U.S. Department
of Transportation
Federal Aviation Administration

Advisory Circular

Subject: General Guidance and Specifications for Aeronautical Surveys: Establishment of Geodetic Control and Submission to the National Geodetic Survey

Date: Draft
Initiated By: AAS-100

AC No: 150/5300-16B
Change:

1 Purpose.

This AC explains the specifications for establishing geodetic control on or near an airport. It also describes how to submit the information to the National Geodetic Survey (NGS) for approval and inclusion in the National Spatial Reference System (NSRS) in support of aeronautical information surveys.

2 Cancellation.

This AC cancels AC 150/5300-16A, *General Guidance and Specifications for Aeronautical Surveys: Establishment of Geodetic Control and Submission to the National Geodetic Survey*, dated September 15, 2017.

3 Application.

The Federal Aviation Administration and the NGS Aeronautical Survey Program recommend the guidance and specifications in this AC for establishing on-airport geodetic control and submitting it to NGS for approval and inclusion in the NSRS in support of aeronautical information surveys. This AC does not constitute a regulation and in general is not mandatory. However, use of these guidelines is mandatory for surveys that are funded under Federal grant assistance programs. It also provides one, but not the only, acceptable means of meeting the requirements of Title 14 Code of Federal Regulations (CFR) part 139, *Certification of Airports*. Mandatory terms such as “must” apply only to those who conduct aeronautical information surveys using Airport Improvement Program (AIP) or Passenger Facility Charge Program (PFC) funds or those who seek to demonstrate compliance by use of the specific method described by this AC.

4 Audience.

Engineering and surveying companies contracted by state aviation agencies or local airport authorities to perform an aeronautical information survey of an airport should read this AC thoroughly and other related advisory circulars before commencing an airport project.

5 Principal Changes.

The AC incorporates the following principal changes:

1. Reformatted entire document for readability, usability and to provide clarification on some criteria.
2. Updated guidance to recommend meeting datum tie requirements by establishing Temporary Airport control stations (paragraph 2.2.1).
3. In the glossary list (paragraph 4.2), expanded the list and explained obsolete references to HARN.
4. Combined Chapter 6, "Data Formats," with Chapter 7, "Data Medium and File Naming Convention," to form Chapter 6, "Data Formats and Medium."
5. Removed pencil rubbing requirements from paragraph 7.2.9.
6. Updated photographic requirements in subparagraphs of 7.2.10.
7. Updated Table 7-1 and Table 7-2.
8. Rewrote paragraphs (and subparagraphs) 7.7.4.2, "Primary Airport Control Station (PACS) and HARN Tie," 7.7.4.3, "Secondary Airport Control Stations (SACS)," and 7.7.4.4, "Bench Mark Ties."
9. Removed "Single Mark Level Tie (3rd Order)" paragraph.
10. Removed "Observing Sequence for Conventional Level" paragraph and subparagraphs.
11. Removed "Observing Sequence for Digital Level" paragraph and subparagraphs.
12. Removed "Data Submission" paragraph and "Observations for Bench Mark Ties" form.
13. Updated observations scheme for establishing Primary Airport Control Station (PACS) (paragraph 7.7.4.2.1).
14. Added subparagraphs to paragraph 7.8, "Vector Processing," discussing PAGES software for vector processing, the use of International Global Navigation Satellite System (GNSS) (IGS) station coordinates for vector reductions, and the use of the COMPVECS program to analyze repeat baseline checks.
15. Modified vector processing requirements to allow use of the NGS online OPUS-Projects utility (paragraph 7.8.1.2).
16. Change the title of paragraph 7.9 from "PACS Adjustment Processing" to "Adjustment Processing" and updated the listed software and related adjustment

guidelines. Removed “Blue Book Guidance” and SACS Adjustment Processing” subparagraphs.

17. Deleted subparagraph “Format and check B-file” from paragraph 7.10 and updated the adjustment subparagraphs.
18. Updated digital photograph requirements for images of survey marks recovered or described in the project (paragraph 8.2, item 10).
19. Removed “Transmittal Letter” paragraph and form from Chapter 9.
20. Removed third page of examples from Appendix A.
21. Removed “The WDESC Program” and “Mark Types” paragraphs and subparagraphs from Appendix D.
22. Replaced the “Station Table Form” in Appendix E.
23. Updated and expanded session information in Appendix F.
24. Updated software information in Appendix G.
25. Removed Appendix J, Project Submission Checklist, because it is obsolete.
26. Updated entire document to provide up-to-date information, added technical details (such as accuracies and confidence levels), added additional guidance, and made minor editorial changes throughout.

Provided hyperlinks (allowing the reader to access documents located on the internet and to maneuver within this document) throughout this document, identified with underlined text. When navigating within this document, return to the previously viewed page by pressing the “ALT” and “ ←” keys simultaneously.

Figures in this document are schematic representations and are not to scale.

6 Feedback on this AC.

If you have suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

John R. Dermody
Director of Airport Safety and Standards

CONTENTS

Paragraph **Page**

CONTENTS

CONTENTS

FIGURES

CONTENTS

Paragraph **Page**

TABLES

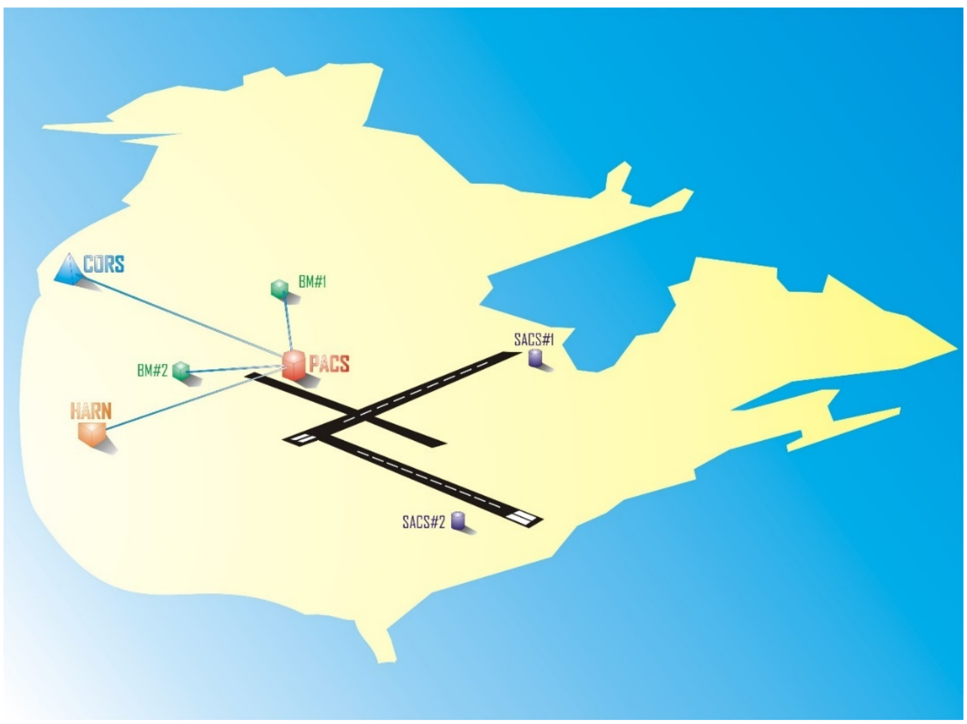
Page Intentionally Blank

CHAPTER 1. INTRODUCTION

1.1 Background.

Perform geodetic control surveys to establish a basic control network for supplemental surveying, engineering, and mapping work on an airport. The establishment of geodetic control by permanent survey monuments in the airport vicinity is critical to the National Airspace System (NAS). These monuments and their accurate connections to the National Spatial Reference System (NSRS) assure accurate relativity between surveyed points on an airport and between these points and other surveyed points and facilities in the NAS, including the navigation satellites. This geodetic control consists of a Primary Airport Control Station (PACS) and two or more Secondary Airport Control Stations (SACS) tied to the NSRS. These survey marks must be used for future aeronautical and engineering projects related to runway/taxiway construction, navigational aid siting, obstruction clearing, road building, and other airport improvement activities. This document provides guidance and specifications for establishing the geodetic control and submitting the data to National Geodetic Survey (NGS) for publication. AC 150/5300-18, *General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards,* identifies the required data, collection methodologies, and accuracies required for the collection of aeronautical information.

Figure 1-1. Illustrates the connection of the airport to other portions of a control network.



Page Intentionally Blank

CHAPTER 2. ADMINISTRATION

2.1 Specifications.

This AC outlines the Federal Aviation Administration (FAA) requirements for on-airport geodetic control and provides general guidance and specifications for establishing this control on airports. The requirements for reporting deviations, unusual circumstances, and other issues described in the following paragraphs apply to these general specifications.

2.2 Airports Requiring Geodetic Control Monumentation.

2.2.1 Permanent Control.

FAA Regional Airports Divisions will determine which airports require permanent geodetic control monumentation in the form of PACS or SACS based on the activity (operational or proposed future construction) at the airport. However, for all airports in the National Plan of Integrated Airport Systems (NPIAS), we recommend establishing temporary control stations.

2.2.2 Temporary Control.

2.2.2.1 The FAA recommends that temporary control be established and tied to the NSRS by using the NGS Online User Positioning System (OPUS).

2.2.2.2 Contracted surveyors should observe the following practices when using the OPUS to establish temporary airport control:

1. Establish two independent but intervisible marks on an airport as a conformity check and perform redundant observations.
2. Observe each mark in two continuous and independent sessions of at least 4 hours and submit these observations to the NGS OPUS site at https://www.ngs.noaa.gov/OPUS/.
3. Review and follow all other NGS requirements outlined for use of the OPUS.
4. Include results of the OPUS sessions in the project report and final deliverables.

2.3 Definitions.

This AC makes use of the following conventions.

2.3.1 Terminology.

- The verb *"must"* means that compliance is required.
- The verb *"should"* denotes a recommendation.

- The contraction *"N/A"* means not applicable.
- The term *"position"* means horizontal position specified as latitude and longitude unless stated otherwise.
- The term *"elevation"* means the distance of a point above a specified datum, measured along the direction of gravity.
- The term *"vertical"* refers to the direction in which the force of gravity acts.
- The term *"height"* means the distance, measured along a perpendicular, between a point and a datum.
- The term *"observation"* refers to the survey measurements resulting in a position and/or elevation for the survey mark in question, whether the mark is an existing mark or a newly set mark.
- The term *"set"* means physically constructed.

2.3.2 Measurements.

Use the U.S. Survey Foot (3.28083333333 feet = 1 meter) for any length conversions or as required by state law. If using a conversion factor other than the U.S. survey Foot, identify the conversion factor used and the reason in the Survey Plan.

2.4 General Requirements.

The selected Contractor must provide all labor, equipment, supplies, material, and transportation to produce and deliver data and related products as required by this AC.

2.5 Modifications.

The Contractor must submit in writing requests for modifications to or deviations from these specifications to the contract issuing authority, NGS, and FAA points of contact (POCs) as soon as a need for them is identified.

2.6 Unusual Circumstances.

The Contractor must notify the contract issuing authority of any unusual circumstances occurring during the performance of the tasks identified by this AC that affect the deliverables or their quality (see Chapter 5). The contract issuing authority, in turn, must notify FAA Airport Surveying-GIS Program Manager and NGS Point of Contacts (POC).

2.7 Reports.

Thorough reporting is required. The Contractor must submit a weekly project status report, a Quality Control Plan (see Chapter 5), a Project Survey Plan (see paragraph 9.3), and a Final Project Report (see Chapter 9) to the contract issuing authority. The airport sponsor/proponent or designated representative will send all required report submittals and documents to the FAA Airport Surveying-GIS Program Manager, who will forward it to NGS.

2.7.1 <u>Weekly Status Reports.</u>

2.7.1.1 The Contractor must submit project status reports via email every Monday afternoon by 2:00 P.M. Eastern Time, from the date of the contract start until the work is complete. These reports must include the following:

1. Percentage complete for each major project task.
2. Status of other work.
3. Completion or expected completion dates for each task.
4. Any unusual circumstances and/or deviations from the guidance in this AC.

2.7.1.2 This report should be brief, up to date, and include the prime Contractor's firm name. These reports must break the work into phases to allow for tracking the project's progress. The following example is a suggested format; however, the percentage complete and completion date are required fields. An "X" or other similar mark in the last column is used to indicate a change in the task status since the last report.

Table 2-1. Sample Weekly Email Status Report

Project Title:	ABC Regional Airport Obstruction Chart Survey			
Contracted Firm Name:	XYZ Engineering			
Project Manager's Name:	Joe Doe			
Project Manager's Position:	P.E.			
Report Date:	7/17/2018YY			
Task	Percentage Complete	Date Completed or Estimated Completion Date	NGS Approval Date	Updated from last report
Reconnaissance	100 %	Dec 01, 2004	Dec 06, 2004	
Survey Plan	100 %	Dec 12, 2004	Dec 18, 2004	
Mark Setting	90 %	Feb 01, 2004		X
Observations	20 %	Feb 15, 2004		X
Vector Processing	%			
Adjustment Processing	%			
Final Project Report	%			
Quality Control	%			
Additional Comments: In this section, provide any required additional comments, unusual circumstances encountered, or approved modifications or deviations from this AC. Be sure to include comments on any changed items indicated in the matrix.				

2.8 Original Data.

Observation logs and other original records generated during this project are legal records and must be retained for data accountability by the Airport Authority. NGS will receive a copy of the original data for quality assurance purposes. Original logs and records must be submitted and must be legible, neat, clear, accurate, and completed in indelible black ink. Original data must be saved, unmodified, in hand-written or electronic form. In the original records (paper or digital), nothing is to be erased or obliterated. All available spaces on the recording forms should be completed. If a mistake is made on a form, draw a single line through the mistake, and write the correction above or to the side. If space is too limited to permit a field correction, restart with a new log sheet; however, do not recopy the form in the office in order to make a “clean” copy. An explanatory note should be made for all corrections to the original recorded figures. It is essential for all hand-recorded information to be neat and legible. All editing of electronic data must be done on a copy of the original. Submit the original version of the data, not a handmade copy, photocopy, or digital copy.

CHAPTER 3. NATIONAL SPATIAL REFERENCE SYSTEM (NSRS)

3.1 Background.

All surveying and positioning must be tied to the NSRS. For further information about the NSRS, refer to Appendix B. For explanations of many of the terms in Chapter 4 of this AC, see https://www.ngs.noaa.gov/faq.shtml.

3.2 Horizontal Control.

The only nationally recognized horizontal datum is North American Datum of 1983, denoted as NAD 83 (YYYY), where YYYY is the "datum tag" corresponding to a specific realization that gives the year the coordinates were determined in an adjustment. It is not the coordinate epoch, nor is it the year of the most recent observations.

Note: The datum tag (realization) is on the NGS datasheet next to the latitude and longitude.

3.3 Vertical Reference.

3.3.1 Use North American Vertical Datum (NAVD) 88 where it is defined (in the conterminous US and parts of Alaska). For information on NAVD 88, refer to the following website: https://www.ngs.noaa.gov/PUBS_LIB/NAVD88/navd88report.htm.

3.3.2 In areas where NAVD 88 bench marks are not available (such as islands and parts of Alaska), use the relevant vertical datum (if available) or make GPS ties to tidal bench marks within the project area, if feasible. For additional information on vertical datums defined by NGS, refer to the NGS "Vertical Datums" web page (https://www.ngs.noaa.gov/datums/vertical/). In situations where the vertical reference is not clear, contact NGS for assistance.

3.4 GEOID Model.

Use the most recent NGS hybrid GEOID model. For information on these models, see https://www.ngs.noaa.gov/GEOID/index.shtml.

Page Intentionally Blank

CHAPTER 4. REFERENCES AND GLOSSARY

4.1 References.

1. Input Formats and Specifications of the National Geodetic Survey Data Base, the "Blue Book." Available online at https://www.ngs.noaa.gov/FGCS/BlueBook/.
2. Station Location Sketch and Visibility Obstruction Diagram. For this and other FAA forms, see https://airports-gis.faa.gov/public/surveyorsIntro.html.
3. National Oceanic and Atmospheric Administration (NOAA) Manual National Ocean Service (NOS) NGS 1, *Geodetic Bench Marks.* Available online at https://www.ngs.noaa.gov/PUBS_LIB/GeodeticBMs/.
4. NGS National Continuously Operating Reference Station (CORS) System. For information on CORS, see https://www.ngs.noaa.gov/CORS/.
5. High Accuracy Reference Network (HARN). For more information on HARN, see https://www.ngs.noaa.gov/PROJECTS/FBN/ (note that the HARN has been superseded by more recent national adjustments in 2007 and 2011).
6. The National Adjustment of 2011. See https://www.ngs.noaa.gov/GEOID/index.shtml.
7. Federal Geodetic Control Subcommittee (FGCS) Specifications and Procedures to Incorporate Electronic Digital/Bar-Code Leveling Systems, version 4.1, 5/27/2004.
8. Standards and Specifications for Geodetic Control Networks, FGCC, 1984 (currently valid only for leveling).
9. NOAA Manual NOS NGS 3, Geodetic Leveling, 1981.
10. FAA Airport Identifiers. See FAA JO 7350.9, *Location Identifiers*.

4.2 Glossary.

Geodetic Glossary, NGS, 1986 (available online at https://www.ngs.noaa.gov/CORS-Proxy/Glossary/xml/NGS_Glossary.xml). For a printed copy, contact NGS at (301) 713-3242 or email info_center@ngs.noaa.gov.

1. ANA–Area Navigation Approach.
2. AZ MK–Azimuth Mark. A marked point established in connection with a triangulation (or traverse) station to provide a starting azimuth for dependent surveys. Keep in mind that some azimuth marks also were positioned, and some have an underground disk. The azimuth mark is usually a pre-stamped survey disk, generally 0.4 to 3.2 km (1/4 to 2 miles) from the main horizontal station. The next consecutive azimuth mark number was used if an earlier number was destroyed. See Appendix A.
3. BM–Bench Mark.
4. CBN–Cooperative Base Network (NGS). Obsolete term no longer used for current survey control.

5. CTCORS–Central Temporary Continuously Operating Reference Station. A permanently monumented control station established near the center of a 300 km (radius) survey area (as defined elsewhere in this document) functioning as a temporary Continuously Operating Reference Station (CORS).
6. CORS–Continuously Operating Reference Station. A permanent GPS facility whose GPS receiver provides observables from the GPS satellites, allowing stations occupied temporarily by GPS receivers to be differentially positioned relative to it. CORS are related to the North American Datum of 1983 (NAD 83) coordinate system at the 1 to 3-centimeter level either by being collocated at VLBI sites used to define the system or by being differentially positioned relative to such a collocated GPS station.
7. DISK–A thin metal plate about 9 cm in diameter with a stem attached to the center of the bottom. The plate is slightly convex (in vertical) and usually round (in horizontal) and contains the mark for which survey information is known or to be determined. The plate usually also contains a designation, year, and the name of the agency setting the plate. It is usually made of bronze, brass, or aluminum and may be set in a drill hole or embedded in concrete.
8. DOD–Department of Defense.
9. FAA–Federal Aviation Administration.
10. FBN–Federal Base Network (NGS). Obsolete term no longer used for current survey control.
11. FGCC–Federal Geodetic Control Committee (changed to FGCS in October 1990).
12. FGCS –Federal Geodetic Control Subcommittee (changed to FGCS in October 1990).
13. GNSS—Global Navigation Satellite System (includes GPS).
14. GPS–Global Positioning System.
15. HARN–High Accuracy Reference Network. Obsolete term no longer used for current survey control. Although HARN is an obsolete term, it is used here to maintain consistency with earlier versions of this document. In this context, a HARN station is a passive mark with NGS-published GPS-derived geometric coordinates (latitude, longitude, and ellipsoid height) referenced to the current realization of NAD 83 and with positional accuracies given at the 95% confidence level.
16. IERS—International Earth Rotation and Reference System Service.
17. IGS—International GNSS Service.
18. ITRF–International Terrestrial Reference Frame.
19. MARK– (1) A dot, the intersection of a pair of crossed lines, or any other physical point corresponding to a point in a survey; (2) the object, such as a disk, on which the mark (1) is placed; (3) the entire monument, consisting of the mark (1), the object on which it occurs (2), and the structure to which the object is fastened.

20. MONUMENT–A structure that marks the location of a point determined by surveying. In the case of a disk in concrete, the monument would be the entire structure. Mark, monument, and station can mean the same thing.
21. NAD 27–North American Datum of 1927.
22. NAD 83–North American Datum of 1983.
23. NAVD 88–North American Vertical Datum of 1988.
24. NGS–National Geodetic Survey, NOAA. Disks inscribed with this name have been set from 1970 to the present.
25. NGVD 29–National Geodetic Vertical Datum of 1929.
26. NOAA–National Oceanic and Atmospheric Administration.
27. NOS–National Ocean Survey, NOAA. Disks inscribed with this NOS name were set from about 1970 to December 3, 1982.
28. NOS–National Ocean Service. Disks inscribed with this NOS name were set from about 1983 to the present.
29. NSRS–National Spatial Reference System.
30. OPUS–Online Positioning User Service (https://www.ngs.noaa.gov/OPUS/). Provides simplified access to high-accuracy National Spatial Reference System (NSRS) coordinates. A GPS data file collected with a survey-grade GPS receiver is uploaded through the OPUS website and an NSRS position is provided via email within a few minutes.
31. PACS–Primary Airport Control Station.
32. RM–Reference Mark. A survey mark of permanent character close to a survey station to which it is related by an accurately measured distance and azimuth. For a triangulation station, reference marks are pre-stamped survey disks, usually within 30 meters (one tape length) of the triangulation station. Standard procedure was to set two reference marks, numbered clockwise from north, with the next consecutive reference number used if an earlier number was destroyed. See Appendix A.
33. SACS–Secondary Airport Control Station.
34. STATION–A physical location or site at which, from which, or to which survey observations have been made. See Mark and Monument.
35. USACE–U.S. Army Corps of Engineers (Blue Book abbreviation is USE).
36. USCG–U.S. Coast Guard.
37. USC&GS–U.S. Coast and Geodetic Survey. Disks inscribed with USC&GS were set from about 1900 to 1970. Over 10 different pre-stampings were used (Bluebook abbreviation is CGS).
38. USE–U.S. Army Corps of Engineers or U.S. Engineers Department (old acronym; present Blue Book abbreviation).
39. WAAS–Wide Area Augmentation System (FAA).

40. WGS 84–World Geodetic System 1984.

CHAPTER 5. QUALITY CONTROL

5.1 Background.

Check all data to ensure it is complete, reliable, and accurate. The Contractor's personnel must become thoroughly familiar with this AC, the appendices, the definitions of surveying terms, and the material covered in the other references and publications, as required. See Chapter 4 for References and Glossary.

5.2 Quality Control Plan.

Submit a Quality Control Plan (QCP) covering all project tasks prior to beginning survey work on this project. The QCP must describe how the Contractor will meet the technical specifications required for the project. The QCP must include at least the following elements: a check of all manual computations (including check marks and initials), a check of all manual data computer entries, a check of file formats, and a check of all reports and data submitted. The Contractor must also describe how data will be backed up and how the Contractor will ensure original data is not modified. See paragraph 7.3, "Project Survey Plan", and Chapter 9, "Deliverables to NGS." Comments on quality control and a copy of the Quality Control Plan must be included in the Final Project Report.

Page Intentionally Blank

CHAPTER 6. DATA FORMATS AND MEDIUM

6.1 Original Data.

Original, raw digital data must be submitted and their formats must be documented in the Final Project Report. Observations for positioning PACS and SACS must be submitted in Blue Book format. See paragraph 4.1.

6.2 Final Data.

Final project data must be submitted in Blue Book format or in the appropriate formats specified by this AC (for example, digital photographs).

6.3 Data Medium.

Submit the data for review and approval to the assigned project directory via the FAA Airports GIS Web Portal: https://airports-gis.faa.gov/agis/actions/PermissionAction?action=showLoginForm.

Page Intentionally Blank

CHAPTER 7. SURVEY WORK

7.1 Purpose.

The establishment of geodetic control provides the required accuracy for aeronautical information, engineering surveys, and mapping to support planning, design, construction, operation, maintenance, and management of airport facilities and establishes a tie to the NSRS. The NSRS provides airports with a common, consistent set of geographical coordinates (reference points) relative to other parts of the National Airspace System. A project may include planning, reconnaissance, mark recovery, mark setting, GPS observations, data processing, data analysis, data adjustment, data submittal in specified formats, and preparing reports. GPS ground surveying methods must be used for Airport Geodetic Control survey work specified in this section.

7.2 Reconnaissance.

Reconnaissance activities for each survey must include, but are not limited to, the following:

1. Review of station descriptions in the NGS database.
2. Coordination with airport authorities (see checklist in Appendix C).
3. Mark recovery.
4. Selection of PACS, SACS, and NSRS ties.
5. Preparation of required descriptions, sketches, photographs, and other documentation.
6. Compilation of a Project Survey Plan.

7.2.1 Control Stations.

The following types of control stations (survey marks) must be considered for use in these projects (see Appendix A for drawings of typical disks):

7.2.1.1 Horizontal.

1. All control stations with a stability code of A, B, or C (see paragraph 7.5 for an explanation of stability codes), and
2. All high-accuracy GPS control stations, including CORS and passive marks with GPS-derived coordinates with published accuracies of 5 cm horizontal and 10 cm ellipsoid height or better, at 95% confidence (historically includes FBN, CBN, HARN, PACS, and SACS stations). Note that “HARN” is an obsolete term, but it is used throughout this document to maintain consistency with previous versions and other legacy uses of this term. In this context, “HARN” is synonymous with high-accuracy passive GPS control.

7.2.1.2 **Vertical.**

Utilize all first-order and second-order NAVD 88 vertical control stations (bench marks) within the project area, sufficient to provide vertical control for the project.

7.2.1.3 **NSRS Tie.**

All horizontal and vertical points used as control must be NSRS published stations.

7.2.2 Database Search.

NGS and U. S. Coast and Geodetic Survey (USC&GS) (former name for NGS) station descriptions are contained in the NGS Integrated Database (NGSIDB) and are available via the NGS website and/or DSWORLD. Perform a database search for all control stations on and around the airport meeting the criteria in paragraph 7.2.1 prior to performing the field reconnaissance. Use the review to develop a priority list of HARN stations and bench marks for use in NSRS ties. Many airports have existing monuments suitable for use as PACS/SACS. Suitable stations are defined as a survey disk, rod, or similar type monument meeting at least a stability code of "C" with a known history of stability, considered suitable for GPS observations, and recovered in good condition. Directly access the NGS database using the NGS website at https://www.ngs.noaa.gov/datasheets/index.shtml.

7.2.3 Contact with Airport Authorities.

7.2.3.1 Close communication with airport management is a critical part of the reconnaissance. Make appointments with airport management well in advance to ensure a qualified airport representative is available to discuss the survey and the procedures for working on the airport. Proper clearances to work in the aircraft operations areas must be obtained before performing any work at an airport. A security and safety briefing may be required before field crews are allowed to work on the airfield. Follow standard safety procedures, and equip all vehicles with flashing yellow lights and aircraft radios. Contact with the airport traffic control tower is mandatory during surveys at controlled airports unless an escort is provided. Interview checklists for these meetings are located in Appendix C of this AC.

7.2.3.2 Inquire about planned construction or changes in the airport layout. Briefly summarize any future construction plans in the Project Survey Plan. Discuss optimal locations for the practical use and survivability of the monuments, and finalize the PACS and SACS monument site selections with airport management. Inquire about underground utilities and other hazards to setting monuments. Emphasize the importance of keeping the area surrounding the monuments, especially the PACS, clear of any future equipment installations or construction that might result in loss of intervisibility between the monuments, loss of visibility to GPS satellites, or a source of multi-path interference.

7.2.4 Mark Recovery.

7.2.4.1 **Search.**

7.2.4.1.1 Make an extensive physical search in the field for all suitable control stations found during the database search(s) described in paragraph 7.2.2. Use existing marks meeting the PACS and SACS requirements before setting a new monument. The use of existing marks reduces the proliferation of marks on airports, reduces mark setting costs, and makes it easier to maintain an accurate, up-to-date survey database. For a discussion of "Existing Monumentation in the Vertical Network," see pages 43-44, *Geodetic Bench Marks*, NGS, 1978.

7.2.4.1.2 Before using an existing mark, thoroughly check the description to confirm the station's identity, stability, and location and to provide input for an updated description or recovery note. Do not stamp existing disks or logo caps.

7.2.4.1.3 NGS has established high-accuracy GPS-derived control marks at many airports within the United States (previously categorized as "A" or "B" order marks). "High accuracy" in this context refers to stations with horizontal and ellipsoid height accuracies less (better) than 5 and 10 cm, respectively, at 95-percent confidence (as published on NGS datasheets). Use these marks if they meet PACS requirements. If there is an existing high-accuracy GPS station just off an airport, and it has visibility onto the airport, an exception requiring the PACS be located on the airport may be granted. If this situation is encountered, make a recommendation, with justification, in the Project Survey Plan for the approval of the FAA and NGS.

7.2.4.1.4 If there is an existing high-accuracy GPS station just off an airport, and appropriate sight lines onto the airport are not available, an exception may be granted if an intermediate station (a third SACS) is set providing visibility from the GPS station through the third SACS to the other two SACS on the airport. The third SACS may be located off the airport. If a situation is encountered at an airport requiring a third SACS, identify the requirement in the Project Survey Plan.

7.2.4.1.5 The contractor must prepare digital updated descriptions or recovery notes in the three-paragraph standard NGS format described in Appendix D for all NSRS marks searched for and all marks used in the project.

7.2.4.2 **Mark Recovery Definition.**

7.2.4.2.1 The "recovery" of a control station includes a physical visit to the station to determine its usability. Check each control station to—

1. Determine proper identity. Check the mark type, disk type, and stamping against the NGS datasheet.
2. Ascertain its unmoved position. Measure the distances and angles to and from the reference marks and/or the distances from the reference points and the Witness Post.
3. Determine its condition, stability, and visibility.

7.2.4.2.2 Prepare a digital updated description or recovery note in NGS format. Submit station descriptions and recovery notes in computer-readable form (D-File) using WINDESC software available online at https://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml#WinDesc. Appendix D provides detailed instructions on writing station descriptions and recovery notes.

7.2.4.3 **Using Marks of Other Organizations.**

An existing mark of another organization meeting the siting, construction, and intervisibility requirements established by this AC may be used as a PACS. Normally this would be limited to a disk set in a drill hole in bedrock or a stainless steel rod if there is an indication the rod was driven to NGS driving requirements. Marks previously established by other organizations may be used for a SACS if they meet all siting, construction, and intervisibility requirements and are stability A, B, or C.

7.2.4.4 **Marks on Private Property.**

Contact property owners and obtain permission before using or setting marks on private property. Take care to return the landscape to the original condition, and ***Do Not*** include the name and phone number of the property owner in the station description unless the land is owned by a business or the owner requests the information be included in the description.

7.2.4.5 **Destroyed Survey Marks.**

A moved, damaged, or very loose NGS or CGS metal survey disk that's stability indicates it can no longer serve as survey mark is to be removed, the recovery notes written describing the mark as destroyed, and the disk sent to NGS. Do not destroy the mark of any other organization without the permission of said organization. Do not describe a mark as destroyed unless the disk is found and returned to NGS.

7.2.4.6 **Damaged Survey Marks.**

Any existing disk selected for use as a PACS or a SACS should be repaired if found loose or with edges exposed. Any work done to repair a disk must be described completely in the digital recovery note. Take extreme care not to alter the existing horizontal or vertical position of the disk. Disk longevity can be increased substantially by simply adding highway epoxy or equivalent when the edges of a disk are exposed. This will prevent ice from forming under the disk or a vandal from prying the disk from its location. For all marks, perform mark maintenance as required, to include replacing logo cap lids if missing. When an unusual situation arises, contact NGS for recommendations before taking any action on the mark. If time permits, send a photograph to NGS along with the description of the situation. Notify NGS of any other marks needing mark maintenance. Examples of mark maintenance problems include loose disks, exposed disk edges, missing logo caps, missing logo cap lids, exposed edge of concrete monuments, or imminent danger of destruction.

7.2.4.7 **Marks Not Found.**

As stated in paragraph 7.2.4.1, make an extensive physical search for all control stations found in the database search(s). If a mark is not found, enter the number of person-hours spent searching for it in the digital recovery note. Do not state the mark is destroyed simply because it was not found. If strong evidence suggests a mark is destroyed, clearly state the evidence, so NGS can determine if it is destroyed and replace it as required.

7.2.4.8 **Marks Recovered but Not Usable.**

For marks recovered but are positively not usable due to complete tree canopy, etc., the recovery requirements may be reduced to just a simple recovery note such as, "RECOVERED AS DESCRIBED. THE MARK CAN NOT BE OCCUPIED BY GPS DUE TO COMPLETE TREE CANOPY." For marginally usable marks, fulfill the normal recovery requirements, including Visibility Diagram and photographs, because, depending on other marks in the area, the mark might be needed.

7.2.5 Bench Mark Reset Procedures.

If the reconnaissance indicates the number and/or distribution of bench marks with good sky visibility is inadequate, bench mark reset procedures may be performed to transfer an elevation from a bench mark to a new survey point having good sky visibility. New marks must be set no more than 560 meters from the original mark. Temporary marks must not be used. Refer to NGS Bench Mark Reset Procedures for more information https://www.ngs.noaa.gov/PUBS_LIB/Benchmark_4_1_2011.pdf.

7.2.6 Visibility.

Adequate GPS satellite visibility is required for all horizontal and vertical stations selected. The visibility should be minimally restricted from 15 degrees above the horizon to the zenith, in all directions; see paragraph 7.4 for details. Minor obstructions are acceptable, but must be depicted on the Station Location Sketch and Visibility Diagram (see Figure 7-1, Figure 7-2 and paragraph 7.2.8). For new stations, select a site relatively free of present and future anticipated obstructions. Utility poles in the GPS field of view are tolerable, and they provide security and a reference to help locate the mark. Set new marks at least 2 meters to the south (if possible) from a pole. Do not use existing marks located within 2 meters of a pole. Marks should not be set or used if within 5 meters of a chain link fence.

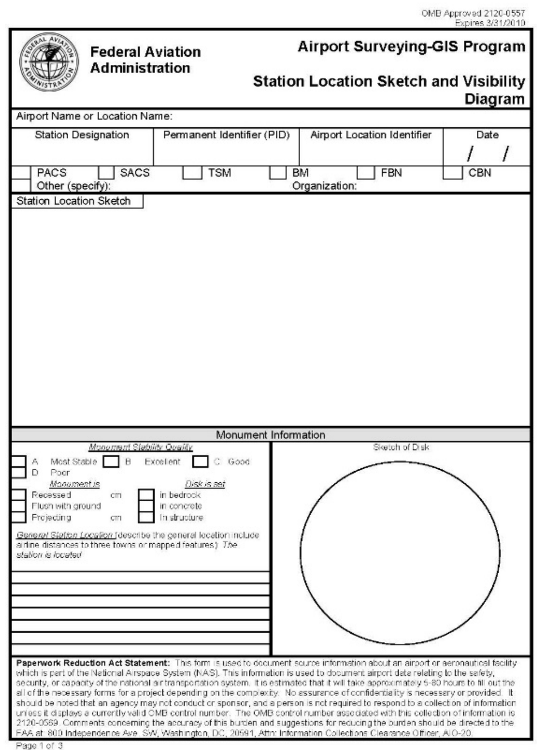
7.2.7 National Spatial Reference System (NSRS) Ties.

Each PACS must be tied to at least one high-accuracy GPS-derived NGS control station and two First- or Second-order NAVD 88 bench mark stations. The stations selected for these ties must be recovered during the field reconnaissance. Details for selecting and positioning the PACS (and Central Temporary Continuously Operating Reference Station (CTCORS)) ties are listed in paragraph 7.7.4. All reconnaissance deliverables required for "suitable" stations are also required for the NSRS ties.

7.2.8 Station Location Sketch and Visibility Diagram.

For all marks, observed and proposed, the contractor must prepare and submit a station location and visibility diagram. The form is available at https://airport-gis.faa.gov/public/surveyorsIntro.html.

Figure 7-1. Station Location Sketch and Visibility Diagram.


OMB Approved 2120-0557
Expires 3/31/2010

Federal Aviation Administration

Airport Surveying-GIS Program

Station Location Sketch and Visibility Diagram

Airport Name or Location Name:

Station Designation	Permanent Identifier (PID)	Airport Location Identifier	Date
			/ /

☐ PACS ☐ SACS ☐ TSM ☐ BM ☐ FBN ☐ CBN
☐ Other (specify): Organization:

Station Location Sketch

Monument Information

Monument Stability Quality
☐ A Most Stable ☐ B Excellent ☐ C Good
☐ D Poor

Monument is
☐ Recessed cm
☐ Flush with ground
☐ Projecting cm

Disk is set
☐ in bedrock
☐ in concrete
☐ In structure

General Station Location (describe the general location include airline distances to three towns or mapped features) *The station is located*

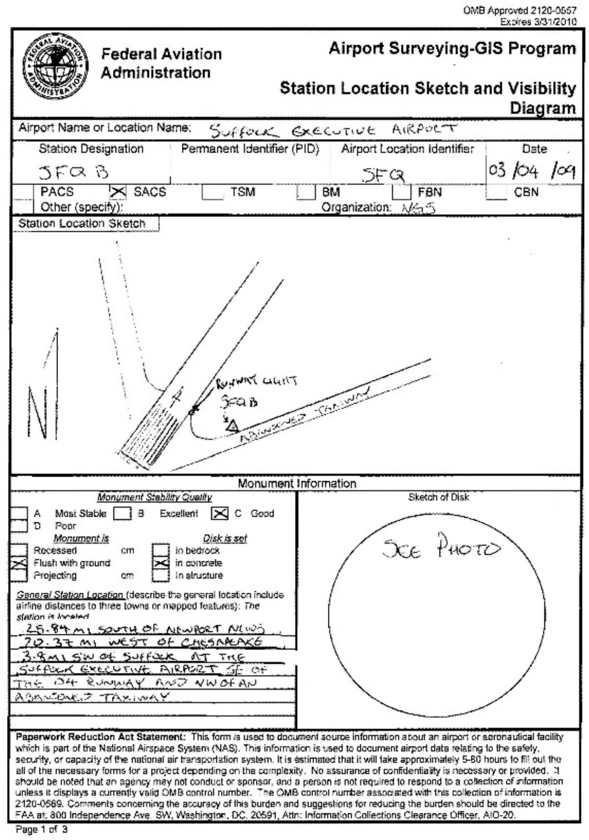
Sketch of Disk

Paperwork Reduction Act Statement: This form is used to document source information about an airport or aeronautical facility which is part of the National Airspace System (NAS). This information is used to document airport data relating to the safety, security, or capacity of the national air transportation system. It is estimated that it will take approximately 5-80 hours to fill out the all of the necessary forms for a project depending on the complexity. No assurance of confidentiality is necessary or provided. It should be noted that an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. The OMB control number associated with this collection of information is 2120-0569. Comments concerning the accuracy of this burden and suggestions for reducing the burden should be directed to the FAA at: 800 Independence Ave. SW, Washington, DC, 20591, Attn: Information Collections Clearance Officer, AIO-20.

Page 1 of 3

The station location sketch and visibility diagram should show the survey marks' relation to nearby features, such as runway ends, taxiways, airport lights, fence lines, and buildings. Label prominent features and draw dashed lines along the reference measurements to indicate the reference objects listed in the description (in NGS standardized format) for the station. The D-File is a clear, concise, accurate and complete description of the station in the NGS standardized format. The description (D-File) should enable one to go with certainty to the immediate vicinity of the mark, and by the measured distances to reference points and the description of the character of the mark, it should inform the searcher of the exact location of the mark and make its identification certain. It should include only essential details of a permanent character." Complete the visibility diagram and sketch the inscription and stamping detail of the disk in the space provided. The form must be neatly and accurately completed.

Figure 7-2. Example Station Location Sketch and Visibility Diagram.



OMB Approved 2120-0557
Expires 3/31/2010

Federal Aviation Administration

Airport Surveying-GIS Program

Station Location Sketch and Visibility Diagram

Airport Name or Location Name: SUFFOCK EXECUTIVE AIRPORT

Station Designation	Permanent Identifier (PID)	Airport Location Identifier	Date
SFQ B		SFQ	03/04/09

PACS [X] SACS [ ] TSM [ ] BM [ ] FBN [ ] CBN
Other (specify): Organization: NGS

Station Location Sketch

Monument Information

Monument Stability Quality

[ ] A Most Stable [ ] B Excellent [X] C Good [ ] D Poor

Monument is: [ ] Recessed cm [X] Flush with ground [ ] Projecting cm

Disk is set: [ ] in bedrock [X] in concrete [ ] In structure

General Station Location (describe the general location include airline distances to three towns or mapped features): The station is located

25.84 MI SOUTH OF NEWPORT NEWS
20.37 MI WEST OF CHESAPEAKE
3.9 MI SW OF SUFFOCK AT THE
SUFFOCK EXECUTIVE AIRPORT SE OF
THE 04 RUNWAY AND NW OF AN
ABANDONED TAXIWAY

Sketch of Disk

SEE PHOTO

Paperwork Reduction Act Statement: This form is used to document source information about an airport or aeronautical facility which is part of the National Airspace System (NAS). This information is used to document airport data relating to the safety, security, or capacity of the national air transportation system. It is estimated that it will take approximately 5-80 hours to fill out the all of the necessary forms for a project depending on the complexity. No assurance of confidentiality is necessary or provided. It should be noted that an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. The OMB control number associated with this collection of information is 2120-0569. Comments concerning the accuracy of this burden and suggestions for reducing the burden should be directed to the FAA at: 800 Independence Ave. SW, Washington, DC, 20591, Attn: Information Collections Clearance Officer, AIO-20.

Page 1 of 3

7.2.9 Pencil Rubbings.

Rubbings are not required.

7.2.10 Photographs.

7.2.10.1 **Purpose of Digital Photos.**

Is to define the digital photographic standards for images of survey marks collected and for other reconnaissance photographs. Many of these images will be stored in the NGS database and available to the public so the subject matter (survey equipment, personnel, background, etc.) must be in good taste and professional in nature. Digital photographs are useful for station (mark) reconnaissance, mark recovery, mark stability assessment, and quality control and as an aid during data processing and data verification. Some projects might require digital photographs during several stages. Generally, three photographs per station are stored in the NGS database.

7.2.10.2 Photographic Requirements.

At least three digital photographs are required for each mark recovered or described during the current project. This requirement is for marks where a written, NGS format, digital description or recovery note is prepared. For consistency within the NGS database, numbers are used to describe the three photographs. The photograph types, digital caption, file name and resolution must meet the criteria described in the NGS Photo Submission Guidelines (https://www.ngs.noaa.gov/web/surveys/photo_submissions/).

Figure 7-3. Examples of the NGS-suggested digital photographs.

BWI D, AB6219, 1, 20071030

Type 1, Close-up

BWI D, AB6219, 2, 20071030

Type 2, Eye-level

BWI D, AB6219, 3NE, 20071030

Type 3, Horizontal

7.2.10.3 Reconnaissance Photographs.

Some, or all, of the digital images described in this section may be required on a given project; refer to the project instructions. Each of these photographs requires a sign, a caption, and the correct file name. The filenames for all reconnaissance photographs must begin with “RE” to indicate reconnaissance. Generally, these recon images will not be loaded in the NGS database but might be required for use during planning and review. All reconnaissance photographs will have digital captions. These captions may be captured on the image or added later. In this AC, “RE” stands for “reconnaissance” and “R” stands for “right” runway. See the project instructions to determine which of the following reconnaissance photographs are required.

7.2.10.4 **Depth of Hole Photographs.**

Take at least one photograph showing the hole dug or drilled for a concrete or rod mark. Place a measuring device (e.g., tape measure or level rod) in the hole, clearly showing the depth of the hole.

7.2.10.5 **Other Required Photographs.**

Take photographs of all stations as outlined in this AC. For RECOVERED STATIONS, take at least three photographs of each existing control station. For PROPOSED SITES OF NEW STATIONS, take two photographs (paragraph 7.2.11) and additionally take three photographs of NEW STATIONS, AFTER SETTING. If the mark is a CONCRETE MARK HOLE, then only a single photograph is required. Additional photographs may be required depending on the airport and surroundings. These additional requirements should be outlined in the Statement of Work for the project.

7.2.11 Proposed New Station Sites.

Use existing marks rather than setting new marks. If required, the contractor must propose sites for new stations and propose the type of mark to be set in the "Comments/recommendations" column of the "Station Table" as defined in paragraph 7.3, item 2. Prepare preliminary digital descriptions and station location sketch and visibility diagrams. Take three photographs of the proposed sites; one at eye level (photo type 1), one oriented vertically downward showing the ground in the area of the proposed mark (photo type 2), and one oriented horizontally showing the nearest satellite obstruction or identifying feature if no obstructions (photo type 3). After the mark is set, capture photo type 1, and update others as required. See paragraph 7.2.10.2 for digital photograph requirements. Proposed sites for new PACS and SACS must be approved by NGS prior to setting the marks. NGS may approve station selections based on preliminary Project Survey Plans to facilitate efficient field operations. New PACS and SACS should only be set if no existing mark can meet the requirements. See paragraph 7.6 for mark setting guidelines.

7.2.12 GPS Positions.

Obtain a hand-held GPS (pseudo-range) position for all marks found and for proposed sites for new marks. Include this position in the text of recovery notes and descriptions. Specify the position in the format *DDD MM SS.ss*. Use the description you wrote to return to the station; this verifies the description and provides a check on the adequacy of the description and the GPS position.

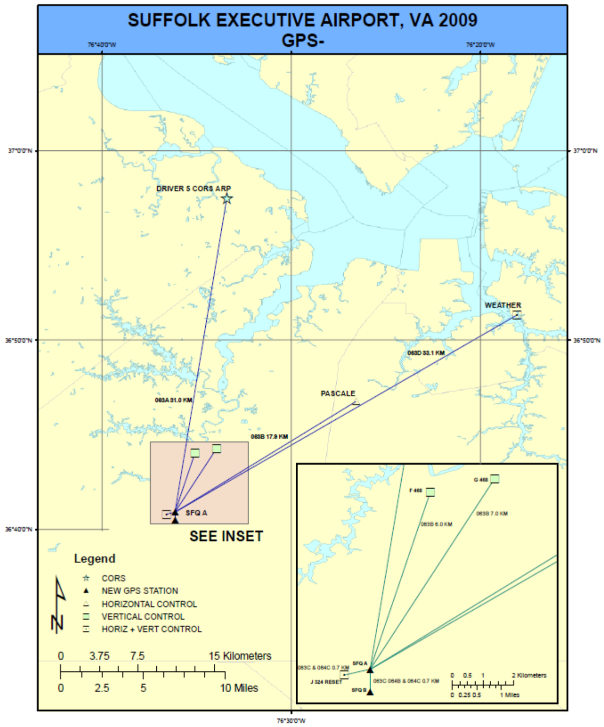
7.3 Project Survey Plan.

After reconnaissance but prior to mark setting or observations, submit a Project Survey Plan to the FAA Airports GIS Program web site. The plan will be reviewed as soon as possible, normally within 20 work days. The contractor must not begin mark setting or data collection until the plan is approved. At minimum, the plan must include the following sections:

1. **Airport Summary Report.** A separate paragraph for each airport to include—airport contact and access information; whether airport is controlled; whether escort is required; airport radio frequencies; intervisibility conditions between the PACS and SACS; comments on any future construction, unusual circumstances, use of witness posts, and any other miscellaneous information. Include any comments or deviations from this AC. The Airport Summary Report can be combined with the Station Table described below.
2. **Station Table.** For each airport, submit a table listing station designation name, PID, establishing agency, order, stability, condition at recovery, and comments for each station. For new stations, include the proposed name in the "Name" column, identify them as "proposed" in the "Type" column, and indicate the proposed type of mark (rod, concrete, disk in bedrock) in the "Comments/Recommendations" column. For existing stations, the name and PID must be used exactly as listed in the NGS database and must be this way in all survey records. For existing stations found but not proposed for use, state the reason(s) in the "Comments/Recommendations" column. Identify the PACS, SACS, and all NSRS ties for the airport. Give status of marks not used and the reason. Appendix E contains both a blank and completed example station table.
3. **Airport Control Plot.** Plot all "suitable" control on or near each airport on an airport map or digital image. Label each station with its designation and indicate if it is a PACS, SACS, Bench Mark, HARN Tie, or subsidiary control. Hand plotting on 8.5 × 11 paper is acceptable. See Appendix E for an example.
4. **Photographs.** Submit photographs in accordance with the NGS photo submission guidelines for all suitable stations recovered during the survey, and for all new monuments that will be set. https://www.ngs.noaa.gov/web/surveys/photo_submissions/.
5. **Station Location Sketch and Visibility Diagrams.** Submit for all suitable stations recovered during the reconnaissance, and for all new monuments set (See paragraph 7.2.8).
6. **Station Descriptions.** Submit Recovery Notes or Descriptions for existing marks. Encode the descriptions using WINDESC software. These descriptions should be used, reviewed, and corrected by GPS observers when they travel to marks. See paragraph 7.2.4.2 and Appendix D for details on writing station descriptions.
7. **GPS Observing Scheme.** If applicable, group airports together for observation/processing simultaneously. Include length of sessions and number of occupations. List available NGS-published CORS, GPS ("HARN") stations, and Bench Marks for each airport. See Appendix F for an example.

8. **Project Vector Diagram.** Depict the entire project area showing all occupied stations, except SACS (because of scale). Symbolically distinguish whether each station is a CORS, PACS, HARN Tie, Bench Mark, or combination. Include 300km (or appropriate scale) dashed circles around CORS and CTCORS, and 50 km circles around PACS. Show the GPS vectors used for processing. For multiple airport projects, make a single diagram for all airports and additional diagrams depicting individual airports or airports grouped together for GPS observations. Provide a scale or note distances from the PACS to the CORS, HARN, and Bench Mark Ties. (See Figure 7-4.)

Figure 7-4. Sample Project Vector Diagram.



9. **Proposed Instrumentation List.** Tabulate the brand and model numbers of GPS equipment.

10. **Data Processing Software.** Specify software name and version for the software used. Ensure the current version of all software is used.

11. **Quality Control Plan.** See Chapter 5.

Note: Printouts of the NGS station datasheets are not required.

7.4 Selection Guidelines for Airport Geodetic Control Surveys.

7.4.1 Requirements.

Establish three permanent survey marks on, or within one km of, the airport. One of these marks must be designated the Primary Airport Control Station (PACS). Horizontal and vertical datum ties must be made directly between the PACS and the National Spatial Reference System (NSRS). The other two marks must be designated Secondary Airport Control Stations (SACS). Horizontal and vertical connections must be made directly between the SACS and the PACS.

7.4.2 Monument Selection.

Proper monument site selection for PACS and SACS is a primary goal for these surveys and must be carefully considered. Consider the following basic factors when using an existing site or selecting a new site.

1. Monument stability.
2. Intervisibility requirements.
3. Visibility from the monuments to airport features such as runways, navigation aids, and airport obstructions off the end of runways
4. Any previous high accuracy connection to the National Spatial Reference System (NSRS).
5. Accessibility and survivability of the monuments.

7.4.3 Use of Existing Stations.

Use existing stations as the PACS and SACS if they meet the accuracy, siting, construction, and other criteria identified in this advisory circular.

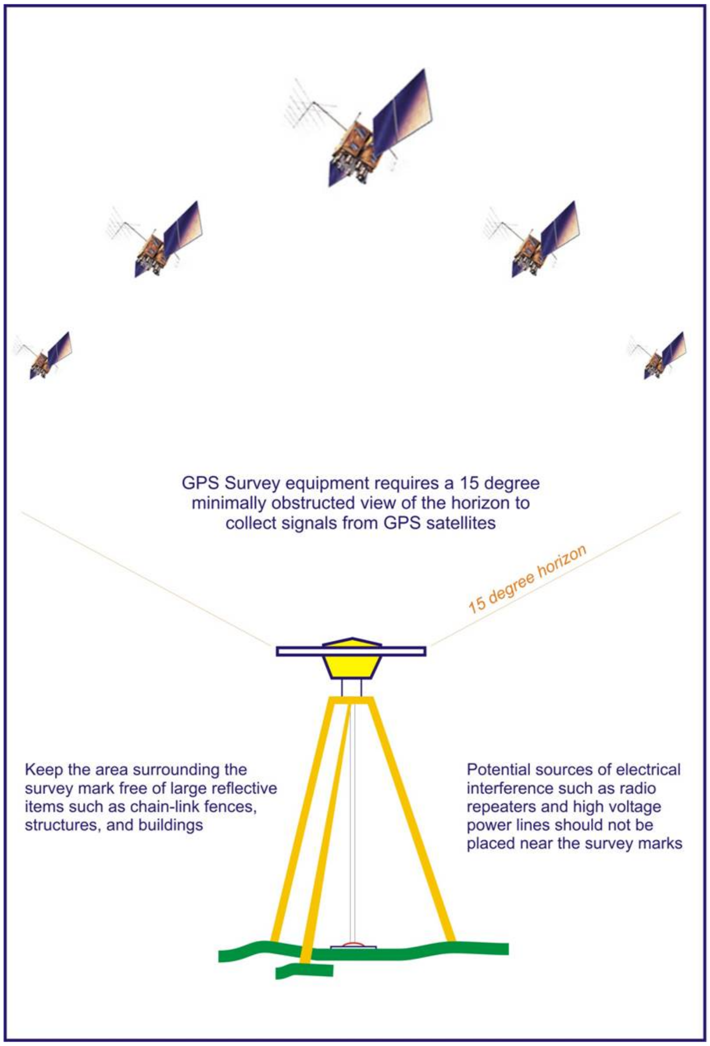
7.4.3.1 **Control Station Selection Priorities–PACS.**

An existing mark may be used as a PACS if the mark meets the stability codes of A or B in that order of preference (see mark stability standards in paragraph 7.5). An existing concrete mark with stability code C (and 4+ feet deep, belled bottom) may be used for a PACS if the monument meets the following seven (7) requirements.

1. The disk already exists.
2. The monument is poured in place in concrete.
3. The monument is a triangulation station, reference mark, azimuth mark, or bench mark bearing the logo “U.S. Coast and Geodetic Survey” or “National Geodetic Survey.”
4. The monument is set below the frost line.
5. The monument is set in non-expansive soils.
6. Figure 7-5 identifies some key points about the proper setup for GPS positioning.
7. The monument shows no evidence of movement.
8. The monument meets all siting, construction, and intervisibility requirements.

Note: An existing high-accuracy NGS GPS (“HARN”) station does not necessarily qualify to be a PACS; it must still meet PACS stability and siting requirements.

Figure 7-5. Identifies some key points about the proper setup for GPS positioning.



7.4.3.2 Control Station Selection Priorities–SACS.

An existing mark may be used as a SACS if the mark meets the stability codes of A, B, or C in that order of preference. Other USC&GS, NGS, or NOS marks should be used as SACS if they meet all siting, construction, and intervisibility requirements.

7.4.4 Monument Accessibility.

The monuments must be accessible to survey crews, and allow for unattended, secure setup of GPS equipment for long periods without hindering airport operations. PACS and SACS must allow for setup of both conventional (optical) and satellite surveying equipment. If possible, SACS should be sited on high ground near the approach end of the primary runways so they can be better utilized for obstruction surveys. Monuments must be established in areas clear of future construction, and should be slightly recessed to protect them from snow removal and mowing equipment. Monuments should not be located in the Runway Safety Area (RSA).

7.4.5 Monument Siting Considerations.

Consider the following items in the siting of all monuments (new or old, control station or local network station) in the project. The object of these standards is to ensure the stations are stable and usable years after the survey is completed. Give equal weight to each consideration item listed below.

1. Adequate GPS satellite visibility (unrestricted at 15 degrees above the horizon). Minor obstructions are acceptable, but must be depicted on the Visibility Obstruction Diagram.
2. Accessible by vehicle (two-wheel drive preferred).
3. Stability, bedrock being most preferred.
4. Permanency.
5. Ease of recovery.
6. Minimal multi-path.
7. Appropriate geographic location and spacing.
8. Location allows efficient use by surveying community.
9. Accessible by public. Public property should be utilized where feasible.
10. No known potential conflict with future development.
11. Aerial-photo identifiable.

7.4.6 PACS and SACS Proximity to Other Airport Features.

7.4.6.1 Establish the PACS in a secure area on airport property. A GPS suitable site should be selected where surveying equipment may be left unattended at the mark with a minimum probability of disturbance.

7.4.6.2 SACS should be established on airport property if practical. However, if the siting requirements, such as, intervisibility and spacing as described below, cannot be met, one SACS may be set off the airport but no further than 1 km from the nearest airport boundary.

7.4.6.3 If establishing the PACS and SACS requires new monumentation, the new monuments should be set no closer than 60 meters from a runway edge, or 60 meters from the imaginary runway extension or within the Runway Safety Areas (RSA). If an existing control station is used, this station should be at least 15 meters from a runway edge. In all cases, PACS and/or SACS should be at least 400 meters apart.

7.4.6.4 Ensure sites selected for use as PACS AND SACS meet the following minimum distance requirements to other airport features.

7.4.6.5 PACS and SACS should be located so that a surveying tripod can be situated over the mark. All marks should be recessed 3-5 cm to avoid disturbance by snow removal or mowing machinery.

7.4.6.5.1 PACS and/or SACS must not be within 305 meters (1000 feet) of the critical side of an—

1. Instrument Landing System (ILS) Glideslope Antenna
2. Instrument Landing System (ILS) Localizer
3. Microwave Landing System Elevation Station
4. Microwave Landing System Azimuth Station

7.4.6.6 PACS and SACS should be strategically located to provide maximum use for subsequent surveys yet situated where the chances of future disturbance will be minimal. An elevated site with runway end visibility is desirable. PACS and SACS should also be located where future station occupation will cause no interference to or from aircraft, including from prop and jet blast.

7.4.7 Intervisibility Choices for PACS and SACS.

In order of priority, the intervisibility choices are—

1. The PACS and both SACS are all intervisible with each other.
2. The PACS is intervisible with both SACS but the SACS are not intervisible with each other.
3. The PACS is intervisible with one SACS and both SACS are intervisible with each other.

7.5 Monument Stability.

Stability codes A, B, and C are defined in the Blue Book, Volume 1, Annex P, with examples given below. Only codes A and B are recommended, however concrete posts may be selected with code C stability if the mark is deemed stable from review of soil conditions and average frost depth.

1. Stability code A = expected to hold an elevation. Examples: rock outcrops; rock ledges; bedrock; massive structures with deep foundations; large structures with foundations on bedrock; or sleeved deep settings (10 feet or more) with galvanized steel pipe, galvanized steel, stainless steel, or aluminum rods. A-stability sleeved settings require sleeve depths of 10 feet or more.
2. Stability code B = probably hold an elevation. Examples: sleeved or unsleeved deep settings; massive retaining walls; abutments and piers of large bridges or tunnels; unspecified rods or pipe in a sleeve less than 10 feet; or sleeved copper-clad steel rods.

3. Stability code C = may hold an elevation but subject to ground movement. Examples: Concrete posts (3 feet or deeper); large boulders; retaining walls for culverts or small bridges; footings or foundation walls of small to medium-size structures; or foundations such as landings, or platforms.

7.6 Mark Setting.

After the Project Survey Plan is approved by NGS, fieldwork may begin. Marks must be set to NGS specifications for type, length, material, stability, stamping, driving, etc. outlined in NOAA Manual NOS NGS1, Geodetic Bench Marks, Floyd, 1978 and this document.

7.6.1 Mark Setting Overview.

7.6.1.1 The importance of setting quality monuments cannot be over emphasized. Properly located and set monuments provide decades of valuable use for surveying operations. Proper attention and workmanship must be given to all the steps in the process including the basic tasks of hole digging, rod driving, concrete mixing and pouring, and finishing the monument. The only physical evidence remaining after a survey is completed are the monuments; therefore, permanency and neatness of the monument and the surrounding area are of utmost importance.

7.6.1.2 Where new marks are required, PACS and SACS must be monumented in accordance with the following criteria: the paragraphs below, and the appendices to this document. Additional requirements are found in: *Federal Base Network Station Selection Guidelines;* and *NOAA Manual NOS NGS1, Geodetic Bench Marks*, Floyd, 1978.

7.6.1.3 Proposed sites for new marks should be discussed with airport management after existing marks are recovered. Inquire about underground utilities and future construction affecting mark longevity. “MISS UTILITY”-type services offered through local utility companies should be contacted before driving rod or digging, and may be required by state or local regulation.

7.6.1.4 The preliminary station descriptions and sketches must be updated after the mark is set, and photo type 1 (close-up, see NGS photo submission guidelines) must be captured along with updates of other photographs, as required. For concrete marks, take a photograph after the hole is dug and before the concrete is poured showing a level rod in the hole (to show the depth of the hole). The file name for this photograph must start with “RE” for reconnaissance; see paragraph 7.2.10.3.

7.6.1.4.1 PACS.

New PACS must meet stability code A or B requirements as defined in paragraph 7.5. New rod marks must meet the “Quality Code B” requirements found in the NGS Document *NOAA Manual NOS NGS1, Geodetic Bench Marks*, Floyd, 1978.

7.6.1.4.2 SACS.

New SACS must meet stability code A, B, or C requirements as defined in paragraph 7.5. Bronze disks set in rock outcrops, massive structures, or as concrete monuments must be used for new SACS. (See paragraph 7.6.3.)

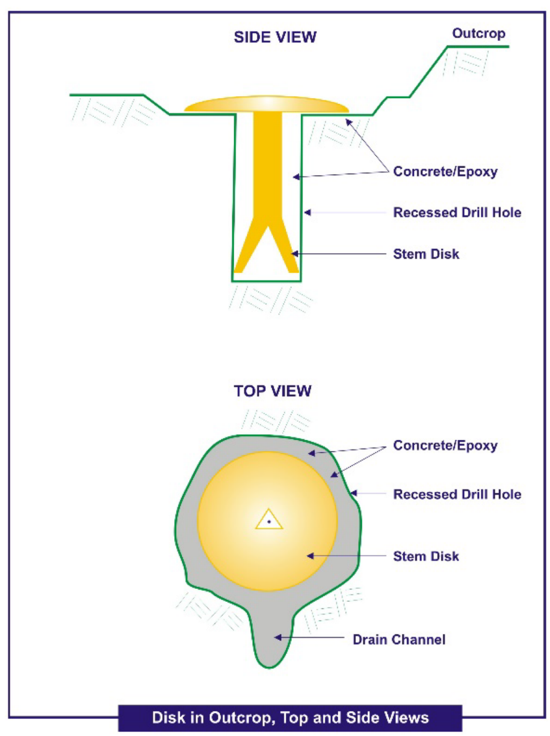
7.6.2 Stamping.

New PACS and SACS must have a unique stamping. Marks set at an airport with an official FAA location identifier must be stamped with that identifier, followed by a sequential letter, followed by the year the mark was set. Disks and "logo caps" must be stamped before they are set in place (e.g. DFW A 2018). Do not use letters "I" and "O" for the sequential letter as these can be confused with numbers "1" and "0" per NGS Bluebook, Annex D.

7.6.3 Bronze Disks.

7.6.3.1 Standard bronze, survey disks must be used for rock outcrop, massive structure, and concrete marks. A rock outcrop in which a disk is set must be hard and a part of the main ledge and NOT a detached fragment. A disk set in a drill hole must be well countersunk and adequately fixed in place using highway epoxy or equivalent material. The disks must be fastened so they will effectively resist extraction, change of elevation, or rotation. Disks also must be well countersunk in areas where snow plowing is possible. If the top of the disk is not below the level of the surrounding material, a snow plow can scrape off the brass from the top of the disk or, worse, break the disk off the stem. (See Figure 7-6.)

Figure 7-6. Illustrates the proper methods for establishing a Bronze Disk in an outcrop.



7.6.3.2 Traditionally, NGS has set disks so the lettering can be read normally (correct side up) when the observer is south of the disk and facing north across the disk.

7.6.3.3 Setting a Disk in Bedrock or a Structure.

Sound bedrock is the most desirable setting for geodetic survey control points. Besides the ease and cost effectiveness with which a disk can be installed in bedrock, it provides the most stable setting for use in terms of both underground activity and disturbances inflicted by people. Always use bedrock when a suitable outcrop exits. As a rule of thumb, the bedrock is considered potentially good if the distance between joints and fissures is greater than 1 meter. The National Geodetic Survey geodetic control disks are made of brass or bronze. They are about 9 centimeters in diameter and have a spherical surface to support the foot of a leveling rod and a center point for plumbing survey equipment. Information is imprinted on this surface to identify the monument and to aid the user in obtaining data on it. This logo is recessed so it does not interfere with the leveling rod or other survey equipment. A deformed shank, about 7.5 centimeters long, is silver-soldered or otherwise attached to the bottom surface of the disk to help prevent the disk from being dislodged.

The step-by-step procedure for setting the disk in bedrock utilizing cement is as follows:

1. Stamp the station designation and setting year on the top surface of the disk using 4.75-millimeter (3/16-inch) alphanumeric steel dies.
2. Pick a fairly level and accessible spot on the outcrop that is fully attached to the bulk of the rock. A simple test can be performed to help determine the condition and integrity of the rock by placing one's hand in the area that the disk will be set, then striking the outcrop with a moderately heavy hammer and feeling for vibration. Sound outcrop will force the hammer to rebound with each impact and vibration through the rock should be minimal at best.
3. Drill a 2.5-centimeter diameter hole about 10 centimeters into the bedrock and recess the area around the top of the hole to a diameter slightly larger than that of the disk. When the installation is completed, the top of the surface of the disk should sit level and slightly below the surface of the surrounding rock. Chisel a drain channel through the low edge of the drilled recess to allow water to drain from around the finished mark. Safety goggles should be worn when drilling into bedrock or masonry.
4. Clean the disk by wetting then rubbing all surfaces with cement to remove unwanted oils and rinse. Fill the depression on the underside of the disk with mortar using a trowel. Hold the disk loosely upside down by the end of the shank, and then gently tap the domed surface of the disk from below with the handle of the trowel several times. This will allow the mortar to settle and trapped air to escape. This is very important because it will prevent the existence of highly undesirable voids under the disk once it is in place.

5. Place the shank of the disk into the drilled hole and press the mark firmly into place. A slight rotation of the disk back and forth and gentle tapping with the end of the trowel handle helps settle the disk completely and evenly into the drilled recess in the bedrock. The disk is considered set when the slight back-and-forth movement stops and the disk sets firmly in place. Work excess mortar around the outer edge of the disk, making sure it is smooth and slightly overlapping the top outside edges of the disk for security. An exposed edge of the disk would provide an area that could be used to dislodge it. Fresh mortar on the upper surface of the disk can be easily cleaned off and out of any stamping.

6. Sprinkle some dry cement on the exposed surface of the disk, and then rub it with a clean rag or short bristled brush using circular strokes. This will clean the disk very nicely, removing all excess mortar from its surface and recessed letters. Rubbing the wet mortar around the edge of the disk in the same manner is done intentionally to finish its surface and help prevent cracking. Brush away loose cement and make sure the finished product has a neat appearance.

7. While the mortar is still wet, it must be covered to prevent heavy rains or other foreign debris from ruining its surface and to conceal the disk from people who might tamper with it. A piece of wood, cardboard, heavy paper, or similar biodegradable item will suffice.

The installation is complete. Once all accumulated trash is picked up, leave the site clean and in good order.

7.6.4 Stainless Steel Rod Marks.

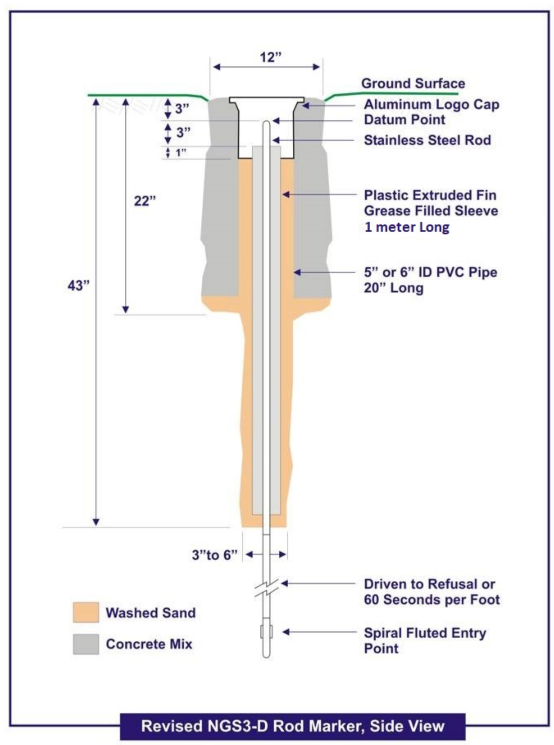
7.6.4.1 A stainless steel rod three-dimensional (3-D) drivable survey monument (see example in Figure 7-7 and a cut-away illustration in Figure 7-8) is the recommended survey marker producing the stability required for most conditions. These monuments are suitable for a PACS if the stability meets code "B" (see paragraph 7.5 for stability requirements) requirements. The principal component of this monument is a 9/16-inch stainless steel rod driven into the ground, utilizing a gasoline-powered reciprocating hammer, until refusal or a reduced driving rate has been achieved. The rod must be driven until the rod refuses to drive further, or until a driving rate of 60 seconds per foot is achieved. The rounded top of the rod is the survey datum point.

Figure 7-7. Example 3-D Monument.

7.6.4.2 Record the length of rod driven for entry into the station description. The minimum acceptable length of rod is 4 meters in non-expansive soils. Greater depths are required for low, medium, and highly expansive soils. (see *Geodetic Bench Marks,* Table 3, page 27) unless the rod becomes embedded in rock and cannot be extracted. New rod marks should be allowed to settle for at least 1 day before observations. A 1-meter long, grease-filled finned sleeve must be used with this mark to improve horizontal stability. These monuments have the upper 1 meter of the rod encased in a 1-inch grease filled plastic extruded fin sleeve held horizontally stable by back-filled, washed sand. Effects of up-and-down ground movement during freeze/thaw or wet/dry conditions are alleviated by the grease-filled sleeve promoting vertical stability. A 5- or 6-inch PVC pipe with attached standard aluminum logo cap protects and identifies the top of the monument. Either a 5- or a 6-inch diameter PVC pipe may be used if the logo cap fits correctly. The logo cap can fit on either the inside or the outside of the pipe.

7.6.4.3 If bedrock is found only a few feet beneath the surface, a concrete mark may be set instead of a rod mark if the concrete will rest directly on the bedrock. Drill several holes in the bedrock so the concrete monument will be affixed to the bedrock. Utilize rebar to anchor the monument if feasible. The area of the bedrock where the concrete will be placed must be brushed or washed off thoroughly. Install a standard concrete monument with brass disk (see paragraph 7.6.4).

Figure 7-8. Cut-Away Illustration of 3-D Monument.



7.6.4.4 Recommended Equipment for Setting Monuments.

This information and photographs in this document are intended only to provide the user with guidelines for planning and implementing this style of survey monument. The distribution of this document or the mention of a commercial company or product contained herein does not constitute, in any way, an endorsement by the FAA, NGS, or any agency of the U.S. Government.

Figure 7-9. Shows the NGS Mark Setting Truck and associated equipment.

7.6.4.4.1 Rod Drivers and Accessories.

- 1–Any driver with a minimum impact force of 25-foot pounds per blow, such as Wacker Model BHB 25 (with tool kit) or Pionjar Model 120 (with tool kit), for driving stainless steel rods.
- 1–Rod Driving Insert, holds machine on rod and acts as impact point while driving rods.
- 1–Shovel Bit, for machine to help start and dig holes (not required but might be helpful).
- 1–Pint Required Oil Type and Calibrated Container, for determining gas/oil mix.
- 1–Gas Container and Gasoline, for driving machine and generator.

7.6.4.4.2 Digging the Hole.

- 1–Post Hole Digger, capable of digging a 4-foot deep hole.
- 1–Gas Powered Post Hole Digger with Augurs (not required but increases productivity).
- 1–Digging Bar, for rocks and hard to dig holes.

7.6.4.4.3 Driving the Rod.

- 1–2-pound Hammer, to start rods, stamp designations, etc.
- 2–8-inch Quality Pipe Wrenches (i.e. Rigid), for attaching lengths of stainless steel rods.
- 1–Bottle Loctite, for cementing threads into the stainless steel rods.

7.6.4.4.4 Finishing the Rod.

- 1–Hack Saw with extra Quality Blades, for cutting stainless steel rod.
- 1–4- or 5-inch Grinder (electric or battery powered), for finishing top of rod.
- 1–Gas Powered Electric Generator, to power grinder and or drill.
- 2–Sanding Disks (medium grade), for grinder.
- 1–Steel File(s), for fine finishing top of rod.
- 1–Centering Sleeve, to help center punch mark on top of rod.
- 1–Center Punch, to punch plumbing point on top center of rod.
- Assorted Sand Paper or Sanding Pad, for fine finish to top of rod.

7.6.4.4.5 Finishing the Monument.

- 1–1/4-inch Stamping Set, for lettering and numbering station designation/date.
- 1–Hand Saw, for cutting 5- or 6-inch PVC pipe.
- 1–Bucket or Wheel Barrel, to mix cement/move unwanted dirt.
- 2–5-gallon Water Containers and Water, to mix cement and clean equipment.
- 1–Hoe, to mix cement (can be replaced by Sharp Shooter Shovel).
- 1–Heavy Rubber Mallet, to help lower logo cap/5- or 6-inch PVC pipe into cement.
- 1–Cement Finishing Trowel, to smooth top of concrete for neat appearance.
- 1–Stiff Vegetable Type Brush, to clean logo cap and hinges.

7.6.4.4.6 Assorted Accessories.

- 1–Tool Box with regular assortment of tools, for incidental repairs: Slotted and Phillips
- Head Screwdrivers, Pliers, Needle Nose Pliers, Wire Cutters, Assorted Wrenches,
- Sockets, Allen Wrenches, Wire Brush.
- 1–Round Nose Shovel, to help dig hole and move unwanted dirt.
- 1–Tile Spade sometimes referred to as a Sharp Shooter Shovel, to help dig hole and mix cement.
- 1–Roll Black Tar Paper (Felt Paper), for making a round form for top of monument.
- 1–30-Meter Tape Measure, for distances in station description.
- Leather or Cotton Gloves.
- Assorted Rags or Paper Towels.

7.6.4.4.7 Materials Required for Each Mark.

- Lengths of 9/16-inch Stainless Steel Rods, 4-foot sections.

- 1–4- to 5-inch piece of Stainless Steel Rod, used as impact point and protection while driving rods.
- Adequate supply of 3/8-inch Threaded Stainless Steel Studs.
- 1–Steel Spiral (fluted) Rod Entry Point, standard order.
- 1–Aluminum Logo Cap, standard order.
- 1–Schedule 40 PVC Pipe, 5- or 6-inch diameter, 24-inch length.
- 1–Plastic Extruded Fin Sleeve, 1-inch diameter, 3-feet minimum length.
- 2–Plastic End Cap Alignment Bushings, center drilled to 9/16-inch (for extruded fin sleeve).
- 1–Pint PVC Cement, can be replaced with adequate Epoxy type.
- 1–Pint PVC Cleaning Solvent, when using PVC cement.
- 1–17-ounce tube, Non-Toxic, Food Grade Grease, with Applicator (i.e. grease gun).
- Ready Mix Concrete (amount depends on width and depth of hole).
- 2–Pounds Portland Cement, added to enhance integrity of ready mix concrete if necessary.
- 0.5–Cubic Feet Washed Sand, fills bottom of hole and inside of PVC pipe around grease sleeve.

7.6.4.5 **Setting Procedures.**

The time required to set an average mark using the following procedures is 2 to 3 hours. Several steps, such as steps 3, 4, and 5, should be accomplished at a maintenance shop.

1. Ensure the monument site selection is discussed with airport management and/or property owners, and the location meets all station siting requirements. Inquire about future construction that might affect mark longevity. (See Figure 7-10.)

Figure 7-10. Initial Site Selection away from traffic areas.

2. Contact "MISS UTILITY"-type services offered by local utility companies to inquire about underground utilities before digging or driving rod.

3. Stamp station designation and year of establishment into the blank area on the collar of the logo cap. (See Figure 7-11.)

Figure 7-11. Stamp the station designation on the collar of the logo cap.

4. Cut a 20-inch section of 5- or 6-inch PVC pipe. Ensure the end that will receive the logo cap is cut true and is clean. Using primer and solvent cement formulated specifically for PVC, glue the stamped aluminum logo cap to the end of the 20-inch PVC section. If this step is performed on site, allow time for the glue to set by digging the hole and driving the rod after preparing the PVC and logo cap.

5. Using a power auger or post hole digger, drill or dig a round hole in the ground 12 to 14 inches in diameter and 22 inches deep. Extend the center of the bottom of the hole by drilling or digging a 3- to 6-inch diameter hole an additional 21 inches for a total depth of 43 inches. This extended area will be back-filled with washed sand around grease-filled sleeve. (See Figure 7-12.)

Figure 7-12. Digging the 43" deep hole; 12"-14" diameter for the top 22" in depth, and 3"-6" diameter for the bottom 21".

(**Note:** Dirt removed with a wheelbarrow)

6. Glue both plastic end cap alignment bushings on a 3-foot section of the plastic extruded fin sleeve. Let glued ends dry completely. Pump food grade grease into capped sleeve until 3/4 full, allowing for displacement by rod and completing the grease filled sleeve.

7. Using a standard 3/8-inch threaded stud coated with Loctite™ (use Loctite™ on all *permanent* connections), attach two 4-foot sections of stainless steel rods together. At one end of the length of rod, attach a standard spiral (fluted) rod entry point with a 3/8-inch threaded stud. On the opposite end, attach a short 4- to 5-inch piece of rod with a 3/8-inch threaded stud. Tighten all connections using two pipe

wrenches a 1/4 to 3/4 turn past the point of contact of all rod ends except the impact point, which will be continually removed. This tightening requires a certain "feel" and ensures that the rod ends are seated together with the greatest possible tension but not to the point of breaking a stud. Rods tightened in this fashion should not vibrate loose when they are driven into the ground.

8. Center the 8-foot-long connected rod into the bottom of the hole and drive with a 2-pound hammer until the rod is secure and as plumb as possible. (See Figure 7-13.) A 2×4 with a 1/2-inch hole can be centered and braced over the hole to help guide the rod straight into the ground. Drive the section of rod to about the top of the hole with a gas-powered reciprocating driver, such as Whacker model BHB 25, Pionjar model 120, or another machine with an equivalent driving force.

Figure 7-13. Starting the stainless steel rod with a hammer.

9. Remove the short piece of the rod (impact point), leaving the threaded stud in the section of rod in the ground. Attach another 4-foot section of rod and, using a new threaded stud, thread on the impact point. This "cycling" of a new stud from impact point into the top of rods in the ground ensures unweakened studs at all connections. Remember to coat threads on the permanent connections with Loctite™. Tighten securely utilizing pipe wrenches as described above in step 6. Always tighten rods maintaining a clockwise pressure to avoid loosening rods already in the ground. Drive the new length of rod into the ground with the reciprocating driver.

10. Repeat step 9 until the rod refuses to drive further (anchored) or until a driving rate of 60 seconds per foot is achieved. (See Figure 7-14.) In the event the rod will not sufficiently slow down to meet desired driving rate, terminate upon reaching 90 feet (22.5 rods). This will leave about 2 feet of rod out of the hole. If possible, let the rod set overnight, then drive the remaining 2 feet of rod to determine whether driving rate has reduced. If the rod feels secure in the ground, use this depth even though the minimum driving rate of 60 seconds per foot has not been met. If the rod turns freely in clockwise direction, contact NGS for a decision about driving additional rods. Sometimes, all that is necessary to achieve a well-anchored rod is driving it a few more feet. In other instances, an additional 100 feet might be required. Indicate in the written station description the depth of rod and whether it was driven to refusal or met the slow driving rate. Also include a description of any unusual mark setting circumstances.

Figure 7-14. Driving the stainless steel rod to refusal.

11. When refusal or prescribed driving rate is reached, cut off the rod with a hacksaw or comparable tool, always removing at least the tapped and threaded portion, leaving the top of rod about 3 inches below ground surface. (See Figure 7-15.)

Figure 7-15. Cutting off the top of the stainless steel rod using a hydraulic cutter approximately 3 inches below the surface.

12. Shape the top of the rod to a smooth, hemispherical surface using a portable grinding machine with a grinding attachment or sanding wheels, files, and sand paper to produce a nicely finished, rounded surface. Ragged edges or grinding marks are not acceptable on the top of the finished rod. (See Figure 7-16.)

Figure 7-16. Finishing the top of the rod.

13. The datum point must then be created by center punching a dimple on top of the rod to provide a plumbing (centering) point. Place the centering sleeve over the top of the rounded rod to facilitate locating the exact center of the rod. Punch a substantial dimple, 1/16-inch deep, into the top of the rod using a punch and hammer or spring-loaded center punch. Several blows might be needed to create a sufficient dimple. Remember, this is the actual survey point, so do not hesitate to spend a few extra minutes to produce a professional, finished product.

14. Insert the grease-filled sleeve, produced in step 6, over the rod with the unfilled portion at the top. (See Figure 7-17.) The upper end of sleeve will fill as the rod displaces grease from the bottom. The datum point on the top of the rod should protrude through top of the sleeve about 3-inches with the sleeve extending to the bottom of the hole. Clean the residual grease off the exposed top of the rod.

Figure 7-17. Preparing one-inch PVC grease filled "finned" sleeve.

15. Back-fill and pack with washed sand the bottom 23 or more inches of the hole around the outside of grease sleeve. (See Figure 7-18.) This fills the bottom of the hole and helps stabilize the sleeve.

Figure 7-18. Backfilling the bottom two feet of the hole with washed sand.

16. Place the 5- or 6-inch PVC pipe and logo cap over and around the grease sleeve and rod in the center of the hole. (See Figure 7-19.) The bottom of the PVC pipe should extend into the top of the sand in the bottom of the hole. Leave the top of the logo cap and PVC pipe slightly higher than the top of the ground surface until the concrete is in place. Back-fill the center of the PVC pipe with washed sand around and to within 1-inch from the top of the grease-filled sleeve. The rod should be centered in the PVC pipe.

Figure 7-19. Preparing to place 5 or 6 inch PVC pipe over and above the centered grease sleeve and stainless steel rod.

17. Mix concrete in a bucket or wheel barrel to a pasty, well-moistened consistency, like mashed potatoes. (See Figure 7-20.) Add Portland cement, if necessary, in sufficient quantity (1 to 2 pounds) to enhance concrete mix or dry an over-moistened mixture to maintain adequate consistency. A good indication of adequate consistency is that the mix neither runs nor falls off the shovel but sluggishly slides off and flattens upon hitting the ground.
18. Pour concrete into the hole around the logo cap and PVC pipe casing, filling to slightly below the ground surface. (See Figure 7-21.)
19. To avoid frost heaving of the PVC collar, a round form should be used to ensure the outside walls of the concrete are vertical and do not produce a mushroom-shaped wedge at the top of the mark. Open the logo cap and grasp the PVC pipe, then shake to settle concrete around the pipe to fill voids. (See Figure 7-22.) Add concrete to within 1/2-inch of the ground surface.

Figure 7-20. Mixing concrete for use in completing the monument.

Figure 7-21. Completed monument and access cover should be slightly lower than the surface of the ground.

Figure 7-22. Shaking the PVC pipe to settle concrete and fill any voids.

20. Trowel smooth the top of the concrete to a fairly smooth finished surface. (See Figure 7-23.) Tap alternate edges of the logo cap, using a rubber mallet or hammer and wooden block, lowering it and attached PVC pipe into the surface of the concrete. Finish the top of the concrete by troweling a smooth, finished surface, round in appearance, and sloped slightly outward to aid drainage of rain water.

Figure 7-23. Trowel the top of the concrete until there is a smooth finished surface.

21. Add sand to the inside of the PVC pipe to bring its level to within 1 inch of the top of the grease sleeve. Clean any overlapping concrete from the surface of the logo cap using the vegetable brush. The finished height of the logo cap and access cover should be slightly lower than the surface of the ground. The logo cap should be approximately in the center of the top of the concrete. The datum point should be about 3 inches below the cover of the logo cap and centered in the 5- or 6-inch PVC pipe. The top of the grease-filled sleeve should be about 3 inches below the datum point and the washed sand 1 inch below top of the sleeve. Clean any cement that might have gotten onto the exposed rod or datum point.

22. Clean all equipment and remove all debris, such as extra cement, excess dirt, and trash, leaving the area in the condition it was found.

7.6.5 Concrete Marks.

New concrete marks, with standard bronze disks, may be used for SACS only. Construction requirements are detailed below. New concrete marks should be set slightly recessed with the ground and allowed to settle for at least 1 day before observations. Disks set in concrete must be centered in the top of the concrete surface and be flush or slightly recessed with the surface of the concrete; the top of the disk must be free of concrete. A round form must be used for the top of all concrete marks and logo cap protective collars. This will help ensure a neat finish and help protect against “mushrooming,” which can result in frost heave. Black tar paper (felt paper) or ready-made cardboard (available at home supply stores) can be used to easily construct a form. All loose concrete and other debris around the construction site must be removed and the site left in excellent condition.

7.6.5.1 Concrete Characteristics.

7.6.5.1.1 General.

The concrete should be workable, strong, and durable. Workability refers to the ease concrete can be effectively placed, consolidated, and finished while remaining free from segregation. Workability depends on the proportions of the ingredients and the shape of the individual particles of aggregate. Strength refers to the ability to withstand external forces without rupturing. For survey monuments, high strength is not the most important property, although strong concrete usually indicates it is durable. Durability is the ability to withstand deterioration over a long time and is primarily influenced by the water tightness of the cured concrete.

7.6.5.1.2 Destructive Forces.

Several forces can lead to weakening or deterioration of concrete. The freezing of water in cured cement exerts great pressure against the inner walls of the pores, tending to break down the concrete. In fresh concrete, the expansion of freezing water breaks the bonds developing between solid particles, making the concrete weak and porous. Leaching and chemical attack are also detrimental effects on concrete. Leaching occurs over a long period when water slowly percolates through concrete and dissolves some of its constituents. Chemical attack is particularly common in alkali soils. Dense, impervious concrete is resistant to these destructive forces.

7.6.5.1.3 Ingredients.

The quality of the ingredients and their proportions help determine how dense and impervious the cured concrete will be. The ingredients include aggregate, cement, and water. The aggregate should be clean (free from silt and clay, harmful chemicals, and organic matter) and well-graded, i.e., it contains proportionate amounts of many particle sizes. In specifying mix proportions, the aggregate is usually divided into two parts—sand (particle size less than 2/3 cm) and gravel (particle size greater than 2/3 cm). Both parts should be well-graded. Porous aggregates split easily or are otherwise weak or permeable resulting in poor concrete. Examples of poor aggregates include shale, claystone, sandstone, and micaceous rocks. Portland cement is designated by one of five types. Type I is for general use where no special properties are needed. Type III is a high-early-strength type for use when concrete will be curing during cold weather. Type V is used where the concrete will be subject to an alkali environment. Types II and IV are not suited for setting marks. Contact local concrete companies to determine the best concrete type for use in the work area. The water used in a concrete mix should be relatively free of impurities such as acids, alkalies, salts, oil, organic matter, and silt. These can decrease the strength and durability of cured concrete. As a rule, do not use water that you would not drink.

7.6.5.1.4 Mixing, Placing, and Curing.

Pre-mixed concrete materials may be used. If raw materials are used, the suitable proportions (by bulk volume) of cement to sand to gravel are 1:2:3. If the gravel is made up of fragmented or angular particles, use a little less gravel and proportionately more sand. Add only enough water to make the mix workable. About half the water added to the mix is used in the chemical reaction (hydration) that causes the paste to harden into binder. If too little water is used, however, the mix will not compact properly, and spaces will be left in the mass. A good indication of the right amount of water is that the mix neither runs nor falls off the shovel but sluggishly slides off and flattens upon hitting the ground.

7.6.5.1.5 Cold Weather Precautions.

The freezing of fresh concrete has a damaging effect because the expansion of water as it freezes separates the solid particles in the mix. This reduces the strength of the bond and makes the concrete more porous and correspondingly less durable. Three protective measures should be taken in cold weather, either singly or in combination.

7.6.5.1.6 Use Warm Ingredients.

During the first 24 hours after a mix has been placed, it develops little heat of its own to prevent freezing. After 24 hours, some heat is developed as a product of the chemical reactions occurring in the mix. The use of warm ingredients is especially beneficial during the first 24 hours. Note, however, that mixing water above 165° F could cause a flash set. To keep the aggregate and cement warm, store them indoors.

1. Use Type III (high-early-strength) cement or special additives that speed curing. Calcium chloride is good for this in amounts not exceeding 2 pounds per 94-pound sack of cement. The calcium chloride should be dissolved in the mixing water instead of mixing it with the other ingredients. Other additives include Thoroguard ™ and Trimix ™. If a large number of concrete marks are being installed by mass production using a “ready-mix” concrete, fast-curing additives should not be added until the concrete is delivered on site.

2. Insulate the finished mark for a week after the concrete is poured. One method is to cover the mark with boards resting on supports. This construction is covered with paper or plastic, then by a layer of straw, Styrofoam, or similar insulating materials more than 15 centimeters thick and finally by a layer of soil 15 to 30 centimeters thick. Pile snow loosely on top if it is available.

7.6.5.2 Constructing Concrete Monuments[1] Steps.

1. Obtain permission from the property owner before proposing new mark locations.
2. Install a tall stake (lath) at each proposed site for a new mark. Write the proposed station name on the stake.
3. Obtain clearance from "MISS UTILITY" or other utility locating services offered by local utility companies (underground utilities) before digging.
4. Drill or dig a 12- to14-inch diameter hole in the ground 3.5 to 8 or more feet deep. The depth depends on frost penetration in the area. The minimum depth is 3.5 feet. Keep the sides of the hole as smooth as possible. The rounded, bottom portion of the monument must extend at least 1 foot below the frost line. See NOAA Manual NOS NGS 1, *Geodetic Bench Marks,* which contains a diagram showing extreme depth of frost penetration.
5. Enlarge the bottom portion of the hole using a shovel, such as a "sharp-shooter" (also called a "drain spade") so the hole is at least 2 inches larger in radius than the main shaft of the hole. This will make the bottom of the monument bell-shaped; see Figure 7-26.
6. Remove or tamp down the loose dirt at the bottom of the hole.
7. Remove any loose dirt that might fall into the hole during concrete installation. A layer of loose dirt from the sides or top of the hole, mixed with the concrete, will create a fracture line (or plane), which could lead to the monument breaking, thus destroying the mark.
8. Procure a round, cardboard form 12 inches in diameter to line the top 12 to 18 inches of the hole. Test fit the form in the top of the hole. This form will help avoid any shoulders or mushrooming effect near the top of the monument, which might allow for frost heave. The form will also help make a neater looking monument. A cardboard, biodegradable, 12-inch diameter form is commercially available. Allow the form to protrude from the ground 2 to 6 inches.
9. Mix the concrete well before it is placed, otherwise the minute particles of cement will not be sufficiently wet and the aggregate will not be completely covered with paste. Prior to adding water, mix the ingredients well. Then, slowly add water and continue to mix. Do not make the mixture too wet.
10. Dampen the hole before concrete is added so moisture will not be drawn from the fresh concrete into the surrounding soil. In no case should it be so wet as to be muddy.

---

[1] Portions of this paragraph apply to concrete collars around rod marks as well as to concrete monuments.

11. Place concrete in the hole. Continuously tamp the mix into a compact mass so it becomes less pervious and consequently more durable. Do not contaminate the interior of the monument with dirt.

12. Place the form into the hole when the level of the concrete is approximately 1 foot below the surface. Continue to be careful not to allow any dirt to fall into the hole.

13. Add concrete until the top is even with or slightly below the surface of the ground. This helps ensure the monument is not struck by lawn mowers, snow plows, etc.

14. Smooth off the top of the monument with a trowel. Create a gentle slope toward the outside so rain water will drain off. Bevel the outside edge of the monument.

15. Stamp the disk prior to installing it in a concrete monument or a drill hole. Stamp the disk on a stamping block that has a curved surface that matches the curvature of the underside of the disk. Neatly stamp the station designation (name) above the triangle, centered below "GEODETIC CONTROL MARK," and then stamp the year below the triangle.

16. Set the disk into position in the top center of the monument with the top of the triangle below the name pointing north (so a visitor facing north will be able to read the disk's lettering). Placing a small amount of concrete on the underside of the disk before setting helps ensure that air is not trapped under the disk.

17. Press the disk into the concrete until the disk edge touches the concrete. Then tap the disk with the handle end of the trowel until the top edge of the disk is flush with or slightly recessed into the concrete (to the point that vandals cannot get a pry bar under the disk). Do not recess the disk a greater amount because this makes a hollow that will collect rainwater and possibly shorten the life of the mark due to freezing action.

18. Clean the disk. Sprinkle some dry cement on the exposed surface of the disk, and then rub it with a clean rag or short bristled brush using circular strokes. This will clean the disk, removing all excess mortar from its surface and recessed letters. Rubbing the wet mortar around the edge of the disk in the same manner is done intentionally to finish its surface and help prevent cracking. Brush away loose cement and make sure the finished product has a neat appearance.

19. Cover the mark for at least 7 days. This prevents rain from making the mix too wet and from ruining the finished surface. It also prevents the surface from drying too rapidly, leaving too little water for complete hydration. In addition, it prevents debris from sticking to the surface of the wet concrete. A 12-inch diameter lid is available

that fits on the 12-inch cylindrical form. This lid will also keep out the dirt during the next step and final clean up.

20. Replace dirt round the form and tamp into place. At the surface, replace dirt and sod around the form and tamp into place.

21. Rake the area until neat, and remove excess materials. Do not leave any construction or other materials at the site. Leave the area as neat as or neater than when you arrived. **Note:** The protruding form and lid must be removed later during survey observations.

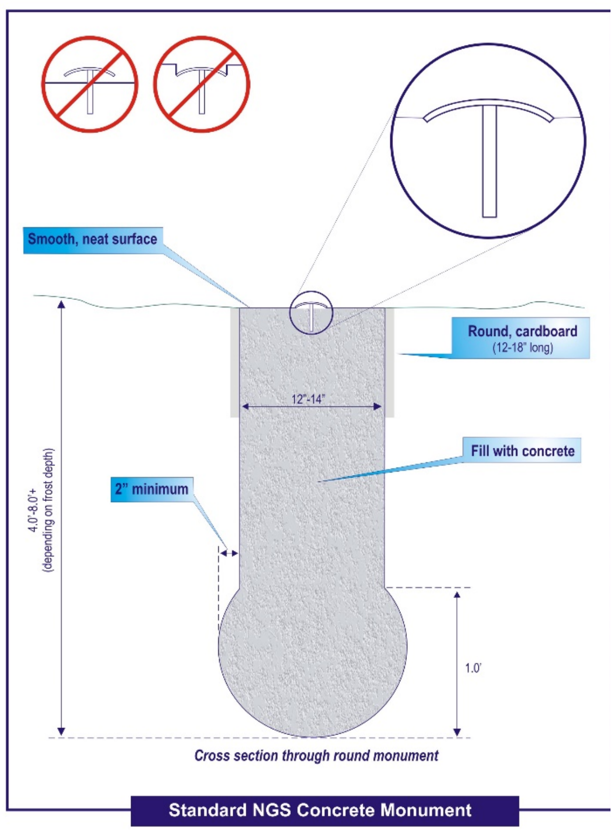
22. Remove excess dirt and dispose of it properly. In some rural areas, there might be a logical spot to dump the extra soil. If the mark is in an area consisting of groomed lawns, the dirt must be removed from the site.

23. Remove excess concrete from the site. Proper planning should minimize excess concrete. Any excess must not be dumped onsite.

24. Installation of NGS Witness Posts (see paragraph 7.6.6) are at the option of the firm. Generally, do not use Witness Posts in areas of high population density nor on airports. They are very useful to future surveyors in more remote areas.

25. Do not add magnetic materials to the monument.

Figure 7-25. Cut-Away Illustration of Concrete Monument.

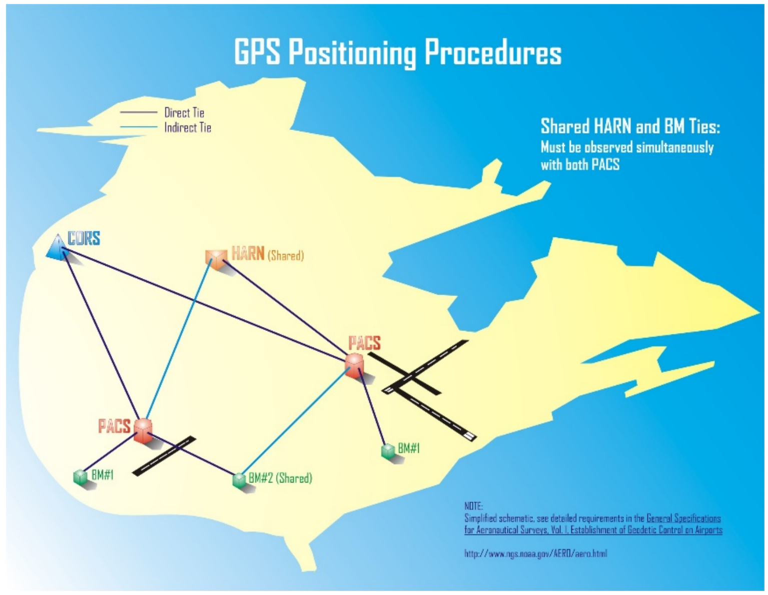


7.6.6 Witness Posts.

Placement of witness posts on airport property must be pre-approved by the airport manager. Witness posts should be used on an airport only when they can be placed in a non-obtrusive area, such as a fence line or no-mow/snow plow area, and should be driven as deep as practical so they do not obstruct any restricted safety areas. Witness posts should not be used when the property owner objects, when the post cannot be driven, or when the mark should not be made easily visible because of a high risk of vandalism.

7.7 GPS Positioning Procedures.

Figure 7-26. Illustrates how PACS are tied to the NSRS.



GPS observation requirements are detailed in the paragraphs below. A GPS equipment list and GPS observation scheme must be approved by NGS prior to commencing the field observations. Observing windows must be selected, and modified as necessary, to maximize satellite visibility and minimize Positional Dilution of Precision (PDOP) for each session. Incorporate any information from Notice Advisory to NAVSTAR Users (NANU) messages, available from the USCG Navigation Center webpage, when scheduling GPS observations to ensure optimal survey conditions.

7.7.1 CORS Selection.

7.7.1.1 The CORS sites selected must be included in the NGS National CORS system. Use as many National CORS sites in the project area as feasible. Position each PACS directly to the nearest National CORS station. In areas such as Alaska where a PACS is not within 300 km of a CORS, a CTCORS must be established.

7.7.1.2 CORS maps, data, and information are available on the NGS National CORS website (see Appendix G for access). Each CORS is designated using a four-character site identifier. Some CORS sites have two or more antennas. CORS sites with multiple antennas normally carry the antenna number as the fourth character. The correct antenna name must be used when downloading data and the antennas coordinate information. Check the "data availability" feature on the NGS CORS website to determine which CORS antenna was in use during observations and to see if there are any gaps in the data. The CORS station coordinate file contains two or three positions based on different reference locations: the Antenna Reference Points (ARP), the L1 phase center, and (for some CORS) an external monument directly below the ARP. All reference location coordinates are given in either the International GNSS Service (IGS) or NAD 83 reference system, along with velocities. Ensure the proper coordinates are used when processing the data.

7.7.1.3 Some CORS sites have nearby monumented control points serving as reference marks for the CORS. The survey marks (usually two) at each CORS site might have names similar to the antenna names. Take care not to confuse the disk names and positions with the antenna names and positions.

7.7.1.4 The weekly *CORS Newsletter* is available through the NGS CORS webpage. The *Newsletter* provides information on the status of the CORS system. Users may subscribe to the newsletter at this site.

7.7.2 CTCORS Selection.

A Central Temporary Continuously Operating Reference Station (CTCORS) must be used if the nearest CORS is more than 300 km from the PACS. The CTCORS must be established by using either an existing permanent GPS base (which is not an NGS CORS), or setting up a GPS receiver on a suitable existing horizontal NSRS station. In both cases it must provide the CORS function in the positioning of the PACS. The position of the CTCORS must be verified by using the GPS observation requirements in paragraph 7.7.4.1. Because of the long distances involved and the additional stations being positioned from the CTCORS, extreme care should be taken during the observation and processing of this data. Separate tripod setups are required at both the CTCORS and the PACS for each session. During all CTCORS operations, ensure the CTCORS antenna remains fixed. Sandbags are recommended to stabilize the tripod, and frequent checks should be made of the antennas centering and height. CTCORS Station Selection Criteria are listed below. The CTCORS station selection must be approved by NGS prior to commencing field observations. The accuracies of the passive GPS stations are published on NGS datasheets at 95% confidence.

Table 7-1. CTCORS Station Selection Criteria.

PRIORITY	TYPE OF STATION	STATION IS BENCH MARK	STATION IS AT AIRPORT
1	Permanent GPS base (not an NGS CORS)	YES	YES
2		YES	NO
3		NO	YES
4		NO	NO
5	Passive NGS ("HARN") GPS control (give higher priority to stations with smaller published accuracy values)	YES	YES
6		YES	NO
7		NO	YES
8		NO	NO

7.7.3 Accuracy Standards.

The required accuracy standards for PACS and SACS are outlined in Table 7-2. The values given are at the 95% confidence level based on final constrained least squares network adjustments. If the orthometric heights are determined using GPS, their accuracies will typically be greater than their corresponding ellipsoid height accuracy, as indicated in the table.

Table 7-2. PACS and SACS Accuracy Standards.

ITEM	HORIZONTAL	VERTICAL	
		ORTHOMETRIC	ELLIPSOID
Primary Airport Control Station (PACS) [1]	3 cm	5 cm	5 cm
Secondary Airport Control Station (SACS) [2]	2 cm	5 cm	4 cm
Wide Area Augmentation System (WAAS) Reference Station [1] (not an NGS CORS)	3 cm	5 cm	5 cm
Wide Area Augmentation System (WAAS) Reference Station [3] (not an NGS CORS)	1 cm	0.2 cm[4]	2 cm

Notes:

[1] Network accuracies (relative to NSRS stations used as constraints).

[2] Local accuracies relative to the PACS and other SACS at the airport.

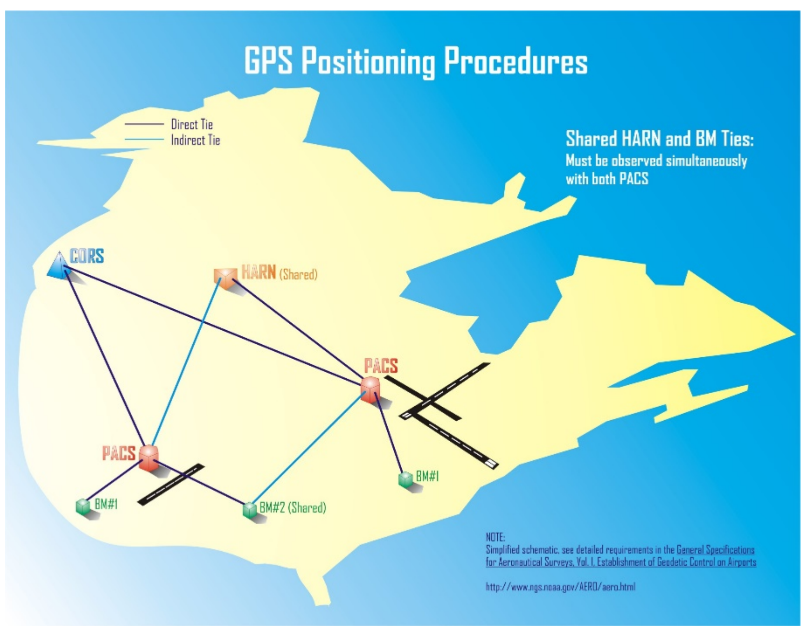
[3] Local accuracies relative to the other WAAS Reference Station at the site.

[4] For leveled height differences between WAAS Reference Stations.

7.7.4 GPS Observation Requirements.

GPS observation requirements are described in the sections below for each type of mark. When 4-hour sessions are specified, at least 4 hours of data in common between all simultaneously occupied stations are required in the final computer reductions. Observation of sessions longer than the minimum is highly recommended. Separate tripod setups are required for each session.

Figure 7-27. PACS are tied to the NSRS. Several PACS can share common points.



7.7.4.1 **CTCORS Sites.**

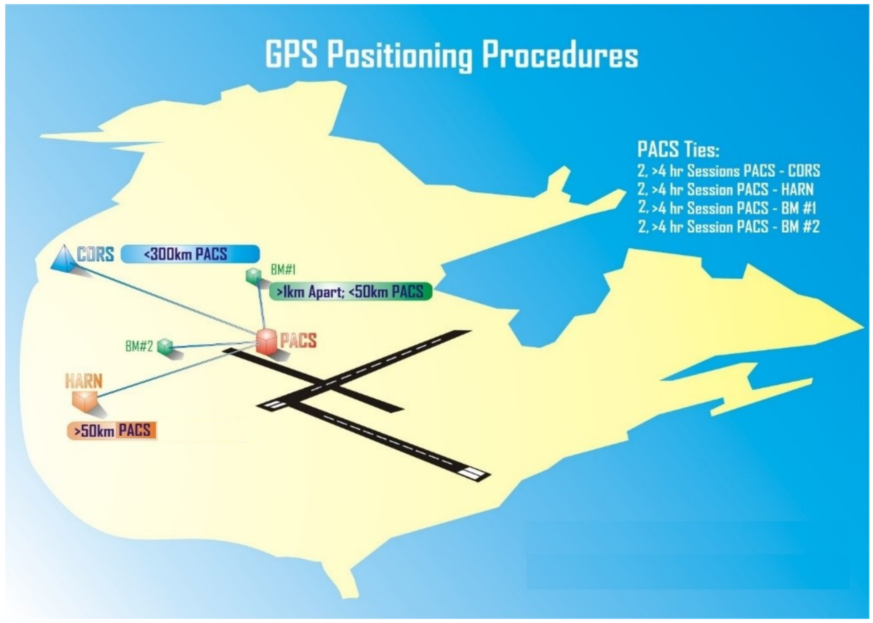
The position of the CTCORS must be checked by observing three or more independent, continuous, simultaneous observation sessions of at least 4 hours with a CORS station. These sessions should be the first sessions observed while positioning various PACS. In addition, one 4-hour session must be used as a check at the end of the project. If the distance between the CORS and CTCORS is greater than 300 km, contact NGS for guidance on increasing the length of observation sessions (this may also be necessary for projects located north of 55° latitude due to lower satellite elevation angles and greater possibility of geomagnetic activity). All CTCORS must be tied by GPS surveys to nearby GPS-suitable, North American Vertical Datum of 1988 (NAVD 88) bench mark(s). See specific requirements in the Bench Mark Ties section in paragraph 7.7.4.4.

7.7.4.2 **Primary Airport Control Station (PACS) and HARN Tie[2].**

7.7.4.2.1 Each PACS must be positioned from the CORS/CTCORS in two or more independent, continuous, observation sessions of at least 4 hours in length. The observations to position the PACS must be performed simultaneously with the CORS/CTCORS observations. The start time of a PACS observing session on subsequent days must be at least 2.5 hours different than the previous PACS session to incorporate different satellite geometry.

[2] If a CTCORS is required for connections, substitute CTCORS for CORS.

Figure 7-28. GPS Positioning of the PACS using CORS and HARN stations.



7.7.4.2.2 All PACS must have a separate positional check by simultaneously observing at least two sessions of 4 hours or more in length with a station. Although HARN is an obsolete term, it is used here to maintain consistency with earlier versions of this document. In this context, a HARN station is a passive mark with NGS-published GPS-derived geometric coordinates (latitude, longitude, and ellipsoid height) referenced to the current realization of NAD 83 and with positional accuracies given at the 95-percent confidence level. The HARN station should be within 50 km of the PACS. The start time of a HARN observing session on subsequent days must be at least 2.5 hours different than the previous HARN session to incorporate different satellite geometry.

7.7.4.2.3 In the case of processing multiple airports, a single HARN station meeting the distance requirements to more than one PACS can be used. Generally, no more than two PACS should be tied to a single HARN station in one session. Use additional observation sessions on the same HARN, or occupy an additional HARN station to satisfy the HARN tie to other PACS in the same area.

7.7.4.2.4 An existing HARN station on an airport should be used as a PACS if it meets the siting, construction, and intervisibility requirements. A separate HARN tie is not required.

7.7.4.2.5 In some situations, it may be preferable to use an NGS CORS in lieu of a HARN station. This can occur if there are no suitable HARN stations near the project site. It can also occur if the HARN(s) used as constraints are not consistent with the PACS or OPUS solutions. In such cases a significant advantage of CORS is that they can be added to a project without any additional fieldwork. But regardless of the reason for using CORS in place of HARN stations, approval for such substitutions must be obtained from NGS.

7.7.4.2.6 Using the Adjust Utility COMPVECS, the vector processing results of the two PACS sessions must check within 1 cm for the north and east components and 3 cm for the up (ellipsoidal height) component. The final adjusted positions of the HARN ties should check within ±3 cm horizontal and ±5 cm ellipsoidal height of the published positions.

7.7.4.3 Secondary Airport Control Stations (SACS).

Each SACS must be observed in two or more independent, continuous sessions of at least 2 hours. The session start times on the day of observation and/or subsequent days must be separated by at least 2.5 hours to ensure a significant change in satellite geometry.

1. These observations must be simultaneous with PACS observations for that airport.
2. Each new SACS must be simultaneously observed with other SACS on the airport
3. If a SACS is also one of the bench marks or a HARN tie (see paragraph 7.7.4.4), the two or more 2-hour sessions are adequate for the tie, rather than the normal 4-hour requirement. This is due to the short distance from the PACS to the SACS. However, the maximum GPS vector length must not exceed 25 km, as stated above (for cases where a vector is not processed between the PACS and the SACS).
4. Using the Adjust Utility COMPVECS, the vector processing results of the two SACS sessions must check within 1 cm for the north and east components and 3 cm for the up (ellipsoidal height) component.

7.7.4.4 Bench Mark Ties.

7.7.4.4.1 Ties to two separate NSRS 1st or 2nd Order NAVD 88 bench marks are required for each PACS and CTCORS station. The ties must be performed by observing each bench mark in at least two 4-hour sessions simultaneously with the PACS or CTCORS. For each bench mark, the start time of observations on subsequent days must be at least 2.5 hours different than the previous session to incorporate different satellite geometry. The two bench marks do not need to be observed during the same session. Bench mark ties must be selected in accordance with the Bench Mark Priority Table on the following page. Use of first-order bench marks is highly desirable. The two bench marks should be as close as possible to, and no further than 50 km from, the PACS or CTCORS. Bench marks should be at least 1 km apart to help ensure they are not both affected by the same upheaval or subsidence effect. If the PACS or CTCORS has a published bench mark elevation, that elevation satisfies one of the bench mark tie requirements. A single bench mark may satisfy one of the tie requirements for more than one PACS if it meets the distance requirements for each PACS. Generally, no more than two PACS should be tied to a single bench mark station in one session. Occupy additional bench marks, or use additional observation sessions on the same bench mark, to satisfy the bench mark ties for other PACS in the same area. Bench mark orthometric heights should agree within ±5 cm of published elevations. All bench mark elevations used in this survey must be published NSRS NAVD 88 bench mark elevations, in meters. Consult NGS for guidance on bench mark controls to use if any checks exceed 5 cm.

7.7.4.4.2 Using the Adjust Utility COMPVECS, the vector processing results of each bench mark session must check within 1 cm for the north and east components and 3 cm for the up (ellipsoidal height) component.

Table 7-3. Bench Mark Priority Table.

PRIORITY	DISTANCE TO CLOSEST FIRST-ORDER BENCH MARK	SELECTION CRITERIA
1	< 25 KM	Use first-order bench mark.
2	25 – 50 KM	Use first-order bench mark if closest; Second-order bench mark may be used if it is less than ½ the distance to the first-order bench mark.
3	> 50 KM	Use a second-order bench mark if it is less than 25 km away; otherwise contact

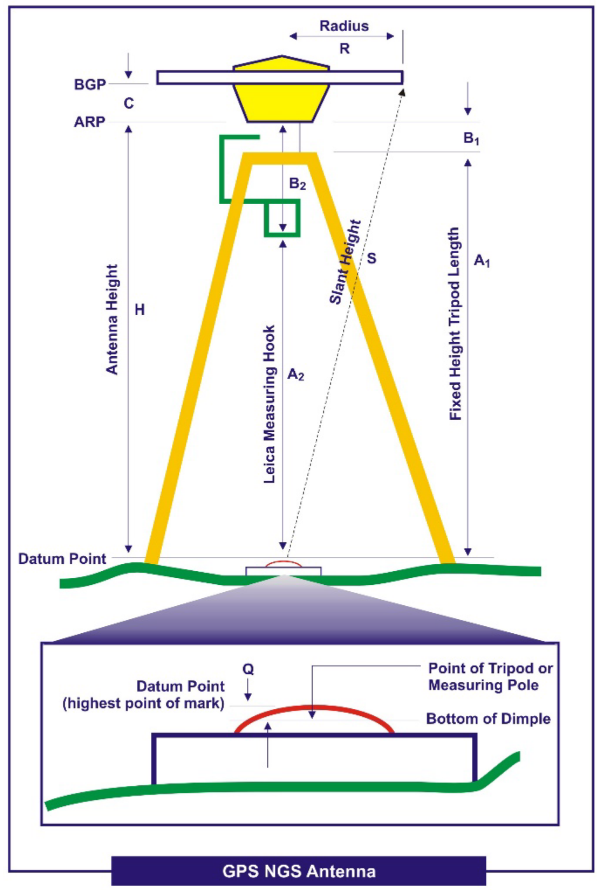
7.7.5 GPS Occupation at All Survey Stations.

GPS observations must be performed using geodetic quality dual frequency GPS receivers. Fixed height tripods must be used whenever practical. Tripods with multiple height settings should be set to the highest position. All tripods must be tested for stability, plumb alignment (straightness of center pole), and height verification at the beginning and end of the project. Optical plummet on Tribrachs (if used) must be checked before and after observations. Examine all tripods for stability with each use. Ensure hinges, clamps, and feet are secure and in good repair. Also, check, and adjust if necessary, the position of the bubble in the circular vial. Separate tripod setups are required for each occupation of a station and for each GPS observing session.

7.7.5.1 **Antenna Setup.**

GPS antenna setups must be done independently for each session. The word “independent” means separate tripod setups, separate height determinations, and separate solutions. The height of instrument (HI) must be measured in both meters and feet. Minimize the mixing of GPS receiver and antenna types used for observations. Record the manufacturer, model number, and serial number of the antenna on the field log. The following instructions are extracted from the NGS *Survey Manual* for reference.

Figure 7-29. GPS NGS Antenna Setup.



7.7.5.2 **GPS Antenna Height Measuring Instructions.**

7.7.5.2.1 Fixed height tripods are preferred over slip-leg tripods, as they reduce the potential for antenna height measurement errors. Use fixed height tripods whenever feasible. If a slip-leg tripod is used, a low tripod setup is preferred to minimize eccentricities, though the antenna should be set high enough to avoid obstructions. Eccentric setups (antenna out of plumb from the station datum point) are to be avoided. Note any eccentricities on the observation log. Tripod legs should be well set and sandbagged or spiked to minimize movement. Plumbing bubbles must be shaded for at least 3 minutes before use to minimize convective currents in the bubble fluid. On tripods with rotating center poles, the bubble must be rotated and checked level throughout a 180-degree arc. Antennas should be oriented towards true north, as closely as can be accomplished with a hand compass. Note the magnetic declination in your local area to convert from magnetic north to true north.

Figure 7-30. Illustration for Antenna Height Measurements.

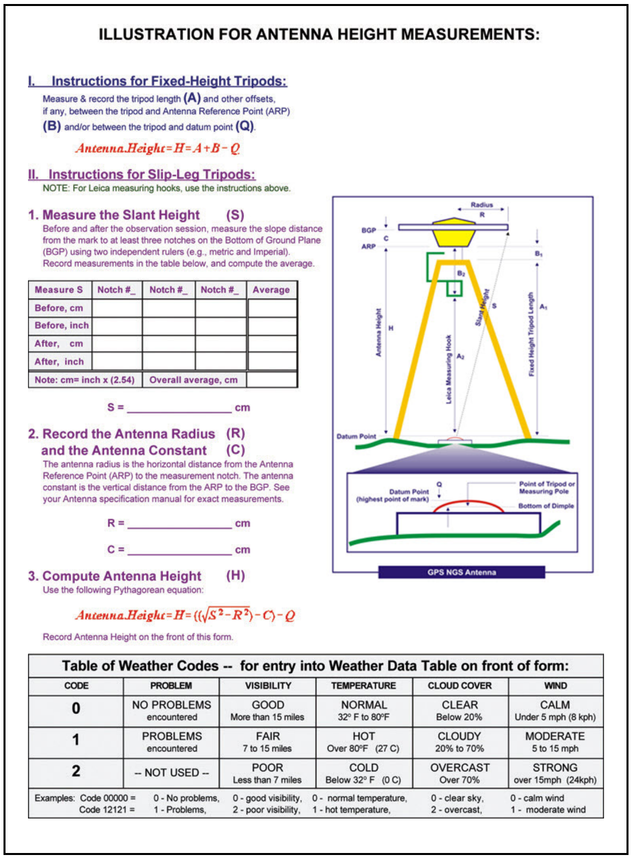


ILLUSTRATION FOR ANTENNA HEIGHT MEASUREMENTS:

I. Instructions for Fixed-Height Tripods:

Measure & record the tripod length **(A)** and other offsets, if any, between the tripod and Antenna Reference Point (ARP) **(B)** and/or between the tripod and datum point **(Q)**.

$$Antenna.Height = H = A + B - Q$$

II. Instructions for Slip-Leg Tripods:

NOTE: For Leica measuring hooks, use the instructions above.

1. Measure the Slant Height (S)

Before and after the observation session, measure the slope distance from the mark to at least three notches on the Bottom of Ground Plane (BGP) using two independent rulers (e.g., metric and Imperial). Record measurements in the table below, and compute the average.

Measure S	Notch #_	Notch #_	Notch #_	Average
Before, cm				
Before, inch				
After, cm				
After, inch				
Note: cm= inch x (2.54)		Overall average, cm		

S = ______________ cm

2. Record the Antenna Radius (R) and the Antenna Constant (C)

The antenna radius is the horizontal distance from the Antenna Reference Point (ARP) to the measurement notch. The antenna constant is the vertical distance from the ARP to the BGP. See your Antenna specification manual for exact measurements.

R = ______________ cm

C = ______________ cm

3. Compute Antenna Height (H)

Use the following Pythagorean equation:

$$Antenna.Height = H = ((\sqrt{S^2 - R^2}) - C) - Q$$

Record Antenna Height on the front of this form.

Table of Weather Codes -- for entry into Weather Data Table on front of form:					
CODE	PROBLEM	VISIBILITY	TEMPERATURE	CLOUD COVER	WIND
0	NO PROBLEMS encountered	GOOD More than 15 miles	NORMAL 32° F to 80°F	CLEAR Below 20%	CALM Under 5 mph (8 kph)
1	PROBLEMS encountered	FAIR 7 to 15 miles	HOT Over 80°F (27 C)	CLOUDY 20% to 70%	MODERATE 5 to 15 mph
2	-- NOT USED --	POOR Less than 7 miles	COLD Below 32° F (0 C)	OVERCAST Over 70%	STRONG over 15mph (24kph)
Examples: Code 00000 = Code 12121 =	0 - No problems, 1 - Problems,	0 - good visibility, 2 - poor visibility,	0 - normal temperature, 1 - hot temperature,	0 - clear sky, 2 - overcast,	0 - calm wind 1 - moderate wind

7.7.5.2.2 The proper recording of antenna height is critical. The Antenna Height used at NGS is the vertical distance between the station datum point and the Antenna Reference Point (ARP). Observers must carefully measure and check this height, and record and describe all measurements and antenna constants. Record all values to 0.0001 meters or 0.001 foot. All measurement computations must be checked and initialed by another person. Fixed-height tripods simplify the measurement of antenna height (H). The calibrated tripod height (A) should be checked with a quick measurement. Ensure that the antenna mates securely with the tripod head, and that any gap (B) between the tripod head and ARP is measured and included. The antenna height can then be computed from the equation:

Antenna Height H= (A + B) - Q

Note: Certain manufacturers' antennas use a measuring hook to determine the vertical distance between the mark and antenna. Record the measured distance from the mark to the hook as A, and the offset from the hook to the ARP as B. Slip-leg tripods antenna height (H) is usually measured by slant-height (S), the distance of the hypotenuse from the station datum point to the bottom edge of the antenna ground plane (BGP). Measure the slant height to at least 3 points around the antenna; these measurements should all agree to within 1 millimeter. Independent measurements of the antenna height above the mark in both metric and Imperial units must be made before and after each session. From the antenna specification sheet in your user's manual, determine the radius (R) of the ground plane and the offset constant (C) between the BGP and the ARP. The antenna height can then be computed from the following Pythagorean equation:

$$\text{Antenna Height } H = ((\sqrt{S^2 - R^2}) - C) - Q$$

7.7.5.2.3 Compare Metric and Imperial measurements using the following equations:

Meters = Feet × (0.3048) Example: 1.286 Meters = 4.219 Feet

Feet = Meters ÷ (0.3048) Example: 5.345 Feet = 1.629 Meters

7.7.5.2.4 Note that the 3-dimensional datum point of a standard survey disk is located at or above the dimple in the disk's center, on a level with the highest point of the disk, where the foot of a level rod would rest. If the point of the fixed-height pole or slant-height measuring rod is recessed significantly below this level to reach the bottom of the dimple (1 millimeter or more), make a careful measurement of the vertical separation (Q) and note this on the observation log.

7.7.5.3 **Epoch Interval and Elevation Mask.**

Collect GPS data at 15- or 30-second epochs using a 15-degree elevation mask, then process the data at a 15- or 30-second interval. When tying to the NSRS, a NGS CORS station with a collection rate of 30 seconds may be used.

7.7.5.4 **Observation Logs.**

7.7.5.4.1 An observation log must be filled out for each occupation of a station. Data recorded on the observation log must include the following equipment information:

1. Receiver manufacturer,
2. Antenna manufacturer,
3. Receiver model number (part number)
4. Antenna model number (part number),
5. The complete serial number of the receiver,
6. The complete serial number of the antenna,
7. Tripod model and serial number, and
8. Tribrach model and serial number.

7.7.5.4.2 Carefully monitor the receiver operation and antenna setup during each observing session. Note any unusual circumstances regarding satellite visibility, receiver operation, equipment malfunction, DOD adjustment of the satellite orbit, obstructions, weather events, tripod stability, etc., on the observation log.

7.7.6 <u>Recommended Equipment.</u>

7.7.6.1 Dual-frequency GPS receivers meeting the following requirements are recommended:

1. The receiver model is evaluated against the Federal Geodetic Control Subcommittee (FGCS) test network.
2. State-of-the-art dual frequency with high quality C/A code or P code pseudo-ranges.
3. Capable of measuring full wavelength L2 carrier phase.

Figure 7-31. GPS Station Observation Log.

OMB Approved 2120-0557
Expires 3/31/2010

Federal Aviation Administration

Airport Surveying-GIS Program

GPS Observation Log Sheet

Station Designation ☐ FBN ☐ CBN ☐ PAC ☐ SAC ☐ BM	Station PID	Date (UTC)
General Location	Station 4 Character ID	Day of Year
Geographic Coordinates (NAD83) Latitude: N ° ' " Longitude: W ° ' "	Project Number GPS -	Airport ID

Observation Session Times (UTC)	NAD83 Ellipsoid Height Meters
Scheduled Start : Stop :	NAVD88 Orthometric Height Meters
Actual Start : Stop :	Meters GEOID _____ GEOID Height
Epoch Interval = Seconds Elevation Mask = Degrees	

Project Name	Station Serial Number (SSN)		Session ID
Agency/Company	Operator Name	Telephone Number ( ) -	Email address

Answer Yes or No to each question, if No explain	Yes	No	Explanation
Antenna plumb before session?	☐	☐	
Antenna plumb after session?	☐	☐	
Antenna oriented to true north?	☐	☐	
Weather observed at antenna height?	☐	☐	
Antenna ground plane used	☐	☐	
Antenna radome used?	☐	☐	
Eccentric observation (> 0.5 mm)?	☐	☐	
Any obstructions above 10°?	☐	☐	
Radio interference source nearby?	☐	☐	

Receiver		Antenna	
Brand		Brand	
Model		Model	
Part Number		Part Number	
Serial Number		Serial Number	
Firmware Version		Cable Length (meters)	
☐Camcorder battery ☐ 12V DC ☐ 110V AC ☐ Other (specify):		Vehicle is parked __________ meters________ (direction) from antenna	

Paperwork Reduction Act Statement: This form is used to document source information about an airport or aeronautical facility which is part of the National Airspace System (NAS). This information is used to document airport data relating to the safety, security, or capacity of the national air transportation system. It is estimated that it will take approximately 5-80 hours to fill out the all of the necessary forms for a project depending on the complexity. No assurance of confidentiality is necessary or provided. It should be noted that an agency may not conduct or sponsor, and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. The OMB control number associated with this collection of information is 2120-0569. Comments concerning the accuracy of this burden and suggestions for reducing the burden should be directed to the FAA at: 800 Independence Ave. SW, Washington, DC, 20591, Attn: Information Collections Clearance Officer, AIO-20.

4. Must function acceptably in an Anti-Spoofing environment.

7.7.6.2 Use GPS antenna models calibrated by NGS (see the NGS Antenna Calibration webpage at https://geodesy.noaa.gov/ANTCAL/.

7.7.6.3 Antennas equipped with a ground plane or choke ring are preferred for observations on the PACS and NSRS ties.

7.8 Vector Processing.

7.8.1 Requirements.

7.8.1.1 Vector processing must be performed using the latest version of the NGS software package PAGE-NT or equivalent. The "equivalent" of PAGE-NT is subjective, based on the software's ability to correct for the same systematic errors that PAGE-NT corrects, apply the NGS required antenna offsets, and reproduce the same results as PAGE-NT. This determination will be made by NGS.

7.8.1.2 The PAGES software is also used for session processing in the online utility OPUS-Projects. In some situations, it may be acceptable to perform vector processing using OPUS-Projects rather than PAGE-NT. If there is interest in using OPUS-Projects for this purpose, contact NGS to determine whether it is a viable option, to obtain approval, and to receive guidance on how to use OPUS-Projects for establishing GPS-derived airport control. Since OPUS-Projects currently requires some occupation and processing strategies that differ from those in this document, it is important to determine whether it will be used during the project planning phase. For additional guidance and requirements when using OPUS-projects refer to ftp://geodesy.noaa.gov/pub/opus-projects/OPUS Projects for FAA General Guidance.pdf. Note that OPUS-Projects (and the entire OPUS product suite) is currently undergoing significant revision, which is why procedures for using it are not included. Future versions of this document will include procedures for using OPUS-Projects.

7.8.1.3 The NGS PAGE-NT software package and User's Manual are available via anonymous FTP from NGS (see Appendix G). Follow the vector processing guidance below, the PAGE-NT User's Manual, and the Vector Processing Outline outlined in Appendix H.

7.8.1.4 The grouping of vectors into processing sessions for each day of observations is determined by two factors: the required reference station and the distances of each solve station from the reference station. This vector distance determines the final solution type to be run in PAGE-NT. Reference station requirements are detailed in the sections below.

7.8.1.5 Use the following table for grouping vectors together into sessions according to vector length:

Table 7-4. PAGE-NT Final Solution Type Determination.

Vector Distance for Processing Session	Final Solution Type
Under 5km	L1 Fixed
Over 5km	Ion-Free Fixed

7.8.1.6 IGS precise orbit data and NGS National CORS data must be used in data processing. For information on downloading CORS data and ephemeris data from NGS via the Internet, see Appendix G.

7.8.1.7 International GNSS Service (IGS) station coordinates must be used for all vector reductions. In this context note that IGS*xx* and International Terrestrial Reference Frame (ITRF*xx*) coordinates can be considered equivalent (where *xx* denotes the two-digit year of the IGS and ITRF realization). Throughout this document the terms IGS and ITRF are used interchangeably when referring to station coordinates. Information about IGS and ITRF is available from the International Earth Rotation and Reference System Service (IERS) at https://www.iers.org/IERS/EN/Home/home_node.html. The current IGS/ITRF epoch must be used in computations. The Antenna Height value entered into the PAGE-NT "Station Information" Menu, "Up" field, is the monument to the Antenna Reference Point (ARP). For example, 2.000 for a fixed-height tripod. The monument for a CORS is generally coincident with the ARP; therefore, 0.000 is entered for a CORS station unless an offset is listed on the CORS coordinate sheet. PAGE-NT will automatically add a constant factor for the ARP to L1 phase center distance when it merges the data.

7.8.1.8 Set the Tropospheric scale height in accordance with the following table:

Table 7-5. Tropospheric Unknown Settings for PAGE-NT Sessions.

Vector Length	Reference Station Setting	Solve Station Setting
Under 3km [1]	OFF/FIXED (Not Highlighted)	OFF/FIXED (Not Highlighted)
3-100km	OFF/FIXED (Not Highlighted)	ON/SOLVE (Highlighted)
100+km	ON/SOLVE (Highlighted)	ON/SOLVE (Highlighted)

[1] If a station is within 3 km of the reference station AND differs in height with the reference station by 5 meters or more, set the tropospheric scale height setting to SLV for that station.

7.8.1.9 Review the PAGE-NT generated plots and text outputs with user-contributed software program VUPOS to analyze each processing session. PAGE-NT's overall RMS-of-fit of the post-fit double-difference residuals should not exceed 2.0 cm. Investigate individual satellites with a relatively high RMS or where integers could not be fixed. Also review the files for input errors, such as improper reference station coordinates, antennae height errors, or improper station names.

7.8.1.10 Use program COMPVECS to analyze repeat baseline checks. Investigate any component exceeding 1 cm in north and east and 3 cm for the up (ellipsoidal height) component.

7.8.2 CORS Vectors.

At least one national CORS must be used for determining a PACS position. However, for several airports observed simultaneously, utilize data from as many national CORS in the project area as feasible. CORS-to-CORS vectors strengthen the GPS network and allow for easier error detection. Discuss with NGS the CORS-to-CORS vectors to be processed. Generally, two 24-hour vectors must be processed between the CORS stations to form an interconnecting network. See paragraph 7.7.1 for more information on CORS data.

7.8.2.1 **CORS-to-CTCORS Vectors.**

Three independent sessions between the CORS and CTCORS are required at the beginning of the project and one session, as a check, at the very end of the project. Process these three sessions using the most recent ITRF coordinates published by NGS for the CORS. If the new computed ITRF coordinates of the CTCORS differ from the NGS ITRF coordinates by more than 3 cm in horizontal or 5 cm in vertical (ellipsoidal or orthometric), call NGS immediately for further instructions. These instructions might include processing additional CORS to CTCORS sessions. Any discrepancy, even if resolved, must be described in the project report. Keep in mind the PACS accuracy requirement is relative to a CORS, not a CTCORS, so any discrepancy in the CTCORS position must be included in the error budget for the PACS. The last session at the CTCORS must be used to again check the position of the CTCORS relative to the CORS.

7.8.2.2 **PACS, SACS, and NSRS Tie Vectors.**

The sequential order of vector processing is listed below. The selection of either L1 or Ion-Free fixed for the final solution type is based on vector lengths. See the Solution Type Determination Table (Table 7-4) for guidance when grouping vectors together for a processing session. Discuss the plan for processing any "shared" HARN and bench mark ties with NGS if more than one airport is observed for the project. Generally, each HARN or bench mark observation should be included in only one processing session. Use the following guidance for preparing the processing plan:

7.8.2.2.1 If a HARN station tie is NOT also a PACS, SACS, or bench mark tie for an airport, and it is more than 50 km from a PACS, it must be processed in the CORS-to-PACS session. In the case of multiple airports using the same HARN, the PACS observed simultaneously with the HARN to "share" the tie must be tied to it indirectly in the group adjustment. Separate processing sessions from each PACS to the HARN are not required.

7.8.2.2.2 If a HARN station tie is NOT also a PACS, SACS, or bench mark tie for an airport, and it is within 50 km of a PACS, it should be processed directly from the closest PACS. In the case of multiple airports using the same HARN, a second nearby PACS observed simultaneously to "share" the HARN tie must be tied to it indirectly in the group adjustment. A separate processing session from the second PACS to the HARN is not required.

7.8.2.2.3 Bench mark ties must be processed to their PACS. In the case of multiple airports, the second, simultaneously observed, PACS must be tied to the bench mark indirectly in adjustment. Again, a processing session from the second PACS to the bench mark is not required.

7.8.2.2.4 Substitute CTCORS for CORS in the steps below if applicable. To check the position of the PACS, the sequential order of vector processing is as follows:

1. Process the first CORS-to-PACS vector, with CORS as reference, using the latest ITRF coordinates. If more than one PACS was observed simultaneously, include these PACS in the session if they conform to the vector distance limitations for the session (see Solution Type Determination, Table 7-4, above). Also include any appropriate HARN and bench mark stations in the session.

2. Process the second CORS-to-PACS vector, with CORS as reference, as above. Again, include appropriate PACS or HARN stations observed simultaneously into this session.

3. Compare the resulting ITRF coordinates of the PACS and NSRS ties used more than once. Use a spreadsheet to show the differences between the sessions and the calculation of the mean (see Appendix I for an example). The two PACS coordinates should compare within ±1 cm for the north and east components and 3 cm for the up (ellipsoidal height) component. If they do, mean the positions and go on to step 4 below. If not, contact NGS. The PACS might need to be reprocessed or reobserved.

4. Process the first PACS to SACS session using the PACS as the reference station and using the mean ITRF position calculated in step 3 above. Process these short lines using the L1 frequency only. This step must be completed individually for each airport (each PACS must be the reference station for its respective SACS).
5. Process the second session SACS data as above. This step must be completed individually for each airport (each PACS must be the reference station for its respective SACS).
6. Compare the ITRF coordinates of the SACS. Include this comparison on the same spreadsheet used for the PACS comparison. Investigate any SACS coordinate comparisons that do not agree within 1 cm for the north and east components and 3 cm for the up (ellipsoidal height) component. This step must be completed individually for each airport (each PACS must be the reference station for its respective SACS).

7.8.2.2.5 Discuss with NGS procedures for processing if a HARN station or bench mark tie also serves as a PACS or SACS.

7.9 Adjustment Processing.

All airports in a project area may be adjusted together if airports located close together share tie stations (CORS, bench mark, HARN). Airports can be adjusted individually. All GPS observations to PACS and SACS must be adjusted together and there must be a single B-file and a single G-file for each airport or group of airports observed as part of the same network. This reduces or eliminates the possibility of no-check stations and improves adjustment performance by increasing network redundancy.

7.9.1 Software.

The ADJUST software package can be downloaded from the NGS website at https://geodesy.noaa.gov/PC_PROD/ADJUST/.

Use the Constrained Adjustment Guidelines to perform the adjustments. Ensure the latest revision is used for each submission.

7.9.2 NSRS Tie Accuracy.

HARN ties should check within ±3 cm horizontal and ±5 cm ellipsoidal height compared to their published positions. Notify NGS immediately if checks exceed these tolerances. Show the coordinate comparisons on a spreadsheet (see Appendix I).

7.9.3 Benchmark (Vertical) Accuracy.

Bench mark orthometric heights should agree within ± 5 cm of published elevations. Notify NGS immediately if checks exceed these tolerances. Show the height comparisons on a spreadsheet (see Appendix I).

7.10 NGS Procedural Outline for Adjusting GPS Data for Airport Geodetic Control Surveys.

The following guidance is recommended to supplement the guidance provided in paragraph 7.9. Apply these procedures to both the PACS and SACS portions of the project.. Refer to NGS Constrained Adjustment Guidelines, Section 3-6, for supplemental guidance on performing the adjustments.

7.10.1 Complete PAGE-NT processing as outlined in paragraph 7.8 and Appendix H:

1. Ensure all fixed coordinates used in processing were correct.
2. Ensure up offset values for each station are equal to the monument to Antenna Reference Point (ARP).
3. Ensure all PFR plots are acceptable.
4. Ensure RMS values in COMBINED.SUM files are acceptable.
5. Ensure all redundant vectors and multiple occupied station results check within 1 cm for the north and east components and 3 cm for the up (ellipsoidal height) component of each other and show comparisons using a spreadsheet (see Appendix I).

7.10.2 Create input files:

1. Use the combined G-file created in PAGE-NT.
2. Ensure all vectors are included in the file.
3. Ensure there are no duplicate or misspelled station IDs or mismatched serial numbers.
4. Check B record, column 52-53, for proper coordinate system code (contact NGS).
5. Make an A-file from scratch with text editor by editing a previous A-file, or using WINDESC to export GPS Project Files.
6. Recommended II and MM records—
   a. II159999999
   b. MM3YYY
7. Make a B-file. A B-file can be created using the CR8BB program, other programs, or a text editor (OPUS-Projects creates one automatically). The B-file serial numbers must match the SERFIL, G-file, and D-file. Designations in the B-file and D-file must match.

7.10.3 Run a Free Adjustment (ADJHF):

1. A-File: Constrain the NAD 83 position and ellipsoid height (EHT) of the CORS station.
   a. For multiple airports, use the CORS station that is centrally located in the project area or that was the reference station for most of the CORS to PACS vectors.

   b. Save copies of each A-file used. Name AFILEHF, etc.

2. B-File: Use clean B-file from paragraph 7.10.2 as input.
   a. Name output file ADJHF.OUT.
   b. Name output B-file BFILEHF.
   c. Analyze results, review residuals on vector components (1 cm for the north and east components and 3 cm for the up (ellipsoidal height) component).
   d. If more than one CORS was used, check the agreement between the computed and published positions of other CORS used in the project.
   e. Check the agreement between the computed and published positions of the HARN and any other published stations used in the project.
   f. If an existing PACS is used in the project, ensure the free adjusted position and ellipsoid height meet or exceed the accuracy requirements from Table 7-2.

7.10.4 Run a Constrained Adjustment (ADJHC):

1. A-file—Constrain NAD83 position and EHT of all HARN, CORS and any other well-fitting horizontal control stations used.
2. B-file—Use BFILEHF as input.
3. Output—Name ADJHC.OUT
4. Name output B-file BFILEHC; review results.

7.10.5 Run the latest version of NGS GEOID software (or run B-file through online interactive utility on the Geoid Page at https://geodesy.noaa.gov/GEOID/) to insert GEOID heights into the B-file. Use BFILEHC as the input file and BFILE.GHT as the output file.

7.10.6 Perform the following two adjustments to obtain orthometric heights for insertion into the output B-file from the Geoid program (BFILE.GHT).

7.10.7 Run a Free Vertical Adjustment (ADJVF):

1. A-File: Constrain the NAD83 horizontal position of one CORS station and the NAVD 88 orthometric height of the best (center of project, high quality) bench mark.
2. B-File: Use BFILE.GHT for input:
   a. Output—Name ADJVF.OUT
   b. Name output B-file BFILEVF.
   c. Review orthometric heights with published NGS values (agree w/in 5 cm).
   d. Use spreadsheet or table to show the comparison results.

7.10.8 Run a Constrained Vertical Adjustment (ADJVC):

1. A-File: Same as ADJVF, except constrain additional orthometric heights of bench marks that worked well in the Free Vertical Adjustment.
2. B-File: Use BFILEVF for input with the output name ADJVC.OUT
3. Name output B- fileBFILEVC; review results and rerun using different constraints in the A-file if necessary.

7.10.9 Run program ELEVUP to transfer orthometric heights from ADJVC to the final B-file:

1. Input horizontal deck—BFILEHC.
2. Vertical deck—BFILEVC.
3. Name the final B-file FNL.BBK.
   a. Double check values in *80* and *86* records against BFILEHC and BFILEVC.

7.10.10 Do not rename any input or output files following the adjustments. Keep all input and output adjust files in a single folder. Run checking programs on the final B-file and correct errors.

1. No error messages are allowed except those relating to the zero antenna height of the CORS; contact NGS for assistance in correcting errors identified by one of the programs.
2. CHKOBS
3. OBSCHK
4. OBSDES (matches B-file with description file)

7.10.11 Write the final project report and submit the following digital files in a :\ProjectName\Adjust\ directory (if applicable, create an %%%%\Adjust\ subdirectory for each grouping of airports adjusted together, where %%%% is a unique ID created for the adjustment group).

7.10.11.1 Adjust Files.

1. FNL.BBK
2. FNL.GFL
3. AFILE*
4. ADJ*.OUT
5. BBIN.* (1st Bluebook)
6. BFILE*
7. BFILE.GHT
8. SERFIL

7.10.11.2 **Output Files from Checking Programs.**

1. CHKOBS.OUT
2. OBSCHK.OUT ("short" and "long" versions)
3. OBSDES.OUT (Checks description files vs B-file). Do not make any duplicate copies of "final" files. Keep all Adjust input and output files in a single directory.

7.10.12 Data Submittal.

Final project data must be submitted in Blue Book format. The Project Sketch, descriptions, photographs, project adjustments, reports, etc., must be digital, non-editable format.. Submit all original data records, see paragraphs 2.7, 6.1, and 7.3 and Chapter 9.

Page Intentionally Blank

CHAPTER 8. FINAL PROJECT REPORT

8.1 Background.

A final project report detailing the GPS observations, vector processing, and adjustment must be submitted to the FAA Airports GIS Program web site and the contracting authority. This report is in addition to the Project Survey Plan described in paragraph 7.3. Photographs, updated sketches, descriptions, and other information concerning mark setting performed for the project must be submitted separately as a supplement to the Project Survey Plan.

8.2 Final Report Contents.

The Final Project Report must contain at least the following sections:

1. An overview discussion of the planning, field work, data collection, data processing, adjustment, and data error analysis. This discussion should include a summary of the results, problems encountered, conditions affecting progress, and any unusual circumstances. Include comments on any deviations from the Project Survey Plan or this AC (include comments from weekly Status Reports).
2. A written description and analysis of the quality control performed; tables showing check positions; and a listing and analysis of all unusual circumstances, discrepancies, and deviations.
3. A listing of personnel who worked in the field and/or were involved with the data processing for this project.
4. A listing of the brand, model number, and serial number of all survey equipment (GPS receivers, antennas, levels, etc.) used in the project. List the quantity, brand, type, and height of fixed height tripods used. Include any instrumentation used for differential leveling if done.
5. A listing of all software, including version, used during the project for RINEX conversion, vector processing, adjustment, and verification (all checking programs).
6. A final station list: use a table format to list each station, the station type (PACS, SACS, etc.), and each observation session for the station.
7. A final Project Vector Diagram: update the vector diagram submitted with the Project Survey Plan (see paragraph 7.3). Submit only a large size, readable plot (approximately 24 × 32 inches). Include processing session designations on the vectors if feasible. Show indirect ties to “shared” HARN stations and bench marks.
8. The vector processing scheme, tabulated by airport and session, listing: reference station and solve stations with their station type; observation time for the vector, solution type (L3 fixed, etc.), and final RMS for the session. Provide any comments on problems encountered or anomalies with the processing session. Note the tropospheric unknown settings for each session. Provide any comments on problems encountered or anomalies with the processing session. This table can be incorporated into the spreadsheet described below.

9. A spreadsheet showing the comparison of the ITRF coordinates (X, Y, and Z) of all repeat baselines and for NSRS ties occupied more than once. Show the solution type, final RMS, and distance for each vector. Show the calculation of the mean PACS coordinate. See Appendix I for an example spreadsheet.

10. A detailed description of the project adjustment. Discuss each of the adjustments separately, including fixed control and the source of the coordinates, ellipsoid heights, and NAVD 88 elevation used. Explain unresolved error messages from the checking programs. Discuss the analysis performed and the results of the adjustments. Submit the spreadsheets or tables used to compare the adjusted coordinates with their published coordinates (see paragraph 7.9).

11. Recommendations for future projects.

CHAPTER 9. DELIVERABLES TO NGS.

9.1 Labor, Equipment, and Other Items.

The contractor must provide all labor, equipment, supplies, materials, and transportation to produce and deliver the products, as required.

9.2 Quality Control Plan.

Before any field work begins, submit to the FAA Airports GIS Program web site and the contracting authority (in paper and digital copies) a Quality Control Plan covering all work (see Chapter 5). NGS will review this plan and respond with an approval or comment letter (or email) as soon as possible, normally within 20 working days.

9.3 Survey Plan.

Before any mark setting or GPS observations begin, the Contractor must submit a Project Survey Plan (see paragraphs 7.3) to the FAA Airports GIS Program web site and the contracting authority. NGS will review this plan and respond with an approval or comment letter (or email) as soon as possible, normally within 20 working days. Field work may commence after the Contractor receives the approval letter (or email).

9.4 Project Status Reports.

See paragraph 2.6.

9.5 Project Sketch (Vector Diagram).

Submit a vector diagram showing all computed vectors. Submit only a large size, readable plot (approximately 24 × 32 inches). Include processing session designations on the vectors if feasible. Submit a paper version and a digital version if possible.

9.6 Field Logs.

Submit the original (scanned) version of all the observation logs, hand-written station descriptions/recovery notes, Station Location Sketch and Visibility Diagrams, digital photographs, etc.

9.7 Vector Processing Output.

Submit COMBINED.SUM files for any difficult to process or those producing questionable results processing sessions. Submit the spreadsheets used for comparing the vector processing results (see Appendix I). Submit paper copies of any other files requested by NGS for quality control.

9.8 Final Project Report.

Submit a Final Project Report covering Airport Geodetic Control Station surveys; see Chapter 9.

9.9 Adjustment and Checking Programs.

Submit all ADJUST and checking programs input and output files in accordance with paragraph 7.10 of this guidance. Also, submit the digital data sheet or coordinate file for stations used for fixed control during the adjustment (CORS log/coordinate sheets, NGS data sheet for HARN and bench mark coordinates, etc.). Submit copies of the coordinate sheet for all CORS and CTCORS stations used during vector processing. Submit the spreadsheets used and/or INVERSE3D program output files used for comparing published coordinates with their adjusted coordinates.

9.10 Original Data.

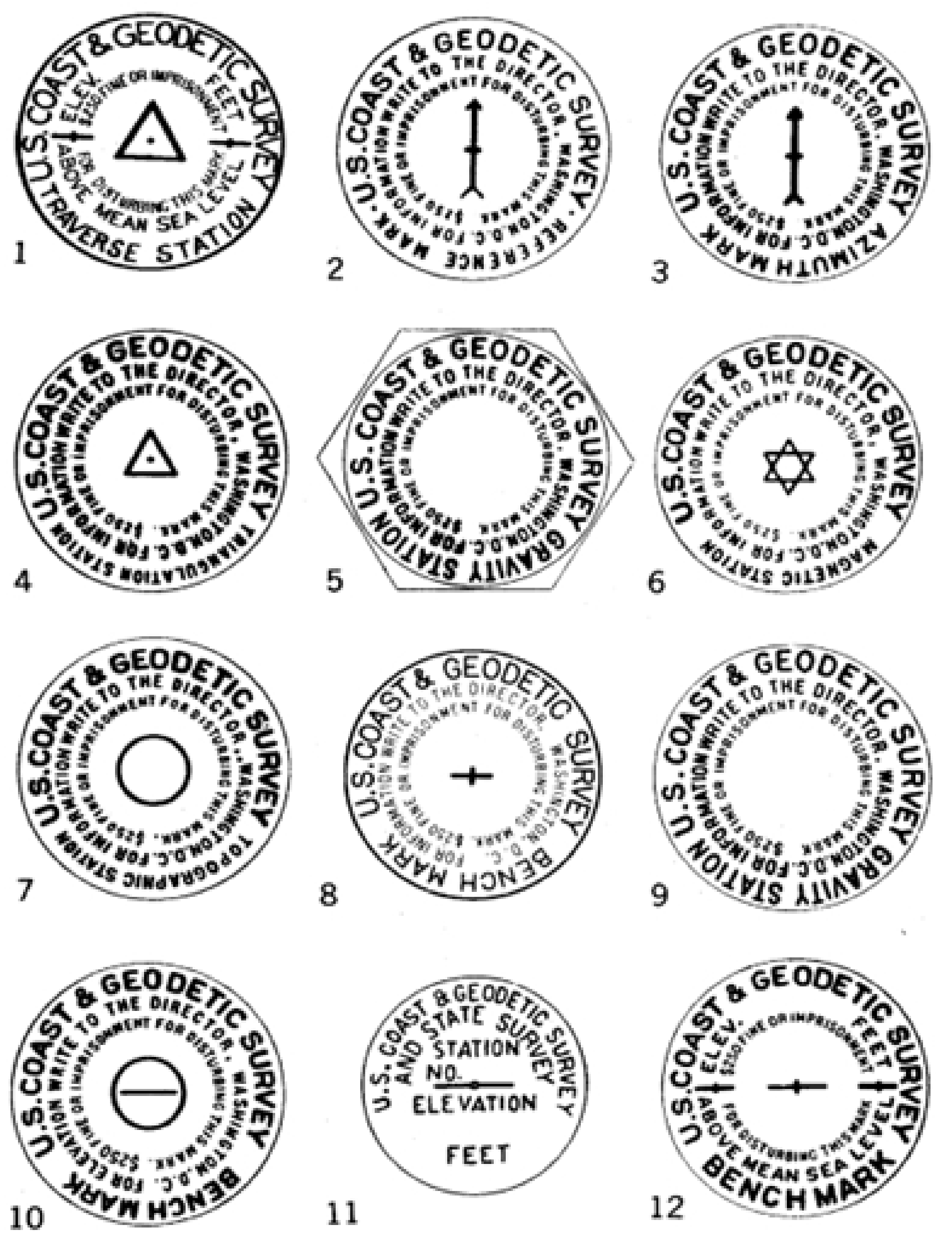
Submit all the original, raw data, RINEX data, precise ephemeris, and PAGE-NT files in accordance with Appendix H. Include the CORS RINEX data files used for processing. For all RAW and RINEX data files not named by their occupied station four-character ID, submit an index of station names to RAW and RINEX file. Submit a detailed directory tree listing, on paper, to be used as an index for locating all processing, adjustment, and supporting files submitted in digital format. Do not list the individual files within the PAGE-NT vector processing directory for each session or the files in the RAW and RINEX data directories. Just provide a summary explanation of the files found in these type directories. Submit any other digital files required by this AC or requested by NGS not previously submitted.

9.11 Descriptions.

Submit the finalized description file from the NGS WINDESC software. This includes the recovery notes submitted with the Survey Plan and the final version of the descriptions of new marks, written after the marks are set. Descriptions and recovery notes should be written by one person and checked, in the field, by another.

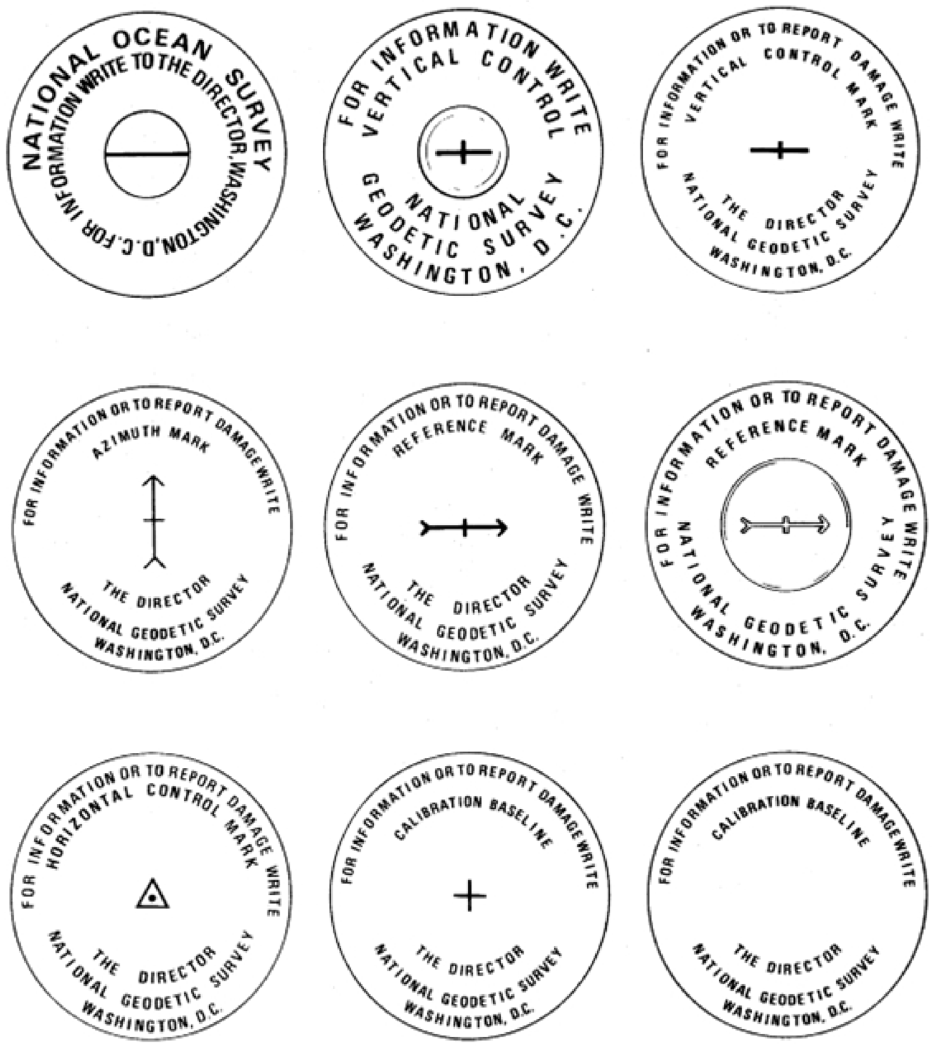
APPENDIX A. SURVEY DISK DIAGRAMS

Figure A-1. Sample Survey Disk.

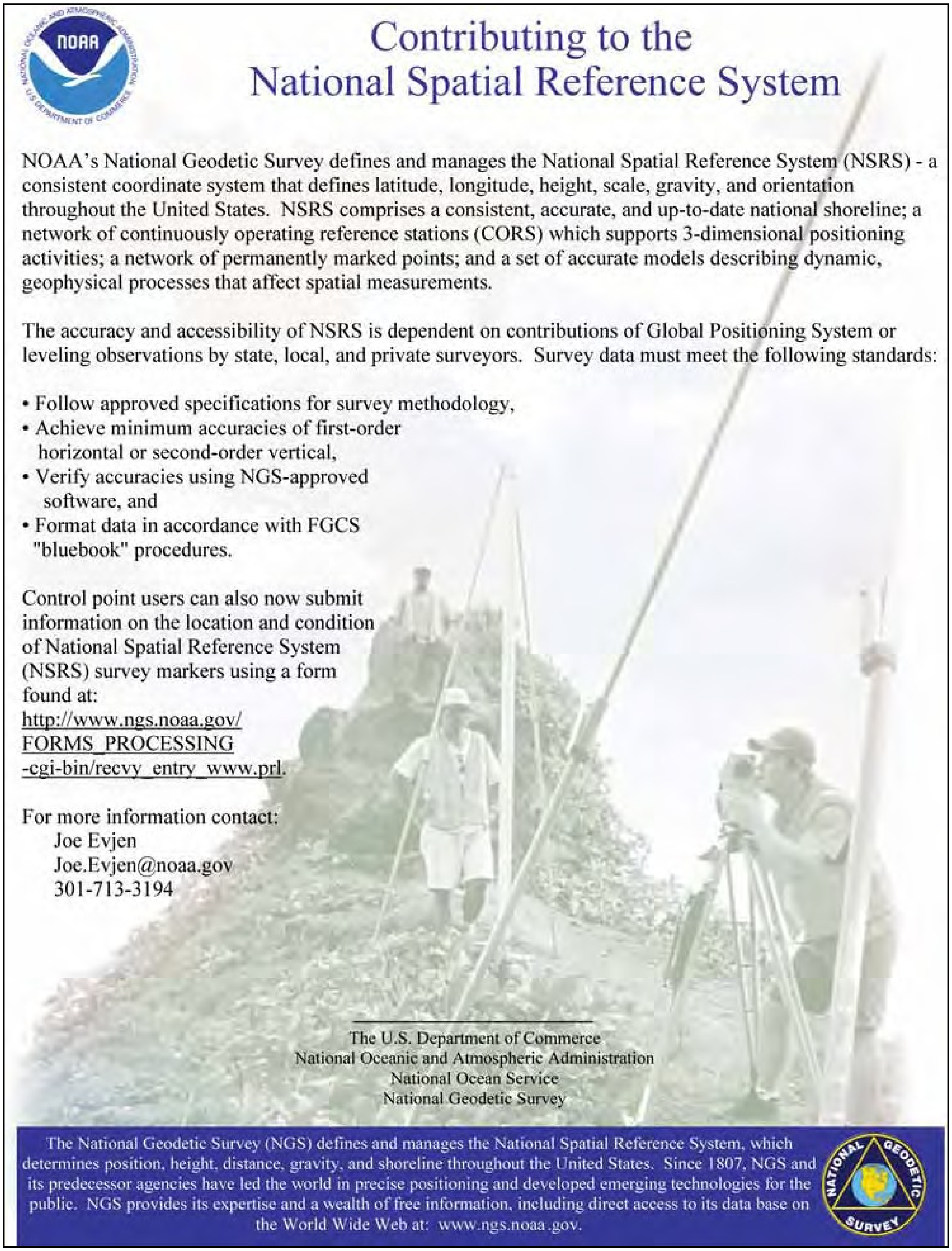


1. Traverse station mark.
2. Reference mark.
3. Azimuth mark.
4. Triangulation station mark.
5. Gravity station mark (old type).
6. Magnetic station mark.
7. Topographic station mark.
8. Geodetic bench mark (new type).
9. Gravity station mark (new type).
10. Tidal bench mark.
11. State Survey mark.
12. Geodetic bench mark (old type).

Figure A-1. Sample Survey Disk (continued).



APPENDIX B. NATIONAL SPATIAL REFERENCE SYSTEM



Contributing to the National Spatial Reference System

NOAA's National Geodetic Survey defines and manages the National Spatial Reference System (NSRS) - a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States. NSRS comprises a consistent, accurate, and up-to-date national shoreline; a network of continuously operating reference stations (CORS) which supports 3-dimensional positioning activities; a network of permanently marked points; and a set of accurate models describing dynamic, geophysical processes that affect spatial measurements.

The accuracy and accessibility of NSRS is dependent on contributions of Global Positioning System or leveling observations by state, local, and private surveyors. Survey data must meet the following standards:

- Follow approved specifications for survey methodology,
- Achieve minimum accuracies of first-order horizontal or second-order vertical,
- Verify accuracies using NGS-approved software, and
- Format data in accordance with FGCS "bluebook" procedures.

Control point users can also now submit information on the location and condition of National Spatial Reference System (NSRS) survey markers using a form found at: http://www.ngs.noaa.gov/FORMS_PROCESSING-cgi-bin/recvy_entry_www.prl.

For more information contact:
Joe Evjen
Joe.Evjen@noaa.gov
301-713-3194

The U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
National Geodetic Survey

The National Geodetic Survey (NGS) defines and manages the National Spatial Reference System, which determines position, height, distance, gravity, and shoreline throughout the United States. Since 1807, NGS and its predecessor agencies have led the world in precise positioning and developed emerging technologies for the public. NGS provides its expertise and a wealth of free information, including direct access to its data base on the World Wide Web at: www.ngs.noaa.gov.

Page Intentionally Blank

APPENDIX C. AIRPORT INTERVIEW CHECKLISTS

C.1 General.

Conduct interviews with the following personnel/departments if they exist at the airport.

C.2 Airport Manager/Operations Manager.

In this interview, obtain permission to enter the airfield for the survey. This interview can also provide valuable insight into the future plans for the airport, including information about construction (recent and on- going), obstruction changes, and operational considerations (scheduled runway closures or special events, high security areas on the field, etc.). The name(s) of the person(s) interviewed must be included on the runway datasheet and in the final project report.

C.3 Airport Engineering.

This interview is only necessary or helpful on larger airports. The Engineering Department can provide specific information about the runway dimensions, construction projects, and current on-airport control stations. They are sometimes helpful in scheduling runway work times. It is helpful to include the name of the point of contact in this department in the final project report in case any questions arise after the survey is completed.

C.4 Air Traffic Control.

If the field party is going to operate on the airport without an escort, it is highly recommended to have a face-to-face interview with the Chief Control Tower Operator or designated representative before entering the airport airside the first time. This interview is critical to operating safely on the airport, obtaining operational factors, and ensuring a good working relationship between the field team and the air traffic controllers.

C.5 FAA Airways Facilities.

This interview is necessary on any airport with FAA navigational facilities. In some cases, the personnel who maintain the facilities for the airport might be located at another site, and portions of the interview might need to be accomplished by telephone. The overall purpose of this interview is to determine all pertinent changes to facilities (including navigational aids) since the previous survey. Additionally, it may be necessary to schedule a technician to accompany the field party to certain facilities to provide access through a gate or monitor the system and associated alarms while survey personnel are in the critical areas of the site. It is recommended to include the name of a point of contact in this department in the final project report in case questions arise after the survey is completed.

C.6 Airport Interview Checklists.

C.6.1 Airport Manager/Operations Manager Interview

	Interview Tasks				Date Completed	Initials of Survey Party Chief
1.	Introduce team and explain purpose of the survey.					
2.	Provide a copy of the proposed survey schedule, with work areas identified—preferably on an airport map or diagram. Obtain approval of schedule, especially for runway time.					
3.	Request permission to work on the airfield, and note each of the following items:	Item	Yes	No		
		Escort required?				
		Radio required?[1]				
		Flashing Light required?				
		Other required items[2]				
4.	Runways—discuss any changes in length, width, or repaving occurring since the last survey. Make note of any items identified.					
5.	Runways—discuss any planned future changes to the runway(s).					
6.	Obtain and review the current airport obstruction chart or airport layout plan, and ask for comments. Make notes directly on the document for field team use.					
7.	Ensure to cover any questions identified in the contract supplementary instructions.					
8.	Discuss changes to planimetry, construction, or facilities. Include planned changes.					

[1] Required Radio Frequency is__________MHz and preferred call sign is__________________________.

[2] List other required Items from line 3 above.

Interview Tasks					Date Completed	Initials of Survey Party Chief
9.	Discuss obstructions relating to the airport.	Discussion Item	Yes	No		
		Has any obstruction clearing been conducted?[3]				
		Are there any plans for obstruction clearing?				
		Are there any new obstructions in the airport vicinity?				
10.	Obtain/verify the airport manager's contact information.	First Name				
		Last Name				
		Address Line 1				
		Address Line 2				
		City				
		State				
		Zip Code				
		Telephone Number				
		Telephone Number				
		Fax Number				
		Email Address				
11.	Discuss field conditions for driving.					
12.	Request keys for gates, as required, or obtain point of contact information for field access	POC Name				
		POC Telephone				
		POC Cell Number				
		Other contact Information	Contact Name			
			Contact Number			

[3] Obstruction Clearing completed by____________________________________in (month) (year)_______.

Obstruction clearing is planned for (month)___________________(year)_________.

Interview Tasks					Date Completed	Initials of Survey Party Chief
13.	Ask about known survey control on the airport.	Discussion Item	Yes	No		
		Installed PACS and SACS in good condition?				
		Is the manager aware of the importance of the PACS and SACS?				
		Are there any other survey control points on the airport?				
14.	Request introduction to Tower Chief or other airport officials.					

		Date
		Date

Name of Survey Party Chief ____

Signature of Survey Party Chief _____________________________________ Date ______

Name of Airport Manager or Designee ________________________________

Signature of Airport Manager or Designee ______________________________ Date ______

C.6.2 Tower Chief/Watch Supervisor Interview

Interview Tasks				**Date Completed**	**Initials of Survey Party Chief**
1.	Discuss radio procedures, call sign, radio communications failure procedures.				
2.	Provide a copy of the proposed survey schedule, with work areas identified—preferably on an airport map or diagram. Obtain approval of schedule especially for runway time.				
3.	Discuss taxiway designations.				
4.	Inquire about restricted areas, radio and visual blind spots.				
5.	Obtain/Verify the Tower Chief's contact information.	First Name			
		Last Name			
		Address Line 1			
		Address Line 2			
		City			
		State			
		Zip Code			
		Telephone Number			
		Telephone Number			
		Fax Number			
		Email Address			
6.	Request information about FAA Facilities personnel.	POC Name			
		POC Telephone			
		POC Cell Number			
		Other contact Information	Contact Name		
			Contact Number		

Name of Survey Party Chief ____

Signature of Survey Party Chief ____ Date ______

Name of Tower Chief or Designee ____

Signature of Tower Chief or Designee ______________________________________ Date ______

C.6.3 FAA Facilities Personnel Interview

Interview Tasks		Date Completed	Initials of Survey Party Chief
1.	Discuss changes to NAVAID systems.		
2.	Discuss any plans for NAVAID changes in the future.		
3.	Provide a copy of the proposed survey schedule, with work areas identified—preferably on an airport map or diagram. Obtain approval of schedule especially for NAVAID critical areas.		
3.	Ask about location, accessibility and associated requirements, and directions to any outlying facilities.		

Name of Survey Party Chief ____

Signature of Survey Party Chief ____ Date ______

Name of FAA Facilities Manager or Designee _______________________________

Signature of FAA Facilities Manager or Designee ____________________________ Date ______

Additional Remarks:

APPENDIX D. WRITING STATION DESCRIPTIONS AND RECOVERY NOTES WITH WINDESC

Along with the positions and the survey marks themselves, descriptions are one of the end products of surveying. All three must be of the highest quality. The descriptions must be complete, accurate, and in standardized format if the station is to be reliably and easily recovered for use in the future. Descriptions must be in the standard three-paragraph NGS format described below under "Description Format."

D.1 General.

D.1.1 Definition of Description Versus Recovery Note.

1. A *description* details the location of a new survey mark or one not previously in the NGS database.
2. A *recovery note* is an update and/or refinement to a description already in the NGS database, written upon a return visit to a survey mark.

D.1.2 Levels of Complexity of Recovery Notes.

D.1.2.1 No Changes.

If an existing station's digital description is complete, accurate, and meets Blue Book requirements, the station may be recovered with a brief recovery note, such as "RECOVERED AS DESCRIBED."

D.1.2.2 Minor Changes.

If minor changes or additions to the description are required, they may be added after the above phrase, such as "RECOVERED AS DESCRIBED, EXCEPT A NEW WOODEN FENCE IS NOW 3 METERS NORTH OF THE STATION." See typical cases listed below.

D.1.2.3 Major Changes.

Where major changes have occurred, major inaccuracies are found, or required information is missing (in any portion of the description), a complete three-paragraph recovery note, with the same format as a new description, is required. If a measurement discrepancy is found, state that the new distance was verified, for example, by taping in both English units and metric units or with two separate measurements taken by two different people. See typical cases listed below.

D.1.2.4 Exemption.

If a recovery note has been written for the station within 1 year and no changes have taken place, a new recovery note is not required. **Note:** This might cause an error message in the description checking software, which can be ignored.

D.1.3 Software.

Descriptions and recovery notes must be properly encoded into a D-file by using NGS WINDESC software. Please refer to the NGS website at https://www.ngs.noaa.gov/FGCS/BlueBook/, Annex P (Geodetic Control Descriptive Data), for information.

Note: WINDESC is used for both new descriptions and for recovery notes.

D.1.4 Checking.

Descriptions must be written by one person and checked by another. Recovery notes should also be checked. For example, a mark setter can draft a description immediately after setting the mark, and an observer can check the description during observations. For existing marks, the reconnaissance person can draft the recovery note and the observer can check it. Descriptions and recovery notes should be written while at the station or immediately after visiting a station so all details are fresh in the writer's mind.

D.1.5 Typical Recovery Note Cases.

1. A brief, one or two sentence recovery note is adequate when—
    a. The mark is found and the description is completely accurate (e.g., "RECOVERED AS DESCRIBED"),
    b. The mark is found and there are one or two minor changes (e.g., "RECOVERED AS DESCRIBED EXCEPT A NEW WOODEN FENCE IS NOW 3 METERS NORTH OF THE STATION"),
    c. The mark is not found (e.g., "MARK NOT FOUND AFTER 3 PERSON-HOUR SEARCH"),
    d. The mark is not found and presumed destroyed, (e.g., "MARK NOT FOUND AND PRESUMED DESTROYED. CONSTRUCTION FOREMAN STATES THAT THE MARK WAS DESTROYED YESTERDAY"), or
    e. The mark is found destroyed (e.g., "THE MARK IS DESTROYED AND THE DISK HAS BEEN SENT TO NGS" or "THE MARK IS DESTROYED AND ITS PHOTOGRAPH HAS BEEN SENT TO NGS"). For NGS to consider a station destroyed, the agency must receive the disk or a photograph showing the destroyed mark.
2. A complete new three-paragraph description or recovery note is required when—
    a. A new mark is set,
    b. An existing mark does not have a PID,
    c. An existing mark does not have an NSRS digital description (i.e., a description is not in the NGS database),
    d. An existing mark has only a brief description not meeting the three-paragraph requirement (many bench marks have only short, one-paragraph descriptions), or

e. An existing mark's description is no longer accurate or complete.

D.2 Description Format.

The original USC&GS Special Publication No. 247, *Manual of Geodetic Triangulation*, states, "A description must be clear, concise, and complete. It should enable one to go with certainty to the immediate vicinity of the mark, and by the measured distances to reference points and the description of the character of the mark, it should inform the searcher of the exact location of the mark and make its identification certain. It should include only essential details of a permanent character" (page 116). NGS still follows these guidelines, so a person with a minimal background in surveying and no local geographic or historical knowledge can easily find the mark by logically following the text of the description.

D.2.1 First Paragraph.

D.2.1.1 The first paragraph is the **description of locality.** This part of the description begins by referring to the airline distance and direction (cardinal or intercardinal point of the compass) from the **three** nearest, well-known mapped geographic feature(s), usually the nearest cities or towns. Use three references equally spaced around the horizon, if possible. **In writing the description, always progress from the farthest to the nearest reference point.** Distances in this part of the description must be in kilometers (followed by miles) or meters (followed by feet) and recorded to one decimal place. Detailed measurements that appear elsewhere in the description should not be repeated in this paragraph. Points of the compass should be fully spelled out. Do not use bearings or azimuths. State the name, address, and phone number of public-sector property owners (however, phone numbers of private property owners are NOT included). State any notice and security access requirements for reaching the station. Also, state any unusual transportation methods that might be required to reach the station.

D.2.1.2 Sample first paragraph:

STATION IS LOCATED ABOUT 12.9 KM (8.0 MILES) SOUTHWEST OF EASTON, ABOUT 6.4 KM (4.0 MILES) NORTHWEST OF CAMBRIDGE, AND ABOUT 3.6 KM (2.2 MILES) EAST OF SMITHVILLE ON PROPERTY OWNED BY MR. H.P. LAYTON, AND KNOWN AS OLD GOVERNOR JACKSON'S ESTATE.

D.2.2 Second Paragraph.

D.2.2.1 The second paragraph contains the **directions *to reach* the station.** This section is one of the most useful parts of a description. It usually enables a stranger to go directly to a station without a delay due to a detailed study of maps or of making local inquiries. It is a route description that should start from a definite point, such as (1) the nearest intersection of named or numbered **main** highways (ideally Interstate and U.S. highways, or at least those shown on commonly used road maps) and approximately where that intersection is or (2) some definite and well-known geographical feature (e.g., main post office or county courthouse) and its name and general location. Odometer distances must be given to tenths of kilometers (followed by tenths of miles). For roads with names and numbers, give both.

1. The format for the first leg of the "to reach" paragraph:
    a. FROM THE MAIN POST OFFICE IN DOWNTOWN SMITHVILLE or FROM THE INTERSECTION OF INTERSTATE XX AND STATE HIGHWAY YY, ABOUT 3 MI NORTH OF SMITHVILLE,
    b. GO A DIRECTION (north, northeast, northerly, northeasterly, etc.),
    c. ON A ROAD (name or number of road or highway or both if it has both a name and number),
    d. FOR A DISTANCE (kilometers followed by miles in parentheses), and
    e. TO SOMETHING (intersection, fork in road, T-road left or T-road right, etc.).
2. The format for all other legs:
    a. TURN LEFT (or RIGHT) or TAKE RIGHT (or LEFT) FORK or CONTINUE STRAIGHT AHEAD,
    b. GO A DIRECTION (north, northeast, northerly, northeasterly, etc.),
    c. ON ROAD (name or number of road or highway or both if it has both a name and number),
    d. FOR A DISTANCE (kilometers followed by miles in parentheses), and
    e. TO SOMETHING (intersection, fork in road, side-road left or right, station on left or right, etc.).
3. All five parts of each leg must be included in each segment.

D.2.2.2 Sample second paragraph:

TO REACH THE STATION FROM THE INTERSECTION OF INTERSTATE 300 AND MAIN STREET (STATE HIGHWAY 101) IN JONESVILLE, GO EASTERLY ON HIGHWAY 101 FOR 3.7 KM (2.3 MILES) TO AN INTERSECTION. TURN RIGHT AND GO SOUTH ON MILLER ROAD FOR 5.1 KM (3.2 MILES) TO A SIDE-ROAD

RIGHT. CONTINUE SOUTH ON MILLER ROAD FOR 6.6 KM (4.1 MILES) TO AN INTERSECTION. TURN LEFT AND GO EASTERLY ON SMITH ROAD FOR 2.4 KM (1.5 MILES) TO STATION ON THE LEFT IN THE FENCE LINE.

D.2.2.3 Use the word “EAST” if the road goes due east and “EASTERLY” if the road wanders in a general easterly direction. Use intermediate references, such as Miller Road above, if the distance becomes longer than about 5 miles. The place of the end of vehicle travel should be mentioned. If walking is required, note the approximate time required to travel the necessary distance. If travel to the station is by boat, the place of landing should be stated.

D.2.3 Third Paragraph.

D.2.3.1 The third paragraph provides details of the mark and reference measurements. It is made up of six parts:

1. The station mark type,
2. How the mark is set, (include size and shape of concrete post, if applicable.
3. Reference measurements, (start with furthest permanent object)
4. The handheld GPS position, and
5. PACS or SACS designation, if appropriate.

D.2.3.2 These sections are not enumerated (e.g., a., b., c.) in the description but must be in the stated order and include the stated information.

1. State what the mark is:

   Example: THE MARK IS AN NGS HORIZONTAL DISK, or A USC&GS TRIANGULATION DISK, or A STAINLESS STEEL ROD, or A CHISELED “X”, ETC.

2. State how and in what the mark is set:

   Example: THE MARK IS SET IN A DRILL HOLE IN BEDROCK, or SET IN A SQUARE CONCRETE MONUMENT, or IS A ROD DRIVEN TO REFUSAL, ETC. A GREASE-FILLED SLEEVE ONE M LONG WAS INSTALLED

D.2.3.3 The description must specify whether the rod was driven to refusal or met the slow driving rate (this is specified in Appendix G, part C-11, as 60 seconds per foot or 90 feet). Also, state if a grease-filled sleeve was installed and its length. For a rod mark, the diameter of the stainless steel rod and the diameter of the PVC pipe with the aluminum cap should be in English units, and the length of the plastic sleeve should be given in metric units only.

1. State if the mark projects above the ground, is flush, or is recessed and the amount (for a rod mark, state the above-ground measurement for both the rod and the logo cap):

   Example: MARK PROJECTS 15 CM (5 IN), or MARK IS FLUSH WITH THE GROUND, or MARK IS RECESSED 20 CM (8 IN); or LOGO CAP IS FLUSH WITH THE GROUND AND TOP OF ROD IS 10 CM (3.9 IN) BELOW THE TOP OF THE LOGO CAP.

2. State the depth of the mark, if known:

   Example: CONCRETE MONUMENT, 1.2 M (4 FT) DEEP, or ROD DRIVEN TO REFUSAL AT 15 M (49 FT).

3. State reference distances and directions from three or more permanent objects in the mark's immediate vicinity (farthest to nearest):

   Example: IT IS 20.7 M (67.9 FT) SOUTHWEST OF POWER POLE #2345, 15.2 M (49.9 FT) WEST OF THE EDGE OF HIGHWAY 134, AND 3.4 M (11.1 FT) NORTH OF A FENCE LINE.

4. Examples of objects used as references include existing reference marks, witness posts, center lines of roads, edges of runways, ditches, power or telephone poles, or buildings. Start with the farthest distance. Horizontal distances should be used. If slope distances were measured, state this in the paragraph. The distances must be in meters (followed by English measurement units in parentheses, except as noted in c. above), and the directions must be cardinal and inter-cardinal directions, fully spelled out, such as "NORTH," "NORTHEAST," or "NORTH-NORTHEAST." If the station is a Primary or Secondary Airport Control Station mark, the third paragraph must end with the appropriate designation of Primary or Secondary Airport Control Station:

   Example: THIS STATION IS DESIGNATED AS A PRIMARY AIRPORT CONTROL STATION.

D.2.3.4 Sample for a rod mark:

THE STATION IS THE TOP-CENTER OF A 1.43 CM (9/16 IN) STAINLESS STEEL ROD DRIVEN TO REFUSAL DEPTH OF 18 M THE LOGO CAP IS MOUNTED ON A 13 CM (5 IN) DIAMETER PVC PIPE. A 1 M (3.3 FT) LONG GREASE-FILLED SLEEVE WAS INSTALLED. LOGO CAP IS FLUSH WITH THE GROUND AND TOP OF ROD IS 10 CM (3.9 IN) BELOW THE TOP OF THE LOGO CAP. THE MARK IS 32.4 M (101.74 FT) NORTHEAST OF NORTHEAST CORNER OF THE HOUSE, 16.62 M (54.5 FT) NORTH OF WATER PUMP ALONGSIDE OF HEDGE AROUND OLD FLOWER GARDEN, AND 4 M (12.96 FT) NORTH OF NORTHEAST CORNER OF HIGH HEDGE ENCLOSING OLD FLOWER GARDEN.

D.2.3.5 Sample for a concrete monument:

THE STATION IS AN NGS HORIZONTAL DISK, SET IN A ROUND 30 CM (12-INCH) CONCRETE MONUMENT 1.2 M (4 FT) DEEP AND 0.3 M (12 IN) IN DIAMETER. IT IS SET FLUSH WITH THE GROUND. IT IS 32.4 M (101.74 FT) NORTHEAST OF NORTHEAST CORNER OF THE HOUSE, 16.62 M (54.5 FT) NORTH OF WATER PUMP ALONGSIDE OF HEDGE AROUND OLD FLOWER GARDEN, AND 4 M (12.96 FT) NORTH OF NORTHEAST CORNER OF HIGH HEDGE ENCLOSING OLD FLOWER GARDEN. THE HH1 GPS IS: 304050.2N, 1201020.4W.

D.3 Important Points Regarding Descriptions.

D.3.1 Names.

Use the station designation (name) and PID, exactly as listed in the NGS database, in all survey records. Do not add dates, agency acronyms, or other information to the name, nor the stamping. Frequently the stamping and the official station designation are not the same. For example, stampings include the year set, but designations generally do not.

D.3.2 Terminology.

Correct NGS survey terminology must be used in all station descriptions and reports (see *Geodetic Glossary*, NGS, 1986).

D.3.3 Distances.

All measurements are assumed to be horizontal unless labeled “slope.” Distances measured from a line (e.g., the center line of a road or a fence line) are assumed to be measured perpendicular to that line. The origin of measurements at the junction of two roads is assumed to be the intersection of center lines of both roads. Measurements are assumed to be from the center of an object (i.e., power pole) unless stated otherwise.

D.3.4 Repair.

Any work done to repair a mark must be described completely in the updated recovery note. A repair strengthens the mark but must not change its position. For example, adding concrete or epoxy around a disk where some is missing is a repair.

D.3.5 Reference Mark Names.

Reference marks are abbreviated “RM x” in descriptions, but on “Reference Mark” disks they are stamped “NO. x.”

D.3.6 Description (D-File) Checking.

Run the digital D-file through the WINDESC program's checking procedure, one of several procedures within the WINDESC Software Suite, to identify format and coding errors. This procedure is accessed by (1) running the WINDESC program and (2) selecting the Check->Dfile(.dsc file) menu item.

D.3.7 Metric Conversion.

Use 3.2808333333 feet equals one meter.

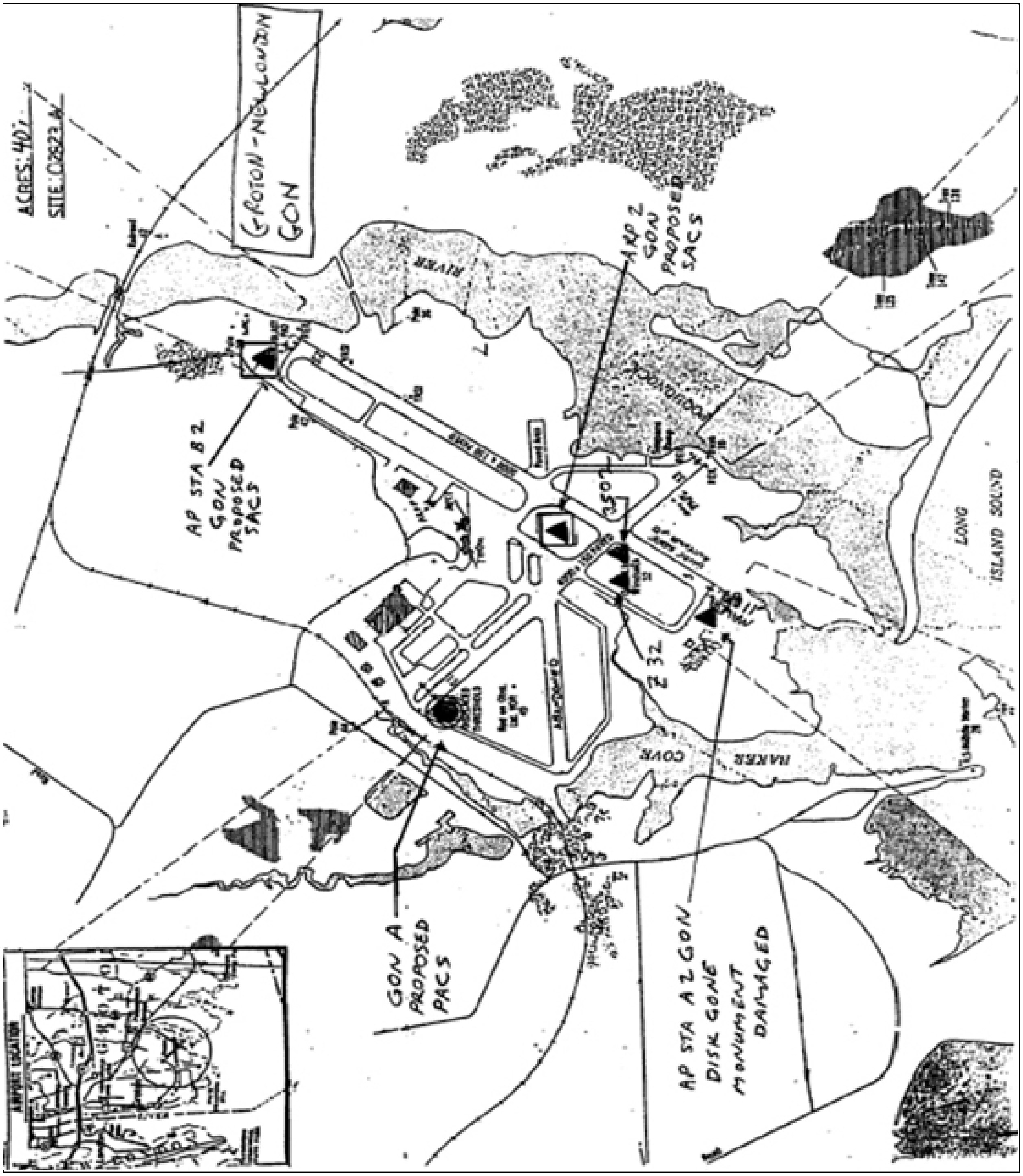
D.3.8 Abbreviations.

- Meter = M
- kilometer = KM
- centimeter = CM
- mile = MI
- nautical mile = NM
- feet = FT
- inch = IN.

APPENDIX E. STATION TABLE FORM

STATION NAME	PID	TYPE	AGENCY	VERT ORDER	STABILITY	CONDITION AT RECOVERY	COMMENTS
SFQ A	N/A	PACS	NGS		B	NEW	PROPOSED PACS, SS ROD MARK
SFQ B	N/A	SACS	NGS		C	NEW	PROPOSED SACS, BENCH MARK DISK
J 324 RESET 1983	FX2636		NGS	3	C	GOOD	PROPOSED SACS, EXISTING BENCH MARK
PASCALE	FX4376	CBN	NGS	3	C	GOOD	HARN TIE
F 468	FX2236		NGS	1	B	GOOD	BM TIE
G 468	FX2233		NGS	1	B	GOOD	BM TIE
WEATHER	DG9068		NGS	1	C	GOOD	BM TIE* (>25KM)
VA GLOUCESTER PT CORS ARP	DJ5202	CORS	NGS	CORS			CORS TIE

Figure E-1. Airport Control Plot.



APPENDIX F. EXAMPLE GPS OBSERVATION SCHEME

ANA Multi-Airport GPS Observation Scheme
Maine ANA Survey, 1998

AIRPORT(S) Auburn-Lewiston Municipal Airport (LEW)
Augusta State Airport (AFN)

Observation Day – Day 1 (045)
Number of Receivers used – 10
CORS Tie: BRU1
HARN Tie – A 196
Observers – Contractor Inc. (2) and Subcontractor Inc. (2)

<table>
<tr><th>LEW</th><th>AFN</th></tr>
<tr><td>PACS – LEW A
Session A – 8:00 – 13:30 (5.5 hours)
Session B – 14:00 – 19:00 (5.0 hours)</td><td>PACS – AUG AP STA C
Session A – 8:00 – 13:30 (5.5 hours)
Session B – 14:00 – 19:00 (5.0 hours)</td></tr>
<tr><td>SACS #1 – LEW AP STA B
Session A – 8:00 – 10:30 (2.5 hours)
Session B – 14:00 – 16:30 (2.5 hours)</td><td>SACS #1 – AUG AP STA B
Session A – 8:00 – 10:30 (2.5 hours)
Session B – 14:00 – 16:30 (2.5 hours)</td></tr>
<tr><td>SACS #2 – ARP 1964
Session A – 8:00 – 10:30 (2.5 hours)
Session B – 14:00 – 16:30 (2.5 hours)</td><td>SACS #2 – AUG A
Session A – 8:00 – 10:30 (2.5 hours)
Session B – 14:00 – 16:30 (2.5 hours)</td></tr>
<tr><td>BM #1 – E171
Session A – 8:00 – 13:30 (5.5 hours)
Session B – 14:00 – 19:00 (5.0 hours)</td><td>BM #1 – G 31
Session A – 8:00 – 13:30 (5.5 hours)
Session B – 14:00 – 19:00 (5.0 hours)</td></tr>
<tr><td colspan="2">BM #2 – G 171
Session A – 8:00 – 13:30 (5.5 hours)
Session B – 14:00 – 19:00 (5.0 hours)

HARN – A 196
Session A – 8:00 – 13:30 (5.5 hours)
Session B – 14:00 – 19:00 (5.0 hours)</td></tr>
</table>

Remarks: Session duration is fixed, start and end times are approximate depending on travel times, dates of survey, satellite status, weather conditions, airport logistics, etc. Stations used for multiple airports are listed on the center of the page.

Detailed station information is listed in the station table.

Page Intentionally Blank

APPENDIX G. INFORMATION, DATA, AND SOFTWARE AVAILABLE ON THE INTERNET

G.1 Websites

1. **NGS Aeronautical Survey Program:** https://www.ngs.noaa.gov/AERO/aero.html
2. **NGS:** https://www.ngs.noaa.gov

   NGS presents a wealth of information on its data products, software programs, and user services, as well as links to other helpful sites.
3. **CORS and IGS Ephemeris Data:** https://www.ngs.noaa.gov/CORS/

   Information on the National CORS system and access to CORS and Precise Ephemeris data downloads are available from NGS. Use the "User Friendly CORS" utility to download customized RINEX data sets and IGS ephemeris. The latest coordinate files and other metadata for each CORS site are also available. The "Data Availability" feature can be used to determine if a CORS site is missing data for a particular time period.
4. **USCG Navigation Center GPS Website:** http://www.navcen.uscg.gov/

   This site provides information on the status of the GPS constellation and provides NANU message postings and notices for outages at WAAS and DGPS sites.
5. **GPS Antenna Calibration Site:** https://www.ngs.noaa.gov/ANTCAL/

   This site provides information on which antennas have been calibrated.

G.2 Data and Software.

1. **PAGE-NT**

   PAGE-NT is a menu-driven suite of programs used to process GPS data and is suitable for projects requiring the highest accuracy. A User's Manual, the software, and sample data sets can be downloaded from the NGS anonymous ftp server:

   ftp: ftp.ngs.noaa.gov
   login: anonymous
   password: your complete email address

   Once logged on, go to the /pub/pnt6 directory and download all the files using binary transfer mode. The input1 and results1 directories contain the sample data sets. Follow the setup instructions in the PAGE-NT User's Manual.
2. **ADJUST**

   The ADJUST and ADJUST UTILITIES software package can be downloaded from NGS (https://www.ngs.noaa.gov) by accessing the "PC Software" link. Check the site for the latest version of each program. The software performs a least squares adjustment on horizontal, vertical angle, and/or GPS observations. The program includes data checking programs and other utilities in addition to the adjustment software. This software package has numerous options, such as choice of ellipsoid, and includes sample input data. The ADJUST source code is also available.

3. **ADJUST Utilities**

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

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

b. COMPVECS computes differences in GPS vector components for multiple vectors per baseline.

c. CR8SER extracts data from a GPS Blue Book file to create a station serial number file (serfil).

d. DIFLATLON computes change in position and height between two B-files.

e. ELEVUP creates a B-file that combines the B-file output from the constrained horizontal adjustment with the B-file output from the constrained vertical adjustment. This new B- file 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.

f. MAKE86 adds *86* records to the B-file. If the existing *80* records contain orthometric heights, these are added to the new *86* records.

g. PREPLT2 tabulates vector residuals from ADJUST output file.

G.3 Other Software Programs

Below is a select listing of other software that is currently accessible online. For the full and most recent list of NGS programs, visit the NGS PC Software webpage. Online interactive versions of some of these programs are available from the NGS PC Software website at https://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml.

1. **WINDESC** organizes control point descriptions in accordance with NGS's description file (D-file) format.

2. **HTDP i**s a horizontal time-dependent positioning software program that 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.

3. **INVERS3D** is the three-dimensional version of program INVERSE, and is the tool for computing not just the geodetic azimuth and ellipsoidal distance, but also the mark-to- mark distance, the ellipsoid height difference, the dx, dy, dz (differential X, Y, Z used to express GPS vectors), and the dn, de, du (differential north, east, up using the FROM station as the origin of the neu coordinate system). The program requires geodetic coordinates as input, expressed as either (1) latitude and longitude in degrees, minutes, and seconds or decimal degrees along with the ellipsoid heights

for both stations, or (2) rectangular coordinates (X, Y, Z in the Conventional Terrestrial Reference System) for each station. The program works exclusively on the GRS80 ellipsoid, and the units are meters. Both types of coordinates may be used in the same computation. The program reads input geodetic positions as positive north and positive west.

4. **VUPOS** is user-contributed software downloaded from NGS that allows users to view post-fit residual, elevation, and coverage plots output from PAGE-NT Processing

5. **DSWORLD** is user-contributed software downloaded from NGS that allows users to search for and plot existing geodetic control.

Page Intentionally Blank

APPENDIX H. OUTLINE FOR PROCESSING AIRPORT GEODETIC CONTROL SURVEYS WITH PAGE-NT

1. Place raw data files (zip format acceptable) in the following directory:
   :\ProjectName\RawData\DOY\

   Project Name is two-letter state ID, plus ANA
   DOY = Day of Year of Observation Files

2. Place RINEX data files, TEQC summary file, and precise orbit files (.SP3 format) in the following directory:
   :\ProjectName\RinexData\DOY\

3. Ensure the latest cors_**.bin, igs**.bin, and ant_info.* files are in the :\pnt*\ directory.

4. Create a SERFIL, and place into the following directory:
   :\ProjectName\serfil\.
   Create a GFILE directory (:\ProjectName\gfile\).

5. Establish a session processing outline based on the procedures in step 6. Create a directory for each processing session:
   (:\ProjectName\DOY\DOYS\).

   S = Processing session letter

6. Process each session following the procedures in the PAGE-NT documentation.

   - Use the latest ITRF coordinates for the Antenna Reference Point (ARP) [or monument if applicable] of each CORS station.
   - Ensure the proper antenna height (monument to ARP) and model number is input in the station information menus.
   - OMIT the PACS station from the triple difference solution for the PACS to UNKNOWN sessions, and be sure to enter the proper (derived mean) coordinates for the PACS into the station information menu.
   - Use the default meteorological values.
   - Put in the proper session letter for the session (Merge RINEX Files screen).
   - Turn off Tropospheric Unknowns for stations if required (Baseline Processing Options screen: Off = Fix = Not Highlighted; On = Solve = Highlighted in Blue [default]).

7. To run a L1 solution, first run a L3 solution. If the results are satisfactory, rename the output file "combined.sum" to "combinedL3.sum." Return to the Baseline Processing Options screen, and select "L1" for the frequency of solution. Save the change before exiting the menu. Select check box 6 (only) under the RUN menu to run another combined solution. Rename the output "combined.sum" file "combinedL1.sum."

8. Review the combined.sum, float.rms, and fixed.rms files for each session. View plots using VUPOS. Review other files as necessary to analyze the processing session.

9. Create a G-file for each session by running SINEX2G under the Utilities menu. Ensure the gfile.inp file is correct before each run. Save the individual G-file for each session by naming it DOYSgf and saving it in the gfile directory or processing directory for the session. Run SINEX2G again, appending the session G-file to the project G-file by editing the gfile.inp file to save the file in the :\ProjectName\gfile\ directory with the name “gfile”.

10. Submit a spreadsheet showing the positions and X, Y, Z value differences between sessions for each station.

11. Edit the “#/File Types To Delete During Clean Up” section of the default.txt file to delete only the following files, then run “Clean Up Output Directory” from the Run menu. Submit all of the remaining data in the :\ProjectName\ directory and subdirectories on CD-ROM or other pre-approved medium to NGS with the project report.

    Files to be DELETED:

    - *.00
    - *.dat
    - *.scn
    - *.prn
    - *.out
    - *.pom
    - *.new
    - eclipse
    - sum-*.flt
    - sum-*.fix
    - *.sp3
    - *.18o
    - *.18n

12. Place copies of the following files used during vector processing in the :\ProjectName\ directory for submittal:

    - *.atx
    - cors*.bin
    - igs*.bin
    - default.txt (template)

APPENDIX I. EXAMPLE COORDINATE COMPARISON SPREADSHEET

Tennessee ANA Survey 1999
Vector Processing Results

Paris Henry County Airport (HZD) - Day 244

CORS - mem2

	Observed ITRF Coordinates						
PACS - HZD A	**X**	**Y**	**Z**	**SOLN**		**RMS**	**KM**
244A	138517.6508	-5157909.9332	3736955.8065	L3X		0.0146	172
244B	138517.6602	-5157909.9284	3736955.8076	L3PFX		0.0170	
difference	-0.0094	-0.0048	-0.0011				
MEAN	138517.6555	-5157909.9308	3736955.8071				
SACS1 - FAA HZD A							
244F	138244.3948	-5158611.2409	3735995.7541	L1X		0.0057	1
244G	138244.3946	-5158611.2392	3735995.7494	L1X		0.0073	
difference	0.0002	-0.0017	0.0047				
SACS2 - HZD C							
244F	138364.7295	-5158170.6200	3736597.6080	L1X	0.0057	0.5	
244G	138364.7285	-5158170.6243	3736597.6115	L1X	0.0073		
difference	0.0010	0.0043	-0.0035				
	Adjusted vs. Published NAD 83						
HARN-GPS 15	**X**	**Y**	**Z**				
244C obs. (NAD83)	145521.9648	-5141684.5452	3758877.3789	L3X		0.0113	28
published. (NAD83)	145521.9690	-5141684.5610	3758877.3980				
difference	-0.0042	0.0158	-0.0191				
BM1 - F 181	**NAD 83 EHT (m)**	**NAVD 88 (m)**					
244D obs.	144.223	172.572		L3X		0.0116	22
published	N/A	172.628					
difference		-0.0560					
BM2 - Y 161	**NAD 83 EHT (m)**	**NAVD 88 (m)**					
244E obs.	94.516	122.698		L3X		0.0129	39
published	N/A	122.739					
difference		-0.0410					

Comments: 12-minute gap in CORS data from 1318-1330

GPS 15 also observed in session 242A -see sheet2 for vector comparison

ITRF Coordinate Comparison for Multiple Occupied Stations HARN and Bench Marks

ITRF vector comparison for GPS 15-

Observed ITRF Coordinates

HARN-GPS 15	X	Y	Z	SOLN	RMS	KM
244C	145521.3912	-5141683.0467	3758877.2319	L3X	0.0113	28
242A	145521.3883	-5141683.0334	3758877.2145	L3PFX	0.0152	191
Difference	0.0029	-0.0133	0.0174			

ITRF vector comparison for GPS 32-

Observed ITRF Coordinates

HARN-GPS 32	X	Y	Z	SOLN	RMS	KM
254C	90432.9992	-5169962.2991	3721755.0682	L1X	0.0099	13
265C	90432.9988	-5169962.3238	3721755.0829	L3X	0.0099	50
266C	90433.0042	-5169962.3131	3721755.0756	L1X	0.0085	17
Max Difference	0.0054	-0.0247	0.0147			

ITRF vector comparison for ...-

Advisory Circular Feedback

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) mailing this form to Manager, Airport Engineering Division, Federal Aviation Administration ATTN: AAS-100, 800 Independence Avenue SW, Washington DC 20591 or (2) faxing it to the attention of the Airport Engineering Division at (202) 267-3688.

Subject: AC 150/5300-16B Date: ______________________

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph __________ on page ______________.

☐ Recommend paragraph ______________ on page ______________ be changed as follows:

____
____
____

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

____
____
____

☐ Other comments:

____
____
____

☐ I would like to discuss the above. Please contact me at (phone number, email address).

____
____
____

Submitted by: ____________________________ Date: _____________________________

Page Intentionally Blank