२०६१ माघ ५ - ६ गते जियोडेटिक नेटवर्क सुदृढीकरण कार्यशाला गोष्ठीको अवसरमा विमोचित

जोग मेहर श्रेष्ठ
मन्त्री
भूमि सुधार तथा व्यवस्था

२०६१ माघ ५

His Majesty's Government

Survey Department
Geodetic Survey Branch

Geodetic Survey
and
Global Positioning System

DEFINITION OF A SURVEYOR(11)

A surveyor is a professional person with the academic qualification and technical expertise to practice the science of measurement; to assemble and assess land and geographic related information; to use that information for the purpose of planning and implementing the efficient administration of the land, the sea and structure thereon; and to instigate the advancement and development of such practice.

Geodetic Survey
and
Global Positioning System

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Publisher:

Geodetic Survey Branch
Survey Department
Kathmandu

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First edition: 500 copies
2004 AD

Printed By:
Ashmi Printing Press
Buddhanager, Kathmandu, Nepal
Tel: 4780463

PREFACE

Over the years, surveying has been a dynamic science. New techniques are introduced very often for the efficient and accurate work of surveying. For example, early days chains with links were used for the distance measurement. These days electronic distance measuring equipment are used for this purpose. Electronically devised total station theodolite can measure the angle and distance simultaneously. It also consists the facility of the coordinate computation. Recently, Global Positioning System (GPS) is gaining popularity in surveying. The co-ordinate offered by GPS is free from influence of gravity with consistent global coordinate system. GPS coordinate can also be transformed to the national coordinate system. GPS technique is established technically with an efficient and economical method of position determination by geodetic accuracy. It can be used to provide the higher order geodetic control points and extension of geodetic network of the country. In Nepal, GPS technique was used for the establishment of ground control points since 1989 by the private agencies. Survey Department has introduced GPS techniques for the network extension since 1992 and still using for the geodetic network extension of the country.

It is realized that books of foreign writers and the user's manual of the equipment available in Nepal are not sufficient to guide the work with the GPS receiver and its subsequent computation adjustment. It is this reason that the author has tried to write a book on Geodetic Survey and Global Positioning System. This book covers the subject of the history of geodesy by space technology, theory behind geodetic surveying, GPS working principle and GPS field work with data processing. The author is in hope that this book will be useful for the surveyors, engineers and geo-informatics community who are involved on surveying with global positioning system and geographic information system. Constructive criticisms from the readers are always welcome.

The author is especially grateful and wishes to express his gratitude to the Deputy Director General, Geodetic Survey Branch, Survey Department, His Majesty's Government of Nepal for giving him the opportunity to publish this book.

AUTHOR

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Chapter I

1. Introduction

1.1 History of Geodesy by Space Technology

Geodesy is that branch of science, which is related with the mathematics, physics, astronomy and the space technology to get the information on the size, shape of the earth and position of any object on the earth surface. Geodetic survey deals with the determination of the size and shape of the earth and the measurement of all the data needed to define the size, shape, position and elevation of any part of the earth surface. Lunching of the first satellite by USA during 1957 allowed space technology to be applied in geodetic survey. Observation of artificial satellite simultaneously from two distant points on the earth i.e. satellite triangulation and satellite laser ranging satellite equipped with laser reflector remains important on positioning two distant objects. ANNA 1B was lunched in 1962 and was followed by a number of artificial satellites for geodetic survey purposes. In 1965 the geodetic satellite GEOS A was lunched with laser reflector. Measurement of distance to the moon was carried out in 1965 by the use of laser reflector, which has been left on the moon from Apollo 11.

Satellite navigation i.e. signals from satellite are utilized in positioning ships and later used for positioning ground control points on the islands. Very Long Baseline Interferometer (VLBI) technique is used on the measurement of two distant points i.e. baselines across continents and oceans. Global Positioning System (GPS) was developed for navigation by USA during 1978. This system was aimed at the positioning of observation points by simultaneously receiving signals from various satellites around the earth. There are several GPS satellites, which are going around the earth. A differential GPS can be used for Geodetic survey application.

1.2 GPS application in Nepal

For the first time, Global positioning system was introduced in Nepal by Japanese consultant (JICA) during 1988 AD for the establishment of ground control points for photogrammetric aerial triangulation on east rapti irrigation project and lumbini zone topographic mapping project. Later during 1990's Survey Department with the collaboration of university of Colorado USA has lunched a program of measuring geodetic control points at different locations on the himalayan belt by GPS receivers. Repeated measurements were made on consecutive years to study the plate movements occurring at a global scale and local diastrophism occurring within the Himalayan region. Survey Department has started to use GPS technique for the geodetic network extension and provide control points for surveying and mapping activities of the country since 1992.

Similarly, many government and private agencies in Nepal are also using GPS for determining the position, height and time in low accuracy according to their need. Mostly, receivers used for this type of operation are small and portable with the low cost compared to the geodetic measurement. Nepalese airlines are also using GPS signals for determining their position, height and time during aerial navigation.

Chapter II

2. Geodetic Survey

Information on positions is one of the most basic factors which people need for securing their survival. Geodetic survey gives accurate information on position which is required for the development activities of any country. The service to offer people a system to identify a position itself is regarded as the responsibility of the government. Standard technical procedures to identify the position with control points have been developed and a geodetic system of a country is built up by forming a network of control points at a uniform density througout the country.The main aims of geodetic surveys are :

(a) Establishment and maintanance of national and global three-dimensional geodetic control networks on land, recognizing the plate movement of the earth.

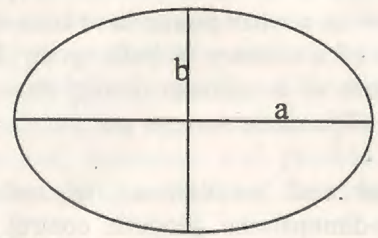
(b) Measurement and representation of geodynamic phenomena (polar motion, earth tydes and crustal motion)

(c) Determination of the gravity field of the earth including temporal variation.

The actual shape of the earth's surface is undulated with mountains, rivers, lakes and plain area. The undulated shape of the earth is difficult to experess mathematically. An ellipsoid "a shape produced by rotating an ellipse around its minor axis" is selected as the first approximation shape of the earth and this ellipsoid has no physical surface but is a mathematically defined surface. There are many different ellipsoid used all over the countries depending upon the shape and size of the country. Each country have defined a mapping system/reference frame based on local ellipsoid.

2.1 Spheroid and projection system :

The Everest spheroid 1830, one of the oldest spheroid, was selected to use in Nepal. The main decision to select this spheroid is that the neighbour countries India, Pakistan, Bangladesh and Sri-lanka are also using this spheroid and it is easier for the connection of geodetic network to the neighbouring countries. The Everest spheroid is deifned as follows :



a = 6377276.345 m f = 1:300.8017

b = 6356075.413m e^2 =0.00663784663

Fig. 1a Spheroid

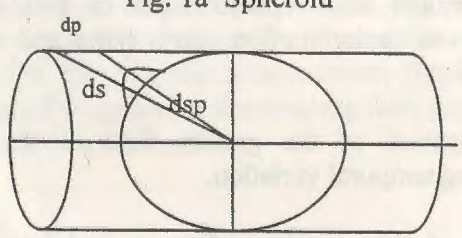


Fig 1b. Cylindrical projection

ds: actual slope distance on the earth surface

dsp: distance corrected to the spheroid.

dp: distance on the projection plane.

dsp – dp: length distortion

$\mathbf{dp = \lambda . dsp}$

λ : scale factor introduced at the central meridian

All the measurement of angle and distance on the earth should be projected on the spheroid and then to project it on to a plane surface. There are several system of projection. Projecting three dimentional object on to a plane is not possible without any distortion at all. Therefore, we have to look for projection with neglegible distortion. In Nepal, Universal Tranverse Mercator projection (UTM) is used. Measurement and recording of co-ordinates are usually done by northing, easting and height (above the mean sea level). Latitude, longitude and height are also used to represent three dimentional curved surface. Map projection allows to represent a three dimensional curved surface on a flat piece of paper.

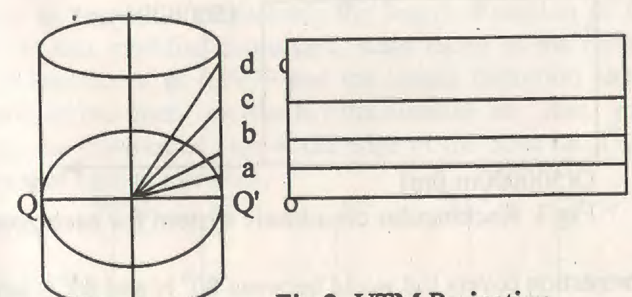


Fig 2 UTM Projection

True lengths are only represented when plane cuts the spheroid i.e. point Q and Q'.

UTM Projection has the following characteristics.

- Parallels are straight line and the spacing between them increases away from the standard parallel i.e. equator.
- Meridians are equi-spaced straight lines perpendicular to the parallels.
- Length of all parallels are equal so that scale factor rapidly increases away from the standard parallel.
- Scale factor along the meridian increases away from the equator.

- Central meridian is projected at its actual length. In the case of central meridian touching the spheroid, the length distortion along the central meridian is zero.
- The false easting and false northing are defined as the origin of grid projection to avoid the negative value of the grid co-ordinates. (origin of X co-ordinate i.e. northing is the equator and Y co-ordinate i.e. easting is central meridian with 500,000m false co-ordinate).

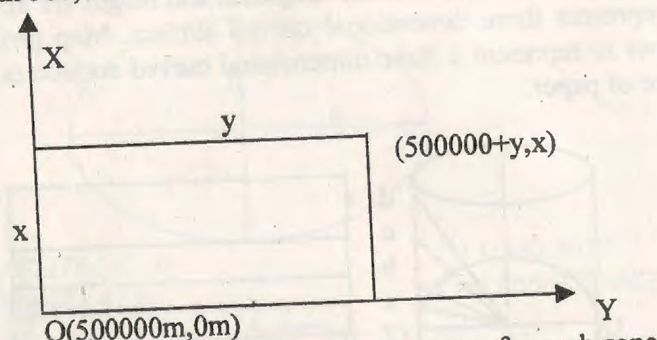
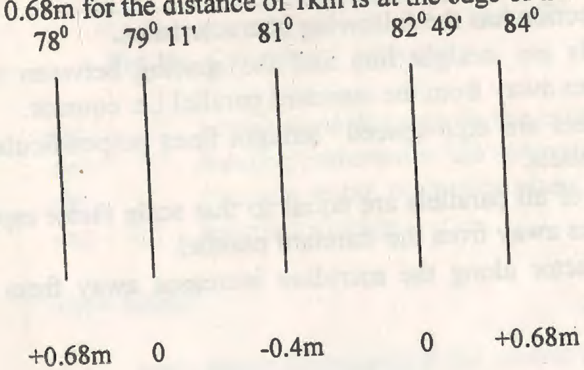


Fig.3 Rectangular coordinate system for each zone

UTM projection covers the world between 80^0 N and 80^0 S latitude. The UTM is split into zones of 6^0 longitude with the scale factor 0.9996 at the central meridian.The length distortion of -0.4m for the distance of 1km is in the central meridian and the length distortion of + 0.68m for the distance of 1km is at the edge of the zone.



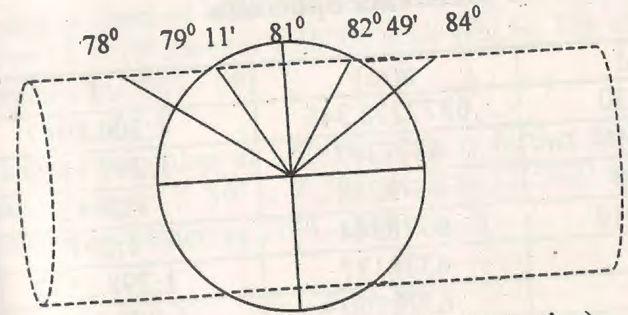


Fig.4 Errors distribution (UTM Projection)

Modified universal transverse mercator projection i.e.zones of 3^0 belt is used in Nepal for minimising the length distortion of the projection. In this modified projection, scale factor at the central meridian is introduced as 0.9999 and the length distortion at the central meridian becomes -0.10m fo r the distance of 1km and + 0.18m for the distance of 1km at the edge of the zone i.e. 1^0 30' west and east of central meridian.

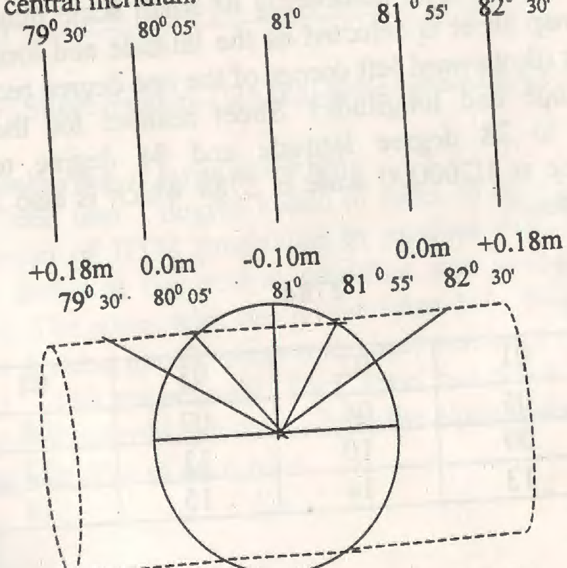


Fig. 5 Errors distribution(UTM modified)

Reference Spheroids

Spheroid	a(m)	f
1.Everest 1830	6377276.345	1:300.8017
2.Bessel 1841	6377397	1:299.1528
3.Clarke 1856	6378288	1:294.5
4.Hayford 1910	6378344	1:297
5.WGS 1984	6378137	1:298.2572
6.GRS 1967	6378160	1:298.24716
7. GRS 1980	6378137	1:298.2572
8.Fisher 1968	6378150	1:298.3
9.S.America1969	6378160	1:290.25
10.Austrailian	6378160	1:298.25

2.2 Sheet numbering of small scale map

Small scale map at 1:1M scale covers Nepal in one map sheet of moderate size. The numbering of small scale map at 1:200000 scale map sheet is selected as the latitude and longitude degree number (downward left corner of the one degree rectangle corner of latitude and longitude). Sheet number for the area of 27 degree to 28 degree latitude and 84 degree to 85 degree longitude at 1:200000 scale is 2784 which is also called as one degree sheet.

84^0 **2784** 85^0
28^0 28^0

01	02	03	04
05	06	07	08
09	10	11	12
13	14	15	16

27^0 27^0
84^0 85^0

Fig. 6. Sheet number 1:50,000 scale (**2784-08**)

1 degree sheet of 1:200000 scale sheet is devided into 16 parts to form 15' x 15' sheet at 1:50000 scale (fig.6). The sheet number is writtern as 2784 - 08.

The sheet number at 1:50000 scale is further devided into four parts to form 7' 30" x 7' 30" sheet at 1:25000 scale. The sheet number is written as 2784 - 08A (fig.7)

2784-08

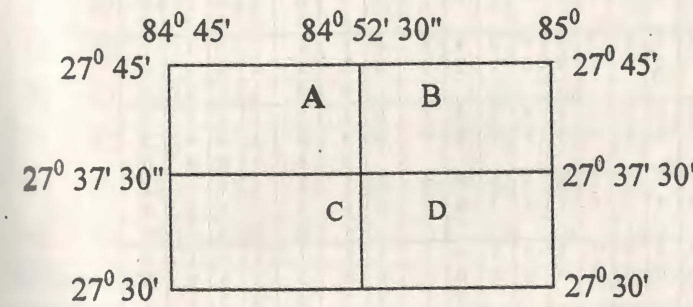


Fig. 7. Sheet number 1:25,000 scale (**2784-08A**)

2.3 Sheet numbering of large scale map

Nepal is devided into 3 degree zones in order to minimize the length distortion of UTM projection to produce map at large scale. Scale factor at the central meridian was introduced as shown above. The zones with central meridian 81^0, 84^0 and 87^0 longitude are divided into 60 parts with sheet number 1 - 60, 61 - 120 and 121 - 180 respectively. Each sheet has 50km x 50km sheet size with the northing starting from the equator and 500km at the central meridian of each zone.

Easting of each zone starts from 350000m and ends to 650000m and northing of each zone starts from 2900km and ends to 3400km.

3400000m | 3400000m

1	2	3	4	5	6	61	62	63	64	65	66	121	122	123	124	125	126
7	8	9	10	11	12	67	68	69	70	71	72	127	128	129	130	131	132
13	14	15	16	17	18	73	74	75	76	77	78	133	134	135	136	137	138
19	20	21	22	23	24	79	80	81	82	83	84	139	140	141	142	143	144
25	26	27	28	29	30	85	86	87	88	89	90	145	146	147	148	149	150
31	32	33	34	35	36	91	92	93	94	95	96	151	152	153	154	155	156
37	38	39	40	41	42	97	98	99	100	101	**102**	157	158	159	160	161	162
43	44	45	46	47	48	103	104	105	106	107	108	163	164	165	166	167	168
49	50	51	52	53	54	109	110	111	112	113	114	169	170	171	172	173	174
55	56	57	58	59	60	115	116	117	118	119	120	175	176	177	178	179	180

2900000m | 2900000m

81° | 84° | 87°

350000m | 650000m 350000m | 350000m 650000m | 650000m

Fig.8. Sheet numbering at 1:100,000 scale(102)

(a) **1:10000 and 1:5000 scale maps**

A sheet of 50km x 50km (fig.8) is divided into 10 x 10 division (100 sheets) for 1:10000 scale with 5km x 5km sheet size. The sheet number of 1:10000 scale map is writtern as 102 - 089.

3100000mE | **102** | 3100000mE

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	**89**	90
91	92	93	94	95	96	97	98	99	100

3050000mN | 3050000mN
600000mE | 650000m E

Fig.9 Sheet numbering at 1:10,000 scale(**102-089**)

Each sheet of 1:10000 scale is divided into four parts for 1:5000 scale maps. The sheet number is written as 102 - 089 - 4.

306000mN | 3060000mN
640000mE | **102-089** | 645000mE

1	2
3	4

3055000mN | 3055000mN
640000mE | 645000mE

Fig 9a Sheet numbering 1:5000 scale (**102-089-4**)

(b) Sheet numbering of 1:2500 cadastral plan.
A sheet of 50km x 50km (fig.8) is divided into 40 x 40 divisio (1600 sheets) for 1:2500 scale with 1.25m x 1.25km sheet siz Sheet number 102 with easting 600 - 650km, northing 3050 3100km is divided as:

3100000mN 3100000m
600000mE **102** 650000mE

1	2	3		38	39	40
41	42	43		78	79	80
81	82	83		118	119	120
1481	1482	1483		1518	1519	1520
1521	1522	1523		1558	1559	1560
1561	1562	1563		1598	1599	**1600**

3050000mN 3050000mN
600000mE 650000mE

Fig. 10 Sheet number at 1:2500 scale cadastral plan(**102-1600**)

c) Sheet numbering of 1:1250 scale cadastral plan.
A sheet of 1.25km x 1.25km at 1:2500 scale (fig.10) is fur divided into 4 parts to form a sheet number 102 - 1600 - 4 1:1250 scale cadastral plan with 625m x 625m sheet size.

102-1600

648750mE 650000mE
3051250mN 3051250mN

1	2
3	4

648750mE 650000mE
3050000mN 3050000mN

Fig. 10a. Sheet number 1:1250 scale (**102-1600-4**)

) Sheet numbering of 1:500 scale cadastral plan.
sheet of 1.25km x 1.25km at 1: 2500 scale (fig.10) is divided to 5x 5 division (25 sheets) to form a sheet number 102 - 600- 25 for 1:500 scale with 250m x 250m sheet size.

102-1600

051250mN 3051250mN
648750mE 650000mE

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	**25**

3050000mN 3050000mN
648750mE 650000mE

Fig. 10b. Sheet number of 1:500 scale (**102-1600-25**)

.4 Numbering of Geodetic station in Nepal.
According to the accuracy standard different types of geodetic stations are needed to establish the ground control points. The size of the pillars and numbering of the pillar are made distinct to identify them according to their type. There are different types of geodetic stations in Nepal. The numbering system of these stations is as follows :

(i) Basic first order geodetic points :

The basic first order stations, as used for geodetic frame-work for the first order geodetic points, is known by the name of the station. e.g. Hatyal. There are only seven basic first order points in Nepal.The Distance between two closed stations is about 30-65 km apart.

(ii) First order geodetic points :

The numbering of the geodetic points is based on each grid sheet of 50km x 50km (fig.8). Every station has its number with the grid sheet number. First order geodetic points has one figure number with its grid sheet i.e. 1/102 or 1 Nalapani (102). The distance between two closed stations is about 20-30 km apart distributed all over the country.

(iii) Second order geodetic points :

The second order geodetic points are numbered from 10-99 with the grid sheet number. i.e. 10/102. These points are based on first order geodetic points and the distance between two closed station of this order is about 10km-15km apart.

(iv) Third order geodetic points :

The third order geodetic points are numbered from 100-999 with the grid sheet number i.e.100/102. These points are established on the basis of first/second order geodetic points. The distance between two locational points of third order points is about 5 km apart. GPS method is utilised to establish the geodetic control points of third order in triplicate points at one location.

(v) Fourth order ground control:

The fourth order geodetic points are numbered from 1000-9999 with the grid sheet number i.e. 1000/102. Temporary points are numbered from 10000-99999 with the grid sheet number.

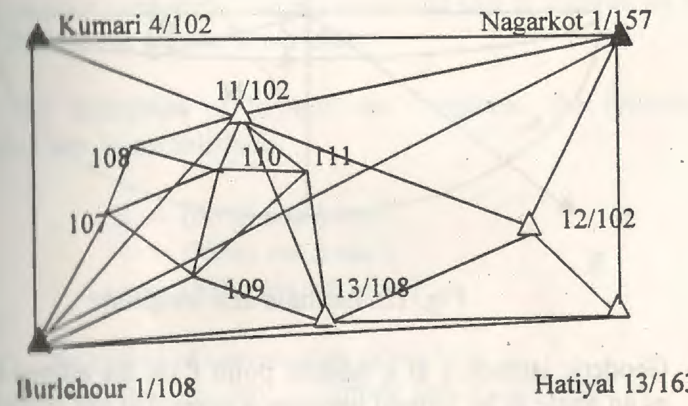


Fig.11. Numbering system of geodetic net

Geodetic control

Geodetic control surveying is a kind of survey to determine position (latitude, longitude, and elevation) of points, on the earth. Horizontal geodetic control relates to latitude and longitude of points. Nepal has adopted Everest spheroid 1830 as its reference surface for surveying. A datum plane is needed to describe the position of a specific point on the ground. The mean sea level of Indian Ocean is taken as the datum plane for the height reference. The geoid is generally used as the datum plane of ground height.

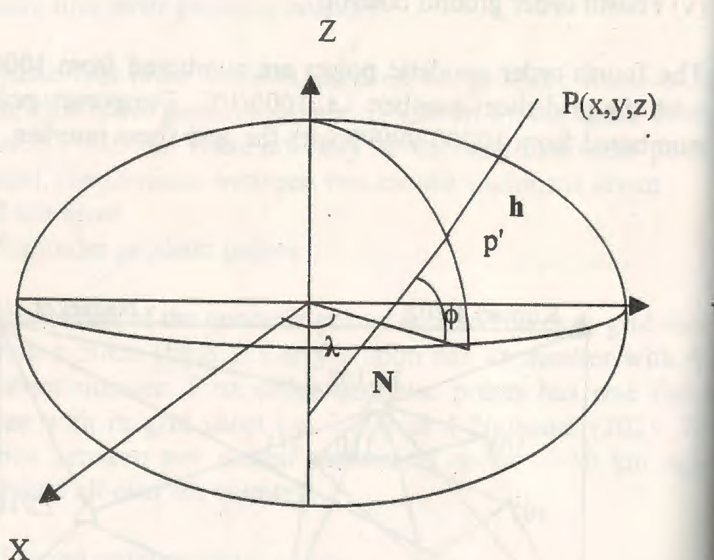


Fig. 12. Latitude and longitude

Geodetic latitude ϕ at a random point P on the ellipse is defined as an angle to be formed between a normal at the point P and the major axis.

In the ellipse, we have :

$$\frac{x^2}{a^2} + \frac{z^2}{b^2} = 1$$

$$\frac{dz}{dx} = -\frac{b^2}{a^2} \cdot \frac{x}{z} \quad \text{or} \quad \frac{dz}{dx} = \tan(\phi + 90^0)$$

from the above definition.

$$\text{Thus : } x = \frac{a \cos\phi}{(1 - e^2 \sin\phi)^{1/2}}$$

$$z = a(1 - e^2)\sin\phi$$

$$e^2 = \frac{a^2 - b^2}{a^2}$$

The latitude of a point is the angular measure of the arc of great circle passing through the poles and the point considered form the equator towards the north or south. The longitude of a point is the angular measure of the arc measured east or west along the equator from the standard meridian.

From the definition of latitude and longitude, the following relations can be established.

$$x = (N+h)\cos\phi\cos\lambda$$
$$y = (N+h)\cos\phi\sin\lambda$$
$$z = [N(1 - e^2) + h\}\sin\phi$$

N : radius of curvature in prime vertical

From this, geodetic longitude can be calculated as $\lambda = \tan^{-1} y/x$ and geodetic latitude and the height can be found from:

$$N_k = a / (1 - e^2 \sin^2 \phi\, k\text{-}1)^{1/2}$$

$$h_k = \frac{(x^2 - y^2)^{1/2}}{\cos\phi_{k-1} - N_k}$$

$$\phi_k = \tan^{-1}[\{z/(x^2 + y^2)^{1/2}\} \cdot (1 + e^2 N_{k-1} \sin\phi/z)]$$

Iteration calculation with initial values of $N_o = a$, $h_o = 0$, $\phi_o = \tan^{-1}\{z/(x^2 + y^2)^{1/2}\}$ until $(\phi_k - \phi_{k-1}) <$ required accuracy.

This gives the geodetic latitude, longitude and height. Similarly transformation to cubic rectangular co-ordinates can be done with the transformation procedure.

Geodetic control surveying can either be done by traditional theodolite / distance metre method or global positioning system using satellites. Procesing of geodetic co-ordinates from the geodetic observation and transformation of geodetic co-ordinates to the rectangular co-ordinates of prescribed projection is done by the computer software efficiently.

2.5.1 Transformation of Geodetic coordinates:

If it is necessory to compare coordinates between geodetic system e.g WGS 1984 and Everest 1830 and coordinate values must be transformed from one system to another. Assume that coordinates in geodetic system is based on rectangular coordinate and relation between them is defined, the relationship among the rectangular coordinates is represented as:

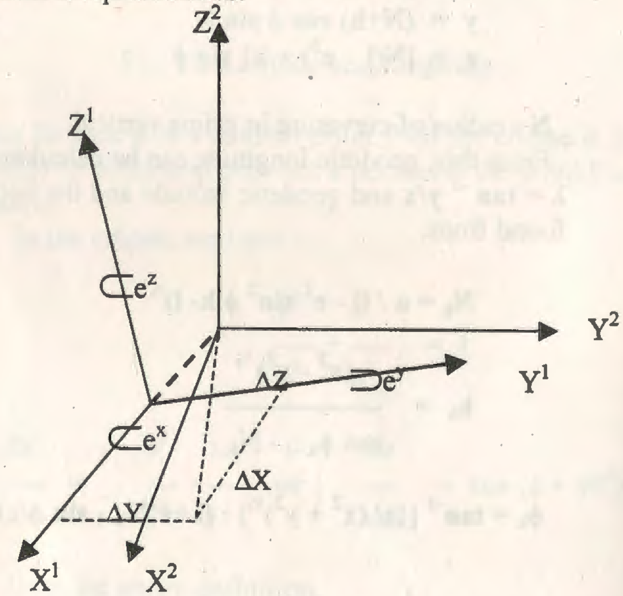


Fig 12a Transformation of geodetic coordinates

If the coordinates of WGS 1984 are based on rectangular coordinate system and relationship between WGS 1984 and Everest 1830 is known They can easily be transformed.

$$\begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \end{bmatrix} = (1+S).R_3.R_2.R_1.\begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \end{bmatrix} + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix}$$

S is scale factor

ΔX, ΔY and ΔZ are the shifts

and Rotations R_1,R_2 and R_3 represents matrices for x,y,z axes:

$$R_1 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{pmatrix} \quad R_2 = \begin{pmatrix} \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \\ \sin\theta & 0 & \cos\theta \end{pmatrix}$$

$$R_3 = \begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Considering the component of revolution e_x, e_y, and e_z is sma
we have the following:

$$\begin{pmatrix} X_1 \\ Y_1 \\ Z_1 \end{pmatrix} = (1+S) \begin{pmatrix} 1 & e_z & -e_y \\ -e_z & 1 & e_x \\ e_y & -e_x & 1 \end{pmatrix} \begin{pmatrix} X_2 \\ Y_2 \\ Z_2 \end{pmatrix} + \begin{pmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{pmatrix}$$

From this equation, the transformation parameters (rotatio shifts and scale) are calculated. Rectangular coordinates of o geodetic system are transformed to another geodetic coordin system by substituting these parameters on the ab transformation equation. Care should be taken to avoid t degradation of the computational accuracy on this type multidigit computation.

Similarly, we can also find the geodetic latitude, longitude a height from these rectangular coordinates.

2.5.2 Geodetic net of Nepal

In Nepal, 7 laplace stations are established to control the azimuth for geodetic control net of the country. Altogether 68 first order geodetic controls are available distributed all over the country (except the himalayan part). The basic first order geodetic stations are established in such away that the distance between two close stations are within 30 - 65km apart. Similarly, first order geodetic net has the stations 20 - 30km apart.

Fig.13 Geodetic net of Nepal

Based on the geodetic net of Nepal, second order point are established at a distance of 10km-15km apart. Similarly, third order and fourth order major points are established at about 5km and 1km apart respectively.

2.6 Vertical Control

Levelling is the operation of getting the height difference between two points. A datum plane is needed to describe the position of a specific point on the ground surface. Mean sea level of Indian ocean is taken as the datum plane for height (geoid) and level is carried out to the rigidly constructed point at the Nepal - Indian boarder. Height and its determination is done by means of levelling and correction in the difference of height should be applied through a measured value of gravity for th long levelling route.

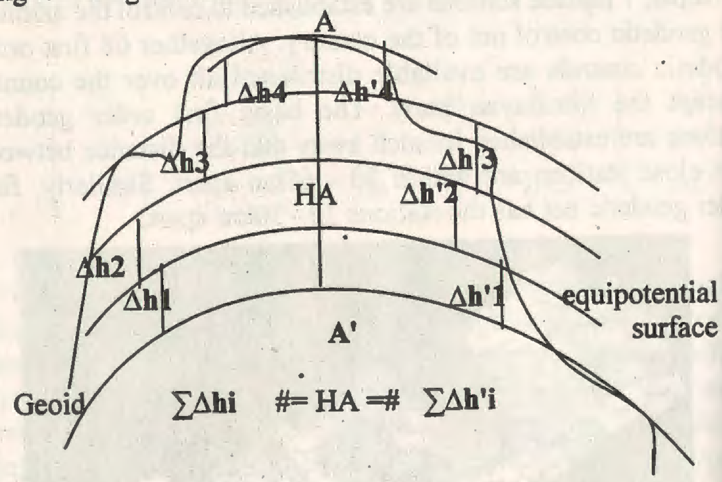


Fig. 14.Geo-potential surface

$$g = \frac{GM}{r^2} = -\frac{dw}{dr}$$

w is called the potential of g, G: gravitational consta
M: mass of the earth
Let **wo** be the potential on the geoid and **wa** be th potential on the ground, the difference between them the geo potential number.

$$\textbf{wo-wa} = \int_0^a g\,dh = C$$

$$Ca = \sum_{i=0}^{a} gi\ \Delta hi$$

where
C: geopotential number, **Δh**: height diffirence
g: gravity

Dynamic height is found by dividing the geopotential number C by an orbitrary normal gravity value (γ_0)

$$H = \frac{C}{\gamma_0} \text{ and } H = \sum_{i=0}^{a} \Delta hi + \sum_{i=0}^{a} \{(gi - \gamma_0) / \gamma_0\} \cdot \Delta hi$$

where
Δhi = height difference between bench marks.
ΣΔhi = height at point A measured through leveling.

$\bar{g}i = \frac{1}{2}(gi\text{-}1 + gi)$: mean value of surface gravity at bench mark i - 1 and i.

γ_0 = normal gravity at sea level

Orthometric height is the length measured along the vertical line between geoid and given point.

$$H = \frac{C}{g'a} \quad \text{and}$$

$$H = \sum_{i=0}^{a} \Delta hi + \sum_{i=0}^{a} \{(gi - \gamma_0) / \gamma_0\} \Delta hi - \{(g'a - \gamma_0) / \gamma_0\} \sum_{i=0}^{a} \Delta hi$$

where ,

g'a = mean gravity value below the ground surface along the vertical line AA' (can not be measured have to be estimated)

γ_0 = normal gravity value below the ground standard latitude.

As it is difficult to determine the orthometric height precisely, the normal height H is determined as

$$H = \frac{C}{\gamma'a}$$

C = geopotential number
$\gamma'a$ = mean normal gravity along the vertical line.

$$H = \sum_{i=o}^{a}\Delta hi + \sum_{i=o}^{a} \{ gi - \gamma_0) / \gamma_0\}\Delta hi - \{ (\gamma'_A - \gamma_0) / \gamma_0\} * \sum_{i=o}^{a}\Delta hi$$

assume γ_0 = normal gravity on the ellipsoid o and **B = 0.0003086 gal/m** to produce

$$\bar{\gamma} = \gamma_0 - B(H/2)$$

The normal height is a length from an ellipsoid to a point whose normal geopotential is equal to that at point A.

2.7 Gravity field and geodetic observation

An equipotential surface best resembling the actual figure of the earth is said to be geoid. The shape of the geoid can be epressed by using the height N above the reference ellipsoid and N is said to be geoidal height or undulation.

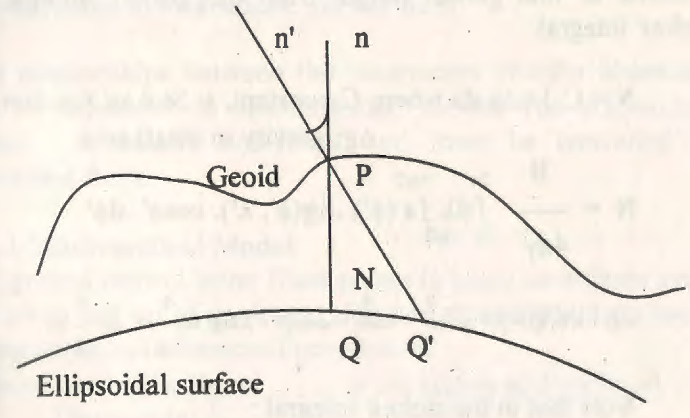


Fig.15. Geoidal height and deflection of vertical

The direction of the gravity is termed a plumb line and is perpendicular to the gravity equipolential surface. The direction of plumb line can be astronomically found by observing stars. This plumb line direction found by observing stars is expressed by latitude and longitude. On the other hand geodetic co-ordinates are determined based on normal of geodetic reference ellipsoid. An angle between the plumb line and the normal of the reference ellipsoid is called deflection of vertical.

Prime vertical component of deflection of vertical is calculated as **($\lambda a - \lambda g$) cos ϕ**

where,

λa = astronomic longitude
λg = geodetic longitude
ϕ = latitude

A gravity anomaly refers to the degree of deviation of actual gravity values from a gravity model of the earth, geoidal height indicates some deviation from the reference ellipsoid. It is possible to find geodal height from the gravity anomaly as stokes' integral.

$N = C \int s.\Delta g.ds$ where C:constant, s: Stokes' function
Δg: gravity in small area

$$N = \frac{R}{4\pi\gamma} \int_0^{2\pi} d\lambda \int_{-\pi/2}^{+\pi/2} s(\phi') . \Delta g(\phi', \lambda') . \cos\phi' . d\phi'$$

$$s(\phi) = s(R, \phi) = \{1 + \text{cosec}\frac{\phi}{2} - 6\sin\frac{\phi}{2} - \text{cosec}\{5 + 3\log(\sin\frac{\phi}{2} + \sin^2\frac{\phi}{2})\}\}$$

Note that in the stokes' integral :
"Measurement value of gravity of the earth as a whole is required."

The height obtain by global positioning system is free fro influence of gravity i.e the height from reference ellipsoid. Levelling height is from geoid surface. The geoidal height ca be found by GPS survey at bench marks.

On the earth the value of gravity (g) is 978 centimetre per secon per second at the equator and 983 centimetre per second per second (gal) at the poles i.e gravity at any point on the earth i not constant. Gravity reference system i.e, international gravity standardization (modified on 1979) is used for all the countri and fundamental gravity base stations are established on different part of the world. In Nepal gravity transfer was made different time from Shree Lanka and Bangkok.

Kathmandu airport station gravity val
g = 978661.22 ± 0.047 mgal.

Bangkok airport station gravity value: **D6230**
Bangkok g = 978300.10 ± 0.032 mgal.

2.8 Adjustment of geodetic survey data

The relationships between the parameters and the observables can be expressed on mathematical model. The mathematical model is usually non-linear and must be converted into linearised form.

2.8.1 Mathematical Model

For ground control some fixed points in some coordinate system are given and set of angle and distance measurement are used to compute the coordinates of new points.
Denote bearing by β_{ij} : $_i$ is the station and $_j$ tarjet
Distance by d_{ij}

Observation are assumed to possess a normal distribution

$$\beta_{ij} = \text{Arc tan}\{(X_j - X_i) / (Y_j - Y_i)\} + 0_i$$
$$d_{ij} = \{(X_j - X_i)^2 + (Y_j - Y_i)^2\}^{1/2}$$

Linearised equations are made from the above two equations and the system of n correction equation will be formed as mentioned below:

$$A\,x = \check{o} + v$$

A: coefficient matrix (n,u)
x: vector of the u unknown
ŏ: vector of the n observation
v : vector of the corresponding n residuals

The adjusted unknowns *x* are obtained by

$x = (A^T P A)^{-1} A^T P\, \check{o}$ where *P* weight matrix of the observation *x*

$x = Q_{xx}A^TP\,\delta$ where $Q_{xx} = N^{-1} = (A^TPA)^{-1}$ weight coefficient matrix of the unknowns.

The estimator $\sigma^2_0 = \dfrac{v^TPv}{n-u}$

The residuals v are obtained by

$$v = Ax - \delta = -Q_{vv}P\,\delta$$

$Q_{vv} = (Q - AN^{-1}A^T)$ where Q_{vv} :weight coefficient matrix of the residuals

2.8.2 Errors

An error is defined as the difference between observed value and the true value. Blunders, systematic and Random errors are the main types of errors in surveying. After blunders are eliminated and all systematic errors are corrected, there will be some more errors in the observation. These are random errors and are treated as stochastic model instead of the functional model.

2.8.3 Error ellipse and ellipsoid

Error ellipse and ellipsoid are used to evaluate the accuracy of position surveyed in two- and three- dimensional space respectively.

Varience and covarience matrix of computed coordnate of a point P(x,y) is given as:

$$\sigma_p^{\,2} = \begin{pmatrix} \sigma_x^{\,2} & \sigma_{xy} \\ \sigma_{xy} & \sigma_y^{\,2} \end{pmatrix}$$

The family of error ellipses about the computed position:

$$\frac{X^2_t}{\sigma_{xt}^{\,2}} + \frac{Y^2_t}{\sigma_{yt}^{\,2}} = C_1$$

where

$$2\sigma_{xt}^{\,2} = (\sigma_x^{\,2}+\sigma_y^{\,2}) + \{(\sigma_x^{\,2} - \sigma_y^{\,2})^2 + 4\sigma_{xy}^{\,2}\}^{1/2}$$
$$2\sigma_{y\,t}^{\,2} = (\sigma_x^{\,2}+\sigma_y^{\,2}) - \{(\sigma_x^{\,2} - \sigma_y^{\,2})^2 + 4\sigma_{xy}^{\,2}\}^{1/2}$$

$\tan 2\theta = 2\sigma_{xy} / (\sigma_x^{\,2} - \sigma_y^{\,2})$ where x_t and y_t is the major and minor axis of the error ellipse and θ is the angle which the x_t axis makes with the X axis.

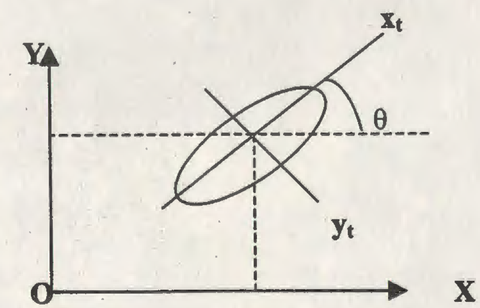
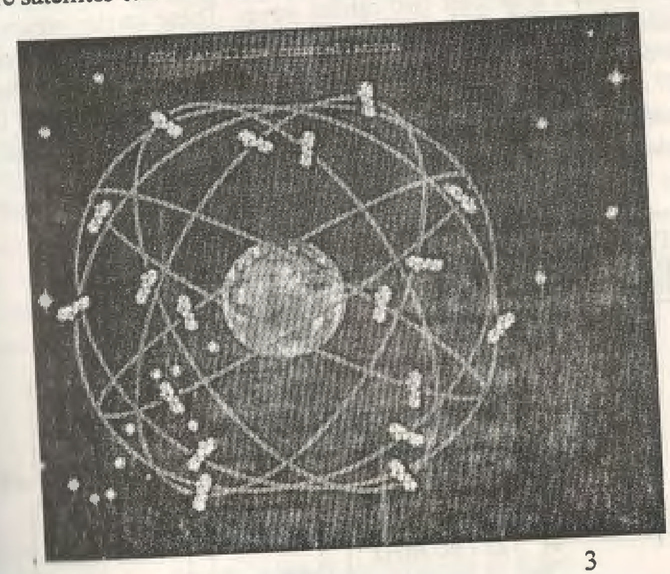


Fig 15a Error ellipse

Chapter III

3. Global Positioning System

Global Positioning System (GPS) is sometimes called NAVSTAR (Navigation System with Time and Ranging). GPS satellite was developed for military purposes and operated under the control of Department of Defense of the United States of America. These satellites are more than 24 in numbers with altitude of about 20,000 km above the earth and go around the earth by 1/2 sidereal day. Four or more satellites can be observed anytime at any place of the earth.



3

Fig. 16. GPS Satellite constellation

3.1 GPS configuration

The total GPS configuration is divided into 3 parts.

(a) The space segment: Satellite orbiting the earth

(b) The control segment: Stations positioned on the earth equator to control the satellites

(c) The user segment: Anybody that receives and uses the GPS signals

3.1.1 The space segment

The space segment consist of the constellation of 18 satellite in orbit at an altitude of about 20,000km in six equally spaced orbit planes each containing three satellites which will guarantee that there will be at least 4 satellites visible above the horizon at any point of the earth surface at any time. For geodetic measurement at least four satellites are required visible above the horizon at any point of the earth surface at any time with a 15^0 cut-off angle. Each GPS satellites have very accurate atomic clocks on board, which operates on 10.23 MHz fundamental frequencies. Orbit time around the earth for satellite is 11 hours 58 minutes. If the orbit of the satellite passes through the observer's zenith, satellite would be visible for about 5 hours
The satellites broadcast two carrier waves. These carrier waves are in L_1 and L_2 band and travel to earth at the speed of light. L_1 carries wave is broadcasted at 1575.42 MHz and L_2 carrier wave is broadcasted at 1227.60 MHz. L2 carrier wave has two codes modulated upon it. One is coarse acquisition code (C/A code) modulated at 1.023 MHz and precision code (P code) modulated at 10.23 MHz

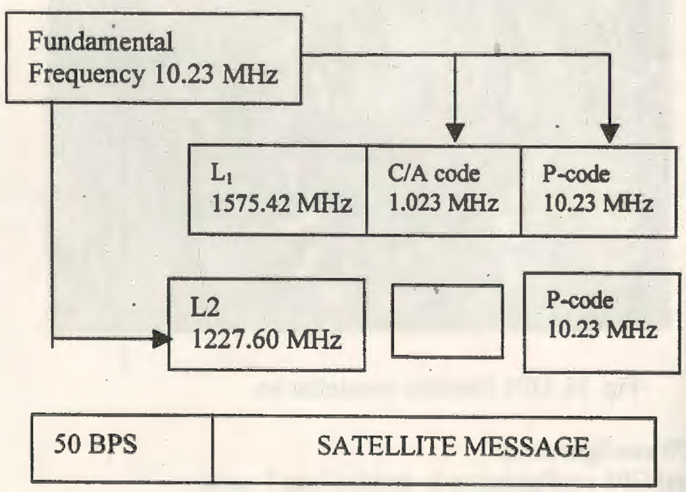


Fig.17 Satellite signals

3.1.2 The control segment

Control segment consist of the following station:

- 4 monitor stations(MS)
- Upload station(ULS)
- Master control station(MCS)

Monitor stations are located at Hawaii, Alaska,Guam,Elmandorf AFB and Colorado Spring. The upload station and master control station are located at Colorado Spring. The function of the ULS is to upload data into the navigation processor located in each satellite. Control segment tracks the GPS Satellite updates their orbiting position and calibrates and syncronises their clocks. The control segment has also the function to determine the orbit of each satellite and predict its path for the following 24 hours, which enables the GPS receivers to know the expected position of satellites. Master control station in Colorado springs processed the signals received from other stations to determine any errors in each satellite and sent back the information to the monitor station equipped with ground antennas and uploaded to the satellites.

3.1.3 The user segment

The user segment comprises of anybody that receives and uses the GPS signals for determining their position or time.

Surveying agencies are the major users of the GPS signals for the control point extension. Aerial navigation, marine navigation, vehicle location and machine control are other examples of applications within user segment.

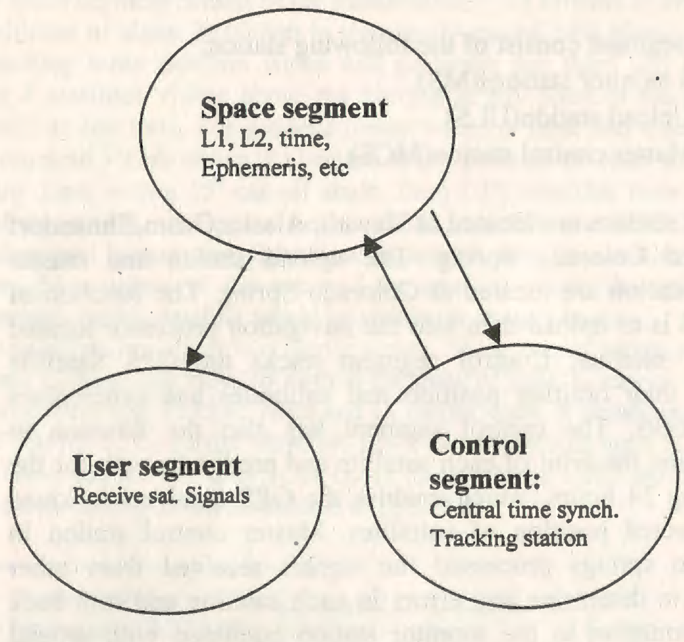


Fig .18 GPS configuration

3.2 GPS working principle

Accuracy of obtaining a position using GPS depends upon the type of GPS receiver used and available methods used for post processing. There are three types of techniques used in GPS.

(a) Autonomous Navigation
(b) Differentially corrected Global Positioning (DGPS)
(c) Differential phase positioning

These techniques are utilized for the position determination according to the purpose and accuracy requirement.

3.2.1 Autonomous Navigation

This technique uses the stand alone receiver where ships that are far away at sea which instantaneously gives a position and height /time to a user. The accuracy obtain is better than 50m. Receiver used for this type of operation are small portable with low cost.

Simple navigation by GPS receiver is based on measuring the distance from the satellites to the receivers on the earth by the method of resection as used on surveying.

If we know the distances to three points relative to our position, we can determine position relation to those three points. Newton's law of motion says :

Distance = velocity x time

The velocity is the velocity of the radio signal (290,000km/sec.). The time is the time taken for the radio signal to travel from the satellite to the GPS receiver. The satellite signal codes based on time (C/A code), which has very accurate atomic clock, can be matched or correlate with the receiver generated code, so that the time taken for the radio signal to travel from the satellite to the GPS receiver is calculated.

If we express the phase of the wave in ϕ rad, wave length in λ (m) and frequency in f, distance can be calculated as

Distance, $D = \frac{\phi}{2\pi} . \lambda + N. \lambda$ where N is wave number

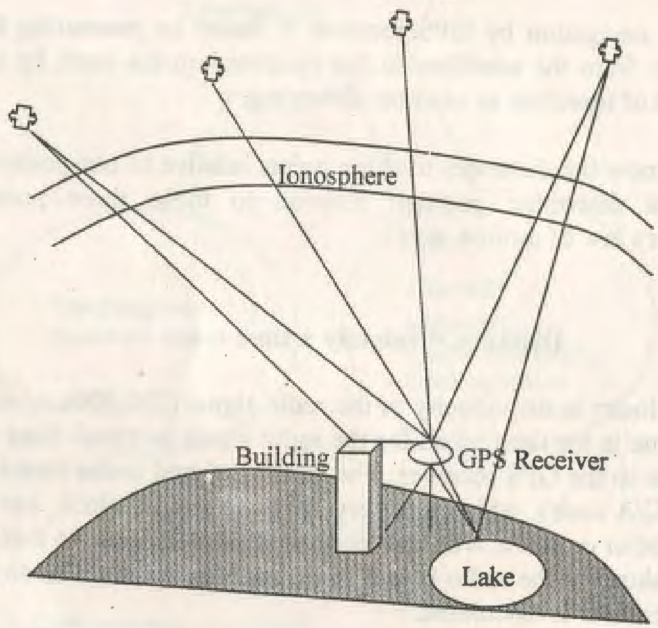


Fig 19. Ionosphere, satellite elevation and multipath

Sources of error on GPS Survey can degrade the position from theoretical few metres to tens of metre. These error sources are :

(a) Ionespheric and atmospheric delays
(b) Satellite and receiver clock errors
(c) Multi path
(d) Dilution of precision
(e) Selective availability (S/A)
(f) Anti spoofing(A/S)

(a) Ionespheric and atomospheric delays :

Satellite signal passess through the ionosphere and atmospheric delays can introduce an error in the position derived. The amount of delay caused by the atmosphere can be of several factors e.g. satellite elevation, the density of the ionosphere affected by the sun and water vapour etc;. Signals from low elevation satellite will be affected more in the atmospheric delays than signals from higher elevation satellite.High elevation satellites are observed, to avoid the errors in the position due to atmospheric delays. Sun increases the density of ionosphere in the day time and slows down the signal. An accurate estimation of delay can be made by dual frequency GPS receiver.Water vapour contanied in the atmosphere can also affect the GPS signal. The effect which can result in the position degrade can be reduced by using atmospheric model.

(b) Satellite and receiver clock error :

Clock in the satellite are accurate to 3 nano seconds. They are sometime drift slightly and can be corrected using control segment.

(c) Multipath errors :

Multipath occurs when the receiver antenna is positioned close to the reflective surface. This affects the accuracy in positon. Multipath error can be reduces by using special antennas or avoiding the reflected surface.

(d) Dilution of precision :

The Dilution of Precision (DoP) is a measure of the strength of satellite geometry and is related to the spacing and position of the satellite in the sky. DoP can magnify the effect of satellite ranging errors. Well spaced satellite is preferred to minimise the possible error margin. DoP can be of different types e.g. VDoP (Vertical), H DoP (Horizontal), PDoP (Positional) and GDoP (Geometric). GDoP is the combination of all the factors which gives accuracy degradation in three dimension position and time.

(e) Selective availability (S/A) :

Selective availability is a degradation in position accuracy applied by the US department of Defense to the GPS signals. Users of differential systems are not signigicantly affected by S/A.

(f) Anti Spoofing (A/S) :

Anti spoofing is similar to S/A. It's intention is to deny the access of P-code. Anti spoofing encrypts the P-code with signal called Y-code. Only users with military GPS receivers can decrypt the Y-code.

3.2.2 Differentially Corrected Global Positioning System (DGPS)

Various types of errors (out lined above) affecting the measurement of satellite range can be reduced by using DGPS techniques. The reference receiver at the base station of known co-ordinates are set in such a way that the reference receiver can work out the difference between the computed and measured range values i.e. corrections. These corrections are received on the rover receiver at required position through radio data link. It calculates and applies the range correction to the satellites. Multiple rover receivers can receive corrections from a reference receiver.

3.2.3 Differential phase positioning

In this method of positioning, minimum of two receivers are always used simultaneously and involves a lot of statistical analysis. The reference receiver is positioned at a known co-ordinated point and the other receivers are free to rove around. The base line between the reference and rover receiver are calculated.

The basic technique is to measure the distances to four satellites and computing a position from those ranges. This method of resection is usually used for surveying.

GPS relative positioning are classified as follows :

(a) Static positionig
(b) Kinematic positioning
(c) Pseudo kinematic / pseudo static positiong
(d) Rapid static positioning

(a) Static positioning :

GPS receivers are installed at different observation points and are kept to receive signals from the satellite during observation. This technique is used for measuring base lines, techtonic plate studies etc.

(b) Kinematic positioning :

A GPS receiver is fixed at one observation point, while the other receiver travels among several points for observation. The roving receivers must continue to receive signal radio waves during travelling. Real time kinematic (RTK) uses of radio data link to transmit satellite data from the reference to the rover. The kinematic technique is typically used for detail surveying.

(c) Pseudo kinematic / static positioning :
In this method of observation, short time static positioning is repeated at intervals of one or two hours and the receivers moves to other observation points one after another during these intervals. An observation is conducted two times at one points (reoccupation).This method is similar in working mode to kinematic positioning, while it is similar in principle of base line analysis to static positioning.

(d) Rapid static positioning :
In rapid static positioning survey, a reference point is selected and one or more rover receivers operate with respect to it and signals being received from more than four satellites allows position determination. Coming signals from more than four satellite and p-code information makes it possible to reduce observation hours to several minutes at one point. This method is used for establishing local control network, network densification etc. and much faster than the static technique.
Principle of finding base line vector through observation of the carrier phase under GPS are explained as follows :

In observing satellite number P with the receiver number K, assume that we obtain ϕ pk as the carrier phase, then this value is the diffirence between the received phase of the satellite ϕ p and the receiver phase ϕ k.

$$\phi pk^{(t)} = \phi p^{(t)} - \phi k^{(t)} + Npk$$

where **Npk** is the corresponding ambiguity.

"Ambiguity is the unknown integer number of cycles of the reconstructed carrier phase contained in an unbroken

set of measurements from a single satellite pass at a single receiver."

The received signal has travelled the distance *d* between the satellite at the time of transmission and the receiver at the velocity of light c and therefore there is a lag of ***d*pk/c * f** as compared with the phase of satellite at the time of transmission.

$$\phi pk^{(t)} = \frac{f}{c} \cdot dpk + Npk$$

Assume;

Dtp errorrs in the clock of satellite and **Dtk** be the error in the clock of receiver

Then, the equation becomes :

$$\phi pk^{(t)} = \frac{f}{c} \cdot dpk + Npk + f\,(Dtp - Dtk)$$

Observing two satellites **k** and **l** at the receiving point **P** and we will find the difference :

$$\phi pk^{(t)} - \phi pl^{(t)} = \frac{f}{c}\,(dpk - dpl) + (Npk - Npl) - f\,(Dtk - Dtl)$$

This differance is called single diffirence

$$\phi\, qk^{(t)} - \phi ql^{(t)} = \frac{f}{c} (dqk - dql) + (Nqk - Nql) - f\,(Dtk - Dtl)$$

Observing the two satellite **k** and **l** at another receiv[e] point **q** we can find another single difference.

$$DD(pq : kl) = \frac{f}{c} (dpk - dpl - dqk + dql) + (Npk - Npl - Nqk + Nql)$$

We find difference between these two single differe[nce] and the result is called double difference

$$\phi\, qk^{(t)} - \phi ql^{(t)} = \frac{f}{c} (dqk - dql) + (Nqk - Nql) - f\,(Dtk - Dtl)$$

- By considering double difference the error in the sate[llite] clock is also eliminated. If four satellites are observ[ed] one observation point, three independent dou[ble] differences are created in one observation ep[och]. Similarly, if GPS observation is made at a known po[int] and an unknown point, unknown parameters become for three observed double differences i.e. x, y, z, N_{12}, N and N_{14} where x,y,z are the coordinate and N_{12}, N_{13}, N are the integer ambiguity. Method of least squa[re] utilized to estimate unknown parameters by obse[rving] more than once.

.3 Satellite signals

Signals transmitted by the satellite are the frequency codes and message/ephemeries. GPS satellites transmit on two frequencies one at 1575.42MHZ called L1 and the other at 1227.6MHZ called L2. GPS employs a "pseudo random noise" PRN signals modulation structure for the following purposes:

- To provide the precise time marks
- To separate the various satellite signals
- To obtain signal processing advantages against multipath and jamming signals

The actual navigation signal is modulated on the carrier frequency using a binary PRN code generated by a mathematical algorithm at the satellite. Two types of PRN code are generated by each satellite i.e. C/A code (coarse acquisition) and P-code (precision). The satellite transmit a message at a rate of 50 bits per second. This message contains all the information to compute the satellite position. A message is 37500 bits long and divided into 25 frames. The length of the frame is 1,500 bits which corresponds to 30 seconds. The frame is divided into 5 subframe each consisting of 10 words. Each word contains 30 bits. Subframes contain the following:

Subframe 1: Clock correction parameter
Subframe 2 / 3: Satellite ephemeries
Subframe 4: Alphanumeric message for future application.
Subframe 5: Almanac data for satellite

.4 Measurement techniques

GPS measurement techniques are divided into four parts.

- Pseudorange
- carrier phase
- Integrated doppler count
- clock offset

Pseudorange measurement are made using the C/A-code or P-code. The code is transmitted at the satellite at a discrete position defined by the satellite message and the code is then detected at the receiver. One can compute the pseudorange as the difference between the two times, multiplied by the propogation velocity. A more refined estimate of range to the satellite may be determined by the measurement of the received phase angle of the L1 carrier frequency. The reconstructed carrier signals is an unmodulated sine wave. The frequency of the received signal at the receiver is different from satellite signal. Frequency change is due to relative motion between the satellite and the receiver and is known as Doppler shift. The integrated doppler count is then the sum of the difference in the number of cycles detected at the receiver, relative to the internal receiver frequency standard, measured over a given time interval. PS time,Satellite time and local time are the three different time scales. To be able to relate these times to one another, it is necessory to know their offset to a referrence time at the moment of event

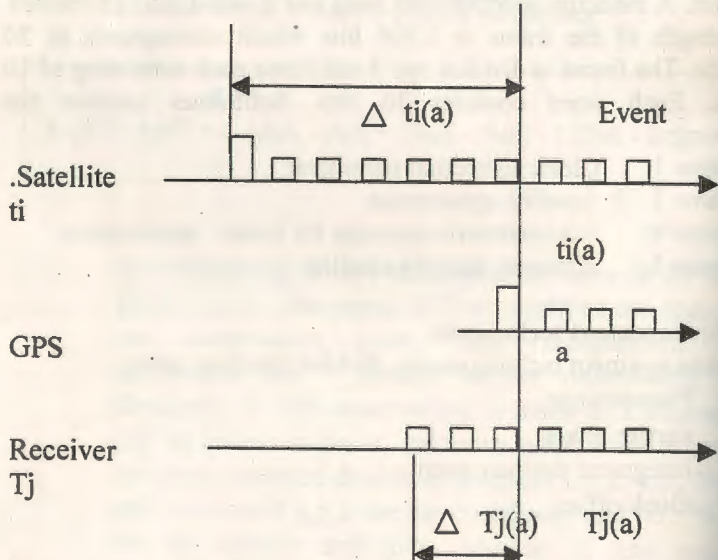


Fig. 19a. Clock offset to GPS time

Chapter IV

A. Geodetic Surveying with GPS

In traditional surveying, measurement were conducted always in relation to the direction of gravity and positioned the observation results on the reference ellipsoid. The datum is fixed on the ground and reference ellipsoid is established as a locally consistent system. In GPS surveying, geometric relations are directly determined between two distant points with reference co-ordinate system which is based on centre of the earth and the axis of rotation. The co-ordinates obtained from GPS surveying is free from the enfluence of gravity with consistent global co-ordinate system and distortion of geodetic networks is corrected by very long baseline interferemetry (VLBI).

It is possible, now a days, to determine the transformation parameters between GPS global co-ordinate system and local geodetic co-ordinate system, so that traditional surveying co-ordinates can be converted to global co-ordinate or vice versa. The advantages of GPS technique over the traditional surveying techniques are identified as follows:

(a) Intervisibility between points is not required
(b) GPS can be used in day or night and in any weather
(c) It is superior in operational efficiency to traditional surveying methods.

GPS is rapidly spreading in surveying, however GPS method has also some limitations :

(a) Satellite view could be blocked by tall building or objects as GPS antenna needs clear view for at least four satellite (visibility in the sky) and thus GPS can not be used indoors. It is difficult to use it in town centre and wood land areas.

(b) Similarly, as the process of measurement and analy
is closed, it is difficult to verify appropriateness
values beeing obtained by observation.

The surveying with GPS should follow the following steps.

(i) Preparation of plan of operation
(ii) Reconnaissance and monumentation
(iii) Preparation of station description card and diagram
(iv) Observation
(v) Data down load and preliminary computation
(vi) Co-ordinate transformation and adjustment
(vi) Data archieve

4.1 Plan of GPS Operation

In the planning process of surveying with global positioni
system, important factors are the numbers of receivers, observe
and observation schedule. Other factors which requi
consideration includes the condition of satellites, arrangement
known points and selection of ground points to provide c
ordinates. Besides this, we have to consider the overall planin
geometric dilution of precision, selecting good windows a
observation time to prepare plan of GPS operation.

4.1.1 Overall Planning

The overall planning of GPS surveying should consider th
following :

- The number of points and required accuracy
- Connection to existing control
- Keep base line as short as possible for hig accuracy
- The best ways of observation an computation
- Consideration of using two reference statio
- Use temporary reference stations for:
  - Indipendent check
  - Occupation of points twice in different windows
  - Closing traverse loop
- Use good windows

4.1.2 Geometric Dilution of Precision (GDOP)

A low geometric dilution of precision (GDOP) value indicates the good geometry. Poor satellite geometry can be compared with danger circle in traditional surveying resection. A GDOP of 5 or lower is ideal. A GDOP of less than 8 is usually taken in GPS surveying.

4.1.3 Selecting good windows

The satellite summary, GDOP, elevation and sky plot panels in the survey design compenent of post processing GPS software will help to select good windows. It is advisable to have the following condition to be fulfilled wherever possible for high precision geodetic surveying.

- 5 or more satellite above 20^0 cut off angle
- GDOP ≤ 5
- Recompute the GDOP if a satellite is obstructed

4.1.4 Observation Time

The observation time required for accurate result depends on base line length, number of satellites, satellite geometry, ionosphere etc. Night GPS observation is suitable to measure baselines as the ionospheric disturbance is much lower at night (base line range doubled or observation time halved) . Observation time on static observation method with GDOP ≤ 8 of baseline length 15 to 30km is about 2 hours at day time and 1 hour at night using dual frequency sensor. Considering the above, surveyors should prepare an operational planning for survey tasks. This includes :

- Define the survey task and planning schedule.
- Selection of surveyors and survey helpers
- Number of GPS receivers and other equipment to be used for survey
- Days required for the survey and the duration of the GPS survey
- Vehicle and other logistic support with co-ordinator of survey task execution

4.2 Reconnaissance and Monumentation

Reconnaissance means looking for and selecting the best position for the GPS observation. Surveying with global positioning system could be done to establish higher order to lower order geodetic stations. In addition to this detail topographic survey or the cadastral survey could also be done by kinematic global positioning system. Reconnaissance and monumentation of GPS surveying for geodetic network extension based on the existing geodetic network of the country shall be done and deal with accordingly. To establish the third order station, we have to begin with planning on 1:25000 scale topographic maps. Approximate location of stations, based on the higher order (first/second order) geodetic stations, could be sketched out a frame work on this base map. The third order geodetic stations provide the frame work for foulth order station which are the skeleton for cadastral or other type of large scale surveying.

Having found the location of a GPS station, it is necessary to site it in a safe place where it is unlikely to be disturbed. A good site should have the following characteristics:

- No obstruction above the 15^0 cut off angle.
- No reflecting surfaces that could cause multi path
- Safe away from traffic, possible to leave the receiver unattended
- No powerfull transmeter in the vicinity

The distance between two location of third order geodetic stations is about 5km apart. The GPS station of third order should be selected at one location in such away that three stations which are visible at one another are establish at one location for the future network extention by theodolite traversing. The result of the reconnaissance should be explained in the description card and on a recconnaissance diagram. The diagram of observation should be updated after completion of reconnaissance.

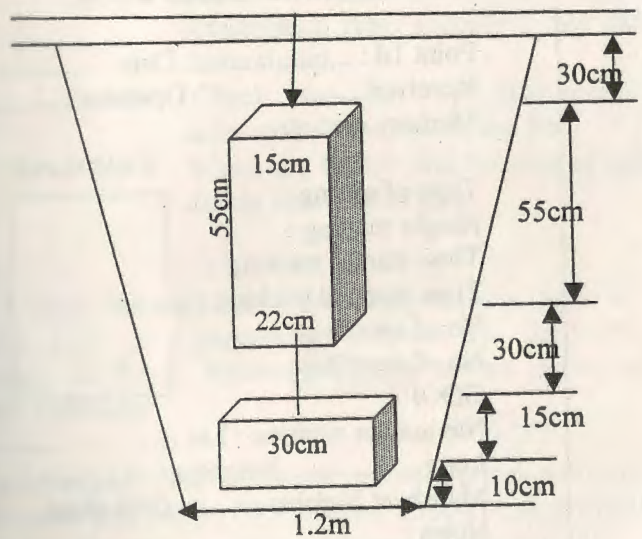


Fig. 20. Pillars and monumentation

The monumentation consists of digging a hole on the ground and placement of marks in the same vertical. The set of monumentation consists of 1 wooden lath of 2m long with some cutting on it, 2 big and 1 small iron stakes, 1 wooden hammer, plumb bob, spirit level, 2 chisels, steel tape, string and small nails. A hole is made at the station position by digging 1.2 x 0.8 meters side and 1.4 meter deep.

Monument the lower mark [concrete slap with mark] and up
mark [concrete pillar with mark] in the same vertical with
help of plumb bob.The verical length between the concrete pil
and the slab should be 30cm. If the upper pillar is lost, low
marks will help to reconstruct the upper pillar.After complet
of monumentation of the GPS station. Description card and t
diagram should be updated.

GPS FIELD WORKING BOOK

Point Id : ....Date ....
Receiver .... Operator : ....
Memory card no.
Field sketch

Type of setting :
Height reading :
Time started tracking :
Time stopped tracking :
No of epochs :
No of satellites :
GDOP :
Navigation position : Lat ....
Long .... Height ... ...
Mapsheet Number..........Grid sheet......
Notes :

Fig. 21. Field book with sketch

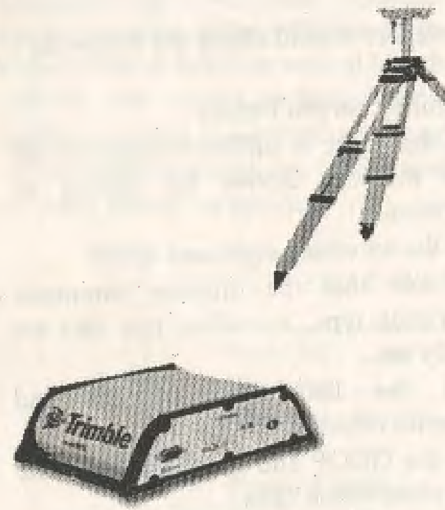
GPS field observation

fore field mobilisation surveyors should check the following :

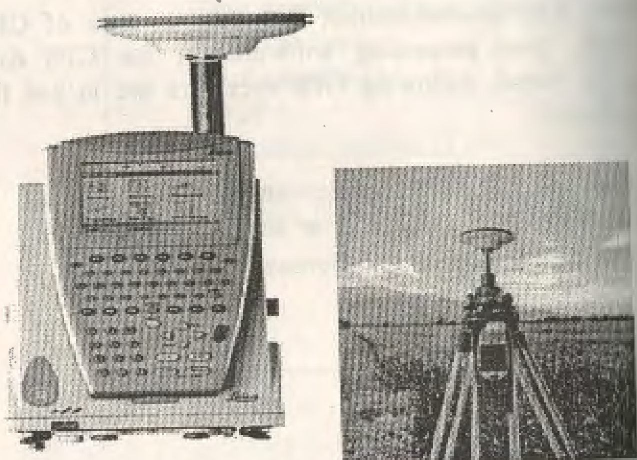
- Use a fully charged battery.
- Check that there is sufficient capacity left in the memory device for storing all observation.
- Check the antenna height and offset
- Make sure that the mission parameter (observation type, recording rate etc) are correctly set.
- Check the list of instrument and accessories required for the field.
- Watch the GDOP and number of satellite during observation time.

ow a days, international market has various type of GPS ceivers and post processing software for the GPS data ocessing. In Nepal, following GPS receivers are in use for odetic purposes:

- Astech LD_SSL GPS receivers and Astech software
- Leica SR200/500 GPS receiver and Ski-pro software
- Trimble GPS receiver and Bernese Software



Trimble GPS receivers



Leica GPS receivers

Fig.22 GPS receivers and antennas

In this book operation of Lieca - SR 500 GPS receiver sy... and Ski-pro software will be explained in detail, however ...

... system are not so much different in operation ... be handled with the help of manuals of respective ...

... SR 500 GPS receiver system has the following components :

- Each unit has SR 510 or SR 520 or SR 530 sensor
- A single frequency SR 510 sensor requires an AT 501 antenna
- SR 520 and SR 530 sensors needs dual frequency antenna AT 502 or at 503 or AT 504 (chockxist)
- A cable to connect the sensor and antenna
- A TR 500 terminal with a keyboard and display
- Batteries (cam corder) and tripod for antenna

Setting up System

... system for rapid static survey is performed as follows :

- Centre and level the tripod precisely above the station. Place and lock the carrier in the tribrach. Mount the antenna onto the carrier.
- Connect the antenna with the cable to the sensor.
- Plug two batteries into the sensor (external GEP71 battery can also be used)
- Attach the terminal to the sensor and insert a pc-card into the sensor and hang it on the tripod.

... the terminal requires some interaction between the users ... terminal.

The main menu looks :

Main\

1. Survey
2. Stakeout
3. Applications
4. Utilities
5. Job
6. Configure
7. Transfer

The use of cursor up/down keys on the terminal can highlight th menu item or pressing the number of menu will get straight t the menu item.

(b) Entering information on survey pannel

Point Id and antenna height can be entered by the use o alphanumeric keys on the terminal. Use the enter key t conclude the input - CE key to correct any typing error. So input field expects a predefined input. The input f configuration set, job and antenna has to be made pres ENTER on config set and confirm the selection by pressing CONT. The CONFIG key allows to change configuratio parameter. STATUS key provides direct access to all sys status information. ESC key allows to escape from the scr without executing a command.

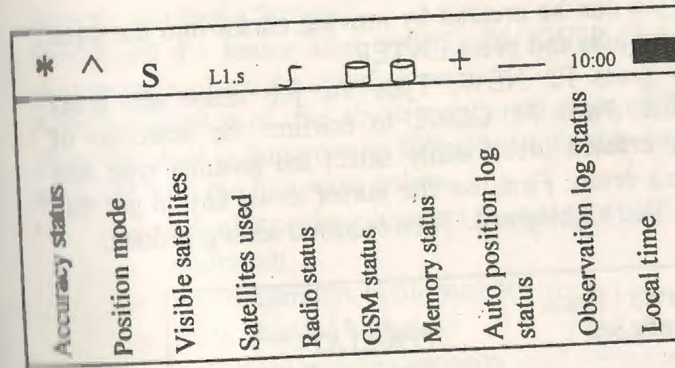
(c) Steps of GPS rapid static measurement are :

Step 1 :- Power on

Turn on the sensor by pressing on button on the termi

Step 2 :- Study the icons

Top part of screen which contants icon looks like this



As soon as the position icon is visible the sensor is in a stage where operation can commence. Any obstacle will block the view of number of satellite used differ from the number of visible satellite.

Step 3 :- Format your memory card (if required)

press 4 utilities icon and ENTER
press 2 to get access to the format memory module panel and ENTER.

For pc-card format press F1 CONT for internal memory press ENTER allows to select internal memory and press ENTER.
Then press F1 CONT.
ESC can be used any time if formatting is not required.

Utilities \ format memory module device: Internal	Utilities \ format memory module device: PC-card

Step 4 :- Survey

Survey operation can start pressing 1 in the main panel and ENTER.
For static survey one should select the PP-STAT configuration set. Press ENTER.

New job can be created by moving cursor into the input field for jobs and press ENTER.

Now press F2 NEW. Type the job name and press ENTER. Press F1 CONT to confirm the selection of newly created job. Finally select the antenna type and antenna setup. First use the cursor down key to get this input field highlighted. Then required setting is done.

Survey \ Begin	
Config set:	PPR-STAT
Job:	Test
Co-ordinate sys:	WGS84 Geodetic
Antenna:	AT502 Tripod

Step 5 :- Logging raw data

It is time to check again the icons on the top of display. The position icon should be available and number of satellites visible and used are equal (more than 4). Press F1 OCCUPY which activates logging of raw data. Raw data is logged at predefined intervals (10 seconds observation recording rate by default and can be changed). Enter a point Id by filling in the input field and use the height hook to determine the height of antenna above the survey marker. Insert the hight hook into the carrier and measure the hight between the white mark at the bottom of the height hook and the survey marker. Enter this reading into the antenna height field. Once sufficient amount of data has been collected the survey of the point can be completed by pressing F1 STOP. Conclude the survey sequence by pressing F1- STORE. Finally press SHIFT- F6- QUIT.

Survey \ Test	
Point Id:	Point 15 /123
Ant Height:	1.536m
GDOP:	6.8

Step 6 :- Ending a Survey

Switch off the sensor after SHIFT- F6- QUIT. Put the equipment back on the shipping case.

After completion of the above mentioned steps of field observation, it is important to filling out a field book for each site with the following points.

- No obstructions above 15^0 cut-off angle and multipath
- No transmitters in the vicinity
- Fully charged batteries
- Sufficient memory capacity
- Check antenna height and offset
- Correct configuration parameters
- Good windows and the GDOP ≤ 8
- Tribrachs : bubble and optical plummet
- Use mobile or radio to maintan contact between reference point and rover point

[illegible] Importing the GPS data

After completion of the GPS observation of one session, GPS raw data from the receiver should be transfered to computer by SKIpro(software for GPS Processing) directly via a pc-card slot or via a card reader or receiver or from a disk with backup raw data. During data transfer the points should be taken care off :

- Point identification i.e make sure that points which are observed twice have the same point number. Different points have different identification.
- Compare the height reading with field book.
- Check spelling, upper lower case letter, spaces for point number.
- Always make a back up on a diskette or on the hard disk. Make directory for each card.
- After importing all the data and making back up copy erase and reuse the memory card.

Chapter V

5. GPS Data Processing

Before starting GPS data processing one should consider the following task carefully :

- Connections to existing controls
- Long lines or short lines
- Obtaining good initial WGS 84 co-ordinate for one point
- The transformation of WGS 84 to local co-ordinate
- Data processing parameters
- Computation of network of temporary reference stations
- Data import / point identification

5.1 Installation of Ski-pro software

System requirement for the Ski-pro software which is used for GPS data processing is as follows :

- Windows 95 or windows 98 or windows 2000 operative system
- PC with pentium processor 200 Mhz
- 64 MB RAM
- 300 MB free space on hard disk
- RS 232 COM port
- Parallel port
- 1.4 MB 3.5m disk drive
- Mouse installed
- CD - ROM drive

To install Ski-pro software insert the CD ROM labelled GPS system 500SW. The install shield will start and guide you the installation process. Typical or compact options are given. For software protection key (dongle) compact option is chosen.

5.2 Processing Software Components

Ski-pro software for processing GPS data collected from Le GPS receiver runs on windows platform. Ski-pro G processing software consists of following components.

1. Project management
2. Co-ordinate set management
3. Co-ordinate system management
4. Antenna management
5. Code list management
6. Sensor transfer
7. Raw data import
8. ASCII import / export
9. Rinex import / export
10. Datum and map
11. Data processing and adjustment
12. G IS / CAD export

Project Management

All GPS data that is collected and that belongs together can b organised within a single project. It is possible to create, op and edit projects. This component can also be used to attach an modify co-ordinate system.

Coordinate Set Management

A coordinate set is a list of point coordinates that are stor independently from projects. Points can be added manually or b importing.

Co-ordinate System Management

A co-ordinate system provides the information necessary t convert co-ordinates to cartesian, geodetic or grid representatio and to transforms co-ordinates between the WGS 84 and lo system. It is linked to a data base that stores the parameters

Antenna Management

It allows us to define and edit the parameters of different GPS antenna used. This information is stored on database and can be used for data processing.

Code list Management

This contains coding information that may be assigned to points during measurement in the field. It may be attached to a project.

Sensor transfer

This component allows us to down load data from a sensor and upload data to a sensor by a serial cable or PCM CIA memory card.

Raw data import

This allows us to imports GPS field data in the ski-pro software. There is the provision to import precise ephemeris data.

ASCII import / export

ASCII imports component enables us to import co-ordinates and baselines from pre-defined or user defined files. ASCII export component enables to export data form ski-pro software. Co-ordinate information may be exported to ASCII files in user defined or predefined formats.

Rinex import / export

Rinex import enables us to import GPS observation data collected with other party receivers in RINEX format. RINEX export enables us to export GPS raw data to an ASCII file in RINEX format.

Datum and Map

This component provides us a tool to determine transformation parameters that can be used to transorm WGS 84 co-ordinate to local co-ordinate system.

Data processing and adjustment

Data processing allows us to process GPS observation achieve WGS 84 co-ordinates and its accuracy. Adjustme allows us least square adjustment on a network of basel vectors and terrestrial data.

GIS / CAD Export

It enables us to write the point co-ordinates to Auto CAD, mi station (DGN) or map info (MIF) format.

5.3 Pre-processing GPS data

This section of pre-processing GPS data will explain how create a project, import GPS real time data, check the dat view/edit and finally to export these co-ordinates to a ASC file. Dongle connection to the computer is not needed for th process.

Step I :- Import GPS raw data

- ➔ From the Start menu select Programs, Ski and click Ski-pro.
- ➔ From the Import menu or Toolbar : sel GPS Raw Data.

  Or

  From the Tools list bar : select Import Raw data.
- ➔ Under files of type : select GPS 500 raw d
- ➔ Under look in : select the directory of sam data .... \ski-pro\sample data\sys 500\ r time\ data\Geodb.
- ➔ From the browser select the job RT sampl
- ➔ Click import.
- ➔ Right click on Projects and select New.
- ➔ Under location enter a path.

  e.g. c:\ski-pro\data\projects
- ➔ Enter a Project Name e.g. ADHIKARY 1

- ➔ Click OK.
- ➔ Back in the Assign dialogue. Click the Setting tab : Here select the import co-ordinate system and components (auto solve) and the co-ordinate system will be automatically attached to the project. Make sure both option are checked.
- ➔ Click the field book tab to create a field book report.
- ➔ Select co-ordinate type Local and Grid.
- ➔ Click Preview : to view the report.
- ➔ Click General tab select Assign and Close.

Step II :- View / edit component

The view / edit project to window opens directly.

- ➔ Use the toolbar to zoom into the detail points.
- ➔ Right-click on the background, select Graphical Settings and change the settings.
- ➔ Right click on point and select properties if the point is not within the zooming extend scroll to point and edit point toolbar botton.
- ➔ Click the Mean tab in the property sheet The property page displays the two solutions and their differences.
- ➔ Click OK.

Step III :- Exporting co-ordinates to ASCII file.

- ➔ From the Export menu select ASCII (dialog box appears)
- ➔ Under Shave in select a path.
- ➔ Under Shave as type select Custom ASCII file.
- ➔ Enter a file name e.g. RT sample 1.
- ➔ Click the settings and select the format file.
- ➔ Change co-ordinate class to main.

- ➔ Use the Browser to select the file.
- ➔ To continue, click on the Co-ordinate system
- ➔ Make sure the co-ordinate system sample R is selected.
- ➔ Click on OK.
- ➔ Click Save to write the file to the hard disk

5.4 Post - Processing

Post-Processing software requires dongle to be connected to th computer. A rapid static network has been measured and r data is in the directories. This post processing comprises of th following steps :

Step I :- Importing GPS raw data.

- ➔ From Start select Program, Ski-pro then cl on Ski-pro.
- ➔ From import menu or toolbar select GPS Data.

  Or

  From the Tools List Bar select Import G Raw Data.
- ➔ Under files of type : select GPS 500 Data.
- ➔ Under Look in : select the directory th contains the sample data.
- ➔ Check include subfolders.
- ➔ Right click on Projects and select New.
- ➔ Under Location enter a path.
- ➔ Enter a Project Name.
- ➔ Click OK to confirm.
- ➔ Back in the Assign dialog select Assign then Close.

Step II :- Processing Baselines

This step explains how to process and store baselines. A base line is always process between a reference point and a rover point.

- ➔ Click on tabs below the windows view/edit shows a graphical representation of each point of the project.
- ➔ Right-click on a point and select Properties.
- ➔ Change the point class to Control and change the co-ordinates accordingly.
- ➔ Click OK to confirm.
- ➔ Click the Data-proc tab at the bottom of the windows.
- ➔ Right click on the background of the graphical windows, click on Select Mode and then Rover.
- ➔ Click on the horizontal bars of the first instant of points. The colour of the Rover intervals changes to Green.
- ➔ Right click the horizontal bar of a point and select References. The colour of the reference interval changes to red.
- ➔ Right click on the background and select Process or click Process from the toolbar.

Result view will be display to examine and store the processed baseline. Ambiguity status can be of Yes, Yes*, No and ?. Yes ambiguity means the determination of the integer number of cycles between the satellites and the GPS receivers was successful i.e. baseline calculation is correct.

- ➔ Right click on the selected points and select Store. To verify that the baselines have been store click the view / edit tab at the bottom of the windows.
- ➔ Right click in the background and select Graphical settings.

To complete the network it is required to process the remaining processing runs.

➔ Click Data-proc tab.

➔ Right click on the background and click on Deselect All and select the second instant of the points with Rover and reference points. Process and store.

In View / Edit it will be noticed that the point symbol have changed for all points. (i.e. measured, averaged and reference points)

➔ Right click on a point and select Properties. Click the Mean tab on the top of the property sheet. Solutions and their differences to the weighted average will display.

➔ Click OK or Cancel to exit the property sheet.

➔ Click the Points tab at the bottom of windows.

➔ Right click on any column header and select Auto arrange.

Now, it is prossible to sort the list, to display / and hide the information and finally print the content of the report view. WGS 84 co- ordinates are now available for all the observed points.

Step III :- Creating a co-ordinate system.

Software deals with the co-ordinate system in cartesian (x,y.z), Geodetic (lat, long, height) and Grid (easting, northing and height) format.

➔ Open the co-ordinate system management :- from the Tools menu or Management list bar, select Co-ordinate System Management.

➔ In the Tree view right click on Projection and select New. Fill the property page. (Name :

UTM, Type : UTM modified, Zone : ?, Serial number ?, Hemisphere : Northern)

➔ Click OK to confirm.

➔ In the tree view right click on Co-ordinate system and select New. Fill the property page (Name : PP sample, Transformation : none, Ellipsoid : everest 1830, Projection : UTM modified.)

➔ Click OK to confirm.

➔ From Window menu select Close.

Step IV :- Importing an ASCII file

This step imports the local control points from a user defined ASCII file and creats co-ordinate set.

➔ From Imports menu click ASCII

➔ Choose the file type Text files.

➔ Under Look in select the directory that contains the data.

➔ Select the file Local.txt. Under co-ordinate system select Local.

➔ Click Import : user defined ASCII file import wizard step 1 of 4 appears

➔ Click Free and then Next to continue : user defined ASCII file import wizard step 2 of 4 appears.

➔ Check space and then Next to continue : wizard step 3 appears.

➔ Right click on the first column heading (o) and select Point Id.

➔ Right click on the second column heading (1) and select co-ordinates and then easting.

➔ Select Northing and elevation Height for the third (2) and fourth (3) column respectively.

➔ Click on next to continue : wizard step 4 appears.

- ➔ Click on Finish to close the wizard.
- ➔ Right click on co-ordinate sets and select New : Property sheet appears.
- ➔ Enter the Co-ordinate set Name : PPsample local.
- ➔ Select the co-ordinate system PPsample from the list.
- ➔ Click on OK.
- ➔ Click on Assign and the Close.
- ➔ From the window menu select Close.

Step V :- Calculate the Transformation Parameters.

Two sets of co-ordinates are needed to calculate transformation parameters. First set in WG S 84 co-ordinate system and second set in Local co-ordinate.

- ➔ From the Tools menu click Datum / map.
- ➔ In the upper Tree view open the Projects folder and select PP sample.
- ➔ In the lower Tree view open co-ordinate sets folder and select PP sample local.
- ➔ Click on the Match tab to continue : datum and map view appears.
- ➔ Right click on the background in one of the view and select configuration.
- ➔ Under Transformation select Classical 3D and confirm with OK.
- ➔ Right click on the background and select Auto Match.
- ➔ Click the Results tap to continue : result and residuals ae displays.
- ➔ Right click on the background and Store.
- ➔ Enter a name e.g. PP sample WGS local check the two boxes and click on OK.

Step VI :- Co-ordinate system with a project

This step shows to use a co-ordinate system with a project and switch between WGS 84 and local co-ordinates.

- ➔ From management List Bar : select Project Manager.
- ➔ Right click on the Project PP sample and select Properties.
- ➔ Click on the co-ordinate tab : project properties dialog appears to verify the parameters.
- ➔ Click OK to continue.

- ➔ Right click on the project PP sample and select Open : the project windows opens with the test used views active.
- ➔ Select the points tab : displays the WGS 84 co-ordinates in geodetic format

- ➔ From the Toolbar click on Local and then Grid : the view displays local co-ordinate.

Step VII :- Exporting co-ordinate to an ASCII

This step export co-ordinates to a user defined ASCII file. Assuming project is still open :

- ➔ From Export menu select ASCII

- ➔ Under Save in select a path.

- ➔ Under Save as type select Text file.

- ➔ Enter a file name : PP sample 1.

- ➔ Click on the settings button to change the export settings : user defined export setting page appears.
- ➔ Change co-ordinate type to Local and Grid.
- ➔ Change co-ordinate class to Main.
- ➔ To continue click on the Points tab.
- ➔ Double click on Point Id then Easting then Northing then Ell height.
- ➔ To continue click on the co-ordinate system : make sure that co-ordinate system PP sample WGS local is selected.
- ➔ Click on OK and finally click Save.

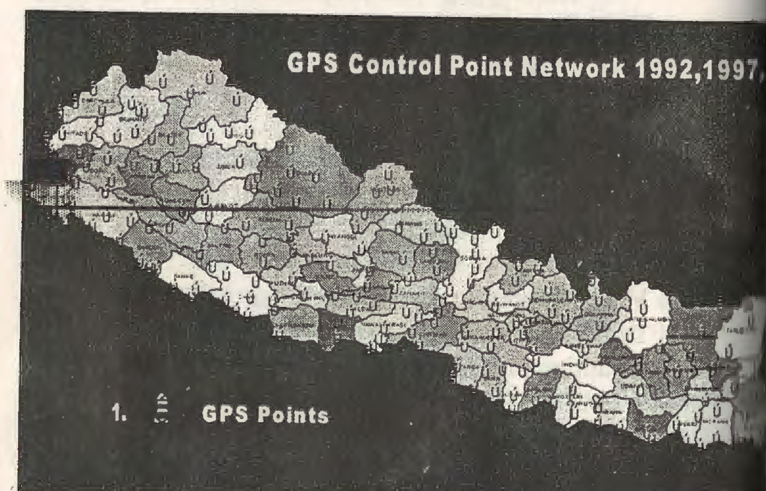


Fig.23 GPS precise control network of Nepal

Chapter VI

6. Detail survey with GPS

Detail survey using global possitioning system is possible for large scale topographic mapping. Kinematic measurements will provide the trajectory of a moving antenna. It is only time related not point. Stop and go measurements deliver co-ordinates for discrete points which are occupied for a short period of time. Thus, kinematic and stop and go survey with static initialization on reference site will achieve position accuracy on the centimeter level. Co-ordinates of the points can be obtained and plotted to make a large scale topographic map .

6.1 Kinematic and stop and go surveying

Kinematic and stop and go surveying is an efficient way of measuring many points quickly and efficiently, provided the following criteria are met.

i. Distance between the reference receiver and the rover is fairly short i.e less than 3km baseline.
ii. The surveying area is fairly open with not many obstructions between points.
iii. The rover is kept perferctly steady during the static initialization.
iv. A static re-initialization is always carried out after a complete loss of lock.
v. Satellite geometry is strong i.e. minimum of 5 satellite should be visible.

GPS antenna can be mounted on a range pole and the sensor can be stored in the sytem 500 minipac or whole sensor can be kept on the range pole itself. The kinematic and stop and go measurements are taken as the following steps :

Step I :- Setting up the reference site.
Observation rate of 2 or 5 seconds is chosen and it should be th same for roving sensor and that logging of static data is turn o It should be confirmed that the reference receiver is operated an environment which is suitable for GPS measurements (fre obstructions). 5 minutes of dual frequency static observation a base line not longer than 3km is taken.

Step II :- Starting the rover sensor

- ➔ Kinematic and stop and go surveys are par the survey operation. Select a suita configuration set. "PP -KIS".
- ➔ Static initialization has to be set to "Y Data logging parameters are set correctly kinematic and stop and go surveys. Loggi for both static and moving observations m be turned on.
- ➔ Select a job and antenna set up (e.g. AT50 AT501 for SR510 sensor)
- ➔ Press F1 CONT to proceed
- ➔

Step III :- Measurements

- ➔ After F1 CONT : survey panel appears st with a static point measurement. Measu point for a few minutes (3-5 min) make su the antenna is steady.
- ➔ Take the measurements of the starting joint processing F1 OCUPY to start logging sta observation followed by pressing F1 Stop an F1 Store to store point Id aid antenna heigh Observation are logged while moving Now is ready to move the antenna
- ➔ If the discreate points has to be measured th press F1 ocupy and hold for a few secon and F1 Stop and F1 store to complete

point measurement. If we are interested on the trajectory of the antenna then just get moving which gives time lagged co-ordinates for every epoch.

Note that another static initialisation is necessary if obstructions is caused during observation.

Step IV :- Ending a kinematic and stop and go operation.

Pressing SHIFT F6 QUIT will end the kinematic and stop and go operation.

Kinematic on the fly and post processing

Kinematic on the fly measurement provides the trajectory of a moving sensor without the necessity of a static initialisation. The sensor can be moved from the first observation epoch onwords. Dual frequency phase measurement can give accurate results. SR 510 and SR 530 sensors are used for this method. At least 5 satellites are needed on L1 and L2 frequency to allow a fixing of ambiguities in post processing. Discrete points can also be measured.

Step I :- Configuration parameters

- ➔ Logging parameter are set correctly.
- ➔ The parameter "static Init" must be set to NO while logging of static observation.
- ➔ Moving observations must be set to Yes.
- ➔ Recording rate at the rover sensor should be same as on reference site.

Step II :- Measurement

- ➔ As soon as main survey panel is accessed, data logigng commences according to the configured logging parameter.

➔ F1 occupy will change the status from moving to static. F1 stop and F1 store measuremt mode will switch to moving.

➔ Occupy points only once 2 minute of cycle slip free data before start occupying points.

Step III :- Post Processing

Ski- pro will treat the data as so called mixed tracks. Both static and moving data is contained in one and the same chain of measurements. Kinematic on the fly is ideal if :

- A window with more than 6 satellites
- Distance between reference and rover should be kept short (<3km).
- End a track after 20 points and then reinitialize again.
- Include independent checks in the measurements i.e. include known point

Post - processing of kinematic and stop and go or on the fly is similar to the processing of static survey observation. Data processing will compute and provide a position for each static point by averaging the results of each epoch of data which was taken during the static occupation.

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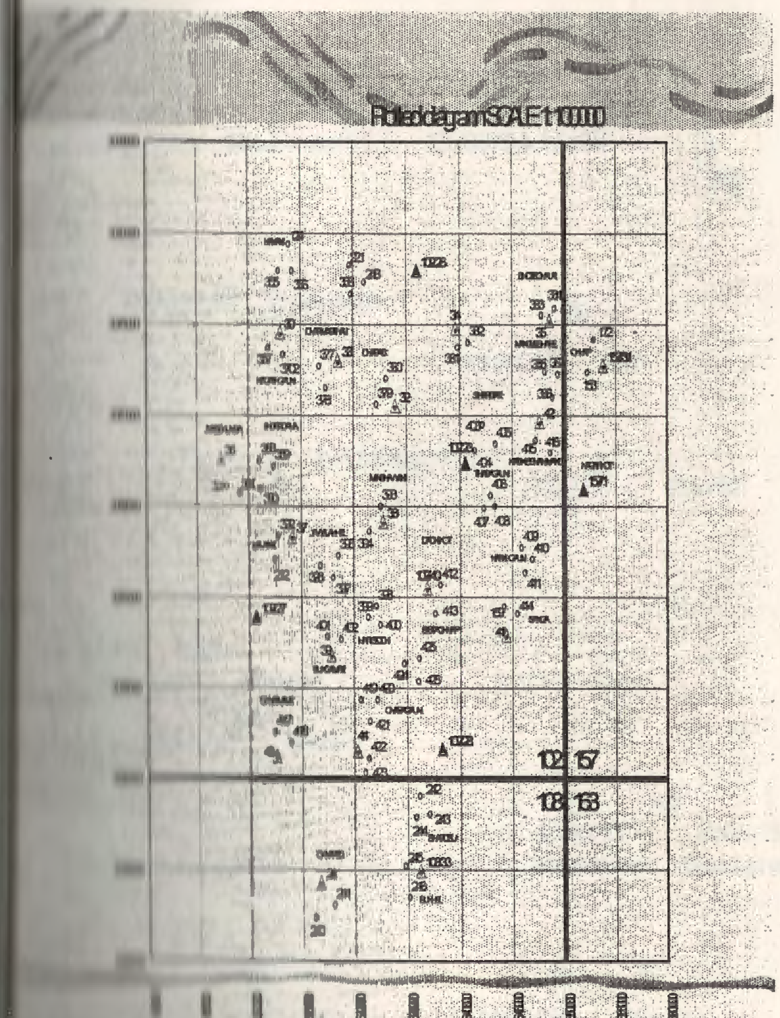
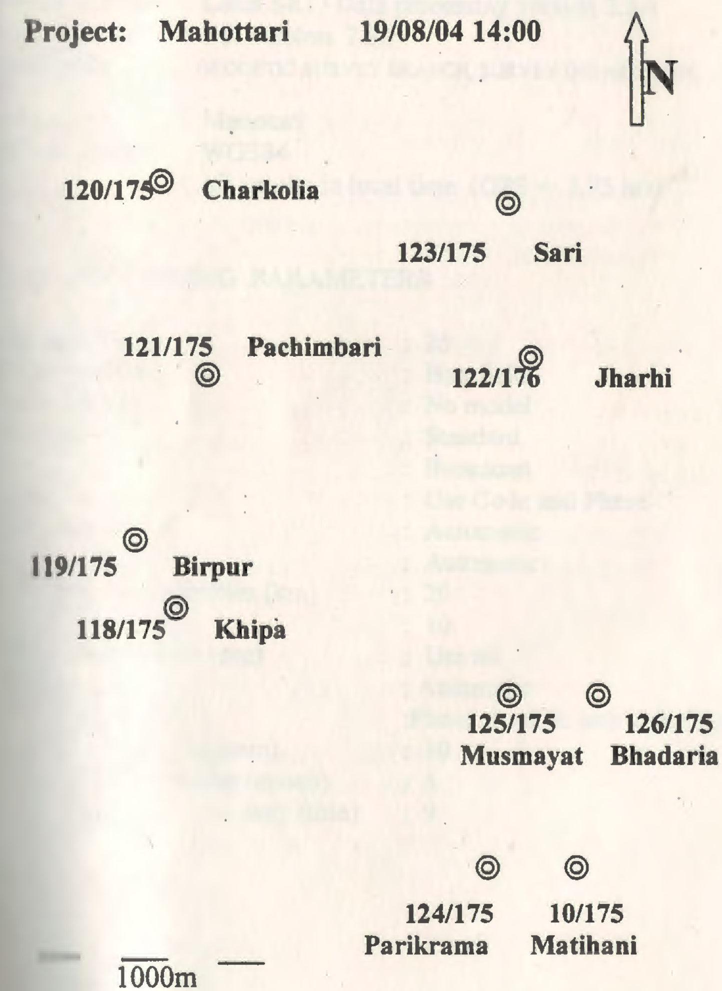
Appendix I
Extension of geodetic control using GPS



Appendix II
Geodetic Control Diagram with GPS Stations



Appendix III
GPS Raw data and preprocessing

OE_PS PROJECT SETTINGS

Processing software : Leica SKI / Data processing version 2.3-1
Processing kernel : PSI version 2.30
General header : GEODETIC SURVEY BRANCH, SURVEY DEPARTMENT, NEPAL
Project name : Mahotari
Coordinate system : WGS84
Time : All results in local time (GPS + 5.75 hrs)

OE_PP PROCESSING PARAMETERS

Cut off angle (deg) : 25
Troposphere model : Hop field
Ionosphere model : No model
Solution type : Standard
Ephemeris : Broadcast
Data used : Use Code and Phase
Phase Frequency : Automatic
Code Frequency : Automatic
Limit to resolve ambiguities (km) : 20
A priori rams (mm) : 10
Sampling rate for static (sec) : Use all
Phase processing : Automatic
Cycle slip detection :Phase check & loss lock flag
Phase measurement rms (mm) : 10
Update rate for kinematics (epoch) : 5
Min. time to fix amb. - L1 only (min) : 9

GE_SS SATELLITE SELECTION

Manually disabled satellites : None

GE_BO BASELINE OVERVIEW

Total no of baselines computed : 3

BL i	CH id	Rover	Reference	First common ep	Amb	Frq	Obs M
1	1	175124Parikrama	175010Matihani	03/20/01 02:16:00 PM	Y	1+5	STS
2	2	175125Musmayat	175010Matihani	03/20/01 02:16:00 PM	Y	1+5	STS
3	3	175126Bhadariya	175010Matihani	03/20/01 02:24:00 PM	Y	1+5	STS

GE_IC INITIAL COORDINATES

Reference :

Point id : 175010Matihani

X 413544.3443m Y 5691266.2013m Z 2839883.8295m
Lat 26 36 44.37000 N Lon 85 50 38.48000 E h 15.0500m

Rover :

Point id : 175124Parikrama

X 413892.0142m Y 5691292.4796m Z 2839779.7019m
Lat 26 36 40.59681 N Lon 85 50 26.01476 E h 14.3758m

Point id : 175125Musmayat

X 413869.7221m Y 5690937.7471m Z 2840494.4199m
Lat 26 37 6.53189 N Lon 85 50 25.88838 E h 16.8087m

Point id : 175126Bhadariya5690959

X 413507.1003m Y .6236m Z 2840498.1647m
Lat 26 37 6.70576 N Lon 85 50 39.01962 E h 14.4889m

[illegible] ====== NEW STATIC CHAIN ======

[illegible] 175124Parikrama 175010Matihani 03/20/01 02:16:00 PM

[illegible] START / END (COMMON) EPOCHS

03/20/01 02:16:00 PM to 03/20/01 03:20:00 PM

[illegible] OPERATION INFORMATION

	Rover	Reference
Point id	175124Parikrama	175010Matihani
Sensor/Controller id	1641 /94883	1616 /94884
Operation mode	STS	STS
Observation rate (s)	15.0	15.0
Ht reading/Ant offset (m)	1.500 /0.441	1.324 /0.441
Eccentricity E/N/H (m)	0.000 /0.000 /0.000	0.000 /0.000/0.000

[illegible] SATELLITE INFORMATION

SV id	L1 phase	L2 phase	L1 code	L2 code
[illegible]	187	177 S	187	177
[illegible]	257	248 S	248	239
[illegible]	24	0 S	24	0
[illegible]	257	254 S	248	245
[illegible]	257	257 S	257	257
[illegible]	129	129 S	129	129

BL_EA.1 ELEVATION / AZIMUTH

sat id : hh:mm:ss	PDOP	GDOP	24	5	4	10	7
14:16:00	4.8	5.7	65/329	43/308	40/ 32	38/184	26/91
14:16:15	4.8	5.7	65/330	43/308	40/ 32	38/184	26/91
14:16:30	4.8	5.7	65/330	43/308	40/ 32	38/184	26/91
14:16:45	4.8	5.7	65/330	43/308	40/ 32	38/184	26/91
14:17:00	4.9	5.8	65/330	43/308	40/ 32	38/184	26/91
14:17:15	4.9	5.8	65/331	43/308	40/ 32	38/184	26/91
14:17:30	4.9	5.8	65/331	44/308	40/ 32	39/184	26/91
14:17:45	4.9	5.8	65/331	44/308	40/ 32	39/184	26/92
14:18:00	4.9	5.8	65/332	44/308	40/ 32	39/184	26/92
14:18:15	4.9	5.9	65/332	44/308	40/ 32	39/184	26/92
14:18:30	5.0	5.9	65/332	44/308	40/ 32	39/184	26/92
14:18:45	5.0	5.9	65/332	44/307	39/ 32	39/184	26/92
14:19:00	5.0	5.9	65/333	44/307	39/ 32	39/184	26/92
14:19:15	5.0	5.9	65/333	44/307	39/ 33	39/184	26/92
14:19:30	5.0	6.0	64/333	44/307	39/ 33	40/184	26/92
14:19:45	5.0	6.0	64/333	44/307	39/ 33	40/184	25/92
14:20:00	5.1	6.0	64/334	44/307	39/ 33	40/184	25/93
14:20:15	5.1	6.0	64/334	44/307	39/ 33	40/184	25/93
14:20:30	5.1	6.0	64/334	45/307	39/ 33	40/184	25/93
14:20:45	5.1	6.1	64/334	45/307	39/ 33	40/184	25/93
14:21:00	5.1	6.1	64/335	45/307	39/ 33	40/184	25/93
14:21:15	5.1	6.1	64/335	45/306	39/ 33	40/184	25/93
14:21:30	5.1	6.1	64/335	45/306	38/ 33	40/184	25/93
14:21:45	5.2	6.1	64/335	45/306	38/ 33	41/184	25/93

sat id : hh:mm:ss	PDOP	GDOP	24	5	4	10
14:22:00	5.6	6.8	64/336	45/306	38/ 33	41/184
14:22:15	5.7	6.8	64/336	45/306	38/ 33	41/184
14:22:30	5.7	6.8	64/336	45/306	38/ 33	41/184
....						
14:47:15	6.4	7.9	58/357	52/292	30/ 41	54/183
14:47:30	6.4	7.9	58/357	52/292	30/ 41	54/183

14:47:45	6.4	7.9	58/357	52/292	30/ 41	54/183	
sat id :			24	5	4	10	30
hh:mm:ss	PDOP	GDOP					
14:48:00	3.4	4.2	58/357	52/292	29/ 41	54/183	25/314
14:48:15	3.4	4.2	58/357	52/291	29/ 41	54/183	25/314
14:48:30	3.5	4.2	58/357	53/291	29/ 41	54/183	25/314
....							
15:02:00	3.9	4.7	54/ 6	55/281	25/ 45	61/183	30/310
15:02:15	3.9	4.7	54/ 6	55/281	25/ 45	62/183	30/310
15:02:30	3.9	4.7	54/ 7	55/281	25/ 46	62/183	30/310

sat id : hh:mm:ss	PDOP	GDOP	24	5	10	30
15:02:45	6.6	8.4	54/ 7	55/280	62/183	30/310
15:03:00	6.7	8.5	54/ 7	55/280	62/183	30/310
15:03:15	6.7	8.6	54/ 7	55/280	62/183	30/310
....						
15:19:30	15.2	19.7	50/ 16	56/266	71/181	35/304
15:19:45	15.6	20.2	49/ 16	56/266	71/181	35/304
15:20:00	15.9	20.7	49/ 17	56/265	71/181	35/304

BL_PL1 PROCESSING INFORMATION

General Information

Reference receiver type	: SR299
Reference antenna type	: Internal
Rover receiver type	: SR299
Rover antenna type	: Internal
Total number of used measurements	: 2176
Root mean square unit weight	: 0.2893

BL_FS.1 FARA STATISTICS

Ambiguity Resolution Description:

Ambiguity tests:
test 1 - rms float not significantly bigger than rms a priori
test 2 - rms fix not significantly bigger than rms a priori
test 3 - rms fix is significantly smaller than rms fix 2

Ambiguity Resolution at : 15:17:45 successful

3rd test passed alpha 0.001 [%]

Ambiguity Values

Reference Satellite(s): 24/L1 24/L2
Ambiguity exclusions : 7/L2 7/L1

set#	5/L1	5/L2	4/L1	4/L2	10/L1	10/L2	30/L1	30/L2
1	133	20	142	9	99	26	19	6
2	131	20	143	8	99	26	16	5

rms float 2.5 [mm] a priori 10.0 [m
rms fix 2.9 [mm] ratio 7.088

Ambiguity Resolution at : 15:18:45 successful

3rd test passed alpha 0.001 [%

Ambiguity Values

Reference Satellite(s): 10/L1 10/L2

set#	7/L1
1	111
2	112

rms float 2.9 [mm] a priori 10.0 [mm]
rms fix 2.9 [mm] ratio 4.2032

BL_CS.1 CYCLE SLIP INFORMATION

Total no of cycle slips : 0

BL_FC.1 FINAL COORDINATES

Rov:175124Parikrama Ref:175010Matihani Amb:Y Proc: L1+L2
phase 03/20/01 02:16:00 PM

Cartesian :

X	413892.0146m	Y	5691292.4781m	Z	2839779.7010m
dX	347.6703m	dY	26.2768 m	dZ	-104.1285 m
sX	0.0002 m	sY	0.0005 m	sZ	0.0003 m

Geodetic :

Lat	26 36 40.59681 N	Lon	85 50 26.01474 E	h	14.3741 m
dLat	-3.77319	dLon	-12.46526	dh	-0.6759 m
sLat	0.0002 m	sLon	0.0002 m	sh	0.0006 m

Distance :

Slope 363.8789 m sSlope 0.0002 m

BL_VC.1 VARIANCE-COVARIANCE MATRIX

---

a posteriori rms : 0.2893

Co-factor matrix (upper triangle [m*m]) :

	qx	qy	qz
qx	+4.6632300E-007	+2.3325001E-008	+4.3204999E-008
qy		+3.1612119E-006	+1.7546290E-006
qz			+1.3265389E-006

CH.2 ===== NEW STATIC CHAIN =====

BL.2 175125Musmayat 175010Matihani 03/20/01 02:16:00 PM

BL_SE.2 START / END (COMMON) EPOCHS

03/20/01 02:16:00 PM to 03/20/01 03:21:15 PM

BL_OI.2 OPERATION INFORMATION

	Rover	Reference
Point id	175125Musmayat	175010Matihani
Sensor/Controller id	532 /96519	1616 /94884
Operation mode	STS	STS
Observation rate (s)	15.0	15.0
Ht reading/Ant offset (m)	1.266 /0.441	1.324 /0.441
Eccentricity E/N/H (m)	0.000 /0.000 /0.000	0.000 /0.000 /0.000

BL_SI.2 SATELLITE INFORMATION

SV id	L1 phase	L2 phase	L1 code	L2 code
4	186	128 S	186	128
5	262	253 S	262	253
10	262	259 S	262	259
24	262	262 S	262	262
30	131	60 S	131	60

BL_EA.2 ELEVATION / AZIMUTH

```
sat id :                       24       5       4      10       7
hh:mm:ss PDOP GDOP
14:16:00  4.8  5.7       65/329  43/308  40/ 32  38/184  26/ 91
.................
14:21:45  5.2  6.1       64/335  45/306  38/ 33  41/184  25/ 93

sat id :                       24       5       4      10
hh:mm:ss PDOP GDOP
14:33:00  5.6  6.8       64/336  45/306  38/ 33  41/184
.................
14:37:45  6.4  7.9       58/357  52/292  30/ 41  54/183
sat id :                       24       5       4      10      30
hh:mm:ss PDOP GDOP
14:38:00  3.4  4.2       58/357  52/292  30/ 41  54/183  25/314
14:38:15  3.4  4.2       58/357  52/291  29/ 41  54/183  25/314
.................
[illegible]  3.7  4.5    56/  2  54/286  27/ 43  58/183  28/312
```

sat id : 24 5 4 10
hh:mm:ss PDOP GDOP
14:55:45 6.2 7.6 56/ 2 54/286 27/ 43 58/183
14:56:00 6.2 7.5 56/ 2 54/286 27/ 44 58/183

sat id : 24 5 4 10 30
hh:mm:ss PDOP GDOP
14:56:15 3.7 4.5 56/ 3 54/286 27/ 44 58/183 28/312
.
....
.
14:57:30 3.7 4.5 55/ 3 54/285 27/ 44 59/183 28/312

sat id : 24 5 10 30
hh:mm:ss PDOP GDOP
14:57:45 5.9 7.4 55/ 4 54/284 59/183 28/312

sat id : 24 5 4 10 30
hh:mm:ss PDOP GDOP
14:58:00 3.7 4.6 55/ 4 54/284 26/ 44 59/183 28/312
.
.
.
15:02:15 3.9 4.7 54/ 6 55/281 25/ 45 62/183 30/310
sat id : 24 5 4 10
hh:mm:ss PDOP GDOP
15:02:30 5.8 7.1 54/ 7 55/280 25/ 46 62/183

sat id : 24 5 10 30
hh:mm:ss PDOP GDOP
15:02:45 6.6 8.4 54/ 7 55/280 62/183 30/310
.
....
.
15:21:15 18.1 23.4 49/ 17 55/264 72/181 35/303

III_PI.2 PROCESSING INFORMATION

General Information

Reference receiver type : SR299
Reference antenna type : Internal
Rover receiver type : SR399
Rover antenna type : Internal
Total number of used measurements : 2089
Root mean square unit weight : 0.4402

III_FS.2 FARA STATISTICS

Ambiguity Resolution Description:

Ambiguity tests:

test 1 - rms float not significantly bigger than rms a priori
test 2 - rms fix not significantly bigger than rms a priori
test 3 - rms fix is significantly smaller than rms fix 2

Ambiguity Resolution at : 15:17:45 successful

3rd test passed alpha 0.001 [%]

Ambiguity Values

Reference Satellite(s): 24/L1 24/L2
Ambiguity exclusions : 7/L2 7/L1

[illegible]	5/L1	5/L2	4/L1	4/L2	10/L1	10/L2	30/L1	30/L2
1	163	-394	198	-343	163	-306	55	-474
2	163	-394	199	-342	163	-306	52	-473

rms float 4.3 [mm] a priori 10.0 [mm]
rms fix 4.4 [mm] ratio 4.5264

CH.3 ===== NEW STATIC CHAIN =====

BL.3 175126Bhadariya 175010Matihani 03/20/01 02:24:00 PM

BL_SE.3 START / END (COMMON) EPOCHS

03/20/01 02:24:00 PM to 03/20/01 03:21:15 PM

BL_OI.3 OPERATION INFORMATION

	Rover	Reference
Point id	175126Bhadariya	175010Matihani
Sensor/Controller id	1645 /94879	1616 /94884
Operation mode	STS	STS
Observation rate (s)	15.0	15.0
Ht reading/Ant offset (m)	1.345 /0.441	1.324 /0.441
Eccentricity E/N/H (m)	0.000 /0.000 /0.000	0.000 /0.000 /0.0

BL_SI.3 SATELLITE INFORMATION

SV id	L1 phase	L2 phase	L1 code	L2 code
4	155	47 S	155	47
5	230	230 S	230	230
10	230	181 S	230	181
24	230	230 S	230	230
30	134	134 S	134	134

BL_EA.3 ELEVATION / AZIMUTH

---

sat id :			24	5	10	4	
hh:mm:ss	PDOP	GDOP					
14:24:00	5.8	7.0	64/337	46/305	42/184	38/ 34	
14:47:45	6.4	7.9	58/357	52/292	54/183	30/ 41	
sat id :			**24**	**5**	**10**	**4**	**30**
hh:mm:ss	PDOP	GDOP					
14:48:00	3.4	4.2	58/357	52/292	54/183	30/ 41	25/314
15:01:30	3.9	4.7	54/ 7	55/280	62/183	25/ 46	30/310

sat id :			24	5	10	30
hh:mm:ss	PDOP	GDOP				
15:02:45	6.6	8.4	54/ 7	55/280	62/183	30/310
15:21:15	18.1	23.4	49/ 17	55/264	72/181	35/303

BL_PI.3 PROCESSING INFORMATION

General Information

Reference receiver type	:	SR299
Reference antenna type	:	Internal
Rover receiver type	:	SR299
Rover antenna type	:	Internal
Total number of used measurements	:	1801
Root mean square unit weight	:	0.2893

BL_FS.3 FARA STATISTICS

Ambiguity Resolution Description:

Ambiguity tests:
test 1 - rms float not significantly bigger than rms a prio
test 2 - rms fix not significantly bigger than rms a prior
test 3 - rms fix is significantly smaller than rms fix 2

Ambiguity Resolution at : 15:21:15 successful

3rd test passed alpha 0.001 [%]

Ambiguity Values

Reference Satellite(s): 24/L1 24/L2

set#	5/L1	5/L2	10/L1	10/L2	4/L1	4/L2	30/L1	30/L2
1	14	-1	-17	-65	32	26	-19	-17
2	12	-1	-17	-65	33	25	-22	-18

rms float 2.8 [mm] a priori 10.0 [mm]
rms fix 2.9 [mm] ratio 5.3354

BL_CS.3 CYCLE SLIP INFORMATION

Total no of cycle slips : 0

BL_FC.3 FINAL COORDINATES

Rov:175126Bhadariya Ref:175010Matihani Amb:Y Proc: L1+L2
phase 03/20/01 02:24:00 PM

Cartesian :

X	413507.1005	m	Y	5690959.6253	m	Z	2840498.1663	m
dX	-37.2438	m	dY	-306.5760	m	dZ	614.3368	m
sX	0.0002	m	sY	0.0006	m	sZ	0.0004	m

Geodetic :

Lat	26 37 6.70578 N		Lon	85 50 39.01962 E		h	14.4912	m
dLat	22.33578		dLon	0.53962		dh	-0.5588	m
sLat	0.0002	m	sLon	0.0002	m	sh	0.0007	m

Distance :
Slope 687.5941 m sSlope 0.0002 m

BL_VC.3 VARIANCE-COVARIANCE MATRIX

A posteriori rms : 0.2893

Co factor matrix (upper triangle [m*m]) :

	qx	qy	qz
qx	+6.6181202E-007	+3.9216201E-007	+2.7788300E-007
qy		+4.1977009E-006	+2.5520069E-006
qz			+2.0432440E-006

Appendix IV

Computation and adjustment results of post processing

Coordinate set:	Mahottari 57 –WGS 84
Coordinate type:	Cartesian
Refference Ellipsoid:	WGS 1984
Projection set:	Undefined
Unit:	m

Point Id	X-cartesian	Y-cartesian	Z-cartesian N
010 Matihani	413544.3443	5691266.2013	2839883.8295
[illegible] Khira	419582.7628	5689894.6769	2841734.2920
[illegible] Birpur	419785.4512	5689686.9853	2842118.0711
[illegible] Charko..	419267.0169	5688969.8306	2843622.0776
[illegible] Pachim..	418737.1882	5689100.5282	2843439.9265
[illegible] Jharhi	416097.7636	5689513.6028	2843002.0444
[illegible] Sari	416113.9709	5689094.3685	2843836.1035
[illegible] Parikrama	413892.0166	5691292.4727	2839779.6978
[illegible] Musmayat	413869.7230	5690937.7450	2840494.4211
[illegible] Bhadariya	413507.1001	5690959.6211	2840498.1656

Coordinate set: Mahottari 57 –WGS 84
Coordinate type: Geodetic
Referrence Ellipsoid: WGS 1984
Projection set: Undefined
Unit: m

Point Id	Latitude	Longitude	Ell.Height
010 Mat..	26 36 44.370000 N	85 50 38.480000 E	15.05m
118 Khira	26 37 51.617200 N	85 46 57.154100 E	15.49m
119 Birpur	26 38 05.563400 N	85 46 49.293700 E	15.71m
120 Chark.	26 39 00.221300 N	85 47 06.080300 E	16.60m
121 Pachi.	26 38 53.596200 N	85 47 25.534100 E	16.80m
122 Jharhi	26 38 37.691000 N	85 49 01.806500 E	16.01m
123 Sari	26 39 07.988100 N	85 49 00.116300 E	17.45m
124 Parikr.	26 36 40.596792 N	85 50 26.014657 E	14.36m
125 Musm.	26 37 06.531950 N	85 50 25.888341 E	16.80m
126 Bhada.	26 37 06.705822 N	85 50 39.019625 E	14.48m

Coordinate set: Mahottari 57
Coordinate type: Grid
Referrence Ellipsoid: Everest 1830
Projection set: NEP MOD UTM 87
Unit: m

Point Id	Easting	Northing	Ell height
10 Mati..	385137.6290	2944597.7990	45.1314
118 Khira	379034.2941	2946724.3495	45.3283
119 Birpur	378820.9643	2947155.6589	45.5305
120 Charko.	379301.2816	2948833.4977	46.4260
121 Pachim.	379837.3717	2948624.4834	46.6512
122 Jharhi	382495.4153	2948110.0198	45.9700
123 Sar	382457.3071	2949042.9517	47.3949
124 Parikra.	384791.7210	2944484.7909	44.4372
125 Musm.	384795.4641	2945283.0428	46.8699
126 Bhada.	385158.7716	2945285.1051	44.5634

Coordinate set:	Mahottari 57
Coordinate type:	Geodetic
Referrence Ellipsoid:	Everest 1830
Projection set:	NEP MOD UTM 87
Unit:	m

Point Id	Latitude	Longitude	Ell.Height
10 Mati.	26 36 42.599874 N	85 50 47.243275 E	45.1314 m
118 Khir	26 37 49.856793 N	85 47 05.890403 E	45.3283 m
119 Birp	26 38 03.804347 N	85 46 58.029294 E	45.5305 m
120 Chark.	26 38 58.466722 N	85 47 14.819228 E	46.4260 m
121 Pachi.	26 38 51.840705 N	85 47 34.275384 E	46.6512 m
122 Jharhi	26 38 35.932439 N	85 49 10.559807 E	45.9700 m
123 Sari	26 39 06.232211 N	85 49 08.870043 E	47.3949 m
124 Parikr.	26 36 38.826554 N	85 50 34.776251 E	44.4372 m
125 Musm.	26 37 04.763976 N	85 50 34.650475 E	46.8699 m
125 Musm.	26 37 04.937633 N	85 50 47.783452 E	44.5634 m

3D Tranformation Parameter

Parameter Set:	Mahottari 57 pr1
Ellipsoid System A:	WGS 1984
Ellipsoid System B:	Everest 1830
Transformation Model :	Bursa- Wolf

Rotation Origin Xo:	0.000 m
Yo:	0.000 m
Zo:	0.000 m

Shift along the X-axis :	-295.835 m
Shift along the Y-axis :	-713.735 m
Shift along the Z- axis	-262.090 m
Rotation about the X- axis :	0.061938"
Rotation about the Y- axis :	0.052461"
Rotation about the Z- axis :	0.061881"
Scale factor :	-3.261631 ppm

Glossary

Accuracy:-
The closeness of results of observation computation or estimates to the true values or to values which are accepted as beeing true values.

Almanac :-
Library of coarse satellite orbital data used to calculate satellite position, rise time, elevation and azimuth.

Ambiguity :-
The unknown integer number of cycles of the reconstructed carrier phase contained in an unbroken set of measurements from a single satellite pass at a single receiver.

Atmospheric propogation delay :-
Time delay affecting satellite signals due to tropospheric layers of the earth's atmosphere.

Azimuth :-
A horizontal angle measured clock wise from north direction.

Baseline :-
The length of the three dimentional vector between a pair of stations for which GPS data collected and processed with differential techniques.

Binary biphase modulation :-
Phase changes of either 0^0 or 180^0 on the constant frequecy carrier. GPS signals are bi phase modulated.

C/A code :-
The Coarse / acquisition GPS code modulated on the GPS L1 signal. This code is a sequences of 1023 pseudorandom binary bi phase modulation on the GPS carrier at a chipping of 1.023 Mhz. Thus having a code repetition period of one millisecond.

Cartesian co-ordinate :-
The co-ordinates of a point in space given in three mutual perpendicular dimension (x, y, z) from the origin.

Carrier :-
A radio wave having at least one charactenstics (frequency, amplitude, phase) which may be varied from a known reference value by modulation.

Carrier frequency :-
The frequency of the unmodulated fundamental output of a radio transmitter.

Chip :-
The time interral of either a zero or a one in a binary pulse code.

Clock offset :-
Constant difference in the time reading of two clocks.

Coordinate:-
Linear or angular quantities which designate the position that a point occupies in a given reference system.

Code :-
A system used for communication in which orbitrary choosen strings of zeros and ones are assigned definite meanigns.

Cut off angle :-
The minimum elevation angle below which no more GPS satellite are locked by the sensors.

Cycle slip :-
A discontinuity of an integer number of cycles in the measured carrier beat phase resulting from a temporary loss of lock of a GPS satellite signal.

Deflection of vertical :-
The angle between the normal to the ellipsoid and the vertical (true plumb line).

Differences measurements :-
A single difference measurement is the instantaneous difference in phase of a received signal measured by two receivers simultaneonly observing one statellite.
A double difference measurement is obtained by differenting the single difference for one satellite with respect to the corresponding single difference for a chosen reference satellite .
A triple difference measurement is the differnce between a double difference at one epoch of time and the save double difference at another epoch of time.

Differential positioning :-
Detemination of relative co-ordinates between two or more receivers which are simultaneously tracking the same GPS signals.

Dilution of precision (DOP) :-
The DOP factor indicates the geometrical strength of the satellite constellation at the time of measurement. Standard term in the case of GPS is GDOP : three position co-ordinates plus clock offset i.e. geometric dilution of precision.

Doppler shift :-
The apparent change in frequency of a received signal due to the rate of change of the range between the transmitter and receiver.

Eccentricity :-
The ratio of the distance from the centre of an ellipse to its focus to the semi major axis.

$$e^2 = \frac{a^2 - b^2}{a^2}$$: a and b are the semi major and minor axis.

Ephemeris :-
A list of positions or locations of a calestial object as a function of time.

Epoch :-
A particular fixed instant of time used as a reference point on a time scale.

Error:
The difference between an observed or computed values of a quantity and the ideal or true value of that quantity.

Geodetic control:-
Coordinates which takes into account the size and shape of the earth.

Geoid :-
The particular equipotential surface which concides with mean sea level and which may be imagined to extend through the continents i.e. surface perpendicular to the direction of the force of gravity.

Greenwich mean time (GMT) :-
The mean solar time of the meridian of greenwich used as a standard time.

Ionospheric delay :-
A wave propogating through the ionosphere experiences delay.

Kinematic positioning :-
Determination of a time series of sets of co-ordinates for a moving receiver.

L-Band
The radio frequency band extending from 390 Mhz to 1550 Mhz. The frequencies of GPS lie on this L-Band.

Least square adjustment:-
A method of adjusting observation in which the sum of square of all the deviations or the residuals derived in fitting the observation to a mathematical model is made a minimum.

Multipath error :-
A positioning error resulting from inteference between radio waves which have travelled between the transmitters and the receiver by two paths of different electrical lengths.

NAVSTAR :-
Acronym for Navigation System with Time and Ranging.

Orthometic height :-
The distance of a point above the geoid measured along the plumb line through the point (height above mean sea level).

P-code :-
The precise GPS code-a very long sequence of pseudo random binary biphase modulations on the GPS carrier at a chipping rate of 10.23 Mhz.

Post processing :-
The process of computing positions in non-real-time, using data previously collected by GPS receivers.

Pseudolite :-
The ground based differential GPS station which transmits a signal with a structure similar to that of an actual GPS satellites.

Pseudo random noise (PRN) code. :-
Any group of binary sequences that appear to be randomly distributed but can be exactly distributred. The sequences has a lake noise, but can be exactly distributred. The sequences has a minimum auto carrection value except at zero lag.

Pseudo range :-
A measure of the apparent signal propogation time from the satellite to the receiver antenna scaled into distance by the speed of light.

Rhumb line :-
Trajectory between two points with constant bearing.

Rinex :-
Receiver Independen Exchange format. A set of standard definitions and formats to promote the free exchange of GPS data.

Selective availability (S A) :-
Degradation of point positioning accuracy for civil users by the US Department of Defense. This is produced by either clock dithering or orbit degradation.

Time zone :-
Time zone is equal to the difference between local time and the Greewich mean time . Time zone = Local Time - GMT.

Transformation:-
The process of projecting a point of a coordinates from its plane onto another plane by translation, rotation and scale change.

Trans location:-
The Method of using simultaneous data from separate satations to delermine the relative position of one station with respect to another station.

Universal time :-
Local solar mean time at greenwich meridian.

UT	Abbreviation for universal time
UT0	UT as deduced directly from observation of stars
UT1	UT0 corrected for polar motion
UT2	UT1 corrected for seasonal variation
UTC	Universal time coordinated, uniform atomic time system kept very close to UT2 by offset

WGS 84 :-
World geodetic system 1984. The system on which all GPS measurement and results are based.

Y-Code: -
An encrypted version of the P-code that is transmitted by a GPS satellite when in the anti-spoofing mode.

Zenith angle :-
Vertical angle with 0^0 on the horizon and 90^0 directly over head.

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2. Triplet and quadruplets in on-line photogrammetric triangulation ITC journal 1984-4 Enschede The Netherlands
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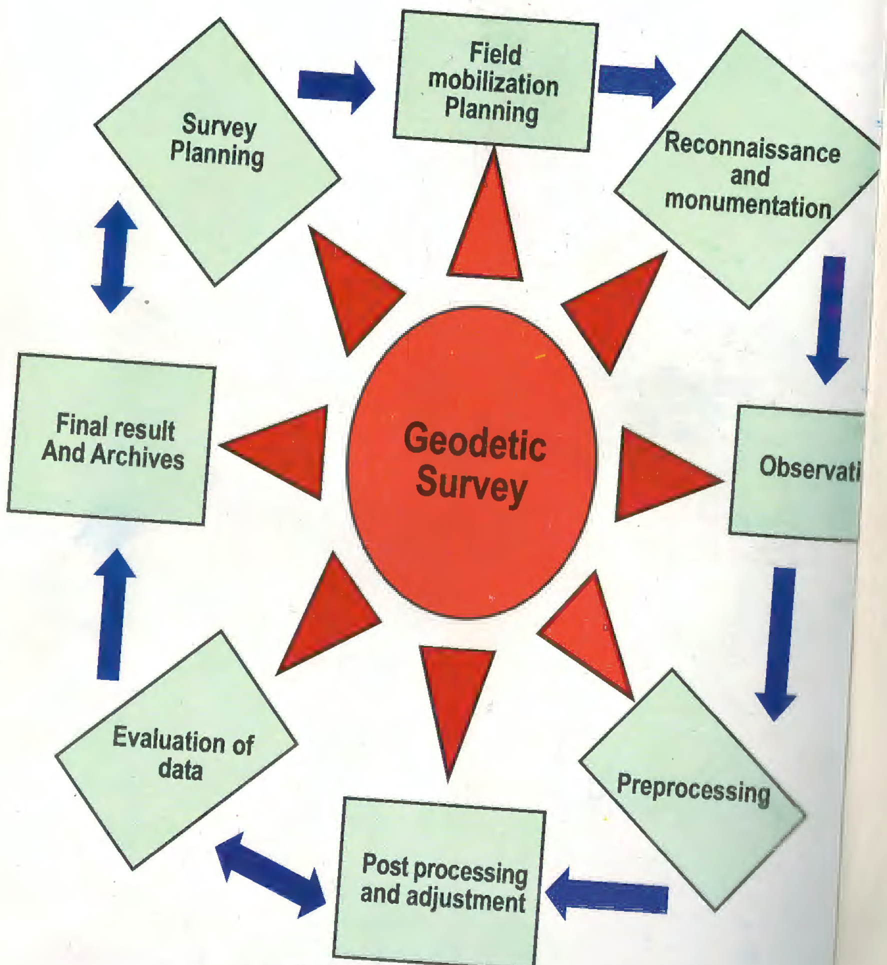

Survey Planning
Field mobilization Planning
Reconnaissance and monumentation
Observati
Preprocessing
Post processing and adjustment
Evaluation of data
Final result And Archives
Geodetic Survey