Scope of Work

HEIGHT MODERNIZATION
PRIMARY BASE NETWORK 'Zone 2-East' SURVEY PLAN

Project Title is "**Primary Base Network - Zone 2-East"**

Summary

This survey is a Dept. of Natural Resources (DNR) Height Modernization contract, which will be implemented through a Memorandum of Understanding with the SRCW. Work will be completed through a qualifications based professional services contract and funded with NOAA Height Modernization Award No. NA08NOS4000362. The survey consists of all global positioning system (GPS) measurements and adjustments necessary to derive Order 'A' NAD83 (NSRS2007) latitude & longitude and 2 cm or better precision NAVD88 ellipsoid heights on 12 existing 1st & 2nd Order benchmarks. The project extent is defined by a maximum latitude 49° 00' 00" N, the minimum latitude 47° 02' 00" N, the maximum longitude 119° 32' 00" W, and the minimum longitude 117° 02' 00" W and covers portions of 6 Counties. This project will require approximately 18, 6-hour sessions using 6 GPS receivers. Approximately 7 National Spatial Reference System A- and B-order three-dimensional control stations will be used to control the survey. Additional vectors will be measured from continuously operating reference stations that are part of the NGS CORS network, NGS Co-Op CORS network, Plate Boundary Observatory, and the Washington State Reference Network (WSRN), which constitute the primary geodetic project control.

Additional to the processing, adjustment and analysis of Zone 2, all WSRN stations within Zone 2 will be incorporated into the network and submitted to the NGS as new stations.

Deliverables

Any and all written reports, survey records and other written documents (deliverables) referenced in this scope of work shall be due from the A/E by December 31, 2009. All required deliverables must be delivered to the National Geodetic Survey, Observations and Analysis Division at this address:

NOAA/NGS
SSMC 3 Station 8400 Attn: Deb Brown
1315 East West Highway
Silver Spring, MD 20910

and a digital copy delivered to the DNR Project Manager at david.steele@dnr.wa.gov or PO Box 47030, Olympia, WA 98504-7030. All oral reports must be presented at the location requested by the DNR.

Acceptance

Upon delivery of the work, the deliverables specified in this Scope of Work will be reviewed for completeness and compliance with the contract by the DNR project manager. This review will be completed within ten (10) working days of receipt of the final product and a written acceptance report sent to the A/E.

The project **time period** is proposed for July-December 2009. For the State of Washington the project manager shall be:

David Steele, PLS
Geodetic Survey Director
DNR, Engineering Division
PO Box 47030
Olympia, WA 98504-7030
360-902-1171 office
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David.Steele@dnr.wa.gov

Control Station Table This is a list of all available FBN, CBN, PAC, and HARN control in the project area. Stations shown in bold type are preferred because of stability, good network accuracy, best sky visibility, or spacing. Coordinates listed are NAD83 (NSRS 2007). Recovery details and photos are available for all of these stations, recovered during 2008.

PID	Designation	Control Type	Network Acc. –cm N, E, ellipsoid	Vert Order, Stability	Latitude	Longitude
Zone 2 Stations and Zone 3 Connections						
SV0680	**FELTS**	**CBN**	**0.55 0.51 1.37**	**1st C**	**47 39 58.21623(N)**	**117 19 05.42499(W)**
SV0760	Z 231	FBN	0.63 0.61 1.31	1st A	47 58 09.35205(N)	117 19 58.46253(W)
SW0500	J 388	CBN	2.12 1.55 6.00	2nd A	47 37 10.51105(N)	119 18 30.22416(W)
SW1017	**K 510**	**CBN**	**1.27 1.10 2.74**	**1st A**	**47 55 29.01425(N)**	**118 57 20.48312(W)**
TO0325	**R 46**	**CBN**	**1.29 1.23 2.61**	**1st C**	**48 41 54.81398(N)**	**117 24 38.95132(W)**
TO0445	**K 24**	**HARN**	**0.73 0.55 1.61**	**1st C**	**48 12 27.50330(N)**	**117 43 53.77708(W)**
TO0496	**L 280**	**CBN**	**1.61 1.49 3.25**	**1st C**	**48 55 34.58713(N)**	**117 46 48.02495(W)**
TO0513	**Z 264**	**FBN**	**0.49 0.37 1.16**	**1st C**	**48 32 29.33414(N)**	**117 53 15.09591(W)**
TO0718	Y 481	CBN	1.27 1.22 2.43	1st B	48 21 24.59944(N)	117 18 17.37024(W)
TO1166	**JUSTICE**	**FBN**	**0.47 0.35 1.04**	**2nd C**	**48 10 45.15219(N)**	**117 03 31.07929(W)**
TP0881	P 513	FBN	0.57 0.39 1.31	1st B	48 41 39.41533(N)	119 27 05.80759(W)
TP0722	F 395	CBN	2.06 1.72 4.08	2nd C	48 32 38.98140(N)	119 44 24.29893(W)
TP1393	CIA	CBN	1.22 1.10 2.70	2nd A	48 08 05.23862(N)	118 58 26.08422(W)
TP1394	NW VLBA	FBN	0.49 0.37 1.18	2nd C	48 07 51.03009(N)	119 40 57.70815(W)

Primary Base Station Network Table This is a list of stations at which to establish 3-D positions in the project area. Recovery details and photos are available for all of these stations recovered during 2008. The coordinates listed were acquired using a navigation quality GPS receiver and should get you to the marks.

PID	Designation	Control Type	Vert Order, Stability	Latitude	Longitude
Zone 2 –New Stations and Zone 3 Connections					
SV0393	M 134	benchmark	2nd C	47 52 05. (N)	116 44 36. (W)
SV0955	X 204	benchmark	2nd C	47 45 09. (N)	117 51 29. (W)
SW0047	Q 57	benchmark	2nd C	47 40 50. (N)	118 22 32. (W)
SW0368	S 284	benchmark	1st C	47 56 59. (N)	118 41 27. (W)
SW0987	F 509	benchmark	1st B	47 35 43. (N)	118 47 09. (W)
TO0264	N 283	benchmark	1st C	48 23 03. (N)	116 58 50. (W)
TO0493	M 236	benchmark	1st C	48 48 38. (N)	117 59 49. (W)
TO0750	G 483	benchmark	1st B	48 52 23. (N)	117 21 09. (W)
TP0003	Z 22	benchmark	1st A	48 58 45. (N)	118 13 32. (W)
TP0099	S 281	benchmark	1st C	48 35 56. (N)	118 20 53. (W)
TP0172	V 31	benchmark	1st C	48 05 19. (N)	118 03 32. (W)
TP0186	F 30	benchmark	1st C	48 11 24. (N)	118 48 16. (W)
TP0294	20 56	benchmark	1st C	48 36 16. (N)	118 36 09. (W)
TP0793	T 511	benchmark	1st A	48 09 04. (N)	119 19 03. (W)
TP0808	J 512	benchmark	1st B	48 22 04. (N)	119 29 25. (W)

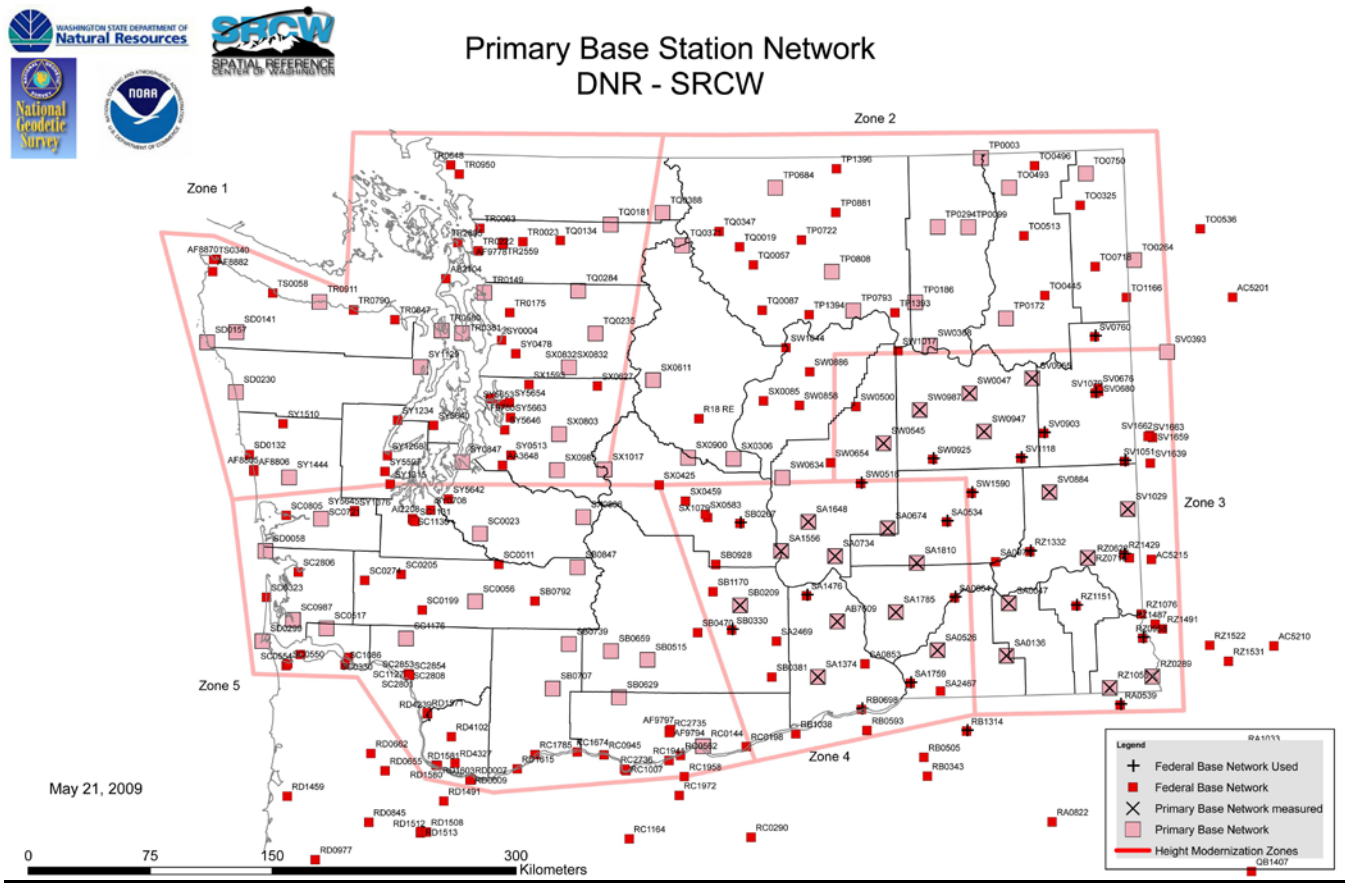
Station Recovery Notes

All recoveries from were made during 2008 and **have not** been reported to NGS.

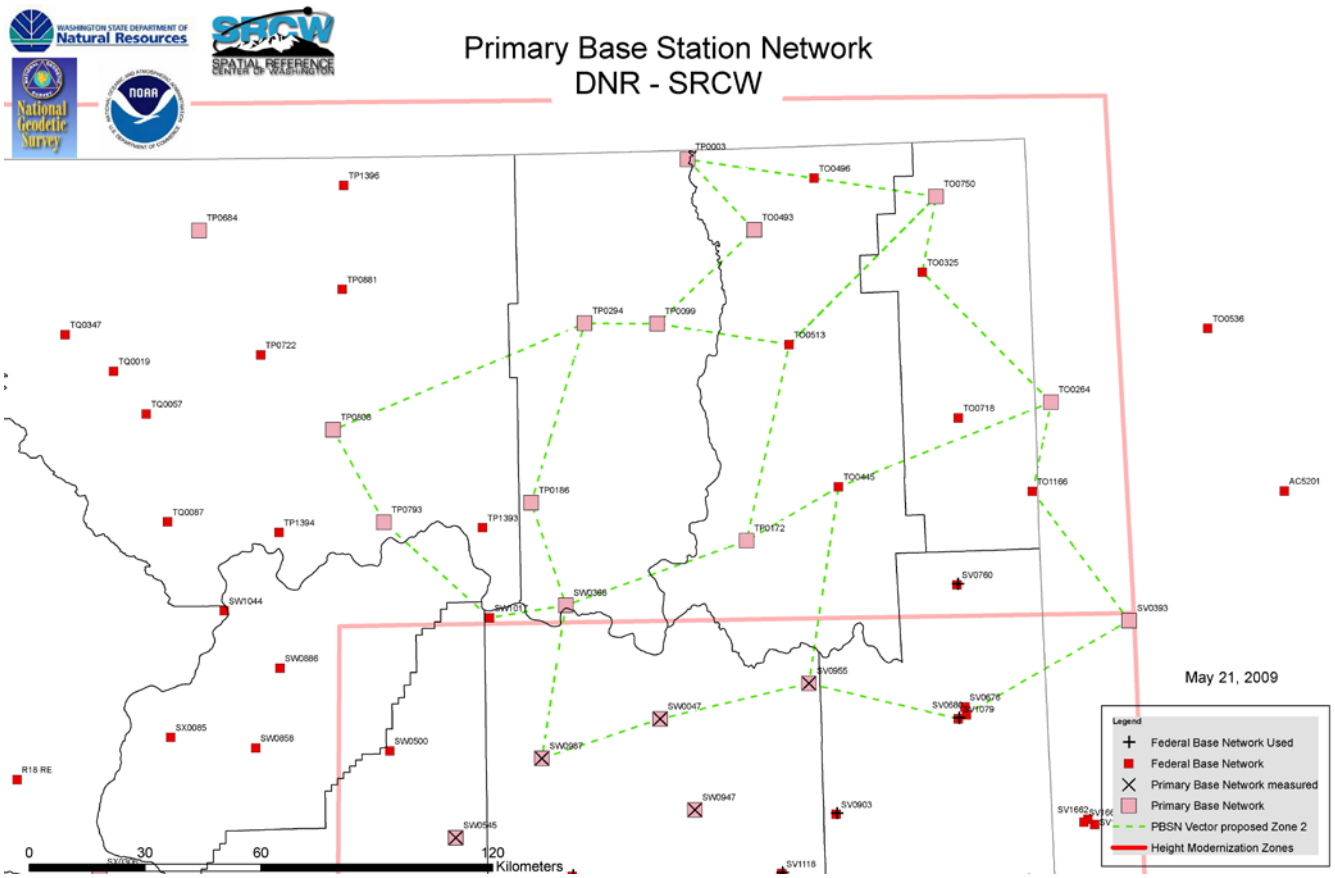
GPS satellite visibility diagrams

Recovery details (a separate document) include obstruction comments for all stations recovered during 2008. All stations listed above have adequate sky visibility to be useable for high order GPS measurements.

Primary Base Network Zones Figure 1



Primary Base Network -Zone 2 session planning Figure 2



Instrumentation This project will follow guidance from "Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques" Version 5.0 to achieve Order A positional quality and "Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm) Version 4.3" also known as NOAA Technical Memorandum NOS NGS-58 to achieve 2 cm or better ellipsoid heights. Since this project is intended to establish 2 cm or better precision ellipsoid heights on Primary Control Stations only, specific details have been copied from NGS-58 for simplicity.

The following requirements are for 2-centimeter standards.

a. Dual-frequency, full-wavelength GPS receivers are required for base lines greater than 10 km and are the preferred type of GPS receiver for all observations, regardless of base-line distance. Geodetic-quality antennas with ground planes are required. Whenever possible, antennas used during a project should be identical; otherwise corrections must be made for antenna phase patterns. Different makes and models of antennas have different antenna phase patterns. If antenna phase patterns are not accounted for, mixing different antennas in a project can cause vertical discrepancies of as much as 10 cm.

b. The manufacturer, model, and complete serial numbers of all receivers and antennas must be included on each station Session Observation Log.

Observing Procedure The survey shall be referenced to at least three existing National Spatial Reference System A- or B-order three-dimensional control stations near the project area (listed in tables on pages 1 and 2 of this plan). The survey will also consist of 12 new primary base stations, all of which are existing 1st and 2nd order NGS benchmarks.

A sample project with observing scheme is depicted in figure 2 located, on page 4 of this plan.

For control stations and primary base stations, receivers shall collect data continuously and simultaneously for at least three, 6-hour sessions (longer than the minimum specification to ensure adequate data) on at least 2 different days and different times during each day.

Detailed GPS observation plan

The observing scheme for all **primary base stations** requires that each primary base station must be connected to at least its two nearest primary base station neighbors and nearest control station according to the observing procedure stated above. Primary base stations must be traceable back to two control stations along independent paths.

The observing scheme for **all** stations requires that all adjacent stations (base lines) be observed at least three times on 3 different days and at different times of the day. The purpose is to ensure different atmospheric conditions (different days) and significantly different satellite geometry (different times) for the base line measurements.

For Example; observations on the second day should be completed between 27 and 33 hours after the completion of the first day's observations if the first day's observations were begun **prior to** 12:00 noon. **Or**, the observations should be completed between 15 and 21 hours after the completion of the first day's observations if the first day's observations were begun **after** 12:00 noon. This is necessary since the satellite constellation geometry repeats itself every 12 hours.

Examples:	First-day observations	Second-day observations
	Begun during:	**Completed anytime between:**
	8:00 a.m. to 8:30 a.m.	11:30 a.m. and 5:30 p.m.
	10:30 a.m. to 11:00 a.m.	2:00 p.m. and 8:00 p.m.
	1:00 p.m. to 1:30 p.m.	4:30 a.m. and 10:00 a.m.
	3:30 p.m. to 4:00 p.m.	7:00 a.m. and 12:30 p.m.

(Note that the second day of observations does not need to follow immediately after the first day. Satellite geometry moves ahead, or precesses, 4 minutes per day. If the second observations are not performed within 1 week of the first, this daily 4-minute change must be accounted for when meeting the different satellite geometry requirement.)

Selection of control stations for the current project shall be limited to: High Precision Geodetic Network (HPGN)/HARN; either Federal Base Network (FBN) or Cooperative Base Network (CBN) stations, which are 1st or 2nd Order bench marks of A- or B-stability quality or other stations that meet those accuracy standards.

Coordinate observations with local, existing NGS CORS and WSRN Stations, which are collecting phase data with dual-frequency receivers.

Meteorological data must be collected at the control stations and primary base stations. Weather data consist of wet- and dry-bulb temperatures (or dry-bulb temperature and relative humidity) and atmospheric pressure. For sessions greater than 2 hours, record weather data at the beginning, middle, and end of each session. Meteorological data shall also be collected immediately after an obvious weather front passes during a session and also immediately before it passes, if possible. Atmospheric pressure measurements must be made at approximately the same height as the GPS antenna phase center. Record on the observing log the time and where the weather data were gathered and any abnormal weather conditions. (Note that even though all of these data may not used in the vector processing, they may be helpful during the analysis of the results and in future reprocessing with more robust software.)

Before taking weather observations, the meteorological instruments should be allowed ample time (approximately 10 minutes) to stabilize to ambient conditions. Observations of wet- and dry-bulb temperatures must be observed and recorded to at least the nearest 1 degree Celsius. Barometric readings must be observed and recorded to at least the nearest 1 millibar. Meteorological data should be collected at or near the antenna phase center. All equipment must be checked for proper calibration.

Antenna set-up is critical to the success of the project. Plumbing bubbles on the antenna pole of the fixed-height tripod must be shaded when plumbing is performed. Plumbing bubbles must be shaded for at least 3 minutes before checking and/or re-plumbing. The perpendicularity of the poles must be checked at the beginning of the project and any other time there is suspicion of a problem. For the 2-Centimeter Standard: **Fixed-height tripods are required for all receivers**.

A rubbing of the mark must be made or a photograph taken at each occupation of a station. When not feasible to make the required rubbing or photograph, a plan sketch of the mark must be substituted, accurately recording all markings.

Vector Processing:
Follow the guidelines in **Annex L: Guidelines for submitting GPS Relative Positioning Data.**

The following requirements are for 2-centimeter standards. A summary of the guidelines is listed in table 1 at the end of this section.

1. Final vector processing and quality review of collected data shall be accomplished using NGS' guidance in Annex L of "Input Formats and Specifications of the NGS Data Base".

2. Use precise ephemerides. NGS' precise ephemerides are available from the U.S. Coast Guard Bulletin Board System or the NGS World Wide Web site. The Coast Guard Bulletin Board System number is (703)313-5910 and the NGS web site address is http://www.ngs.noaa.gov The USCG web site address is http://www.navcen.uscg.mil/navcen.htm

3. For sessions greater than 30 minutes, process data using 30-second epoch intervals. (Note that using a smaller epoch interval may improve ease of data processing.)

4. For sessions greater than 30 minutes, use only satellite data tracked above the 15-degree elevation angle.

5. Final processing shall consist of **fixing all integers** for each vector for all sessions except to some control sites. For short base lines, under 10 km, the L1 fixed solution may be the best choice. For vectors greater than 40 km to control sites, a session may consist of a set of partially or completely fixed vectors and in the worst possible scenario may also include float solutions where no integers could be fixed.

A model to account for tropospheric effects must be used. The project report must state which model was used. Measured meteorological data should be used only when it has been determined that the instruments have been properly calibrated and the measurements accurately represent the current atmospheric conditions at the station. If standard meteorological data are used instead of actual measured values, the processing software must account for changes in standard default values due to the station's location and height above the vertical datum. For base lines greater than 15 kilometers or with "large" height differences, a relative tropospheric scale parameter should be solved for, along with the base line vector components.

6. The quality of collected data shall be determined from the double-difference residual plots and RMS values. Final coordinates and their quality assessment shall be determined by using least-squares adjustment software and by analysis of repeated vectors and free-adjustment residuals and loop misclosures (most loops consisting of repeated vectors).

7. RMS values for each computed base line (adjacent station pairs) must not exceed 1.5 cm.

8. Re-observation criteria:
For the 2-Centimeter Standard: For station pairs involving control stations, must re-observe any control station base line where the ellipsoid height difference between the repeat observations exceeds 5.0 cm. When re-observing base lines that exceed tolerance values, the new observation must agree with an old base line which was observed using the criteria in number 6. of the Observations section above, i.e., the two base line measurements must contain significantly different satellite geometry.

Table 1. -- Summary of Guidelines.

	Control 2 and 5 cm	**Primary Base** **2 cm**	Primary Base 5 cm	Secondary Base 2 cm	Secondary Base 5 cm	Local Network 2 cm	Local Network 5 cm
Dual Frequency Required	Yes, if base line is greater than 10 km	**Yes, if base line is greater than 10 km**	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km	Yes, if base line is greater than 10 km
Geodetic Quality Antenna with Ground Plane	Yes	**Yes**	Yes	Yes	Yes	Yes	Yes
Min. Number of Stations	3	**3**	3	No Minimum	No Minimum	No Minimum	No Minimum
Occupation Time	5 Hours	**5 Hours**	5 Hours	30 Minutes [1]	30 Minutes [1]	30 Minutes [1]	No Minimum [1]
Number of Days Station is Occupied	3	**3**	3	2 [2]	2 [2]	2 [2]	2 [2]
Max. Distance Between Same or Higher-Order Stations	75 km	**40 km**	50 km	15 km	20 km	10 km	20 km
Average Distance Between Stations	No Maximum	**No Maximum**	No Maximum	No Maximum	No Maximum	7 km	10 km
Repeat "**Base Line**"	YES [3]	**YES [3]**	YES [3]	YES [3]	YES [3]	YES [3]	YES [3]
Collect Met Data	Yes	**Yes**	Yes	Yes	Yes	No	No
Fixed Height Pole	Yes	**Yes**	No	Yes	No	Yes	No

Rubbing of Mark	Yes	**Yes**	Yes	Yes	Yes	Yes	Yes
Precise Ephemerides	Yes	**Yes**	Yes	Yes	Yes	Yes	Yes
Fix Integers	Yes [4]	**Yes** [5]	Yes [5]	Yes	Yes	Yes	Yes

Notes for Table of Summary of Guidelines:

[1] Analyses have indicated that when following all guidelines in this document, 30 minutes of observations over base lines that are typically less than 10 kilometers will meet the standards. For base lines greater than 10 km, but less than 15 km, 1 hour sessions should meet the standards. For observing sessions greater than 30 minutes, collect data at 15-second epoch interval. For sessions less than 30 minutes, collect data at 5-second epoch interval. Track satellites down to at least 10-degree elevation cut-off.
[2] Base lines must be re-observed on different days with significantly different satellite geometry.
[3] The observing scheme requires that all adjacent stations have base lines observed at least twice on two different days with significantly different geometry.
[4] If base line is greater than 40 kilometers, a partially fixed or float solution is permitted.

Data Submission to NGS:
Upon completion of the survey the following deliverables will be submitted to the National Geodetic Survey in compliance with the "*POLICY OF THE NATIONAL OCEAN SERVICE REGARDING THE INCORPORATION OF GEODETIC DATA OF OTHER ORGANIZATIONS INTO THE NATIONAL GEODETIC SURVEY DATA BASE"*

The survey data will be submitted in the automated formats specified in the Federal Geographic Data Committee (FGDC), Federal Geodetic Control subcommittee (FGCS), publication Input Formats and Specifications of the National Geodetic Survey Data Base (September 1994 [*updated*]), which describes the formats and procedures of submitting data for adjustment and assimilation into the NGS data base.

Data standards and accuracies must be verified, using currently available NGS software, by the SURVEYOR prior to submitting the survey project to NGS.

1. The project accession number is of the form GPS-xxx. (The project accession number **will be *assigned by NGS after receipt and processing of the completed project***.)

2. A project report and the data elements listed in Annex L of "Input Formats and Specifications of the NGS Data Base" must be transmitted to NGS. Quality checks for conformance to NGS format standards shall be performed using software programs COMPGB and OBSDES.

3. Latitude, longitude, and ellipsoid heights, as well as X, Y, and Z coordinates shall be provided in both NAD 83 and ITRF coordinate systems. See Appendix C for more information on transformation parameters and related information.

Definitions:

Accuracy

Local Accuracy - The local accuracy of a control point is a value expressed in cm that represents the uncertainty in the coordinates of the control point relative to the coordinates of the other directly connected, adjacent control points at the 95 percent confidence level. The reported local accuracy is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point.

Network Accuracy - The network accuracy of a control point is a value expressed in cm that represents the uncertainty in the coordinates of the control point with respect to the geodetic datum at the 95 percent confidence level. For National Spatial Reference System (NSRS) network accuracy classification, the datum is considered to be best supported by NGS. By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

Base Stations

Primary - Stations evenly distributed that surround the local network. These stations relate the local network to NSRS to the 5-cm, or better, standard through simultaneous observations with control stations. They can be newly established stations and be part of the local network.

Secondary - Stations evenly distributed throughout the local network that ensure that the local network does not contain a significant medium wavelength (20-30 km) ellipsoid height error through simultaneous observations with primary base stations. These stations may be newly established stations and are part of the local network. They are located between Primary Base Stations.

Control Stations

A- or B-order three-dimensional stations that surround the project area in at least three different quadrants. These stations relate the local network to the National Spatial Reference System through simultaneous observations with primary base stations. They must be referenced to NSRS and they provide the network accuracy. They may be newly established stations in the survey project if A- or B-order specifications and procedures are used to establish them. These procedures are not covered in this document; please contact NGS for additional information.