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QUALITY ANALYSIS OF GPS DATA PROCESSED BY EARTH GRAVITATIONAL MODEL (EGM2008) OF HILLA AREA, IRAQ

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ABSTRACT
The main objective of this study is to examine the concept and techniques of involving geoid in GPS height observation to be detected as a leveling tool. The paper extends to the relationship between the obtained heights and the use of the modern global geoid model EGM2008 available for the study area (Hilla, central Iraq). The present analysis was carried 22 points observed by GPS and level devices available in the study area. Evaluation by comparisons of geoid heights computed from the model with those available GPS leveling stations of the study area were determined. Then, the standard deviations are calculated as an indicator for the accuracy of the US website OPUS for the study area. Most accurate results of GPS data are obtained using the static method in geodetic works after being processed through the US website OPUS. The results accuracy of the data observed by GPS after processing by EGM2008 model is within the range ± 0.041 m. Finally, as an evaluation, it can be stated from results of the computed geoid accuracy is acceptable and the present geoid model EGM2008 is considered as the optimal geoid so far for the study area.

INTRODUCTION
The Global Positioning System (GPS) is the only fully functional Global Navigation Satellite System (GNSS), GPS is used to determine the position, velocity and time thus GPS Technology has different applications in different fields such as Industry, Agriculture, Mapping, Geographical Information System (GIS) Data Collection, Public Safety, Surveying, Telecommunications, Military (Intelligence & Target Location, Navigation and Weapon Aiming & Guidance), Science (Archeology, Atmospheric sciences, Environmental, Geodesy, Geology & Geophysics, Oceanography and Wildlife) and Transportation. Global positioning systems (GPS) can offer three-dimensional positioning over the world, but provide ellipsoidal heights, which are geometric heights, instead of orthometric heights, which have physical meanings. Orthometric heights can be calculated from the potential difference of the reference equipotential surface and the actual point, while the potential difference can be determined with the combination of heights that need to know the geoid undulation at the station. Therefore, Determination of the geoid has been one of the main research areas in Geodesy for decades. More and more accurate geo-potential models (earth models) have been developed. The modern models can provide the geoid heights of any point on the earth surface with an accuracy ranging from 30 cm to a few meters (Rapp, 1997; Chen and Yang, 2001). With the development of GPS, positioning technique great attention has been paid to the precise determination of local/regional geoid. The development of the Earth Gravitational Model 2008 (EGM2008) model is a significant contribution for modeling the Earth's gravity and geoid.

The present study will examine the concept and techniques of involving geoid in GPS height observation to be detected as a leveling tool. The paper extends to the relationship between the obtained heights and the use of the global geoid model (Earth Gravitational Model EGM2008) available for the study area. Thus, the main objective of this study is to determine the accuracy of GPS data after achieving an extensive analysis of these data after processing by Earth Gravitational Model (EGM2008) in US website OPUS of Hilla area, central Iraq.

THEORETICAL BACKGROUND

Geoid-Ellipsoid Relationship

The impact of Global Positioning System (GPS) on all aspects of surveying is significant and widespread. GPS provides simple and readily applicable concepts and procedures to achieve accurate positions. GPS has been used extensively in various geodetic and geophysical applications. GPS provides positions in a three-dimensional coordinate system. Whether, working autonomous using pseudo range or in differential carrier phase positioning techniques, one obtains a set of X, Y, Z coordinates. Using a reference ellipsoid, the X, Y, Z coordinate may be transformed into geographic coordinate's latitude (φ), longitude (λ) and ellipsoid height (h) (Schwarz. et al., 1987). Unfortunately, ellipsoid heights cannot be used in applications unless it is transformed into an orthometric height defined with respect to an adopted equipotential surface. This orthometric height is known to be classically defined by the traditional geodetic leveling and reference to mean sea level, i.e. approximating the equipotential surface (geoid). Accordingly, the transformation of the ellipsoidal height to an accurate orthometric height has become a concern for many geodesists. This transformation is mainly based on the basic relationship between ellipsoidal heights, h, and orthometric heights, H, as follows (Figure 1) (El-Ashquer, 2010).

$$h = H + N \tag{1}$$

where:

N: the geoid undulation or geoidal height.
H : the orthometric height.
h : the ellipsoidal height.

This relation assumes one datum for both the ellipsoidal height and the geoidal height. If we consider the ellipsoidal height defined with respect to WGS84 the datum associated with the GPS system, hence, the geoidal height would be reference to the same datum; otherwise, systematic errors and biases could occur. Consequently, the main problem in such a transformation is the adoption of a reference ellipsoid to be compatible with the orthometric height determined by GPS and the local heights. In addition, the computation of geoidal height, N, which is known by geoid determination, gives rise to further systematic errors due to the neglect of short wavelength of the local gravity field. The short wavelengths of the gravity field can be deduced from local gravity data and terrain models (El-Ashquer, 2010).

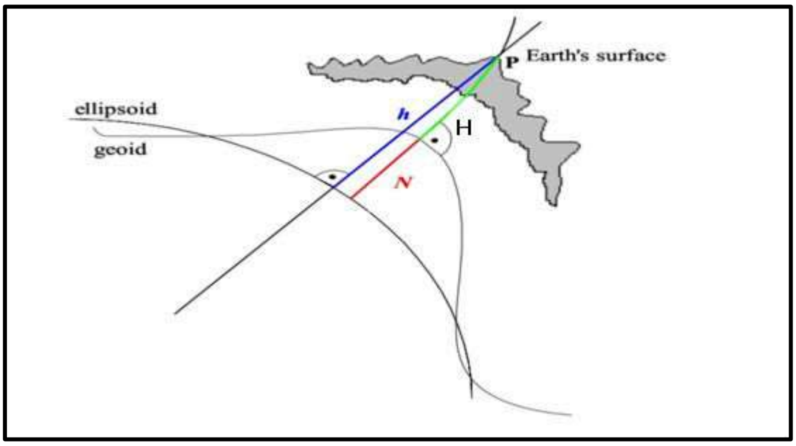

Figure 1: Relationship between ellipsoidal (h), orthometric (H) and geoid height (N) (El-Ashquer, 2010).

Global Positioning System (GPS)

Satellite Geodesy comprises the observational and computational techniques which allow the solution of geodetic problems by the use of precise measurements to, from, or between artificial, mostly near-Earth, satellites (Seeber, 2003).

TRANSIT system is one of the early and successful satellite systems which used the Doppler Effect to determine range rates or range differences (Leick, 1995). Unfortunately, the system was unable to provide the accuracy needed in high precision geodesy. Two main problems with TRANSIT were the large time gaps in coverage.

Since nominally a satellite would pass over head every 90 minutes because of only six transit satellites were available.

GPS is not the only venture into Global Navigation Satellite Systems (GNSS).The Russians have developed a parallel system of satellite positioning known as GLONASS (Global Orbiting Navigation Satellite System). Owing to economic difficulties GLONASS has not been operating at its full capacity for some time and is not widely used by the surveying market (although recently, December 2002, the Russian authorities have shown a renewed commitment to a full GLONASS constellation in the next few years) (Hofmann et al., 2000).

GPS Observation Techniques

There are many observation techniques with GPS. The selection of the technique depends upon the purpose of the observations, the desired accuracy, the type and the number of the available receivers and the location of the points to be positioned. The main observing techniques used in GPS surveying are (Leick, 1995):

1. Static Surveys.
2. Rapid Static Surveys.
3. Kinematic Surveys.

Earth Gravitational Model 2008 (EGM2008)

This model developed by the NGA, EGM2008 is the first-ever global model that is capable of resolving the Earth's gravity field beyond spherical harmonic degree 2000 (Pavlis et al., 2008; Hirt, 2011; Pavlis, et al., 2012). The EGM2008 set of spherical harmonic coefficients is complete to degree 2190 and order 2159. With the release of the EGM2008, a considerable improvement has been in high-resolution global gravity field modeling. The model allows determination of the Earth's gravity field globally with a spatial resolution of ~9 km (or ~5 arc minutes) in the latitudinal direction, which is 6 times higher than that of EGM96. Pavlis et al., 2012 have pointed out that the discrepancies between the EGM2008 geoid heights and independent GNSS/leveling values are on the order of ±5 to ±10 cm over areas covered with high quality gravity data.

Also, they have claimed that the accuracy of EGM08, as gauged from comparisons with independent data, is 3 to 6 times higher than that of EGM96, depending on the gravitational function. Especially, unlike previous GGMs, the EGM2008 contains gravity data of 15' resolution for Asian regions. Furthermore, the gravity data provided by GRACE satellite system has greatly contributed to development of EGM2008.

METHODOLOGY

STUDY AREA

The study area (Figure 2) is about 10568 km^2 located between (405523 E to 498739 E and 3540836 N to 3641517 N) in meter unit, or (43° 59′ 59″ λ to 44° 59′ 31″ λ and 31° 59′ 58″ φ to 32° 54′ 42″ φ) in degree unit. The area of study is located in central Iraq almost in Babylon Governorate. It is bordered by Wasit Governorate from east, Bagdad and Al-Anbar Governorates from north, Karbala and Al-Najaf Governorates from west, and Diwaniyah Governorate from south. Tigris River is passing through the north-eastern corner of the study area while Euphrates River is passing through the west of the region which is subdivided into two branches namely, Shatt Al-Hilla and Shatt Al-Hindiya.

Figure 2: Geographic location of the study area (Babylon Governorate).

AVAILABLE DATA

Different sorts of data are available for the selected area of study, which thought to be enough and enable the achievement of the mentioned proposed objectives. The available data can be classified in two parts: GPS data (GPS utilizes coordinates determination and ellipsoid height), leveling data (Precise leveling is used to determine the difference of the orthometric height).

GPS Data

GPS points have been measured by Iraqi General Directorate of Surveying. The number of these points is twenty two for study area. They are distributed irregularly by GPS Topcon GR-3 instrument. These fixed terrestrial points have been observed by using the "static method", which is considered as the best method for highly precise geodesic works which can be summarized as follows:

After the pillar construction is completed in the ground with certain specifications according to the nature of the work, the observation procedures start. The GPS device is installed (only one piece, the base) on this pillar and recording some information, such as monitoring time and instrument height and leaving the device for a time not less than four hours. After the completion of this process, the instrument is shut down. At this stage, the field work is completed.

While, the office work includes connecting the GPS device to the computer for transforming the data to a specified file from GPS device to the computer. These data must be corrected. To achieve such corrections, the data are sent to US website, which is free site specialized in corrections and is called OPUS (abbreviated from Online Positioning User Service). This foundation is one of the three main institutions in the world that provides data to

GPS devices for processing service through a special program. One can directly enter to the home page of OPUS website, where this website will do the corrections process. Also from this website, one can download the data and receiving the results by an e-mail within short time. This e-mail contains information about the time of observation, start and end time as well as the points which have been sent before corrections and the corrected data. In this work, the data were sent after nearly two weeks to get the most accurate results.

The minimum distance between two points is 5.635 km, and the maximum distance is 75.170 km. Figures 3 and 4 illustrate the distribution of these points on satellite image with their contour map, respectively. Table 1 presents the data observed by GPS with respect to the ellipsoid height. The highest elevation point is 31.441 m, while the lowest elevation point is 17.600 m, with an average of elevation of 24.192 m.

Table 1: GPS data with respect to the ellipsoid height.

Point No.	Easting (m)	Northing (m)	Spheroid height (m)
1	445659.0625	3592819.705	25.565
2	443736.4095	3584152.914	23.064
3	442835.174	3597549.897	24.941
4	443602.3035	3613534.55	28.546
5	457277.384	3600852.997	24.062
6	431730.219	3621461.546	31.441
7	470106.7765	3573983.262	20.384
8	469123.416	3584645.152	22.061
9	463508.833	3623595.086	26.481
10	492143.9105	3576685.804	17.600
11	440229.459	3564725.336	21.729
12	483945.991	3579141.807	20.697
13	429021.061	3589523.304	28.200
14	423898.439	3607111.648	29.851
15	448046.979	3621834.969	26.357
16	457010.584	3610160.108	22.405
17	473168.579	3610649.462	23.109
18	467089.286	3599922.995	22.192
19	483087.541	3588724.458	22.752
20	456046.461	3578802.567	23.594
21	456851.685	3564086.973	21.832
22	443410.214	3574166.394	25.371

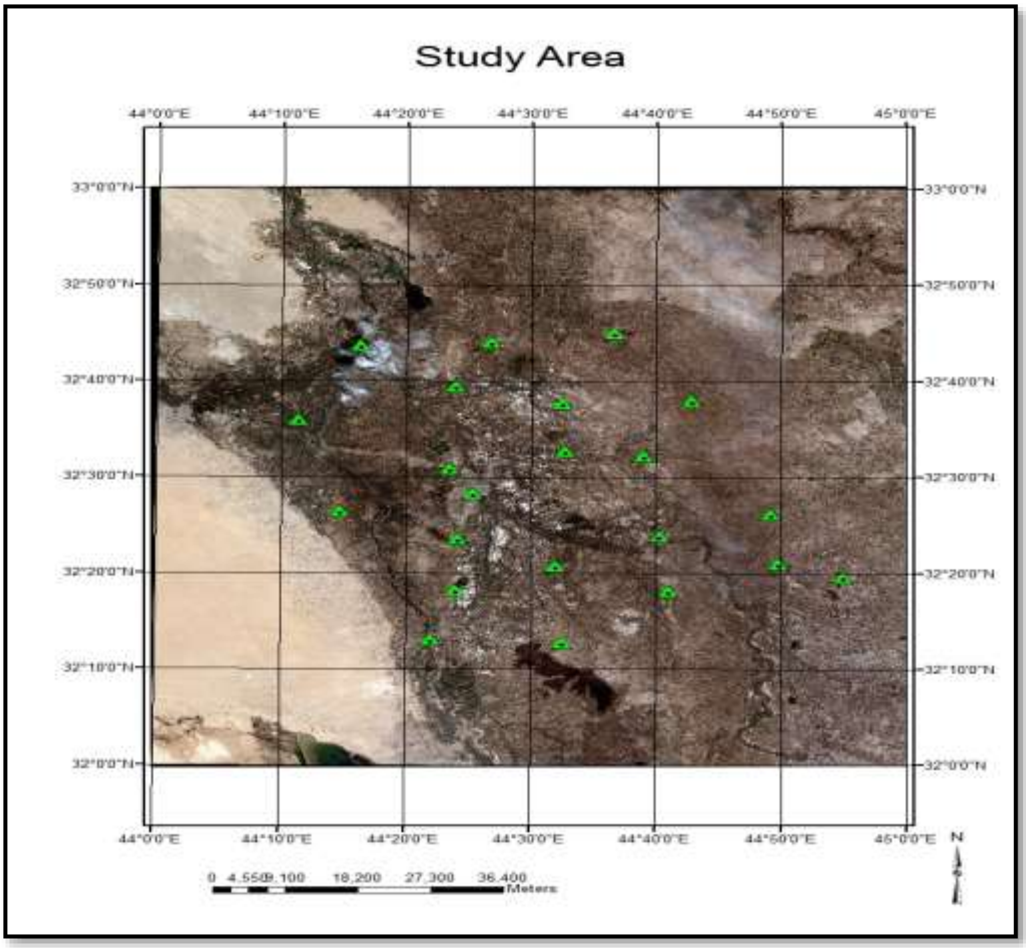

Figure 3: The distribution of points observed by GPS on satellite image for the study area.

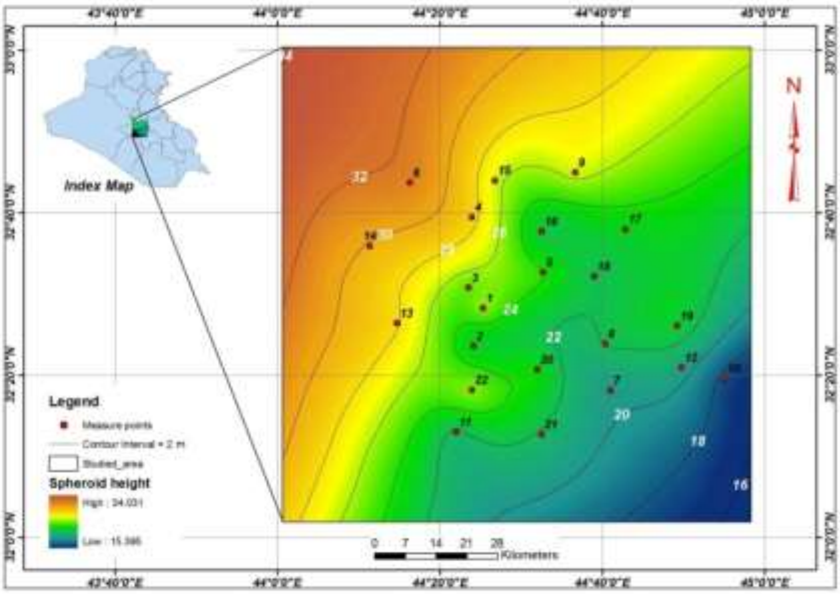

Figure 4: Contour map for points observed by GPS.

Leveling Data (Precise leveling)

Precise leveling points have been measured by General Directorate of Surveying. The number of these points is twenty two in the study area. These points are distributed randomly with irregular spaces, and do not cover all the study area. These elevation points are computed by a precise level method and very accurately. Figure 5 shows the distribution of these points on satellite image for the study area, while Figure 6 depicts a contour map for the elevation of these points observed by level. The minimum distance between two points was 5.635 km, and the maximum distance between two points was 75.170 km, as illustrated in Figure 5. Table 2 presents the data observed by precise leveling to the orthometric height. The highest elevation point is 33.402 m, the lower elevation point is 22.254 m, and the average of elevation is 27.305 m.

Table 2: Leveling data with respect to the orthometric height.

Point No.	Easting (m)	Northing (m)	Orthometric height (M.S.L) (m)
1	445659.0625	3592819.705	28.318
2	443736.4095	3584152.914	25.736
3	442835.174	3597549.897	27.530
4	443602.3035	3613534.55	31.031
5	457277.384	3600852.997	27.226
6	431730.219	3621461.546	33.402
7	470106.7765	3573983.262	24.210
8	469123.416	3584645.152	25.750
9	463508.833	3623595.086	29.554
10	492143.9105	3576685.804	22.254
11	440229.459	3564725.336	24.449
12	483945.991	3579141.807	25.017
13	429021.061	3589523.304	30.275
14	423898.439	3607111.648	31.634
15	448046.979	3621834.969	29.003
16	457010.584	3610160.108	25.469
17	473168.579	3610649.462	26.760
18	467089.286	3599922.995	25.771
19	483087.541	3588724.458	26.982
20	456046.461	3578802.567	26.851
21	456851.685	3564086.973	25.272
22	443410.214	3574166.394	28.210

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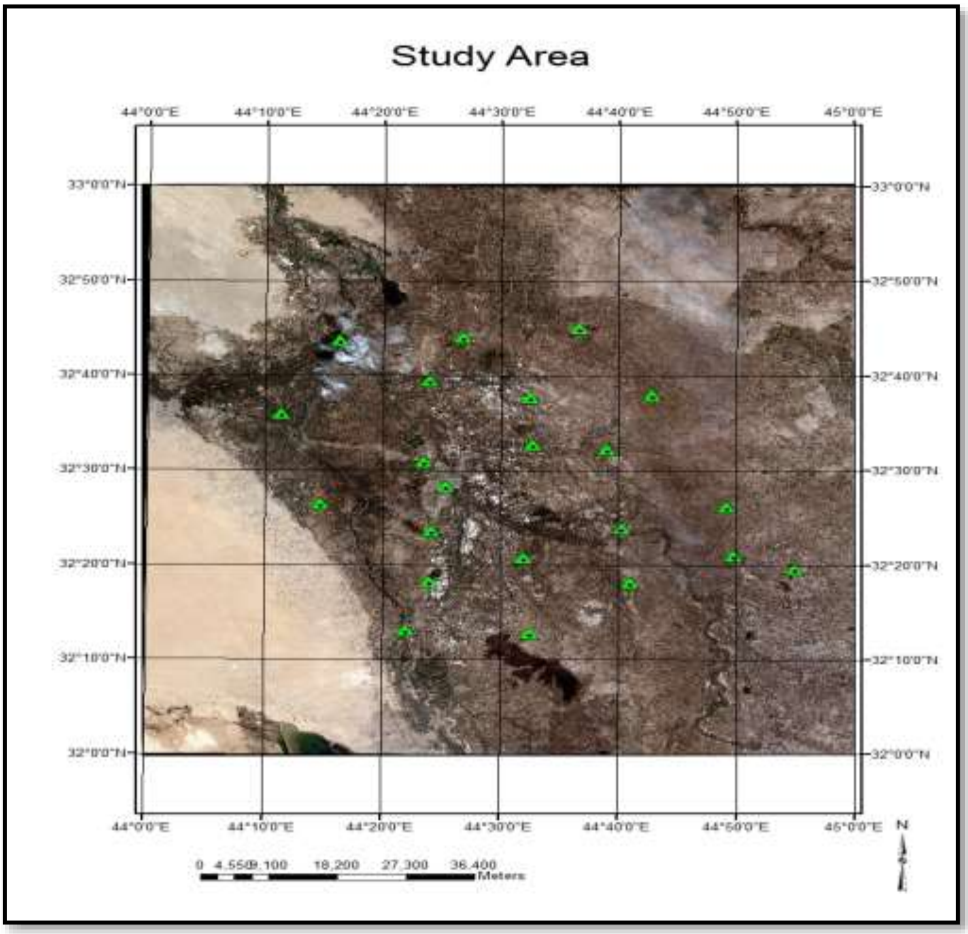

Figure 5: The distribution of points observed by level on satellite image for the study area.

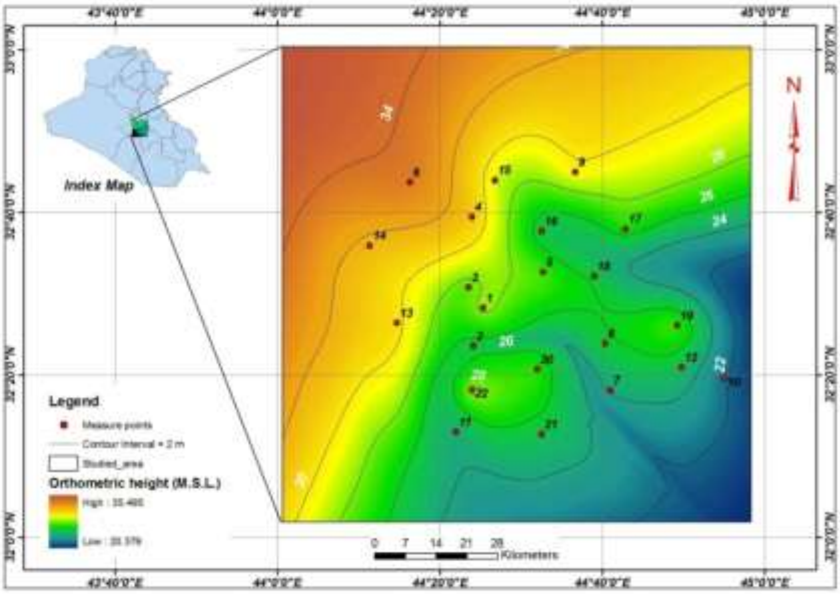

Figure 6: Contour map of points observed by level for the study area.

RESULTS AND DISCUSSION

There is no doubt that the level device is the most accurate method to calculate the orthometric heights for the surveying points above sea level. But, this method is no longer keep pace with the rapid development of new urban communities and the big projects in new areas due to several reasons. Of these reasons are the difficulty to work with this method, it takes a long time, besides its high cost. Therefore, it was necessary to search for an alternate method which can overcome these difficulties. This alternative method depends on the use of geoid model to calculate orthometric heights by GPS devices to determine the global coordinates which can cover the largest areas of the world. So, it will be compared after processing to determine the accuracy for the study area.

The data observed by GPS have been processed by EGM2008 model for transformation to orthometric height, the data must be corrected, so they are sent to OPUS website the US free website specialized in corrections. The data were sent after nearly two weeks to get the most accurate results. Then, information about the time of observation, start and end time as well as the points before corrections and after corrections have been provided by this website. Results of this processing are presented in Table 3. The highest elevation point is 33.426 m, the lowest elevation point is 22.196 m, while the average elevation is 27.334 m. Figure 7 shows a contour map for the undulation values for these points within the study area.

Table 3: The GPS data after processing by EGM2008 model.

Point No.	Easting (m)	Northing (m)	Orthometric height by EGM2008 model (m)
1	445659.0625	3592819.705	28.347
2	443736.4095	3584152.914	25.813
3	442835.174	3597549.897	27.578
4	443602.3035	3613534.55	31.083
5	457277.384	3600852.997	27.250
6	431730.219	3621461.546	33.426
7	470106.7765	3573983.262	24.275
8	469123.416	3584645.152	25.820
9	463508.833	3623595.086	29.618
10	492143.9105	3576685.804	22.196
11	440229.459	3564725.336	24.466
12	483945.991	3579141.807	25.059
13	429021.061	3589523.304	30.326
14	423898.439	3607111.648	31.689
15	448046.979	3621834.969	29.031
16	457010.584	3610160.108	25.496
17	473168.579	3610649.462	26.798
18	467089.286	3599922.995	25.837
19	483087.541	3588724.458	26.999
20	456046.461	3578802.567	26.786
21	456851.685	3564086.973	25.316
22	443410.214	3574166.394	28.141

By comparing Figure 7 with Figure 6, it can be seen the great similarity between them. Thus, one can say that is an evidence for the good results obtained after being processed through the US website OPUS. Therefore, the use of static method in geodesic works gives the best results and the most accurate for use in engineering projects.

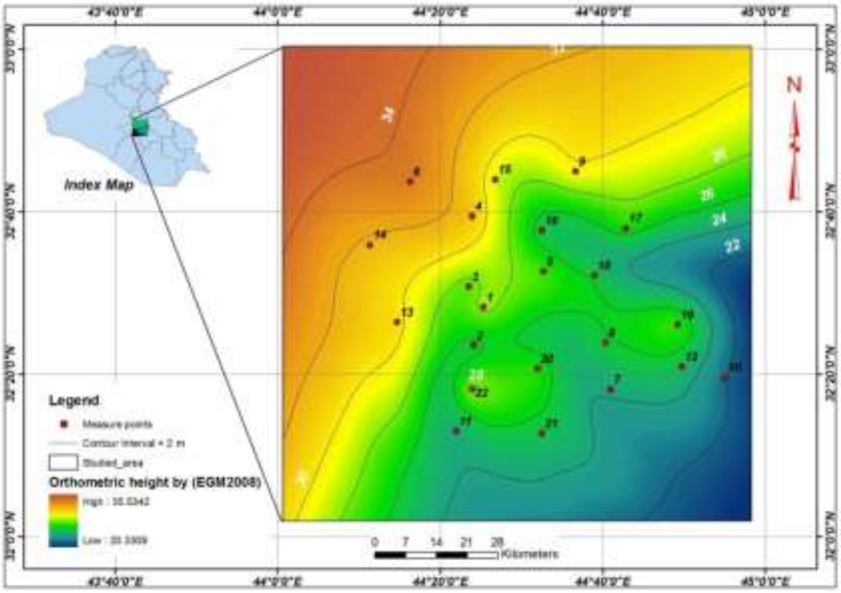

Figure 7: Contour map for orthometric height GPS data.

Table 4 presents the results of the data observed by GPS after processing by EGM2008 model and compared with precise leveling data. It is clearly shown that the accuracy of results for GPS data is within the range ± 0.041 m, as illustrated in Figure 8.

Finally, as an evaluation, in the light of the extensive analysis of the results and other observations, it can be stated from the results of the computed geoid accuracy is acceptable and the present geoid model EGM2008 is considered as the optimal geoid so far for the study area.

Table 4: Comparison of leveling data with GPS processed data.

Method	Maximum (m)	Minimum (m)	Mean (m)	Standard deviation (m)
Precise leveling	33.402	22.254	27.305	2.631
GPS processed data	33.426	22.196	27.334	2.638
Difference	0.069	-0.077	-0.029	±0.041

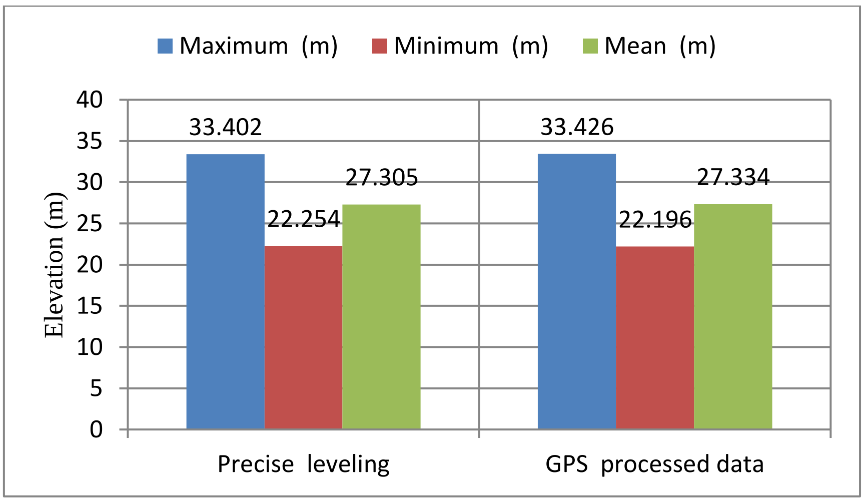

Figure 8: Accuracy of GPS data after processing.

CONCLUSIONS

In the light of the extensive analysis of the results and other observations, the following major conclusions can be drawn as follows:

1. The modern Earth Gravitational Model (EGM2008) has been evaluated by comparisons of geoid heights computed from the model with those available GPS leveling stations of the study area.
2. Most accurate results of GPS data are obtained using the static method in geodetic works after being processed through the US website OPUS. The results of the data observed by GPS after processing by EGM2008 model and compared with precise leveling data attained an accuracy of GPS data within the range ± 0.041 m.
3. As an evaluation, it can be stated from the results that the computed geoid accuracy is acceptable and the present geoid model EGM2008 is considered as the optimal geoid so far for the study area.

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