CHAPTER II
GEODETIC SURVEYS
HORIZONTAL & VERTICAL CONTROL NETWORK

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Historical Background

2.1 Triangulation of Sri Lanka was commenced in 1857 and this network has been re computed by Mr. J.E. Jackson, Asst. Supdt. Of Surveys in 1933. This Network consisted of 110 primary Trigonometrical Stations. The accuracy of the network was around 1:20,000. Later this network was densified through secondary, tertiary & minor Trigonometrical Stations. Primary, Secondary & Tertiary traverse network between the trigonometrical stations was also established to densify control further.

2.2 During 1980's it was found that the accuracy provided by the above network was not adequate to meet the challenges of new technological developments in the field of surveying such as Cadastral Surveys, Construction Surveys, Engineering Surveys, Land Information Systems (LIS) & Geographical Information Systems (GIS) etc. Hence the Survey Department organized a seminar to find solutions for the above problems in February 1992. As a result, it was decided to upgrade the control network by using triangulation, trilateration & Global Positioning System (GPS) observations.

Sri Lanka Datum (SLD99)

2.3 A tedious program was commenced in 1992 to upgrade the control network of Sri Lanka by Triangulation, Trilateration and Global Positioning Systems (GPS). Finally in 1999 the entire horizontal network was upgraded and the new control network was established. It consists 273 Control points in following categories.

1.	Base Station (ISMD)	= 01
2.	No of Principal(AA) GPS Stations	= 10
3.	No of Primary(A) GPS Stations	= 194
4.	No of Trigonometrical (TN, TO) Stations	= 48
5.	No of Fundamental Bench Marks(FBM)	= 20
	Total	= 273

2.4 This new system was named as SLD99 and parameters related to that are given below.

I.	Reference Local Ellipsoid	:	*Everest-1830*
	Semi Major axis	:	*a = 6377276.3450m*
	Semi Minor axis	:	*b = 6356075.4131m*
			1/f - 300.801699999584
			{f= (a-b)/a}

II. Datum Transformation

a) 7-Parameters Datum Transformation (from WGS84 to Reference Local Ellipsoid)

Transformation Method	:	Bursa Wolf
Translation ΔX	:	0.2933 m
Translation ΔY	:	-766.9499 m
Translation ΔZ	:	-87.7131 m
Rotation about X axis	:	0.1957040”
Rotation about Y axis	:	1.6950677”
Rotation about Z axis	:	3.4730161
Scale factor	:	1.0000000393 or 0.0393 ppm

b) 3-Parameters Datum Transformation (from WGS84 to Reference Local Ellipsoid)

Some hand held type GPS devices supports only 3-Parameters for datum transformation instead of 7-Parameters described above.

Translation ΔX	:	97.000 m
Translation ΔY	:	-787.000 m
Translation ΔZ	:	-86.0000 m

III. Map Projection Parameters

a) Transverse Mercator projection parameters

Map Projection	:	*Transverse Mercator*
Longitude of the Origin	:	*80⁰ 46’ 18.16710” E*
Latitude of the Origin	:	*07⁰ 00’ 1.69750” N*
Scale factor	:	*0.9999238418*
False Northing	:	*500,000.00m*
False Easting	:	*500,000.00m*

Pidurutalagala Trigonomerical Station in old Triangulation Network has been used as the origin of the projection as used in the old system.

This projected coordinate system is defined as National Coordinate System (National Grid System).

b) **Universal Transverse Mercator (UTM) Projection Parameters**

Instead of the Transverse Mercator projection Parameters described above, some hand held type GPS devices support only UTM parameters for the projection to get the Grid Coordinates.

Map Projection	:	*UTM*
Longitude of the Origin	:	*80⁰ 46’ 18.16710” E*
Scale factor	:	*0.9999238418*

False Northing : *-273,992.00m*
False Easting : *500,000.00m*

2.5 The control points of SLD99 are classified according to their accuracies as follows.

GNSS Control	**Accuracy**
Principal control points (AA)	1:700,000
Primary control points (A)	1:200,000
Secondary control points (B)	1:100,000
Tertiary control points (C)	1: 50,000

Global Navigation Satelite System- GNSS

2.6 Specifications for Establishing GNSS Control Points are as follows.

	Establishment of GNSS control Station	Principal (AA)	Primary (A)	Secondary (B)	Tertiary (C)
1	Accuracy	1:700,000	1:200,000	1:100,000	1:50,000
2	Mode of Observation	Static	Static	Static	Static
3	Length of GNSS observation session	3 Sessions of 8 Hours	3 Hours	3 Hours	45 minutes
4	GDOP	<4	<4	<6	< 6
5	GNSS receivers	Dual frequency	Dual frequency	Dual frequency	Dual frequency
6	Adjustment	Network	Network	Network	Network
7	Loop closure	1:1,000,000	1:200,000	1:100,000 or < 3 cm	1:50,000 or < 5 cm
8	No. of Base stations	3	3	3	2
9	Station spacing	50-100km	15 – 30 km	4-8 km	100m-500m between consecutive 3 points and 2km between 2 sets

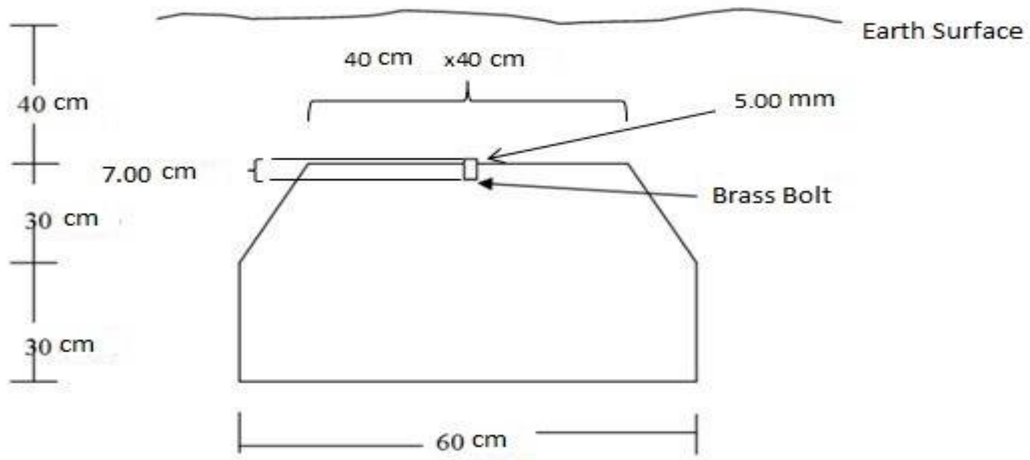
2.7 Usage of Monuments for GNSS Control Points

Order of the Control Point	Types of Monuments to be used
Principal	A3, B1, B2, B3
Primary	A3, B1, B2, B3
Secondary Order	A4, B1, B2, B3
Tertiary	A5, A6, B1, B2, B3

Measurements of Permanent Control Points (Monuments Type)

2.8 Monument Type : A3

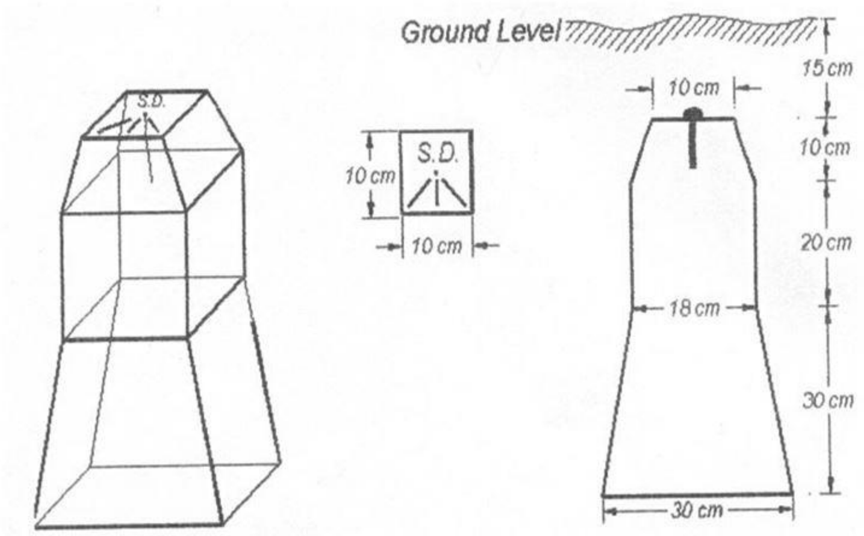
Brass Bolt on Large Concrete Block with following dimensions. Monument should be constructed in situ.

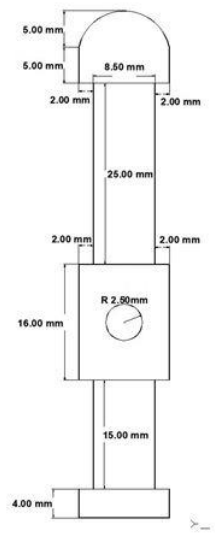


Description :- Brass bolt in Concrete Block

2.9 Monument Type : A4

Brass Bolt in Concrete Monument with following dimensions .



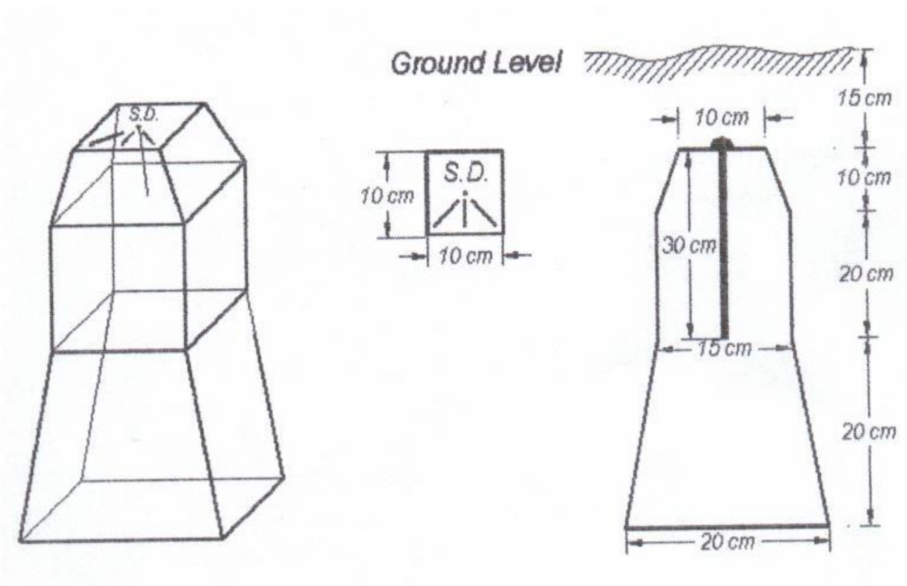


Cross Section of the Bolt

Description :- Brass bolt in Concrete Monument

2.10 Monument Type : A5

Brass Rod in Concrete Monument with following dimensions.

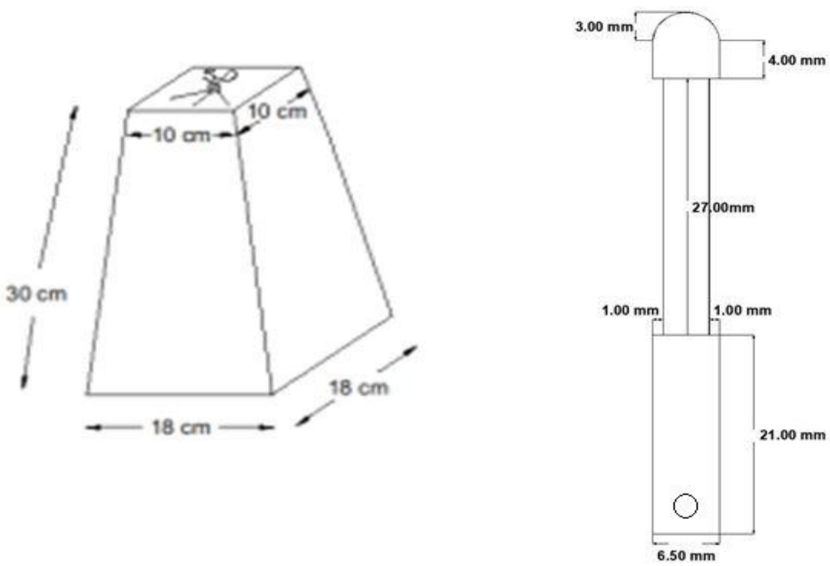


Description :- Brass Rod in Concrete Monument (3mm dimension of brass rod)

2.11 Monument Type : A6

Brass bolt in Concrete Monument with following dimensions.

A6 MONUMENT

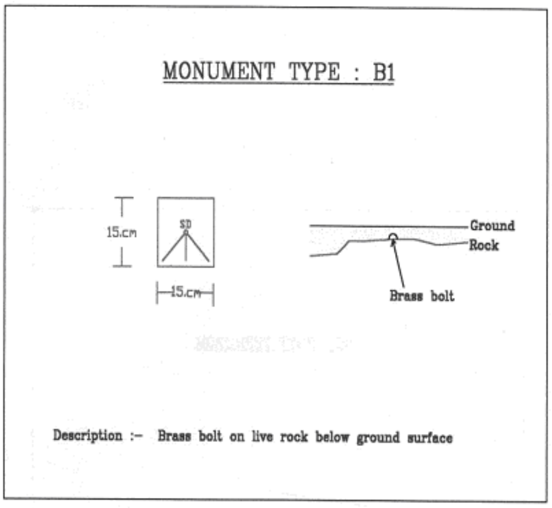


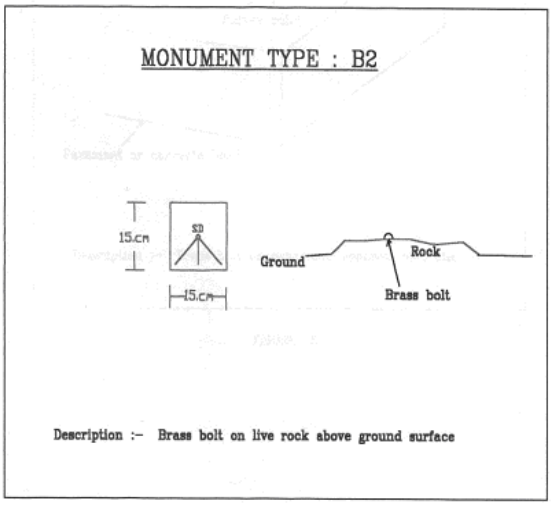
Cross Section of the Bolt

Description :- Brass Bolt in Concrete Monument

2.12 Monument Type : B1 & B2

Brass Bolt on Live Rock Below Ground Surface (B1) or Above Ground Surface.(B2) with following dimensions. Brass bolt 7.5cm to be buried on live rock

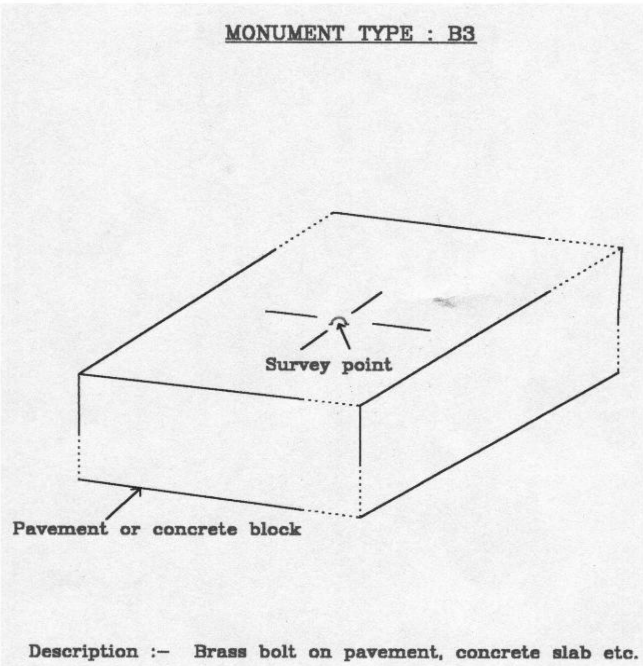




Description :- Brass Bolt in Live Rock

2.13 Monument Type : B3

Brass Bolt in Concrete Slab or Pavement. Brass bolt of 7 cm to be buried into concrete slab or pavement.

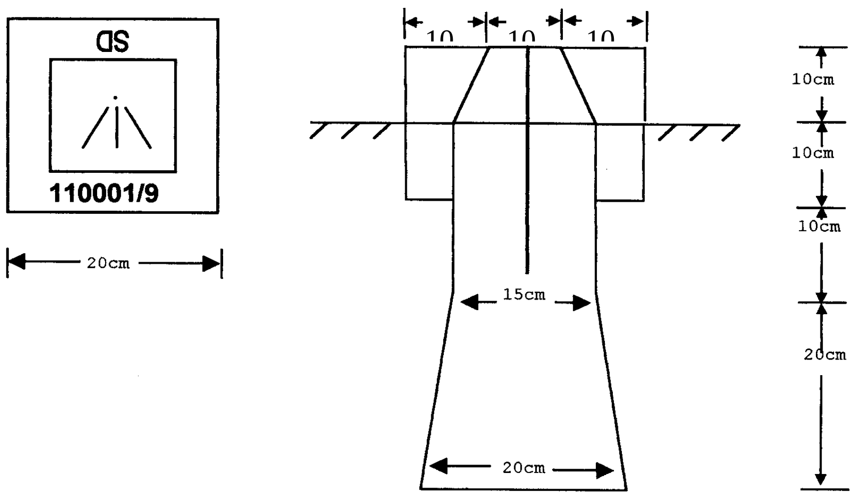


Description :- Brass Bolt on pavement or concrete slab

2.14 Monument Type : B4

Brass Rod in Concrete Monument with following dimensions (Surface Monument)

Monument should be buried underground with 10 cm projected above ground and to be covered with a concrete tapered base 30X30 cm.



Diameter of the rod is 3mm and length 30 cm

Description :- Brass Rod in Concrete Monument

Numbering of GNSS Control Points

2.15 Numbering system adopted for assigning numbers in Principal & Primary Control Networks are described below.

Station	Point No
Base Station at ISM, Diyatalawa	ISMD
Principal Control Points	AA01-AA10
Primary Control Points	A001, A002, ….
Old Triangulation Points	TO034,TO037, ….
New Triangulation	TN036,TN048, ...

Geodetic Survey Unit (SGO, ISM) and Provincial Geodetic Survey Units are responsible for numbering Secondary and Tertiary GNSS Control points. In order to adopt a uniform system for each unit and to identify the accuracy level (Secondary or Tertiary) point numbers should be assigned in the following manner.

Secondary Point No: *PQ***B***XXXXX* Tertiary Point No: *PQ***C***XXXXX*

PQ - District Code used in Cadastral Maps (See Annexure I of Chapter XXI)

Third Digit- **B** for Secondary & **C** for Tertiary GNSS points

XXXXX	Geodetic Survey Unit, ISM	00001-40000
	Provincial Geodetic Survey Unit, WP / SGO	40001-50000
	Provincial Geodetic Survey Unit, NWP	50001-60000
	Provincial Geodetic Survey Unit, SP	60001-70000
	Provincial Geodetic Survey Unit, CP	70001-80000
	Provincial Geodetic Survey Unit, NP	80001-90000

Establishment of Survey Control Points with GNSS Technology

2.16 Requirements to establish Secondary GNSS (B-Type) controls will be identified by Geodetic Survey Unit and it is to be implemented through respective Districts. Tertiary GNSS controls (C-Type) will be established according to the District level requirements. Every Tertiary GNSS control station should consists of two successive GNSS control stations which are inter visible and at least 100m apart from each other. This required for the starting of traverses form the GNSS control station with azimuth control and correct identification. Therefore tertiary GNSS control station means a set of three GNSS control stations and all these three points should have clear visibility of satellites.

Thorough investigation should be carried out in order to determine the availability of pre-established GNSS controls in the concern area as per specifications depicted in para 2.6 Should not available any controls, only new GNSS control points to be established.

2.17 General constraints in selecting GNSS control points.

(i) Good Sky Visibility (15^0 cut of angle above horizon)

(ii) Undisturbed location due to natural or human activities and preferably in state lands / properties.

(iii) Easy access to the location

(iv) Suitability to set up any type of survey equipment in future work

2.18 Establishing Monuments & Preparation of Location Diagram

(i) Correct type of monument to be buried / constructed at selected locations vide specifications in para 2.8 - 2.14.

(ii) Assign district reference numbers for new controls

(iii) A clear complete diagram to be prepared for each control point in a Field Book giving all information shown in **Annexure 1.** Minimum of 3 tie measurements for prominent permanent features should be shown in the diagram. An approximate coordinate of monument to be taken with Hand Held GPS receiver and mentioned in field note.

(iv) Prepare a 1:50,000 location diagram / kml file showing newly established control points

(v) Scan relevant FB pages and named those images with respective reference number

(vi) Submit an approximate coordinate listing of new controls to Geodetic Survey Unit along with documents mention in above (iv) & (v)

Work flow in the Geodetic Survey Units

2.19 Once the control point requests are received to the Geodetic Survey Unit, the following procedure should be carried out.

(i) On receipt of a formal request from the District Senior Supdt of Surveys along with all required documents mentioned above, DSG (Geodetic) will assign the work to a Provincial / ISM / SGO Geodetic Unit to attend the survey.

(ii) Provincial / ISM / SGO Geodetic Survey Unit should prepare a detail programme for the requested survey task and execute the same accordingly.

(iii) During the data collection at each station, a GNSS observation record sheet as per **Annexure II** should be filled and submitted with the recorded data for processing.

(iv) Point numbers to be assigned for Secondary & Tertiary GNSS Control points as described in 2.15 above.

(v) Finalize and include data to the control point Database.

2.20 Data Storing & Final Coordinates

(i) GNSS observation data and the processed data should be stored in the relevant Provincial Geodetic Survey Unit.

(ii) Diagrams of all Secondary & Tertiary GPS control points surveyed by Provincial / ISM / SGO Geodetic Survey Units should also be filed in Provincial Geodetic Survey Unit.

(iii) Scanned images along with the list of adjusted coordinates as per table shown in the **Annexure III** should be sent to DSG (Geodetic) at the completion of each job.

(iv) DSG (Geodetic) will make necessary arrangements to update records and receive them to relevant District Snr.S.S. and to all Provincial Geodetic Survey Units.

(v) DSG(Geodetic) shall make arrangement to store the Finalized coordinates & data in the office of DSG (Geodetic).

Control Traversing

2.21 With the introduction of Global Navigation Satellite System (GNSS) technology for horizontal ground control, requirement of establishing long distance traverses has been decreased. However, traverses have been categorized into three main groups according to their accuracy.

Control Survey Traversing	Accuracy
First order traverse control points	1:50,000
Second order traverse control points	1:30,000
Third order traverse control points	1:20,000

2.22 Usage of Monuments for Control Survey Traverses are as follows.

Order of the Traverse	Types of Monuments to be used
First Order	A6, B1, B2, B3
Second Order	A6, B1, B2, B3
Third Order	A6, B1, B2, B3, Rock Landmarks,

2.23 Specification for each Control Survey Traverses are as follows.

Traverse	Start	End
1st Order	Tertiary GNSS	Tertiary GNSS
2nd Order	Tertiary GNSS or 1st order Traverse Station	Tertiary GNSS or 1st order Traverse Station
3rd Order	Tertiary GNSS or 1st order Traverse Station or 2nd order Traverse Station	Tertiary GNSS or 1st order Traverse Station or 2nd order Traverse Station

In general maximum precautions should be taken in making linear and angular measurements in order to maintain high standards of accuracy. Requirement of the Survey decides the order of the traverse to be run. Following specifications should be followed to achieve accuracies of traverses in each category.

		Type of Control Traverses			
		1st Order	2nd Order	3rd Order	Total Station detail
Angular	Angular Observation accuracy nearest	1”	3”	5′′	5′
	Angular closing error limit	30”	1′	2′	3′
	Method of Angular measurements	Included angle	Included angle	Included angle	Azimuth

	Number of Horizontal zeros (Hz)	6 (0^0,30^0,60^0 , 90^0, 20^0,150^0)	4 (0^0, 45^0, 90^0, 135^0)	2 (0^0, 90^0)	
	Number of Vertical zeros (V)	4	2	1	
	Faces	2	2	2	
	Max. Std dev of mean of Hz	± 4”	± 8”	± 12”	
	Max. Std dev of mean of V	± 8”	± 20”	± 30”	
Linier measurements	Station Spacing (m)	200-800	100-300	50-100	
	Length measurements	Dual direction	Dual direction	Dual direction	One direction
	Permissible Discrepancy. in mm between mean of D/R measurements	5mm	5mm	5mm	Not applicable
	Max. Std dev of mean of distance measurement	5mm	5mm	5mm	
	Standard Correction (Temperature & Pressure to be fed at the time of observation	Yes	Yes	Yes	
	Instrument & Target Height	Yes	Yes	Yes	
	Accuracy of Instrument & Target Height	± 10 mm	± 10 mm	± 10 mm	
	Accuracy of Temperature	± 1° C	± 1° C	± 1° C	
	Accuracy of Pressure	± 5 mbar	± 5 mbar	± 5 mbar	
Accuracy	Azimuth Control (Az)	20 Stations	25 Stations	30 Stations	
		3 Intermediate Tertiary GNSS to be established in case of exceeding above limit			
	Azimuth Closure (Az)	5”√N ; N is no of Stns	10”√N ; N is no of Stns	20”√N ; N is no of Stns	
	MSL Correction	Yes	Yes	Yes	
	Coordinate closing limits Value of C (C√K , K – length of traverse in km)	0.2	0.3	0.4	

Guide Lines for Control Survey Traversing

2.24 A proposed traverse diagram on 1:50,000 scale should be prepared under the direction of relevant District Senior Supdt. of Surveys prior to commencement of traversing and Traverse no should be obtained. A register should be maintained at every District Survey Office to issue traverse numbers for 1st, 2nd and 3rd order traverses.

2.25 Special attention should be given to selection of suitable sites for monuments with a view to their easy identification, stability and free of disturbances. Correct type of monument to be buried at selected locations vide specifications in para 3.1

Two surveyors are expected to be deployed for field work (one for observations and other for recording).

2.26 A clear diagram has to be prepared for each traverse point in EDM traverse Field Book. Minimum of tie measurements for prominent permanent features should be shown and additional information, e.g., proximity to culverts or gardens, which would facilitate identifying the locality of the monument, should also be given. Diagrams and the observations should be recorded in EDM Field Book as per specimen in **Annexure IV**.

Angular & Distance measurements

2.27 Suitable survey equipment should be selected and field procedure should be followed to achieve the accuracy of the proposed traverse. Anyhow all instruments and accessories to be used should be calibrated and checked for adjustment before field work of each traverse.

2.28 Optical or laser plummets should be used for centering the instruments and targets. Instruments and targets should be centered to within ± 2mm over the survey mark. Optical plummet should be checked at each station for verticality by rotating through 360°. The center mark should be coincided with the center mark of the monument at any position.

Whenever the difference between F/L and F/R readings of the instrument from l80° by more than 30", the instrument should be adjusted for collimation error. Also, when difference between F/L and F/R readings of vertical angles depart from 360° by more then 30" the instrument should be adjusted. This adjustment has to be done under the direction of District Senior Superintendent of Surveys.

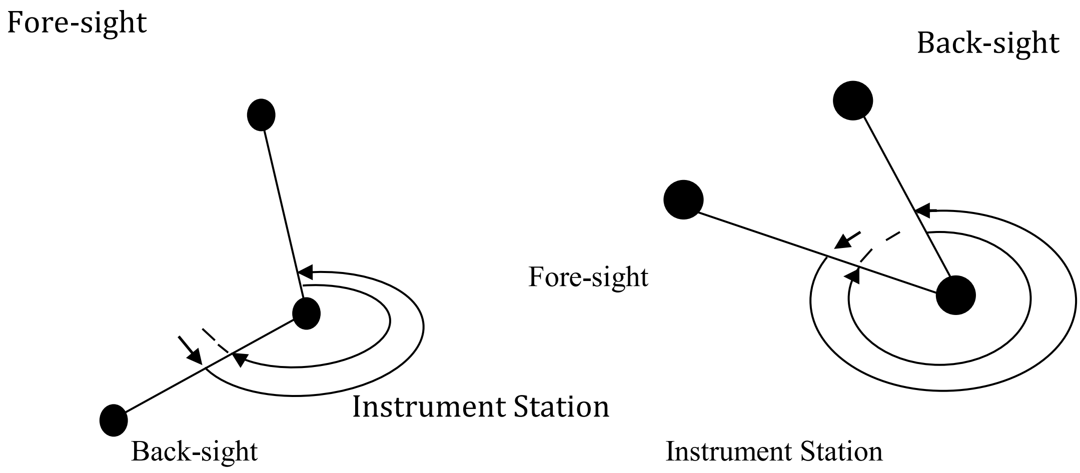
2.29 Independent observations at each station will be made for angular and distance measurements. It is necessary to take appropriate no zeros set observations for both horizontal angles and vertical angles according to the order of traverse as per specifications in para 2.23

Temperature & Pressure to be applied to the instrument at the time of observation and the *ppm* to be recorded. Instrument & Target heights should be measured to nearest ± 10 mm and to be recorded. Prism Constant of the reflector to be applied to the instrument before making distance measurements.

Traverse Observation Procedure

2.30 Always use three tripod system for traverse observations. Tripods should be centered accurately over the traverse point. Independent included angle-measuring technique to be adopted for all control traverses. In this method the clockwise angle from back-sight to fore-sight to be measured in both faces.

In this method clockwise angle from back-sight to fore-sight to be measured in Face Left and anti-clockwise angle from fore-sight to back-sight to be measured in Face Right.



2.31 Following four steps will complete first independent angle (Zero).

(a) Observe the back-sight in face left. Set the instrument reading to zero setting. Observe and record the horizontal angle, zenith angle & slope distance to back-sight target in face left (FL).

(b) Then swing the telescope in clockwise direction and observe fore-sight without over shooting the target. Record the horizontal angle, zenith angle and slope distance & to fore-site target.

(c) Turn the telescope slightly to pass over the fore-sight target and invert the telescope to change the face to face right (FR). Observe the fore-sight target in anti- clockwise direction without over shooting the target and record the horizontal angle, zenith angle and slope distance & to fore-site target.

(d) Then observe back-sight in anti-clockwise direction without over shooting the target and record the horizontal angle, zenith angle and slope distance & to fore-site target.

2.32 Change face to FL and unclamp the upper plate and rotate clockwise approximately to the next zero position [(n-1)*180°/N ; N - Number of Zeros, n - nth Zero] approximately. Clamp the upper plate, unclamp the lower plate and turn the instrument clockwise until back-sight target is in sight and repeat the same procedure (a) to (d) above to complete second independent angle (zero).

Repeat the above steps until completion of required number of zeros.

2.33 At the end of each zero, observer must check the means and standard deviations are within the allowed errors according to the EDM traverse technical specifications. If the error is exceeding the allowed error new observation should be taken.

Data Reduction, Computation and Adjustment

2.34 Observations recorded on Field Book at each station should be reduced to compute mean Hz included angle, mean V angles and mean distances for each zero settings. After rejecting blunders, computed data to be extracted into abstract sheet as Specimen shown in **Annexure V.**

Mean of the included angles, vertical angles and distances in the abstract to be computed and data exceeding the limits giving in the specifications to be rejected.

The maximum azimuth misclosure allowed for traverses will be calculated from the formulas 5"√N, 10"√N, 15"√N for 1st , 2nd and 3rd order of traverses respectively ; where N is total no of stations of the traverse.

2.35 Azimuth of each traverse leg to be computed using mean angles and misclosure with the Azimuth of the closing leg. Misclosure to be checked and error to be distributed equally if the closure is within permissible limits.

Mean distances should be corrected for calibration errors by applying Constant Error & Scale Error.

2.36 The maximum linear misclosure allowed for traverses will be calculated from the formula C√K meters, where K will be the length of the traverse in km. The value of C with respect to traverse order is given in para 2.23

Linear misclosure shall be distributed according to the Bowditch Rule or any other suitable method if the misclosure is within permissible limits.

2.37 Finally adjusted azimuth and corrected distances or included angles and distances to be used for traverse computation & adjustment.

SDCAD software or any other software acceptable to the Department can be used for Traverses computation and adjustment.

This chapter describes Control Survey Traverses in 1st, 2nd and 3rd order and detail traversing has been described in Chapter XXII.

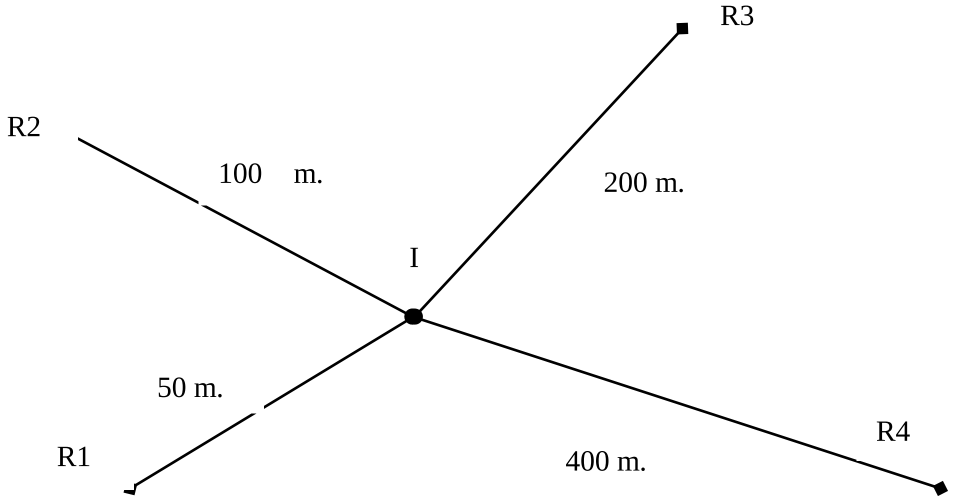
Traverse & Station Numbering System

2.38 Traverses should be numbered sequentially for each category in each district. Traverse number consists of the traverse order, district number and sequential number. First two letters generally denote the class of control traverse followed by a hyphen and two digits for identification of the District followed by a hyphen and four digits sequential identification number. (e.g. is 15th First order Traverse in Kurunegala District will be numbered as E1-42-0015). This number should be obtained from District Senior Supdt of Surveys for each traverse.

2.39 Station number of a control traverse will be generated with traverse number and sequential two digit number for station identification. (e.g. 24th traverse station of 18th Second order Traverse in Kandy District will be numbered as E2-32-0018-24). Assigned district code numbers are given in Annexure XII of Chapter XXII

Calibration of EDM Instrument

2.40 Periodic calibration of EDM Instrument is essential to safeguard the accuracy of distance measurements but full calibration is tedious and time consuming. Further the instrument will have to be taken to a especially prepared/constructed Calibration Base at ISM, Diyatalawa or SGO, Colombo. In order to avoid this difficult situation, it has been decided to do a performance check for every EDM Instrument once in month or after surveying approximately 500 survey lines or whichever comes first.



(I - Instrument Station, R1, R2, R3, R4 Reflector Stations.)

For this purpose a test field must be established closer to every Divisional Survey Office. This test field consists of one instrument station preferably closer to the office and four other easily accessible reflector stations at approximately 50, 100,200, 300 meters away from instrument station. These stations can be along straight lines such as a road, or as shown in the diagram above. A4 type monuments can be used for this purpose. It is preferred if one additional reflector station is established at a distance little more than 1 km away. The reference lengths of the lines are determined with the working EDM instruments immediately after full calibration at ISM or SGO Calibration Base. This will give the actual reference values (standard lengths) and should be recorded in a logbook maintained for the home test field for future reference.

The reflector stations should be selected such that the elevation or depression of the lines from instrument station not to exceed 5 degrees.

The surveyors who are working with the EDM instruments should measure these lines and enter the logbook. Horizontal distances should be measured and recorded in F/L and F/R positions in the home test field record sheets. The temperature and pressure should also be recorded and fed to the instrument when measuring each of the lines. The mean values of the horizontal distances should be corrected for the calibration parameters for the fully calibrated instruments. The calibrated horizontal distances finally should be recorded in the log book.

A logbook consisting of home test field record sheets and log sheets for one set of the home test field lines should be maintained by the Superintendent of Surveys. The differences with the standard distances should be checked by the Superintendent of Surveys and his comments on the instrument should make in the log book itself. If the difference of the all measured distances are differed by $\pm$ 0.020m or more with the standard distances, it is recommended that the check be repeated very carefully. If the second comparison check confirms the results of first, it is necessary to do the full calibration, otherwise it will be considered that the instrument is not in good working condition.

District/ Provincial Senior Supdt. of Surveys and Provincial Surveyor General must scrutinize these logbook whenever they visit the Divisional Survey Offices.

Geodetic Vertical Control

2.41 The earliest level recorded are dated 1865 and 1000 miles single leveling completed in 44 years. Old level lines formed no network since leveling was only done as the need for it arose. Between 1904 and 1909 the standard of leveling was improved and more attention was given to construction of permanent Benchmarks. In 1909 more staff was deployed and leveling operations were undertaken systematically. As a part, new network was tied down to the mean sea level determinations made by the Great Trigonometry Survey of India at Colombo, Galle and Trincomalee between 1884 and 1895.

During the period of 1909 - 1914, supplementary benchmarks were constructed and 650 miles of double leveling completed. Work was stopped at the outbreak of 1st World War in 1914 and operation was resumed in 1923 and 200 miles completed by 1924.

In 1925 whole leveling procedure was reviewed and decided to start afresh with modern instruments and methods of precision. The leveling was done with precise levels as well as invar staves. And grate care was adopted in leveling procedures in order to achieve results of the highest accuracy. The geodetic leveling network comprises of 59 FBM, 5 SBM, and 4000 km of double-leveling forming 27 circuits.

The primary leveling network covers entire country and compares favorably with leveling of high accuracy in other countries of the world.

From then on, leveling has been extended by secondary, tertiary and minor leveling to provide height control for all development projects in Sri Lanka. In this process 6 FBM constructed in 1924, 31 FBM in 1925, 22 FBM in 1926 and principle net work was completed by 1928.

Observation and adjustment of Geodetic Leveling Network of Sri Lanka was completed in 1926-1930 and the results were published by Surveyor General in 1932 through "The Geodetic Leveling of Ceylon- Vol I and II".

2.42 Datum

Mean Sea Level of Sri Lanka is treated as the reference level or datum for Orthometric heighting. All geodetic leveling should be based on this datum.

2.43 Fundamental Benchmarks (FBM)

There were 59 Fundamental Bench Marks built on large masses of rock similar in design to BMs of Ordnance Survey with a bolt in the underground chamber (Lower bolt) and a bolt in a pillar above ground (Upper bolt).

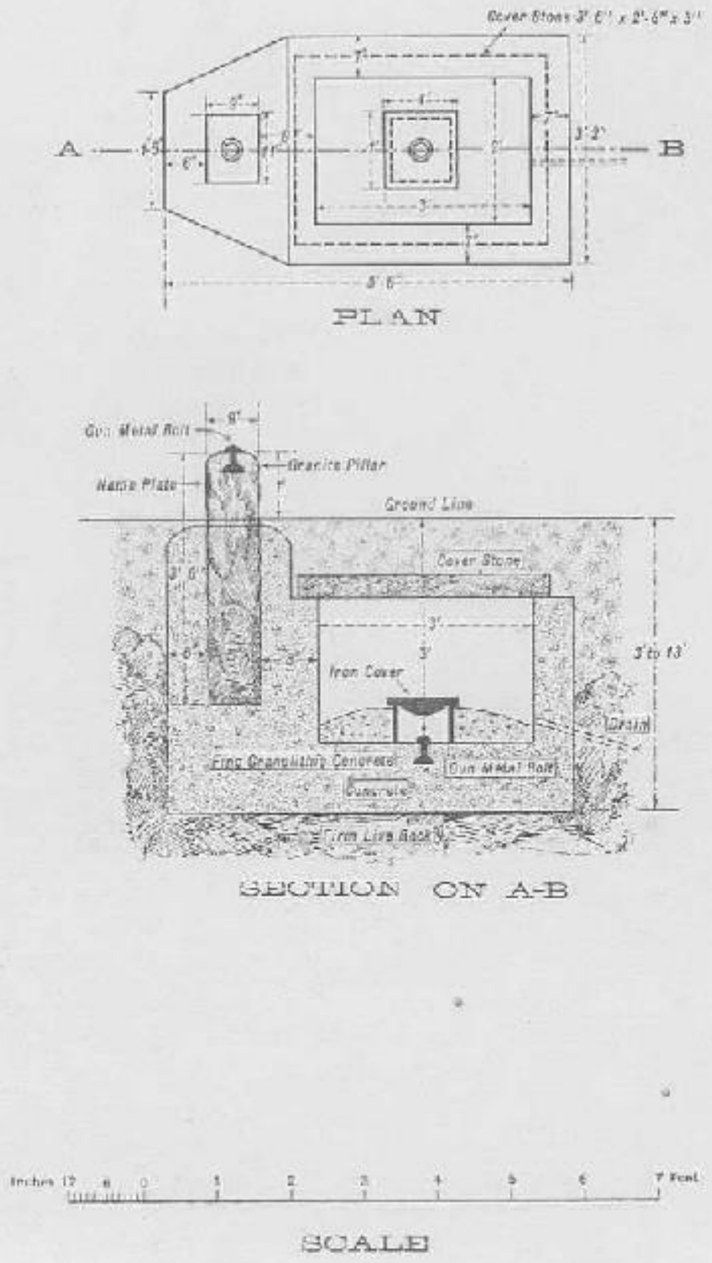
2.44 Standard Benchmarks (SBM)

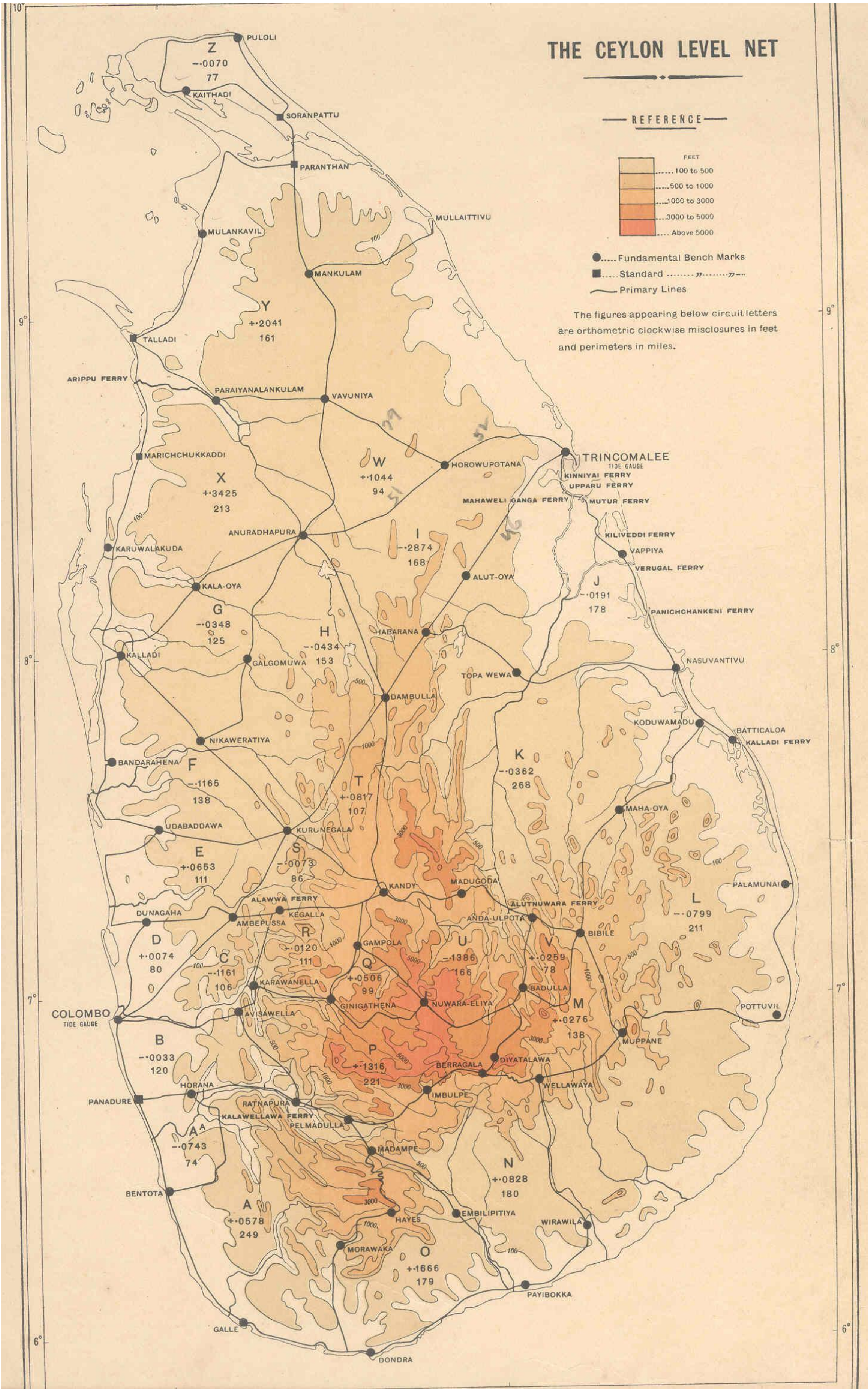
Standard Benchmarks, of which there are 5, of the form of bolts set in large concrete block constructed in situ at a depth below ground surface of 1 m. These were constructed instead of FBMM in locations where solid rock foundations could not be found. Even though they are named as Standard (SBM), their accuracy remains similar to FBMM.

2.45 Primary Level Network

Primary Level Network consists of Fundamental Benchmarks and series of Primary level lines run among them. This network has already been established and fully described in volume I of the Report on the Geodetic Leveling of Ceylon. The descriptions and values of Primary benchmarks are published in volumes II of the same Report. Following diagram depicts location of FBMM /SBMM and Preliminary level lines with their respective numbers. Monuments have been used for leveling are described in the **Annexure VI** and the monument types currently used for leveling are described in para 2.21, 2.23, 2.24 and 2.49

FUNDAMENTAL BENCH MARK




THE CEYLON LEVEL NET
REFERENCE
FEET
100 to 500
500 to 1000
1000 to 3000
3000 to 5000
Above 5000
Fundamental Bench Marks
Standard
Primary Lines
The figures appearing below circuit letters are orthometric clockwise misclosures in feet and perimeters in miles.
PULOLI
KAITHADI
SORANPATTU
PARANTHAN
MULLAITTIVU
MULANKAVIL
MANKULAM
TALLADI
ARIPPU FERRY
PARAIYANALANKULAM
VAVUNIYA
MARICHCHUKKADDI
HOROWUPOTANA
TRINCOMALEE
TIDE GAUGE
KINNIYAI FERRY
UPPARU FERRY
MAHAWELI GANGA FERRY
MUTUR FERRY
ANURADHAPURA
KARUWALAKUDA
KILIVEDDI FERRY
VAPPIYA
VERUGAL FERRY
ALUT-OYA
KALA-OYA
PANICHCHANKENI FERRY
HABARANA
KALLADI
GALGOMUWA
NASUVANTIVU
TOPA WEWA
DAMBULLA
KODUWAMADU
BATTICALOA
KALLADI FERRY
NIKAWERATIYA
BANDARAHENA
MAHA-OYA
UDABADDAWA
KURUNEGALA
PALAMUNAI
KANDY
MADUGODA
ALAWWA FERRY
ALUTNUWARA FERRY
DUNAGAHA
AMBEPUSSA
KEGALLA
ANDA-ULPOTA
BIBILE
GAMPOLA
KARAWANELLA
BADULLA
GINIGATHENA
NUWARA-ELIYA
POTTUVIL
COLOMBO
TIDE GAUGE
AVISAWELLA
MUPPANE
DIYATALAWA
BERRAGALA
WELLAWAYA
HORANA
IMBULPE
PANADURE
RATNAPURA
KALAWELLAWA FERRY
PELMADULLA
MADAMPE
BENTOTA
EMBILIPITIYA
HAYES
WIRAWILA
MORAWAKA
PAYIBOKKA
GALLE
DONDRA
Z −·0070 77
Y +·2041 161
X +·3425 213
W +·1044 94
I −·2874 168
J −·0191 178
G −·0348 125
H −·0434 153
K −·0362 268
F −·1165 138
T +·0817 107
E +·0653 111
S −·0073 86
L −·0799 211
D +·0074 80
C −·1161 106
R −·0120 111
Q +·0506 99
U −·1386 166
V +·0259 78
M +·0276 138
B −·0033 120
P +·1316 221
AA −·0743 74
N +·0828 180
A +·0578 249
O +·1666 179

Leveling

2.46 Secondary(SL) & Tertiary(TL) Leveling

Secondary level lines were run to break down the Primary Level Network and to densify the vertical control. Tertiary (TL) and Minor (ML) leveling are run for the further densification of leveling. Detail leveling is done in order to determine the elevation of required points.

2.47 Numbering of Level Lines

In numbering level lines prefixes PL for Primary level lines, SL-Secondary Level lines, TL-Tertiary Level lines, ML-Minor Level lines and DL-Detail Level lines are followed by their respective level line number. For geodetic leveling (PL, SL, TL) level line numbers will be assigned by Geodetic Survey Unit. Minor & Detail Level line numbers to be assigned by respective districts. This number should be written on level books, diagrams and corresponding documents.

2.48 Numbering of Benchmarks

Benchmark number of a level line will be generated with 3 digit level line number and sequential 3 digit number for station identification. (e.g. 134^{th} benchmark of 18^{th} tertiary level line will be numbered as TL-018-138).

Benchmark numbers of Minor & Detail level lines will be numbered in district level. It will be generated with district number, 3 digit level line number and sequential 3 digit number for station identification.

e.g. 120^{th} benchmark of 15^{th} Minor Level line in Matara District will be numbered as ML-82-015-120

e.g. 120^{th} benchmark of 15^{th} Detail Level line in Matara District will be numbered as DL-82-015-120

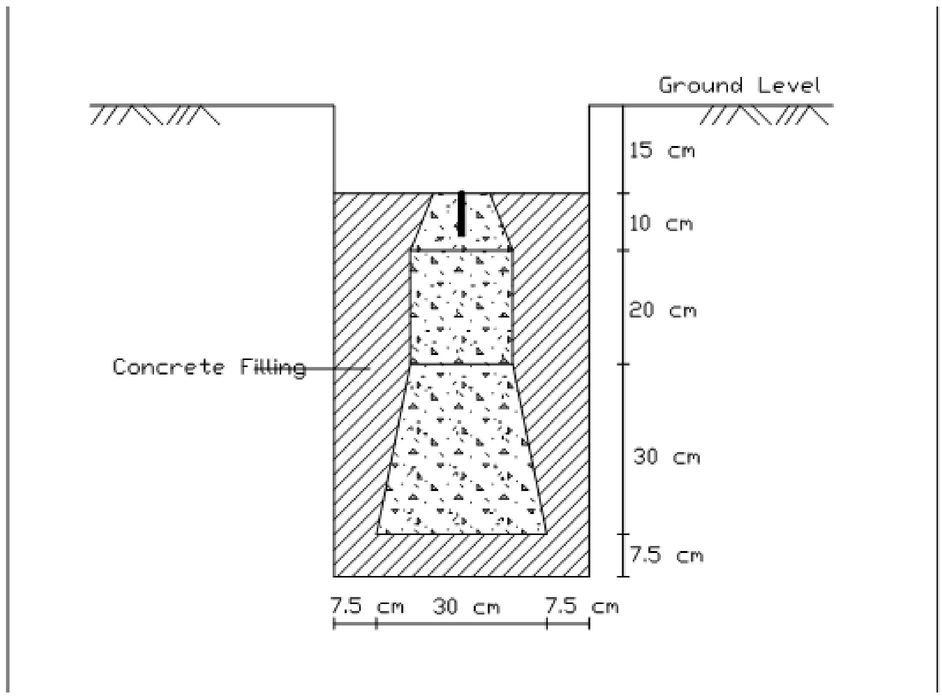
2.49 Specifications for Geodetic Leveling

	Type of Geodetic Level Lines	Primary(PL)	Secondary (SL)	Tertiary (TL)	Minor(ML)	Detail (DL)
1	Instrument	Digital Level with 0.2mm accuracy for 1 km double run or better	Digital Level with 0.2mm accuracy for 1 km double run or better	Digital Level with 1.0mm accuracy for 1 km double run or better	Digital Level with 1.5mm accuracy for 1 km double run or better	Digital Level with 1.5mm accuracy for 1 km double run or better
2	Monument Type	A4, B1,B2	A4, B1, B2	A6	A6	E
3	Starting Point	LB of FBM / SBM	LB of FBM / SBM / PL	PL or SL	PL, SL or TL	
	Ending Point	LB of FBM / SBM	LB of FBM / SBM /PL/ SL	SL or TL	TL or ML	
3	Procedure	Precise	Precise	Precise or Ordinary	Ordinary	Ordinary
4	Mode of Observation (B-Back Sight, F – Fore Sight)	BFFB	BFFB	BF	BF	BF
5	Allowable discrepancy between two back Sights or two Fore Sight readings	0.05 mm	0.05 mm	-	-	-
6	Allowable discrepancy in distance between back Sight & Fore Sight	0.5m	0.5m	1m	2m	2m
7	Maximum Length of Level line	-	-	20 km	12km	5km
8	Min distance between Instrument & Staff	7m	7m	-	-	-
9	Max distance between Instrument & Staff	50 m	50m	60m	60m	60m
10	Allowed Error Closure (m)	$0.00276\sqrt{K}$; K: length of line in km	$0.004\sqrt{K}$; K: length of line in km	$0.006\sqrt{K}$ K: length of line in km	$0.010\sqrt{K}$ K: length of line in km	$0.024\sqrt{K}$ K: length of line in km

2.50 Establishment of Level lines (PL, SL & TL)

The Deputy Surveyor General (Geodetic) will direct all primary, secondary and tertiary leveling. Field work will be carried out by officers assigned to Geodetic Survey Units. However establishment of benchmarks in a level line will be carried out by relevant district. All level lines should be established considering following criteria.

a) Every 500m interval BM should be established and their base and the collar should be concreted as depicted below.



A4 monument with base & collar concreted

b) No obstacles should be above the BM to enable holding leveling staves vertically and the BM location should be suitable to set up bipod or any other surveying instruments and work conveniently.

c) BM bolt should emerge minimum 5 mm above concrete to facilitate free movements of leveling staves.

On successful competition of monumentation, following documents should be prepared and send them to DSG (Geodetic) for further action.

a) A complete diagram to be prepared for each BM in a Field Book giving all information shown in **Annexure X**. Minimum of 3 tie measurements for prominent permanent features should be shown in the diagram. An approximate coordinate of monument to be taken with Hand Held GPS receiver and mentioned in field note.

b) Prepare a 1:50,000 location diagram / kml file showing newly established control points.

c) Scan relevant FBB pages and name those images with respective reference number.

With the receipt of all documents at the completion of monumentation a considerable period of time should be lapsed to settle before commencement of leveling.

Where new level line starts or closes on an old established benchmark (not a Fundamental Benchmark), the existence of the old benchmark must be verified by running a test leveling to another known benchmark in the vicinity.

With the commencement of field process, raw data of geodetic leveling should be downloaded and printout to be pasted on a numbered level book under relevant loop of the level line as per specimen in Annexure **VII**. Anyhow this format could be somewhat different from the instrument to instrument.

Height difference of benchmarks in each loop obtained by forward and backward leveling will be extracted to an abstract form given in Annexure **VIII**. Results in a abstract form will be scrutinized to determine the loops that are not in the permissible limit and to re-level the misclosed loops. With the acceptance of all loops in the level line adjustment will be done using the format shown in Annexure **IX**.

A clear complete diagram as in Annexure **X** showing the location, tie measurements, approximate coordinates and height will be prepared for each benchmark in the level line and report on level line will be published by DSG (Geodetic).

2.51 Specification for Conventional Methods

At present digital levels and bar-coded staves are used for Geodetic Leveling. Therefore most of the procedures adopted in past have diminished. However, different settings have to be made in the instruments according to their make & accuracy to achieve the standards required.

Followings are the conditions of agreement for Primary and Secondary leveling with conventional methods. Chapter V in Technical Instructions fully describes the manual operations of precise leveling.

	Conditions of Agreement	Must not exceed	
		Primary	Secondary
i	The differences of the stadia hair readings	0.006096m	0.012192m
ii	The differences of the level hair readings on one staff (back or fore)	0.000457m	0.000610m
iii	The difference of the sum of the stadia hair and the sum of the level hair readings	0.001067m	0.001524m
iv	The stadia distance	38.1m	41.1m
v	The discrepancy between back and fore leveling for each section and for each line ; where k is the distance in kilometers.	$0.00276\sqrt{K}$	$0.00386\sqrt{K}$

For other types of leveling, the following accuracy should be maintained. The limits of errors are as follows.

.

Primary ….. $= 0.003\sqrt{K}$

Secondary ….. $=0.004\ \sqrt{K}$

Tertiary	.....	= 0.006√K
Minor	.....	= 0.010√K
Detail	.....	= 0.024√K
For Detail surveys to observe reduced levels	......	= For 1 Km or a fraction of one Km 0.02 m (2cm)

where K is the length of level line in kilometers.

2.52 Verification of Fundamental Benchmarks

Senior Supdt of Surveys in District/ Province should inspect or arrange for the inspection by a competent officer of all Fundamental Benchmarks in their district/ province annually and submit a report in the given form to Senior Supdt of Surveys (Geodetic) for further action with copy to relevant Provincial Surveyor General. However Provincial Surveyor General concerned should take proper action accordingly if he considers that special action is required in connection with any Fundamental Benchmarks.

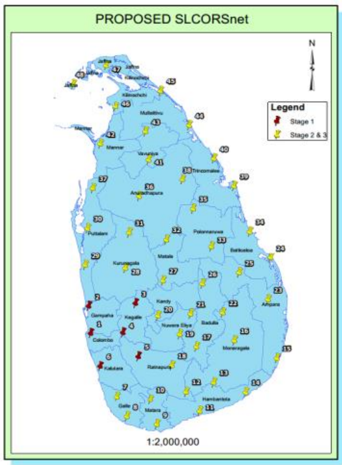
If found any benchmarks in PL, SL or TL are destroyed or missing, Senior Supdt of Surveys in relevant District should inform to DSG (Geodetic Surveys).

Establishment of Survey Control Points) using SLCORSnet

2.53 Surveying with SLCORSnet (Sri Lanka Continuously Operating Reference Station Network)

The Continuously Operating Reference Station Network which is governed by the Survey Department of Sri Lanka is known as the SLCORSnet. The SLCORSnet comprises of physical GNSS reference stations at remote designated locations that transmit the collected GNSS raw data lively to the Control Centre based in Colombo at the Survey General's Office. This raw data is processed using a GNSS network processing software housed at the Control Centre, which then will be transmitted to the users in the field over the internet based on their geographic locations in the form of RTCM corrections. Online delivery of RINEX raw data and online post-processing services are provided as real-time web services from the SLCORSnet.

This System is used to give highly accurate value for positions using GNSS technology. By connecting several reference stations, a network is formed to act as a virtual reference network for clients to log in and obtain RTK corrections to increase the positional accuracy.



Stage 1: 6 Stations

Stage 2: 42 Stations

Established SLCORSnet-Stage I (6 Stations) and Proposed SLCORSnet

2.54 In Stage I of the SLCORSnet, six CORS stations were already established covering the Western part of the country in Colombo, Awissawella, Katana, Rathnapura, Kegalle and Kaluthara.

To work using the SLCORSnet, create a user login by visiting the link in the official departmental website or directly www.slcorsnet.survey.gov.lk. After registering under the SLCORSnet, all these services can be used with the given user login.

While configuring, the work mode of the project should be configured by giving the required details as the following.

Domain/IP	: 222.165.190.67
Port	: 2101
Source	: VRS or VRS_BDS
User Name	: geoTest
Password	: xxxxxxx

Give the username and the password created in the SLCORSnet
Eg: user name: geoTest

NETWORK RTK (Network Real Time Kinematic)

2.55 Network RTK with SLCORSnet (Network Real Time Kinematic)

To reach centimeter-level — or even better — accuracy of positioning, typically requires the use of precise dual-frequency carrier phase observations. Furthermore, these observations are usually processed using a differential GNSS (DGNSS) algorithm, such as real time kinematic

(RTK) or post-processing (PP). The virtual reference station (VRS) concept can help to satisfy this requirement using a network of reference stations.

2.56 Online-RINEX Delivery: GNWEB:

SLCORSnet Geo++® GNWEB is an internet client application for the online provision of RINEX & Virtual RINEX from the SLCORSnet reference station network.

GNWEB offers internet users the opportunity to generate RINEX data for each provided GNSS reference station individually or virtual RINEX data for a user defined position to reduce distance dependent GNSS error sources. The user receives a report of the data availability and thus can check the suitability of the data prior to the actual download. The data requested by users are provided for a certain time period on the GNWEB server for download.

2.57 Procedure For the Establishment of Control points using Network RTK Solution (NRTK) of SLCORSnet

Below Steps should be followed to establish a Control Point.

- Points should be established at a location with clear sky visibility.
- GNSS receiver should be fixed on Tripod over the point.
- Select Precise Solution at the Configuration and set precision HRMS=0.015& VRMS=0.030
- Select Network RTK and VRS correction method (VRS or VRS_BDS)
- Select the average observation as 25
- Wait for the correction is fixed.
- Antenna height should be correctly measured and entered to the Controller before starting the data recording.

2.58 Monument

Landmark or Rock Landmark should be used for the Network RTK GNSS Control points.

2.59 Numbering System for Control Points

District Survey office is responsible for numbering and maintaining the records of Network RTK GNSS Control points. In order to adopt a uniform system for each District and to identify the accuracy level, Network RTK Control point numbers should be assigned in the following manner.

Network RTK Control Point No: *PQRSTU***N***XXX*

PQ	-	District Code used in Cadastral Maps
RSTU	-	GN Code used in Cadastral Map
N	-	**N** for Network RTK GNSS Control points
XXX	-	Point No.

2.60 Location Diagram

Location diagram as shown below should be prepared by the Surveyor at the time of recording data. No re-production of location diagram should be attended at the office.

GNSS OBSERVATION RECORD FORM
Control Point Establishment Using Network RTK of SLCORSnet

District : DS Area : Village / GN Division :

Point No. :

Location Diagram

Network RTK Method

1. VRS ☐ 2. VRS - BDS ☐

Network RTK Solution:

N –
E –
h –

Note: Network RTK Solution should be fixed for recording

Surveyor Signature: ……………………… Surveyor Name: …………………………….

Date: …………………………………

Procedure for capturing Detail Survey points using Network RTK Solution of SLCORSnet

2.61 Below steps should be followed to capture the detail survey points and survey points with the proper prospection diagram of the proposed survey area.

Detail surveys using Network RTK Solution

- Select Network RTK and VRS correction method. (VRS or VRS_BDS)
- Select Precise Solution at the configuration and set precision HRMS=0.050 & VRMS=0.100
- Select the average observation as 5
- The receiver must be clamped vertically over the station by using level bubble
- Wait till the correction shows the fixed status to record the details

2.62 There are three types of data storage.

- Auto
- Float
- Fixed

- Auto and Float are not accurate and these are not allowed to use. Always check the correction type before recording the data.

2.63 It is obvious that all the detail points cannot be observed using the GNSS receivers due to the ground conditions like sky visibility (15^0cut of angle above horizon). In case of non-availability of satellite coverage at the boundary points, two or three points to be established visible to each boundary point. Hence EDMs happened to be utilized to pick up those details with self-established control points (NRTK Control points) by using the SLCORSnet and GNSS receiver in RTK mode. These control points should also be established in such a way that easy access to the location and suitability to set up any type of survey equipment in future work.

2.64 There are many methods can be adopted to pick up details according to the following cases.

I. Use the chain and tape, if detail points are within 10 m from the line joining NRTK control points and book as usual in the field book.

II. Use radiation method using Total station & NRTK control points and book as usual in the field book.

III. Use resection method using Total station & NRTK control points and book as usual in the field book.

IV. Use the Total station normally using the self - established NRTK control points and book as usual in the field book.

Detail Operating Instructions for the use of available GNSS receivers

2.65 One of the basic concepts of the establishment of the SLCORS network is to expedite the detail level data capturing using the GNSS receivers, compatible to work with the SLCORS network. This illustrates the operating instructions for the use of CHC i80 & Topcon GR-5 Receivers.

Note: Before leaving the office, observe the point by connecting with network RTK with a known point. For this purpose few control points can be established in your office premises.

See the following guidelines for the usage of Topcon GR-5 and CHC i80 receivers.
Users / Surveyors are expected to maintain the accuracies for network control points and detail (Topo) points with the following settings.

2.66 Specifications for Topcon GR5 receiver

Specification	Control Points	Detail (Topo) Points
Measure Continuous Average	25	5
Precision: HRMS	0.015	0.050
Precision: VRMS	0.030	0.100
Solution	Fixed Only	Fixed Only

2.67 Specifications for CHC i80 receiver

For Control Points

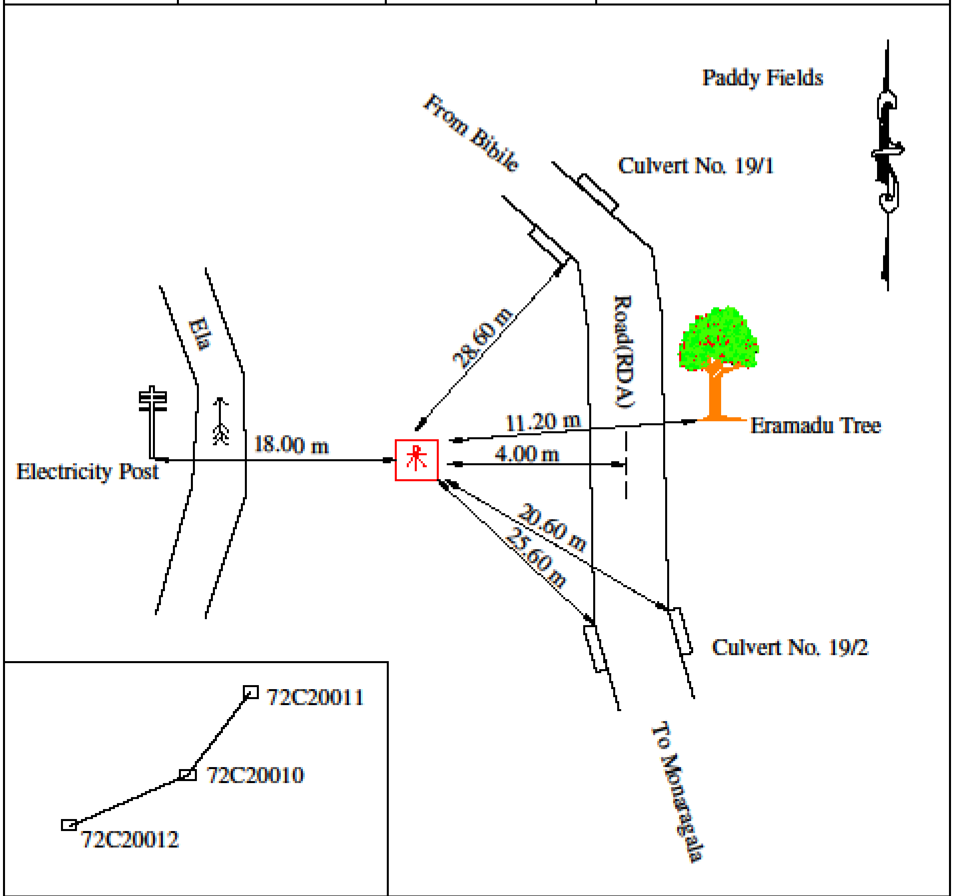
Observation times	25
Horizontal precision	0.015
Vertical precision	0.030
Horizontal Tolerance	0.10 m
Vertical Tolerance	0.20 m
Diff delay limitation	5
Repeated Time	1
Measured Intervals	60
Fixed Delay Limitation	5
Qualification Rate (%)	80

ForDetail (Topo) Points

Observation times	5
Horizontal precision	0.050
Vertical precision	0.100
Offset Tolerance	0.100 m
Tilt Tolerance	0.020 m
Increment	1
Track File	Track.csv
Offset warning	✓
Auto Centre	✓
Fixed solution	✓

D.S.R. 2.18 **Annexure I**

DESCRIPTION OF GNSS CONTROL POINT			Client Point ID: MO 004 Geodetic Point ID: 72C20010
PROVINCE	Uva	DISTRICT	Monaragala
D.S.DIVISION	Medagama	STATION	Bakiniella
PREPARED BY:		CHECKED BY:	
NAME	U.D.P. Pathirana	NAME	P. L. Y. Seneviratne
DESIGNATION	Govt. Surveyor	DESIGNATION	Supdt. of Surveys
DATE	2014.01.10	DATE	2014.01



Remarks: The Point is situated in between 19/1 and 19/2 culverts along Bibila- Monaragala road. Bakiniella village, Medagama.

MONUMENT TYPE: A6							GEODETIC ID: 72C20010		
WGS 84 COORDINATES							NATIONAL GRID COORDINATES		
LATITUDE			LONGITUDE			ELLIPSOIDAL HEIGHT (m)	NORTHING (m)	EASTING (m)	EVEREST HEIGHT(m)
°	'	"	°	'	"				
7	00	30.11598	81	16	54.58569	161.001	500866.282	556136.524	

REQUISITION NO:	MISSION	PROJECT
ISM / 2014 / MG / 01	Tertiary GNSS	Monaragala District Dencification

D.S.R. 2.19 **Annexure II**

Annexure II

GNSS OBSERVATION RECORD SHEET

Geodetic Survey Unit

Location Diagram

From Point	EDM DISTANCE To Point	Distance (m)	Grid Distance (m)	Difference (m)
1.	....	....	....	....
2.	....	....	....	....
3.	....	....	....	....

MISSION: *TGPS / SGPS / TITLE / GCP / MISC/..........* *Reqn. No.:.......................................*

PROJECT:................................. **JOB** *(STATION NAME)*:.........................

OBSERVATION TYPE: *STATIC / KINEMATIC / REALTIME*

RECEIVER TYPE: *SYS.500 / SYS.1200*

SERIAL NO:............................ **PICKET NO:**.....................

DESCRIPTION OF POINT :...

SKY VISIBILITY: *GOOD / FAIR / POOR*

SATS.AVAILABLE			GDOP	PDOP	BAT.LEVEL		FREE MEMORY
L1	*L2*	*TOTAL*			A	B	
							MB
							MB

OBSERVER : .... **RECORDER/OTHERS :** ....

OBSERVATION : *START :* .... *END :* ....

HEIGHT READING (m) : 1........... 2............. *MEAN:*.............

REFERENCE ELLIPSOID : *WGS84 / EVEREST*

APPROXIMATE:	*D*	*M*	*S*
Latitude			
Longitude			
Height (m)			

REMARKS : ....

PHOTO No:...................... **DATE : 20**..........................

PREPARED BY : .... **CHECKED BY :** ....

Page 1 of 2

D.S.R. 2.19 Annexure II

Annexure II

GPS OBSERVATION RECORD FORM

Geodetic Survey Unit

- **SATELLITE AVAILABILITY , GEOMETRY AND BATTERY LEVEL**

TIME	SATELLITE	GDOP	BAT. LEVEL	REMARKS

- **EQUIPMENT CHECK LIST AND FIELD PROCEDURES**

ACTIVITY	*DESCRIPTION*	*DONE*	*REMARKS*
Departure to site	Batteries		Fully charged. Back-up available
	Tripod		
	Try Brach		
	Try Brach Adaptor		
	Tape Measure		
	Pen/Pencil		
	Compass		For orienting sensors
	Observation schedule		Allow enough time to at 1st site early
	Routes, site access verified		Dead measurement sketches
	Station sheet		
	Station description		
	Network Map		If required
	Flashlight		If necessary
	Equipment manuals		If necessary
	GPS receiver		Make sure there is enough memory
	GPS battery cable		If external battery used.
	Vehicle gassed up		
On site	Set up Equipment		
	Measure Ht. and record		
	Measure antenna offset and record		
	Start survey		Verify settings
	Receiver normal		Does it behave as expected? If any malfunction on port error and error message time.
	Expected satellites tracked		
	Cycle slips only where expected		E.g. Satellite(s) behind building
	Battery strength OK?		
	Field sheet filled?		
End of session	Plan move to next site		
	Measure Height and record		
	Verify antenna offset		
	Stop session, take down equipment		
	Is battery good for next session		If not start next session with backup
	Field sheet turned in		
Return at end	Field sheet return		
	Equipment cleaned and stored		
	De-briefing		Anything peculiar has happened
	Batteries on charge		
	Vehicle gassed up		

Page 2 of 2

D.S.R. 2.20 **Annexure III**

Annexure III

Client Point Id	SD Point Id	Reqn. No.	WGS-84 Coordinates			Everest Coordinates			Grid Coordinates			Hz Quality [B,C,RTK etc]	MSL Height Quality [PL,SL..]	Remarks
			Lat [d,m,s]	Lon [d,m,s]	Ellipsoidal Ht (m)	Lat [d,m,s]	Lon [d,m,s]	Ellipsoidal Ht (m)	N (m)	E (m)	MSL Ht (m)			

Surveyed & Computation by :

Name	Designation	Signature

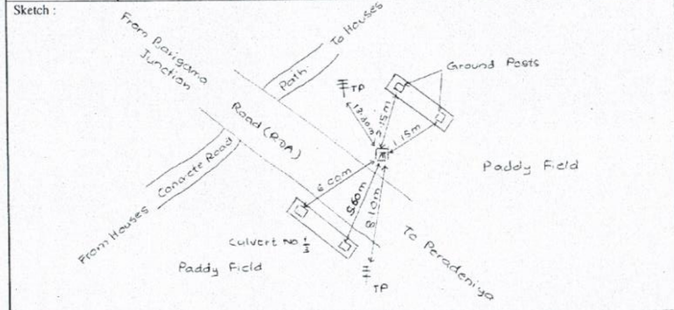
Certified by :

S. Kodikara
Senior Supdt. Of Surveys
Provincial Geodetic Unit
Southern Province
2014-05-

D.S.R. 2.26 [**Annexure IV**]

Traverse No. :	E1-32-0012				
Station Occupied :	E1-32-0012-01				
Description :	A6 Monument				
Observed :	J.M.K.R. Jayasekara				
Recorder :	J.M.K.R. Jayasekara				
Instrument Used :	SOKKIA CX 102 (S. No. BC0366)				
Ht. of Instrument :	1.40 m	St. Elevation :			
Temperature	24 °C	Pressure of M. S. L. Ht.	882	Atmospheric Dial Setting	44

Sketch :



Remarks : Located at App. 350m from Barigama Junction towards Peradeniya.

Signature and Name :	J.M.K.R. Jayasekara	Date : 2014/03/17	
		N.	E.
Adjusted Co-ordinates :		535898.512	478754.419

Station Observed	32C20042			E132001202			32C20042			E132001202		
Ht. of Target :	1.58 m			1.60 m			1.58 m			1.60 m		
VERTICAL ANGLES AND DISTANCES												
Face Left :	91°	52'	35"	85°	19'	24"	91°	52'	29"	85°	19'	27"
Face Right :	268	07	59	274	41	03	268	07	55	274	41	04
Sum :												
Angle :	-01	52	18	04	40	49.5	-01	52	17	04	40	48.5
Slope Distance : 1	91.025			140.901			91.026			140.902		
2	91.026			140.901			91.027			140.901		
Mean Slope Distance :	91.026			140.901			91.027			140.902		
Horiz. Distance :												
Elevation :												
HORIZONTAL ANGLES												
Face Left :	00°	00'	00"	157°	50'	16"	30°	00'	30"	187°	50'	58"
Face Right :	179	59	40	337	50	11	210	00	22	07	50	48
Mean :	359	59	50	157	50	13.5	30	00	26	187	50	53
Angle :				157	50	23.5				157	50	27
Face Right:												
Face Left :												
Mean :												
Angle :												
Face Left :												
Face Right :												
Mean :												
Angle :												
Face Right :												
Face Left :												
Mean :												
Angle :												
Mean Angle :												

D.S.R. 2.34 **Annexure V**

Job: ISM/2014 /KN/33	Traverse No: EI-32-0012	FB No: : GEO 0104	Prepared by : J·M·K·R· Jayasekara	Page 9 of 10 Pages

Instrument Station: E132001201 Instrument Height = 1·40 m FB Page No: 2-6

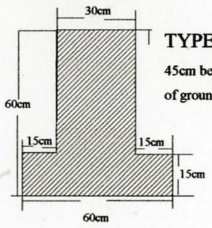
Zero Position	REF Station	REF T.H.	VA to Ref. d m s	Dist to Ref. mean FL/FR	Target Stn 1	Stn 1 T.H.	VA to Stn 1 d m s	Dist. to Stn 1 mean FL/FR	HA to Stn 1 from Ref. d m s	Target Stn 2	Stn 2 T.H.	VA to Stn 2 d m s	Dist. to Stn 2 mean FL/FR	HA to Stn 2 from Ref. d m s
		m		m		m		m						
00° 00′	32020042	1·58	$\bar{0}$1 52 18·0	91·026	E132001202	1·60	04 40 49·5	140·901	157 50 23·5					
45° 00′	”	”	$\bar{0}$1 52 17·0	91·027	”	”	04 40 48·5	140·902	157 50 27·0					
90° 00′	”	”	$\bar{0}$1 52 18·5	91·027	”	”	04 40 49·0	140·903	157 50 14·5					
135° 00′	”	”	$\bar{0}$1 52 17·5	91·028	”	”	04 40 50·0	140·902	157 50 26·0					
MEAN			$\bar{0}$1 52 17·75	91·027			04 40 49·25	140·902	157 50 22·75					
Std. Div.														

Instrument Station: Instrument Height = m FB Page No:

Zero Position	REF Station	REF T.H.	VA to Ref. d m s	Dist to Ref. mean FL/FR	Target Stn 1	Stn 1 T.H.	VA to Stn 1 d m s	Dist. To Stn 1 mean FL/FR	HA to Stn 1 from Ref. d m s	Target Stn 2	Stn 2 T.H.	VA to Stn 2 d m s	Dist. To Stn 2 mean FL/FR	HA to Stn 2 from Ref. d m s
MEAN														
Std. Div.														

D.S.R. 2.45 **Annexure VI**

TYPES OF SURVEY DEPARTMENT BENCHMARKS

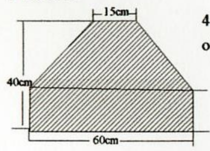


TYPE A

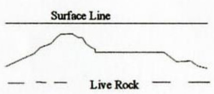
45cm below surface of ground

Bronze bolt set in concrete block embedded in the earth to a depth generally 45cm , impressed as for Type C. Dimension and shape of block varriable but volume more than 45 cm cube.

TYPE A ^

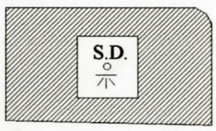


45cm below surface of ground



TYPE B

Bronze bolt set in cement in face of dressed rock below ground surface . Dressed surface 15cm square , impressed as for Type C.

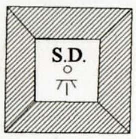


TYPE C

Bronze bolt set in cement, In rock concrete or masonary above ground surface . impressed with S.D. and Benchmark Sign.

TYPE D(OBSOLETE)

See Plate III of report on the Geodetic Levelling

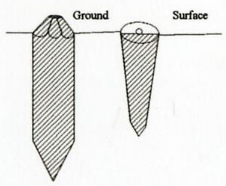


TYPE E

Bronze bolt set in rectangulations block(large). Surface of block 8cm above ground surface.

TYPE F

Bronze bolt set in rectangulations block(small). Dressed surface same as Type E.



TYPE G(TEMPORARY)

Wooden stake 8cm diameter 30cm long or Cement Picket 8cm diameter 20cm long.

TYPE H

Conerete block top 8cm square , base 10cm square, side 20cm crowsfoot impressed on top: centre mark: 2cm diameter without bolt. Buried flush with ground

36

D.S.R. 2.50 **Annexure VII**

Annexure VII

Raw data of Geodetic Leveling

P.L No. .... Fore Levelling from B M No. .... to B M No. ....

Pt. No.	Staff Readings		Re. Level	Distance		Remarks
	BS	FS		BS	FS	
0	1.30215		0.00000	20.526		BM1
1	0.04880	2.99458	-1.69243	12.188	20.472	TP
2	0.45838	2.54939	-4.19302	14.942	11.926	TP
3	0.61600	2.20561	-5.94025	14.958	14.854	TP
4	0.14893	2.55015	-7.87440	14.937	15.061	TP
5	0.20297	2.67234	-10.39781	13.077	14.935	TP
6	0.17229	2.63815	-12.83299	19.763	12.872	TP
7	0.21460	2.97552	-15.63622	19.993	19.510	TP
8	0.40782	2.69809	-18.11971	19.896	19.854	TP
9	0.05798	2.63592	-20.34781	24.926	19.964	TP
10	0.06857	2.75626	-23.04609	21.975	24.815	TP
11	0.90832	2.25248	-25.23000	26.808	21.893	TP
12	0.85436	2.04324	-26.36492	24.949	26.364	TP
13	0.66622	2.06810	-27.57866	51.467	24.872	TP
14		1.69857	-28.61101		51.465	BM2
		Total Distance		300.405	298.857	

No. of Stations - ....
Distance Leveled - ....
Traveled - ....
Weather - ....
Date - ....
Time - ....

....
Signature

D.S.R. 2.50 **Annexure VIII**

ABSTRACT SHEET FOR PRECISE LEVELING

P. L. No:- GPL-4 (2012)

From Kandy FBM to Dambulla FBM

Loops No.	Line No	Levelling Book No.	Levelling Book Page	No. of Instrument Stations	Direction	Difference of Height (m) +	Difference of Height (m) -	Mean Difference of Height with Sign of Forward Levelling +	Mean Difference of Height with Sign of Forward Levelling -	Distance (m)	Discrepancies (mm) Allowable	Discrepancies (mm) Actual	Discrepancies (m) (Forword - Backward)	Cum. Of Discrepacies (m)	Total Distance (Km)	Remarks	Height
																FBM Kandy	557.19912
1	FBM-BM1	PL. 30	1	8	Forward		17.36559	-	17.365825	340	1.60934	-0.47	-0.00047	-0.00047	0.34		539.83330
	BM1-FBM	PL. 30	2	10	Backward	17.36606											
2	BM1-BM2	PL. 30	3	14	Forward		28.61101	-	28.611655	600	2.13789	-1.29	-0.00129	-0.00176	0.94		511.22164
	BM2-BM1	PL. 30	4	14	Backward	28.61230											
3	BM2-BM3	PL. 30	5	16	Forward		0.72019	-	0.720675	800	2.46862	-0.97	-0.00097	-0.00273	1.74		510.50097
	BM3-BM2	PL. 30	6	16	Backward	0.72116											
4	BM3-BM4	PL. 30	7	34	Forward		34.06674	-	34.067500	1620	3.51291	-1.52	-0.00152	-0.00425	3.36		476.43347
	BM4-BM3	PL. 30	9	34	Backward	34.06826											
5	BM4-BM5	PL. 30	11	18	Forward		22.33158	-	22.332080	1200	3.02343	-1.00	-0.00100	-0.00525	4.56		454.10139
	BM5-BM4	PL. 30	12	18	Backward	22.33258											
6	BM5-BM6	PL. 30	13	20	Forward		6.68559	-	6.686505	1060	2.84159	-1.83	-0.00183	-0.00708	5.62		447.41488
	BM6-BM5	PL. 30	14	20	Backward	6.68742											
7	BM6-BM7	PL. 30	15	16	Forward		3.89742	-	3.897760	1250	3.08577	-0.68	-0.00068	-0.00776	6.87		443.51712
	BM7-BM6	PL. 30	16	16	Backward	3.89810											
99	BM98-BM99	PL. 42	10	8	Forward	1.33618		1.335730	-	640	2.20800	0.90	0.00090	-0.00785	67.54		182.458200
	BM99-BM98	PL. 42	11	8	Backward		1.33528										
100	BM99-BM100	PL. 42	12	10	Forward	9.15053		9.150100	-	480	1.91218	0.86	0.00086	-0.00699	68.02		191.608300
	BM100-BM99	PL. 42	13	10	Backward		9.14967										
101	BM100-BM101	PL. 42	14	8	Forward		6.51541	-	6.515450	540	2.02818	-0.08	-0.00008	-0.00707	68.56		185.092850
	BM101-BM100	PL. 42	15	8	Backward	6.51549											
102	BM101-BM102	PL. 42	16	8	Forward	1.82659		1.826390	-	630	2.19068	0.40	0.00040	-0.00667	69.19		186.919240
	BM102-BM101	PL. 42	16	8	Backward		1.82619										
103	BM102-BM103	PL. 43	1	6	Forward		3.21853	-	3.218690	360	1.65600	-0.32	-0.00032	-0.00699	69.55		183.700550
	BM103-BM102	PL. 43	1	6	Backward	3.21885											
104	BM103-BM104	PL. 43	2	8	Forward		0.14489	-	0.145030	460	1.87192	-0.28	-0.00028	-0.00727	70.01		183.555520
	BM104-BM103	PL. 43	2	8	Backward	0.14517											
105	BM104-BM105	PL. 43	3	10	Forward		1.30603	-	1.306435	530	2.00931	-0.81	-0.00081	-0.00808	70.54		182.249085
	BM105-BM104	PL. 43	3	10	Backward	1.30684											
106	BM105-BM106	PL. 43	4	8	Forward		5.38823	-	5.388505	500	1.95161	-0.55	-0.00055	-0.00863	71.04		176.860580
	BM106-BM105	PL. 43	4	8	Backward	5.38878											
107	BM106-BM107	PL. 43	5	8	Forward		6.72912	-	6.729320	540	2.02818	-0.40	-0.00040	-0.00903	71.58		170.131260
	BM107-BM106	PL. 43	5	8	Backward	6.72952											
108	BM107-BM108	PL. 43	6	12	Forward	3.62357		3.623125	-	1000	2.76000	0.89	0.00089	-0.00814	72.58		173.754385
	BM108-BM107	PL. 43	7	12	Backward		3.62268										
109	BM108-FBM	PL. 43	8	16	Forward		9.53266	-	9.533460	1120	2.92091	-1.60	-0.00160	-0.00974	73.70	FBM Dambulla	164.220925
	FBM-BM108	PL. 43	9	16	Backward	9.53426											
				2546				345.073530	738.051725	73,190	23.61212	-9.74	-0.00974				164.2171
								MSL Height =	-392.978195								0.003825

Prepared by : ....

Name :
Designation :
Date :

Checked by : ....

Name :
Designation :
Date :

Certified by : ....

Name :
Designation :
Date :

D.S.R. 2.50

Annexure IX

ANNNEXURE X

ADJUSTMENT SHEET FOR PRECISE LEVELING

P.L No: GPL- 4 (2012)

From Kandy FBM to Dambulla FBM

Date:- 24/01/2013

B.M	Mean Height Difference (m)	Distance (m)	Obtain Height Before Adjutment(m)	*Correction(m)	Adjusted BM Height (m)	BM ID
Kandy FBM			557.199120	0.000000	557.199120	FBM Kandy LB
FBM-BM1	-17.365825	340	539.833295	-0.000035	539.833260	PL-004-001
BM1-BM2	-28.611655	600	511.221640	-0.000070	511.221570	PL-004-002
BM2-BM3	-0.720675	800	510.500965	-0.000105	510.500860	PL-004-003
BM3-BM4	-34.067500	1620	476.433465	-0.000140	476.433325	PL-004-004
BM4-BM5	-22.332080	1200	454.101385	-0.000175	454.101210	PL-004-005
BM5-BM6	-6.686505	1060	447.414880	-0.000211	447.414669	PL-004-006
BM6-BM7	-3.897760	1250	443.517120	-0.000246	443.516874	PL-004-007
BM7-BM8	2.181800	970	445.698920	-0.000281	445.698639	PL-004-008
BM8-BM9	0.095340	900	445.794260	-0.000316	445.793944	PL-004-009
BM9-BM10	2.380250	1350	448.174510	-0.000351	448.174159	PL-004-010
BM10-BM11	3.151150	1100	451.325660	-0.000386	451.325274	PL-004-011
BM11-BM12	4.797185	1180	456.122845	-0.000421	456.122424	PL-004-012
BM12-BM13	25.170565	770	481.293410	-0.000456	481.292954	PL-004-013
----	----	----	----	----	----	----
----	----	----	----	----	----	----
BM97-BM98	-6.771490	350	181.122470	-0.003439	181.119031	PL-004-098
BM98-BM99	1.335730	640	182.458200	-0.003474	182.454726	PL-004-099
BM99-BM100	9.150100	480	191.608300	-0.003509	191.604791	PL-004-100
BM100-BM101	-6.515450	540	185.092850	-0.003544	185.089306	PL-004-101
BM101-BM102	1.826390	630	186.919240	-0.003579	186.915661	PL-004-102
BM102-BM103	-3.218690	360	183.700550	-0.003614	183.696936	PL-004-103
BM103-BM104	-0.145030	460	183.555520	-0.003650	183.551870	PL-004-104
BM104-BM105	-1.306435	530	182.249085	-0.003685	182.245400	PL-004-105
BM105-BM106	-5.388505	500	176.860580	-0.003720	176.856860	PL-004-106
BM106-BM107	-6.729320	540	170.131260	-0.003755	170.127505	PL-004-107
BM107-BM108	3.623125	1000	173.754385	-0.003790	173.750595	PL-004-108
BM108-FBM	-9.533460	1120	164.220925	-0.003825	164.217100	FBM Dambulla LB
		73,700				

$$\text{*Correction} = \frac{\text{(Actual value-Obtained value)}}{\text{No. of Stations}} \text{ X Station No.}$$

FBM Kandy= 557.199120 m
Obtained error = -0.003825 m
Allowable error = 0.023694 m

Prepared by: .... Checked By: .... Certified by: ....

Name:
Designation:
Date:

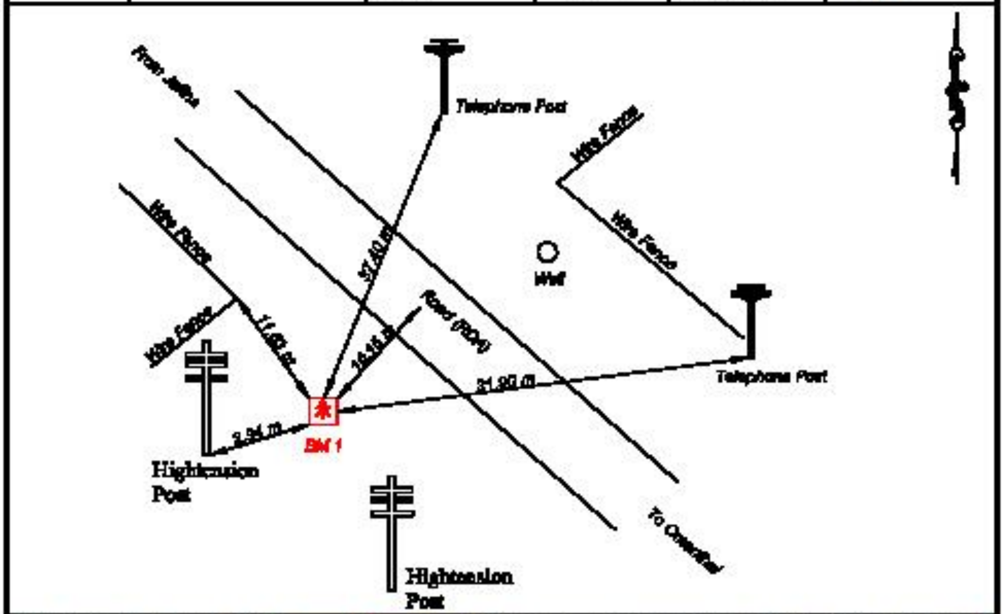
Name:
Designation:
Date:

Name:
Designation:
Date:

D.S.R. 2.50 **Annexure X**

DESCRIPTION OF BENCH MARK

Preliminary Level Line	PL-075	B. M. NO	PL-075-001	TYPE	"A"
	Mankulam - Vavuniya	Height in meters	54.52584	Approximate Location (SLD 95)	
		Depth	13 cm	Northing (m)	733612
Duration	Nov to Dec 2011	Datum	M. S. L.	Easting (m)	464910



Remarks	Located in between 220 and 221 Km Posts. ● PL-075-001
Levelled by	D.M.U.S.J. Dissanayake (App. Surveyor) & G.K.S.K. Warnasuriya (App. Surveyor)
Checked by	P. L. Y. Seneviratne (Supdt. Of Surveys - Geodetic Survey Unit)