Astronomy And Gravity Surveying In Nepal

Punya Prasad Oli
Former Director General

1. *Abstract*

Astronomical observations and gravity measurements were carried out in Nepal along the boundary since 1800. They are very important due to high deflection of verticals with irregular variation. It is also impractical to carry out precise levelling with conventional method due to large variation of relief at a short distance. Absolute gravity points are established in Siddharthanagar- Pokhara and Eastern part of Nepal in 1996 with micro gal accuracy. The gravity observations carried out on first order and some GPS stations. Gravity and astronomical observations are necessary in GNSS method of establishment of control points to compute orthometric (geoidal) heights.

Astronomical observations of points are useful to calculate deviation of verticals to determine the GPS heights, controlling the geodetic network and change in longitude, latitude and azimuth of control points and crustal and local dynamics. The fixed astronomical observatories are now used to determine the precise positioning of points.

Astronomical observations carried out in Nepal since the Prehistoric era. Chhatedhunga (stone hinges) are visible all over in hills of Nepal. The book Sumati Tantra" in 576-880 and "Sumati Shidhanta" written 1409 written and later in Sanskrit and Nepali. However, no modern survey records are available of astronomical and gravity observations for survey work before 1924.

The first survey of Nepal carried out astronomical and gravity observations in 1924-27 to produce 1=" 4 mile maps and in 1950-58 to produce 1"= 1 miles maps, were produced. Base line and astronomical observations carried out during boundary survey 1960-61. After establishment of Geodetic and Astronomical Branch on Survey Department, modern astronomical observations were carried out using astronomical theodolites like Wild T4, DKM3 /Circum Zenithal manually to determine the latitude, longitude, azimuth and deviation of verticals in 1970-90. Geodetic astronomy will be used in future to determine deviation of verticals to determine precise height, geoidal spheroidal separation and cm or better height determination. Geodetic total station, digital imaging sensor, GPS for timing and determination of geodetic coordinates, and personal computer will be used in the field.

Gravimetry will be extensively used in determination precise coordinate, geopotential datum instead of mean sea level and geoidal spheroidal separation. The absolute and relative gravimeters using digital technology are available of mgals (1 mgal= 3.25 mm of height) precision. Nepal is facing same problem of lack of dense control points point with required accuracy as in 1970s where topographical control points with accuracy of 2-18 m and at 25 Km interval and lack of surveyors and draftsmen. The 0.5 -1m accurate and at about 1 Km distance plannimetric control points was the requirement of that time for cadastral mapping. The plannimetric and height control points of cm accuracy and at about 5 Km distance for digital mapping, and environmental and infrastructural development works, and survey graduates to operate the modern automatic instruments and technologies are the requirement of present time.
It is recommended that the survey Department conduct study to strengthen the Nagarkot observatory and first and second order control networks and provide cm accuracy control points on urban areas, and level network on Himalayan Region.

2. Definition of Terms

Astronomical observation

Astronomical observation are the observations of celestial bodies to determine azimuth, deviation of verticals, figure of earth, correction of coordinates and observation for astronomical events.

Equipotential Surface

Equipotential Surface is the surface where the gravitational potential is same along the surface, which is also called levelled surface.

Deviation of verticals

Deviation of verticals at any point on ground is the angle between plumb lines and spheroidal normal.

GNSS (Global Navigation Satellite System)

GNSS (Global Navigation Satellite System) is the methods of determination of spheroidal coordinates using navigational satellites of systems like GPS, Glonass. These points may be continuously observed Receiver (COR) or accurately fixed points repeated every 5/10 years.

Gravimetry

Gravimetry is branch of geodesy where acceleration due to gravity(g) at different points on/over the earth surface is measured to study the shape/form of the earth, distribution of density within it and its external gravity field and to determine equipotential surface.

Geoidal- spheroidal separation (N)

Geoidal- spheroidal separation (N) is difference of height between geoid and reference spheroid surface at point measured along the plumb line.

3. Background

Nepal is situated on the slope of Himalayas where elevation varies 60 m to 8850m at short distance. There are few roads and deviation of vertical varies from -21" at Bhadrapur, Jhapa, to -43" at Nagarkot and -70" at Siranchok. The geoidal - spheroidal separation varies from 12 m at Sandakphu (Ilam), 0 m at Nagarkot and to - 21 m at Nepalganj. It is also difficult to carry out precise spirit levelling in northern part of Nepal. Therefore, it is required to be carried out either by trigonometrical or GPS levelling along with Astro-geodetic and gravimetric observations. The nearest sea shore of Bay of Bengal is more than 850 km in foreign countries. The elevations in Nepal are based on the 1930 mean sea level of Bay of Bengal. It is required to convert the mean sea level datum to equipotential datum surface in Nepal.

The equipotential surfaces are also not parallel/variation of gravity to each other due to isostasy, where the thicker crust and Moho (rocks) varies in thickness 20-47 km below the surface of Nepal.

The India plate is colliding with Eurasian plate 20 Km below the Himalaya at northern part of Nepal and it is approaching each other at the speed of 18 mm/year at north- east direction and rising 10mm/year. The other southern parts are changing with various degrees of movement and height is rising 2 mm and 4 mm per at tarai and hill respectively. Some places are also sinking due to geological or human activities.

The control points established and coordinated for surveying and mapping are being used for development purposes. Their accuracy and the status (rate of movement) are needed to verify and required to reobserve to achieve the required accuracy. It is very critical for large scale construction and scientific purposes. There are also lacks of awareness on accuracy requirement and importance of these points to public and surveyors.

During mapping and crystal dynamics study, gravity observations were made at first order (Trigonometrical, some spirit levelling and GPS) control points. Absolute gravity points were established Bhairahawa - Pokhara and eastward. The astronomical observations were made on control points in hill and tarai. It is also required to establish along Himalayan and north of Himalayan regions.

The control points mostly established 1970- 2000, which may have moved more than decimetres and will not be sufficient for precise mapping and development works. The educational situation is also changing. There will be lack of educated and trained staffs to handle the recent development of surveying and mapping technologies.

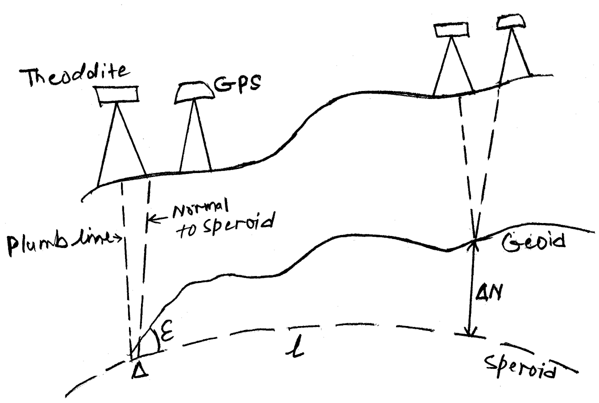
4. Introduction

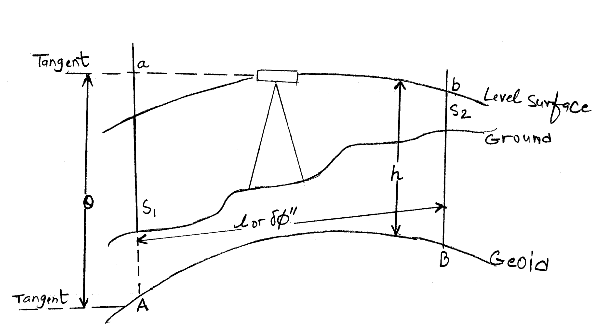
Most of geodetic control data required as control points of surveying and mapping, planning and implementation of development activities. Present and future surveying and mapping will be creation of accurate spatial data (digital maps) for development and GIS. Therefore, control points are required of cm accuracy. Earlier decimetre or 1m accurate 4^{th} order points are longer useful to surveying and mapping for development works. The trigonometrical control points are also not available on most of the urban areas and tarai areas, where development activities are taking place at greater speed. The control points/ land surfaces are also moving at different rate and points are also destroyed by development and other activities. The heights of trigonometrical control points need to be accurately measured. Therefore, it is high time the Geodetic Survey Branch should establish or re-observe all 1st, 2nd and 3rd order trigonometrical control points using GPS with appropriate gravimetric/astronomical observations. All GPS control points data be available to development projects including established by National Geographical Information Infrastructure Project.

Geodetic control points are generally established with GNSS (Global Navigation Satellite System e.g. GPS) or conventional methods. Bench Marks established using precise spirit levelling along the roads. Combining GPS with gravimetric observations or spirit levelling will also be used for precise levelling about 5 Km intervals. The coordinates (WGS84) obtained from GNSS are spheroidal coordinates and are required to convert geoidal/ orthometric heights and national coordinates system.

Astronomical observations will be carried out to observe azimuth and deviations of verticals i.e. deflection plumb line at that place. The latitude and longitude and polar motion will be better determined by GPS continuously Operating Receiver (COR), which are generally maintained at 100- 500 Km interval.

Gravity observations are required to observe at every BM (2 Km) in mountain and 5-10 Km interval in tarai with accuracy of ±0.1 m gal. Equipotential surface or equal gravity surface may not be parallel to each other that depends inner structure of rock. The geoid /orthometric height difference be define as following.





$$\delta o = \delta h + \theta l = \delta h - \frac{hl}{g}\left(\frac{dym}{dl}\right)$$

where δh = diff. of staff readings

δo = diff. of orthometric height,

$$\theta = -\frac{h}{g}\left(\frac{dgm}{dl}\right) = \frac{Bb - Ab}{AB} = \frac{diff.equipotatialsuface}{dis\tan cebetweentwostaff}$$

$$g = \frac{1}{h} = 978.032\,(1 + 0.0053\sin^2\phi - \frac{2h}{R})\ \text{gal} \quad \text{------------- (1)}$$

$$g = \frac{1}{h} = 978.03184558(1 + 0.00530236\sin^2\phi + 5.850 \times 10^{-6}\sin^2 2\phi + 3.2 \times 10^{-8}\sin^2\phi.\sin^2 2\phi) \quad \text{(1a)}$$

Where l = length is between to staffs

g = geopotential or gravity at a point,

R = mean radius of earth

h, ϕ = height and latitude of the point respectively.

The deviation of verticals also affects the vertical angle, as following,

$$\Delta N = NB - NA = \frac{1}{2}(\psi A'' + \psi B'')l\sin l'' ....2$$

$$\psi = -(n\sin A + \xi\cos A)$$

Where η, ξ deviation of verticals obtained from astronomical observation.

A= Azimuth

ΔN is error in height due to deviation of verticals.

$$\varepsilon^2 = \eta^2 + \xi^2$$

$$\Delta N = l * \tan\varepsilon, \quad (3)$$

Where l is distance between points.

5. Historical Background

5.1. Astronomical observation

Astronomical observations were carried out in Nepal since prehistoric era. Stone hinges (Chhatedhungas) are visible from Memeng, Sikkim border, Chhatedhunga, Dolphu, Mugu and west ward. The books "Sumati Tantra" in 576-880, "Sumati Siddhanta" and "Bhaswati" were translated in Nepali language 1496-1845 and various books were written in Sanskrit/Nepali after unification of Nepal 1793. However, records of modern astronomical surveying are not available before 1924.

Earlier astronomical works were mostly used for determination of azimuth by sun/star or Polaris observations. Availability of good Theodolites, latitude, longitude, azimuth and deviation of verticals were observed.

Latitude, longitude, azimuth and baseline were observed at Kathmandu valley and azimuths were cheeked during 1924-27, and at 25-30 stations during 1950- 58 survey to compile 1"- 1mile maps of Nepal.

Systematic astronomical observations were carried out after establishment of Geodetic Survey Branch (then, Trigonometrical Survey Branch) in 1968. The astronomical observations for azimuth and deviation of verticals carried out, at Nagarkot and other 6 stations during 1971/72&1976/77 with the cooperation of Czechoslovakia survey team. The observation for , azimuth and deviation of verticals were observed other 35 statious during 1981-84 with cooperation 19th Squadron of British Army.

The astronomical observatory, fundamental stations were established in 1972 and circum Zenithal instrument was set up in 1977 and observations were made for Polar motion at Mahadev Pokhari. Various astronomical events were observed since than. However, GPS superseded astronomical observations for establishment of control points and crustal dynamics in 1992 on word. Astronomical observations will continued to be important for precise determination of coordinates, and deviation on of verticals.

5.2 Gravity observation

Precise gravity data are necessary to adjust any precise survey measurements like levelling, GPS or study of geology. The gravity observation was carried out during Great Triangulation of India in 1800-40 with precise pendulum observations to the stations on or near the boundary and the study of Gulatee in Eastern Nepal in 1852. Gravity Division was established in 1980 and gravity measurement were made on BMs.

The gravity observations were carried out at the trig. Stations and on some bench marks during the High Trig. Survey works in 1981-84 using La Coste Romberg and Warden Gravimeters.

Absolute gravity data was transferred to Gauchar (Tribhuwan) Airport from Bangkok in 1970. It was strengthened in 1990.

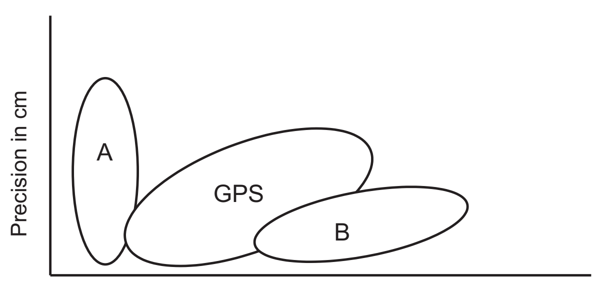
The gravity observations to milli-gal accuracy were observed in most of the first order GPS stations, crustal dynamic study and some other 2nd order GPS control stations in 1992-96 to provide control points for topographic mapping. It was also observed during the crustal dynamic study in 1990-2004 with the assistance of Colorado University.

Dept. of Mines and Geology is also conducting various types of gravimetric survey for prospecting mineral resources and seismic study since 1971 with or without assistance of friendly countries.

The absolute gravity stations at Kodari, Kathmandu, Sim Bhanjhyang , Mahadev Pokhari, Simraha, Biratnagar, Bairahawa and Tansen (8 stations) were established with the assistance of National Geodetic Survey , USA with few micro gal accuracy in 1996 using JILAG 6 Gravimeter. Western part of the country could not be observed due to lack of bridges along the highway and time constrain.

6. Present status of Technology

Precision Requirement and Methods



A= Terrestrial Method
B= VLBI/SLR

6.1 Astronomy

The present situation of Astro-geodetic surveying in developed country is as following:

Determination of deviation of verticals is the main tasks of geodetic astronomy and astronomical theodolite is replaced by digital technique such as total station/ astrolabe, charged couple devices (CCD) sensors, GPS receiver as an atomic clock and instrument to determine geodetic coordinates and computer in the field. The operations are more or less automatic. Crustal dynamics, polar motion, etc are determined by GPS observations. The regions, like Himalayan with high deviations of verticals and variation coordinates need to study for deviation of verticals at a closer interval.

The astronomy used to determine deviation of verticals, precise levelling, and cm level coordinates with gravity data in mountainous area, geophysical prospecting, validation of gravimetric modelling and GPS and gravimetric heights, precise (0.1 mm) geoidal height, astronomical positioning at sea. Fixed telescopes, space telescopes, satellites or probes carry out the study of solar system and deep space.

The instruments and techniques used in astro-geodetic works and accuracy achievable are as following as described by Christian Hirt, Hanover, Germany and Beat Burki, Zurich, Switzerland in 2006:

i) Geodetic coordinates (f,l) are easily determined by GPS on related reference spheroid. The differential positioning techniques will give coordinates (f,l,H) in some centimetres accuracy (milli arc second, mas).
ii) Star catalogues: - The 1-mas -Hypparcos star catalogue is available. The highly densified catalogue of couple of millions stars Tycho-2 and UCOC were compiled. Their accuracy level is of 0."2- 0."1. In coming 10 years time, micro arc second accuracy catalogue will be available.
iii) Image coordinates (x, y):- The digital image acquired by CCD sensors is highly sensitive and applied digital image processing. The accuracy of single pointing of star and computation will be about 0."2- 0."4 within 20 minutes observations.
iv) Refraction: - The error due to unknown factors of atmospheric refraction is yet being studied. The zenith atmospheric refraction on flat area is about 0.01" and 0."1 in mountain areas.
v) Timing: - The accurate timing will be provided by GPS, which is done synchronizing with GPS time scale and transferring to astronomical observations. The accuracy will be microsecond to nanosecond depending on the transfer device.
vi) Tilt Measurement: - The levelling of instrument is done by electronic level (tilt sensor) which has sensitivity of 0."04 - 0."05.

Gyroscopes are also developing to required accuracy.

6.2. Gravimetry:

Gravimetry along with GPS will bring the coordinates to the ground surface or geoids surface. Absolute gravimeters are miniaturized and in portable sized and weights. The accuracy of ±1 mgal could be achieved using gravimeters like potable La Coste - Romberg gravimeters. The Relative gravimeters have also improved their accuracy better than mgal to tens of m gal. The air borne or satellites borne gravimeters are also used for mineral study and global geoidal observations. Developed countries are planning to use gravimetric geoid based vertical datum like USA, Canada planning to switch gravimetric based vertical datum in 2012. Most of the developed countries are planning to establish control points 1 cm accuracy using GPS and gravimetric observations. So, it is developing very fast and software of various gravimeters are also available in the market.

7. Present Situation in Nepal

7.1. Astronomy

The astronomical instrument - Kern DKM3 are being used in Geodetic Branch. Circum Zenithal instruments are no longer used which may be used with CCD sensors, GPS and computer. Ministry Environment, science & Technology also installed 42 cm Mead Telescope at Mahadev Pokhari.

7.2. Gravimetry

Geodetic Survey Branch has Worden Gravity Meters of accuracy ± 10 m gal? and trained operators and one researcher. Similarly Dept. of Mines and geology has some instruments.

It will require one absolute portable gravimeter and relative gravimeters for observation on BMs at 2 Km interval in hill and 10 Km intervals in tarai area or as per the method establishment of control points. The branch is also required to assist graduate level courses in gravimetry observation training and education.

Education in astrometry (geodetic astronomy) and facilities are non-existence. The training materials accession and book are also not available in the market. There are few persons who can carry out the astronomical observations.

8. Future courses of actions

The digital mapping, and planning and development activities necessitated precise control point of 1cm accuracy x, y, height, which can only be provided by knowing deviation of verticals, gravimetry or precise levelling. The Geodetic Survey Branch should study the available technology and carryout the re-observation of Ist & 2nd order control points and established new accurate control points on 100 or so urbane areas of Nepal. The following actions should be taken for the development of astronomical and gravity observation:

8.1 Astronomical observation

i) Deviations of verticals should be observed in hill and mountain stations after studying requirements and available technologies and their suitability.

ii) An observatory is established to study solar system and deep space to a suitable location north of the Himalayas.

iii) Geoidal spheroidal separation to be determined in tarai and valleys 5-10 km interval using GPS and precise levelling.

iv) Survey Training and education be reform to cater the needs of astronomical and gravimetric observations.

8.2. Gravimetry

i) Gravimetric observation covering the whole country is carried out after studying the available technology, geoidal shape of the country and requirement precise and accurate plan and height control points. Possibly a set of absolute gravimeter and new sets of relative gravimeters may require carrying out the works.

ii) The vertical datum of Nepal, 1930 mean sea level of Bay of Bengal is re-defined by gravimetric datum from new observations.

iii) The absolute gravity stations also be established western and northern part of country.

iv) The branch should publish at regular interval the geoidal spheroidal separation maps /data of Nepal.

9. Recommendation

Lot of works carried out in Nepal on astronomical and gravimetric observations with or without assistance foreign donors. The technology is developing and younger educated surveyors//researchers are also needed and cater the need of modern technologies. The astronomical and gravimetric activities should lead to cater the needs of national and societal services.

The meter accuracy control points are no longer useful to digital mapping and development works of urban and rural areas. Therefore, the branch should study and direct it activities to cater the needs of development activities.

References

Supplementary materials "General Himalayan Earthquakes and the Tibet plateaus" - by Nicol Fildl and Roger Bilhan, Colorado University.

Report and results of survey in nepal 1981 to 1984. DOMS/DOD UK

Geodesy by G Bomford, 1975, Oxford at the Clarendern Press.

The National Geodetic 10 year Plan, Mission Vision & Strategy, NOAA, Department of Commerce (NGS 10 years plan) 2/12/07.

Opportunities for Surveyors in modern Land Markets, Prof I .P. Williamson, Australia, August 2005, FIG.

Status of Geodetic Astronomy at the Beginning of 21st Century, Christian Hirt, Hanover, Germany, and Beat Burki, Zurich, Switzerland, 2006

Comparative Study between Astro-geodetic Methods used in determining vertical Deflection, O. Badescu, R. Popescu, P Popescu, Bucharest, Romania.

Final Report of Ground Control Surveys, Vol 3, Definition of Gravimetric Geoid, Department of Survey, FM-International FINNMAP, June 1997.

Appendix 1

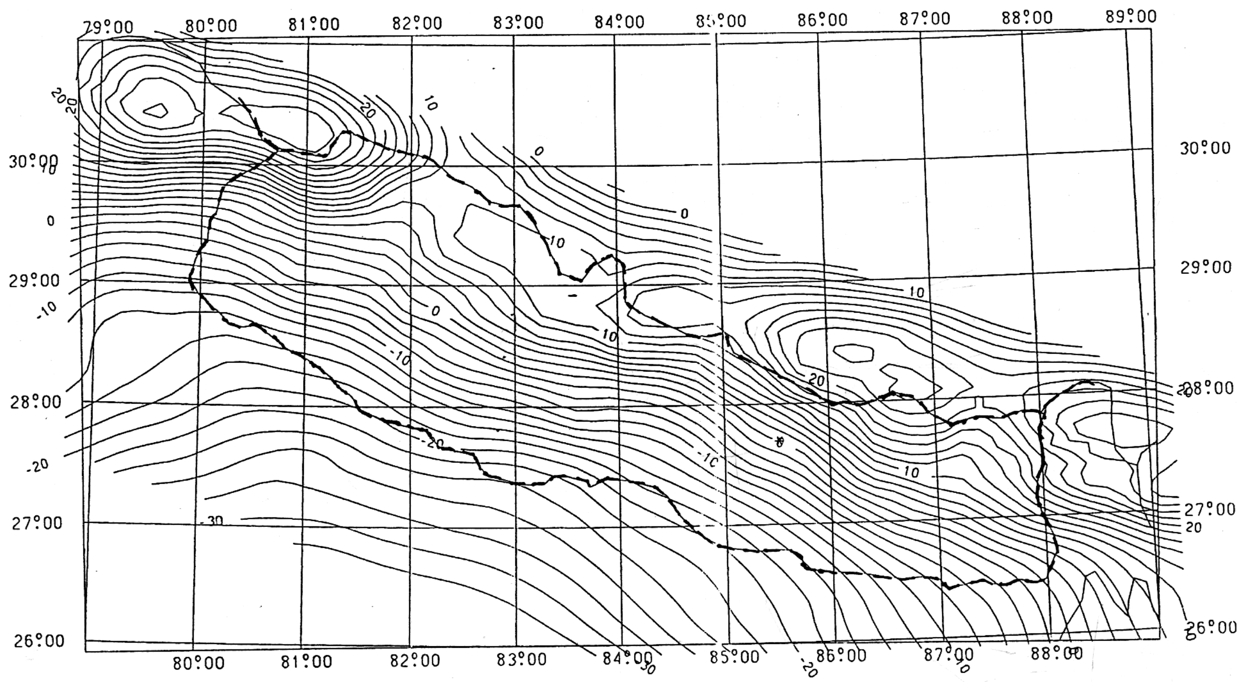
Nepal Datum Everest Spheroid- Deflection of the Verticals

Nepal Station Ref.	Station Name (*Denotes a former Survey of India station)	Nepal Datum Everest Spheroid 1830, Preliminary geodetic position		Deflection of the verticals		Geoidal Spheroidal separation N	India MSL elevation (L=leveled value)	Remarks
		Latitude N	Longitude E					
		° ' "	° ' "	Meridian " ξ	Prime vertical. " η	m	m	
	Bhadrapur Doppler 31348	26.5482	88.0906	-13.9	-15.9	3	86.84L	
	Harkate	26.8319	88.0893	-44	-12 Est.(±5")	8	1839.4	
	*Sandakphu	27.1033	88.0006	-46.4	-14.4	12	3631.6	
	Mainachuli	26.6912	87.8275	-32	-18 Est.(±5")	3	652.2	
	Batase Danda	26.9797	87.7058	-42	-25 Est.(±5")	6	2271.8	
11/166	Tinjure Danda	27.1785	87.4539	-36.8	-16.5	7	3033.0	
4/172	Dhaje (Doppler 31343)	26.8658	87.3948	-42.8	-23.7	0	2047.6	
	Biratnagar TWR, S leg	26.4611	87.2887	-15.4	-18.9	-3	73.31L	
1/171	Bopung sokope	26.9501	86.9482	-42	-20 Est.(±5")	-3	1782.1	
1/165	*Laore Danda	27.3722	86.9224	-48.9	-17.7	6	3619.6	
	Rajbiraj Doppler 31349	26.5452	86.751	-18	-20 Est. (±3")	-7	71.7	
2/171	*Chitretham	27.0201	86.6166	-38	-18 Est. (±3")	-4	2344.4	
1/164	Dimba (Doppler 31356)	27.4651	86.3661	**-48.6**	**-42.5**	4	3356.3	
2/164	Rachnetham Danda	27.1172	86.3051	-42	-25 Est. (±5")	-5	2212.5	
	Siraha Astro. stn	26.6594	86.2182	-15.1	-21.4	-11	77.8	
3/164	Lendrungchuli	27.2233	86.0338	-44	-28 Est. (±5")	-5	1898.5	
12/163	Bag Dhunga	27.5613	85.9766	-43.7	-33.1	2	3149.1	
	Janakpur Doppler 31350	26.7103	85.9269	-10	-22 Est. (±3")	-12	70.09	
13/163	Hatiyal danda	27.4348	85.5971	-47.3	-28.1	-5	2631.4	
	Malangawa astro STN	26.8634	85.5721	-11.3	-25.9	-13	82.33L	
12/157	*Nagarkot (pillar)	27.692	85.5223	-37.0	-21.6	0	2165.32	
19/108	Gairikhop danda	27.1977	85.399	-37	-25 Est. (±3")	-12	866.5	

1/108	Burichour danda	27.5104	85.1627	**-50.1**	**-32.6**	-9	2505.4	
4/102	*Kumari	27.8089	85.1412	-32	-28.2	-3	2070.1	
	Birganj M/W TWR, center	27.014	84.8811	-13	-13 Est. (±3")	-17	82.14L	
1/107	Chaure danda	27.4411	84.8124	-36.5	-23.8	-12	725.1	
1/101	Sirai chuli	27.7621	84.6335	-40.9	-34.2	-8	1945.2	
1/095	Siranchok danda	28.0837	84.6031	**-61.9**	**-33.6**	-2	1972.6	
1/094	Thaprek (Doppler 31342)	28.0837	84.1873	-48.9	-8.2	-2	1281.6	
16/100	*Deochuli	27.7673	84.1819	-43.7	-12.7	-10	1933.4	
	Mandarthan	27.4954	83.8999	-29.6	-22 Est. (±5")	-16	834.2	
20/093	Thumko ko juro	28.1448	83.7665	-53.7	-5.6	3	2266.5	
3/099	Huwakot	27.7648	83.6069	-50.1	-17.7	-13	1845.4	
	Bhairawa Doppler 31352	27.5072	83.5868	-28.6	-14.9	-18	103.83L	
1/092	Ghumti pahad	28.2479	83.3903	-63.8	-11.0	0	3163.2	
13/098	Masina ko lekh	27.8912	83.1651	-51.5	-11.3	-11	2275.3	
1/091	Siulabang	28.3598	82.9565	-57.4	-27.8	1	3626.9	
1/085	Chaitidhuri	28.4952	82.6425	-32.3	-31.6	0	3052.5	
2/091	Ranja (Doppler 31344)	28.0624	82.5751	-46.7	-26.1	-11	1707.1	
1/030	Ghartigara	28.6778	82.262	-39.9	-39.3	0	1871.4	
1/036	Nigalchula	28.3395	82.0547	**-44.8**	**-37.9**	-12	2408.6	
1/029	*Katti	28.7199	81.8167	-37.2	-41.5	-7	2791.5	
	Nepalganj (Doppler 31347)	28.134	81.5766	-20.1	-17.0	-21	143.2	
2/028	*Banspani	28.5405	81.4772	-35.1	-30.0	-15	1586.4	
2/022	Banskando	28.9918	81.3368	-36.3	-22.2	-9	2252.3	
3/028	Naulakot	28.7268	81.1668	-39.5	-25.4	-15	1554.8	
1/027	Pandon	28.8797	80.9633	-40.7	-22.9	-15	1775.1	
	Dhangadhi (Doppler 31345)	28.7055	80.591	24.9	-14.8	-20	172.6	
1992-96 Topographical Survey 1st order Control Points								
WN 131		28.59121	84.64078			7.6	3558.75	
128		28.64125	84.09138			7.7	3381.12	
127		29.18236	83.96167			4.1	3809.44	
124		28.78073	83.72463			5.7	2736.4	
121		28.4917	83.3369			-1.3	2037.33	
120		28.87196	83.31327			6	3965.13	
118		29.45013	83.1819			4.8	3900.91	
115		28.98551	82.82122			2.1	2502.88	
109		29.12114	82.59108			2.2	3034.77	
107		29.58162	82.45611			4.4	2964.88	
103		29.53918	82.08211			1.5	2979.05	

100		29.08186	82.08726			7.4	3048.16	
98		29.14113	81.72046			-5.1	3072.23	
95		29.50333	81.67016			0.4	1404.45	
92		29.97096	81.48756			9.7	2970.86	
88		29.75318	81.28777			10.1	2533.9	
83		30.1341	80.98216			23	3625.76	
81		29.84403	80.54292			6.4	886.3	
79		28.45469	82.62003			-11.3	2545.63	
EN 1/75	Chhekampar	28.4889	85.0538			7.3	3016.46	
8	Kyangjin	28.2114	85.5694			15	3857	
12	Lapche Gau	28.12	86.1656			19.8	3867.39	
19	Namche	27.7692	86.7168			19.4	3554.51	
26	Subhangdanda	27.5528	87.3389			17.1	2007.9	
28	Tinjure Danda	27.2131	87.4711			10.9	2786.68	
41	Lamosangu	27.7403	85.8214			3.6	1380.37	
42	Jiri	27.6353	86.2328			8.4	1918.95	
131	Ghunsa	27.6594	87.9353			21.4	3407.31	

Map No. 1



Geoid NEPAL97

NB. 1. Nagarkot as datum
2. Contour v i. (Spheroidal -geoidal separation) is 2m
3. International Boundary Approximate