Part VII: Control Surveying

Control Surveying consists of research, measurements, calculations and reports detailing the horizontal and vertical reference systems established for the survey.

7.1. Sources of Information

7.1.1 Federal

Current National Spatial Data Infrastructure (NSDI) *Geospatial Positioning Accuracy Standards* published by the Federal Geodetic Control Subcommittee (FGCS) of the Federal Geographic Data Committee (FGDC) may be downloaded in .PDF or .WPD formats from the following Internet address: **http://www.fgdc.gov/standards/documents/standards/accuracy**

A variety of programs are available from the National Geodetic Survey that will prove indispensable in the planning, conducting, processing and evaluation of high order control surveys. Software may be accessed at the following Internet site: **http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml**

A brief description of those the surveyor may find especially helpful is reproduced in **Annex C** to this chapter for convenience.

Data Sheets: NOAA/NGS Data Sheets are available on the Internet at the following address: **http://www.ngs.noaa.gov/datasheet.html**

The data sheets provide location, elevation and descriptors of points included in the NSDI data base. Searches can be performed over an area or from a point and radius. This is the primary data source for anyone conducting high order vertical or horizontal control surveys.

7.1.2 MDOT

The Michigan Department of Transportation maintains a substantial data base consisting of past survey records. These data should be obtained and checked. Particular attention should be paid to datums as many have been used throughout MDOT history.

MDOT maintains an office for an NGS National Geodetic Advisor. Telephone number is (517) 377-1510.

7.1.3 Local

Local records consisting of those acquired and maintained by public and private entities can serve as a valuable resource. It is the responsibility of the surveyor to evaluate and check data from all sources to ensure consistency and reliability.

7.2 Minimal Requirements for Horizontal and Vertical Primary Control

To establish primary horizontal control for the Michigan Department of Transportation, the Global Positioning System (GPS) is the method of choice.

7.2.1 Primary Horizontal Control Networks

Until further notice specifications found in "Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, Version 5.0"; Federal Geodetic Control Committee; Rockville, MD; 1988 should be used for MDOT primary control surveys, especially those whose points will be entered into the National Spatial Data Infrastructure. See **Part V, "The Global Positioning System"**.

Optimum results will occur when the following guidelines are adhered to.

1. Use control points that are of an accuracy standard equal to or better than that desired on the new points.

2. Use a minimum of three known horizontal control points and four known vertical control well disbursed throughout the network.

3. Datums are consistent.

    a. The values of horizontal control points known in NAD83(19XX) are used with vertical control points known in NAVD 1988.

b. Definition of horizontal coordinate values may change when NGS performs a readjustment. This is reflected in the datum definition of the control point. Users need to make sure that all horizontal points used for control conform to the same datum definition. Coordinates of a point defined on the NAD83(1994) datum may differ slightly from the same point defined on the NAD83(1996) datum. Be consistent.

4. Simultaneously observe points that are close together (less than 2 kilometers apart).

5. Independently observe all points two times and at least 10% of all points three times.

6. Keep new points within the perimeter of known control points.

7. Observe additional known horizontal and vertical control points to be used as check points.

8. When setting new points, keep the monumentation consistent with the accuracy of the desired results. This will insure repeatability at a later date.

9. Use the MDOT GPS Data sheet for observations on primary control networks. A sample form is included as **Annex B** to this chapter.

10. A minimally constrained least squares network adjustment is a measure of the quality of the observations. It should be performed first. If results are not satisfactory, insure that blunders have been eliminated and that systematic errors have been accounted for.

11. A properly constrained least squares network adjustment is a measure of the quality of the control. If results are unsatisfactory, observe additional control points.

12. Avoid using trivial vectors in the network adjustments. The estimated number of independent vectors available for a project can be estimated using the following formula (FGCC, 1988):

$$b = (r-1)s$$

Where: b = estimated number of independent vectors available

r = the number of GPS receivers used for each observing session

s = number of observing sessions scheduled for the project

Figure 7-1 shows the number of non-trivial vectors resulting from four receivers observing simultaneously for a single session..

$$b = (r-1)s$$
$$= (4-1)1$$

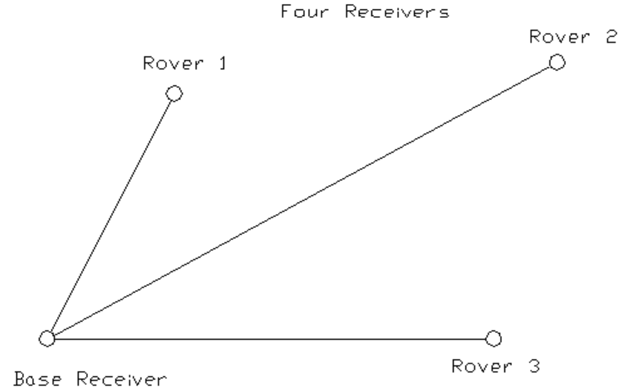
3 independent, non-trivial vectors

13. A minimum of two, independent three dimensional vectors must remain for each point in the network after both minimally constrained and fully constrained adjustments are performed. Vectors between fixed control points should not be used in the constrained adjustment.

> "An independent baseline measurement in an observing session is achieved when the data used are not simply different combinations of the same data used in computaton of other baseline vectors observed in that session." (ANSLIC, 1996)

14. Keep baseline distances under 40 kilometers for high accuracy surveys and adjust observation times accordingly. In a static mode, best results will be achieved with an observation time of one hour for the first 20 kilometers, then an additional thirty minutes for each ten kilometers of baseline length thereafter.

Figure 7-1
Non-Trivial Base Lines,
Four Receivers



15. GPS antenna heights should be measured and recorded in both English and metric units at three points along the perimeter of the antenna.

7.2.2 Primary Vertical Control Networks

Primary Vertical control is that used to densify existing first and second order NGS control and to provide a framework for further intermediate project control.

7.2.3 Standards of Accuracy

Primary vertical control shall meet Federal Geodetic Control Subcommittee (FGCS) Second Order, Class I standards. "Interim FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems" FGCSVERT (ver. 4.0 7/15/94) should be consulted for standards and specifications. Portions are reproduced in Tables 7-1 and 7-2 for convenience.

With bar-coded scale rods, the following observing sequence should be used:

Backsight
Backsight distance, standard error
Foresight
Foresight distance, standard error
Off-level/re-level
Foresight, standard error
Backsight, standard error.

Optimum results will be obtained when the following guidelines are adhered to.

1.1. Primary vertical control will be established by differential leveling using a digital level and calibrated invar level rods.

2. A minimum of four vertical reference control points, spaced throughout the network, certified as meeting or exceeding accuracy standards greater than or equal to the desired end results of the control net will be used.

3. Instruments will be checked daily by running the collimation program and storing acceptable results.

4. Leveling will begin and close on two of the benchmarks described above.

Table 7-1.
Level Network Geometry

Order	First	First	Second	Second	Third
Class	I	II	I	II	
Benchmark spacing not more than (km)	3	3	3	3	3
Average benchmark spacing not more than (km)	1.6	1.6	1.6	3.0	3.0
Line length between network control points not more than (km)	300[a]	100[a]	50[a]	50[a]	25[b]
Minimum benchmark ties	6	6	4	4	4

5. The distance from the leveling instrument to the backsight and to the foresight should be balanced within 10% of each other.

6. Sight distance will be no greater than 60 meters nor less than 10 meters.

7. All observations will be direct readings taken at least 0.50 meters above the base of the level rod.

8. Level rods will be held in a vertical position determined by the use of a level bubble. Level bubbles will be checked and adjusted as needed and at intervals consistent with those for the instrument.

9. Turning points shall be established on substantial objects to include marks on concrete or rock outcroppings, driven turn pins, turning plates (turtles) weighing at least 7 kg, or similar objects. Screw drivers, chaining pins or the like are not acceptable turning points.

10. New project benchmarks will be set at intervals not to exceed 500 meters.

Table 7-2
Field Procedures
Electronic Digital/Bar-Code Leveling Systems (Modified)

Order	First	First	Second	Second	Third
Class	I	II	I	II	
Section Running	DR, or MDS	DR, or MDS	DR	DR	DR
Difference of forward and backward sight lengths never to exceed: per setup (m) per section (m)	 2 4	 5 10	 5 10	 10 10	 10 10
Maximum sight length (m)[1]	50	60	60	70	90
Minimum ground clearance of line of sight (m)	0.5	0.5	0.5	0.5	0.5
Even number of setups when not using leveling rods with detailed calibration	Yes	Yes	Yes	Yes	....
Determine temperature gradient for the vertical range of the line of sight at each setup	Yes	Yes	Yes	....	....
Maximum section misclosure (mm)	$3\sqrt{D}$	$5\sqrt{D}$	$6\sqrt{D}$	$8\sqrt{D}$	$12\sqrt{D}$
Maximum loop misclosures (mm)	$4\sqrt{E}$	$5\sqrt{E}$	$6\sqrt{E}$	$8\sqrt{E}$	$12\sqrt{E}$
$\Delta h_1 - \Delta h_2$ for one setup not to exceed (mm) for MDS procedure	0.30	0.30	0.60	0.70	1.30
Use multiple reading option to obtain each observation - minimum number of readings	3	3	3	3	3

mm = millimeters
m = meters
D = Shortest one way length of section in km
E = Length of loop in km
DR = Double Run
MDS = Modified, Double Simultaneous Procedure.

Note: 1. Maximum sight length permitted unless the manufacturer recommends a maximum sight length which is less.

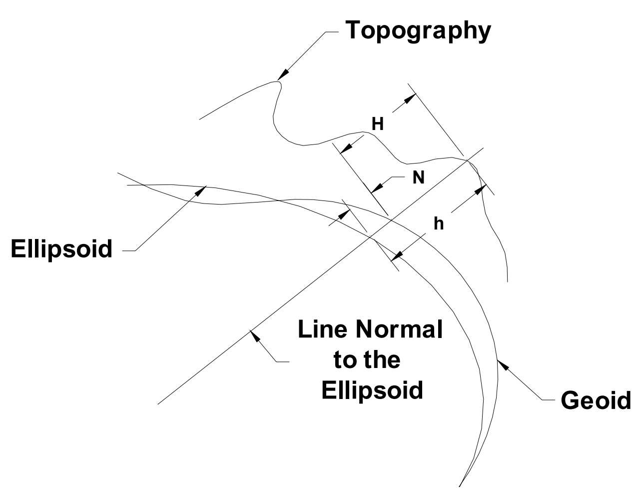
11. Properly weighted, single, simultaneous, minimally constrained and fully constrained least squares adjustments will be performed. Points not meeting desired standards will be re-observed from opposite directions.

7.2.4 GPS Heights

GPS is a three dimensional system. Total accuracy depends upon the accuracy of all components. The user must, therefore, factor in heights as well as known horizontal control. Orthometric heights are those derived from differential leveling and referenced to a datum such as NAVD 88. Ellipsoid heights relate to and are normal to the reference ellipsoid, currently the World Geodetic System (WGS) of 1984. Geoid heights are the differences between orthometric heights and ellipsoid heights.

Geoid height models such as GEOID 96 or GEOID 99 are readily available and are incorporated into many GPS processing packages. They will yield satisfactory results for many applications. Users may find it advantageous to develop local geoids which may be determined by taking the difference between the known orthometric height of a point and the known ellipsoid height of a point.

Figure 7.2
Height Transformation Options



H = Height above the Geoid, also known as orthometric height derived from differential leveling operations.

h = Height above the Ellipsoid, derived from GPS observations

N = The difference between geiod height and ellipsoid height, approximated by modeling packages such as GEOID 96/99 or derived from observations.

$$H = h - N$$

$$h = H + N$$

1. If the geoid is above the ellipsoid, N is positive
2. If the geoid is below the ellipsoid, as in Michigan, N is negative.

7.3 Reconnaissance and Monumentation

7.3.1 Primary Control Stations

Preferred primary control stations, both horizontal and vertical, are those of the National Spatial Reference System (NSRS). Recovery information documented in DDPROC*.HA data sheets shall be submitted for all NSRS control stations for which a search was conducted whether these stations were actually used in the survey or not. Knowing that a control station is erroneous or lost can be as valuable to future operations as knowing a station's current status.

7.3.2 Monumentation.

Monuments set for NSRS densification or for primary project control shall be permanent in nature and removed from proposed construction activity. An ideal monument is a metal disk, oriented North, set in a large bridge abutment or substantial rock out cropping. An acceptable monument consists of a metal disk, oriented North, set in poured concrete 1 foot in diameter, 5 feet deep, belled at the bottom.

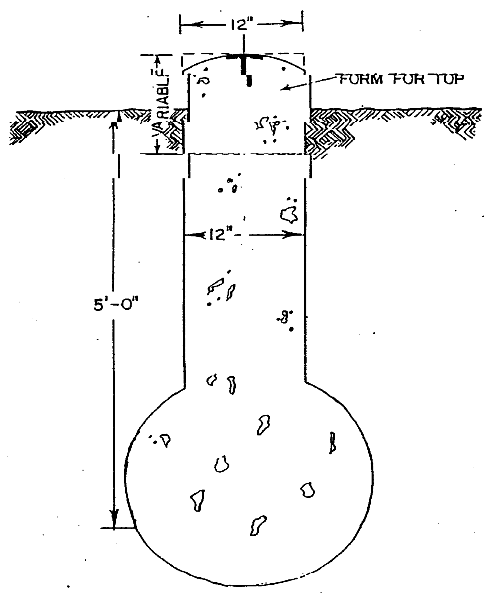
7.3.3 Monument Pairs

Control monuments are typically set in pairs, monuments in the pair being intervisible and located from 0.5 to 1 mile apart. Monument pairs are set at intervals between 3 to 10 miles apart or as needed.

The concrete monument is normally poured in place in a hole dug in the ground, using a top form only. The hole has a square or circular cross section depending upon the shape of the top form. It is dug to a depth of 5 feet (sufficient to extend below the frost line),then additional material is removed from the bottom to create the bell having a total diameter of about 18 inches.

Figure 7-3

Primary Control Monument



Concrete is poured and tamped in the hole until a level is reached where the top form is set. The form should be set before the last 1.0' of concrete is poured. The purpose of the form is to avoid shoulders on or mushrooming of the monument. The top of the monument shall be flush with the ground or protrude from 0.16' to 0.49' above the ground. The form is a simple device that can be fabricated from a cement bag with the top and bottom removed.

The top of the monument is smoothed and beveled with a trowel. The disk with the stamping oriented North is pressed into the center of the monument and recessed slightly.

7.3.4 Visibility Diagrams

Visibility diagrams shall be completed for each existing control point sought, found or set in the conduct of the control survey. Rubbings or detailed photographs shall be included. Standards shall conform to those used in DDPROC. A sample form is shown included as **Annex A** to this chapter.

7.3.5 Witnessing

Reference points will be established for all permanent monuments. Directions and a distances from the monument to the reference point shall be measured. A minimum of four reference points shall be established for each monument. Reference points should be permanent in nature, readily identifiable and surround the monument.

7.4 Michigan High Accuracy Reference Network (HARN)

The High Accuracy Reference Network (HARN) provides a system of horizontal control throughout the State of Michigan. These specially designated points were established to A or B order accuracies. Subsequent to the establishment of HARN, other points in the NSDI were adjusted to it. HARN datum (NAD83-1994) is the preferred datum for horizontal control for MDOT projects.

7.5 Documentation and Submission of Data to NOAA/NGS

Should it be necessary to submit primary control for inclusion into the NSDI coordination shall be made with the Design Surveys Supervising Surveyor and the MDOT National Geodetic Advisor.

7.6 Geodetic Network Accuracy Standards

7.6.1 Standards for Horizontal, Ellipsoid Height and Orthometric Height

Standards for geodetic control surveys shall conform to the model adapted from those developed by the Federal Geodetic Control Subcommittee/Federal Geographic Data Committee (FGDC-STD-007-1998) and reproduced in Table 7.3 below. These standards differ from the class and order system formerly used. References in this manual to specifications to achieve class and order standards are meant to be consistant with desired accuracy standards.

"The reporting standard in the horizontal component is the radius of a circle of uncertainty, such that the true or theoretical location of the point falls within that circle 95% of the time. The reporting standard in the vertical component is a linear uncertainty value, such that the true or theoretical location of the point falls within +/- of that linear uncertainty value 95% of the time."

Table 7.3 -- Accuracy Standards

Horizontal, Ellipsoid Height, and Orthometric Height

Accuracy Classification	95-Percent Confidence Less Than or Equal to:
1-Millimeter	0.001 meters
2-Millimeter	0.002 "
5-Millimeter	0.005 "
1-Centimeter	0.010 "
2-Centimeter	0.020 "
5-Centimeter	0.050 "
1-Decimeter	0.100 "
2-Decimeter	0.200 "
5-Decimeter	0.500 "
1-Meter	1.000 "
2-Meter	2.000 "
5-Meter	5.000 "
10-Meter	10.000 "

A data set may contain one set of accuracy values for the horizontal component and a different set of accuracy values for the vertical component. Accuracy values must be expressed in the same unit of measure (feet or meters) as the results of the survey proper. Table 7.4 relates the desired accuracy standard to the 95% confidence interval.

Table 7.4
Relationship Between Accuracy Standards
and 95% Confidence Intervals

Accuracy Classification	95% Confidence Interval	Remarks
	Less than or Equal to:	
sub- millimeter		Reserved for CORS
1 - millimeter	0.001 meters	Accuracy between 0 and 1mm
2 - millimeters	0.002 meters	Accuracy between 0 and 2mm
5 - millimeters	0.005 meters	Accuracy between 0 and 5mm
1 - centimeter	0.010 meters	Accuracy between 0 and 1cm
2 - centimeter	0.020 meters	etc.
5 - centimeter	0.500 meters	
1 - decimeter	0.100 meters	
2 - decimeter	0.200 meters	
5 - decimeter	0.500 meters	
1 - meter	1.000 meters	
2 - meter	2.000 meters	
5 - meter	5.000 meters	
10 - meter	10.000 meters	

Source: “Draft Geospatial Positioning Accuracy Standards; Federal Geographic Data Committee; January, 1997.

Providers and users must both fully understand the desired results before the survey is begun.

7.6.2 Accuracy Classification

FGDC standards define four steps leading to accuracy classification.

1. Examination of survey measurements, field records, sketches and other documentation to verify compliance with the specifications for the intended accuracy of the survey.

2. Reviewing the results of a minimally constrained, least squares adjustment of the survey measurements to ensure correct weighting of the observations and freedom from blunders.

3. Computing accuracy measures by weighting datum values in accordance with the network accuracies of the existing network control. This is in contrast to a constrained adjustment where coordinates are obtained by holding fixed the datum values in accordance with the network accuracies of the existing network control.

4. Checking the survey accuracy by comparing minimally constrained adjustment results against established control. The result must meet a 95% confidence level. If the comparison fails, then both the survey and network measurements must be scrutinized to determine the source of the problem.

Unacceptable statistical results means that there is a problem with either the survey or with the network control. **Randomly dithering weights to pass statistical tests is a practice that will not be accepted.** Find the problem, then readjust.

7.6.3 Estimating Positional Accuracy

FGCC standards use a circle of uncertainty rather than the classical error ellipse in determining the quality of survey results. Statistical and testing methodology may be found in "Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy"; Subcommittee for Base Cartographic Data, Federal Geographic Data Committee; Reston, VA; 1998.

7.7 Intermediate Project Control

Intermediate project control is that established for property surveys, alignment, mapping, photo control and similar applications.

7.7.1 Methodology (Horizontal)

Responsibility of achieving required accuracies lies with the field surveyor. Techniques may vary. For intermediate project control, the Global Positioning System, classical traverse or a combination of the two may be used. In designing a survey it must be realized that intermediate project control results can never be better than the primary control used and thus the surveyor must be certain that the primary control used must be of a quality better than or at least equal to the desired results.

7.7.2 Standards of Accuracy

Alignment points and intermediate traverse points have a maximum radius of uncertainty of 0.07 feet or below at the 95% confidence level.

7.7.3 Classical Traversing

When using the traverse method for establishing intermediate project control, the following guidelines shall be adhered to.

1. Intermediate control traverses are to be closed and adjusted between two or more pairs of primary control points with known coordinates.
2. All intermediate control points are either part of the traverse (occupied) or measured from at least two points that are part of the traverse. Open ended traverses are not acceptable.
3. Distances between traverse points should not be less that 300 feet.
4. No distance shall be adjusted by more than a ratio of 50 parts per million of that distance nor shall any angle be adjusted by more than 5 seconds.
5. Targets shall be attached to tribrachs and mounted on tripods.
6. Horizontal distances shall be measured twice, once in a forsight mode, once in a backsight mode.

7. Horizontal angles shall be measured twice in the direct position, twice in the reversed position.

8. Zenith angles shall be measured once direct and once reversed.

9. Intermediate control traverses shall be analyzed and adjusted by a suitable least squares adjustment program acceptable to the Supervising Land Surveyor, MDOT Design Division.

7.7.4 GPS

When using GPS to establish intermediate project control, the following guidelines shall be adhered to.

1. GPS observations shall conform to the specifications for intermediate control surveys and meet standards consistent with intermediate control traverses.

2. GPS intermediate horizontal control surveys shall be tied into three known horizontal control points and four known vertical control points published by NGS or established by primary horizontal/vertical control surveying methods.

3. GPS horizontal control shall form a network with at least 20% of all points being occupied twice. Points less than 1 mile apart shall be occupied simultaneously.

4. Minimally constrained and fully constrained least squares adjustments shall be performed. Vectors containing normalized residuals of 2 or higher in any component shall be removed and the network readjusted. Two vectors shall remain for each intermediate project control point.

5. Maximum standard deviation for any coordinate shall not exceed +/-0.01 feet. The radius of the circle of uncertainty at the 95% confidence region shall not exceed 0.07 feet.

6. Final coordinates shall be derived from a fully constrained least squares network adjustment holding three primary control horizontal points and four vertical control points as fixed.

7.7.5 Combined Observations

Classical surveying observations may be combined with GPS vectors in performing intermediate project control surveys. Further details may e found in **Appendix H**: “GPS/Classical Integration”. The software used in combining observations must be capable of rigorous least squares adjustment and must be approved by the MDOT survey project manager.

7.7.6 Monumentation of Intermediate Control

When establishing alignment, no less that two intervisible horizontal control points no more than one kilometer apart shall be established along each tangent. Sufficient control points shall be established to permit construction survey crews to stake out the alignment without further traverse. Control points should be established at all Points of Intersection, Points of Curvature, Points of Tangency at at intersections with U.S. Public Land Survey System (PLSS) control lines.

A 18 inch long #4 or larger reinforcing rod may be set in hard surface roads preferably protected by a monument box with cover. The type of monument to be used off of a hard surface road shall be 3 feet long #4 or larger reinforcing rod capped with a device identifying the surveyor. A chiseled “+” in a massive concrete structure or rock outcropping is acceptable. If points are corners of the PLSS, requirements of P.A. 74 of 1970 as amended shall be adhered to. The setting of parallel offset points is permitted providing that such points are clearly identified in the surveyor’s report.

No less than four witnesses will be established for all intermediate control points. A witness shall consist of a direction observed to the dearest degree and distance measured to the nearest hundredth of a foot from the intermediate control point to the witness point.

7.8 Intermediate Vertical Control

7.8.1 Standard of Accuracy

Intermediate vertical project control networks shall meet an unadjusted error of closure not greater than 0.06 feet times the square root of the distance leveled in miles, unless otherwise directed. Benchmarks will be set at intervals not to exceed 1640 feet. Networks shall begin and end on at least two NGS published benchmarks or benchmarks set to MDOT primary control standards.

Adjustments shall be made using rigorous, least squares methodology acceptable to the

Supervising Surveyor, Design Surveys and only when raw data meets standards. The maximum standard deviation on any benchmark elevation shall not exceed +/- 0.07 feet. Portions of networks not meeting standards shall be re-observed in an opposite direction and if no blunders can be determined, additional known benchmarks shall be observed. All points in the network shall be contained in a single, simultaneous, properly constrained adjustment.

7.8.2 Methodology

Surveys to establish intermediate vertical control will most likely meet minimum standards of the following guidelines are adhered to.

1. Leveling instruments shall be tested at the beginning of each project and adjusted if necessary then at 20 day intervals for the duration of the project.

2. Leveling will begin and close on NGS first or second order vertical control points or on points established by MDOT standards for primary vertical control. Third order points or the adjusted values on points meeting these standards combined with at least one higher order point may be used if MDOT accuracy standards can still be met.

3. All project benchmarks must be part of the network. “Side shots” are not acceptable.

4. Turning points shall be established on substantial objects to include marks on concrete or rock outcroppings, driven turn pins, “turtles” or similar objects. Screw drivers, chaining pins or the like are not acceptable turning points.

5. Sight distances shall be no greater than 200 feet nor less than 30 feet. Backsights and foresights shall be ballanced to within 10% their respective distances.

6. Level rods must be held vertically. All observations shall be direct readings taken at a distance of no less than 1.5 feet from the base of the rod.

7. Benchmark descriptions shall include the type of monument, stampings or unique identifying features, location by coordinates or station plus and out.

8. Photo targets lying within 300 feet of the level network shall be included in the level network.

7.9 Deliverables

As appropriate, the following documents will be submitted with all control surveys. Hard copies or digital copies as identified below will be transmitted.

A. Surveyor's Report (hard copy)

- Scope of Work
- Uncertainties in Control
- Uncertainties in Observations
- Uncertainties in Final Results
- Recommendations

B. Instrument Test Results (hard copy)

C. Reconnaissance Results (hard copy and digital in form of DDPROC*.HA file)

D. Photographs or Rubbings or All Primary Control Monuments Found or Set (hard copy)

E. Control Used (hard copy)

F. Network Diagram(s) (hard copy)

G. Observation Schedules (hard copy)

H. Field Notes/Sketches (hard copy)

I. Un-edited Observation Electronic Data Files (digital)

J. Explanation of a-priori weighting scheme (hard copy)

K. Results of Minimally Constrained Least Squares Adjustment (hard copy, digital)

L. Results of Fully Constrained Least Squares Adjustment (hard copy, digital)

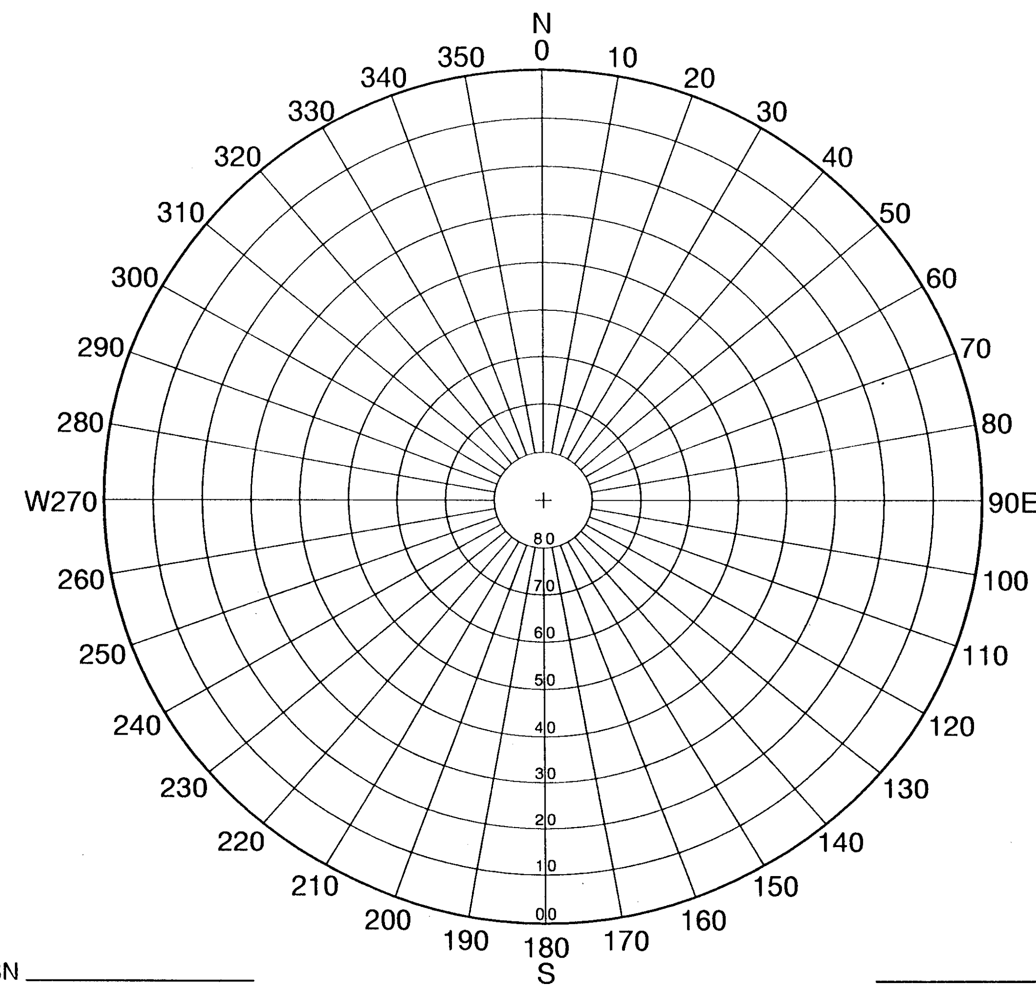
M Coordinate List with Standard Deviations and 95% Radii of Uncertainty (hard copy, digital)

N. Elevation List with Standard Deviations and 95% Confidence Intervals (hard copy, digital)

O. Point Descriptions and Witness Lists (hard copy, digital copy)

Annex A, Part VII, Visibility Diagram (A)

STATION VISIBILITY DIAGRAM



SSN ____________________   ________________ DATE

PID ____________________   ________________ ORGANIZATION

ELEVATION ____________ m. ft.   ____________________ MAP SCALE

LATITUDE __________________________   ____________________________ MAP SHEET

LONGITUDE __________________________   ____________________________ OBSERVER

STATION NAME ______________________________________

Observer's height __________ ft. in. m.
at time of observations

Notes:

Indicate distance, direction, frequency and power of known RF sources
Show peripheral marks and required ties
Show distance to nearest edge of all obstructions exceeding 20 degrees or
indicate antenna height needed to clear 20 degrees.

Annex A, Part VII, Visibility Diagram (B)

GEODETIC CONTROL STATION DESCRIPTION

10* SSN ______ DR CODE ____ REC CODE ____ LAT __________ LON __________ APPROX ELEV __________
QUAD ________________ STATE/COUNTY ___ / ________________ APP ______ PID ___________
13* DESIGNATION ________________________
UNDERGROUND MARKER TYPE _____ MAG CODE _____ SET CODE ____ TR CODE ___ PACK TIME __ : ______
15* ALIAS ____________
20* CODE/SET BY __ / __________ YEAR ______ CHIEF __________
CODE/RECOVERY __ / __________ DATE ____ / ____ / ____ CHIEF ______ CONDITION __________
28* TYPE _____ MAG CODE _____ CODE/SETTING ____ / __________
STABILITY CODE ______ AGENCY INSCRIPTION __________
28* STAMPING ____

STATION IS LOCATED ____

TO REACH FROM ____

STATION IS ____

Annex B, Part VII, GPS Data Sheet

G P S D A T A S H E E T

MARK STAMPED:____________________   STATION SPN:__ __ __ _

UNIQUE IDENT:____________   ____/____/____ (JULIAN DAY)   __________ (YEAR)

SESSION ( )

ANTENNA HEIGHT:		FEET	METERS		FEET	METERS
BEFORE:	TAPE	___.___	___.___	AFTER:	___.___	___.___
	ROD	___.___	___.___		___.___	___.___

SESSION ( )

ANTENNA HEIGHT:		FEET	METERS		FEET	METERS
BEFORE:	TAPE	___.___	___.___	AFTER:	___.___	___.___
	ROD	___.___	___.___		___.___	___.___

NOTE: **DO NOT FILL IN THIS BOX IN THE FIELD**

LAT. ____ ___ ___.________N   LON. 0 ___ ___ ___.________W

ELEVATION: ________.______ METERS

(CIRCLE ONE)
M = Map, Barometeric or scaling
V = Non-reciprocal vertical angle
E = Derived from ellipsoidal height
B = Known bench mark elevation

OBSERVER'S INITIALS: ___ ___ ___

(CIRCLE ONE):
RECEIVER COLOR: 001=WHITE 002=GREEN 003=RED 004=BLUE

LENGTH OF CABLE USED: 10 METER 30 METER

COMMENTS:____

DATE OF OCCUPATION: __ __ ____

	SESSION ( )	SESSION ( )
LOCAL TIME:	____:____to____:____	____:____to____:____
UTC TIME:	____:____to____:____	____:____to____:____

(+ 5 HOURS EST or + 4 DST)

WEATHER: __ __ __ __ __ / __ __ __ __ __ (SEE WEATHER CODES)
(BEFORE) (AFTER)

Annex C, Part VII, NGS Software

ADJUST ***(Version 4.12)*** [**manual available**]

Performs a least squares adjustment on horizontal, vertical angle, and/or GPS observations. The program comprises six data checking programs in addition to the adjustment software. This software package has numerous options, such as choice of ellipsoid, and includes sample input data. The **source code** is also available.

ADJUST UTILITIES

Suite of programs that are used in conjunction with PC program ADJUST. This group of programs includes:

BBACCUR which provides a formatted listing of the external and internal accuracies which have been computed by program ADJUST-- sorted in numerical ascending order of external accuracy. Output from program ADJUST, run with accuracies, is used as input.

CLUSTER used to identify geodetic stations which are common to two data sets with respect to name or a given position tolerance.

ELEVUP creates a bfile which combines the bfile output from the constrained horizontal adjustment with the bfile output from the constrained vertical adjustment. This new bfile contains *80* records with adjusted positions from the horizontal and *86* records with the ellipsoidal heights from the horizontal adjustment and the orthometric heights and geoid heights from the vertical adjustment.

ELLACC which computes ellipsoidal height order and class for a project. Output from program ADJUST, run with accuracies, is used as input.

MAKE86 which adds *86* records to the bfile. If the existing *80* records contain orthometric heights, these are added to the new *86* records.

MODGEE scales the standard errors assigned to the observations in the gfile. Input is a gfile and the scaling factor.

QQRECORD adds qq records to the Afile (used by program ADJUST) to compute accuracies for all observed lines. Either the gfile (for GPS projects) or the bfile (for classical terrestrial projects) can be used as input.

CALIBRAT *(Version 1.0)*

This program is used to determine the scale and constant corrections for electronic distance measuring instruments by making measurements over previously determined base lines. The formulas used in the program are found in NOAA Technical Memorandum NOS NGS-10, "Use of Calibration Base Lines."

COMPGB *(Version 1.1)*

Tests the consistency and compatibility of the Blue Book B file (GPS project and station occupation data) and G file (GPS vector data transfer file).

CR8BB *(Version 4.0)*

Reformats GPS project information to fit the requirements of the National Geodetic Survey data base. The file created, which is called the B-file, contains project information, station information, and survey measurements. The CR8BB software functions independently of the type of GPS receivers used in a project.

CR8G *(Version 1.1)*

Formats reduced vector data to Blue Book specifications.

CR8SER *(Version 1.1)*

Extracts data from GPS Blue Book G file to create a station serial number file (serfil) for GPS observations.

DDPROC *(Version 3.00.01)*

The DDPROC Program organizes control point descriptions in accordance with the National Geodetic Survey's new (description file (D-FILE) format. Users may still use **DDPROC V2.33** [**manual available**] to submit descriptions in the unified description format to NGS, or they may use the programs contained in DDPROC V03.00.00 to submit descriptions in D-FILE format.

DEFLEC96 ***(Version 3.10)***

Computes deflections of the vertical and Laplace corrections for the conterminous United States, Alaska, Puerto Rico, Virgin Islands, and Hawaii.

DSPLOT ***(Version 1.4)***

Digital Data Sheet (DSDATA) plot program. Used to plot DSX created index files on the terminal screen. DSX is the DSDATA extraction program. Although DSPLOT was primarily developed to work with DSDATA and DSX, the program will plot any file which is in the same format as a DSX created index file. The documentation file DSPLOT.DOT contains a sample of this format. cost: Free with purchase of DSDATA

DSSELECT ***(Version 3.4)***

Digital Data Sheet (DSDATA) Data Item Selection program. Allows for extraction of various data items from a DSDATA file into a separate file. Output is one record per station with data items separated by a delimiter for easy database loading. cost: Free with purchase of DSDATA

DSWIN ***(Version 1.8)***

DSWIN is windows based software for Data Sheet view and extraction. It displays a list of county names as found on your CD-ROM. Click on a county and a list of stations appears. Click on a station from the list and a data sheet appears. You may save the data sheet to a file or print it. The search feature allows for filtering the station list by: Point Radius, Min/Max Box, Station Name, or PID. You may also filter by type of control, such as 1st order bench marks only

DSX ***(Version 6.04)***

Digital Data Sheet (DSDATA) extraction program. Extracts individual of groups of data from a DSDATA file. Includes options to extract by Station Identifier, Station Name, Area, and more. Also includes utilities for manipulating the data such as joining two of more DSDATA files or splitting a DSDATA file into smaller files. cost: Free with purchase of DSDATA

ENHANCEMENTS ***(Version 20)*** [**manual available**]

Performs field check computations, such as tape standardization, eccentric reduction, datum transformation, triangle (plane, spherical, geodetic), special (three-point fix, intersection, resection), geodetic (traverse, inverse, direct) computations, solar observation for azimuth, and State plane coordinate system computations on the NAD 27 and NAD 83 datums.

GAPP ***(Version 2.1)***

The GPS-Assisted Phototriangulation Package (GAPP) performs aero- triangulation adjustments that incorporate observations of the position of a GPS antenna mounted on an aircraft. GAPP can also be used to adjust conventional aerotriangulation data.

GEOID96 ***(Version 3.10)***

Computes geoid height values for the conterminous United States, Alaska, Puerto Rico, Virgin Islands, and Hawaii. Suitable for conversion of NAD83 GPS ellipsoidal heights into NAVD88 orthometric heights.

G96SSS ***(Version 3.10)***

Computes geoid height values for the conterminous United States. Gravimetric geoid for scientific studies.

GPPCGP ***(Version 2.0)***

Converts NAD 27 State plane coordinates to NAD 27 geographic positions (latitudes and longitudes) and conversely. Includes defining constants for all NAD 27 plane coordinate zones.

HTDP ***(Version 2.2)***

This horizontal time-dependent positioning software program allows users to predict horizontal displacements and/or velocities at locations throughout the United States. This software also enables users to update geodetic coordinates and/or observations from one date to another.

INTERORB ***(Version 1.0)***

Interpolates binary GPS orbit files with a record length of 52.

INVERSE/FORWARD3D ***(Version 1.0)***

Comprises four programs - Inverse (Version 2.0) which computes the geodetic azimuth and distance between two points, given their geographic positions; Forward (Version 2.0) which computes the geographic position of a point, given the geodetic azimuth and distance from a point with known geographic position; and the three-dimensional versions of these programs . INVERS3D (Version 1.0) and FORWRD3D (Version 1.0), which include the height component.

LOOP ***(Version 4.03)***

Determines the loop misclosures of GPS base lines using the delta x, delta y, delta z vector components computed from a group of observing sessions.

LVL_DH ***(Version 2.0)***

Estimates the leveled height difference between two bench marks by removing the orthometric correction from the differences of published heights.

MTEN4 ***(Version 20)*** [**manual available**]

Computes and verifies classical horizontal field observations (angles and distances), and formats these data to conform to Blue Book specifications. MTEN4 does not adjust field observations, but performs certain field check computations, but performs certain field check computations such as triangle computations, distance reductions, and trigonometric height computations, distance reductions, and trigonometric height computations. MTEN4 allows four-digit station numbers and new position codes set forth in the Blue Book.

NADCON ***(Version 2.1)*** [**manual available**]

Transforms geographic coordinates between the NAD 27, Old Hawaiian, Puerto Rico, or Alaska Island datums and NAD 83 values. Recommended for converting coordinate data for mapping, low-accuracy surveying, or navigation.

PCVOBS ***(Version 2.10)***

Simplifies entering vertical observation data records into Blue Book format. The program formats the data onto a computer disk which can then be sent to NGS for further processing and incorporation of the data into the National Geodetic Reference System.

PROMPTER ***(Version 1.0)***

Creates horizontal control point records in Blue Book format with geodetic positions in geographic coordinates, state plane coordinates, or Universal Transverse Mercator coordinates.

SPCS83 ***(Version 2.0)***

Converts NAD 83 state plane coordinates to NAD 83 geographic positions and conversely. Includes defining constants for NAD 83 coordinate zones. State plane coordinates are entered or computed to 1 mm accuracy, while the latitudes and longitudes entered or computed correspond to approximately 0.3 mm accuracy.

TOLADD ***(Version 1.0)***

Adds a user-specified shift in seconds to each input latitude and longitude.

UTMS ***(Version 1.1)***

Converts geographic coordinates (latitudes and longitudes) on the Clarke 1866, GRS 80/WGS 84, International, WGS 72, or any user-defined reference ellipsoid to Universal Transverse Mercator (UTM) coordinates, and vice-versa.

VERTCON ***(Version 2.0)***

Computes the modeled difference in orthometric height between the North American Vertical Datum of 1988 (NAVD 88) and the National Geodetic Vertical Datum of 1929 (NGVD 29) for a given location specified by latitude and longitude. This conversion is sufficient for many mapping purposes.

VFPROC ***(Version 3.33)*** [**manual available**]

Computes and verifies vertical field observations(leveling data), and formats these data to conform to Blue Book specifications. VFPROC does not perform a least squares adjustment, but checks the observational and descriptive data for completeness and consistency.

Technical Manuals are available for the following programs:

- ADJUST
- DDPROC
- ENHANCEMENTS
- MTEN4
- NADCON
- VFPROC

Contact NGS Information Services for prices

Part VII Bibliography

Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, Version 5.0. Rockville. Maryland: Federal Geodetic Control Committee, 1988.

Hoffman-Wellenhof, B., H. Lichtenegger, and J. Collins. *GPS Theory and Practice*. 2nd ed. New York, New York: Springer-Verlag, 1993.

Interim FGCS Specifications and Procedures to Incorporate Electronic Digital/Bar Code Leveling Systems. Silver Spring, Maryland: NOAA, National Geodetic Survey, 1994.

Leick, Alfred. *GPS Satellite Surveying*. New York, New York: John Wiley and Sons, 1990.

National Spatial Data Infrastructure Geospatial Positioning Accuracy Standards. Reston, Virginia: Federal Geodetic Control Subcommittee, Federal Geographic Data Committee, U.S. Geological Survey, 1998.

Standards and Practices for Control Surveys. Bruce, ACT: The Intergovernmental Committee on Surveying and Mapping, Australian Surveying and Land Information Group, 1997.

Van Sickle, Jan. *GPS for Land Surveyors*. Chelsea, Michigan: Ann Arbor Press, Inc.,1996.

Standards of Practice (Interim). Lansing, Michigan: Michigan Department of Transportation, 1998.

Standards and Practices for Control Surveys.

http://www.anzlic.org.au/icsm/publications/sp1/sp1.htm

Wells, David, Norman Beck, Demitris Delikaraoglou, Alfred Kleusberg, Edward J. Krakkiwski, Gerard Lachapelle, Richard B. Langley, Mete Nakiboglu, Klaus-Peter Schwarz, Hames M. Tranquilla, Petr Vanicek. *Guide to GPS* Positioning. Fredericton, New Brunswick, Canada: Canadian GPS Associates, 1987.