*	94.014
MSP49	306744.833	2155617.87	*89.4918*	91.683
MSP48	307092.103	2155352.36	*85.6351*	85.634
MSP47	307263.485	2155213.02	*84.017*	82.354
MSP46	307389.291	2155114.57	*83.3013*	81.153
MSP45	307561.211	2154982.76	*81.4987*	79.708
MSP44	307724.566	2154845.62	*80.0732*	80.656
MSP43	307925.077	2154690.61	*78.0323*	79.004
MSP42	308150.259	2154488.99	*76.8741*	76.878

MSP41	308294.517	2154397.34	*76.9173*	77.034
MSP40	307415.291	2153221.35	*89.9545*	85.679
MSP39	307202.606	2153492.71	*91.4604*	89.512
MSP38	307046.368	2153851.94	*91.8424*	91.755
MSP37	306942.741	2154041.36	*92.595*	91.79
MSP36	306792.558	2154308.89	*92.6289*	90.528
MSP35	306640.309	2154633.95	*92.6784*	94.189
MSP34	306576.168	2154856.98	*92.5323*	92.505
MSP33	306280.004	2155087.05	*94.6973*	92.465
MSP32	306047.732	2155231.86	*96.9343*	93.019
MSP31	305873.497	2155323.54	*99.0338*	95.428
MSP30	305695.493	2155402.95	*101.1845*	99.129
MSP29	305520.316	2155489.69	*103.2658*	103.271
MSP28	305317.084	2155616.5	*105.5703*	107.38
MSP27	305133.763	2155748.14	*107.6595*	109.409
MSP26	304856.513	2155378.09	*109.9851*	109.98
MSP25	304979.876	2155241.01	*108.7657*	108.162
MSP24	305165.887	2155014.59	*106.229*	108.108
MSP23	305277.275	2154868.01	*104.0877*	104.086
MSP22	305544.69	2154560.63	*105.0867*	106.353
MSP21	305731.749	2154332.43	*104.9678*	106.006
MSP20	305918.564	2154097.93	*104.1758*	104.182
MSP19	306111.289	2153878.66	*103.4217*	102.994

MSP18	306298.946	2153653.19	*101.8768*	101.885
MSP17	306488.128	2153426.62	*100.6604*	103.001
MSP16	306674.639	2153196.64	*99.6715*	103.323
MSP15	306855.06	2152959.91	*98.049*	100.398
MSP14	307042.86	2152737.42	*95.7215*	95.722
MSP13	308710.452	2154928.21	*69.5277*	69.328
MSP12	308584.877	2155035.94	*69.6805*	69.652
MSP11	308388.117	2155178.23	*72.3049*	72.86
MSP10	308154.871	2155358.58	*74.7903*	73.071
MSP9	307921.442	2155536.66	*77.1319*	72.354
MSP8	307684.888	2155715.97	*79.4776*	73.666
MSP7	307450.875	2155894.28	*82.2298*	77.73
MSP6	307218.262	2156071	*84.6844*	82.039
MSP5	306984.418	2156252.97	*87.2937*	87.298
MSP4	306745.112	2156429.04	*89.3139*	90.838
MSP3	306516.477	2156603.39	*91.1903*	90.901
MSP2	306289.101	2156778.11	*92.8078*	91.046
MSP1	306051.842	2156955.21	*94.822*	94.824

Table : (6.4) IWD Second test

Point Code	Easting(m)	Northing(m0	Observed H(m)	Computed H(m)
SCOR SW	304846.533	2155373.488	*110.08*	110.233
SCOR SE	307040.139	2152726.383	*95.784*	95.918
SCOR NW	306057.06	2156965.559	*97.499*	94.865
SCOR NE	308722.024	2154934.84	*69.506*	69.485
MSP55	305666.292	2156442.78	*101.153*	101.315
MSP54	305887.892	2156277.493	*99.388*	97.918
MSP53	306094.686	2156122.132	*96.681*	94.982
MSP52	306257.856	2155995.142	*94.836*	92.834
MSP51	306395.422	2155880.183	*93.14*	91.152
MSP50	306569.089	2155734.921	*91.777*	89.189
MSP49	306744.833	2155617.87	*89.492*	87.289
MSP48	307092.103	2155352.364	*85.635*	84.116
MSP47	307263.485	2155213.021	*84.017*	82.833
MSP46	307389.291	2155114.572	*83.301*	81.978
MSP45	307561.211	2154982.764	*81.499*	80.935
MSP44	307724.566	2154845.622	*80.073*	80.173
MSP43	307925.077	2154690.61	*78.032*	79.355
MSP42	308150.259	2154488.994	*76.874*	78.926
MSP41	308294.517	2154397.341	*76.917*	78.494

MSP40	307415.291	2153221.348	*89.954*	92.292
MSP39	307202.606	2153492.712	*91.46*	91.837
MSP38	307046.368	2153851.935	*91.842*	91.079
MSP37	306942.741	2154041.355	*92.595*	90.986
MSP36	306792.558	2154308.892	*92.629*	91.124
MSP35	306640.309	2154633.947	*92.678*	91.401
MSP34	306576.168	2154856.982	*92.532*	91.397
MSP33	306280.004	2155087.046	*94.697*	93.95
MSP32	306047.732	2155231.856	*96.934*	96.318
MSP31	305873.497	2155323.544	*99.034*	98.252
MSP30	305695.493	2155402.953	*101.184*	100.339
MSP29	305520.316	2155489.692	*103.265*	102.499
MSP28	305317.084	2155616.504	*105.57*	105.189
MSP27	305133.763	2155748.136	*107.66*	107.816
MSP26	304856.513	2155378.086	*109.985*	110.133
MSP25	304979.876	2155241.013	*108.765*	108.273
MSP24	305165.887	2155014.586	*106.229*	105.65
MSP23	305277.275	2154868.006	*104.087*	104.2
MSP22	305544.69	2154560.628	*105.086*	101.239
MSP21	305731.749	2154332.434	*104.968*	99.509
MSP20	305918.564	2154097.931	*104.176*	98.085
MSP19	306111.289	2153878.659	*103.422*	96.92
MSP18	306298.946	2153653.189	*101.876*	96.094

MSP17	306488.128	2153426.616	*100.66*	95.563
MSP16	306674.639	2153196.64	*99.671*	95.356
MSP15	306855.06	2152959.914	*98.049*	95.498
MSP14	307042.86	2152737.417	*95.722*	95.864
MSP13	308710.452	2154928.205	*69.528*	69.669
MSP12	308584.877	2155035.937	*69.68*	69.681
MSP11	308388.117	2155178.225	*72.304*	72.305
MSP10	308154.871	2155358.577	*74.7903*	71.739
MSP9	307921.442	2155536.664	*77.1319*	73.136
MSP8	307684.888	2155715.973	*79.4776*	74.859
MSP7	307450.875	2155894.283	*82.2298*	76.855
MSP6	307218.262	2156071.001	*84.6844*	79.134
MSP5	306984.418	2156252.969	*87.2937*	81.702
MSP4	306745.112	2156429.044	*89.3139*	84.675
MSP3	306516.477	2156603.386	*91.1903*	87.78
MSP2	306289.101	2156778.109	*92.8078*	91.147
MSP1	306051.842	2156955.208	*94.822*	94.963

Table (6.5): from first polynomial test

Point Code	Easting(m)	Northing(m)	Observed H(m)	Computed H(m)
SCOR SW	304846.533	2155373.49	*110.08*	110.1778
SCOR SE	307040.139	2152726.38	*95.784*	95.7641
SCOR NW	306057.06	2156965.56	*97.499*	91.137
SCOR NE	308722.024	2154934.84	*69.506*	69.4401
MSP55	305666.292	2156442.78	*101.153*	97.2816
MSP54	305887.892	2156277.49	*99.388*	95.4941
MSP53	306094.686	2156122.13	*96.681*	93.8247
MSP52	306257.856	2155995.14	*94.836*	92.5199
MSP51	306395.422	2155880.18	*93.14*	91.4458
MSP50	306569.089	2155734.92	*91.777*	90.0868
MSP49	306744.833	2155617.87	*89.492*	88.5989
MSP48	307092.103	2155352.36	*85.635*	85.7718
MSP47	307263.485	2155213.02	*84.017*	84.007
MSP46	307389.291	2155114.57	*83.301*	83.378
MSP45	307561.211	2154982.76	*81.499*	81.9675
MSP44	307724.566	2154845.62	*80.073*	80.6658
MSP43	307925.077	2154690.61	*78.032*	79.0162
MSP42	308150.259	2154488.99	*76.874*	77.2538
MSP41	308294.517	2154397.34	*76.917*	75.9901

MSP40	307415.291	2153221.35	*89.954*	89.8311
MSP39	307202.606	2153492.71	*91.46*	91.217
MSP38	307046.368	2153851.94	*91.842*	91.6554
MSP37	306942.741	2154041.36	*92.595*	92.1167
MSP36	306792.558	2154308.89	*92.629*	92.8047
MSP35	306640.309	2154633.95	*92.678*	93.3005
MSP34	306576.168	2154856.98	*92.532*	93.1946
MSP33	306280.004	2155087.05	*94.697*	95.5958
MSP32	306047.732	2155231.86	*96.934*	97.6019
MSP31	305873.497	2155323.54	*99.034*	99.1657
MSP30	305695.493	2155402.95	*101.184*	100.8132
MSP29	305520.316	2155489.69	*103.265*	102.4004
MSP28	305317.084	2155616.5	*105.57*	104.1419
MSP27	305133.763	2155748.14	*107.66*	105.6428
MSP26	304856.513	2155378.09	*109.985*	110.0516
MSP25	304979.876	2155241.01	*108.765*	109.222
MSP24	305165.887	2155014.59	*106.229*	108.0397
MSP23	305277.275	2154868.01	*104.087*	107.3694
MSP22	305544.69	2154560.63	*105.086*	105.584
MSP21	305731.749	2154332.43	*104.968*	104.3758
MSP20	305918.564	2154097.93	*104.176*	103.1864
MSP19	306111.289	2153878.66	*103.422*	101.8689
MSP18	306298.946	2153653.19	*101.876*	100.6229

MSP17	306488.128	2153426.62	*100.66*	99.3573
MSP16	306674.639	2153196.64	*99.671*	98.1264
MSP15	306855.06	2152959.91	*98.049*	96.9804
MSP14	307042.86	2152737.42	*95.722*	95.6942
MSP13	308710.452	2154928.21	*69.528*	69.5896
MSP12	308584.877	2155035.94	*69.68*	70.5902
MSP11	308388.117	2155178.23	*72.304*	72.2459
MSP10	308154.871	2155358.58	*74.7903*	74.1617
MSP9	307921.442	2155536.66	*77.1319*	76.0806
MSP8	307684.888	2155715.97	*79.4776*	78.0222
MSP7	307450.875	2155894.28	*82.2298*	79.9329
MSP6	307218.262	2156071	*84.6844*	81.8273
MSP5	306984.418	2156252.97	*87.2937*	83.7093
MSP4	306745.112	2156429.04	*89.3139*	85.6646
MSP3	306516.477	2156603.39	*91.1903*	87.5041
MSP2	306289.101	2156778.11	*92.8078*	89.3221
MSP1	306051.842	2156955.21	*94.822*	91.2312

Table (6.8): from second polynomial test

Point Code	Easting	Northing	Observed H	Computed H
SCOR SW	304846.533	2155373.488	*110.08*	110.071
SCOR SE	307040.139	2152726.383	*95.784*	95.765
SCOR NW	306057.06	2156965.559	*97.499*	97.531
SCOR NE	308722.024	2154934.84	*69.506*	69.465
MSP55	305666.292	2156442.78	*101.153*	98.688
MSP54	305887.892	2156277.493	*99.388*	97.607
MSP53	306094.686	2156122.132	*96.681*	96.269
MSP52	306257.856	2155995.142	*94.836*	95.058
MSP51	306395.422	2155880.183	*93.14*	93.964
MSP50	306569.089	2155734.921	*91.777*	92.479
MSP49	306744.833	2155617.87	*89.492*	90.802
MSP48	307092.103	2155352.364	*85.635*	87.275
MSP47	307263.485	2155213.021	*84.017*	85.436
MSP46	307389.291	2155114.572	*83.301*	84.053
MSP45	307561.211	2154982.764	*81.499*	82.155
MSP44	307724.566	2154845.622	*80.073*	80.427
MSP43	307925.077	2154690.61	*78.032*	78.455
MSP42	308150.259	2154488.994	*76.874*	76.877
MSP41	308294.517	2154397.341	*76.917*	76.307

MSP40	307415.291	2153221.348	*89.954*	91.376
MSP39	307202.606	2153492.712	*91.46*	92.126
MSP38	307046.368	2153851.935	*91.842*	92.399
MSP37	306942.741	2154041.355	*92.595*	92.935
MSP36	306792.558	2154308.892	*92.629*	92.344
MSP35	306640.309	2154633.947	*92.678*	94.752
MSP34	306576.168	2154856.982	*92.532*	94.823
MSP33	306280.004	2155087.046	*94.697*	97.505
MSP32	306047.732	2155231.856	*96.934*	99.472
MSP31	305873.497	2155323.544	*99.034*	100.851
MSP30	305695.493	2155402.953	*101.184*	102.165
MSP29	305520.316	2155489.692	*103.265*	103.273
MSP28	305317.084	2155616.504	*105.57*	104.858
MSP27	305133.763	2155748.136	*107.66*	105.648
MSP26	304856.513	2155378.086	*109.985*	109.99
MSP25	304979.876	2155241.013	*108.765*	108.98
MSP24	305165.887	2155014.586	*106.229*	107.594
MSP23	305277.275	2154868.006	*104.087*	106.882
MSP22	305544.69	2154560.628	*105.086*	105.48
MSP21	305731.749	2154332.434	*104.968*	104.722
MSP20	305918.564	2154097.931	*104.176*	104.148
MSP19	306111.289	2153878.659	*103.422*	101.985
MSP18	306298.946	2153653.189	*101.876*	100.084

MSP17	306488.128	2153426.616	*100.66*	98.466
MSP16	306674.639	2153196.64	*99.671*	97.197
MSP15	306855.06	2152959.914	*98.049*	96.32
MSP14	307042.86	2152737.417	*95.722*	95.717
MSP13	308710.452	2154928.205	*69.528*	69.528
MSP12	308584.877	2155035.937	*69.68*	70.884
MSP11	308388.117	2155178.225	*72.304*	72.989
MSP10	308154.871	2155358.577	*74.79*	75.594
MSP9	307921.442	2155536.664	*77.132*	78.197
MSP8	307684.888	2155715.973	*79.478*	80.765
MSP7	307450.875	2155894.283	*82.23*	83.184
MSP6	307218.262	2156071.001	*84.684*	85.432
MSP5	306984.418	2156252.969	*87.294*	87.525
MSP4	306745.112	2156429.044	*89.314*	89.573
MSP3	306516.477	2156603.386	*91.19*	91.501
MSP2	306289.101	2156778.109	*92.808*	93.268
MSP1	306051.842	2156955.208	*94.822*	94.821

Table (6.10) Z values by kriging technique

Residual(v) IDW 1	Residual(v) IWD 2	Residual(v) Poly 1	Residua(v) Poly 2	*Residual(v) Kringing*
0.1	0.09	-0.153	0.0978	0.009
0.064	0.064	-0.133	-0.0199	0.02
2.679	2.679	2.633	-6.362	-0.032
-0.033	-0.023	0.021	-0.0659	0.041
4.182	4.212	-0.162	-3.8714	2.464
2.468	2.598	1.468	-3.8939	1.781
-0.028	0.731	1.699	-2.8563	0.413
-1.263	1.026	2.003	-2.3161	-0.221
2.409	1.25	1.988	-1.6942	-0.824
-2.822	2.237	2.587	-1.6902	-0.701
3.098	2.191	2.202	-0.8931	-1.31
-4.744	-0.001	1.519	0.1368	-1.64
-4.16	-1.663	1.184	-0.01	-1.419
-2.998	-2.148	1.323	0.077	-0.752
-2.001	-1.791	0.564	0.4685	-0.657
-0.696	0.583	-0.099	0.5928	-0.353
-0.057	0.972	-1.323	0.9842	-0.423
0.004	0.004	-2.052	0.3798	-0.003
-0.122	0.117	-1.576	-0.9269	0.611
-3.015	-4.275	-2.337	-0.1229	-1.422

-1.159	-1.939	-0.376	-0.243	-0.666
-0.627	-0.737	0.764	-0.1866	-0.557
-0.655	-0.805	1.609	-0.4783	-0.34
-2.161	-2.101	1.505	0.1757	0.284
-3.291	1.511	1.278	0.6225	-2.074
-3.607	-0.027	1.135	0.6626	-2.292
-3.803	-2.232	0.747	0.8988	-2.807
-3.435	-3.915	0.617	0.6679	-2.538
-2.746	-3.606	0.781	0.1317	-1.817
-1.715	-2.055	0.846	-0.3708	-0.981
0.006	0.005	0.766	-0.8646	-0.007
1.93	1.81	0.381	-1.4281	0.712
2.979	1.749	0.157	-2.0172	2.012
-0.005	-0.005	0.148	0.0666	-0.005
0.185	-0.604	0.492	0.457	-0.214
0.649	1.879	0.572	1.8107	-1.365
0.397	-0.002	-0.113	3.2824	-2.794
2.906	1.266	3.848	0.498	-0.393
1.978	1.038	5.459	-0.5922	0.246
-2.994	0.006	6.09	-0.9896	0.028
0.811	-0.428	6.501	-1.5531	1.437
2.276	0.008	5.783	-1.2531	1.792
3.73	2.34	5.0978	-1.3027	2.194

4.161	3.651	4.315	-1.5446	2.474
2.619	2.349	2.551	-1.0686	1.729
0.002	-0.001	-0.143	-0.0278	0.004
-0.002	-0.2	-0.142	0.0616	-0.003
-1.069	-0.029	-0.001	0.9102	-1.203
-2.135	0.555	-0.001	-0.581	-0.684
-3.899	-1.719	3.051	-0.6286	-0.804
-5.408	-4.778	3.996	-1.0513	-1.065
-6.422	-5.812	4.618	-1.4554	-1.287
-6.15	-4.5	5.372	-2.2969	-0.954
-4.935	-2.645	5.55	-2.8571	-747
-2.456	0.004	5.591	-3.5844	-0.231
-0.576	1.524	4.638	-3.6493	-0.259
-0.379	-0.289	3.409	-3.6862	-0.311
-1.172	-1.762	1.661	-3.4857	-0.46
0.012	0.002	-0.142	-3.5908	0.001

Table (6.13) residuals between observed and computed H values

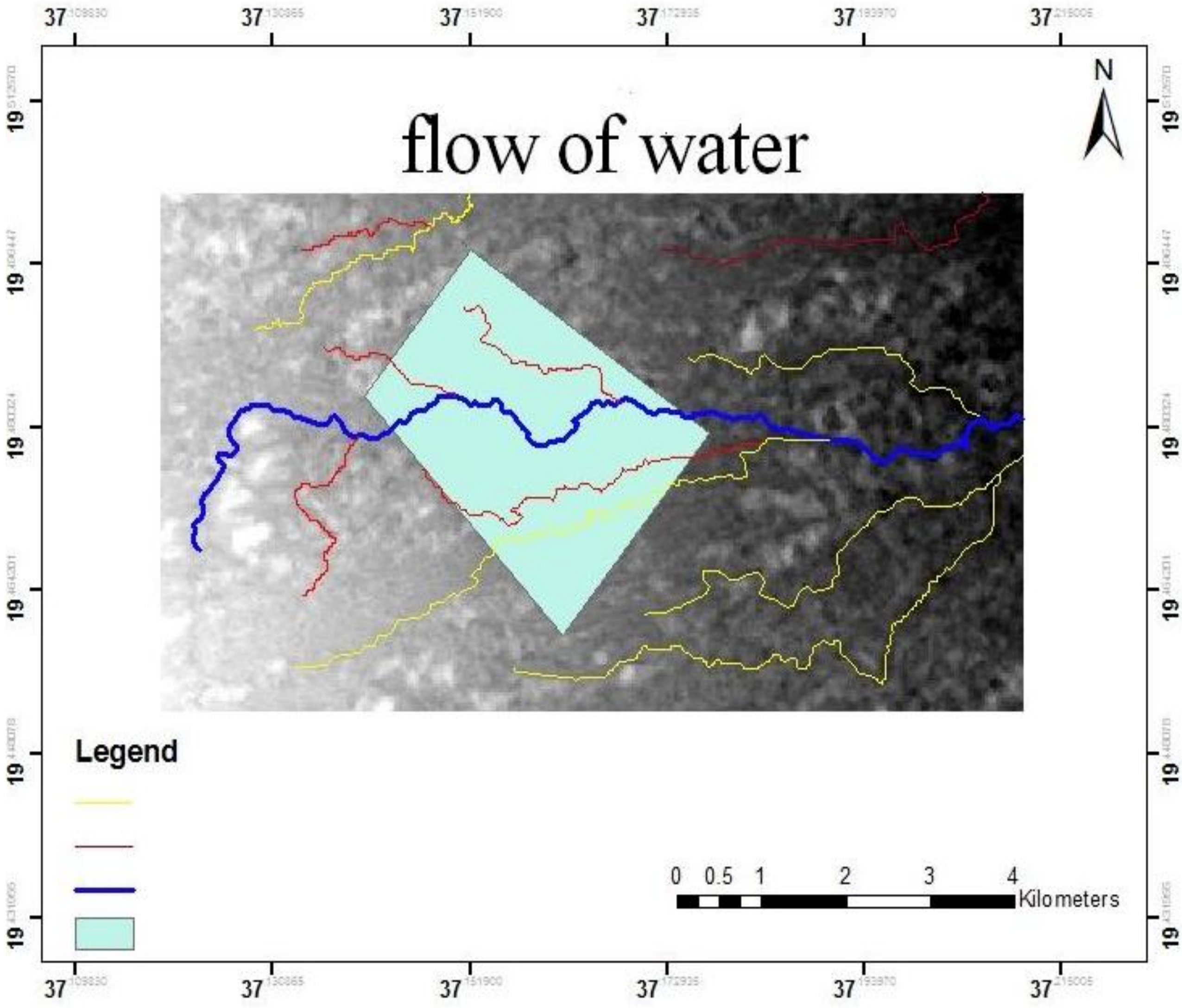

Figure (6.2) water flow at study area

Raster DEM layer

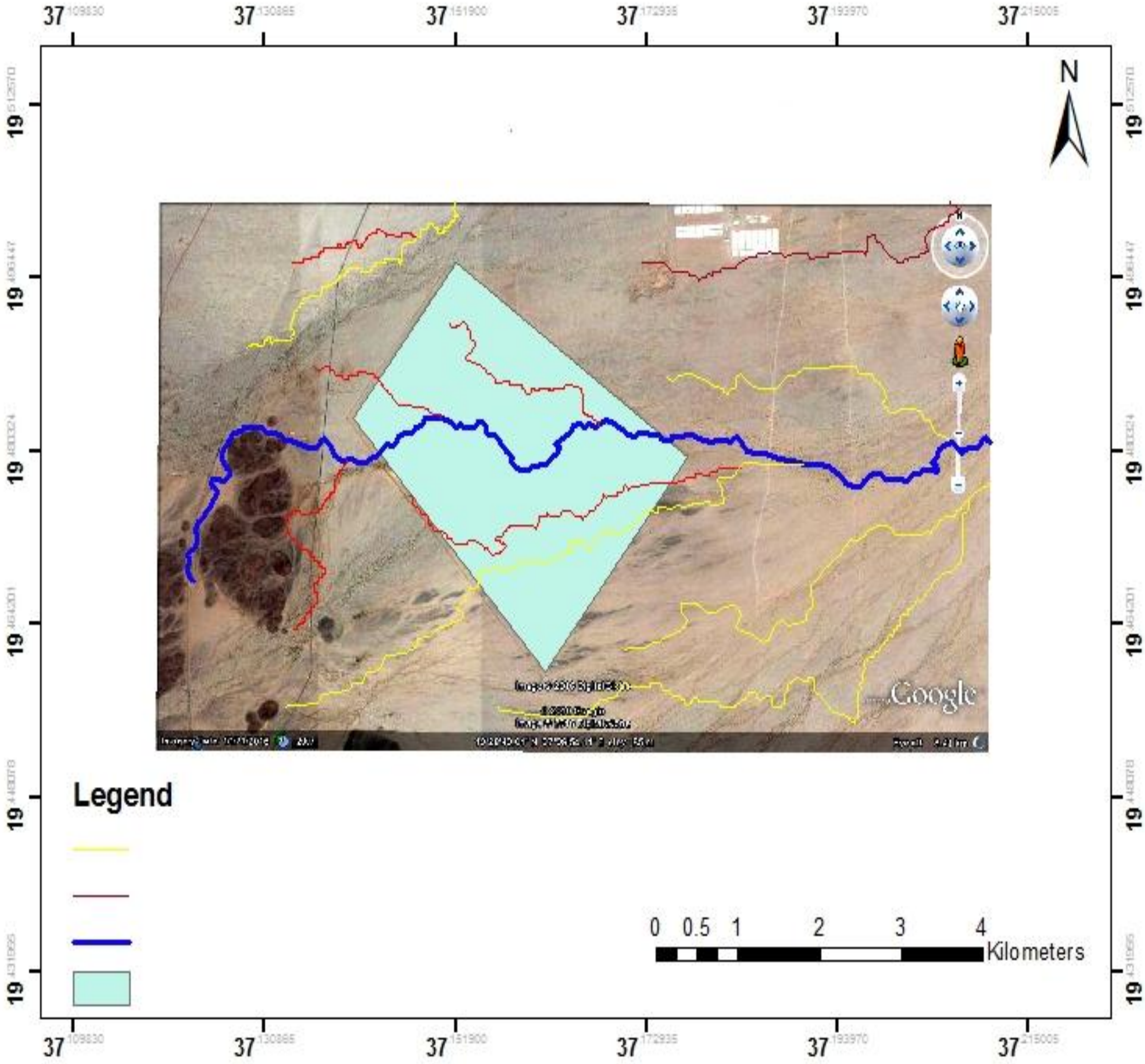

Figure (6.3) water flow at study area

Raster Google Image layer