MINISTRY OF CONSTRUCTION ---------	SOCIALIST REPUBLIC OF VIETNAM Independence – Freedom – Happiness
No.: 04/2006/QĐ-BXD	*Hanoi, 28th February 2006*

DECISION

On promulgating TCXDVN 364 : 2006 " *The technical specification for Engineering survey - GPS monitoring and processing* "

MINISTER OF CONSTRUCTION

- Based on the Governmental Resolution No. 36 / 2003 / NĐ-CP dated 4 / 4 / 2003 regulating the functions, obligations, rights and organization of Ministry of Construction;

- With consideration of the request from the Director of Department of Science and Technology,

DECIDES

Article 1. TCXDVN 364: 2006 "The technical specification for Engineering survey – GPS monitoring and processing" is promulgated attached to this Decision.

Article 2. This Decision shall come into effect after 15 days from the date of publication.

Article 3. Office Manager of the Ministry, Director of Department of Science and Technology and Heads of relevant agencies are responsible for executing this Decision ./.

P.P THE MINISTER
VICE MINISTER

Signed

Nguyễn Văn Liên

Cc:
- As mentioned in Article 3
- Government Office
- Publication
- Ministry of Judiciary
- Dept. of legislation
- Files

TCXDVN 364: 2006

THE TECHNICAL SPECIFICATION FOR ENGINEERING SURVEY – GPS MONITORING AND PROCESSING

HANOI -2006

Foreword

TCXDVN 364 : 2006 "The technical specification for engineering survey – GPS monitoring and processing" promulgated attached to the Decision No. 04/2006/QĐ-BXD dated 28/2/2006.

The technical specification for Engineering survey - GPS monitoring and processing

1. Field of application

This technical specification is for GPS monitoring and processing when establishing survey network and ground control network to serve for construction and horizontal displacement of the project.

2. Definition and interpretation of technical terms

- Observation session – Duration of receiving signals continuously at the observation station from the time of switching on until the time of switching off;
- (Simultaneous observation) – Observation values of 2 receivers or more receiving signals from the same satellite;
- Simultaneous observation loop – Observation loop of the vectors formed by 3 same session receivers;
- Independent observation loop – Observation loop of baselines;
- Antenna height – The height from the average center of receiving antenna phase to the benchmark center.
- Ephemeris – The coordinate value in the orbit of satellite at different times. Ephemeris is transmitted in two types: Broadcast Ephemeris and Precise Ephemeris;
- Broadcast Ephemeris – Radio signals transmitted by satellite contain data of orbit parameters forecast of satellite at certain time;
- Precise Ephemeris - Satellite orbit parameters observed and defined through general processing by some stations are used for positioning satellite accurately;
- Single baseline- Baseline calculated from a pair of receiving antenna at any two points of the same observation session.
- Multiple baseline - m-**1** baseline solved from m-**1** equation when observing simultaneously with m receivers;
- Single differential – Difference of phase values to the same satellite of two GPS stations with the same observation session.
- Double differential – Difference of two single differentials of two satellites from GPS stations with the same observation session;
- Triple differential - Difference of two double differentials of two stations to one pair of satellite at two different times;
- Percentage of data rejection – Percentage between the rejected data and the required data.

3. General regulations

3.1 GPS monitoring in engineering survey should be executed in accordance with an approved technical proposal in order to define accurately coordinates of GPS points for establishment of geodetic network for a short time and with high economic effectiveness;

3.2 GPS monitoring in engieering survey shall be executed in orders as follows:

- Collecting original data and documents;
- Selecting time and coordinate system;
- Preparing technical proposal and submitting it for approval;
- Selecting points and installing benchmarks;
- Selecting equipment
- Monitoring;
- Recording data at the site;
- Data processing;
- Reporting.

3.3 Levels and methods of GPS measurement specified in the technical proposal are selected based on the required accuracy to define the quantity of arrangement, quantity of displacement and features of each project item.

3.4 When using GPS technology in combination with total station in establishment of control network for construction and observation of project displacement and deformation, reference should be made to the Technical Specification for "Engineering survey in construction of houses and projects – General requirements".

4. Coordinates and Time system

4.1 Coordinates system

4.1.1 GPS is monitored using global coordinates system WGS – 84 (Worldwide geodetic system). When it is required to use HN-72 coordinates system or other coordinates system, calculation shall be made for coordinates transformation. Basic geometric parameters of global Elipxoid and reference Elipxoid of the coordinates systems shall be in accordance with Table 1. VN-2000 coordinates system has basic geometric parameters of Elipxoid completely the same as Worldwide Geodetic system WGS – 84.

4.1.2 When GPS is monitored with the requirements of using local coordinates system or independent coordinates system, calculation shall be made for transformation of coordinates and the following technical parameters are required:

- Geometric parameters of reference Elipxoid;
- Longitude of central meridian;
- Constant added to ordinate, abscissa;
- Normal elevation of projecting surface;
- Coordinate of initial point and azimuth;

4.1.3 When calculating for transforming Worldwide geodetic system of GPS network to regional coordinate system, the following requirements shall be satisfied: Adjustment of GPS network in Gauss flat right-angle coordinate system (Ko = 1), with axial longitude Lo not over 20 Km from the survey area. If projection UTP 6 degrees (Ko = 0.9996) is used, the axial longitude is within 160Km – 200 Km away from the survey area. If projection UTP 3 degrees (Ko = 0.9999) is used, the axial longitude is within 70Km – 110 Km away from the survey area. When Gauss projection is selected, Ellipxoid Krasovxky shall be used, and when UTM projection is used, Ellipxoid WGS – 84 shall be used.

Table 1 – Basic geometric parameters

	Global Elipxoid	Reference Elipxoid
Coordinate system / **Parameters**	**WGS - 84**	**HN-72**
Major semi-axis a(m)	6378137	6378245
Minor semi-axis b (m)	6356752.3142	6356863.019
Oblateness α	1/298.257223563	1/298.3
First square eccentricity e^2	0.00669437999013	0.0066934216
Second square eccentricity e'^2	0.00673949674222 7	0.0067385254

4.1.4 When calculating for transforming GPS elevation to normal elevation, national elevation system with national elevation benchmark shall be used.

4.1.5 Time in GPS monitoring is Universal time coordinated UTC. If Vietnamese time is wanted, transformation shall be executed (Hanoi time = GPS time + 7).

5. Technical design of GPS network

5.1. Classification of GPS network

5.1.1 Based on the average distance between two adjacent points and its accuracy, GPS networks are classified to be class II, III, IV and grades 1. When establishing GPS network, it is possible to execute in orders including all grades, classes or over network or tie network.

5.1.2 Accuracy of the distance between two adjacent points of all grades of GPS network is calculated according to the formula

$$\sigma = \sqrt{a^2 + (b.10^{-6}.D)^2} \qquad (5.1)$$

Accuracy of azimuth of distance is calculated according to the formula:

$$m_\alpha = \sqrt{p''^2 + \frac{q''^2}{D^2}} \quad (5.2)$$

Where:

a - Fixed error (mm);

b - Proportional error coefficient

D - Measured distance (km)

With receiver 4600 LS : a=5mm; b=1; p" =1; q"=5.

Or

$$m_\alpha = \frac{m_D}{D}\rho'' \quad (5.3)$$

5.1.3 Main technical specification of all grades of GPS network shall be in accordance with Table 2. The shortest distance between two adjacent points is 1/2 to 1/3 of the average distance; the longest distance is 2 ÷3 times the average distance. When the distance is less than 200m, the RMS error of distance shall be less than 20mm.

Table 2- Main technical specification of GPS network established for mapping

Class/Grade	Average distance (km)	a (mm)	b (1 x 10⁻⁶)	Relative error of the shortest distance
II	9	≤ 10	≤ 2	1/120 000
III	5	≤ 10	≤ 5	1/80 000
IV	2	≤ 10	≤ 10	1/45 000
1	1	≤ 10	≤ 10	1/20 000
2	< 1	≤ 15	≤ 20	1/10 000

5.1.4 For the GPS network established for control of construction and observation of displacement and deformation of the project, it is required to be based on the accuracy requirements of each project so that the network design shall satisfy the requirements.

5.2 Principles of network establishment and design

5.2.1 Prior to design of GPS network, it is required to collect the following data:

- Available biggest maps of the construction site;
- Documents of ground and levelling control network available in the survey area, including summary report of network establishment;
- Documents of soil investigation, hydro-geotechnical, transport, waterways system and other documents relevant to the development plan of the survey area.

5.2.2 The design of GPS network shall be based on the actual requirements and based on the detailed investigation and study of available original documents and data of the construction site. In GPS network, it is not necessary for the points to be seen from each other, however, in order to make dense the network by traditional measurement method, each GPS point shall be seen at least from another point.

5.2.3 In the network design, to make best use of available geodetic data and maps, it is recommended to use the available coordinates system of the survey. For the available control points, if meeting with the requirements of GPS network, their benchmarks shall be made best use of.

5.2.4 GPS network shall be formed with one or more independent observation loops and traverse lines. The total of distances in an independent observation loop, traverse lines in all grades of GPS network shall follow the regulations specified in Table 3.

Table 3- Regulations of total of distances in independent observation loop or traverse lines for grades/ classes of GPS network

Classes/ Grades	II	III	IV	1	2
Total of distances in independent observation loop or traverse lines	≤ 6	≤ 8	≤ 10	≤ 10	≤ 10

GPS network used for ground control for construction and observation of displacement shall form observation loop with maximum 4 sides.

5.2.5 In order to calculate the coordinates of GPS points in horizontal coordinates system, it is required to have initial data in horizontal coordinates system and to connect to some local control points. For big projects, the points of connection should be over 3, for small projects, the points of connection shall be 2 or 3 points.

5.2.6 In order to calculate the normal elevation of GPS points, it is required to connect elevations to GPS points according to the regulations as follows:

- In order to connect elevations, it is required to apply geometric levelling method with accuracy from class IV or more or other method of levelling with equivalent accuracy shall be applied.
- The normal elevations of GPS points, after calculating and analysing, if meeting with the requirements in accuracy, may be used for mapping and for general geodetic forms (not high accuracy is required).

5.2.7 For construction control network required high accuracy and observation network of displacement and deformation, it is required to estimate the accuracy of the factors to be considered of GPS network designed according to close method based on indirect adjustment and the required accuracy shall be satisfied.

6. Selecting GPS points and installing GPS benchmarks

6.1 Selecting GPS points

6.1.1 The person selecting points must have a good understanding of the requirements, purposes, natural and social conditions of the survey area, base on the approved technical design to execute survey and select GPS points at the site.

6.1.2 The location of selected GPS points must satisfy the following requirements:

- The location of the selected points must be in accordance with the technical design, convenient for the connection and for the next survey works.
- The selected points shall be at the location with stable soil/ rock foundation, used for a long time and ensured safety in measurement.
- The location of selected points shall be convenient for installation of receiver and operations, spacious and the mask angle of the satellite must be cut off 15^0;
- The location of selected points shall be convenient for receiving satellite signals, avoiding signal disturbance because they are too close to broadcasting stations and multipath errors because of reflection of signals from the objects surrounding the survey points. The location of selected points shall be over 200m far from the high – capacity radio wave tramission stations (such as television tower, microwave station…) and over 50m far from high voltage cables.
- Convenient for monitoring.
- Existing ground control benchmarks should be made use of if they meet with the above requirements;

6.1.3 The points selection shall obey the following regulations:

- Drawing diagram of control points at the site (including the points with existing benchmarks) according to the format specified in Appendix A;
- GPS points may be named after village names, mountain names, place names, company names, project names. When the existing points are made use of, their names shall not be changed. The names of points should be specified in such a way that they are convenient for the computer;
- When levelling connection is required at the selected point, the person selecting the point shall survey the levelling at the site and provide proposals.
- When the existing points are made use of, it is required to check the stability, perfectibility, safety and appropriateness with the specifications of GPS points;

6.2 Installing benchmarks

6.2.1 Specification of benchmarks and GPS points of all grades shall be in accordance with the national current standard.

6.2.2 Permanent benchmarks are installed for GPS points of all grades. When installing the benchmark, the borehole bottom shall be filled with brick, gravels or placed with one bliding concrete layer.

6.2.3 The benchmarks may be precast RC benchmarks with the specifications according to the national current standard, or cast-in-situ benchmarks, or it is possible to make use of stone base or concrete base with markers at the site.

6.2.4 The land area used for installing GPS points shall be accepted by relevant authorities, the land owners should settle procedures for transferring of land use right and procedures for authorizing to preserve the benchmarks.

6.2.5 The documents to be handed over after selecting points for installing benchmarks

- Diagram of GPS points.
- Diagram of GPS network.
- Documents of land use right and certificate of benchmark preservation.
- Summary of points selection and benchmarks installation

7. Technical specifications of equipment

7.1 Selecting receivers: The selection of GPS receivers shall be executed according to Table 4; The receivers may be single or dual frequency; the measurements are wave phase

Table 4- Selection of GPS receivers

Item \ Grade/ Class	II	III	IV	1	2
Typical accuracy	≤ 5mm +2.10^{-6}D	≤ 5mm +2.10^{-6}D	≤ 5mm +2.10^{-6}D	≤ 5mm +2.10^{-6}D	≤ 10mm +2.10^{-6}D
Number of simultaneous receivers	≥ 3	≥ 3	≥ 2	≥ 2	≥ 2

7.2 Calibrating receivers

7.2.1 Newly bought or serviced GPS receivers shall be wholy calibrated prior to use.

7.2.2 Calibration of GPS receiver
- General checking;
- Checking power lines;
- Checking humidity of the receiver
- Calibrating receiving canal
- Measuring for checking.

7.2.3 General checking shall be according to the following regulations:
- Receiver and antenna shall be appropriate. Sufficient engine and assessories;
- Perfect cover and antenna; perfect components and assessories, bolts working well.
- Instructions for use of receiver, instructions for use of special software.

7.2.4 Checking power lines shall be as follows:
- Checking power cables, connection to socket, male plug;
- Checking indicator lamp, trying power to the receiver;
- Buttons and displays working well;
- Measuring to know the working speed of receiving system and to see whether signals are lost during the reception or not.

7.2.5 Measuring for checking: After general checking and checking power lines, it is required to measure for checking GPS receiver as follows:
- Measuring for checking the stability of receivers according to the method and regulations as stated in Appendix C;
- Measuring for checking the stability of phase center according to the method and standard as stated in Appendix D;
- Measuring for checking the accuracy of the measurement results at different measured distances in standard lengths. When checking the receiver, it is necessary to balance and set up a plumb to the accuracy of ± 1mm. The standard line is on the North directional antenna. The antenna height is measured to the accuracy of 1mm. The difference between the measurement result and the standard length is smaller than the accuracy of the receiver.

7.2.6 When using the receiver for measuring at high grades/ classes, the receiver shall be annually calibrated prior to use as specified in Appendix C and D. Any part repaired or replaced shall be calibrated.

7.2.7 During the utilization, it is required to frequently calibrate the optical center to ensure centering accuracy. The method for calibration is as presented in Appendix E.

7.3 Servicing receiver

7.3.1 During the measurement at the site, GPS receiver shall at all times be preserved. When handling GPS, measures shall be taken to prevent from vibration, sunlight, wind, dust, humidity, or corrosion. The receiver operated with punch button keys should be located in box in transportation.

7.3.2 The plugs, the joints between the receiver and the conductor shall be kept clean. When the receiver is connected to the external power source, it is required to check carefully whether the voltage is appropriate with the voltage of the receiver or not. When installing battery, electrodes shall be paid attention to. The conductor of receiving antenna shall not be twisted and shall not be laid on hard or rough surface, the strength of the conductor shall be checked every six months.

7.3.3 When the receiver is not used, it is required to be located in box with foam rubber bed. The receiver should be located at spacial and dry place. When the damp-proof bag turns to pink or red, it should be replaced immediately.

7.3.4 If the receiver is left unused for a long time, its operation shall be checked every one or two months. The batteries shall be kept in a dry place, against power loss, the batteries shall be charged and the capacitance shall be checked every one or two months.

7.3.5 It is strictly prohibited to dismantle casually the parts of the receiver. In case of problems, minutes shall be taken and repair and service shall be done by skilled persons.

8. Monitoring

8.1 Basic technical specification

8.1.1 The basic technical specification in monitoring GPS of all grades shall be in accordance with Table 5.

8.1.2 When observing GPS of all grades, the Position Dilution of Precision PDOP of all grades/ classes of GPS network shall be < 6, (the number of satellites shall be ≥ 6).

8.1.3 In engineering survey, when monitoring GPS, it is not required to monitor meteorological factors but it is recommended to record climate conditions such as sunny, shady, cloudy or cloudless ...

8.2 Plan for monitoring

8.2.1 Prior to monitoring, it is required to use the softwares PLAN or QUICK PLAN to prepare monitoring plan and to prepare forecasts of the satellites able to be observed. The forecast includes: Name of satellites, height of satellites, and azimuths, the best time to observe well the satellites group, the dillution of precision in three-dimensional space. SV ≥ 6. When there are many screening objects surrounding the monitoring point, it is required to prepare plan for monitoring according to the actual screening at the points.

8.2.2 The coordinates for preparing forecast for the satellites are the average degrees of longitude and latitude. The time for forecasting should be the average time when monitoring. When the monitoring area is big and the monitoring time is extended, it is required to prepare forecast for each sub area with different monitoring time and Broadcast Ephemeris with less than 20 days of age shall be used.

8.2.3 Based on the number of receivers, designed GPS network and the satellite forecast, plan for monitoring shall be prepared including: Monitoring time, data of stations, name of stations, data of receivers,etc. as required in Appendix F.

8.2.4 The time of each monitoring shall not be less than 30 minutes provided that the the number of observation satellites is not smaller than 6 and PDOP is not greater than 5. The monitoring time may be extended for long distance or the conditions for receiving signals at the monitoring point are not good. The minimum for each monitoring should be referred to Table 6.

Table 5- Basic technical specifications when monitoring GPS of all grades

Item	**Grade/ Class** / **Monitorng method**	**Class II**	**Class III**	**Class IV**	**Grade 1**	**Grade 2**
Angle of satellites (^{0})	Static Rapid static	≥ 15	≥ 15	≥ 15	≥ 15	≥ 15
Number of usable observation satellites	Static Rapid static	≥ 4	≥ 4 ≥ 5	≥ 4 ≥ 5	≥ 4 ≥ 5	≥ 4 ≥ 5
Average repetition of monitoring at stations	Static Rapid static	≥ 2	≥ 2 ≥ 2	≥ 1.6 ≥ 1.6	≥ 1.6 ≥ 1.6	≥ 1.6 ≥ 1.6
Observing time: Shortest time of signal receiving (minutes)	Static Rapid static	≥ 90	≥ 60 ≥ 20	≥ 45 ≥ 15	≥ 45 ≥ 15	≥ 45 ≥ 15
Frequency of signal receiving (s)	Static Rapid static	10 ÷60	10 ÷60	10 ÷60	10 ÷60	10 ÷60

Table 6- Minimum time of each observation session

Distance [km]	**Time of observation session [minutes]**
0-1	20-30
1-5	30-60
5-10	60-90
10-20	90-120

8.3 Preparation

8.3.1 Prior to monitoring, it is required to check battery capacity. There must be sufficient receiver and accessories.

8.3.2 Prior to signal receiving, it is required to check the internal memory capacity of the receiver or magnetic disk whether there is still sufficient space for record or not.

8.3.3 Installation of antenna shall satisfy the following requirements:

- After coming to the monitoring station, receiver shall be stably located before locating antenna (in case receiver and antenna are separated from each other);
- Antenna installed on tripod shall be set up a plumb with accuracy <1mm, the antenna shall be balanced so that the circular buble is in the middle;
- When monitoring at the benchmark with obligatory centering, it is required to remove cover of benchmark center before installing antenna;
- Directional antenna shall always be to the North with accuracy ± 5^0 . Where it is difficult for direction, it is required to place directional marker

first, the monitoring shall be based on the directional marker for antenna direction.

8.4 Monitoring

8.4.1 GPS monitoring includes the following actions: Starting GPS receiver at the monitoring station and receiving signals recorded to the memory of the receiver.

8.4.2 It is recommended to use at least 3 GPS receivers with single frequency or dual frequency with accuracy parameter a ≤ 5mm, b ≤ 2ppm and with optical center for monitoring GPS network.

8.4.3 Optical center of GPS receiver shall be calibrated prior to use, ensuring center error ≤ ± 1mm

8.4.4 The monitoring team shall strictly follow the time specified in the plan, ensuring simultaneous observation of a satellites group. Any change in time compared with the plan shall shall be approved by the person in charge. The monitoring team is not permitted to change the plan by their own.

8.4.5 The conductors from the antenna to the receiver and assessories shall be carefully checked prior to receiving signals.

8.4.6 Before switching on receiver for each observation session, it is required to measure antenna height with special tape in mms, to record name of stations, dates, name of observation session, antenna height. After switching off receiver, remeasurement of antenna height shall be executed for checking, difference in antenna heights between two measurements shall not be beyond ± 2mm and the average value shall be recorded. If the difference is beyond the limit, causes shall be found out and solutions shall be proposed. The causes and solutions shall be noted.

8.4.7 After the receiver starts to receive data, the monitoring person may use functions of keyboard, select menu, looking for information of monitoring stations, number of satellites receiving signals, satelitte numbers, proportion of signal disturbance, results of immediate positioning, data recording (for receivers with control keyboards)

8.4.8 When the receiver is recording the results, normally the monitoring person shall note the data in turns as specified in the record book. When the monitoring time is over 60 minutes, notes shall be recorded every 30 minutes. The format of record book is as shown in Apepndix H.

8.4.9 During each monitoring, the following actions shall be prohibited: Switching off the receiver and restarting; trial monitoring (except problems occur); changing the satellite angle; changing the frequency of signals receiving; changing the location of antenna; pressing close key and deleting information.

8.4.10 During each observation session, the monitoring person is not allowed to leave from the receiver and he has to monitor at all times the working status of the receiver, to monitor power source and satellite situation, and to record data; also, preventing the receiver from being displaced by vibration, preventing the satellite signals from being screened by other persons and objects near the antenna.

8.4.11 When the receiver is under operation, it is not allowed to use walkies talkies or mobile phones near the receiver. In case of thunder or heavy rains, the receiver shall be switched off, monitoring shall be stopped and antenna shall be kept away to be against thunders.

8.4.12 During monitoring, the receiver shall be ensured to operate and to record data properly. All of the data shall be saved to hard disk and floppy disks after one day of monitoring to avoid loss of data.

9. Recording at the site

9.1 The followings shall be recorded:
- Name of stations;
- Date of monitoring/ day in the year, weather conditions, name of observation session;
- Starting time, finishing time, UTC time shall be used, hours and minutes shall be recorded;
- Receivers: Type of engine, name of engine and name of antenna.
- Longitude, latitude and approximate elevation of the station. Longitude and latitude shall be recorded up to minutes, and elevation shall be recorded up to 0.1m;
- Antenna height shall be the average result of the two measurements before and after receiving signals, the elevation shall be recorded up to 0.001m;
- Voltage of battery, number of satellites, satellites numbers, proportion of signals disturbance (SNR), level of screening and others as necessary;

9.2 Requirements when recording at the site
- The original data and the items recorded as required shall be at once recorded at the site clearly, free from dirts and rubs, re-recording shall not be allowed;
- After each day of monitoring, the results of satellites receiving of the sessions shall be saved to the external memory or to computer;
- Any interruption or processing to the data from the receiver shall not be allowed.

10. Data processing

10.1 Calculating baseline

10.1.1 The results of GPS monitoring may be processed by softwares GPSurvey 2.35 or Trimble Geomatic Office or other softwares with similar properties;

10.1.2 For short distance < 10km, only Broadcast Ephemeris shall be used for calculation, only distances with FIX solution and with RATIO not smaller than 2. are accepted. In case the solution is not FIX solution, it is required to note the error of signal multipath. If the distance at automatic mode does not receive FIX solution, the distances shall be processed by interruption method. In case FIX solution is not received by interruption method, remonitoring shall be taken.

10.1.3 When processing by interruption method, it is possible to reject satellite in bad conditions or to reduce monitoring time, however it is not allowed to reduce over 20% of the time for signals receiving.

10.1.4 The original coordinates used for calculating baseline should be the adjusting value of coordinates in WGS –84 of the points positioned by single point positioning method (absolute) for the signals receiving period over 30 minutes.

10.1.5 In each observation sesison with several simultaneous receivers, it is possible to calculate separately for each baseline or it is possible to select independent baseline and calculate by way of processing several baselines.

10.1.6 All of the baselines shall be measured simultaneously for less than 35 minutes, it is required to take fixed solution of double difference as appropriate to be the final results.

10.2 Checking the results of calculating abseline

10.2.1 When processing the data of one observation session for network class II and III, the proportion of used data must not be less than 80%.

10.2.2 While selecting processing model for each baseline, for the same model of line solution in one monitoring, the relative closing error in distances of any triangles shall not be beyond the limit specified in Table 7.

Table 7- Limited relative closing errors

n \ D	0,10 km	0,15 km	0,20 km	0,50 km	1,00 km	2,00 km	3,00 km	4,00 km
3	1:8160	1:12200	1:16300	1:40600	1:80000	1:151600	1:210000	1:255000
4	1:9430	1:14100	1:18800	1:46900	1:92400	1:175000	1:242500	1:294500
5	1:10500	1:15800	1:21000	1:52400	1:103400	1:195700	1:271200	1:329200
6	1:11500	1:17300	1:23000	1:57400	1:113200	1:214400	1:297000	1:360700

Note: In the above table, D is the average distances in the figure, n is the total of distances in close figure.

10.2.3 Whether each baseline shall be processed separately or several baselines shall be processed, in the whole GPS network, independent baselines shall be selected to form independent loops; The relative closing error in coordinates and the relative closing error in length of the independent loops shall be in accordance with the followings:

$$\left.\begin{aligned} \omega_x &\le 2\sqrt{n}\sigma \\ \omega_y &\le 2\sqrt{n}\sigma \\ \omega_z &\le 2\sqrt{n}\sigma \\ \omega &\le 2\sqrt{3n}\sigma \end{aligned}\right\} \qquad (10.1)$$

Where : σ is the length accuracy

ω is the loop closing error, $\omega = \sqrt{\omega_x^2 + \omega_y^2 + \omega_z^2}$

n is the total of distances in independent loop

$$\sigma = \sqrt{a^2 + (b.10^{-6}.D)^2}$$

10.2.4 The difference in length of the baseline shall not be beyond the limit

$$d_s \le 2\sqrt{2}\sigma$$

10.3 Supplementary monitoring and remonitoring

10.3.1 For any reason, one control point cannot be connected to two required independent baselines, supplementary monitoring shall be taken at that point or at least one independent baseline shall be remonitored.

10.3.2 It is possible to reject the baseline when the length of the remonitored baseline, closing error of simultaneous loop and closing error of independent loop are beyond the limit, but it shall ensure that the independent loop after rejecting baseline still have the total of distances not beyond the limit as specified in Section 5.2.4; otherwise, the baseline or relevant … shall be remonitored.

10.3.3 If because the location of points does not meet with the requirements of GPS monitoring, the specified limit of error is still not ensured although the baseline is remonitored several times, additional new points shall be selected based on the technical specification for re-monitoring.

10.4 Adjusting GPS network

10.4.1 When the quality has been checked in accordance with the specifications, all of independent baselines shall be taken to form a close loop, the 3-D vectors of the distances and their variance-covariance matrix... shall be taken as the information for monitoring value, 3-D coordinates in WGS – 84 of one point as the initial data and GPS network shall be adjusted freely. The results of free network adjustments shall show coordinates of points in WGS – 84, the adjustments of the three increments of coordinates of baseline, distances and the information of accuracy in point location. This process shall calculate from spacial rectangular coordinates XYZ to the geodetic coordinates and elevations BLH , then changed to the plane rectangular coordinates x,y.

10.4.2 It is possible to use all of the distances including independent distances to adjust the network if all of the distances are confirmed not to have crude errors (error due to measuring antenna height, error due to signal disturbance or multipath).

10.4.3 Based on the values of the measurements defined by adjustment of free network, executing dependent adjustment in 3-D or 2-D space, in the national coordinates system or regional coordinates system.

10.4.4 In dependent adjustment, the absolute value of the adjustment ($V_{\Delta x};V_{\Delta y};V_{\Delta z}$) of baselines shall satisfy the following requirements:

$$\left.\begin{array}{l} V_{\Delta x} \le 3\sigma \\ V_{\Delta y} \le 3\sigma \\ V_{\Delta z} \le 3\sigma \end{array}\right\} \qquad (10.2)$$

If beyond the error limit, it is possible to see that the baseline or the adjacent baseline contains crude error, it is required to apply the available method in software or the proposed method to reject the baseline with crude error, until to the satisfaction of the above requirements.

10.4.5 The difference in adjustments ($dV_{\Delta x}$, $dV_{\Delta y}$, $dV_{\Delta z}$) of the same baseline in restrained adjustment and in free network adjustment after rejecting crude error shall satisfy the following requirements:

$$\left.\begin{array}{l} dV_{\Delta x} \le 2\sigma \\ dV_{\Delta y} \le 2\sigma \\ dV_{\Delta z} \le 2\sigma \end{array}\right\} \qquad (10.3)$$

10.4.6 Adjustment of GPS network in plane normal coordinates shall be in accordance with Section 4.1.3.

10.4.7 Using the initial point of coordinates shall be in accordance with the used reference frame (in coordinates and projection). For GPS network, only one initial point is enough. If more than one initial points are used, it is required to consider carefully the quality of the initial points. Relative RMS Error of distances measurements after network adjustments shall not be over ± 10mm.

10.4.8 When adjusting by the software Trimnet Plus of GPSurvey 2.35, it is possible to adjust GPS network in association with the distance measurements or angle measurements by total station in order to improve the accuracy as well as the reliability of GPS network.

10.4.9 In order to define elevations for the points in GPS network, when adjusting the netwrok, it is possible to use Geoid EGM –96 or OSU91A model or Geoid model with sufficient accuracy in association with initial points of elevations – the points with known levelling in National elevations network.

10.4.10 In the network, there shall be at least 3 initial elevation points arranged at different directions of the network. Within the network less than 2 Km, the accuracy in defining elevations for the remaining points in the network shall be similar to the accuracy in levelling class IV if the elevation initial points are connected with the accuracy of levelling class III.

10.4.11 For GPS network in mountainous areas, the accuracy in defining elevations is lower than in plain areas. The network points may reach the accuracy of technical levelling if the elevations of initial points are connected with the accuracy of levelling class IV.

10.4.12 The results of adjustments shall include the following information::

- Information of baselines ΔX, ΔY, ΔZ;
- Closing error and the weakest closing error;
- Distance azimuths, distance, difference in elevations and corresponding adjustments;
- Spacial normal coordinates XYZ;
- Geodetic coordinates and elevations B,L,H;
- Plane normal coordinates and levelling after adjustment.
- Assessment of distance error, relative distance error and distance azimuth error after adjustment.

10.4.13 In case the coordinates system does not follow the national coordinates system, the coordinates after adjustments by the software for GPS network processing shall be changed to the project coordinates system according to the optimum positioning method owing to at least 3 double points (are the points with coordinates in both systems). The double points shall be arranged evenly to the directions at the marginal area of the network.

- The coordinates of GPS network points after adjustments shall be changed to the project coordinates system according to the optimum positioning method; it is possible to use the formula of changing flat coordinates with 4 parameters as follows:

$$X_1 = X_o + m.x_i \cos\varphi - m.y_i. \sin\varphi$$
$$Y_1 = Y_o + m.y_i \cos\varphi + m.x_i. \sin\varphi \qquad (10.4)$$

- In order to define the parameters Xo, Yo , φ and m in the formulae (10.4), the method of least square number.
- It is possible tp use simple afin formula to change coordinates between two plane normal coordinates systems. The formula is as follows:

$$x_2 = a_o + a_1 x_1 + a_2 y_1$$
$$y_2 = b_o + b_1 x_1 + b_2 y_1 \qquad (10.5)$$

The parameters a_o, a_1, a_2, b_o, b_1, b_2 in the formula (10.5) shall be defined according to the method of least square number based on the points song trùng.

11. Reporting

11.1 After completing all of the GPS monitoring, the report shall be prepared with the following contents:

- Current status of the survey area, geographical and natural conditions;
- Assignments, available geodetic documents of the survey area, purpose of survey and requirements in accuracy;
- The contractor, commencement date, technical specifications, technical staff, types and quantity of receivers, calibration, monitoring method, supplementary monitoring, re-monitoring, monitoring situation, coincident points, scope of works, man-day;
- Checking site data, original data, contents, method, and software after processing the data;
- Analysing the site data and calculating checking at the site.
- Implementation of the technical proposal and specifications;
- Remaining problems in the reports and problems to be explained;
- Appendix (Tables, drawings).

11.2 Reports submission

- Technical design;
- Forecast of visible satellites and monitoring plan
- Site recording (including softwares, CDs), record book and other notes;
- Documents, results of calculating and processing data;
- Diagram of GPS network;
- Summary report and results;
- Documents of selecting points for benchmarks installment in accordance with Section 6.3

Appendix A
(For reference)
Diagram of GPS points

Date .... Recorder............................ Drawer:.............................
Checker:..................

Point names and grades/ classes	GPS Point	Name		Soil properties	
		Number			
	Adjacent points (Name, symbol, distance, tình trạng ngắm thông)			Benchmarks conditions (1 or 2 levels, Newly selected or existing)	
				Name of existing point	
Point's locality					
Way to the point					
On the topographical map scale 1:........ with name of sheet				Approximate coordinates	x: y:
					B: L:

Appendix B
(For reference)
GPS benchmarks of all grades and benchmarks diagram

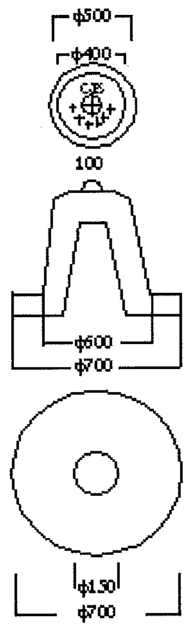


Figure B.1 – Procelain GPS benchmark

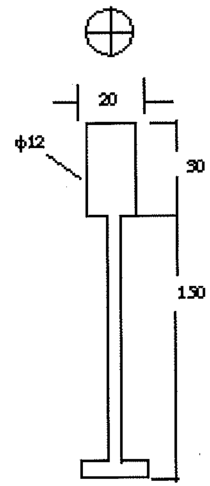


Figure B.2- Iron GPS benchmark

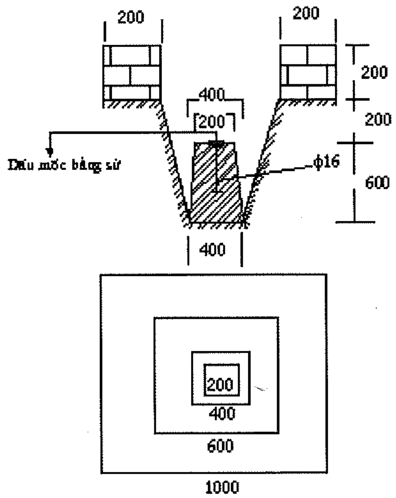


Figure B.3- Construction of GPS points in the midland and in the mountain

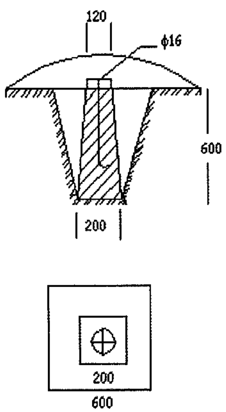


Figure B.4 – Construction of GPS benchmark Grade I, grade II

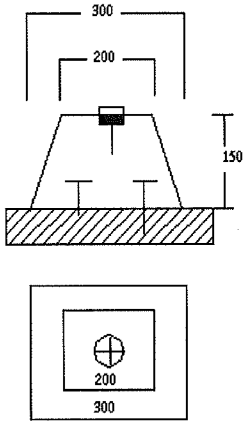


Figure B.4 – Construction of GPS benchmark attached to rocky mountains

Appendix C
(For reference)
Calibration of receiver stability by monitoring on the standard length

C.1 When calibrating power divider to separate the received signal of 1 antenna into 2 or more than 2 lines with the same phase capacity, then using method of quadratic differential processing in order to process data, calculating the increments of coordinates, the length of distance compared with the available standard length to find out errors in the receiver. Such monitoring rejects error in satellite graphs, eccentricity of antenna, error in delay of signals, error in secondary signal, plummet error vv... thus, it is also the calibration method of error in gauge of the receiver, delay of signal in the receiver and relevant errors in the power wires in the receiver.

C.2 Arrangement for monitoring

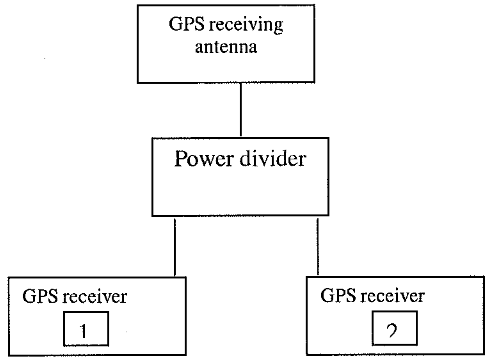


Figure C.2- Diagram of capacity division

C.2.1 Selecting the place with the mask angle of the satellite must be cut off 15^0, free from screening to locate antenna. The antenna and power divider shall be connected in accordance with Figure C.2

C.2.2 Connecting power of two receivers at both ends of the standard length, simultaneously receiving signals of 4 satellites or more for $1^h – 1.5^h$.

C.2.3 Changing the location, connecting power from the power divider to the receiver, monitoring once more

C.2.4 Using special software to calculate coordinates, length of the standard line, the difference must be less than 1mm, otherwise it shall be repaired at the workshop or the grade shall be lower.

APPENDIX D

(For reference)

Calibrating the stability of phase antenna

D.1 This work is executed at the yard with standard length

D.2 When calibrating, using two receivers and antenna located at both ends of standard lines. Setting up a plumb, marking the antenna to the North. Monitoring for some time, then changing receiver and antenna and monitoring once more. If the length of the standard yard is at a right angle with the measured length, monitoring once more as above. If there is no second length as above, one fixed antenna is to the North, the second antenna turns clockwise 90^0, 180^0, 270^0, monitoring as above.

D.3 Using special software to calculate 3-D coordinates, increments in coordinates and the line length, the difference must not be over twice the standard error of the receiver. Otherwise it shall be repaired at the workshop or the grade shall be lower.

APPENDIX E

(For reference)

Calibrating and adjusting optical center

E.1 Method of calibration

The receiver base shall be located balanced on a tripod. On the ground is placed one sheet of plotting paper, reading out the location of optical axis. Loosing the screw to remove the receiver base to another location in such a way that the border of the tripod still enclose the receiver base, rebalance the receiver, reading out the location of optical axis, changing the receiver base to the third location, following the same steps as above. If the three locations of optical axis coincide, that's right. If there is any triangle with errors, calibration is required.

E.2 Method of checking

Defining the center of the triangle with errors, twisting two screws in the middle of the cross of the center, slightly removing so that the cross center coincides with the triangle with errors, repeating the sections several times until precision.

APPENDIX F
(For reference)
GPS Monitoring Table

Order of monitoring (first, second …)	Time of monitoring from…… to…	Name and symbol of the monitoring point	Name and symbol of the monitoring point	Name and symbol of the monitoring point	Name and symbol of the monitoring point	Name and symbol of the monitoring point	Name and symbol of the monitoring point
		Quantity of receiver	Quantity of receiver	Quantity of receiver	Quantity of receiver	Quantity of receiver	Quantity of receiver
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

APPENDIX G
(For Reference)
Specification and method of antenna height measurement

G.1 When locating the antenna on the receiver base, using the calibrated steel tape to measure twice the distance from the benchmark center to the surface of the receiver base, the average value of the two measurements with difference of 2mm is h_1 , measuring the antenna thickness h_2, and measuring from the upper line of the antenna to highest point of the antenna, we have h_3, the antenna height is

$$h = h_1 + h_2 + h_3 \qquad (G.1)$$

G.2 When installing the antenna on the tripod, measuring with meter stick.

G.2.1 When there is specialized meter stick, measuring the antenna height from the benchmark center to the specified mark on the antenna.

G.2.2 It is possible to use meter stick, measuring the distance from the benchmark center to the specified mark on the antenna at 3 locations 120^0 far from each other, the average value of the three measurements with difference of less than 2mm is L, the antenna radius is known to be R, the antenna height is:

$$h = \sqrt{L^2 - R^2} \qquad (G.2)$$

G.2.3 When the specialized tape is not available, a small steel tape is used to measure the distance from the benchmark center to 3 locations into 120^0 on the tripod, the average value of the three measurements with difference less than 2mm is L, measuring the height from antenna bottom to antenna top – h_3, the antenna radius is known to be R, the antenna height is

$$h = \sqrt{L^2 - R^2} + h_3 \qquad (G.3)$$

G.3 When locating antenna on the base, using small steel tape to measure the distance from the benchmark center to the lower part of antenna - h', then adding the antenna thickness h'', we have:

$$h = h' + h'' \qquad (G.4)$$

APPENDIX H
(Tham khảo)
Recording at site in GPS monitoring

Recording at site in GPS monitoring for the Project

Name of monitoring person	Date of monitoring:........................	(session) ....
Name of monitoring point...........	Symbol of monitoring point	Ordinal number of monitoring

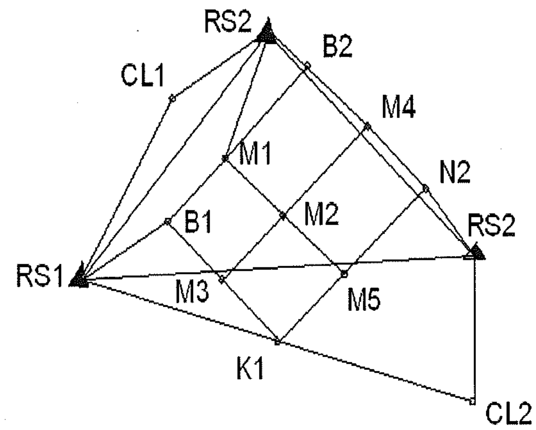
Weather conditions ...

Approximate coordinates of the point	Point commentary
Longitude E	New point
Latitude N	National control point:.....................
Elevation (m)	Point of levelling grade:......
Time of monitoring	
Commencement	Completion
Equipment No...........	Antenna No. ....
Antenna height (m)	Check data after measurement..............
1......... 2............3..........	Average......................
Diagram of antenna height measurement	Scheme of monitoring points and screening

Notes about the monitoring
1- Battery voltage
2- Satellite signal receiving
3- Ratio of SNR signal disturbance
4- Problems
5- Other notes

Appendix I
(For reference)
Example: GPS monitoring and processing in engineering survey

I. GPS monitoring diagram (traverseline class IV)



II. Site investigation
Base network RS1, RS2, RS3 is developed based on the two base cadastral points 116444 and GPS-01, their coordinates are in HN – 72 coordinates system, projection Gauss – Kruger, central longitude $105^0 45'$. Coordinates of original points and the points RS1, RS2, RS3. After measurement and calculation, the coordinates are shown in the following table:

No.	Point	Coordinates		M_P(m)	H(m)
		X(m)	Y(m)		
1	116444	2319654.405	507188.070	0.0000	5.356
2	GPS-01	2326761.489	503083.271	0.0000	6.756
3	RS1	2323786.779	503559.500	0.0041	5.840
4	RS2	2324072.255	503787.489	0.0041	6.638
5	RS3	2323781.290	504010.160	0.0039	7.050

II.1 Preparing monitoring plan
Prior to monitoring, it is required to prepare monitoring plan according to the conditions of selection as follows

Monitoring area	Hanoi
Latitude φ	$21^0 10'00$
Longitude λ	$105^0 45'00$
Height H	10m
Number of satellites	>6

PDOP	<5
Signal receiving time	45 –60 phút

II.2 Measurements at site

The measurements of traverseline points class IV are executed on 23/3/2005 with 4 single frequency receivers TRIMBLE 4600LS No. 0220105177, 0220105186, 0220292157 and 0220313121. Prior to satellite observation, connecting geometric technical levelling class III for all points of traverseline network and using these elevations as original points to adjust GPS network. The observation of satellites are executed in good weather conditions, all of the distances are measured in 07 sessions. Refer to diagram of network presented in page 29.

III. Results of network calculation and adjustment

III.1 Distance calculation

The distances are processed with WAVE module in GPS survey 2.35. At first, using " Default" prpocessing, for the distances under standard, executing "Advance Controls".

After distance calculation, we have 43 distances, all have FIXED solutions. Minimum Variance RATIO is 3.4. Maximum Variance RATIO is 14.89

III.2 Calculating for checking

The checking of results is executed by calculating closing error of closing loop. The results of calculating coordinates closing error f_X, f_Y, f_Z for the triangles are presented in Table 2. Maximum relative closing error does not exceed 1:37223, then all of the distance measurements are of very good quality, accepted for network adjustment.

In addition to GPS monitorings in the sessions, for the distances which can be seen directly from each other, the distance shall be measured with the total station TCR – 303, for the purpose of checking GPS monitoring results and in case of appropriateness, the masurements length shall be incorporated in network adjustment.

III.3 Network adjustment

After checking the measurements results, the network adjustment shall be executed with TRIMNET Plus module of GPSurvey 2.35. The network is adjusted in HN-72 coordinates system with projection Gauss- Kruger ($m_O = 1$), on Ellipxoid Krasovxky, the central longitude is $105^0 45'$. The elevations defined with geometric levelling of all points in the network are called original data, unchanged (FIX). The GPS network is adjusted with 25 distance values with total stations TCR-303. The RMS error of distance measurement is 2mm + 2ppmD. In data input, the distances are considered to be Network Distances.

The weight calculated for all GPS solutions according to the alternatives. The weights of the distances measured with total stations are calculated based on The RMS error of distance measurement of the equipment. After calculating, the RMS error network reference factor is 1.0 and the test results χ - square (Chi-Square) with $\alpha = 95\%$ is PASS.

The coordinates after adjustment are presented in Table 4. The geodetic coordinates are presented in Table 5.

Results of flat coordinates and elevelations after adjustment are presented in Table 6.

The GPS processing is referred to the tables: From Table 1 to Table 7.

The results of calculation (from page 32 to page 42) are processed with special softwares.

TABLE 1. TABLE OF COORDINATES INCREMENTS AND ERRORS OF CARTESIAN COORDINATE SYTEM WITH ELIPSOID: WGS-84

SES.	B. P	E.Point	DX(m)	DY(m)	DZ(m)	RATIO	RE.VAR	RMS
0826	B1	H2	-237.031	-92.874	63.481	9.7	7.612	.012
0821	B1	M2	-151.821	-41.180	-2.503	12.6	2.746	.007
0821	B1	M3	-64.439	11.199	-72.298	12.2	3.085	.007
0826	B1	M4	-236.111	-92.943	64.660	5.2	14.891	.013
0826	B1	RS1	84.748	47.546	-63.210	10.6	6.969	.011
0822	B2	RS2	64.738	-8.536	66.424	17.2	2.184	.005
0820	CL1	M1	-52.739	9.530	-61.530	19.6	1.253	.004
0820	CL1	RS1	107.341	111.617	-207.990	3.9	4.337	.007
0826	K1	CL2	-240.146	-28.405	-100.931	23.2	3.129	.006
0826	K1	M3	66.111	-10.292	75.048	18.1	3.996	.006
0821	M1	B1	75.328	54.534	-83.240	17.6	2.378	.006
0821	M1	M2	-76.494	13.354	-85.743	18.1	1.771	.005
0821	M1	M3	10.889	65.733	-155.537	15.9	2.192	.005
0820	M1	RS1	160.079	102.086	-146.461	3.4	6.052	.008
0822	M2	B2	-19.981	-62.523	139.587	15.6	2.756	.006
0823	M2	H2	-85.218	-51.683	65.983	13.8	4.561	.007
0822	M2	M4	-84.294	-51.762	67.141	8.7	4.767	.008
0823	M2	N2	-150.549	-40.812	-7.588	19.9	3.219	.006
0822	M2	RS2	44.757	-71.059	206.011	12.4	3.262	.006
0825	M3	CL2	-306.257	-18.112	-175.978	29.3	2.496	.005
0821	M3	M2	-87.383	-52.378	69.795	20.4	1.666	.005
0822	M4	B2	64.313	-10.759	72.446	8.4	4.843	.008
0826	M4	H2	-.932	.090	-1.152	33.7	5.171	.009
0827	M4	H2	-.924	.074	-1.171	11.4	6.697	.008
0822	M4	RS2	129.051	-19.297	138.870	8.0	5.604	.009
0824	M5	CL2	-152.732	23.830	-170.806	15.8	3.028	.006
0825	M5	CL2	-152.734	23.831	-170.806	20.8	2.822	.005
0823	M5	H2	-19.076	-62.127	140.946	18.6	4.252	.007
0825	M5	K1	87.411	52.236	-69.875	18.4	3.494	.006
0823	M5	M2	66.142	-10.443	74.964	26.3	2.616	.005
0825	M5	M3	153.522	41.944	5.173	16.1	4.189	.007
0823	M5	N2	-84.407	-51.256	67.376	25.5	2.841	.006
0824	M5	N2	-84.408	-51.258	67.378	20.5	2.816	.006
0824	M5	RS3	-131.782	-41.321	9.439	20.5	2.199	.005
0824	N2	CL2	-68.325	75.090	-238.183	26.0	2.040	.005
0823	N2	H2	65.331	-10.872	73.570	18.2	3.804	.007
0824	N2	RS3	-47.377	9.934	-57.941	29.7	1.326	.004
0826	RS1	H2	-321.780	-140.419	126.693	17.2	4.094	.007
0826	RS1	M4	-320.857	-140.491	127.866	10.4	5.715	.008
0820	RS2	CL1	84.461	48.185	-58.738	29.2	.754	.003
0820	RS2	M1	31.722	57.716	-120.268	16.3	1.461	.005
0820	RS2	RS1	191.801	159.804	-266.727	4.4	4.580	.007
0825	RS3	CL2	-20.949	65.152	-180.244	24.9	1.638	.004

- Maximum RATIO:(M4 -H2) RATIO= 33.700
- Minimum RATIO:(M1 -RS1) RATIO= 3.400
- Maximum R.VARIANCE:(B1 -M4) R.VA = 14.891
- Minimum R.VARIANCE :(RS2 -CL1) R.VA = .754
- Maximum RMS :(B1 -M4) RMS = .013
- Minimum RMS :(RS2 -CL1) RMS = .003

TABLE 2. CLOSING ERROR

TT	Closing loop			fX	fY	fZ	fXYZ	[D](m)	fXYZ:[D]
1	RS1	CL1	RS2	-.001	.002	.001	.002	738.243	1: 301386
2	RS1	RS2	M1	.000	-.002	-.002	.003	742.239	1: 262421
3	CL1	RS2	M1	.000	.001	.000	.001	332.320	1: 332320
4	RS1	M1	B1	-.003	-.006	.011	.013	480.519	1: 37295
5	B1	M1	M2	-.001	.000	.000	.001	397.814	1: 397813
6	B1	M2	M3	.001	-.001	.000	.001	378.312	1: 267507
7	M1	M2	M3	.000	-.001	-.001	.001	408.379	1: 288767
8	M2	M5	M3	-.003	.009	.004	.010	383.242	1: 37223
9	M2	RS2	B2	.000	.000	.000	.001	469.865	1: 469865
10	B2	M4	M2	.000	-.002	.000	.002	371.271	1: 185635
11	M2	H2	M5	.000	.001	.001	.001	375.252	1: 265343
12	H2	N2	M5	.000	.001	.000	.001	373.743	1: 373743
13	N2	RS3	M5	-.002	-.001	-.004	.005	333.478	1: 72770
14	M5	RS3	CL2	.001	.001	.001	.002	561.598	1: 324238
15	N2	RS3	CL2	-.001	-.004	-.002	.005	527.217	1: 115048
16	M5	CL2	K1	.003	-.001	.000	.003	615.905	1: 194766
17	M3	M5	CL2	.003	-.002	-.001	.004	743.281	1: 198650
18	M3	CL2	K1	.000	.001	.001	.001	716.261	1: 506472

- BEST CLOSING LOOP :M3 CL2 K1 REACHES 1: 506472
- WORST CLOSING LOOP :M2 M5 M3 REACHES 1: 37223

TABLE 3.1. ADJUSTED AZIMUTH ANGLE MEASUREMENTS

GEODETIC COORDINATES SYSTEM ELLIPSOID KRASOVSKI

NO.	Beginning	Ending	Survey area	Ma	SHC	PVbs
1	RS2	CL1	236ú10'21.440	3.482	5.867	236ú10'27.308
2	RS2	M1	199ú41'21.882	3.493	9.328	199ú41'31.211
3	CL1	RS1	211ú00'53.165	3.460	3.468	211ú00'56.633
4	CL1	M1	143ú49'03.286	4.505	1.934	143ú49'05.221
5	M1	RS1	229ú17'49.157	4.836	.821	229ú17'49.979
6	M1	M2	142ú45'49.169	2.863	1.614	142ú45'50.784
7	M1	M3	189ú38'09.672	3.048	4.911	189ú38'14.583
8	M1	B1	224ú23'10.504	4.879	3.931	224ú23'14.436
9	B1	M2	91ú03'25.448	3.696	-2.649	91ú03'22.798
10	B1	M3	142ú46'23.442	4.452	-.649	142ú46'22.792
11	M3	M2	52ú45'52.601	4.274	.556	52ú45'53.157
12	M2	B2	13ú34'27.631	2.502	-2.009	13ú34'25.621
13	M2	RS2	353ú51'42.824	1.831	-2.224	353ú51'40.600
14	M2	M4	52ú45'56.765	4.235	-4.993	52ú45'51.772
15	M4	B2	322ú45'53.582	4.978	1.605	322ú45'55.188
16	M4	RS2	321ú22'03.797	2.723	-.010	321ú22'03.787
17	B2	RS2	319ú54'20.251	3.483	-1.397	319ú54'18.854
18	M5	M2	322ú45'41.677	3.518	-3.436	322ú45'38.240
19	M5	H2	13ú07'02.840	2.924	-.422	13ú07'02.417
20	M5	N2	52ú44'39.879	3.360	-1.833	52ú44'38.045
21	M2	H2	53ú28'29.749	4.375	-.480	53ú28'29.269
22	M2	N2	92ú48'30.799	2.758	-4.372	92ú48'26.426
23	N2	H2	322ú44'35.254	4.222	-4.736	322ú44'30.518
24	M5	RS3	85ú45'20.979	3.273	-3.458	85ú45'17.520
25	M5	CL2	142ú24'30.900	1.894	-1.208	142ú24'29.691
26	M5	N2	52ú44'38.948	4.020	-.902	52ú44'38.045
27	N2	RS3	145ú22'23.927	4.586	-5.930	145ú22'17.997
28	N2	CL2	169ú54'22.505	1.500	-1.718	169ú54'20.786
29	RS3	CL2	179ú15'49.585	2.064	-.827	179ú15'48.757
30	M5	CL2	142ú24'29.457	2.040	.233	142ú24'29.691
31	M5	K1	232ú45'10.985	3.965	.491	232ú45'11.477
32	M5	M3	271ú54'22.392	3.811	-1.838	271ú54'20.554
33	K1	CL2	114ú17'24.350	2.055	-.180	114ú17'24.169
34	K1	M3	322ú45'51.033	5.525	-1.889	322ú45'49.143
35	M3	CL2	122ú04'45.036	1.328	-.746	122ú04'44.290
36	M4	H2	143ú55'41.185	326.613	149.883	143ú58'11.068
37	B1	RS1	234ú35'17.599	12.248	-14.530	234ú35'03.069
38	B1	H2	74ú55'28.284	6.705	3.523	74ú55'31.807
39	B1	M4	74ú37'07.595	9.432	13.813	74ú37'21.409
40	RS1	H2	68ú43'42.329	3.381	-3.346	68ú43'38.982
41	RS1	M4	68ú30'24.276	4.119	1.814	68ú30'26.091
42	M4	H2	144ú16'06.181	971.838	75.112	143ú58'11.068
43	RS2	RS1	218ú36'39.027	2.623	4.220	218ú36'43.248

Maximum azimuth error : M4 - H2 ma(max)=971.838
Minimum azimuth error : M3 - CL2 ma(min)= 1.328
Maximum azimuth adjustment : M4 - H2 Va(max)=149.883
Minimum azimuth adjustment : M4 - RS2 Va(min)= .010

TABLE 3.2. ADJUSTED DISTANCE MEASUREMENTS,

GEODETIC COORDINATES SYSTEM ELLIPSOID KRASOVSKI

NO.	Beginning	Ending	Distances measured	MD	Adjusted value	Dbs
1	RS2	CL1	113.6004	.0014	.0014	113.6018
2	RS2	M1	137.1184	.0024	-.0017	137.1166
3	CL1	RS1	259.3035	.0046	.0039	259.3075
4	CL1	M1	81.5976	.0025	-.0027	81.5949
5	M1	RS1	239.7830	.0046	.0049	239.7879
6	M1	M2	115.6767	.0027	-.0046	115.6721
7	M1	M3	169.2075	.0024	-.0028	169.2046
8	M1	B1	124.8087	.0018	.0005	124.8093
9	B1	M2	157.3262	.0026	-.0017	157.3245
10	B1	M3	97.4911	.0035	-.0028	97.4882
11	M3	M2	123.4932	.0015	-.0003	123.4929
12	M2	B2	154.2459	.0017	-.0015	154.2444
13	M2	RS2	222.4672	.0019	-.0014	222.4658
14	M2	M4	119.5481	.0023	-.0028	119.5452
15	M4	B2	97.4696	.0026	-.0022	97.4673
16	M4	RS2	190.5559	.0027	-.0029	190.5530
17	B2	RS2	93.1452	.0017	-.0002	93.1450
18	M5	M2	100.5139	.0019	-.0013	100.5125
19	M5	H2	155.2079	.0022	-.0013	155.2065
20	M5	N2	119.5452	.0018	.0011	119.5464
21	M2	H2	119.5229	.0023	.0003	119.5232
22	M2	N2	156.1634	.0020	.0002	156.1637
23	N2	H2	98.9897	.0023	-.0019	98.9878
24	M5	RS3	138.4311	.0022	.0016	138.4328
25	M5	CL2	230.3669	.0024	.0002	230.3671
26	M5	N2	119.5478	.0020	-.0013	119.5464
27	N2	RS3	75.5008	.0020	-.0033	75.4975
28	N2	CL2	258.9168	.0019	-.0004	258.9164
29	RS3	CL2	192.7984	.0019	.0026	192.8010
30	M5	CL2	230.3685	.0021	-.0013	230.3671
31	M5	K1	123.4980	.0025	.0001	123.4982
32	M5	M3	159.2325	.0023	.0001	159.2327
33	K1	CL2	262.0378	.0020	-.0008	262.0370
34	K1	M3	100.5390	.0026	-.0015	100.5374
35	M3	CL2	353.6781	.0018	-.0019	353.6761
36	M4	H2	1.4855	.0023	-.0031	1.4823
37	B1	RS1	115.9148	.0066	.0149	115.9298
38	B1	H2	262.3727	.0050	.0019	262.3747
39	B1	M4	261.8548	.0072	-.0065	261.8482
40	RS1	H2	373.2436	.0042	.0131	373.2567
41	RS1	M4	372.8759	.0053	.0060	372.8819
42	M4	H2	1.4959	.0068	-.0136	1.4823
43	RS2	RS1	365.3330	.0044	.0056	365.3386

Maximum length error : B1 - M4 md(max)= .0072
Minimum length error : RS2 - CL1 md(min)= .0014
Maximum length adjustment : B1 - RS1 Vd(max)= .0149
Minimum length adjustment : M5 - K1 Vd(min)= .0001

TABLE 3.3. ADJUSTED ELEVATION DIFFERENCE MEASUREMENTS

GEODETIC COORDINATES SYSTEM   ELLIPSOID KRASOVSKI

NO.	Beginning	Ending	Difference High	Mh	Adjusted value	dHbs
1	RS2	CL1	.7774	.0037	-.0035	.7739
2	RS2	M1	.6753	.0051	-.0059	.6694
3	CL1	RS1	-1.5501	.0095	-.0094	-1.5595
4	CL1	M1	-.1028	.0047	-.0019	-.1047
5	M1	RS1	-1.4484	.0111	-.0067	-1.4551
6	M1	M2	.6868	.0049	-.0016	.6851
7	M1	M3	.5281	.0054	-.0001	.5279
8	M1	B1	.0196	.0053	.0040	.0236
9	B1	M2	.6669	.0062	-.0057	.6612
10	B1	M3	.5090	.0065	-.0049	.5041
11	M3	M2	.1590	.0048	-.0020	.1569
12	M2	B2	-1.0511	.0057	-.0043	-1.0554
13	M2	RS2	-1.3486	.0061	-.0065	-1.3552
14	M2	M4	-1.0209	.0075	-.0085	-1.0294
15	M4	B2	-.0291	.0078	.0028	-.0263
16	M4	RS2	-.3276	.0083	.0015	-.3260
17	B2	RS2	-.2970	.0051	-.0030	-.3000
18	M5	M2	.6921	.0051	.0036	.6958
19	M5	H2	-.4401	.0063	-.0012	-.4413
20	M5	N2	-.4528	.0053	.0013	-.4515
21	M2	H2	-1.1308	.0069	-.0066	-1.1374
22	M2	N2	-1.1444	.0059	-.0031	-1.1475
23	N2	H2	.0125	.0062	-.0026	.0099
24	M5	RS3	-.2629	.0062	.0038	-.2591
25	M5	CL2	-1.0239	.0062	.0003	-1.0235
26	M5	N2	-.4547	.0060	.0031	-.4515
27	N2	RS3	.1884	.0053	.0037	.1921
28	N2	CL2	-.5672	.0052	-.0050	-.5722
29	RS3	CL2	-.7595	.0054	-.0050	-.7646
30	M5	CL2	-1.0220	.0043	-.0014	-1.0235
31	M5	K1	-.3231	.0048	-.0016	-.3248
32	M5	M3	.5422	.0052	-.0035	.5386
33	K1	CL2	-.6989	.0045	.0000	-.6989
34	K1	M3	.8648	.0051	-.0016	.8632
35	M3	CL2	-1.5636	.0040	.0012	-1.5623
36	M4	H2	-.0954	.0079	-.0128	-.1082
37	B1	RS1	-1.4687	.0122	-.0102	-1.4789
38	B1	H2	-.4748	.0127	-.0011	-.4759
39	B1	M4	-.3478	.0181	-.0201	-.3680
40	RS1	H2	.9957	.0095	.0070	1.0028
41	RS1	M4	1.1170	.0119	-.0062	1.1107
42	M4	H2	-.1182	.0129	.0100	-.1082
43	RS2	RS1	-.7707	.0097	-.0147	-.7854

Maximum elevation difference error : B1 - M4 mH(max)= .0181
Minimum elevation difference error : RS2 - CL1 mH(min)= .0037
Maximum elevation difference adjustments : B1 - M4 VH(max)= .0201
Minimum elevation difference adjustments : K1 - CL2 VH(min)= .0000

TABLE 3.4 GEOID ELEVATION AND AND ADJUSTMENTS OF GEOID ELEVATION

GEODETIC COORDINATES SYSTEM ELLIPSOID KRASOVSKI

NO	Point	Zdo	Mz	Adjusted value	Zbs	MZbs
1	B1	-28.1117	.0046	-.0007	-28.1124	.0043
2	B2	-28.1114	.0046	.0008	-28.1106	.0043
3	CL1	-28.1150	.0046	.0004	-28.1145	.0044
4	CL2	-28.0966	.0046	.0004	-28.0961	.0045
5	H2	-28.1079	.0046	.0008	-28.1071	.0041
6	K1	-28.1048	.0046	.0002	-28.1046	.0041
7	M1	-28.1122	.0046	.0003	-28.1118	.0042
8	M2	-28.1081	.0046	-.0006	-28.1088	.0039
9	M3	-28.1083	.0046	.0006	-28.1077	.0041
10	M4	-28.1080	.0046	.0008	-28.1071	.0041
11	M5	-28.1046	.0046	-.0006	-28.1053	.0039
12	N2	-28.1045	.0046	-.0022	-28.1067	.0041
13	RS1	-28.1120	.0046	-.0009	-28.1129	.0045
14	RS2	-28.1146	.0046	.0009	-28.1137	.0045
15	RS3	-28.1018	.0046	-.0023	-28.1042	.0042

TABLE 3.5. ADJUSTED ELECTRO-OPTICAL DISTANCE MEASUREMENTS

GEODETIC COORDINATES SYSTEM ELIPSOID KRASOVSKI

NO	Beginning	Ending	Distances measured	MD	Adjusted value	$D_{Adjusted}$
1	B2	M2	154.2410	.0048	.0052	154.2462
2	B2	M4	97.4700	.0047	-.0014	97.4685
3	B2	RS2	93.1480	.0047	-.0019	93.1461
4	CL1	M1	81.5990	.0047	-.0031	81.5959
5	CL2	K1	262.0420	.0049	-.0018	262.0401
6	CL2	M5	230.3680	.0048	.0019	230.3699
7	H2	M2	119.5220	.0047	.0026	119.5246
8	H2	M4	1.4800	.0047	.0022	1.4823
9	K1	M5	123.4960	.0047	.0036	123.4997
10	M2	M4	119.5440	.0047	.0026	119.5466
11	M2	M5	100.5150	.0047	-.0013	100.5137
12	M2	N2	156.1610	.0048	.0045	156.1655
13	M5	N2	119.5480	.0047	-.0001	119.5479
14	M5	RS3	138.4340	.0047	.0004	138.4345
15	N2	RS3	75.5030	.0047	-.0045	75.4984
16	H2	CL2	349.9170	.0050	.0039	349.9210
17	M4	CL2	351.3190	.0050	.0078	351.3268
18	B2	CL2	444.3280	.0051	.0047	444.3328
19	H2	CL1	231.1390	.0048	-.0021	231.1369
20	M4	CL1	229.8840	.0048	-.0041	229.8799
21	CL1	M3	233.5240	.0048	-.0009	233.5231
22	CL1	B1	159.9140	.0048	.0017	159.9158
23	B2	M1	120.9250	.0047	.0019	120.9270
24	B2	CL1	154.5730	.0048	.0001	154.5731
25	H2	B2	98.9530	.0047	-.0025	98.9505

Maximum length error : B2 - CL2 md(max)= .0051
Minimum length error : B2 - M4 md(min)= .0047
Maximum length adjustment : M4 - CL2 Vd(max)= .0078
Minimum length adjustment: M5 - N2 Vd(min)= .0001

TABLE 4. CARTESIAN COORDINATES SYTEM AFTER ADJUSTMENT

CARTESIAN COORDINATES SYTEM REFERENCE ELIPSOID : KRASOVSKI

NO.	NAME	X(m)	Y(m)	Z(m)
1	B1	-1620455.4110	5732240.0874	2272114.4911
2	B2	-1620627.2084	5732136.3748	2272251.5733
3	CL1	-1620478.0028	5732176.0169	2272259.2578
4	CL2	-1620826.1101	5732233.1772	2271866.2193
5	H2	-1620692.4484	5732147.2130	2272177.9704
6	K1	-1620585.9611	5732261.5775	2271967.1487
7	M1	-1620530.7405	5732185.5472	2272197.7295
8	M2	-1620607.2317	5732198.9025	2272111.9882
9	M3	-1620519.8482	5732251.2827	2272042.1940
10	M4	-1620691.5201	5732147.1335	2272179.1286
11	M5	-1620673.3734	5732209.3436	2272037.0245
12	N2	-1620757.7820	5732158.0877	2272104.4036
13	RS1	-1620370.6536	5732287.6312	2272051.2622
14	RS2	-1620562.4686	5732127.8346	2272317.9966
15	RS3	-1620805.1604	5732168.0260	2272046.4684

TABLE 5. GEODETIC COORDINATES AFTER ADJUSTMENTS

GEODETIC COORDINATES SYSTEM REFERENCE ELLIPXOID: KRASOVXKI

NO.	NAME	B	L	H(m)	h(m)
1	B1	21 0 23.90677	105 47 6.52339	-20.780	7.332
2	B2	21 0 28.68625	105 47 13.22473	-21.175	6.936
3	CL1	21 0 28.94800	105 47 7.87968	-20.702	7.413
4	CL2	21 0 15.27276	105 47 18.94016	-21.832	6.264
5	H2	21 0 26.12367	105 47 15.29645	-21.255	6.852
6	K1	21 0 18.77937	105 47 10.67092	-21.137	6.968
7	M1	21 0 26.80626	105 47 9.54716	-20.805	7.307
8	M2	21 0 23.81133	105 47 11.97006	-20.118	7.991
9	M3	21 0 21.38239	105 47 8.56500	-20.275	7.833
10	M4	21 0 26.16266	105 47 15.26627	-21.147	6.960
11	M5	21 0 21.20905	105 47 14.07555	-20.812	7.293
12	N2	21 0 23.56147	105 47 17.37092	-21.264	6.843
13	RS1	21 0 21.72300	105 47 3.25141	-22.259	5.854
14	RS2	21 0 31.00354	105 47 11.14802	-21.476	6.638
15	RS3	21 0 21.54119	105 47 18.85593	-21.070	7.034

TABLE 6. TABLE OF PLANE COORDINATES AND ELEVATIONS AFTER ADJUSTMENT

HN-72 SYSTEM, CENTRAL LONGITUDE: 105 45 0.

PROJECTION SCALE m0=1.0000

(ALTERNATIVE OF 3 ORIGINAL BENCHMARKS: RS1,RS2,RS3)

NO.	Symbol	X(m)	Y(m)	Mp(m)	Elevation h
1	B1	2323853.962	503653.980	.0022	77.332
2	B2	2324001.000	503847.480	.0015	6.936
3	CL1	2324009.015	503693.115	.0017	7.413
4	CL2	2323588.503	504012.639	.0020	6.264
5	H2	2323922.201	503907.329	.0016	6.852
6	K1	2323696.294	503773.796	.0025	6.968
7	M1	2323943.156	503741.286	.0016	7.307
8	M2	2323851.062	503811.280	.0013	7.991
9	M3	2323776.337	503712.959	.0019	7.833
10	M4	2323923.400	503906.457	.0017	6.960
11	M5	2323771.042	503872.105	.0014	7.293
12	N2	2323843.414	503967.258	.0014	6.843
13	RS1	2323786.779	503559.500	.0000	5.854
14	RS2	2323072.255	503787.489	.0000	6.638
15	RS3	2323781.290	504010.160	.0000	7.034

- MINIMUM POINT LOCATION ERROR: .000 m ; POINT (RS1)

- MAXIMUM POINT LOCATION ERROR: .003 m ; POINT (K1)

TABLE 7. RELATIVE ERROR OF DISTANCES AND AZIMUTH DISTANCES

FLAT COORDINATES SYSTEM GAUSS ELLIPSOID KRASOVSKI

NO.	Beginning point	Ending point	D (m)1	MD(m)	MD:D	P.VI	MfV
1	B1	CL1	159.916	.0017	1: 93109	14^{0} 09' 56"	2.21
2	B1	H2	262.378	.0016	1: 159541	74^{0} 55' 31"	1.48
3	B1	M1	124.811	.0012	1: 100920	44^{0} 23' 14"	2.85
4	B1	M2	157.326	.0014	1: 111623	91^{0} 03' 22"	1.99
5	B1	M3	97.489	.0017	1: 55863	142^{0} 46' 22"	2.65
6	B1	M4	261.851	.0017	1: 150090	74^{0} 37' 21"	1.53
7	B1	RS1	115.931	.0014	1: 84394	234^{0} 35' 02"	2.97
8	B2	CL1	154.573	.0015	1: 106559	272^{0} 58' 20"	2.26
9	B2	CL2	444.333	.0015	1: 287436	158^{0} 10' 46"	.78
10	B2	H2	98.950	.0014	1: 72750	142^{0} 46' 59"	2.96
11	B2	M1	120.927	.0013	1: 91670	241^{0} 25' 22"	2.77
12	B2	M2	154.246	.0011	1: 135908	193^{0} 34' 25"	1.62
13	B2	M4	97.469	.0013	1: 74559	142^{0} 45' 55"	2.89
14	B2	RS2	93.146	.0011	1: 85196	319^{0} 54' 18"	2.42
15	CL1	H2	231.137	.0015	1: 149300	112^{0} 03' 41"	1.51
16	CL1	M1	81.596	.0015	1: 54243	143^{0} 49' 05"	2.87
17	CL1	M2	233.523	.0017	1: 139050	175^{0} 07' 31"	1.30
18	CL1	M4	229.880	.0016	1: 143983	111^{0} 51' 58"	1.58
19	CL1	RS1	259.311	.0012	1: 213424	211^{0} 00' 56"	.97
20	CL1	RS2	113.603	.0011	1: 108143	56^{0} 10' 27"	1.48
21	CL2	H2	349.921	.0015	1: 232711	342^{0} 29' 06"	.97
22	CL2	M1	262.040	.0014	1: 181900	294^{0} 17' 24"	1.44
23	CL2	M2	353.680	.0014	1: 244615	302^{0} 04' 44"	.88
24	CL2	M4	351.327	.0015	1: 231433	342^{0} 24' 30"	.975
25	CL2	M5	230.370	.0011	1: 207075	322^{0} 24' 29"	1.07
26	CL2	N2	258.920	.0013	1: 201626	349^{0} 54' 20"	1.07
27	CL2	RS3	192.803	.0013	1: 145924	359^{0} 15' 48"	1.55
28	H2	M2	119.525	.0012	1: 103079	233^{0} 28' 29"	2.16
29	H2	M4	1.482	.0012	1: 1213	323^{0} 58' 10"	+++
30	H2	M5	155.208	.0012	1: 126428	193^{0} 07' 02"	1.68
31	H2	N2	98.989	.0012	1: 82334	142^{0} 44' 30"	2.39
32	H2	RS1	373.261	.0011	1: 326337	248^{0} 43' 38"	.66
33	K1	M3	100.539	.0016	1: 63321	322^{0} 45' 48"	3.23
34	K1	M5	123.500	.0015	1: 81647	52^{0} 45' 11"	2.55
35	M1	M2	115.673	.0014	1: 82677	142^{0} 45' 50"	1.73
36	M1	M3	169.207	.0014	1: 123732	189^{0} 38' 14"	1.70
37	M1	RS1	239.791	.0010	1: 245349	229^{0} 17' 49"	1.14
38	M1	RS2	137.118	.0012	1: 118091	19^{0} 41' 31"	1.75
39	M2	M3	123.494	.0011	1: 117292	232^{0} 45' 52"	2.22

40	M2	M4	119.547	.0012	1: 96658	52^0	45'	51"	2.21
41	M2	M5	100.514	.0010	1: 100606	142^0	45'	38"	1.85
42	M2	N2	156.166	.0010	1: 150412	92^0	48'	26"	1.44
43	M2	RS2	222.468	.0010	1: 225342	353^0	51'	40"	.84
44	M3	M5	159.235	.0011	1: 139471	91^0	54'	20"	1.66
45	M4	RS1	372.886	.0012	1: 305252	248^0	30'	25"	.68
46	M4	RS2	190.555	.0012	1: 155783	321^0	22'	03"	1.33
47	M5	N2	119.548	.0009	1: 126948	52^0	44'	37"	1.78
48	M5	RS3	138.434	.0010	1: 140979	85^0	45'	17"	1.56
49	N2	RS3	75.498	.0010	1: 74199	145^0	22'	17"	2.63

RESULTS OF THE NETWORK ACCURACY ASSESSMENT

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- **STANDARD RMS ERROR : .94**
- **SHORTEST DISTANCE: 1.482 m ; SIDE (H2 -M4)**
- **LONGEST DISTANCE : 444.333 m ; SIDE (B2 -CL2)**
- **AVERAGE DISTANCE : 181.716 m**
- **MINIMUM RELATIVE ERROR : 1/ 326337 ; SIDE (H2 -RS1)**
- **MAXIMUM RELATIVE ERROR: 1/ 1213 ; SIDE (H2 -M4)**
- **MINIMUM AZIMUTH ERROR : .66" ; SIDE (H2 -RS1)**
- **MAXIMUM AZIMUTH ERROR : 184.14" ; SIDE (H2 -M4)**

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