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Local Geospatial Geoid Determination for Rivers State, Nigeria

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Abstract: The increasing use of the Global Navigation Satellite System (GNSS) particularly the United States NAVSTAR Global Positioning System (GPS) has brought about the need to obtain accurate geoid model locally or globally to enable the ease of obtaining orthometric heights from the ellipsoidal heights from GPS. This phenomenon is a critical spatial infrastructure which serves as reference surface required to model terrain characteristics and monitoring of changes on the earth or near-earth surfaces. A lot of engineering activities are going on in Rivers State of Nigeria in Delta Region including the need to monitor hazards which require accurate orthometric heights because of the nature of the terrain. The aim of this work is to determine a local geometric geoid for Rivers State, Nigeria. The GRAVSOFT software was adapted and used to compute and assess its accuracy. Sixty-one (61) points established and the spirit level heights of these points were obtained and fifty-six (56) out of the sixty-one was used to create the model while the remaining selected five points was set aside for validation. The difference between the geometric undulation (N^{GPS}) and EGM2008 undulation (N^{EGM08}) was determine and gridded using least square collocation gridding module (GEOGRID) and then the final geoid (the draped geoid) is obtained by adding the gridded difference to EGM08 undulation. The Results of the Root Mean Square (RMS) is ±0.012m post fit for the fifty-six and ±0.050m for the validation points within the study area and without drapen is ±0.655m.
Keywords: Global Navigation Satellite System, Global Positioning System, Geoid, Gravsoft, Ellipsoid Heights, Root Mean Square Error)

I. INTRODUCTION

In most engineering and surveying work, orthometric heights relative to the geoid, a close approximation to the mean sea level, are required (Erol & Celik, 2004), the combination of data obtained by the Global Positioning System(GPS), levelling and geoid information has been a key procedure for various geodetic application. The geoid is a surface of constant potential energy that coincides with mean sea level over the oceans.However, the mean sea level is not quite a surface of constant potential due to dynamic processes within the ocean and the actual equipotential surfaceunder the continents is warped by the gravitational attraction of the overlying masses. However, geodesists define the geoid as though these masses were always underneath the geoid rather than above it(Alade, 2017).Hence, the main function of the geoid in geodesyis to serve as a reference surface for heights determination.

One of the elements that makes a topographic map a vital tool is the elevations contained in it. These elevations are referenced to the geoid and are required by many professionals including engineers for design of highways, railroads, canals, transmission lines, pipelines and other facilities; architects for architectural and landscape designs; planners for the design of good layout plans; engineers for engineering designs and construction, geomatics experts for geo-models of the earth with digital elevation models and maps. They are also important for watershed management and erosion control. The advent of high definition surveys such as satellite based positioning techniques, especially Global Positioning System (GPS), which is presently used in a wide range of geodetic and surveying applications, has brought tremendous changes in the processes of precise geodetic control establishment; data acquisition techniques have become more efficient, accuracies greatly improved with new areas of applications opened up, orthometric heights can thus, be acquired indirectly through geodetic heights from GPS if the geoid over the area is known (Moka and Agajelu, 2006). The heights obtained using GPSsatellite-based system is referenced to the ellipsoid, which is geocentric (World Geodetic System 1984).Since the ellipsoidal heights from GPS are basically geometric in nature and therefore, do not reflect the direction of flow under the influence of gravity, heights from GPS are of little or no direct meaning in engineering construction and geodetic applications (Featherstone et al 1998). Therefore, to utilize the opportunities provided by this technique, the need for the transformation between ellipsoidal heights to orthometric heights becomesparamount.Therefore, thiswork attempts modelling the geoid geometrically using the GRAVSOFT as adapted and assessing its accuracywith respect to engineering application within the study area. The study area has experienced an increase in construction and engineering activities in addition to the need for hazard monitoring and evaluation which will require the provision of unique and acceptable reference surface for the ease of transformation of height information from one reference system to another. The scoperequires getting the coordinates (that is Easting, Northings and Ellipsoidal Heights) of all points within this area from GPS observation as well as their Mean Sea Level heights obtained from Spirit Levelling for the same points, then applying the Gravsoft Program to compute for the best–fit geoidal undulation for the study area.

1.2 Study Area

The study area covers about eight local government area of Rivers State, which is known as the Greater Port Harcourt City Development Authority, South-South of Nigeria. It covers an area of 779. 483Sq.Kilometer. The study area lies between 04^o 15' N to 04^o 25' in latitude and 05^o 20'and07^o15'EinLongitude

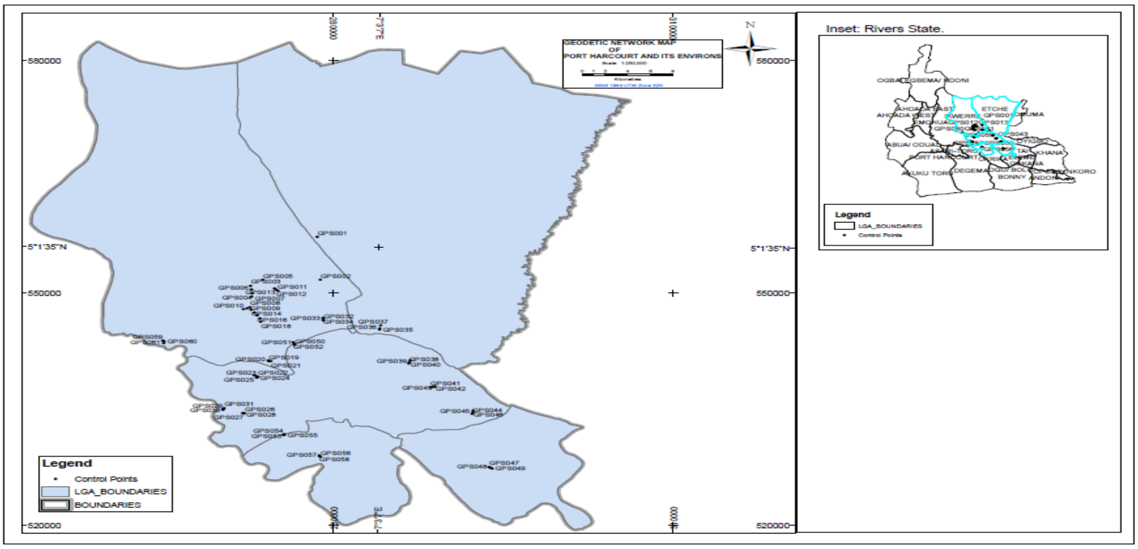


Fig.1.0 Map of Rivers State showing the Distribution of Points (After Alcon Survey, 2009)

II. GEOID MODEL DEVELOPMENT

Basically, there are three methods that are used to compute a geoid model: gravimetric methods, geometric method and the combined or hybrid method.

Gravimetric methods use gravity observations from satellite, land and ship-based sources to map the Earth's gravity field. The advantage of this technique is that it is relatively easy to collect data over a large area such as the entire Earth. An example of a global gravimetric model is the EGM08 (Earth Gravitational Model 2008). It was released by the National Geospatial Intelligence Agency EGM Development Team. It is a 2.5-minute grid of geoid ellipsoid separation values based on satellite observation (National Geospatial Intelligence Agency).

Gravimetric methods require gravity values observed at points on the surface of the earth or reduced to the mean sea level or in space outside the earth's surface. The gravity data must be of sufficient density, Dagogo et al 2014. Presently, this is a serious problem in applying gravimetric method for geoid determination in Nigeria; the paucity of gravity values of sufficient coverage, (Moka, 2011). The applicable formula, when using terrestrial gravity data reduced to the geoid, as derived by Stokes, after whom it was named, (Heiskanen, & Moritz,1967; Moka, 2011)

$$N = \frac{R}{4\pi G} \iiint_{\sigma} \Delta g S(\psi) d\psi \qquad \dots (1.0)$$

Where
N = geoid undulation (height)
R = mean radius of the earth
G = mean gravity of the earth
S(ψ) = Stokes function

$$= \frac{1}{\sin(\frac{\psi}{2})} - 6\sin\frac{\psi}{2} + 1 - 5\cos\omega - 3\cos\omega \ln\left(\sin\frac{\psi}{2} + \sin^2\frac{\psi}{2}\right) \dots (2.0)$$

Δg = (g – γ) = gravity anomaly
γ = normal (reference) gravity

Stokes integral formula requires that gravity values be known throughout the earth and that there should be no external masses outside the geoid. Also, the reference gravity must be that of a reference ellipsoid that has the same volume as the earth so as to enclose a mass that is numerically equal to the mass of the earth. Again, the reference ellipsoid must be geocentric. This method yields geoid undulations with respect to a geocentric reference ellipsoid. Currently, modern methods are applied to circumvent the need to reduce gravity to the geoid. In this case, surface gravity anomalies are used in Molodenski's Integral formula, and height anomalies ζ are computed and subsequently converted to geoid heights N(Bernhand &Moritz, 2005).

III. COMPUTATION OF THE GEOMETRIC GEOID MODEL

The geoidal undulation for all the points within the study area was determined using Earth Global Model 2008.The values of the Geoidal undulation of the GPS points were determine using a Fortran program written by Simeon A. Holmes and Nikolaos K. Pavlis. This program computes the GEOID HEIGHTS with respect to WGS 84 by spherical harmonics synthesis. The latitude and longitude of all the points were arranged in notepad software suite and saved as dot dat (e.g. Input.dat). Then the program will generate the undulations for all the points imputed in the output file (e.g. output.dat)after the program is run.

Also, the geometric geoidal undulation was also determine using the equation below;

$\varepsilon = N^{GPS} - N^{EGM}$ (after Forsberg et'al, 2008)… (3.0).

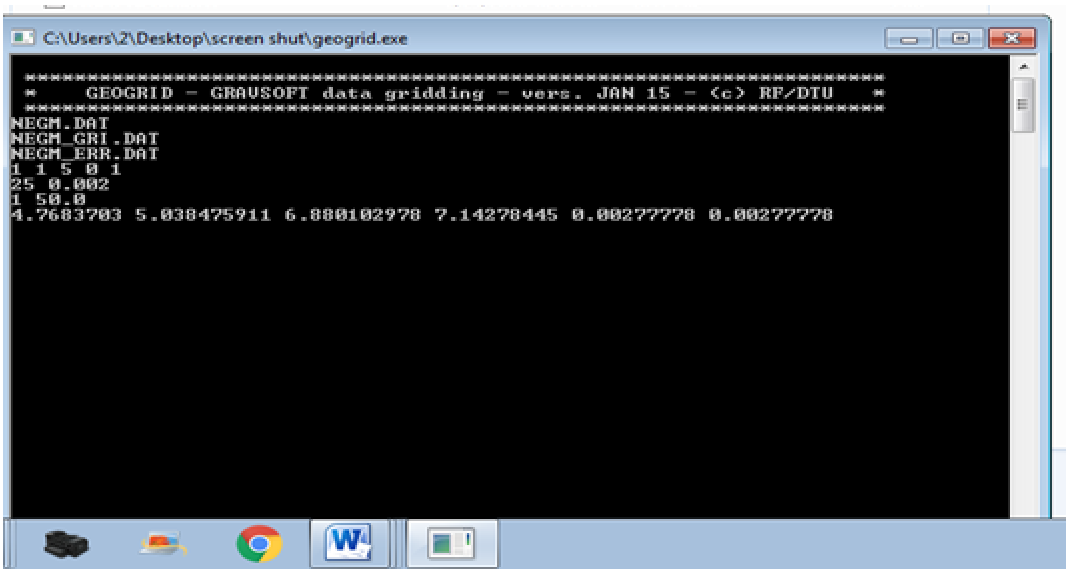
$N^{draped} = N^{EGM} + \varepsilon^{grid}$ (after Forsberg et' al 2008)--- … (4.0)

In order to test the validity of the technique employed in this research, five points were set aside as validation points out of the sixty-one (61) points. So Ellipsoidal height for the 56 points from the GPS observation as well as the leveled heights for the same GPS points from the spirit levelling over the study area was computed using the Microsoft excel work sheet. Also, the Geoidal undulation for the Earth Global Model ($N^{EGM)}$ and the geometric (N^{GPS}) denoted by the symbol (ε) in equation (3.0) is determine using the Microsoft excel worksheet.

IV. PROCESSING USING THE GRAVSOFT PROGRAM

The GRAVSOFT is a basic program used in physical geodesy for geoid modeling, and also to manipulate arithmetic problem and handling of data files, either in point format or grids format. The GEOGRID, GCOMB and GEOIP were used in this work. The GEOGRID is a program in the GRAVSOFT suite that does gridding of irregularly distributed data into a regular rectangular grid form using least squares prediction technique. From the data the maximum and the minimum of the latitude and longitude of the points were specified and including the grid interval. The data must be arrange/entered in this format in a note pad:

Number, Latitude, Longitude, Height, Geoid value and save as data file with the extension (e.g. **oba.dat**). Having arrange the data in the above format in a note pad, for the EGM values of the 56 points (i. e N^{EGM})and also the difference (ε) obtain between the computed value of the undulation(N^{GPS}) to that of the (N^{EGM}) in another note pad. The gridding was done separately. When the executable file of the program is run, the following information will be provided for it to create a gridded file and a gridded error file for (N^{EGM}) and(N^{GPS}) respectively. Figure 2.0 is a screen shot of the gridded geoidal undulation for the $N^{EGM2008}$ and ε=(N^{GPS}-$N^{EGM2008}$) as run in the Gravsoft program.



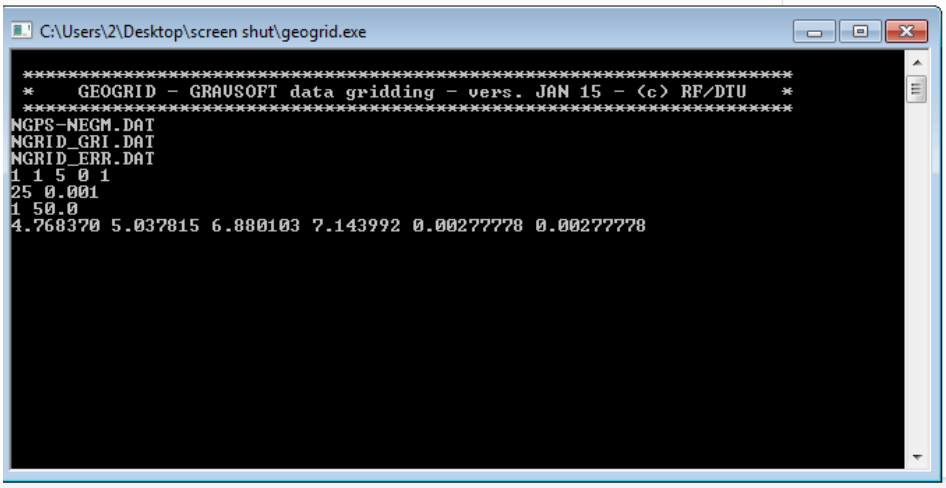


Fig. 2.0 Screenshot of the Interface of the Gravsoft Program

The GCOMB is a program in the GRAVSOFT suite used for Adding or Subtracting two gridfiles into one. The grids must have the same grid spacing (interval) and relative positions, but not necessarily the same coverage area. The two gridded files obtained for $N^{EGM2008,}$ and $\varepsilon = (N^{GPS} - N^{EGM2008})$ respectively will serve as the input files that is needed to be combined to form one single grid. This single new gridded file will be the final geoid i.e. the draped geoid surface. Then the validation points as well as the remaining 56points will be interpolated using the GEOIP.

Having entered the first and second grid files as input data then it will create an output data that will contain the new combine grid file upon which the interpolation will be done.

The GEOIP is a program in the GRAVSOFT suite that does interpolate using bilinear or spline method to carry out the interpolation. The bilinear interpolation was done from the grid file to point file. The results obtained from GCOMB which is a grid file and a point file that have the points to be interpolated as well as the validation point are created.

4.1. Plotting of the Model

The G2SUR is a subroutine program in the GRAVSOFT suite that converts the GRAVSOFT grid file to SUFFER grid file. Thus, the final geoid (draped) was converted to SUFFER acceptable format for plotting and viewing.

4.2 Root Mean Square Error

A statistical test is one of the ways in checking the reliability of any model or design being carried out in order to give credence to the work being develop or computed. In this work, the Root Mean Square Error was used as a statistical test.The Root Mean Square Error (RMSE) also called the root mean square deviation is a statistical tool used in measuring the difference between values predicted by a model and the values actually observed from the environment or data set being modelled. These differences obtained are called the residuals, and the Root Mean Square Error serves to aggregate them into a single measure of predictive power.

The Root Mean Square Error of a model prediction with respect to the estimated variable Xmodel is define as the square root of the mean squared error and is given below;

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n-1}} \qquad \ldots (5.0)$$

Where X_{obs} is the observed values, X_{model} is the modelled values, n-1 is the degree of freedom

V. RESULTS AND DISCUSSION

The result of the computation of the geoidal undulation (N^{egm}) for the fifty-six points as performed in the Fortran program and the geoidal undulation (N^{gps}) from difference between the ellipsoidal heights and the spirit level heights and as well as their discrepancies are tabulated in table 1.0.

The fifty-six points selected out of the sixty-one points and the differences in undulation was used to create the model using the least squares collocation technique as implemented in the Gravsoft was used, the residual obtained is shown in table 2.0, which showed centimeter level accuracy with a corresponding RMSE of ±0.012. For the model a statistical analysis of the residual was conducted using the Root Mean Square Error (RMSE) and the result is shown in table 2.0 and table 3.0 without draping .By way of validating the model within the study area, the five points that was set aside was used by inserting the coordinate (i.e., latitude, longitude) and the ellipsoidal height obtain from the GPS, the geoidal undulation for those point are determine as shown in table 4.0 from the geoidal map of the final draped geoid of the study area in figure 3.0. The RMSE is ±0.053 and showed a good recoverability of the validation points.

However, since heights obtained from the network was ellipsoidal heights, the presence of a geoid model of the area will facilitate the determination of the required orthometric height need for any engineering activity within the study area.

Table1.0: Table showing the Difference between Geoidal Undulation (EGM08) and Spirit Leveled Heights

STN	LAT.	LONG.	ELLIP. HEIGHT (m)	M.S.L. HEIGHT (m)	N=h-H	EGM08	DIFF.08
GPS001	5.0384	7.0027	47.654	29.513	18.142	18.869	-0.727
GPS 02	4.98834	7.00544	42.542	24.294	18.248	18.904	-0.656
GPS 03	4.97225	6.95118	38.771	20.630	18.141	18.832	-0.691
GPS 04	4.98817	6.95968	41.357	23.096	18.261	18.833	-0.572
GPS 05	4.97687	6.95053	39.485	21.289	18.196	18.828	-0.632
GPS 06	4.96842	6.95077	38.351	20.218	18.133	18.834	-0.701
GPS 07	4.95495	6.94708	34.627	16.476	18.151	18.839	-0.688
GPS 08	4.95378	6.94428	36.819	18.648	18.171	18.836	-0.665
GPS 09	4.97802	6.96892	38.155	20.165	17.990	18.854	-0.864
GPS 10	4.97662	6.97037	39.661	21.445	18.216	18.857	-0.641
GPS 11	4.97517	6.97196	40.589	22.342	18.247	18.86	-0.613
GPS 12	4.95314	6.95045	35.359	17.181	18.178	18.845	-0.667
GPS 13	4.94971	6.95284	34.766	16.580	18.186	18.85	-0.664
GPS 14	4.94659	6.95511	34.756	16.568	18.188	18.856	-0.668
GPS 15	4.94301	6.95738	34.79	16.592	18.198	18.861	-0.663
GPS 16	4.93924	6.95796	34.784	16.569	18.215	18.865	-0.650
GPS 17	4.89316	6.96472	29.266	10.986	18.280	18.904	-0.624
GPS 18	4.89405	6.96434	29.87	11.580	18.290	18.903	-0.613
GPS 19	4.8933	6.96628	30.338	12.024	18.314	18.905	-0.591
GPS 20	4.8751	6.95599	32.335	14.017	18.318	18.906	-0.588
GPS 21	4.87564	6.95483	33.256	14.933	18.323	18.905	-0.582
GPS 22	4.87383	6.95501	33.065	14.742	18.323	18.906	-0.583
GPS 23	4.8766	6.95283	33.532	15.444	18.088	18.902	-0.814
GPS 24	4.832461	6.945637	20.18	1.920	18.260	18.93	-0.670
GPS 25	4.832444	6.944887	19.557	1.275	18.282	18.93	-0.648
GPS 26	4.832328	6.944122	20.699	2.426	18.273	18.929	-0.656
GPS 27	4.83648	6.928271	20.239	1.970	18.269	18.912	-0.643
GPS 28	4.837388	6.928478	20.984	2.730	18.254	18.912	-0.658
GPS 29	4.838183	6.929087	23.319	5.059	18.260	18.911	-0.651
GPS 30	4.940823	7.007985	37.527	19.234	18.293	18.935	-0.642
GPS 31	4.94228	7.008016	38.369	20.091	18.278	18.934	-0.656
GPS 32	4.943984	7.007761	39.567	21.279	18.288	18.933	-0.645
GPS 33	4.930137	7.052699	40.67	22.311	18.359	19.005	-0.646
GPS 34	4.931736	7.05285	40.87	22.521	18.349	19.004	-0.655
GPS 35	4.935098	7.053557	38.757	20.393	18.364	19.004	-0.640
GPS 36	4.890884	7.076114	34.478	16.082	18.396	19.047	-0.651
GPS 37	4.89461	7.077475	37.128	18.740	18.388	19.048	-0.660
GPS 38	4.862921	7.093362	37.962	19.542	18.420	19.076	-0.656
GPS 39	4.863447	7.095126	38.177	19.755	18.422	19.078	-0.656
GPS 40	4.863901	7.096991	36.294	17.872	18.422	19.08	-0.658
GPS 41	4.832048	7.126734	34.411	15.906	18.505	19.121	-0.616
GPS 42	4.835731	7.127621	31.881	13.650	18.231	19.121	-0.890

GPS 43	4.769963	7.1403	32.793	14.291	18.502	19.139	-0.637
GPS 44	4.769414	7.141167	33.017	14.515	18.502	19.14	-0.638
GPS 45	4.76837	7.142784	33.822	15.310	18.512	19.141	-0.629
GPS 46	4.911981	6.985297	35.117	16.834	18.283	18.918	-0.635
GPS 47	4.913762	6.984875	35.499	17.227	18.272	18.916	-0.644
GPS 48	4.915312	6.983789	35.254	16.965	18.289	18.914	-0.625
GPS 49	4.807219	6.976287	29.336	10.995	18.341	18.975	-0.634
GPS 50	4.80699	6.977222	29.173	10.798	18.375	18.976	-0.601
GPS 51	4.781655	7.006075	28.033	9.558	18.475	19.018	-0.543
GPS 52	4.782322	7.005458	27.536	9.062	18.474	19.017	-0.543
GPS 53	4.783297	7.00524	27.441	8.824	18.617	19.016	-0.399
GPS 54	4.916897	6.880103	20.494	2.330	18.164	18.791	-0.627
GPS 55	4.916108	6.881155	20.982	2.819	18.163	18.792	-0.629
GPS 56	4.913982	6.880881	20.672	2.488	18.184	18.794	-0.610

Table 2.0 Difference between Observed and Computed Geoid heights from the Model (Post fit) and the Root Mean Square Error

STN. ID	LAT Degree Decimal	LONG Degree Decimal	GPS HEIGHT(h)	Geoid Und. N=(h-H)m	Geoid Model. (N*) m	Difference
1	5.03848	7.00273	47.654	18.14	18.148	-0.008
2	4.98834	7.00544	42.542	18.25	18.25	0
4	4.97225	6.95118	38.771	18.14	18.151	-0.011
5	4.98817	6.95968	41.357	18.26	18.233	0.027
6	4.97687	6.95053	39.485	18.2	18.179	0.021
7	4.96842	6.95077	38.351	18.13	18.137	-0.007
9	4.95495	6.94708	34.627	18.15	18.164	-0.014
10	4.95378	6.94428	36.819	18.17	18.172	-0.002
11	4.97802	6.96892	38.155	17.99	18.015	-0.025
12	4.97662	6.97037	39.661	18.22	18.202	0.018
13	4.97517	6.97196	40.589	18.25	18.228	0.022
14	4.95313	6.95045	35.359	18.18	18.169	0.011
15	4.94971	6.95284	34.766	18.19	18.181	0.009
16	4.94659	6.95511	34.756	18.19	18.192	-0.002
17	4.94301	6.95738	34.79	18.2	18.205	-0.005
18	4.93924	6.95796	34.784	18.21	18.205	0.005
19	4.89316	6.96472	29.266	18.28	18.289	-0.009
20	4.89405	6.96434	29.87	18.29	18.274	0.016
21	4.8933	6.96628	30.338	18.31	18.315	-0.005
22	4.8751	6.95599	32.335	18.32	18.298	0.022
23	4.87564	6.95483	33.256	18.32	18.302	0.018
24	4.87383	6.95501	33.065	18.32	18.292	0.028
25	4.8766	6.95283	33.532	18.09	18.1	-0.01
26	4.83246	6.94564	20.18	18.26	18.276	-0.016
27	4.83244	6.94489	19.557	18.28	18.273	0.007
28	4.83233	6.94412	20.699	18.27	18.269	0.001
29	4.83648	6.92827	20.239	18.27	18.251	0.019
30	4.83739	6.92848	20.984	18.25	18.256	-0.006
31	4.83818	6.92909	23.319	18.26	18.259	0.001
32	4.94082	7.00799	37.527	18.29	18.285	0.005
33	4.94228	7.00802	38.369	18.28	18.289	-0.009
34	4.94398	7.00776	39.567	18.29	18.295	-0.005
35	4.93014	7.0527	40.67	18.36	18.357	0.003
36	4.93174	7.05285	40.87	18.35	18.357	-0.007

37	4.9351	7.05356	38.757	18.36	18.355	0.005
38	4.89088	7.07611	34.478	18.4	18.408	-0.008
40	4.89461	7.07747	37.128	18.39	18.382	0.008
41	4.86292	7.09336	37.962	18.42	18.446	-0.026
42	4.86345	7.09513	38.177	18.42	18.422	-0.002
43	4.8639	7.09699	36.294	18.42	18.395	0.025
44	4.83205	7.12673	34.411	18.5	18.489	0.011
46	4.83573	7.12762	31.881	18.23	18.223	0.007
47	4.76996	7.1403	32.793	18.5	18.524	-0.024
48	4.76941	7.14117	33.017	18.5	18.51	-0.01
49	4.76837	7.14278	33.822	18.51	18.478	0.032
50	4.91198	6.9853	35.117	18.28	18.283	-0.003
51	4.91376	6.98488	35.499	18.27	18.281	-0.011
52	4.91531	6.98379	35.254	18.29	18.277	0.013
54	4.80722	6.97629	29.336	18.34	18.353	-0.013
55	4.80699	6.97722	29.173	18.38	18.366	0.014
56	4.78165	7.00608	28.033	18.48	18.508	-0.028
57	4.78232	7.00546	27.536	18.47	18.495	-0.025
58	4.7833	7.00524	27.441	18.62	18.613	0.007
59	4.9169	6.8801	20.494	18.16	18.165	-0.005
60	4.91611	6.88115	20.982	18.16	18.173	-0.013
61	4.91398	6.88088	20.672	18.18	18.163	0.017
					R.M.S Error	**0.012**

Table 3.0 Difference between Observed and Computed Geoidal Undulation from Gravimetric Geoid (EGM2008) without drappen and the Root Mean Square Error

STN	LAT Degree Decimal	LONG Degree Decimal	GPS HEIGHT(h)	N=h-H	EGM 2008	DIFF
GPS 01	5.038475911	7.002731106	47.654	18.142	18.869	-0.727
GPS 02	4.988341858	7.005441514	42.542	18.248	18.904	-0.656
GPS 04	4.972244803	6.951180808	38.771	18.141	18.832	-0.691
GPS 05	4.988165797	6.959676808	41.357	18.261	18.833	-0.572
GPS 06	4.976870211	6.950525386	39.485	18.196	18.828	-0.632
GPS 07	4.968417417	6.950765697	38.351	18.133	18.834	-0.701
GPS 09	4.95495015	6.947081147	34.627	18.151	18.839	-0.688
GPS 10	4.953781161	6.944284003	36.819	18.171	18.836	-0.665
GPS 11	4.978015694	6.968921853	38.155	17.990	18.854	-0.864
GPS 12	4.976619567	6.970370336	39.661	18.216	18.857	-0.641
GPS13	4.975173192	6.971955836	40.589	18.247	18.86	-0.613
G[S 14	4.953134586	6.950453306	35.359	18.178	18.845	-0.667
GPS 15	4.949708683	6.952838769	34.766	18.186	18.85	-0.664
GPS 16	4.946587319	6.955108775	34.756	18.188	18.856	-0.668
GPS 17	4.943006336	6.957377311	34.79	18.198	18.861	-0.663
GPS 18	4.939244417	6.957961819	34.784	18.215	18.865	-0.650
GPS 19	4.893158592	6.964717458	29.266	18.280	18.904	-0.624
GPS 20	4.89404995	6.964342617	29.87	18.290	18.903	-0.613
GPS 21	4.893297169	6.966278353	30.338	18.314	18.905	-0.591
GPS 22	4.875097889	6.955985178	32.335	18.318	18.906	-0.588
GPS 23	4.875640256	6.954831264	33.256	18.323	18.905	-0.582
GPS 24	4.873833222	6.955013361	33.065	18.323	18.906	-0.583
GPS 25	4.876598708	6.952834056	33.532	18.088	18.902	-0.814
GPS 26	4.832460906	6.945637275	20.18	18.260	18.93	-0.670
GPS 27	4.832444461	6.9448869	19.557	18.282	18.93	-0.648
GPS 28	4.832327742	6.944121753	20.699	18.273	18.929	-0.656
GPS 29	4.836480189	6.928271461	20.239	18.269	18.912	-0.643
GPS 30	4.837388344	6.928477733	20.984	18.254	18.912	-0.658

GPS 31	4.838183467	6.929087211	23.319	18.260	18.911	-0.651
GPS 32	4.940823194	7.007985167	37.527	18.293	18.935	-0.642
GPS 33	4.942280164	7.008015719	38.369	18.278	18.934	-0.656
GPS 34	4.943984306	7.007760989	39.567	18.288	18.933	-0.645
GPS 35	4.930137067	7.052698958	40.67	18.359	19.005	-0.646
GPS 36	4.931735783	7.052849775	40.87	18.349	19.004	-0.655
GPS 37	4.935097586	7.053556919	38.757	18.364	19.004	-0.640
GPS 38	4.890883953	7.076113975	34.478	18.396	19.047	-0.651
GPS 40	4.8946095	7.07747475	37.128	18.388	19.048	-0.660
GPS 41	4.862920831	7.093361511	37.962	18.420	19.076	-0.656
GPS 42	4.863447247	7.095125922	38.177	18.422	19.078	-0.656
GPS 43	4.863901311	7.09699115	36.294	18.422	19.08	-0.658
GPS 44	4.832048442	7.126734136	34.411	18.505	19.121	-0.616
GPS 46	4.835730717	7.127621192	31.881	18.231	19.121	-0.890
GPS 47	4.769962542	7.140300147	32.793	18.502	19.139	-0.637
GPS 48	4.769413628	7.141166558	33.017	18.502	19.14	-0.638
GPS 49	4.7683703	7.14278445	33.822	18.512	19.141	-0.629
GPS 50	4.911981411	6.985296881	35.117	18.283	18.918	-0.635
GPS 51	4.913761719	6.984875258	35.499	18.272	18.916	-0.644
GPS 52	4.91531205	6.983788856	35.254	18.289	18.914	-0.625
GPS 54	4.807218517	6.976286997	29.336	18.341	18.975	-0.634
GPS 55	4.806990144	6.977222258	29.173	18.375	18.976	-0.601
GPS 56	4.781655028	7.006075439	28.033	18.475	19.018	-0.543
GPS 57	4.782321533	7.005458108	27.536	18.474	19.017	-0.543
GPS 58	4.783296731	7.005240433	27.441	18.617	19.016	-0.399
GPS 59	4.916896858	6.880102978	20.494	18.164	18.791	-0.627
GPS 60	4.91610835	6.881154569	20.982	18.163	18.792	-0.629
GPS 61	4.913981969	6.880881275	20.672	18.184	18.794	-0.610
				R.M.S Error		**0.655m**

Table 4.0 Heights Derived from the Model for the Validation Points

Station	**Lat. Degree Decimal**	**Long. Degree Decimal**	**Geoid Model. (N*) m**	**Geoid Undu. (N)m**	**Ellipsoidal Height**	**Orthometric Height from model H*=(h-N*)**	**Observed Orthometric Height (H)m**	**Dff.= H-H*(m)**
GPS 03	4.98113	6.96651	18.145	18.155	40.065	21.920	21.910	0.010
GPS 08	4.95607	6.94939	18.161	18.195	36.427	18.266	18.232	-0.034
GPS 39	4.89241	7.07691	18.392	18.388	36.043	17.651	17.655	0.004
GPS 45	4.83378	7.1273	18.369	18.455	33.432	15.063	14.977	-0.087
GPS 53	4.80793	6.97719	18.374	18.324	29.078	10.704	10.754	0.050
						R.M.S Error		**0.053**

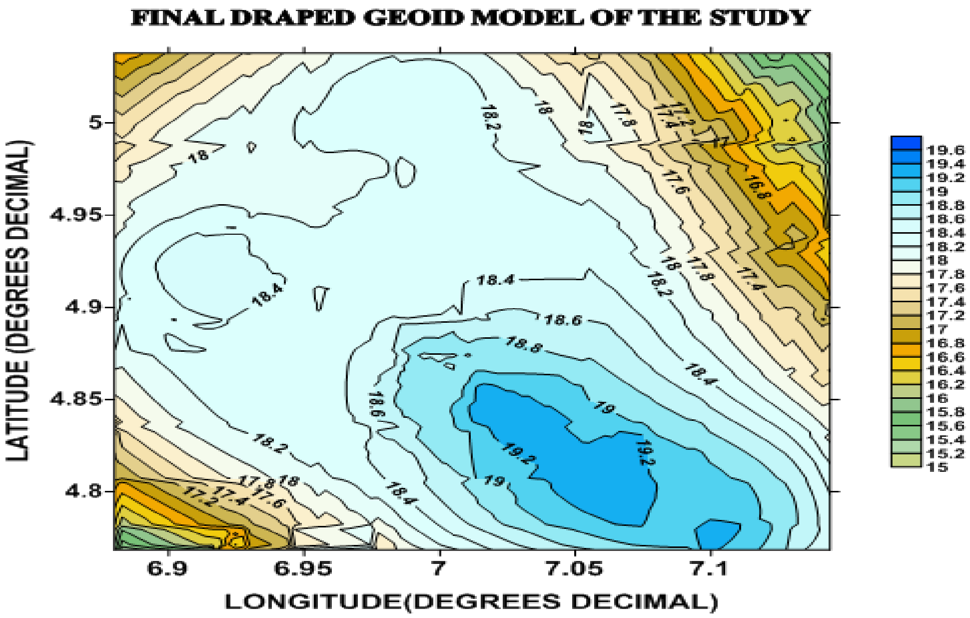


Fig 3.0. TheFinal Draped Geoid Model of the Study Area

VI. CONCLUSION

In the absence of sufficient gravity data for national gravimetric geoid, GPS/Levelling method has proven to be an efficient method of realizing local geoid models for small area. The least squares collocation approach as implemented in the Gravsoft program to provide the best fit (draped) local geoid surface is adequate for most mapping and engineering works. In this work, the performance and applicability of surface fitting methods in geoid modelling using GPS/Levelling measurement in a local area was evaluated as a way of providing adequate national geodetic infrastructure. Local GPS/Levelling geoid has the advantage of high precision and practicality of use, its use is limited as the model only provides reliable results for points within the coverage area of the model, to the exclusion of points outside. Thus, it is important to have a national geodetic infrastructure and for providing uniform height systems

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