Study of Existing Geodetic Datum of Nepal and Reviewing the Test Results of Seven Parameter Transformation

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Abstract:

In Nepal there exist different coordinate systems based on different geodetic datum. The existence of these datum and coordinate systems are poorly known. In this literature the geodetic datum that is in existence in one way or other are illustrated and discussed. The next common problem encountered by users is the availability of authentic precise transformation parameter between National geodetic datum and World Geodetic Datum 1984 (WGS84) ; global datum used by global positioning system (GPS). There can exist a considerable difference in the position between local and the global system and the difference could be of several hundred meters.

Based on the availability of data three sets of transformation parameters has been determined. The tests have been carried out to evaluate the accuracy of the transformation parameter in this region. The final or third set of transformation parameter is recommended to transform the topographical data base of scale 1: 50,000 and 1: 25.000 of the whole country into WGS84 and vise versa and the parameter has been adopted by NGIIP of Survey Department of Nepal. The same set of transformation parameter can be used to transform the co-ordinates between Nepal datum and WGS84 in 87, 84 and 81 central meridian region, The final (third) set of transformation parameter is recommended in transforming the coordinates of whole country. The accuracy of the transformation parameters are specified and can be used accordingly. This study will ultimately provide standardization and ease in transforming the coordinates from global datum (WGS84) to national geodetic datum of Nepal.

1. Introduction:

The national and regional surveying and mapping works are all based on one single framework of geodetic control which is considered as a primary network of the country. The importance of the geodetic frame work for the country is beyond justification and is applied in almost all development works of the country such as defense, satellite lunching, missiles projecting etc, construction of major infrastructures of the country (dams, roads, sewerage system, irrigation, hydropower stations etc).

The development of the Geographic Information System since last two decades has exemplified its importance and widened its application in many more sectors such as in the study of environmental change, disaster management, and creating the digital database in developing an information system.

The concept of the position defined by co-ordinate system is the most essential part in the process of map-making and to the performance of the spatial search and analysis of geographic information. In order to plot the geographical feature on the map it is necessary to define the position of points on the features with respect to a common frame of reference or the co-ordinate system in other words.

In the other hand all the observations and measurements for accurate mapping are carried out on the physical surface of the earth where as computations and representation of the earth surface into paper in the form of map requires mathematical figure of the earth. In order words there has to have some relationship between the mathematical earth (ellipsoid) and the physical earth (geoid). In the geodetic terms we need to define best fitting ellipsoid and geoid. The best fitting ellipsoid is that particular ellipsoid which best fits the spread of the earth surface of a particular country. Therefore there are different ellipsoids of different country and hence different countries have different origin and different datum defined by certain parameters.

The positions on the earth's surface are normally defined in two systems Cartesian and the Geographic co-ordinate system. In the Cartesian co-ordinate system positions are defined by their perpendicular distances from the set of fixed axes. Different values are specified for these axes in different countries.

The geographical coordinates constitute degrees of latitude and longitude. This is a form of spherical polar coordinate system in which two angles are measured with respect to the planes through the center of the ellipsoid representing the shape of the earth.

The latitude and longitude refer to the position in 3D space and for the cartographic works it is necessary to transform them in 2D map grid system. Such transformation is called projection. The projection refers to the transformation of the earth's surface either directly to a plane or to a cylindrical or a conical surface which having been conceptually warped around the earth which then form a flat surface when unrolled.

The choice of projection in a particular country is usually governed by a desire to minimize the distortion to best possible extent. Therefore it is important to appreciate the process of map projection and the way in which they introduce internal changes in scale and give rise to these distortions.

As a consequence due to the adoption of variety of map projection there are different map-grid co-ordinate systems in use among them some of which are unique to a particular mapping organization of the country. Therefore the organizations dealing in compilation of database or electronic maps with data from different sources often becomes necessary to transform from one coordinate system to another in order to work within a single unifying framework.

The significance of the study of the coordinate system of this region will benefit many researchers working in various disciplines and using geographic information system a part of their research. The use of remotely sensed data for environmental studies, disaster related matters and many more has widely been in use due to the availability of high resolution satellite images but it requires to have a relationship between the satellite images and ground location in other words called geo-referencing. To establish this relationship the understating of the coordinate system is needed and also integrating to the national grid of the particular country if required then further knowledge of the parameters of datum chosen by the particular country will be a must.

2. Geodetic Datum:

Precise positioning of points on the surface of the earth is one of the fundamental goal of geodesy. In order to define such point a starting point with respect to the reference system and a reference ellipsoid is necessary. The primary or the first order network is defined by means of well defined three-dimensional reference system of co-ordinates related to the earth fixed reference system. Such a reference system is defined by the dimension of the reference ellipsoid in terms o five parameters such as semi-major axis 'a' and flattening 'f' and its position represented by regional X, Y, Z or φ, λ, h system specifying the orientation with respect to the global system, hence with respect to earth or geoid.

Usually the centre of the ellipsoid does not coincide with the earth's centre of mass but that axes are made parallel to the earth's axis of rotation with a pre assumption that global Xg, Yg, Zg rectangular co-ordinate system, has the origin which lies on the earth's centre of mass and a Z axis coinciding with the mean rotating axis of the earth, X - axis passing through the mean of the Greenwich meridian. The Y - axis as defined by the plane which is perpendicular to X and Z - axis (Torge, 1991, pl 38).

Determination of the parameters of such a reference datum defined by shape, size, and orientation of ellipsoid of revolution in other words the three dimensional co-ordinate system requires the high precision surface and spatial measurements. This work requires highly trained and skilled manpower.

Survey Department of Nepal (SDN) adopted Everest Spheroid (1830) parameter as the reference datum.

3. Indian Datum:

The Indian datum is defined by the following parameters

Reference Spheroid : Everest (1830)
a = 20922931.80 ft.
f = 1/300.8017
Indian datum origin : Kalianpur
Latitude (φ) = 24° 07′ 11.25"
Longitude (λ) = 77° 39′ 17.57"
Deflection of vertical in the
meridian (ξ) = -0.29"
prime vertical (η) = 2.87"
Geoid height (N) = 0 meters

Survey of India (SOI) established control points in Nepal for the topographical mapping in the scale 1 = 1 mile. The co-ordinates of these control points were derived by using Everest Spheroid

(1830) parameters. The coordinates of these controls were provided to Survey Department of Nepal, Geodetic Survey Branch (GSB) by Survey of India.

Geodetic Survey Branch (GSB) established second, third and fourth order network of control points in the districts where cadastral survey has to be done. The computation and the adjustments was done based on co-ordinates of points made available from SOI converted into UTM rectangular system modified for Nepal large scale mapping (Triangulation instruction book). As these coordinates were not from rigorous primary geodetic network it is called the provisional co-ordinates. As referred by late Z. M. Wiedner former director of GSB in his final report these coordinates are basically used for the cadastral purpose should be named as cadastral co-ordinates.

4. Problems identified in SOI co-ordinates:

4.1 Difference in semi-major axis:

Geodetic Survey Branch (GSB) established second and lower order networks calculated in plane rectangular UTM (modified) system with the same value of the Everest Spheroid. As the Govt. of Nepal decided to adopt metric system in the country it was necessary to used the factor of conversion from foot to meter (This factor of conversion was taken from TM5 - 241 - 7, Department of Army Technical Manual: Universal Transverse Mercator Grid Table 0 - 45).

The conversion factor and the value of semi-major axis was

1 Indian foot = 0.30479841 m

a = 6 377 276.345 m

Adopting the Everest Spheroid (1830) with the value of semi-major axis stated above using SOI controls GSB started to establish new control points. Subsequently latter it was found that the conversion factor adopted in India was

1 Indian foot = 0.3047996 m

Therefore the value of semi-major axis comes to be

a = 6 377 301.243 m

Since these values are used in Survey of India and apply to all SOI co-ordinates made available and used in GSB, the major axis is incorrect by 24.898 m (phuyal et.al 1992). Because of the difference of the semi-major axis, there will be a different values of co-ordinates of the SOI points converted to the rectangular UTM system, also in the coordinates of the points established by GSB and the difference have to be verified.

4.2 Correction in Longitude:

The survey of India (SOI) established a series of control point in Nepal and these points are based on the Indian datum. The Indian datum origin is based on the astronomically determined values at Kalianpur. Because the published value of geodetic longitude (λ) on the Indian datum require a correction of - 3.16 seconds of arc to agree with accepted definition of datum origin therefore the prime vertical component in $[\lambda a - (\lambda g - 3''.16)] . \cos\theta$ and similarly, the Laplace azimuth condition is $Aa - Ag = [\lambda a - 3''.16] . \sin\theta$ (Report and Results of Geodetic Survey of Nepal 1981-84) or (see Bomford 3rd Ed. pp117) therefore the values of longitude of points established by SOI in Nepal and the other values derived from these values require correction of -3.16" seconds of arc.

4.3 Features of Survey of India (SOI) Triangulation Network (1946-63):

In report made available to Geodetic Survey Branch such as co-ordinates, statement of the results and triangulation chart of control points survey made during 1964-63, following features were identified.

Nine different series of triangulation chains were established to make framework of control for the topographical mapping (1" = 1 mile) of Nepal.

The average and maximum triangular errors in nine different series are given below.

Table - 1

Series	Instrument used	Average Triangular error (seconds)	Maximum Triangular error (seconds)	Closing error on Base	Remarks
1	2	3	4	5	6
A	1 arc second Theodolite	3"	8"	1/42000	Adjusted series
B	do	5"	17"	1/15000	do
C	do	4"	12"	1/5000	do
D	do	4"	13"	1/12000	do
F (main)	do	3	10"	1/14000	Unadjusted (closing error not adjusted)
E (a)	do	4	10"	-	do
E (b)	do	4	10"	1/10000	do
E (c)	do	5	10"	-	Unadjusted series
F (sub)	do	3	16"	-	do

The remaining triangulation network inside Nepal was based on stations of the above series with average triangular error 5 seconds and maximum triangular error 30 seconds.
(Source:SOI Report, 27 June 1977)

The table -1 shows the triangulation series do not form a single network and are not homogeneous. The triangulation series named F(main), E(a) and E(b); the closing error in these chain were not adjusted where as E(c) and F(sub) the chains are left unadjusted. The reason behind this could be perhaps the starting and closing of the triangulation chain was not done in higher order stations or may be mis-closure were exceeding this tolerance or the accuracy obtained was enough for the topographical mapping project.

5. National Geodetic datum (Nepal Datum):

Geodetic Survey Branch (GSB) was aware of the requirement of National Geodetic datum defined by the network of points of first order controls. With the agreement between the government of Nepal and the United Kingdom's Directorate of Military Survey, Ministry of Defense (MODUK) established the first order geodetic control net of 68 points in the country. The task was completed in 1986.

The Datum was defined as in above:

References ellipsoid: Everest (1830)
Semi-major axis (a) 6 377 276.345 m
Flattening (f) 1/300.8017 and (e^2 = 0.00663784663)
With the Geodetic Origin Station 12/57 Nagarkot defined as
Latitude (φg) = 27^0 41' 31".04 N
Longitude (λg) = 85^0 31' 20".23 E
meridian (ξ) = -37".03
Prime Vertical = -21".57
and assuming the geoid height
(N) = 0 meter

The deflections quoted are derived from an astronomic position observed by Czechoslovak Geodetic Institute.

The Nepal datum represents a rigorous reference system. The net in properly oriented to the conventional origin (CIO) and the scale of the net is consistent with the international standards of length defined by the Doppler satellite observation.

As stated in the Report submitted by MODUK, the geographical co-ordinates of first order points are of high standard and hence fulfill the requirement of a rigorous Geodetic datum in Nepal.

6. Definition of WGS-84 Co-ordinate System:

The WGS-84 (World Geodetic System – 1984) is a Conventional Terrestrial System (CTS), realized by modifying the Navy Navigational Satellite System (NNSS), or TRANSIT, Doppler Reference Frame in origin and scale and rotating it to bring its reference meridian into coincidence with the Bureau International de l'Heure (BIH) – defined Zero meridian.

The origin of WGS-84 system is the centre of mass of the earth. Its Z-axis lies along the direction of Conventional Terrestrial Pole (CTP) for polar motion and the X-axis lies along inter-section of the WGS-84 Reference meridian plane and the plane of CTP Equator. The Y-axis of this system completes a right-handed, Earth-Centered, Earth-Fixed (ECEF) orthogonal co-ordinates system, measured in the plane of CTP Equator 90^o degree East of X-axis.

The origin and orientation of co-ordinates axis in WGS-84 have been defined by the X,Y,Z co-ordinates established under the control of the 5 GPS monitoring stations located at Hawaii, Colorado Springs, Ascension, Diego Garcia and Kwajalein.

The WGS-84 is an earth-fixed global reference frame, including an earth model and is defined by a set of primary and secondary parameters. The primary parameters are as follows:

Semi-major axis (a)	6378137 m
Flattening (f)	1/298.257223563
Angular velocity (ω)	7.292115 X $10^{(-5)}$ (Radian per second)
Geocentric gravitational Constant (GM)	398600.5 Km^3s^{-2}

(Mass of the earth's atmosphere included) $-484.16685 \times 10^{-6}$
Normalized 2nd degree
zonal harmonic coefficient
of the gravitational constant

7. GPS Observation in Nepal:

In co-operation with University of Colorado and Massachusetts Institute of technology established the precise Global Positioning System (GPS) Geodetic network throughout the country:

The objective of establishing precise GPS geodetic network was

i) To provide a precise control grid for the geodetic survey throughout the country and
ii) To establish large scale strain grid to measure the north-south shortening, east-west extension and quantifying the uplift of the terrain across the Himalayan collision zone (Bilham & Jackson, 1991)

The observation took place from March 25, 1991 and ended on April 12, 1991. The instruments used for the observation were Trimble 4000 SSI and ASTECH XII GPS receivers. Three stations were held fixed during the campaign. Nagarkot (NAGA), the central station of GPS network. Jomsom (JOMO) located in the high Himalayas of the central Nepal. Simikot (SIMI), located the high Himalayas of Western Nepal. The station Nagarkot was fixed because this station is the central station of First-order conventional national network. Each site was occupied with minimum of five days with each data measurement session exceeding 8 hours per day.

The best co-ordinate values in WGS 84 reference system for station related to Nagarkot were determined from a network solution of all stations. The network consist of 28 precise GPS controls.
Any spatial measurements that need to be carried out in future with reference to the ground control based on WGS-84, I suggest to use this network as basis for further spatial measurements.

8. ENTMP and WNTMP GPS observation:

The Eastern Nepal Topographical Mapping Project ENTMP & Western Nepal Topographic Mapping Project WNTMP was launched in order to produce new topographical map series of the country of 1954-60.

Geodetic controls over the project area was established by using the static relative GPS survey. In ENTMP a total of 101 stations were established and observed, the network consisting of 29 primary stations and 72 secondary stations. Instruments used for this field survey were Astech LD-XII GPS receivers. These instruments are 12 channel and dual frequency receivers.

In case of Western Nepal the ground control survey was carried out in two parts. First part was completed during January- April 1996 and second part during September – November 1996. During the first part 62 and during the second part 65 ground control GPS –stations were monumented premarked and observed. Among them 51 were the primary stations and 76 were the secondary stations.

8.1 Observations:

One session per day was observed using four to eight GPS satellites. The length of the observation session was 180 minutes in the primary network. Carrier phase observation of GPS satellites were processed using L2 corrected L1 phase measurements and double differences phase observations. Astech Inc's Geodetic post-processing software (GPPS), version 4.4.01 was used for the data processing. The adjustment of the network was done by using in FILNET (version 3.0.00) adjustment program.

One sigma accuracy of the baselines in the Network are all better than 1-5 ppm.

8.2 Datum defied:

The datum is defined by the following parameters.

Reference Spheroid: Everest (1830)

$a = 6\ 377\ 276.345$

$1/f = 300.8017$

Initial Station Nagarkot:

Latitude (φg) = $27^0\ 41'\ 32''.956$ N

Longitude (λg) = $85^0\ 31'\ 24''.941$ E

Defection of vertical in the

meridian (ξ) = $-37''.03$

Prime Vertical (η) = $-21''.57$

(See Yrjola and Jarvina 1993)

As compared the parameters of Nepal datum in section 5 it showed the difference in geodetic latitude and longitude. The observed difference is

$\theta E - \theta N = 1''.916$

$\lambda E - \lambda N = 4''.311$

The elevation difference between IMSL height and ellipsoidal height from GPS in found as 13.631 meters.

The apparent differences observed is because the initial stations Nagarkot is close to the fundamental station 12/157 Nagarkot but not to it.

The table below shows the different datums.

Table – 2 Comparison of datums of Nepal

Datum	India	MODUK	ENTMP	WGS84
Source	Sources of India	MODUK	ENMP project report	SDN & University of Colorado
Ref. Spheroid	Everest 1830	Everest 1830	Everest 1830	WGS84
a (semi-major axis)	20922931.80 ft.	6 377 276.345 m	6 377 276.345 m	6 378 137.00 m
1/f (flattening)	300.8017	300.8017	300.8017	298.2572235
Origin latitude (θ)	24^0 07' 11".26 N	24^0 41' 31".04 N	24^0 41' 32".956 N	27^0 41' 33".778 N
Origin Longitude (λ)	77^0 39' 17".576 E	85^0 31' 20".23 E	85^0 31' 24".941 E	85^0 31' 16".384 E
Defection of (ξ) in meridian	-0".29	-37".03	-37".03	-
Defection in P. vertical	2".28	-21".57	21".57	-
Separation (N)	0	0	0	-

From the Table-1 it is obvious that there exists four different sets of co-ordinates on four different datum. The transformation parameters between these datum has to be established.

9. Datum Transformation parameters:

WGS-84 coordinate system is being adopted universally as the standard form of Geographical Coordinate Representation System. World wide development in the GPS and GIS system and its international adoption has created an environment in developing a common base of reference in exchanging the geographic data. This system came into existence only towards the end of 20th Century. Prior to that local coordinate system had been in use. Thus most of the maps, records and data are available in local systems of the particular country. The coordinates, maps and records related to land are considered of very important property of the nation from the defense point of view therefore these information are kept secret by the nation and its national policy. The precise transformations parameters of the country are not made available to users still today.

With the increasing exchange of geographic information locally and globally positions defining the location need to be available in terms of both locally adopted datum and global datum. The process of mathematical conversion of the positions from one system to another is called datum transformation.

10. Transformation models:

Several mathematical models have been developed which describe the functional relationship between pairs of three dimensional coordinates. The two most commonly used mathematical models to transform positions between the reference systems are

- Bursa-Wolf (Bursa, 1962, Wolf, 1963) and
- Molodensky (Molodensky et.al., 1962)

These are the standard models due to their extensive use around the world over a number of years. The only difference between these two methods is Molodensky uses local origin about which the transformation is performed where as Bursa-Wolf method uses reference system origin. It has been shown that both methods gives the identical results provided full statistical information (variance and covariance of parameters and positions) is carried out through the transformation process (Harvey, 1996). In most cases Bursa-Wolf method is preferred as it does not require local origin coordinates to be maintained along with the transformation parameter equation.

10.1 BURSA-Wolf transformation model:

The Bursa-Wolf method assumes a similarity three dimensioned relationship between two consistent sets of Cartesian coordinate through seven parameters:

- three translations (ΔX, ΔY, ΔZ)
- three rotations around X, Y, Z axis respectively (ε,ψ, ω)
- a scale change (ΔL)

If U, V and W represent the Cartesian components of a station in reference frame 1 say Everest and X, Y, Z represent the Cartesian component of same stations in reference frame number 2 say WGS-84, the transformation can be expressed as:

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{vmatrix} + (1 + \Delta L)\ R \begin{vmatrix} U \\ V \\ W \end{vmatrix} \qquad (1)$$

where R represents a 3 x 3 rotation matrix and defined a

$$R = R_1(\varepsilon)\, R_2(\psi)\, R_3(\omega)$$

If all three angles are small the above rotation matrix can be written in its simplified form by setting sine of an angle equal to the angle itself, cosine of the angle equal to 1 and the product of sines equal to zero.

Thus after simplification the above matrix will appear as

$$R = \begin{vmatrix} 1 & \omega & -\Psi \\ -\omega & 1 & \varepsilon \\ \psi & -\varepsilon & 1 \end{vmatrix} \qquad (2)$$

The transformation equation (1) can now be written as

$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{vmatrix} + (1+\Delta L) \begin{vmatrix} 1 & \omega & -\psi \\ -\omega & 1 & \varepsilon \\ \psi & -\varepsilon & 1 \end{vmatrix} \begin{vmatrix} U \\ V \\ W \end{vmatrix} \qquad (3)$$

Method of estimation of transformation parameters

A point physically identifiable on the surface of Earth which has been assigned coordinates in at least two separate systems of coordinates is termed as collocated station. The Cartesian coordinates of sufficient number of collocated stations (U, V, W, X, Y, Z) can be used as observations in a least square adjustment for the seven transformation parameters. The model in symbolical form can be written as:

$$F(L, X) = 0 \qquad (4)$$

where

L = observations (U, V, W, X, Y, Z).
X = parameters (ΔX, ΔY, ΔZ, ΔL, ω, ψ, ε)

By arranging the equations (3) into this form will result in

$\Delta X + U + w V - y W + \Delta L U + w \Delta L V - \psi \Delta L W - X = 0$ (3-1)
$\Delta Y + V - w U + e W + \Delta L V - w \Delta L U + e \Delta L W - Y = 0$ (3-2)
$\Delta Z + W + \psi U - \varepsilon V + \Delta L W + \psi \Delta L W - \varepsilon \Delta L V - Z = 0$ (3-3)

These three equations represent the functional relationship between any two closely oriented, closely scaled, ortho normal Cartesian coordinates systems. Since the observations (6 Cartesian components per station) have systematic and other errors with them, the usual combined least squares procedure of minimizing the weighted sum of residuals squared (V^TPV) is followed.

11. Datum Transformation parameters of Nepal:

The present study is focused on the estimation of transformation parameters between Everest and WGS-84 in order to transform the digital data of the topographical maps or the ground control points (GCP).

The topographical mapping project was launched in order to update the topographical maps of the country. The topographical maps of Nepal are prepared and published in two parts. One of the Eastern Nepal and other of the Western Nepal. In both cases geodetic control was done by GPS/GNSS survey. As the main aim of the project was to provide control for the topographical mapping, it was felt important to transform GPS control from WGS84 to local datum. It was found that the distribution of common points has a good network geometry for transformation. Hence for the derivation of the seven parameter transformation controls considered from ENTMP and WNTMP was given considerable weight.

Similarly in the process of the determination of the transformation parameter of WNTMP 22 collocated points (the common points between the reference frame i.e. WGS-84 and Everest 1830) first order points based on Nepal datum were used.

One of the main aim of the projection system adopted by the country is to produce geographical data in a unique system which helps data users to share data; Nepal used Modified Transverse Mercator System. In this context country is divided by three central meridians which are 81, 84 and 87 respectively. The three central meridians are chosen in order to limit the distortion specially in the areas farther away from the central meridian. Therefore 3 zones are selected for the mapping of the country. Based on this zoning system the seven parameter transformations were computed and prescribed for the adoption.

11.1.1 First set of Transformation Paramerter:

In the computation of the first set of transformation parameter 3-dimentional coordinates based on WGS-84 were taken as the controls established by ENTMP. This network consists of 29 primary stations and 72 secondary stations. A total of 11 primary GPS points are common stations in first order geodetic network of Nepal. From these 11 stations only 9 stations are used for the derivation of the transformation parameter. The 9 stations of first order network of Nepal based on Nepal datum were obtained from appendix (1) report of Ministry of Defense United Kingdom (MODUK). The Bursa-Wolf method was used to estimate the transformation parameter.

The values of the transformation (WGS-84 to Local and vise versa) parameters are as follows:

Table -3. Transformation Parameter from Nepal Datum to WGS 84

	Estimated Values	**Standard Deviation**
Translation in X axis(m)	319.746	+/-32.749
Translation in Y axis (m)	763.154	+/-35.425
Translation in Z axis (m)	232.625	+/-53.437
Rotation in X axis(Sec)	-1.650	+/-1.964
Rotation in Y axis (Sec)	-0.407	+/-1.693
Rotation in Z axis(Sec)	-1.042	+/-0.681
Scale factor(ppm)	-1.867	+/-3.217

Source Manandhar, N. : Geoid Studies of Nepal, Thesis submitted for Master of Engineering, School of Geomatic Engineering, University of New South Wales, Sydney.

This transformation parameter has been used to transform the topographic database of 1: 25000, and 1: 50,000 series.. The necesssary test has been conducted by National Geographic Information Infrastructure Project (NGIIP). This parameter has been adopted in transforming the topographic data base of the country.

11.1.2 Transformation of coordinates of 84 & 87-Central Meridian :

In order to test the accuracy of the transformation parameter given in table -1 the second and third order coordinates in WGS-84 of 84 & 87-central meridian were transformed to Nepal datum. Then the transformed coordinates were compared with existing second and third order cordinates of the same points.

The deviation between same particular points was quantified by computing the distance using the set of cordinates of the same points. Maximum and minimum difference between X and Y co-ordintes were computed along with distance between two points. The results are tabulated in table-2.

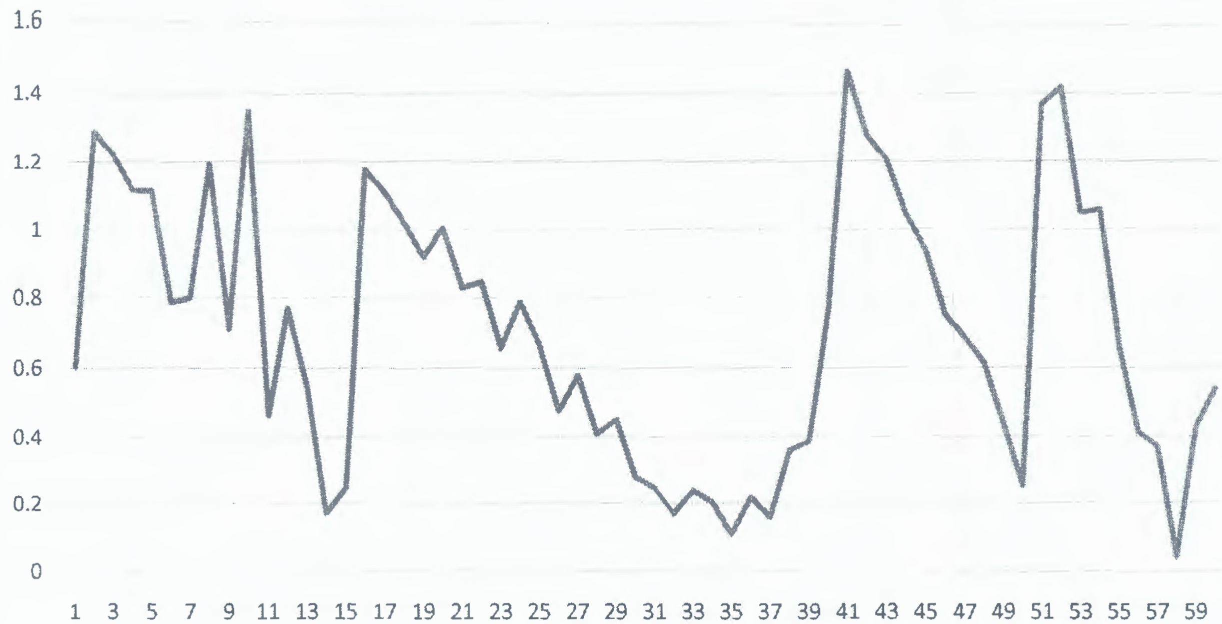
The variation in the second and third order Transformed coordinates and National coordinates in 87 CM

Table-4.

	Difference in X coordinates(ΔX)	**Difference in Y coordinates(ΔY)**	**Distance between the points**
Maximum Value in (m)	0.3959	0.0493	1.4639
Minimun Value in (m)	-0.5286	-1.4172	0.0403
Average			0.7078

Refering table-4 the average deviation between the transformed points are found to be 0.7078m therefore this parameter can be used in the map of scale 1: 3000 or smaller. The graphical representation of the above table is given below.

The variation in the second and third order Transformed coordinates and National coordinates in 87 CM



11.1.3 Transformation of coordintes of 84-Central Meridian :

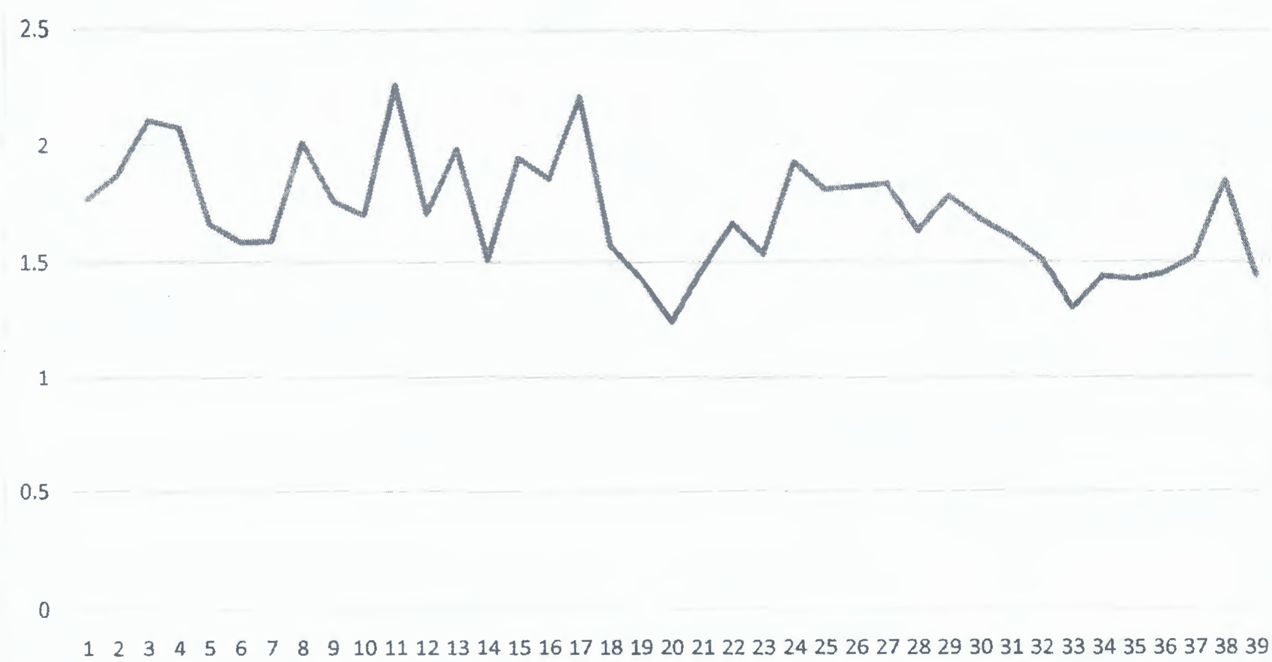
The variation in the second and third order Transformed coordinates and National coordinates in 84 CM

Table no -5

	Difference in X coordinates(ΔX)	Difference in Y coordinates(ΔY)	Distance between the points
Maximum Value in (m)	-1.2429	0.5710	2.2612
Minimun Value in (m)	-2.2395	-0.4131	1.2451
Average			1.70715

Refering table-5 the average deviation between the transformed points are found to be 1.70715m therefore this parameter can be used in the map of scale 1: 7000 or smaller. The graphical representation of the above table is given below.

The variation in the second and third order Transformed coordinates and National coordinates in 84 CM



11.1.4 Transformation of coordintes of 81-Central Meridian :

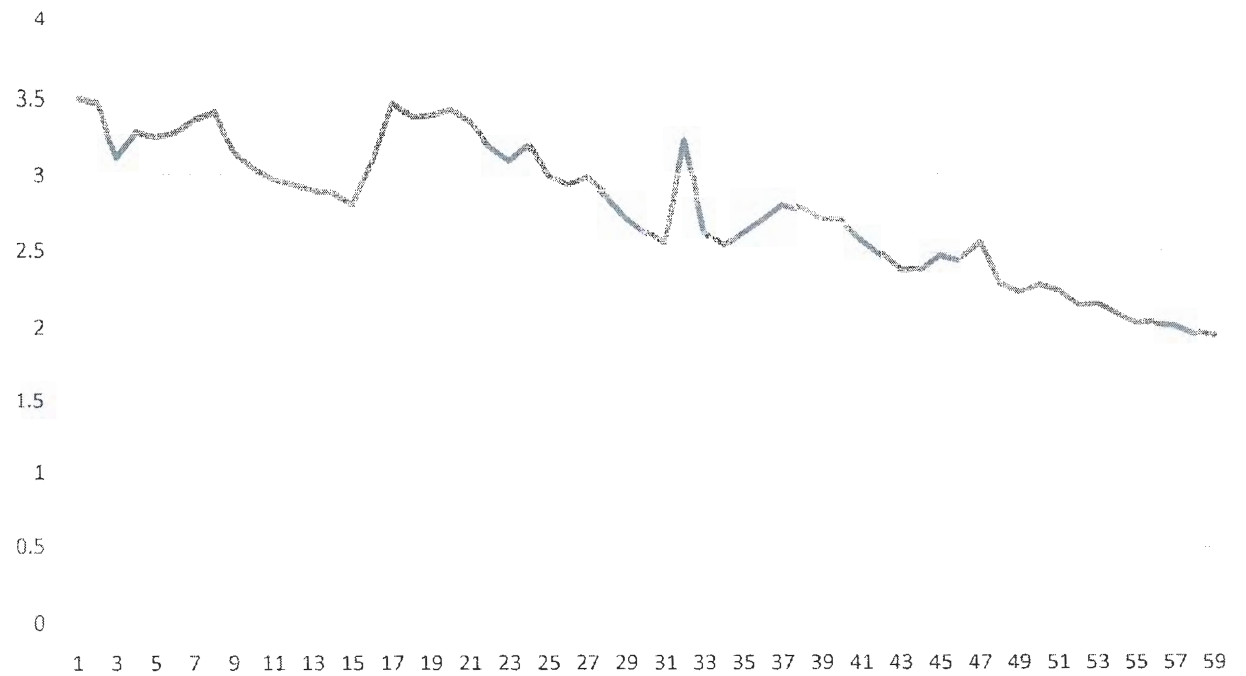
The variation in the second and third order Transformed coordinates and National coordinates in 81 CM

Table-6

	Difference in X coordinates(ΔX)	**Difference in Y coordinates(ΔY)**	**Distance between the points**
Maximum Value in (m)	-1.9424	0.4063	3.5039
Minimun Value in (m)	-3.5040	-0.3764	1.9410
Average			2.787

Refering table-6 the average deviation between the transformed points are found to be 2.787m therefore this parameter can be used in the map of scale 1: 12000 or smaller. The graphical representation of the above table is given below.

The variation in the second and third order Transformed coordinates and National coordinates in 81 CM



From the statistics of table-4 the first set of parameter when tested for 81- central meridian the parameter support in the transfrmation of coordinate to meet the map scale of 1: 12,00 of t0 or smaller and deviation is 2.787 meter therefore second set of transformation parameter is computed for more accurate results.

11.2 Second set of Transformation Paramerter:

In the computation of the second set of transformation parameter 3-dimentional coordinates based on WGS-84 were taken as the controls established by WNTMP. This network consists of 51 primary stations and 76 secondary stations. A total of 22 primary GPS points are common stations in first order geodetic network of Nepal. These 22 stations are used for the derivation of the transformation parameter. 22 stations of first order network of Nepal based on Nepal datum were obtained from appendix (1) report of Ministry of Defense United Kingdom (MODUK). The Bursa-Wolf method was used to estimate the transformation parameter.

The values of the transformation (WGS-84 to Local and vise versa) parameters are as follows:

Table- 7

	Estimated Values	Standard Deviation
Translation in X axis(m)	284.6605	27.489
Translation in Y axis (m)	-364.9433	27.71
Translation in Z axis (m)	-1104.589	49.56
Rotation in X axis(Sec)	-29.0859	1.74
Rotation in Y axis (Sec)	12.362	0.739
Rotation in Z axis(Sec)	-14.8460	0.754
Scale factor(ppm)	3.027	2.546

In order to test the accuracy of the transformation parameter given in table -5 the second and third order coordinates in WGS-84 of 81-central meridian were transformed to Nepal datum. Then the transformed coordinates were compared with existing second and third order cordinates of the same points.

As in the previous test, the deviations between same particular points were quantified by computing the distance using the set of cordinates of the same points. Maximum and minimun difference between X and Y co-ordintes were computed along with distance between two points. The results are tabulated in table-6.

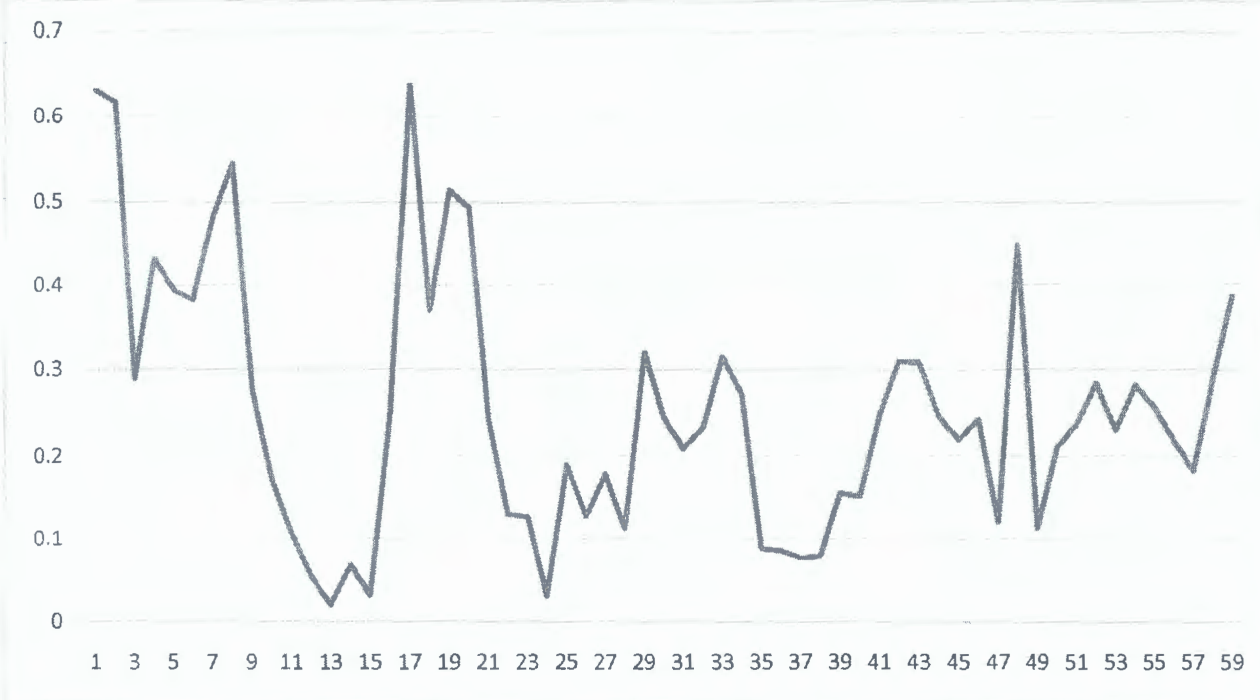
The variation in the second and third order Transformed coordinates and National coordinates in 81 CM

Table- 8

	Difference in X coordinates(ΔX)	Difference in Y coordinates(ΔY)	Distance between the points
Maximum Value in (m)	0.1347	0.4268	0.6385
Minimun Value in (m)	-0.2765	-0.6319	0.01941
Average			0.2540

Referring table-8 the average deviation between the transformed points are found to be 0.254 m therefore this parameter can be used in the map of scale 1: 1000 or smaller. The graphical representation of the above table is given below.

The variation in the second and third order transformed coordinates and National coordinates in 81 CM



11.3 Third set of Transformation Paramerter:

In the computation of the third set of transformation parameter 3-dimentional coordinates based on WGS-84 were taken as the controls established by WNTMP and ENTMP. This network consists of all together 80 primary stations and 148 secondary stations. A total of 33 primary GPS points were common stations in first order geodetic network of Nepal. These 33 stations are used for the derivation of the transformation parameter. 33 stations of first order network of Nepal based on Nepal datum were obtained from appendix (1) report of Ministry of Defense United Kingdom (MODUK). The Bursa-Wolf method was used to estimate the transformation parameter.

The values of the transformation (WGS-84 to Local and vise versa) parameters are as follows:

Table- 9

	Estimated

	Values
Translation in X axis(m)	124.3813
Translation in Y axis (m)	-521.6700
Translation in Z axis (m)	-764.5137
Rotation in X axis(Sec)	-17.1488
Rotation in Y axis (Sec)	8.11536
Rotation in Z axis(Sec)	-11.1842
Scale factor(ppm)	2.1105

In order to test the accuracy of the transformation parameter given in table -9 the second and third order coordinates in WGS-84 were transformed to Nepal datum. Then the transformed coordinates were compared with existing second and third order coordinates of the same points.

As in the previous test, the deviations between same particular points were quantified by computing the distance using the set of coordinates of the same points. Maximum and minimum difference between X and Y co-ordintes were computed along with distance between two points. The results are tabulated in table-6.

The variation in the second and third order Transformed coordinates and National coordinates in 81 CM

Table- 10

	Difference in X coordinates(ΔX)	Difference in Y coordinates(ΔY)	Distance between the points
Maximum Value in (m)	0.2385	0.883	0.8842
Minimun Value in (m)	0.0024	0.01	0.0693
Average			0.4076

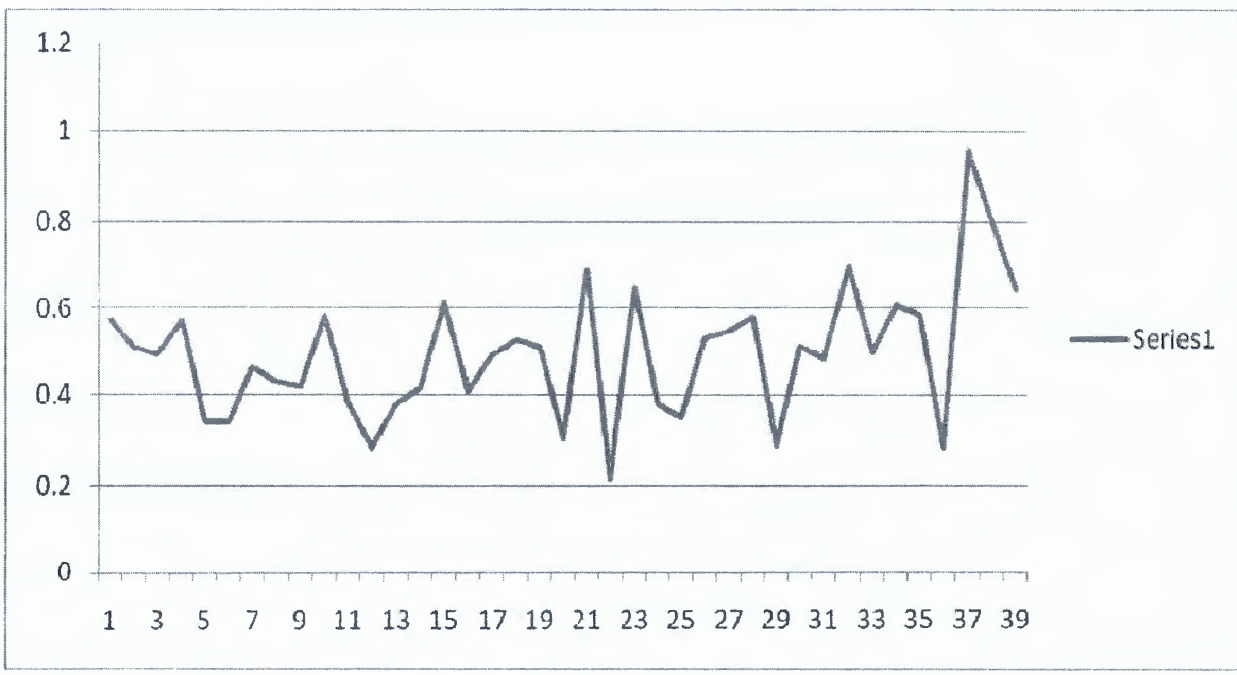
Referring table-10 the average deviation between the transformed points are found to be 0.407 m therefore this parameter can be used in the map of scale 1: 1700 or smaller. The graphical representation of the above table is given below.

The variation in the second and third order Transformed coordinates and National coordinates in 84 CM

Table- 11

	Difference in X coordinates(ΔX)	Difference in Y coordinates(ΔY)	Distance between the points
Maximum Value in (m)	**0.3421**	**0.9493**	**0.9569**
Minimun Value in (m)	0.5725	0.0284	0.2137
Average			0.4946

Referring table-10 the average deviation between the transformed points are found to be 0.4946 m therefore this parameter can be used in the map of scale 1: 2000 or smaller. The graphical representation of the above table is given below.

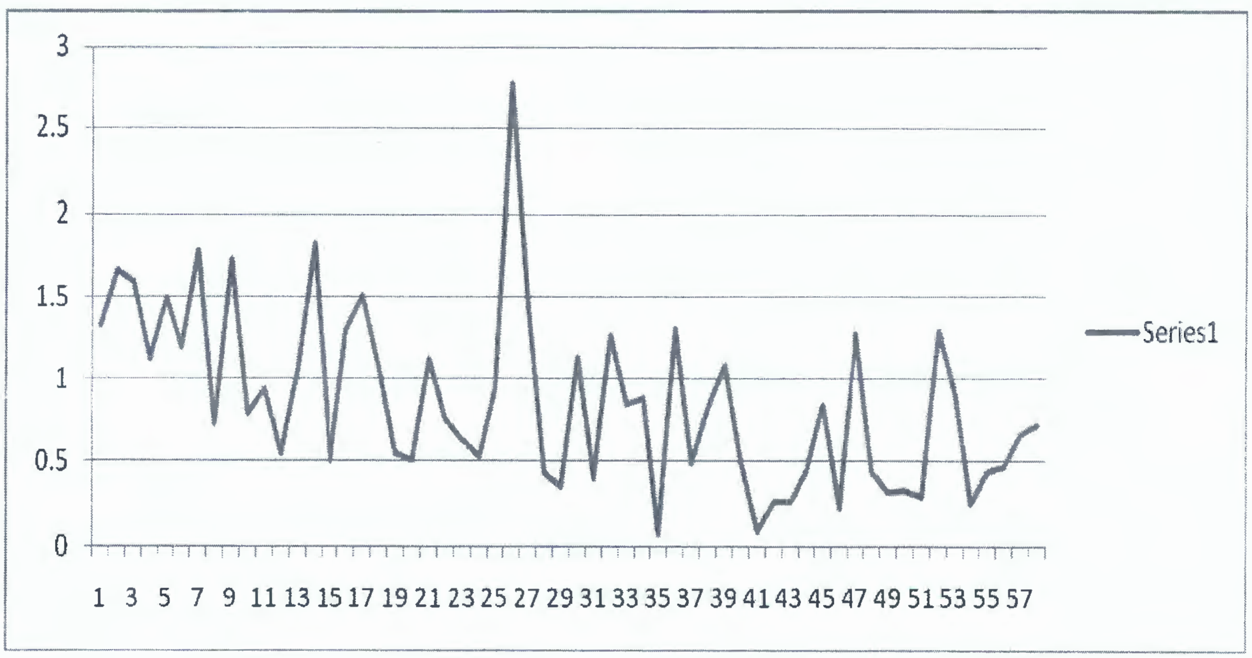


The variation in the second and third order Transformed coordinates and National coordinates in 87 CM

Table- 12

	Difference in X coordinates(ΔX)	Difference in Y coordinates(ΔY)	Distance between the points
Maximum Value in (m)	**1.0717**	**2.7447**	**2.7737**
Minimun Value in (m)	0.5733	1.828	0.077912
Average			0.872848

Referring table-10 the average deviation between the transformed points are found to be 0.872 m therefore this parameter can be used in the map of scale 1: 3500 or smaller. The graphical representation of the above table is given below.



The values of the transformation (Everest1830 to WGS-84) parameters are as follows:

Table- 13

	Estimated Values
Translation in X axis(m)	-124.3813
Translation in Y axis (m)	521.6700
Translation in Z axis (m)	764.5137
Rotation in X axis(Sec)	17.1488
Rotation in Y axis (Sec)	-8.11536
Rotation in Z axis(Sec)	11.1842
Scale factor(ppm)	-2.1105

Comparison of Transformed coordinates from Everest Spheroid to WGS 84 Ellipsoid using parameters of table-13 is shown in table-14.

Table 14

Station Name		Everest Spheroid Coordinate	WGS 84 Coordinate	Transformed Coordinate from Everest to WGS 84 Using Parameter
Siranchok	Latitude	28 05 01.38	28 05 02.58	28 05 02.592
	Longitude	84 36 11.00	84 36 2.719	84 36 02.715
Chaure dada	Latitude	27 26 27.85	27 26 29.28	27 26 29.293
	Longitude	84 48 44.45	84 48 36.117	84 48 36.1292
Dhaje	Latitude	26 51 56.88	26 51 58.66	26 51 58.70
	Longitude	84 36 11.00	84 36 2.719	84 36 02.760
Laure Dada	latitude	27 22 19.7400	27 22 21.33	27 22 21.365
	longitude	86 55 20.7600	86 55 11.43	86 55 11.422
Biratnagar	latitude	26 29 00.94	26 29 02.846	26 29 02.891
	longitude	87 16 01.17	87 15 51.742	87 15 51.764

12. Conclusion and Recommendation:

It has been felt essential that the integration of the coordinates of first, second, third, and lower order triangulation points in National Geodetic datum is essential to bring homogeneity in co-ordinate system of country.

The relationship between Nepal datum and WGS-84 co-ordinates is of immense requirement in present context. In order to bring the uniformity and consistency in coordinate conversion it is very important to determine reliable transformation parameters.

Three sets of transformation parameters has been determined. Third set or final set of transformation parameter which has been determined is recommended to use as a National Transformation parameter of the whole hole country. These parameters can be used for scales 1:1700 for 81 central meridian, 1:2000 for 84 central meridian and 1: 3500 for 87 central meridian.

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