PalestinePolytechnicUniversity

College of Engineering

Civil & Architectural Engineering Department

Surveying and Geomatics Engineering

Graduation Project

Transformation between GNSS coordinates and Palestinian coordinatessystem in West Bank

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Hebron-West Bank

Palestine

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الإهداء

إلى الرحمة المهداة في زمن الظلم والظلمات ... رسول الله صلى الله عليه وسلم

إلى ورثة الأنبياء بعلمهم ...علماؤنا الأجلاء

إلى من عبدت لي بحبها طريق الجنان ... نبع الحنان أمي الحبيبة

إلى الذي تناثرت قطرات العرق على جبينه كقطر الندى مجتهدا ليوفر لي الحياة الكريمة ...والدي الحبيب

إلى الذين كانوا لي أنسا في معمعان الحياة ... إخواني وأخواتي

إلى الذين رفعوا لواء العشق الأبدي عبورا نحو جنان الرحمن شهداؤنا الأماجد

إلى البيارق الخافقة في سماء العزة والإباء ... أسيراتنا وأسرانا البواسل

إلى أقصانا ومسرانا مَهْوَ القلوب وإلى كل ذرة من أرض الرباط فلسطين بأهلها وطهرها وقفارها ..

إلى ثورات الصحوة العربية المجيدة بشهدائها وجرحاها وحرائرها من المحيط إلى الخليج ...

إلى كل الإخوة والأخوات الذين ساهموا وعملوا في هذا المشروع، بتشجيعهم ودعائهم المتواصل، والذين كان لهم صدق مؤازرتنا في تنفيذه.

" وقل اعملوا فسيرى الله عملكم ورسوله والمؤمنون، وستردون إلى عالم الغيب والشهادة فينبئكم بما كنتم تعملون"

إليكم جميعا نهدي هذا العمل

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ABSTRACT

Transformation between GNSS coordinates and Palestinian coordinate system in the West Bank

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This project aims to transform the Palestinian coordinates system (Palestine 1923 Grid) in the West Bank to GNSS coordinate system. Specially the WGS 84 system. This is required as the new GPS/GNSS systems, technologies and algorithms enabled the use of baseline measurement in very long distances. Currently, there are hundreds of GNSS points measuring continuously and providing the raw data of the GNSS observations and their adjusted coordinates worldwide over the Internet. These points will be used for the transformation between the Palestinian coordinates system and WGS 84 system.

The project applies the transformation in the West Bank. In this area, a group of the original triangulation points (Trigs) from the Palestinian geodetic network with their original easting, northing, and height of coordinates (E,N,H) are going to be reference point for this project. These points will be used to build a 3D network using the measured coordinate by GNSS receivers. A least squares solution is going to be applied to calculate the geographic (λ, ϕ, h)/geocentric coordinates (X,Y,H) in the WGS 84 system (Palestine 1923 _ Grid).

Finally, the relation between the Palestinian system and the GNSS coordinates must be defined. This is applied by applying 3D coordinate transformation. The errors and differences between the two systems are going to be introduced and analyzed at the end of the project.

ملخص

التحويل بين احداثيات GNSS ونظام الاحداثيات الفلسطيني في الضفة الغربية

صالح الناطور عبد الحفيظ المحتسب

سامرسرحان علاء رجوب

المشرف:

الدكتور غادي زكارنة.

الهدف من هذا المشروع هو تحويل نظام الإحداثيات الفلسطينية في الضفة الغربية (Palestine 1923 Grid) الى نظام الاحداثيات GNSS وخصيصا في نظام WGS 84.ونحتاج في هذا المشروع لاستخدام أنظمة GNSS /GPS بتقنياتها وأساليبها الحديثة,والتي تمكننا من قياس المسافات والخطوط بين النقاط يصل مداها لمسافات طويلة تصل الى مئات وآلاف الكيلومترات .وحاليا يوجد المئات من النقاط في نظام GNSS/GPS والتي تأخذ القراءات بشكل مستمر حيث تتوفر قراءات هذه النقاط وإحداثياتها المضبوطة في جميع انحاء العالمعلى الانترنت . حيثسيتم استخدام هذه النقاط للربط بين نظام الاحداثيات الفلسطيني ونظام WGS 84 .

في هذا المشروع سيتم ربط أنظمة الإحداثيات لمنطقة الضفة الغربية. حيث يتم استخدام نقاط الشبكات المثلثية الجيودويسية في فلسطين في هذا المشروع سوفيتم استخدامهذه النقاط لتكون النقاط المرجعية في عملية تحويل أنظمة الإحداثيات . كما سيتم بناء شبكة ثلاثية الأبعاد بالاعتماد على هذه النقاط وسيتم احتساب الإحداثيات عن طريق GNSS أو الإحداثيات المركزية حسب نظام الاحداثيات WGS 84 واستخدام الاحداثيات المتوفره Palestine 1923 _Grid .

وأخيرا يجب تعريف العلاقة بين نظام الإحداثيات الفلسطينية ونظام الإحداثيات الأرضي الدولي. وهذا يطبق عن طريق اجراء نظام تحويل ثلاثي للأبعاد,الأخطاء الناتجة التحويل بين النظامين سوف يتم حسابها وتحليلها بنهاية المشروع.

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CHAPTER ONE

INTRODUCTION

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1.1 Background

The Global Navigation Satellite Systems (GNSS) aresystems of satellites thatcontinuously provide positioning possibilities with global coverage. They allow small electronic receivers to determine their location (longitude, latitude, and altitude) to a high precision (within a few meters to sub centimeter) using time radio signals transmitted along a line of sight by satellites. The signals also allow the electronic receivers to calculate the current local time to high precision.

The global geocentric reference frame and coordinates system known as the World Geodetic System 1984 (WGS84) has been developedcontinuously since its creation in the mid-1980s. The WGS84 continues to provide a single, common, accessible 3-dimensional coordinate system for globally data collected from different sources. Some of this geospatial data requires a high degree of accuracy and requires a global reference frame which is free of any significant distortions or biases. For this reason, a series of improvements to WGS84 were developed in the past years, which served to refine the original version.The data collected by the GNSS according to the WGS84 reference system can easilybe transformed to any local coordinates system.

Real Time Kinematic (RTK) is one of the most common poisoning methods in GNSS. It is a Kinematic method of GNSS survey carried out in real time. The Reference Station has a radio (link/ internet connection) attached and rebroadcasts the data and correction it receives from the satellites to rover station. The virtual reference station (VRS) concept of RTK can help to satisfy this requirement using a network of reference stations, to cover a wide area and high positioning accuracy using continuously operation network of reference stations and internet connections to the users.

1.2 Objective

This project aims to transform between the Palestinian coordinates system (Palestine 1923 Grid) in Palestine specified in this project for the west bankand

WGS84coordinate system, which is used as a reference system for the GNSS. This is required, as the new GPS/GNSS systems, technologies and algorithms enabled the use of baseline measurement in very long distances, from meters to thousands of kilometers. Using reference geodetic triangulation points with known coordinates in the Palestinian coordinates system (Palestine 1923 Grid); the transformation parameters are going to be calculated by means of least squares. This would require the GNSS measurement of the WGS84 coordinates for these triangulation points.

1.3 Time Table:

The time schedulein table (1-1) shows the stages of developing theoretical work, practical work and the process project that includes(literature review, organizing the scope, data collection, and the final presentation).

Table (1-1) Time Schedule for this semester.

Weeks / Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**16**
Project idea	→															
literature review		→														
organizing the scope						→										
data collection									→							
Observation of points											→					
Presentation																★
Weeks / Tasks	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	**32**
Observation of points	→								→							
calculations										→			→			
Data Analysis														→		
Presentation																★

1.4 Methodology

The Methodology of work in this project will be achieved by observing several Palestinian geodetic triangulation points using the GNSS, covering the area of the west bank.Least squares solution.Are going to be applied to find the reference transformation parameters for the between the WGS84 system and the Palestine 1923 Grid system, as a final result, with the analysis of the accuracy of this transformation.

1.5 Project Scope

This project consists ofseven chapters as follows:

- Chapter One: A simple explanation aboutthe projectand an introductionto whatwill bedonein the project.
- Chapter Two: Introducesthe history of geodetic network of Palestine.
- Chapter Three: gives an introduction about GNSS systems and satellite positioning methods.
- Chapter Four: Discusses the figure of the earth reference coordinates system including difference (types of three dimensional coordinates and the projected coordinates).
- Chapter Five: Shows the precedence and the observation of field work.
- Chapter Six: The results of calculations that involve the WGS84 coordinates and Palestinian coordinates, the transformation parameters and there analysis.
- Chapter Seven:Discussions of recommendation.

CHAPTER TWO

GEODETIC NETWORK OF PALESTINE

2.1 Introduction

2.2 Historical Background

2.3Field Work

2.1 Introduction

In the nineteenth century, after generations of strategic and religious interest inthe Holy Land, Palestine was subjected to intensive geographical, historical, and Archaeological research and scientific studies. During this period, the cartography of theCountry entered the modern era. Explorers, travelers, and military officers began tomap the land by modern surveying and mapping methods.

The main aim of nineteenth-century surveying and mapping activities focused on the mapping ofJerusalem and of the coastal towns for their strategic and religious importance. The explorers and surveyors who came to the Palestine were primarily concerned with the study of Jerusalem, and the productionof different maps of the Holy City that appeared also served as a catalyst for the mapping of other towns in the interior of Palestine. The coastal towns were mainly mapped by British military expeditions in the early 1840s.

2.2 Historical Background

2.2.1 Jerusalem and theirtowns

Four stages can be distinguished in the development of Jerusalem city maps in the Nineteenth century:-

- As a start in 1818, about 200geometric control points were measured as a basis for the new and corrected mapping of the city. After that, in 1833 an English architect constructed a map from his sketches and measurements, drew a panorama of the city, and prepared a detailed plan of the Temple Mount and its sites and that was the most important contribution.
- The second stage is represented by the map (scale 1:4,800) of two Royal Engineers, Lieutenants J.F.A.Symonds and E. Aldrich, from surveys conducted in March 1841, with particular attention to places of military interest.

- The third stage is the map of the Dutch naval officer Lieutenant C.M.W.van de Velde, which was based largely on the measurements of Symonds and Aldrich, the Swiss Dr T. Tobler (1845), and van de Velde's own corrections.

- And eventually the most important work was the survey, in 1864–1865, by a party of Royal Engineers under the command of Captain Charles Wilson, It was the first time that a practical mapping project in Jerusalem had beenentrusted to a survey party, for Wilson was authorized with the preparation of a map to serve the planning of a municipal drainage and water supply System for the city. To this end he laid out a local triangulation network and mapped the city on a scale of 1:2,500 and its surroundings at 1:10,000. During those years an Italian architect, E. Pierotti, who worked for the Turkish administration, also mapped Jerusalem and several specific site.{1}

2.2.2 Surveying of the coasts, lakes, and Jordan River

Maps based on original surveys of the marine environments of Palestine constitute a separate branch in the cartography of the country, include surveys of the Mediterranean and Red Sea coastlines, usually carried out by the British Admiralty, or of the interior carried out by the Royal Engineers; and surveys of lakes and the Jordan River conducted by explorers and travelers with experience in map-making.

The measurements along the Mediterranean coast aimed at correcting the overly broken appearance of the coastline in earlier maps, establishing the correct bearing to true north and mapping port and coastal fortifications. The earliest-known recorded surveys of the coastline were of Haifa Bay carried out in 1764 by J.Roux and in 1772 by the Russian Navy, as mentioned earlier. The British began surveys in 1840 by parties on both sea and land. The Admiralty surveyors worked along the Acre coast in 1840 and1843, and the Royal Engineers, commanded by Alderson, surveyed and devoted special attention to the coastal defenses. In 1847 the Admiralty surveyed the

anchorage at Jaffa, and in 1862 the second naval survey under Commander Mansell11 provided data on ports, inlets, and the depth of the sea bottom.

One of the important objectives of the coastal surveying and mapping of Palestine was the Gulf of Aqaba. The Gulf–a strategically important intrusion of the Red Sea into Ottoman territory, was a great interest to British military intelligence. It seems that the first maps of the Red Sea ports were drawn up as early as the mid-eighteenth century, and later, at the turn of the century. The first Admiralty surveys of the Red Sea coasts were managed in 1830–1834 and published in 1843, prior to the surveys of the Mediterranean coasts of Syria. The first survey of the head of the Gulf of Aqaba was made by the Major H.H.Kitchener as part of Edward Hull's geological operation to the Arava Valley in 1883–1884 on behalf of the Palestine Exploration Fund. {1}

2.2.3 Nineteenth century Surveying

The maps of Palestine produced from surveys in the nineteenth century can be divided into two groups: topographic maps and smaller-scale orientation maps. Jacobin's map was the first modern map of Palestine that may be considered topographic. It was drawn up in1799 by a small team of topographical engineers who accompanied the French expeditionary force in its march from Egypt to the walls of Acre.

The French were the first to base their cartographic measurements on a triangulation system, and the first to mark out control points in Palestine. Jacobin constructed his maps from baselines measured from points near Alexandria and Cairo and on a coordinate system determined from a starting point of the tip of the pyramid of Giza. The sheets were drawn to a scale of 1:100,000–an entirely new scale in the history of cartography.

The first full survey of Palestine was conducted by an expedition of Royal Engineers in 1841. At the initiative of Lieutenant Symonds, the surveyors prepared to work in Syria and Palestine. Symonds assumed responsibility for the mapping of Palestine; Alderson, Aldrich, and Sky ring mapped the area within the triangulation network laid out by Symonds; Major Charles Richard Scott drafted the map. Symonds measured

two triangulation systems, one from Acre to the Sea of Galilee by way of Safad, and the other from Jaffa to the Dead Sea via Jerusalem. The chains were measured from two baselines—near Acre and Ramle—and the two were connected by joint measurements to form one triangulation network. In this way, more exact positions of additional settlements and sites were determined, and the levels of the Sea of Galilee and the Dead Sea were calculated in relation to that of the Mediterranean. Nevertheless, the measurements of the depression of the Sea of Galilee (–100 meters) were far off the mark (approximately -212 meters). They cast doubt on the value of the entire work and gave rise to severe criticism. {1}

2.2.4 Ottoman maps and surveying

In the Ottoman period, even in its latter years, no central authority existed for directing the mapping of Palestine. We have relatively little information on Turkish mapping activity in the country, and this may well reflects the actual level of such activity. There was a military survey department in Turkey, but its purview did not extend to Palestine until the final phase of the First World War in 1917–1918.

The absence of an Ottoman mapping authority in Palestine was also felt in the realm of civil engineering. Although in the Ottoman administration of Palestine a Chief Engineer prepared maps, many surveyed projects were done by foreign countries such as the route of the railway from Jaffa to Jerusalem was surveyed by the Belgian partners in the enterprise in1890, and the branch line of the Hejaz railway in Palestine by German and Italian engineers in 1905. And even the measurements of the administrative demarcation line between Egypt and Palestine in 1906 were carried out by the Survey of Egypt, with the agreement and signature of Turkish officials.

When the war broke out, the Turkish military survey teams measured control points from Syria as far as Medina in the Hejaz. During 1917 they were busy preparing twelve sheets, five of which covered various parts of Palestine: Gaza, Jerusalem, Haifa, Jaffa, and Nablus. From the spring to mid-summer of 1917 they began work on the Jerusalem and Gaza sheets, and completed the preparations for the Nablus sheet in 1918, on the eve of the general retreat before the advancing British forces. In

November 1918 they returned to Istanbul. We do not know whether, or to what extent, these maps were used by Turkish units on the Palestine front. It seems that the maps were completed and printed after the war. They are not mentioned in official British accounts of the Palestine campaigns. {1}

2.2.5 Maps of the First World War

The First World War brought to Palestine two armies–British and German—with extensive knowledge and a long cartographic heritage. However, the existing maps of Palestine did not answer the requirements for the planning of military operations, and both armies had to prepare suitable tactical maps as best they could. Under the pressure of circumstance they constructed such maps by a combination of methods, partly from existing maps and in part from new surveys.

The British were better organized and showed more intelligence in their mapping than the Germans. They were under less pressure and were more open to cartographic initiatives deriving from the war needs. At the beginning of 1917, the army was no longer fighting in virtually uninhabited open areas with sparse landscape features, as in north Sinai, but now faced defensive lines based on key towns. From now on, the army had to force a way through trenches, built-up obstacles, and populated areas, and lacked detailed maps that showed every feature of the terrain. For this kind of warfare and tactical operations, the maps the army had used until then were of no use. They were unsuited to artillery range-finding, to trench warfare and combat patrols, or for spotting targets identified by aerial photography.

In an effort to give the mapping activities greater impetus, the War Office in London on 14 March 1917 ordered the formation of the 7th Field Survey Company, Royal Engineers, which constituted a significant expansion of the initial surveying unit. The company continued with the work it was already involved in, but now increasingly incorporated data from aerial photographs. In this way a series of 1:20,000scale maps were prepared of the area between Gaza and Beersheba to an unprecedented degree of detail, and mapping was begun of a standard 1:40,000-scale series.

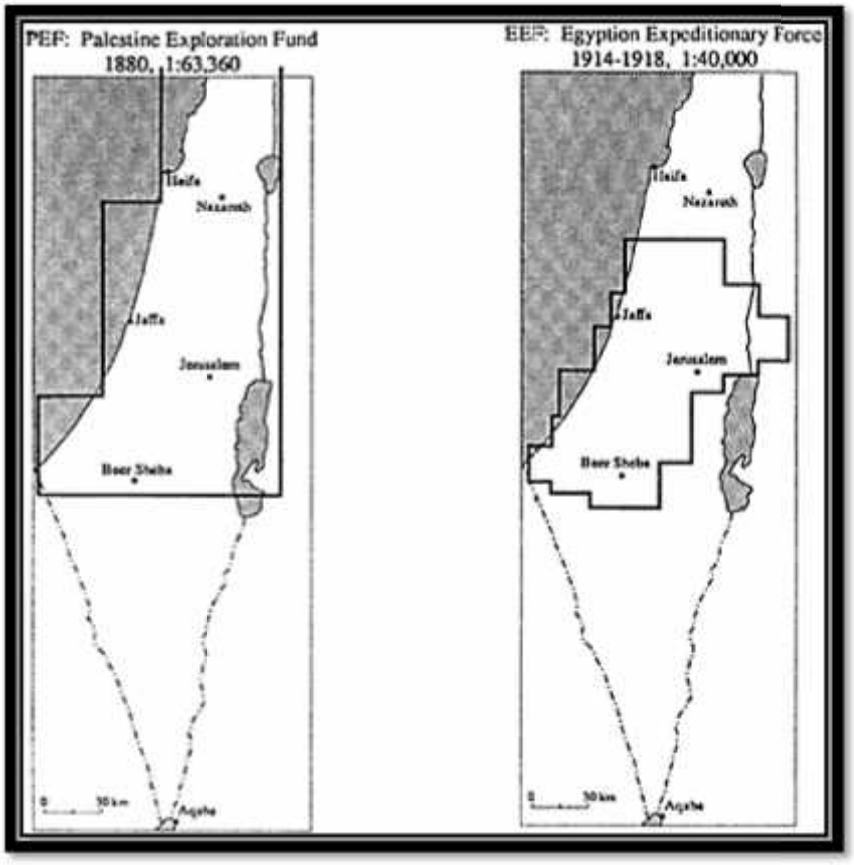


Figure (2-1): Series of topographical maps of Palestine at the end of the First World War {1}.

The new maps immeasurably improved the organization of tactical intelligence particularly of aerial intelligence—since targets could be marked on them with great precision. The unit laid out a triangulation network on baselines measured nearRafah and at Auja, north of Jericho; elevations were measured trigonometrically, and forthe first time the relief was indicated on these maps by a combination of contour and form lines. In all, the British surveyed and mapped an extensive area, including 1,280square kilometers with the help of aerial photographs between Gaza and Beersheba, and3,840 square kilometers by means of aerial photographs in the rest of the area, including about 3,000 square kilometers that was mapped while this region was still in Turkish hands. Another sheet, Parts of Nimrin B-7 & Salt C-7', was prepared for the region east of the Jordan from north of the Dead Sea in June 1918 as a record of Allenby's failed breakthrough to assaultin March 1918. The standard mapping on a scale of 1:40,000 encompassed the central regions of Palestine and was only completed to a distance of 50 kilometers beyond the front line - the line of the

'Two Aujas'–and included Allenby's range of breakthrough in the western Auja sector (today, in Tel Aviv). For the area north of this line, the Hadera-Samaria line, the army relied on the maps updated by means of aerial photographs in the interval before the last offensive against the Turks, in September 1918. {1}

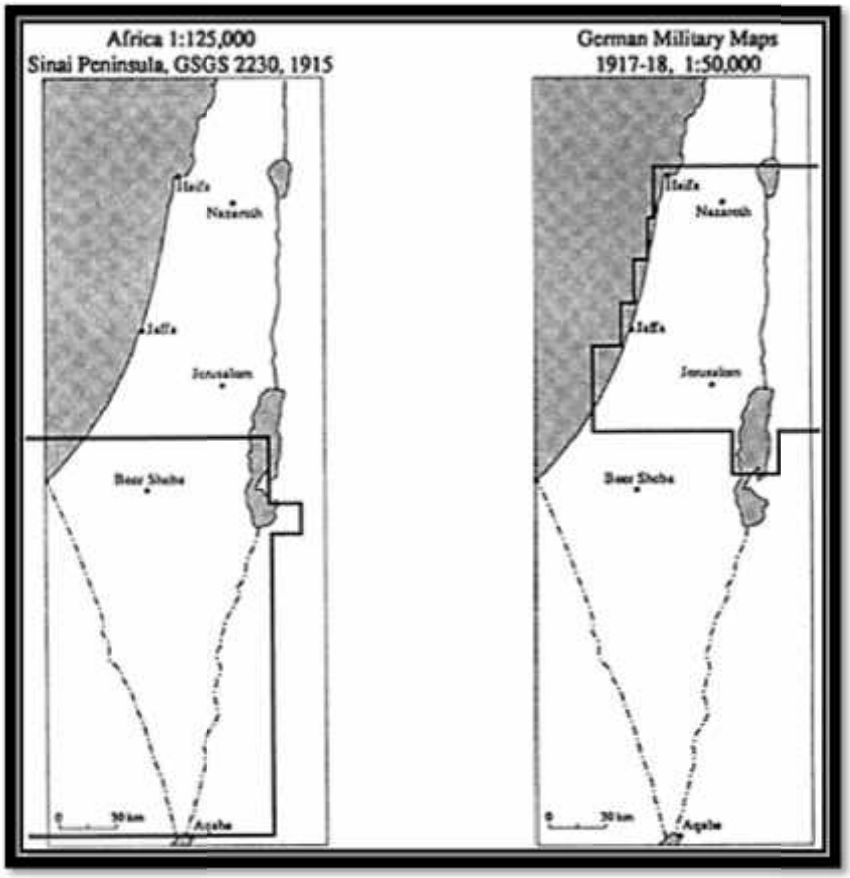


Figure (2-2): Series of topographical maps of Palestine at the end of the First World War {1}.

2.2.6 Palestine Department of Surveys (1920)

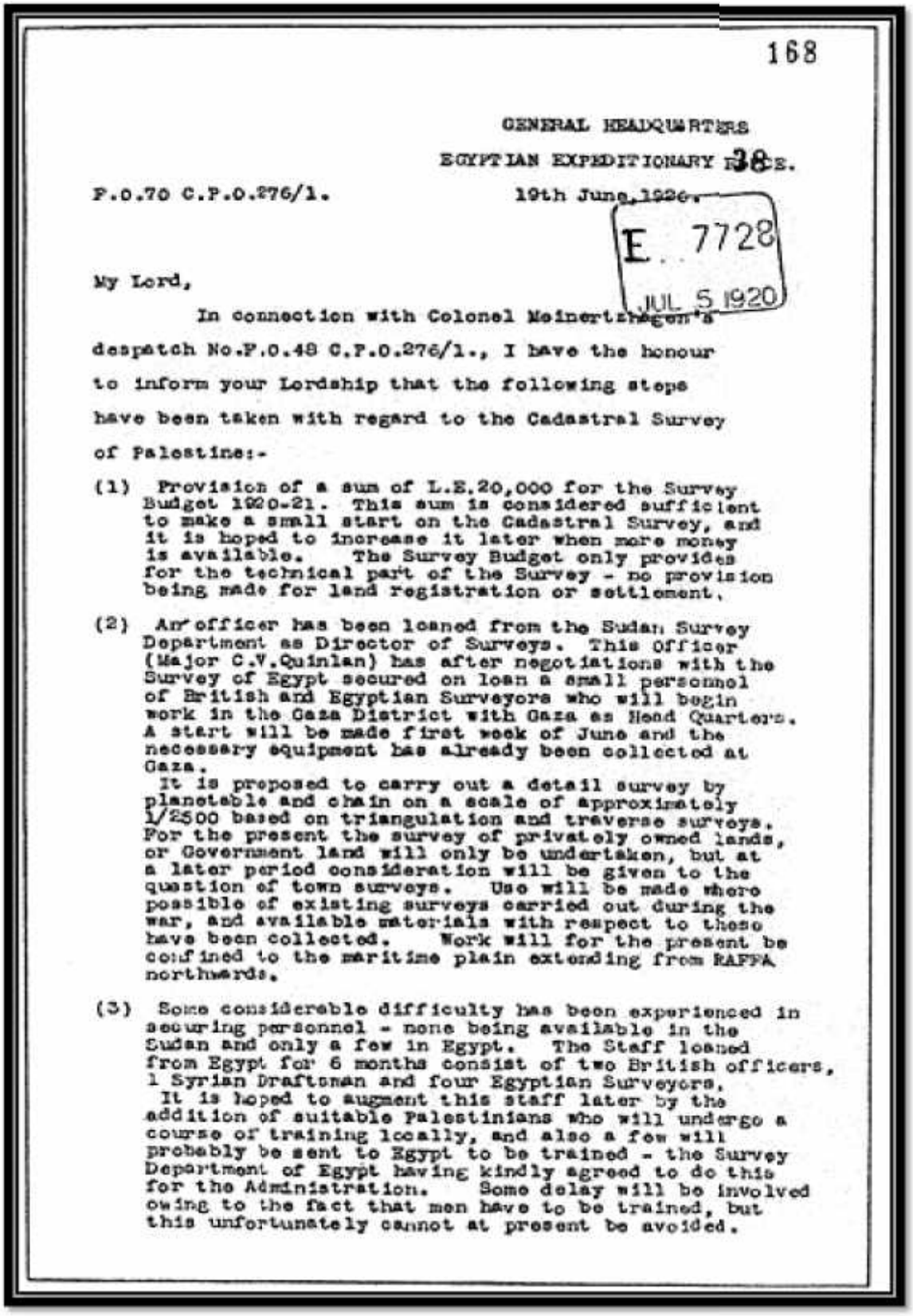
At the San Remo conference in April 1920, which decided the fate of the Ottoman Empire, the British were entrusted with the Mandate over Palestine. The British Government appointed Herbert Samuel High Commissioner for Palestine.

On 1 April 1920 the command began preparations for transferring theOttoman Empireadministration and formed several departments that had not existed previously, such as the Agriculture and the Survey Departments. Nevertheless, although the steps

pertaining to land were postponed until the formation of the civilian government, survey matters were immediately advanced. The first step was taken on 19 May 1920, with the announcement in the Official Gazette that a special Department of Surveys, which until then had been a function of the Legal Branch of the military administration, now existed in Palestine and that it would come under the Financial Department. The new hierarchy recalled the situation in Egypt, where the Survey Department was part of the Ministry of Finance.

The second step was taken that same month, when the command was published for thefirst time published the Cadastral Survey Ordinance (1920). This ordinance was intended to make surveys in the Gaza and Beersheba districts possible by giving the surveyors authority to enter private lands in order to measure and stake out boundaries of parcels, with the aim of implementing a cadastral survey.

We have only fragmentary information on the details of the activities of the PalestineSurvey Department during the final days of Ottoman Empire and it is not clear so we get enough in what we have already introduced. {1}



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GENERAL HEADQUARTERS
EGYPTIAN EXPEDITIONARY FORCE.

P.O.70 C.P.O.276/1. 19th June, 1920.

38

E. 7728
JUL 5 1920

My Lord,

In connection with Colonel Meinertzhagen's despatch No.P.O.48 C.P.O.276/1., I have the honour to inform your Lordship that the following steps have been taken with regard to the Cadastral Survey of Palestine:-

(1) Provision of a sum of L.E.20,000 for the Survey Budget 1920-21. This sum is considered sufficient to make a small start on the Cadastral Survey, and it is hoped to increase it later when more money is available. The Survey Budget only provides for the technical part of the Survey - no provision being made for land registration or settlement.

(2) An officer has been loaned from the Sudan Survey Department as Director of Surveys. This Officer (Major C.V.Quinlan) has after negotiations with the Survey of Egypt secured on loan a small personnel of British and Egyptian Surveyors who will begin work in the Gaza District with Gaza as Head Quarters. A start will be made first week of June and the necessary equipment has already been collected at Gaza.
It is proposed to carry out a detail survey by planetable and chain on a scale of approximately 1/2500 based on triangulation and traverse surveys. For the present the survey of privately owned lands, or Government land will only be undertaken, but at a later period consideration will be given to the question of town surveys. Use will be made where possible of existing surveys carried out during the war, and available materials with respect to these have been collected. Work will for the present be confined to the maritime plain extending from RAFFA northwards.

(3) Some considerable difficulty has been experienced in securing personnel - none being available in the Sudan and only a few in Egypt. The Staff loaned from Egypt for 6 months consist of two British officers, 1 Syrian Draftsman and four Egyptian Surveyors.
It is hoped to augment this staff later by the addition of suitable Palestinians who will undergo a course of training locally, and also a few will probably be sent to Egypt to be trained - the Survey Department of Egypt having kindly agreed to do this for the Administration. Some delay will be involved owing to the fact that men have to be trained, but this unfortunately cannot at present be avoided.

Figure (2-3): The 'Bols dispatch', –apparently the first (known) document to give details of the initial operation of the Survey Department, {1}.

2.3 Field Work

2.3.1The geodetic infrastructure

The professional organization of the surveying system is the key to reliable mapping. In Palestine, the first organizational step entailed the establishment of a suitable geodetic infrastructure of base measurements for all the plan metric and altimetric surveys and mapping. The system was built up step by step from three groups of surveys: layout and measurement of triangulation points; the measuring of spot heights according to the precise leveling method; and the determining of a geodetic projection for the country.

The basic measurements of control points were intended almost exclusively for the cadastral survey, so that large-scale maps could be prepared in order to show the boundaries of landed property at a degree of precision suitable for appending as graphic descriptions to the kushans (title deeds). Survey is the technical term for determining the location of objects by measurements in the field;the methods of surveying vary with the scope of the project.

Accordingly, a five-point geodetic master plan was worked out:-

- A suitable national coordinate's grid was decided upon for the country. The grid was based on a meridian line passing through Jerusalem and a transverse geodetic projection tangential to this meridian, from which the cartographic projection of the map of Palestine would be made.
- A major triangulation net of 100 fixed points would be laid out. Considering the size of the country, the major net would be of second order precision with 15–kilometer-long measured sides of the triangles.
- A secondary triangulation net of 2,000 measured points with sides about 5 kilometers long on average, a distance about a third of that of the major net would also be laid out.
- By the traverse method, a net of some 12,000 control points and polygons would be measured at distances not to exceed 400 meters between points.
- A detailed cadastral survey would be carried out by the plane table method.

2.3.2Triangulation survey

The actual preparations for setting up a triangulation system commenced only in February 1921.The first step was for the survey parties to lay out geodetic points throughout the entire country, to measure their values, and to provide mathematical bases for the survey nets. The geodetic points required for mapping are classed in three categories:

- Fixed points, or trigonometric stations, are determined by trigonometric methods and must be in sight of each other for the surveying observations.
- Spot heights are determined by precise leveling and not necessarily in relation to the trigonometric net.
- Gravimetric points, for the determination of the figure of the Earth.

In 1923 the major triangulation net of ninety-five fixed points was completed and marked in the field. In that year the gaps were closed and fixed points were measured also in the mountain area north of Ramallah (the Beth-El Mountains) and the Jericho Valley, and in March 1925 the triangulation of Hebron was begun. The Survey Department added five new points to the major triangulation net, and forty-three to the secondary net of third-order triangulation so as to cover the 'newly acquired territory' by the survey. In this way the number of points in the major triangulation net reached 100. {1}

2.3.3Joining the Network to the neighboring countries

One of the means of control over the accuracy of a national triangulation net is itsstage to nets of neighboring countries. The Survey Department wished to check the precision of its observations according to the surveys of the French in Syria and the Egyptians in Sinai.

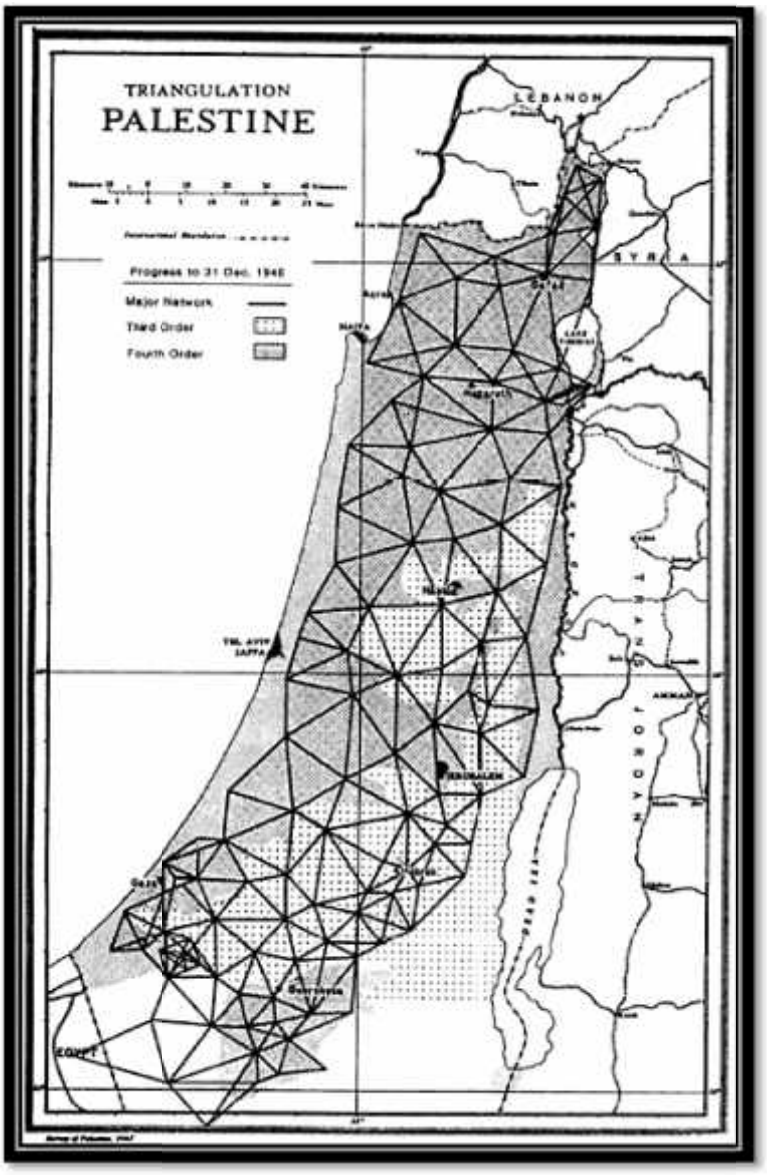


Figure (2-4): Triangulation system in Palestine at the end of the Second WorldWar{1}.

The junction between the French and the Palestine nets was finally affected in 1928, by observations to the two points of the major triangulation net: to Point 73 at Safad and Point 38 at Hunan (Margulies). The French observations were conducted from Mount Hermon, from Tell Abu Nida, from Kafr el-Ma on the Golan Heights, from Jebel.

Figure (2-5): Survey post on Jebel Jarmaq (Mount Meron) for the geodetic junction between Palestine and Syria and Lebanon {1}.

In the course of these surveys the data concerning the geographic longitude and latitude, the astronomic azimuth, and the calculated running distance between the two points were checked. The calculations were done in Paris and discrepancies were discovered between the surveyed and the calculated data. There was thus a need to return to the field and revise the survey in Palestine, though in fact their revision was carried out only after the establishment of Israel. Further computations to strengthen the geodetic tie with Syria were conducted at other points during the Second World War at the request of the British Army, aiming at one continuous geodetic system in the entire region. {1}

Figure (2-6): Junction of Syrian and Palestinian principal triangulations {1}.

2.3.4Spot heights and benchmarks

The measuring of topographic spot heights of triangulation points in the field is done in two ways:

- Trigonometrically: - In the trigonometric method the elevations are calculated according to readings of vertical angles in the course of plan metric observations to determine the positions of triangulation points.

- Precise leveling: - In the precise leveling method heights are measured from a base point of established topographic height, by measuring the elevation differentials from point to point and calculating the height of the new point in reference to the measured height of the previous point.

These elevation points join to make up measured lines that are resected or measured in circular loops to obtain checks on the accuracy of the measurement and the closing of a series of measurements. Like the triangulation points, the

elevation points are also marked in the field as benchmarks cut into the margins of roads, culverts, and the like**.**

Figure (2-7): Leveling survey in the Kabara swamps{1}.

The basic starting point for measuring heights is the mean sea level. In 1921 the MSL was measured for the first time at the Gaza beach and precise leveling conducted to the baseline at Imara. From then until 1927 no further country-wide leveling surveys were conducted in Palestine. In 1927 a medimarmeter was installed in the jetty wall of Jaffa, and in August 1928 another such instrument was installed in the customs jetty at Haifa. By means of these instruments a divergence was discovered between the heights at the two measuring stations and the spot heights arrived at by chain surveys from the Imara baseline: a difference of +90 centimeters at Jaffa, 110 kilometers from the starting point at Imara, and a difference of+1.20 meters at Haifa, at a distance of 173 kilometers. {1}

In 1928 a recording of the level of the Sea of Galilee was begun, the first systematic monitoring of the seasonal variations in the level of the Sea of Galilee and the Dead Sea as a result of climatic factors. At Jaffa the medimarmeter was replaced by a tidal gauge that could be read more easily and conveniently, and since the readings at Haifa and Jaffa were almost identical, and the differences between them were ascribed to the winds, it was decided to close the Haifa station in August 1930.

2.3.5The geodetic projection

A single country, groups of countries, or the entire surface of the globe can be represented by means of different methods of cartographic and geodetic projections. A projection is the transfer of a point from one plane to another. Mapping theory entails ways of projecting parallels and meridians from the global surface of the earth upon the flat map. Cartographic projections enable large parts of the globe to be represented on small-scale maps, as in atlases, so that a general idea can be obtained of the parallels and meridians on the map.

We do not know what prior considerations led the British to select any particular geodetic projection for Palestine. The decision narrowed down between two projections: Gauss-Conformal, known as Transverse Mercator Projection, and Cassini Soldner, since these were accepted as convenient projections for both cadastral and topographic mapping. In 1922 the survey experts in Palestine fixed upon the Cassini geodetic projection with rectangular coordinates as calculated by Soldner as the projection for Palestine, based on the Jerusalem central meridian.More details about Cassini soldner will be discussed in chapter (4).

From its geometrical attributes and its transverse construction, the Cassini projection answers the geodetic needs of Palestine within a strip 50–80 kilometers wide on both sides of a central meridian, usually passing through the center of the area to be mapped. The British bestowed this honor on Jerusalem, so that the meridian became the central longitudinal line, even though it did not divide the country down the middle. The meridian of Jerusalem goes through the Jaffa Gate, and the main triangulation point82’M, which became the reference point of the system, was fixed higher up, on top of the Mar Elias monastery hill south of Jerusalem. {1}

Figure (2-8): Mar Elias Monastery south of Jerusalem; triangulation point 82'M was positioned on top of the hill{1}.

In the geodetic projection, importance is given not to the transfer of the elliptic geographic gratitude of meridians and parallels, but to the replacement with a rectangular national grid system. The Surveys Directorate decided that the grid would encompass all the parts of the country to be mapped—which did not include the Negev south of Beersheba. Therefore, its staff established a trigonometrically station at the top of the 'Ali el-Muntar hill, which dominates the town of Gaza, in the heart of the area that was the first to be mapped in detail, and gave it values of 100–100 in the national grid. This point became the true origin of the Palestine grid. In this way the zero point, or the false origin, of the Palestine axial system was 100 kilometers west and 100 kilometers south in north Sinai, near Jebel Maghara. The choice of the true point of origin was not a good one because it left the southern Negev with negative values south of the zero line. Thus, for example, Elat would have been given a negative northern coordinate of −116. In order to avoid negative values, the British set the value of the zero line at 1,000, so that any place south of the line would have positive values; Elat would thus be at 884 of the northern coordinate. {1}

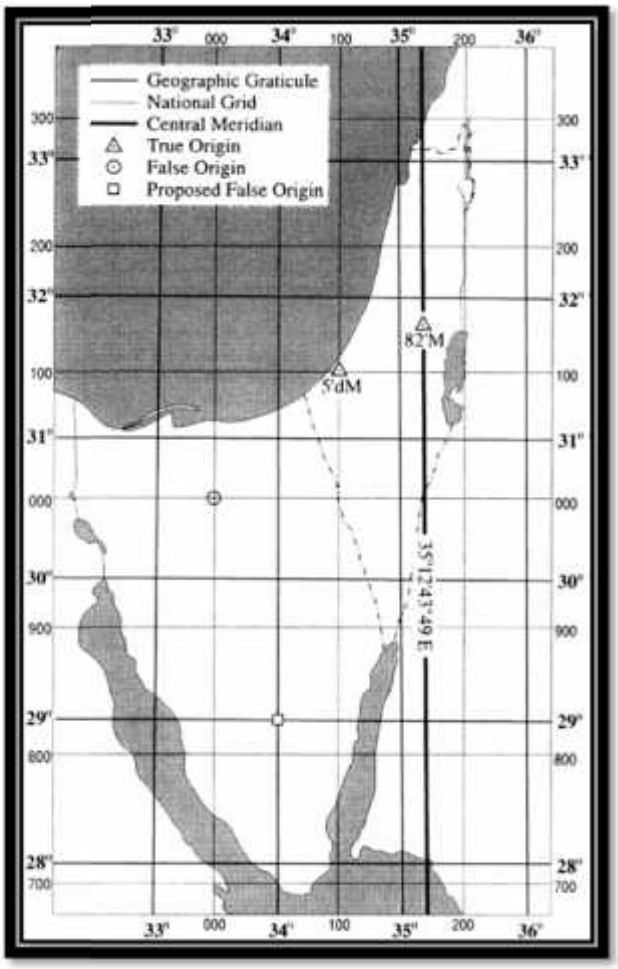


Figure (2-9): System of reference of the Palestine grid{1}.

When Richards conducted the check of the surveys in Palestine in 1925, he argued against this peculiar layout of the national grid. He remarked that the zero point of the main axes ought to have been at the intersection of the geographical coordinates 34° longitude and 29° latitude, which fall in south Sinai, so that all of Palestine would be within the positive values of the national grid. Richards also commented on the determination of the central meridian of the projection at Jerusalem, which it would have been better to move eastwards, for example to the Jordan Valley, so that in due course it would be possible to extend the grid system to Transjordan. These comments had no practical connotations, since the entire system was already in operation. The episode is mentioned here only to illustrate the absolute professional independence of the Directors of the Palestine Survey Department, despite the prestige of the Survey of Egypt, which assisted the local department in its first steps.

CHAPTER THREE

GLOBAL NAVIGATION SATELLITE SYSTEM

3.1 Introduction

3.2 Definition of the GNSS

3.3 GNSS Segment

3.4 Global Navigation Satellite Systems

3.5 GNSS Signal

3.6The Principle of GNSS positioning

3.7 GNSS Errors and Biases

3.8 GNSS Position Modes

3.9 GNSS Relative Positioning

3.10 GNSS Reference System

3.1 Introduction

Since earliest times, the human have interest to determine his position and his location with respect to other locations. He developed many methods to do that and he also used the sun and the stars to help him to determine his position. The oldest he used was the stars to determine his position with respect to the position of the stars this method give us an approximate location not the true location. Today with live in the era of precision we need to determine the position with high accuracy; so the human was needed to develop other methods that give us the needed accuracy so he send satellites to the space and developed them to help him in the positioning of his place.

3.2 Definition of the GNSS

Global Navigation Satellite System is a system used for positioning, tracking, and mapping in most cases is mentioned as synonymous with navigation; GNSS is the means that has translated the theoretical concept of navigation into an actual system, a quite friendly receiver, a commonly accepted and increasingly needed service.

In the past it was named Global Position System (GPS) which was developed by the US Military to allow the soldiers to autonomously determine their position within 10 to 20 meters accuracy without any other radio (or otherwise) communications.

Global coverage for the system is generally achieved by a satellite constellation of 20–30 medium Earth orbit (MEO) satellites spread between several orbital planes. The actual systems vary, but use orbital inclinations of >50° and orbital periods of roughly twelve hours (at an altitude of about 20,000 kilometers (12,000 mi)).{4}

3.3 GNSS Segment

GNSS consist of three distinct segments as shown in figure (3-1):

1. The space segment, the satellite or space vehicles.
2. The control segment, the ground tracking and monitoring stations.
3. The user segment, all users and there GNSS receivers.

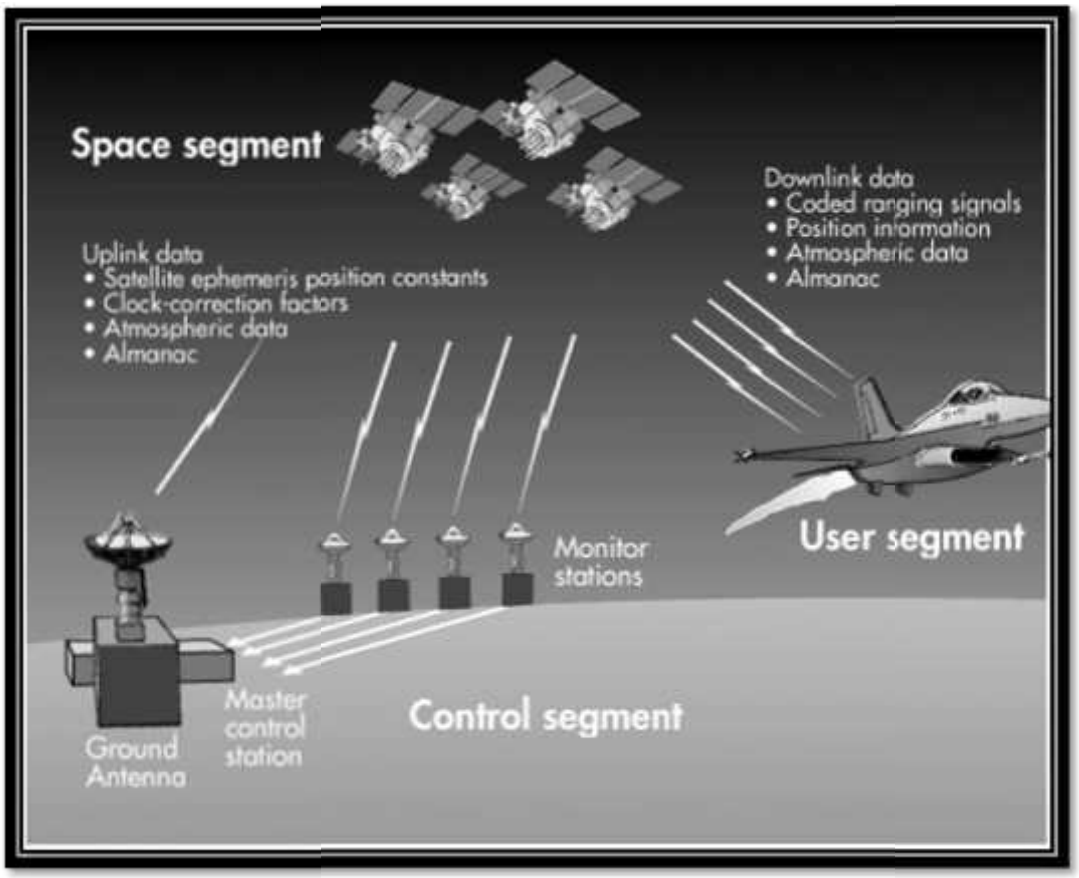


Figure (3-1): GNSS segments{2}.

3.3.1 Space Segment

GNSS uses a constellation of satellites, each transmitting a composite ranging signal that includes a navigation message. The latter contains the information required to determine the coordinates of the satellites and bring the satellite clocks in line with the GNSS time.

Facts about GNSS

1. Each satellite weighs approximately 900 kilograms and is about five meters wide with the solar panels fully extended.
2. The base size of the constellation includes 21 operational satellites with three orbiting backups, for a total of 24.
3. They are located in six orbit satellites approximately 20,200 kilometers altitude. Each of the six orbits is inclined 55 degrees up from the equator, and is spaced 60 degrees apart, with four satellites located in each orbit.

4. The orbital period is 12 hours, meaning that each satellite completes two full orbits each 24-hour day.

3.3.2 Control Segments

Monitoring of the GNSS satellites, through checks of their operational health and determining their positions in space, is carried out by the operational control segment (OCS),As an example figure (3-2) show the control segments of the GPS. In particular, the segment takes care of: maintaining the satellites in due orbit through small maneuvers; introducing corrections andadjustments to satellite clocks and payload; tracking the GNSS satellites anduploading navigation data to each satellite of the constellation; and providing through commands major relocations in case of satellite failure.As shown in figure (3-3).{4}

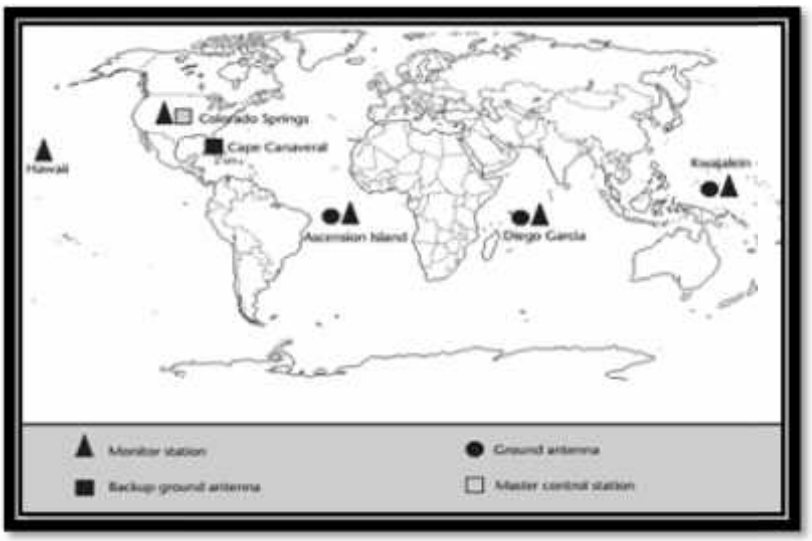


Figure (3-2): GPS control segment{3}.

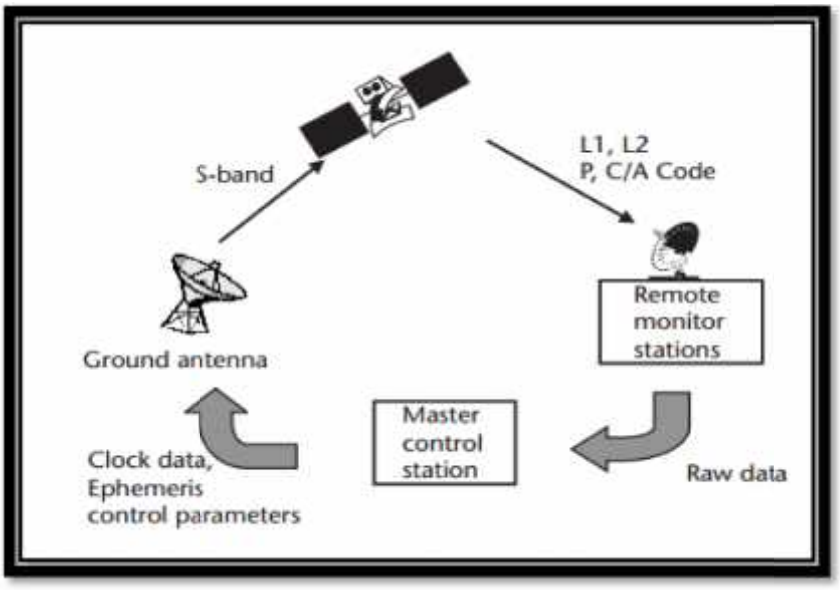


Figure (3-3): Basic structure and data flow of the GNSS control segment {3}.

3.3.3 User segment

The user segment includes all military and civilian users. With a GNSS receiver connected to a GNSS antenna, a user can receive the GNSS signals, which can be used to determine his or her position anywhere in the world. GNSS is currently available to all users worldwide for free.

3.4 Global Navigation Satellite Systems

Different countries have developed that satellite navigation, the global system are, as shown in table (3-1):

1. GPS: The Global Positioning System (GPS) is a satellite-based navigation system that was developed by the U.S. Department of Defense (DOD) in the early1970s.
2. GLONASS is an all-weather global navigation satellite system developed by Russia. The GLONASS satellite system has much in common with the GPS system.
3. Galileo is a satellite-based global-navigation system proposed by Europe. Galileo is a civil-controlled satellite system to be delivered through a public-private partnership.

4 China has recently launched two domestically built navigation satellites, which form the first generation of a satellite-based navigation system. It is an all-weather regional navigation system, which is known as the Beidou Navigation System.

The satellites are placed in geostationary orbits at an altitude of approximately 36,000 km above the Earth's surface. The primary use of the system is in land and marine transportation.{4}

Table (3-1) Global Navigation Systems

System	GPS	GLONASS	Galileo
Political entity	United States	Russian Federation	European Union
Coding	CDMA	FDMA/CDMA	CDMA
Orbital height	20,180 km(12,540 mi)	19,130 km (11,890 mi)	23,220 km (14,430 mi)
Period	11.97hours(11□ h58□ m)	11.26hours(11□ h16□ m)	14.08 hours (14□ h5□ m)
Evolution per sidereal day	2	17/8	17/10
Number of satellites	At least 24	31, including,24 operational, 1 in preparation, 2 on maintenance, 3 reserve 1 on tests	4 test bed satellites in orbit, 22 operational satellites budgeted
Frequency	1.57542 GHz (L1 signal) 1.2276 GHz (L2 signal)	Around 1.602 GHz (SP) Around 1.246 GHz (SP)	1.164–1.215 GHz (E5a and E5b) 1.260–1.300 GHz (E6) 1.559–1.592 GHz (E2-L1-E11)
Status	Operational	Operational, CDMA in preparation	In preparation

3.5 GNSS Signals

Each GPS satellite transmits data on two frequencies, L1 (1575.42 MHz) and L2 (1227.60 MHz). The atomic clocks aboard the satellite produces the fundamental L-band frequency, 10.23 Mhz. The L1and L2 carrier frequencies are generated by multiplying the fundamental frequency by 154 and 120, respectively, as shown in

table(3-3). Two pseudorandom noise (PRN) codes, along with satellite ephemerides (Broadcast Ephemerides), ionospheric modeling coefficients, status information, system time, and satellite clock corrections, are superimposed onto the carrier frequencies, L1 and L2. The measured travel times of the signals from the satellites to the receivers are used to compute the pseudoranges.

The Course-Acquisition (C/A) code, sometimes called the Standard Positioning Service (SPS), is a pseudorandom noise code that is modulated onto the L1 carrier. Because initial point positioning tests using the C/A code resulted in better than expected positions, the DoD directed "Selective Availability" (SA) in order to deny full system accuracy to unauthorized users. SA is the intentional corruption of the GPS satellite clocks and the Broadcast Ephemerides. Errors are introduced into the fundamental frequency of the GPS clocks. This clock "dithering" affects the satellite clock corrections, as well as the pseudorange observables. Errors are introduced into the Broadcast Ephemerides by truncating the orbital information in the navigation message.

The Precision (P) code, sometimes called the Precise Positioning Service (PPS), is modulated onto the L1 and L2 carriers allowing for the removal of the first order effects of the ionosphere. The P code is referred to as the Y code if encrypted. Y code is actually the combination of the P code and a W encryption code and requires a DoD authorized receiver to use it. Originally the encryption was intended as a means to safe-guard the signal from being corrupted by interference, jamming, or falsified signals with the GPS signature. Because of the intent to protect against "spoofing," the encryption is referred to as "Anti-spoofing" (A-S). A-S is either "on" or it's "off;" there is no variable effect of A-S as there is with SA.{4}

Table (3-2): Differentiate between CA code and PY code.

CA code	PY code
Called the standard positing service (SPS)	called the Precise Positioning Service (PPS)
pseudorandom noise code that is modulated onto the L1 carrier	modulated onto the L1 and L2 carriers
the DoD directed "Selective Availability" (SA) in order to deny full system accuracy to unauthorized users	P code is referred to as the Y code if encrypted
	Y code combination of the P code and a W encryption code
	requires a DoD authorized receiver

Table (3-3): GNSS Signal Codes and Carrier Frequencies

Carrier L_band		Codes		Satallite Massege
		Civilian C/A-code	Malitriy PY-code	
L1	1575.42 Mhz 19cm wavelength	Present 293 m wavelengh	Present 29.3 m wavelength	User messages Satellite constants Satellite positions
L2	1227.60 MHz 24cm wavelength	Not present	Present 29.3 m wavelength	

3.6 The Principle of GNSS positioning

The idea behind GNSS is rather simple. If the distances from a point on the Earth (a GNSS receiver) to three GNSS satellites are known along with the satellite locations, then the location of the point (or receiver) can be determined by simply applying the well-known concept of resection.

As mentioned before, each GNSS satellite continuously transmits a microwave radio signal composed of two carriers, two codes, and a navigation message. When a GNSS receiver is switched on, it will pick up the GNSS signal through the receiver antenna. Once the receiver acquires the GNSS signal, it will process it using its built-in software. The partial outcome of the signal processing consists of the distances to the GNSS satellites through the digital codes (known as the pseudoranges) and the satellite coordinates through the navigation message.

Theoretically, only three distances to three simultaneously tracked satellites are needed. In this case, the receiver would be located at the intersection of three spheres; each has a radius of one receiver-satellite distance and is centered on that particular satellite Figure (3-4). From the practical point of view, however, a fourth satellite is needed to account for the receiver clock offset.

The accuracy obtained with the method described earlier was until recently limited to 100m for the horizontal component, 156m for the vertical component, and 340 ns for the time component, all at the 95% probability level.

This low accuracy level was due to the effect of the so-called selective availability, a technique used to intentionally degrade the autonomous real-time positioning accuracy to unauthorized users. With the recent presidential decision of terminating the selective availability, the obtained horizontal accuracy is expected to improve to about 22m (95% probability level). To further improve the GNSS positioning accuracy, the so-called differential method, which employs two receivers simultaneously tracking the same GNSS satellites, is used. In this case, positioning accuracy level of the order of a subcentimeter to a few meters can be obtained.

Other uses of GNSS include the determination of the user's velocity, which could be determined by several methods. The most widely used method is based on estimating the Doppler frequency of the received GNSS signal. It is known that the Doppler shift occurs as a result of the relative satellite-receiver motion.{4}

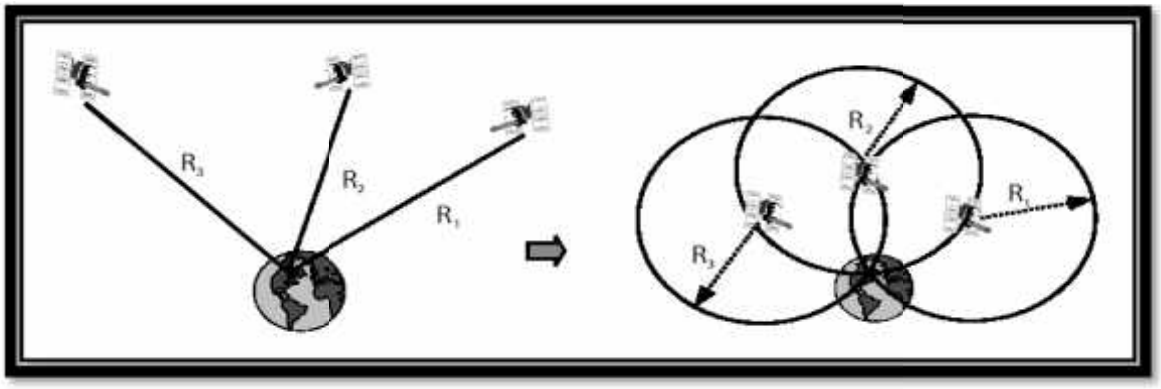


Figure (3-4): Basic idea of GNSS positioning {3}.

- **Calculating the distance to the satellite**

$$R = V \times T \qquad (3.1)$$

Where:

R:Distance.

V:Basic idea of GNSS positioning 300,000 kilometers per second.

T:Time in transit.

3.7 GNSS Errors and Biases

The GNSS mesurments may be affected by many error and baises this error can be classified in four groupes they are listed in Figure (3-5).

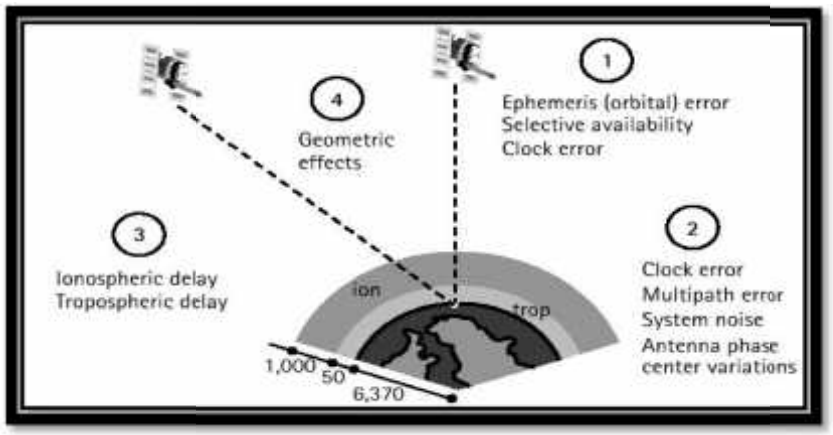


Figure (3-5): GNSS errors and biases {3}.

1. The errors originating at the satellites:
    - ❖ Ephemeris or orbital error.
    - ❖ Selective availability.
    - ❖ Satellite clock error
2. The errors originating at the receiver:
    - ❖ Receiver clock error.
    - ❖ Multipath error.
    - ❖ Receiver noise.
    - ❖ Antenna phase center variations.
3. The signal propagation errors:
    - ❖ Ionospheric delay.
    - ❖ Tropospheric delay**.**
4. The Geometric effects.

3.7.1 SélectiveAvailability(AntiSpoofing)

GNSS was originally designed so that real-time autonomous positioning and navigation with the civilian C/A code receivers would be less precise than military P-

code receivers. Surprisingly, the obtained accuracy was almost the same from both receivers. To ensure national security, the U.S. DoD implemented the so-called selective availability (SA) on Block II GPS satellites to deny accurate real-time autonomous positioning to unauthorized users. SA was officially activated on March 25, 1990.{3}

3.7.2 Satellite clock error

GNSS satellite use clock with high accuracy but it isn't perfect they include some error. Their stability is about 1 to 2 parts in 10^{13} over a period of one day. This means that the satellite clock error is about 8.64 to 17.28 ns per day. The corresponding range error is 2.59m to 5.18m, which can be easily calculated by multiplying the clock error by the speed of light (299,729,458 m/s).

3.7.3 Receiver measurments noise

The receiver measurement noise results from the limitations of the receiver's electronics. Generally, a GPS receiver performs a self-test when the user turns it on. However, for high-cost precise GPS systems, it might be important for the user to perform the system evaluation. Two tests can be performed for evaluating a GPS receiver (system):

1. Zero baseline test.
2. Short baseline test.

3.7.4 Ionosphere and troposphere refraction

At the uppermost part of the earth's atmosphere, ultraviolet and X-ray radiations coming from the sun interact with the gas molecules and atoms. These interactions result in gas ionization: a large number of free "negatively charged" electrons and "positively charged"" atoms and molecules. Such a region of the atmosphere where gas ionization takes place is called the ionosphere. It extends from an altitude of approximately 50 km to about 1,000 km or even more, as shown in figure(3-6).

The troposphere is the electrically neutral atmospheric region that extends up to about 50 km from the surface of the earth. The troposphere is a not dispersive medium for radio frequencies below 15 GHz.{3}

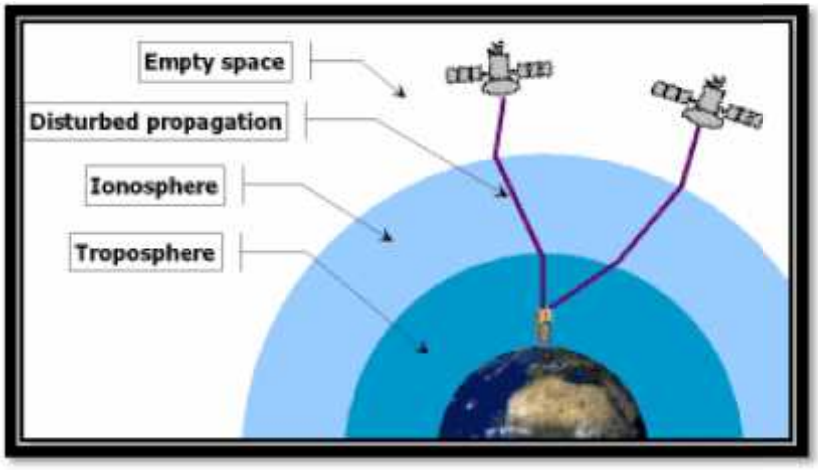


Figure (3-6): Influenced propagation of radio waves through the earth's atmosphere {3}.

Both ionosphere and troposphere cause bending of the signals. This bending of radio waves is called refraction. The problem with the Ionosphere is the electrically charged particles that drag on the incoming signal. In the troposphere, the problem is with the water vapor content which does the same thing. These problems are even further exacerbated when a satellite is low on the horizon. This is because a line tangent to the surface of the Earth (or nearly so) passes through a much thicker layer of atmosphere than if that line were pointing straight up.

To deal with refractions the satellite's NAV-massage includes an atmospheric refraction model that compensates for as much as 50-70% of the error and to use a dual-frequency receiver which simultaneously collects the signals on both the Ll and L2 carriers. Because the amount of refraction that a radio wave experiences is inversely proportional to its frequency, using two different frequencies transmitted through the same atmosphere at the same time makes it relatively easy to compute the amount of refraction taking place and compensate it.{3}

3.7.5 Mask Angle

cut-off angle: The point above the observer's horizon below which satellite signals are no longer tracked and/or processed. 15° to 25° is typical,as shown in figure (3-7).

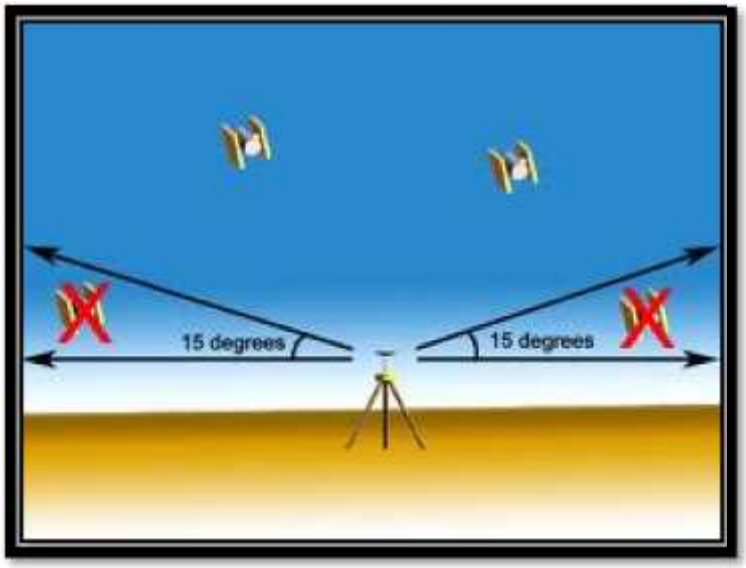


Figure (3-7):Mask angle {4}.

3.7.6 Multi path Error

Multipath error occurs when the GPS signal arrives at the receiver antenna through different paths. These paths can be the direct line of sight signal and reflected signals from objects surrounding the receiver antenna see Figure(3-8).

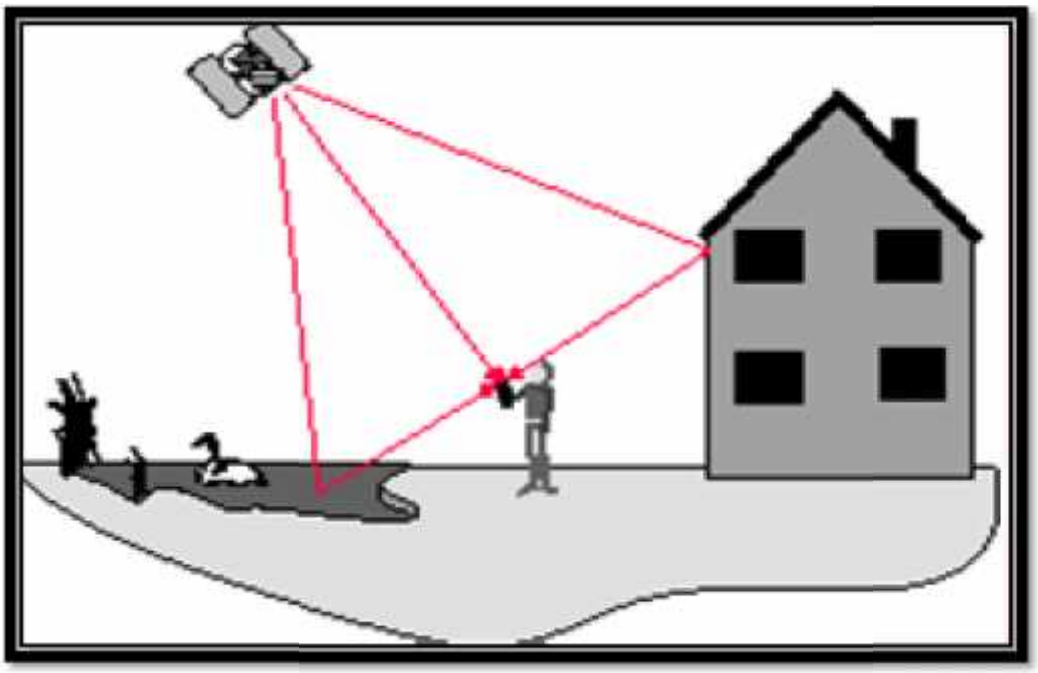


Figure (3-8):Multi path error {4}.

There are several options to reduce the effect of multipath:

1. The straightforward option is to select an observation site with no reflecting objects in the vicinity of the receiver antenna.
2. Another option to reduce the effect of multipath is to use a chock ring antenna (a chock ring device is a ground plane that has several concentric metal hoops, which attenuate the reflected signals).
3. As the GNSS signal is right-handed circularly polarized while the reflected signal is left-handed, reducing the effect of multipath may also be achieved by using an antenna with a matching polarization to the GNSS signal (i.e., right-handed). The disadvantage of this option, however, is that the polarization of the multipath signal becomes right-handed again if it is reflected twice.

3.7.7 Reciver Clock error

GNSS reciever use inexpensive crystal clocks, which are much less accurate than the satellite clocks. As such, the receiver clock error is much larger than that of the GNSS satellite clock. It can, however, be removed through:

1. Differencing between the satellites or
2. It can be treated as an additional unknown parameter in the estimation process.

3.7.8 Geometric arrangement of the satellites

The effect of satellite geometry is quantified in the measure called dilution of precision, or DOP. When satellites are widely spaced the overlap area of the two zones of possible satellites range error is relatively small, this area called area of positional ambiguity. Figure (3-9) illustrates the low DOP, while figure (3-10) shows high DOP.

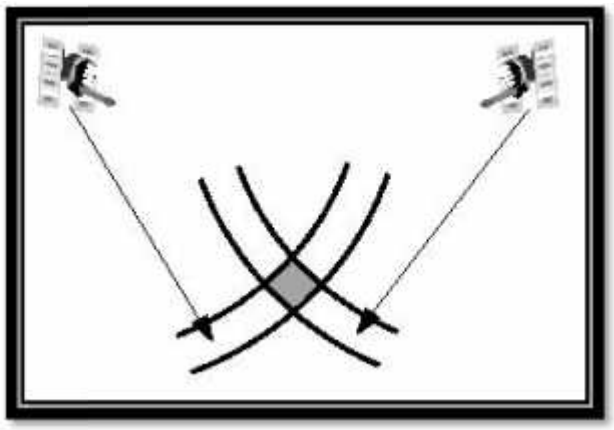


Figure (3-9): Well-spaced satellites Low uncertainty of position {4}.

The best way to minimize the effect of DOP is to observe as many satellites as possible. And these are the values of dilution of precision:

1. A DOP value less than 2 is considered excellent.
2. A DOP value between 2 and 3 is considered very good.
3. A DOP value between 3 and 5 is considered good.
4. A DOP value greater than 5 and less than 6 is considered fair.

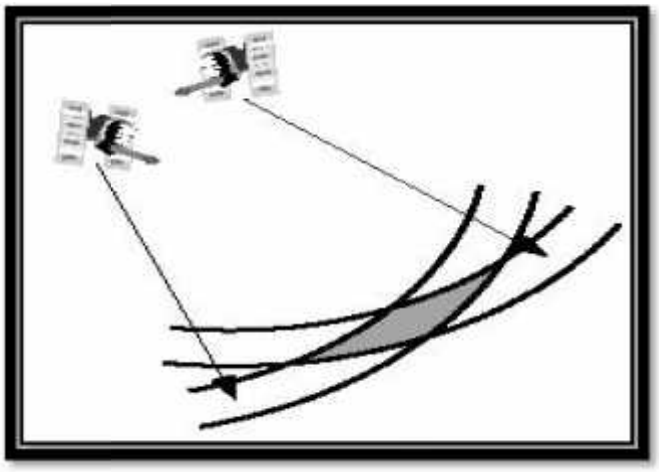


Figure (3-10): Poorly spaced satellites High uncertainty of position {4}.

Different types of Dilution of Precision or DOP can be calculated depending on the dimension; these values are calculated by the covariance matrix of the position generated from least squares adjustment:

- Vertical Dilution of Precision(VDOP): Gives accuracy degradation in vertical direction.

$$VDOP = \frac{\pm_z}{\pm} \quad (3.2)$$

- Horizontal Dilution of Precision(HDOP): Gives accuracy degradation in horizontal direction.

$$HDOP = \frac{1}{\pm} * \sqrt{\pm_x^2 + \pm_y^2}) \quad (3.3)$$

- Positional Dilution of Precision(PDOP): Gives accuracy degradation in 3D position.

$$PDOP = \frac{1}{\pm} * \sqrt{\pm_x^2 + \pm_y^2 + \pm_z^2}) \quad (3.4)$$

- Time dilution of precision(TDOP): Gives accuracy in time.

$$TDOP=\frac{\pm_b}{\pm} \quad (3.5)$$

- Geometric Dilution of Precision(GDOP): Gives accuracy degradation in 3D position and time.

$$GDOP=\frac{1}{\pm}*\sqrt{\pm_x^2+\pm_y^2+\pm_z^2+\pm_b^2)} \quad (3.6)$$

Where:

$\pm$ = is the measured RMS error of the pseudorange.

$\pm_x,\pm_y,\pm_y =$ Are the measured RMS errors of the user position in the xyz directions.

$\pm_b =$ Is the measured RMS user clock error expressed in distance.

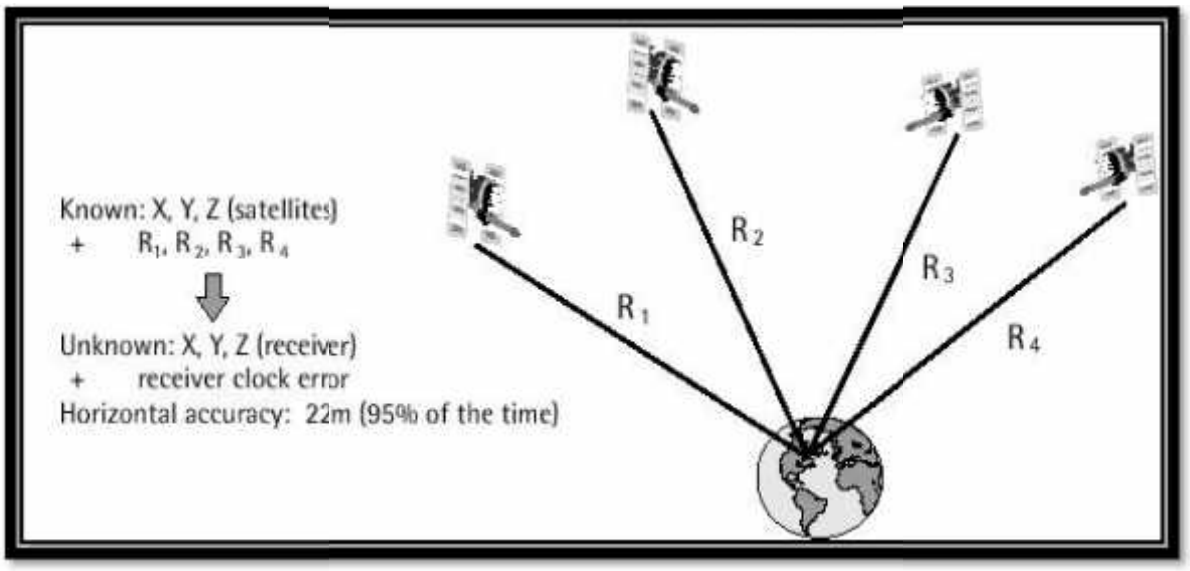
3.8 GNSS Position Modes

Positioning with GPS can be performed by either of two ways: point positioning or relative positioning

3.8.1 GNSS Point Positioning

Involves only one GNSS receiver that is, one GNSS receiver simultaneously tracks four or more GPS satellites to determine its own coordinates with respect to the center of the Earth,as shown Figure (3-11). Almost all of the GNSS receivers currently available on the market are capable of displaying their point positioning coordinates.

To determine the receivers point position at any time, the satellite coordinates as well as a minimum of four ranges to four satellites are required.{3}



Figure(3-11): Principal of GNSS point {4}.

3.9 GNSS Relative Positioning

GNSS relative positioning, also called differential positioning, employs two GNSS receivers simultaneously tracking the same satellites to determine their relative coordinates,as shown Figure (3-12). Of the two receivers, one is selected as a reference, or base, which remains stationary at a site with precisely known coordinates. The other receiver, known as the rover or remote receiver, has its coordinates unknown. The rover receiver may or may not be stationary, depending on the type of the GNSS operation. A minimum of four common satellites is required for relative positioning.

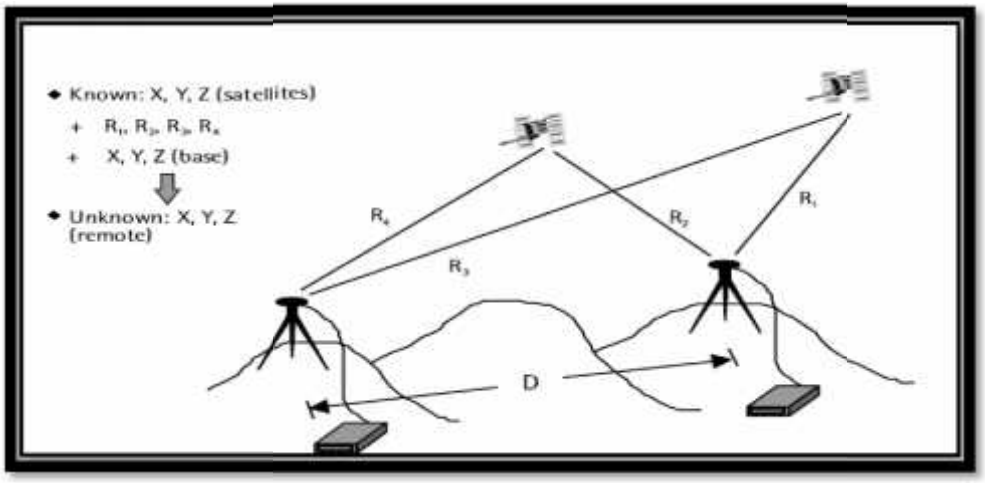


Figure (3-12): principle of GNSS relative positioning {4}.

Differential GNSS carrier phase surveying is used to obtain the highest precision from GNSS and has direct application to most topographic and engineering survey activities. DGNSS uses three Different GNSS differential surveying techniques:

1.Static.
2. Fast Static.
3. Real Time Kinematic.
4. Wide Area RTK.

3.9.1 Static GNSS Survey Techniques

This was the first method to be developed for GNSS surveying. It can be used for measuring long baselines (usually 20km (16 miles) and over).

The base should placed over an point whose coordinates known with high accuracy and the rover will placed over an point whose coordinates are unknown. Both GNSS receivers must receive signals from the same four (or more) satellites for a period of time that can range from a few minutes to several hours, depending on the conditions of observation and precision required.

Static GNSS has the capability to produce relative positions at the sub-centimeter level on relatively short distances (a few hundred kilometers) and at the centimeter level over long distances (up to thousands of kilometers)

3.9.2 Fast Static GNSS Survey Techniques

This technique is similar to the static technique. The different between them that the rover receiver spends less time over the station.

Fast static surveying requires that one receiver be placed over a known control point. A rover receiver occupies each unknown station for 5-20 min, depending on the number of satellites and their geometry.

The accuracy of fast static surveys is similar to static surveys of 0.03 feet (1 centimeter) or less. This method can be used for medium-to high accuracy survey.

3.9.3 RTK Surveying Techniques

RTK stands for Real Time Kinematic. It is a Kinematic on the Fly survey carried out in real time.The Reference Station has a radio link attached and rebroadcasts the data it receives from the satellites.

The Rover also has a radio link and receives the signal broadcast from the Reference. The Rover also receives satellite data directly from the satellites via its own GNSS Antenna. These two sets of data can be processed together at the Rover to resolve the ambiguity and therefore obtain a very accurate position relative to the Reference receiver.

Once the Reference Receiver has been set up and is broadcasting data through the radio link, the Rover Receiver can be activated.

When it is tracking satellites and receiving data from the Reference, it can begin the initialization process. This is similar to the initialization performed in a post-processed kinematic on the fly survey, the main difference being that it is carried out in real-time.

Once the initialization is complete, the ambiguities are resolved and the Rover can record point and coordinate data.

RTK surveys can be accurate to within 0.05 to 0.10 feet (2– 3 centimeters), providing a good static network and calibration were performed prior to performing the RTK survey. As shown in figure (3-13).{3}

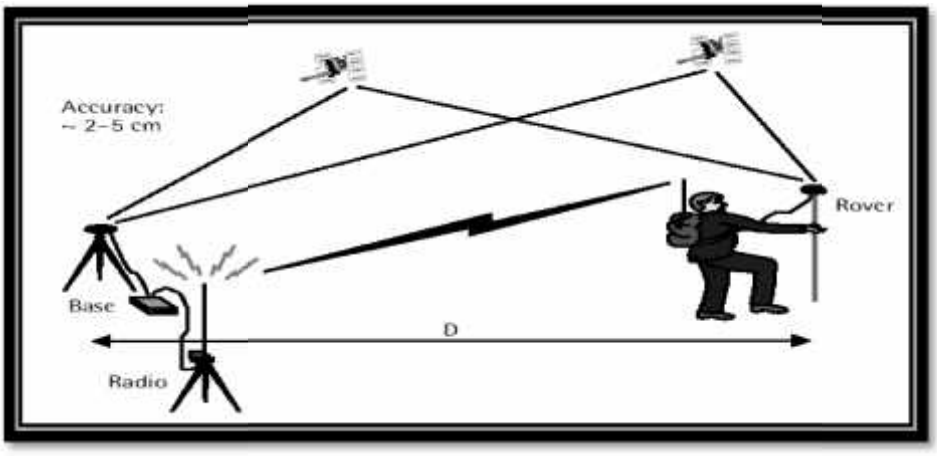


Figure (3-13): RTK GNSS Surveying {4}.

3.9.4 Wide Area (RTK)

3.9.4.1 Virtual reference station (VRS)

The “Virtual Reference Station” concept is based on having a network of GPS reference stations continuously connected via data links to a control center. A computer at the control center continuously gathers the information from all receivers, and creates a living database of Regional Area Corrections. These are used to create a Virtual Reference Station, situated only a few meters from where any rover is situated, together with the raw data, which would have come from it. The rover interprets and uses the data just as if it has come from real reference station. The resulting performance improvement of RTK is dramatic. The implementation of the VRS idea into a functional system solution follows the following principles. First we need a number of reference stations (at least three), which are connected to the network server via some communication links.{5}

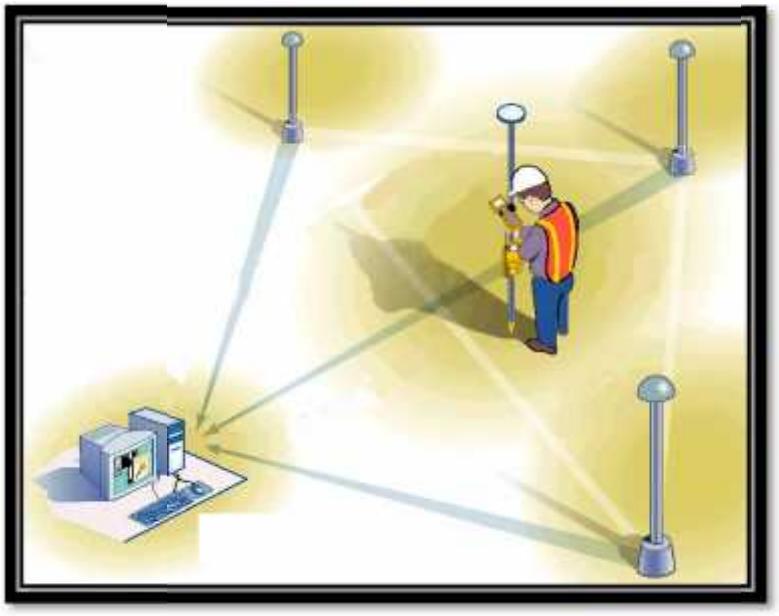


Figure (3-14): Network Sketch {5}.

The GPS rover sends its approximate position to the control center that is running GPS Net. It does this by using a mobile phone data link, such as GSM, to send a standard NMEA position string called GGA. This format was chosen because it is available on most receivers. The control center will accept the position, and responds by sending RTCM correction data to the rover. As soon as it is received, the rover will

compute a high quality DGPS solution, and update its position. The rover then sends its new position to the control center.

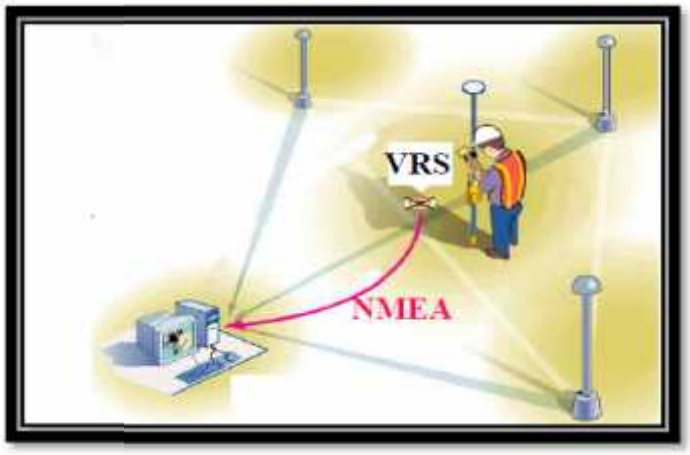


Figure (3-15): Rover transmits NMEA message for VRS position to the network server {5}.

The network server will now calculate new RTCM corrections so that they appear to be coming from a station right beside the rover. It sends them back out on the mobile phone data link (e.g.GSM). The DGPS solution is accurate to +/-1 meter, which is good enough to ensure that the atmospheric and ephemeris distortions, modeled for the entire reference station network, are applied correctly.

This technique of creating raw reference station data for a new, invisible, unoccupied station is what gives the concept its name, “The Virtual Reference Station Concept”. Using the technique, it is possible to perform highly improved RTK positioning within the entire station network. {5}

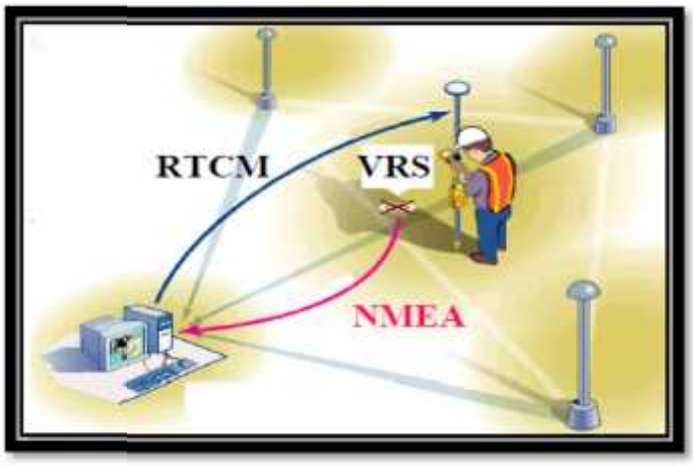


Figure (3-16): Network server transmits RTCM correction stream for VRS position {5}.

3.9.4.2 Area Correction Parameter (ACP)

→Each reference base covers a part of the region.

→A single (closest) base transfers the correction to the rover.

→The baselines are less than 30km.

→Special case FKP-method (Flaechen-Korrektur-Parameter): corrections are

Interpolated from the surrounding base stations.

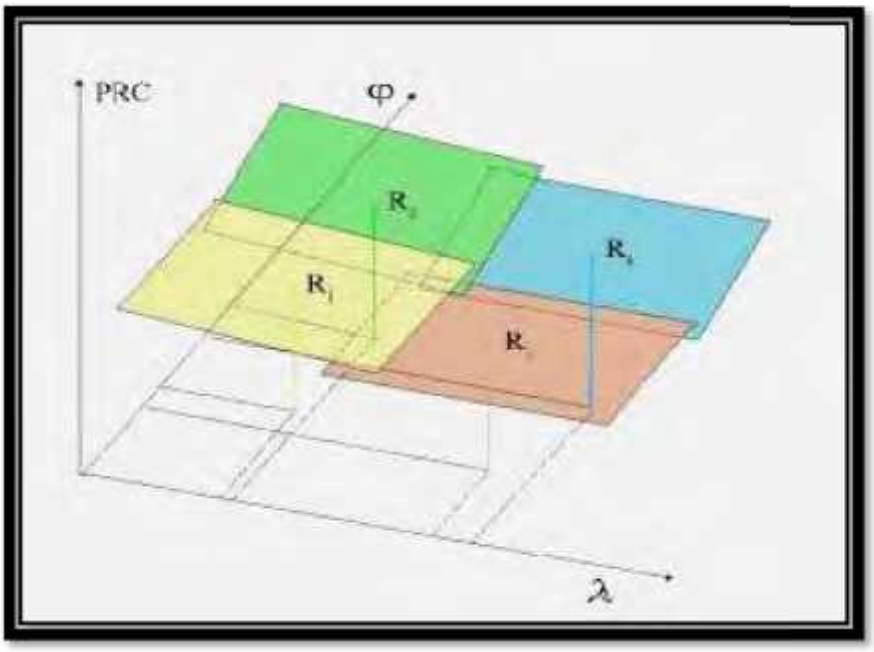


Figure (3-17): Correction Parameter (ACP) {4}.

3.9.4.3 Master Auxiliary Concept (MAC)

The Master Auxiliary Concept (MAC) is different than the VRS and ACP, since it just broadcasts all the information and error models for each reference station in simplex mod e. The burden of modeling the GNSS-Positioning error is totally on the rover side to calculate itand then uses it to compute its corrected observations. Mainly, the transmitted data includesthe data of the master reference station, and the data of other auxiliary reference stations aretransmitted as offset from master reference station to compact the size of the message.{4}

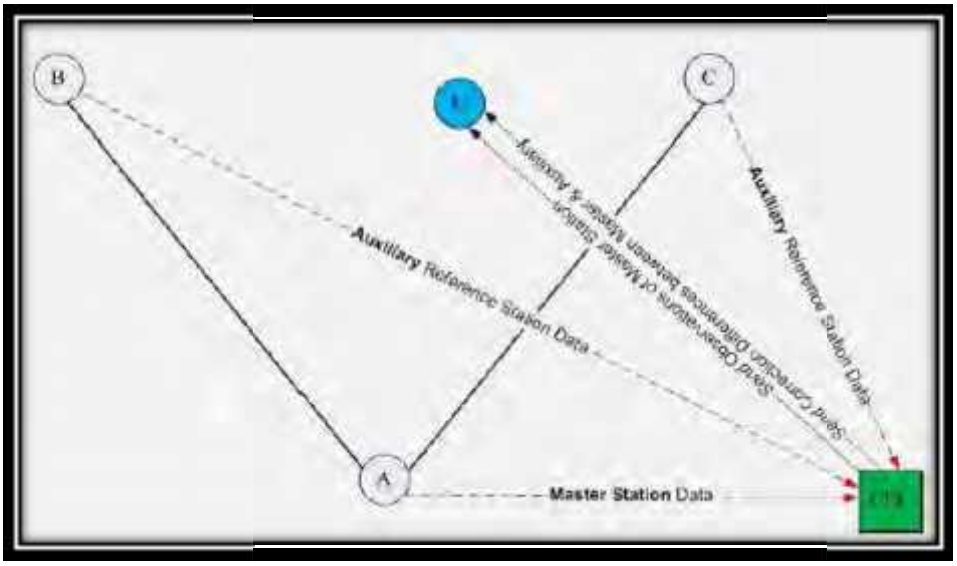


Figure (3-18): Master Auxiliary Concept (MAC) {4}.

Table (3-4) shows the requirement, application, and accuracy, for each type of relative GNSS position (Static, Rapid Static (Fast), and Real Time Kinematic).

Table (3-4) GNSS Relative Positioning

Concept	Requirements	Applications	Accuracy
Static (Post-processing)	•L1 or L1/L2 GNSS S receiver •computer for post-processing. •45 min to 1 hr minimum observation time	• Control surveys (that require high accuracy)	• Sub centimeter level
Rapid Static (Post-processing)	• L1/L2 GNSS receiver • 5-20 min observation time	• Control surveys (that require medium to high accuracy	• Sub centimeter level
Real Time Kinematic (Real-Time)	For post-processing: • L1/L2 GNSS receiver • Computer For real-time: • L1/L2 GNSS receiver • Internal or external processor (computers) • Radio/modem data link set	• Real-time high accuracy surveys • Location surveys • Medium accuracy control surveys • Photo control • Continuous topo	• Sub decimeter level

3.10 GNSS Reffernce System

The World Geodetic System is a standard for use in cartography, geodesy, and navigation it comprises a standard coordinates frame for the earth, a standard spherical reference surface for raw altitude data, and a gravitational equipotential surface that defines the nominal sea level.

The latest revision is (WGS84) which was valid up to about 2010. Earlier schemes included WGS72, WGS66, WGS60. WGS84 is the referenced coordinate system used by the Global Positioning System, as shown in figure (3-5).

Table (3-5): parameter of WGS 84

Ellipsoidal name	Semi major axis (a in meters)	Semi minor axis (a in meters)
WGS 84	6378137	298.257223563

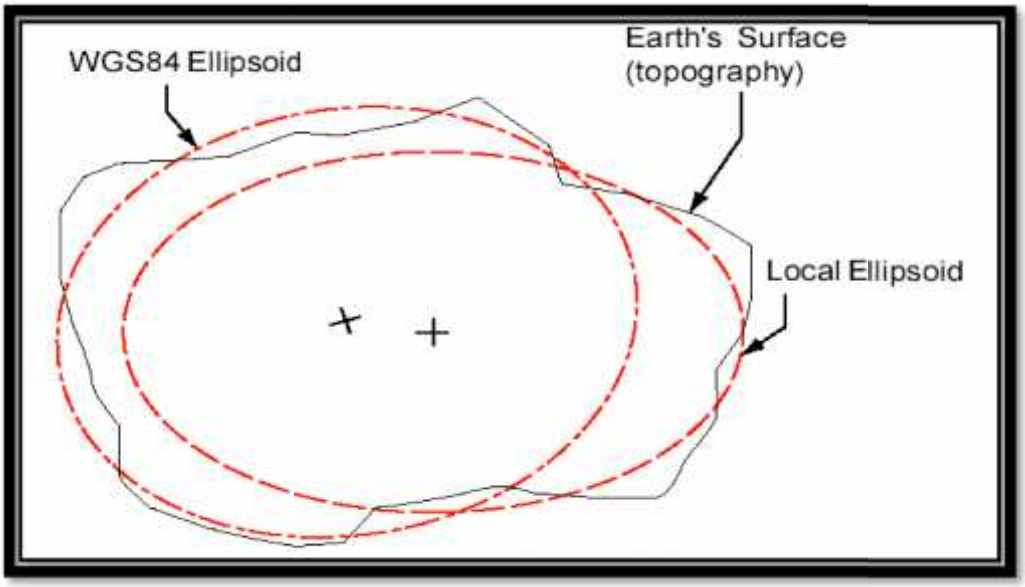


Figure (3-19): WGS 84 {4}.

The other geometric parameters are computed using the following equations:

$$r = a(1+n^2/4)/(1+n) \quad (3\text{-}7)$$

$$n = f/(2-f) \quad (3\text{-}8)$$

$$e^2 = f(2-f) \quad (3\text{-}9)$$

$$e'^2 = e^2/(1-f)^2 \tag{3-10}$$

$$b=a(1-f) \tag{3-11}$$

The absolute positions obtained from GPS are based on the 3-D WGS84 ellipsoid. Coordinate outputs are on a Cartesian system(X-Y-Z) relative to WGS84 rectangular coordinate. These coordinate can be transformed to λ, ¤ , and h by an iterative solution where:

$$\text{a} = \tan^{-1}\frac{Y}{X} \tag{3-12}$$

$$¤ = \tan^{-1}\left(\frac{Z}{\sqrt{X^2+Y^2}}\left(1-e^2\frac{N}{N+h}\right)^{-1}\right) \tag{3-13}$$

$$h = \frac{\sqrt{X^2+Y^2}}{\cos ¤} - N \tag{3-14}$$

$$N = \frac{a^2}{\sqrt{a^2\cos^2 ¤ + b\ \sin^2 ¤}} \tag{3-15}$$

As initial value to start the iterative solution:

$$¤ = \tan^{-1}\frac{Z}{\sqrt{X^2+Y^2}}\left(1-e^2\right)^{-1} \tag{3-16}$$

The inverse problem to find the X, Y, and z, from λ, ¤ , and h;

$$X = (N+h)\cos ¤\ \cos \text{a} \tag{3-17}$$

$$Y = (N+h)\cos ¤\ \cos \text{a} \tag{3-18}$$

$$Z = ((1-e^2)N+h)\sin ¤ \tag{3-19}$$

These coordinates can be transformed to local datum system using 3D similarity transformation according to the following equations:

$$X\,(\text{Local}) = X\,(\text{WGS 84}) + \Delta X \qquad (3\text{-}20)$$

$$Y\,(\text{Local}) = Y\,(\text{WGS 84}) + \Delta Y \qquad (3\text{-}21)$$

$$Z\,(\text{Clarke 1880}) = Z\,(\text{WGS 84}) + \Delta Z \qquad (3\text{-}22)$$

Where: $\Delta X = 230.00$ m, $\Delta Y = 71.00$ m, $\Delta Z = -273$ m

CHAPTER FOUR

COORDINATES SYSTEMS

4.1 Introduction

4.2 Coordinate Systems

4.3 Conversion between positions coordinates systems

4.4 Map Projection of Palestine

4.1Introduction:

A coordinate system is a set of rules that state the correspondence between coordinates and points. a coordinate is one of a set of N numbers individuating the location of a point in an N-dimensional space. A coordinate system is defined once a point known as origin, a set of N lines, called axes, all passing for the origin and having well-known relationships to each other, and a unit length are established.

In GNSS application, the position of a point in a coordinate system can be expressed in Figure (4-1).

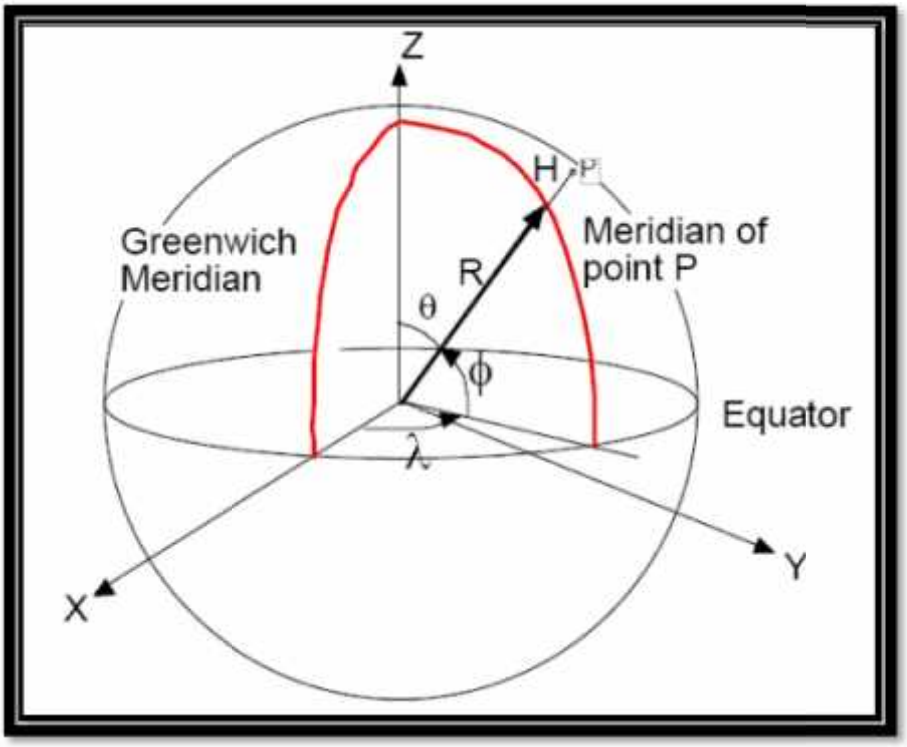


Figure (4-1): Geodetic coordinate{6}.

- Cartesian coordinates (x, y, z);

$$X = (R+H)\cos\phi\cos \quad (4\text{-}1)$$

$$Y = (R+H)\cos\phi\sin \quad (4\text{-}2)$$

$$Z = (R+H)\sin\phi \quad (4\text{-}3)$$

$$r = R+H \quad (4\text{-}4)$$

$$r = \sqrt{X^2 + Y^2 + Z^2} \quad (4\text{-}5)$$

$$= \tan^{-1}\frac{Y}{X} \quad (4\text{-}6)$$

$$\boldsymbol{\phi} = \tan^{-1}\frac{Z}{\sqrt{X^2+Y^2}} \quad (4\text{-}7)$$

- Ellipsoidal or geodetic (also called geographic) coordinates (, $\boldsymbol{\phi}$, H): λ is the latitude, ¤ is the longitude, and h is the height above the surface of the earth.

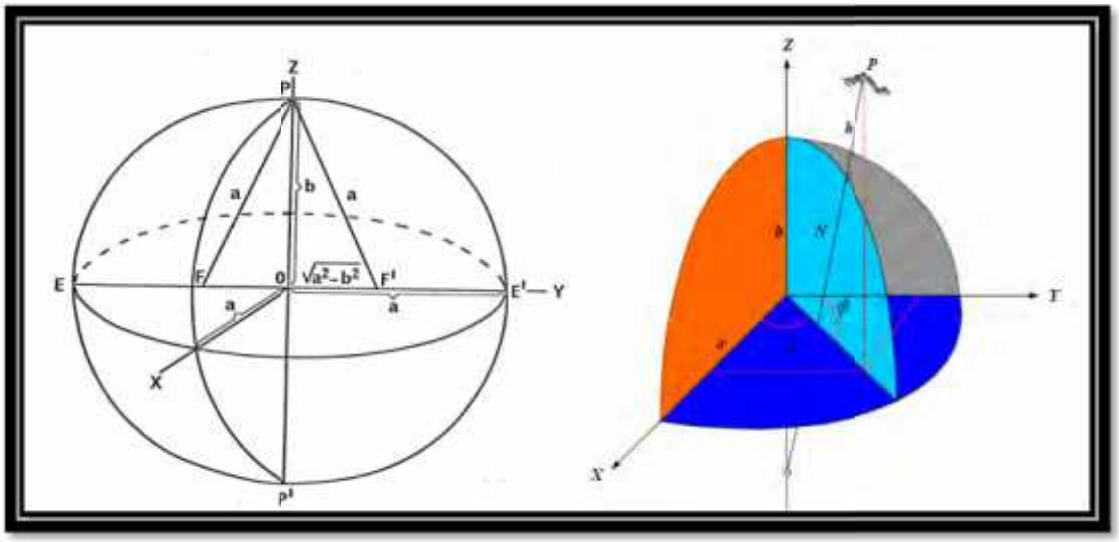


Figure (4-2): Ellipsoidal coordinates {7}.

$$f = \frac{a-b}{a} \quad (4\text{-}8)$$

$$e^2 = \frac{a^2-b^2}{a^2} = f(2-f) \quad (4\text{-}9)$$

$$c = \frac{a^2}{b} = \frac{a}{1-f} \quad (4\text{-}10)$$

$$n = \frac{a-b}{a+b} \quad (4\text{-}11)$$

$$W = (1 - e^2 \sin^2 Bi^R)^{1/2} \quad (4\text{-}12)$$

$$V = (1 + e^2 \cos^2 Bi^R)^{1/2} \quad (4\text{-}13)$$

$$N = \frac{a}{W} \quad (4\text{-}15)$$

$$M = \frac{c}{V^3} \quad (4\text{-}16)$$

Where:

f :The flattening of the ellipsoid.

e^2 :The first eccentricity squared.

c :The polar radius of curvature.

n : Second flattening.

W : First auxiliary quantity.

V : Second auxiliary quantity.

M :Radius of curvature in the meridian.

N :Radius of curvature in the prime vertical.

4.2 Coordinate Systems

We have several coordinate systems here are the most important three systems are:

- Geographic coordinate system.
- Cartesian coordinate system.
- Top centric coordinate system.

4.2.1 Geographic Coordinat System

A geographic coordinate system is a coordinate system that enables every location on the Earth to be specified by a set of numbers or letters. The coordinates are often chosen such that one of the numbers represents vertical position, and two or three of the numbers represent horizontal position. A common choice of coordinates is latitude, longitude and elevation, as shown in figure (4-3).

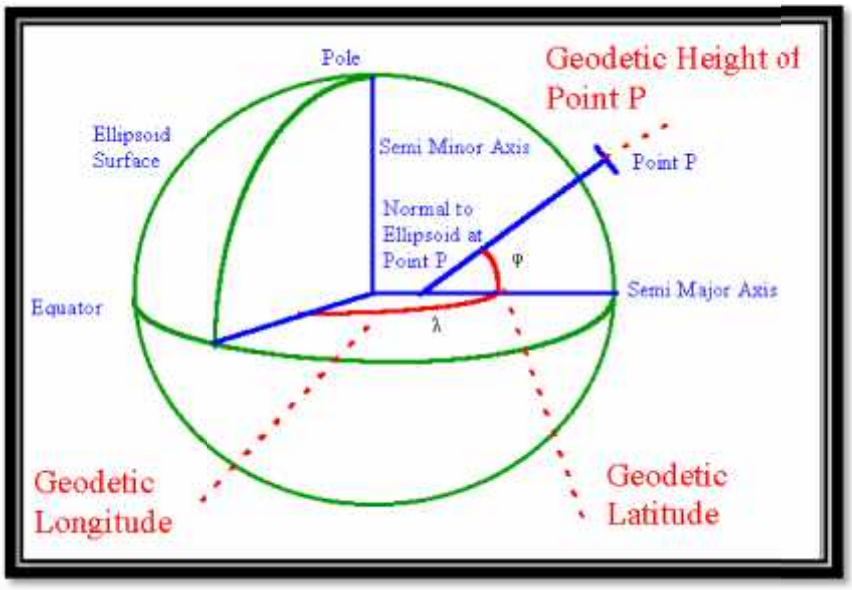


Figure (4-3): Geographic coordinate system{7}.

The latitude(φ) of a point on the Earth's surface is the angle between the equatorial plane and a line that passes through that point and is normal to the surface of a reference ellipsoid which approximates the shape of the Earth.

The Longitude(λ) of a point on the Earth's surface is the angle east or west from a reference meridian to another meridian that passes through that point. All meridians are halves of great ellipses (often improperly called great circles), which converge at the north and south poles.

The geodetic (ellipsoid or normal) height (h) at a point is the distance from the reference ellipsoid to the point in the direction normal to the ellipsoid.

4.2.2 Cartesian Coordinat system

A Cartesian coordinate system is a coordinate system that specifies each point uniquely in a plane by a pair of numerical coordinates, which are the signed distances from the point to two fixed perpendicular directed lines, measured in the same unit of length. Each reference line is called a coordinate axis or just axis of the system, and the point where they meet is its origin, usually at ordered pair (0, 0). The coordinates can also be defined as the positions of the perpendicular projections of the point onto the two axes, expressed as signed distances from the origin.

CHAPTER four COORDINATE SYSTEM

A Cartesian coordinate system in a plane has two perpendicular lines (the x-axis and y-axis), as shown figure (4-4); in three-dimensional space,it has three (the x-axis, y-axis, and z-axis), as shown figure (4-5).

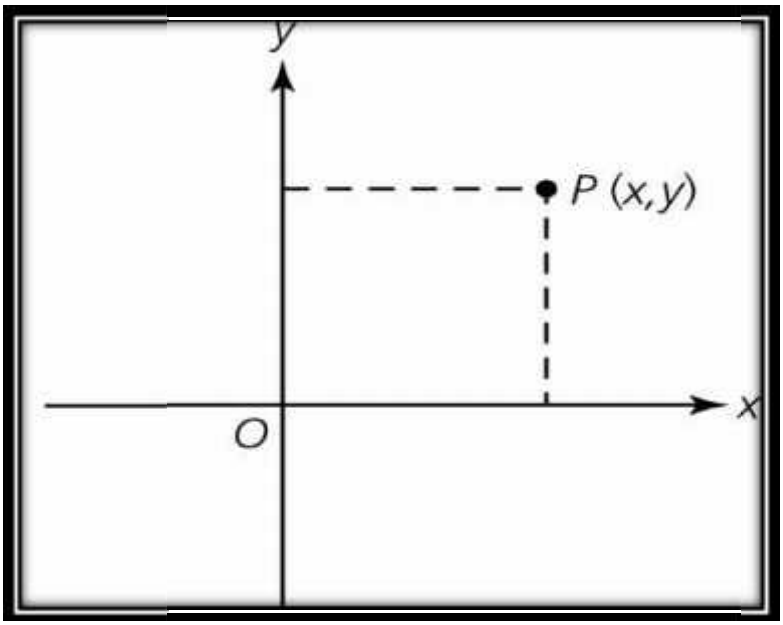


Figure (4-4): Two-dimensional space of Cartesian coordinate{7}.

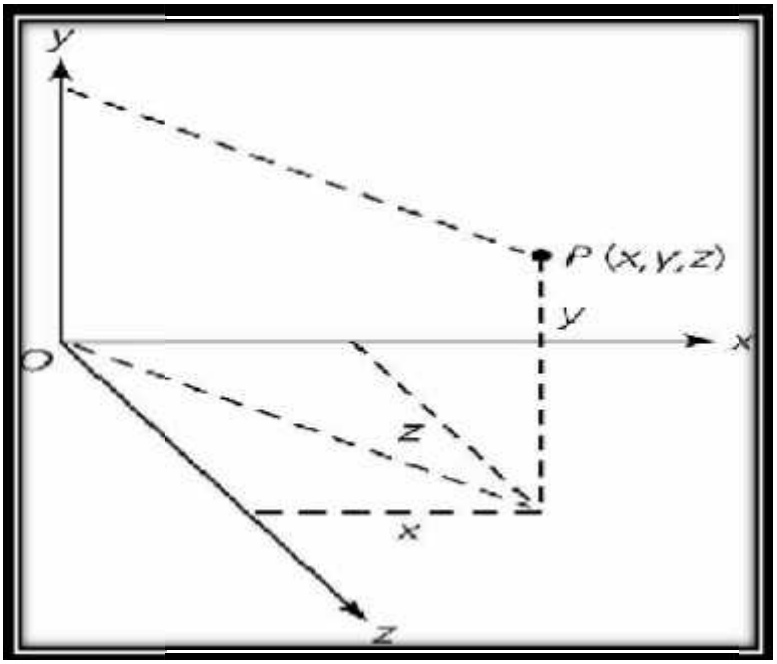


Figure (4-5): Three-dimensional space of Cartesian coordinate{7}.

4.2.3 Topocentric Coordinat System

Point of origin with known geographic coordinate P0 (λ,φ, h)or (X,Y, Z). The x-direction is defined to the north by the horizon, the y-direction is to the east, and the z-direction is perpendicular to the xy-plane to above in the zenith direction. The position of the point is defined by the slope (s) distance, Azimuth (ze), and zenith angle or (x,y,z) local coordinates with respect to the point P. {7}

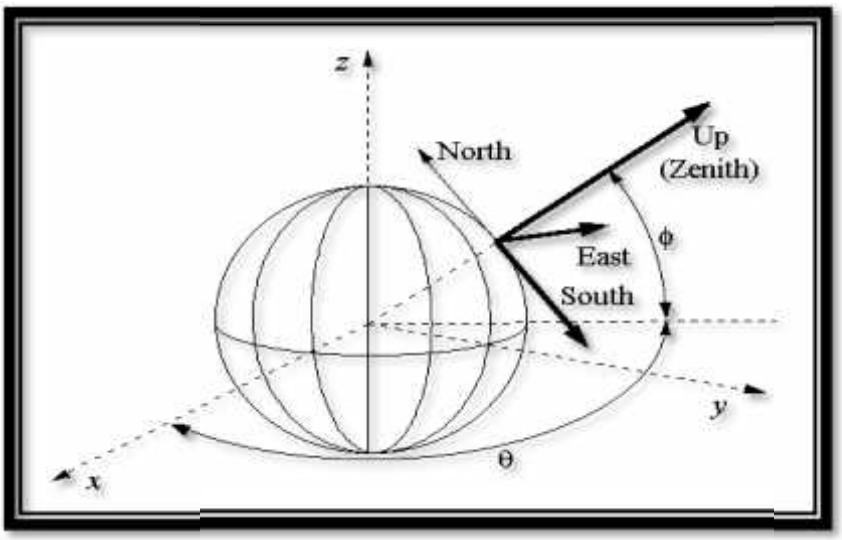


Figure (4-6): Top centric Coordinate System{7}.

The position of the point is defined by the zenith (ze), distance (S) and Azimuth (AZ) measured clockwise from the north.

Where:

$$\begin{aligned} x &= S\cos Az\sin ze \\ y &= S\sin Az\sin ze \\ z &= S\cos ze \end{aligned} \qquad (4.17)$$

If geocentric coordinates are used

$$X = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}, \quad x = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \qquad (4.18)$$

To convert from topocentric to geocentric coordinate the following can be applied in matrix form.

$$\Delta X = Ax \tag{4.19}$$

$$\begin{bmatrix}\Delta X\\ \Delta Y\\ \Delta Z\end{bmatrix} = \begin{bmatrix}-\sin\ddot{}_0\cos\alpha_0 & -\sin\alpha_0 & \cos\ddot{}\cos\alpha_0\\ -\sin\ddot{}_0\sin\alpha_0 & \cos\alpha_0 & \cos\ddot{}_0\sin\alpha_0\\ \cos\ddot{}_0 & 0 & \sin\ddot{}_0\end{bmatrix}\begin{bmatrix}x\\ y\\ z\end{bmatrix} \tag{4.20}$$

$$X = X_{po} + \Delta X$$

$$x = A^{-1}\Delta X = A^{T}\Delta X \tag{4.21}$$

4.3 Conversion between position coordinates systems

Any Cartesian coordinate system can be transformed to another Cartesian coordinate system through three succeeded rotations if their origins are the same and if they are both right-handed or left-handed coordinate systems. These three rotational matrices are:

$$R_1(\mu) = \begin{pmatrix}1 & 0 & 0\\ 0 & \cos\mu & \sin\mu\\ 0 & -\sin\mu & \cos\mu\end{pmatrix} \tag{4.22}$$

$$R_2(¤) = \begin{pmatrix}\cos¤ & 0 & -\sin¤\\ 0 & 1 & 0\\ \sin¤ & 0 & \cos¤\end{pmatrix} \tag{4.23}$$

$$R_3(©) = \begin{pmatrix}\cos© & \sin© & 0\\ -\sin© & \cos© & 0\\ 0 & 0 & 1\end{pmatrix} \tag{4.24}$$

Where (μ . ¤ . ©) is the rotating angle, which has for a counter-clock wise rotation as viewed from the positive axis to the origin R_1, R_2 And R_3 are called the rotating matrix around the x, y, and z-axis, respectively.

For two Cartesian coordinate systems with different origins and different length units, the general transformation can be given in vector (matrix) form as

$$X_t = X_0 + «RX_s \tag{4.25}$$

OR

$$\begin{pmatrix} x_t \\ y_t \\ z_t \end{pmatrix} = \begin{pmatrix} \mathrm{T_X} \\ \mathrm{T_Y} \\ \mathrm{T_Z} \end{pmatrix} + «R \begin{pmatrix} x_s \\ y_s \\ z_s \end{pmatrix} \tag{4.26}$$

$$\mathrm{R} = R_3(©) * R_2(¤) * R_1(\mu) \tag{4.27}$$

Where μ is the scale factor (or the ratio of the two length units), and R is a transformation matrix that can be formed by three suitably succeeded rotations.

x_t: target system Andx_s:source system denote the new and old coordinates, respectively; T_x, T_y, T_zdenotes the translation vector and is the coordinate vector of the origin of the old coordinate system in the new one. This case of transformation is known 3D conformal coordinate transformation or 3D similarity transformation.

If rotational angles(μ . ¤ . ©) is very small, then one has sin μ ≈μ and cos ¤ ≈1. In such a case, the rotational matrix can be simplified. If the three rotational angles (μ . ¤ . ©)in R of Eq are very small then R can be written as:

$$R = \begin{pmatrix} 1 & © & -¤ \\ -© & 1 & \mu \\ ¤ & -\mu & 0 \end{pmatrix} \tag{4.28}$$

Where:(μ .¤ .©)are small rotating angles around the x, y and z-axis, respectively. This type of transformation is called Helmert transformation.

4.4 Map Projection of Palestine

4.4.1Transverse Mercator

Used by USGS for many quadrangle maps at scales from 1:24,000 to 1:250,000; such maps can be joined at their edges only if they are in the same zone with one central meridian. Also used for mapping large areas that are mainly north–south in extent.

Distances are true only along the central meridian selected by the mapmaker or else along two lines parallel to it, but all distances, directions, shapes, and areas are reasonably accurate within 15° of the central meridian. Distortion of distances, directions, and size of areas increases rapidly outside the 15° band. Because the map is conformal, however, shapes and angles within any small area (such as that shown by a USGS topographic map) are essentially true.

Graticule spacing increases away from central meridian. Equator is straight. Other parallels are complex curves concave toward nearest pole.

Central meridian and each meridian 90° from it are straight. Other meridians are complex curves concave toward central meridian. {7}

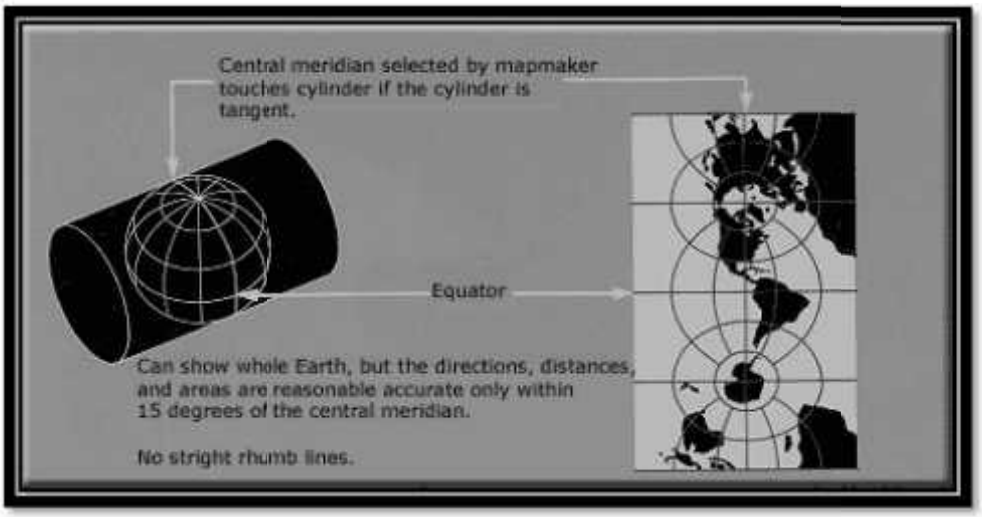


Figure (4-7): Cylindricalmathematically projected on cylinder tangent to a meridian. (Cylinder may also be secant){7}.

The formulas to derive the projected Easting and Northing coordinates are in the form of a series as follows:

Easting:

$$E = FE + k_0 \nu \left| A + (1 - T + C)\frac{A^3}{6} + (5 - 18T + T^2 + 72C - 52e^2)\frac{A^5}{120} \right| \quad (4.29)$$

Northing:

$$N \quad (4.30)$$

$$= FN + k_0 \left\{ M - M_0 + \nu \tan\varphi \left| \frac{\frac{A^2}{2} + \frac{A^4}{24}(5 - T + 9C + 4C^2)}{+(61 - 58T + T^2 + 600C - 330e'^2)\frac{A^6}{720}} \right| \right\}$$

Scale factor:

$$k = k_0 \left| \frac{(1 + e'^2 \cos^2\varphi)(E - FE)}{2k_0^2 V^2} \right| \quad (4.31)$$

Where:

$T = \tan^2\varphi$ (4.32)

$$C = \frac{e^2}{1-e^2}cos^2\varphi = e'^2 cos^2\varphi \quad (4.33)$$

, with λ and λ_0 in radianscos φA = ($-\lambda_0$)

$$M = a.\begin{bmatrix} \left(1-\frac{e^2}{4}-\frac{3e^4}{64}-\frac{5e^6}{256}-\cdots\right).\varphi \\ -\left(\frac{3e^2}{8}+\frac{3e^4}{32}+\frac{45e^6}{1024}+\cdots\right)\sin 2\varphi \\ +\left(\frac{15e^4}{256}+\frac{45e^6}{1024}+\cdots\right)\sin 4\varphi \\ -\left(\frac{35e^6}{3072}+\cdots\right)\sin 6\varphi+\cdots \end{bmatrix} \quad (4.34)$$

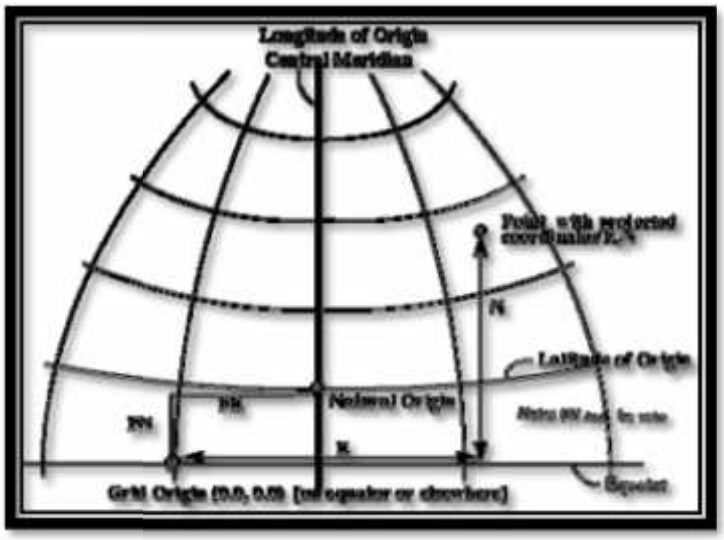


Figure (4-8): with ϕ in radians and M0 for ϕ 0, the latitude of the origin, derived in the same way{7}.

The reverse formulas to convert Easting and Northing projected coordinates to latitude and longitude are:

$$\varphi = \varphi_1 - \frac{V_1 \tan\varphi}{\rho_1}$$

$$\lambda = \lambda_0 + \Big| \begin{matrix} D-(1+2T_1+C_1)\frac{D^3}{6} \\ +(5-2C_1+28T_1-3{C_1}^2+8e'^2+24{T_1}^2)\frac{D^5}{120} \end{matrix} \Big| / \cos\varphi_1 \quad (4.36)$$

And where:

$= \frac{a}{\sqrt{1-e^2 sin^2\varphi_1}} \vee 1$ (4.37)

$p_1 = \frac{a\ 1-e^2}{1-e^2 sin^2\varphi_1\ ^{3/2}}$ (4.38)

$\varphi_1 = \mu_1 + (3\epsilon_1/2 - 27\epsilon_1^{\ 3}/32 + \ldots) \sin 2\mu_1$

$+ (21\epsilon_1^{\ 2}/16 - 55\epsilon_1^{\ 4}/32 + \ldots) \sin 4\mu_1$

$+ (151\epsilon_1^{\ 3}/96 + \ldots) \sin 6\mu_1$

$+ (1097\epsilon_1^{\ 4}/512 - \ldots.) \sin 8\mu_1 + \ldots$(4.39)

And where

$\epsilon_1 = \frac{1-(1-e^2)^{1/2}}{1+(1-e^2)^{1/2}}$ (4.40)

$\mu_1 = \frac{\mu_1}{a(1-e^2/4-3e^4/64-5e^6/256-\cdots)}$ (4.41)

$M_1 = M_0 + (N - FN)/k_0$ (4.42)

$T_1 = tan^2\varphi_1$ (4.43)

$C_1 = e'^2 cos\ \varphi$ (4.44)

$e'^2 = e^2/\ 1 - e^2$ (4.45)

D = $\frac{E-EF}{v_1 k_0}$, with ν 1= (ν for ϕ 1) (4.46)

In Palestine there a coordinates system named **Palestine Transverse Mercator(PTM)** or **Palestine_1923_Belt** with the following parameters:

Figure (4-9): Palestine Transverse Mercator (PTM){7}.

Other common system in use is the **Israeli Transverse Mercator (ITM),** with the following parameters:

Figure (4-10): Israeli Transverse Mercator (ITM){7}.

4.4.2 Cassini Projection

The Cassini-Soldner projection is the ellipsoidal version of the Cassini projection for the sphere.

- In is Transverse Cylindrical
- It is not conformal but as it is relatively simple to construct.
- It was extensively used in the last century and is still useful for mapping areas

With limited longitudinal extent.

- It has now largely been replaced by the conformal Transverse Mercator which it Resembles.
- It has a straight central meridian along which the scale is true.
- All other meridians and parallels are curved.
- The scale distortion increases rapidly with increasing distance from the central Meridian to the east or west.

The formulas to derive projected Easting and Northing coordinates are:

Easting:

$$E=FE+\upsilon\ \ A-T*A^3\ _6-\ 8-T+8C\ T*A^5\ _{120} \quad (4.47)$$

Northing:

$$N=FN+M-M_0+\upsilon\ \tan\varphi\ \ A^2\ _2+\ 5-T+6C\ \ A^4\ _{24} \quad (4.48)$$

Scale factor at given azimuth:

$$k=1+\ E-FE\ ^2.cos^2Az.\frac{1-e^2sin^2\varphi}{2a^2.(1-e^2)} \quad (4.49)$$

Where

$$A=\ \lambda-\lambda_0\ .cos\varphi \quad (4.50)$$

$$T=tan^2\varphi \quad (4.51)$$

$$c=\frac{e^2}{1-e^2}cos^2\varphi \quad (4.52)$$

And M, the distance along the meridian from equator to latitude ϕ , is given by:

$$M = a\left[\begin{array}{l} \left(1-\frac{e^2}{4}-\frac{3e^2}{64}-\frac{5e^6}{256}-\cdots\right)\varphi \\ -\left(\frac{3e^2}{8}+\frac{3e^4}{32}+\frac{45e^6}{1024}+\cdots\right)\sin 2\varphi \\ +\left(\frac{15e^4}{256}+\frac{45e^6}{1024}+\cdots\right)\sin 4\varphi \\ -\left(\frac{35e^6}{3072}+\cdots\right)\sin 6\varphi \end{array}\right] \quad (4.53)$$

With ϕ in radians.

M0 is the value of M calculated for the latitude of the chosen origin. This may not necessarily be chosen as the equator.

To compute latitude and longitude from Easting and Northing the reverse formulas are:

$$\varphi = \varphi_1 - \frac{v_1 \tan\varphi_1}{\rho_1}\left[\frac{D^2}{2} - \left(1+3T_1\right)\frac{D^4}{24}\right] \quad (4.54)$$

$$\lambda = \lambda_0 + \left[D - T_1 D^3/3 + (1+3T_1)T_1 D^5/15\right]/\cos\varphi_1 \quad (4.55)$$

where ρ1 is ρ calculated at ϕ = ϕ 1, and ϕ 1 is the latitude of the point on the central meridian which has the same Northing as the point whose coordinates are sought, and is found from:

$$\varphi 1 = \frac{a}{1-e^2\sin^2\rho 1} \quad (4.56)$$

$$\rho 1 = \frac{a(1-e^2)}{1-e^2\sin^2\varphi 1\ 3/2} \quad (4.57)$$

$$\varphi_1 = \mu_1 + \left(\frac{3e_1}{2} - \frac{27e_1^3}{32} + \cdots\right)\sin 2\mu_1$$

$$+\left(\frac{21e_1^2}{16} - \frac{55e_1^4}{32} + \cdots\right)\sin 4\mu_1$$

$$+\left(\frac{151e_1^3}{96} + \cdots\right)\sin 6\mu_1$$

$$+\left(\frac{1097e_1^4}{512} - \cdots\right)\sin 8\mu_1 + \cdots \quad (4.58)$$

Where:

$$e_1 = \frac{1-(1-e^1)^{1/2}}{1+(1-e^2)^{1/2}} \quad (4.59)$$

$$\mu_1 = \frac{M_1}{a.(1-e^2/4-3e^4/64-5e^6/256-\cdots)} \quad (4.60)$$

$$M_1 = M_0 + (N - FN) \quad (4.61)$$

$$T_1 = tan^2\varphi_1 \quad (4.62)$$

$$D = (E - FE)/\upsilon_1 \quad (4.63)$$

The Palestinian grid named **Palestine_1923_Grid** is built using Cassini projection with the following parameters:

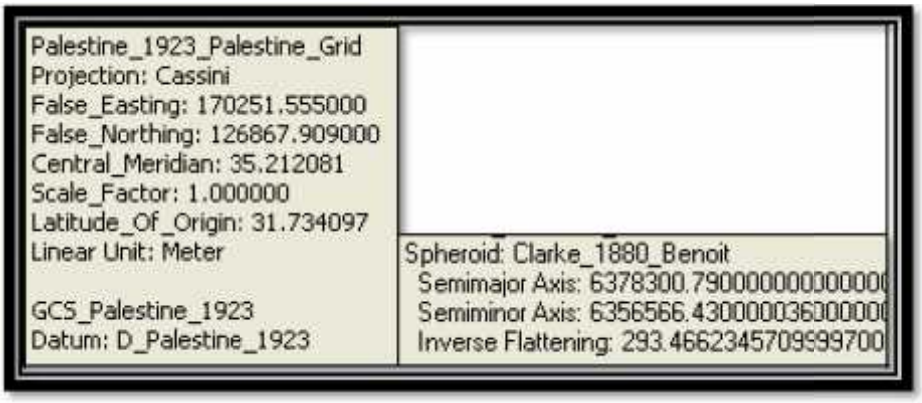


Figure (4-11): Palestine_1923_Grid{7}.

The so called Israeli old grid is the same of Palestine grid, but 1 million is added to the northing value:

Figure (4-12): Israeli old grid{7}.

4.4.3 Universal Transverse Mercator projection

The most familiar and commonly used Transverse Mercator in the oil industry is the Universal Transverse Mercator (UTM) whose natural origin lies on the equator.

The National Imagery and Mapping Agency (NIMA) (formerly the Defense Mapping Agency) adopted a special grid for military use throughout the world called the Universal Transverse Mercator (UTM) grid.

In this grid, the world is divided into 60 north-south zones, each covering a strip 6° wide inlongitude.Thesezonesarenumberedconsecutivelybeginningwith Zone1,between180°and174°westlongitude,andprogressingeastwardtoZone60,between174°and 180° east longitude.

Ineach zone,coordinatesare measurednorthandeastinmeters. Thenorthing valuesare measuredcontinuouslyfrom zero at the Equator,inanortherlydirection.Toavoid negativenumbersforlocationssouthofthe Equator,NIMA'scartographersassignedthe Equator an arbitrary false northingvalue of 10,000,000 meters.

Acentral meridianthroughthemiddle of each 6°zoneisassignedaneasting value of 500,000 meters.Gridvaluestothe westofthiscentral meridianarelessthan500,000;to the east, more than 500,000. The referencescale factor at the central meridian 0.9996.{7}

To find the central meridian of a UTM zone:

$$\text{Central\_Meridian} = (\text{Zone\_\#} \times 6 - 3) - 180$$

To find which zone you belong to at a given longitude:

$$\text{Zone} = \text{int}\left\{\frac{(\lambda+180)}{6}\right\}+1$$

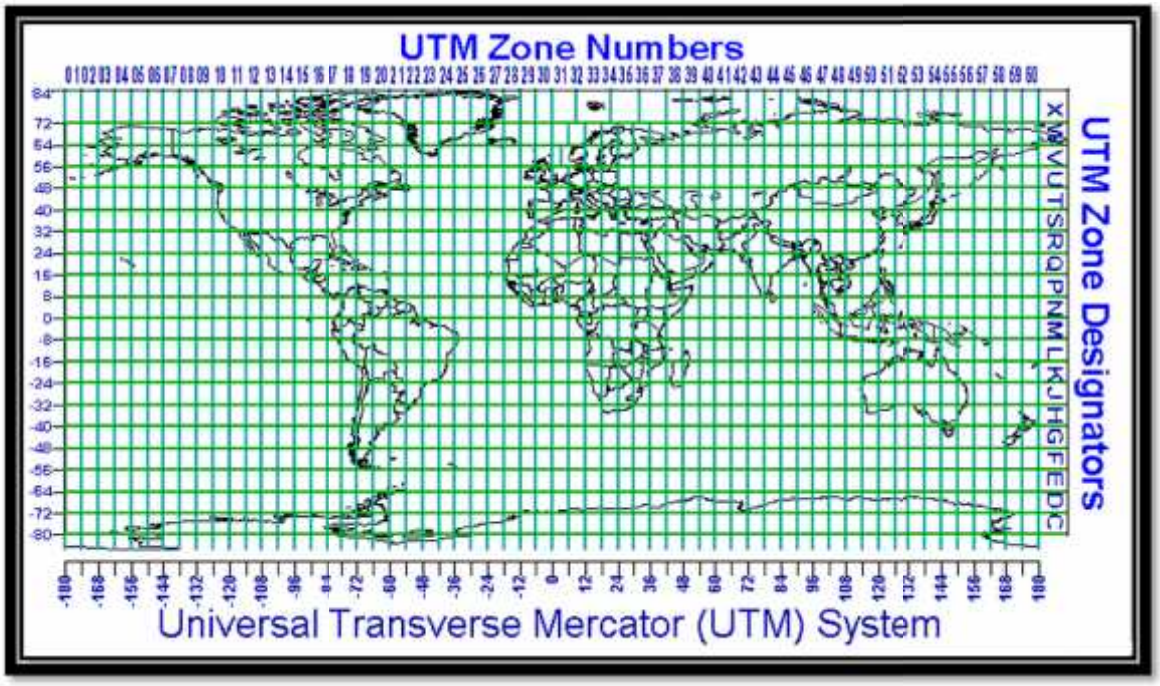


Figure (4-13): (UTM)Zone number{8}.

CHAPTER SIX

CALCULATIONS

6.1 Introduction

6.2 Mathematical model

6.3 Data processing

6.4Three dimensional transformation

6.1Introduction

Afterfinishing the fieldwork in the west bank, 76 triangulation points distributed all over the west bank were observed, to cover the whole area of the west bank as possible.

Finally the calculations using these points, for different methods used are discussed in this chapter.

6.2 Mathematical model

6.2.1 Three -Dimensional Conformal Coordinate Transformation

The three-dimensional conformal coordinate transformation is also known as the seven-parameter similarity transformation. Transforms points from one three-dimensional coordinate system to another. It is applied in the process of reducing data from GNSS surveys and is also used extensively in the field of photogrammetry. The three-dimensional conformal coordinate transformation has to besolving, for seven parameters, three rotations ($Ø_1$, $Ø_2$, $Ø_3$), three translations (T_1, T_2, T_3) and one scale factor(S).

The three dimensional conformal coordinate's transformation in reads:-

$$X = S(r_{11}x + r_{21}y + r_{31}z) + T_x \quad (6.1)$$

$$Y = S(r_{12}x + r_{22}y + r_{32}z) + T_y \quad (6.2)$$

$$Z = S(r_{13}x + r_{23}y + r_{33}z) + T_z \quad (6.3)$$

$$r_{11} = \cos\theta_2 \cos\theta_3 \quad (6.4)$$

$$r_{12} = \sin\theta_1 \sin\theta_2 \cos\theta_3 + \cos\theta_1 \sin\theta_3 \quad (6.5)$$

$$r_{13} = -\cos\theta_1 \sin\theta_2 \cos\theta_3 + \sin\theta_1 \sin\theta_3 \quad (6.6)$$

$$r_{21} = -\cos\theta_2 \sin\theta_3 \quad (6.7)$$

$r_{22} = -\sin\theta_1 \sin\theta_2 \sin\theta_3 + \cos\theta_1 \cos\theta_3$ (6.8)

$r_{23} = \cos\theta_1 \sin\theta_2 \sin\theta_3 + \sin\theta_1 \cos\theta_3$ (6.9)

$r_{31} = \sin\theta_2$ (6.10)

$r_{32} = -\sin\theta_1 \cos\theta_2$ (6.11)

$r_{33} = \cos\theta_1 \cos\theta_2$ (6.12)

For a unique solution, seven observation equations must be used. This requires a minimum of two control stations with known XY coordinates and also xy coordinates, plus three stations with known Z and (x, y ,z) coordinates. If there is more than the minimum number of control points, a least-squares solution can be applied.

$$\begin{bmatrix} \left(\frac{\partial X}{\partial S}\right)_0 & 0 & \left(\frac{\partial X}{\partial \theta_2}\right)_0 & \left(\frac{\partial X}{\partial \theta_3}\right)_0 & 1 & 0 & 0 \\ \left(\frac{\partial Y}{\partial S}\right)_0 & \left(\frac{\partial Y}{\partial \theta_1}\right)_0 & \left(\frac{\partial Y}{\partial \theta_2}\right)_0 & \left(\frac{\partial Y}{\partial \theta_3}\right)_0 & 0 & 1 & 0 \\ \left(\frac{\partial Z}{\partial S}\right)_0 & \left(\frac{\partial Z}{\partial \theta_1}\right)_0 & \left(\frac{\partial Z}{\partial \theta_2}\right)_0 & \left(\frac{\partial Z}{\partial \theta_3}\right)_0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} dS \\ d\theta_1 \\ d\theta_2 \\ d\theta_3 \\ dT_x \\ dT_y \\ dT_z \end{bmatrix} = \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix} \quad (6.13)$$

$\frac{\partial X}{\partial S} = r_{11}x + r_{21}y + r_{31}z$ (6.14)

$\frac{\partial Y}{\partial S} = r_{12}x + r_{22}y + r_{32}z.$ (6.15)

$\frac{\partial Z}{\partial S} = r_{13}x + r_{23}y + r_{33}z.$ (6.16)

$\frac{\partial Y}{\partial \theta_1} = -S\,(r_{13}x + r_{23}y + r_{33}z).$ (6.17)

$\frac{\partial Z}{\partial \theta_1} = S\,(r_{12}x + r_{22}y + r_{32}z).$ (6.18)

$\frac{\partial X}{\partial \theta_2} = S\,(-x \sin\theta_2 \cos\theta_3 + y \sin\theta_2 \sin\theta_3 + z \cos\theta_2).$ (6.19)

$\frac{\partial Y}{\partial \theta 2}$ = S (x sinθ_1 cosθ_2 cosθ_3 – y sinθ_1 cosθ_2 sinθ_3 + z sinθ_1 sinθ_2). (6.20)

$\frac{\partial Z}{\partial \theta 2}$ = S (-x cosθ_1 cosθ_2 cosθ_3 + y cosθ_1 cosθ_2 sinθ_3 – z cosθ_2 sinθ_2). (6.21)

$\frac{\partial X}{\partial \theta 3}$ = S (r_{21}x – r_{11}y). (6.22)

$\frac{\partial Y}{\partial \theta 3}$ = S (r_{22}x – r_{12}y). (6.23)

$\frac{\partial Z}{\partial \theta 3}$ = S (r_{23}x – r_{13}y). (6.24)

6.2.2Helmert Transformation

Local data such as Palestine_1923-Grid can be converted to Earth-centered-Earth-fixed (ECEF) coordinate systems. This means that the Z- axis is nearly aligned with the Conventional Terrestrial Pole. X-Axis with the Greenwich Meridian and the origin is at the mass center of the Earth. International datum's such as the International Terrestrial Reference Frame use the same dentitions for the axes, origin, and ellipsoid, but differ slightly due to the difference in the datum points used in its definition. Thus, the rotational parameters and translations between two ECEF coordinate systems are usually very small. The scale factor between two datum's using the same units of measure should be nearly 1.

The transformation of coordinates from one local datum to another datum is performed as:

$$X_{LD} = sRX_{GD} + T \quad (6.25)$$

S = 1 + Δs. (6.26)

$$R = \begin{bmatrix} 1 & \bar{}_3 & -\bar{}_2 \\ -\bar{}_3 & 1 & \bar{}_1 \\ \bar{}_2 & -\bar{}_1 & 1 \end{bmatrix} = \mathrm{I} + \begin{bmatrix} 0 & \Delta\bar{}_3 & -\Delta\bar{}_2 \\ -\mathrm{X}\bar{}_3 & 0 & \Delta\bar{}_1 \\ \Delta\bar{}_2 & -\Delta\bar{}_1 & 0 \end{bmatrix} = \mathrm{I} + \Delta R \quad (6.27)$$

$$T = T_0 + \Delta T. \tag{6.28}$$

$$T_0 = \begin{matrix} x \\ y \\ z \end{matrix}_{LD} - \begin{matrix} x \\ y \\ z \end{matrix}_{GD} \quad \text{And} \quad \Delta T = \begin{matrix} \Delta T_x \\ \Delta T_y \\ \Delta T_z \end{matrix} \tag{6.29}$$

The design of the least squares solution reads:-

$$X_{LDi} - X_{GDi} - T_0 = j_i \, dx \tag{6.30}$$

$$J_i = \begin{matrix} x_i & 0 & -z_i & y_i & 1 & 0 & 0 \\ y_i & z_i & 0 & -x_i & 0 & 1 & 0 \\ z_i & -y_i & x_i & 0 & 0 & 0 & 1 \end{matrix} \tag{6.31}$$

$$dx = \begin{matrix} \Delta S \\ \Delta\theta_1 \\ \Delta\theta_2 \\ \Delta\theta_3 \\ \Delta T_x \\ \Delta T_y \\ \Delta T_z \end{matrix} \tag{6.32}$$

6.3 Data processing

Inthe project the west bank was divided to three zones; north, middleand south of the west bank this is to access to a better accuracy and larger covered area.

The table below shows an example ofthepoints.

Table (6- 1): registered coordinates and WGS84 coordinates.

Point ID	WGS 84			Palestine_1923_Grid		
	latitude	longitude	H	E	N	h
799D	32° 32’ 28.85588" N	35° 13’ 17.68601" E	129.74	171066.13	216350.7	108.56
523S	32° 29’ 13.66304" N	35° 18’ 51.94351" E	144.53	179794.28	210343.12	124.97
149T	32° 28’ 20.28840" N	35° 20’ 31.53713" E	179.16	182397.17	208701.37	158.13
300T	32° 27’ 35.33973" N	35° 19’ 09.06541" E	213.73	180244.82	207314.87	193.96
1078S	32° 25’ 10.74688" N	35° 19’ 31.06957" E	391.87	180824.64	202860.76	371.82
1076S	32° 25’ 42.20879" N	35° 18’ 59.77585" E	372.74	180005.87	203829.47	351.74
701E	32° 26’ 53.23028" N	35° 16’ 24.06243" E	326.40	175936.27	206014.34	305.12
702E	32° 26’ 36.40028" N	35° 16’ 29.01769" E	294.91	176065.94	205495.92	273.84
132T	32° 24’ 54.73267" N	35° 11’ 41.34843" E	401.36	168551.6	202361.6	380.48
744E	32° 27’ 38.27550" N	35° 14’ 28.50572" E	311.29	172917.58	207400.21	189.98
326V	32° 29’ 41.33440" N	35° 22’ 24.91227" E	331.13	185353.72	211202.81	309.97
993R	32° 31’ 02.86951" N	35° 11’ 40.21056" E	249.97	168522.92	213702.42	230.2
579S	32° 28’ 12.08304" N	35° 15’ 22.70202" E	264.01	174332.52	208442.16	243.89
543W	32° 24’ 20.89429" N	35° 11’ 49.79176" E	379.64	168772.13	201319.42	360.01
283P	32° 21’ 13.48387" N	35° 10’ 14.68571" E	424.80	166284.91	195546.68	332.24

There are two cases in this project, first case which include the heights of the points in calculation, and the second one assumed that the height of points equal zero. This

Assumption aims to see whether the heights will affect the solution, on reason for this is the heights for triangulation points in Palestine are not clear.

6.3.1Case 1

In this case the heights of points were included in the calculation, andit's considered on threesteps.

1- Data preparation.
2- The pre –processing check.
3- Three-dimensional transformations.

6.3.1.1Data preparation

First step in the calculation was preparation of points this mainly includes the transformation of triangulation points coordinates from (E, N, H) to (X, Y, Z) based on Palestine _1923 and the transformation coordinates of the GNSS from (lat, long, h) to (X, Y, Z) based on WGS84.figure (6-1) shows an example of the coordinates conversions.

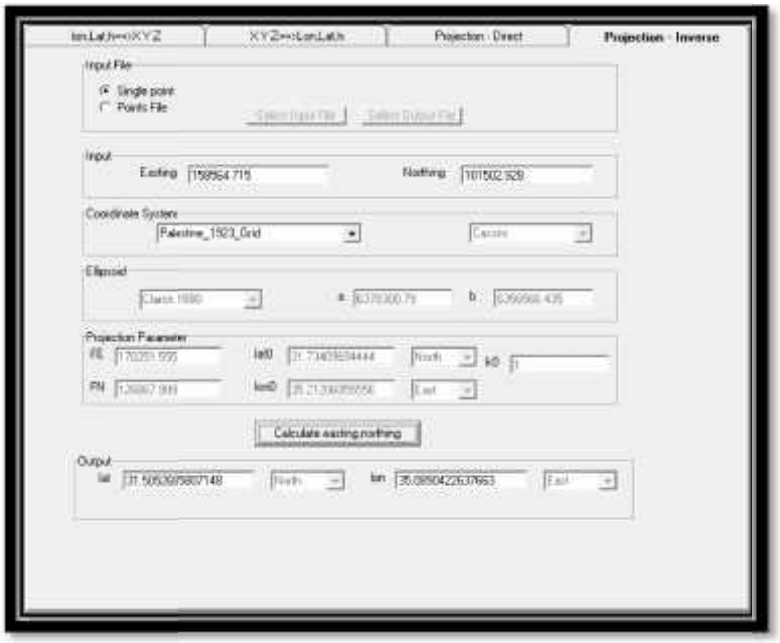


Figure (6-1): Example of the coordinate's conversions**.**

In this step the data was imported as text file containing the coordinates wanted to be Transformed from (E, N) to (lat, long) on Palestine_1923, Figure (6-2) shows an example of text file was imported.

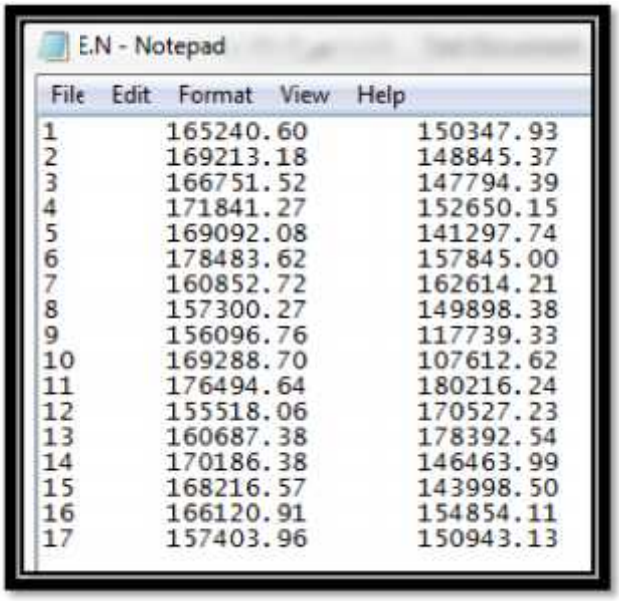
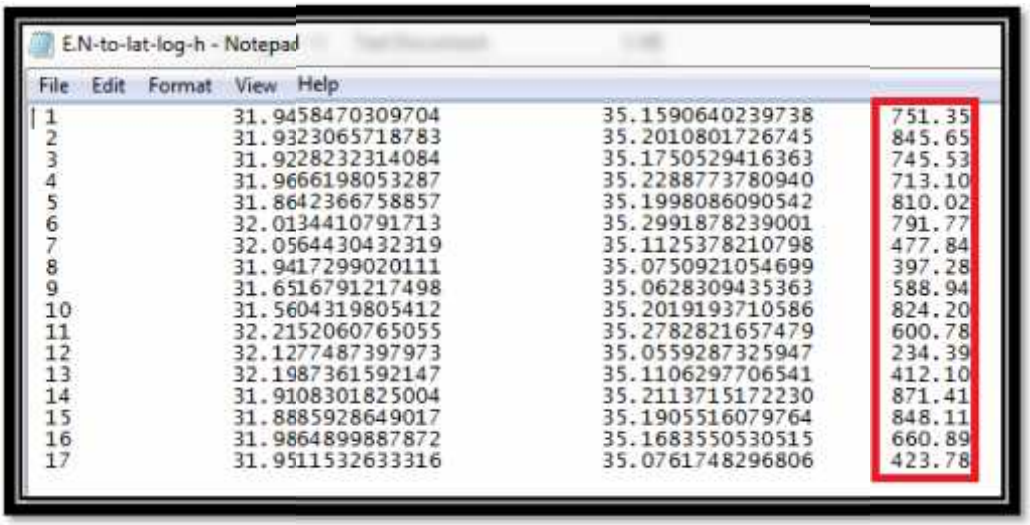
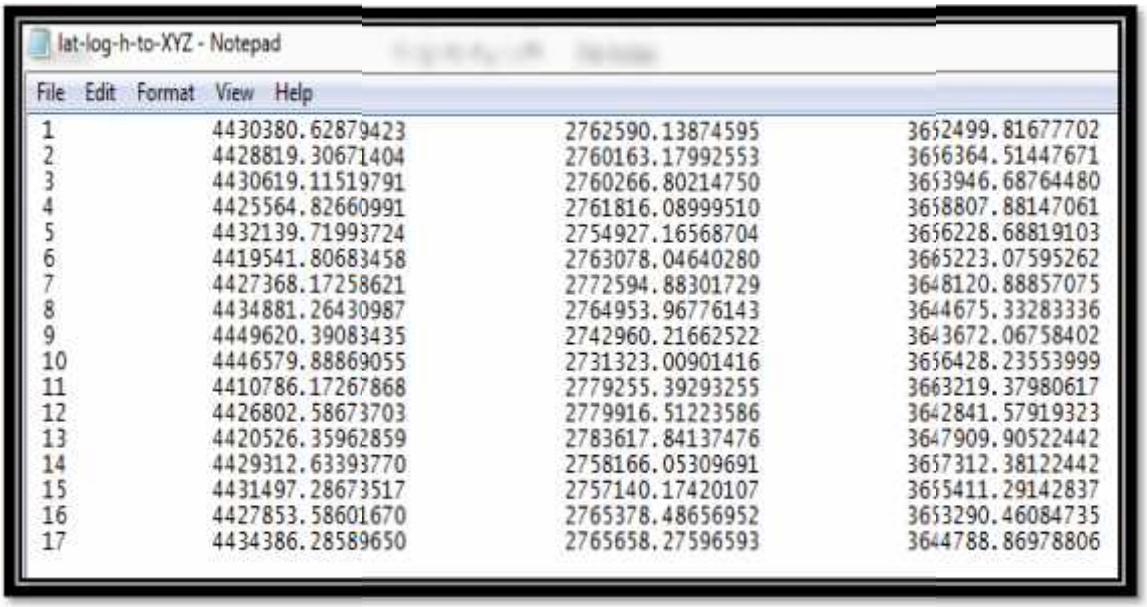


Figure (6-2): example of text file.

After wards t the heights of points wereadded to the new text file, as shown in Figure (6-3) the new text file can be used as input for the transformation from (lat, long, h) to (X, Y, Z) on Palestine_1923.Figure (6-4) shows the transformation results. Figure (6-



3): points heights were added.


lat-log-h-to-XYZ - Notepad

File Edit Format View Help

1	4430380.62879423	2762590.13874595	3652499.81677702
2	4428819.30671404	2760163.17992553	3656364.51447671
3	4430619.11519791	2760266.80214750	3653946.68764480
4	4425564.82660991	2761816.08999510	3658807.88147061
5	4432139.71993724	2754927.16568704	3656228.68819103
6	4419541.80683458	2763078.04640280	3665223.07595262
7	4427368.17258621	2772594.88301729	3648120.88857075
8	4434881.26430987	2764953.96776143	3644675.33283336
9	4449620.39083435	2742960.21662522	3643672.06758402
10	4446579.88869055	2731323.00901416	3656428.23553999
11	4410786.17267868	2779255.39293255	3663219.37980617
12	4426802.58673703	2779916.51223586	3642841.57919323
13	4420526.35962859	2783617.84137476	3647909.90522442
14	4429312.63393770	2758166.05309691	3657312.38122442
15	4431497.28673517	2757140.17420107	3655411.29142837
16	4427853.58601670	2765378.48656952	3653290.46084735
17	4434386.28589650	2765658.27596593	3644788.86978806

Figure (6-4): transformation results

Finally, the coordinates based on WGS84 coordinates system, are transformed formgeographic (lat , long,h) to geocentric (X,Y,Z)as shown in Figure(6-5) ,Figure(6-6) shows the geocentric coordinates (X,Y,Z) based on WGS84of the points .

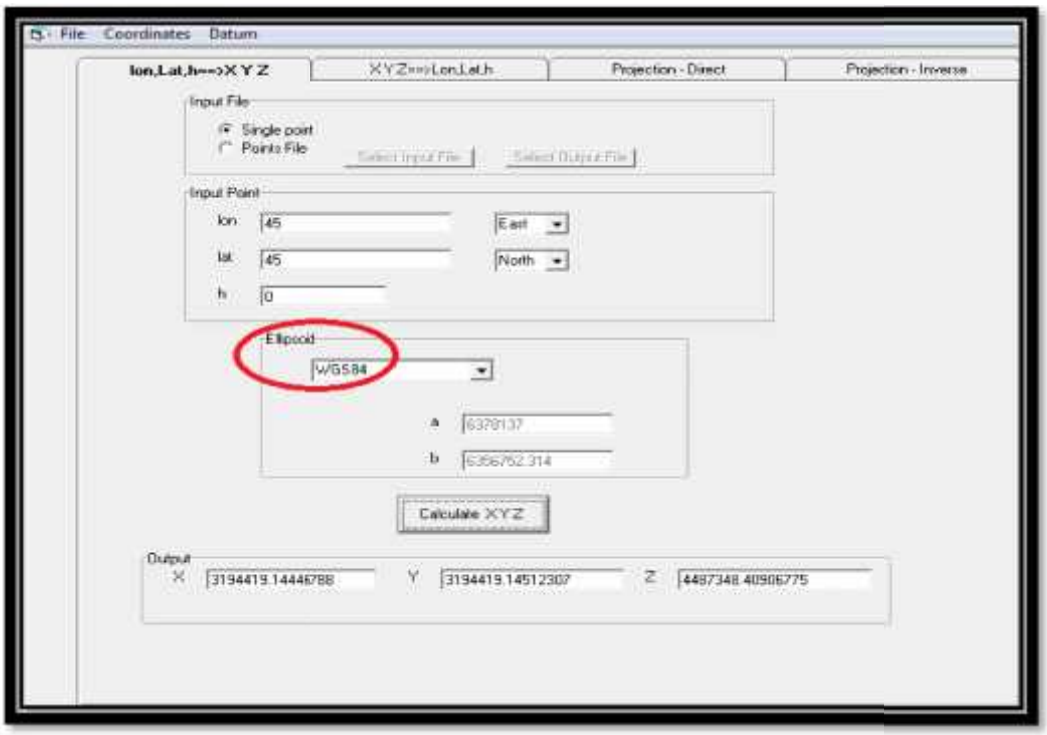
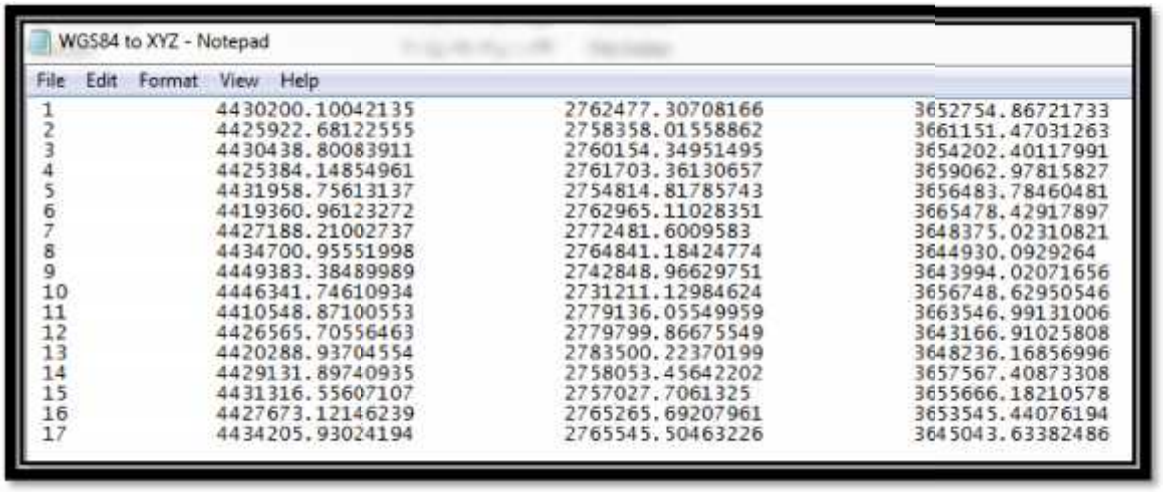


Figure (6-5): show coordinates transformation (lat, long, h) to (X, Y, Z).


WGS84 to XYZ - Notepad

File Edit Format View Help

1	4430200.10042135	2762477.30708166	3652754.86721733
2	4425922.68122555	2758358.01558862	3661151.47031263
3	4430438.80083911	2760154.34951495	3654202.40117991
4	4425384.14854961	2761703.36130657	3659062.97815827
5	4431958.75613137	2754814.81785743	3656483.78460481
6	4419360.96123272	2762965.11028351	3665478.42917897
7	4427188.21002737	2772481.6009583	3648375.02310821
8	4434700.95551998	2764841.18424774	3644930.0929264
9	4449383.38489989	2742848.96629751	3643994.02071656
10	4446341.74610934	2731211.12984624	3656748.62950546
11	4410548.87100553	2779136.05549959	3663546.99131006
12	4426565.70556463	2779799.86675549	3643166.91025808
13	4420288.93704554	2783500.22370199	3648236.16856996
14	4429131.89740935	2758053.45642202	3657567.40873308
15	4431316.55607107	2757027.7061325	3655666.18210578
16	4427673.12146239	2765265.69207961	3653545.44076194
17	4434205.93024194	2765545.50463226	3645043.63382486

Figure (6-6): coordinates of points in (X, Y, Z).

6.3.1.2The pre-processing check

The pre-processing checkaimsto makea firstcheck forthe calculationand measurements.This check is done by excel tables, where ΔX, ΔY, ΔZ are the difference between (XYZ) on palestine_1923 and (XYZ) on WGS84. The points having a difference with huge difference are excluded.

$$\Delta X = X\_(Palestine\_1923) - X\_WGS84 \quad (6.34)$$

$$\Delta Y = Y\_(Palestine\_1923) - Y\_WGS84 \quad (6.35)$$

$$\Delta Z = Z\_(Palestine\_1923) - Z\_WGS84 \quad (6.36)$$

The Figure (6-7) shows an example of the pre-processing check and the points that wereexcluded from the points.

	Palestine_1923			WGS			Pre-processing		
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ
1	4430380.629	2762590.139	3652499.817	4430200.1	2762477.307	3652754.867	180.5283729	112.8316643	-255.0504403
2	4428819.307	2760163.18	3656364.514	4425922.681	2758358.016	3661151.47	2896.625488	1805.164337	-4786.955836
3	4430619.115	2760266.802	3653946.688	4430438.901	2760154.35	3654202.401	180.3143588	112.4526326	-255.7135351
4	4425564.827	2761816.09	3658807.881	4425384.149	2761703.361	3659062.978	180.6780603	112.7286885	-255.0966877
5	4432139.72	2754927.166	3656228.688	4431958.756	2754814.818	3656483.785	180.9638059	112.3478296	-255.0964138
6	4419541.807	2763078.046	3665223.076	4419360.961	2762965.11	3665478.429	180.8456019	112.9361193	-255.3532264
7	4427368.173	2772594.883	3648120.889	4427188.21	2772481.601	3648375.023	179.9625588	113.282059	-254.1345375
8	4434881.264	2764953.968	3644675.333	4434700.956	2764841.184	3644930.093	180.3087899	112.7835137	-254.760093
9	4449620.391	2742960.217	3643672.068	4449383.385	2742848.966	3643994.021	237.0059345	111.2503277	-321.9531325
10	4446579.889	2731323.009	3656428.236	4446341.746	2731211.13	3656748.63	238.1425812	111.8791679	-320.3939655
11	4410786.173	2779255.393	3663219.38	4410548.871	2779136.055	3663546.991	237.3016732	119.337433	-327.6115039
12	4426802.587	2779916.512	3642841.579	4426565.706	2779799.867	3643166.91	236.8811724	116.6454804	-325.3310649
13	4420526.36	2783617.841	3647909.905	4420288.937	2783500.224	3648236.169	237.4225831	117.6176729	-326.2633455
14	4429312.634	2758166.053	3657312.381	4429131.897	2758053.456	3657567.409	180.7365284	112.5966749	-255.0275087
15	4431497.287	2757140.174	3655411.291	4431316.556	2757027.706	3655666.182	180.7306841	112.4680686	-254.8906774
16	4427853.586	2765378.487	3653290.461	4427673.121	2765265.692	3653545.441	180.4645543	112.7944899	-254.9799146
17	4434386.286	2765658.276	3644788.87	4434205.93	2765545.505	3645043.634	180.3556546	112.7713337	-254.7640368

Figure (6-7): an example of the pre-processing check.

6.3.2Case2:Excluding the heights

The heights in this case were assumed to be equal to zero. The reason is that the heights of the triangulation points are not precise or not known.

6.3.2.1 Data preparation

First step in the calculation was preparation of points this mainly includes the transformation of triangulation points coordinates from (E, N, H=0) to (X, Y, Z) based on Palestine _1923 and the transformation coordinates of the GNSS from (lat, long, h=0) to (X, Y, Z) based on WGS84.

In this step the data was imported as text file containing the coordinates wanted to be Transformed from (E, N) to (lat, long) on Palestine_1923, Figure (6-8) shows an example of text file was imported.

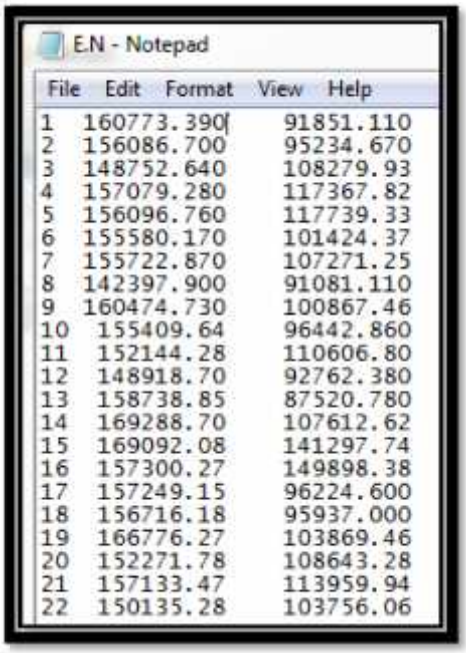
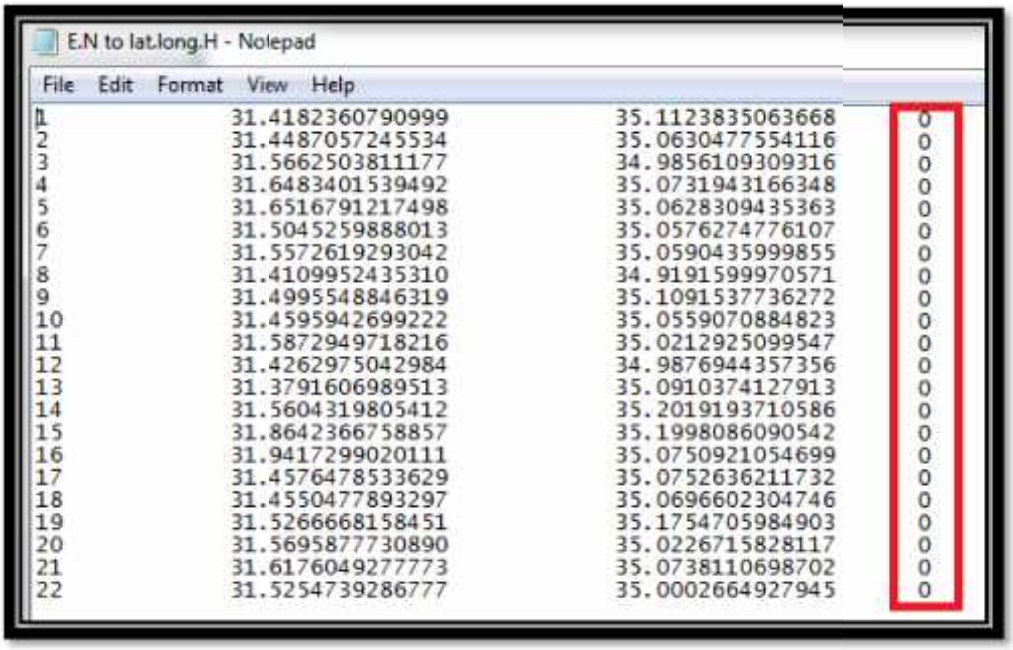


Figure (6-8): an example of text file.

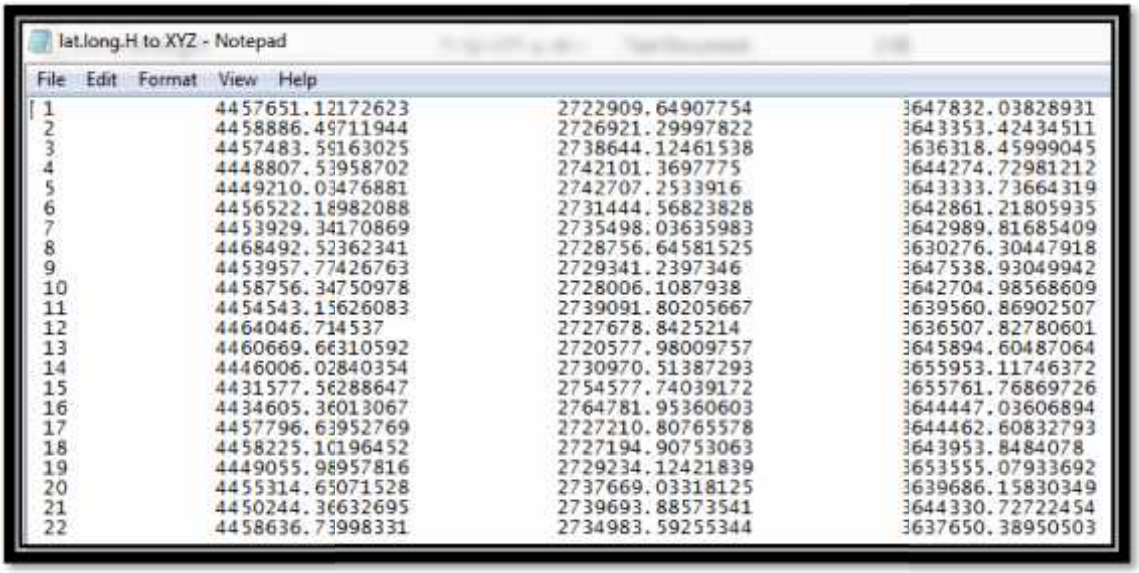
After wards t the heights of points were added to the new text file, as shown in Figure (6-9) the new text file can be used as input for the transformation from (lat, long, h=0) to (X, Y, Z) on Palestine_1923. Figure (6-10) shows the transformation results.


E.N to lat.long.H - Notepad

File Edit Format View Help

1	31.4182360790999	35.1123835063668	0
2	31.4487057245534	35.0630477554116	0
3	31.5662503811177	34.9856109309316	0
4	31.6483401539492	35.0731943166348	0
5	31.6516791217498	35.0628309435363	0
6	31.5045259888013	35.0576274776107	0
7	31.5572619293042	35.0590435999855	0
8	31.4109952435310	34.9191599970571	0
9	31.4995548846319	35.1091537736272	0
10	31.4595942699222	35.0559070884823	0
11	31.5872949718216	35.0212925099547	0
12	31.4262975042984	34.9876944357356	0
13	31.3791606989513	35.0910374127913	0
14	31.5604319805412	35.2019193710586	0
15	31.8642366758857	35.1998086090542	0
16	31.9417299020111	35.0750921054699	0
17	31.4576478533629	35.0752636211732	0
18	31.4550477893297	35.0696602304746	0
19	31.5266668158451	35.1754705984903	0
20	31.5695877730890	35.0226715828117	0
21	31.6176049277773	35.0738110698702	0
22	31.5254739286777	35.0002664927945	0

Figure (6-9): points heights were assumed to be equal zero.


lat.long.H to XYZ - Notepad

File Edit Format View Help

1	4457651.12172623	2722909.64907754	3647832.03828931
2	4458886.49711944	2726921.29997822	3643353.42434511
3	4457483.59163025	2738644.12461538	3636318.45999045
4	4448807.53958702	2742101.3697775	3644274.72981212
5	4449210.03476881	2742707.2533916	3643333.73664319
6	4456522.18982088	2731444.56823828	3642861.21805935
7	4453929.34170869	2735498.03635983	3642989.81685409
8	4468492.52362341	2728756.64581525	3630276.30447918
9	4453957.77426763	2729341.2397346	3647538.93049942
10	4458756.34750978	2728006.1087938	3642704.98568609
11	4454543.15626083	2739091.80205667	3639560.86902507
12	4464046.714537	2727678.8425214	3636507.82780601
13	4460669.66310592	2720577.98009757	3645894.60487064
14	4446006.02840354	2730970.51387293	3655953.11746372
15	4431577.56288647	2754577.74039172	3655761.76869726
16	4434605.36013067	2764781.95360603	3644447.03606894
17	4457796.63952769	2727210.80765578	3644462.60832793
18	4458225.10196452	2727194.90753063	3643953.8484078
19	4449055.98957816	2729234.12421839	3653555.07933692
20	4455314.65071528	2737669.03318125	3639686.15830349
21	4450244.36632695	2739693.88573541	3644330.72722454
22	4458636.73998331	2734983.59255344	3637650.38950503

Figure (6-10): An example of transformation results.

Finally, the coordinates based on WGS84 coordinates system, are transformed form geographic (lat,long, h=0) to geocentric (X, Y, Z) as shown in Figure (6-11). Figure (6-12) shows the geocentric coordinates (X, Y, Z) based on WGS84 of the points.

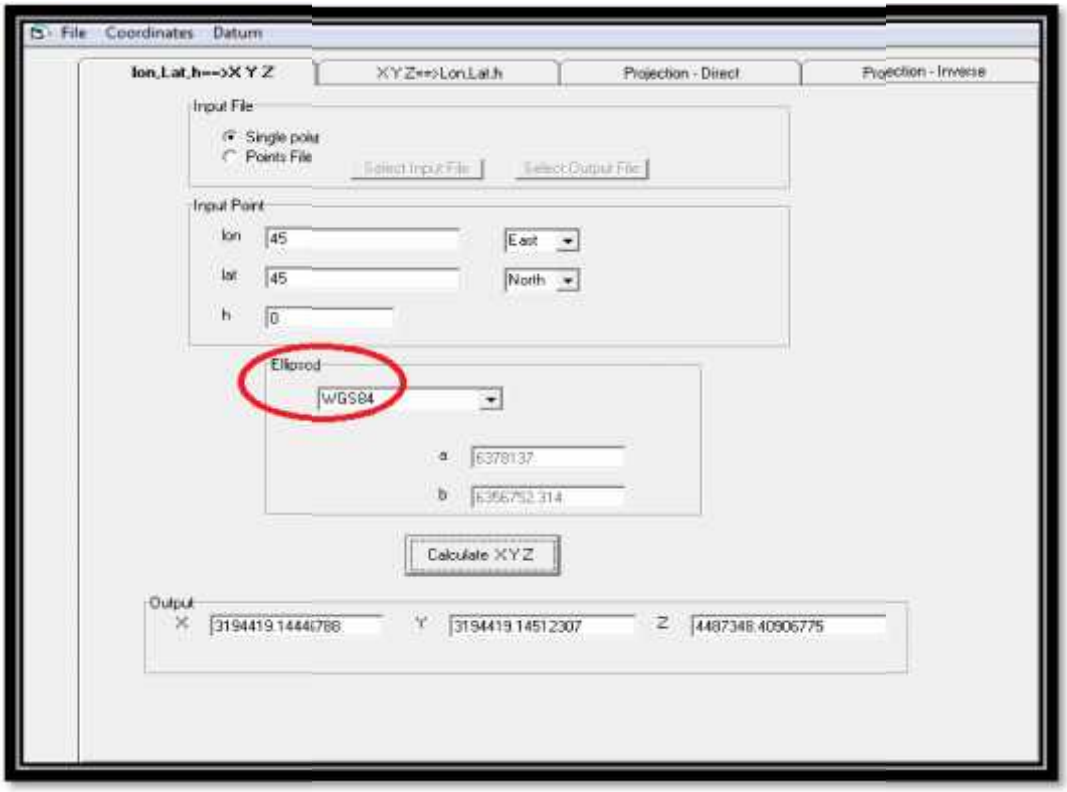


Figure (6-11): show coordinates transformation (lat, long,h) to (X, Y, Z).

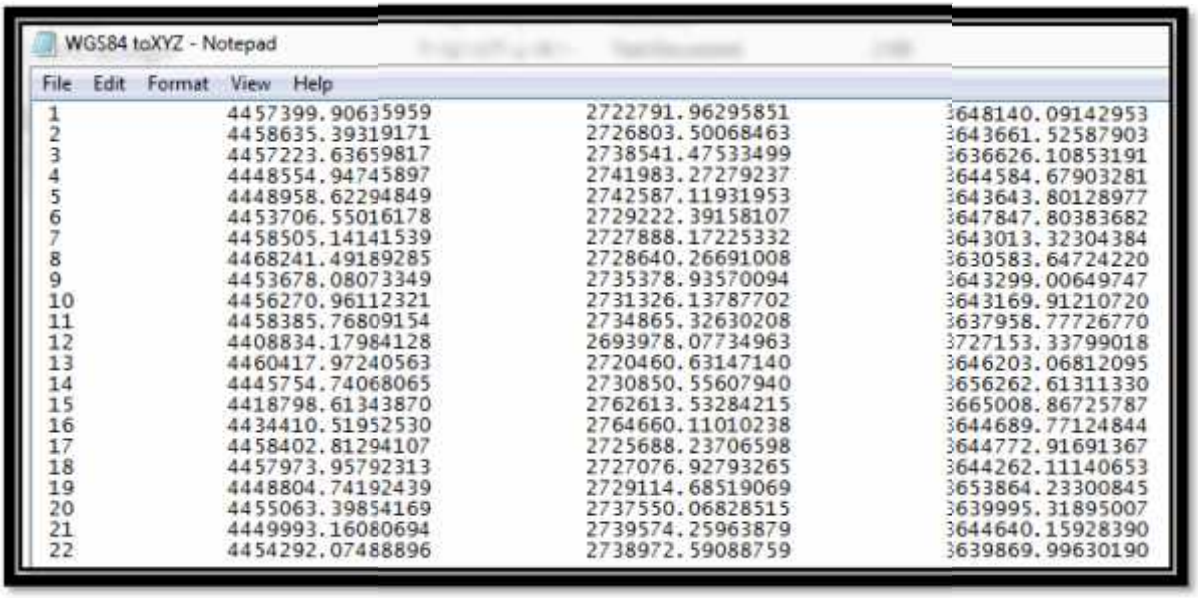


Figure (6-12): The coordinates of points in (X, Y, Z) on WGS84.

6.3.2.2The pre-processing check

The pre-processing check aims to make a firstcheck for the calculation and measurements. This check is done by excel tables, where ΔX, ΔY, ΔZ are the difference between (XYZ) on palestine_1923 and (XYZ) on WGS84. The points having a difference with huge difference are excluded.

$$\Delta X = X\_(Palestine\_1923) - X\_WGS84 \quad (6.34)$$
$$\Delta Y = Y\_(Palestine\_1923) - Y\_WGS84 \quad (6.35)$$
$$\Delta Z = Z\_(Palestine\_1923) - Z\_WGS84 \quad (6.36)$$

The Figure (6-13) shows an example of the pre-processing check and the points that were excluded from the points.

	Palestine_1923			WGS84			Pre- processing		
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ
1	4457651.122	2722909.649	3647832.038	4457399.906	2722791.963	3648140.091	251.2153666	117.686119	-308.0531402
2	4458886.497	2726921.3	3643353.424	4458635.393	2726803.501	3643661.526	251.1039277	117.7992936	-308.1015339
3	4457483.592	2738644.125	3636318.46	4457223.637	2738541.475	3636626.109	259.9550321	102.6492804	-307.6485415
4	4448807.54	2742101.37	3644274.73	4448554.947	2741983.273	3644584.679	252.592128	118.0969851	-309.9492207
5	4449210.035	2742707.253	3643333.737	4448958.623	2742587.119	3643643.801	251.4118203	120.1340721	-310.0646466
6	4456522.19	2731444.568	3642861.218	4453706.55	2729222.392	3647847.804	2815.639659	2222.176657	-4986.585777
7	4453929.342	2735498.036	3642989.817	4458505.141	2727888.172	3643013.323	-4575.799707	7609.864107	-23.50618975
8	4468492.524	2728756.646	3630276.304	4468241.492	2728640.267	3630583.647	251.0317306	116.3789052	-307.342763
9	4453957.774	2729341.24	3647538.93	4453678.081	2735378.936	3643299.006	279.6935341	-6037.695966	4239.924002
10	4458756.348	2728006.109	3642704.986	4456270.961	2731326.138	3643169.912	2485.386387	-3320.029083	-464.9264211
11	4454543.156	2739091.802	3639560.869	4458385.768	2734865.326	3637958.777	-3842.611831	4226.475755	1602.091757
12	4464046.715	2727678.843	3636507.828	4408834.18	2693978.077	3727153.338	55212.5347	33700.76517	-90645.51018
13	4460669.663	2720577.98	3645894.605	4460417.972	2720460.631	3646203.068	251.6907003	117.3486262	-308.4632503
14	4446006.028	2730970.514	3655953.117	4445754.741	2730850.556	3656262.613	251.2877229	119.9577935	-309.4956496
15	4431577.563	2754577.74	3655761.769	4418798.613	2762613.533	3665008.867	12778.94945	-8035.79245	-9247.098561
16	4434605.36	2764781.954	3644447.036	4434410.52	2764660.11	3644689.771	194.8406054	121.8435036	-242.7351795
17	4457796.64	2727210.808	3644462.608	4458402.813	2725688.237	3644772.917	-606.1734134	1522.57059	-310.3085857
18	4458225.102	2727194.908	3643953.848	4457973.958	2727076.928	3644262.111	251.1440414	117.979598	-308.2629987
19	4449055.99	2729234.124	3653555.079	4448804.742	2729114.685	3653864.233	251.2476538	119.4390277	-309.1536715
20	4455314.651	2737669.033	3639686.158	4455063.399	2737550.068	3639995.319	251.2521736	118.9648961	-309.1606466
21	4450244.366	2739693.886	3644330.727	4449993.161	2739574.26	3644640.159	251.20552	119.6260966	-309.4320594
22	4458636.74	2734983.593	3637650.39	4454292.075	2738972.591	3639869.996	4344.665094	-3988.998334	-2219.606797

Figure (6-13): an example of the pre-processing check.

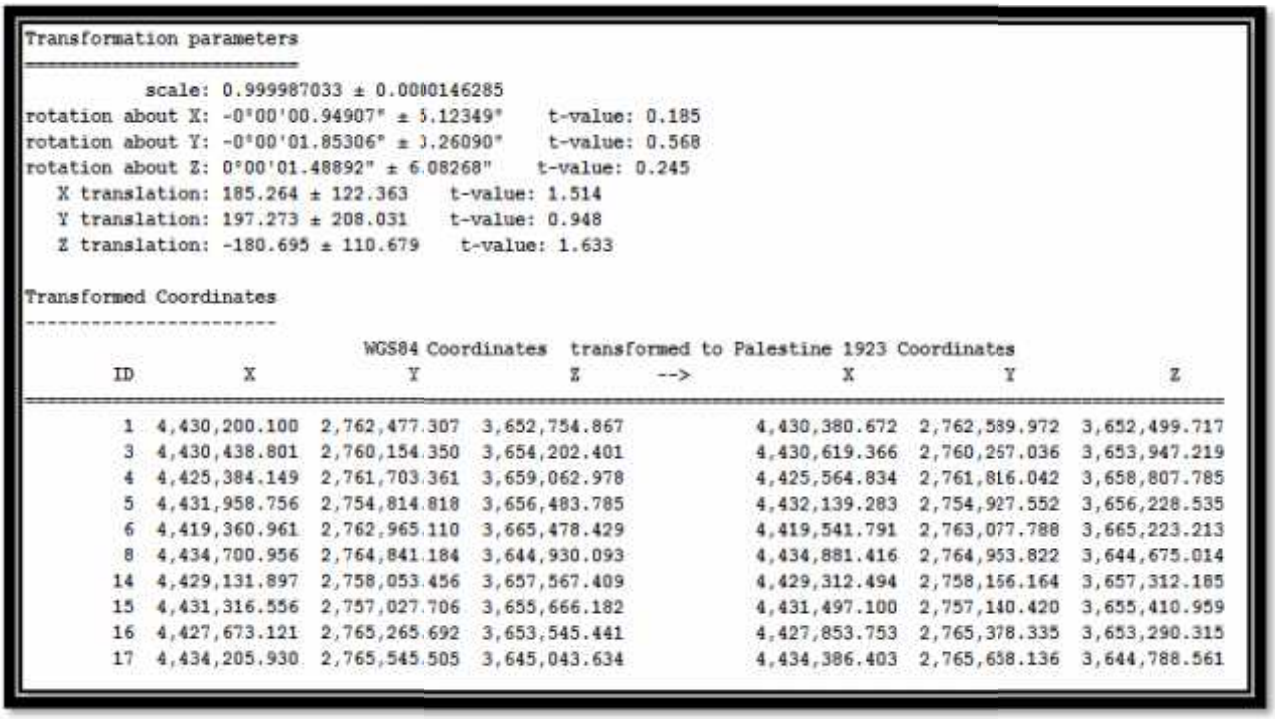
6.4 Three Dimensional transformations

There are two methods used for theThree Dimensional coordinates transformation in this project, these are the Helmet Transformation and Three Dimensional conformal transformation.

6.4.1Helmert Transformation

The Helmert transformation was used to make a three Dimensional transformations for three parts (north, middle, south) of west bank in addition to complete solution of the west bank.

The results of transformation are shown in Figure(6-14) .the figure shows the fourth Iterations and the parameters of transformation forth middle of the west bank, All results of the iterations will be shown in the appendix (A).In each iteration, points with huge residuals where excluded from the next iteration.



Transformation parameters

```
          scale: 0.999987033 ± 0.0000146285
rotation about X: -0°00'00.94907" ± 5.12349"    t-value: 0.185
rotation about Y: -0°00'01.85306" ± 3.26090"    t-value: 0.568
rotation about Z: 0°00'01.48892" ± 6.08268"    t-value: 0.245
   X translation: 185.264 ± 122.363    t-value: 1.514
   Y translation: 197.273 ± 208.031    t-value: 0.948
   Z translation: -180.695 ± 110.679    t-value: 1.633
```

Transformed Coordinates

	WGS84 Coordinates			transformed to Palestine 1923 Coordinates		
ID	X	Y	Z -->	X	Y	Z
1	4,430,200.100	2,762,477.307	3,652,754.867	4,430,380.672	2,762,589.972	3,652,499.717
3	4,430,438.801	2,760,154.350	3,654,202.401	4,430,619.366	2,760,257.036	3,653,947.219
4	4,425,384.149	2,761,703.361	3,659,062.978	4,425,564.834	2,761,816.042	3,658,807.785
5	4,431,958.756	2,754,814.818	3,656,483.785	4,432,139.283	2,754,927.552	3,656,228.535
6	4,419,360.961	2,762,965.110	3,665,478.429	4,419,541.791	2,763,077.788	3,665,223.213
8	4,434,700.956	2,764,841.184	3,644,930.093	4,434,881.416	2,764,953.822	3,644,675.014
14	4,429,131.897	2,758,053.456	3,657,567.409	4,429,312.494	2,758,156.164	3,657,312.185
15	4,431,316.556	2,757,027.706	3,655,666.182	4,431,497.100	2,757,140.420	3,655,410.959
16	4,427,673.121	2,765,265.692	3,653,545.441	4,427,853.753	2,765,378.335	3,653,290.315
17	4,434,205.930	2,765,545.505	3,645,043.634	4,434,386.403	2,765,638.136	3,644,788.561

Figure (6-14): fourth Iterations and the parameters of transformation for the middle of the west bank.

6.4.2 Three Dimensional conformal transformation

This transformation used to transform points known in X, Y and Z in WGS84 coordinates system to Palestine _1923 system for three parts (north, middle, south) of the west bank.Figure (6-15) shows a sample input file for the solution.

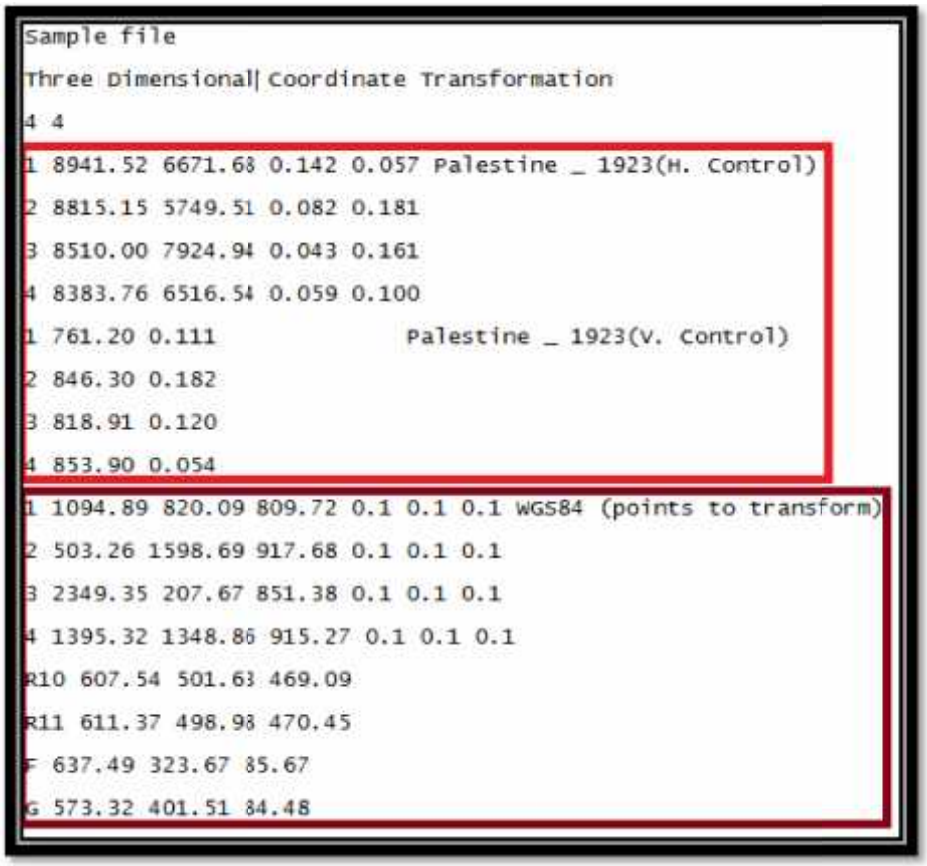


Figure (6-15): an example about that file.

The results of transformation are shown in Figure(6-16) .the figure shows the fourth Iterations and the parameters of transformation forth middle of the west bank, All results of the iterations will be shown in the appendix (A).In each iteration, points with huge residuals where excluded from the next iteration.

Transformation Coefficients

Scale = 0.9999870326 +/- 0.0000146285
x-rot = 0°00'00.9" +/- 0°00'05.1"
y-rot = 0°00'01.9" +/- 0°00'03.3"
z-rot = 359°59'58.5" +/- 0°00'06.1"
Tx = 185.266 +/- 122.3622
Ty = 197.268 +/- 208.0312
Tz = -180.693 +/- 110.6782

Standard Deviation of Unit Weight >> 15.419
Degrees of Freedom: 11

Palestine 1923 Coordinates(CONTROL COORDINATES)

NAME	X	Vx	Y	Vy	Z	Vz
1	4430380.629	0.043	2762590.139	-0.167	3652499.817	-0.100
3	4430619.115	0.250	2760266.802	0.234	3653946.688	0.531
4	4425564.827	0.007	2761816.090	-0.048	3658807.881	-0.096
5	4432139.720	-0.437	2754927.166	0.386	3656228.688	-0.154
6	4419541.807	-0.016	2763078.046	-0.258	3665223.076	0.137
8	4434881.264	0.151	2764953.968	-0.146	3644675.333	-0.319

WGS84 Coordinates transformed to Palestine 1923 Coordinates

NAME	X	Y	Z	Sx	Sy	Sz
1	4430380.672	2762589.972	3652499.717	0.139	0.137	0.138
3	4430619.366	2760267.036	3653947.219	0.134	0.132	0.133
4	4425564.834	2761816.042	3658807.785	0.148	0.146	0.147
5	4432139.283	2754927.552	3656228.535	0.230	0.194	0.210
6	4419541.791	2763077.788	3665223.213	0.252	0.244	0.247
8	4434881.416	2764953.822	3644675.014	0.245	0.234	0.238
14	4429312.494	2758166.164	3657312.185	0.158	0.147	0.151

Figure (6-16): second Iterations and the parameters of transformation for the middle of the west bank.

6.4.3 Helmert Transformationexcluding the heights

The Helmert transformation was used to make a three Dimensional transformations for three parts (north, middle, south) of west bank in addition to complete solution of the west bank.

The results of transformation are shown in Figure(6-17) .the figure shows the fourth Iterations and the parameters of transformation forth middle of the west bank, All results of the iterations will be shown in the appendix (A).In each iteration, points with huge residuals where excluded from the next iteration.

Transformation parameters

```
          scale: 0.999973724 ± 0.0000170074
rotation about X: 0°00'15.15752" ± 5.06529"    t-value: 2.992
rotation about Y: 0°00'06.16518" ± 4.36067"    t-value: 1.414
rotation about Z: 0°00'12.58266" ± 4.93426"    t-value: 2.550
   X translation: 311.082 ± 121.260    t-value: 2.565
   Y translation: 193.583 ± 174.175    t-value: 1.111
   Z translation: -145.486 ± 144.251    t-value: 1.009
```

Transformed Coordinates

	WGS84 Coordinates			transformed to Palestine 1923 Coordinates		
ID	X	Y	Z	--> X	Y	Z
1	4,457,399.906	2,722,791.963	3,648,140.091	4,457,650.919	2,722,910.176	3,647,831.892
2	4,458,635.393	2,726,803.501	3,643,661.526	4,458,886.752	2,726,921.204	3,643,353.186
4	4,448,554.947	2,741,983.273	3,644,584.679	4,448,807.470	2,742,101.260	3,644,274.898
8	4,468,241.492	2,728,640.267	3,630,583.647	4,468,493.102	2,728,756.375	3,630,275.803
13	4,460,417.972	2,720,460.631	3,646,203.068	4,460,668.822	2,720,578.579	3,645,895.181
14	4,445,754.741	2,730,850.556	3,656,262.613	4,446,006.309	2,730,969.865	3,655,953.260
18	4,457,973.958	2,727,076.928	3,644,262.111	4,458,225.333	2,727,194.708	3,643,953.716
19	4,448,804.742	2,729,114.685	3,653,864.233	4,449,056.195	2,729,233.677	3,653,555.161
20	4,455,063.399	2,737,550.068	3,639,995.319	4,455,315.617	2,737,667.438	3,639,686.179
21	4,449,993.161	2,739,574.260	3,644,640.159	4,450,245.497	2,739,692.226	3,644,330.597

Figure (6-17): show the second Iterations and parameters of transformation for the south of west bank

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1Conclusion

7.2 Recommendations

7.1Conclusions

After analysis the results from calculations conclude the following.

1. 76 points were observed, All over the West Bank. But in a pre-processing, it was noted that some points had Mistakes (blander). These points were excluded from the solution as shown in chapter (6-3.2.1). These points are shown in figure (7.1).

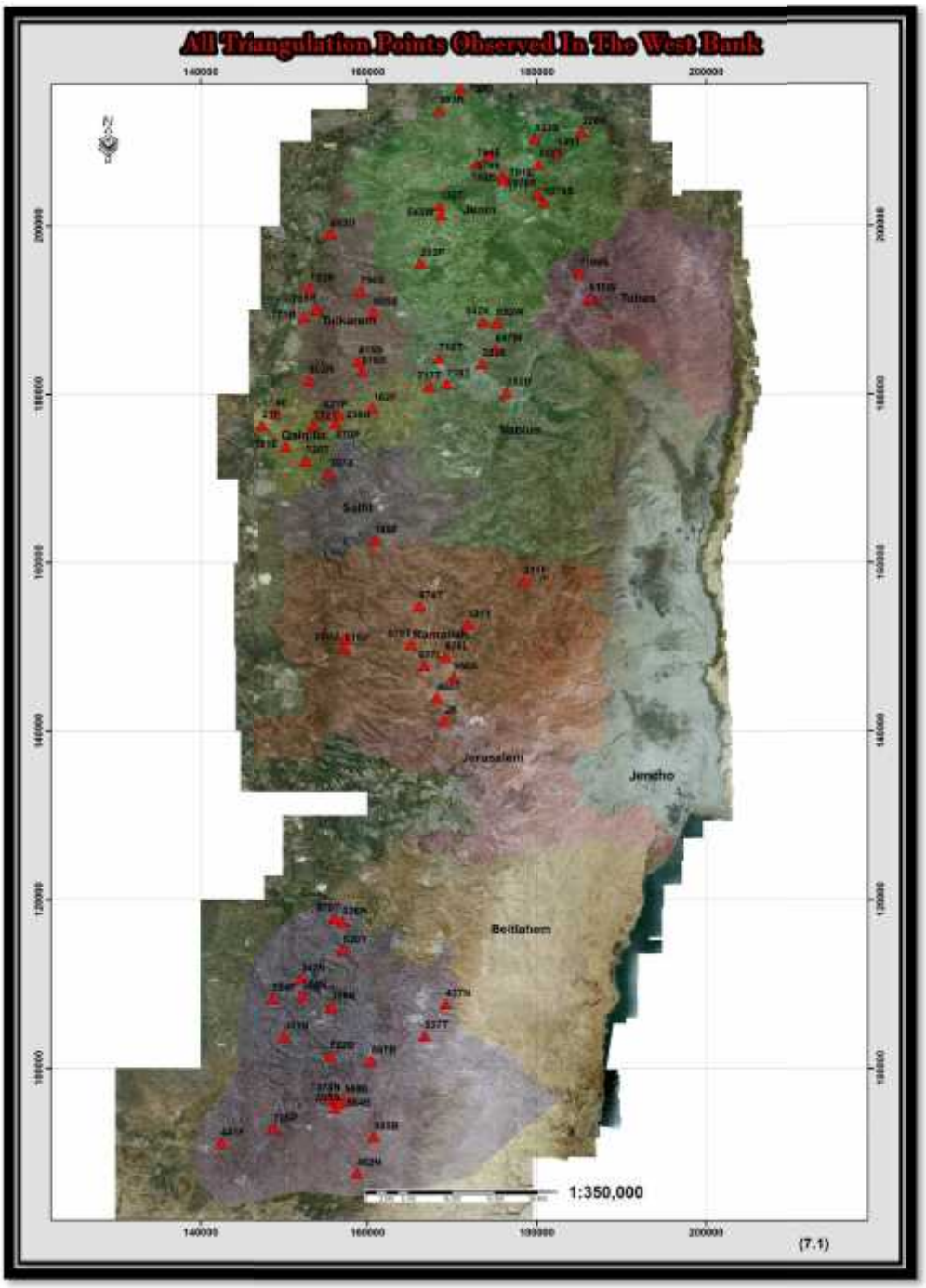


Figure (7-1): The observed points.

2. a solution was developed for a network of the 40 triangulation points that were distributed all over the west bank using (E, N, H) in Palestine 1923 Grid system and (X, Y, Z) WGS84 the range of the residuals was (± 45 cm).
3. a solution was developed for a network of the 35 triangulation points that were distributed all over the west bank using (E, N, H) Palestine 1923 and (X, Y, Z) WGS84 without the heights (h=0) ,range of the residuals (± 45 cm).

Table (7- 1): parameter In Helmert And 3D Conformal.

Area	Helmert	3D Conformal
North-West bank	**scale: 0.999952241 ± 0.0000089257** **μ ":0°00'20.49755" ± 5.40394"** **Ø: 0°00'11.15815" ± 1.93173"** **κ: 0°00'04.91644" ± 6.88821"** **T_X : 579.031 ± 113.374** **T_Y : -6.108 ± 238.881** **T_Z : -114.491 ± 82.311**	**Scale = 0.3572844596 +/- 78.1126810102** **"x-rot = 29°04'20.0" +/- 108°26'10.8** **"y-rot = -226°06'25.4" +/- 197°06'58.9** **"z-rot = 168°52'14.4" +/- 84°52'48.7** **Tx =1216974.133 +/- 617993256.6606** **Ty = 4553193.485 +/- 730980940.6189** **Tz = -1992563.777 +/- 580872072.6605**
Middle-West bank	**scale: 0.999987033 ± 0.0000146285** **ω: -0°00'00.94907" ± 5.12349"** **Ø: -0°00'01.85306" ± 3.26090"** **K: 0°00'01.48892" ± 6.08268"** **T_X: 185.264 ± 122.363** **T_Y: 197.273 ± 208.031** **T_Z:-180.695 ± 110.679**	**Scale = 0.9999870326 +/- 0.0000146285** **"x-rot = 0°00'00.9" +/- 0°00'05.1** **"y-rot = 0°00'01.9" +/- 0°00'03.3** **"z-rot = 359°59'58.5" +/- 0°00'06.1** **Tx = 185.266 +/- 122.3622** **Ty = 197.268 +/- 208.0312** **Tz = -180.693 +/- 110.6782**
South-West bank	**scale: 0.999970744 ± 0.0000179089** **ω: 0°00'15.02431" ± 5.32760"** **Ø: 0°00'10.88049" ± 4.58908"** **K: 0°00'09.20351" ± 5.20434"** **T_X : 439.276 ± 127.704** **T_Y : 123.017 ± 183.425** **T_Z : -249.081 ± 151.911**	**Scale = -0.4983198348 +/- 328.9914736741** **"x-rot = 125°37'33.4" +/- 98°24'48.0** **"y-rot = 15°39'46.6" +/- 81°41'05.9** **"z-rot = 82°00'40.8" +/- 254°07'08.5** **Tx =-23904.112 +/- 3550331057.1794** **Ty = 2732220.738 +/- 6293877170.4360** **Tz = 449932.483 +/- 4700687229.3925**

7.2 Recommendations

1. To get high accuracy and precisionStatictechniques should be used to observe triangulation points.

2. In the field work,Jericho and Bethlehem districts could not be covered, because they are mostly in the Israel military area or they are many the areas of Settlements.

3. Werecommend Palestinian land Authority to forming Committeefor updating and pursuance the triangulation points in the west bank.

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APPENDIX-A

CALCULATION PROTOCOL

A-1 Solution Including the Height (Case 1)

A-2 Solution without Including the Height (Case 2)

A-1 Solution Including the Height (Case 1)

In the first case, the height where used in calculating (X, Y, Z) coordinates.

For the triangulation point, these are orthometrice heights which cover not precisely measured. Table (A-1) (A-2) and (A-3) show the registered coordinates of the control points for the different parts of the West Bank in Pal_1923Grid system.

Table (A-1):-registered coordinates in the north of the west bank in (E, N).

#	E	N	#	E	N
1	171066.1	216350.7	24	149095.6	177710.4
2	179794.3	210343.1	25	153639	176230.2
3	180244.8	207314.9	26	156596.3	177579.2
4	180824.6	202860.8	27	153118.7	181710
5	175936.3	206014.3	28	159351.5	182755.4
6	168551.6	202361.6	29	159177.2	192259.4
7	185353.7	211202.8	30	155625.3	199034.1
8	168522.9	213702.4	31	178483.6	157845
9	174332.5	208442.2	32	160852.7	162614.2
10	166284.9	195546.7	33	182397.2	208701.4
11	186254.2	191429.7	34	180005.9	203829.5
12	175126	185396.5	35	176065.9	205495.9
13	173777.8	188618.9	36	172917.6	207400.2
14	176494.6	180216.2	37	168772.1	201319.4
15	168441.6	184299.9	38	185037.6	194360.4
16	169348.4	181306	39	173564.5	183636.7
17	152430.3	189125.8	40	175284.3	188513.4
18	153226.9	192521.9	41	153983.2	190067.9
19	160711.5	189707.7	42	167342	180964.9
20	160687.5	178393	43	152720.8	172117.8
21	155518	170527.1	44	156276.6	176536.6
22	150347.4	173830.6	45	154797.4	177543
23	147550.3	176307.1	46	158978.3	183966.5

Table (A-2):-registered coordinates in the middle of the west bank in (E, N).

#	E	N	#	E	N
1	165240.6	150347.93	10	169288.7	107612.6
2	169213.18	148845.37	11	176494.6	180216.2
3	166751.52	147794.39	12	155518.1	170527.2
4	171841.27	152650.15	13	160687.4	178392.5
5	169092.08	141297.74	14	170186.4	146464
6	178483.62	157845	15	168216.6	143998.5
7	160852.72	162614.21	16	166120.9	154854.1
8	157300.27	149898.38	17	157404	150943.1
9	156096.76	117739.33			

Table (A-3):-registered coordinates in the South of the west bank in (E, N).

#	E	N	#	E	N
1	160773.39	91851.11	12	148918.7	92762.38
2	156086.7	95234.67	13	158738.9	87520.78
3	148752.64	108279.93	14	169288.7	107612.62
4	157079.28	117367.82	15	169092.1	141297.74
5	156096.76	117739.33	16	157300.3	149898.38
6	155580.17	101424.37	17	157249.2	96224.6
7	155722.87	107271.25	18	156716.2	95937
8	142397.9	91081.11	19	166776.3	103869.46
9	160474.73	100867.46	20	152271.8	108643.28
10	155409.64	96442.86	21	157133.5	113959.94
11	152144.28	110606.8	22	150135.3	103756.06

The projected coordinates (E, N) were converted to Geographic coordinates (, ϕ, h) with the assumption that (h = H), the covered coordinates are shown in tables (A-4) (A-5) and (A-6).

Table (A-4):- Triangulation points coordinates that are transformed to (lat, long, h) in the north of the West bank.

#	Lat	Long	h	#	Lat	Long	h
1	32.5410837	35.220732	108.56	24	32.1924264	34.9877114	116.49
2	32.4868679	35.3135851	124.97	25	32.1791533	35.0359177	252.33
3	32.4595556	35.3183462	193.96	26	32.1913589	35.0672539	316.49
4	32.4193836	35.3244632	371.82	27	32.2285637	35.0303025	156.05
5	32.4478579	35.2725138	305.12	28	32.2380696	35.0964129	389.22
6	32.414931	35.1939892	380.48	29	32.3237758	35.0944522	323.54
7	32.4945588	35.3727453	309.97	30	32.3848287	35.0566274	103.51

8	32.517201	35.1936635	230.2	31	32.0134411	35.2991878	791.77
9	32.4697588	35.2554695	243.89	32	32.056443	35.1125378	477.84
10	32.3534684	35.1699217	332.24	33	32.4720375	35.3412559	158.13
11	32.3162342	35.3819923	354.74	34	32.4281268	35.3157688	351.74
12	32.2619296	35.2637912	668.04	35	32.4431822	35.2738896	273.84
13	32.2909948	35.2494955	548.15	36	32.4603669	35.2404159	189.98
14	32.2152061	35.2782822	600.78	37	32.405533	35.1963352	360.01
15	32.2520492	35.1928541	370.43	38	32.3426795	35.369118	506.21
16	32.2250508	35.2024792	568.55	39	32.2460651	35.2472139	590.25
17	32.2954293	35.0228607	87.46	40	32.2900371	35.2654874	602.11
18	32.3260683	35.0312574	568.75	41	32.3039493	35.0393308	141.89
19	32.300778	35.1107718	319.55	42	32.2219711	35.1811965	480.48
20	32.1987401	35.1106305	412.1	43	32.1420528	35.0262572	203.8
21	32.1277477	35.0559278	234.39	44	32.181953	35.0638793	276
22	32.1574602	35.0010664	173.2	45	32.1910093	35.0481787	255.53
23	32.1797411	34.9713569	73.55	46	32.2489873	35.0924386	318.61

Table (A-5):- Triangulation points coordinates that are transformed to (lat, long, h) in the middle of the West bank.

#	Lat	Long	h	#	Lat	Long	h
1	31.94584703	35.15906402	751.35	10	31.56043198	35.20191937	824.2
2	31.93230657	35.20108017	845.65	11	32.21520608	35.27828217	600.78
3	31.92282323	35.17505294	745.53	12	32.12774874	35.05592873	234.39
4	31.96661981	35.22887738	713.1	13	32.19873616	35.11062977	412.1
5	31.86423668	35.19980861	810.02	14	31.91083018	35.21137152	871.41
6	32.01344108	35.29918782	791.77	15	31.88859286	35.19055161	848.11
7	32.05644304	35.11253782	477.84	16	31.98648999	35.16835505	660.89
8	31.9417299	35.07509211	397.28	17	31.95115326	35.07617483	423.78
9	31.65167912	35.06283094	588.94				

Table (A-6):- Triangulation points coordinates that are transformed to (lat, long, h) in the South of the West bank.

#	Lat	Long	h	#	Lat	Long	h
1	31.41823608	35.11238351	794.29	12	31.4262975	34.98769444	669.29
2	31.44870572	35.06304776	774.12	13	31.3791607	35.09103741	796.08
3	31.56625038	34.98561093	805.21	14	31.56043198	35.20191937	824.2
4	31.64834015	35.07319432	638.89	15	31.86423668	35.19980861	810.02
5	31.65167912	35.06283094	588.94	16	31.9417299	35.07509211	397.28
6	31.50452599	35.05762748	913.81	17	31.45764785	35.07526362	810.69
7	31.55726193	35.0590436	875.47	18	31.45504779	35.06966023	774.24
8	31.41099524	34.91916	643.29	19	31.52666682	35.1754706	942.61
9	31.49955488	35.10915377	902.79	20	31.56958777	35.02267158	614.98
10	31.45959427	35.05590709	739.5	21	31.61760493	35.07381107	849.42
11	31.58729497	35.02129251	567.75	22	31.52547393	35.00026649	730.17

Finally the geographic coordinates (, ϕ, h) are transformed to geocentric coordinates (X, Y, Z) as shown in table (A-7) (A-8) and (A-9).

Table (A-7):-coordinates that are transformed to (X, Y, Z)in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397675	2806063	3657721	**24**	4427256	2787174	3636576
2	4395323	2798713	3666141	**25**	4425398	2784574	3641034
3	4396446	2796484	3666612	**26**	4423160	2784481	3643917
4	4398197	2793268	3667269	**27**	4423231	2788538	3640469
5	4399573	2797211	3662526	**28**	4419366	2787126	3646606
6	4405474	2797410	3655453	**29**	4415252	2793771	3646391
7	4391872	2797344	3671602	**30**	4414157	2799670	3642830
8	4400388	2805214	3655337	**31**	4419542	2763078	3665223
9	4399382	2799452	3660947	**32**	4427368	2772595	3648121
10	4409739	2793485	3653243	**33**	4394572	2796637	3668665
11	4400086	2783364	3672465	**34**	4398228	2794230	3666470
12	4409350	2783376	3661946	**35**	4399705	2796791	3662633
13	4408629	2786050	3660581	**36**	4400617	2799225	3659552
14	4410786	2779255	3663219	**37**	4405792	2796598	3655654
15	4413464	2784909	3655345	**38**	4399603	2785903	3671388
16	4414392	2782587	3656332	**39**	4410965	2782688	3660399
17	4420327	2793921	3639754	**40**	4407846	2785452	3662061
18	4418713	2796209	3640793	**41**	4419062	2794042	3641281
19	4415490	2791441	3647870	**42**	4415632	2783037	3654351
20	4420526	2783618	3647910	**43**	4427688	2782014	3640129
21	4426803	2779916	3642841	**44**	4423771	2783851	3643587
22	4428276	2784044	3637822	**45**	4424163	2785075	3642150
23	4428723	2786729	3635065	**46**	4419000	2788072	3646205

Table (A-8):-coordinates that are transformed to (X, Y, Z)in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4430380.629	2762590.139	3652499.817	10	4446579.889	2731323.009	3656428.236
2	4428819.307	2760163.18	3656364.514	11	4410786.173	2779255.393	3663219.38
3	4430619.115	2760266.802	3653946.688	12	4426802.587	2779916.512	3642841.579
4	4425564.827	2761816.09	3658807.881	13	4420526.36	2783617.841	3647909.905
5	4432139.72	2754927.166	3656228.688	14	4429312.634	2758166.053	3657312.381
6	4419541.807	2763078.046	3665223.076	15	4431497.287	2757140.174	3655411.291
7	4427368.173	2772594.883	3648120.889	16	4427853.586	2765378.487	3653290.461
8	4434881.264	2764953.968	3644675.333	17	4434386.286	2765658.276	3644788.87
9	4449620.391	2742960.217	3643672.068				

Table (A-9):- coordinates that are transformed to (X, Y, Z) in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4458205.608	2723248.351	3648288.9	12	4464514.613	2727964.744	3636891.599
2	4459427.054	2727251.889	3643798.139	13	4461225.776	2720917.155	3646352.253
3	4458045.684	2738989.47	3636780.144	14	4446579.889	2731323.009	3656428.236
4	4449252.659	2742375.727	3644641.85	15	4432139.72	2754927.166	3656228.688
5	4449620.391	2742960.217	3643672.068	16	4434881.264	2764953.968	3644675.333
6	4457159.952	2731835.459	3643386.111	17	4458362.594	2727557.05	3644928.473
7	4454539.991	2735873.082	3643492.705	18	4458765.662	2727525.58	3644398.705
8	4468942.695	2729031.55	3630644.537	19	4449712.746	2729637.005	3654098.1
9	4454587.481	2729727.118	3648058.157	20	4455743.74	2737932.697	3640039.096
10	4459272.715	2728322.039	3643129.736	21	4450836.354	2740058.33	3644818.83
11	4454939.223	2739335.343	3639886.69	22	4459146.581	2735296.335	3638069.201

The GNSS measured coordinates for the triangulation points in the west bank are (Lat, long, h) in WGS84 system, these coordinates are given in table (A-10) (A-11) and (A-12).

Table (A-10):-GNSS coordinatesin the north of the west bank in (Lat, long, h) in WGS84.

#	Lat	Long	h	#	Lat	Long	h
1	32.5413489	35.2215794	129.74	24	32.1927268	34.9885158	137.05
2	32.4871286	35.3144288	144.53	25	32.1794512	35.0367224	272.8
3	32.4598166	35.3191848	213.73	26	32.1916541	35.0680608	336.95
4	32.4196519	35.3252971	391.87	27	32.2288595	35.0311116	176.67
5	32.4481195	35.2733507	326.4	28	32.2383606	35.097225	409.68
6	32.4152035	35.194819	401.36	29	32.3240627	35.0952722	344.15
7	32.4948151	35.3735867	331.13	30	32.3851151	35.0574517	122.05
8	32.5174638	35.1945029	249.97	31	32.0134423	35.2992073	812.61
9	32.4700231	35.2563061	264.01	32	32.0564376	35.1125516	498.43
10	32.3537455	35.170746	424.8	33	32.4723023	35.3420936	179.16
11	32.3165029	35.3828174	375.6	34	32.4283913	35.3166044	372.74
12	32.2622084	35.2646082	688.92	35	32.4434445	35.2747271	294.91
13	32.2912713	35.2503154	569.22	36	32.4606321	35.2412516	311.29
14	32.2154868	35.2791004	621.57	37	32.405804	35.1971644	379.64
15	32.2523332	35.1936685	391.43	38	32.3429465	35.3699485	527.12
16	32.2253334	35.2032908	589.16	39	32.2463454	35.2480286	611.22
17	32.2957223	35.0236757	106.57	40	32.2903147	35.2663058	623.03
18	32.3263592	35.0320755	106.87	41	32.3042407	35.0401471	160.77
19	32.3010626	35.1115878	339.92	42	32.2222572	35.1820098	501.01
20	32.1990321	35.1114394	432.51	43	32.1423532	35.0270582	224.22
21	32.1280468	35.0567285	254.95	44	32.1822489	35.0646851	296.49
22	32.1577615	35.0018681	193.68	45	32.1913057	35.0489849	276.23
23	32.1800432	34.9721596	94.03	46	32.249278	35.0932515	339.23

Table (A-11):-GNSS coordinatesin the Middle of the west bank in (Lat, long, h) in WGS84.

#	Lat	Long	h	#	Lat	Long	h
1	31.94584459	35.15908422	772.272	10	31.56075383	35.20267178	843.09
2	31.93230744	35.25109827	866.424	11	32.21548678	35.27910037	621.572
3	31.92282214	35.17507551	767.147	12	32.12804681	35.05672847	254.95
4	31.96662004	35.22889599	733.992	13	32.19903213	35.11143942	432.51
5	31.86423794	35.19982839	830.877	14	31.91082971	35.21139009	892.278
6	32.01344227	35.29920733	812.607	15	31.88859265	35.19056948	868.958
7	32.05643763	35.11255156	498.43	16	31.98648918	35.16837404	681.832
8	31.94172647	35.07511185	418.205	17	31.9511506	35.07619474	444.68
9	31.65200433	35.0635925	609.623				

Table (A-12):-GNSS coordinatesin the South of the west bank in (Lat, long, h) in WGS84.

#	Lat	Long	h	#	Lat	Long	h
1	31.41857089	35.11312187	813.313	12	31.42663724	35.98843389	687.14
2	31.44904025	35.06378769	793.07	13	31.37949924	35.09178074	814.76
3	31.56678291	34.98634752	525.871	14	31.56075383	35.20267178	843.09
4	31.64869103	35.07395439	658.207	15	32.01344227	35.29920733	830.877
5	31.65200433	35.0635925	609.623	16	31.94172647	35.07511185	418.205
6	31.49988316	35.10990124	933.5	17	31.43993875	35.07602761	829.664
7	31.45992864	35.05664977	895.15	18	31.45538122	35.0704018	793.202
8	31.41134005	34.91989465	661.38	19	31.5269914	35.17621978	961.906
9	31.55759091	35.0597956	921.66	20	31.56991847	35.02342403	634.002
10	31.50485825	35.05837405	758.47	21	31.61793193	35.07456543	868.75
11	31.52580713	35.00101091	586.85	22	31.58762332	35.02204462	748.9

APPENDIX-A CALCULATION PROTOCOL

The Transformation of the GNSS geographic coordinates to geocentric coordinates (X, Y, Z) in WGS89 system is given in table (A-13) (A-14) and (A-15).

Table (A-13):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397438.186	2805940.659	3658051.309	24	4427018.57	2787057.61	3636901.77
2	4395084.459	2798589.732	3666470.558	25	4425161.11	2784456.75	3641360.02
3	4396208.254	2796360.925	3666941.137	26	4422922.53	2784363.3	3644243.14
4	4397959.145	2793146.182	3667597.458	27	4422994.04	2788420.3	3640795.12
5	4399336.237	2797089.227	3662855.715	28	4419128.59	2787007.53	3646932.81
6	4405237.654	2797288.818	3655782.017	29	4415014.84	2793652.42	3646717.87
7	4391634.844	2797221.28	3671932.422	30	4413918.31	2799549.49	3643156.25
8	4400150.825	2805091.09	3655666.104	31	4419360.96	2762965.11	3665478.43
9	4399144.798	2799329.656	3661275.622	32	4427188.21	2772481.6	3648375.02
10	4409551.844	2793395.77	3653612.528	33	4394334.92	2796514.56	3668994.76
11	4399848.413	2783242.782	3672793.228	34	4397990.54	2794107.63	3666799.45
12	4409112.864	2783256.708	3662273.066	35	4399468.32	2796669.15	3662962.21
13	4408391.755	2785929.674	3660908.997	36	4400449.5	2799146.69	3659938.85
14	4410548.87	2779136.054	3663546.99	37	4405554.89	2796476.2	3655982.15
15	4413226.84	2784790.034	3655671.977	38	4399366.19	2785781.48	3671716.71
16	4414154.735	2782468.059	3656658.372	39	4410727.72	2782568.61	3660726.03
17	4420088.735	2793802.24	3640079.344	40	4407609.6	2785332.41	3662388.82
18	4418142.438	2795879.433	3640842.62	41	4418824.2	2793922.49	3641606.79
19	4415253.142	2791321.78	3648196.378	42	4415394.42	2782918.25	3654677.95
20	4420288.937	2783500.224	3648236.168	43	4427450.54	2781897.23	3640454.18
21	4426565.706	2779799.867	3643166.91	44	4423533.61	2783734.2	3643913.35
22	4428038.625	2783927.972	3638147.768	45	4423926.21	2784957.59	3642475.83
23	4428486.09	2786612.807	3635390.322	46	4418763.07	2787954.02	3646531.61

Table (A-14):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4430200.1	2762477.307	3652754.867	10	4446341.746	2731211.13	3656749
2	4425922.681	2758358.016	3661151.47	11	4410548.871	2779136.055	3663547
3	4430438.801	2760154.35	3654202.401	12	4426565.706	2779799.867	3643167
4	4425384.149	2761703.361	3659062.978	13	4420288.937	2783500.224	3648236
5	4431958.756	2754814.818	3656483.785	14	4429131.897	2758053.456	3657567
6	4419360.961	2762965.11	3665478.429	15	4431316.556	2757027.706	3655666
7	4427188.21	2772481.601	3648375.023	16	4427673.121	2765265.692	3653545
8	4434700.956	2764841.184	3644930.093	17	4434205.93	2765545.505	3645044
9	4449383.385	2742848.966	3643994.021				

Table (A-15):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4457967.665	2723138.777	3648607.903	12	4409308.61	2694267.974	3727557.117
2	4459189.176	2727142.182	3644117.135	13	4460987.127	2720807.766	3646671.464
3	4457590.726	2738767.017	3636927.633	14	4446341.746	2731211.13	3656748.63
4	4449013.519	2742265.925	3644962.907	15	4419373.605	2762973.015	3665488.986
5	4449383.385	2742848.966	3643994.021	16	4434700.956	2764841.184	3644930.093
6	4454357.67	2729621.396	3648384.703	17	4458982.118	2726042.401	3645249.694
7	4459130.186	2728270.599	3643527.485	18	4458527.75	2727415.699	3644717.871
8	4468704.317	2728922.902	3630962.241	19	4449474.934	2729525.814	3654418.38
9	4454320.939	2735773.769	3643828.437	20	4455505.754	2737821.887	3640359.18
10	4456800.303	2731650.581	3643605.585	21	4450598.613	2739946.997	3645139.38
11	4458795.531	2735116.683	3638295.389	22	4454814.506	2739293.837	3640299.784

A preprocessing step was made by calculating the geocentric coordinated differenced. The point with extremely difference from other pointe is excluded as shown in table (A-16) (A-17) and (A-18).

$$\Delta X = X\_(Palestine\_1923) - X\_WGS84 \quad \text{(A-1)}$$

$$\Delta Y = Y\_(Palestine\_1923) - Y\_WGS84 \quad \text{(A-2)}$$

$$\Delta Z = Z\_(Palestine\_1923) - Z\_WGS84 \quad \text{(A-3)}$$

Table (A-16):- results of the pre-processing check in the north of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	237.0100247	122.59324	-330.36314	24	236.928664	116.746807	-325.606006
2	238.0761461	123.482472	-329.273276	25	237.044308	117.039493	-325.689548
3	237.7390148	123.094664	-328.943744	26	237.09285	117.43974	-325.941236
4	237.7559278	122.091848	-328.695741	27	236.956199	117.47219	-326.155382
5	236.534768	122.181735	-329.565219	28	237.157053	118.194952	-326.481243
6	236.8195683	120.977557	-328.537311	29	237.094202	119.065544	-327.277484
7	236.7830231	123.19637	-330.113152	30	238.503925	120.333136	-326.402485
8	237.4039403	122.967551	-328.764332	31	180.843532	112.934932	-255.35505
9	237.3616922	122.52871	-328.841043	32	179.962209	113.282378	-254.134356
10	187.3148344	88.772562	-369.278097	33	237.052134	122.314458	-329.642509
11	237.1120354	121.097092	-328.480635	34	236.96393	122.042489	-329.377172
12	236.9440609	119.56723	-327.519938	35	236.766058	122.225292	-329.509434
13	236.7572939	119.851037	-327.861214	36	167.599324	77.9989405	-387.110766
14	237.3030659	119.338526	-327.61053	37	237.600639	121.588326	-327.766837
15	236.8058894	118.835624	-327.210069	38	237.200632	121.479244	-328.980086
16	236.9421199	118.92825	-326.757821	39	236.823157	119.23017	-327.332082
17	238.0262021	118.813265	-325.812424	40	236.881153	119.80601	-327.672104

18	570.8625543	329.829424	-50.0084717	41	238.206939	119.148995	-325.834603
19	237.0251089	119.147477	-326.809296	42	237.205591	118.691228	-326.815925
20	237.1899094	117.898437	-326.196096	43	237.051933	116.570354	-325.306813
21	236.9851368	116.593624	-325.41724	44	237.06509	117.291775	-325.863171
22	236.9838525	116.506511	-325.338195	45	236.90461	117.17344	-325.981961
23	236.9543553	116.504809	-325.366393	46	237.04289	118.216314	-326.642025

Table (A-17):- results of the pre-processing check in the Middle of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	180.5283729	112.8316643	-255.0504403	10	238.1426	111.8792	-320.394
2	2896.625488	1805.164337	-4786.955836	11	237.3017	119.3374	-327.612
3	180.3143588	112.4526326	-255.7135351	12	236.8812	116.6455	-325.331
4	180.6780603	112.7286885	-255.0966877	13	237.4226	117.6177	-326.263
5	180.9638059	112.3478296	-255.0964138	14	180.7365	112.5967	-255.028
6	180.8456019	112.9361193	-255.3532264	15	180.7307	112.4681	-254.891
7	179.9625588	113.282059	-254.1345375	16	180.4646	112.7945	-254.98
8	180.3087899	112.7835137	-254.760093	17	180.3557	112.7713	-254.764
9	237.0059345	111.2503277	-321.9531325				

Table (A-18):- results of the pre-processing check in the South of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	237.9427612	109.5741308	-319.0034024	12	55206	33696.77	-90665.5
2	237.8784057	109.7065183	-318.9962653	13	238.6488	109.3897	-319.211
3	454.9584056	222.4531749	-147.4892826	14	238.1428	111.8789	-320.394
4	239.1398384	109.8015528	-321.056348	15	12766.12	-8045.85	-9260.3
5	237.0059632	111.2502811	-321.9531325	16	180.3086	112.7835	-254.76
6	2802.282726	2214.062646	-4998.592653	17	-619.524	1514.649	-321.221
7	-4590.195568	7602.483335	-34.78016644	18	237.9121	109.8809	-319.166
8	238.3782658	108.6480399	-317.7047962	19	237.8118	111.1917	-320.28
9	266.5419659	-6046.651358	4229.720901	20	237.9856	110.8094	-320.084
10	2472.41243	-3328.541956	-475.8490561	21	237.7415	111.3325	-320.549
11	-3856.307641	4218.659832	1591.300776	22	4332.074	-3997.5	-2230.58

A.1.1 HelmertTransformations

The results of all iteration for Helmert transformation for triangulation points in the west bankare given in the following protocols.

Calculation Protocol

Helmert Transformation: North of the West Bank	FirstIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,397,675.196	2,806,063.252	3,657,720.946
4	4,398,196.901	2,793,268.274	3,667,268.762
5	4,399,572.772	2,797,211.409	3,662,526.150
6	4,405,474.474	2,797,409.796	3,655,453.479
8	4,400,388.229	2,805,214.057	3,655,337.340
9	4,399,382.160	2,799,452.185	3,660,946.781
11	4,400,085.525	2,783,363.879	3,672,464.748
12	4,409,349.808	2,783,376.275	3,661,945.546
13	4,408,628.512	2,786,049.525	3,660,581.136
14	4,410,786.173	2,779,255.393	3,663,219.380
15	4,413,463.646	2,784,908.870	3,655,344.767
16	4,414,391.677	2,782,586.987	3,656,331.614
17	4,420,326.762	2,793,921.053	3,639,753.531
19	4,415,490.167	2,791,440.928	3,647,869.568
20	4,420,526.127	2,783,618.122	3,647,909.972
25	4,425,398.159	2,784,573.791	3,641,034.325
26	4,423,159.624	2,784,480.741	3,643,917.194
27	4,423,230.992	2,788,537.769	3,640,468.967
28	4,419,365.747	2,787,125.729	3,646,606.332
29	4,415,251.938	2,793,771.484	3,646,390.589
30	4,414,156.813	2,799,669.824	3,642,829.850

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,397,438.186	2,805,940.659	3,658,051.309	1.2405	-1.2611	1.2371
4	4,397,959.145	2,793,146.182	3,667,597.458	-1.2085	-0.3180	0.3717
5	4,399,336.237	2,797,089.227	3,662,855.715	0.6504	-0.7840	1.0768
6	4,405,237.654	2,797,288.818	3,655,782.017	0.8264	-0.5092	0.3545
8	4,400,150.825	2,805,091.090	3,655,666.104	0.9233	-2.0174	-0.1638
9	4,399,144.798	2,799,329.656	3,661,275.622	0.1159	-1.1941	0.2067
11	4,399,848.413	2,783,242.782	3,672,793.228	-1.7471	0.7609	0.8555
12	4,409,112.864	2,783,256.708	3,662,273.066	-0.9169	0.8637	0.3942
13	4,408,391.755	2,785,929.674	3,660,908.997	-0.4141	0.5782	0.5346
14	4,410,548.870	2,779,136.054	3,663,546.990	-1.7126	1.0187	0.8100
15	4,413,226.840	2,784,790.034	3,655,671.977	-0.2345	0.8583	0.2106
16	4,414,154.735	2,782,468.059	3,656,658.372	-0.6321	0.7289	-0.0502
17	4,420,088.735	2,793,802.240	3,640,079.344	0.2995	-0.5817	-1.3646
19	4,415,253.142	2,791,321.780	3,648,196.378	0.5793	-0.0321	-0.4759
20	4,420,288.937	2,783,500.224	3,648,236.168	-0.2642	0.7352	-0.3460

25	4,425,161.114	2,784,456.751	3,641,360.015	0.3936	0.7712	-0.6499
26	4,422,922.532	2,784,363.301	3,644,243.136	0.1569	0.7349	-0.5123
27	4,422,994.035	2,788,420.297	3,640,795.122	0.8595	0.5172	-0.5403
28	4,419,128.589	2,787,007.534	3,646,932.814	0.1536	0.4834	-0.3350
29	4,415,014.844	2,793,652.418	3,646,717.867	0.8045	-0.0030	-0.1611
30	4,413,918.309	2,799,549.490	3,643,156.252	0.1265	-1.3499	-1.4526

Standard deviation: 0.8580

Transformation parameters

scale: 1.000004383 ± 0.0000124671

rotation about X: 0°00’11.76064" ± 3.81070" t-value: 3.086

rotation about Y: 0°00’12.16333" ± 3.08771" t-value: 3.939

rotation about Z: 0°00’18.41852" ± 3.78664" t-value: 4.864

X translation: 184.131 ± 89.447 t-value: 2.059

Y translation: 293.134 ± 133.419 t-value: 2.197

Z translation: -444.488 ± 104.077 t-value: 4.271

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	x	Y	Z
1	4397438.19	2805940.66	3658051.31	4397676.44	2806061.99	3657722.18
4	4397959.15	2793146.18	3667597.46	4398195.69	2793267.96	3667269.13
5	4399336.24	2797089.23	3662855.72	4399573.42	2797210.63	3662527.23
6	4405237.65	2797288.82	3655782.02	4405475.30	2797409.29	3655453.83
8	4400150.83	2805091.09	3655666.10	4400389.15	2805212.04	3655337.18
9	4399144.80	2799329.66	3661275.62	4399382.28	2799450.99	3660946.99
11	4399848.41	2783242.78	3672793.23	4400083.78	2783364.64	3672465.60
12	4409112.86	2783256.71	3662273.07	4409348.89	2783377.14	3661945.94
13	4408391.76	2785929.67	3660909.00	4408628.10	2786050.10	3660581.67
14	4410548.87	2779136.05	3663546.99	4410784.46	2779256.41	3663220.19
15	4413226.84	2784790.03	3655671.98	4413463.41	2784909.73	3655344.98
16	4414154.74	2782468.06	3656658.37	4414391.05	2782587.72	3656331.56
17	4420088.74	2793802.24	3640079.34	4420327.06	2793920.47	3639752.17
19	4415253.14	2791321.78	3648196.38	4415490.75	2791440.90	3647869.09
20	4420288.94	2783500.22	3648236.17	4420525.86	2783618.86	3647909.63
25	4425161.11	2784456.75	3641360.02	4425398.55	2784574.56	3641033.68
26	4422922.53	2784363.30	3644243.14	4423159.78	2784481.48	3643916.68
27	4422994.04	2788420.30	3640795.12	4423231.85	2788538.29	3640468.43
28	4419128.59	2787007.53	3646932.81	4419365.90	2787126.21	3646606.00
29	4415014.84	2793652.42	3646717.87	4415252.74	2793771.48	3646390.43
30	4413918.31	2799549.49	3643156.25	4414156.94	2799668.47	3642828.40
33	4394334.92	2796514.57	3668994.76	4394571.67	2796636.76	3668666.04
34	4397990.54	2794107.63	3666799.45	4398227.22	2794229.36	3666471.07
35	4399468.32	2796669.15	3662962.21	4399705.47	2796790.54	3662633.75
37	4405554.89	2796476.20	3655982.15	4405792.45	2796596.64	3655654.03
38	4399366.19	2785781.48	3671716.71	4399601.84	2785903.34	3671388.91
39	4410727.72	2782568.62	3660726.03	4410963.78	2782688.81	3660399.03
40	4407609.60	2785332.41	3662388.82	4407845.80	2785452.99	3662061.49
41	4418824.20	2793922.49	3641606.79	4419062.44	2794040.92	3641279.54
42	4415394.42	2782918.25	3654677.95	4415630.89	2783037.69	3654351.18
43	4427450.54	2781897.23	3640454.18	4427687.81	2782014.78	3640128.12

44	4423533.61	2783734.20	3643913.35	4423770.83	2783852.30	3643586.97
45	4423926.21	2784957.59	3642475.84	4424163.62	2785075.58	3642149.40
46	4418763.07	2787954.02	3646531.61	4419000.49	2788072.71	3646204.71

Helmert Transformation: North of the West Bank	SecondIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
6	4,405,474.474	2,797,409.796	3,655,453.479
13	4,408,628.512	2,786,049.525	3,660,581.136
15	4,413,463.646	2,784,908.870	3,655,344.767
16	4,414,391.677	2,782,586.987	3,656,331.614
19	4,415,490.167	2,791,440.928	3,647,869.568
20	4,420,526.127	2,783,618.122	3,647,909.972
25	4,425,398.159	2,784,573.791	3,641,034.325
26	4,423,159.624	2,784,480.741	3,643,917.194
27	4,423,230.992	2,788,537.769	3,640,468.967
28	4,419,365.747	2,787,125.729	3,646,606.332
29	4,415,251.938	2,793,771.484	3,646,390.589

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
6	4,405,237.654	2,797,288.818	3,655,782.017	0.5178	-1.1246	0.2734
13	4,408,391.755	2,785,929.674	3,660,908.997	-0.4994	0.2413	0.6729
15	4,413,226.840	2,784,790.034	3,655,671.977	-0.3424	0.5108	0.4105
16	4,414,154.735	2,782,468.059	3,656,658.372	-0.6968	0.4428	0.1947
19	4,415,253.142	2,791,321.780	3,648,196.378	0.3051	-0.5641	-0.3714
20	4,420,288.937	2,783,500.224	3,648,236.168	-0.4130	0.3741	-0.0665
25	4,425,161.114	2,784,456.751	3,641,360.015	0.1748	0.3450	-0.3447
26	4,422,922.532	2,784,363.301	3,644,243.136	-0.0375	0.3293	-0.2248
27	4,422,994.035	2,788,420.297	3,640,795.122	0.5732	-0.0002	-0.3200
28	4,419,128.589	2,787,007.534	3,646,932.814	-0.0622	0.0389	-0.1253
29	4,415,014.844	2,793,652.418	3,646,717.867	0.4804	-0.5935	-0.0989

Standard deviation: 0.4793

Transformation parameters

scale: 0.999996314 ± 0.0000147346 t-value: 67867.438

rotation about X: 0°00’16.58410" ± 4.83545" t-value: 3.430

rotation about Y: 0°00’11.85193" ± 3.52601" t-value: 3.361

rotation about Z: 0°00’14.04078" ± 4.94474" t-value: 2.840

X translation: 273.217 ± 106.262 t-value: 2.571

Y translation: 136.102 ± 175.736 t-value: 0.774

Z translation: -343.007 ± 123.801 t-value: 2.771

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -	-> x	Y	Z
6	4,405,237.65	2,797,288.82	3,655,782.02	4,405,474.99	2,797,408.67	3,655,453.75
13	4408391.76	2785929.67	3660909.00	4408628.01	2786049.77	3660581.81
15	4413226.84	2784790.03	3655671.98	4413463.30	2784909.38	3655345.18
16	4414154.74	2782468.06	3656658.37	4414390.98	2782587.43	3656331.81
19	4415253.14	2791321.78	3648196.38	4415490.47	2791440.36	3647869.20
20	4420288.94	2783500.22	3648236.17	4420525.71	2783618.50	3647909.91
25	4425161.11	2784456.75	3641360.02	4425398.33	2784574.14	3641033.98
26	4422922.53	2784363.30	3644243.14	4423159.59	2784481.07	3643916.97
27	4422994.04	2788420.30	3640795.12	4423231.57	2788537.77	3640468.65
28	4419128.59	2787007.53	3646932.81	4419365.68	2787125.77	3646606.21
29	4415014.84	2793652.42	3646717.87	4415252.42	2793770.89	3646390.49
33	4394334.92	2796514.57	3668994.76	4394571.49	2796636.23	3668665.89
34	4397990.54	2794107.63	3666799.45	4398227.06	2794228.87	3666470.99
35	4399468.32	2796669.15	3662962.21	4399705.23	2796789.98	3662633.64
37	4405554.89	2796476.20	3655982.15	4405792.16	2796596.05	3655653.97
38	4399366.19	2785781.48	3671716.71	4399601.85	2785903.06	3671388.98
39	4410727.72	2782568.62	3660726.03	4410963.75	2782688.55	3660399.25
40	4407609.60	2785332.41	3662388.82	4407845.74	2785452.68	3662061.63
41	4418824.20	2793922.49	3641606.79	4419062.07	2794040.29	3641279.63
42	4415394.42	2782918.25	3654677.95	4415630.80	2783037.38	3654351.43
43	4427450.54	2781897.23	3640454.18	4427687.62	2782014.40	3640128.49
44	4423533.61	2783734.20	3643913.35	4423770.64	2783851.90	3643587.27
45	4423926.21	2784957.59	3642475.84	4424163.40	2785075.15	3642149.69
46	4418763.07	2787954.02	3646531.61	4419000.25	2788072.24	3646204.90

Helmert Transformation: North of the West Bank | ThirdIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
13	4,408,628.512	2,786,049.525	3,660,581.136
15	4,413,463.646	2,784,908.870	3,655,344.767
16	4,414,391.677	2,782,586.987	3,656,331.614
19	4,415,490.167	2,791,440.928	3,647,869.568
20	4,420,526.127	2,783,618.122	3,647,909.972
25	4,425,398.159	2,784,573.791	3,641,034.325
26	4,423,159.624	2,784,480.741	3,643,917.194
27	4,423,230.992	2,788,537.769	3,640,468.967
28	4,419,365.747	2,787,125.729	3,646,606.332
29	4,415,251.938	2,793,771.484	3,646,390.589

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
13	4,408,391.755	2,785,929.674	3,660,908.997	-0.1334	-0.1213	0.5180
15	4,413,226.840	2,784,790.034	3,655,671.977	-0.1162	0.2966	0.3084
16	4,414,154.735	2,782,468.059	3,656,658.372	-0.4576	0.2743	0.0301
19	4,415,253.142	2,791,321.780	3,648,196.378	0.3525	-0.7922	-0.2388
20	4,420,288.937	2,783,500.224	3,648,236.168	-0.3926	0.3658	-0.0909
25	4,425,161.114	2,784,456.751	3,641,360.015	0.0183	0.4637	-0.2518
26	4,422,922.532	2,784,363.301	3,644,243.136	-0.1188	0.3861	-0.1749
27	4,422,994.035	2,788,420.297	3,640,795.122	0.4172	0.0188	-0.1393
28	4,419,128.589	2,787,007.534	3,646,932.814	-0.0650	-0.0385	-0.0615
29	4,415,014.844	2,793,652.418	3,646,717.867	0.4956	-0.8532	0.1006

Standard deviation: 0.3927

Transformation parameters

scale: 0.999974805 ± 0.0000141382 t-value: 70728.800

rotation about X: 0°00'13.66996" ± 4.75489" t-value: 2.875

rotation about Y: 0°00'09.98480" ± 3.18777" t-value: 3.132

rotation about Z: 0°00'11.90862" ± 5.68624" t-value: 2.094

X translation: 364.066 ± 118.304 t-value: 3.077

Y translation: 201.816 ± 192.488 t-value: 1.048

Z translation: -263.870 ± 105.214 t-value: 2.508

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
13	4,408,391.76	2,785,929.67	3,660,909.00		4,408,628.38	2,786,049.40	3,660,581.65
15	4413226.84	2784790.03	3655671.98		4413463.53	2784909.17	3655345.08
16	4414154.74	2782468.06	3656658.37		4414391.22	2782587.26	3656331.64
19	4415253.14	2791321.78	3648196.38		4415490.52	2791440.14	3647869.33
20	4420288.94	2783500.22	3648236.17		4420525.73	2783618.49	3647909.88
25	4425161.11	2784456.75	3641360.02		4425398.18	2784574.25	3641034.07
26	4422922.53	2784363.30	3644243.14		4423159.51	2784481.13	3643917.02
27	4422994.04	2788420.30	3640795.12		4423231.41	2788537.79	3640468.83
28	4419128.59	2787007.53	3646932.81		4419365.68	2787125.69	3646606.27
29	4415014.84	2793652.42	3646717.87		4415252.43	2793770.63	3646390.69
33	4394334.92	2796514.57	3668994.76		4394572.12	2796635.38	3668665.84
34	4397990.54	2794107.63	3666799.45		4398227.62	2794228.14	3666470.91
35	4399468.32	2796669.15	3662962.21		4399705.69	2796789.26	3662633.67
37	4405554.89	2796476.20	3655982.15		4405792.43	2796595.50	3655654.09
38	4399366.19	2785781.48	3671716.71		4399602.51	2785902.46	3671388.67
39	4410727.72	2782568.62	3660726.03		4410964.10	2782688.28	3660399.03
40	4407609.60	2785332.41	3662388.82		4407846.14	2785452.30	3662061.44
41	4418824.20	2793922.49	3641606.79		4419061.96	2794040.14	3641279.91
42	4415394.42	2782918.25	3654677.95		4415630.99	2783037.24	3654351.30
43	4427450.54	2781897.23	3640454.18		4427687.44	2782014.61	3640128.54
44	4423533.61	2783734.20	3643913.35		4423770.55	2783851.99	3643587.32
45	4423926.21	2784957.59	3642475.84		4424163.28	2785075.22	3642149.77
46	4418763.07	2787954.02	3646531.61		4419000.25	2788072.15	3646204.99

Helmert Transformation: North of the West Bank	Fourth Iteration (Final)

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
13	4408628.512	2786049.525	3660581.136
15	4413463.646	2784908.870	3655344.767
16	4414391.677	2782586.987	3656331.614
20	4420526.127	2783618.122	3647909.972
25	4425398.159	2784573.791	3641034.325
26	4423159.624	2784480.741	3643917.194
27	4423230.992	2788537.769	3640468.967
28	4419365.747	2787125.729	3646606.332

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
13	4408391.755	2785929.674	3660908.997	0.1025	-0.2981	0.1568
15	4413226.840	2784790.034	3655671.977	0.0791	0.1361	0.1306
16	4414154.735	2782468.059	3656658.372	-0.2102	0.2303	-0.0879
20	4420288.937	2783500.224	3648236.168	-0.2707	0.2277	-0.0181
25	4425161.114	2784456.751	3641360.015	0.0369	0.2415	-0.0278
26	4422922.532	2784363.301	3644243.136	-0.0629	0.1856	-0.0256
27	4422994.035	2788420.297	3640795.122	0.3536	-0.3849	-0.0460
28	4419128.589	2787007.534	3646932.814	-0.0283	-0.3382	-0.0820

Standard deviation: 0.2292.

Transformation parameters:

Scale: 0.999952241 ± 0.0000089257.

Rotation about X: 0°00’20.49755" ± 5.40394" t-value: 3.793.

rotation about Y: 0°00’11.15815" ± 1.93173" t-value: 5.776

rotation about Z: 0°00’04.91644" ± 6.88821" t-value: 0.714

X translation: 579.031 ± 113.374 t-value: 5.107

Y translation: -6.108 ± 238.881 t-value: 0.026

Z translation: -114.491 ± 82.311 t-value: 1.391

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	--> X	Y	Z
13	4408391.76	2785929.67	3660909	4408628.61	2786049.23	3660581.29
15	4413226.84	2784790.03	3655671.98	4413463.73	2784909.01	3655344.9
16	4414154.74	2782468.06	3656658.37	4414391.47	2782587.22	3656331.53
20	4420288.94	2783500.22	3648236.17	4420525.86	2783618.35	3647909.95
25	4425161.11	2784456.75	3641360.02	4425398.2	2784574.03	3641034.3
26	4422922.53	2784363.3	3644243.14	4423159.56	2784480.93	3643917.17
27	4422994.04	2788420.3	3640795.12	4423231.35	2788537.38	3640468.92
28	4419128.59	2787007.53	3646932.81	4419365.72	2787125.39	3646606.25
33	4394334.92	2796514.57	3668994.76	4394572.27	2796634.75	3668664.86
34	4397990.54	2794107.63	3666799.45	4398227.78	2794227.63	3666470.09
35	4399468.32	2796669.15	3662962.21	4399705.76	2796788.61	3662632.86
37	4405554.89	2796476.2	3655982.15	4405792.4	2796594.82	3655653.48
38	4399366.19	2785781.48	3671716.71	4399602.89	2785902.33	3671388.02
39	4410727.72	2782568.62	3660726.03	4410964.39	2782688.25	3660398.79
40	4407609.6	2785332.41	3662388.82	4407846.41	2785452.16	3662061.06
41	4418824.2	2793922.49	3641606.79	4419061.8	2794039.49	3641279.78

42	4415394.42	2782918.25	3654677.95	4415631.21	2783037.16	3654351.22
43	4427450.54	2781897.23	3640454.18	4427687.5	2782014.49	3640128.88
44	4423533.61	2783734.2	3643913.35	4423770.62	2783851.81	3643587.5
45	4423926.21	2784957.59	3642475.84	4424163.3	2785074.99	3642149.95
46	4418763.07	2787954.02	3646531.61	4419000.26	2788071.8	3646204.95

Calculation Protocol

Helmert Transformation: Middle of the West Bank	FirstIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4430380.63	2762590.14	3652499.82
2	4428819.31	2760163.18	3656364.51
3	4430619.12	2760266.80	3653946.69
4	4425564.83	2761816.09	3658807.88
5	4432139.72	2754927.17	3656228.69
6	4419541.81	2763078.05	3665223.08
7	4427368.17	2772594.88	3648120.89
8	4434881.26	2764953.97	3644675.33
9	4449620.39	2742960.22	3643672.07
10	4446579.89	2731323.01	3656428.24
11	4410786.17	2779255.39	3663219.38
12	4426802.69	2779916.46	3642841.49
13	4420526.13	2783618.12	3647909.97

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,430,200.100	2,762,477.307	3,652,754.867	217.0303	134.7437	-366.8617
2	4,425,922.681	2,758,358.016	3,661,15.470	-2,431.40	-1,5.7368	4,081.80
3	4,430,438.801	2,760,154.350	3,654,202.401	220.7716	158.7558	-383.8494
4	4,425,384.149	2,761,703.361	3,659,062.978	281.5077	131.4071	-424.2002
5	4,431,958.756	2,754,814.818	3,656,483.785	215.8638	215.3380	-415.9794
6	4,419,360.961	2,762,965.110	3,665,478.429	356.1940	104.5891	-478.3449
7	4,427,188.210	2,772,481.601	3,648,375.023	227.0910	28.3426	-307.2899
8	4,434,700.956	2,764,841.184	3,644,930.093	150.7415	122.2834	-291.8322
9	4,449,383.385	2,742,848.966	3,643,994.021	-33.2850	376.1501	-262.5585
10	4,446,341.746	2,731,211.130	3,656,748.630	39.1061	483.7518	-401.9768
11	4,410,548.871	2,779,136.055	3,663,546.991	367.1239	-82.5572	-354.6030
12	4,426,565.706	2,779,799.867	3,643,166.910	156.2759	-48.7199	-173.8311
13	4,420,288.937	2,783,500.224	3,648,236.169	22.6057	-101.5907	-210.7466

Standard deviation: 927.7527

Transformation parameters

scale: 0.989453934 ± 0.0137540160

rotation about X: -0°02'50.55080" ± 4182.75502" t-value: 0.041

rotation about Y: -0°07'03.08520" ± 5324.45715" t-value: 0.079

rotation about Z: -0°04'38.79837" ± 3100.16209" t-value: 0.090

X translation: 43399.851 ± 119124.402 t-value: 0.364

Y translation: 26444.345 ± 111636.640 t-value: 0.237

Z translation: 44631.490 ± 162063.593 t-value: 0.275

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z ->	X	Y	Z
1	4430200.10	2762477.31	3652754.87	4430597.66	2762724.88	3652132.96
2	4425922.68	2758358.02	3661151.47	4426387.90	2758636.44	3660446.32
3	4430438.80	2760154.35	3654202.40	4430839.89	2760425.56	3653562.84
4	4425384.15	2761703.36	3659062.98	4425846.33	2761947.50	3658383.68
5	4431958.76	2754814.82	3656483.79	4432355.58	2755142.50	3655812.71
6	4419360.96	2762965.11	3665478.43	4419898.00	2763182.64	3664744.73
7	4427188.21	2772481.60	3648375.02	4427595.26	2772623.23	3647813.60
8	4434700.96	2764841.18	3644930.09	4435032.01	2765076.25	3644383.50
9	4449383.39	2742848.97	3643994.02	4449587.11	2743336.37	3643409.51
10	4446341.75	2731211.13	3656748.63	4446619.00	2731806.76	3656026.26
11	4410548.87	2779136.06	3663546.99	4411153.30	2779172.84	3662864.78
12	4426565.71	2779799.87	3643166.91	4426958.97	2779867.74	3642667.66
13	4420288.94	2783500.22	3648236.17	4420753.73	2783516.53	3647699.23
14	4429131.90	2758053.46	3657567.41	4429556.41	2758342.32	3656893.29
15	4431316.56	2757027.71	3655666.18	4431715.54	2757331.87	3655006.84
16	4427673.12	2765265.69	3653545.44	4428095.21	2765479.84	3652922.60
17	4434205.93	2765545.51	3645043.63	4434541.49	2765772.39	3644497.43

Helmert Transformation: Middle of the West Bank | SecondIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,430,380.629	2,762,590.139	3,652,499.817
3	4,430,619.115	2,760,266.802	3,653,946.688
4	4,425,564.827	2,761,816.090	3,658,807.881
5	4,432,139.720	2,754,927.166	3,656,228.688
6	4,419,541.807	2,763,078.046	3,665,223.076
8	4,434,881.264	2,764,953.968	3,644,675.333
9	4,449,620.391	2,742,960.217	3,643,672.068
10	4,446,579.889	2,731,323.009	3,656,428.236
12	4,426,802.587	2,779,916.512	3,642,841.579
13	4,420,526.360	2,783,617.841	3,647,909.905

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,430,200.100	2,762,477.307	3,652,754.867	21.7853	1.8584	-27.2000
3	4,430,438.801	2,760,154.350	3,654,202.401	22.2254	0.5401	-25.6674
4	4,425,384.149	2,761,703.361	3,659,062.978	18.0577	0.7696	-23.0138
5	4,431,958.756	2,754,814.818	3,656,483.785	22.8158	-3.1391	-24.9731
6	4,419,360.961	2,762,965.110	3,665,478.429	13.3615	0.7180	-18.4634
8	4,434,700.956	2,764,841.184	3,644,930.093	25.3445	4.2857	-32.5981
9	4,449,383.385	2,742,848.966	3,643,994.021	-19.9480	-8.6696	33.1568
10	4,446,341.746	2,731,211.130	3,656,748.630	-23.1335	-18.3730	39.6069
12	4,426,565.706	2,779,799.867	3,643,166.910	-37.5952	10.5278	37.3581
13	4,420,288.937	2,783,500.224	3,648,236.169	-42.9120	11.4821	41.7921

Standard deviation: 27.4085

Transformation parameters

scale: 1.000696216 ± 0.0004629550

rotation about X: -0°00’13.15563" ± 137.80184" t-value: 0.095

rotation about Y: 0°00’08.66387" ± 191.44912" t-value: 0.045

rotation about Z: -0°00’10.71400" ± 103.74977" t-value: 0.103

X translation: -2584.935 ± 4317.100 t-value: 0.599

Y translation: -1805.733 ± 3540.801 t-value: 0.510

Z translation: -3187.885 ± 5673.769 t-value: 0.562

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4430200.10	2762477.31	3652754.87		4430402.41	2762592.00	3652472.62
3	4430438.80	2760154.35	3654202.40		4430641.34	2760267.34	3653921.02
4	4425384.15	2761703.36	3659062.98		4425582.88	2761816.86	3658784.87
5	4431958.76	2754814.82	3656483.79		4432162.54	2754924.03	3656203.72
6	4419360.96	2762965.11	3665478.43		4419555.17	2763078.76	3665204.61
8	4434700.96	2764841.18	3644930.09		4434906.61	2764958.25	3644642.74
9	4449383.39	2742848.97	3643994.02		4449600.44	2742951.55	3643705.22
10	4446341.75	2731211.13	3656748.63		4446556.76	2731304.64	3656467.84
12	4426565.71	2779799.87	3643166.91		4426764.99	2779927.04	3642878.94
13	4420288.94	2783500.22	3648236.17		4420483.45	2783629.32	3647951.70
14	4429131.90	2758053.46	3657567.41		4429333.50	2758164.70	3657288.18
15	4431316.56	2757027.71	3655666.18		4431519.81	2757138.47	3655385.66
16	4427673.12	2765265.69	3653545.44		4427873.50	2765382.14	3653263.81
17	4434205.93	2765545.51	3645043.63		4434411.20	2765663.03	3644756.38

Helmert Transformation: Middle of the West Bank | ThirdIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,430,380.629	2,762,590.139	3,652,499.817
3	4,430,619.115	2,760,266.802	3,653,946.688
4	4,425,564.827	2,761,816.090	3,658,807.881
5	4,432,139.720	2,754,927.166	3,656,228.688
6	4,419,541.807	2,763,078.046	3,665,223.076
8	4,434,881.264	2,764,953.968	3,644,675.333
9	4,449,620.391	2,742,960.217	3,643,672.068

10 4,446,579.889 2,731,323.009 3,656,428.236

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,430,200.100	2,762,477.307	3,652,754.867	2.3867	5.6850	-7.5388
3	4,430,438.801	2,760,154.350	3,654,202.401	6.2604	2.2271	-8.1132
4	4,425,384.149	2,761,703.361	3,659,062.978	2.5751	-6.9228	1.8828
5	4,431,958.756	2,754,814.818	3,656,483.785	14.2791	-4.3424	-13.4002
6	4,419,360.961	2,762,965.110	3,665,478.429	-0.5021	-19.0195	14.7939
8	4,434,700.956	2,764,841.184	3,644,930.093	-0.7860	21.5049	-16.8025
9	4,449,383.385	2,742,848.966	3,643,994.021	-20.4938	15.5628	13.9897
10	4,446,341.746	2,731,211.130	3,656,748.630	-3.7187	-14.6985	15.1900

Standard deviation: 13.9537

Transformation parameters

scale: 1.001059218 ± 0.0003072174

rotation about X: -0°03'50.12145" ± 101.00948" t-value: 2.278

rotation about Y: -0°02'32.22934" ± 111.50534" t-value: 1.365

rotation about Z: -0°03'27.32839" ± 73.56209" t-value: 2.818

X translation: -4428.661 ± 2407.029 t-value: 1.840

Y translation: -3185.759 ± 2865.635 t-value: 1.112

Ztranslation: -3943.824 ± 3572.021 t-value: 1.104

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4430200.10	2762477.31	3652754.87		4430383.02	2762595.82	3652492.28
3	4430438.80	2760154.35	3654202.40		4430625.38	2760269.03	3653938.57
4	4425384.15	2761703.36	3659062.98		4425567.40	2761809.17	3658809.76
5	4431958.76	2754814.82	3656483.79		4432154.00	2754922.82	3656215.29
6	4419360.96	2762965.11	3665478.43		4419541.31	2763059.03	3665237.87
8	4434700.96	2764841.18	3644930.09		4434880.48	2764975.47	3644658.53
9	4449383.39	2742848.97	3643994.02		4449599.90	2742975.78	3643686.06
10	4446341.75	2731211.13	3656748.63		4446576.17	2731308.31	3656443.43
14	4429131.90	2758053.46	3657567.41		4429321.69	2758160.84	3657305.77
15	4431316.56	2757027.71	3655666.18		4431508.29	2757138.32	3655399.77
16	4427673.12	2765265.69	3653545.44		4427851.14	2765383.74	3653288.67
17	4434205.93	2765545.51	3645043.63		4434384.30	2765679.91	3644773.34

Helmert Transformation: Middle of the West Bank | Fourth Iteration (Final)

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4430380.629	2762590.139	3652499.817
3	4430619.115	2760266.802	3653946.688
4	4425564.827	2761816.090	3658807.881
5	4432139.720	2754927.166	3656228.688
6	4419541.807	2763078.046	3665223.076
8	4434881.264	2764953.968	3644675.333

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4430200.100	2762477.307	3652754.867	0.0433	-0.1671	-0.1002
3	4430438.801	2760154.350	3654202.401	0.2505	0.2336	0.5313
4	4425384.149	2761703.361	3659062.978	0.0072	-0.0484	-0.0960
5	4431958.756	2754814.818	3656483.785	-0.4367	0.3862	-0.1536
6	4419360.961	2762965.110	3665478.429	-0.0155	-0.2582	0.1372
8	4434700.956	2764841.184	3644930.093	0.1513	-0.1461	-0.3186

Standard deviation: 0.3084.

Transformation parameters.

Scale: 0.999987033 ± 0.0000146285

Rotation about X: -0°00’00.94907" ± 5.12349" t-value: 0.185

Rotation about Y: -0°00’01.85306" ± 3.26090" t-value: 0.568

Rotation about Z: 0°00’01.48892" ± 6.08268" t-value: 0.245

X translation: 185.264 ± 122.363 t-value: 1.514

Y translation: 197.273 ± 208.031 t-value: 0.948

Z translation: -180.695 ± 110.679 t-value: 1.633

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	X	Y	Z
1	4430200.10	2762477.31	3652754.87	4430380.67	2762589.97	3652499.72
3	4430438.80	2760154.35	3654202.40	4430619.37	2760267.04	3653947.22
4	4425384.15	2761703.36	3659062.98	4425564.83	2761816.04	3658807.79
5	4431958.76	2754814.82	3656483.79	4432139.28	2754927.55	3656228.54
6	4419360.96	2762965.11	3665478.43	4419541.79	2763077.79	3665223.21
8	4434700.96	2764841.18	3644930.09	4434881.42	2764953.82	3644675.01
14	4429131.90	2758053.46	3657567.41	4429312.49	2758166.16	3657312.19
15	4431316.56	2757027.71	3655666.18	4431497.10	2757140.42	3655410.96
16	4427673.12	2765265.69	3653545.44	4427853.75	2765378.34	3653290.32
17	4434205.93	2765545.51	3645043.63	4434386.40	2765658.14	3644788.56

Calculation Protocol

Helmert Transformation: South of the West Bank	FirstIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,458,205.608	2,723,248.351	3,648,288.900
2	4,459,427.054	2,727,251.889	3,643,798.139
3	4,458,045.684	2,738,989.470	3,636,780.144
4	4,449,252.659	2,742,375.727	3,644,641.850
5	4,449,620.391	2,742,960.217	3,643,672.068
6	4,457,159.952	2,731,835.459	3,643,386.111
7	4,454,539.991	2,735,873.082	3,643,492.705
8	4,468,942.695	2,729,031.550	3,630,644.537
9	4,454,587.481	2,729,727.118	3,648,058.157
10	4,459,272.715	2,728,322.039	3,643,129.736
11	4,454,939.223	2,739,335.343	3,639,886.690
12	4,464,514.613	2,727,964.744	3,636,891.599
13	4,461,225.776	2,720,917.155	3,646,352.253
14	4,446,579.889	2,731,323.009	3,656,428.236
15	4,432,139.720	2,754,927.166	3,656,228.688
16	4,434,881.264	2,764,953.968	3,644,675.333

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,457,967.665	2,723,138.777	3,648,607.903	598.34501	1,490.1352	-9,365.7429
2	4,459,189.176	2,727,142.182	3,644,117.135	-482.7825	8,577.4631	-5,858.1659
3	4,457,590.726	2,738,767.017	3,636,927.633	171.0046	-248.0158	-228.1538
4	4,449,013.519	2,742,265.925	3,644,962.907	6,973.9589	-3,185.0886	-5,963.3917
5	4,449,383.385	2,742,848.966	3,643,994.021	6,667.5654	-3,598.7153	-5,214.4745
6	4,454,357.670	2,729,621.396	3,648,384.703	648.9449	4,374.2731	-4,296.8091
7	4,459,130.186	2,728,270.599	3,643,527.485	4,358.1219	238.1755	-5,663.1856
8	4,468,704.317	2,728,922.902	3,630,962.241	-7,971.1941	7,752.8615	4,073.1401
9	4,454,320.939	2,735,773.769	3,643,828.437	3,017.3828	8,059.7038	-9,894.0260
10	4,456,800.303	2,731,650.581	3,643,605.585	-996.8684	8,542.1024	-5,160.6943
11	4,458,795.531	2,735,116.683	3,638,295.389	3,659.6284	-1,471.1133	-3,120.7770
12	4,409,308.610	2,694,267.974	3,727,557.117	-15,494.4434	-3,103.6910	20,780.5233
13	4,460,987.127	2,720,807.766	3,646,671.464	-1,685.1872	13,379.2884	-7,993.7131
14	4,446,341.746	2,731,211.130	3,656,748.630	9,416.6765	4,885.5385	-15,191.4276
15	4,419,373.605	2,762,973.015	3,665,488.986	16,923.5129	-11,952.6857	-11,702.6911
16	4,434,700.956	2,764,841.184	3,644,930.093	17,477.6273	-20,694.7899	-5,215.3866

Standard deviation: 9412.3721

Transformation parameters

scale: 0.237588130 ± 0.0769612202

rotation about X: -6°08’45.45510" ± 21000.72079" t-value: 1.054

rotation about Y: -3°36’17.25004" ± 19603.67690" t-value: 0.662

rotation about Z: -4°59’09.11549" ± 26452.65447" t-value: 0.679

X translation: 3401404.986 ± 663452.706 t-value: 5.127

Y translation: 2088571.472 ± 845177.769 t-value: 2.471

Z translation: 2769294.465 ± 548438.996 t-value: 5.049

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4,457,967.67	2,723,138.78	3,648,607.90		4,458,803.95	2,734,738.49	3,638,923.16
2	4459189.18	2727142.18	3644117.14		4458944.27	2735829.35	3637939.97
3	4457590.73	2738767.02	3636927.63		4458216.69	2738741.45	3636551.99
4	4449013.52	2742265.93	3644962.91		4456226.62	2739190.64	3638678.46
5	4449383.39	2742848.97	3643994.02		4456287.96	2739361.50	3638457.59
6	4454357.67	2729621.40	3648384.70		4457808.90	2736209.73	3639089.30
7	4459130.19	2728270.60	3643527.49		4458898.11	2736111.26	3637829.52
8	4468704.32	2728922.90	3630962.24		4460971.50	2736784.41	3634717.68
9	4454320.94	2735773.77	3643828.44		4457604.86	2737786.82	3638164.13
10	4456800.30	2731650.58	3643605.59		4458275.85	2736864.14	3637969.04
11	4458795.53	2735116.68	3638295.39		4458598.85	2737864.23	3636765.91
12	4409308.61	2694267.97	3727557.12		4449020.17	2724861.05	3657672.12
13	4460987.13	2720807.77	3646671.46		4459540.59	2734296.44	3638358.54
14	4446341.75	2731211.13	3656748.63		4455996.57	2736208.55	3641236.81
15	4419373.61	2762973.02	3665488.99		4449063.23	2742974.48	3644526.00
16	4434700.96	2764841.18	3644930.09		4452358.89	2744259.18	3639459.95
17	4458982.12	2726042.40	3645249.69		4458934.74	2735534.91	3638184.12
18	4458527.75	2727415.70	3644717.87		4458790.45	2735865.35	3638099.56
19	4449474.93	2729525.81	3654418.38		4456740.99	2735932.30	3640593.38
20	4455505.75	2737821.89	3640359.18		4457792.16	2738386.34	3637374.36
21	4450598.61	2739947.00	3645139.38		4456653.80	2738667.96	3638637.59
22	4454814.51	2739293.84	3640299.78		4457596.61	2738723.28	3637408.10

Helmert Transformation: South of the West Bank | SecondIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,458,205.608	2,723,248.351	3,648,288.900
6	4,457,159.952	2,731,835.459	3,643,386.111
7	4,454,539.991	2,735,873.082	3,643,492.705
8	4,468,942.695	2,729,031.550	3,630,644.537
9	4,454,587.481	2,729,727.118	3,648,058.157
10	4,459,272.715	2,728,322.039	3,643,129.736
11	4,454,939.223	2,739,335.343	3,639,886.690
15	4,432,139.720	2,754,927.166	3,656,228.688
16	4,434,881.264	2,764,953.968	3,644,675.333

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,457,967.665	2,723,138.777	3,648,607.903	-803.1743	2,622.9814	-984.1548
6	4,454,357.670	2,729,621.396	3,648,384.703	-2,572.3335	-861.4258	3,713.2301
7	4,459,130.186	2,728,270.599	3,643,527.485	3,795.1485	-5,996.2201	-199.9744
8	4,468,704.317	2,728,922.902	3,630,962.241	-3,077.1790	1,273.1321	2,781.2633
9	4,454,320.939	2,735,773.769	3,643,828.437	-6.2373	6,060.175	-4,564.2340
10	4,456,800.303	2,731,650.581	3,643,605.585	-2,756.9576	4,217.5933	208.3819
11	4,458,795.531	2,735,116.683	3,638,295.389	3,158.1545	-4,102.2586	-733.4076
15	4,419,373.605	2,762,973.015	3,665,488.986	-4,936.2444	2,429.9584	4,141.2317
16	4,434,700.956	2,764,841.184	3,644,930.093	4,380.5970	-6,266.6758	-453.0526

Standard deviation: 3970.4007

Transformation parameters

scale: 0.785504168 ± 0.0601008383

rotation about X: 0°18'47.97111" ± 26693.87092" t-value: 0.042

rotation about Y: 0°02'42.44486" ± 26229.47038" t-value: 0.006

rotation about Z: 0°13'59.03823" ± 17097.77646" t-value: 0.049

X translation: 949206.266 ± 469700.304 t-value: 2.021

Y translation: 585405.932 ± 769233.585 t-value: 0.761

Z translation: 790247.654 ± 896171.188 t-value: 0.882

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	X	Y	Z
1	4,457,967.67	2,723,138.78	3,648,607.90	4,457,402.43	2,725,871.33	3,647,304.75
6	4454357.67	2729621.40	3648384.70	4454587.62	2730974.03	3647099.34
7	4459130.19	2728270.60	3643527.49	4458335.14	2729876.86	3643292.73
8	4468704.32	2728922.90	3630962.24	4465865.52	2730304.68	3633425.80
9	4454320.94	2735773.77	3643828.44	4454581.24	2735787.29	3643493.92
10	4456800.30	2731650.58	3643605.59	4456515.76	2732539.63	3643338.12
11	4458795.53	2735116.68	3638295.39	4458097.38	2735233.08	3639153.28
15	4419373.61	2762973.02	3665488.99	4427203.48	2757357.12	3660369.92
16	4434700.96	2764841.18	3644930.09	4439261.86	2758687.29	3644222.28
18	4458527.75	2727415.70	3644717.87	4457858.46	2729212.37	3644231.08
19	4449474.93	2729525.81	3654418.38	4450748.17	2730940.47	3651836.21
21	4450598.61	2739947.00	3645139.38	4451669.87	2739082.91	3644503.45
22	4454814.51	2739293.84	3640299.78	4454982.37	2738535.59	3640707.34

Helmert Transformation: South of the West Bank | ThirdIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,458,205.608	2,723,248.351	3,648,288.900
2	4,459,427.054	2,727,251.889	3,643,798.139
4	4,449,252.659	2,742,375.727	3,644,641.850
5	4,449,620.391	2,742,960.217	3,643,672.068
8	4,468,942.695	2,729,031.550	3,630,644.537
13	4,461,225.776	2,720,917.155	3,646,352.253
14	4,446,579.889	2,731,323.009	3,656,428.236
16	4,434,881.264	2,764,953.968	3,644,675.333

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,457,967.665	2,723,138.777	3,648,607.903	4.2846	-3.9275	-1.5443
2	4,459,189.176	2,727,142.182	3,644,117.135	0.2932	1.5943	-1.3175
4	4,449,013.519	2,742,265.925	3,644,962.907	-14.698	1.1115	16.2276
5	4,449,383.385	2,742,848.966	3,643,994.021	-13.2144	0.8265	16.9320
8	4,468,704.317	2,728,922.902	3,630,962.241	-3.1367	18.6048	-11.5179
13	4,460,987.127	2,720,807.766	3,646,671.464	5.5121	-1.5089	-5.1822
14	4,446,341.746	2,731,211.130	3,656,748.630	-2.4732	-15.7069	14.3283
16	4,434,700.956	2,764,841.184	3,644,930.093	23.4332	-0.9942	-27.9258

Standard deviation: 13.9735

Transformation parameters

scale: 1.000441308 ± 0.0002743936

rotation about X: -0°02'22.78298" ± 87.73884" t-value: 1.627

rotation about Y: -0°01'33.97134" ± 109.97944" t-value: 0.854

rotation about Z: -0°02'11.21898" ± 61.64980" t-value: 2.128

X translation: -1654.962 ± 2381.846 t-value: 0.695

Y translation: -1406.568 ± 2319.845 t-value: 0.606

Z translation: -1784.699 ± 3385.215 t-value: 0.527

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	X	Y	Z
1	4,457,967.67	2,723,138.78	3,648,607.90	4,458,209.89	2,723,244.42	3,648,287.36
2	4459189.18	2727142.18	3644117.14	4459427.35	2727253.48	3643796.82
4	4449013.52	2742265.93	3644962.91	4449237.96	2742376.84	3644658.08
5	4449383.39	2742848.97	3643994.02	4449607.18	2742961.04	3643689.00
8	4468704.32	2728922.90	3630962.24	4468939.56	2729050.16	3630633.02
13	4460987.13	2720807.77	3646671.46	4461231.29	2720915.65	3646347.07
14	4446341.75	2731211.13	3656748.63	4446577.42	2731307.30	3656442.56
16	4434700.96	2764841.18	3644930.09	4434904.70	2764952.97	3644647.41
18	4458527.75	2727415.70	3644717.87	4458765.73	2727526.28	3644398.31
19	4449474.93	2729525.81	3654418.38	4449712.00	2729624.85	3654108.69
20	4455505.75	2737821.89	3640359.18	4455733.79	2737938.16	3640046.28
21	4450598.61	2739947.00	3645139.38	4450825.31	2740057.77	3644832.30

Helmert Transformation: South of the West Bank | Fourth Iteration (Final)

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4458205.608	2723248.351	3648288.900
2	4459427.054	2727251.889	3643798.139
4	4449252.659	2742375.727	3644641.850
8	4468942.695	2729031.550	3630644.537
13	4461225.776	2720917.155	3646352.253
14	4446579.889	2731323.009	3656428.236

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4457967.665	2723138.777	3648607.903	-0.0448	0.6240	-0.0163
2	4459189.176	2727142.182	3644117.135	0.3994	-0.0071	-0.1193
4	4449013.519	2742265.925	3644962.907	0.0658	-0.0290	0.2778
8	4468704.317	2728922.902	3630962.241	0.3945	-0.3835	-0.6537
13	4460987.127	2720807.766	3646671.464	-0.8410	0.6009	0.5766
14	4446341.746	2731211.130	3656748.630	0.0261	-0.8053	-0.0651

Standard deviation: 0.5585.
Transformation parameters:
==========
Scale: 0.999970744 ± 0.0000179089
Rotation about X: 0°00’15.02431" ± 5.32760" t-value: 2.820
Rotation about Y: 0°00’10.88049" ± 4.58908" t-value: 2.371
Rotation about Z: 0°00’09.20351" ± 5.20434" t-value: 1.768
X translation: 439.276 ± 127.704 t-value: 3.440
Y translation: 123.017 ± 183.425 t-value: 0.671
Z translation: -249.081 ± 151.911 t-value: 1.640

Transformed Coordinates:
WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	X	Y	Z
1	4457967.665	2723138.777	3648607.903	4458205.563	2723248.975	3648288.883
2	4459189.176	2727142.182	3644117.135	4459427.454	2727251.881	3643798.02
4	4449013.519	2742265.925	3644962.907	4449252.725	2742375.698	3644642.128
8	4468704.317	2728922.902	3630962.241	4468943.09	2729031.167	3630643.883
13	4460987.127	2720807.766	3646671.464	4461224.935	2720917.756	3646352.83
14	4446341.746	2731211.13	3656748.63	4446579.915	2731322.204	3656428.17
18	4458527.75	2727415.699	3644717.871	4458766.028	2727525.464	3644398.684
19	4449474.934	2729525.814	3654418.38	4449713.059	2729636.627	3654098.278
20	4455505.754	2737821.887	3640359.18	4455744.814	2737931.165	3640039.202

A.1.2Three Dimensional Transformations

The results of all iteration for three dimensional transformations for triangulation points in the west bank are given in the following.

Calculation Protocol

Three Dimensional Transformations: North of the West Bank	First Iteration(Final)

.Coordinates of MEASURED POINTS in palestine_1923

NAME	X	Y	Z	SxSySz		
1	4397438.186	2805940.659	3658051.309	0.020	0.020	0.020
4	4397959.145	2793146.182	3667597.458	0.020	0.020	0.020
5	4399336.237	2797089.227	3662855.715	0.020	0.020	0.020
6	4405237.654	2797288.818	3655782.017	0.020	0.020	0.020
8	4400150.825	2805091.090	3655666.104	0.020	0.020	0.020
9	4399144.798	2799329.656	3661275.622	0.020	0.020	0.020
11	4399848.413	2783242.782	3672793.228	0.020	0.020	0.020
12	4409112.864	2783256.708	3662273.066	0.020	0.020	0.020
13	4408391.755	2785929.674	3660908.997	0.020	0.020	0.020
14	4410548.870	2779136.054	3663546.990	0.020	0.020	0.020
19	4415253.142	2791321.780	3648196.378	0.020	0.020	0.020
29	4415014.844	2793652.418	3646717.867	0.020	0.020	0.020
30	4413918.309	2799549.490	3643156.252	0.020	0.020	0.020

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z
1	4397675.196	2806063.252	3657720.946
4	4398196.901	2793268.274	3667268.762
5	4399572.772	2797211.409	3662526.150
6	4405474.474	2797409.796	3655453.479
8	4400388.229	2805214.057	3655337.340
9	4399382.160	2799452.185	3660946.781
11	4400085.525	2783363.879	3672464.748
12	4409349.808	2783376.275	3661945.546
13	4408628.512	2786049.525	3660581.136
14	4410786.173	2779255.393	3663219.380
19	4415490.167	2791440.928	3647869.568
29	4415251.938	2793771.484	3646390.589
30	4414156.813	2799669.824	3642829.850

Transformation Coefficients.

Scale = 0.3572844596 +/- 78.1126810102

X-rot = 29°04’20.0" +/- 108°26’10.8"

Y-rot = -226°06’25.4" +/- 197°06’58.9"

Z-rot = 168°52’14.4" +/- 84°52’48.7"

Tx = 1216974.133 +/- 617993256.6606

Ty = 4553193.485 +/- 730980940.6189

Tz = -1992563.777 +/- 580872072.6605

Standard Deviation of Unit Weight >> 186686798.291

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Vx	Y	Vy	Z	Vz
1	4397675.20	-1035886.81	2806063.25	985186.69	3657720.95	-5680029.00
4	4398196.90	-1034435.75	2793268.27	1003327.31	3667268.76	-5689887.50
5	4399572.77	-1036509.25	2797211.41	997424.00	3662526.15	-5684268.50
6	4405474.47	-1042788.38	2797409.80	995939.50	3655453.48	-5674189.00
8	4400388.23	-1038595.25	2805214.06	985860.13	3655337.34	-5676331.50
9	4399382.16	-1036664.88	2799452.19	994264.44	3660946.78	-5682680.00
11	4400085.53	-1035001.00	2783363.88	1017012.56	3672464.75	-5694471.00
12	4409349.81	-1044721.50	2783376.28	1015150.44	3661945.55	-5679320.00
13	4408628.51	-1044398.88	2786049.53	1011474.56	3660581.14	-5678183.00
14	4410786.17	-1045677.88	2779255.39	1020697.00	3663219.38	-5679981.50
19	4415490.17	-1052608.13	2791440.93	1002341.94	3647869.57	-5661658.50
29	4415251.94	-1052697.13	2793771.48	999077.94	3646390.59	-5660215.50
30	4414156.81	-1052503.50	2799669.82	990870.19	3642829.85	-5656911.00

WGS84 coordinates transformed to Palestine _1923 coordinates.

NAME	X	Y	Z	Sx	Sy	Sz
1	3361788.389	3791249.934	-2022308.094	5.2822E+11	1.39674E+12	2.27774E+12
4	3363761.121	3796595.571	-2022618.647	5.24712E+11	1.39748E+12	2.26819E+12
5	3363063.492	3794635.431	-2021742.246	5.2571E+11	1.39869E+12	2.2717E+12
6	3362686.103	3793349.308	-2018735.318	5.25448E+11	1.40423E+12	2.27404E+12
8	3361792.955	3791074.174	-2020994.025	5.27843E+11	1.39927E+12	2.27808E+12
9	3362717.256	3793716.64	-2021733.167	5.2633E+11	1.39848E+12	2.27334E+12
11	3365084.555	3800376.447	-2022006.261	5.21917E+11	1.39955E+12	2.2614E+12
12	3364628.311	3798526.738	-2017374.351	5.21423E+11	1.40817E+12	2.2648E+12
13	3364229.64	3797524.068	-2017601.634	5.22189E+11	1.40746E+12	2.26658E+12
14	3365108.309	3799952.417	-2016762.025	5.20226E+11	1.40967E+12	2.26223E+12
19	3362881.983	3793782.872	-2013788.711	5.23287E+11	1.41389E+12	2.27328E+12
29	3362554.827	3792849.416	-2013824.989	5.23934E+11	1.4136E+12	2.27495E+12
30	3361653.259	3790539.981	-2014081.138	5.25597E+11	1.4125E+12	2.27906E+12
33	3363401.072	3795876.795	-2024270.317	5.25823E+11	1.39405E+12	2.26944E+12
34	3363609.259	3796179.754	-2022559.907	5.24972E+11	1.39749E+12	2.26893E+12
35	3363102.93	3794778.851	-2021678.401	5.25589E+11	1.39884E+12	2.27144E+12
37	3362775.88	3793622.185	-2018594.844	5.2521E+11	1.40456E+12	2.27355E+12
38	3364811.563	3799437.844	-2022218.009	5.22633E+11	1.39896E+12	2.26311E+12
39	3364589.584	3798467.078	-2016541.418	5.2115E+11	1.40975E+12	2.2649E+12
40	3364391.992	3797948.479	-2018045.13	5.22069E+11	1.40672E+12	2.26582E+12
41	3362177.65	3791906.941	-2011783.949	5.23803E+11	1.41728E+12	2.27663E+12

Calculation Protocol

Three Dimensional Transformations: Middle of the West Bank	First Iteration

Coordinates of MEASURED POINTS in palestine_1923.

NAME	X	Y	Z	SxSySz		
1	4430200.100	2762477.307	3652754.867	0.020	0.020	0.020
2	4425922.681	2758358.016	3661151.470	0.020	0.020	0.020
3	4430438.801	2760154.350	3654202.401	0.020	0.020	0.020
4	4425384.149	2761703.361	3659062.978	0.020	0.020	0.020
5	4431958.756	2754814.818	3656483.785	0.020	0.020	0.020
6	4419360.961	2762965.110	3665478.429	0.020	0.020	0.020
7	4427188.210	2772481.601	3648375.023	0.020	0.020	0.020
8	4434700.956	2764841.184	3644930.093	0.020	0.020	0.020
9	4449383.385	2742848.966	3643994.021	0.020	0.020	0.020
10	4446341.746	2731211.130	3656748.630	0.020	0.020	0.020
11	4410548.871	2779136.055	3663546.991	0.020	0.020	0.020
12	4426565.706	2779799.867	3643166.910	0.020	0.020	0.020
13	4420288.937	2783500.224	3648236.169	0.020	0.020	0.020

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z
1	4430380.629	2762590.139	3652499.817
2	4428819.307	2760163.180	3656364.514
3	4430619.115	2760266.802	3653946.688
4	4425564.827	2761816.090	3658807.881
5	4432139.720	2754927.166	3656228.688
6	4419541.807	2763078.046	3665223.076
7	4427368.173	2772594.883	3648120.889
8	4434881.264	2764953.968	3644675.333
9	4449620.391	2742960.217	3643672.068
10	4446579.889	2731323.009	3656428.236
11	4410786.173	2779255.393	3663219.380
12	4426802.587	2779916.512	3642841.579
13	4420526.360	2783617.841	3647909.905

Transformation Coefficients

Scale = 0.9891555013 +/- 0.0269034637

x-rot = 0°04’49.7" +/- 2°16’02.8"

y-rot = 0°06’00.3" +/- 2°58’08.6"

z-rot = -359°54’56.6" +/- 1°42’24.5"

Tx = 44093.294 +/- 237063.8265

Ty = 27886.463 +/- 218257.5567

Tz = 41891.768 +/- 314060.9928

Standard Deviation of Unit Weight >> 90736.269

Degrees of Freedom: 32

Solution did not converge in 10 iterations.

APPENDIX-A CALCULATION PROTOCOL

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Vx	Y	Vy	Z	Vz
1	4430380.629	-1848.917	2762590.139	-808.636	3652499.817	-1275.888
2	4428819.307	-4498.114	2760163.180	-2474.187	3656364.514	3166.589
3	4430619.115	-1845.411	2760266.802	-784.724	3653946.688	-1294.571
4	4425564.827	-1784.801	2761816.090	-815.920	3658807.881	-1337.031
5	4432139.720	-1850.837	2754927.166	-727.658	3656228.688	-1329.990
6	4419541.807	-1710.384	2763078.046	-847.504	3665223.076	-1394.210
7	4427368.173	-1837.804	2772594.883	-915.902	3648120.889	-1210.172
8	4434881.264	-1914.479	2764953.968	-816.797	3644675.333	-1195.781
9	4449620.391	-2100.060	2742960.217	-554.028	3643672.068	-1174.386
10	4446579.889	-2029.232	2731323.009	-450.579	3656428.236	-1325.243
11	4410786.173	-1698.119	2779255.393	-1039.462	3663219.380	-1263.285
12	4426802.587	-1907.617	2779916.512	-992.315	3642841.579	-1071.223
13	4420526.360	-1836.697	2783617.841	-1049.613	3647909.905	-1109.293

WGS84 coordinates transformed to Palestine _1923 coordinates.

NAME	X	Y	Z	SxSySz		
1	4428531.712	2761781.503	3651223.929	4884.454	6294.457	7130.213
2	4424321.193	2757688.993	3659531.103	4518.829	6028.905	6764.163
3	4428773.704	2759482.078	3652652.116	4784.165	6213.705	7039.854
4	4423780.026	2761000.170	3657470.851	4662.704	6146.560	6888.871
5	4430288.883	2754199.507	3654898.698	4588.996	6050.297	6874.181
6	4417831.423	2762230.542	3663828.866	4505.259	6050.994	6690.905
7	4425530.369	2771678.981	3646910.716	5255.041	6607.178	7439.663
8	4432966.786	2764137.170	3643479.552	5207.995	6522.381	7439.349
9	4447520.331	2742406.189	3642497.681	4823.943	6118.193	7174.551
10	4444550.656	2730872.430	3655102.992	4103.072	5576.638	6525.929
11	4409088.054	2778215.931	3661956.095	4975.740	6470.875	7048.738
12	4424894.970	2778924.197	3641770.356	5593.478	6880.457	7736.605
13	4418689.663	2782568.228	3646800.612	5515.512	6856.004	7630.852
14	4427489.848	2757397.393	3655979.955	4625.505	6095.541	6889.157
15	4429649.016	2756388.594	3654094.153	4665.501	6114.409	6941.020
16	4426029.453	2764534.863	3652014.170	4921.122	6338.822	7143.024
17	4432476.301	2764832.972	3643593.696	5218.676	6534.032	7447.232

Three Dimensional Transformations: Middle of the West Bank | Second Iteration(Final)

Coordinates of MEASURED POINTS in palestine_1923.

NAME	X	Y	Z	SxSySz		
1	4430200.100	2762477.307	3652754.867	0.020	0.020	0.020
3	4430438.801	2760154.350	3654202.401	0.020	0.020	0.020
4	4425384.149	2761703.361	3659062.978	0.020	0.020	0.020
5	4431958.756	2754814.818	3656483.785	0.020	0.020	0.020
6	4419360.961	2762965.110	3665478.429	0.020	0.020	0.020
8	4434700.956	2764841.184	3644930.093	0.020	0.020	0.020

APPENDIX-A CALCULATION PROTOCOL

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z
1	4430380.629	2762590.139	3652499.817
3	4430619.115	2760266.802	3653946.688
4	4425564.827	2761816.090	3658807.881
5	4432139.720	2754927.166	3656228.688
6	4419541.807	2763078.046	3665223.076
8	4434881.264	2764953.968	3644675.333

Transformation Coefficients

Scale = 0.9999870326 +/- 0.0000146285

X-rot = 0°00'00.9" +/- 0°00'05.1"

Y-rot = 0°00'01.9" +/- 0°00'03.3"

Z-rot = 359°59'58.5" +/- 0°00'06.1"

Tx =185.266 +/- 122.3622

Ty =197.268 +/- 208.0312

Tz =-180.693 +/- 110.6782

Standard Deviation of Unit Weight >> 15.419

Degrees of Freedom: 11

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Vx	Y	Vy	Z	Vz
1	4430380.629	0.043	2762590.139	-0.167	3652499.817	-0.100
3	4430619.115	0.250	2760266.802	0.234	3653946.688	0.531
4	4425564.827	0.007	2761816.090	-0.048	3658807.881	-0.096
5	4432139.720	-0.437	2754927.166	0.386	3656228.688	-0.154
6	4419541.807	-0.016	2763078.046	-0.258	3665223.076	0.137
8	4434881.264	0.151	2764953.968	-0.146	3644675.333	-0.319

WGS84 coordinates transformed to Palestine _1923 coordinates.

NAME	X	Y	Z	SxSySz		
1	4430380.672	2762589.972	3652499.717	0.139	0.137	0.138
3	4430619.366	2760267.036	3653947.219	0.134	0.132	0.133
4	4425564.834	2761816.042	3658807.785	0.148	0.146	0.147
5	4432139.283	2754927.552	3656228.535	0.230	0.194	0.210
6	4419541.791	2763077.788	3665223.213	0.252	0.244	0.247
8	4434881.416	2764953.822	3644675.014	0.245	0.234	0.238
14	4429312.494	2758166.164	3657312.185	0.158	0.147	0.151
15	4431497.100	2757140.420	3655410.959	0.179	0.161	0.168
16	4427853.753	2765378.335	3653290.315	0.176	0.157	0.165
17	4434386.403	2765658.136	3644788.561	0.250	0.236	0.241

APPENDIX-A CALCULATION PROTOCOL

Three Dimensional Transformations: South of the West Bank | First Iteration(Final)

Coordinates of MEASURED POINTS in palestine_1923.

NAME	X	Y	Z	Sx	Sy	Sz
1	4457967.665	2723138.777	3648607.903	0.020	0.020	0.020
2	4459189.176	2727142.182	3644117.135	0.020	0.020	0.020
8	4468704.317	2728922.902	3630962.241	0.020	0.020	0.020
13	4460987.127	2720807.766	3646671.464	0.020	0.020	0.020

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z
1	4458205.608	2723248.351	3648288.900
2	4459427.054	2727251.889	3643798.139
8	4468942.695	2729031.550	3630644.537
13	4461225.776	2720917.155	3646352.253

Transformation Coefficients.

Scale = -0.4983198348 +/- 328.9914736741

X-rot = 125°37'33.4" +/- 98°24'48.0"

Y-rot = 15°39'46.6" +/- 81°41'05.9"

Z-rot = 82°00'40.8" +/- 254°07'08.5"

Tx = -23904.112 +/- 3550331057.1794

Ty = 2732220.738 +/- 6293877170.4360

Tz = 449932.483 +/- 4700687229.3925

Standard Deviation of Unit Weight >> 285498494.748

Degrees of Freedom: 5

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z	Sx	Sy	Sz
1	481881.936	5773664.56	-309029.118	16069441635	10651154340	34268241917
2	484306.902	5772840.71	-310702.193	16080287810	10656080213	34283184398
8	486288.323	5770565.341	-318261.244	16135781838	10712174373	34281811349
13	480833.506	5773384.912	-310864.067	16084115769	10670537256	34256391262
18	484400.153	5772935.584	-310255.949	16076838739	10651976382	34284831876
20	490132.663	5771959.615	-310007.274	16070360587	10628276600	34328392903

WGS84 coordinates transformed to Palestine _1923 coordinates.

NAME	X	Y	Z	Sx	Sy	Sz
1	481881.936	5773664.56	-309029.118	16069441635	10651154340	34268241917
2	484306.902	5772840.71	-310702.193	16080287810	10656080213	34283184398
8	486288.323	5770565.341	-318261.244	16135781838	10712174373	34281811349
13	480833.506	5773384.912	-310864.067	16084115769	10670537256	34256391262
18	484400.153	5772935.584	-310255.949	16076838739	10651976382	34284831876
20	490132.663	5771959.615	-310007.274	16070360587	10628276600	34328392903

A-2 Solution without Including the Height (Case 2)

In the Second case, the height where not used in calculating (X, Y, Z) coordinates.

For the triangulation point, because the orthometrice heights which cover not precisely measured. Table (A-19) (A-20) and (A-21) show the registered coordinates of the control points for the different parts of the West Bank in Pal_1923Grid system.

Table (A-19):-registered coordinates in the north of the west bank in (E, N).

#	E	N	#	E	N
1	171066.1	216350.7	24	149095.6	177710.4
2	179794.3	210343.1	25	153639	176230.2
3	180244.8	207314.9	26	156596.3	177579.2
4	180824.6	202860.8	27	153118.7	181710
5	175936.3	206014.3	28	159351.5	182755.4
6	168551.6	202361.6	29	159177.2	192259.4
7	185353.7	211202.8	30	155625.3	199034.1
8	168522.9	213702.4	31	178483.6	157845
9	174332.5	208442.2	32	160852.7	162614.2
10	166284.9	195546.7	33	182397.2	208701.4
11	186254.2	191429.7	34	180005.9	203829.5
12	175126	185396.5	35	176065.9	205495.9
13	173777.8	188618.9	36	172917.6	207400.2
14	176494.6	180216.2	37	168772.1	201319.4
15	168441.6	184299.9	38	185037.6	194360.4
16	169348.4	181306	39	173564.5	183636.7
17	152430.3	189125.8	40	175284.3	188513.4
18	153226.9	192521.9	41	153983.2	190067.9
19	160711.5	189707.7	42	167342	180964.9
20	160687.5	178393	43	152720.8	172117.8
21	155518	170527.1	44	156276.6	176536.6
22	150347.4	173830.6	45	154797.4	177543
23	147550.3	176307.1	46	158978.3	183966.5

Table (A-20):-registered coordinates in the Middle of the west bank in (E, N).

#	E	N	#	E	N
1	165240.6	150347.93	10	169288.7	107612.6
2	169213.18	148845.37	11	176494.6	180216.2
3	166751.52	147794.39	12	155518.1	170527.2
4	171841.27	152650.15	13	160687.4	178392.5
5	169092.08	141297.74	14	170186.4	146464
6	178483.62	157845	15	168216.6	143998.5
7	160852.72	162614.21	16	166120.9	154854.1

8	157300.27	149898.38	17	157404	150943.1
9	156096.76	117739.33			

Table (A-21):-registered coordinates in the South of the west bank in (E, N).

#	E	N	#	E	N
1	160773.39	91851.11	12	148918.7	92762.38
2	156086.7	95234.67	13	158738.9	87520.78
3	148752.64	108279.93	14	169288.7	107612.62
4	157079.28	117367.82	15	169092.1	141297.74
5	156096.76	117739.33	16	157300.3	149898.38
6	155580.17	101424.37	17	157249.2	96224.6
7	155722.87	107271.25	18	156716.2	95937
8	142397.9	91081.11	19	166776.3	103869.46
9	160474.73	100867.46	20	152271.8	108643.28
10	155409.64	96442.86	21	157133.5	113959.94
11	152144.28	110606.8	22	150135.3	103756.06

The projected coordinates (E, N) were converted to Geographic coordinates (, ϕ) with the assumption that (h = 0), the covered coordinates are shown in tables (A-22) (A-23) and (A-24).

Table (A-22):- Triangulation points coordinates that are transformed to (lat, long) in the north of the West bank.

#	Lat	Long	#	Lat	Long
1	32.54108369	35.22073197	24	32.19242639	34.98771144
2	32.48686787	35.31358507	25	32.17915335	35.03591768
3	32.45955562	35.31834625	26	32.19135893	35.06725394
4	32.41938357	35.3244632	27	32.2285637	35.0303025
5	32.44785793	35.27251384	28	32.23806957	35.09641292
6	32.41493102	35.1939892	29	32.32377583	35.09445223
7	32.49455877	35.37274534	30	32.38482875	35.05662736
8	32.51720103	35.19366353	31	32.01344108	35.29918782
9	32.46975875	35.25546949	32	32.05644304	35.11253782
10	32.35346838	35.1699217	33	32.47203746	35.34125589
11	32.31623419	35.38199234	34	32.42812678	35.31576884
12	32.26192965	35.2637912	35	32.4431822	35.27388961
13	32.29099477	35.24949552	36	32.46036687	35.24041593
14	32.21520608	35.27828217	37	32.405533	35.19633517
15	32.25204918	35.19285405	38	32.34267955	35.369118
16	32.22505076	35.20247916	39	32.24606506	35.2472139

17	32.29542929	35.02286068	40	32.29003706	35.26548744
18	32.32606825	35.0312574	41	32.3039493	35.03933084
19	32.30077798	35.11077184	42	32.22197106	35.18119648
20	32.19874013	35.11063051	43	32.14205278	35.02625718
21	32.12774766	35.05592778	44	32.18195303	35.06387926
22	32.1574602	35.00106644	45	32.19100928	35.04817867
23	32.1797411	34.97135693	46	32.24898734	35.09243859

Table (A-23):- Triangulation points coordinates that are transformed to (lat, long) in the Middle of the West bank.

#	Lat	Long	#	Lat	Long
1	31.94584703	35.15906402	10	31.56043	35.20192
2	31.93230657	35.20108017	11	32.21521	35.27828
3	31.92282323	35.17505294	12	32.12775	35.05593
4	31.96661981	35.22887738	13	32.19874	35.11063
5	31.86423668	35.19980861	14	31.91083	35.21137
6	32.01344108	35.29918782	15	31.88859	35.19055
7	32.05644304	35.11253782	16	31.98649	35.16836
8	31.9417299	35.07509211	17	31.95115	35.07617
9	31.65167912	35.06283094			

Table (A-24):- Triangulation points coordinates that are transformed to(lat,long)in the South of the West bank.

#	Lat	Long	#	Lat	Long
1	31.41823608	35.11238351	12	31.4262975	34.98769444
2	31.44870572	35.06304776	13	31.3791607	35.09103741
3	31.56625038	34.98561093	14	31.56043198	35.20191937
4	31.64834015	35.07319432	15	31.86423668	35.19980861
5	31.65167912	35.06283094	16	31.9417299	35.07509211
6	31.50452599	35.05762748	17	31.45764785	35.07526362
7	31.55726193	35.0590436	18	31.45504779	35.06966023
8	31.41099524	34.91916	19	31.52666682	35.1754706
9	31.49955488	35.10915377	20	31.56958777	35.02267158
10	31.45959427	35.05590709	21	31.61760493	35.07381107
11	31.58729497	35.02129251	22	31.52547393	35.00026649

Finally the geographic coordinates (, ϕ, h=0) are transformed to geocentric coordinates (X, Y, Z) as shown in table (A-25) (A-26) and (A-27).

Table (A-25):-coordinates that are transformed to (X, Y, Z)in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397600.432	2806015.547	3657658.336	**24**	4427174.735	2787123.515	3636509.373
2	4395236.517	2798658.443	3666069.046	**25**	4425223.29	2784463.759	3640889.465
3	4396312.456	2796399.079	3666500.061	**26**	4422940.406	2784342.738	3643735.359

4	4397940.817	2793105.636	3667053.774	**27**	4423122.898	2788469.623	3640379.393
5	4399362.558	2797077.756	3662349.953	**28**	4419096.386	2786955.853	3646382.549
6	4405211.99	2797243.122	3655234.191	**29**	4415028.237	2793629.936	3646204.578
7	4391658.446	2797208.694	3671422.869	**30**	4414085.26	2799624.441	3642770.395
8	4400229.599	2805112.932	3655204.666	**31**	4418993.879	2762735.484	3664765.555
9	4399214.136	2799345.266	3660806.002	**32**	4427036.888	2772387.419	3647846.043
10	4409509.731	2793339.204	3653051.878	**33**	4394463.153	2796567.626	3668573.652
11	4399841.1	2783209.262	3672259.344	**34**	4397985.25	2794075.764	3666266.74
12	4408888.561	2783085.116	3661559.859	**35**	4399516.42	2796671.445	3662474.562
13	4408250.097	2785810.385	3660264.778	**36**	4400486.182	2799141.413	3659442.119
14	4410371.226	2778993.933	3662872.4	**37**	4405544.105	2796440.124	3655446.877
15	4413207.632	2784747.324	3655131.277	**38**	4399254.643	2785682.132	3671094.717
16	4413998.667	2782339.255	3656003.864	**39**	4410556.847	2782430.65	3660058.06
17	4420266.218	2793882.786	3639703.338	**40**	4407430.895	2785189.595	3661713.51
18	4418319.763	2795960.228	3640466.136	**41**	4418964.216	2793979.552	3641199.493
19	4415269.213	2791301.242	3647685.776	**42**	4415299.392	2782827.547	3654074.295
20	4420240.858	2783438.488	3647672.95	**43**	4427546.276	2781925.015	3640011.901
21	4426640.203	2779814.423	3642706.865	**44**	4423579.476	2783731.171	3643428.929
22	4428155.499	2783968.966	3637723.084	**45**	4423986.077	2784963.315	3642003.111
23	4428672.033	2786697.214	3635022.8	**46**	4418779.633	2787933.128	3646021.795

Table (A-26):-coordinates that are transformed to (X, Y, Z)in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4429859.39	2762265.117	3652067.153	10	4446006.028	2730970.514	3655953.117
2	4428232.865	2759797.693	3655877.041	11	4410371.226	2778993.933	3662872.4
3	4430101.886	2759944.569	3653517.205	12	4426640.099	2779814.474	3642706.951
4	4425070.66	2761507.701	3658396.534	13	4420241.091	2783438.207	3647672.883
5	4431577.563	2754577.74	3655761.769	14	4428708.264	2757789.707	3656809.931
6	4418993.879	2762735.484	3664765.555	15	4430908.784	2756774.026	3654922.528
7	4427036.888	2772387.419	3647846.043	16	4427395.358	2765092.304	3652909.801
8	4434605.36	2764781.954	3644447.036	17	4434092.012	2765474.742	3644545.338
9	4449210.035	2742707.253	3643333.737				

Table (A-27):-coordinates that are transformed to (X, Y, Z)in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4457651.122	2722909.649	3647832.038	12	4464046.715	2727678.843	3636507.828
2	4458886.497	2726921.3	3643353.424	13	4460669.663	2720577.98	3645894.605
3	4457483.592	2738644.125	3636318.46	14	4446006.028	2730970.514	3655953.117
4	4448807.54	2742101.37	3644274.73	15	4431577.563	2754577.74	3655761.769
5	4449210.035	2742707.253	3643333.737	16	4434605.36	2764781.954	3644447.036
6	4456522.19	2731444.568	3642861.218	17	4457796.64	2727210.808	3644462.608

7	4453929.342	2735498.036	3642989.817	18	4458225.102	2727194.908	3643953.848
8	4468492.524	2728756.646	3630276.304	19	4449055.99	2729234.124	3653555.079
9	4453957.774	2729341.24	3647538.93	20	4455314.651	2737669.033	3639686.158
10	4458756.348	2728006.109	3642704.986	21	4450244.366	2739693.886	3644330.727
11	4454543.156	2739091.802	3639560.869	22	4458636.74	2734983.593	3637650.39

The GNSS measured coordinates for the triangulation points in the west bank are (Lat, long) in WGS84 system, these coordinates are given in table (A-28) (A-29) and (A-30).

Table (A-28):-GNSS coordinatesin the north of the west bank in (Lat, long) in WGS84.

#	Lat	Long	#	Lat	Long
1	32.54134886	35.22157945	**24**	32.1927268	34.98851583
2	32.48712862	35.31442875	**25**	32.17945123	35.03672241
3	32.45981659	35.31918484	**26**	32.1916541	35.06806076
4	32.41965191	35.3252971	**27**	32.22885952	35.03111155
5	32.44811952	35.27335068	**28**	32.23836056	35.09722499
6	32.41520352	35.19481901	**29**	32.32406271	35.09527218
7	32.49481511	35.37358674	**30**	32.38511513	35.05745167
8	32.51746375	35.19450293	**31**	32.01344227	35.29920733
9	32.47002307	35.25630612	**32**	32.05643763	35.11255156
10	32.35374552	35.17074603	**33**	32.47230233	35.34209365
11	32.31650291	35.3828174	**34**	32.42839133	35.3166044
12	32.26220843	35.26460816	**35**	32.44344452	35.27472714
13	32.29127125	35.25031537	**36**	32.46063208	35.24125159
14	32.21548678	35.27910037	**37**	32.40580397	35.19716438
15	32.25233322	35.19366849	**38**	32.34294654	35.36994853
16	32.2253334	35.20329084	**39**	32.24634542	35.2480286
17	32.29572229	35.02367568	**40**	32.29031469	35.26630579
18	32.32635919	35.03207545	**41**	32.30424074	35.04014714
19	32.30106259	35.11158777	**42**	32.22225722	35.18200982
20	32.19903213	35.11143942	**43**	32.14235315	35.02705824
21	32.12804681	35.05672847	**44**	32.18224893	35.06468511
22	32.15776146	35.00186807	**45**	32.19130574	35.04898487
23	32.18004321	34.97215959	**46**	32.24927801	35.09325152

Table (A-29):-GNSS coordinatesin the Middle of the west bank in (Lat, long) in WGS84.

#	Lat	Long	#	Lat	Long
1	31.94584459	35.15908422	**10**	31.56075	35.20267
2	31.93230744	35.25109827	**11**	32.21549	35.2791
3	31.92282214	35.17507551	**12**	32.12805	35.05673

4	31.96662004	35.22889599	**13**	32.19903	35.11144
5	31.86423794	35.19982839	**14**	31.91083	35.21139
6	32.01344227	35.29920733	**15**	31.88859	35.19057
7	32.05643763	35.11255156	**16**	31.98649	35.16837
8	31.94172647	35.07511185	**17**	31.95115	35.07619
9	31.65200433	35.0635925			

Table (A-30):-GNSS coordinatesin the South of the west bank in (Lat, long) in WGS84.

#	Lat	Long	#	Lat	Long
1	31.41857089	35.11312187	**12**	31.42663724	35.98843389
2	31.44904025	35.06378769	**13**	31.37949924	35.09178074
3	31.56678291	34.98634752	**14**	31.56075383	35.20267178
4	31.64869103	35.07395439	**15**	32.01344227	35.29920733
5	31.65200433	35.0635925	**16**	31.94172647	35.07511185
6	31.49988316	35.10990124	**17**	31.43993875	35.07602761
7	31.45992864	35.05664977	**18**	31.45538122	35.0704018
8	31.41134005	34.91989465	**19**	31.5269914	35.17621978
9	31.55759091	35.0597956	**20**	31.56991847	35.02342403
10	31.50485825	35.05837405	**21**	31.61793193	35.07456543
11	31.52580713	35.00101091	**22**	31.58762332	35.02204462

The Transformation of the GNSS geographic coordinates to geocentric coordinates (X, Y, Z) in WGS89 system is given in table (A-31) (A-32) and (A-33).

Table (A-31):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397348.837	2805883.647	3657976.483	**24**	4426923.553	2786997.795	3636823.188
2	4394984.979	2798526.388	3666387.011	**25**	4424972.062	2784337.793	3641203.4
3	4396061.108	2796267.327	3666817.573	**26**	4422689.144	2784216.377	3644049.541
4	4397689.255	2792974.775	3667370.872	**27**	4422871.66	2788343.147	3640693.71
5	4399111.365	2796946.254	3662667.226	**28**	4418845.073	2786828.729	3646697.262
6	4404960.77	2797112.999	3655550.689	**29**	4414776.896	2793501.854	3646520.002
7	4391407.114	2797076.229	3671740.729	**30**	4413833.941	2799495.979	3643086.147
8	4399978.574	2804981.28	3655522.033	**31**	4418798.613	2762613.533	3665008.867
9	4398962.915	2799213.918	3661123.227	**32**	4426842.651	2772265.197	3648088.334
10	4409258.503	2793209.942	3653367.837	**33**	4394211.63	2796436.102	3668891.128
11	4399589.618	2783079.074	3672575.742	**34**	4397733.826	2793944.533	3666583.973
12	4408637.207	2782956.449	3661875.316	**35**	4399265.14	2796539.992	3662791.9
13	4407998.799	2785681.342	3660580.472	**36**	4400234.987	2799010.237	3659759.23
14	4410119.569	2778865.548	3663187.996	**37**	4405292.965	2796309.94	3655763.325
15	4412956.316	2784619.33	3655446.379	**38**	4399003.042	2785551.531	3671411.588
16	4413747.483	2782211.347	3656318.734	**39**	4410305.546	2782302.283	3660373.283
17	4420014.964	2793755.611	3640018.181	**40**	4407179.58	2785060.665	3662029.097

18	4418068.492	2795832.639	3640781.273	**41**	4418712.944	2793852.142	3641514.486
19	4415018.106	2791173.191	3648000.866	**42**	4415047.996	2782699.909	3654389.276
20	4419989.544	2783311.693	3647987.402	**43**	4427295.068	2781799.549	3640325.485
21	4426388.967	2779688.879	3643020.47	**44**	4423328.219	2783604.947	3643743.018
22	4427904.315	2783843.531	3638036.673	**45**	4423734.833	2784837.114	3642317.202
23	4428420.875	2786571.771	3635336.427	**46**	4418528.324	2787805.91	3646336.579

Table (A-32):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4429664.347	2762143.235	3652310.155	**10**	4445754.741	2730850.556	3656262.613
2	4425322.204	2757983.781	3660651.404	**11**	4410119.569	2778865.548	3663187.996
3	4429906.575	2759822.774	3653760.466	**12**	4426388.967	2779688.878	3643020.47
4	4424875.504	2761385.937	3658639.579	**13**	4419989.544	2783311.693	3647987.402
5	4431382.124	2754456.395	3656004.842	**14**	4428513.054	2757668.098	3657052.926
6	4418798.613	2762613.533	3665008.867	**15**	4430713.587	2756652.557	3655165.404
7	4426842.65	2772265.198	3648088.334	**16**	4427200.373	2764970.441	3653152.718
8	4434410.519	2764660.11	3644689.772	**17**	4433897.143	2765352.919	3644788.092
9	4448958.623	2742587.119	3643643.801				

Table (A-33):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4457399.906	2722791.963	3648140.091	**12**	4408834.18	2693978.077	3727153.338
2	4458635.393	2726803.501	3643661.526	**13**	4460417.972	2720460.631	3646203.068
3	4457223.637	2738541.475	3636626.109	**14**	4445754.741	2730850.556	3656262.613
4	4448554.947	2741983.273	3644584.679	**15**	4418798.613	2762613.533	3665008.867
5	4448958.623	2742587.119	3643643.801	**16**	4434410.52	2764660.11	3644689.771
6	4453706.55	2729222.392	3647847.804	**17**	4458402.813	2725688.237	3644772.917
7	4458505.141	2727888.172	3643013.323	**18**	4457973.958	2727076.928	3644262.111
8	4468241.492	2728640.267	3630583.647	**19**	4448804.742	2729114.685	3653864.233
9	4453678.081	2735378.936	3643299.006	**20**	4455063.399	2737550.068	3639995.319
10	4456270.961	2731326.138	3643169.912	**21**	4449993.161	2739574.26	3644640.159
11	4458385.768	2734865.326	3637958.777	**22**	4454292.075	2738972.591	3639869.996

A preprocessing step was made by calculating the geocentric coordinated differenced. The point with extremely difference from other pointe is excluded as shown in table (A-34) (A-35) and (A-36).

$$\Delta X = X\_(Palestine\_1923) - X\_WGS84 \quad \text{(A.4)}$$
$$\Delta Y = Y\_(Palestine\_1923) - Y\_WGS84 \quad \text{(A.5)}$$
$$\Delta Z = Z\_(Palestine\_1923) - Z\_WGS84 \quad \text{(A.6)}$$

Table (A-34):- results of the pre-processing check in the north of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	251.5951156	131.9002585	-318.1464745	24	251.1821305	125.7207584	-313.8153105
2	251.5381316	132.0550022	-317.96486	25	251.2278483	125.9655112	-313.9347917
3	251.3482463	131.7521427	-317.5117803	26	251.2615372	126.3609336	-314.1823136
4	251.5614066	130.8613983	-317.0980562	27	251.2377843	126.476613	-314.3172616
5	251.1927778	131.5026164	-317.2728493	28	251.3127322	127.1244129	-314.7129331
6	251.2204975	130.1237774	-316.4984435	29	251.3411455	128.0820331	-315.424229
7	251.3326995	132.4650258	-317.8598031	30	251.3189536	128.461633	-315.7519359
8	251.0250637	131.6520244	-317.3670595	31	195.2652817	121.9513631	-243.3125128
9	251.2206232	131.3487218	-317.2241659	32	194.23714	122.2218645	-242.291214
10	251.2281914	129.2624269	-315.9582389	33	251.5230481	131.524322	-317.4756711
11	251.48172	130.1886284	-316.3977646	34	251.4240382	131.2307773	-317.2330098
12	251.3543635	128.6668855	-315.4570216	35	251.2801772	131.4528899	-317.3382917
13	251.2977711	129.0426005	-315.6942651	36	251.1952425	131.1755502	-317.110147
14	251.6566379	128.3857115	-315.5960561	37	251.1404478	130.1845219	-316.4480066
15	251.316006	127.9934263	-315.1025836	38	251.6014642	130.6004638	-316.8702746
16	251.183464	127.9080081	-314.8700024	39	251.3018034	128.3670137	-315.2230828
17	251.2539226	127.1745338	-314.8438923	40	251.3148933	128.9300451	-315.5863434
18	251.2710002	127.5889798	-315.1370741	41	251.2710874	127.4098594	-314.9929911
19	251.1069234	128.0515325	-315.0893461	42	251.3966129	127.6378112	-314.9814631
20	251.3144316	126.7948203	-314.4521458	43	251.2087037	125.4665017	-313.5841506
21	251.2357624	125.5439308	-313.6051578	44	251.2569791	126.2241236	-314.0884712
22	251.1844754	125.4353884	-313.588818	45	251.2434914	126.2013558	-314.0914925
23	251.157563	125.4425138	-313.6268559	46	251.3089178	127.2188201	-314.7837049

Table (A-35):- results of the pre-processing check in the Middle of the west bank.

Pre- processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	195.0426076	121.8820698	-243.0023187	10	251.2875329	119.9580295	-309.4955952
2	2910.66158	1813.912032	-4774.362845	11	251.6566265	128.3854892	-315.595875
3	195.3115252	121.795823	-243.260243	12	251.1318018	125.5957858	-313.518986
4	195.1557594	121.7636381	-243.0450662	13	251.5470903	126.5140744	-314.5193909
5	195.4384972	121.3450186	-243.0735875	14	195.2094774	121.6090812	-242.9948987
6	195.2652756	121.951252	-243.3124223	15	195.1969505	121.4685402	-242.8758044
7	194.2374901	122.221546	-242.2913956	16	194.9845877	121.8628446	-242.9175376
8	194.8407858	121.8435517	-242.7354337	17	194.8686003	121.822814	-242.753412
9	251.4117916	120.1341187	-310.0646466				

Table (A-36):- results of the pre-processing check in the South of the west bank.

Pre- processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	251.2153666	117.686119	-308.0531402	12	55212.5347	33700.76517	-90645.51018
2	251.1039277	117.7992936	-308.1015339	13	251.6907003	117.3486262	-308.4632503
3	259.9550321	102.6492804	-307.6485415	14	251.2877229	119.9577935	-309.4956496
4	252.592128	118.0969851	-309.9492207	15	12778.94945	-8035.79245	-9247.098561
5	251.4118203	120.1340721	-310.0646466	16	194.8406054	121.8435036	-242.7351795
6	2815.639659	2222.176657	-4986.585777	17	-606.173413	1522.57059	-310.3085857
7	-4575.79971	7609.864107	-23.50618975	18	251.1440414	117.979598	-308.2629987
8	251.0317306	116.3789052	-307.342763	19	251.2476538	119.4390277	-309.1536715
9	279.6935341	-6037.69597	4239.924002	20	251.2521736	118.9648961	-309.1606466
10	2485.386387	-3320.02908	-464.9264211	21	251.20552	119.6260966	-309.4320594
11	-3842.61183	4226.475755	1602.091757	22	4344.665094	-3988.99833	-2219.606797

A.2.1 HelmertTransformations

The results of all iteration for Helmert transformation for triangulation points in the west bankare given in the following protocols.

Calculation Protocol

Helmert Transformation: North of the West Bank	FirstIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
4	4,397,940.817	2,793,105.636	3,667,053.774
6	4,405,211.990	2,797,243.122	3,655,234.191
10	4,409,509.731	2,793,339.204	3,653,051.878
11	4,399,841.100	2,783,209.262	3,672,259.344
12	4,408,888.561	2,783,085.116	3,661,559.859
13	4,408,250.097	2,785,810.385	3,660,264.778
14	4,410,371.226	2,778,993.933	3,662,872.400
15	4,413,207.632	2,784,747.324	3,655,131.277
16	4,413,998.667	2,782,339.255	3,656,003.864
17	4,420,266.218	2,793,882.786	3,639,703.338
18	4,418,319.763	2,795,960.228	3,640,466.136
19	4,415,269.213	2,791,301.242	3,647,685.776
28	4,419,096.386	2,786,955.853	3,646,382.549
29	4,415,028.237	2,793,629.936	3,646,204.578
30	4,414,085.260	2,799,624.441	3,642,770.395

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
4	4,397,689.255	2,792,974.775	3,667,370.872	0.0256	-1.1503	0.8400
6	4,404,960.770	2,797,112.999	3,655,550.689	0.5363	-1.3918	0.4161
10	4,409,258.503	2,793,209.942	3,653,367.837	0.3033	-0.7212	0.1845
11	4,399,589.618	2,783,079.074	3,672,575.742	-0.4133	-0.0633	0.5399
12	4,408,637.207	2,782,956.449	3,661,875.316	-0.3454	0.5633	-0.0125
13	4,407,998.799	2,785,681.342	3,660,580.472	-0.1453	0.0850	0.1096
14	4,410,119.569	2,778,865.548	3,663,187.996	-0.8660	0.9458	0.3217
15	4,412,956.316	2,784,619.330	3,655,446.379	-0.2468	0.7033	-0.2367
16	4,413,747.483	2,782,211.347	3,656,318.734	-0.2424	0.8566	-0.3579
17	4,420,014.964	2,793,755.611	3,640,018.181	0.2439	0.2550	-0.4881
18	4,418,068.492	2,795,832.639	3,640,781.273	0.3446	-0.0915	-0.3449
19	4,415,018.106	2,791,173.191	3,648,000.866	0.2868	0.0377	-0.3732
28	4,418,845.073	2,786,828.729	3,646,697.262	-0.1640	0.8472	-0.4463
29	4,414,776.896	2,793,501.854	3,646,520.002	0.1735	-0.1114	-0.1235
30	4,413,833.941	2,799,495.979	3,643,086.147	0.5091	-0.7643	-0.0286

Transformation parameters

scale: 0.999976665 ± 0.0000111833

rotation about X: 0°00'10.29547" ± 3.27929" t-value: 3.140

rotation about Y: 0°00'03.01937" ± 2.92876" t-value: 1.031

rotation about Z: 0°00'08.29739" ± 4.49699" t-value: 1.845

X translation: 295.540 ± 107.982 t-value: 2.737

Y translation: 188.738 ± 142.065 t-value: 1.329

Z translation: -155.648 ± 76.775 t-value: 2.027

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
4	4,397,689.255	2,792,974.775	3,667,370.872		4,397,940.842	2,793,104.486	3,667,054.614
6	4,404,960.770	2,797,112.999	3,655,550.689		4,405,212.527	2,797,241.731	3,655,234.607
10	4,409,258.503	2,793,209.942	3,653,367.837		4,409,510.034	2,793,338.483	3,653,052.063
11	4,399,589.618	2,783,079.074	3,672,575.742		4,399,840.686	2,783,209.199	3,672,259.884
12	4,408,637.207	2,782,956.449	3,661,875.316		4,408,888.216	2,783,085.679	3,661,559.846
13	4,407,998.799	2,785,681.342	3,660,580.472		4,408,249.952	2,785,810.470	3,660,264.887
14	4,410,119.569	2,778,865.548	3,663,187.996		4,410,370.360	2,778,994.879	3,662,872.722
15	4,412,956.316	2,784,619.330	3,655,446.379		4,413,207.385	2,784,748.027	3,655,131.040
16	4,413,747.483	2,782,211.347	3,656,318.734		4,413,998.424	2,782,340.111	3,656,003.506
17	4,420,014.964	2,793,755.611	3,640,018.181		4,420,266.462	2,793,883.041	3,639,702.849
18	4,418,068.492	2,795,832.639	3,640,781.273		4,418,320.107	2,795,960.136	3,640,465.791
19	4,415,018.106	2,791,173.191	3,648,000.866		4,415,269.500	2,791,301.280	3,647,685.403
28	4,418,845.073	2,786,828.729	3,646,697.262		4,419,096.222	2,786,956.700	3,646,382.102
29	4,414,776.896	2,793,501.854	3,646,520.002		4,415,028.411	2,793,629.825	3,646,204.454
30	4,413,833.941	2,799,495.979	3,643,086.147		4,414,085.769	2,799,623.677	3,642,770.367
37	4,405,292.965	2,796,309.940	3,655,763.325		4,405,544.679	2,796,438.688	3,655,447.283
38	4,399,003.042	2,785,551.531	3,671,411.588		4,399,254.240	2,785,681.564	3,671,095.625
39	4,410,305.546	2,782,302.283	3,660,373.283		4,410,556.511	2,782,431.386	3,660,057.906
40	4,407,179.580	2,785,060.665	3,662,029.097		4,407,430.705	2,785,189.912	3,661,713.497
41	4,418,712.944	2,793,852.142	3,641,514.486		4,418,964.455	2,793,979.697	3,641,199.095
42	4,415,047.996	2,782,699.909	3,654,389.276		4,415,298.954	2,782,828.513	3,654,074.088
46	4,418,528.324	2,787,805.910	3,646,336.579		4,418,779.525	2,787,933.853	3,646,021.375

Helmert Transformation: North of the West Bank | SecondIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
10	4,409,509.731	2,793,339.204	3,653,051.878
11	4,399,841.100	2,783,209.262	3,672,259.344
12	4,408,888.561	2,783,085.116	3,661,559.859
13	4,408,250.097	2,785,810.385	3,660,264.778
15	4,413,207.632	2,784,747.324	3,655,131.277
17	4,420,266.218	2,793,882.786	3,639,703.338
18	4,418,319.763	2,795,960.228	3,640,466.136
19	4,415,269.213	2,791,301.242	3,647,685.776
29	4,415,028.237	2,793,629.936	3,646,204.578

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
10	4,409,258.503	2,793,209.942	3,653,367.837	0.3018	-0.8830	0.3095
11	4,399,589.618	2,783,079.074	3,672,575.742	-0.0734	-0.2612	0.2841
12	4,408,637.207	2,782,956.449	3,661,875.316	-0.2235	0.5146	-0.1215

13	4,407,998.799	2,785,681.342	3,660,580.472	-0.0367	-0.0069	0.0493
15	4,412,956.316	2,784,619.330	3,655,446.379	-0.2473	0.7053	-0.2377
17	4,420,014.964	2,793,755.611	3,640,018.181	-0.0246	0.2631	-0.1715
18	4,418,068.492	2,795,832.639	3,640,781.273	0.1015	-0.1403	-0.0154
19	4,415,018.106	2,791,173.191	3,648,000.866	0.1670	-0.0053	-0.1967
29	4,414,776.896	2,793,501.854	3,646,520.002	0.0350	-0.1862	0.0999

Transformation parameters

scale: 0.999958524 ± 0.0000089892

rotation about X: 0°00'08.62908" ± 4.34293" t-value: 1.987

rotation about Y: 0°00'01.96474" ± 3.54841" t-value: 0.554

rotation about Z: 0°00'06.91796" ± 7.22023" t-value: 0.958

X translation: 375.530 ± 158.446 t-value: 2.370

Y translation: 239.276 ± 226.114 t-value: 1.058

Z translation: -89.270 ± 59.252 t-value: 1.507

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
10	4,409,258.503	2,793,209.942	3,653,367.837		4,409,510.033	2,793,338.321	3,653,052.188
11	4,399,589.618	2,783,079.074	3,672,575.742		4,399,841.026	2,783,209.001	3,672,259.629
12	4,408,637.207	2,782,956.449	3,661,875.316		4,408,888.338	2,783,085.630	3,661,559.737
13	4,407,998.799	2,785,681.342	3,660,580.472		4,408,250.061	2,785,810.378	3,660,264.827
15	4,412,956.316	2,784,619.330	3,655,446.379		4,413,207.385	2,784,748.029	3,655,131.039
17	4,420,014.964	2,793,755.611	3,640,018.181		4,420,266.194	2,793,883.049	3,639,703.166
18	4,418,068.492	2,795,832.639	3,640,781.273		4,418,319.864	2,795,960.087	3,640,466.121
19	4,415,018.106	2,791,173.191	3,648,000.866		4,415,269.380	2,791,301.237	3,647,685.580
29	4,414,776.896	2,793,501.854	3,646,520.002		4,415,028.272	2,793,629.750	3,646,204.678
37	4,405,292.965	2,796,309.940	3,655,763.325		4,405,544.741	2,796,438.424	3,655,447.410
38	4,399,003.042	2,785,551.531	3,671,411.588		4,399,254.568	2,785,681.327	3,671,095.413
39	4,410,305.546	2,782,302.283	3,660,373.283		4,410,556.600	2,782,431.372	3,660,057.810
40	4,407,179.580	2,785,060.665	3,662,029.097		4,407,430.840	2,785,189.814	3,661,713.410
41	4,418,712.944	2,793,852.142	3,641,514.486		4,418,964.217	2,793,979.682	3,641,199.392
42	4,415,047.996	2,782,699.909	3,654,389.276		4,415,298.923	2,782,828.573	3,654,074.080
46	4,418,528.324	2,787,805.910	3,646,336.579		4,418,779.355	2,787,933.908	3,646,021.536

Helmert Transformation: North of the West Bank | ThirdIteration(Final)

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
10	4409509.731	2793339.204	3653051.878
11	4399841.100	2783209.262	3672259.344
12	4408888.561	2783085.116	3661559.859
13	4408250.097	2785810.385	3660264.778
17	4420266.218	2793882.786	3639703.338
18	4418319.763	2795960.228	3640466.136
19	4415269.213	2791301.242	3647685.776
29	4415028.237	2793629.936	3646204.578

Coordinates from WGS84:

ID	X	Y	Z	VX	VY	VZ
10	4409258.503	2793209.942	3653367.837	0.2791	-0.8054	0.2762
11	4399589.618	2783079.074	3672575.742	-0.0708	-0.1402	0.1890
12	4408637.207	2782956.449	3661875.316	-0.2477	0.6301	-0.1785

13	4407998.799	2785681.342	3660580.472	-0.0581	0.0991	-0.0047
17	4420014.964	2793755.611	3640018.181	-0.0789	0.3317	-0.1576
18	4418068.492	2795832.639	3640781.273	0.0536	-0.0780	-0.0056
19	4415018.106	2791173.191	3648000.866	0.1266	0.0760	-0.2096
29	4414776.896	2793501.854	3646520.002	-0.0039	-0.1133	0.0908

Standard deviation: 0.3071.

Transformation parameters:

==========

Scale: 0.999955212 ± 0.0000082131

Rotation about X: 0°00'08.72456" ± 4.78791" t-value: 1.822

Rotation about Y: 0°00'02.02667" ± 3.71588" t-value: 0.545

Rotation about Z: 0°00'06.93731" ± 8.04291" t-value: 0.863

X translation: 390.945 ± 172.915 t-value: 2.261

Y translation: 247.327 ± 252.913 t-value: 0.978

Z translation: -77.235 ± 53.805 t-value: 1.435

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	X	Y	Z
10	4409258.503	2793209.942	3653367.837	4409510.01	2793338.399	3653052.155
11	4399589.618	2783079.074	3672575.742	4399841.029	2783209.122	3672259.533
12	4408637.207	2782956.449	3661875.316	4408888.314	2783085.746	3661559.68
13	4407998.799	2785681.342	3660580.472	4408250.039	2785810.484	3660264.773
17	4420014.964	2793755.611	3640018.181	4420266.139	2793883.117	3639703.18
18	4418068.492	2795832.639	3640781.273	4418319.816	2795960.15	3640466.13
19	4415018.106	2791173.191	3648000.866	4415269.339	2791301.318	3647685.567
29	4414776.896	2793501.854	3646520.002	4415028.233	2793629.823	3646204.668
37	4405292.965	2796309.94	3655763.325	4405544.731	2796438.493	3655447.366
38	4399003.042	2785551.531	3671411.588	4399254.573	2785681.439	3671095.321
39	4410305.546	2782302.283	3660373.283	4410556.57	2782431.489	3660057.759
40	4407179.58	2785060.665	3662029.097	4407430.821	2785189.923	3661713.351
41	4418712.944	2793852.142	3641514.486	4418964.166	2793979.751	3641199.401
42	4415047.996	2782699.909	3654389.276	4415298.88	2782828.685	3654074.05
46	4418528.324	2787805.91	3646336.579	4418779.304	2787933.999	3646021.532

APPENDIX-A CALCULATION PROTOCOL

Calculation Protocol

Helmert Transformation: Middle of the West Bank	FirstIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,429,859.390	2,762,265.117	3,652,067.153
3	4,430,101.886	2,759,944.569	3,653,517.205
4	4,425,070.660	2,761,507.701	3,658,396.534
5	4,431,577.563	2,754,577.740	3,655,761.769
6	4,418,993.879	2,762,735.484	3,664,765.555
8	4,434,605.360	2,764,781.954	3,644,447.036

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,429,664.347	2,762,143.235	3,652,310.155	0.1121	-0.1230	-0.0424
3	4,429,906.575	2,759,822.774	3,653,760.466	-0.1529	-0.0169	0.1965
4	4,424,875.504	2,761,385.937	3,658,639.579	0.0566	-0.0179	-0.0545
5	4,431,382.124	2,754,456.395	3,656,004.842	-0.2815	0.4837	-0.0248
6	4,418,798.613	2,762,613.533	3,665,008.867	0.0140	-0.2402	0.1636
8	4,434,410.519	2,764,660.110	3,644,689.772	0.2516	-0.0857	-0.2384

Transformation parameters

scale: 0.999990353 ± 0.0000113038
rotation about X: -0°00'00.40896" ± 3.99472"
rotation about Y: -0°00'00.33247" ± 2.52574" t-value: 0.132
rotation about Z: -0°00'00.34640" ± 4.66878" t-value: 0.074
X translation: 236.639 ± 94.554 t-value: 2.503
Y translation: 148.208 ± 160.785 t-value: 0.922
Z translation: -206.148 ± 85.525 t-value: 2.410

Transformed Coordinates:
WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4,429,664.347	2,762,143.235	3,652,310.155		4,429,859.502	2,762,264.994	3,652,067.111
3	4,429,906.575	2,759,822.774	3,653,760.466		4,430,101.733	2,759,944.553	3,653,517.402
4	4,424,875.504	2,761,385.937	3,658,639.579		4,425,070.717	2,761,507.683	3,658,396.479
5	4,431,382.124	2,754,456.395	3,656,004.842		4,431,577.281	2,754,578.224	3,655,761.744
6	4,418,798.613	2,762,613.533	3,665,008.867		4,418,993.893	2,762,735.244	3,664,765.718
8	4,434,410.519	2,764,660.110	3,644,689.772		4,434,605.612	2,764,781.868	3,644,446.798
14	4,428,513.054	2,757,668.098	3,657,052.926		4,428,708.235	2,757,789.889	3,656,809.828
15	4,430,713.587	2,756,652.557	3,655,165.404		4,430,908.745	2,756,774.365	3,654,922.319
16	4,427,200.373	2,764,970.441	3,653,152.718		4,427,395.548	2,765,092.167	3,652,909.675
17	4,433,897.143	2,765,352.919	3,644,788.092		4,434,092.240	2,765,474.669	3,644,545.119

Helmert Transformation: Middle of the West Bank	SecondIteration(Final)

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4429859.390	2762265.117	3652067.153
3	4430101.886	2759944.569	3653517.205
4	4425070.660	2761507.701	3658396.534

5	4431577.563	2754577.740	3655761.769
6	4418993.879	2762735.484	3664765.555
8	4434605.360	2764781.954	3644447.036

Coordinates from WGS84:

ID	X	Y	Z	VX	VY	VZ
1	4429664.347	2762143.235	3652310.155	0.1121	-0.1230	-0.0424
3	4429906.575	2759822.774	3653760.466	-0.1529	-0.0169	0.1965
4	4424875.504	2761385.937	3658639.579	0.0566	-0.0179	-0.0545
5	4431382.124	2754456.395	3656004.842	-0.2815	0.4837	-0.0248
6	4418798.613	2762613.533	3665008.867	0.0140	-0.2402	0.1636
8	4434410.519	2764660.110	3644689.772	0.2516	-0.0857	-0.2384

Standard deviation: 0.2382.

Transformation parameters.

Scale: 0.999990353 ± 0.0000113038

Rotation about X: -0°00’00.40896" ± 3.99472" t-value: 0.102

Rotation about Y: -0°00’00.33247" ± 2.52574" t-value: 0.132

Rotation about Z: -0°00’00.34640" ± 4.66878" t-value: 0.074

X translation: 236.639 ± 94.554 t-value: 2.503

Y translation: 148.208 ± 160.785 t-value: 0.922

Z translation: -206.148 ± 85.525 t-value: 2.410

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->X	Y	Z
1	4429664.35	2762143.24	3652310.16	4429859.50	2762264.99	3652067.11
3	4429906.58	2759822.77	3653760.47	4430101.73	2759944.55	3653517.40
4	4424875.50	2761385.94	3658639.58	4425070.72	2761507.68	3658396.48
5	4431382.12	2754456.40	3656004.84	4431577.28	2754578.22	3655761.74
6	4418798.61	2762613.53	3665008.87	4418993.89	2762735.24	3664765.72
8	4434410.52	2764660.11	3644689.77	4434605.61	2764781.87	3644446.80
14	4428513.05	2757668.10	3657052.93	4428708.24	2757789.89	3656809.83
15	4430713.59	2756652.56	3655165.40	4430908.75	2756774.37	3654922.32
16	4427200.37	2764970.44	3653152.72	4427395.55	2765092.17	3652909.68
17	4433897.14	2765352.92	3644788.09	4434092.24	2765474.67	3644545.12

APPENDIX-A CALCULATION PROTOCOL

Calculation Protocol

Helmert Transformation: South of the West Bank	FirstIteration

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4,457,651.122	2,722,909.649	3,647,832.038
2	4,458,886.497	2,726,921.300	3,643,353.424
4	4,448,807.540	2,742,101.370	3,644,274.730
5	4,449,210.035	2,742,707.253	3,643,333.737
8	4,468,492.524	2,728,756.646	3,630,276.304
13	4,460,669.663	2,720,577.980	3,645,894.605
14	4,446,006.028	2,730,970.514	3,655,953.117

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4,457,399.906	2,722,791.963	3,648,140.091	-0.3158	0.6225	-0.0789
2	4,458,635.393	2,726,803.501	3,643,661.526	0.1817	0.1130	-0.3047
4	4,448,554.947	2,741,983.273	3,644,584.679	-0.4323	0.5496	0.1128
5	4,448,958.623	2,742,587.119	3,643,643.801	0.8149	-1.5803	0.1927
8	4,468,241.492	2,728,640.267	3,630,583.647	0.7924	-0.0228	-0.9486
13	4,460,417.972	2,720,460.631	3,646,203.068	-0.8665	0.6236	0.5899
14	4,445,754.741	2,730,850.556	3,656,262.613	-0.1745	-0.3056	0.4368

Transformation parameters

scale: 1.000003044 ± 0.0000214417 t-value: 46638.158
rotation about X: 0°00’15.32040" ± 6.09361" t-value: 2.514
rotation about Y: 0°00’06.25135" ± 6.01282" t-value: 1.040
rotation about Z: 0°00’12.67647" ± 5.60646" t-value: 2.261
X translation: 180.562 ± 156.193 t-value: 1.156
Y translation: 112.993 ± 196.654 t-value: 0.575
Z translation: -252.092 ± 191.936 t-value: 1.313

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4,457,399.906	2,722,791.963	3,648,140.091		4,457,650.806	2,722,910.272	3,647,831.959
2	4,458,635.393	2,726,803.501	3,643,661.526		4,458,886.679	2,726,921.413	3,643,353.120
4	4,448,554.947	2,741,983.273	3,644,584.679		4,448,807.107	2,742,101.919	3,644,274.843
5	4,448,958.623	2,742,587.119	3,643,643.801		4,449,210.850	2,742,705.673	3,643,333.929
8	4,468,241.492	2,728,640.267	3,630,583.647		4,468,493.316	2,728,756.623	3,630,275.356
13	4,460,417.972	2,720,460.631	3,646,203.068		4,460,668.797	2,720,578.604	3,645,895.195
14	4,445,754.741	2,730,850.556	3,656,262.613		4,446,005.854	2,730,970.208	3,655,953.554
18	4,457,973.958	2,727,076.928	3,644,262.111		4,458,225.240	2,727,194.926	3,643,953.667
19	4,448,804.742	2,729,114.685	3,653,864.233		4,449,055.830	2,729,233.966	3,653,555.388
20	4,455,063.399	2,737,550.068	3,639,995.319		4,455,315.445	2,737,667.961	3,639,685.995
21	4,449,993.161	2,739,574.260	3,644,640.159		4,450,245.175	2,739,692.815	3,644,330.546

Helmert Transformation: South of the West Bank	SecondIteration(Final)

Coordinates from Palestine 1923 Grid.

ID	X	Y	Z
1	4457651.122	2722909.649	3647832.038
2	4458886.497	2726921.300	3643353.424
4	4448807.540	2742101.370	3644274.730
8	4468492.524	2728756.646	3630276.304
13	4460669.663	2720577.980	3645894.605
14	4446006.028	2730970.514	3655953.117

Coordinates from WGS84:

ID	X	Y	Z	VX	VY	VZ
1	4457399.906	2722791.963	3648140.091	-0.2023	0.5269	-0.1466
2	4458635.393	2726803.501	3643661.526	0.2552	-0.0961	-0.2384
4	4448554.947	2741983.273	3644584.679	-0.0697	-0.1099	0.1683
8	4468241.492	2728640.267	3630583.647	0.5779	-0.2710	-0.5014
13	4460417.972	2720460.631	3646203.068	-0.8413	0.5993	0.5759
14	4445754.741	2730850.556	3656262.613	0.2801	-0.6492	0.1422

Standard deviation: 0.5304.

Transformation parameters.

Scale: 0.999973724 ± 0.0000170074

Rotation about X: 0°00’15.15752" ± 5.06529" t-value: 2.992

Rotation about Y: 0°00’06.16518" ± 4.36067" t-value: 1.414

Rotation about Z: 0°00’12.58266" ± 4.93426" t-value: 2.550

X translation: 311.082 ± 121.260 t-value: 2.565

Y translation: 193.583 ± 174.175 t-value: 1.111

Z translation: -145.486 ± 144.251 t-value: 1.009

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4457399.91	2722791.96	3648140.09		4457650.92	2722910.18	3647831.89
2	4458635.39	2726803.50	3643661.53		4458886.75	2726921.20	3643353.19
4	4448554.95	2741983.27	3644584.68		4448807.47	2742101.26	3644274.90
8	4468241.49	2728640.27	3630583.65		4468493.10	2728756.38	3630275.80
13	4460417.97	2720460.63	3646203.07		4460668.82	2720578.58	3645895.18
14	4445754.74	2730850.56	3656262.61		4446006.31	2730969.87	3655953.26
18	4457973.96	2727076.93	3644262.11		4458225.33	2727194.71	3643953.72
19	4448804.74	2729114.69	3653864.23		4449056.20	2729233.68	3653555.16
20	4455063.40	2737550.07	3639995.32		4455315.62	2737667.44	3639686.18
21	4449993.16	2739574.26	3644640.16		4450245.50	2739692.23	3644330.60

APPENDIX-A

CALCULATION PROTOCOL

A-1 Solution Including the Height (Case 1).

A-2 Solution without Including the Height (Case 2).

A-1 Solution Including the Height (Case 1).

In the first case, the height where used in calculating (X, Y, Z) coordinates.

For the triangulation point, these are orthometrice heights which cover not precisely measured. Table (A-1) (A-2) and (A-3) show the registered coordinates of the control points for the different parts of the West Bank in Pal_1923Grid system.

Table (A-1):-registered coordinates in the north of the west bank in (E, N).

#	E	N	#	E	N
1	171066.1	216350.7	24	149095.6	177710.4
2	179794.3	210343.1	25	153639	176230.2
3	180244.8	207314.9	26	156596.3	177579.2
4	180824.6	202860.8	27	153118.7	181710
5	175936.3	206014.3	28	159351.5	182755.4
6	168551.6	202361.6	29	159177.2	192259.4
7	185353.7	211202.8	30	155625.3	199034.1
8	168522.9	213702.4	31	178483.6	157845
9	174332.5	208442.2	32	160852.7	162614.2
10	166284.9	195546.7	33	182397.2	208701.4
11	186254.2	191429.7	34	180005.9	203829.5
12	175126	185396.5	35	176065.9	205495.9
13	173777.8	188618.9	36	172917.6	207400.2
14	176494.6	180216.2	37	168772.1	201319.4
15	168441.6	184299.9	38	185037.6	194360.4
16	169348.4	181306	39	173564.5	183636.7
17	152430.3	189125.8	40	175284.3	188513.4
18	153226.9	192521.9	41	153983.2	190067.9
19	160711.5	189707.7	42	167342	180964.9
20	160687.5	178393	43	152720.8	172117.8
21	155518	170527.1	44	156276.6	176536.6
22	150347.4	173830.6	45	154797.4	177543
23	147550.3	176307.1	46	158978.3	183966.5

Table (A-2):-registered coordinates in the middle of the west bank in (E, N).

#	E	N	#	E	N
1	165240.6	150347.93	10	169288.7	107612.6
2	169213.18	148845.37	11	176494.6	180216.2
3	166751.52	147794.39	12	155518.1	170527.2
4	171841.27	152650.15	13	160687.4	178392.5
5	169092.08	141297.74	14	170186.4	146464
6	178483.62	157845	15	168216.6	143998.5
7	160852.72	162614.21	16	166120.9	154854.1
8	157300.27	149898.38	17	157404	150943.1
9	156096.76	117739.33			

Table (A-3):-registered coordinates in the South of the west bank in (E, N).

#	E	N	#	E	N
1	160773.39	91851.11	12	148918.7	92762.38
2	156086.7	95234.67	13	158738.9	87520.78
3	148752.64	108279.93	14	169288.7	107612.62
4	157079.28	117367.82	15	169092.1	141297.74
5	156096.76	117739.33	16	157300.3	149898.38
6	155580.17	101424.37	17	157249.2	96224.6
7	155722.87	107271.25	18	156716.2	95937
8	142397.9	91081.11	19	166776.3	103869.46
9	160474.73	100867.46	20	152271.8	108643.28
10	155409.64	96442.86	21	157133.5	113959.94
11	152144.28	110606.8	22	150135.3	103756.06

The projected coordinates (E,N) were converted to Geographic coordinates (, ϕ, h) with the assumption that (h = H), the covered coordinates are shown in tables (A-4) (A-5) and (A-6).

Table (A-4):- Triangulation points coordinates that are transformed to (lat, long, h) in the north of the West bank.

#	Lat	Long	h	#	Lat	Long	h
1	32.5410837	35.220732	108.56	24	32.1924264	34.9877114	116.49
2	32.4868679	35.3135851	124.97	25	32.1791533	35.0359177	252.33
3	32.4595556	35.3183462	193.96	26	32.1913589	35.0672539	316.49
4	32.4193836	35.3244632	371.82	27	32.2285637	35.0303025	156.05
5	32.4478579	35.2725138	305.12	28	32.2380696	35.0964129	389.22
6	32.414931	35.1939892	380.48	29	32.3237758	35.0944522	323.54
7	32.4945588	35.3727453	309.97	30	32.3848287	35.0566274	103.51

8	32.517201	35.1936635	230.2	31	32.0134411	35.2991878	791.77
9	32.4697588	35.2554695	243.89	32	32.056443	35.1125378	477.84
10	32.3534684	35.1699217	332.24	33	32.4720375	35.3412559	158.13
11	32.3162342	35.3819923	354.74	34	32.4281268	35.3157688	351.74
12	32.2619296	35.2637912	668.04	35	32.4431822	35.2738896	273.84
13	32.2909948	35.2494955	548.15	36	32.4603669	35.2404159	189.98
14	32.2152061	35.2782822	600.78	37	32.405533	35.1963352	360.01
15	32.2520492	35.1928541	370.43	38	32.3426795	35.369118	506.21
16	32.2250508	35.2024792	568.55	39	32.2460651	35.2472139	590.25
17	32.2954293	35.0228607	87.46	40	32.2900371	35.2654874	602.11
18	32.3260683	35.0312574	568.75	41	32.3039493	35.0393308	141.89
19	32.300778	35.1107718	319.55	42	32.2219711	35.1811965	480.48
20	32.1987401	35.1106305	412.1	43	32.1420528	35.0262572	203.8
21	32.1277477	35.0559278	234.39	44	32.181953	35.0638793	276
22	32.1574602	35.0010664	173.2	45	32.1910093	35.0481787	255.53
23	32.1797411	34.9713569	73.55	46	32.2489873	35.0924386	318.61

Table (A-5):- Triangulation points coordinates that are transformed to (lat, long, h) in the middleof the West bank.

#	Lat	Long	h	#	Lat	Long	h
1	31.94584703	35.15906402	751.35	10	31.56043198	35.20191937	824.2
2	31.93230657	35.20108017	845.65	11	32.21520608	35.27828217	600.78
3	31.92282323	35.17505294	745.53	12	32.12774874	35.05592873	234.39
4	31.96661981	35.22887738	713.1	13	32.19873616	35.11062977	412.1
5	31.86423668	35.19980861	810.02	14	31.91083018	35.21137152	871.41
6	32.01344108	35.29918782	791.77	15	31.88859286	35.19055161	848.11
7	32.05644304	35.11253782	477.84	16	31.98648999	35.16835505	660.89
8	31.9417299	35.07509211	397.28	17	31.95115326	35.07617483	423.78
9	31.65167912	35.06283094	588.94				

Table (A-6):- Triangulation points coordinates that are transformed to (lat, long, h) in the Southof the West bank.

#	Lat	Long	h	#	Lat	Long	h
1	31.41823608	35.11238351	794.29	12	31.4262975	34.98769444	669.29
2	31.44870572	35.06304776	774.12	13	31.3791607	35.09103741	796.08
3	31.56625038	34.98561093	805.21	14	31.56043198	35.20191937	824.2
4	31.64834015	35.07319432	638.89	15	31.86423668	35.19980861	810.02
5	31.65167912	35.06283094	588.94	16	31.9417299	35.07509211	397.28
6	31.50452599	35.05762748	913.81	17	31.45764785	35.07526362	810.69
7	31.55726193	35.0590436	875.47	18	31.45504779	35.06966023	774.24
8	31.41099524	34.91916	643.29	19	31.52666682	35.1754706	942.61
9	31.49955488	35.10915377	902.79	20	31.56958777	35.02267158	614.98
10	31.45959427	35.05590709	739.5	21	31.61760493	35.07381107	849.42
11	31.58729497	35.02129251	567.75	22	31.52547393	35.00026649	730.17

Finally the geographic coordinates (, ϕ, h) are transformed to geocentric coordinates (X, Y, Z) as shown in table (A-7) (A-8) and (A-9).

Table (A-7):-coordinates that are transformed to (X, Y, Z)in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397675.2	2806063.25	3657720.95	10	4409739.16	2793484.54	3653243.25
2	4395322.54	2798713.21	3666141.29	11	4400085.53	2783363.88	3672464.75
3	4396445.99	2796484.02	3666612.19	12	4409349.81	2783376.28	3661945.55
4	4398196.9	2793268.27	3667268.76	13	4408628.51	2786049.53	3660581.14
5	4399572.77	2797211.41	3662526.15	14	4410786.17	2779255.39	3663219.38
6	4405474.47	2797409.8	3655453.48	15	4413463.65	2784908.87	3655344.77
7	4391871.63	2797344.48	3671602.31	16	4414391.68	2782586.99	3656331.61
8	4400388.23	2805214.06	3655337.34	17	4420326.76	2793921.05	3639753.53
9	4399382.16	2799452.18	3660946.78	18	4418713.3	2796209.26	3640792.61
#	X	Y	Z	#	X	Y	Z
19	4415490.17	2791440.93	3647869.57	33	4394571.98	2796636.88	3668665.12
20	4420526.13	2783618.12	3647909.97	34	4398227.51	2794229.67	3666470.07
21	4426802.69	2779916.46	3642841.49	35	4399705.09	2796791.38	3662632.7
22	4428275.61	2784044.48	3637822.43	36	4400617.1	2799224.69	3659551.74
23	4428723.04	2786729.31	3635064.96	37	4405792.49	2796597.78	3655654.38
24	4427255.5	2787174.36	3636576.17	38	4399603.39	2785902.96	3671387.73
25	4425398.16	2784573.79	3641034.33	39	4410964.54	2782687.84	3660398.7
26	4423159.62	2784480.74	3643917.19	40	4407846.48	2785452.22	3662061.15
27	4423230.99	2788537.77	3640468.97	41	4419062.41	2794041.64	3641280.96
28	4419365.75	2787125.73	3646606.33	42	4415631.62	2783036.94	3654351.13
29	4415251.94	2793771.48	3646390.59	43	4427687.59	2782013.8	3640128.87
30	4414156.81	2799669.82	3642829.85	44	4423770.68	2783851.49	3643587.49
31	4419541.81	2763078.05	3665223.08	45	4424163.11	2785074.76	3642149.85
32	4427368.17	2772594.88	3648120.89	46	4419000.11	2788072.24	3646204.96

Table (A-8):-coordinates that are transformed to (X, Y, Z)in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4430380.629	2762590.139	3652499.817	10	4446579.889	2731323.009	3656428.236
2	4428819.307	2760163.18	3656364.514	11	4410786.173	2779255.393	3663219.38
3	4430619.115	2760266.802	3653946.688	12	4426802.587	2779916.512	3642841.579
4	4425564.827	2761816.09	3658807.881	13	4420526.36	2783617.841	3647909.905
5	4432139.72	2754927.166	3656228.688	14	4429312.634	2758166.053	3657312.381
6	4419541.807	2763078.046	3665223.076	15	4431497.287	2757140.174	3655411.291
7	4427368.173	2772594.883	3648120.889	16	4427853.586	2765378.487	3653290.461
8	4434881.264	2764953.968	3644675.333	17	4434386.286	2765658.276	3644788.87
9	4449620.391	2742960.217	3643672.068				

Table (A-9):- coordinates that are transformed to (X, Y, Z) in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4458205.608	2723248.351	3648288.9	12	4464514.613	2727964.744	3636891.599
2	4459427.054	2727251.889	3643798.139	13	4461225.776	2720917.155	3646352.253
3	4458045.684	2738989.47	3636780.144	14	4446579.889	2731323.009	3656428.236
4	4449252.659	2742375.727	3644641.85	15	4432139.72	2754927.166	3656228.688
5	4449620.391	2742960.217	3643672.068	16	4434881.264	2764953.968	3644675.333
6	4457159.952	2731835.459	3643386.111	17	4458362.594	2727557.05	3644928.473
7	4454539.991	2735873.082	3643492.705	18	4458765.662	2727525.58	3644398.705
8	4468942.695	2729031.55	3630644.537	19	4449712.746	2729637.005	3654098.1
9	4454587.481	2729727.118	3648058.157	20	4455743.74	2737932.697	3640039.096
10	4459272.715	2728322.039	3643129.736	21	4450836.354	2740058.33	3644818.83
11	4454939.223	2739335.343	3639886.69	22	4459146.581	2735296.335	3638069.201

The GNSS measured coordinatesfor the triangulation points in the west bank are (Lat, long, h) in WGS84 system, these coordinates are given in table (A-10) (A-11) and (A-12).

Table (A-10):-GNSS coordinatesin the north of the west bank in (Lat, long, h) in WGS84.

#	Lat	Long	h	#	Lat	Long	h
1	32.5413489	35.2215794	129.74	24	32.1927268	34.9885158	137.05
2	32.4871286	35.3144288	144.53	25	32.1794512	35.0367224	272.8
3	32.4598166	35.3191848	213.73	26	32.1916541	35.0680608	336.95
4	32.4196519	35.3252971	391.87	27	32.2288595	35.0311116	176.67
5	32.4481195	35.2733507	326.4	28	32.2383606	35.097225	409.68
6	32.4152035	35.194819	401.36	29	32.3240627	35.0952722	344.15
7	32.4948151	35.3735867	331.13	30	32.3851151	35.0574517	122.05
8	32.5174638	35.1945029	249.97	31	32.0134423	35.2992073	812.61
9	32.4700231	35.2563061	264.01	32	32.0564376	35.1125516	498.43
10	32.3537455	35.170746	424.8	33	32.4723023	35.3420936	179.16
11	32.3165029	35.3828174	375.6	34	32.4283913	35.3166044	372.74
12	32.2622084	35.2646082	688.92	35	32.4434445	35.2747271	294.91
13	32.2912713	35.2503154	569.22	36	32.4606321	35.2412516	311.29
14	32.2154868	35.2791004	621.57	37	32.405804	35.1971644	379.64
15	32.2523332	35.1936685	391.43	38	32.3429465	35.3699485	527.12
16	32.2253334	35.2032908	589.16	39	32.2463454	35.2480286	611.22
17	32.2957223	35.0236757	106.57	40	32.2903147	35.2663058	623.03
18	32.3263592	35.0320755	106.87	41	32.3042407	35.0401471	160.77
19	32.3010626	35.1115878	339.92	42	32.2222572	35.1820098	501.01
20	32.1990321	35.1114394	432.51	43	32.1423532	35.0270582	224.22
21	32.1280468	35.0567285	254.95	44	32.1822489	35.0646851	296.49
22	32.1577615	35.0018681	193.68	45	32.1913057	35.0489849	276.23
23	32.1800432	34.9721596	94.03	46	32.249278	35.0932515	339.23

Table (A-11):-GNSS coordinatesin the Middle of the west bank in (Lat, long, h) in WGS84.

#	Lat	Long	h	#	Lat	Long	h
1	31.94584459	35.15908422	772.272	10	31.56075383	35.20267178	843.09
2	31.93230744	35.25109827	866.424	11	32.21548678	35.27910037	621.572
3	31.92282214	35.17507551	767.147	12	32.12804681	35.05672847	254.95
4	31.96662004	35.22889599	733.992	13	32.19903213	35.11143942	432.51
5	31.86423794	35.19982839	830.877	14	31.91082971	35.21139009	892.278
6	32.01344227	35.29920733	812.607	15	31.88859265	35.19056948	868.958
7	32.05643763	35.11255156	498.43	16	31.98648918	35.16837404	681.832
8	31.94172647	35.07511185	418.205	17	31.9511506	35.07619474	444.68
9	31.65200433	35.0635925	609.623				

Table (A-12):-GNSS coordinatesin the South of the west bank in (Lat, long, h) in WGS84.

#	Lat	Long	h	#	Lat	Long	h
1	31.41857089	35.11312187	813.313	12	31.42663724	35.98843389	687.14
2	31.44904025	35.06378769	793.07	13	31.37949924	35.09178074	814.76
3	31.56678291	34.98634752	525.871	14	31.56075383	35.20267178	843.09
4	31.64869103	35.07395439	658.207	15	32.01344227	35.29920733	830.877
5	31.65200433	35.0635925	609.623	16	31.94172647	35.07511185	418.205
6	31.49988316	35.10990124	933.5	17	31.43993875	35.07602761	829.664
7	31.45992864	35.05664977	895.15	18	31.45538122	35.0704018	793.202
8	31.41134005	34.91989465	661.38	19	31.5269914	35.17621978	961.906
9	31.55759091	35.0597956	921.66	20	31.56991847	35.02342403	634.002
10	31.50485825	35.05837405	758.47	21	31.61793193	35.07456543	868.75
11	31.52580713	35.00101091	586.85	22	31.58762332	35.02204462	748.9

The Transformation of the GNSS geographic coordinates to geocentric coordinates (X, Y, Z) in WGS89 system is given in table (A-13) (A-14) and (A-15).

Table (A-13):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397438.186	2805940.659	3658051.309	24	4427018.57	2787057.61	3636901.77
2	4395084.459	2798589.732	3666470.558	25	4425161.11	2784456.75	3641360.02
3	4396208.254	2796360.925	3666941.137	26	4422922.53	2784363.3	3644243.14
4	4397959.145	2793146.182	3667597.458	27	4422994.04	2788420.3	3640795.12
5	4399336.237	2797089.227	3662855.715	28	4419128.59	2787007.53	3646932.81
6	4405237.654	2797288.818	3655782.017	29	4415014.84	2793652.42	3646717.87
7	4391634.844	2797221.28	3671932.422	30	4413918.31	2799549.49	3643156.25
8	4400150.825	2805091.09	3655666.104	31	4419360.96	2762965.11	3665478.43
9	4399144.798	2799329.656	3661275.622	32	4427188.21	2772481.6	3648375.02
10	4409551.844	2793395.77	3653612.528	33	4394334.92	2796514.56	3668994.76
11	4399848.413	2783242.782	3672793.228	34	4397990.54	2794107.63	3666799.45
12	4409112.864	2783256.708	3662273.066	35	4399468.32	2796669.15	3662962.21
13	4408391.755	2785929.674	3660908.997	36	4400449.5	2799146.69	3659938.85
14	4410548.87	2779136.054	3663546.99	37	4405554.89	2796476.2	3655982.15
15	4413226.84	2784790.034	3655671.977	38	4399366.19	2785781.48	3671716.71
16	4414154.735	2782468.059	3656658.372	39	4410727.72	2782568.61	3660726.03
17	4420088.735	2793802.24	3640079.344	40	4407609.6	2785332.41	3662388.82
18	4418142.438	2795879.433	3640842.62	41	4418824.2	2793922.49	3641606.79
19	4415253.142	2791321.78	3648196.378	42	4415394.42	2782918.25	3654677.95
20	4420288.937	2783500.224	3648236.168	43	4427450.54	2781897.23	3640454.18
21	4426565.706	2779799.867	3643166.91	44	4423533.61	2783734.2	3643913.35
22	4428038.625	2783927.972	3638147.768	45	4423926.21	2784957.59	3642475.83
23	4428486.09	2786612.807	3635390.322	46	4418763.07	2787954.02	3646531.61

Table (A-14):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4430200.1	2762477.307	3652754.867	10	4446341.746	2731211.13	3656749
2	4425922.681	2758358.016	3661151.47	11	4410548.871	2779136.055	3663547
3	4430438.801	2760154.35	3654202.401	12	4426565.706	2779799.867	3643167
4	4425384.149	2761703.361	3659062.978	13	4420288.937	2783500.224	3648236
5	4431958.756	2754814.818	3656483.785	14	4429131.897	2758053.456	3657567
6	4419360.961	2762965.11	3665478.429	15	4431316.556	2757027.706	3655666
7	4427188.21	2772481.601	3648375.023	16	4427673.121	2765265.692	3653545
8	4434700.956	2764841.184	3644930.093	17	4434205.93	2765545.505	3645044
9	4449383.385	2742848.966	3643994.021				

Table (A-15):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4457967.665	2723138.777	3648607.903	12	4409308.61	2694267.974	3727557.117
2	4459189.176	2727142.182	3644117.135	13	4460987.127	2720807.766	3646671.464
3	4457590.726	2738767.017	3636927.633	14	4446341.746	2731211.13	3656748.63
4	4449013.519	2742265.925	3644962.907	15	4419373.605	2762973.015	3665488.986
5	4449383.385	2742848.966	3643994.021	16	4434700.956	2764841.184	3644930.093
6	4454357.67	2729621.396	3648384.703	17	4458982.118	2726042.401	3645249.694
7	4459130.186	2728270.599	3643527.485	18	4458527.75	2727415.699	3644717.871
8	4468704.317	2728922.902	3630962.241	19	4449474.934	2729525.814	3654418.38
9	4454320.939	2735773.769	3643828.437	20	4455505.754	2737821.887	3640359.18
10	4456800.303	2731650.581	3643605.585	21	4450598.613	2739946.997	3645139.38
11	4458795.531	2735116.683	3638295.389	22	4454814.506	2739293.837	3640299.784

A preprocessing step was made by calculating the geocentric coordinated differenced. The point with extremely difference from other pointe is excluded as shown in table (A-16) (A-17) and (A-18).

$$\Delta X = X\_(Palestine\_1923) - X\_WGS84 \quad \text{(A.1)}$$
$$\Delta Y = Y\_(Palestine\_1923) - Y\_WGS84 \quad \text{(A.2)}$$
$$\Delta Z = Z\_(Palestine\_1923) - Z\_WGS84 \quad \text{(A.3)}$$

Table (A-16):- results of the pre-processing check in the north of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	237.0100247	122.59324	-330.36314	24	236.928664	116.746807	-325.606006
2	238.0761461	123.482472	-329.273276	25	237.044308	117.039493	-325.689548
3	237.7390148	123.094664	-328.943744	26	237.09285	117.43974	-325.941236
4	237.7559278	122.091848	-328.695741	27	236.956199	117.47219	-326.155382
5	236.534768	122.181735	-329.565219	28	237.157053	118.194952	-326.481243
6	236.8195683	120.977557	-328.537311	29	237.094202	119.065544	-327.277484
7	236.7830231	123.19637	-330.113152	30	238.503925	120.333136	-326.402485
8	237.4039403	122.967551	-328.764332	31	180.843532	112.934932	-255.35505
9	237.3616922	122.52871	-328.841043	32	179.962209	113.282378	-254.134356
10	187.3148344	88.772562	-369.278097	33	237.052134	122.314458	-329.642509
11	237.1120354	121.097092	-328.480635	34	236.96393	122.042489	-329.377172
12	236.9440609	119.56723	-327.519938	35	236.766058	122.225292	-329.509434
13	236.7572939	119.851037	-327.861214	36	167.599324	77.9989405	-387.110766
14	237.3030659	119.338526	-327.61053	37	237.600639	121.588326	-327.766837
15	236.8058894	118.835624	-327.210069	38	237.200632	121.479244	-328.980086
16	236.9421199	118.92825	-326.757821	39	236.823157	119.23017	-327.332082
17	238.0262021	118.813265	-325.812424	40	236.881153	119.80601	-327.672104

18	570.8625543	329.829424	-50.0084717	41	238.206939	119.148995	-325.834603
19	237.0251089	119.147477	-326.809296	42	237.205591	118.691228	-326.815925
20	237.1899094	117.898437	-326.196096	43	237.051933	116.570354	-325.306813
21	236.9851368	116.593624	-325.41724	44	237.06509	117.291775	-325.863171
22	236.9838525	116.506511	-325.338195	45	236.90461	117.17344	-325.981961
23	236.9543553	116.504809	-325.366393	46	237.04289	118.216314	-326.642025

Table (A-17):- results of the pre-processing check in the Middle of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	180.5283729	112.8316643	-255.0504403	10	238.1426	111.8792	-320.394
2	2896.625488	1805.164337	-4786.955836	11	237.3017	119.3374	-327.612
3	180.3143588	112.4526326	-255.7135351	12	236.8812	116.6455	-325.331
4	180.6780603	112.7286885	-255.0966877	13	237.4226	117.6177	-326.263
5	180.9638059	112.3478296	-255.0964138	14	180.7365	112.5967	-255.028
6	180.8456019	112.9361193	-255.3532264	15	180.7307	112.4681	-254.891
7	179.9625588	113.282059	-254.1345375	16	180.4646	112.7945	-254.98
8	180.3087899	112.7835137	-254.760093	17	180.3557	112.7713	-254.764
9	237.0059345	111.2503277	-321.9531325				

Table (A-18):- results of the pre-processing check in the South of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	237.9427612	109.5741308	-319.0034024	12	55206	33696.77	-90665.5
2	237.8784057	109.7065183	-318.9962653	13	238.6488	109.3897	-319.211
3	454.9584056	222.4531749	-147.4892826	14	238.1428	111.8789	-320.394
4	239.1398384	109.8015528	-321.056348	15	12766.12	-8045.85	-9260.3
5	237.0059632	111.2502811	-321.9531325	16	180.3086	112.7835	-254.76
6	2802.282726	2214.062646	-4998.592653	17	-619.524	1514.649	-321.221
7	-4590.195568	7602.483335	-34.78016644	18	237.9121	109.8809	-319.166
8	238.3782658	108.6480399	-317.7047962	19	237.8118	111.1917	-320.28
9	266.5419659	-6046.651358	4229.720901	20	237.9856	110.8094	-320.084
10	2472.41243	-3328.541956	-475.8490561	21	237.7415	111.3325	-320.549
11	-3856.307641	4218.659832	1591.300776	22	4332.074	-3997.5	-2230.58

A.1.1 Helmert

The results of final iteration for Helmert transformation for triangulation points in the west bank. Are given in the following protocols.

Calculation Protocol

Table (A-19):- results of the Helmert Transformation in the North of the West Bank case1.

Helmert Transformation: North of the West Bank	Fourth Iteration
Coordinates from Palestine 1923 Grid.	

ID	X	Y	Z
13	4408628.512	2786049.525	3660581.136
15	4413463.646	2784908.870	3655344.767
16	4414391.677	2782586.987	3656331.614
20	4420526.127	2783618.122	3647909.972
25	4425398.159	2784573.791	3641034.325
26	4423159.624	2784480.741	3643917.194
27	4423230.992	2788537.769	3640468.967
28	4419365.747	2787125.729	3646606.332

1st
2nd
3rd
4th : North

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
13	4408391.755	2785929.674	3660908.997	0.1025	-0.2981	0.1568
15	4413226.840	2784790.034	3655671.977	0.0791	0.1361	0.1306
16	4414154.735	2782468.059	3656658.372	-0.2102	0.2303	-0.0879
20	4420288.937	2783500.224	3648236.168	-0.2707	0.2277	-0.0181
25	4425161.114	2784456.751	3641360.015	0.0369	0.2415	-0.0278
26	4422922.532	2784363.301	3644243.136	-0.0629	0.1856	-0.0256
27	4422994.035	2788420.297	3640795.122	0.3536	-0.3849	-0.0460
28	4419128.589	2787007.534	3646932.814	-0.0283	-0.3382	-0.0820

Standard deviation: 0.2292.

Transformation parameters:

scale: 0.999952241 ± 0.0000089257 .
rotation about X: 0°00'20.49755" ± 5.40394" t-value: 3.793.
rotation about Y: 0°00'11.15815" ± 1.93173" t-value: 5.776
rotation about Z: 0°00'04.91644" ± 6.88821" t-value: 0.714
X translation: 579.031 ± 113.374 t-value: 5.107
Y translation: -6.108 ± 238.881 t-value: 0.026
Z translation: -114.491 ± 82.311 t-value: 1.391

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	--> X	Y	Z
13	4408391.76	2785929.67	3660909	4408628.61	2786049.23	3660581.29
15	4413226.84	2784790.03	3655671.98	4413463.73	2784909.01	3655344.9
16	4414154.74	2782468.06	3656658.37	4414391.47	2782587.22	3656331.53
20	4420288.94	2783500.22	3648236.17	4420525.86	2783618.35	3647909.95
25	4425161.11	2784456.75	3641360.02	4425398.2	2784574.03	3641034.3
26	4422922.53	2784363.3	3644243.14	4423159.56	2784480.93	3643917.17
27	4422994.04	2788420.3	3640795.12	4423231.35	2788537.38	3640468.92
28	4419128.59	2787007.53	3646932.81	4419365.72	2787125.39	3646606.25
33	4394334.92	2796514.57	3668994.76	4394572.27	2796634.75	3668664.86
34	4397990.54	2794107.63	3666799.45	4398227.78	2794227.63	3666470.09
35	4399468.32	2796669.15	3662962.21	4399705.76	2796788.61	3662632.86
37	4405554.89	2796476.2	3655982.15	4405792.4	2796594.82	3655653.48
38	4399366.19	2785781.48	3671716.71	4399602.89	2785902.33	3671388.02
39	4410727.72	2782568.62	3660726.03	4410964.39	2782688.25	3660398.79
40	4407609.6	2785332.41	3662388.82	4407846.41	2785452.16	3662061.06
41	4418824.2	2793922.49	3641606.79	4419061.8	2794039.49	3641279.78
42	4415394.42	2782918.25	3654677.95	4415631.21	2783037.16	3654351.22
43	4427450.54	2781897.23	3640454.18	4427687.5	2782014.49	3640128.88
44	4423533.61	2783734.2	3643913.35	4423770.62	2783851.81	3643587.5
45	4423926.21	2784957.59	3642475.84	4424163.3	2785074.99	3642149.95
46	4418763.07	2787954.02	3646531.61	4419000.26	2788071.8	3646204.95

Table (A-20):- results of the Helmert Transformation in the Middle of the West Bank case1.

Helmert Transformation: Middle of the West Bank	Fourth Iteration
Coordinates from Palestine 1923 Grid. ID X Y Z ========== 1 4430380.629 2762590.139 3652499.817 3 4430619.115 2760266.802 3653946.688 4 4425564.827 2761816.090 3658807.881 5 4432139.720 2754927.166 3656228.688 6 4419541.807 2763078.046 3665223.076 8 4434881.264 2764953.968 3644675.333	1st 2nd 3rd 4th : Middle

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4430200.100	2762477.307	3652754.867	0.0433	-0.1671	-0.1002
3	4430438.801	2760154.350	3654202.401	0.2505	0.2336	0.5313
4	4425384.149	2761703.361	3659062.978	0.0072	-0.0484	-0.0960
5	4431958.756	2754814.818	3656483.785	-0.4367	0.3862	-0.1536
6	4419360.961	2762965.110	3665478.429	-0.0155	-0.2582	0.1372
8	4434700.956	2764841.184	3644930.093	0.1513	-0.1461	-0.3186

Standard deviation: 0.3084.

Transformation parameters.

==========

Scale: 0.999987033 ± 0.0000146285

Rotation about X: -0°00'00.94907" ± 5.12349" t-value: 0.185

Rotation about Y: -0°00'01.85306" ± 3.26090" t-value: 0.568

Rotation about Z: 0°00'01.48892" ± 6.08268" t-value: 0.245

X translation: 185.264 ± 122.363 t-value: 1.514

Y translation: 197.273 ± 208.031 t-value: 0.948

Z translation: -180.695 ± 110.679 t-value: 1.633

Transformed Coordinates

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	X	Y	Z
1	4430200.10	2762477.31	3652754.87	4430380.67	2762589.97	3652499.72
3	4430438.80	2760154.35	3654202.40	4430619.37	2760267.04	3653947.22
4	4425384.15	2761703.36	3659062.98	4425564.83	2761816.04	3658807.79
5	4431958.76	2754814.82	3656483.79	4432139.28	2754927.55	3656228.54
6	4419360.96	2762965.11	3665478.43	4419541.79	2763077.79	3665223.21
8	4434700.96	2764841.18	3644930.09	4434881.42	2764953.82	3644675.01
14	4429131.90	2758053.46	3657567.41	4429312.49	2758166.16	3657312.19
15	4431316.56	2757027.71	3655666.18	4431497.10	2757140.42	3655410.96
16	4427673.12	2765265.69	3653545.44	4427853.75	2765378.34	3653290.32
17	4434205.93	2765545.51	3645043.63	4434386.40	2765658.14	3644788.56

Table (A-21):- results of the Helmert Transformation in the South of the West Bank case1.

Helmert Transformation: South of the West Bank	Fourth Iteration
Coordinates from Palestine 1923 Grid. ID X Y Z ========== 1 4458205.608 2723248.351 3648288.900 2 4459427.054 2727251.889 3643798.139 4 4449252.659 2742375.727 3644641.850 8 4468942.695 2729031.550 3630644.537 13 4461225.776 2720917.155 3646352.253 14 4446579.889 2731323.009 3656428.236	1st 2nd 3rd 4th : South

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4457967.665	2723138.777	3648607.903	-0.0448	0.6240	-0.0163
2	4459189.176	2727142.182	3644117.135	0.3994	-0.0071	-0.1193
4	4449013.519	2742265.925	3644962.907	0.0658	-0.0290	0.2778
8	4468704.317	2728922.902	3630962.241	0.3945	-0.3835	-0.6537
13	4460987.127	2720807.766	3646671.464	-0.8410	0.6009	0.5766
14	4446341.746	2731211.130	3656748.630	0.0261	-0.8053	-0.0651

Standard deviation: 0.5585.

Transformation parameters:

==========

Scale: 0.999970744 ± 0.0000179089

Rotation about X: 0°00'15.02431" ± 5.32760" t-value: 2.820

Rotation about Y: 0°00'10.88049" ± 4.58908" t-value: 2.371

Rotation about Z: 0°00'09.20351" ± 5.20434" t-value: 1.768

X translation: 439.276 ± 127.704 t-value: 3.440

Y translation: 123.017 ± 183.425 t-value: 0.671

Z translation: -249.081 ± 151.911 t-value: 1.640

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4457967.665	2723138.777	3648607.903		4458205.563	2723248.975	3648288.883
2	4459189.176	2727142.182	3644117.135		4459427.454	2727251.881	3643798.02
4	4449013.519	2742265.925	3644962.907		4449252.725	2742375.698	3644642.128
8	4468704.317	2728922.902	3630962.241		4468943.09	2729031.167	3630643.883
13	4460987.127	2720807.766	3646671.464		4461224.935	2720917.756	3646352.83
14	4446341.746	2731211.13	3656748.63		4446579.915	2731322.204	3656428.17
18	4458527.75	2727415.699	3644717.871		4458766.028	2727525.464	3644398.684
19	4449474.934	2729525.814	3654418.38		4449713.059	2729636.627	3654098.278
20	4455505.754	2737821.887	3640359.18		4455744.814	2737931.165	3640039.202

A.1.2Three Dimensional Transformations

The results of final iteration for three dimensional transformations for triangulation points in the west bank are given in the following.

Table (A-25):- results of the Three Dimensional Transformations in the North of the West Bank case1.

Three Dimensional Transformations: North of the West Bank	First Iteration

.Coordinates of MEASURED POINTS in palestine_1923

NAME	X	Y	Z	SxSySz		
1	4397438.186	2805940.659	3658051.309	0.020	0.020	0.020
4	4397959.145	2793146.182	3667597.458	0.020	0.020	0.020
5	4399336.237	2797089.227	3662855.715	0.020	0.020	0.020
6	4405237.654	2797288.818	3655782.017	0.020	0.020	0.020
8	4400150.825	2805091.090	3655666.104	0.020	0.020	0.020
9	4399144.798	2799329.656	3661275.622	0.020	0.020	0.020
11	4399848.413	2783242.782	3672793.228	0.020	0.020	0.020
12	4409112.864	2783256.708	3662273.066	0.020	0.020	0.020
13	4408391.755	2785929.674	3660908.997	0.020	0.020	0.020
14	4410548.870	2779136.054	3663546.990	0.020	0.020	0.020
19	4415253.142	2791321.780	3648196.378	0.020	0.020	0.020
29	4415014.844	2793652.418	3646717.867	0.020	0.020	0.020
30	4413918.309	2799549.490	3643156.252	0.020	0.020	0.020

1st: North
2nd
3rd
4th

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z
1	4397675.196	2806063.252	3657720.946
4	4398196.901	2793268.274	3667268.762
5	4399572.772	2797211.409	3662526.150
6	4405474.474	2797409.796	3655453.479
8	4400388.229	2805214.057	3655337.340
9	4399382.160	2799452.185	3660946.781
11	4400085.525	2783363.879	3672464.748
12	4409349.808	2783376.275	3661945.546
13	4408628.512	2786049.525	3660581.136
14	4410786.173	2779255.393	3663219.380
19	4415490.167	2791440.928	3647869.568
29	4415251.938	2793771.484	3646390.589
30	4414156.813	2799669.824	3642829.850

Transformation Coefficients.

Scale = 0.3572844596 +/- 78.1126810102

X-rot = 29°04'20.0" +/- 108°26'10.8"

Y-rot = -226°06'25.4" +/- 197°06'58.9"

Z-rot = 168°52'14.4" +/- 84°52'48.7"

Tx = 1216974.133 +/- 617993256.6606

Ty = 4553193.485 +/- 730980940.6189

Tz = -1992563.777 +/- 580872072.6605

Standard Deviation of Unit Weight >> 186686798.291

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Vx	Y	Vy	Z	Vz
1	4397675.20	-1035886.81	2806063.25	985186.69	3657720.95	-5680029.00
4	4398196.90	-1034435.75	2793268.27	1003327.31	3667268.76	-5689887.50
5	4399572.77	-1036509.25	2797211.41	997424.00	3662526.15	-5684268.50
6	4405474.47	-1042788.38	2797409.80	995939.50	3655453.48	-5674189.00
8	4400388.23	-1038595.25	2805214.06	985860.13	3655337.34	-5676331.50
9	4399382.16	-1036664.88	2799452.19	994264.44	3660946.78	-5682680.00
11	4400085.53	-1035001.00	2783363.88	1017012.56	3672464.75	-5694471.00
12	4409349.81	-1044721.50	2783376.28	1015150.44	3661945.55	-5679320.00
13	4408628.51	-1044398.88	2786049.53	1011474.56	3660581.14	-5678183.00
14	4410786.17	-1045677.88	2779255.39	1020697.00	3663219.38	-5679981.50
19	4415490.17	-1052608.13	2791440.93	1002341.94	3647869.57	-5661658.50
29	4415251.94	-1052697.13	2793771.48	999077.94	3646390.59	-5660215.50
30	4414156.81	-1052503.50	2799669.82	990870.19	3642829.85	-5656911.00

WGS84 coordinates transformed to Palestine _1923 coordinates.

NAME	X	Y	Z	Sx	Sy	Sz
1	3361788.389	3791249.934	-2022308.094	5.2822E+11	1.39674E+12	2.27774E+12
4	3363761.121	3796595.571	-2022618.647	5.24712E+11	1.39748E+12	2.26819E+12
5	3363063.492	3794635.431	-2021742.246	5.2571E+11	1.39869E+12	2.2717E+12
6	3362686.103	3793349.308	-2018735.318	5.25448E+11	1.40423E+12	2.27404E+12
8	3361792.955	3791074.174	-2020994.025	5.27843E+11	1.39927E+12	2.27808E+12
9	3362717.256	3793716.64	-2021733.167	5.2633E+11	1.39848E+12	2.27334E+12
11	3365084.555	3800376.447	-2022006.261	5.21917E+11	1.39955E+12	2.2614E+12
12	3364628.311	3798526.738	-2017374.351	5.21423E+11	1.40817E+12	2.2648E+12
13	3364229.64	3797524.068	-2017601.634	5.22189E+11	1.40746E+12	2.26658E+12
14	3365108.309	3799952.417	-2016762.025	5.20226E+11	1.40967E+12	2.26223E+12
19	3362881.983	3793782.872	-2013788.711	5.23287E+11	1.41389E+12	2.27328E+12
29	3362554.827	3792849.416	-2013824.989	5.23934E+11	1.4136E+12	2.27495E+12
30	3361653.259	3790539.981	-2014081.138	5.25597E+11	1.4125E+12	2.27906E+12
33	3363401.072	3795876.795	-2024270.317	5.25823E+11	1.39405E+12	2.26944E+12
34	3363609.259	3796179.754	-2022559.907	5.24972E+11	1.39749E+12	2.26893E+12
35	3363102.93	3794778.851	-2021678.401	5.25589E+11	1.39884E+12	2.27144E+12
37	3362775.88	3793622.185	-2018594.844	5.2521E+11	1.40456E+12	2.27355E+12
38	3364811.563	3799437.844	-2022218.009	5.22633E+11	1.39896E+12	2.26311E+12
39	3364589.584	3798467.078	-2016541.418	5.2115E+11	1.40975E+12	2.2649E+12
40	3364391.992	3797948.479	-2018045.13	5.22069E+11	1.40672E+12	2.26582E+12
41	3362177.65	3791906.941	-2011783.949	5.23803E+11	1.41728E+12	2.27663E+12

Table (A-26): results of the Three Dimensional Transformations in the Middle of the West Bank case1.

Three Dimensional Transformations: Middle of the West Bank

First Iteration

1st: Middle
2nd
3rd
4th

Coordinates of MEASURED POINTS in palestine_1923.

NAME	X	Y	Z	SxSySz		
1	4430200.100	2762477.307	3652754.867	0.020	0.020	0.020
3	4430438.801	2760154.350	3654202.401	0.020	0.020	0.020
4	4425384.149	2761703.361	3659062.978	0.020	0.020	0.020
5	4431958.756	2754814.818	3656483.785	0.020	0.020	0.020
6	4419360.961	2762965.110	3665478.429	0.020	0.020	0.020
8	4434700.956	2764841.184	3644930.093	0.020	0.020	0.020

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z
1	4430380.629	2762590.139	3652499.817
3	4430619.115	2760266.802	3653946.688
4	4425564.827	2761816.090	3658807.881
5	4432139.720	2754927.166	3656228.688
6	4419541.807	2763078.046	3665223.076
8	4434881.264	2764953.968	3644675.333

Transformation Coefficients

Scale = 0.9999870326 +/- 0.0000146285
X-rot = 0°00'00.9" +/- 0°00'05.1"
Y-rot = 0°00'01.9" +/- 0°00'03.3"
Z-rot = 359°59'58.5" +/- 0°00'06.1"
Tx =185.266 +/- 122.3622
Ty =197.268 +/- 208.0312
Tz =-180.693 +/- 110.6782
Standard Deviation of Unit Weight >> 15.419
Degrees of Freedom: 11

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Vx	Y	Vy	Z	Vz
1	4430380.629	0.043	2762590.139	-0.167	3652499.817	-0.100
3	4430619.115	0.250	2760266.802	0.234	3653946.688	0.531
4	4425564.827	0.007	2761816.090	-0.048	3658807.881	-0.096
5	4432139.720	-0.437	2754927.166	0.386	3656228.688	-0.154
6	4419541.807	-0.016	2763078.046	-0.258	3665223.076	0.137
8	4434881.264	0.151	2764953.968	-0.146	3644675.333	-0.319

WGS84 coordinates transformed to Palestine _1923 coordinates.

NAME	X	Y	Z	SxSySz		
1	4430380.672	2762589.972	3652499.717	0.139	0.137	0.138
3	4430619.366	2760267.036	3653947.219	0.134	0.132	0.133
4	4425564.834	2761816.042	3658807.785	0.148	0.146	0.147

5	4432139.283	2754927.552	3656228.535	0.230	0.194	0.210
6	4419541.791	2763077.788	3665223.213	0.252	0.244	0.247
8	4434881.416	2764953.822	3644675.014	0.245	0.234	0.238
14	4429312.494	2758166.164	3657312.185	0.158	0.147	0.151
15	4431497.100	2757140.420	3655410.959	0.179	0.161	0.168
16	4427853.753	2765378.335	3653290.315	0.176	0.157	0.165
17	4434386.403	2765658.136	3644788.561	0.250	0.236	0.241

Table (A-27): results of the Three Dimensional Transformations in the South of the West Bank case1.

Three Dimensional Transformations: South of the West Bank	First Iteration
Coordinates of MEASURED POINTS in palestine_1923.	1st: South 2nd 3rd 4th

NAME	X	Y	Z	SxSySz		
1	4457967.665	2723138.777	3648607.903	0.020	0.020	0.020
2	4459189.176	2727142.182	3644117.135	0.020	0.020	0.020
8	4468704.317	2728922.902	3630962.241	0.020	0.020	0.020
13	4460987.127	2720807.766	3646671.464	0.020	0.020	0.020

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z
1	4458205.608	2723248.351	3648288.900
2	4459427.054	2727251.889	3643798.139
8	4468942.695	2729031.550	3630644.537
13	4461225.776	2720917.155	3646352.253

Transformation Coefficients.

Scale = -0.4983198348 +/- 328.9914736741

X-rot = 125°37'33.4" +/- 98°24'48.0"

Y-rot = 15°39'46.6" +/- 81°41'05.9"

Z-rot = 82°00'40.8" +/- 254°07'08.5"

Tx = -23904.112 +/- 3550331057.1794

Ty = 2732220.738 +/- 6293877170.4360

Tz = 449932.483 +/- 4700687229.3925

Standard Deviation of Unit Weight >> 285498494.748

Degrees of Freedom: 5

Coordinates of CONTROL POINTS in WGS84.

NAME	X	Y	Z	Sx	Sy	Sz
1	481881.936	5773664.56	-309029.118	16069441635	10651154340	34268241917
2	484306.902	5772840.71	-310702.193	16080287810	10656080213	34283184398
8	486288.323	5770565.341	-318261.244	16135781838	10712174373	34281811349
13	480833.506	5773384.912	-310864.067	16084115769	10670537256	34256391262
18	484400.153	5772935.584	-310255.949	16076838739	10651976382	34284831876
20	490132.663	5771959.615	-310007.274	16070360587	10628276600	34328392903

WGS84 coordinates transformed to Palestine _1923 coordinates.						
NAME	X	Y	Z	Sx	Sy	Sz
1	481881.936	5773664.56	-309029.118	16069441635	10651154340	34268241917
2	484306.902	5772840.71	-310702.193	16080287810	10656080213	34283184398
8	486288.323	5770565.341	-318261.244	16135781838	10712174373	34281811349
13	480833.506	5773384.912	-310864.067	16084115769	10670537256	34256391262
18	484400.153	5772935.584	-310255.949	16076838739	10651976382	34284831876
20	490132.663	5771959.615	-310007.274	16070360587	10628276600	34328392903

A-2 Solution without Including the Height (Case 2).

In the Second case, the height where notused in calculating (X, Y, Z) coordinates.

For the triangulation point, becausethe orthometrice heights which cover not precisely measured. Table (A-28) (A-29) and (A-30) show the registered coordinates of the control points for the different parts of the West Bank in Pal_1923Grid system.

Table (A-28):-registered coordinates in the north of the west bank in (E, N).

#	E	N	#	E	N
1	171066.1	216350.7	24	149095.6	177710.4
2	179794.3	210343.1	25	153639	176230.2
3	180244.8	207314.9	26	156596.3	177579.2
4	180824.6	202860.8	27	153118.7	181710
5	175936.3	206014.3	28	159351.5	182755.4
6	168551.6	202361.6	29	159177.2	192259.4
7	185353.7	211202.8	30	155625.3	199034.1
8	168522.9	213702.4	31	178483.6	157845
9	174332.5	208442.2	32	160852.7	162614.2
10	166284.9	195546.7	33	182397.2	208701.4
11	186254.2	191429.7	34	180005.9	203829.5
12	175126	185396.5	35	176065.9	205495.9
13	173777.8	188618.9	36	172917.6	207400.2
14	176494.6	180216.2	37	168772.1	201319.4
15	168441.6	184299.9	38	185037.6	194360.4
16	169348.4	181306	39	173564.5	183636.7
17	152430.3	189125.8	40	175284.3	188513.4
18	153226.9	192521.9	41	153983.2	190067.9
19	160711.5	189707.7	42	167342	180964.9
20	160687.5	178393	43	152720.8	172117.8
21	155518	170527.1	44	156276.6	176536.6
22	150347.4	173830.6	45	154797.4	177543
23	147550.3	176307.1	46	158978.3	183966.5

Table (A-29):-registered coordinates in the Middle of the west bank in (E, N).

#	E	N	#	E	N
1	165240.6	150347.93	10	169288.7	107612.6
2	169213.18	148845.37	11	176494.6	180216.2
3	166751.52	147794.39	12	155518.1	170527.2
4	171841.27	152650.15	13	160687.4	178392.5
5	169092.08	141297.74	14	170186.4	146464
6	178483.62	157845	15	168216.6	143998.5
7	160852.72	162614.21	16	166120.9	154854.1
8	157300.27	149898.38	17	157404	150943.1
9	156096.76	117739.33			

Table (A-30):-registered coordinates in the South of the west bank in (E, N).

#	E	N	#	E	N
1	160773.39	91851.11	12	148918.7	92762.38
2	156086.7	95234.67	13	158738.9	87520.78
3	148752.64	108279.93	14	169288.7	107612.62
4	157079.28	117367.82	15	169092.1	141297.74
5	156096.76	117739.33	16	157300.3	149898.38
6	155580.17	101424.37	17	157249.2	96224.6
7	155722.87	107271.25	18	156716.2	95937
8	142397.9	91081.11	19	166776.3	103869.46
9	160474.73	100867.46	20	152271.8	108643.28
10	155409.64	96442.86	21	157133.5	113959.94
11	152144.28	110606.8	22	150135.3	103756.06

The projected coordinates (E, N) were converted to Geographic coordinates (, ϕ, h) with the assumption that (h = 0), the covered coordinates are shown in tables (A-31) (A-32) and (A-33).

Table (A-31):- Triangulation points coordinates that are transformed to (lat, long) in the north of the West bank.

#	Lat	Long	#	Lat	Long
1	32.54108369	35.22073197	24	32.19242639	34.98771144
2	32.48686787	35.31358507	25	32.17915335	35.03591768
3	32.45955562	35.31834625	26	32.19135893	35.06725394
4	32.41938357	35.3244632	27	32.2285637	35.0303025
5	32.44785793	35.27251384	28	32.23806957	35.09641292
6	32.41493102	35.1939892	29	32.32377583	35.09445223
7	32.49455877	35.37274534	30	32.38482875	35.05662736

8	32.51720103	35.19366353	31	32.01344108	35.29918782
9	32.46975875	35.25546949	32	32.05644304	35.11253782
10	32.35346838	35.1699217	33	32.47203746	35.34125589
11	32.31623419	35.38199234	34	32.42812678	35.31576884
12	32.26192965	35.2637912	35	32.4431822	35.27388961
13	32.29099477	35.24949552	36	32.46036687	35.24041593
14	32.21520608	35.27828217	37	32.405533	35.19633517
15	32.25204918	35.19285405	38	32.34267955	35.369118
16	32.22505076	35.20247916	39	32.24606506	35.2472139
17	32.29542929	35.02286068	40	32.29003706	35.26548744
18	32.32606825	35.0312574	41	32.3039493	35.03933084
19	32.30077798	35.11077184	42	32.22197106	35.18119648
20	32.19874013	35.11063051	43	32.14205278	35.02625718
21	32.12774766	35.05592778	44	32.18195303	35.06387926
22	32.1574602	35.00106644	45	32.19100928	35.04817867
23	32.1797411	34.97135693	46	32.24898734	35.09243859

Table (A-32):- Triangulation points coordinates that are transformed to (lat, long) in the Middle of the West bank.

#	Lat	Long	#	Lat	Long
1	31.94584703	35.15906402	10	31.56043	35.20192
2	31.93230657	35.20108017	11	32.21521	35.27828
3	31.92282323	35.17505294	12	32.12775	35.05593
4	31.96661981	35.22887738	13	32.19874	35.11063
5	31.86423668	35.19980861	14	31.91083	35.21137
6	32.01344108	35.29918782	15	31.88859	35.19055
7	32.05644304	35.11253782	16	31.98649	35.16836
8	31.9417299	35.07509211	17	31.95115	35.07617
9	31.65167912	35.06283094			

Table (A-33):- Triangulation points coordinates that are transformed to(lat,long)in the South of the West bank.

#	Lat	Long	#	Lat	Long
1	31.41823608	35.11238351	12	31.4262975	34.98769444
2	31.44870572	35.06304776	13	31.3791607	35.09103741
3	31.56625038	34.98561093	14	31.56043198	35.20191937
4	31.64834015	35.07319432	15	31.86423668	35.19980861
5	31.65167912	35.06283094	16	31.9417299	35.07509211
6	31.50452599	35.05762748	17	31.45764785	35.07526362
7	31.55726193	35.0590436	18	31.45504779	35.06966023
8	31.41099524	34.91916	19	31.52666682	35.1754706
9	31.49955488	35.10915377	20	31.56958777	35.02267158
10	31.45959427	35.05590709	21	31.61760493	35.07381107
11	31.58729497	35.02129251	22	31.52547393	35.00026649

Finally the geographic coordinates (, ϕ) are transformed to geocentric coordinates (X, Y, Z) as shown in table (A-34) (A-35) and (A-36).

Table (A-34):-coordinates that are transformed to (X, Y, Z)in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397600.432	2806015.547	3657658.336	12	4408888.561	2783085.116	3661559.859
2	4395236.517	2798658.443	3666069.046	13	4408250.097	2785810.385	3660264.778
3	4396312.456	2796399.079	3666500.061	14	4410371.226	2778993.933	3662872.4
4	4397940.817	2793105.636	3667053.774	15	4413207.632	2784747.324	3655131.277
5	4399362.558	2797077.756	3662349.953	16	4413998.667	2782339.255	3656003.864
6	4405211.99	2797243.122	3655234.191	17	4420266.218	2793882.786	3639703.338
7	4391658.446	2797208.694	3671422.869	18	4418319.763	2795960.228	3640466.136
8	4400229.599	2805112.932	3655204.666	19	4415269.213	2791301.242	3647685.776
9	4399214.136	2799345.266	3660806.002	20	4420240.858	2783438.488	3647672.95
10	4409509.731	2793339.204	3653051.878	21	4426640.203	2779814.423	3642706.865
11	4399841.1	2783209.262	3672259.344	22	4428155.499	2783968.966	3637723.084
#	X	Y	Z	#	X	Y	Z
23	4428672.033	2786697.214	3635022.8	35	4399516.42	2796671.445	3662474.562
24	4427174.735	2787123.515	3636509.373	36	4400486.182	2799141.413	3659442.119
25	4425223.29	2784463.759	3640889.465	37	4405544.105	2796440.124	3655446.877
26	4422940.406	2784342.738	3643735.359	38	4399254.643	2785682.132	3671094.717
27	4423122.898	2788469.623	3640379.393	39	4410556.847	2782430.65	3660058.06
28	4419096.386	2786955.853	3646382.549	40	4407430.895	2785189.595	3661713.51
29	4415028.237	2793629.936	3646204.578	41	4418964.216	2793979.552	3641199.493
30	4414085.26	2799624.441	3642770.395	42	4415299.392	2782827.547	3654074.295
31	4418993.879	2762735.484	3664765.555	43	4427546.276	2781925.015	3640011.901
32	4427036.888	2772387.419	3647846.043	44	4423579.476	2783731.171	3643428.929
33	4394463.153	2796567.626	3668573.652	45	4423986.077	2784963.315	3642003.111
34	4397985.25	2794075.764	3666266.74	46	4418779.633	2787933.128	3646021.795

Table (A-35):-coordinates that are transformed to (X, Y, Z)in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4429859.39	2762265.117	3652067.153	10	4446006.028	2730970.514	3655953.117
2	4428232.865	2759797.693	3655877.041	11	4410371.226	2778993.933	3662872.4
3	4430101.886	2759944.569	3653517.205	12	4426640.099	2779814.474	3642706.951
4	4425070.66	2761507.701	3658396.534	13	4420241.091	2783438.207	3647672.883
5	4431577.563	2754577.74	3655761.769	14	4428708.264	2757789.707	3656809.931
6	4418993.879	2762735.484	3664765.555	15	4430908.784	2756774.026	3654922.528
7	4427036.888	2772387.419	3647846.043	16	4427395.358	2765092.304	3652909.801
8	4434605.36	2764781.954	3644447.036	17	4434092.012	2765474.742	3644545.338
9	4449210.035	2742707.253	3643333.737				

Table (A-36):-coordinates that are transformed to (X, Y, Z)in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4457651.122	2722909.649	3647832.038	12	4464046.715	2727678.843	3636507.828
2	4458886.497	2726921.3	3643353.424	13	4460669.663	2720577.98	3645894.605
3	4457483.592	2738644.125	3636318.46	14	4446006.028	2730970.514	3655953.117
4	4448807.54	2742101.37	3644274.73	15	4431577.563	2754577.74	3655761.769
5	4449210.035	2742707.253	3643333.737	16	4434605.36	2764781.954	3644447.036
6	4456522.19	2731444.568	3642861.218	17	4457796.64	2727210.808	3644462.608
7	4453929.342	2735498.036	3642989.817	18	4458225.102	2727194.908	3643953.848
8	4468492.524	2728756.646	3630276.304	19	4449055.99	2729234.124	3653555.079
9	4453957.774	2729341.24	3647538.93	20	4455314.651	2737669.033	3639686.158
10	4458756.348	2728006.109	3642704.986	21	4450244.366	2739693.886	3644330.727
11	4454543.156	2739091.802	3639560.869	22	4458636.74	2734983.593	3637650.39

The GNSS measured coordinates for the triangulation points in the west bank are (Lat, long) in WGS84 system, these coordinates are given in table (A-37) (A-38) and (A-39).

Table (A-37):-GNSS coordinatesin the north of the west bank in (Lat, long) in WGS84.

#	Lat	Long	#	Lat	Long
1	32.54134886	35.22157945	24	32.1927268	34.98851583
2	32.48712862	35.31442875	25	32.17945123	35.03672241
3	32.45981659	35.31918484	26	32.1916541	35.06806076
4	32.41965191	35.3252971	27	32.22885952	35.03111155
5	32.44811952	35.27335068	28	32.23836056	35.09722499
6	32.41520352	35.19481901	29	32.32406271	35.09527218
7	32.49481511	35.37358674	30	32.38511513	35.05745167
8	32.51746375	35.19450293	31	32.01344227	35.29920733
9	32.47002307	35.25630612	32	32.05643763	35.11255156
10	32.35374552	35.17074603	33	32.47230233	35.34209365
11	32.31650291	35.3828174	34	32.42839133	35.3166044
12	32.26220843	35.26460816	35	32.44344452	35.27472714
13	32.29127125	35.25031537	36	32.46063208	35.24125159
14	32.21548678	35.27910037	37	32.40580397	35.19716438
15	32.25233322	35.19366849	38	32.34294654	35.36994853
16	32.2253334	35.20329084	39	32.24634542	35.2480286
17	32.29572229	35.02367568	40	32.29031469	35.26630579
18	32.32635919	35.03207545	41	32.30424074	35.04014714
19	32.30106259	35.11158777	42	32.22225722	35.18200982
20	32.19903213	35.11143942	43	32.14235315	35.02705824
21	32.12804681	35.05672847	44	32.18224893	35.06468511

22	32.15776146	35.00186807	45	32.19130574	35.04898487
23	32.18004321	34.97215959	46	32.24927801	35.09325152

Table (A-38):-GNSS coordinatesin the Middle of the west bank in (Lat, long) in WGS84.

#	Lat	Long	#	Lat	Long
1	31.94584459	35.15908422	10	31.56075	35.20267
2	31.93230744	35.25109827	11	32.21549	35.2791
3	31.92282214	35.17507551	12	32.12805	35.05673
4	31.96662004	35.22889599	13	32.19903	35.11144
5	31.86423794	35.19982839	14	31.91083	35.21139
6	32.01344227	35.29920733	15	31.88859	35.19057
7	32.05643763	35.11255156	16	31.98649	35.16837
8	31.94172647	35.07511185	17	31.95115	35.07619
9	31.65200433	35.0635925			

Table (A-39):-GNSS coordinatesin the South of the west bank in (Lat, long) in WGS84.

#	Lat	Long	#	Lat	Long
1	31.41857089	35.11312187	12	31.42663724	35.98843389
2	31.44904025	35.06378769	13	31.37949924	35.09178074
3	31.56678291	34.98634752	14	31.56075383	35.20267178
4	31.64869103	35.07395439	15	32.01344227	35.29920733
5	31.65200433	35.0635925	16	31.94172647	35.07511185
6	31.49988316	35.10990124	17	31.43993875	35.07602761
7	31.45992864	35.05664977	18	31.45538122	35.0704018
8	31.41134005	34.91989465	19	31.5269914	35.17621978
9	31.55759091	35.0597956	20	31.56991847	35.02342403
10	31.50485825	35.05837405	21	31.61793193	35.07456543
11	31.52580713	35.00101091	22	31.58762332	35.02204462

The Transformation of the GNSS geographic coordinates to geocentric coordinates (X, Y, Z) in WGS89 system is given in table (A-40) (A-41) and (A-42).

Table (A-40):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the North of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4397348.837	2805883.647	3657976.483	24	4426923.553	2786997.795	3636823.188
2	4394984.979	2798526.388	3666387.011	25	4424972.062	2784337.793	3641203.4
3	4396061.108	2796267.327	3666817.573	26	4422689.144	2784216.377	3644049.541
4	4397689.255	2792974.775	3667370.872	27	4422871.66	2788343.147	3640693.71
5	4399111.365	2796946.254	3662667.226	28	4418845.073	2786828.729	3646697.262
6	4404960.77	2797112.999	3655550.689	29	4414776.896	2793501.854	3646520.002
7	4391407.114	2797076.229	3671740.729	30	4413833.941	2799495.979	3643086.147
8	4399978.574	2804981.28	3655522.033	31	4418798.613	2762613.533	3665008.867

9	4398962.915	2799213.918	3661123.227	32	4426842.651	2772265.197	3648088.334
10	4409258.503	2793209.942	3653367.837	33	4394211.63	2796436.102	3668891.128
11	4399589.618	2783079.074	3672575.742	34	4397733.826	2793944.533	3666583.973
12	4408637.207	2782956.449	3661875.316	35	4399265.14	2796539.992	3662791.9
13	4407998.799	2785681.342	3660580.472	36	4400234.987	2799010.237	3659759.23
14	4410119.569	2778865.548	3663187.996	37	4405292.965	2796309.94	3655763.325
15	4412956.316	2784619.33	3655446.379	38	4399003.042	2785551.531	3671411.588
16	4413747.483	2782211.347	3656318.734	39	4410305.546	2782302.283	3660373.283
17	4420014.964	2793755.611	3640018.181	40	4407179.58	2785060.665	3662029.097
18	4418068.492	2795832.639	3640781.273	41	4418712.944	2793852.142	3641514.486
19	4415018.106	2791173.191	3648000.866	42	4415047.996	2782699.909	3654389.276
20	4419989.544	2783311.693	3647987.402	43	4427295.068	2781799.549	3640325.485
21	4426388.967	2779688.879	3643020.47	44	4423328.219	2783604.947	3643743.018
22	4427904.315	2783843.531	3638036.673	45	4423734.833	2784837.114	3642317.202
23	4428420.875	2786571.771	3635336.427	46	4418528.324	2787805.91	3646336.579

Table (A-41):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the Middle of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4429664.347	2762143.235	3652310.155	10	4445754.741	2730850.556	3656262.613
2	4425322.204	2757983.781	3660651.404	11	4410119.569	2778865.548	3663187.996
3	4429906.575	2759822.774	3653760.466	12	4426388.967	2779688.878	3643020.47
4	4424875.504	2761385.937	3658639.579	13	4419989.544	2783311.693	3647987.402
5	4431382.124	2754456.395	3656004.842	14	4428513.054	2757668.098	3657052.926
6	4418798.613	2762613.533	3665008.867	15	4430713.587	2756652.557	3655165.404
7	4426842.65	2772265.198	3648088.334	16	4427200.373	2764970.441	3653152.718
8	4434410.519	2764660.11	3644689.772	17	4433897.143	2765352.919	3644788.092
9	4448958.623	2742587.119	3643643.801				

Table (A-42):- GNNS coordinates transformed to (X, Y, Z) in WGS84 in the South of the West bank.

#	X	Y	Z	#	X	Y	Z
1	4457399.906	2722791.963	3648140.091	12	4408834.18	2693978.077	3727153.338
2	4458635.393	2726803.501	3643661.526	13	4460417.972	2720460.631	3646203.068
3	4457223.637	2738541.475	3636626.109	14	4445754.741	2730850.556	3656262.613
4	4448554.947	2741983.273	3644584.679	15	4418798.613	2762613.533	3665008.867
5	4448958.623	2742587.119	3643643.801	16	4434410.52	2764660.11	3644689.771
6	4453706.55	2729222.392	3647847.804	17	4458402.813	2725688.237	3644772.917
7	4458505.141	2727888.172	3643013.323	18	4457973.958	2727076.928	3644262.111
8	4468241.492	2728640.267	3630583.647	19	4448804.742	2729114.685	3653864.233
9	4453678.081	2735378.936	3643299.006	20	4455063.399	2737550.068	3639995.319
10	4456270.961	2731326.138	3643169.912	21	4449993.161	2739574.26	3644640.159
11	4458385.768	2734865.326	3637958.777	22	4454292.075	2738972.591	3639869.996

A preprocessing step was made by calculating the geocentric coordinated differenced. The point with extremely difference from other pointe is excluded as shown in table (A-43) (A-44) and (A-45).

$$\Delta X = X\_(Palestine\_1923) - X\_WGS84 \quad (A.4)$$
$$\Delta Y = Y\_(Palestine\_1923) - Y\_WGS84 \quad (A.5)$$
$$\Delta Z = Z\_(Palestine\_1923) - Z\_WGS84 \quad (A.6)$$

Table (A-43):- results of the pre-processing check in the north of the west bank.

Pre-processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	251.5951156	131.9002585	-318.1464745	24	251.1821305	125.7207584	-313.8153105
2	251.5381316	132.0550022	-317.96486	25	251.2278483	125.9655112	-313.9347917
3	251.3482463	131.7521427	-317.5117803	26	251.2615372	126.3609336	-314.1823136
4	251.5614066	130.8613983	-317.0980562	27	251.2377843	126.476613	-314.3172616
5	251.1927778	131.5026164	-317.2728493	28	251.3127322	127.1244129	-314.7129331
6	251.2204975	130.1237774	-316.4984435	29	251.3411455	128.0820331	-315.424229
7	251.3326995	132.4650258	-317.8598031	30	251.3189536	128.461633	-315.7519359
8	251.0250637	131.6520244	-317.3670595	31	195.2652817	121.9513631	-243.3125128
9	251.2206232	131.3487218	-317.2241659	32	194.23714	122.2218645	-242.291214
10	251.2281914	129.2624269	-315.9582389	33	251.5230481	131.524322	-317.4756711
11	251.48172	130.1886284	-316.3977646	34	251.4240382	131.2307773	-317.2330098
12	251.3543635	128.6668855	-315.4570216	35	251.2801772	131.4528899	-317.3382917
13	251.2977711	129.0426005	-315.6942651	36	251.1952425	131.1755502	-317.110147
14	251.6566379	128.3857115	-315.5960561	37	251.1404478	130.1845219	-316.4480066
15	251.316006	127.9934263	-315.1025836	38	251.6014642	130.6004638	-316.8702746
16	251.183464	127.9080081	-314.8700024	39	251.3018034	128.3670137	-315.2230828
17	251.2539226	127.1745338	-314.8438923	40	251.3148933	128.9300451	-315.5863434
18	251.2710002	127.5889798	-315.1370741	41	251.2710874	127.4098594	-314.9929911
19	251.1069234	128.0515325	-315.0893461	42	251.3966129	127.6378112	-314.9814631
20	251.3144316	126.7948203	-314.4521458	43	251.2087037	125.4665017	-313.5841506
21	251.2357624	125.5439308	-313.6051578	44	251.2569791	126.2241236	-314.0884712
22	251.1844754	125.4353884	-313.588818	45	251.2434914	126.2013558	-314.0914925
23	251.157563	125.4425138	-313.6268559	46	251.3089178	127.2188201	-314.7837049

Table (A-44):- results of the pre-processing check in the Middle of the west bank.

Pre- processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	195.0426076	121.8820698	-243.0023187	10	251.2875329	119.9580295	-309.4955952
2	2910.66158	1813.912032	-4774.362845	11	251.6566265	128.3854892	-315.595875
3	195.3115252	121.795823	-243.260243	12	251.1318018	125.5957858	-313.518986
4	195.1557594	121.7636381	-243.0450662	13	251.5470903	126.5140744	-314.5193909
5	195.4384972	121.3450186	-243.0735875	14	195.2094774	121.6090812	-242.9948987
6	195.2652756	121.951252	-243.3124223	15	195.1969505	121.4685402	-242.8758044
7	194.2374901	122.221546	-242.2913956	16	194.9845877	121.8628446	-242.9175376
8	194.8407858	121.8435517	-242.7354337	17	194.8686003	121.822814	-242.753412
9	251.4117916	120.1341187	-310.0646466				

Table (A-45):- results of the pre-processing check in the South of the west bank.

Pre- processing							
#	ΔX	ΔY	ΔZ	#	ΔX	ΔY	ΔZ
1	251.2153666	117.686119	-308.0531402	12	55212.5347	33700.76517	-90645.51018
2	251.1039277	117.7992936	-308.1015339	13	251.6907003	117.3486262	-308.4632503
3	259.9550321	102.6492804	-307.6485415	14	251.2877229	119.9577935	-309.4956496
4	252.592128	118.0969851	-309.9492207	15	12778.94945	-8035.79245	-9247.098561
5	251.4118203	120.1340721	-310.0646466	16	194.8406054	121.8435036	-242.7351795
6	2815.639659	2222.176657	-4986.585777	17	-606.173413	1522.57059	-310.3085857
7	-4575.79971	7609.864107	-23.50618975	18	251.1440414	117.979598	-308.2629987
8	251.0317306	116.3789052	-307.342763	19	251.2476538	119.4390277	-309.1536715
9	279.6935341	-6037.69597	4239.924002	20	251.2521736	118.9648961	-309.1606466
10	2485.386387	-3320.02908	-464.9264211	21	251.20552	119.6260966	-309.4320594
11	-3842.61183	4226.475755	1602.091757	22	4344.665094	-3988.99833	-2219.606797

A.2.1 Helmert

The results of final iteration for Helmert transformation for triangulation points in the west bank. Are given in the following protocols.

Calculation Protocol

Table (A-46):- results of the Helmert Transformation in the North of the West Bank case2.

Helmert Transformation: North of the West Bank	Third Iteration
Coordinates from Palestine 1923 Grid. ID X Y Z ========== 10 4409509.731 2793339.204 3653051.878 11 4399841.100 2783209.262 3672259.344 12 4408888.561 2783085.116 3661559.859 13 4408250.097 2785810.385 3660264.778 17 4420266.218 2793882.786 3639703.338 18 4418319.763 2795960.228 3640466.136 19 4415269.213 2791301.242 3647685.776 29 4415028.237 2793629.936 3646204.578	1st 2nd 3rd : North 4th

Coordinates from WGS84:

ID	X	Y	Z	VX	VY	VZ
10	4409258.503	2793209.942	3653367.837	0.2791	-0.8054	0.2762
11	4399589.618	2783079.074	3672575.742	-0.0708	-0.1402	0.1890
12	4408637.207	2782956.449	3661875.316	-0.2477	0.6301	-0.1785
13	4407998.799	2785681.342	3660580.472	-0.0581	0.0991	-0.0047
17	4420014.964	2793755.611	3640018.181	-0.0789	0.3317	-0.1576
18	4418068.492	2795832.639	3640781.273	0.0536	-0.0780	-0.0056
19	4415018.106	2791173.191	3648000.866	0.1266	0.0760	-0.2096
29	4414776.896	2793501.854	3646520.002	-0.0039	-0.1133	0.0908

Standard deviation: 0.3071.

Transformation parameters:

==========

Scale: 0.999955212 ± 0.0000082131

Rotation about X: 0°00'08.72456" ± 4.78791" t-value: 1.822

Rotation about Y: 0°00'02.02667" ± 3.71588" t-value: 0.545

Rotation about Z: 0°00'06.93731" ± 8.04291" t-value: 0.863

X translation: 390.945 ± 172.915 t-value: 2.261

Y translation: 247.327 ± 252.913 t-value: 0.978

Z translation: -77.235 ± 53.805 t-value: 1.435

Transformed Coordinates:

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z -->	X	Y	Z
10	4409258.503	2793209.942	3653367.837	4409510.01	2793338.399	3653052.155
11	4399589.618	2783079.074	3672575.742	4399841.029	2783209.122	3672259.533

12	4408637.207	2782956.449	3661875.316	4408888.314	2783085.746	3661559.68
13	4407998.799	2785681.342	3660580.472	4408250.039	2785810.484	3660264.773
17	4420014.964	2793755.611	3640018.181	4420266.139	2793883.117	3639703.18
18	4418068.492	2795832.639	3640781.273	4418319.816	2795960.15	3640466.13
19	4415018.106	2791173.191	3648000.866	4415269.339	2791301.318	3647685.567
29	4414776.896	2793501.854	3646520.002	4415028.233	2793629.823	3646204.668
37	4405292.965	2796309.94	3655763.325	4405544.731	2796438.493	3655447.366
38	4399003.042	2785551.531	3671411.588	4399254.573	2785681.439	3671095.321
39	4410305.546	2782302.283	3660373.283	4410556.57	2782431.489	3660057.759
40	4407179.58	2785060.665	3662029.097	4407430.821	2785189.923	3661713.351
41	4418712.944	2793852.142	3641514.486	4418964.166	2793979.751	3641199.401
42	4415047.996	2782699.909	3654389.276	4415298.88	2782828.685	3654074.05
46	4418528.324	2787805.91	3646336.579	4418779.304	2787933.999	3646021.532

Table (A-47):- results of the Helmert Transformation in the Middle of the West Bank case2.

Helmert Transformation: Middle of the West Bank	Second Iteration
Coordinates from Palestine 1923 Grid. ID X Y Z ========== 1 4429859.390 2762265.117 3652067.153 3 4430101.886 2759944.569 3653517.205 4 4425070.660 2761507.701 3658396.534 5 4431577.563 2754577.740 3655761.769 6 4418993.879 2762735.484 3664765.555 8 4434605.360 2764781.954 3644447.036	1st 2nd : Middle 3rd 4th

ID	X	Y	Z	VX	VY	VZ
1	4429664.347	2762143.235	3652310.155	0.1121	-0.1230	-0.0424
3	4429906.575	2759822.774	3653760.466	-0.1529	-0.0169	0.1965
4	4424875.504	2761385.937	3658639.579	0.0566	-0.0179	-0.0545
5	4431382.124	2754456.395	3656004.842	-0.2815	0.4837	-0.0248
6	4418798.613	2762613.533	3665008.867	0.0140	-0.2402	0.1636
8	4434410.519	2764660.110	3644689.772	0.2516	-0.0857	-0.2384

Standard deviation: 0.2382.

Transformation parameters.

==========

Scale: 0.999990353 ± 0.0000113038

Rotation about X: -0°00'00.40896" ± 3.99472" t-value: 0.102

Rotation about Y: -0°00'00.33247" ± 2.52574" t-value: 0.132

Rotation about Z: -0°00'00.34640" ± 4.66878" t-value: 0.074

X translation: 236.639 ± 94.554 t-value: 2.503

Y translation: 148.208 ± 160.785 t-value: 0.922

Z translation: -206.148 ± 85.525 t-value: 2.410

Transformed Coordinates.
WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4429664.35	2762143.24	3652310.16		4429859.50	2762264.99	3652067.11
3	4429906.58	2759822.77	3653760.47		4430101.73	2759944.55	3653517.40
4	4424875.50	2761385.94	3658639.58		4425070.72	2761507.68	3658396.48
5	4431382.12	2754456.40	3656004.84		4431577.28	2754578.22	3655761.74
6	4418798.61	2762613.53	3665008.87		4418993.89	2762735.24	3664765.72
8	4434410.52	2764660.11	3644689.77		4434605.61	2764781.87	3644446.80
14	4428513.05	2757668.10	3657052.93		4428708.24	2757789.89	3656809.83
15	4430713.59	2756652.56	3655165.40		4430908.75	2756774.37	3654922.32
16	4427200.37	2764970.44	3653152.72		4427395.55	2765092.17	3652909.68
17	4433897.14	2765352.92	3644788.09		4434092.24	2765474.67	3644545.12

Table (A-48):- results of the Helmert Transformation in the South of the West Bank case2.

Helmert Transformation: South of the West Bank	Second Iteration
Coordinates from Palestine 1923 Grid. ID X Y Z ========== 1 4457651.122 2722909.649 3647832.038 2 4458886.497 2726921.300 3643353.424 4 4448807.540 2742101.370 3644274.730 8 4468492.524 2728756.646 3630276.304 13 4460669.663 2720577.980 3645894.605 14 4446006.028 2730970.514 3655953.117	1st 2nd : South 3rd 4th

Coordinates from WGS84.

ID	X	Y	Z	VX	VY	VZ
1	4457399.906	2722791.963	3648140.091	-0.2023	0.5269	-0.1466
2	4458635.393	2726803.501	3643661.526	0.2552	-0.0961	-0.2384
4	4448554.947	2741983.273	3644584.679	-0.0697	-0.1099	0.1683
8	4468241.492	2728640.267	3630583.647	0.5779	-0.2710	-0.5014
13	4460417.972	2720460.631	3646203.068	-0.8413	0.5993	0.5759
14	4445754.741	2730850.556	3656262.613	0.2801	-0.6492	0.1422

Standard deviation: 0.5304.
Transformation parameters.
==========
Scale: 0.999973724 ± 0.0000170074
Rotation about X: 0°00'15.15752" ± 5.06529" t-value: 2.992
Rotation about Y: 0°00'06.16518" ± 4.36067" t-value: 1.414
Rotation about Z: 0°00'12.58266" ± 4.93426" t-value: 2.550
X translation: 311.082 ± 121.260 t-value: 2.565
Y translation: 193.583 ± 174.175 t-value: 1.111
Z translation: -145.486 ± 144.251 t-value: 1.009

Transformed Coordinates.

WGS84 Coordinates transformed to Palestine 1923 Coordinates

ID	X	Y	Z	-->	X	Y	Z
1	4457399.91	2722791.96	3648140.09		4457650.92	2722910.18	3647831.89
2	4458635.39	2726803.50	3643661.53		4458886.75	2726921.20	3643353.19
4	4448554.95	2741983.27	3644584.68		4448807.47	2742101.26	3644274.90
8	4468241.49	2728640.27	3630583.65		4468493.10	2728756.38	3630275.80
13	4460417.97	2720460.63	3646203.07		4460668.82	2720578.58	3645895.18
14	4445754.74	2730850.56	3656262.61		4446006.31	2730969.87	3655953.26
18	4457973.96	2727076.93	3644262.11		4458225.33	2727194.71	3643953.72
19	4448804.74	2729114.69	3653864.23		4449056.20	2729233.68	3653555.16
20	4455063.40	2737550.07	3639995.32		4455315.62	2737667.44	3639686.18
21	4449993.16	2739574.26	3644640.16		4450245.50	2739692.23	3644330.60