GLOBAL POSITIONING SYSTEM ON CADASTRAL SURVEY OF NEPAL

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KEY WORDS: Cadastral survey, global positioning system, geodetic control, and adjustment

ABSTRACT

Preparation of a series of cadastral maps and distribution of the land ownership certificates to each landowner of the whole kingdom of Nepal has been completed recently. However, half of the cadastral mapping of the country was carried out without the national coordinate system references and attention has given to map the private cultivated land, public land and government land with settlements during the cadastral surveying and mapping of the country. During the cadastral mapping of the country, it was realized that a national system of geodetic network of different order of ground control is required to prepare the large-scale map of the whole of the kingdom of Nepal. Everest spheroid 1830 and UTM
(modified with three degree zone) projection system was selected for the geodetic reference and the higher order and lower order geodetic control networks was established with the traditional geodetic survey equipment i.e., theodolite and distance meter.

This paper describes the observation procedure and the adjustment results with the accuracy standard of the geodetic control network of Nepal established in different time using different types of equipment and techniques. Attempt has been made to give some idea on the use of Global Positioning System GPS control network extension for the production of large-scale cadastral plan of the country. A pilot project was selected to evaluate the results of the GPS techniques with that of the traditional theodolite and distance meter techniques for the control points extension of the large scale cadastral mapping of the densely populated area of the country.

1. INTRODUCTION

1.1 Land in Nepal

Kingdom of Nepal has an area of 147181 sq. km. and a population of over 23million (2001 census). Population density of the country is 157.73 per square kilometer. Himalayan region, north of Nepal, is difficult for accessibility and cultivated land / population is very small. The mountain region, middle part of the country and terai (flat ground) region, southern part of the country, has its cultivated lands and most of the people live on this part of the country. Land in Nepal is categorized into government, public, trust and private lands. The government and public land consist of all that land defined by the Land (survey and measurement) act 1963. Government land includes the land occupied by the roads, railways, forest, rivers, ponds and other lands in its possession. Similarly public land constitutes the land of public importance as defined by the Land (survey and measurement) act 1963.Nepal is a country of temples. It has got its own religious and cultural importance. People and the government has donated the land/trust land, so that the income of the land will support to preserve its cultural heritage and maintain the religious activities of the temple.

1.2 Geodetic control

In Nepal, Survey of India has established Triangulation survey frameworks during 1954-60 under the Colombo plan agreement for the surveying and mapping activities in Nepal. These controls are mainly used for the preparation of topographic base map at 1" to 1 mile. Survey of India did the fieldwork and subsequent computation and adjustment with the following reference system.

Reference spheroid: Everest1830 a=20922931.8ft f=1/300.8017 e^2= 0.00663784663

Origin: Kalianpur h.s Latitude 24° 07' 11.26"N

Longitude: 77° 39' 17.57"E

Meridian: -0.29"

Prime vertical: +2.28"

The survey department with the collaboration of the government of United Kingdom has established the geodetic Triangulation survey network of Nepal during 1981-1984 and the subsequent mathematical adjustment with final result was completed on 1986. Eastern and western Nepal topographic mapping project (1991 &1997) has also established Geodetic Control Net of Nepal for the preparation of topographic base map of Nepal with the following geodetic reference system which is different from the survey of India geodetic reference system.

Reference spheroid: Everest (1830) a=6377276.345m f=1/300.8017 e^2 = 0.00663784663

Origin: 12/157 NAGARKOT

Latitude= 27° 41' 31.04"N

Longitude = 85° 31' 20.23"E

Meridian = -37.03"

Prime vertical =-21.57"

Vertical Datum of leveling network of Nepal is based on Birjung and Bhairahawa fundamental benchmarks of Survey of India values relative to the mean sea level.

Use of Global positioning System

The Global Positioning System (GPS) is a satellite based navigation system and is designed to operate 24 hours in all weather for Global coverage. The system has three segments. A space segment including 24 GPS satellites in 6 orbital planes. They transmit the data of ephimeride, almanac line, satellite health, ranging signal and atmospheric conditions. A control segment includes the ground monitor command and control function. It performs the tracking, orbital determination, time synchronization function. A user segment includes GPS receiver, which tracks the satellites and identifies the individual satellites. The receiver decodes the satellite signals and computes the position such as latitude, longitude and altitude. GPS is used for the position determination on the earth surface with the following reference system.

Reference system: World Geodetic System 1984 (WGS84) origin at the earth's center.

Semi major axis (a): 6378137.00m

1/f 298.2572235

Origin latitude 27° 41' 33.778"N

Longitude 85° 31' 16.384"E

Global positioning system (GPS) was introduced in Nepal by the Japanese consultant in 1988 for the establishment of control points for photogrammetric triangulation in Lumbini zone mapping project (JICA). Latter on Survey department with the collaboration of University of Colorado (USA), Eastern and Western topographical mapping project has established the GPS Higher order control points in Nepal. As a result of these experiences, in 1994 Survey Department has introduced the GPS technology for the extension of geodetic network of Nepal. Now a day's GPS is the main techniques for the extension of higher order controls in Nepal.

The University of Colorado and Massachusetts Institute of Technology established the precise Global Positioning system (GPS) geodetic Net during 1991. The instruments used for the observation were Tremble 4000SST and ASTECH SLLGPS receiver. Three stations at Nagarkot, JomSom and Simikot were held fixed during the observation and each station was occupied with minimum of five days of at least 8 hours per day with each data measurement. The raw data file of the Ashtech and Tremble were converted to RINEX format using Berness V.3.3 GPS software.

The Eastern Nepal Topographical Mapping Project 1994.established some of the first order Geodetic Control in Nepal covering eastern and central development region of Nepal. The existing first order Geodetic Control Net 1981-84 were checked and utilized during the observation and adjustment of Geodetic Control Net of eastern Nepal Topographical Mapping Project. The methodology for the observation of first order geodetic control net of 1981-84 was according to the traditional theodolite and distance meter. However the eastern Nepal topographical mapping project utilizes the method of Global Positioning System (GPS) for the observation and subsequent adjustment thereof. The project has established 13 new geodetic primary stations with the help of existing 16 geodetic first order points.

Geodetic Control over the ENTMP project area was established by using the static relative GPS Survey. Altogether 29 primary stations (13 new and 16 old) were established and observed by using Astech LD_SLL GPS receivers. One season per day was observed with four to eight satellite in 180 minutes. Astech Inc's Geodetic Post Processing Software version 4.4.01 with fillnet version 3.0.00 adjustment program was used for the processing and adjustment of data transformation of WGS4 coordinates to UTM (Nepal System) was done by affine transformation.

The Western Nepal Topographical Mapping Project (WNTMP) consists of western, mid western and Far Western regions of Nepal. The project is implemented in co-operation with HMG survey Department Nepal and FM International OY (FINNMAP). The ground control Survey was based on GPS (Global Positioning System) measurement. Altogether 51 primary GPS stations were established and computed as free network using one existing point of ENTMP as initial stations. WGS-84 co-ordinates were transformed to Nepal reference datum by affine transformation and orthometric heights were computed by geoid model. The survey of ground control points was based on the use of global positioning System (GPS). ASHTECH GPS receiver made observations with four dual frequencies using station relative positioning. Observation time for all seasons was planned to 180 minutes were down loaded in micro computer and field computation were carried out using astech Inc's Geodetic post processing software (GPPS) version 4.4.01.First order network consist of 121 base lines and 51 stations. The adjustment was done as " free network adjustment" using only one first order point as fixed point using Ashtech Inc.'s FILLMAP software version 3.0.00. The accuracy was controlled over 1-sigma accuracy of the base line. These varied mainly between 0.9 to 2.2 ppm.

1.3 Nepalese Cadastral survey

Cadastre has existed, in some form, in Nepal since 300 AD. The role of cadastre for tax assessing was commenced in about 1300AD. Land registration process was introduced during 1923 AD in order to give the assurance of the transacted amount of money during land transaction. With the introduction of the land survey (survey and measurement) act 1963,the the cadastral map become the legal documents defining the boundaries of all land properties and provide the basic data for land administration including land taxation and become an integral part of the land registration process.

Preparation of a series of nationwide cadastral maps of kingdom of Nepal was initiated during 1964. Cadastral survey was designed to serve the tenancy reform of 1964 to combine the twin objectives of tenancy as well as revenue survey with less emphasis on the usual cadastral objectives. National geodetic network was not available on those days to prepare large scale cadastral map of the country. Out of 75 district of Nepal, Cadastral maps of 38 district were prepared without the national geodetic control points forming the island map sheets of cultivated land The areas of land parcels quoted in the land register as well as the ownership certificate are at the variances with the true physical areas This causes problems at the time of land subdivision for sale or transfer.

Surveying of remaining 37 districts was carried out with national geodetic control and emphasis is given to meet the cadastral surveying objectives. Cadastral survey office was established in each district after the completion of the cadastral surveying of the district. Updating the cadastral maps and documents should be done by this survey office at the time of land subdivision for sale or transfer in theprocess of land administration. Nine survey offices are engaged on different district to update those cadastral maps and documents which does not serve the cadastral surveying objectives. All these maps are based on the controls provided by the GPS technology.

2. GEODETIC SURVEY NETWORK OF NEPAL

2.1 Laplace stations for azimuth

In 1976-77 astronomic observation for position and azimuth at 7 stations in Nepal was carried out in collaboration with the Czechoslovak Geodetic Institute. The following points were taken into account while establishing the laplace stations.

- The astronomic positions were observed by the Latitude and Longitude methods of time transits of pairs of stars at equal altitude using T4 thedolites. Times were recorded by impersonal micrometer operation of quartz crystal clocks.
- Standard error value is of the order of ± 0.10 to ± 0.20 seconds arc in both latitude and longitude.
- In 1981-84 geodetic Survey astronomic positions were observed by the position line method of timed altitude of balanced sets of stars using T3 thedolites.
- Hand switch operation quartz crystal clock and mechanical chronometer recorded times.
- Azimuth observations reduced by black's method, which provide deflection component values, were observed at some station using the same equipment as the position line observations.

Geodetic Network was established at 68 different places distributed all over the country. The high Himalayan part of Nepal was not included on the net as it is not accessible for the ground observation.

The control net includes 13 of the 14 Doppler Station established in 1984, existing stations of Survey of India survey framework of 1954-60 and newly monumented survey stations. The control net also includes microwave communication control with an associated ground station sites in the terai region of Nepal. All the Laplace station (Astronomic Observation during 1976-77) together with some of the additional astronomic observations were included in the observation of Geodetic net of 1981-84.

2.2 Horizontal angle and length measurement of the geodetic network

Wild T3 Theodolites (occasionally wild T2 Theodolites) are used for the horizontal angle observation of the geodetic network (1981-84). A set of observations consisted of 8 rounds and two sets of observations of an angle during a single period and further two sets or another occasion by different observer were observed (i.e. 4 sets in 32 rounds). Additional sets were observed if 4 individual sets exceeded 2 seconds arc or misclosure of 3 angles of a triangle exceed 3 seconds arc. For verticality of the theodolite the inclination greater than 10 30' readings of horizontal plate level were recorded.

EDM microwave equipment operating on a carrier frequency of 10 GHZ, instruments are used for length measurement. Tellumat model MRA5, Tellumat Model CMW6 and Microfix model 100c instruments were also used for length measurement. For air temperature reading a mercury thermometer tested in a psychrometer in agreement to within 0.5 degree Celsius and dry bulb temperature was correct to one degree. For air pressure reading aneroid barometer of digital reading type and altimeter instrument were used.

2.3 Vertical angle observation and computation:

The vertical angle observation was carried out during geodetic survey network observation (1981-1984). The computation of vertical angle observation and subsequent height determination was carried out and results were found as follows.

- Values of the combined curvature and refraction correction factor were derived in seconds of arc per kilometers of line length.
- Standard derivation of an observed value of the combined curvature and refraction correction is ± 0.2 sec/km.
- The variation in refraction on lines between "hill stations" is very small and does not differ much by time of observation.
- The variation in refraction on lines between hill station and plain station is a marked difference and it was taken account in selecting the most probable value.
- Misclosure value i.e. mean value of the height differences observed on each line, range from a minimum of less than 0.1m to 4.1m with an average value of 1.1m.
- The typical standard error uncertainly in an observed height difference was of the order of ±1.0m for a line of 40km in length.
- Net consists of 261 observed height differences on 138 lines.
- At some Micro Communication Centre sites there is a discrepancy between elevation value from the level net.

2.4 Adjustment of plan control and its analysis

A number of trial adjustment were made using different types of data available in the Survey Department of Nepal (i.e. Doppler observation 1980-81, ground survey Laplace azimuth, astro azimuth observation 1981-84 and Geodetic Survey net observation 1981-84 etc).

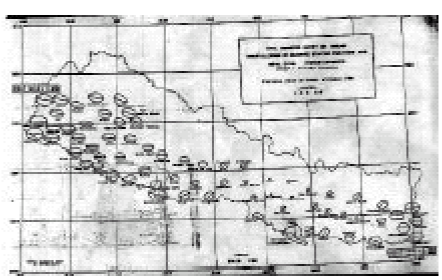
The bias Parameters was introduced in the adjustment to allow for systematic bias in some classes of observation. Care was taken that the standardization of the instruments for length measurement to be used was made by the manufacturer and with proper atmospheric correction formulation principle. Thus the effect of scale bias in the length is removed in the adjustment.

The adjustment of the net was made by the least square method of variation of geographic coordinates on the reference spheroid and "Nagarkot Station" was held fixed to its defined position. All the observational data was expressed in terms of the reference spheroid.

The Standard error of unit weight determined in the solution was 1.15 and standard error uncertainly of each azimuth value was based on the estimated positional accuracy of ±0.5 metre over the length of the line concerned.

Standard error (se) uncertain in the adjusted–Positions of the stations relation to the fixed origin station (i.e. Nagarkot) vary from zero up to ±0.30m in latitude and ± 0.45m in longitude at the east and west extremes.

A plot of the obsolute error ellipses of the adjusted stations shows that the direction of the major axes tends to be radial from the fixed origin**.**



3. GPS GROUND CONTROLS IN CADASTRAL SURVEYING

Cadastral surveys are the surveys carried out to support registration of interest in land. They usually result in the preparation of the cadastral maps and land registration documents. Cadastral survey in Nepal is carried out in three different scale i.e, 1:2500 scale maps for the agriculture land,1:1250 scale maps for the semi urban land and 1:500 scale maps for the urban land of the country. At least six ground controls are provided on each sheet of the cadastral map. Since 1994AD,Geodetic survey branch initiated to use the GPS technology to provide the ground control network. They are placed at about 5km apart on the basis of existing geodetic net of higher precision. GPS control survey is completed on 8 districts out of 38 uncontrolled cadastral mapping districts of Nepal and 11 district are in progress.

In order to see the results of the GPS techniques with that of the traditional theodolite traverse existing lower order ground controls are selected and GPS observations on those points were made and the results are evaluated and found that the accuracy is well within the cadastral standard. Sample result of the coordinates and the differences are shown below.

Station No	Traverse coordinates		GPS coordinates		Difference	
	Y	X	Y	X	Y	X
G3	626920.422	3066671.838	626920.413	3066671.819	-0.009	-0.019
G2	626847.403	3066574.53	626847.414	3066574.514	0.011	-0.018
T1	626855.43	3066541.045	626855.438	3066541.003	0.008	-0.042
T2	626882.053	3066444.362	626882.046	3066444.297	-0.007	-0.065
T3	626794.519	3066350.082	626794.5	3066350.055	-0.019	-0.027
T4	626925.418	3066395.973	626925.408	3066395.962	-0.01	-0.011
T5	627053.106	3066305.452	627053.061	3066305.41	-0.045	-0.042
T6	627151.535	3066321.927	627151.481	3066321.848	-0.054	-0.079
T7	627088.925	3066366.578	627088.902	3066366.528	-0.023	-0.05
T8	627124.475	3066457.04	627124.471	3066456.99	-0.004	-0.052
14121	626948.366	3066547.753	626948.379	3066547.747	0.013	-0.006
G1	627002.66	3066529.41	627002.665	3066529.392	0.005	-0.01

4. CONCLUSION

Survey department of Nepal has been using GPS technology for the extension of ground control to provide control for large-scale mapping. At the moment though, there is not much GPS activity in the area of cadastral surveying, attempt should be done to go further to use the potentiality of GPS technology e .g, Real time Kinematics' Systems for the rapid point layout of the individual parcel. The use of GPS technology into this area of data collection in cadastral surveying is a change that will therefore have to necessitate certain changes in the institutional and technical framework of the survey department.

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