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RELATIVE STUDY OF THE ACCURACY OF SPIRIT LEVELING AND GNSS LEVELING

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1.0 INTRODUCTION

The conventional spirit leveling technique and its variants have served the engineering needs of mankind for several years being the basic methods used for height determination by the early surveyors (Vanicek et al, 1980; Odumosu et al, 2016). However, the stressful procedure associated with the field observation as well as the error prone nature of the final computation in spirit leveling makes the technique a rather laborious and time consuming one. The advent of GNSS positioning on the other hand has revolutionised leveling exercise. Modern day surveyors simply take advantage of the 3D positioning capability of satellite positioning techniques to obtain instantaneous height information (Blewitt, 1997).

Several researches has been done to validate the suitability of the interchangeable use of these two height measurement systems especially for engineering purposes (Olaleye et al, ; Nnam et al, 2015), but scientific enquiry of the observational accuracies in the observational techniques yielding both height systems has not been investigated using the method of propagation of errors of the ordinary least squares.

2.0 STUDY AREA

The study was carried out around the arena of Michael Okpara Square, which is located at the heart of Enugu urban. The two known government control points used were MS28 and its azimuth station, SS1MS28. MS28 is located in front of Enugu state Government House while SS1MS28 is located in front of Enugu state House of assembly as shown in figure 1.0 below.

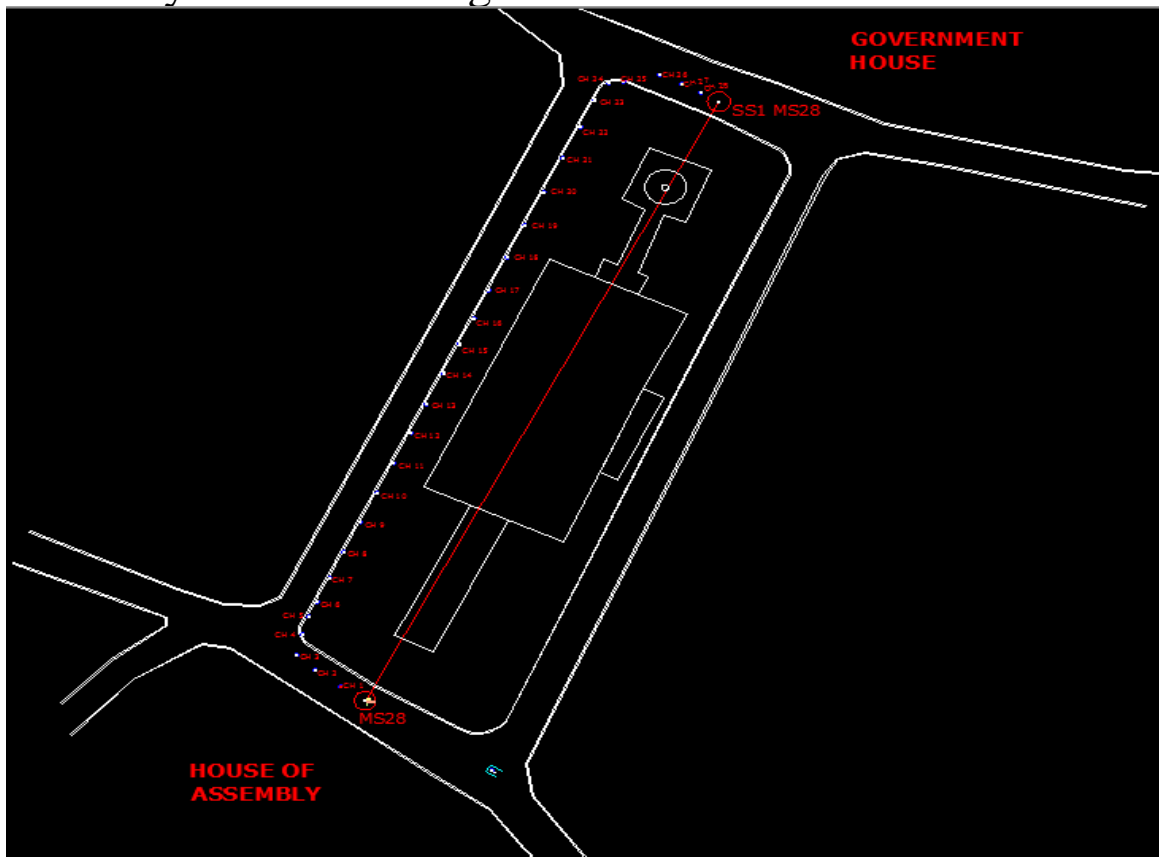


figure 1.0 : Diagram showing the study location

3.0 METHODOLOGY

Twenty eight leveled points along a profile were used for this study. The leveled points covered a distance of about 1km and all standard procedures for eliminating systematic errors and blunders in the observation were followed. The points were located between two standard benchmarks of known Orthometric height. The standard benchmarks used were MS28 and SS1MS28. The height of all points were then determined using both the spirit leveling and GNSS leveling technique.

Spirit Leveling: The two peg test and other tests were performed prior and post field observation to ensure suitability of results and complete elimination of systematic errors. All observations were ensured to have been taken with the level instrument set mid-way between back and foresight. The network observation began on a known benchmark and was closed on another known benchmark. Two lines of spirit leveling were performed along the same route, the first line was observed from the MS28 to SS1MS28 while a closing line was again observed from SS1MS

GNSS Leveling: The static method of observation was employed during the GNSS observations. By static observation, each point was occupied for 25minutes. During the observation, all positioning specifications such as the minimum GDOP, VDOP and HDOP were strictly adhered to. Also error due to multipath was avoided by ensuring that all observations were conducted in open areas with minimal signal interference with buildings and other structures.

3.0 METHODOLOGY CONTD.

The ordinary least squares method of data adjustment is a statistically robust method of determining best fit parameters as well as standard error of observations and parameters. This it does by minimizing the sum of squares of weighted residuals (Okwashi and Asuquo, 2012)

The typical leveling route network adjustment observation equation model was used to generate the design matrix after which all other parameters were determined. The observation equation formed were 28 for each station as exemplified in equ. 1

$$CH1 = BM1 + dH1 + V1$$

$$CH2 = CH1 + dH2 + V2$$

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$$CH28 = CH27 + dH28 + V28$$



equ. 1

The weight matrix was however constituted based on the squares of the distance of each leveling point from the starting benchmark.

4.0 RESULTS AND DISCUSSIONS

Spirit leveling height reduction and adjustment

The forward and reverse line of the spirit leveling operation was computed using the conventional height of instrument method. The mean of results obtained from the height of instrument method computation in both forward and reverse lines of leveling are as presented in table 2. As a check towards ensuring the absence of systematic errors, standard computational checks were employed as summarized in table 1 below:

Table 1: Check on Leveling computation

Forward leveling line	Reverse leveling line
Sum of back sight = 6.5811	Sum of back sight = 11.2975
Sum of fore sight = 9.14141	Sum of fore sight = 8.7372
Difference = -2.56031	Difference = 2.5603

GNSS Leveling orthometric height determination

An empirical geoid model of the study area was used to convert the GNSS/Leveling determined heights into their orthometric equivalent. The determined orthometric heights were then subjected to similar adjustment exercise as the spirit leveled elevation differences and the obtained results are as presented in table 3:

Table 2: Summary of adjustment of spirit level heights

Sta_ID	Mean spirit level Ht(m)	Least squares adj Results				Residual (Level Ht - Adj Ht)
		Mean Adj Ht(m) _spirit Level	Std. dev(m)	Error (m)	Std. dev_unit weight (m)	
CH 1	189.6696	189.669	0.0001	0.00009	0.00000234	0.0006
CH 2	188.9810	188.980	0.0002	0.00010		0.0006
CH 3	188.7697	188.769	0.0003	0.00013		0.0005
CH 4	188.86974	188.869	0.0005	0.00015		0.0005
CH 5	188.9698	188.969	0.0006	0.00016		0.0004
CH 6	189.0699	189.069	0.0008	0.00018		0.0004
CH 7	189.1699	189.169	0.0010	0.00019		0.0006
CH 8	189.26998	189.270	0.0012	0.00021		0.0004
CH 9	189.37004	189.370	0.0014	0.00022		0.0003
CH 10	189.4701	189.470	0.0017	0.00023		0.0003
CH 11	189.5702	189.570	0.0019	0.00025		0.0003
CH 12	189.67022	189.670	0.0022	0.00026		0.0002
CH 13	189.77028	189.770	0.0024	0.00028		0.0002
CH 14	189.8703	189.870	0.0027	0.00028		0.0002
CH 15	189.8756	189.875	0.0030	0.00029		0.0001
CH 16	189.9345	189.934	0.0033	0.00030		0.0001
CH 17	189.9704	189.970	0.0036	0.00028		0.0002
CH 18	190.1270	190.127	0.0039	0.00031		0.0000
CH 19	190.3450	190.345	0.0042	0.00035		0.0001
CH 20	190.4267	190.427	0.0046	0.00033		0.0001
CH 21	190.5346	190.535	0.0049	0.00030		0.0001
CH 22	190.5612	190.561	0.0052	0.00038		0.0001
CH 23	190.7214	190.721	0.0056	0.00035		0.000050
CH 24	190.8645	190.864	0.0059	0.00033		0.000033
CH 25	191.2118	191.212	0.0062	0.00031		0.000008
CH 26	191.4592	191.459	0.0067	0.00044		0.000033
CH 27	191.6065	191.607	0.0071	0.00042		0.000008
CH 28	191.9539	191.954	0.0075	0.00039		-0.000017

Table 3: Summary of adjustment of GNSS/Leveling derived heights

Sta_ID	Mean spirit level Ht(m)	Least squares adj Results				Residual (Level	Ellipsoidal Ht (m)
		Adj GNSS derived Ht(m) _spirit Level	Std. dev(m)	Error (m)	Std. dev_unit weight (m)	Ht - Adj Ht)	
CH 1	189.6696	189.857	0.003	0.00065	0.0004036	-0.1874	211.6116
CH 2	188.9810	189.095	0.013	0.00153		-0.1140	211.3496
CH 3	188.7697	189.150	0.025	0.00270		-0.3799	211.8042
CH 4	188.86974	188.841	0.042	0.00408		0.0292	211.1082
CH 5	188.9698	188.601	0.059	0.00525		0.3684	211.2560
CH 6	189.0699	189.070	0.071	0.00630		-0.0005	211.1250
CH 7	189.1699	189.069	0.085	0.00630		0.1008	211.0238
CH 8	189.26998	189.672	0.099	0.00856		-0.4024	210.9271
CH 9	189.37004	189.596	0.113	0.00969		-0.2255	210.8503
CH 10	189.4701	189.445	0.127	0.01082		0.0247	210.7002
CH 11	189.5702	189.374	0.141	0.01199		0.1965	210.6285
CH 12	189.67022	189.266	0.156	0.01316		0.4038	210.5213
CH 13	189.77028	189.457	0.170	0.01429		0.3137	210.4115
CH 14	189.8703	189.835	0.184	0.01542		0.0353	210.3385
CH 15	189.8756	189.971	0.198	0.01655		-0.0949	210.2255
CH 16	189.9345	189.831	0.212	0.01768		0.1037	210.1363
CH 17	189.9704	189.737	0.226	0.01881		0.2332	209.9923
CH 18	190.1270	189.841	0.240	0.01998		0.2860	209.9392
CH 19	190.3450	190.716	0.255	0.02115		-0.3705	209.9706
CH 20	190.4267	190.265	0.269	0.02228		0.1617	211.2201
CH 21	190.5346	190.440	0.283	0.02341		0.0944	211.6953
CH 22	190.5612	190.536	0.297	0.02454		0.0250	211.7913
CH 23	190.7214	190.725	0.311	0.02567		-0.0034	211.9799
CH 24	190.8645	190.861	0.325	0.02680		0.0038	212.1158
CH 25	191.2118	191.198	0.339	0.02797		0.0135	212.4534
CH 26	191.4592	191.473	0.354	0.02914		-0.0134	212.7278
CH 27	191.6065	191.637	0.368	0.03027		-0.0305	212.8921
CH 28	191.9539	191.954	0.382	0.01542		0.0004	213.2086

5.0 DISCUSSION OF RESULTS

Tables 2 and 3 indicate significant differences between the spirit-leveled adjusted heights and the GNSS/Leveling derived heights. Table 4 shows a summary of statistics of the adjustment of the results from both observational techniques; while tables 5 and 6 show the stations with the strongest and weakest standard deviations and error propagation levels in both techniques. The non correspondence of the maximum and minimum value station in both techniques shows the random and independent nature of the error in both observations.

It is however obvious as shown in figures 1, 2 and 3 that the spirit leveling heights generally have lower observational standard deviation and propagated error than the GNSS/Leveling observations. The results therefore show that although the spirit leveling provides better observational accuracy with standard deviation ranging from $\pm 0.0001\text{m}$ – $\pm 0.0075\text{m}$ and propagated error ranging between 0.0001m – 0.0004m within the study area, the GNSS/Leveling is also able to produce observed height to about $\pm 0.4\text{m}$ residual from the spirit leveled heights with standard deviation ranging from $\pm 0.003\text{m}$ – $\pm 0.382\text{m}$ and propagated error ranging between 0.00065m – 0.03027m .

Table 4: Stations with Maximum and minimum observational error in both techniques

	Summary of observed error values							
	Maximum error				Minimum error			
	Sta ID	Obs Residual	Std dev	Prop. Error	Sta_ID	Obs Residual	Std dev	Prop. Error
Spirit Lev	CH1	0.0006	0.0001	0.00065	CH25	0.000008	0.0071	0.0004
GNSS/Lev	CH12	0.4038	0.156	0.013	CH8	-0.4024	0.099	0.00969

Table 5: stations with maximum and minimum observational standard deviation

	Sta_ID	max. Std dev	min. Std dev
Spirit Lev	CH1	0.0075	0.0001
GNSS/Lev	CH12	0.382	0.003

	Sta_ID	min. Pro error	Sta_ID	max. Pro error
Spirit Lev	CH1	0.0001	CH27	0.0004
GNSS/Lev	CH1	0.00065	CH27	0.03027

Comparative plot of propagated Error in both observation techniques

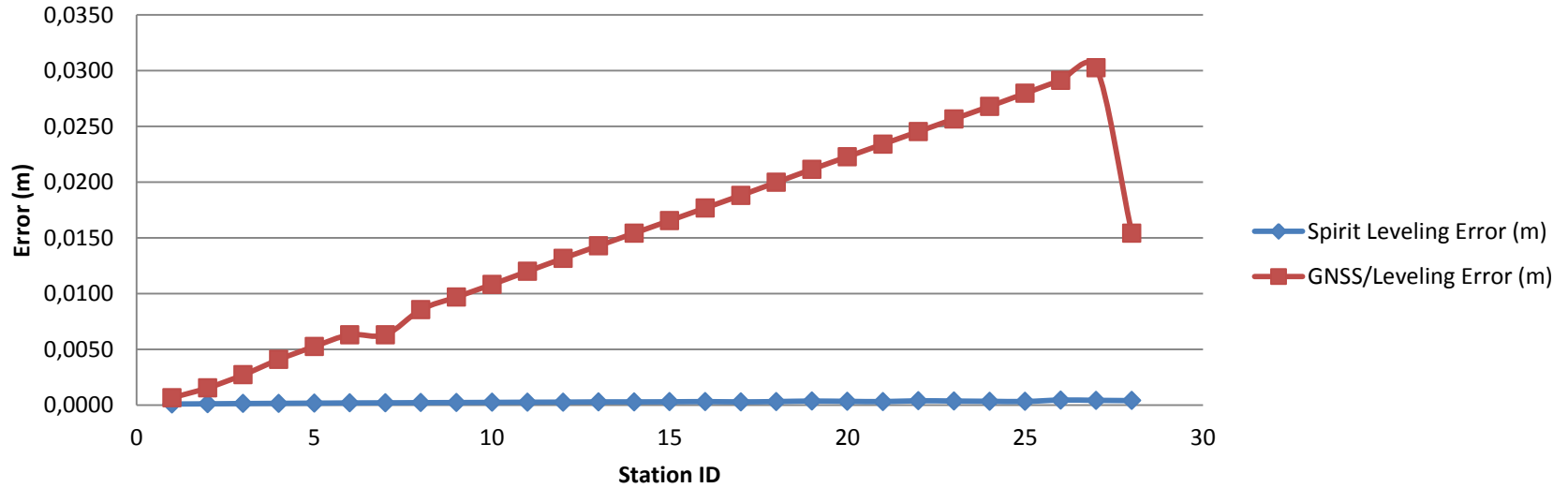


Figure 2: plot of values of propagated error from both techniques

Comparative plot of Orthometric and Ellipsoidal Heights

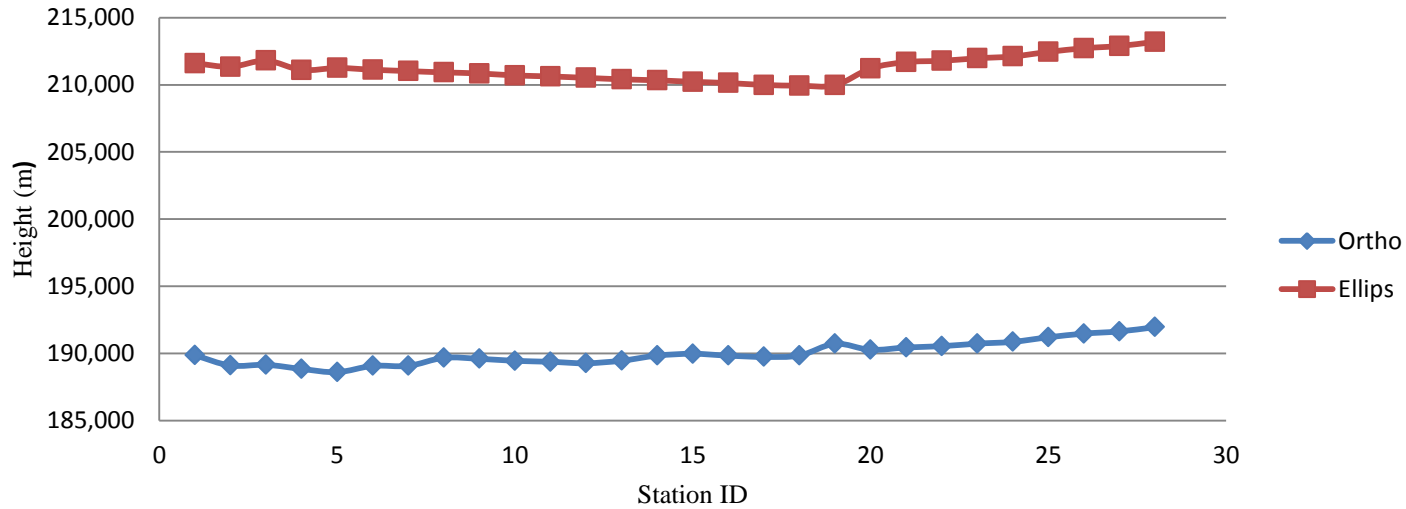


Figure 3: Orthometric and ellipsoidal heights pattern along the observed profile.

Comparative plot of observed differences between final adjusted result from both techniques.

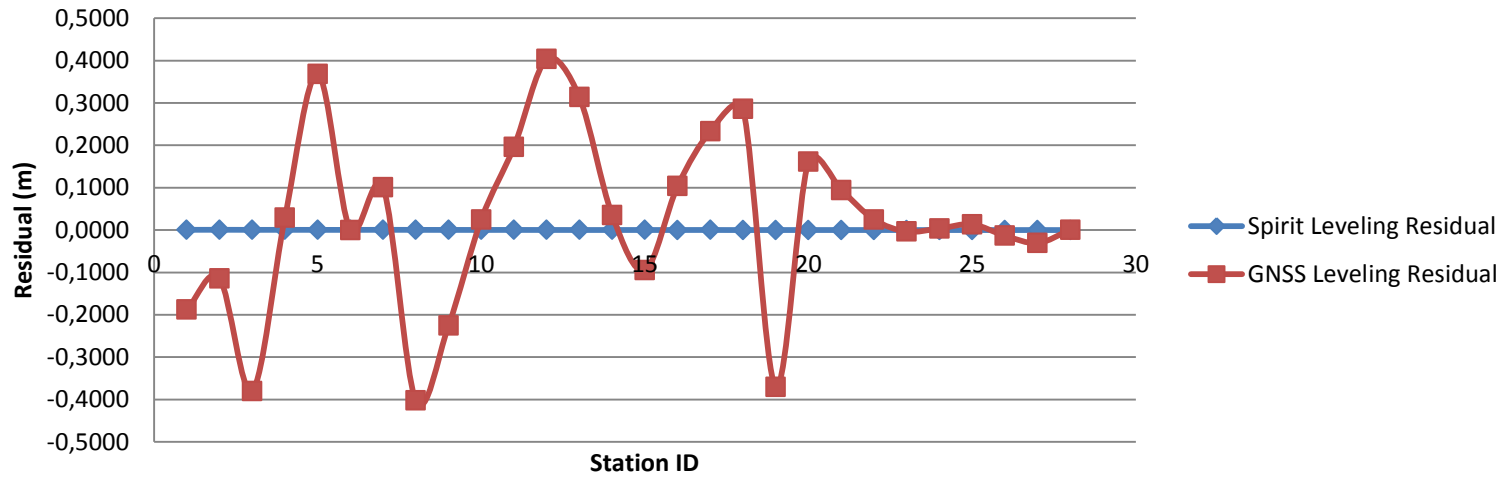


Figure 4: plot of residuals of adjusted spirit leveled heights and adjusted GNSS/Leveling heights

Comparative plot of observation standard deviation of both techniques

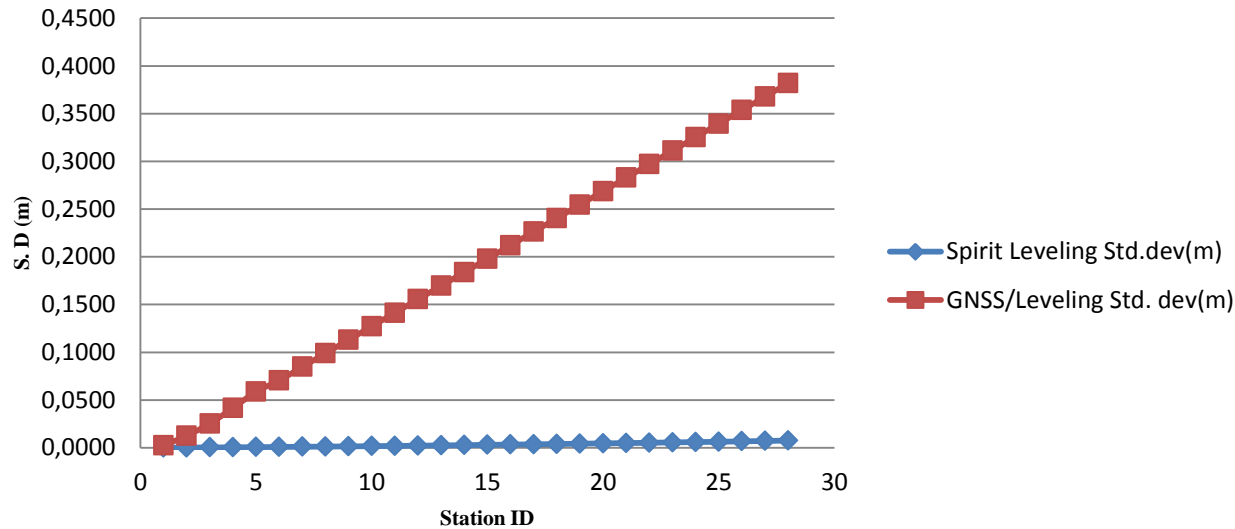


Figure 5: plot of values of standard deviation at stations from both techniques.

6.0 CONCLUSION

This experiment has identified the spirit leveling technique as the more accurate observational technique of leveling although, the GNSS/Leveling method of observation was similarly found to yield observations with third order accuracy standard errors. This method of leveling is therefore suggested as a suitable alternative in engineering and other non-geodetic surveys for quick height determination once a suitable geoid model of the area is available. The study similarly disallows the replacement of Orthometric heights with ellipsoidal heights. It is suggested that increased occupation time during observations might increase the accuracy obtained in the GNSS/Leveling operation.

7.0 REFERENCES

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