National Geodetic Survey Positioning America for the Future   **geodesy.noaa.gov**
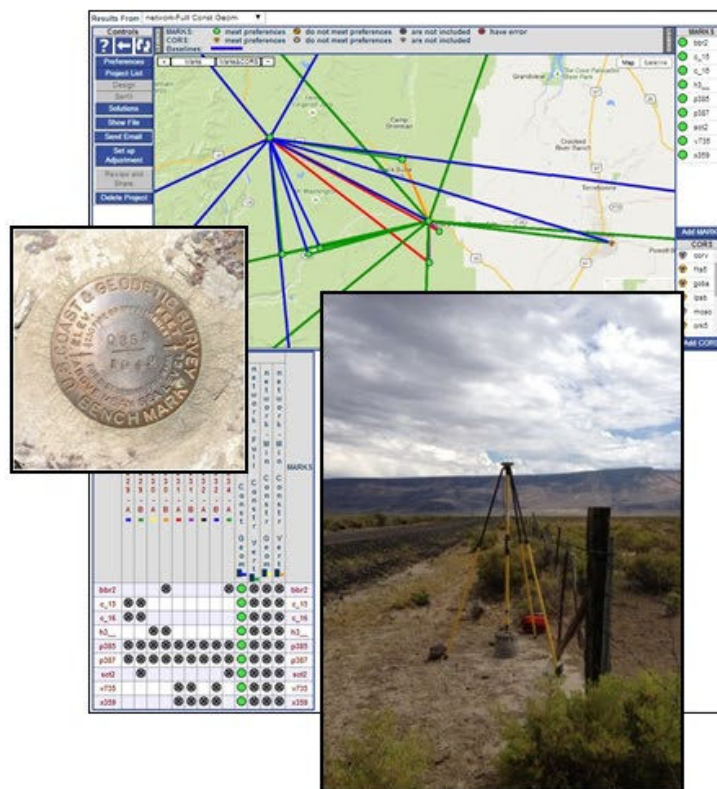
OPUS Projects

Online Position User Service
Baseline Processing and Adjustment Software
User Guide

June 2021

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Abstract

This document presents instructions for the successful use of OPUS Projects (hereafter referred to as OP), the first version of OP specifically designed to streamline the process by which a user processes and submits campaign-style GNSS surveys for inclusion in the National Geodetic Survey's authoritative database of survey control, known as the Integrated Database, or "**IDB**." As a result of a successful NGS review and acceptance, the project files are archived by NGS and the authoritative, least squares-adjusted coordinates are published and made available to anyone with an internet connection via the **NGS Datasheets**. Throughout the document, this entire process is simply referred to as "**submission to NGS**." This version of OPUS Projects (OP) has a very similar look and feel to previous versions, until the user specifies an official NGS-issued GNSS **Project Tracking ID** (provided through the [Survey Project Proposal](#) portal). The inclusion of this Tracking ID in OP unlocks new features of the software specifically for projects intended for submission to NGS. Note that although OP will support multiple GNSS constellations in the future, at the time of this manual's publication, only **GPS** data files are supported.
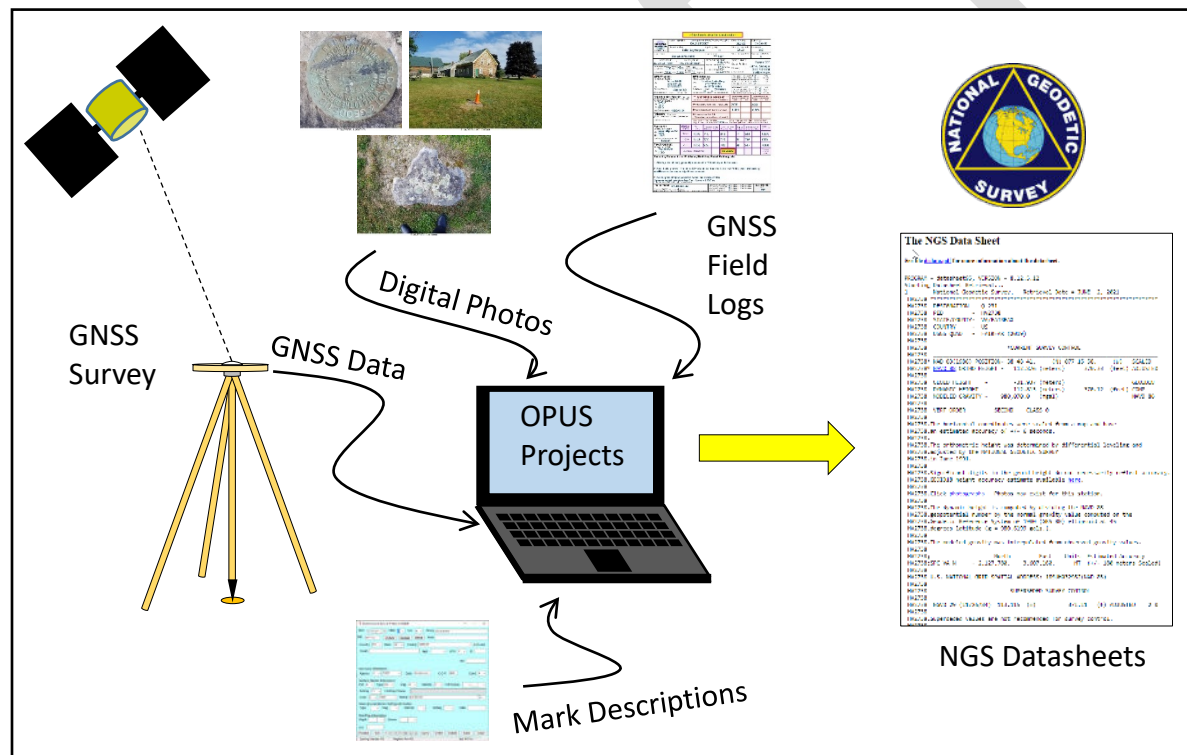
Figure i: OPUS Projects supports the submission of GNSS survey data to NGS for publication on Datasheets

Revision History

Draft v1.0 (First Draft) – 20 September, 2020 – Submitted for NGS internal review

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Draft v.1.1 – 04 January 2021 – Submitted for external review

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Draft v1.2 – 18 February 2021 – Approved by the NGS Products & Services Committee

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Living Document

The OPUS Projects User Guide is designed to be a "living document" and will be updated with new information and resources as the OPUS suite of programs evolve over time. As this current edition of the document is being prepared for publication, an even newer and better version of OPUS Projects will be made available to users on the NGS Beta internet site.

If you have any question or comment regarding this User Guide, or if you discover any errors, please contact the OPUS Projects Team at ngs.opus.projects@noaa.gov.

If there are any topics or resources that you would like NGS to add to this User Guide or to the training materials on OPUS Projects, please contact the NGS Training Coordinator at nos.ngs.corbin.training.center@noaa.gov.

Acknowledgements

This document was made possible by the dedicated support of an entire team comprised of:

Mark Schenewerk, Julie Prusky, Philippe Hensel, Dan Gillins, Dave Zenk, Kevin Jordan, Bill Stone, Boris Kanazir, Jeff Jalbrzikowski, Erika Little, Michael Dennis, Dan Prouty, and Rick Foote.

The authors wish to thank John May and Ed Carlson for their help in revising the first draft, as well as Dave Streitz (MNDT) and Mark Huber (USACE) for their revisions to the second draft.

Special thanks to Ying Jin for helping to bring this document to production.

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Conventions Used Throughout the Document

> Useful tips are presented in green text bubbles

> ⚠ General cautionary statements are presented in yellow text bubbles with the "caution" red triangle

> ⚠ Critically important cautionary statements are given in the red text bubble

More information on selected terms and acronyms are found in the Glossary. Selected terms are highlighted in **bold** font when first used.

Disclaimer

Mention of specific commercial product, process, or service, or the use of any trade, firm or corporation name is for the information and convenience of the public, and does not constitute endorsement, recommendation, or favoring by the Department of Commerce

Quick Start Guide

QS1. If you would like to submit your least squares-adjusted campaign-style GNSS project to NGS, an official Project Tracking ID will be required. This ID is issued by NGS upon successful review of a Survey Project Proposal. We recommended you coordinate this with your NGS Regional Geodetic Advisor. If you do not intend to submit your project to NGS, then skip this step.

Figure QS1: NGS Survey Project Proposal Form

The uploaded Network sketch should identify the project's network baseline design (baselines connecting the **user marks** and **CORS**s). The design plays a role in both **session processing** and network adjustment in OP (See Section 10 of this manual).

QS2. Create your project in OP.
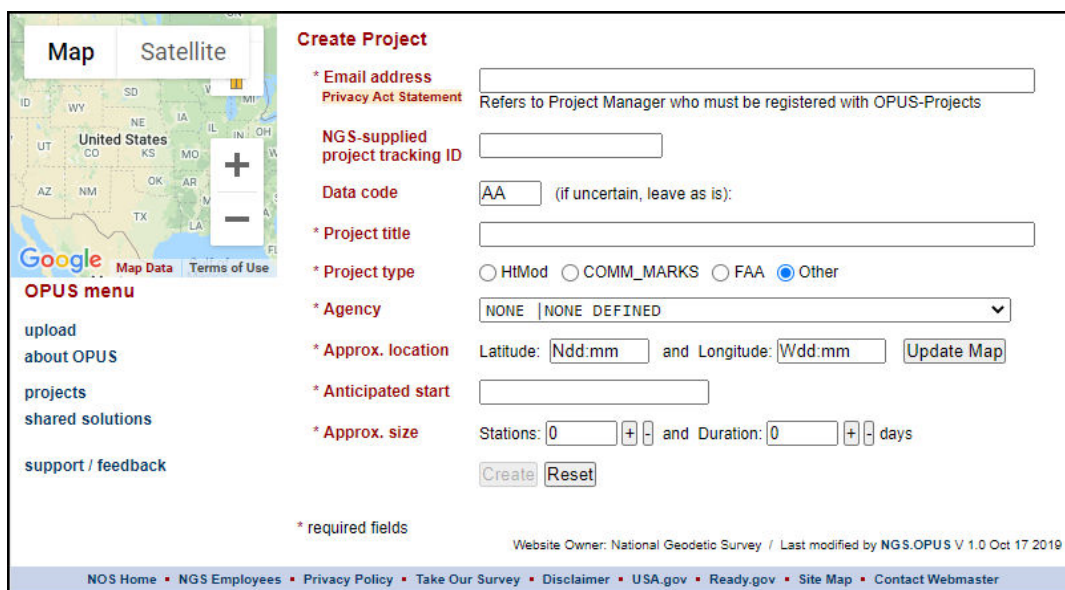
Figure QS2: Input screen to create a project in OPUS Projects

Creation of a project is limited to email addresses associated with attendees of NGS OPUS Projects Manager's Training classes. Please see the NGS training calendar for upcoming class offerings or contact an NGS Regional Geodetic Advisor for additional information. To unlock the advanced capabilities of OP, an NGS-supplied Project Tracking ID will need to be entered at this step [see Step 1, or enter "0000" (four zeros) as a dummy variable to access the advanced capabilities].

QS3. Review your project Preferences to make sure preferences match project requirements.
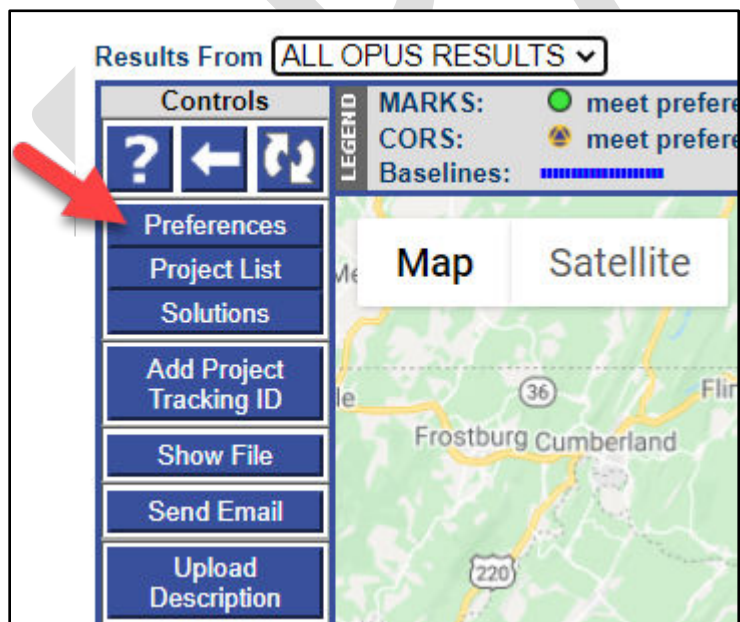
Figure QS3: Location of the Preferences button on the OP Manager's Page

QS4. If submitting the project to NGS, upload [WinDesc](#) Description Files for all user marks to OP (not CORSs). A WinDesc tutorial is provided in Appendix 1. If photos are already available, load them via the "Upload A Photo" button on the individual mark pages. When GNSS Observation Field Logs are available, they can be loaded from the Manager's Page. If you do not intend to submit your project to NGS, then skip this step.
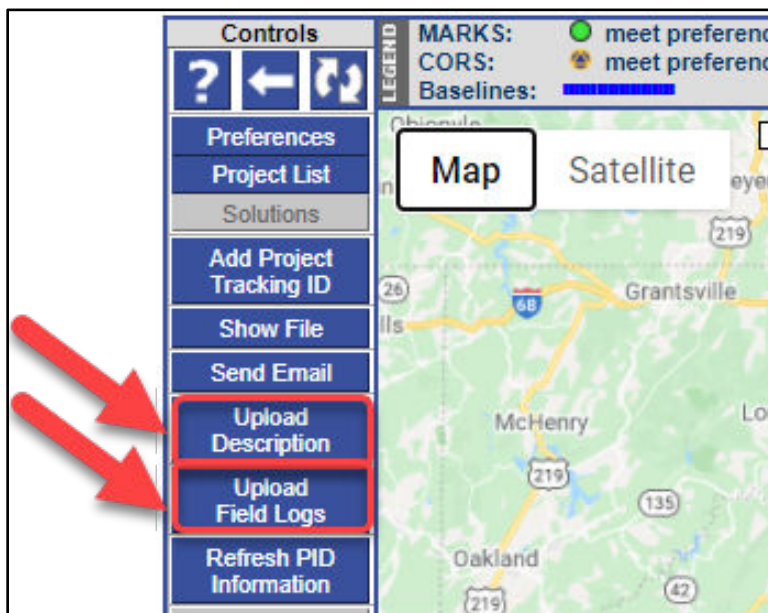
Figure QS4a: Location of upload descriptions and field log buttons on the OP Manager's Page
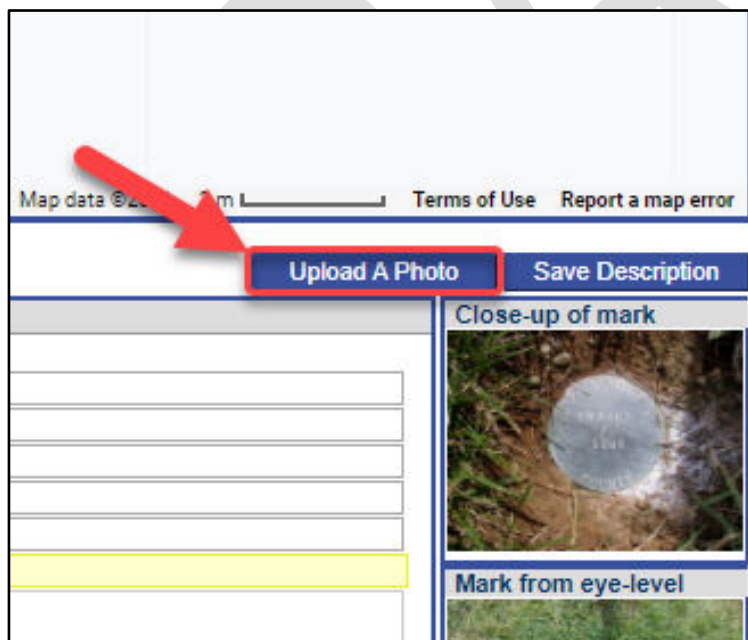
Figure QS4b: Upload a photo button on the user mark page

QS5. Load static GNSS observation files through the [OPUS upload portal](#).

Figure QS5: OPUS GNSS data file upload page

QS6. Review OPUS solutions (Show File) and OP visualizations (Manager's Page, **Session** pages, Mark pages) to make sure observations are correct, data quality is good, and four-character ID assignments and sessions are as expected.

Figure QS6: OPUS single file processing results are available under "Show File" and on the individual user mark page

QS7. CORS Selection: select the best CORSs for use as control for session **baseline processing** and network adjustments. CORS and IGS Stations should be added to the project using the "Add/Del CORS" button on the Manager's Page. Typically, 4 to 8 stations should be selected, including at least one within 200 km of the observed user marks to function as a session baseline processing "**hub** station." A detailed, step-by-step procedure is provided in Section 9. Add one distant station (300 to 800 km away) to help model the tropospheric delays.
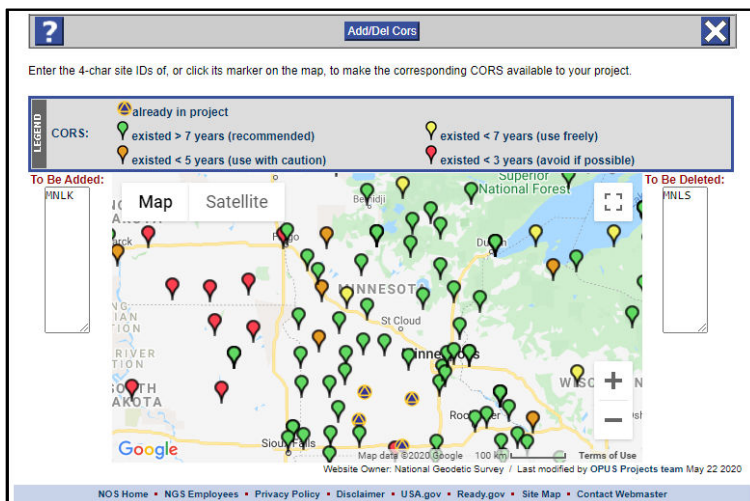
Figure QS7: Add/Delete CORS pop-up window

QS8. Conduct session processing. Only constrain the hub(s) in lat/lon/ellipsoid height (3D) during session processing.
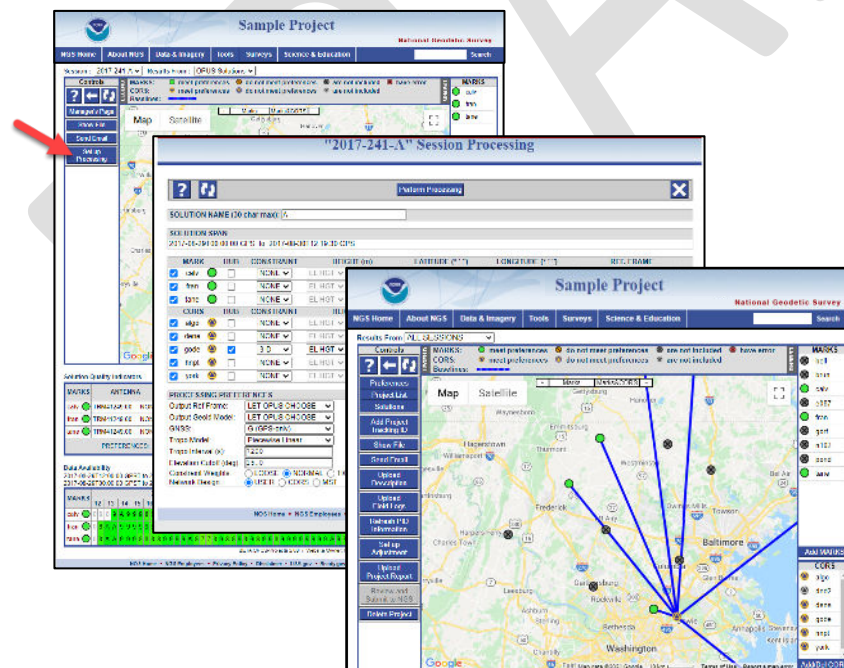
Figure QS8: Session processing sequence

Review results of session processing to ensure project specifications have been met (review session outputs in email attachments or under "Show File" from the Manager's Page).

QS9. A) If no Project Tracking ID (real or "dummy") has been associated with the project, network adjustments are performed on all selected sessions. Typically the CORS are held fixed in 3D. Any vertical user marks with known or published orthometric heights may be constrained vertically at those heights.   See Section 11, Network Adjustments.

B) If a Project Tracking ID was used, then the next step is a series of five sequential network adjustments (see below). After each step, carefully review the results and especially the **shifts** in the coordinates. You may have to go back and reject some observations (or remove some **constraints**) and reprocess some sessions.

Figure QS9: Network adjustment window showing sequence of five network adjustments when a NGS Tracking ID is used.

a. Preliminary network adjustment: constrain the hub(s) (3D) and float all other stations. Make sure you have at least two good occupations (>2 hrs) per user mark.

b. Horizontal free network adjustment (minimally constrained - same design as the Preliminary): constrain only one station (3D), typically a hub. This adjustment uses a different processing engine compared to the Preliminary adjustment. Analyze residuals, make sure they are small.

c. Horizontal constrained network adjustment: constrain all CORSs (3D) except the distant CORS. Constrain the (published) adjusted horizontal coordinates for all observed user marks with published lat/lon's. Evaluate the coordinate shifts for the signs of any outliers. Evaluate the F-test result (see Section 12 for more guidance on applying the F-test).

d. Vertical free network adjustment (minimally constrained): constrain one hub in 2D; constrain to one (published) adjusted orthometric height (1D). Analyze residuals, make sure they are small.

e. Vertical constrained network adjustment: constrain one hub (2D), float all other CORSs. Constrain all user marks that have published, adjusted orthometric heights. Evaluate the vertical shifts as well as the results of the F-test.

QS10. Review project, verify field logs, photos, descriptions, finalize the project report, and submit to NGS.

1 Introduction

OP is a web-based geodetic application which enables the baseline processing of simultaneous, static GNSS observations, called **sessions**, followed by a least squares adjustment of the sessions. Results are tied to the National Spatial Reference System (NSRS). Collectively, the data, session **solutions**, least squares adjustment and additional metadata are called a project. OP provides a user-friendly map and graphic interfaces to visualize the project and solutions. It also provides useful quality assurance and quality control functionality as well as file organization features to assist in processing. The new OP builds on the success of previous versions of the application to provide the same look and feel and ease of operation, but fully replaces legacy methods of **PAGE-NT** GPS processing and NGS **ADJUST** software programs, and provides an updated method of submitting least squares adjusted, campaign-style GPS projects to NGS.
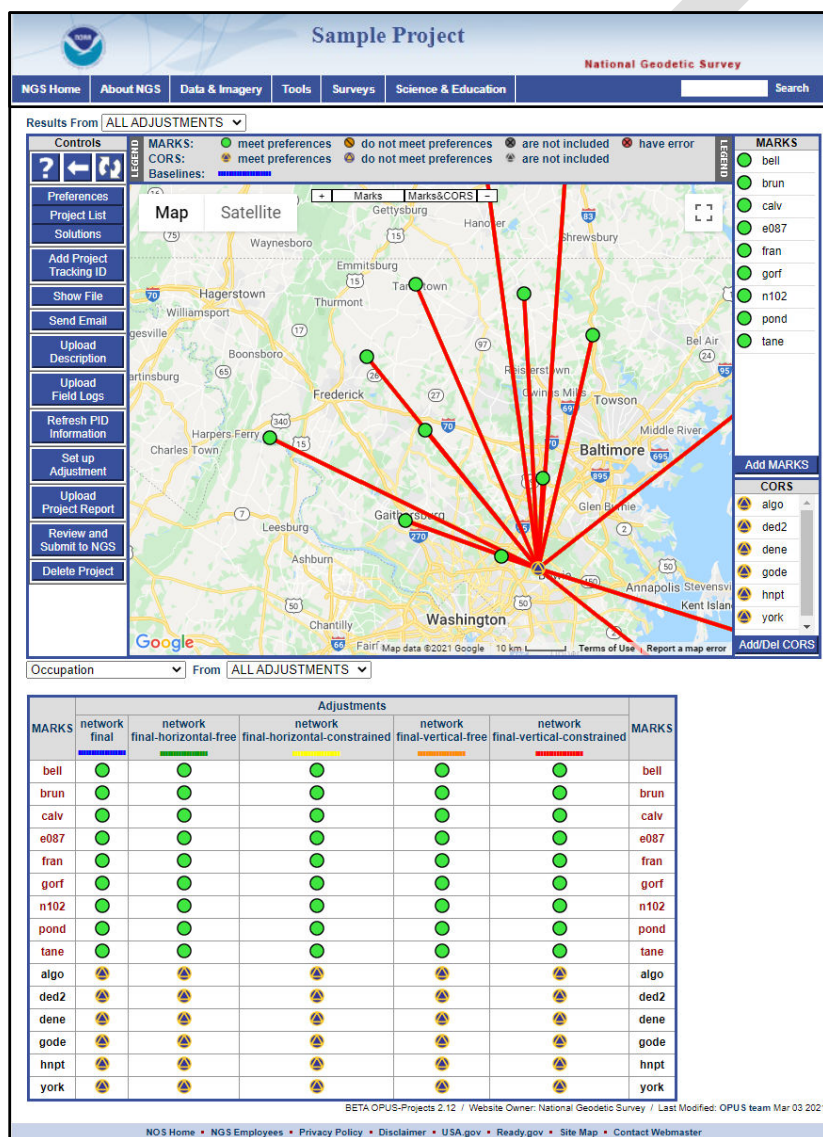
Figure 1-1: Sample OPUS Projects Manager's Page showing all five network adjustments

Access to OP is through the Projects link on the OPUS upload web page at http://geodesy.noaa.gov/OPUS/, or directly using the URL: http://geodesy.noaa.gov/OPUS-Projects/.

Figure 1-2: OPUS Projects Create, Session, and Manager access page

To create OP projects, the user must have completed the OPUS Projects Manager Training. Training options include both in-person classes and webinars. To see the availability of and register for a live workshop, go to the NGS Calendar of Upcoming Classes. To access online materials visit the web page for the NGS Testing and Training Center. To request additional training, contact ngs.training@noaa.gov or your regional geodetic advisor.

Upon project creation, a set of unique keywords is automatically created, which provides online access to the project. To add data to the project, a user uploads static GNSS, dual-frequency observation files to OPUS, providing the specific antenna type, the vertical height to the Antenna

Reference Point (**ARP**), and the project ID keyword referred to above. After uploading all static GNSS files, OP performs session baseline processing using the same software that has traditionally been used in the bluebooking process (**PAGES**).

Once the user moves on to the Network Adjustments phase, the workflow shown in the figure below depends on whether the user has previously associated a Project Tracking ID to the project. Without a Project Tracking ID, the software **GPSCOM** is used to compute any and all adjustments the user wishes to specify. Conversely, if a Project Tracking ID (either the ID assigned thru the Survey Project Proposal process, or the "dummy" ID "0000") has been associated with the project, then **GPSCOM** is used to compute a *Preliminary Adjustment* while a subsequent, sequential set of adjustments (*Horizontal Free*, *Horizontal Constrained*, *Vertical Free*, *Vertical Constrained*) is computed using **ADJUST**. Please refer to the Glossary for more information on these programs.

> ⚠️ The user should decide at the outset which network adjustment process is required to meet project objectives (i.e. with NGS Project Tracking ID or without). Once a NGS project Tracking ID (or "dummy" ID) has been associated with the project, it cannot be un-associated with that project. An official NGS Project Tracking ID, however, can always replace the "dummy" ID (but not the other way around!).

The decision of whether to use ADJUST or GPSCOM will be primarily driven by whether or not the user intends on submitting the project to NGS. If that is the goal, then the project must have an official Project Tracking ID assigned. Users not interested in submitting to NGS may still want to ensure that their project remains aligned to the latest realization of the NSRS. In that case, the dummy tracking ID "0000" can be used. Note that GPSCOM may provide a better alignment to the International Terrestrial Reference Frame (ITRF) and can potentially solve for more sources of error in the GPS network solutions compared to ADJUST, although these solutions might not have an ideal alignment with the latest realization of the NSRS reference frame.

Regardless of the pathway chosen, the resulting solution reports contain coordinates for the observed user marks[1] as well as Continuously Operating GNSS Reference Stations, or CORSs[2], included in the project's processing. These coordinates are reported in the current geometric (aka "horizontal") datum realization of the National Spatial Reference System (NSRS), as well as the ITRF.

> Throughout the manual, "CORS" or the plural "CORSs" is meant to refer to continuously operating GNSS reference stations in the NOAA CORS Network (NCN) and/or the International GNSS Service (IGS) network.

Figure 1-3: Conceptual diagram of workflow in OPUS Projects

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[1] Throughout the manual, the term "user mark" refers to a mark whose GNSS observations have been brought into the project by the user through the OPUS upload page. See Glossary for more information.
[2] OPUS Projects accesses active GNSS control from the NOAA CORS Network (NCN) in addition to certain IGS stations which are not part of the NCN. For simplicity, this manual refers to them both as "CORS" (singular)) or "CORSs" (plural).
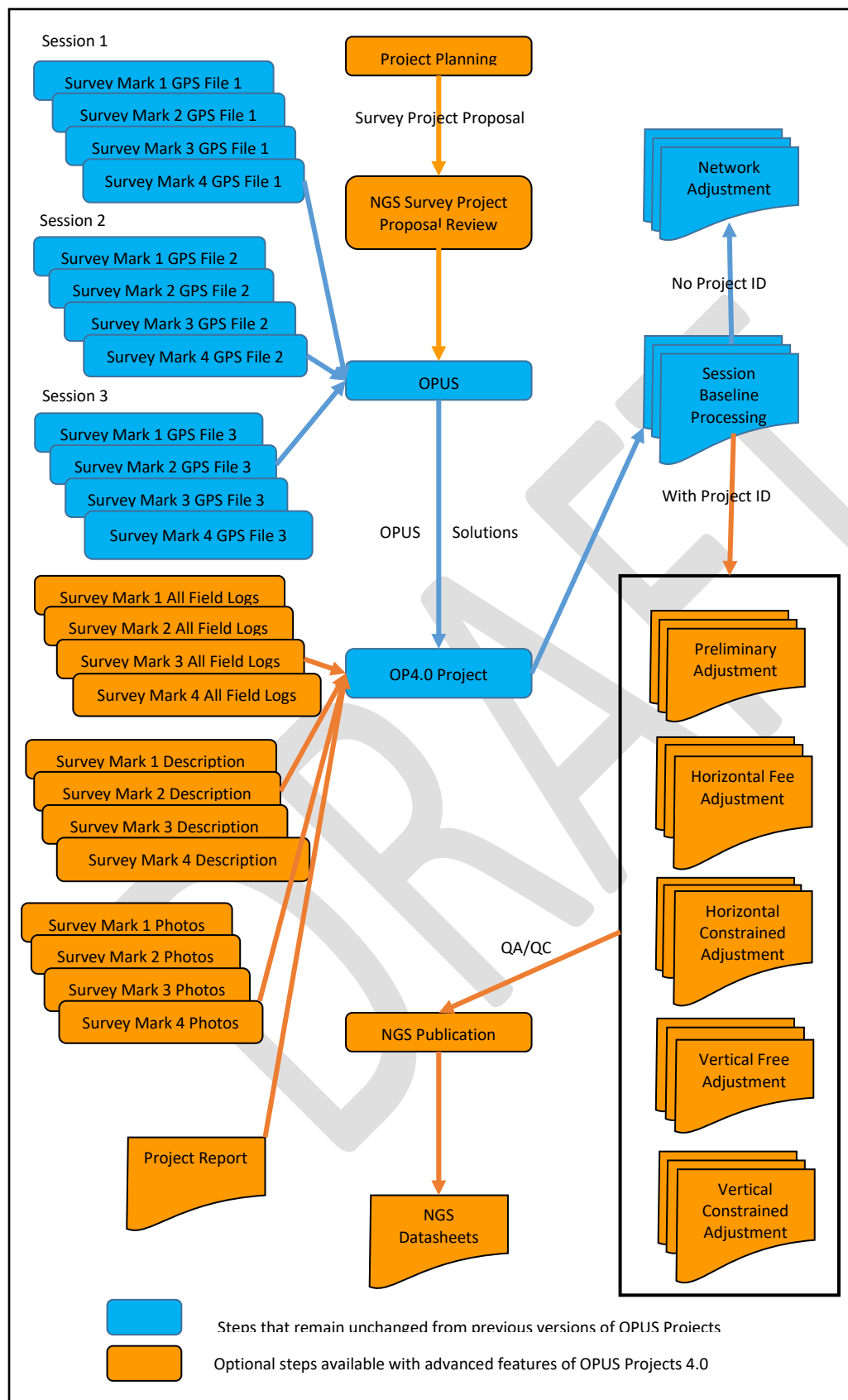
Figure 1-3: Conceptual diagram of OPUS Projects workflow

The diagram contains the following labeled elements:

Session 1
- Survey Mark 1 GPS File 1
- Survey Mark 2 GPS File 1
- Survey Mark 3 GPS File 1
- Survey Mark 4 GPS File 1

Session 2
- Survey Mark 1 GPS File 2
- Survey Mark 2 GPS File 2
- Survey Mark 3 GPS File 2
- Survey Mark 4 GPS File 2

Session 3
- Survey Mark 1 GPS File 3
- Survey Mark 2 GPS File 3
- Survey Mark 3 GPS File 3
- Survey Mark 4 GPS File 3

- Survey Mark 1 All Field Logs
- Survey Mark 2 All Field Logs
- Survey Mark 3 All Field Logs
- Survey Mark 4 All Field Logs

- Survey Mark 1 Description
- Survey Mark 2 Description
- Survey Mark 3 Description
- Survey Mark 4 Description

- Survey Mark 1 Photos
- Survey Mark 2 Photos
- Survey Mark 3 Photos
- Survey Mark 4 Photos

- Project Planning
- Survey Project Proposal
- NGS Survey Project Proposal Review
- OPUS
- OPUS Solutions
- OP4.0 Project
- Project Report
- NGS Publication
- NGS Datasheets

- Network Adjustment
- No Project ID
- Session Baseline Processing
- With Project ID
- Preliminary Adjustment
- Horizontal Fee Adjustment
- Horizontal Constrained Adjustment
- Vertical Free Adjustment
- Vertical Constrained Adjustment
- QA/QC

Legend:
- Steps that remain unchanged from previous versions of OPUS Projects
- Optional steps available with advanced features of OPUS Projects 4.0

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OP was created to provide users with NSRS three-dimensional coordinate results for GNSS networks and a relatively easy route for submission to NGS. In the future, a much more expansive OPUS suite of tools will enable the simultaneous processing and adjustment of a variety of geodetic survey data, including additional types of GNSS data (e.g. real time kinematic vectors), leveling, distances and angles. This will fully support the new NSRS geospatial database and the new terrestrial reference frames and geopotential datum of 2022.

1.1 Intended Audience

This manual is intended for the community of GNSS practitioners who are already highly skilled in running GNSS campaign-style surveys, are very familiar with **post-processing** GNSS observations, and who understand the theory of least squares adjustments as it pertains to GNSS data. However, one does not need a degree in geodesy or surveying science to successfully use this manual and OP. Although many geodetic and surveying terms are used throughout the document, a glossary is included to remove confusion on the use of terminology. NGS has also published a number of educational products which may be very useful in bringing the user up to speed on a number of these topics. Please see the NGS educational videos and online lessons.

1.2 Disclaimers

OP is a web-based utility implying that access to the Internet and use of a web browser are required. JavaScript must be enabled in your browser and pop-up blocking may have to be turned off. There is no implied guarantee that your browser will be compatible with OP. If you have difficulty configuring your browser, try a different browser or contact your workshop (or webinar) instructor or the OPUS Projects team.

Your email address is registered with NGS when you attend an OPUS Projects for Managers Workshop. Registering your email address allows you to create projects in OP. This is similar to registering to **share** a solution result through OPUS. If your email address changes and you would like your new email address to be associated with your projects, then please contact the OPUS Projects Team.

Always follow your project's specifications. This 'User Guide for OP should not be considered an endorsement for any specific project **network design**, field technique, hardware or software. Nor does it represent specific NGS project guidelines. The following websites provide guidance for some project types:

http://www.fgdc.gov/
http://geodesy.noaa.gov/AERO/aero.html
http://geodesy.noaa.gov/heightmod/

1.3 Helpful Resources

OPUS Projects Manager Training Videos
ADJUST guidelines - for background information on the least squares tool that is built in to OPUS Projects
Input Formats and Specifications of the National Geodetic Survey Data Base (The NGS "Bluebook")
WinDesc (download link)
FAA AC-16 specifications
NOAA Technical Memorandum NOS NGS 58
NOAA Technical Memorandum NOS NGS 59
GNSS Positioning: Survey Planning and Data Acquisition - online on-demand video lesson

2 NGS Survey Proposal

If the intention is to use OP to submit a GNSS survey project to NGS, the user is required to submit a survey proposal via the NGS Survey Proposal form. The form can be reached by clicking on the "Surveys" tab on the NGS home page, and selecting "Survey Project Proposal Form" at the bottom of the drop-down list. It is recommended to submit the proposal prior to data collection, in case any changes to the plan are recommended.

It is also recommended to contact your regional geodetic advisor to discuss the project requirements prior to submitting the proposal. The advisor can assist in the selection of the appropriate local control.

If the user is not interested in submitting the project to NGS, skip to Step 3, "Create your project in OP."

Figure 2-1: NGS home page showing how to access NGS Survey Project Proposal Form

The form requests general information about the scope of your project, including title, state, whether the project is GNSS or leveling (the proposal form supports both kinds of projects), and approximately how many stations and over what period of time the survey is to be conducted.

Figure 2-2: The NGS Survey Project Proposal Form

The form requires the uploading of a survey network sketch, an observation schedule, and a photo of the type of user marks included in the project.

Mark type is mainly reserved for photos or sketches identifying the kinds of *new* user marks set for the project. If no new user marks are being set, the photos or sketches can reflect the most typical kind of user mark included in the project. Examples of mark types are available from the [**Help**] link on the Survey Project Proposal page.

The Network sketch refers to the identification of the project's network baseline design, with baselines identified between the project's user marks and CORSs. Examples are available by clicking on the [**Sample**] link on the Survey Project Proposal page, and are also explored in Section 10 of this manual. The sketch should also inherently reflect processing decisions for which marks are to be held constrained (in which dimensions), and which are to be unconstrained.

> Consider the quality of the coordinates and heights of any mark used as a constraint in the project, including known uncertainties

The observation schedule lists the days, times of day, and the corresponding marks observed with GNSS, which can provide an idea of the eventual GNSS observation sessions involved. The schedule also specifies how many times each user mark will be observed as part of this project, or otherwise provides information regarding the procedures to be followed for creating the GNSS observation sessions in the project. Two samples are available from the links on the Survey Project Proposal page [**Sample 1**, **Sample 2**].

The only absolute requirement to successfully use OP for submitting a project to NGS is to have at least two, independent, ≥ 2-hour GNSS occupations on each user mark included in the project. However, NGS recommends following procedures outlined in the technical documents Zilkoski et al. (1997) and Zilkoski et al. (2008). Similarly, if conducting work for the Federal Aviation Administration (FAA), please consult the reference document AC-16.

> ⚠️ NGS requires at a minimum two, independent, ≥ 2-hour GNSS occupations on each survey mark to be included in the project.

> ⚠️ There is a programmed limit of 99 project marks plus (including) CORS maximum *per session*

> ⚠️ Disclaimer: this User Guide is a guide to using OPUS Projects for post-processing and adjusting campaign-style GNSS survey data. It is not a reference manual for policies and procedures relating to survey practices for conducting GNSS campaign-style surveys.

Once the form is submitted, the project information will be reviewed by NGS to ensure the project can meet the stated objectives (including desired accuracies). Once accepted, the project will be issued a unique Project Tracking ID.

> Submit the proposal at least two weeks prior to the onset of the fieldwork. NGS will review the proposal and provide a NGS tracking ID if the project meets NGS standards, and may offer suggestions if/where appropriate.

3 Create Your Project in OP

Navigate to OPUS Projects:

Figure 3-1: Access to OPUS Projects by way of the OPUS Front Page

3.1 Create Your New Project

Figure 3-2: Create New Project

When you create a new project in OP, there are a number of required fields to fill in, marked with an asterisk (*). The fields are explained below:

Figure 3-1: * Fields, Information to Enter

Email address (required): Enter the email address used when you registered for OPUS Projects for Managers training.

NGS-supplied Project Tracking ID (optional; required for submission for submission to NGS): If your intent is to submit your data to NGS, you will need to have an official NGS Project Tracking ID. Tracking IDs are issued through the Survey Project Proposal page (Section 2). It is recommended that you submit a survey proposal even if you are unsure whether you will submit the project to NGS, as this will result in a professional review of

your project plan. Note that the tracking ID can be entered into OP at any point. If you do not intend to submit your data to NGS, but you want to unlock the advanced features, "0000" may be entered as a dummy ID in the field upon creation of the project. The "dummy" ID enables all the same features as with an official NGS Project Tracking ID, minus the ability to submit the project to NGS.

> ⚠️ If you do not include a Project Tracking ID (or dummy ID), the advanced features of OP4.0 will not become available

> If you have not originally entered a valid NGS Project Tracking ID or the "dummy" ID, you can always add the ID to the project at a later date from the Manager's Page.

Data code (optional): This user-specified code can be used to identify different parts of a project that all fall under the same Project Tracking ID.

> If a valid NGS Project Tracking ID has been associated with the project, the following fields will be automatically filled; otherwise, the user may complete the fields manually

Project title (required): Enter a short descriptive name for your project (e.g. West Side Densification Survey).

Project type (required): The options are: Height Mod, COMM_MARKS, FAA, or "Other." This item is used only for internal tracking of Height Modernization, NGS Commemorative Marks, and the Federal Aviation Administration's Aeronautical Survey Program projects. No specific choice will have any impact on your project. For more information on these project types, see the Survey Proposal Page. Most users will simply accept the default choice of OTHER.

Agency (required): This identifies the category and name for the agency submitting the project. If you have already identified a NGS Project Tracking ID, the Agency field will be automatically filled with the agency identified in the project proposal. If no Project Tracking ID was identified, or you used the dummy tracking ID "0000," then this field must be filled out manually by selecting the appropriate registered agency. The easiest way to proceed is to begin typing the agency code in the text box: the appropriate code should appear from the drop-down menu. If you are an individual, or do not want your work to be associated with an agency, you can keep the default value "NONE | NONE DEFINED." If you would like to request an agency code, please contact ngs.annexc@noaa.gov to have an agency code assigned.

Approximate location (required): You can enter the approximate coordinates for the center of your project (to the nearest minute of latitude and longitude) or you can click on the map in the upper left-hand corner of the page to identify the approximate survey location. Clicking on the map will auto-fill the Latitude and Longitude fields on the page.

Figure 3-2: Click Map

Anticipated start (required): Click in the box to open a calendar, and select the anticipated start date for your project.

Approximate size (required): Enter the estimated number of user marks to be observed in your project, as well as the estimated number of days your project will last.

For projects to be submitted to NGS, the project must contain at a minimum two-2 hours sessions for all stations.

Figure 3-3: Create Project

When all required fields have been entered, the Create button will become active. When clicked, the project will be created.

3.2 Access to Your Project

Once created, an email will be sent to the address provided, giving you a unique Project Identifier, Manager Keyword, and Session Keyword. If you do not receive an email, check your spam folder, as this is an automatic response from OP.
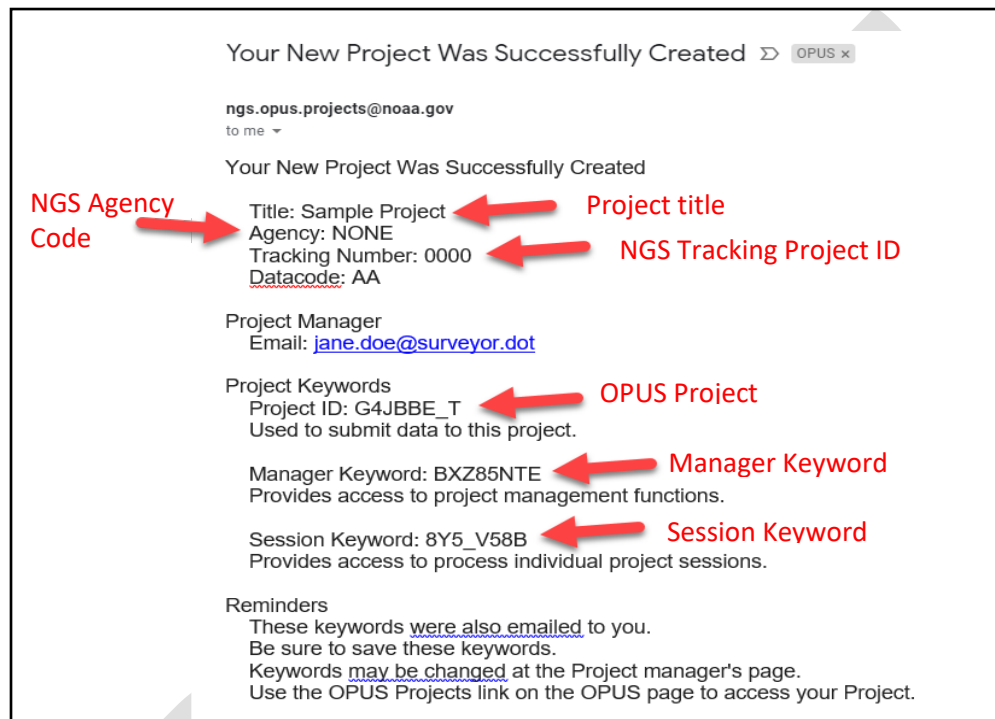
Figure 3-4: Project Creation Confirmation Report

All keywords are sent to the project manager. The keywords function to control access to the project, and allow the project manager to exert some influence/control on access and roles in processing the project:

- The **Project ID** may be shared thereby permitting other people (such as field crew members) to upload data to your project.

- The **Project ID** and the **Manager Keyword** give the project manager complete access to all parts of the project.

- The **Project ID** and **Session Keyword** give limited access to the project's mark pages and **session processing** pages. This is useful if other people will help with user mark metadata management and session processing who do not need full access to the manager's functions.

- The **Project ID** must be unique for each project but the manager and session keywords are allowed to be the same for more than one project.

- The **Project ID** and keywords can be challenging because they are randomly generated, but the project manager can replace them through the project's Preferences (see Section 4).

> Under "project Preferences" (see below) change the Project ID and Keywords into codes that make sense to you. If the ID has already been assigned to another project, you will be prompted to choose another ID

Note that project roles will be assigned to users depending on how they interface with OP.

- Anyone who loads GNSS observation data into the project using the **Project ID** will have their emails listed as Field Members (so they can receive emails from the project manager or session processors - this feature is explained in Section 7).

- Anyone who processes a session using the **Project ID** and **Session Keyword** will have their email included in the Processor list (see Section 7).

- Anyone can be added to a "cc list" (see Project Preferences, next section) to receive copies of adjustment reports and related emails from the project sent by the project manager.

> It is recommended to create you project in OP4.0 *prior* to the field campaign to take advantage of quality assurance/quality control capabilities of the program.

4 Review and Edit Project Preferences

Before any data are uploaded into a project, open the project using the Project ID and Manager Keyword. Review the preferences to best leverage the capabilities of the software. If data are uploaded prior to modifying the preferences, the results may not be displayed correctly.
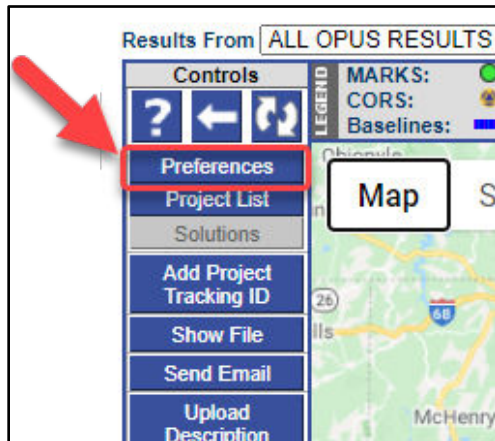
Figure 4-1: Review and Edit Project Preferences

Click on the **Preferences** button to open your project preferences.

A pop-up window will open (make sure your browser will accept pop-up windows). Across the top of the window, as is typical of all OP pop-up windows, there is a central action button (e.g. **Save Changes and Close**), a right-hand Cancel/Close ( ) button, a left-most Help (?) button, and a Refresh button ( ) immediately right of the Help button:

Figure 4-2: Save Project Preferences

Note that the window contains five main tabs:

1) Project Title, ID and Keywords (opened by default)
2) Data & Solution Quality Thresholds
3) Data Processing Defaults
4) Session Definition
5) Mark Co-location Definition
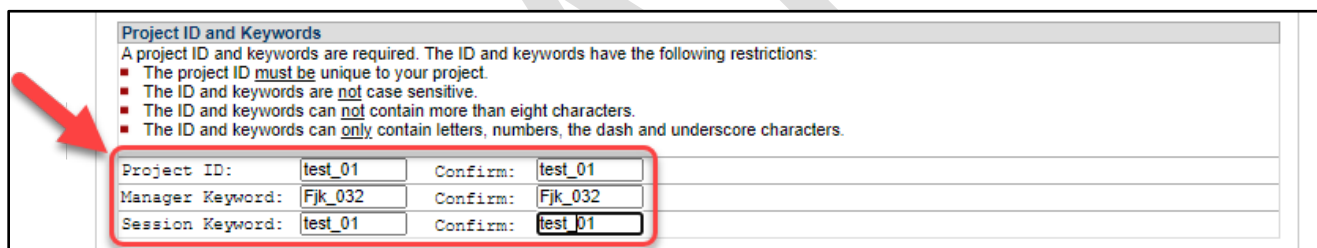
These tabs and the preferences contained therein are explained below.

Click the "Save Changes and Close" to save your updated project preferences. Or click X to abandon changes without saving them.

4.1 Project Title, ID and Keywords

The Project Title, as well as the NGS Tracking ID, Data Code, and Organization were added to the project when the project was created (or when the "Add NGS Project Tracking ID" feature was selected). They cannot be changed, and are repeated here as a convenience.

Project ID and Keywords can be changed in the Preferences window. Choose names that make sense to you. Note the restrictions imposed on ID and Keywords (red arrow, below):

Figure 4-3: Project Title, ID and Keywords Report

Project IDs are unique among all projects currently in existence. The manager's email address is associated with the project at creation and the two are associated together for the life of the project. Manager and session keywords exist only inside the project and may be used in other projects. Lost or forgotten project IDs and keywords may be recovered using the "Project List" button on the Manager's Page, assuming you have access to another of your previous projects (see section 7.1). If you do not have access to previous projects, check your inbox for the original email from OPUS providing you the credentials. If the credentials were altered, you will need to contact the [OPUS Help Desk](#) for assistance.

4.2 Adding Emails to the Project Team

Session solutions, network adjustment results and other reports and notices will be sent to the project manager's email address. The manager can have copies of these emails *automatically* copied (CC) to others on the project team (Field Members or Processors) by adding their emails to the CC list. Emails can also be removed as needed. Add an email address in the text box to the right of the "Add To CC List" button (red arrow in figure below):

Figure 4-4: CC'ing Team Members

Click on the **Add To CC List** button, and the address will now appear on the "CC Manager Emails To:" list. If you wish to remove an email address, select the address from the dropdown list of "AVAILABLE EMAILS" and lick on the **Remove From CC List** button.

4.3 Data and Solution Quality Thresholds

Data & Solution Quality Thresholds help identify blunders (e.g. an unrealistic antenna height) as well as poor quality data (too few observations used in the GNSS solution, or higher than expected uncertainties). Thresholds also define how processing results are displayed on the project's web pages. This includes the OPUS processing results produced when data files are uploaded to the project, as well as the results of session baseline processing and network adjustments. The thresholds will flag individual GNSS observation files and specific user marks/CORSs that do not meet the identified quality criteria. For more information on Quality Thresholds, see OPUS page (https://geodesy.noaa.gov/OPUS/about.jsp#accuracy). A notification is emailed to the person uploading a data file if its OPUS results fail any of these quality metrics (see Section 6.4). This gives OP a limited, near real-time problem detection capability if data files can be uploaded while teams are still in the field. For this reason, it is best to set these preferences prior to the field campaign for maximum utility.

> The default values of the preference parameters are appropriate for most projects. A project manager might consider relaxing or tightening the thresholds as needed to support project specifications.

OP default Data & Solution Quality Thresholds:

Figure 4-5: Data & Solution Quality Thresholds

Ephemeris:

If PRECISE is chosen but the "final precise" ephemerides are not yet available (see **ephemeris**, in Glossary), OP will warn that the manager's preference was not met. If BEST AVAILABLE is chosen, there is no relevant flag or warning to issue. If the user intends to submit the project to NGS, or otherwise wants to make sure that the very best ephemerides are used, it is recommended to (re)process the project's sessions after two or three weeks from the date of the last GNSS observation. By this time the "final precise" ephemerides should be available for OP to use.

> ⚠️ For publication, NGS requires that the "final precise" ephemerides be used in processing

The minimum and maximum Antenna Reference Point (ARP) heights are designed to catch blunders (e.g. typographical entry errors). NGS does not recommend antenna heights over three meters to ensure antenna stability.

Minimum Observations Used / Minimum Ambiguities Fixed:

The minimum observations used and minimum ambiguities fixed relate to how noisy the data are, and if there were obstructions which impeded the efficient tracking of each satellite. *Higher values are better*.

Maximum Solution RMS:

The solution's Root Mean Square (**RMS**) is an estimate of the three-dimensional error associated with the post-processed solution. The definition of RMS differs slightly depending on the stage of processing within OP. In the case of an OPUS solution, the RMS is computed as the sum of squared residuals between observed and computed values of phase signal at each observation epoch, for each of the CORSs selected by OPUS. For session processing, the computation is similar, except that the differences are summed for the network of baselines in the session. *The lower the RMS, the better*.

Maximum Uncertainties:

Height, Latitude and Longitude uncertainties relate to the disaggregation of three-dimensional error into each of the three one-dimensional components. The definition of these uncertainties depends on the stage of processing within OP. In the case of initial OPUS solutions, these errors are expressed as "**peak-to-peak**" errors which approximate 1.7 times the expected standard deviation among the different one-dimensional coordinate estimates (see OPUS Accuracy for more information). For session baseline processing these uncertainties refer to one standard deviation. As a rule of thumb, maximum latitude and longitude uncertainties should be around 4 cm, and maximum height uncertainty should be about 8 cm for individual OPUS solutions. *The lower the uncertainties, the better*.

> ⚠️ Any recommended thresholds for uncertainties, residuals, differences, errors, etc. given in this document are provided as general guidelines, and are not to be interpreted as standards or project specifications. Refer to your project specifications for exact thresholds.

These thresholds have to be interpreted within the context of a GNSS project. If an observation file is very long, a lower percent observations used, or a lower percent ambiguities fixed may still result in an acceptable solution. In addition, after session processing, quality metrics relative to the initial OPUS solutions often

improve (often having to do with the manual selection of CORSs used to control the larger project). Refer to Section 6.4 for checking the quality of your solutions.

> A particular GNSS data file may be flagged as not meeting the Data & Solution Quality Thresholds set of the project but still may process successfully.

4.4 Data Processing Defaults

Data processing preferences govern aspects of both session processing and network adjustments. The defaults will generally ensure good results and are consistent with NGS recommended best practices.

> ⚠️ Although the defaults can be changed at any time, changes made *after* processing may not be reflected in the already completed processing results requiring one to reprocess some or all of the session solutions and network adjustments.

Figure 4-6: Data Processing Defaults

Output Reference Frame:

Coordinates in the current ITRF/IGS are always included in the Processing Reports, but the coordinates in an additional reference frame (user selected) will be reported if possible. The default is "LET OPUS CHOOSE." OPUS will choose the current realization of NAD 83 (required for submission to NGS), but other options are available.

Output Geoid Model:

A pull-down menu is used for the Output Geoid Model, so GNSS-derived ellipsoid heights can be converted to orthometric heights. The default, 'LET OPUS CHOOSE," uses the latest NGS hybrid geoid model applicable to the project location (required for submission to NGS) though other models are available, including some gravimetric geoids.

> ⚠️ The conversion from ellipsoid heights to orthometric heights is done as a purely algebraic removal of the geoid undulation from the ellipsoid height. Those users familiar with "Height Modernization" should not confuse this conversion with an actual least squares adjustment performed in the orthometric height domain.

GNSS:

Currently the only choice in the "GNSS" pull-down menu is "G" (GPS-only), but the capability to use other GNSS in the data processing may be added in the future. Note that you may upload data files (**RINEX**) containing GLONASS data and the NGS may archive it, but the GLONASS data is currently stripped out automatically when processed by OPUS.

Tropo Model and Tropo Interval*:*

OP provides limited user control over how the effects of water vapor on the satellite signals as they traverse the tropospheric portion of the atmosphere, commonly called the tropo corrections, are parameterized (or modeled) in order to remove them. For submission of your project to NGS, it is recommended to keep the **tropo model** at piecewise linear approximation, with a **tropo interval** of 7200 seconds (2 hours). For additional information, see "**Tropospheric Modeling**" in the Glossary.

Elevation Cutoff:

The default Elevation Cutoff mask, in degrees above the horizon, can be specified. Data from satellites below the specified mask will be ignored. The default for new projects is 15 degrees. You will be given the opportunity to adjust the Elevation Cutoff mask separately for each session you process. This is a good idea for sessions containing user marks with impaired sky visibility.

Constraint Weights:

Constraint weights are only applied to user marks or CORSs selected to be held as constrained points in the project processing. Weights can be individually set in the sessions, and they can also be set here as defaults for all session processing and network adjustments. There is no differentiation between the weights applied to horizontal and vertical constraints. Users can select the constraint weights of choice for session processing and network adjustments with one exception: if a Project Tracking ID is used, constraint weights cannot be changed in the network adjustments; they are set to "NORMAL" for all network adjustments.

> **LOOSE**   -allows up to one meter of float for the constrained points in the processing.
>
> **NORMAL -**allows up to one centimeter of float for the constrained points in the processing (this is the recommended choice).
>
> **TIGHT**   -allows up to one-tenth of a millimeter of float for the constrained points in the processing (effectively fixing and not allowing the constrained control points to move).

4.5 Session Definition

Field crews should attempt to simultaneously start and end observations on the user marks in the survey network in order to form GNSS sessions for processing in OP. The **Session Definition** provides some control over how OP groups near-simultaneous data files together for processing. See Appendix 2 for more details on how OP arranged observation files into sessions. Typically, the default values work well and do not need to be

changed. However, if OP does not group the data files according to the survey plan, then these values can be changed prior to session processing. After processing begins, the values are disabled (grayed out). Session processing must be deleted to re-enable modifying these settings.

Figure 4-7: Session Definition

Minimum Data Duration:

The Minimum Data Duration default setting is 1800 seconds (30 minutes). Since OP currently requires that all static data files are at least 7200 seconds (2 hours) in duration, then this default setting ensures that OP will in fact consider all uploaded static data as part of a session. Changing the Minimum Data Duration to something larger than 7200 seconds will instruct OP to filter data to meet that requirement. For example, if it were set to 10,800 seconds, then only static data files at least 3 hours in duration will be considered.

Minimum Session Overlap Multiplier:

The Minimum Session Overlap Multiplier helps OP arrange observations into different sessions. The multiplier instructs OP on the least allowable overlap for any pair of simultaneous GNSS observations in a session. For a pair of GNSS observations to be considered in a session, the overlap in time must be more than the product of this multiplier and the duration of the shortest observation. For example, consider two observations where one starts at 10:00 and ends at 12:00 and another starts at 11:00 and ends at 13:10. If the multiplier was set to 0.5, and since the shortest occupation is two hours, then the minimum session overlap is one hour. These two observations overlap by one hour (from 11:00 to 12:00) so they would be grouped together in a session. Before considering changing the default values, verify whether or not OP has correctly binned your observations into sessions that make sense for your project. If sessions are changed using the multiplier after session processing has occurred, the sessions will be automatically deleted. For more information on how OP groups observation data into sessions is given in Appendix B.

4.6 Mark Co-location Definition

The Mark Co-location Definition defines how data files are associated with user marks. The definition can only be modified prior to session processing. Two options are available:

Figure 4-8: Mark Co-location Definition Settings

Mark ID: if the first four characters of a RINEX file correctly identifies a unique user mark in your project (**see Section 5**), there should be no co-location problem: OP will group the RINEX files by their respective four-character IDs. However, if the names of GNSS observation files subsequently uploaded to OPUS do not start with a four-character ID unique to each user mark, OP will group the observation files by their position.

> Co-location by Mark ID is only meant to help organize files in OP. Ultimately, files are arranged by coordinates (positions), even if Mark ID was initially selected. In addition, observations can be manually associated to specific user marks after loading. See "Manage Data Files" in Section 7.3.10.

Position: this is the default setting for OP. GNSS observations files are grouped by the positions (latitude/longitude) given in their respective OPUS solutions. Data files whose OPUS solution positions fall within the Maximum Position Difference specified (1 m is the new project default, but this can be changed) will be grouped together. OP will attempt to name each user mark uniquely. If all the data files associated with a user mark, and only the data files associated with that mark, use the same first four characters in their file names, the user mark will be given that four-character name, even if the co-location definition is selected as "Position." Otherwise, a name will be automatically generated starting with "a001." If "a001" is already in use, the numeric portion will be incremented until a unique name is created (e.g. a002, a003, etc.).

> Most GNSS receiver software will automatically name observation files starting with the serial number of the receiver (or at least its last four digits). If receivers are used on different marks throughout the project, this will result in OP assigning sequential codes to each mark name. To avoid this, make sure the RINEX file names start with the corresponding four-character mark ID.

4.7 Saving Your Preferences

After modifying any preferences, make sure you save your changes.

Figure 4-9: Saving Your Preferences

5 Naming Files Correctly for Best Results in OP

Processing a GNSS campaign for submission to NGS requires strict adherence to some file naming conventions. All naming conventions revolve around the assignment of unique four-character IDs to each user mark in your project. Ideally, this assignment is done at the onset of the project (and probably during the project planning stage of the project). That way, photos, GNSS observation logs, and GNSS observation files can be named and labeled according to these IDs. This will reduce confusion for both the user and the NGS project reviewers and will make everything consistent throughout the project. The user may want to check the four-character IDs with the IDs of surrounding CORSs: if the same IDs are used for both, the user may become confused between a user mark and a CORS. However, this will not cause any problems within OP. Note that GNSS observation files are uploaded into the project from the main OPUS home page, while the other file types need to be submitted from within OP.

5.1 RINEX Files Naming Convention for GNSS Observations

```
     2.10             OBSERVATION DATA    G (GPS)            RINEX VERSION / TYPE
teqc  2005Nov4        NGS-D               20061026 19:36:22UTCPGM / RUN BY / DATE
Solaris 5.8|UltraSparc IIi|cc SC5.5|=+-|*Sparc              COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION       COMMENT
H 179                                                       MARKER NAME
2123                                                        MARKER NUMBER
OPUS.PROJECTS        NGS                                    OBSERVER / AGENCY
4624K01584           TRIMBLE NETR5                          REC # / TYPE / VERS
30212716             TRM55971.00                            ANT # / TYPE
      0.0000            0.0000         0.0000               APPROX POSITION XYZ
      2.0000            0.0000         0.0000               ANTENNA: DELTA H/E/N
    1      1                                                WAVELENGTH FACT L1/2
    6    L1    L2    C1    P2    P1    D1                    # / TYPES OF OBSERV
   15.0000                                                  INTERVAL
          LOUISIANA Height Modernization 2006               COMMENT
              National Geodetic Survey                      COMMENT
          Approximate Lat, Lon : 30.590, -90.487            COMMENT
SNR is mapped to RINEX snr flag value [1-9]                 COMMENT
  L1: 3 -> 1; 8 -> 5; 40 -> 9                               COMMENT
  L2: 1 -> 1; 5 -> 5; 60 -> 9                               COMMENT
  2006    10     2    20    23    30.0000000      GPS       TIME OF FIRST OBS
                                                            END OF HEADER
```

Figure 5-1: RINEX File Header

- When a GNSS observable file is uploaded, OPUS attempts to convert the file into RINEX ("**R**eceiver **IN**dependent **EX**change" format, shown above), if it is not already in that format. In converting an observable file to RINEX, OPUS will rename the file using the standard naming conventions **aaaadddb.yyo**
  - **aaaa** is the unique four-character mark ID (alphanumeric) assigned to each user mark in the project. This comes from the first four characters of the file that is uploaded to OPUS. To easily associate observation files to specific user marks, make sure to start the observation file name with a four-character ID for the mark. Otherwise, the user can still assign this Mark ID within OPUS-Projects by clicking on the "Change Mark ID" utility.

- o **ddd** is the day-of-year of the start of the day (numeric), this is sometimes called the Julian Day number
- o **b** is a letter representing the starting hour of the data in UTC (a = 00, b = 01, c = 02, ..., x = 23 and special case 0 = 24 hr data set)

Start Time	RINEX Hour	Start Time	RINEX Hour	Start Time	RINEX Hour	Start Time	RINEX Hour
00:00	a	06:00	g	12:00	m	18:00	s
01:00	b	07:00	h	13:00	n	19:00	t
02:00	c	08:00	i	14:00	o	20:00	u
03:00	d	09:00	j	15:00	p	21:00	v
04:00	e	10:00	k	16:00	q	22:00	w
05:00	f	11:00	l	17:00	r	23:00	x

Figure 5-2 RINEX UTC hour naming convention

- o **yy** is the two digit year (numeric)
- o **o** identifies the file as a GNSS observation file (as opposed to the n, the navigation file)

- ● The four-character mark ID is the first four characters of the uploaded file. OP will also assign each point observed with this same four-character ID. Therefore, each GNSS observable file should already be named starting with its respective four-character mark ID.

> ⚠ Make sure to name each GNSS data file so that the name begins with a four-character ID you wish to assign to each project mark in your survey. That will ensure consistency between data files and project marks in OP

- ● Using this naming convention, a sample RINEX file would be named **g287009q.19o**
  - o **g287** would be the user mark's four-character ID
  - o **009** would refer to an observation started on January 9
  - o **q** would refer to 16:00 UTC (observation file start time)
  - o **19** would refer to the calendar year 2019
  - o **o** refers to the GNSS observation file

If OPUS cannot convert the file to RINEX successfully, an error message will be displayed. You may have to convert the file yourself using software from your receiver vendor.

5.2 Description Files and Naming Conventions

There are five different kinds of description files that need to be loaded for a project to be submitted to NGS. All files are created through the NGS software WinDesc. Please refer to Appendix A for step-by-step instructions for creating and checking description files using this software. The different file types include:

- ● .des - this is the native WinDesc file format
- ● .dsc - this is the ASCII version of the description file which is ultimately loaded into the NGS database
- ● .err - this is the error report that is generated when checking the description file. No errors can appear if the project is to be published by NGS.

- .dis - this is the "discrepancy" file which compares each mark's new descriptive information with any information on that mark already present in the NGS database. This file highlights any potential changes to be made to the description in the database
- .nbr - this is the "neighbor" file which lists all marks already in the NGS database that may be found close to each particular user mark in the project. This ensures the correct mark has been identified.

5.3 Photos

For successful submission of the project to NGS, three (3) photos in *.jpg format must be uploaded for each user mark observed (photo can be uploaded on the individual mark pages):

1. a close-up of the mark clearly showing the disk stamping and logo;
2. an eye-level photo looking down at the mark;
3. a horizon photo showing the mark in the background.

Figure 5-2: Example Photos: Close-up, Eye-level and the Horizon

For photo files to be uploaded correctly, they have to follow a strict naming convention. The photo file name is divided into four parts, each part separated by a dash ("-"):

1. The file name starts with the NGS six-character Permanent Identifier (PID) for the mark in question. If the PID is unknown (e.g. a new mark), then the file name will start with the second element, below:

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2. The second element is the mark's designation, with underscores taking the place of any spaces in the designation name.
3. The third element describes the type of photo (1, 2, or 3). Note that a #3 photo should also include the azimuth of the photo (e.g. 3NW).
4. The last element is the date the photo was taken (yyyymmdd)

The filenames for the three example photos in Figure 5.3 would be:

PE0732-F_130-1-20190806.JPG
PE0732-F_130-2-20190806.JPG
PE0732-F_130-3S-20190806.JPG

Other example filenames would be the following:

LQ0471-BANKS-1-20180111.jpg
AH8939-WEST_RIVER-2-20160907.jpg
AS0240-872_8690_TIDAL_1-3E-20110918.jpg

The three sample photos shown above show an optional caption. See the NGS Photo Submission Guidelines for more information. Additionally, the process of formatting and editing mark photos is briefly described in Appendix A using the WinDesc software utility.

5.4 GNSS Observation Logs Naming Convention

- GNSS observation logs provide important metadata for all GNSS observations taken in the field.

> ⚠️ If continuous GNSS data files are uploaded into your project as observation files, you will not have corresponding field logs, but rather Site Info files, which will need to be uploaded in lieu of field logs.

- GNSS observation logs document exactly how the GNSS occupation was set up and taken down. These logs include information on equipment, antenna heights, start and stop times, and many other pieces of information critical to proper quality assurance and quality control of a GNSS project. For this reason, they are required for submission of a project to NGS. More information on GNSS observation Logs can be found here: https://www.ngs.noaa.gov/surveys/forms/. GNSS observation logs have to be in *.pdf or *txt or *.doc
- GNSS observation log file name should generally match its corresponding RINEX file. As an example, say the RINEX file named **g287009q.03o** is stored in OP. Then:
- **g287-009-q-2003.pdf** should be used for corresponding GNSS observation log PDF file
    - **g287** = four-character Mark ID for the observed user mark. In this way, both the GNSS observation files and the GNSS observation logs will start with the same respective Mark ID.
    - **009** = calendar day of the year of the occupation in GNSS Time.
    - **q** = starting hour of the occupation in GNSS Time where a = 00:00 and x = 23:00 (this is meant to deal with multiple occupations on the same user mark per day; letters identical to how OPUS automatically assigns hours for uploaded RINEX file names).
    - **2003** = year (note that log files specify the year as yyyy).

5.5 Naming Problem Examples

- OPUS takes the first four characters of the uploaded data file (proprietary data file or RINEX file) as the four-character mark ID
- GNSS receiver manufacturers often use different naming schemes
- Trimble files (for two different stations) *1A_NBS9_27342580.t01* and *1A_NGP9_47252580.t01* were converted to RINEX files *1A_NBS9_27342580.15o* and *1A_NGP9_47252580.15o*
- For *1A_NBS9_27342580.15o* we have the following naming convention:
  - *1* = day 1
  - *A* = session A
  - *NBS9* = station
  - *2734* = last four digits of GNSS receiver serial number
  - *258* = calendar day of year
  - *0* = daily data file number (0, 1, 2, 3… consecutively for each GPS day)
- Attempt to upload two files whose names start with the same four-characters and whose data's starting hour is n (13) results in the following outcomes:
  - *1A_NBS9_27342580.15o* is converted to the RINEX standard name **1a_n258n.15o**
  - *1A_NGP9_47252580.15o* is converted to the RINEX standard name **1a_n258n.15o**
- Two different Trimble files were converted to the same RINEX standard name!
- If these two files are uploaded to OP, the first file would create a point marked "1a_n," but the second file might end up with another user mark called "a001."
- If OPUS cannot convert the file to RINEX successfully, an error message will be displayed. You may have to convert the file yourself using software from your receiver vendor.

6 Loading GNSS Observation Files

Now that your project is created, parameters set, and files correctly named, you can begin uploading the observation files to the project through the main OPUS home page. Note that OPUS currently accepts only static observations (e.g. ≥ 2 hrs RINEX file).

> Section 5.1 covers helpful tips for naming RINEX files so project marks and OP data files are consistent

> When uploading data ensure you are using the correct OP4.0 Project ID and Keywords. Having ready access to the field logs ensures the correct antenna type and height are entered correctly. We can not stress enough about naming your GNSS observations files correctly with meaningful 4-char IDs. Also please ensure that your profile is disabled or updated with your current project.

Figure 5-3: OPUS processing customization options

6.1 How To Load GNSS Observations into OPUS

OPUS should be capable of ingesting the most common vendor-specific GNSS file formats. If the file format is not recognized, OPUS will show a file upload error. In that case, refer to your vendor for tools to convert your proprietary file format to the Receiver Independent EXchange format (RINEX).

The information required for successful uploading to your project includes:

- GNSS observation file name (either RINEX file or other file format supported by OPUS: see https://geodesy.noaa.gov/OPUS/about.jsp#rinex_file for more information on data files supported)
- Antenna type and model (to apply the correct antenna phase center offset; see NGS Antenna Calibration for more information)
- Antenna height (meters) -this is the vertical distance from the vertical point of reference of the user mark to the GNSS Antenna Reference Point (ARP).

> ⚠️ OP will retain antenna heights to the fourth decimal place (0.0001 m) in its computations, but will only display antenna heights rounded to the nearest millimeter in output files and tables (0.001 m)

- Email address

To add the observation to your project, the user must click on the "Options" button and submit the project identifier that was assigned to the project upon its creation:

Figure 6–1: Project Identifier Option

> ⚠️ If the user's profile is used, be careful that the correct antenna model and antenna height are selected. Using the profile can be a powerful tool, but it can also lead to unintended consequences if the user is not careful.

> Delete My Profile before each new project is populated with observation data to make sure unintended errors are not introduced when data are uploaded into a new project

ZIPPING FILES: If all of your antennas are the same type and model (i.e. they all have the exact same antenna center offset per the antenna calibration) and were all set at the same height, you can bulk upload the observation files after first zipping them into one *.zip file, and pointing to the zipped file at the time of upload.

6.2 Results of a Successful Load

Once you have successfully uploaded, a confirmation screen will appear:

Figure 6-2: Options Customization Confirmation Report, "Skip Description" National Spatial Reference Network Inclusion or Not

Review all the data on the screen. For example, note the name of the data file uploaded, as well as the RINEX file it was converted to. This will help you track output options in OP. Double check the antenna type, antenna height, and project ID.

If the upload is successful, the screen will prompt you to provide descriptive information about the mark observed. If you are going to submit your project to NGS, there is no need to fill out this descriptive information here. Click on the button "**skip description**," to be taken back to the main OPUS upload page (or hit the <Back> button on your browser). If you are *not* going to submit your project to NGS, feel free to provide identification information here. You will also be prompted with the option to share your observation via the OPUS Share database.

⚠ If you plan on submitting your project to NGS for publication, there is no need to fill in the descriptive mark information within the OPUS upload pages. Mark descriptions will need to be created outside of OP, using WinDesc.

Note that OPUS cannot handle observation files that cross the UTC 2400-0000 hour boundary more than once. If your files cross the boundary more than once, you will have to edit the observation files, breaking it into smaller, shorter files. Data files of 24 hours are recommended. Your vendor software may offer that capability, as well as teqc and WinTEQC.

Successfully uploading a GNSS observation file to OPUS will result in a Solution Report being sent to both the user's email address and the Project itself.

Successful Upload with a "Project Verification" Email: OPUS may upload successfully, but the project preferences may not have been met. In such a case, the file **will** be uploaded to the project, and the user will receive an email advising of which parameters were not met.

```
The RINEX file listed below will be uploaded to
Sample OPUS Project        (g546sp83)
but it will be flagged because its OPUS solution
did not meet all the quality control preferences
for this project. A summary is given below.

RINEX FILE: OK    0187096n.18o
ANTENNA:   OK    CHCX90D-OPUS   NONE
ARP HGT:   OK    2.000m

RMS:       OK    0.020m
EPHEMERIS: OK    igr19955.eph (rapid)
OBS USED:  WARNING 55% > 80.0% preferred
FIXED AMB: OK    83%
LAT RANGE: OK    0.010m
LON RANGE: OK    0.007m
HGT RANGE: OK    0.014m
```

Figure 6-3: Data upload verification email indicating a project preference was not met

6.3 Results of an Unsuccessful Load

If OPUS aborts processing the data file for any reason and does not generate a solution report, the data file will not be uploaded to the project.

Figure 6-4: Rejection of an upload to OPUS providing an explanation of probably cause

There are a number of reasons an observation file may be rejected. The most common are listed below:

1. File is in an unrecognized file format that OPUS is unable to convert internally to RINEX (user needs to convert to RINEX first)
2. No baseline solutions to the CORS could be generated (typically a problem if not enough/good GNSS data was made available in the uploaded observation file)
3. Zeros as the estimated (**a priori**) coordinates (RINEX header)
4. Multiple coordinates in the RINEX header, indicative that the antenna was moved to another location)
5. Maximum duration exceeded (more than one 24h - 0h UTC time crossing)

6.4 Checking Your OPUS Solution Results

Note that an observation file may be successfully processed in OPUS and loaded into the project despite not meeting the data **Quality Thresholds** defined in the Project Preferences (Section 4.3, above). If any of the Quality Thresholds are not met, OP will send a warning email message to the project member who is uploading the file. The warning message simply helps highlight potential issues. The icons used in OP to identify and display the user marks and their corresponding OPUS solutions will indicate whether the solutions met the Quality Thresholds (see Section 7). Prompt review of OPUS solutions will help ensure maximum efficiency in the field, so return trips to project sites won't have to be made if any solution was sub-optimal.

> ⚠️ Anyone uploading GNSS observation files to the project should carefully review each project mark's OPUS solution as soon as possible to verify the quality of the observation

OPUS Solution results can be found in an email sent to the project manager, as well as to the email address used to upload the GNSS observation file. They can also be found within the project, by clicking on the "Show File" button on the Manager's Page:

Figure 6-5: Show File button to access all solution reports

Select the appropriate user mark and session to view the available OPUS Solution:

Figure 6-6: OPUS Solution results

Things to check in an OPUS solution:

- The start and stop times are correct and in accordance with the survey plan.
- Solution results consistent with the project preferences

- If this observation is on a user mark already present in the NGS database, compare the OPUS result to the corresponding datasheet's coordinates. Do they match within the combined uncertainties of GNSS and the published coordinates? If they match, that validates the observation. If they don't match, is there anything else about the observation that may point to a blunder? Was an antenna extension used? Was the correct mark observed? Note that a discrepancy does not necessarily mean a bad observation, but a good check is always a good validation of one's procedures.
- Typically, the coordinates for the first OPUS solution for a user mark will be used as the **a priori coordinates** for the processing (refer to the Glossary for more information on a priori coordinates). In the rare occurrence that the project manager wishes to change the a priori coordinate for a user mark, it should be done now before any sessions are processed that contain the mark. This may be accomplished by navigating to the mark's web page and editing the a priori coordinate values (Section 7.3.12).

Quick checks can also be made by clicking the user mark icons on the Manager's Page map. This will cause an information "bubble" to appear displaying the list of data files associated with the user mark and related information such as antenna type and ARP height entered with the upload (see section 7 and figure below).

Figure 6-7: Manager's Page, showing information on data files associated with a user mark

A more thorough check can be made from the user mark web pages. To access these pages from the Manager's Page, make sure the "Occupation" from "ALL OPUS Results" table is shown (see red arrow in image below).

Figure 6-8: Manager's Page showing "Occupation" information from the "ALL OPUS Results" Report Table

Click on one of the MARKS to open web page for that mark:

Figure 6-9: Click on a user marks for access to the corresponding Mark page

Sample Project

National Geodetic Survey

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education | Search

Controls
? ← ↻
Manager's Page
Show File
Send Email
Change Mark ID
Remove Mark

MARK [fran ▼]

[Map] [Satellite]
+ This Mark | All Marks | Marks&CORS | −

Project Marks, | Project CORS | Published Marks,

Google   Map data ©2021   2 m   Terms of Use   Report a map error

MARK [fran ▼] Description Summary

Upload A Photo | Save Description

Description

PID	JV7214 — This is a Height Modernization Survey Station.
stamping*	FRANKS 1999
designation*	FRANKS
type*	D = Disk / DD = Survey disk (other agency)
setting*	7 = Set in top of concrete monument
	specific setting — no value —
description*	RECOVERED AS DESCRIBED.
23 chars (500 chars max)	
stability	C = May hold, commonly subject to ground movement
magnetic	— no selection —
application	— no selection —
condition	Recovered in good condition
* required fields	

Close-up of mark
Mark from eye-level
Horizon View

MARK [fran ▼] Occupations

Manage Data Files | Save Occupations

DATA FILE	SPAN		HARDWARE					
fran241m.17o	Start	2017-08-29T12:24:30 GPS	Antenna	Model:	TRM41249.00 NONE ▼	S/N:	60120878	Height (m):	2.000
	End	2017-08-30T12:13.30 GPS	Receiver	Model:	TRIMBLE R7	S/N:	0220375172	Firmware:	2.32
fran242n.17o	Start	2017-08-30T13:28:30 GPS	Antenna	Model:	TRM41249.00 NONE ▼	S/N:	60120878	Height (m):	2.000
	End	2017-08-31T15:35.30 GPS	Receiver	Model:	TRIMBLE R7	S/N:	0220375172	Firmware:	2.32
fran243q.17o	Start	2017-08-31T16:00:00 GPS	Antenna	Model:	TRM41249.00 NONE ▼	S/N:	60120878	Height (m):	2.000
	End	2017-09-01T10:24:30 GPS	Receiver	Model:	TRIMBLE R7	S/N:	0220375172	Firmware:	2.32

MARK [fran ▼] Processing Results From [A PRIORI (JV7214 published with HTDP(3.2.7) NAD_83(2011) velocities.) ▼]

Manage Coordinates

Scale uncertainties by [1.0x (68.3%) ▼].

Coordinate Source: A PRIORI (JV7214 published with HTDP(3.2.7) NAD_83(2011) velocities.)

	ITRF2014 (2010.0000)	NAD_83(2011) (2010.0000)			
REF FRAME:	ITRF2014 (2010.0000)	NAD_83(2011) (2010.0000)	COORDINATE SYSTEM:	SPC 1900 MD	UTM 18
LAT:	N39:29:55.92648 ±0.002 m	N39:29:55.89605 ±0.002 m	NORTHING:	203438.814 sft	4374723.884 m
EAST LON:	E282:40:21.66495 ±0.002 m	E282:40:21.68275 ±0.002 m	EASTING:	371646.266 sft	299686.280 m
WEST LON:	W077:19:38.33505 ±0.002 m	W077:19:38.31730 ±0.002 m	CONVERGENCE:	-0.20544444°	-1.48080556°
EL HGT:	73.996 ±0.003 m	75.264 ±0.003 m	POINT SCALE:	1.00000891	1.00009307
X:	1081185.293 ±0.002 m	1081186.052 ±0.002 m	COMBINED FACTOR:	0.99999710	1.00008126
Y:	-4808264.736 ±0.002 m	-4808266.18 ±0.002 m	U.S. NATIONAL GRID:	18STJ9988874723	
Z:	4035253.647 ±0.002 m	4035253.729 ±0.002 m			

ORTHO HGT: 108.02 ±0.0104 m (H = h − N WHERE N = GEOID12B HGT)

DATA FILE	ANTENNA		HEIGHT (m)	EPH TYPE	OBS (%)	FIXED (%)	RMS (m)	LAT (m)	LON (m)	HGT (m)	Uploaded (UTC)	OBSERVER
fran241m.17o	TRM41249.00	NONE	2.000	precise	94.9	93.4	0.014	0.002	0.004	0.017	2017-10-18T15:12	jay.howard
fran242n.17o	TRM41249.00	NONE	2.000	precise	95.8	95.6	0.014	0.006	0.006	0.003	2017-10-18T15:14	jay.howard
fran243q.17o	TRM41249.00	NONE	2.000	precise	95.5	90.8	0.017	0.002	0.004	0.018	2017-10-18T15:15	jay.howard
Preferences				Best Available	≥80.0	≥80.0	≤0.025	≤0.020	≤0.020	≤0.040	Preferences	

MARK [fran ▼] Processing Results Plots

Scale uncertainties by [1.0x (68.3%) ▼]. Show [ ] preferences [☐] network [◇] session [○] OPUS [△] published.

The "zero" point coordinates, N39:29:55.927312139741844, W077:19:38.33953, 73.984 m el. height, are the mean of all opus solutions.

MARK [fran ▼] Processing Results Table

Scale uncertainties by [1.0x (68.3%) ▼]. Show [ ] preferences [☐] network [◇] session [○] OPUS [△] published.

The "zero" point coordinates, N39:29:55.927312139741844, W077:19:38.33953, 73.984 m el. height, are the mean of all opus solutions.

△ PUBLISHED	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
JV7214	0.4 ±0.0	-0.6 ±0.0	1.1 ±0.0	ITRF2014	2017-08-31T01:20:24
○ OPUS SOLUTIONS	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
fran241m.17o	-0.2 ±0.2	-0.1 ±0.4	0.5 ±1.7	ITRF2014	2017-08-30T00:13:40
fran242n.17o	0.0 ±0.6	0.3 ±0.6	-0.9 ±0.3	ITRF2014	2017-08-31T02:30:28
fran243q.17o	0.2 ±0.2	-0.2 ±0.4	0.4 ±1.8	ITRF2014	2017-09-01T01:17:02

BETA OPUS-Projects 2.10 / Website Owner: National Geodetic Survey / Last Modified: OPUS team

NGS Home • NGS Employees • Privacy Policy • Disclaimer • USA.gov • Ready.gov • Site Map • Contact Webmaster

Figure 6-10: User Mark web page

On the individual mark pages, the data files are also listed along with related information, and some information can be changed (e.g. a MarkID, antenna type, antenna height). Additionally, data files can be reassigned to another user mark if OP made the original assignment incorrectly. See Section 7.3 for more information.

> ⚠️ Ultimately, OP arranges observation files according to coordinates, not names. If a file was incorrectly names, you can correct the mark name from the project mark's web page

> ⚠️ Note that some changes on a mark page may be superseded once the corresponding mark's description file has been loaded into the project

Rarely, other information associated with a user mark, such as the state plane coordinate zone, may need to be changed. This can be done through the 'Manage Coordinates' control on the user mark page (Section 7.3).

This is also a good time for the project manager to verify that the appropriate user mark IDs are correctly assigned. If the GNSS data files followed the recommended file naming convention (Section 5.1, above), the user's mark IDs should be correctly assigned (recall that the four-character user mark ID are normally taken from the first four characters of the vendor proprietary file type or RINEX file uploaded through OPUS to your project). If inconsistencies are found, mark ID's such as a001, a002, etc. will appear. These are "placeholder" names automatically generated by OP. It is recommended to change these names to keep project nomenclature as consistent as possible with GNSS observation logs, datasheets and other files associated with the project. A mark's ID can be changed on its individual mark page See Section 7.3.4.

> Once you have opened a MARK page, you can easily navigate among other user marks by using the pull-down menu at the top of each data display field.

Finally, although session processing can begin before all data for the session are uploaded, this is not recommended. Processing before all data are available may be prudent if errors or inconsistencies are found and cannot be otherwise rectified, but should be avoided otherwise.

Please always bear in mind that if a session is processed before all of its data are uploaded, it is almost certain that the session will need to be reprocessed after all data has been uploaded. The user has the option to delete individual sessions or overwrite the session by reprocessing using the same session name or reprocessing the session but changing the session name thus keeping both sessions.

7 Walking Through OP Visualizations

This section introduces the user to some of the major OP visualizations, accessible from the Manager's Page and Mark Page(s). Many of the web page characteristics are shared among the different pages, so they are only presented once to avoid repetition.

7.1 The Project Manager's Web Page

Figure 7-1: The Project Manager's web page

Elements numbered in the figure above are explained in the corresponding subsections below:

7.1.1 Notices

Notices about OP and, very rarely, a message specific to a project (no other project will see these specific messages) may appear at the top of the Manager's, Session and Marks web pages. An email link to the OPUS Projects Team will appear with any notices and messages so that follow-up questions can be asked if needed.
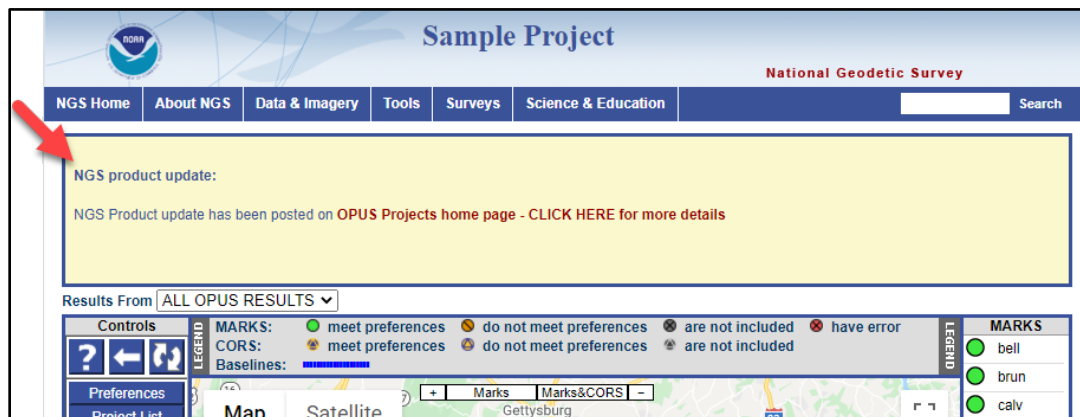
Figure 7-2: The Notices banner on the OPUS Projects Manager's Page

7.1.2 Results Selection Menu

Below the web page's banner (and any notices) is a pull down menu to select from a list of the solution results available. Broadly, there are three categories: network adjustment, session solutions, and OPUS solutions. As work in a project progresses, displaying all types of results simultaneously becomes confusing. This menu provides a simple "filter" to help emphasize the results of most interest.
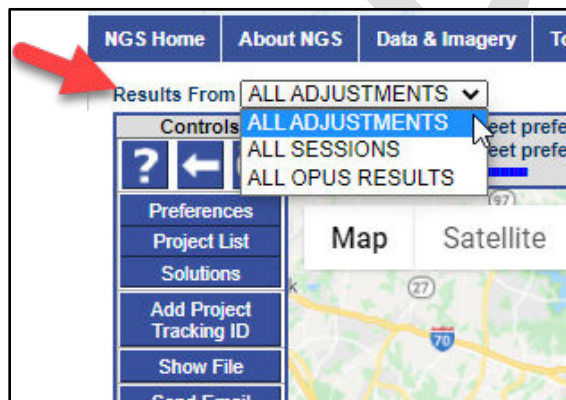
Figure 7-3: Drop-down menu location for displaying results on the Manger's Page

7.1.3 Project Map

The Manager's, Session and Marks web pages are built around a Google Map Services™ interactive map to help orient users within the project and its geographic region. As project members upload observation data to the project through OPUS, icons representing the user marks will appear on the map. CORSs used by OPUS during its processing of the project data will be added to the project at upload or can be added to the project later. Different icons are used to reflect a user mark's status in the project.

> All marks observed are displayed on the map, as well as all CORSs used in the individual OPUS solutions. This does not mean that all marks were observed in all sessions, nor that all CORSs were available or are automatically selected in all sessions.

Within the map display to the upper-left, there are typical zoom controls (+/-) and controls to zoom specifically to the project's 'Marks' or 'Marks & CORS.'
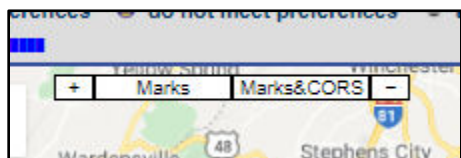
Figure 7-4: Map zooming toggles

At the upper-left corner of the map you may set the map background as either Terrain (digital elevation model), Satellite (satellite imagery if available), or Map (towns, streets & highways). You also have the option to click and drag (pan) the map to view nearby areas.
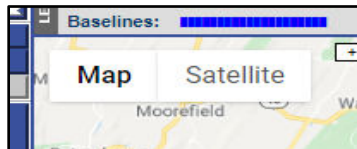
Figure 7-5: Map background options

Holding the cursor over a user mark icon will cause the icon to lighten in color and the mark's ID to appear.
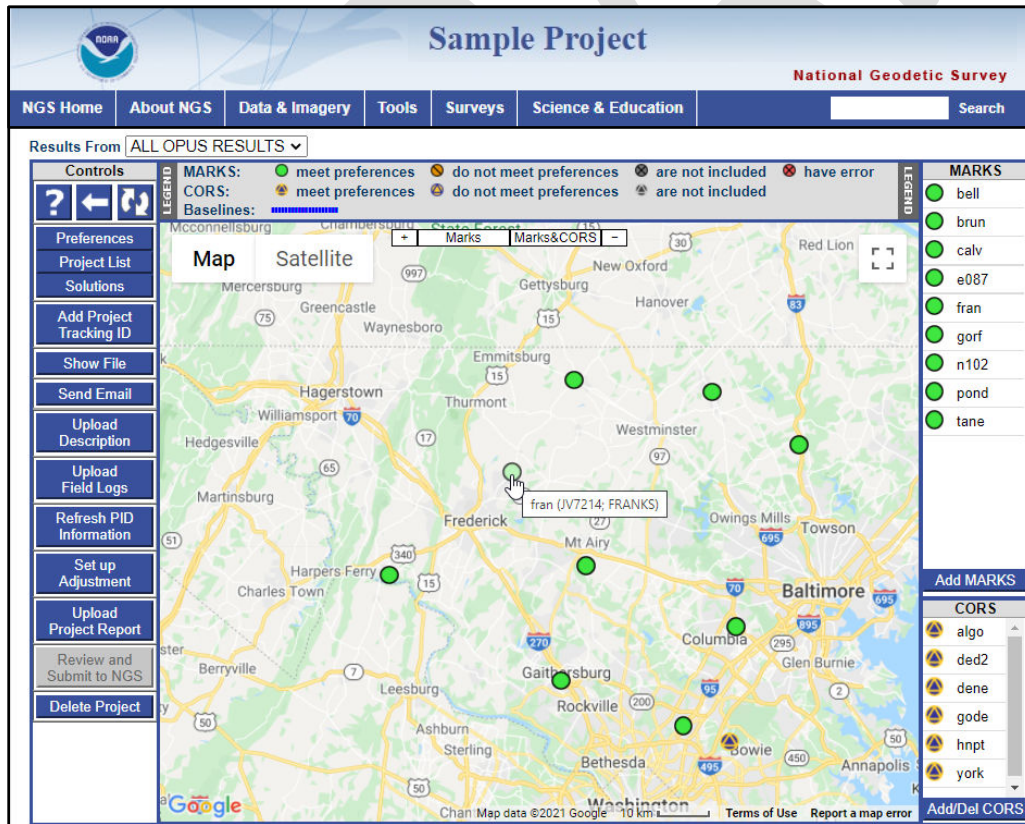
Figure 7-6: Mark ID shown by hovering over mark

Clicking a mark icon on the map (or under the **MARKS** list) will cause information about the data files associated with that user mark to appear in an information 'bubble.'

Figure 7-7: Mark data information shown when clicking on a user mark icon

The mark ID is given at the top of the information bubble. If the mark is a user mark (not a CORS), the ID acts as a convenience link to navigate to the summary web page of that mark. A table listing all of the uploaded data files for a particular user mark is also shown in the bubble. More than one file for a mark means data observed at the mark is in multiple sessions. Note that the antenna type and ARP height associated with each file are also shown for the record. The project team member who uploaded the files is assigned as the 'OBSERVER.' Their name is a convenience link to send them an email message.

Similarly, hovering the cursor over a CORS icon will create a bubble containing the four-character CORS ID, its Permanent Identifier (PID), and designation.

Clicking on the CORS icon on the map (or under the **CORS** list) will cause information about the CORS data to appear in an information 'bubble.' Data availability for each of the sessions identified in the project will be displayed under "**STATUS**." Additional information such as antenna type, antenna height, data file, etc. are also given in the table.
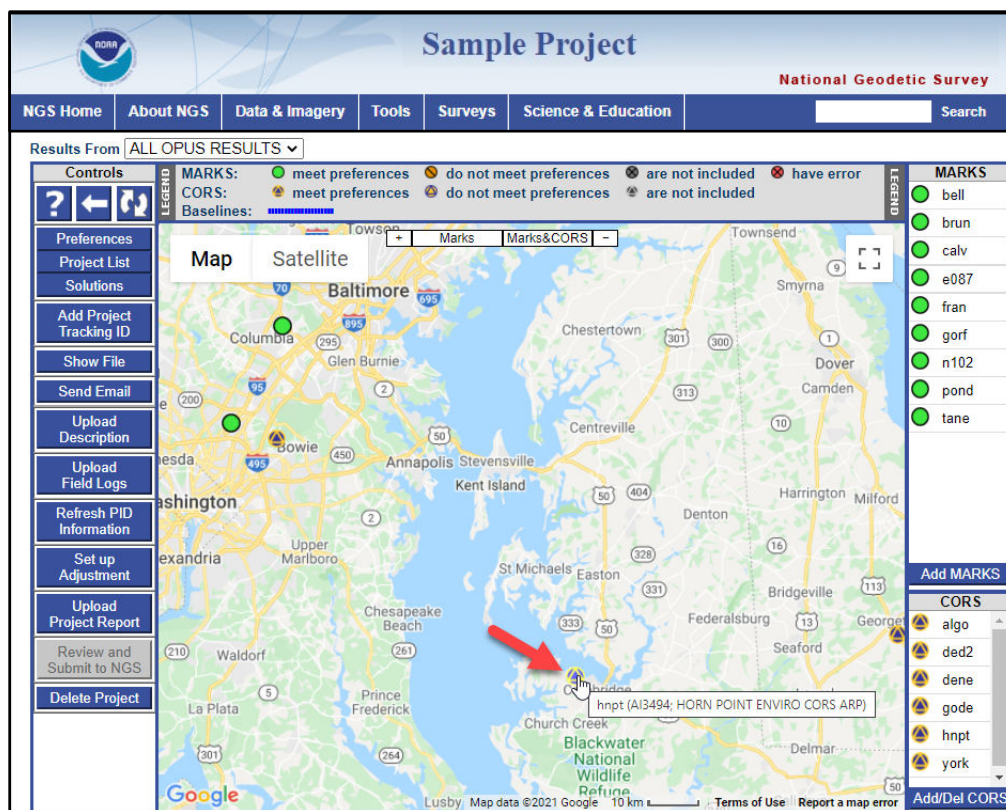
Figure 7-8: CORS ID shown when hovering over a CORS
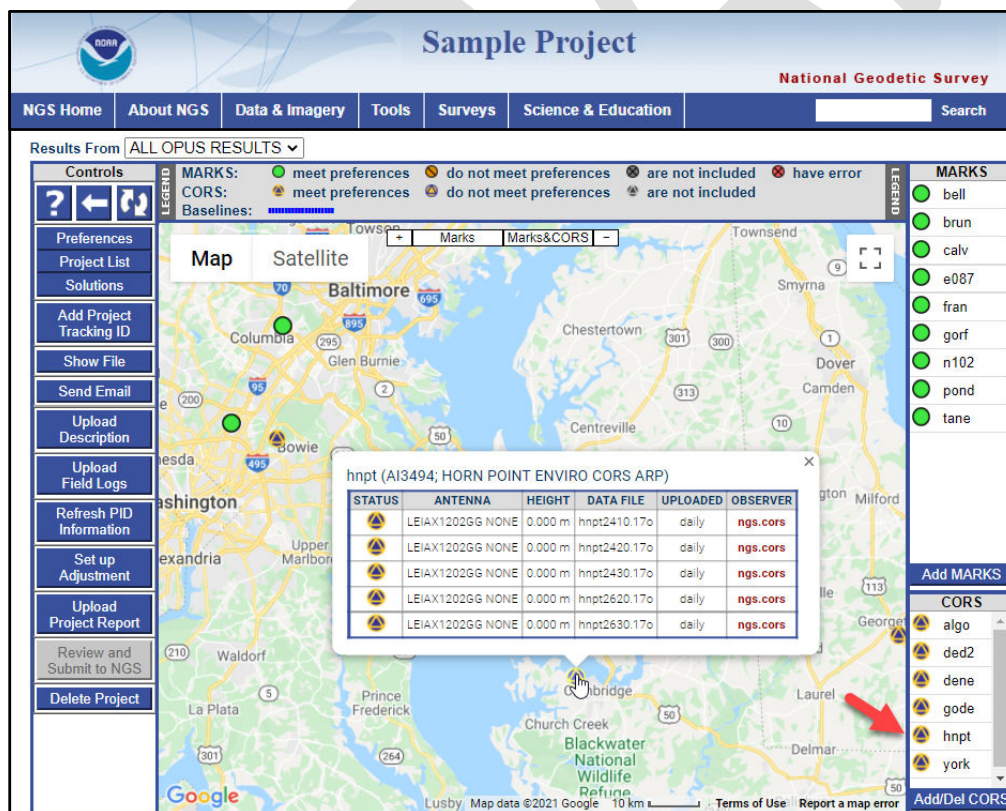
Figure 7-9: CORS data information shown when clicking on the CORS icon

7.1.4 Controls Bar

Controls for common manager tasks appear on the left side of the map.
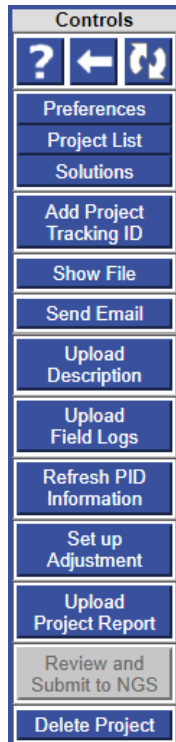
Controls differ somewhat among the different web pages available in OP4.0. They also differ between the Manager's Page and the session processing page, and may differ according to the steps you have already accomplished.

Figure 7-10: The Controls bar

7.1.4.1 Help, Back and Refresh

Figure 7-11: Top page control options

Help (**), Back (** **), and Refresh (** **)** buttons appear at the top of the controls. The **Help** button is under development and may ultimately provide the same resource as this document. The **Back** "moves back" to the previous web page in the browser's history. Its action is identical to the browser's back control. The **Refresh** button forces the project to be scanned and the current page reloaded. Use this OP refresh button rather than the one for the browser.

7.1.4.2 Preferences
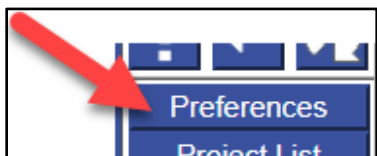
Figure 7-12: Preferences button on the Controls bar

The **Preferences** button enables access to preferences, described in Section 4.

7.1.4.3   Project List

Figure 7-13: Project List button on the Controls bar

The **Project List** button sends an email to the project manager listing all projects created under the manager's email address. The provided information includes project IDs, keywords, and titles. This can come in very handy for recovering lost or forgotten project information.

7.1.4.4   Solutions
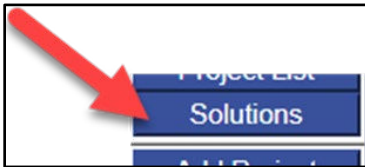
Figure 7- 14: Solutions button on the Controls bar

The **Solutions** button opens a new window enabling the manager to rename Session Solutions and Network Adjustments, as well as delete the solutions and adjustments (allowing them to be re-computed). More on Session Solutions in Section 10, and Network Adjustments in Section 11.

Figure 7- 15: Manage Solutions pop-up window

7.1.4.5 Add Project Tracking ID
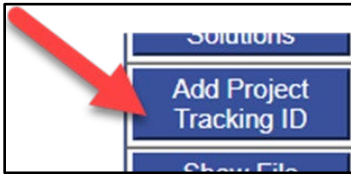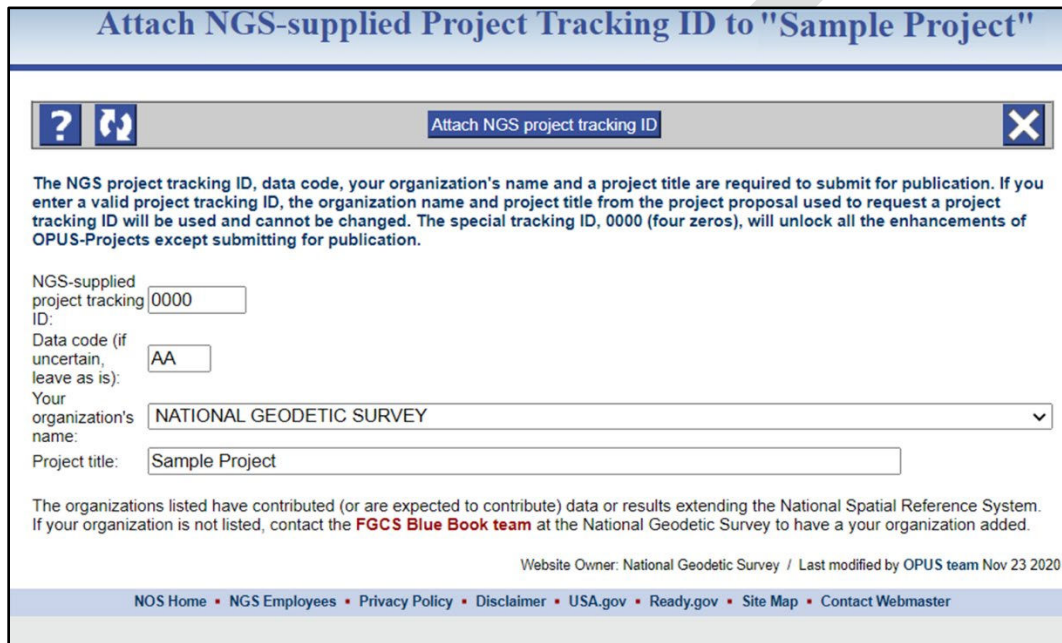
Figure 7-16: Add Tracking ID button on the Controls bar

Clicking on the **Add Project Tracking ID** button will open a separate window in which the user can input the NGS-provided Project Tracking ID (an outcome of submitting a survey project proposal to NGS). Recall that a Project Tracking ID unlocks the advanced features of OP.

Figure 7-17: Attach NGS Project Tracking ID pop-up window

7.1.4.6 Show File

Figure 7- 18: Show File button on the Controls bar

The **Show File** button reveals a pop-up window for displaying all available solution reports.
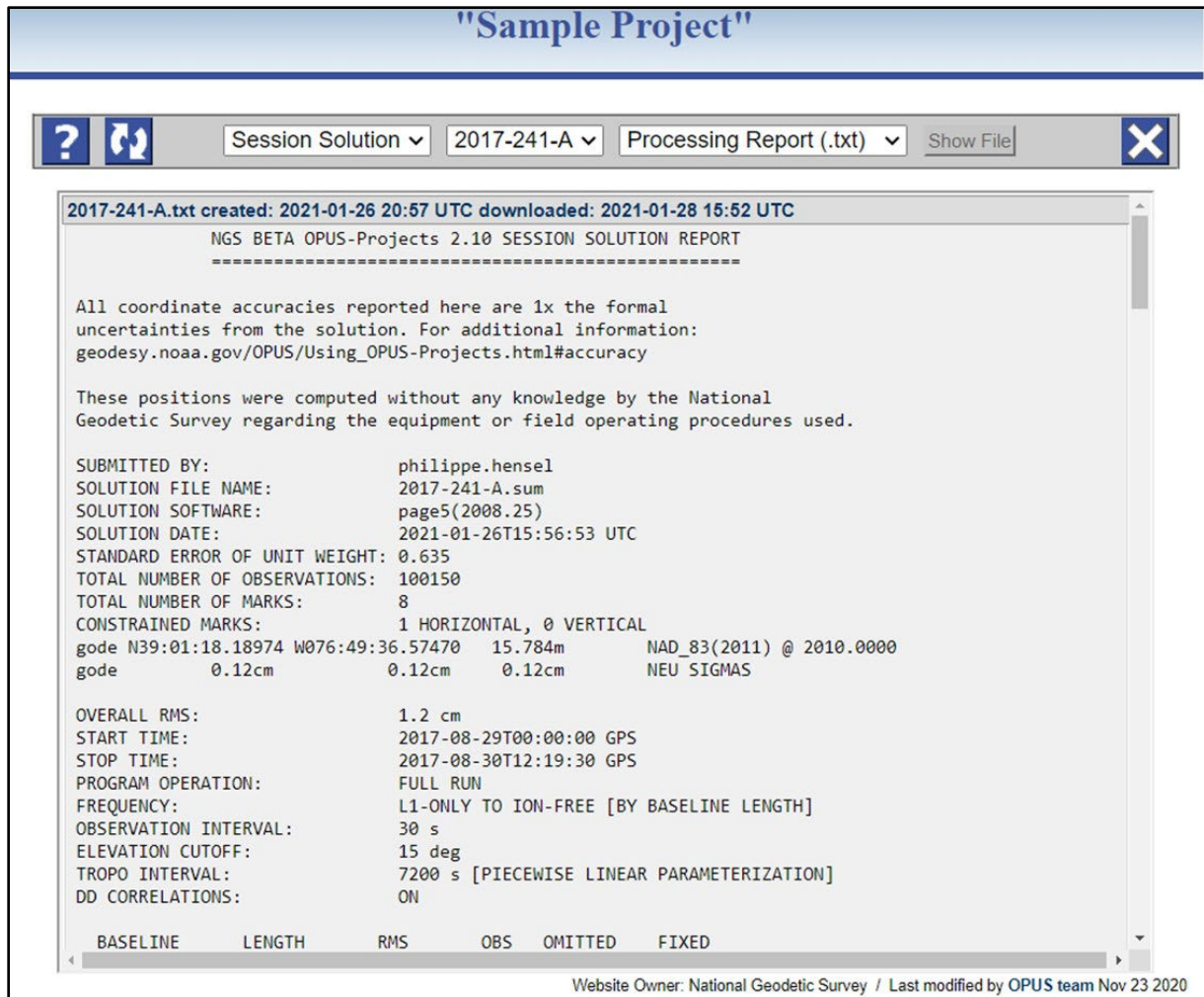
Figure 7- 19: Pop-up window showing a sample solution from a processed session

Standard pop-up window controls appear at the top, and the window offers a choice of available reports:

● Individual OPUS solutions
● Session processing results
● Network adjustment results

Below the controls is a header providing the report's name, its creation and download (current) times. Then the report is displayed. Some browsers offer a print option by right-clicking (right mouse button) anywhere in the report. All browsers should allow the report's text to be copied and pasted into another file using the method typical of the operating system.
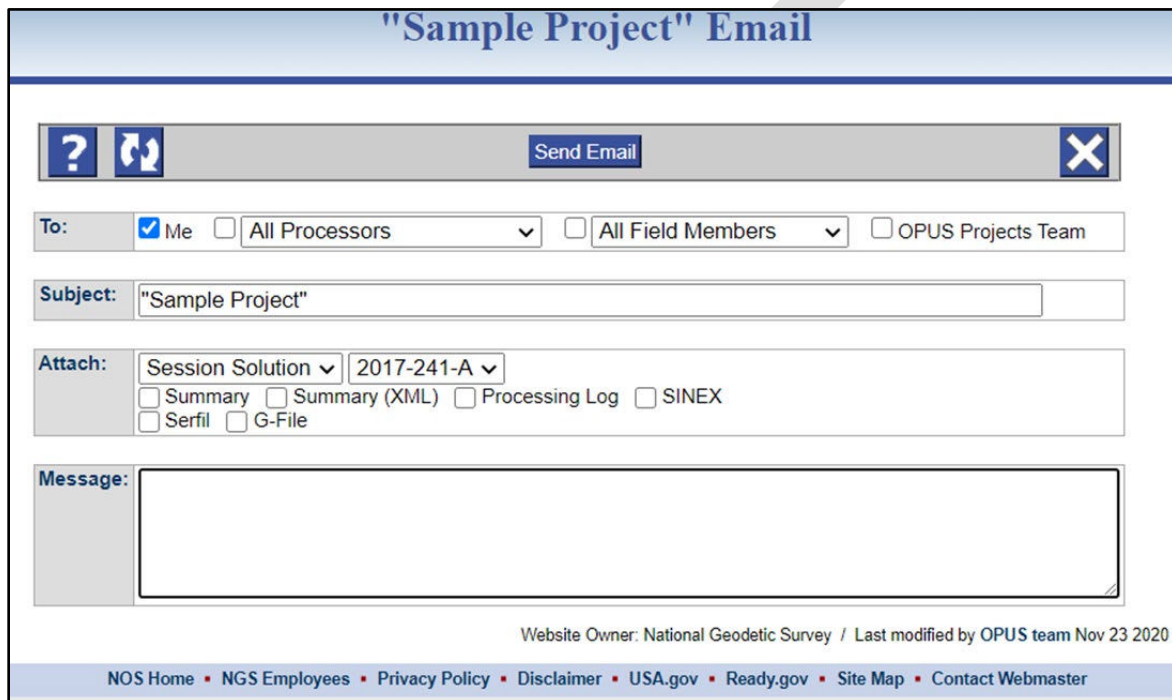
⚠️ The output file names available via the "Show Files" menu can be somewhat different from the output file names received by the project manager via email. A table cross-walking the file names is provided in Section 11.

7.1.4.7 Send Email

Figure 7-20: Send Email button on the Controls bar

Send Email displays a pop-up window with basic controls permitting the project member viewing this page to send emails to members of the project team, including herself or himself, or the OPUS Projects team.

Figure 7-21: Send Email Message pop-up window

Pop-up window controls appear across the top. Below these controls, the email's recipients can be selected from the project team (either Processors or All Field Members). "Field Members" are the email addresses associated with individual OPUS uploads to the project so there will always be email addresses under the "All Field Members" selection. A subject line can be added in the next text box. The emails can include available OP reports as attachments. These can be selected by using the controls next to the "Attach" box. Finally, there is an entry field for a short text message.

7.1.4.8 Upload Description
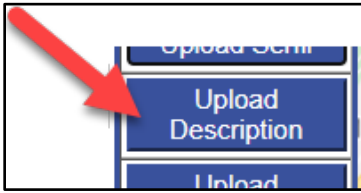
Figure 7-22: Upload Description button on the Controls bar

Clicking on the **Upload Description** button opens a pop-up window providing information on the types of description files needed (5 in all). The user is able to navigate to the corresponding files and upload them to the project from this window. Appendix A provides a tutorial for building description files.

Figure 7-23: Choose WinDesc Description Files for loading into project (pop-up window)

Note that description files are only required for user marks observed in the project. Formal descriptions for CORSs are not needed unless the user intends to supersede published values for a particular CORS. In that case, a new description file for that CORS will need to be created and uploaded.

7.1.4.9   Upload GNSS Observation Field Logs
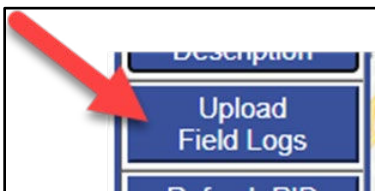
Figure 7-24: Upload Field Logs button on the Controls bar

Click on the **Upload Field Logs** button to select and upload your PDF, Microsoft Word, or ASCII text files (optionally as a single zip file). Field logs do not modify anything within the actual project, but they are required for all occupations if submitting to NGS.

Figure 7-25: Choose Field Log to upload pop-up window

Please refer to the following links for a sample GNSS observation field log and visibility diagram:

GNSS observation field log: https://www.ngs.noaa.gov/RSD/forms/obslog.pdf
GNSS visibility diagram: https://www.ngs.noaa.gov/surveys/forms/visibility.pdf
Additional field forms and information: https://www.ngs.noaa.gov/surveys/forms/

> ⚠ Although there is no mechanism for you to see that your log files have been loaded, you will only get a response if there is a problem with the load.

7.1.4.10 Refresh PID Information
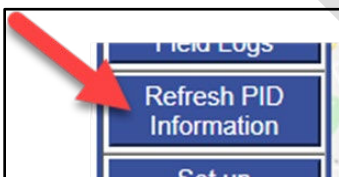
Figure 7-26: Refresh PID Information button on the Controls bar

Permanent Identifiers, or PIDs uniquely identify marks in the NGS database. Clicking the **Refresh PID Information** button will retrieve the latest information from NGS on user marks with PIDs whose descriptions have already been entered into OP. If the button is pressed but there are no PIDs associated

with any user marks, an error message will be displayed. If there is any differing information between the NGS database and OP (e.g. updated coordinates), the new information will replace what is in OP. This is recommended prior to session processing, to make sure you have the latest (correct) information for the PIDs in your project.

ngs.noaa.gov says

Will retrieve the latest datasheets for marks with PIDs and update the published information for those marks only as needed. Please be aware that if the published coordinates for a mark have been superseded, in other words have changed, any processing results including that mark will be deleted.

Click "OK" to continue or "Cancel" to stop this process now.

OK   Cancel

Figure 7-27: Confirmation or Cancel PID Refresh

 Refresh PID Information will only overwrite any original information loaded directly from the datasheets. It will not overwrite information supplied either by the user or OPUS.

 If PID information has changed in the NGS database after the user has conducted session processing and/or adjustments, and the user then refreshed PID information, prior session processing and/or adjustments will disappear.

7.1.4.11 Set up Adjustment

Figure 7-28: Setup Adjustment button on the Controls bar

From the Manager's Page, the **Set up Adjustment** button will be active if at least one session in the project has already been processed (more on session processing in Section 10). Clicking on the **Set up Adjustment** button opens an adjustment processing window. If an NGS Project Tracking ID has been associated with the project, five consecutive adjustment steps are identified (without the Tracking ID, this part of the window is blank):

1) Preliminary
2) Horizontal free
3) Horizontal constrained
4) Vertical free
5) Vertical constrained

The procedures for running these adjustments are covered in Sections 11 and 12. Note that the adjustments are meant to be sequential, so not all adjustments are available at any given time.

Figure 7-29: Setup Adjustment Type, Include Available Solutions pop-up window

7.1.4.12 Upload Project Report
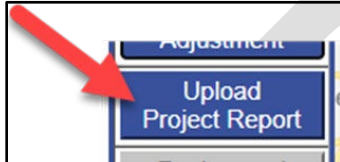
Figure 7-30: Upload Project Report button on the Controls bar

The **Upload Project Report** button allows the user to load a completed Project Report into the project. The report will not modify anything in the project, but it is a required input for submission to NGS.

7.1.4.13 Review and Submit to IDB
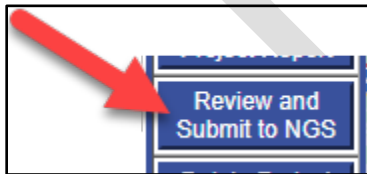
Figure 7-31: Review and Submit to NGS button on the Controls bar

The **Review and Submit to IDB** button runs a set of programs to ensure that all required files are present and that there are no structural errors with the data files to be submitted to NGS. Specifically, the user will be provided a checklist showing the status of all required adjustment steps and uploaded files, and which of these may be missing. The programs CHKOBS and OBSCHK are run, and the output provided (see Section 11 and the Glossary for more information).

7.1.4.14 Delete Project

Figure 7-32: Delete Project button on the Controls bar

Clicking the **Delete Project** button will initiate a three-step process that, if completed, will delete the project from your own manager list of projects. First a confirmation message appears:
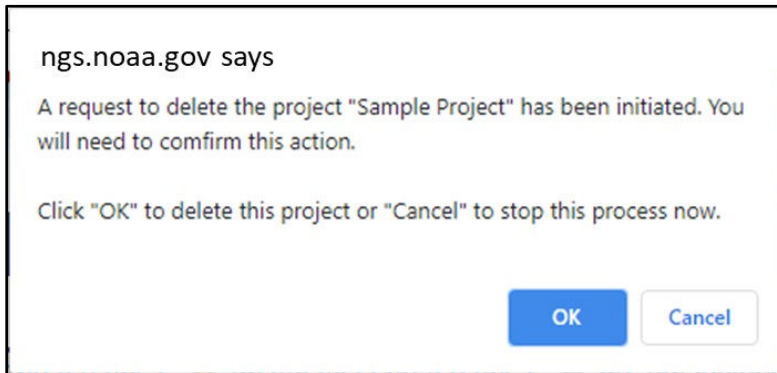
Figure 7-33: Delete Project confirmation pop-up window

Cancel will immediately end this process without the project having been deleted.

OK will send an email to the project manager. If the email is ignored, the process is canceled without the project having been deleted. A reply to the email implies consent and the project is deleted. A confirmation email is sent to the project manager.

7.1.5 Marks and Sessions Table

The Marks and Sessions table at the lower left of the Manager's Page shows the list of user marks associated with GNSS observation files that have been loaded into the Project through OPUS (Section 5). The default display includes which marks were observed in each of the project's sessions ("Occupations" and "All OPUS Results"), and whether the observations met the minimum quality metrics as defined in the user preferences.

OP assigns session names as follows: "yyyy-ddd-X," where "yyyy" is the four-digit year, "ddd" is the three-digit GPS day of year, and "X" is the individual session within that day. By default, the first session is named "A." If there are multiple sessions in the same GPS day, the next session will be named "B," and so on.

Clicking on the Session ID will open the Session Page for that session.

Figure 7-34: MARKS and Sessions Table showing summary occupation data for all sessions

In addition, the user can select from a number of different displays, including "Solution Statistics," shown below:

	ations ed	solutions count	Obs Used	Obs Used(%)	AMB Fixed(%)	North P2P(cm)	East P2P(cm)	Up P2P(cm)	MARKS
		2	35269	98.3	93.0	0.2	0.1	0.4	bell
		2	39592	98.6	95.0	0.3	0.2	0.6	brun
		3	48146	99.5	87.7	0.4	0.3	2.7	calv
		4	66472	93.7	92.8	0.7	0.7	1.4	e087
		3	41384	99.4	96.7	0.3	1.0	1.4	fran
		2	39025	98.4	96.5	0.0	0.2	0.8	gorf
		2	38039	99.2	96.2	0.2	0.2	1.4	n102
		2	35522	97.9	93.1	0.2	0.2	0.6	pond
tane	3	3	45092	99.2	91.4	1.7	0.4	0.5	tane
algo	5	5	104788	99.8	99.4	0.44	0.58	1.23	algo
ded2	4	4	86889	93.5	96.3	0.22	0.48	1.08	ded2
dene	5	5	99652	99.5	92.2	0.36	0.93	1.53	dene
gode	5	5	902012	98.1	96.0	0.06	0.1	0.02	gode
hnpt	5	5	111563	99.6	98.7	0.33	0.14	0.8	hnpt
york	5	5	110579	98.7	99.0	0.28	0.34	1.01	york

Figure 7-35: Solution Statistics for All Sessions Table that can be displayed on the Manager's Page

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The user can also toggle between displaying the table for all OPUS solutions, all sessions, or adjustment results (once sessions have been processed or an adjustment has been made).

7.1.6 Color Coding Marks, CORS and Baselines

The Manager's Page shows all user marks included in the project (upper right-hand corner) as well as all of the CORSs. The icons relate to how the Quality Thresholds were met for user marks. Icons also identify which CORSs were available for each user mark's solutions. As more data are loaded into the project, more marks, CORS, and sessions will appear.

🟢	Mark Solution met Quality Thresholds
🟡	Some of the mark's Quality Thresholds were not met
⊗	Mark is not included
⊗	Mark has error
🔺	CORS met Quality Thresholds
🔺	CORS did not meet all Quality Thresholds
🔺	CORS not included
▬	Baseline
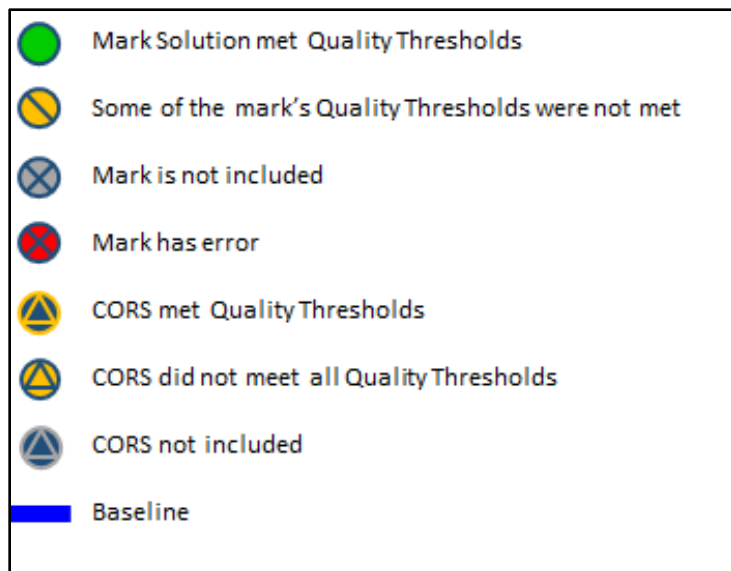
Figure 7-36: Symbology for distinguishing between user marks, CORSs, and baselines

The user marks are also listed in the OPUS output table below the map, showing the different sessions OPUS generated based on the Session Definition metrics set in the Preferences.

Note that a user mark may meet the Data & Solution Quality Thresholds (🟢) immediately based on the particular OPUS solution included in the project. A mark that initially did not meet the thresholds   (🟡) may eventually meet them based on subsequent session or network processing. Similarly, a CORS may not meet the project preferences (🔺) but still be included and used in the project.

Once a session solution completes, the baselines defined in the processing appear on the map. Each session processed will automatically be assigned a **different color** (e.g. blue, yellow, orange, red). This provides the Manager with an intuitive view of multiple sessions presented on the map display. Similarly, after a network adjustment, the baselines defined in the constituent session solutions of that adjustment will be shown as solid color lines on the map.

7.1.7 MARK and CORS Lists

To the right of the map are lists of user marks and included CORSs.
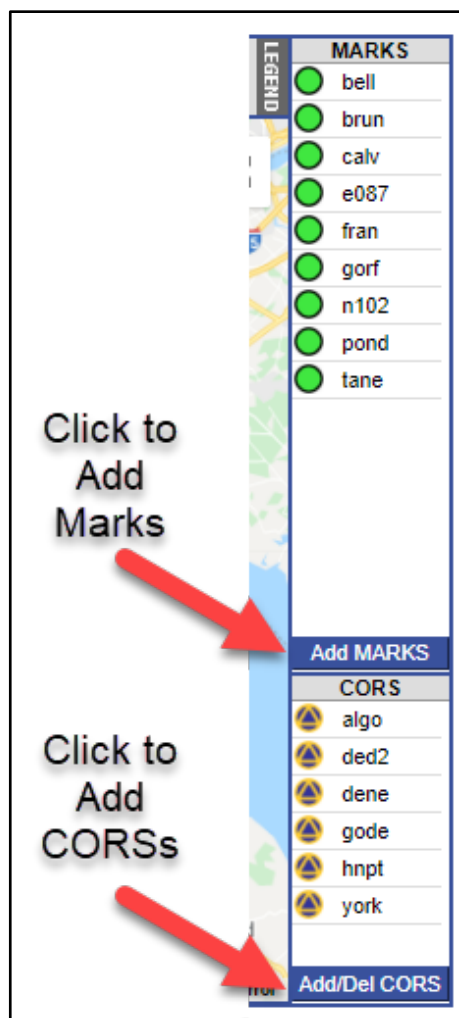
Figure 7-37 Add Marks and Add/Delete CORS buttons on the Manger's Page

Like the map icons, holding the cursor over a user mark's ID in the list will cause the icon to brighten, and clicking (typical left mouse button) a mark ID in the list causes that user mark's information bubble to appear on the map identifying its location.

Below the user marks list to the right of the map is the **Add MARKS** button. This button acts as a link to redirect the user to the OPUS Upload web page where more GNSS observations on user marks may be added.
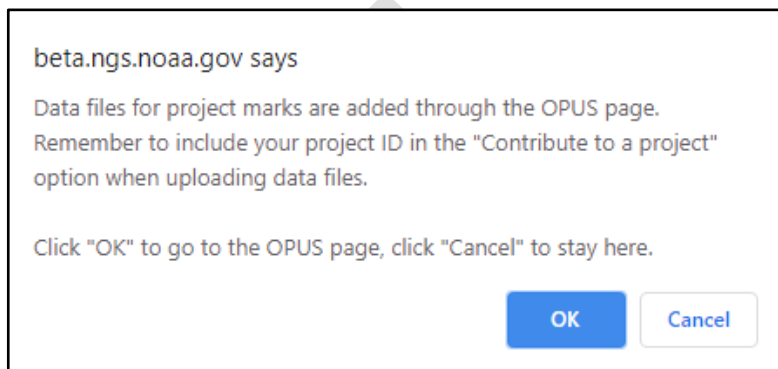
Figure 7-38: Reminder pop-up window for uploading observation files to the project through the OPUS upload page

> Using the "Add CORS" feature while on the Manager's Page assures that the CORSs selected will be used in every session

Below the CORS list, at the bottom right of the map, is the **Add/Del CORS** button. Clicking this button opens a new popup window with controls to add additional CORS to **all sessions** in the project.

The map appearing in the **Add/Del CORS** window is similar to the map on the Manager's Page. You may zoom in and out and drag the map to other areas. Notice the icons are color coded to reflect how long they have existed as a CORS. As you zoom in to the map notice that the sites that have been operational for shorter periods of time begin to appear. In stable areas of the country, the longer a CORS has been in operation, the better estimate of its velocity, and the greater the expectation that the CORS data will overlap with your project. Guidelines for selecting CORSs are presented in Section 9.
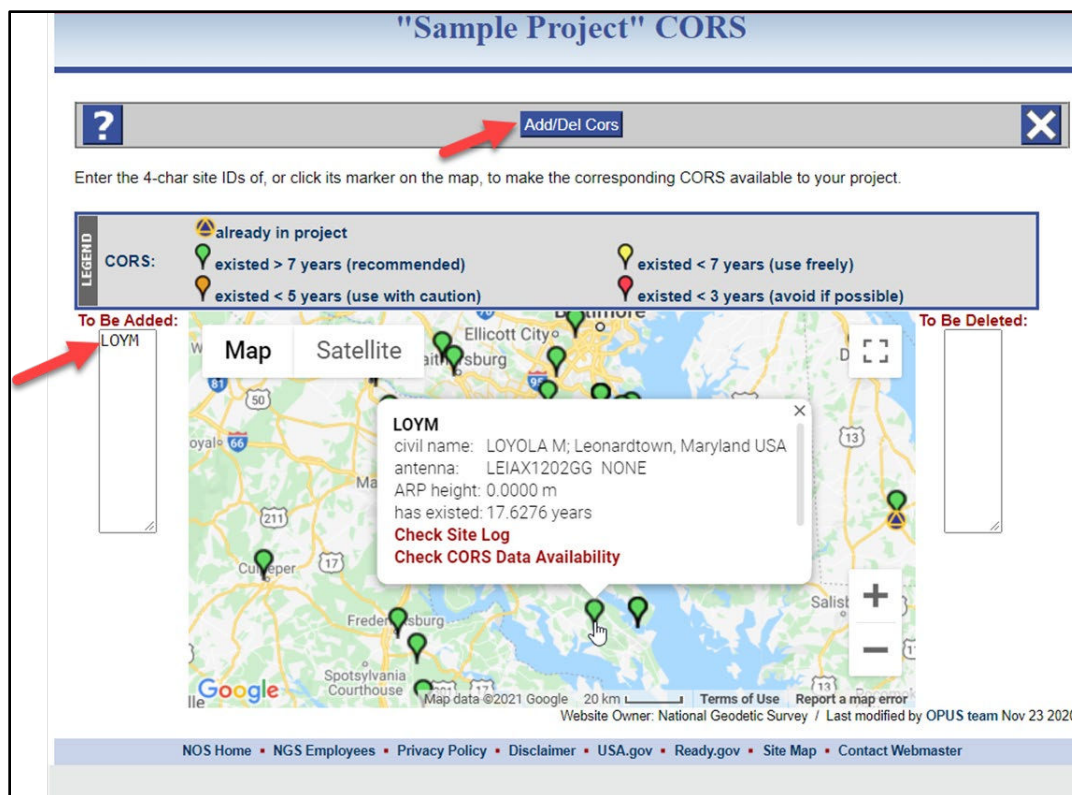
Figure 7-39: The Add/Del CORS management pop-up window

Move the cursor over the CORS icon to see the CORS ID. Clicking on the icon gives you the option (within the information bubble) to check the CORS site log as well as the data availability. You can also add that particular station to a list on the left side of the window. When you have completed adding CORS to that list, click the Add/Del Cors button at the top of the web page to populate the project with those additional stations.

> ⚠️ If you add CORSs after a given session has been processed (see "Session Processing," Section 7.2, below), you will have to re-process that session again.

7.1.8 Email the OPUS Projects Team

At the bottom of the Manager's, Session and Marks web pages, an email link to the OPUS Projects Team always appears providing a convenient method to ask questions or make comments. The project manager may receive more than one reply from NGS staff depending on the subject of the email.
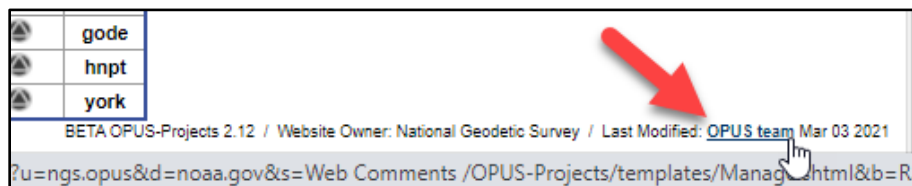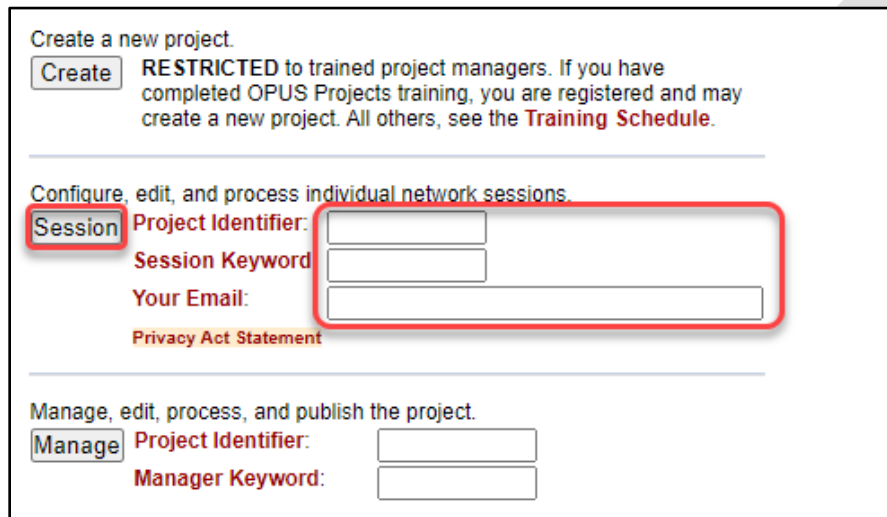
Figure 7-40: Submitting Comments to & Asking Questions of the OPUS team

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7.2 Sessions and Solutions Page

Session processing is the processing of two or more GNSS data files whose contents were collected with substantial time (observation) overlap to estimate the coordinates of the marks at which the data were collected with respect to one or more marks chosen to act as reference stations. For more explanation of session processing, see Section 10.

The project manager can access a session web page from the project Manager's Page by clicking on the Session ID (see 7.1.5, above). Other project members can access the session pages by entering the Project ID and Session Keyword as well as their email address in the OP gateway page:

Figure 7-41: Restricted access to session processing

The Session Page looks very similar to the Manager's Page, except that there is less functionality in the controls on the left panel and the table on the lower left. The Map features remain essentially the same as in the Manager's Page.

Sample Project

National Geodetic Survey

| NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education | | Search |

Session : 2017-241-A   Results From : OPUS Solutions

Controls

LEGEND
MARKS: ● meet preferences ◐ do not meet preferences ⊗ are not included ⊗ have error
CORS: 🔺 meet preferences 🔺 do not meet preferences 🔺 are not included
Baselines: ▬▬▬▬▬▬

MARKS
● calv
● fran
● tane

Manager's Page
Show File
Send Email
Set up Processing

Map | Satellite

Marks | Marks&CORS

(Google map showing Baltimore, Washington, Frederick, Gettysburg, Hagerstown, Westminster, etc.)

Add MARKS

CORS
🔺 algo
🔺 dene
🔺 gode
🔺 hnpt
🔺 york

Add/Del CORS

Map data ©2021 Google   10 km   Terms of Use   Report a map error

Solution Quality Indicators

MARKS	ANTENNA		HEIGHT (m)	EPH TYPE	OBS (%)	FIXED (%)	RMS (m)	LAT (m)	LON (m)	HGT (m)
calv ●	TRM41249.00	NONE	2.001	precise	96.0	97.0	0.014	0.002	0.004	0.003
fran ●	TRM41249.00	NONE	2.000	precise	94.9	93.4	0.014	0.003	0.006	0.028
tane ●	TRM41249.00	NONE	1.802	precise	94.2	95.4	0.014	0.011	0.014	0.016
PREFERENCES:			Best Available		≥80.0	≥80.0	≤0.025	≤0.020	≤0.020	≤0.040

Data Availability
2017-08-29T12:00:00 GPST to 2017-08-30T14:00:00 GPST in 30 minute cells
2017-08-29T00:00:00 GPST to 2017-08-30T12:19:30 GPST time windowing for session 2017-241-A

MARKS	2017-08-29												2017-08-30													
	12	13	14	15	16	17	18	19	20	21	22	23	00	01	02	03	04	05	06	07	08	09	10	11	12	13
calv ●	0 0 0	9 A 9 9 9	8 8 8	9 9 9 9	A 8 7 7	8 9 8 8	9 8 9 8	9 9 8 8	9 9 9 9 9	A 9 8 8	7 7 8	9 9 8 7	8 A 0
fran ●	0	8 A A 9 9 9 9 9	8 8	9 9 9 9	A 8 7 7	8 9 8 8	9 8 9 8	9 9 8	9 9 9 9 9 9 9	A 9 8 8	7 7 8	9 9 9 8	0 0 0 0
tane ●	0	8 A A 9 9 9 8	8 8 8	9 9 9 A	8 7 7	8 9 8 8	9 8 9 8	9 9 8	9 9 9 9 9 9 9	A 9 8 8	7 7 8 9	0 0 0 0 0 0

NOS Home • NGS Employees • Privacy Policy • Disclaimer • USA.gov • Ready.gov • Site Map • Contact Webmaster

Figure 7-42: Sessions Page prior to session processing

7.2.1 Solution Quality Indicators

Below the map, near the bottom of the web page is a table listing selected solution quality values for all user marks in this session.

Solution Quality Indicators

MARKS	ANTENNA		HEIGHT (m)	EPH TYPE	OBS (%)	FIXED (%)	RMS (m)	LAT (m)	LON (m)	HGT (m)
calv ●	TRM41249.00	NONE	2.001	precise	96.0	97.0	0.014	0.002	0.004	0.003
fran ●	TRM41249.00	NONE	2.000	precise	94.9	93.4	0.014	0.003	0.006	0.028
tane ●	TRM41249.00	NONE	1.802	precise	94.2	95.4	0.014	0.011	0.014	0.016
PREFERENCES:			Best Available		≥80.0	≥80.0	≤0.025	≤0.020	≤0.020	≤0.040

Figure 7-43: Solution Quality Indicators

The values are checked against the project's solution quality thresholds. If a value does not meet its preference threshold it is highlighted using an orange background color and border. In addition, the mark's icon is changed to reflect this condition. The **Solution Quality Indicators** in the example above shows that the processing results for this session meet the project's preferences with green open-circle icons and no highlighted cells. In the example below, one occupation did not meet the quality threshold for percent ambiguities fixed (threshold was 80%):

Solution Quality Indicators

MARKS	ANTENNA	HEIGHT (m)	EPH TYPE	OBS (%)	FIXED (%)	RMS (m)	LAT (m)	LON (m)	HGT (m)
arno ●	CHCX90D-OPUS NONE	2.000	precise	93.9	97.8	0.015	0.004	0.004	0.005
broa ●	CHCX90D-OPUS NONE	2.000	precise	89.7	91.1	0.016	0.003	0.001	0.002
cov1 ●	CHCX90D-OPUS NONE	2.000	precise	94.2	91.0	0.015	0.001	0.004	0.004
crof ●	CHCX90D-OPUS NONE	1.800	precise	87.3	91.8	0.017	0.003	0.001	0.007
lex1 ⊘	CHCX90D-OPUS NONE	2.000	precise	86.0	76.5	0.017	0.003	0.003	0.009
ros1 ●	CHCX90D-OPUS NONE	2.000	precise	85.2	91.9	0.017	0.008	0.003	0.003
wald ●	CHCX90D-OPUS NONE	2.000	precise	83.8	95.4	0.018	0.003	0.000	0.010
PREFERENCES:		Best Available		≥80.0	≥80.0	≤0.025	≤0.020	≤0.020	≤0.040

Figure 7-44: Session solution quality indicators showing a threshold exceeded

7.2.2   Data Availability

At the bottom of the web page is the **Data Availability** table creating timeline-style graphics indicating data availability for each user mark's data file in that session.

Data Availability
2017-08-29T12:00:00 GPST to 2017-08-30T14:00:00 GPST in 30 minute cells
2017-08-29T00:00:00 GPST to 2017-08-30T12:19:30 GPST time windowing for session 2017-241-A

Figure 7-45: Satellite Data Availability

Each cell represents a time span (its length indicated in the text above the table) and the number therein is the most common number of satellites (mode or modal value) for that span. If the number of satellites is greater than 9 (10, 11, 12, …) the cell will contain the hexadecimal representation (A, B, C,…). The cells in the table are color-coded. White background with gray characters symbolizes less than four satellites were tracked, indicating processing during that time span is not possible. Yellow through dark green background with black characters symbolizes four or more satellites respectively. White cells with characters of the same yellow-to-green color scheme indicate observations were available during the times represented by those cells, but those data are not included in the session. This is less common and only occurs because of time-adjacent sessions when there is not a "clean" start/stop time between the sessions *or when the user excludes a mark from Session Processing*. In this case, the optimal division between the sessions can cause data from one session to be considered to be part of the other.

7.2.3 Add Marks and CORS

The **Add MARKS** button functions the same way as on the Manager's Page. The **Add/Del CORS** button acts as before, but only affects *that* particular session, not the entire project. If the user wishes to add or remove a CORS from all sessions, that is best done on the Manager's Page (see 7.1).

7.2.4 Set Up Processing

Figure 7-46: The Set up Processing button on the Session page Controls bar

Clicking the **Set up Processing** button on the Session page Controls bar allows the user to set up the session's processing parameters. Session processing creates baseline solutions between the hub and each of the selected CORS, as well as between the hub and the user marks. Session processing enables the user to ensure that the project has the correct data for a successful set of network solutions (Section 11). For more information on Session Processing, see Section 10.

7.3 Mark Pages

Descriptions, photographs, occupation information (i.e. metadata) and processing results for individual user marks appear on dedicated web pages for those marks.

A project manager can navigate to these mark pages using the links provided in the **Sessions & Solutions** table; others can navigate to these pages using the links in the **Solution Quality Indicators** table or the **Data Availability** table. These tables always appear directly under the map on their respective web pages. In all cases, the mark IDs that serve as row labels in these tables are links to the corresponding user mark web page. Project members can also navigate to individual user mark web pages using the mark ID in the pop-up bubbles that appear when a mark icon on a map is clicked:

Figure 7-47: Accessing a mark page from the Manager's Page

The mark page has several sections and controls specific to each section. Furthermore, additional controls appear (or are enabled) if a mark's web page is accessed by the project manager.

Figure 7-48: Example mark page

⚠️ If submitting your project to NGS for publication, make sure the Mark Occupation Table is complete.

7.3.1 Map of the User Mark Area

The map in the mark page is similar to the maps seen in the other OP web pages. The default zoom level of the map is very limited to the area near the mark. Zooming out a few levels will show the mark in the context of its surroundings. A slight difference is that the legend allows the user to toggle among the different mark pages. It also allows different elements (and spatial scales) to be viewed, including just the mark itself ("**This Mark**"), all user marks ("**All Marks**"), or all marks including the selected CORSs ("**Marks&CORS**"):
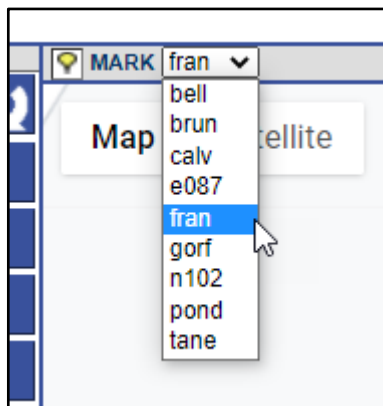
Figure 7-49: Mark page toggling from the map

Toggle among the different user mark web pages.
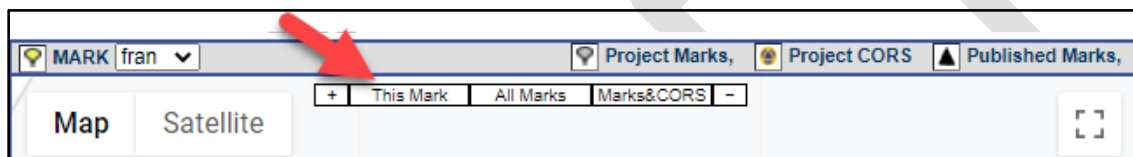
Figure 7-50: Mark page zoom controls

Select desired auto-zoom level or manually zoom in or out.

Four types of marks may appear on the map:

Indicates the location of the mark.

Indicates the locations of other marks in this project. (Initially, the map shows only a small area so other marks in the project may not appear until the map is shifted or "zoomed out.")

Identifies CORS used in the project.

Identifies nearby marks for which NSRS information exists in the NGS database, though not necessarily part of the project, but are shown because they help form the reference frame like the CORS.

A user mark which has a PID in the NGS database.

Clicking on one of these mark icons reveals a pop-up window displaying the mark's datasheet. Recall that a PID can be associated with a user mark when its data files were uploaded, when its description file is loaded, or by using the controls on the project's mark web page.

7.3.2 Standard Datasheet Pop-up Window

Clicking on the icon for a mark with a triangle on the map opens the mark's datasheet in a separate window.

Datasheet for JV7214

```
                            Use Description              Use Coordinates              Use Description & Coordinates

See file dsdata.pdf for more information about the datasheet.

PROGRAM = datasheet95, VERSION = 8.12.5.12
Starting Datasheet Retrieval...
1        National Geodetic Survey,   Retrieval Date = APRIL  2, 2021
 JV7214 ***********************************************************************
 JV7214 HT_MOD      -  This is a Height Modernization Survey Station.
 JV7214 DESIGNATION -  FRANKS
 JV7214 PID         -  JV7214
 JV7214 STATE/COUNTY-  MD/FREDERICK
 JV7214 COUNTRY     -  US
 JV7214 USGS QUAD   -  WALKERSVILLE (2016)
 JV7214
 JV7214                          *CURRENT SURVEY CONTROL
 JV7214  _____
 JV7214* NAD 83(2011) POSITION- 39 29 55.89605(N) 077 19 38.31730(W)   ADJUSTED
 JV7214* NAD 83(2011) ELLIP HT-    75.264 (meters)       (06/27/12)   ADJUSTED
 JV7214* NAD 83(2011) EPOCH   -  2010.00
 JV7214* NAVD 88 ORTHO HEIGHT -   108.02  (meters)      354.4   (feet) GPS OBS
 JV7214  _____
 JV7214  NAVD 88 orthometric height was determined with geoid model    GEOID12B
 JV7214  GEOID HEIGHT     -          -32.770 (meters)                  GEOID12B
 JV7214  GEOID HEIGHT     -          -32.771 (meters)                  GEOID18
 JV7214  NAD 83(2011) X  -  1,081,186.052 (meters)                     COMP
 JV7214  NAD 83(2011) Y  - -4,808,286.180 (meters)                     COMP
 JV7214  NAD 83(2011) Z  -  4,035,253.729 (meters)                     COMP
 JV7214  LAPLACE CORR     -          5.10  (seconds)                   DEFLEC18
 JV7214
 JV7214  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 JV7214  Standards:
 JV7214        FGDC (95% conf, cm)     Standard deviation (cm)    CorrNE
 JV7214           Horiz  Ellip        SD_N  SD_E  SD_h    (unitless)
 JV7214  ----------------------------------------------------------------
 JV7214  NETWORK   0.46  0.53          0.21  0.16  0.27      0.00876692
 JV7214  ----------------------------------------------------------------
 JV7214  Click here for local accuracies and other accuracy information.
 JV7214
 JV7214
 JV7214.The horizontal coordinates were established by GPS observations
 JV7214.and adjusted by the National Geodetic Survey in June 2012.
 JV7214
 JV7214.NAD 83(2011) refers to NAD 83 coordinates where the reference frame has
 JV7214.been affixed to the stable North American tectonic plate. See
 JV7214.NA2011 for more information.
 JV7214
 JV7214.The horizontal coordinates are valid at the epoch date displayed above
 JV7214.which is a decimal equivalent of Year/Month/Day.
 JV7214
 JV7214.The orthometric height was determined by GPS observations and a
 JV7214.high-resolution geoid model using precise GPS observation and
 JV7214.processing techniques.
 JV7214
 JV7214.Significant digits in the geoid height do not necessarily reflect accuracy.
 JV7214.GEOID18 height accuracy estimate available here.
 JV7214
 JV7214.Click photographs - Photos may exist for this station.
 JV7214
 JV7214.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 JV7214
```

Website Owner: National Geodetic Survey / Last modified by OPUS team Nov 23 2020

Figure 7-51: Datasheet Retrieval by way of a user mark with a PID in the NG database

 The banner for this window provides the mark's **Permanent Identifier** or **PID** in the title (JV7214 in the title "Datasheet for JV7214" in the example above). Typical pop-up window controls are located just below the banner: '**Help'** and '**Refresh'** buttons on the left; a '**Close'** button on the right. Below the controls, the datasheet is given.

Use Description applies information from the datasheet to the description elements for this user mark. In other words, the published description can be applied to this mark, but it will not supplant/replace information previously entered at upload or by the project manager.

Use Coordinates allows the user to change the **a priori coordinates** for this user mark with the record mark's (published) datasheet coordinates. For more information on a priori coordinates see the Glossary.

> ⚠️ If a user uploads a published mark's description file, which would include the official coordinates for the mark as published on the NGS datasheet, the a priori coordinates would also change to the published coordinates.

> ⚠️ Caution! Changing the a priori coordinates for a project mark invalidates all existing project processing for that mark. For this reason, it is recommended to "use coordinates" or upload description files prior to any session processing and network adjustments.

Use Description & Coordinates is a simple convenience activating both of the other controls simultaneously.

7.3.3 Controls

The web page's controls appear to the left of the map. Standard controls are always available, but additional controls are provided for the project manager (see 6.1, above).

The **Help**, **Back**, and **Refresh** buttons provide the same features as in other pages. The **Manager's Page** button returns to the Manager's Page. The **Show File** button operates in the same way as in the Manager's Page. It opens a pop-up window for displaying solution reports. As before, the availability of reports depends on the level of processing completed.

Figure 7-52: Show File button on the mark page Controls bar

Figure 7-53: OPUS Solution Report for a user mark

Some browsers offer a print option by right-clicking (right mouse button) anywhere in the report. All browsers should allow the report's text to be copied and pasted into another file using the method typical of the operating system.

7.3.4 Change Mark ID
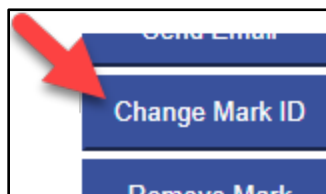
Figure 7-54: The Change Mark ID button on the Mark page Controls panel

The **Change Mark ID** button opens a pop-up window with controls to change this mark's four-character ID. Typical pop-up window controls appear across the top of the window. Below those controls are the rules for a mark ID, then two entry fields: an entry and confirmation field. When the new mark ID field is changed, the confirmation field is enabled (no longer grayed out). To 'Apply Change and Close,' the input and confirmation IDs must match.

In the example below, OP did not find a unique mark ID in the first four characters of the corresponding RINEX file (nor did it find another mark already loaded in the project that lies within the mark co-location preference), so it automatically assigned "a001" as the mark ID. The user may want to use the "Change MARK ID" capability to force OP to use the correct mark ID (in this case, "fran").
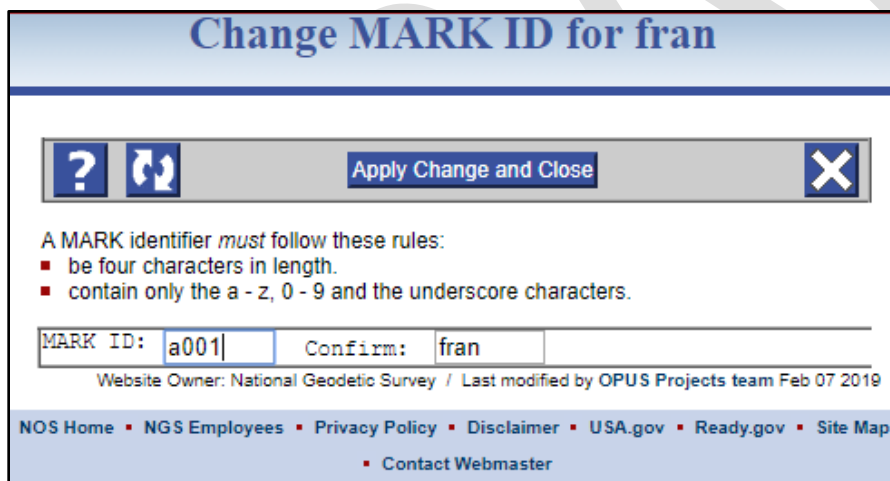
Figure 7-55: Change Mark ID pop-up window

7.3.5 Remove Mark
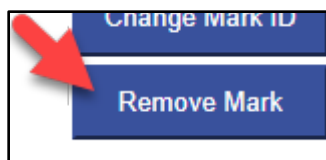
Figure 7-56: The Remove Mark button on the Mark page Controls bar

The "Remove Mark" button will display a message requesting confirmation before removing the mark. If confirmed, the mark, its data files, all processing solutions and network adjustments that include the mark will be removed from the project and the updated Manager's Page will be displayed.

A user may want to remove a mark from a project for a variety of reasons:

- A wrong observation file (e.g. from another project) was loaded to the current project by mistake
- The wrong mark was observed by the field crew
- Only one observation exists for a mark in the project, so there is no redundancy ("no check" solution). If the project is designed to be submitted to NGS, at least two independent observations are required.
- Solution thresholds consistently bad for that mark

> ⚠️ Avoid the temptation to remove a mark if its initial OPUS solution does not meet all Data & Solution Quality Thresholds. Reprocessing the data in Session Solutions can sometimes result in meeting the thresholds. Rather than removing a mark, a session can also be reprocessed by excluding the mark (or excluding the particular data file), thereby easily preserving the option of re-including it if needed.
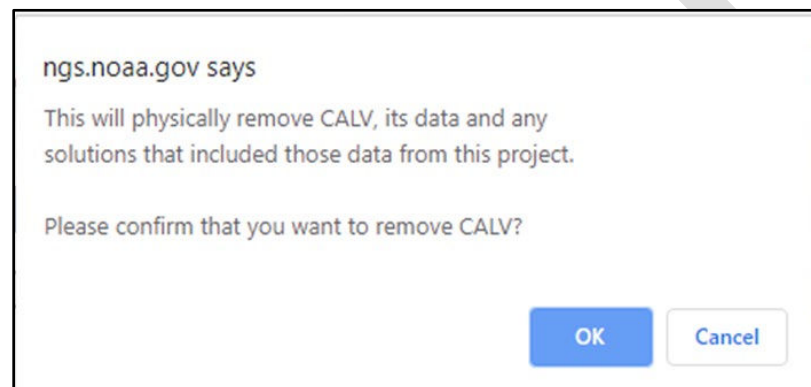
Figure 7-57: Confirmation pop-up window for removing a mark from the project

7.3.6 Mark Description Summary

This part of the window displays descriptive information associated with the mark (Figure 7-56).

This information can be added or changed by the user, unless a description file has been loaded into the project (in which case these fields cannot be modified). It can also be updated with descriptive information from NGS datasheets if the mark has a PID, and the user selected to "Use Description" from the datasheet pop-up window (see 7.3.2, above). However, any descriptive information previously entered by the user will not be overwritten. Note that if a field is editable, any entry by the user replaces whatever OP had there before. The hierarchy used by OP is as follows: Description File>User Input>Datasheets>Descriptive info added after data upload>Nothing (Blank).

Figure 7-58: Mark Description Summary

The list of identifying descriptors on the left column of the table refer to specific data fields within a description file (Appendix A). They are briefly explained below:

PID: Permanent Identifier assigned when new project marks are observed and their data submitted to NGS.

stamping: Typically this is the name assigned to the mark that the original mark-setter struck into the disk (brass or aluminum cap) when the mark was set and/or reset.

designation: The name assigned to the mark, unique for the area and usually descriptive of the mark stamping or location.

type: A physical description of the type of survey monument (e.g. a disk).

setting: The structure to which a mark is affixed. There is a specific setting optional field to add comments about the setting.

description: (for new project marks) A written statement giving distances and directions (swing ties) to local features (posts, trees, building corners, street centerlines, etc.) along with any other salient features (recommended approach, hazards, etc.). This will help future surveyors recover and assess the suitability of the mark for use in their project. The description may be updated.

stability: An estimate of the long-term stability of the mark.

magnetic: This field specifies any magnetic material in or alongside the setting to aid in mark recovery.

application: This is used to identify marks for specific special applications (e.g. tidal bench marks).

condition: A basic estimate of the mark's condition.

7.3.7 Upload a Photo

Clicking on the Upload a Photo button on the right of the mark description summary opens a "Manage Photos for MARK [4-char ID]" window:
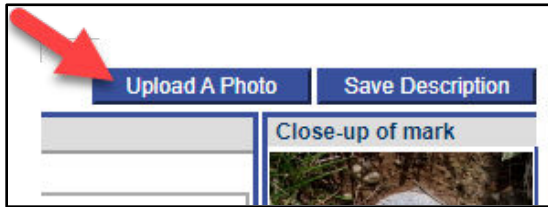
Figure 7-59: Upload A Photo button within the mark description summary

Figure 7- 60: Upload photos pop-up window

The window allows the user to upload one each of three different photos: the closeup photo of the mark itself; an eye-level view of the mark in its setting; and a horizon view showing where the mark is located with respect to surrounding points of reference. Photos should adhere to the NGS Photo Submission Guidelines. There is no bulk-upload method available at this time, so all photos will need to be uploaded individually.

Once loaded, the photos will be displayed in the Mark Description Summary:
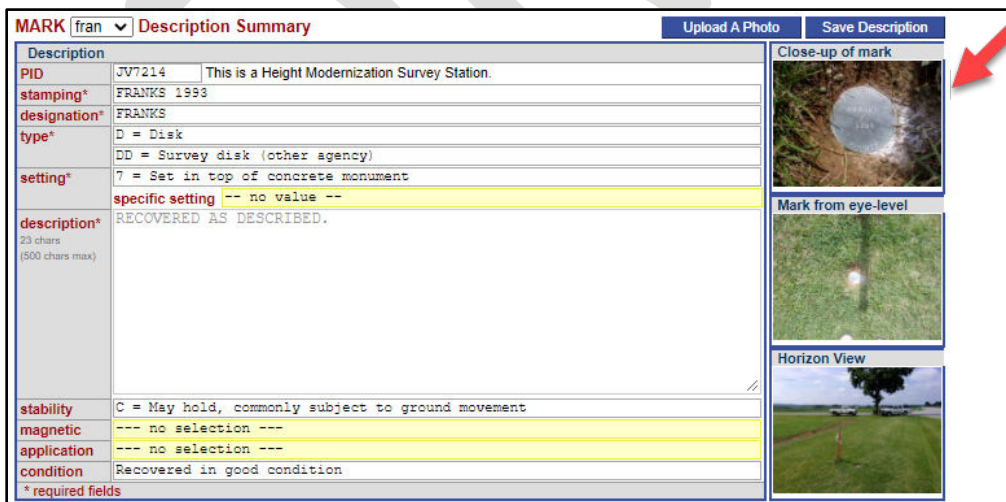
Figure 7- 61: Example showing successfully loaded photos on a mark page

7.3.8 Save Description

This button saves any changes made to the mark description summary, but only within OP. Any changes saved here will not affect the uploaded WinDesc description files.
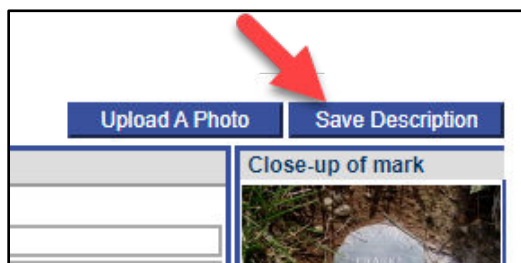
Figure 7-62: Save Description button within the mark description summary

7.3.9 Mark Occupations

This table provides critically important information on the GNSS data associated with the mark. This table needs to be reviewed carefully to ensure that the correct data are associated, such as RINEX files, dates and start/stop times for each occupation, antenna type, antenna serial number, and antenna heights (refer to field logs to confirm).

The antenna type, antenna serial number, and antenna height are all editable in the table. To change the observation file associated with the mark (which may change the data span), click on the "Manage Data Files" button (7.3.10, below).

Figure 7-63: Occupation information on a mark page

7.3.10 Manage Data Files

Clicking on the "Manage Data Files" button opens a pop-up window where the user can either remove an observation (RINEX file) or associate a given RINEX file with another mark:
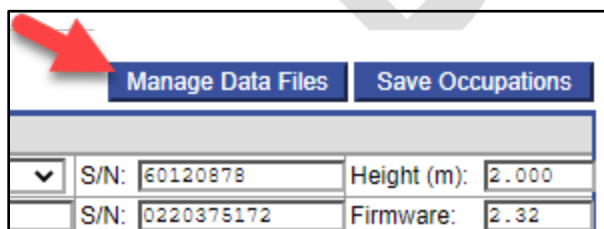
Figure 7-64: Manage Data Files button on the mark occupations table

Figure 7-65: Manage a mark's data file pop-up window

7.3.11 Save Occupations

To save any changes made to the Mark Occupation table, click on the "Save Occupations" button.

Figure 7-66: Save Occupations button on the mark occupations table

7.3.12 Manage Coordinates

Clicking on the "Manage Coordinates" button opens a pop-up window where the coordinates, reference frame, and datum associated with the mark are displayed.

Figure 7-67: Manage Coordinates button on the mark processing results table

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Figure 7-68: Manage a mark's coordinate pop-up window showing coordinates, reference frame, and assumed errors (sigmas)

If the mark description has been imported from NGS datasheets (7.3.2, above), the coordinates will reflect official published values. Otherwise, the information will come from the first OPUS solution computed for that mark (details in Glossary under "**a priori**" entry). The data displayed in this window is important as it will be used in subsequent session processing and network adjustments. Not only are the coordinates important, but also the assumed errors (called "**sigmas**," to the right of the "±" sign), as well as the reference frames and datums. If any changes are made, make sure to click on the Apply Changes button.

> If the project lies outside the NSRS, the Manage Coordinates window is especially useful to make sure a priori coordinates correspond to their known/published values.

> ⚠ The Manage Coordinates tool is only available to user marks, not CORSs

8 Mark Descriptions

Once all the GNSS observation files are successfully loaded into the project, all of the survey marks which were observed as part of the project are now part of the project. The user may want to import mark descriptive information from the datasheets via the individual mark pages as described above in Section 7. However, if the user wishes to submit the project to NGS, a separate description file must be generated outside of OP, and then loaded into the project. **For submitting a project to NGS, it is recommended to load the description files _prior_ to any session processing.** Now is a good time to do this. See Appendix A for guidance on creating WinDesc description files.

Figure 8-1: WinDesc program main screen

9 Selecting CORSs

Typically over 99% of ionospheric delays GNSS signals experience can be removed by using multi-frequency GNSS signals. Post-processing GNSS data using simultaneous observations at known control points (CORSs) removes additional atmospheric influence including tropospheric delays. Selecting the best CORSs for session processing and network adjustments is one of the most critical steps in ensuring a successful outcome, including submission of the project to NGS. Selecting high-quality CORSs is important, because the CORSs in your project will ultimately serve as the control for referencing your survey to the NSRS. Your OP project will have a number of stations already selected, based on the choices OPUS has made in post-processing each individual GNSS observation file (see How Does OPUS Processing Work?). However, the choices made through individual OPUS solutions are rarely the best choices for the entire project. This section steps you through a recommended selection process. Of course, you can develop your own processes for selecting CORSs. The most important takeaway from this section of the manual is to analyze the CORSs to determine the best set for your project.

9.1 Adding or Deleting CORSs

CORSs (including IGS stations) can be added or removed from either the Manager's Page or the Session Page.

> ⚠️ Adding or Deleting a CORS from a Session Page will only add/delete the CORS for that session. Adding or deleting a CORS from the Manager's Page will add/delete the CORS to ALL sessions
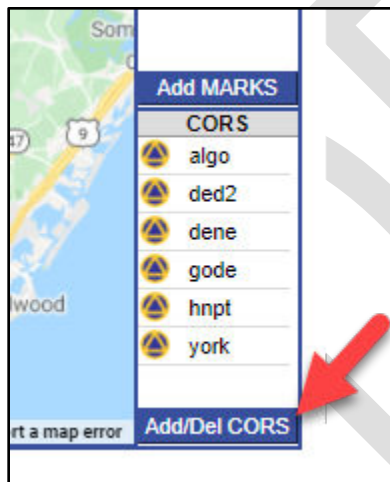
Figure 9-1: Add/Delete CORS button on the project map

Clicking on the Add/Del CORS button opens a new window in which CORSs can be added or removed from the project:
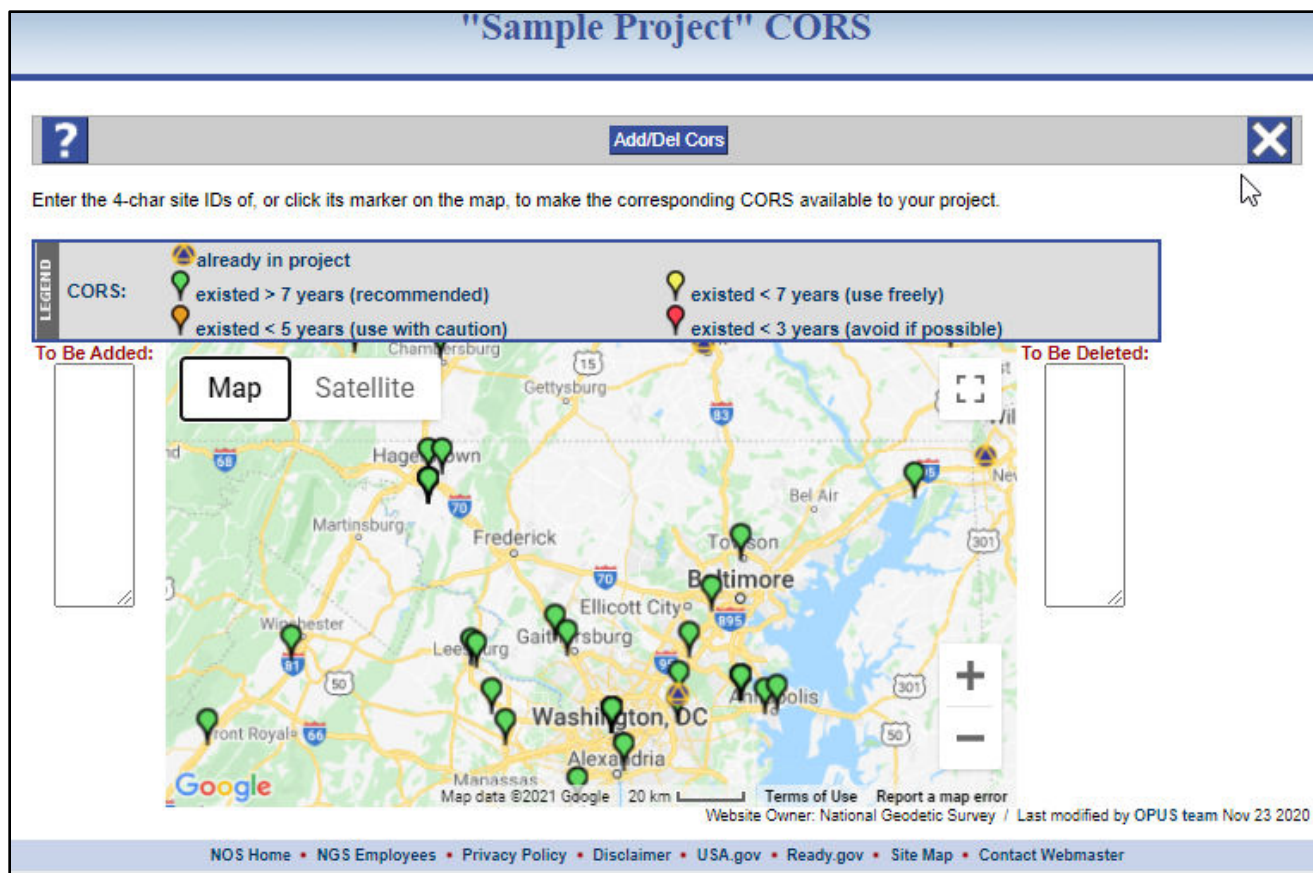
Figure 9-2: Add/Delete CORS pop-up window

The CORSs are displayed according to the legend, which distinguishes the stations based on their cumulative time series. The map is sensitive to the scale: at a small scale, only those CORSs already selected by OPUS to be in the project, and those CORSs with more than 7 years of data are visible. These are the stations that are typically viewed as "candidate" CORSs for your project. As you zoom in (using the +/- toggles on the map, or the wheel of your mouse), CORSs with shorter time series will appear. These are to be used with caution, according to the legend.

> ⚠️ The longer a CORS has been in operation, the greater the likelihood of the relative stability of its coordinates compared to younger stations, except in areas of known land movement, where age may track discrete coordinate shifts

Clicking on a CORS will provide additional information, including the four-character ID, cumulative time series, and links to the site log and data availability. The link to the data availability is particularly handy for determining if the CORS has data available for processing during the entire survey project.
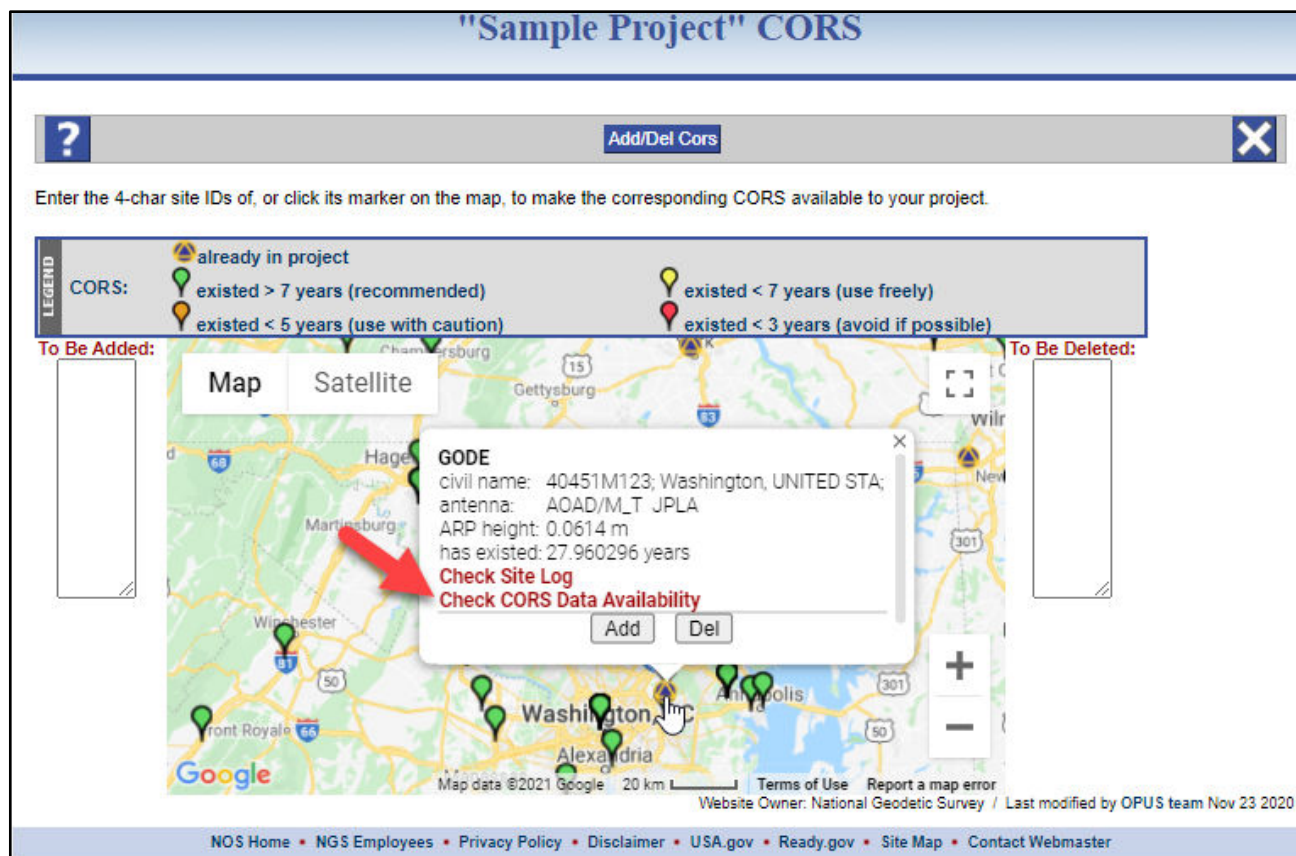
Figure 9-3: CORS information bubble on the Add/Delete CORS window

The user can click the "add" or "delete" button in the window for the CORS you have selected. Alternatively, the user can type the four-character ID into the list for CORSs to be added or deleted. The graphic map interface can be used to help select the CORSs that will eventually be used for controlling the GNSS project

9.2 Selecting Appropriate CORSs for Successful Processing in OP

The following steps will ensure a set of the highest-quality CORS to control your GNSS project. This is especially important if your results are to be submitted to NGS:

9.2.1 Candidate CORSs

Tabulate a list of approximately 6 to 15 "candidate" CORSs for potential use as control in the GNSS survey project. Typically, you should start with the CORSs that get automatically added to your project when you load GNSS observation files through the OPUS file upload portal. These are found on the Manager's Page, to the lower right of the Project Map:
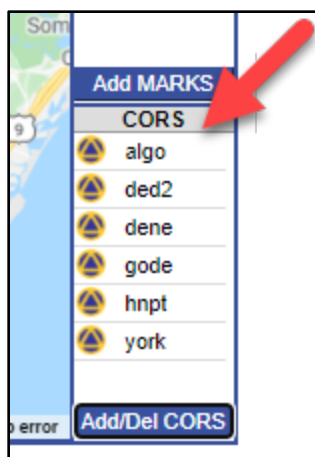
Figure 9-4: List of all CORS included in the project as seen on the Manager's Page

 It is also good practice to identify these candidates prior to the survey campaign. This can be done by entering the location of the centroid of your project on the CORS map. The map will automatically draw a 250 km radius around your identified location (city, ST or lat, long) and list the (up to 20) CORSs found within the circle:
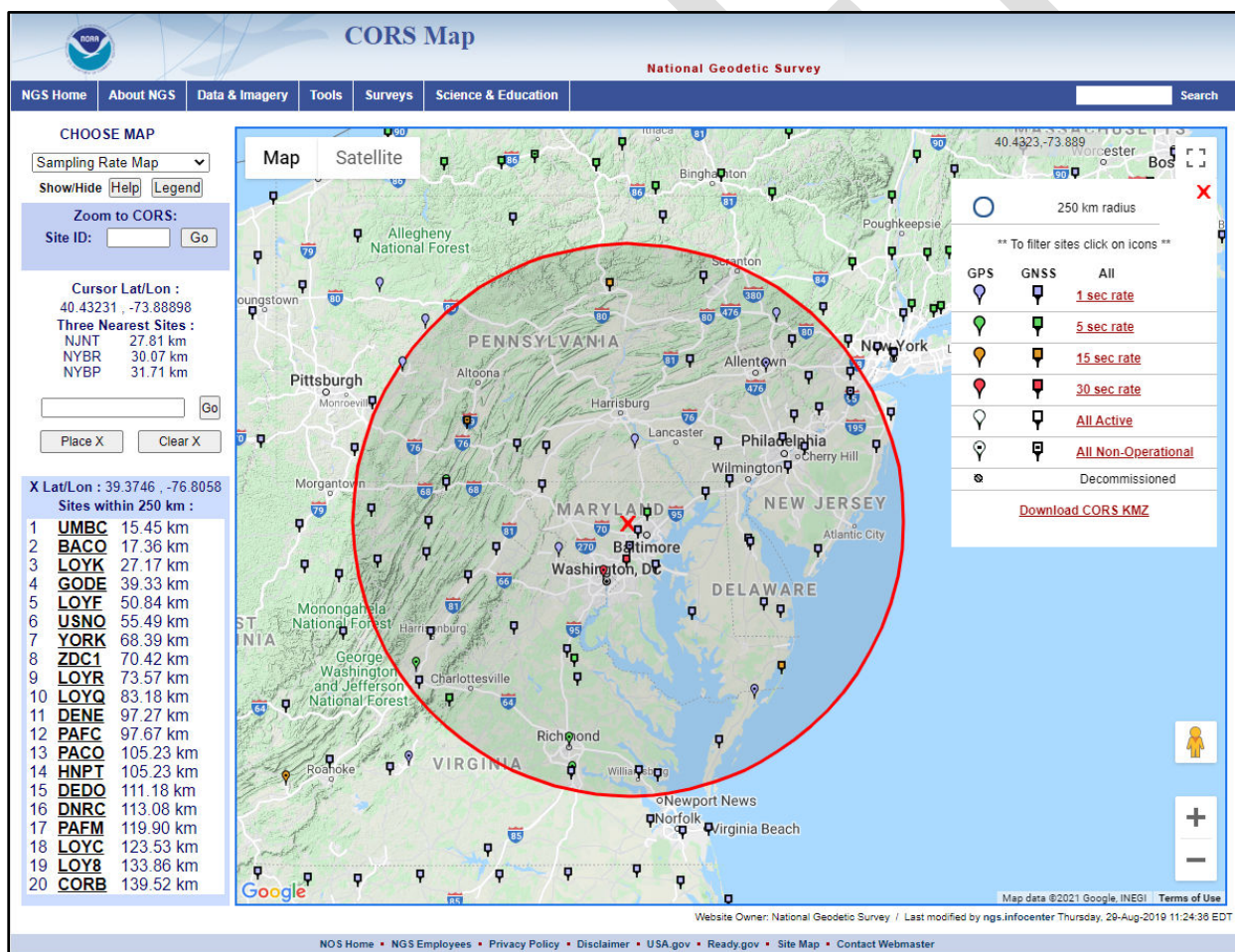
Figure 9-5: Map of CORS stations on the CORS web page, showing a 250 km radius around a selected location

Planning and studying the CORSs prior to the survey will prevent the blind belief that particular stations are functioning properly or operational during the survey (which unfortunately is not always reality). Your regional geodetic advisor is also a great resource to help you select appropriate CORSs for your project.

> To help in the selection of CORSs, it may be useful to construct a spreadsheet to track the important characteristics of each CORS you are considering

It may be helpful to create a spreadsheet to track some of the important variables for each CORS that you are considering. An example of this kind of tracking system is shown in Figure 9.6, below:

	A	B	C	D	E	F	G	H	I	J	K
1	CORSID	Computed Velocity?	Data Available?	Mean_N	Std_N	RMS_N	Mean_E	Std_E	RMS_E	Mean_U	Std_U
2	wdc6	IGS*	yes	-0.24	0.15	0.28	-0.15	0.21	0.26	0.09	0.6
3	corb	yes	yes	0.59	0.13	0.6	-0.02	0.15	0.15	-0.03	0.47
4	anp5	yes	yes	0.17	0.19	0.26	-0.18	0.19	0.27	-0.43	0.66
5	anp6	yes	yes	0.22	0.16	0.27	0.17	0.17	0.24	-0.67	0.58
6	gode	pub. IGS*	yes	0.27	0.16	0.31	-0.21	0.23	0.31	-0.71	0.7
7	hnpt	yes	yes	0.5	0.14	0.52	-0.93	0.18	0.94	-0.04	0.6
8	loyk	yes	yes	0.65	0.15	0.67	0.2	0.18	0.27	-1.35	0.56
9	umbc	yes	yes	1.21	0.13	1.21	-1.24	0.17	1.25	-1.58	0.5
10	loyo	yes	yes	0.13	0.12	0.18	-1.74	0.15	1.75	-2.58	0.54
11	loyf	yes	yes	0.77	0.14	0.78	-0.76	0.21	0.79	-3.02	0.54

See 9.2.2   See 9.2.3   See 9.2.4 and 9.2.6

Figure 9-6: Example of a spreadsheet used to help select the best CORSs for a project

* IGS/published IGS: IGS stations will have computed coordinates and velocities for the latest IGS reference frame.

Choose stations from your list that have data available during the entire survey project (click on the link in the information bubble for the CORS).
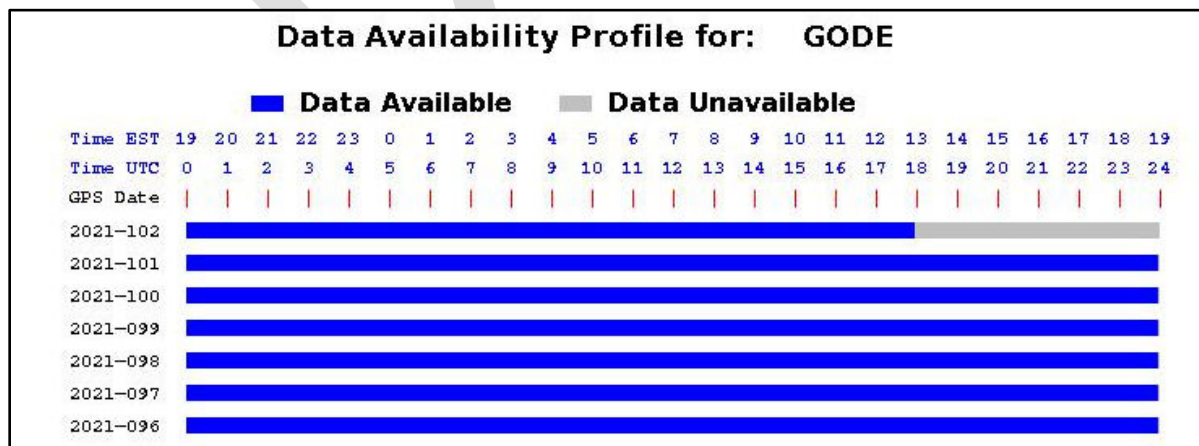
Figure 9-7: Data availability for the CORS "GODE" in early April 2021

Note that Data Availability will only be available for CORSs in the **NOAA CORS Network** ("NCN"). For IGS stations not in the NCN, you will be presented a pop-up window that suggests no data are available:
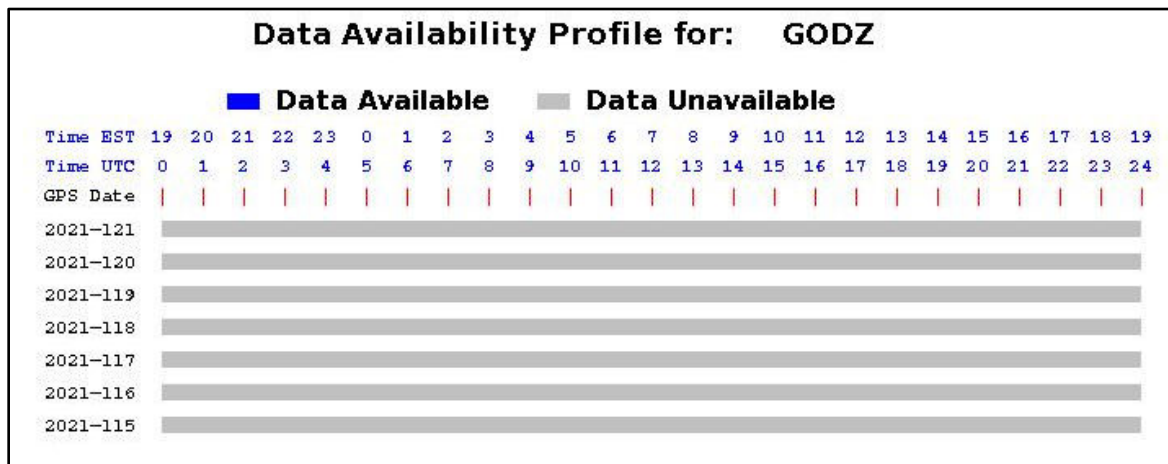
Figure 9-8: Data availability for a CORS not in the NOAA CORS network will appear blank

Please refer to the IGS for data availability: http://www.igs.org/network. Although perfectly continuous data is ideal, for a variety of reasons, you may end up selecting a CORS with some small data gaps.

Determine which CORSs have computed (i.e., measured) velocities rather than modeled velocities. CORS with computed velocities are tabulated in the "composite coordinate tables" available to download directly at: https://noaa-cors-pds.s3.amazonaws.com/coord/coord_14/itrf2014_geo.comp.txt. The user can also see whether or not a CORS has computed velocities by visiting the Site Info page for the CORS and selecting "Coordinates," and then "Position and Velocity.:" For example, the Position and Velocity for the station LOY8 is given in the example below:
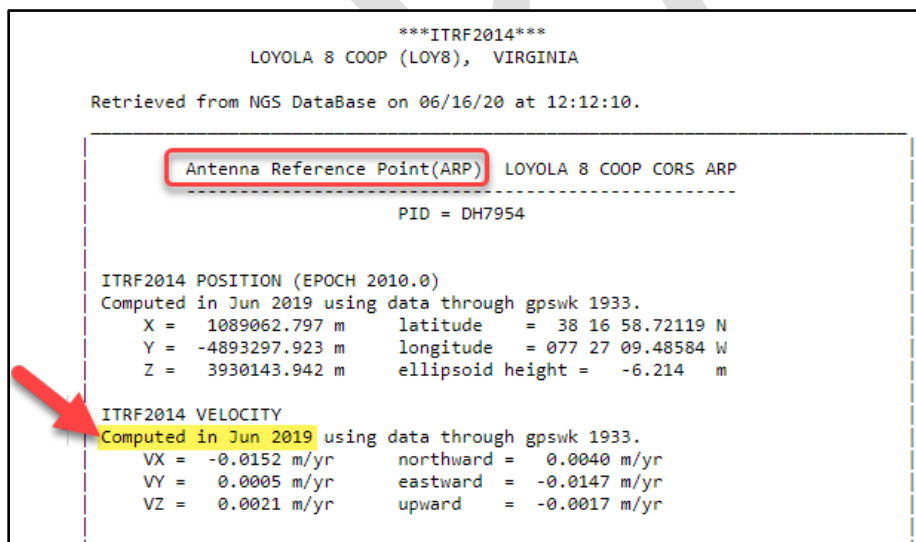
Figure 9-9: Example coordinates page for the CORS LOY8 showing computed velocities

The yellow highlighted text above shows that the velocities are computed, not modeled. Computed CORS velocities are preferred because their velocities are measured from several years of continuous observations.

Modeled CORS have velocities estimated from the Horizontal Time-Dependent Positioning (HTDP) utility, which in most cases ignores vertical motion.

Note that the example above for LOY8 shows the position and velocity with respect to the Antenna Reference Point, or ARP (circled in red). Some CORS will also provide coordinates with respect to the "Monument," or "MON," which in all cases is closer to the ground than the ARP. Not all CORSs will have a MON, but all CORSs will have an ARP. OPUS Projects will always use the lowest reference point, so, in the case of the CORS GODE in the example below, OP will use the coordinates from the MON.

```
                        ***ITRF2014***
              GODDARD SPACE CTR (GODE),  MARYLAND

   Retrieved from NGS DataBase on 06/16/20 at 12:05:19.

 _____
 |                                                        |
 |          Antenna Reference Point(ARP): GODDARD SPACE CTR CORS ARP  |
 |          ---------------------------------------------- |
 |                         PID = AF9646                    |
 |                                                        |
```

******Information snipped out for brevity******

```
 |     Y =  -4831255.141 m     longitude    = 076 49 36.57474 W  |
 |     Z =   3994200.616 m     ellipsoid height =   15.937   m   |
 |                                                        |
 | The NAD_83 (2011) VELOCITY o  the L1 PC is the same as that for the ARP.  |
 |_____|
 |                                                        |
 |          Monument: GODDARD SFC CORS MONUMENT           |
 |          ------------------------------------          |
 |                         PID = AF9647                    |
 |          Inscribed: UNKNOWN                            |
 |                                                        |
 |                                                        |
 | ITRF2014 POSITION (EPOCH 2010.0)                       |
 | Published by the IGS in May 2020.                      |
 |     X =   1130773.670 m     latitude    =  39 01 18.21996 N  |
 |     Y =  -4831253.573 m     longitude   = 076 49 36.59163 W  |
 |     Z =   3994200.435 m     ellipsoid height =   14.498   m  |
 |                                                        |
 | The ITRF2014 VELOCITY of the monument is the same as that for the ARP.  |
 |                                                        |
 |                                                        |
 | NAD_83 (2011) POSITION (EPOCH 2010.0)                  |
 | Transformed from ITRF2014 (epoch 2010.0) position in May 2020.  |
 |     X =   1130774.428 m     latitude    =  39 01 18.18970 N  |
 |     Y =  -4831255.025 m     longitude   = 076 49 36.57472 W  |
 |     Z =   3994200.519 m     ellipsoid height =   15.784   m  |
 |                                                        |
 | The NAD_83 (2011) VELOCITY of the monument is the same as that for the ARP. |
 |_____|
```

Figure 9-10: Example of a CORS coordinates page showing reference to the CORS monument

One way to tell which coordinates OPUS uses is to click on the CORS icon on the map (e.g. Manager's Page): the information bubble will reveal which is the reference point used. The example below shows information bubbles for two different CORSs in the project, one referencing the MON (GODE) and the other referencing the ARP (HNPT):
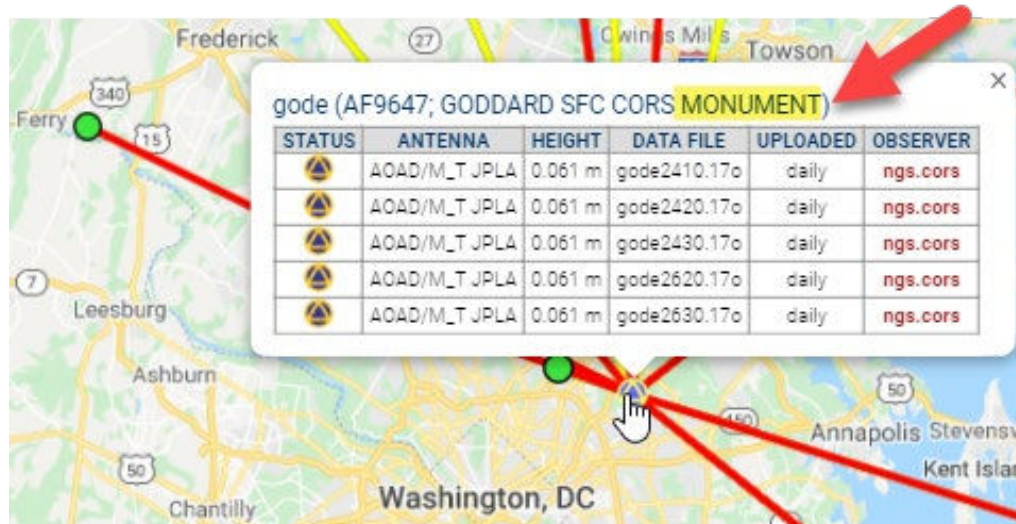
Figure 9-11: Example of a CORS position referencing the monument
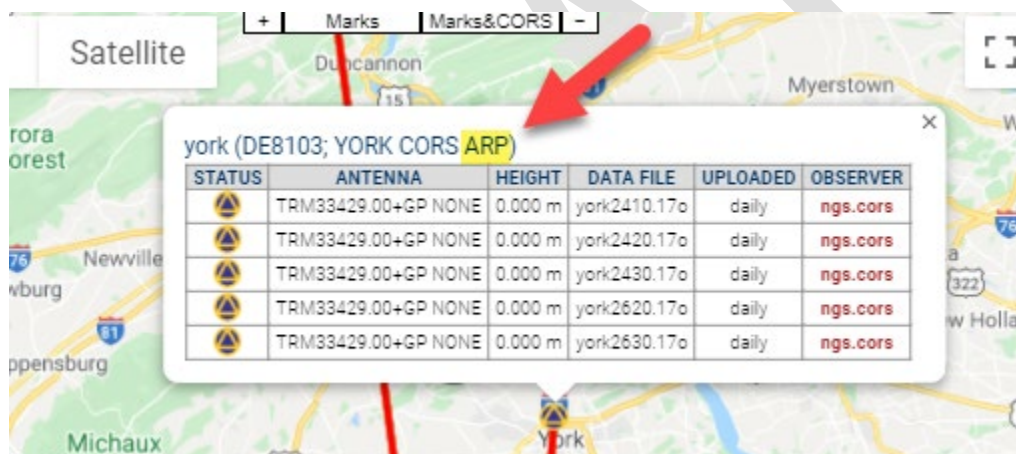
Figure 9-12: Example of a CORS position referencing the Antenna Reference Point (ARP)

The best CORSs have network accuracies estimated to be less than 3 cm in ellipsoid height and 1.5 cm horizontally (95% confidence). Network accuracies are given on the datasheet for the given CORS. Note: some CORSs have very poor network accuracies (on the order of several cm). Such CORSs should be *avoided* for use as control whenever possible.

```
PROGRAM = datasheet95, VERSION = 8.12.5.6
Starting Datasheet Retrieval...
1       National Geodetic Survey,   Retrieval Date = MARCH 16, 2020
 DH7954 ****************************************************************************
 DH7954  CORS         -  This is a GPS Continuously Operating Reference Station.
 DH7954  DESIGNATION -  LOYOLA 8 COOP CORS ARP
 DH7954  CORS_ID      -  LOY8
 DH7954  PID          -  DH7954
 DH7954  STATE/COUNTY-  VA/SPOTSYLVANIA
 DH7954  COUNTRY      -  US
 DH7954  USGS QUAD    -  FREDERICKSBURG (2019)
 DH7954
 DH7954                       *CURRENT SURVEY CONTROL
 DH7954  _____
 DH7954* NAD 83(2011) POSITION- 38 16 58.69166(N) 077 27 09.46858(W)   ADJUSTED
 DH7954* NAD 83(2011) ELLIP HT-    -4.910 (meters)          (06/??/19)   ADJUSTED
 DH7954* NAD 83(2011) EPOCH   -   2010.00
 DH7954  _____
 DH7954  GEOID HEIGHT     -       -32.537 (meters)                      GEOID18
 DH7954  NAD 83(2011) X   -   1,089,063.552 (meters)                    COMP
 DH7954  NAD 83(2011) Y   -  -4,893,299.381 (meters)                    COMP
 DH7954  NAD 83(2011) Z   -   3,930,144.035 (meters)                    COMP
 DH7954
 DH7954  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 DH7954  Standards:
 DH7954       FGDC (95% conf, cm)     Standard deviation (cm)    CorrNE
 DH7954          Horiz  Ellip         SD_N   SD_E   SD_h       (unitless)
 DH7954  ----------------------------------------------------------------
 DH7954  NETWORK   0.15   0.34        0.05   0.07   0.17       -0.26823100
 DH7954  ----------------------------------------------------------------
 DH7954
```

Figure 9-13: CORS network accuracy shown on the station's datasheet

9.2.2 Distance Considerations:

a) Ideally, at least 4-5 CORSs will meet the above characteristics and all lie within 250 km of the center of the project area. These CORSs will be used to control the project.

b) One of these CORS will also serve as the "hub," meaning that the CORS is preferentially selected for inclusion in baselines. In other words, all marks (user marks and CORSs) that are *not* hubs will have a direct baseline connection to the nearest hub. The hub should be centrally located, and lie no more than 100 km away from all user marks in a session. Often, a single station can serve as the hub for the entire project. However, if the project spans large distances such that the 100 km rule cannot be maintained, then multiple hubs will be needed. The same station(s) serving as hub(s) should be designated in each session (see Section 10).

c) At a very minimum, there should be one hub and at least one other CORS controlling the project. If there are not enough stations meeting the criteria explained in the steps above, the user will have to look outside the 250 km radius.

d) For tropospheric decorrelation, a distant CORS lying >250 km, but < 800 km is required. The same characteristics as above hold.

Figure 9-14: Example of CORSs plotted with respect to a 250 km radius from the centroid of the project
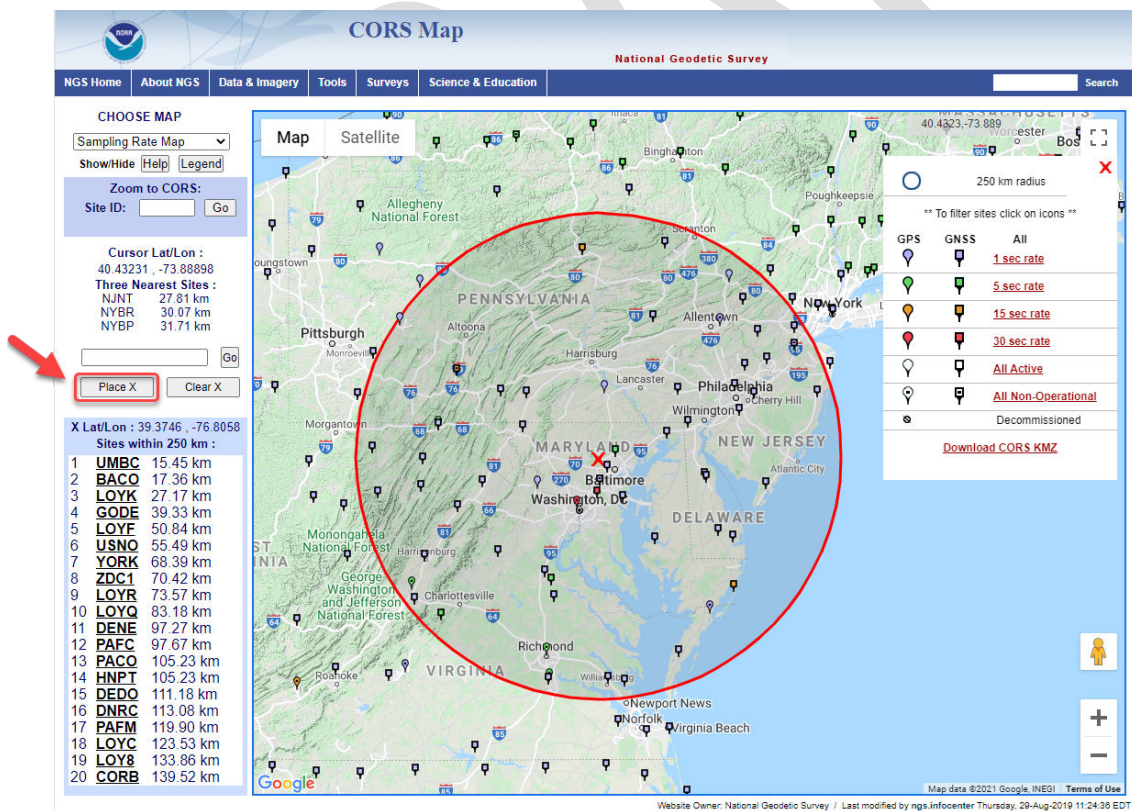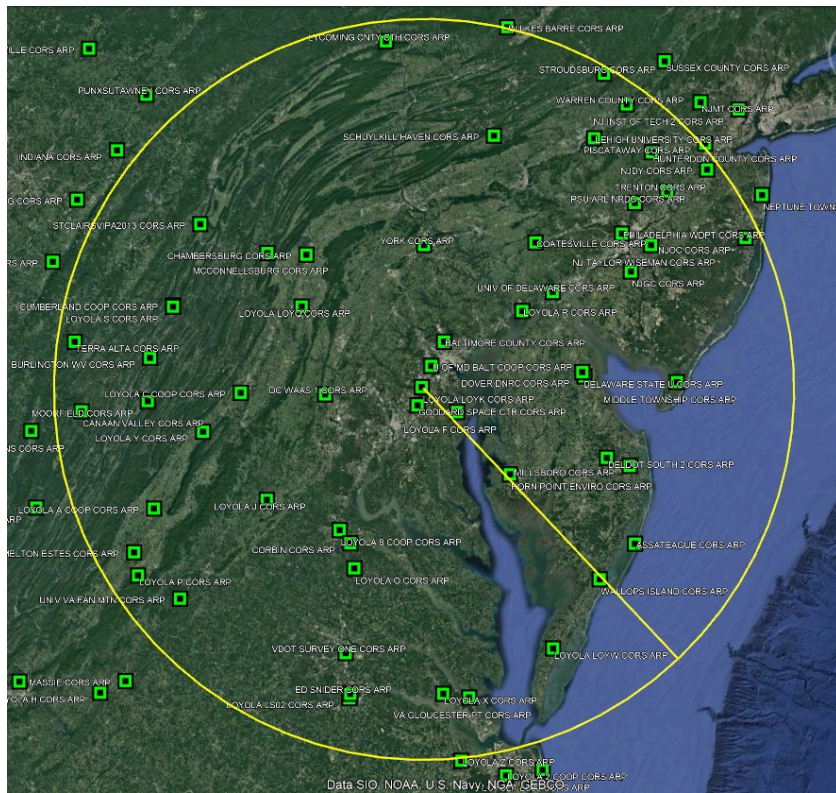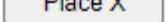
Figure 9-15: CORS map showing CORSs plotted with respect to a 250 km radius from the centroid of the project

- Draw a 250 km radius circle around the center of your project area using the [Place X] button on the NGS CORS Map. Candidate CORSs within the circle could serve as project CORS including the hub during session processing. Plan which CORS will function as the hub for each session. Often, a single station can serve as the hub for the entire project. At a very minimum, there should be one hub and at least one other CORS controlling the project. If there are not enough stations meeting the criteria explained in the steps above, the user will have to look outside the 250 km radius. If the project spans a large area (e.g. more than 500 km), you may need to draw 250 km circles at opposite ends of the project area, and choose more than one hub.
- Stations outside the 250 km radius, up to 800 km. can serve as the "distant" CORS. Distant CORS should not be held as control; rather, they are used to de-correlate the wet component of the tropospheric delay modeling within OP. Consider choosing an IGS station within this zone.

> Due to lack of CORS availability in remote locations, it may be necessary to choose a long distance CORS that exceeds the 800 km distance recommendation

> ⚠️ OP will automatically suggest a CORS to be used as a hub. In most cases, this hub will meet the recommended selection criteria

9.2.3 Data Quality Check

Once a list of candidates has been compiled, download and save their short-term time-series plots. NGS produces these plots for every CORS, but only provides to the public the most recent 90 days. It is best practice to download these plots about 45 days after the middle session of the survey project. In this way, the time-series plot is now "centered" over the time period of the survey project.

> ⚠️ If using OP to process data more than 90 days old, the user will not have access to the corresponding CORS short term plots, and will have to use alternative methods to evaluate short term CORS behavior (e.g. download daily files from the CORS web page)

- Using the centered time-series plots, select the candidates with RMS (in northing, easting, and up) less than 2 cm. Candidates with large spikes, data gaps, or discontinuities should be rejected. Selecting candidates in this manner will provide some assurance that the published coordinates and velocities at the CORS are in agreement with the daily solutions for the CORS.
- The best CORSs should have "consistent" data depicted in 90-day short-term time-series plots. NGS processes each day of GNSS data collected at each CORS and plots the differences between the resulting coordinates and the published coordinates on short-term time-series plots (in terms of delta northing, easting, and up). These plots can be accessed for every CORS at: https://www.ngs.noaa.gov/CORS/coord_info/plots.shtml. CORS with plots that depict significant biases from the published coordinates (more than 2 cm in northing, easting, or up), spikes, or data gaps should be avoided.
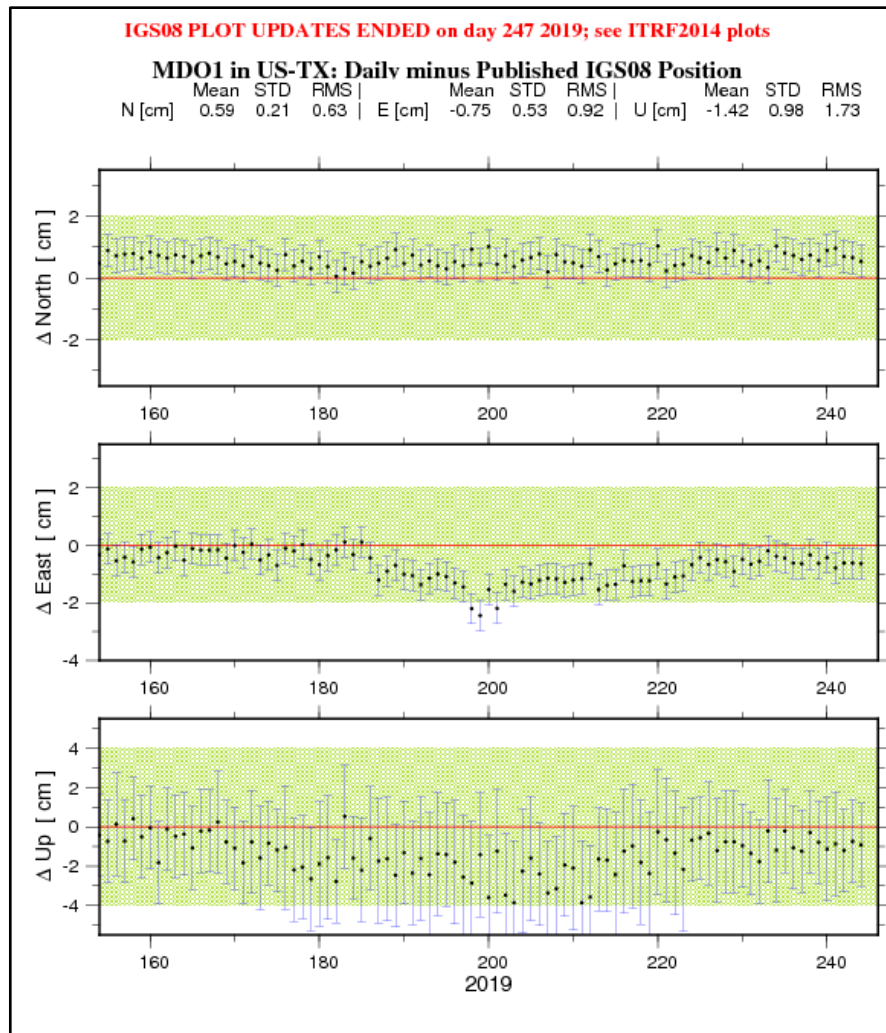
Figure 9-16: Example of a CORS short-term plot showing both bias and random error

A 90-day short-term time-series plot for CORS MDO1 is shown in the figure above. The solid red horizontal line represents zero deviation from the published coordinates (northing, easting, up). The black dots (with error bars) represent the residual difference between the daily solution and the published coordinates at the CORS. In this example, scatter and residuals are negatively biased in the up direction, evidence that the published coordinates are somewhat higher than the daily solutions. It also shows some deviation in the easting around Julian day 200 (July 19), indicating this CORS would not be reliable as control during that time. The mean, standard deviation (STD), and root-mean-square error (RMS) of the daily residuals depicted in this figure (in northing, easting, and up) are also provided as text at the top of the figure; these statistics are helpful for summarizing the repeatability of the data for the CORS.

Below is an example of a short term CORS plot for MNBV which shows less bias and lower error, especially in the up direction:
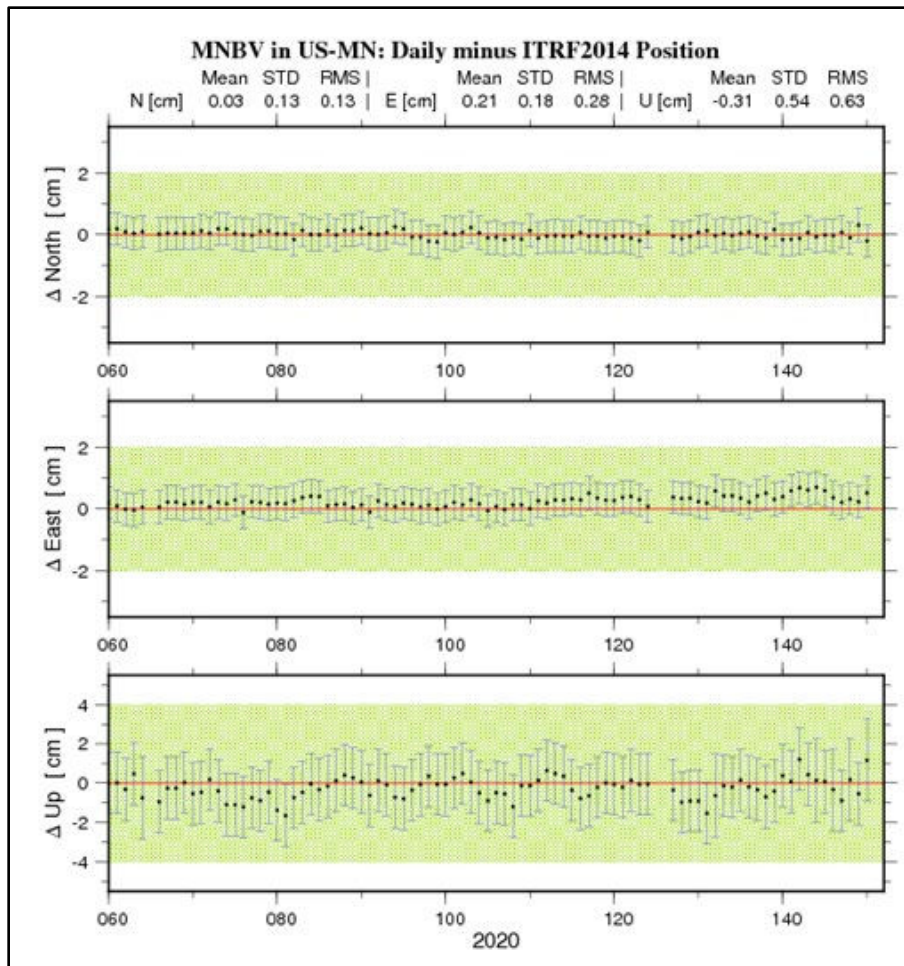
Figure 9-17: Example of a short-term CORS plot exhibiting little bias and low error

9.2.4 Select the Hub

From within the 250 km radius of the user marks, select one candidate to function as the hub for each session. In most cases, the same hub should be used for every session in a survey project. It must be within 250 km of all user marks in the session. Note that for large survey projects where the user marks cover an area greater than 500 km in diameter, it may be necessary to designate more than one CORS to function as a hub for a particular session.

> If questions remain about the suitability of CORS/IGS stations in a given region, consider reaching out to your NGS Regional Geodetic Advisor for guidance

As part of the error-reducing post-processing of GNSS data using the CORS, the moisture content of the troposphere through which the GNSS signals traverse needs to be modeled. The tropospheric model is parameterized using information from the CORSs selected to control the project. If most CORSs are located close to the project, the GNSS signals are all altered/delayed by the same amount, since they all see essentially the same troposphere. This can cause biases in the tropospheric model. This bias can be removed by including a distant CORS in the project.

Therefore, the user must select one distant CORS for tropospheric decoupling (>250 km, but ≤ 800 km). Typically only one distant CORS is needed. Similar rules apply to selecting this CORS as with the other CORSs selected in the project. In addition, it is recommended to verify that there wasn't any extreme weather at this distant CORS (i.e., lightning storms, hurricanes) by checking weather data in that area coinciding with the dates and times of the survey. Extreme weather or passing weather fronts can adversely affect session baseline processing solutions.

In CORS-sparse areas, baselines may be longer by necessity, which may satisfy the tropospheric modelling without having to add an additional long-distance CORS. Likewise, if a network spans more than 250 km a long distance CORS may also be unnecessary.

> The "distant CORS" can either be part of the NOAA CORS Network, or an IGS station available in OP

Once you have selected the CORSs for your project (typically about 4 or 5, plus the distant CORS), it is a good practice to remove the remaining (unwanted) CORSs from your project. That way, no one will be confused regarding which CORSs were intended for project control.

9.3 Add/Del CORS

After selecting the CORSs for your project, you will want to make them available to all sessions. You can do this by adding (and deleting) CORSs from the Manager's Page, as explained in Section 7.1.7.
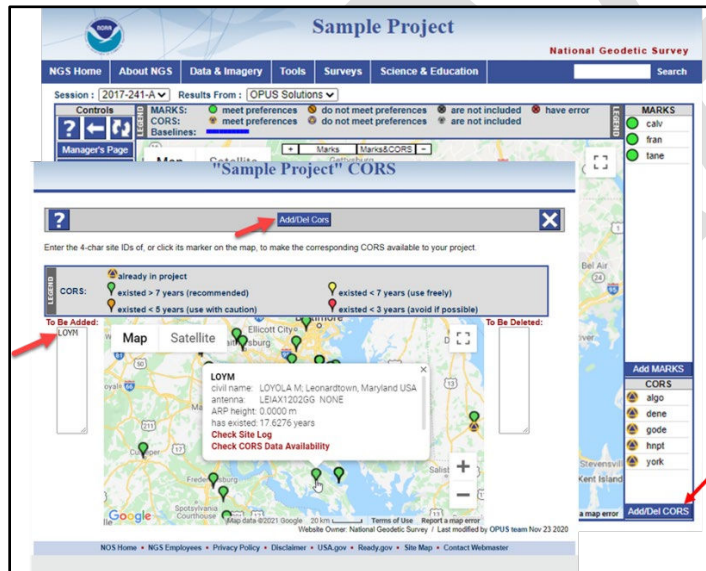
Figure 9-18: Screen captures showing the steps used in adding a CORS from the Manager's Page (see 7.1.7)

10 Session Processing

Session processing is the critical step in which the processor implements the GNSS survey network design. Session Processing calculates the baselines between the hub(s) and the user marks. In addition, a variance-covariance matrix is produced estimating the errors associated with the baselines, and their correlations. Finally, a minimally-constrained adjustment is applied to align the baselines to the NSRS at the hubs.

The Session Network Design default can be changed at processing and, to a limited extent, modified by selecting user marks to be excluded from the processing or to be assigned as hubs. You can only process baselines for marks or hubs that have been simultaneously occupied. The term "hub" means a mark that is preferentially selected for inclusion in baselines. In other words, all marks that are *not* hubs will have a direct baseline connection to the nearest hub.

Session processing leverages common satellite observations and error estimations. As a result, some marks that did not meet project preferences in the initial OPUS solution, may now meet project preferences under session processing. However, care should be taken in including poor observations, as they are likely to degrade the quality of the overall session processing. See Section 4.3 for more information on project preferences.

Session processing can be done as soon as all the data for a given session have been loaded. If additional data for a session come in after that session has already been processed, the session will have to be reprocessed with all of the data. You may want to process the first session and review the results before processing subsequent sessions. This can help avoid confusion regarding which session is being analyzed.

> ⚠️ For publication, NGS required that the "final precise" ephemerides be used in processing

10.1 Session Processing Page

The Session Processing Page is accessed from the individual session pages:

Figure 10-1: Accessing the Session Processing Page

Figure 10-2: Example Session processing page

The SOLUTION NAME is set by default to a letter corresponding to the numerical sequence of the session in a given GPS UTC day. The first session in the day will be assigned the letter "A," the second "B," and so on. The solution name can be changed, although that is not generally recommended (recall that the session name cannot be changed).

The SOLUTION SPAN provides the start and stop times for the session in UTC.

The MARK and CORS tables have the same elements:

- Four-character ID, and whether the mark or CORS has met project preferences
- Whether or not the mark/CORS is selected as a hub
- Whether or not the mark/CORS is selected as a constraint. This means that one or more of the coordinates are held fixed within the adjustment ("fixed" within the selected constraint weights provided in the project preferences). There are three options:
  - 3D: this is a full geometric constraint, holding latitude, longitude, and ellipsoid height fixed (within the selected type of constrained weights).
  - HOR-Only: only the latitude and longitude being constrained
  - VER-Only: only the vertical coordinate (height) is constrained.
- Where the height value is coming from:
  - EL HGT can come from the first session processed, or a published datasheet value

- o GEOID refers to the orthometric height, regardless of the source of that orthometric height (GNSS-derived or leveling-derived).
- Latitude (degrees, minutes, seconds)
- Longitude (degrees, minutes, seconds)
- Processing Preferences: these correspond to the values selected in the Project Preferences (Section 4.4). Network Design is explained in the next section.

10.2 Selecting the Session Network Design

The Network Design selection is identified at the bottom of the session processing page, and the expression of the design can be seen in the table listing the marks and CORSs (which are used as hubs, and which are constrained). There are three options available: "USER," "CORS," and "MST."

Figure 10-3: Example session processing page noting the one hub constrained 3D under "User" selected network design

USER: The default (and design recommended for submission to NGS) is "USER." OP attempts to choose the best hub from the list of CORSs selected for the project. This is typically the closest and/or most centrally located CORS with respect to the user marks. If OP does not select a hub, or if the user disagrees with the hub selection, a new hub will have to be chosen manually. As mentioned in Section 9, certain larger projects may

require multiple hubs if user marks are separated by 500 km or more. If multiple hubs are necessary, then each session's hub must connect to all other hubs. In other words, each hub should be present in all sessions. Note that a hub can also be an active (non-CORS) station if it has 24-hour data files.
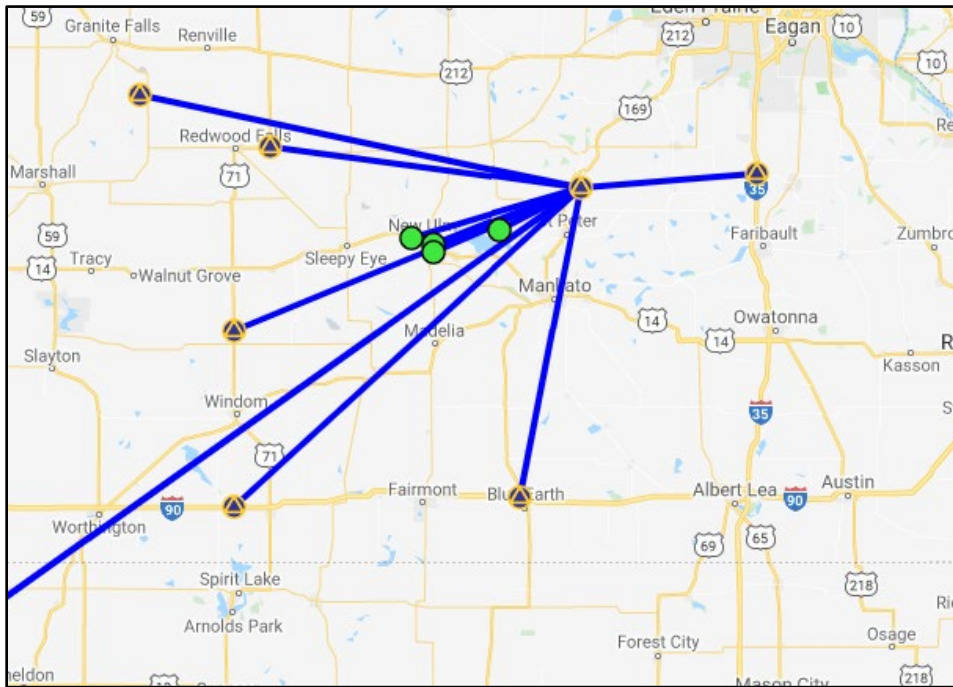
Figure 10-4: Map showing an example of the "hub-and-spoke" network design

> ⚠️ For submission to NGS for publication, NGS recommends a "hub" design that keeps baselines to a maximum of 250 km in length. For most projects, that will mean selecting one hub. For larger area projects, multiple hubs might be necessary

CORS: The CORS Network Design strategy automatically selects all included CORS as hubs. Note that this is not an acceptable design for submission to NGS.
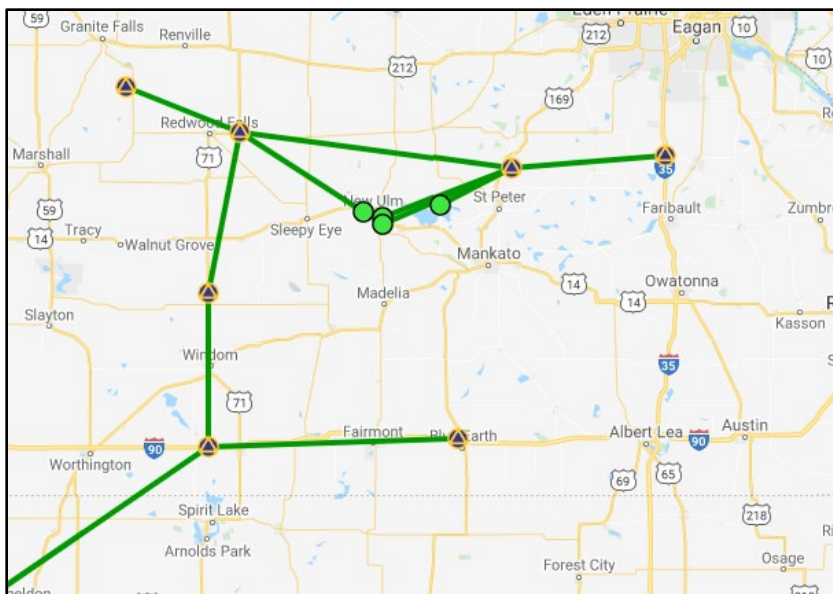
Figure 10-5: Map showing an example of a "CORS" network design

MST: A Minimal Spanning Tree (MST) connects all the user marks and CORS together seeking the fewest and shortest possible unique baselines. All user marks and CORS are designated as hubs. Note that this is not an acceptable design for submission to NGS.
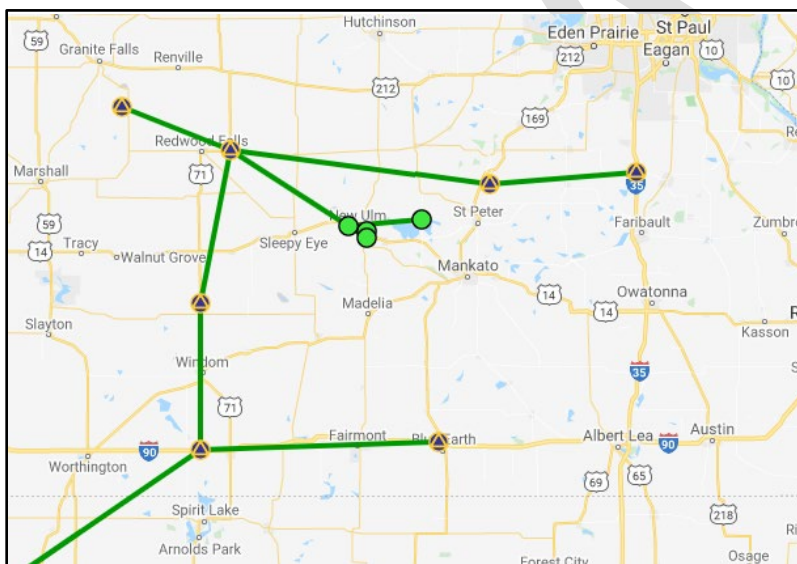
Figure 10-6: Map showing an example of a "MST" network design

⚠️ For any selected design, there is a limit of 99 marks including CORSs/IGS stations *per session*

10.3 Selecting the Constraints

For session processing, NGS recommends <u>constraining only the hub</u> in all three dimensions ("3D" - latitude, longitude, and ellipsoid height). All other CORSs are unconstrained, as are all user marks. If a mark is selected as

a constraint, the coordinate fields in OP become editable, but note that NGS does not recommend altering any coordinate except under exceptional circumstances.

⚠ NGS does not recommend altering any coordinates during session processing

10.4 Processing Preferences and Performing the Processing

Besides network design, other processing preferences need to be carefully considered prior to performing the processing. Please refer to Section 4.4 for more information. Briefly, the recommended preferences include:

- Solution Name (30 char max): OP always identifies solutions according to the session name (e.g. "2020-123-A" see 7.1). A session can be processed multiple times, resulting in multiple solutions for any given session. However, if the solution name is not changed, each new solution will overwrite the previous one. To avoid confusion, it is recommended to append either a character/digit to the root of the session name, or a short ID like "test" or "final." For example, if the default session name is "2020-123-A," then the digits "1," "2,", "3," etc. can be added to differentiate the different re-processings. Final names would be "2020-123-A1," "2020-123-A2," "2020-123-A3," etc.).

Consider creating a session/adjustment log book to identify the choices/decisions made in each session/adjustment run

⚠ Only the first character of a solution name is retained in the output files needed for publication in the NGS database. Therefore, names like "A-test" and "B-test" will be differentiated as "A" and "B," but names like "Test-A" and "Test-B" will be treated as the same solution "T."

⚠ If the session default letter is changed, the "Occupations" table on the Manger's Page will show you BOTH the OPUS solution and the session solution, which can cause confusion.

- Output Reference Frame: LET OPUS CHOOSE (this will ensure the latest supported reference frames)
- Output Geoid Model: LET OPUS CHOOSE (this will ensure the latest geoid model)
- GNSS: G (GPS only)
- Tropo Model: Piecewise Linear
- Tropo Interval (s): 7200
- Elevation Cutoff (deg): 15
- Constrained Weights: NORMAL
- Network Design: USER

When the user is satisfied with the network design and the selection of constraint(s), click the "Perform Processing" button on the top banner.
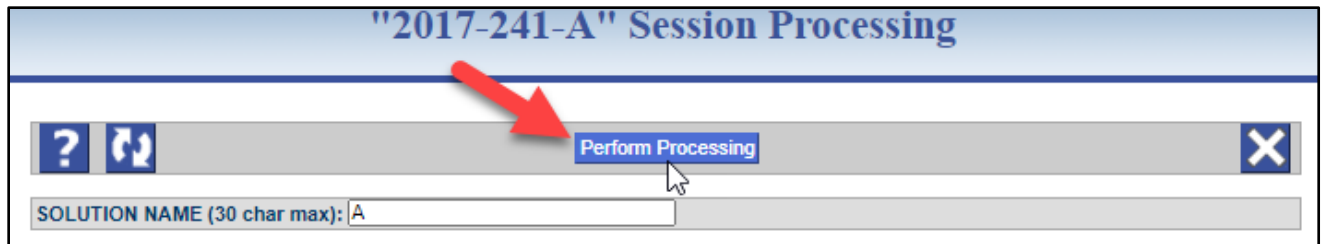
Figure 10-7: The "Perform Processing" button at the top of the Session Processing Page

A confirmation screen will be presented. Examine the confirmation screen to verify that it reflects your intended choices.
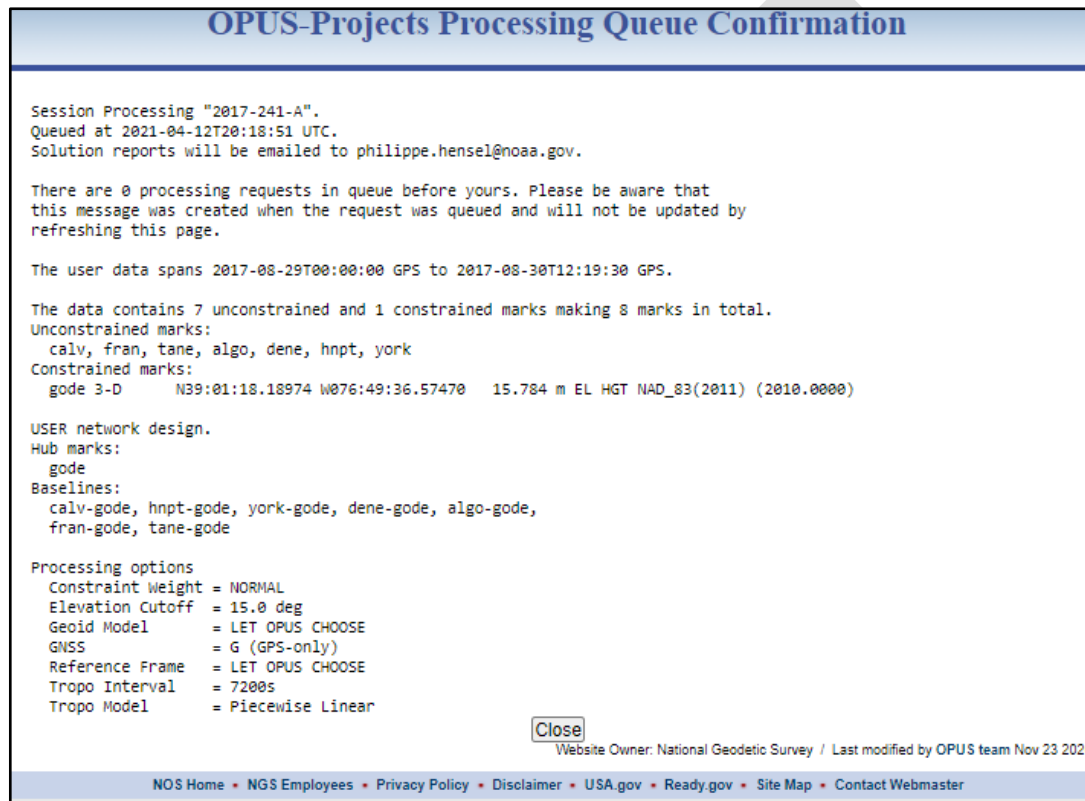
Figure 10-8: The OP Session Processing confirmation window

A short time later (possibly a few minutes[3], depending on the number of baselines to be processed and given the current traffic using OPUS and OP), baselines will appear on the Session and Manager's Pages:

---

[3] An analysis of over 10,000 files uploaded revealed that less than 0.03% of files uploaded took longer than an hour to process. If a solution has not arrived within an hour, contact the OPUS Projects Team.
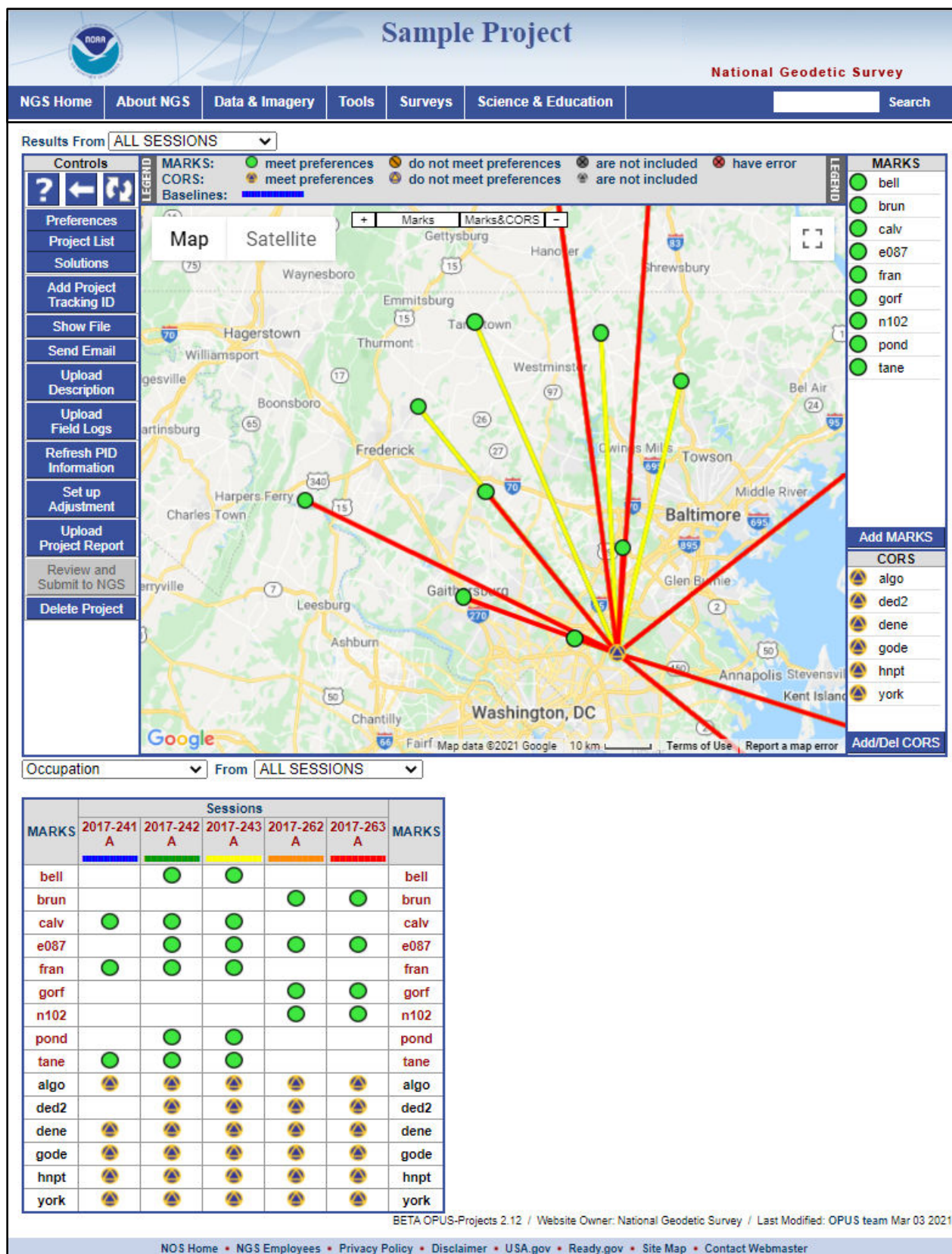
Figure 10-9: Manager's Page showing six successfully processed sessions

10.5 Where to Look for Your Results

OP provides a number of output files containing important information about the results of session processing. There are several ways to access these results.

10.5.1 Email Attachments

Once the processing has been completed, an email with the solutions will automatically be sent to the email address of the person running session processing as well as the project manager.
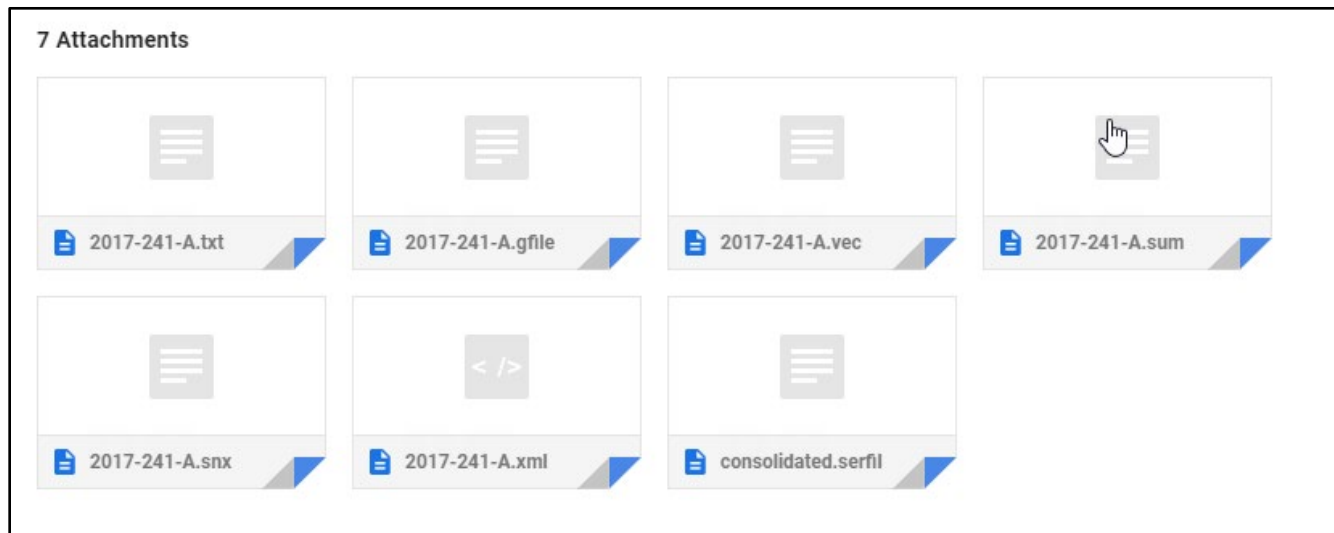
Figure 10-10: The seven email attachments (sent to the project manager) resulting from session processing

For completeness, the seven different attachments provided as a result of session processing are given below:

● .txt file provides the Processing Report. Note that the coordinates are clearly labeled in both the NSRS reference frame and the global reference frame (ITRF). More on how to interpret the Processing Report can be found in Section 10.3.6.
● .gfile is the bluebook **G-file**, is an ASCII text file containing vector components, standard deviations, correlations, and processing information, in standard NGS "Bluebook" format (https://geodesy.noaa.gov/FGCS/BlueBook/pdf/Annex_N.pdf)
● .vec file, showing vectors between user marks/CORS and the hub(s) (delta X, delta Y, delta Z and their associated uncertainties)
● .sum file provides all the details of session processing
● .snx file gives the GNSS solution in **SINEX** format (Solution INdependent EXchange format -an internationally accepted GNSS solution format)
● .xml gives the session processing results (like the .sum file) expressed in an XML format
● .serfil - associates the Mark ID (or Station ID for CORS), SSN, and PID (if it exists) of each Mark/CORS

10.5.2 Show File

All output files can also be reviewed within OP by selecting the "Show File" button under the Controls menu in both the Manager's Page and in the individual mark pages (see Section 7).

See Section 10.4 for more information on reviewing the Processing Report.

10.5.3 Session Pages

Some session solution information is displayed on the individual session pages. Session pages can be accessed from the Manager's Page by showing "Results from" → ALL SESSIONS (see below):
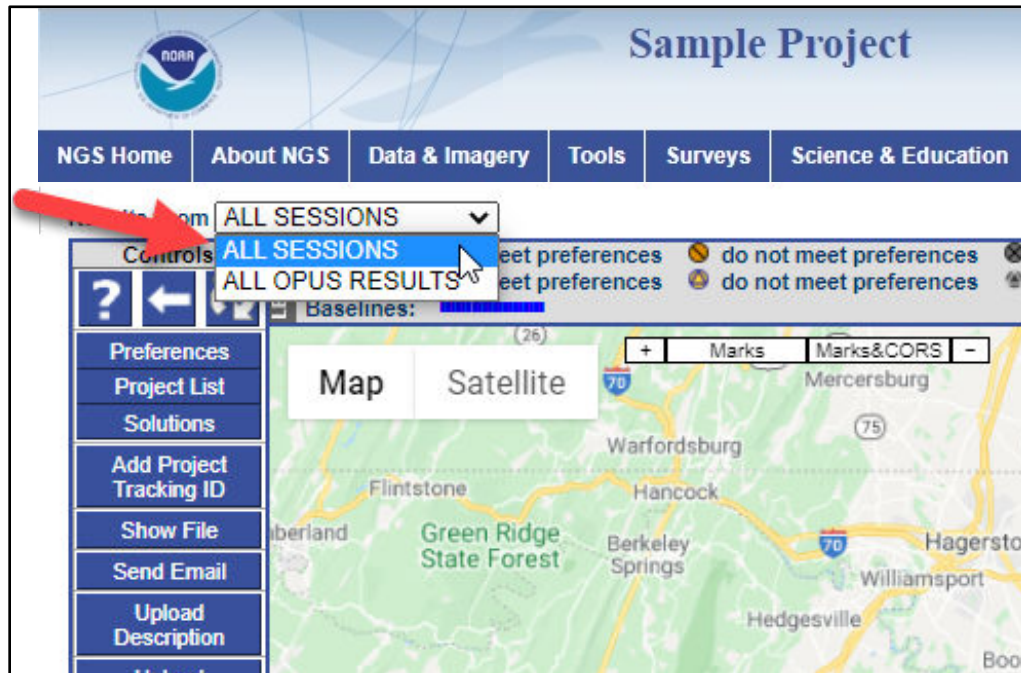
Figure 10-11: Select "ALL SESSIONS" from the Manger's Page to reveal the results of any/all session processing

Selecting "ALL SESSIONS" will refresh the Manager's Page showing the results of any/all session processing.

Figure 10-12: Clicking on the session of interest in the "Occupation" table showing "ALL SESSIONS" will open the session page

Click on the session of interest. In the example above, we have selected session "2017-241-A." This will cause the Session Page to refresh, showing the mark and observation information for that particular session:
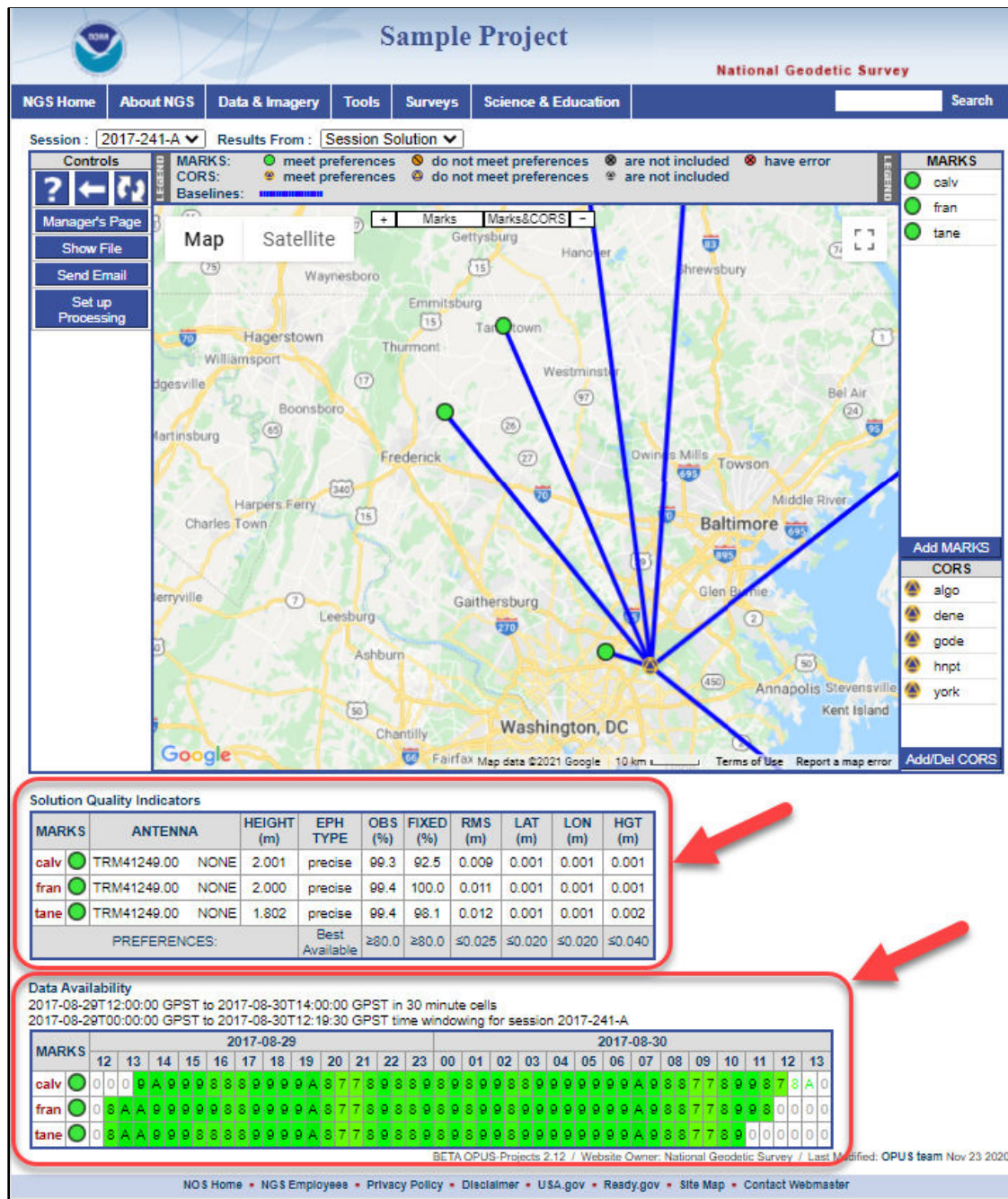
Figure 10-13: Mark information displayed on at particular session page

The Solution Quality Indicators (upper arrow) provide some indications of the quality of the solution, and whether or not the Solution Preferences have been met. The Data Availability graphic (lower arrow) should confirm the session span, as well as satellite tracking.

Although these visualizations offer a quick and easy way to assess solution quality, they do not provide much detail on how the data actually fit together, and for larger projects, may be cumbersome to review.

10.5.4 Mark Pages

Solution visualizations are also given in plots and tables under the individual mark pages (mark pages can be accessed from either the Manager's Page or a Session Page). Make sure the correct session is displayed (see arrow in figure below):
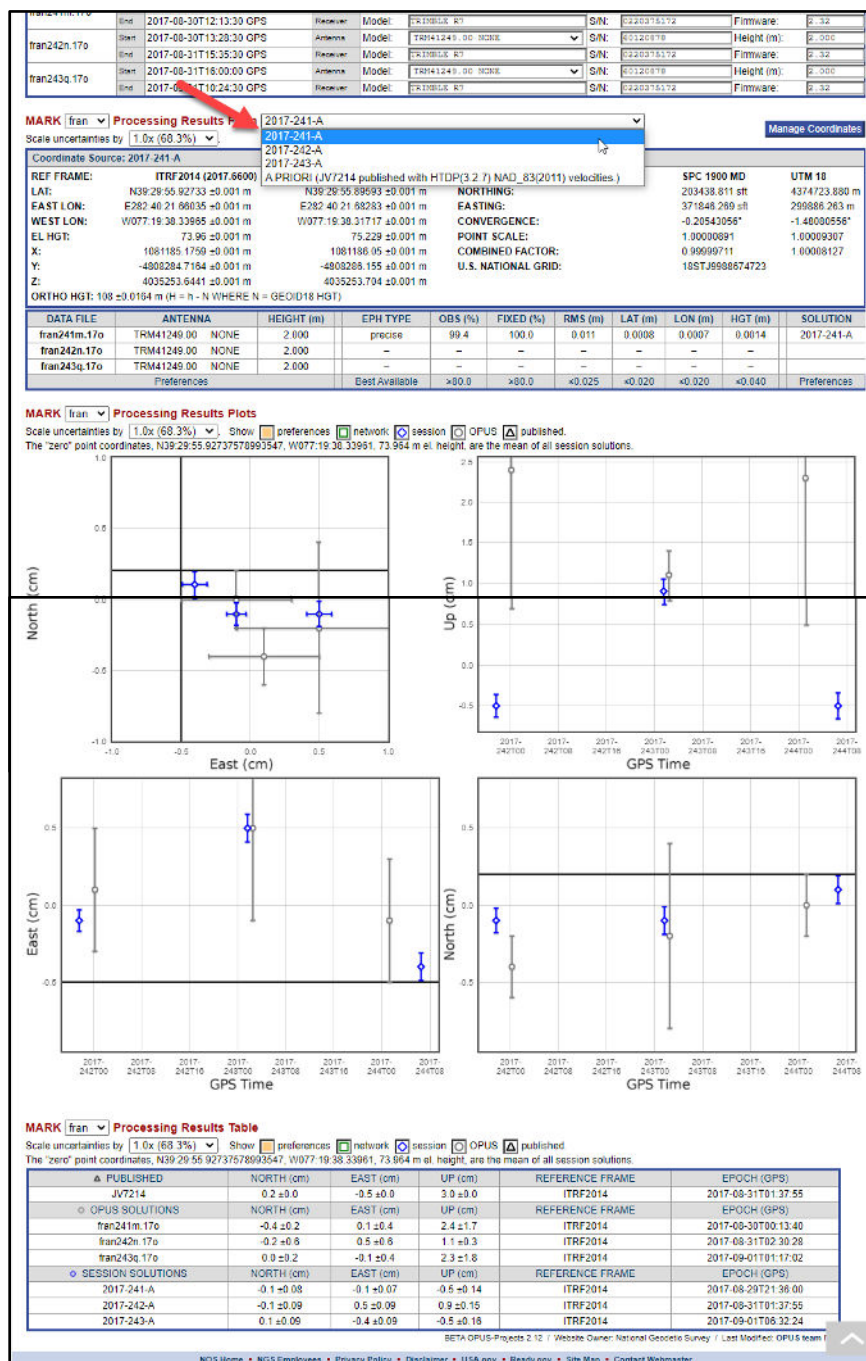
Figure 10-14: Session results presented on a mark page

The Processing Results Plots and Processing Results Table show the **a priori coordinate shifts** which result from the session processing (see Glossary for more information on a priori coordinates). **The shifts should be small**.
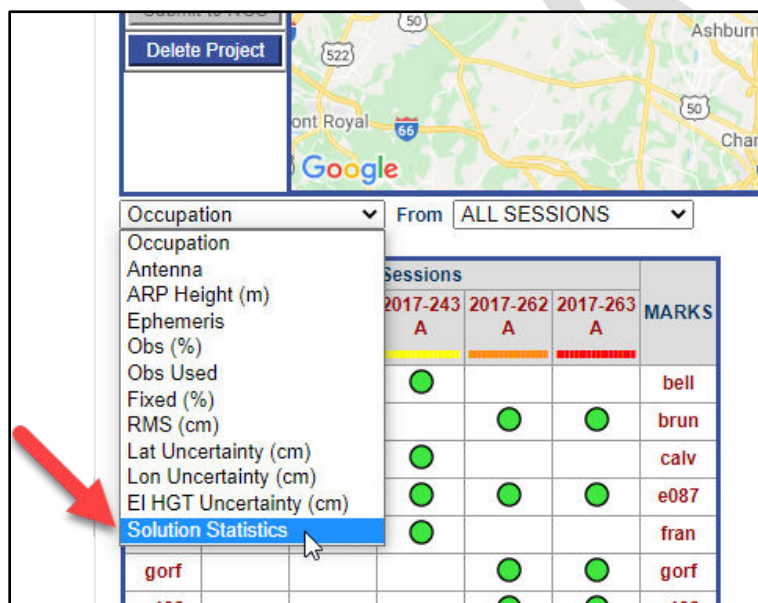
The default uncertainties shown are one sigma (68.3%); the user can select up to 5σ. The symbols in the plot refer to the different sources for the coordinates:

Orange shaded areas indicate where results that fail to meet project preferences will appear

Gray circles are used for OPUS solution results

Blue diamonds are used for session processing solution results

Green squares are used for network adjustment results

The plots are interactive and the axes scale automatically. Moving the cursor over a point causes the point to be accentuated and an information bubble to appear providing information about the point and identifying its source solution. The plots also interact with the Processing Results Table. Moving the cursor over a table row causes the corresponding point in the plots to be accentuated. For small projects, these visualizations may be sufficient, but for larger projects, the more detailed output files may be more efficient to assess solution quality.

10.5.5 Solution Statistics

Finally, once multiple sessions are processed, the user can see a summary of how the sessions compare by selecting "Solution Statistics" in the table under the map on the Manager's Page.

Figure 10-15: Session Solution Statistics are available from the Manager's Page

MARKS	occupations count	occupations used	solutions count	Obs Used	Obs Used(%)	AMB Fixed(%)	North P2P(cm)	East P2P(cm)	Up P2P(cm)	MARKS
bell	2	2	2	35269	98.3	93.0	0.2	0.1	0.4	bell
brun	2	2	2	39592	98.6	95.0	0.3	0.2	0.6	brun
calv	3	3	3	48146	99.5	87.7	0.4	0.3	2.7	calv
e087	4	4	4	66472	93.7	92.8	0.7	0.7	1.4	e087
fran	3	3	3	41384	99.4	96.7	0.3	1.0	1.4	fran
gorf	2	2	2	39025	98.4	96.5	0.0	0.2	0.8	gorf
n102	2	2	2	38039	99.2	96.2	0.2	0.2	1.4	n102
pond	2	2	2	35522	97.9	93.1	0.2	0.2	0.6	pond
tane	3	3	3	45092	99.2	91.4	1.7	0.4	0.5	tane
algo	5	5	5	104788	99.8	99.4	0.44	0.58	1.23	algo
ded2	4	4	4	86889	93.5	96.3	0.22	0.48	1.08	ded2
dene	5	5	5	99652	99.5	92.2	0.36	0.93	1.53	dene
gode	5	5	5	902012	98.1	96.0	0.06	0.1	0.02	gode
hnpt	5	5	5	111563	99.6	98.7	0.33	0.14	0.8	hnpt
york	5	5	5	110579	98.7	99.0	0.28	0.34	1.01	york

Figure 10-16: Example of session solution statistics

> Users can copy and paste the Solution Statistics table into a spreadsheet and thence sort by columns to discover where the largest errors reside

> For larger projects, it may be more efficient to analyze the output files instead of the visualizations provided within OP

10.6 Analyzing the Processing Report

The most thorough approach to evaluating the results of session processing is to look at the Processing Report available through the "Show File" button on the left tool bar.
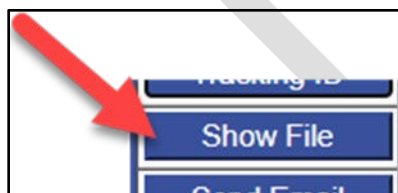
Figure 10-17: The Show File button on the Manager's Page controls bar

Figure 10-18: Example of a session solution processing report (.txt file)*

Critical items to check are the following:

- **The STANDARD ERROR OF UNIT WEIGHT should be near 1.0**. The acceptable range is 0.1 to 1.1. Differences are tolerable, but be wary of order of magnitude differences: 0.725 is OK, but 7.25 and 0.072 are not!
- The **TOTAL NUMBER OF MARKS** should be what the project manager expects.
- Under session processing, only the hub(s) should be constrained (**CONSTRAINED MARKS**: 1).
- **OVERALL RMS should be small** and less than the project preference threshold (typically ≤ 3 cm).
- **START TIME** and **STOP TIME** should be as expected
- The **OBS** count (number of observations used) should be near the expected number, based on the duration of the observation.
- **OMITTED** (% observations omitted), and **FIXED** (% ambiguities fixed) should all reflect project specifications
- **The A PRIORI COORDINATE SHIFTS should all be small** (≤ 2 cm horizontal, ≤ 4 cm vertical).

The table of a priori coordinate shifts ("MARK ESTIMATED - A PRIORI COORDINATE SHIFTS") provides critical information on how the adjustment may have changed an assumed coordinate (on both survey marks and CORSs). Often, a large coordinate shift may result from poor a priori coordinates stemming from the first OPUS solution (see Glossary for more information on a priori coordinates, and Appendix C for coordinate shifts). A large shift might also be due to a bias at a CORS station. The user might want to remove that CORS from the list, and reprocess without that reference station. If there are no other large shifts remaining, that CORS should likely be excluded from all sessions. However, in some instances, the source of large shifts may remain elusive. Larger than recommended shifts may be fine if the peak-to-peak values (seen after multiple sessions are processed) are small (see 10.5.5).

> ⚠ In session processing, peak-to-peaks are a measure of repeatability among your replicate observations (how closely the session solutions match each other). Coordinate shifts indicate how those solutions compare to the a priori coordinates. For published stations, this could indicate a bias in your data, but also possibly a bias in the published coordinate. Only by running repeat session solutions (changing/removing CORSs, stations, or observations) can you attempt to locate the source of any disagreement

10.7 Analyzing the Solution Statistics for ALL SESSIONS

When multiple sessions have been processed, the **Solution Statistics** (FOR ALL SESSIONS), available at the bottom of the Manager's Page, should also be analyzed (Figure 10.19). This same pull-down selector gives access to convenient information in a tabular form. These tables can be highlighted and copy/pasted into spreadsheets or documents.

MARKS	Solution & Statistics									MARKS
	occupations count	occupations used	solutions count	Obs Used	Obs Used(%)	AMB Fixed(%)	North P2P(cm)	East P2P(cm)	Up P2P(cm)	
bell	2	2	2	35269	98.3	93.0	0.2	0.1	0.4	bell
brun	2	2	2	39592	98.6	95.0	0.3	0.2	0.6	brun
calv	3	3	3	48146	99.5	87.7	0.4	0.3	2.7	calv
e087	4	4	4	66472	93.7	92.8	0.7	0.7	1.4	e087
fran	3	3	3	41384	99.4	96.7	0.3	1.0	1.4	fran
gorf	2	2	2	39025	98.4	96.5	0.0	0.2	0.8	gorf
n102	2	2	2	38039	99.2	96.2	0.2	0.2	1.4	n102
pond	2	2	2	35522	97.9	93.1	0.2	0.2	0.6	pond
tane	3	3	3	45092	99.2	91.4	1.7	0.4	0.5	tane
algo	5	5	5	104788	99.8	99.4	0.44	0.58	1.23	algo
ded2	4	4	4	86889	93.5	96.3	0.22	0.48	1.08	ded2
dene	5	5	5	99652	99.5	92.2	0.36	0.93	1.53	dene
gode	5	5	5	902012	98.1	96.0	0.06	0.1	0.02	gode
hnpt	5	5	5	111563	99.6	98.7	0.33	0.14	0.8	hnpt
york	5	5	5	110579	98.7	99.0	0.28	0.34	1.01	york

Figure 10-19: Example solution statistics for all sessions

- Review the "peak-to-peak" ("P2P") values in the table for both the marks observed (given in **red**) and for the CORS (given in **black**). **Smaller is better.** See Glossary for more information on P2P. Values higher than those established in the project preferences should be investigated.
- Use the Session Solution "Summary" page for each session that has a mark or CORS with a high P2P to further investigate the cause of the high P2P.
- If you have high P2P values, drill down to the corresponding Mark Page to see what happened with that particular observation.
- If the user finds a blunder or other easily rectified error, then either that particular observation, or just the corresponding session will have to be reprocessed (depending on where the error lies, and whether it can be fixed within the project itself). Examples of blunders include wrong antenna type or wrong antenna height, as well as wrong association of the observation with its corresponding mark. Check the field logs to verify that the correct information has been entered regarding the corresponding observation(s).
- If the user cannot isolate the error, the user may decide to remove the mark from the survey. In that case, the corresponding session(s) will have to be re-processed.

> ⚠️ If removing an observation on a mark removes redundancy, NGS cannot accept only one solution on a mark (the user may want to re-observe)

Repeat Vectors Check (optional)

In smaller projects for which the single hub model is appropriate, the repeat vectors all emanate from that single hub. Therefore a simple cumulative tabulation of the *.vec results from the sessions can be assembled for manual inspection looking for repeat vectors which fall outside the manager's expected tolerances. This can be done by importing the data into a spreadsheet, or using third-party software. For larger projects, this is

cumbersome and should probably be left to the COMPVECS results produced later in network solutions (see Section 12.1).

10.8 Next Steps

Once the results of all session processing are carefully reviewed, and any errors fixed and sessions re-processed, the project is ready for network adjustment (Section 11).

> Once satisfied with the results of session processing, it is a good idea to delete any sessions that will not be included in the net steps of network processing. Having multiple copies of session processing can also affect "P2P" uncertainty estimates in Solution Statistics and render them unrealistic.

11 Network Adjustments

After completion of session processing, all sessions can be solved together in a Network Adjustment (available only from the Manager's Page), thus creating the final results from your project. Regardless of the final result intended, OP suggests the user begin with a minimally constrained adjustment, also called the "Preliminary Adjustment." This is an important Quality Assurance step for subsequent adjustments.

If the intent is to determine the best set of coordinates in alignment with the latest realization of the NSRS reference frame, including the option to submit to NGS, then a NGS Project Tracking ID must be entered. With a tracking ID, OP steps you through a series of sequential network adjustments using a combination of GPSCOM and ADJUST.

If the project's objectives do *not* include submission to NGS, then a project tracking ID is not required, and the user can run the final adjustment desired. As noted earlier, a dummy project tracking ID of 0000 can be used.
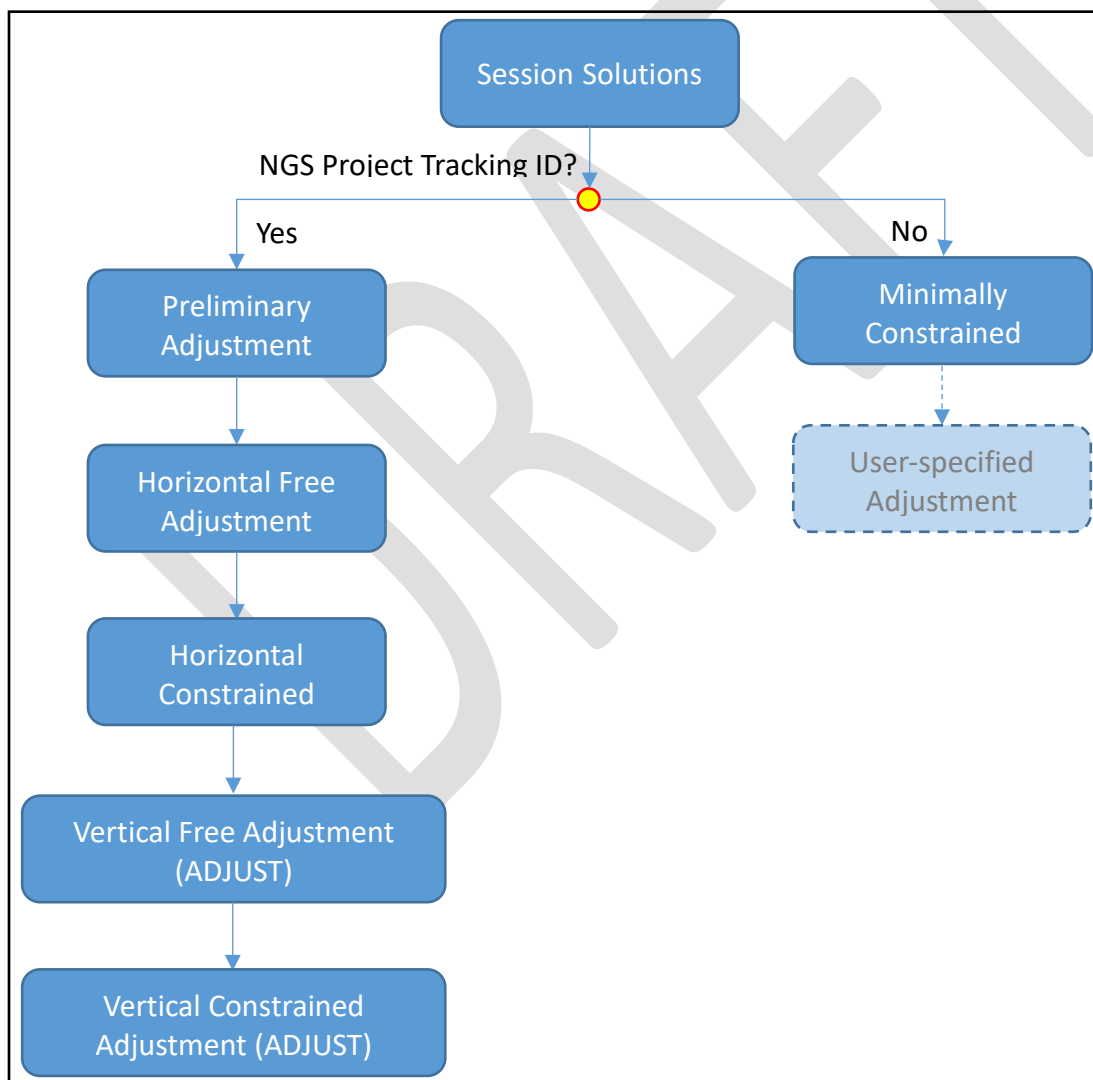
Figure 11-1: Conceptual work flow for running adjustments in OP

11.1 Recommended Network Adjustment Sequence for Alignment with the NSRS

A sequence of five (5) network adjustments ensures that your project is aligned with the NSRS both horizontally and vertically. These steps are automatically generated when a tracking ID is associated with the project and will enable the final coordinates to be consistent with the latest horizontal and vertical datums of the NSRS.

> ⚠️ A user may perform a similar sequence of network adjustments without associating a Project Tracking ID, but the corresponding constraints will have to be selected manually, and all solutions will be provided by GPSCOM instead of ADJUST.

> ⚠️ Although OP4.0 suggests the constraints to use in each adjustment, the user may select other constraints or modify the coordinates in accordance with the accepted Project Proposal. Deviations from the selections suggested by OP should be addressed in the final project report.

Preliminary Adjustment

To begin the network adjustment sequence, the software package GPSCOM is used to combine and adjust all selected sessions into a single network solution in the ITRF (and then transform it into the selected output reference frame; see Preferences Section 4.4). The output of this adjustment provides the necessary inputs for the ADJUST suite of programs in the following steps.

Horizontal Free Adjustment

This and the following three network adjustments use the program ADJUST, aligning the project with the NSRS. Although OP uses the term "horizontal" in reference to an adjustment, it is more correctly interpreted as "geometric," as all three geometric (lat/long/ellipsoid height) coordinates are involved. By constraining only one mark in 3-D, the adjustment allows the least squares solution the maximum freedom to help detect outliers and other problems.

Horizontal Constrained Adjustment

All marks with known geometric coordinates in the NSRS reference frame are constrained to those coordinates in 3-D. This forces alignment of the user marks in the project to the constrained marks. This is sometimes described as propagating the reference frame from the constrained to the unconstrained marks.

Vertical Free Adjustment

As with the horizontal free adjustment, the vertical free is a minimally constrained adjustment used for quality control. The adjustment aligns the marks to the vertical datum. Note that areas with little or no existing control in the appropriate vertical datum may be problematic, but can still be adjusted vertically. For such special situations, take the time to describe it in detail in your Survey Project Proposal.

Vertical Constrained Adjustment

This adjustment forces alignment of the constrained marks to the vertical datum and propagates the vertical datum to the vertical coordinates of the unconstrained marks.

11.2 Recommended Network Adjustment Sequence Without NGS Project Tracking ID

There are any number of reasons why a user may opt not to submit a campaign-style GNSS project to NGS. A project may lie outside the United States and its territories; a project may, for scientific reasons, prefer to be tied to the ITRF; alignment to the NSRS reference frame is not wanted; alignment to a local network/datum may be required, etc. Furthermore, GPSCOM attempts to resolve a larger number of error sources than ADJUST. To support the widest possible client base, OP allows users to remain entirely in GPSCOM. Since the project will *not* be submitted to NGS, there is no need to have users follow the same sequential processing steps as presented in Section 11.1. However, OP will suggest an initial minimally constrained adjustment which is exactly the same as the Preliminary Adjustment shown in 12.1. This will enable the user to evaluate how all sessions fit together without any confounding influence of multiple constraints which may end up being inconsistent. Refer to 12.1 for additional guidance on setting up and analyzing the results from this adjustment. After verifying the correctness of all sessions and observations, the user can then proceed to conduct another (or more) adjustment(s), if needed, with additional constraints.

11.3 Verifying Constraints Prior to an Adjustment

Prior to running network adjustments, it is important to verify that the intended constraints are indeed offered as constraints in the adjustment. Additional scrutiny of the orthometric heights is recommended to ensure that the expected heights are being offered.

> ⚠ OP will only offer as constraints marks with published coordinates. If the user has altered the coordinates on a published mark (e.g. "Manage Coordinates" in the Individual Mark Page), OP will not offer it as a constraint.

> ⚠ In particular cases which must be detailed in the Project Proposal, a user may constrain vertically to a leveled height not yet published by selecting "LEVELING NOT PUBLISHED." The height tag will no longer read the published vertical datum (e.g. "NAVD 88").

11.4 Setting up a Network Adjustment

Setting up a network adjustment involves the same basic functions and screen for each of the adjustments. For simplicity, an overview of the steps involved is presented here.

The first step is to click on the **Set up Adjustment** button on the Manager's Page:

Figure 11-2: Set up Adjustment button on the Manager's Page controls bar

Note that the "Set up Adjustment" button will not be available (greyed out) until at least one session has been

processed: [Set up Adjustment]

Clicking on the "Set up Adjustment" button will open up a new browser window similar to the one seen in session processing. If a Tracking ID is present, the series of five sequential network adjustment steps is listed, with the first step being the Preliminary Adjustment (see highlighted area on the left panel of figure below). Without a Tracking ID, this section of the window is left blank (right panel of figure).

Set up Adjustment with Tracking ID   Set up Adjustment without Tracking ID
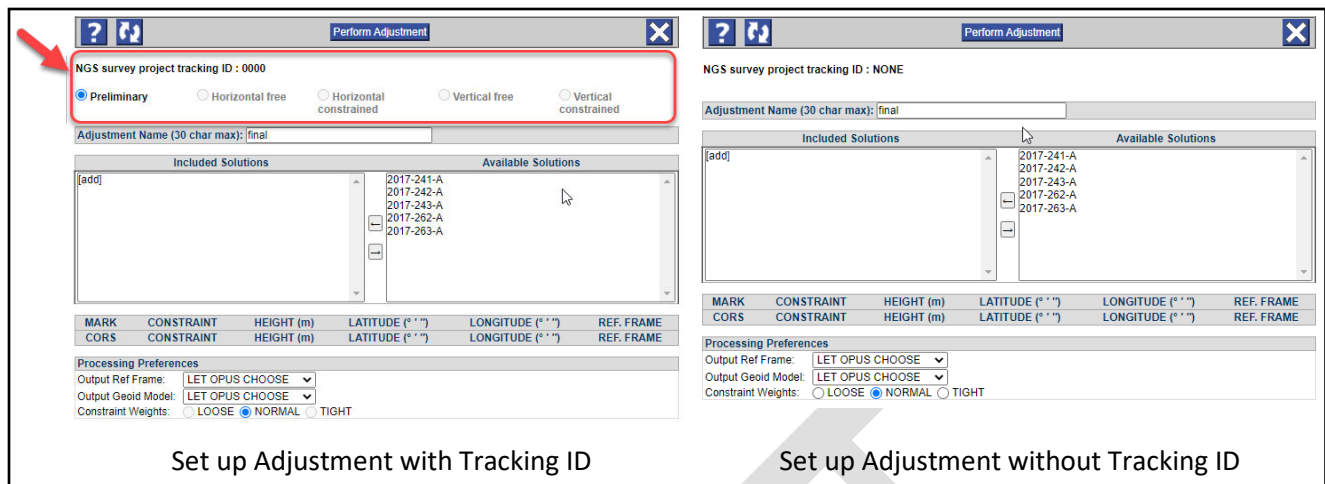
Figure 11-3: Network adjustment windows with NGS Tracking ID and without

To perform an adjustment, the user selects the desired sessions (or solutions) and clicks on the left arrow button [←] to move the sessions/solution(s) from the "Available" table to the "Included" table.

If multiple solutions were performed on a particular session, only one of the solutions for that session should be chosen to take part in the adjustment (see explanation of Session vs Solution in Section 10.4 and in the Glossary). Note that the Preliminary Adjustment is the only step that has all the session processing as available solutions, subsequent adjustments will only show the previous adjustment as possible input.

The user may want to run several alternative preliminary adjustments by varying the combinations of included session solutions and constraints. Each such attempt should be named so that it can be identified later.

Solution Naming Conventions in the adjustment sequence:

In the Preliminary Adjustment, OPUS by default assigns a two-part solution name, starting with the word "network" and ending in the word "final." The two part name is therefore "network-final." The first part of the name ("network") cannot be altered by the user, but the second part can be changed using the "SOLUTIONS" button on the Manager's Page.

Figure 11-4: The Manage Solutions window, enabling the user to rename or delete any solution in the project

The second part of the name can be considered the "root" or "family" name for all the subsequent adjustments, as the two-part name is then carried forward (and cannot be changed). Recall that, although a session solution name can be changed, the session itself cannot.
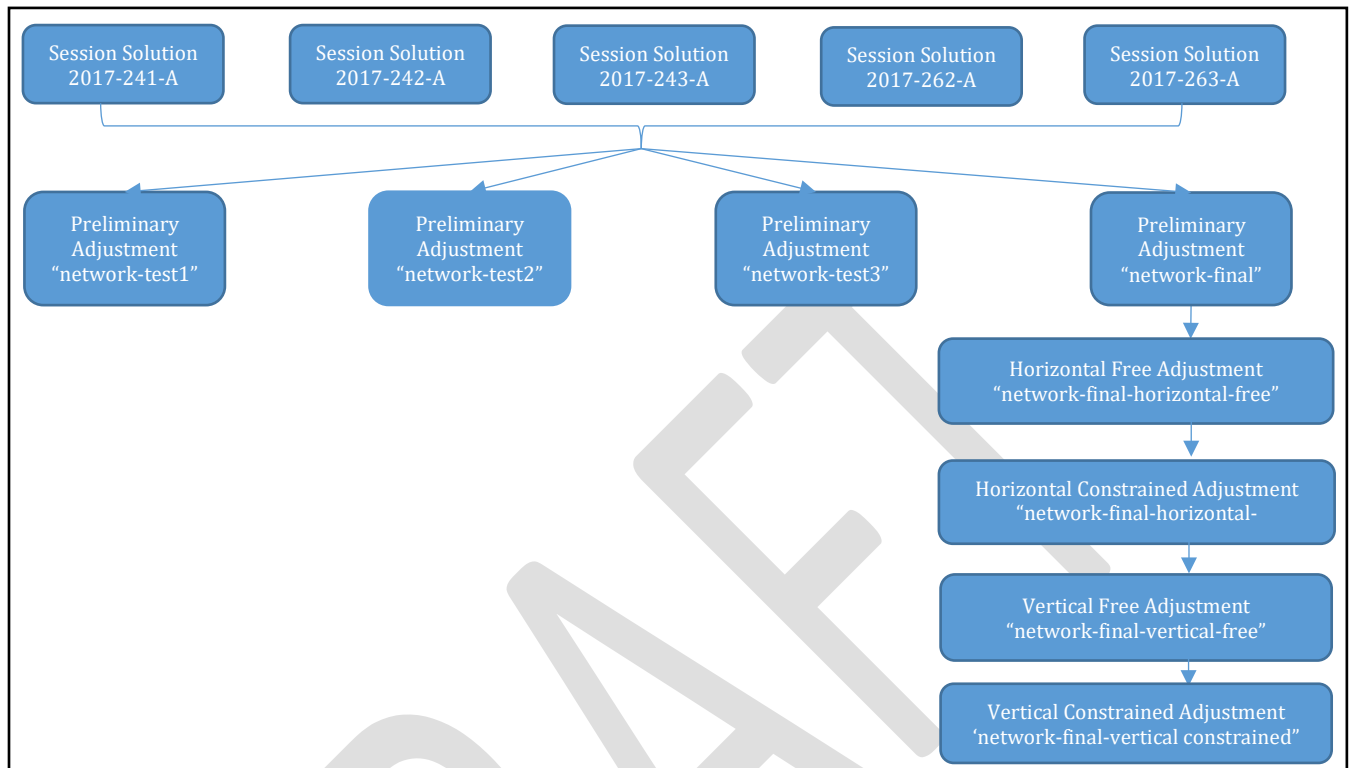
Figure 11-5: Conceptual diagram of the relationships between session solutions and network solutions in OP

Based on the results of the first preliminary adjustment, the user may feel inclined to run more than one of these adjustments. For this reason, it is recommended to change the family name of the first preliminary adjustment to something like "test1," as shown in Figure 11-5. In this way, it will be clear that this adjustment is run using the output of that initial, trial adjustment.

When the user has decided on the final preliminary adjustment, it is recommended to call it "final" *before* proceeding to the subsequent adjustments. The names of the solutions can be altered using the **Solutions** button on the Manager's Page.

> If multiple preliminary solutions are computed, it is recommended to delete all versions except the one to be carried forward to the next step (Horizontal Free Adjustment).

Example List of Preliminary Adjustments:

network-test1
network-test2
network-test3
network-final

> ⚠️ "Final" and "Preliminary" are relative terms. This adjustment represents a "final" step within GPSCOM, but simultaneously, a preliminary step required to enter the ADJUST domain.

Selecting constraints and performing the adjustment

Once the desired content has been moved from the "available" window to the "included" window, a table will be generated with suggested constraints:

Figure 11-6: Sample Network Adjustment window showing the OP recommended selections for a Preliminary Adjustment

OP suggests constraints for each adjustment step. The CONSTRAINT column identifies the type of constraint (NONE, 3-D, VERT) applied to a MARK or CORS. All other stations are grayed out. The user should review the constraints to ensure they are as expected. To add a constraint, choose from the CONSTRAINT drop down menu. To remove a constraint, simply change the box to NONE. Once a mark is selected as a constraint, its latitude, longitude, and height are able to be edited (not recommended). For more information on constraints specific to each of the sequential adjustments intended for submission to NGS, please see Section 12.

In running the adjustment, OP assigns uncertainties to individual marks. For user marks that do not already have published coordinates, the uncertainties come from the OPUS solution used for the mark's a priori coordinates (typically the first observation file for the mark seen in the project). For user marks with published coordinates, the uncertainties are taken from the datasheets. CORS are an exception. While they can be constrained to their NCN coordinates, the coordinates' uncertainties are the RMS values computed from network monitoring results around the time of the project. For examples of the most recent RMS values, find the CORS short-term plots for a station via the NGS CORS page.

⚠️ Estimated uncertainties (sigmas) vary according to the source of the coordinates. You can modify the sigmas by changing the source under "Manage Coordinates" on the individual mark pages. However, for submitting to NGS, any changes must be addressed in the final project report.

Make sure that the "Processing Preferences" below the MARK and CORS tables are correctly set (Output Reference Frame and Output Geoid Model are set to "LET OPUS CHOOSE" and the constraint weights is set to "NORMAL).

Review the entire window to ensure all selections are as you intended them and click the "Perform Adjustment" button at the top:
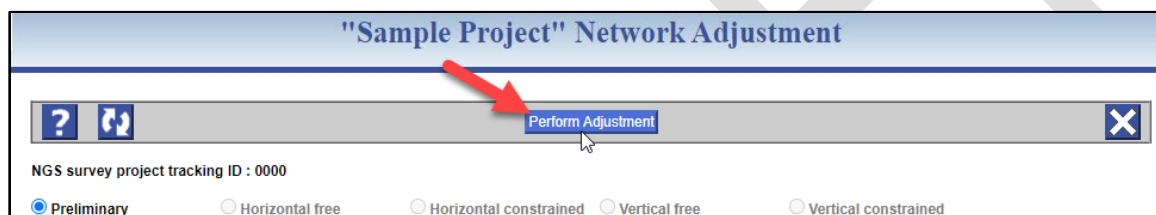
Figure 11-7: The "Perform Adjustment" button on the network adjustment page

A screen acknowledging the submission will appear. Review the screen as it confirms what has been submitted for processing.
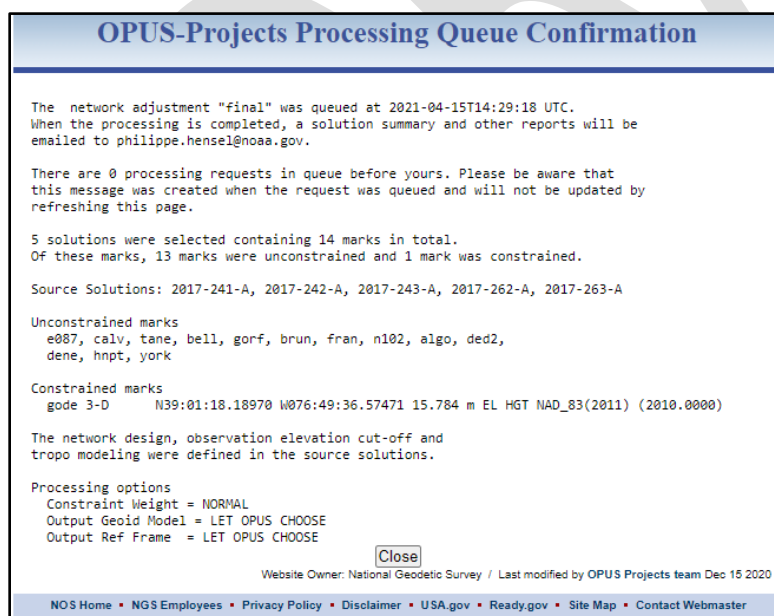
Figure 11-8: Sample network adjustment confirmation pop-up window

11.5 Network Adjustment Results

Once the processing is completed, output files will be available in a manner similar to session processing (email attachments and output files in OP under "Show File").

The body of the email sent to the project manager will have an abbreviated summary of the solution. Note that this summary lists coordinate shifts (shown in the yellow highlight in the sample output below; the shifts will be discussed in more detail in Section 11.7).

Sample Network Adjustment Email

```
NGS OPUS-Projects 2.11 NETWORK ADJUSTMENT REPORT
FOR network-final
FROM PROJECT Sample Project.
SELECTED REPORTS ARE ATTACHED TO THIS EMAIL. ALL REPORTS ARE
AVAILABLE THROUGH THE PROJECT'S WEB PAGE FOR THIS SOLUTION.


                  ABBREVIATED SUMMARY
SUBMITTED BY:                 jane.doe
SOLUTION FILE NAME:          network-final.sum
SOLUTION SOFTWARE:           GPSCOM(2008.25)
SOLUTION DATE:               2021-03-29T15:41:12 UTC
STANDARD ERROR OF UNIT WEIGHT: 0.578
TOTAL NUMBER OF OBSERVATIONS:  264815
TOTAL NUMBER OF MARKS:        9
CONSTRAINED MARKS:           1 HORIZONTAL, 0 VERTICAL
loyf N38:58:28.07428 W076:31:19.88533  -14.498m       NAD_83(2011) @ 2010.0000
loyf      0.12cm         0.10cm      0.13cm        NEU SIGMAS

START TIME:                  2020-10-05T00:00:00 GPS
STOP TIME:                   2020-10-06T23:59:30 GPS
FREQUENCY:                   L1-ONLY TO ION-FREE [BY BASELINE LENGTH]
OBSERVATION INTERVAL:        30 s
ELEVATION CUTOFF:            15 deg
TROPO INTERVAL:              7200 s [PIECEWISE LINEAR PARAMETERIZATION]
DD CORRELATIONS:             ON

    INCLUDED SOLUTION            RMS     SOFTWARE        RUN DATE
-----------------------------------------------------------------------------
 1) 2020-279 A               1.2 cm  page5(2008.25)  2021-03-26T15:43 UTC
 2) 2020-280 A               1.2 cm  page5(2008.25)  2021-03-26T15:44 UTC

   BASELINE      LENGTH       RMS      OBS   OMITTED    FIXED IN SOLUTION(S)
-----------------------------------------------------------------------------
  gode-loyf     26.907 km    1.1 cm   35987    0.4%    94.0%     1, 2
  godz-loyf     26.907 km    1.2 cm   35719    1.0%    96.0%     1, 2
  pip1-loyf     26.964 km    1.2 cm   27877    0.9%   100.0%     1, 2
  84tb-loyf     32.559 km    1.2 cm   25022    1.4%    99.4%     1, 2
  umbc-loyf     35.360 km    1.4 cm   35934    0.8%    97.5%     1, 2
  wdc6-loyf     47.548 km    1.0 cm   34957    0.5%    95.7%     1, 2
  baco-loyf     47.745 km    1.2 cm   35439    2.1%    97.0%     1, 2
  leba-loyf    671.783 km    1.1 cm   33880    0.3%    99.7%     1, 2
```

<mark>MARK ESTIMATED - A PRIORI COORDINATE SHIFTS</mark>
```
-----------------------------------------------------------------------------
  84tb  N:  -0.004 m (0.001 m) E:  -0.003 m (0.001 m) H:  -0.001 m (0.001 m)
  baco  N:   0.003 m (0.001 m) E:   0.000 m (0.001 m) H:  -0.002 m (0.001 m)
  gode  N:   0.003 m (0.001 m) E:  -0.001 m (0.001 m) H:   0.005 m (0.001 m)
  godz  N:   0.004 m (0.001 m) E:   0.000 m (0.001 m) H:   0.003 m (0.001 m)
```

```
   leba  N:   -0.001 m (0.001 m) E:    0.002 m (0.001 m) H:   -0.004 m (0.001 m)
   loyf  N:    0.001 m (0.001 m) E:   -0.001 m (0.001 m) H:    0.000 m (0.001 m)
   pip1  N:   -0.006 m (0.001 m) E:   -0.012 m (0.001 m) H:   -0.025 m (0.001 m)
   umbc  N:    0.003 m (0.001 m) E:   -0.001 m (0.001 m) H:    0.002 m (0.001 m)
   wdc6  N:    0.004 m (0.001 m) E:   -0.001 m (0.001 m) H:   -0.001 m (0.001 m)


ATTACHMENT INVENTORY:
----------------------    -------------------------------------------------
Processing Report (.txt) : network-final.txt
B-file (.bfile)          : network-final.bfile
G-file (.gfile)          : network-final.gfile
Processing Log (.sum)    : network-final.sum
SINEX Output (.snx)      : network-final.snx
Processing Report (.xml) : network-final.xml
Serfil (.serfil)         : consolidated.serfil
```

There are eleven (11) possible output files generated by OP, depending on the type of adjustment run (Table 12-1). The file names vary slightly between the "Show File" window and the email attachments. In the table below, the output file names are given depending on whether they are accessed within OP's "Show File" window, or whether they are viewed from the email attachments. Not every output is provided in each adjustment step: under "Included in" in the table below, P = Preliminary, HF = Horizontal Free, HC = Horizontal Constrained, VF = Vertical Free, and VC = Vertical Constrained. Submission = when the "Review and Submit to IDB" button is clicked.

Table 12-1: Adjustment Results and File Names

OP_Show File	Email Attachment	Included in	Description
Processing Report	Network x x.txt	P, HF, HC, VF, VC	The overall summary of the solution. The report provides a priori shifts (see Section 11.5), coordinates in both the NSRS reference frame (e.g. NAD 83(2011) and the global reference frame (ITRF2014), variance of unit weight, list of no check stations (see Section 7.3.5).
Processing Report (XML)	Network x x.xml	P, HF, HC, VF, VC, Submission	The same output as the .sum file, but expressed in an XML document.
Processing Log	Network x x.sum	P, HF,HC, VF, VC, Submission	For Session Solutions this is the PAGES output. For *Preliminary* Network Solutions and network solutions without a Project Tracking ID, this is the GPSCOM output. For *all subsequent* Network Solutions using a Project Tracking ID, this is the ADJUST output.
SINEX	Network x.snx	P Only	The Solution Independent Exchange file is commonly used in academic applications. It contains enough information to derive the solution or combine the results with others to create new solutions.
B-file	Network x x.bfile	P, HF, HC, VF, VC, Submission	The FGCS standard (formerly known as the bluebook) format of project and occupation data.

Table 12-1: Adjustment Results and File Names (continued)

OP_Show File	Email Attachment	Included in	Description
G-file	Network x x.gfile	P, HF, HC, VF, VC, Submission	The FGCS standard (formerly known as the bluebook) format of relative vectors.
Preplt	Network x x.preplt2	HF, HC, VF, VC	Uses the output of ADJUST to provide a summary of the residuals
COMPVECS	Network x x.cvecs	HF only	Lists a comparison of repeat vectors and their differences, as compared to the first (initial) vector. This is used to find outliers among replicate vectors.
Chkobs	Network x x.chkobs	HF, Submission	Checks the observation dataset (B-file) for correct structure and syntax. Errors in the file should be checked and addressed in the appropriate place such as the Individual User Mark Pages
Obschk (short)	Network x x.obschk.short	HF, Submission	Checks the integrity of the B-file and G-file and provides a summary of issues found. Errors in the file must be checked and resolved if submitting the project to NGS: describe all issues in the project report.
Obschk (long)	Network x x.obschk.long	HF, Submission	Provides the same output as the short version with the addition of listing station occupations and groupings from the B-file and G-file.

The results of a network solution can also be viewed from within the individual user mark pages by selecting the solution name (in the example below, the preliminary network adjustment named "B"):

MARK [fran ▼] **Processing Results From** [network-final ▼] [Manage Coordinates]

Scale uncertainties by [1.0x (68.3%) ▼].

| network-final |
| 2017-241-A |
| 2017-242-A |
| 2017-243-A |
| A PRIORI (JV7214 published with HTDP(3.2.7) NAD_83(2011) velocities.) |

Coordinate Source: network-final

				SPC 1900 MD	UTM 18
REF FRAME:	ITRF2014 (2017.6636)				
LAT:	N39:29:55.92729 ±0.001 m			203438.809 sft	4374723.879 m
EAST LON:	E282:40:21.66034 ±0.001 m	E282:40:21.68284 ±0.001 m	EASTING:	371846.270 sft	299886.263 m
WEST LON:	W077:19:38.33966 ±0.001 m	W077:19:38.31716 ±0.001 m	CONVERGENCE:	-0.20543056°	-1.48080556°
EL HGT:	73.964 ±0.001 m	75.232 ±0.001 m	POINT SCALE:	1.00000891	1.00009307
X:	1081185.1767 ±0.001 m	1081186.051 ±0.001 m	COMBINED FACTOR:	0.99999711	1.00008127
Y:	-4808284.7201 ±0.001 m	-4808286.158 ±0.001 m	U.S. NATIONAL GRID:	18STJ9988674723	
Z:	4035253.6456 ±0.001 m	4035253.705 ±0.001 m			

ORTHO HGT: 108.003 ±0.0163 m (H = h - N WHERE N = GEOID18 HGT)

DATA FILE	ANTENNA		HEIGHT (m)	EPH TYPE	OBS (%)	FIXED (%)	RMS (m)	LAT (m)	LON (m)	HGT (m)	SOLUTION
fran241m.17o	TRM41249.00	NONE	2.000	precise	99.4	97.2	—	0.00086	0.00085	0.00111	network-final
fran242n.17o	TRM41249.00	NONE	2.000	precise	99.4	97.2	—	0.00086	0.00085	0.00111	network-final
fran243q.17o	TRM41249.00	NONE	2.000	precise	99.4	97.2	—	0.00086	0.00085	0.00111	network-final
Preferences				Best Available	≥80.0	≥80.0	≤0.025	≤0.020	≤0.020	≤0.040	Preferences

MARK [fran ▼] **Processing Results Plots**

Scale uncertainties by [1.0x (68.3%) ▼]. Show ☐ preferences ☐ network ◇ session ○ OPUS △ published.

The "zero" point coordinates, N39:29:55.927293407177786, W077:19:38.33966, 73.964 m el. height, are the mean of all network adjustments.

MARK [fran ▼] **Processing Results Table**

Scale uncertainties by [1.0x (68.3%) ▼]. Show ☐ preferences ☐ network ◇ session ○ OPUS △ published.

The "zero" point coordinates, N39:29:55.927293407177786, W077:19:38.33966, 73.964 m el. height, are the mean of all network adjustments.

△ PUBLISHED	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
JV7214	0.5 ±0.0	-0.3 ±0.0	3.1 ±0.0	ITRF2014	2017-08-31T02:07:57
○ OPUS SOLUTIONS	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
fran241m.17o	-0.1 ±0.2	0.2 ±0.4	2.4 ±1.7	ITRF2014	2017-08-30T00:13:40
fran242n.17o	0.0 ±0.6	0.7 ±0.6	1.1 ±0.3	ITRF2014	2017-08-31T02:30:28
fran243q.17o	0.3 ±0.2	0.1 ±0.4	2.4 ±1.8	ITRF2014	2017-09-01T01:17:02
◇ SESSION SOLUTIONS	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
2017-241-A	0.1 ±0.08	0.0 ±0.07	-0.4 ±0.14	ITRF2014	2017-08-29T21:36:00
2017-242-A	0.2 ±0.09	0.7 ±0.09	1.0 ±0.15	ITRF2014	2017-08-31T01:37:55
2017-243-A	0.4 ±0.09	-0.2 ±0.09	-0.4 ±0.16	ITRF2014	2017-09-01T06:32:24
☐ NETWORK SOLUTIONS	NORTH (cm)	EAST (cm)	UP (cm)	REFERENCE FRAME	EPOCH (GPS)
network-final	0.0 ±0.086	0.0 ±0.085	0.0 ±0.111	ITRF2014	2017-08-31T05:08:09

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Figure 11-9: Sample network solution selected from the individual user mark page

11.6 Analyzing Network Adjustment Results

Analyzing the results depends somewhat where one is in the adjustment process. It is helpful to understand that the Processing Report, Processing Log, and individual user mark pages are all providing the same adjustment results, but displayed in various ways to give the user multiple options for analysis.

11.6.1 Processing Report (*.txt file)

The Processing Report provides a summary of the adjustment. It is included for all network adjustments. Near the top of the report, verify that the standard error of unit weight and the number of marks constrained are correct:

```
NGS OPUS-Projects 2.11 NETWORK ADJUSTMENT REPORT
FOR network-final-horizontal-free
FROM PROJECT Sample Project.
SELECTED REPORTS ARE ATTACHED TO THIS EMAIL. ALL REPORTS ARE
AVAILABLE THROUGH THE PROJECT'S WEB PAGE FOR THIS SOLUTION.


                  ABBREVIATED SUMMARY
SUBMITTED BY:                jane.doe
SOLUTION FILE NAME:          network-final-horizontal-free.sum
SOLUTION SOFTWARE:           ADJUST(6.4.3)
SOLUTION DATE:               2021-03-29T15:46:56 UTC
STANDARD ERROR OF UNIT WEIGHT: 1.000
TOTAL NUMBER OF OBSERVATIONS: 264815
TOTAL NUMBER OF MARKS:       9
CONSTRAINED MARKS:           1 HORIZONTAL, 0 VERTICAL
loyf N38:58:28.07428 W076:31:19.88533  -14.498m      NAD 83(2011) @ 2010.0000
loyf      0.13cm         0.38cm    1.97cm      NEU SIGMAS

START TIME:                  2020-10-05T00:00:00 GPS
STOP TIME:                   2020-10-06T23:59:30 GPS
FREQUENCY:                   L1-ONLY TO ION-FREE [BY BASELINE LENGTH]
OBSERVATION INTERVAL:        30 s
ELEVATION CUTOFF:            15 deg
TROPO INTERVAL:              7200 s [PIECEWISE LINEAR PARAMETERIZATION]
DD CORRELATIONS:             ON
```

The report will also show if there are any marks with only one set of observations (typically called a "no check" mark, when the mark does not appear in more than one session; Figure 11.10).

```
network-Preliminary-horizontal-free.txt created: 2020-05-05 13:56 UTC downloaded: 2020-05-26 18:19 UTC
            NGS BETA OPUS-Projects 1.52 NETWORK ADJUSTMENT REPORT
            =================================================

All coordinate accuracies reported here are 1x the formal
uncertainties from the solution. For additional information:
geodesy.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy

These positions were computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating procedures used.

SUBMITTED BY:                kevin.jordan
SOLUTION FILE NAME:          network-Preliminary-horizontal-free.sum
SOLUTION SOFTWARE:           ADJUST(6.4.2)
SOLUTION DATE:               2020-05-05T09:56:11 UTC
STANDARD ERROR OF UNIT WEIGHT: 1.000
TOTAL NUMBER OF OBSERVATIONS: 478056
TOTAL NUMBER OF MARKS:       13
NO-CHECK MARKS:              d871
CONSTRAINED MARKS:           1 HORIZONTAL, 0 VERTICAL
chb6 N45:39:13.28056 W084:27:57.01569  145.877m      NAD_83(2011) @ 2010.0000
chb6       0.25cm         0.17cm     0.42cm      NEU SIGMAS

START TIME:                  2018-06-27T00:00:00 GPS
STOP TIME:                   2018-07-02T23:59:30 GPS
FREQUENCY:                   L1-ONLY TO ION-FREE [BY BASELINE LENGTH]
OBSERVATION INTERVAL:        30 s
ELEVATION CUTOFF:            15 deg
TROPO INTERVAL:              7200 s [PIECEWISE LINEAR PARAMETERIZATION]
DD CORRELATIONS:             ON
```

Figure 11-10: Sample network solution processing report showing a "no check" mark

Further down in the Processing Report are tables listing coordinate shifts (Figure 11.11). The shifts compare coordinates from the current adjustment to one of the following, according to the particular adjustment being run:

1) A priori coordinate: Preliminary Adjustment
2) Coordinates from previous adjustment: HF, HC, VF, VC
3) Published coordinates: HC, VC

The table name describes the shift being shown. The values in parentheses are the uncertainties of the adjusted coordinates. Although these uncertainties are likely optimistic, they are still useful for assessing consistency and overall quality. The shifts themselves are related to the constraint weights set in the user preferences: "loose" constraint weights will allow larger shifts than "tight" constraints weights.

The table itself looks similar across each of the sequential adjustments, regardless of which shifts are being computed. Note that coordinate shifts are given in other adjustment output, and sometimes they refer to separate comparisons. Explanations of what all the shifts represent are given in their respective subsections below.

Regardless of which adjustment the user is running, a well-fitting adjustment results in relatively small shifts, typically 2 cm horizontal, and 4 cm vertical.

```
MARK   ESTIMATED - A PRIORI COORDINATE SHIFTS
-------------------------------------------------------------------------
algo  N:   -0.005 m (0.001 m) E:   -0.003 m (0.001 m) H:   -0.006 m (0.001 m)
bell  N:    0.035 m (0.001 m) E:   -0.122 m (0.001 m) H:   -0.035 m (0.001 m)
brun  N:    0.032 m (0.001 m) E:   -0.122 m (0.001 m) H:   -0.038 m (0.001 m)
calv  N:    0.037 m (0.001 m) E:   -0.137 m (0.001 m) H:   -0.026 m (0.001 m)
ded2  N:   -0.003 m (0.001 m) E:   -0.001 m (0.001 m) H:   -0.018 m (0.001 m)
dene  N:   -0.005 m (0.001 m) E:   -0.002 m (0.001 m) H:   -0.009 m (0.001 m)
e087  N:    0.038 m (0.001 m) E:   -0.138 m (0.001 m) H:   -0.028 m (0.001 m)
fran  N:    0.025 m (0.001 m) E:   -0.110 m (0.001 m) H:   -0.033 m (0.001 m)
gode  N:   -0.003 m (0.001 m) E:   -0.004 m (0.001 m) H:    0.000 m (0.001 m)
gorf  N:    0.028 m (0.001 m) E:   -0.124 m (0.001 m) H:   -0.031 m (0.001 m)
hnpt  N:   -0.004 m (0.001 m) E:   -0.004 m (0.001 m) H:   -0.005 m (0.001 m)
n102  N:    0.025 m (0.001 m) E:   -0.128 m (0.001 m) H:   -0.019 m (0.001 m)
pond  N:    0.027 m (0.001 m) E:   -0.119 m (0.001 m) H:   -0.031 m (0.001 m)
tane  N:    0.030 m (0.001 m) E:   -0.123 m (0.001 m) H:   -0.017 m (0.001 m)
york  N:   -0.004 m (0.001 m) E:   -0.004 m (0.001 m) H:   -0.007 m (0.001 m)
```

Coordinate Shift North

Adjusted Coordinate Uncertainty (N)

Coordinate Shift East

Adjusted Coordinate Uncertainty (E)

Coordinate Shift Ellipsoid Height

Adjusted Coordinate Uncertainty (H)

Figure 11-11: The explanation of a solution processing report showing "MARK ESTIMATED - A PRIORI COORDINATE SHIFTS"

Below the coordinate shifts, the *un*constrained marks are then shown in an OPUS-like solution report format:

```
 york  N:    -0.004 m (0.001 m) E:    -0.004 m (0.001 m) H:    -0.007 m (0.001 m)


 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 UNCONSTRAINED MARKS
 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

 MARK:      algo (algo a  5)

 REF FRAME:       NAD_83(2011) @ 2010.0000              ITRF2014 @ 2017.6885
 X:                918130.075 m    0.001 m           918129.168 m    0.001 m
 Y:              -4346072.651 m    0.001 m         -4346071.314 m    0.001 m
 Z:               4561977.886 m    0.001 m          4561977.895 m    0.001 m
 LAT:          45 57 20.84707      0.001 m        45 57 20.88208      0.001 m
 E LON:       281 55 43.09341      0.001 m       281 55 43.06502      0.001 m
 W LON:        78 04 16.90659      0.001 m        78 04 16.93498      0.001 m
 EL HGT:             201.975 m     0.001 m               200.942 m    0.001 m
 ORTHO HGT:          237.476 m     0.031 m  (= EL HGT - -35.501 GEOID18 HGT)


              UTM COORDINATES
              UTM (Zone 17)
 NORTHING (Y)    5093306.546 m
 EASTING (X)      726948.500 m
 CONVERGENCE     2.10601111 deg
 POINT SCALE     1.00023323
 COMBINED FACTOR 1.00020156


 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

 MARK:      bell (0108; bell    1)

 REF FRAME:       NAD_83(2011) @ 2010.0000              ITRF2014 @ 2017.6651
 X:               1135664.801 m    0.001 m          1135663.926 m    0.001 m
 Y:              -4792046.127 m    0.001 m         -4792044.686 m    0.001 m
 Z:               4039585.549 m    0.001 m          4039585.493 m    0.001 m
 LAT:          39 32 57.82868      0.001 m        39 32 57.86037      0.001 m
 E LON:       283 19 57.10668      0.001 m       283 19 57.08494      0.001 m
 W LON:        76 40 02.89332      0.001 m        76 40 02.91506      0.001 m
 EL HGT:              81.201 m     0.001 m                79.929 m    0.001 m
 ORTHO HGT:          113.504 m     0.015 m  (= EL HGT - -32.303 GEOID18 HGT)


              UTM COORDINATES     STATE PLANE COORDINATES
              UTM (Zone 18)           SPC (1900 MD)
 NORTHING (Y)    4379074.301 m        685862.654 ft US
 EASTING (X)      356730.208 m       1406106.870 ft US
 CONVERGENCE    -1.06193056 deg        0.20870833 deg
 POINT SCALE     0.99985272            1.00001890
 COMBINED FACTOR 0.99983998            1.00000616

 US NATIONAL GRID DESIGNATOR: 18SUJ5673079074 (NAD 83)


 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

Figure 11-12: Network solution processing report showing the coordinates of unconstrained marks

The constrained marks are shown in a similar format, with the addition of shifts between the output adjustment and the input adjustment.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINED MARKS
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


MARK:       gode (gode a  4)
CONSTRAIN: 3-D NORMAL
      N39:01:18.18974 W076:49:36.57470    15.784m        NAD_83(2011) @ 2010.0000
             0.12cm            0.12cm        0.12cm        NEU SIGMAS
SHIFTS N:   -0.003 m (0.001 m) E:   -0.004 m (0.001 m) H:    0.000 m (0.001 m)

REF FRAME:       NAD_83(2011) @ 2010.0000               ITRF2014 @ 2017.6882
X:               1130774.424 m    0.001 m          1130773.551 m    0.001 m
Y:              -4831255.028 m    0.001 m         -4831253.573 m    0.001 m
Z:               3994200.517 m    0.001 m          3994200.451 m    0.001 m
LAT:          39 01 18.18960      0.001 m       39 01 18.22092      0.001 m
E LON:       283 10 23.42510      0.001 m      283 10 23.40353      0.001 m
W LON:        76 49 36.57490      0.001 m       76 49 36.59647      0.001 m
EL HGT:              15.784 m     0.001 m              14.487 m     0.001 m
ORTHO HGT:           48.164 m     0.015 m  (= EL HGT - -32.380 GEOID18 HGT)


              UTM COORDINATES     STATE PLANE COORDINATES
              UTM (Zone 18)          SPC (1900 MD)
NORTHING (Y)     4320774.467 m        150431.504 m
EASTING (X)       341854.662 m        414996.110 m
CONVERGENCE      -1.15043611 deg       0.10868889 deg
POINT SCALE       0.99990796           0.99995308
COMBINED FACTOR   0.99990548           0.99995060

US NATIONAL GRID DESIGNATOR: 18SUJ4185420774 (NAD 83)
```

Figure 11-13: Network solution processing report showing coordinates of a constrained mark and the coordinate shifts between computed and published coordinates

11.6.2 Processing Log (*.sum file)

The contents of the Processing Log will differ somewhat between the Preliminary (GPSCOM) and the subsequent network adjustments (ADJUST). With GPSCOM, the Processing Log and the Processing Report contain similar information (so there is no need to review both). However, for adjustments run with ADJUST (HF, HC, VF, VC), the Processing Log contains important information not contained in the Processing Report (historically referred to as "ADJUST Output):"

- List of constraints and options for the adjustment (known as the adjustment option file for ADJUST, called the "AFILE")
- Options chosen in the ADJUST program are explained
- List of constraints used in the adjustment
- Observational Summary shows the number of vectors per mark and whether the station is fully constrained
- Commencing Adjustment shows the start of the iterative adjustment
- Adjustment Converged shows the final statistics including variance factors
- Blue-Book Statistics give statistics of the input files
- Normalized Residuals
- Residual Statistics
- Adjusted Positions

- Coordinate shifts: Comparison Of Adjusted and Constrained Coordinates and Heights (mostly applies to HC Adjustment). For adjustments with multiple constraints, this is the only location to review the shifts between adjusted and published coordinates.
- Local and Network Accuracies

RESIDUAL STATISTICS is a section of the output that provides multiple listings of the 20 greatest residuals listed by observation number. Additionally, it provides tables which provide a quick glimpse into the quality of the adjustment by providing a max/min list of residuals written in scientific notation for dX, dY, dZ (**Earth-Centered, Earth-Fixed** coordinates), dN (north), dE (east), dL (horizontal length), and dU (up, or vertical), with the corresponding observation number given to the right of each residual.

Large residuals are indicative of a problem. Particularly if they involve stations that also had large shifts as noted in the Processing Report.

	MAX V	OBS #	MIN V	OBS #
DX	3.4D-02	169	-5.1D-02	139
DY	2.5D-02	401	-1.6D-02	257
DZ	1.9D-02	387	-4.1D-02	63
DN	1.4D-02	217	-3.5D-02	61
DE	1.9D-02	137	-2.4D-02	401
DL	3.5D-02	63	1.1D-04	18
DU	5.1D-02	141	-3.7D-02	387

In the example shown above, the largest residual in the project is in the absolute value in the "up" component at 5.1 cm on the observation number 141. Going to that observation in the NORMALIZED RESIDUALS section of the Processing Log, you will find the session number (see below):

NORMALIZED RESIDUALS

		COMPUTED	OBSERVED	V=C-O	SDV	MDE	RN	FROM STATION
				SEC METER		3-SIGMA		SESSION ID
139	DX	-20033.1057	-20033.0551	-0.0506	0.0305	-1.6605	0.0841	(19) TUET
140	DY	128948.4336	128948.4423	-0.0087	0.0150	-0.5775	0.0460	(1) ASPA
141	DZ	-9495.4586	-9495.4540	-0.0046	0.0154	-0.2977	0.0467	0987A
	DN	-9792.7320	-9792.7402	0.0082	0.0114			
	DE	-130473.3288	-130473.3286	-0.0002	0.0121		Vector 4 Solution 10
	DL			0.0082	0.0166		Project ID =
	DU	21.8149	21.7640	0.0509	0.0334		

More information about which observation may have caused a large residual (above) may be confirmed with COMPVECS and Preplt (see below).

11.6.3 COMPVECS Output

COMPVECS output, available from the Horizontal Free adjustment, lists all replicate vectors in the project. Differences are computed against the first (initial) vector. If large residuals are found in the free adjustment Processing Log, this output can help isolate the errant vector. Specifics on how to read and interpret the output is provided in Section 12.2.2.

11.6.4 PREPLT2

PrePlt2, available as an output of ADJUST (HF, HC, VF, VC), is another tool that provides a list of residuals (DN, DE, DU) and baseline lengths pulled from the Processing Log. The output can be easily imported into a spreadsheet or other file type to enable sorting on the size of the residuals in the north, east, and up components. Look for any residuals larger than +/- 0.020m horizontally or +/- 0.040m vertically.

```
      Residual Components(m)  Rej  Baseline  FROM:                                     TO:
Obs#    DN      DE      DU          (m)      SSN   Designation                         SSN   Designation
   4  -0.0027 -0.0018 -0.0024     9722.3946 ( 0101) CALVERTON                        ( 0003) GODDARD SFC CORS MONUMENT
   7  -0.0025 -0.0010 -0.0003    68351.5899 ( 0106) FRANKS                           ( 0003) GODDARD SFC CORS MONUMENT
  10  -0.0019 -0.0048 -0.0003    77589.8247 ( 0109) TANEY                            ( 0003) GODDARD SFC CORS MONUMENT
  13   0.0004 -0.0019  0.0029   776524.7562 ( 0004) ALGONQUIN CORS MONUMENT          ( 0003) GODDARD SFC CORS MONUMENT
  16  -0.0013 -0.0014 -0.0009   102681.1338 ( 0005) CORBIN CORS ARP                  ( 0003) GODDARD SFC CORS MONUMENT
  19   0.0007 -0.0024 -0.0054   118387.9046 ( 0006) UNIV OF DELAWARE CORS ARP        ( 0003) GODDARD SFC CORS MONUMENT
  22  -0.0021 -0.0023 -0.0016   266616.3216 ( 0007) UNIONTOWN CORS ARP               ( 0003) GODDARD SFC CORS MONUMENT
  25  -0.0007 -0.0011  0.0010   188478.1136 ( 0008) SCHUYLKILL HAVEN CORS ARP        ( 0003) GODDARD SFC CORS MONUMENT
  28   0.0001  0.0000  0.0002   107431.4508 ( 0001) YORK CORS ARP                    ( 0003) GODDARD SFC CORS MONUMENT
  31   0.0004  0.0008 -0.0002    62594.5194 ( 0002) DC WAAS 1 CORS ARP               ( 0003) GODDARD SFC CORS MONUMENT
  34  -0.0014 -0.0026 -0.0007    60175.1989 ( 0108) BELL                             ( 0003) GODDARD SFC CORS MONUMENT
  37  -0.0007 -0.0021  0.0023     9722.3946 ( 0101) CALVERTON                        ( 0003) GODDARD SFC CORS MONUMENT
  40  -0.0012 -0.0013  0.0070    44833.4935 ( 0105) E 87                             ( 0003) GODDARD SFC CORS MONUMENT
```

Figure 11-14L Sample output from the PREPLT2 file

11.6.5 CHKOBS

CHKOBS is a program that checks for structural issues with the project data - required for submitting your project to NGS (only available with Project Tracking ID), and can be ignored if you have no intent to publish. The program is run with the Horizontal Free adjustment, as well as at the final step of submitting the project to NGS. Errors and warnings listed in the CHKOBS output file need to be reviewed. If missing data are reported, use the user mark pages to find and fill in the missing data. Any remaining errors or warnings must be written up and explained in the project report.

11.6.6 OBSCHK

The OBSCHK program checks the occupation and the vector data -also required for submitting your project to NGS (only available with Project Tracking ID). The program is run with the Horizontal Free adjustment and upon submission to NGS. Any errors or warnings listed in the OBSCHK output file **must be reconciled**. If errors exist of which you are unsure how to fix please contact the Bluebook Team.

11.7 Sequential Adjustments with Tracking ID

This section of the manual steps the user through each sequential network adjustment required for submission to NGS.

11.7.1 Preliminary Adjustment

Recall that the Preliminary Adjustment is a minimally constrained geometric (3D) adjustment that combines the baseline vectors from the session solutions into one network and creates the files needed as input for the subsequent adjustments. This is a good opportunity to gauge how well the overall network adjustments will be, as the solutions should not change very much in the subsequent steps. In other words, this is a good opportunity to quality assure the overall project.

11.7.1.1 Setting up the Preliminary Adjustment

In the Network Adjustment window, select the available solutions from session processing that you want to include in the adjustment. Do not include more than one solution for a given session (see explanation of Session vs Solution in Section 10.3 and in the Glossary).

> ⚠️ Although all sessions are typically included in the Preliminary Adjustment (and subsequent adjustments), this is not always the case. In rare instances, one or more sessions may be excluded due to poor fit, or unresolved errors in the corresponding observations

OP 4.0 will offer what it believes to be the best constraint: usually a CORS, used as a hub during session processing, close to the center of the project which it believes will provide the best solution. The user can easily change the constraint. If another CORS or mark is preferred, make sure to return the originally selected CORS to CONSTRAINT = NONE. Select only *one* mark/CORS in this preliminary adjustment, even if you have more than one hub.

Figure 11-15: Preliminary Network Adjustment window showing OP recommendation for a single hub 3D constraint

⚠️ REF FRAME should be the latest realization of the NSRS if submitting to NGS for publication

11.7.1.2 Analyzing the Preliminary Adjustment

Review the Processing Report (*.txt). Check to make sure the standard error of unit weight is near 1.0. Verify the total number of marks and that only one mark was constrained horizontally.

The MARK ESTIMATED - A PRIORI COORDINATE SHIFTS represent the shifts from the original a priori coordinate to the new session-adjusted coordinate. The a priori coordinates either come from published datasheets (CORSs and user marks with published coordinates) or from the first OPUS solution seen by the project (user marks that do not have published datasheets). Shifts should be small (smaller than ±2 cm horizontal and ±4 cm vertical). If poor results are indicated (a priori shifts are large, e.g. larger than ±2 cm horizontally and ±4 cm vertically), go back to session processing to see if you can find the offending observation (and exclude it). Refer to Solution Statistics (Section 10.5) to compare among sessions. Also consider collecting the .VEC results into a single text file or spreadsheet and compare among repeat vectors for consistency. See Appendix C, Coordinate Shifts, for more details on shifts and their interpretation. Be careful to ensure at least two occupations remain. If everything looks good, move to the horizontal free adjustment.

⚠️ If all the (a priori) coordinate shifts are similar in magnitude and direction, it is possible that the constraint is biased. Verify the position of the CORS used as the hub. You may try rerunning the adjustment with a different constraint.

11.7.2 Horizontal Free Adjustment

This step aligns the project to the NSRS reference frame. The overall goal is to verify that the field observations and satellite data have produced a set of baseline vectors that agree with each other and which can be aligned to published control in a horizontal constrained adjustment.

11.7.2.1 Setting up the Horizontal Free Adjustment

From the Network Adjustment window, select the Preliminary Network Solution and use the arrow key to transfer it to the left window. OP will suggest the same constraint that was used in the Preliminary Adjustment. If any changes were made to the suggested constraint, it should be mirrored here as well.

11.7.2.2 Analyzing the Horizontal Free Adjustment

Review the summary file provided in the body of the email, which is also given in the Processing Report (.txt). Verify that the standard error of unit weight is equal to 1.0. Check the total number of marks and make sure that only one mark was constrained horizontally. Review the MARK ESTIMATED - A PRIORI COORDINATE SHIFTS table. In this instance, the shifts are from the Preliminary to the Horizontal Free adjustments. A well fitting Horizontal Free adjustment will result in small coordinate shifts and low residuals on all observations, ideally ≤ 2 cm horizontal and ≤ 4 cm vertical for both. If this is not the case, then the user should review the Processing Log (below).

Processing Log (.sum):

Review the 20 greatest residuals: residuals exceeding ±2 cm horizontal and ±4 cm vertical indicate poorly fitting observations or a poorly fitting mark. For stations with more than two occupations, it is usually obvious which is the outlier. If an outlier is found, try to resolve the issue by checking field logs, setup photos, or conferring with the observer to rule out blunders in the field procedures. If there is no obvious cause, you will have to decide whether to remove the observation(s) or mark(s) from the project, or live with a large residual. Care should be taken to prevent a user mark from becoming no-check as explained earlier. It may be a good idea to obtain an additional observation on the mark in question. If this is not possible, it may be necessary to remove the user mark from the project.

COMPVECS Output:

Look for large differences among replicate vectors.

Figure 11-16: Sample COMPVECS output showing: (1) a rejected vector; (2) a session (0987A) with large residuals; and (3) the large residual in the "Up" direction

The first two columns indicate the vector "from" and "to" marks as described by the four-character IDs assigned to the marks and CORSs in the project. The third and fourth columns identify the marks and CORSs by their Station Serial Numbers (SSNs). The fifth column indicates whether the direction of the vector is reversed. The sixth column gives the session number (three-digit GPS day followed by the last digit of the calendar year, followed by the session ID for that day).

Although the COMPVECS file itself is not easily sorted, it can be searched for particular values (e.g. 0.05). If one session appears to result in consistently large differences, take a closer look at that session to see if you can

pinpoint an offending observation. If no errors can be found, you may have to remove that occupation from the analysis and re-process (remember - for submission to NGS, you will need *at least two* observations per mark!).

The example above gives an example of a rejected vector: the letter "R" to the right of the s/R column for vector SSN 0001-0002, session 1037A (#1 in the figure above). Note that the residuals for this vector are uniformly large.

The example also shows where the large residual in the "Up" coordinate in Session 0987A came from (seen previously in the *.sum output in Section 11.7.2): vector 0001-0019, session 0987A (#2 and 3, above).

At this point, if you have isolated an offending observation, or an offending user mark, you will have to decide whether to reprocess, remove the observation or user mark from the project, or

accept the large residual. In the example shown in the COMPVECS table, there are only two observations for the user mark 0019 ("TUET"), so it would be only a guess at which is the bad one. Furthermore, there must be multiple occupations on each user mark so removing one is not an option in this example. Try to resolve the issue. Double check field logs to ensure no blunder exists.

For stations with more than two occupations, it is usually obvious which is the outlier. Inspect the computed minus observed (C-O) residuals in the ADJUST output (see Processing Log or *.sum file). List any outliers in the project report. Attempt to reduce large residuals (e.g. exceeding 2 cm horizontal and 4 cm vertical) by resolving any errors or removing offending observations. Note that these values are guidelines, not rules: refer to your project specifications for specific tolerances.

Below the table of comparisons is a histogram plotting the unadjusted vector differences from the COMPVECS output. The distribution should approximate a bell-shaped curve. Large outliers should be visible, and help the user identify the corresponding residual(s) back in the Processing Log. An example given below is for a histogram in the East component:

```
EAST  Components

   0.9075 (mm)   Residual Mean
  17.3248 (mm) Residual Std Deviation (1 sigma)

Scale:  * = (  1) millimeters


      -> -50.00 (     1) *
-50.00-> -45.00 (     0)
-45.00-> -40.00 (     0)
-40.00-> -35.00 (     0)
-35.00-> -30.00 (     0)
-30.00-> -25.00 (     0)
-25.00-> -20.00 (     1) *
-20.00-> -15.00 (     3) ***
-15.00-> -10.00 (     5) *****
-10.00->  -5.00 (    14) **************
 -5.00->   0.00 (    25) *************************
  0.00->   5.00 (    33) *************************
  5.00->  10.00 (    25) *********************************
 10.00->  15.00 (     7) ***********************
 15.00->  20.00 (     4) *******
 20.00->  25.00 (     3) ****
 25.00->  30.00 (     1) ***
 30.00->  35.00 (     1) *
 35.00->  40.00 (     1) *
 40.00->  45.00 (     0) *
 45.00->  50.00 (     0)
 50.00->        (     0)
```
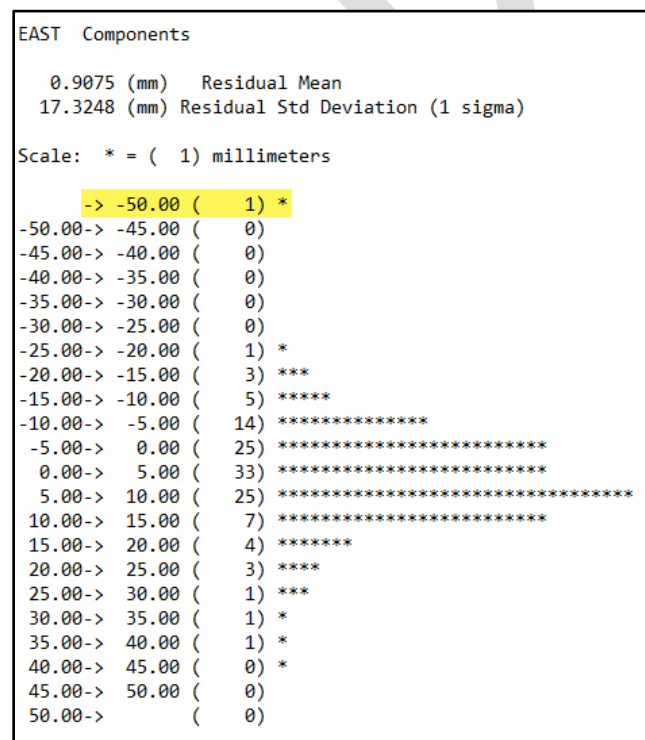
Figure 11-17: Example of a histogram plotting the unadjusted vector differences from the COMPVECS output

If any observations are changed or removed, the corresponding session will be nullified and must therefore be reprocessed. Rerun the preliminary adjustment, and then the horizontal free adjustment. Repeat this process as necessary until you are satisfied with the results of the free adjustment. See https://www.ngs.noaa.gov/PC_PROD/ADJUST/COMPVECS.txt for more information on COMPVECS.

PrePlt2:

PrePlt can be used to import residuals into a spreadsheet for sorting and identification of observations with large (positive or negative) residuals (see Section 11.7.4).

Final thoughts on the Horizontal Free Adjustment

After the completion of the free adjustment analysis, if large residuals remain, they should be listed in the project report, if the project is submitted to NGS. Likewise, all research on the cause of the residuals should be noted/explained in the report.

If any observations are changed or removed, the corresponding session will be nullified and must be reprocessed. If you wish to submit the project to NGS, you will need to rerun the preliminary adjustment, and then the horizontal free adjustment. Repeat this process as necessary until you are satisfied with the results of the free adjustment.

Finally, this is a good time to review the **CHKOBS** and **OBSCHK** output (11.7.5 and 11.7.6). If there are any errors at this stage, they will most likely not go away after any subsequent adjustments. Take the time now to see if they can be resolved. Contact the NGS Bluebook team, if needed, for help in resolving any errors.

11.7.3 Horizontal Constrained Adjustment

The function of this adjustment is to align the observed network with the previously-determined (published) coordinates of passive marks and CORS. The analysis focuses on absolute and relative measures of such an alignment. The results tell you how well your project fits within the existing NSRS.

11.7.3.1 Setting up the Horizontal Constrained Adjustment

On the Network Adjustment page, select the Horizontal Free solution from the "Available Solutions," and bring it to the "Included Solutions." OP will offer all CORSs and user marks with published, geometrically ("3D") adjusted coordinates as constraints in this adjustment step.

Figure 11-18: Sample Horizontal Constrained Adjustment window showing 3-D constraints

Change the distant CORS to "NONE" (recall that this CORS is for tropospheric modelling). As before, verify all elements of the window prior to processing. Perform the adjustment.

11.7.3.2 Analyzing the Horizontal Constrained Adjustment

There are several, if not many, factors to consider in the analysis of a constrained adjustment. The same output files and tools available in the free adjustment are produced in this adjustment with the exception of COMPVECS, OBSCHK, and CHKOBS checking programs. Although we still analyze vector residuals, we focus on the effects that the constraints have had within the network.

> Finding an optimum alignment between an observed network and published control is an iterative process and users may find more than one satisfactory solution

Coordinate Shifts

Best reviewed in the Processing Report (*.txt) or in the body of the email, there are two tables of shifts given. The first one represents the difference between where the Horizontal Constrained adjustment versus the Horizontal Free adjustment want the station to be ("MARK ESTIMATED - HORIZONTAL FREE ADJUSTMENT COORDINATE SHIFTS").

```
MARK  ESTIMATED - HORIZONTAL-FREE ADJUSTMENT COORDINATE SHIFTS
----------------------------------------------------------------------------
algo  N:   -0.004 m (0.002 m) E:    0.002 m (0.001 m) H:    0.016 m (0.004 m)
bell  N:   -0.003 m (0.002 m) E:    0.003 m (0.002 m) H:    0.019 m (0.004 m)
brun  N:   -0.001 m (0.002 m) E:    0.002 m (0.002 m) H:    0.016 m (0.005 m)
calv  N:   -0.001 m (0.002 m) E:    0.002 m (0.002 m) H:    0.016 m (0.005 m)
ded2  N:   -0.002 m (0.002 m) E:    0.001 m (0.001 m) H:    0.017 m (0.004 m)
dene  N:   -0.001 m (0.001 m) E:    0.001 m (0.001 m) H:    0.015 m (0.004 m)
e087  N:   -0.002 m (0.002 m) E:    0.002 m (0.001 m) H:    0.016 m (0.004 m)
fran  N:   -0.001 m (0.002 m) E:    0.002 m (0.002 m) H:    0.015 m (0.005 m)
gode  N:   -0.001 m (0.001 m) E:    0.001 m (0.001 m) H:    0.015 m (0.003 m)
gorf  N:   -0.001 m (0.001 m) E:    0.004 m (0.001 m) H:    0.017 m (0.003 m)
hnpt  N:   -0.001 m (0.001 m) E:    0.001 m (0.001 m) H:    0.015 m (0.003 m)
n102  N:   -0.001 m (0.002 m) E:    0.002 m (0.002 m) H:    0.015 m (0.005 m)
pond  N:   -0.001 m (0.002 m) E:    0.002 m (0.002 m) H:    0.015 m (0.005 m)
tane  N:   -0.002 m (0.002 m) E:    0.002 m (0.002 m) H:    0.015 m (0.005 m)
york  N:   -0.002 m (0.001 m) E:    0.000 m (0.001 m) H:    0.015 m (0.004 m)
```

Figure 11-19: Network solution processing report from the Horizontal Constrained Adjustment showing "MARK ESTIMATED - HORIZONTAL-FREE ADJUSTMENT COORDINATE SHIFTS"

Large shifts (> 2 cm horizontal and > 4 cm vertical) are an indicator that one or more constraints may not fit the current network. Note that all marks in the project are listed in the table.

The second table represents the shifts between the Horizontal Constrained Adjustment and the marks with published (3D) coordinates ("MARK ESTIMATED - PUBLISHED HORIZONTAL COORDINATE SHIFTS"). Note that only the marks which were constrained 3D are given I the table (these were the marks with adjusted/published 3D coordinates).

```
MARK  ESTIMATED - PUBLISHED HORIZONTAL COORDINATE SHIFTS
----------------------------------------------------------------------------
algo N: -0.007 m (0.002 m) E:  0.001 m (0.001 m) U:  0.044 m (0.004 m) CORS
bell N:  0.003 m (0.002 m) E: -0.002 m (0.002 m) U: -0.006 m (0.004 m) OPUS
ded2 N:  0.006 m (0.002 m) E:  0.002 m (0.001 m) U: -0.010 m (0.004 m) CORS
dene N: -0.001 m (0.001 m) E:  0.003 m (0.001 m) U:  0.009 m (0.004 m) CORS
e087 N:  0.008 m (0.002 m) E: -0.018 m (0.001 m) U: -0.001 m (0.004 m) OPUS
gode N: -0.001 m (0.001 m) E:  0.001 m (0.001 m) U:  0.015 m (0.003 m) CORS
gorf N: -0.001 m (0.001 m) E: -0.002 m (0.001 m) U: -0.002 m (0.003 m) OPUS
hnpt N: -0.000 m (0.001 m) E: -0.001 m (0.001 m) U:  0.003 m (0.003 m) CORS
york N: -0.000 m (0.001 m) E:  0.004 m (0.001 m) U:  0.012 m (0.004 m) CORS
```

Figure 11-20: Network solution processing report from the Horizontal Constrained Adjustment showing "MARK ESTIMATED – PUBLISHED HORIZONTAL COORDINATE SHIFTS"

If there are a couple large shifts compared to published coordinates (> 2 cm horizontal and > 4 cm vertical), that may suggest that the published coordinates may no longer match the marks' positions. Many large shifts may be indicative of a bias in the hub (which should be very rare): this would require re-processing the sessions with another hub selected.

Residuals

The residuals (computed - observed or C-O values) are found in the main body of the Processing Log (.sum). Residuals are summed up in the min/max V values and 20 greatest residuals as described earlier in the Horizontal Free output (also see Section 11.7.2). Often you can see that the largest residuals will also appear problematic in the COMPARISON OF ADJUSTED AND CONSTRAINED COORDINATES AND HEIGHTS table which shows shifts between the constrained and the adjusted values of a mark. Large shifts in this table should be analyzed and addressed in the project report.

```
COMPARISON OF ADJUSTED AND CONSTRAINED COORDINATES AND HEIGHTS
ADJUSTED MINUS CONSTRAINED COORDINATE SHIFTS (METERS)
CURRENTLY NO VALUES ARE PRINTED FOR VERTICAL CONSTRAINTS


 ISN   SSN          STATION DESIGNATION        DELTA NORTH   DELTA EAST   DELTA HORIZ   DELTA UP
   1  0108      BELL                               0.0036      -0.0021       0.0042      -0.0064
   4  0105      E 87                               0.0084      -0.0185       0.0203      -0.0014
   6  0104      GORF N                            -0.0006      -0.0027       0.0028      -0.0025
  11     9      DELDOT SOUTH 2 CORS ARP            0.0061       0.0018       0.0064      -0.0099
  12  0006      UNIV OF DELAWARE CORS ARP         -0.0008       0.0033       0.0034       0.0089
  13  0003      GODDARD SFC CORS MONUMENT         -0.0008       0.0014       0.0016       0.0146
  14    10      HORN POINT ENVIRO CORS ARP        -0.0002      -0.0005       0.0006       0.0035
  15  0001      YORK CORS ARP                      0.0000       0.0038       0.0038       0.0123
```

Figure 11-21: Computed - Observed residual values shown in the processing log output for the Horizontal Constrained Adjustment

F-test

In the main body of the email (Processing Report), the user will note the presence of an F-test ("F STATISTIC TEST" shown in the example below):

```
            NGS OPUS-Projects 1.50 NETWORK ADJUSTMENT REPORT
            =================================================

All coordinate accuracies reported here are 1x the formal
uncertainties from the solution. For additional information:
geodesy.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy


These positions were computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating procedures used.


SUBMITTED BY:             jane.doe
SOLUTION FILE NAME:       network-test-horizontal-constrained.sum
SOLUTION SOFTWARE:        ADJUST(6.4.2)
SOLUTION DATE:            2020-04-12T19:11:16 UTC
STANDARD ERROR OF UNIT WEIGHT: 0.997
F STATISTIC TEST:         PASS (1.01 < 1.56 F CRITICAL @ 99% CONFIDENCE)
TOTAL NUMBER OF OBSERVATIONS:  1147209
TOTAL NUMBER OF MARKS:    17
CONSTRAINED MARKS:        7 HORIZONTAL, 0 VERTICAL
corb N38:12:07.82790 W077:22:24.57030   37.237m      NAD_83(2011) @ 2010.0000
corb      0.20cm         0.24cm     0.57cm      NEU SIGMAS
dene N39:40:36.24959 W075:44:34.82882    6.547m      NAD_83(2011) @ 2010.0000
dene      0.19cm         0.20cm     0.62cm      NEU SIGMAS
gode N39:01:18.18974 W076:49:36.57466   15.784m      NAD_83(2011) @ 2010.0000
gode      0.19cm         0.17cm     0.98cm      NEU SIGMAS
nafu N39:55:35.68893 W079:41:50.51020  328.004m      NAD_83(2011) @ 2010.0000
```

Figure 11-22: Processing Report from the Horizontal Constrained Adjustment showing the results of the F-Test

Once the adjustment has been deemed acceptable i.e. all shifts and residuals are reasonable, the F-test should pass. The F-test is a statistical test which helps determine if the variance (variance of unit weight) from a fully constrained adjustment is significantly different from the variance (variance of unit weight) of a minimally constrained adjustment. The variance of unit weight is a critical statistic and should be looked at carefully when evaluating adjustment results. If the fully constrained adjustment fits well with all selected control (the constraints), the value of the variance of unit weight should be close to 1.0. The F-test is performed using a 99% confidence level.

If the F-test fails, it is due either to the errors (sigmas) of the constraints being overly optimistic (too small) or the constrained coordinates not agreeing with the observations (causing excessively large shifts of the constrained coordinates). Failure of the F-test does not automatically mean the constrained adjustment is bad. It is a flag that indicates there may be a problem with the constraints, and that they should be investigated. In addition, the F-test is based on the assumption of a normal ("bell-shaped") probability distribution of the residuals. Networks with a distribution that is significantly non-normal may fail for that reason, even when a constrained adjustment is acceptable.

Since the F-test only gives information about the entire network, if it fails, it is necessary to inspect the network for specific stations that may be causing the failure. A convenient way to do that is provided in the next item (see Constraint Ratio).

Constraint Ratio

If the F-test fails, it is possible that some constraints need to be freed up. It might be the case where some of the shifts are too large. The Constraint Ratio (CR) test provides a way of identifying where the bad shift might be. The CR is essentially a Student's T Test, with the absolute value of the shift between the adjusted, constrained coordinates and the published coordinates, divided by the sigma (σ, or standard deviation) used to constrain the station. It is computed for each component (north, east, and height):

$$CR = |Adjusted\ coordinate - published\ coordinate|/\sigma$$

OP provides the CR for all marks in the final table in the output summary given in the body of the email:

```
MARK   CONSTRAINT   RATIOS
---------------------------------------------------------------------------
ncet  N:  6.279  E:  1.497  U:  1.630  2D:  6.455  3D:  6.657       CORS
nclu  N:  0.331  E:  0.615  U:  0.099  2D:  0.699  3D:  0.706       CORS
ncsl  N:  3.134  E:  0.750  U:  0.719  2D:  3.222  3D:  3.301       CORS
ncwh  N:  0.592  E:  0.706  U:  1.223  2D:  0.921  3D:  1.531       CORS
schy  N:  0.938  E:  0.789  U:  3.490  2D:  1.226  3D:  3.699       CORS
```

Figure 11-23: Constraint Ratio Test as seen in the Processing Report of the Horizontal Constrained Adjustment

The computed CR's are compared to the critical value or 3.0, corresponding to a T-statistic at a 99% confidence level. If the value of CR is greater than 3.0 for any of the three components, that indicates that there *may* be a problem with the constrained station.

If a constraint is deemed problematic, then all three components (lat, lon, ellipsoid height) should be unconstrained in a new Horizontal Constrained adjustment. However, failure of the F-test or CR > 3 does not necessarily require removal of constraints. Both tests are analysis tools that only indicate potential problems;

they are not substitutes for professional judgment. However, the reason for either failure occurring in the final constrained adjustment should be explained in the report.

> ⚠️ A high constraint ratio could be simply due to a very low sigma

Unrealistically small sigma values could result in a warping of the network to fit constrained marks. For this reason, it may be better to free up (release) constraints with CR > 3 for any of the three components. It may be a good idea to review the values for sigmas under Section 7.3.12 "Manage Coordinates," but it is not advised to change them unless they are known to be inaccurate. Freeing an offending constraint is typically the best strategy.

Note your findings in the project report. It may be that a station needs to be freed for the sake of the adjustment, but the newly computed position may not necessarily be updated in the NGS database.

If any constraints are freed, the F-test results should improve. However, users should review the newly adjusted coordinates on user marks to decide if they recommend the user mark be re-determined (re-published). Typically, this would happen if the coordinates have shifted by more than 2 centimeters horizontally or 4 cm vertically from the published coordinates.

Other important results to verify:

Review the network accuracies in the Processing Log (*.sum file) for any indication that some user marks or CORSs might be problematic. Although network accuracies should be less than 2-4 cm, high variability among the accuracies may be more of a problem. Consistently large numbers (e.g. greater than 2 cm) would be less problematic than some values less than 1 cm and others greater than 4 cm. Note that horizontal network accuracies should always be less than vertical accuracies, and that network accuracies for CORSs are usually less than for user marks.

```
NETWORK & LOCAL ACCURACIES (95% CONFIDENCE LEVEL)
COMPUTED USING A POSTERIORI STANDARD DEVIATION OF UNIT WEIGHT


 NETWORK ACCURACIES (CENTIMETERS)

  ISN  SSN    STATION DESIGNATION                       HORIZ    UP
    1 0108 BELL                                          0.43    0.84 CM
    2 0103 BRUNSWICK 2                                   0.48    0.97 CM
    3 0101 CALVERTON                                     0.47    0.92 CM
    4 0105 E 87                                          0.39    0.80 CM
    5 0106 FRANKS                                        0.47    0.95 CM
    6 0104 GORF N                                        0.33    0.64 CM
    7 0102 NBS 102                                       0.48    0.97 CM
    8 0107 POND                                          0.54    1.06 CM
    9 0109 TANEY                                         0.47    0.94 CM
   10 0004 ALGONQUIN CORS MONUMENT                       0.51    0.76 CM
   11    9 DELDOT SOUTH 2 CORS ARP                       0.34    0.74 CM
   12 0006 UNIV OF DELAWARE CORS ARP                     0.29    0.71 CM
   13 0003 GODDARD SFC CORS MONUMENT                     0.28    0.68 CM
   14   10 HORN POINT ENVIRO CORS ARP                    0.28    0.67 CM
   15 0001 YORK CORS ARP                                 0.27    0.71 CM
```

Figure 11-24: Network accuracies as shown in the Processing Log

If the adjustment is still unable to produce a passing F-test, the user may find it helpful to re-run the Horizontal Constrained adjustment constraining only CORS as constraints (except for the distant CORS). This helps isolate possible problems with the passive control (user marks). The user would then compare the resulting position differences between the fully constrained and the CORS-only constrained adjustments. Looking at the user mark shifts between the two adjustments can help identify published user marks that no longer fit the NSRS.

Unconstraining and re-adjusting

To re-determine a user mark, the user will have to re-run the Horizontal Constrained adjustment. Accessing the Network Adjustment window, OP will be expecting the next adjustment in the sequence ("Vertical free"). However, the user can re-select "Horizontal Constrained," and proceed.

When you are satisfied with the constrained adjustment results, proceed to the next step to run the Vertical Free adjustment.

> ⚠️ If the dummy Project Tracking ID "0000" is used and alignment to a vertical datum (e.g. NAVD 88 in the continental USA) is not required, or marks with published heights in a separate vertical datum were not observed, the analysis is complete (no project submission to NGS).

> ⚠️ If you want to submit your project to NGS for publication, all five (5) adjustment steps need to be run, regardless of whether or not you have observed marks with published vertical control

11.7.4 Vertical Free Adjustment

The vertical free adjustment is similar in philosophy to the horizontal free adjustment as it is now aligning the adjustment to the vertical datum.

11.7.4.1 Setting up the Vertical Free Adjustment

In the Network Adjustment window, "Vertical Free" should be identified, and the user should select the Horizontal Constrained solution and bring it to "Included solutions."

Figure 11-25: Sample Vertical Free Adjustment constraint selection

OPUS will typically constrain horizontally the same mark that was used in the Horizontal Free adjustment (constraint now reads "HOR-ONLY"). It will also select what it believes to be the best orthometric height to constrain ("VER-ONLY," typically a user mark with a high accuracy orthometric height published in the vertical datum, located centrally to the project). Note that there may be more than one "best" height to constrain, and the user may override the selection made by OP. Whichever constraint is used, make sure the height is correct.

> If there are no published orthometric heights in the project area, OP will offer an orthometric height computed from the ellipsoid height and the geoid height: OH = EH - GH

11.7.4.2 Analyzing the Vertical Free Adjustment

The results of the Vertical Free Adjustment are similar to that of the Horizontal Free adjustment. The summary information in the body of the email is the best place to verify:

- Make sure there is only one horizontal constraint, and that the vertical constraint is the one that was intended.
- Ensure that the Standard Error of Unit Weight is 1.0.
- Ensure the coordinate shifts are small (VF vs. HC; there should be no surprises at this stage, if the prior adjustments fit well).

For completeness, the user may want to examine the differences between adjusted orthometric heights and published orthometric heights for all user marks which will be constrained in the next step (Vertical Constrained adjustment). Any large differences (e.g. > 4 cm) should be scrutinized prior to the VC adjustment. If

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there is any perceived systematic (vertical) bias, the user may want to select a different vertical constraint and re-run the vertical free adjustment.

If the results look good, the user will move to the final adjustment, the Vertical Constrained Adjustment.

11.7.5 Vertical Constrained Adjustment

As with the horizontal constrained adjustment the project is now being aligned with the local vertical datum. Heights used as control (constrained heights) will greatly affect the heights being determined. It is important that control has no adverse effects on the adjustment.

11.7.5.1 Setting up the Vertical Constrained Adjustment

In a similar manner as before, select the Vertical Free solution from the "Available Solutions." OP will suggest the appropriate 2D ("HOR-ONLY") constraint (or 3D, if the station has a published orthometric height), typically the same CORS or user mark used for horizontal control in the Vertical Free adjustment. OP will also suggest for constraint all user marks in the project that have appropriate published orthometric heights.

Figure 11-26: Sample Vertical Constrained Adjustment constraint selection

Depending on the types of heights available in your area, there may be a number of possible types of vertical constraints in OP. The possible constraints are listed below.

Note that the blank space "_____" in the options below represents an official vertical datum published for the given mark/CORS. Examples include NAVD 88, PRVD02, GUVD02, etc. (see the NGS Vertical Datums table)

OP Vertical Constraint Options:

1. _____ (FGCS LEVELING IN NGSIDB): These are leveled heights that have been adjusted by NGS and are included in the datum network.
2. _____ (GPS HEIGHTS: 2CM/5CM STANDARDS): These are GPS derived heights that meet height modernization standards according to NGS 59 (see Glossary for more information).
3. _____ (FGCS LEVELING POSTED): These are orthometric heights established using FGCS leveling specifications and procedures, adjusted height is POSTED (pre-1991 precise leveling forced to fit the NAVD 88 data; excluded for various reasons from the NAVD 88 general adjustment).
4. _____ (LEVELING RESET): OP uses this term to describe two similar height sources:
   a. LEVELING RESET: heights determined by differential leveling for classical horizontal observation reduction; reset procedures were used to establish the elevation, or
   b. RESET: Third Order reset heights following reset specifications and procedures.
5. _____ (GPS HEIGHTS: DECIMETER ACCURACY): These are GPS derived heights that **do not meet** height modernization standards according to **NGS 59** (see Glossary for more information). Use with caution.

Any of these five options (above) will meet the requirements of vertical constraints for submission to NGS. Two additional options exist, which are always available to the user in OP (but never offered as a constraint by default). They should be used with caution. If submitting the project to NGS, their selection needs to be explained in the project report. Prior approval by NGS is recommended.

6. LEVELING NOT PUBLISHED: These are leveled orthometric heights that have been submitted to NGS which have not yet been loaded into the NGS database (aka "field heights").
7. EL HGT - GEOID__: Where GEOID__ is the current NGS geoid model published in your area. This may be the only option where orthometric heights are not available. Choose all stations used as control in the horizontal adjustment. OP will use the published Ellipsoid Height and subtract the geoid. The resulting heights will be published to the nearest cm. This option is not to be used as control in height modernization projects[4].Use with caution.

Once you have verified that all the constraints are correct, run the adjustment.

11.7.5.2 Analyzing the Vertical Constrained Adjustment

The analysis of the Vertical Constrained adjustment is similar to the one conducted after the Horizontal Constrained adjustment.

> Finding an optimum alignment between an observed network and published control is an iterative process and users may find more than one satisfactory solution

Residuals

The residuals (computed - observed or C-O values) are summed up in the min/max V table found near the end of the Processing Log (.sum) as described earlier, along with the 20 greatest residuals. The DU values are representative of the vertical adjustment.

---

[4] Although not a formal constraint, this selection allows the user to determine an orthometric height by subtracting the Geoid Height from the Ellipsoid Height. Note that this will have important implications for vertical sigmas, and may lead to unintended adjustment statistics.

> ⚠️ Note that some large residuals may be due to differences in the geoid models used to determine heights. If enough control exists it may be worth taking the opportunity to update the height on a mark

Coordinate Shifts

There are three sources of heights to consider in this final step in the adjustments:

1. Adjusted orthometric heights that were constrained in the final adjustment
2. Adjusted orthometric heights from the vertical free adjustment
3. Published orthometric heights
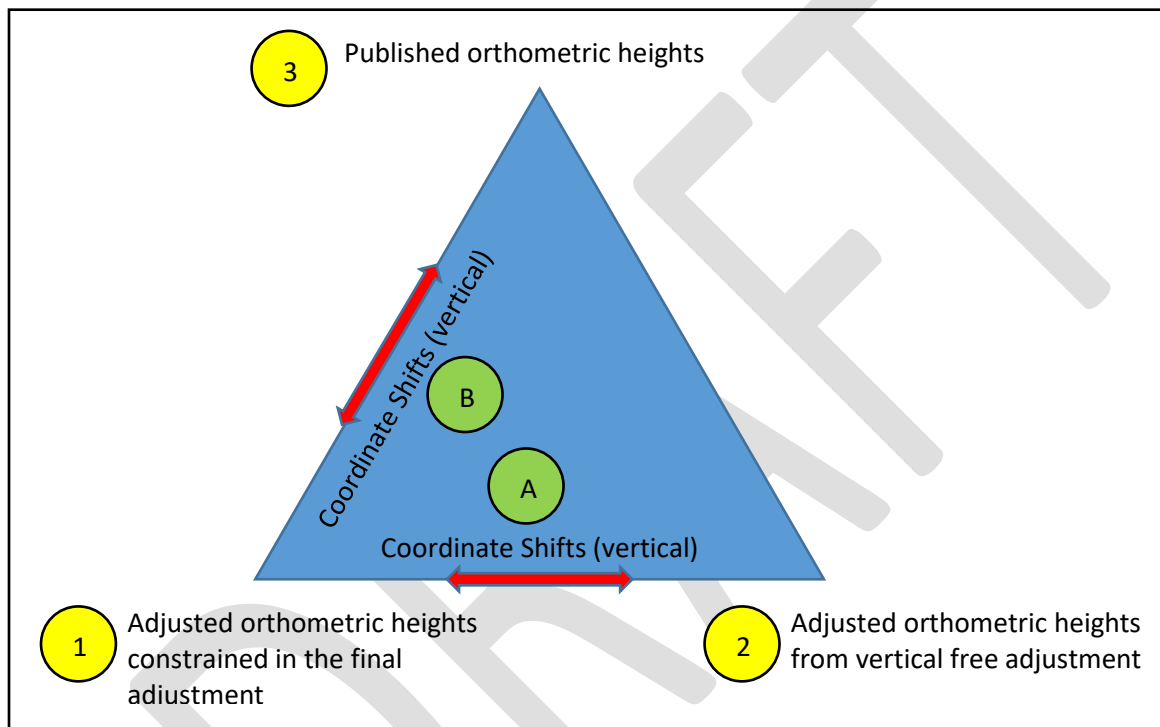
Figure 11-27: Conceptual diagram showing relationship between adjusted heights from three different sources within OPUS Projects: the Horizontal Free Adjustment, the Horizontal Constrained Adjustment, and the published orthometric heights

In the interpretation of the results, keep in mind the estimated **vertical sigmas** that OP may have assigned to the vertical constraints. A larger vertical sigma may allow for larger shifts; see Appendix D for more information.

The first set of vertical coordinates to compare is between the VC and VF adjustments (Ⓐ, above). The coordinate shifts will be presented in the first table under "MARK ESTIMATED - VERTICAL FREE ADJUSTMENT COORDINATE SHIFTS." Large shifts are indicative of poorly fitting vertical control.

If the vertical shifts are small, the next step is to compare the vertical coordinate shifts between the vertically constrained/adjusted heights and the published heights (Ⓑ, above). This is presented in the second table under "MARK ESTIMATED - PUBLISHED VERTICAL COORDINATE SHIFTS." Large shifts may indicate poor control that may have to be freed up for the best-fitting adjustment.

Once the adjustment output looks good, confirm it has passed the F-test to ensure that the vertical constrained adjustment fits well with the identified vertical control. The Standard Error of Unit Weight should be close to 1.0. Review the constraint ratio analysis if the F-test fails.

If all the results look good, you are ready to submit your project to NGS!

> If the user wishes to download/copy the results of the final adjustment, they should be found in an output called "[adjustment name]-FINAL." which is only available under the "Show File" button on the Manager's Page (it is not included in any email attachments)

11.7.6 Final Steps

Prior to submission of the project to NGS, two final steps remain: uploading the final project report, and running the final checks.

11.7.6.1 Final Project Report

Upon completion of the adjustments, the project report should be finalized. A good report builds on the original proposal, providing the purpose and rationale for the survey. The report identifies who was responsible for the field work as well as the processing and adjustments. Most importantly, the report provides details of the analyses, including the identification of any published coordinates that were freed up in the adjustment, and providing explanations for any preferences that were not met. Below is a listing of the major elements to be included in the final project report:

Cover Page:
    Project name and tracking ID
    Geographic location
    Reference Frame/Datums to which the project was aligned
    Submitting agency name and 6-char agency ID
    If applicable:
        On whose behalf the survey was performed for
        Agency that performed the observations
        Agency that performed the adjustment
    Point of contact (name, physical address, telephone number, email address)
    Date of report
    Version of OPUS Projects
Report:
    The purpose of the survey
    A brief chronology of field work including reconnaissance, mark-setting, and observations
    Sketch
    Project Specifications
    Table of user marks: both those marks used as control in the project w/ PIDs and new marks w/o PIDs
    Table of equipment used (model numbers and serial numbers)
    Procedures (timing of planned sessions and duration)
    Conditions affecting progress
    Descriptions, including any iIssues noted in WinDesc's checking programs: Neighbor, Discrep,
        Checkdesc, Obsdes
    Vector processing and any issues (specify hub(s))

Solution statistics table
Adjustments and any issues
      Preliminary
      Horizontal free
            List any issues, resolved or otherwise, such as large residuals and exclusion of observations, etc.
            List all control and its source
            Provide adjustment statistics such as Variance Unit Weight and degrees of freedom
      Horizontal constrained
            List any issues, resolved or otherwise, such as large shifts and residuals, etc.
            List all control and its sources
            List any control that did not fit the network and if it is to be redetermined
            Provide adjustment statistics such as Variance Unit Weight and degrees of freedom
            Provide results of the F-test
      Vertical free
            List all control and its source
            Provide adjustment statistics such as Variance Unit Weight and degrees of freedom
      Vertical constrained
            List any issues, large shifts and residuals, etc.
            List all control and its sources
            List any control that did not fit the network and if it is to be redetermined
            Provide adjustment statistics such as Variance Unit Weight and degrees of freedom
            Provide results of the F-test
      Comments and Recommendations

The report does not have to follow any particular naming convention, but should be in PDF format. The user can upload the file via the [Upload Project Report] button on the Manager's page.
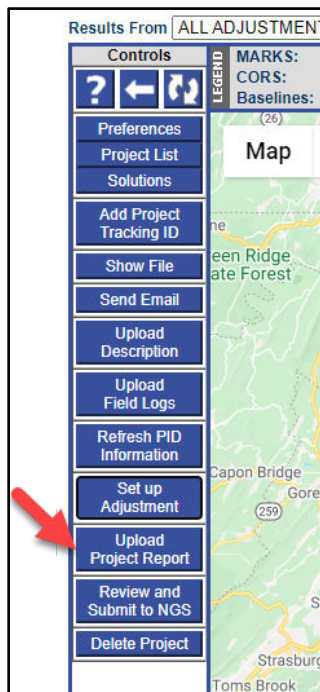
Figure 11-28: Upload Project Report button on the Controls Bar on the Manager's Page

11.7.6.2 Project Submission Checklist

Upon completion of the fifth adjustment, the button labeled "Review and Submit to IDB" on the Manager's Page becomes active:
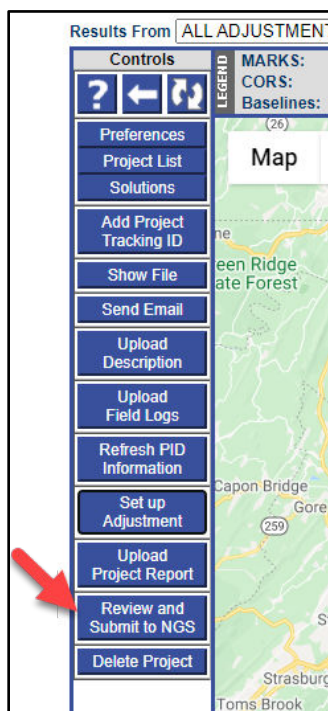
Figure 11-29: The Review and Submit to NGS button on the Controls Bar on the Manager's Page

When the **Review and Submit to NGS** button is clicked, OP runs a series of checks, including CHKOBS and OBSCHK (see 11.7.5 and 11.7.6). In the unlikely event errors are reported by the checking programs please contact the NGS Bluebook team for instructions before hitting the final submit button. If the user has any questions about how to resolve an error, or what is implied by an error message, feel free to contact the NGS Bluebook team as well.

OP also produces a checklist at this stage, showing any missing files. A successful submission will include the following items:
1. An NGS Project Tracking ID has been assigned to the project
2. All five (5) required Description files:
a. *.des
b. *.dscngs.bluebook@noaa.gov
c. *.nbr
d. *.dis
e. *.err
3. Mark photos
4. Field logs (pdf format preferred)
5. Project report (pdf format required)
6. All five network adjustments run, checked, and verified for tolerance to project specifications

Make sure all required files have been successfully loaded into the project prior to submitting the project to NGS. If any items are missing, OP will indicate any missing items.

Once all the checks are completed and files verified, the project can be submitted to NGS by clicking on the "Submit" button. Thank you for using OP to submit your GNSS project to NGS!

Figure 11-30: Example of the result of a project check where two items are missing or incomplete

Acronyms and Glossary

A Priori Coordinates: the initial coordinates assigned to survey marks by OP. This effectively gives a positional starting point for the subsequent least squares adjustment. In the absence of any other information, a priori coordinates come directly from the OPUS solutions for individual user marks. If all observations for a given user mark are loaded prior to accessing the project, OP will sort the solutions according to the dates and times of observations, and will use the first solution as the a priori. If only one observation is loaded prior to accessing the project, OP will use that solution as the a priori, regardless of when the observation was taken. Once the project has been accessed/opened, uploading subsequent observation files and obtaining additional OPUS solutions will not change the a priori coordinate. The user can always verify which RINEX file was used for the ap priori coordinates in the Marks page Processing Results drop-down menu.If the user selects "Use Coordinates" on the mark's datasheet, the published coordinates will automatically replace the a priori coordinates from OPUS. This means that the coordinates from the datasheet are believed to be better than the ones created from your GNSS project. **This should occur rarely**.

A Priori Coordinate Shifts: These numbers (given either in centimeters or meters) show by how much the a priori coordinates changed as a result of the least squares adjustment during session processing or network solutions. Note that even positions held fixed (constraints) will still show small coordinate shifts, especially if the "normal" or "loose" constraint preferences are selected. These preferences allow for small shifts to minimize overall least squares error in the adjustment.

ADJUST: An NGS computer program for the least squares adjustment of horizontal, vertical angle, and **GNSS** survey networks. For **GNSS** networks, the input (reduced) observations are Earth-Centered, Earth-Fixed (ECEF) Cartesian vectors and their uncertainties, obtained from a **GNSS** baseline processing engine (such as **PAGES**). ADJUST is used in OP for horizontal and vertical network adjustments, after initial adjustments using the NGS program **GPSCOM**. ADJUST is also available as a separate PC executable.

Ambiguities: See **Integer Ambiguities**

Antenna Reference Point: The antenna reference point (ARP) is the physical point on the antenna to which antenna calibration values are referenced. ARP is preferably an easily accessible point on the lowest non-removable horizontal surface of the antenna. Typically, the ARP coincides with the axis of attachment of the antenna to a monument or surveying instrument. To identify the ARP for a given antenna, visit the NGS Antenna Calibrations page. (https://www.ngs.noaa.gov/ANTCAL/)

ARP: See "Antenna Reference Point"

B-file: An ASCII text file generated as an output of network adjustment that contains mark coordinates, network and local accuracies, and mark occupation information, in standard "Bluebook" format (https://geodesy.noaa.gov/FGCS/BlueBook/pdf/Chapter%204.pdf).

Baseline Processing: In GNSS-based positioning, baseline processing is the computation of vectors (distance and direction in ΔX, ΔY, ΔZ) between points observed at the same time with GNSS. A vector can be considered as a measurement of a baseline.

Bluebook or **Bluebooking**: This term refers to a collection of defined procedures by which a user could submit observations to NGS for possible inclusion in the authoritative NGS database of survey control (the Integrated Database or "IDB"). Originally, the procedures were published in blue 3 ring binders, and came to be called the bluebooks, which explains the origination of the action term "bluebooking." See "Bluebook" format at: (https://geodesy.noaa.gov/FGCS/BlueBook/pdf/Chapter%204.pdf).

Constraints: OP allows the user to select which marks or CORS have their coordinates held fixed ("constrained") in a least-squares adjustment of all of the GNSS data. Three levels of constraints are available. The

NORMAL constraint weights instruct the program to limit the adjustment to less than about 1 cm, but if it "wants" to be greater than 1 cm, it will, although the constraint will increasingly hinder taking on larger and larger values. Think of it as a rubber band. For adjustments less than a couple cm, the rubber band is not stretched tightly and the adjustment can "easily" reach (take on) any of those values if the solution demands. Beyond that, the rubber band is stretched tighter and tighter. The adjustment can reach (take on) larger values, but it must work harder to do so. Be aware that the rubber band is never slack. It is always "pulling" towards the specified constraint value to some extent. The LOOSE constraint weights instructs the program to limit the adjustment to less than about one meter of float for the constrained points. The TIGHT constraint weights forces the adjustment to less than one-tenth of a millimeter of float for the constrained points in the adjustment (effectively fixing and not allowing the constrained control points to move).

Datasheet: See NGS Datasheet a report containing the published NSRS time dependent coordinates on a survey mark, as well as subsidiary information and metadata such as superseded coordinates, descriptions and recovery history of the survey mark.

Double-differencing: The mathematical process of solving for unknown positional errors inherent in GNSS positioning. The technique applies the *difference* between a GNSS-derived position with its known coordinates at a known point (often called the "base") to the difference between a simultaneously derived GNSS-derived position and its true position at an unknown point (the "rover").

Earth-Centered, Earth-Fixed (**ECEF**): A geographic and Cartesian coordinate system. It represents positions as X, Y, and Z coordinates, with the origin at the center of mass of Earth. Its axes are aligned with the international reference pole (IRP) and international reference meridian (IRM) that are fixed with respect to Earth's surface. The z-axis extends through true north, which does not coincide with the instantaneous Earth rotational axis. The slight "wobbling" of the rotational axis is known as polar motion. The x-axis intersects the sphere of the earth at 0° latitude (the equator) and 0° longitude (prime meridian in Greenwich).

Ephemeris: An electronic data file containing information about the position of a satellite with respect to time. Typically, each satellite retains the latest copy of its ephemeris onboard the satellite, that it broadcasts to the receivers to provide information about its position relative to Earth. This is called the "broadcast ephemeris," and for GPS satellites, the ephemeris files maintained by the US Space Force are uploaded to the satellites from the Master Control Station every 2 hours. The International GNSS Service (IGS) computes additional ephemerides based on both collected and modeled data. Ultra-rapid ephemerides are very similar to the broadcast ones, and include predicted positions in real time. Rapid ephemerides are available with a 17-41 hour latency, and offer slightly improved accuracy. Final ephemerides are considered the best available, and are available with a typical 12-18-day latency. The IGS considers all of its ephemerides "precise."

Elevation Cutoff: This number, expressed in degrees above the horizon, specifies the angle below which data from satellites will be ignored. The default for new projects is a conservative but common value of 15 degrees. By eliminating low elevation satellites, some of the problematic effects of the troposphere and ionospheric delays may be avoided. Pre-planning the GNSS observations on each user mark by preparing a 'mark obstruction diagram' will produce a cleaner data set for each observation. Trees, buildings, hilly topography, etc. reduce satellite visibility, and may cause cycle slips because of temporary losses of signal from a satellite. Most survey grade receivers allow the elevation cutoff to be specified for an individual observation. A common strategy is to set the receiver's elevation cutoff mask at a lower value, such as 10 degrees, then apply a higher elevation cutoff mask for individual session processing.

G-file: An ASCII text file generated as an output of network adjustment that contains vector components, standard deviations, correlations, and processing information, in standard NGS "Bluebook" format (https://geodesy.noaa.gov/FGCS/BlueBook/pdf/Annex_N.pdf).

Geometric Reference Point (**GRP**): The physical point on an antenna mount that defines the placement of the antenna's reference point, or ARP. Like the ARP, the GRP coincides with the axis of attachment of the antenna to a monument or surveying instrument. When a GNSS antenna is properly installed, the GRP and ARP are coincident in space. See "Antenna Reference Point" for more information on the ARP and how it relates to antenna calibrations.

Geoid: Equipotential surface of Earth's gravity field which best fits mean sea level and the continuation of that same surface onto land. It is typically used as the zero reference surface for orthometric heights.

GNSS: Global Navigation Satellite System uses satellites to provide autonomous geo-spatial positioning. It allows electronic receivers to determine their location (longitude, latitude, and altitude (elevation) to high precision (within a few centimeters to metres) using time signals transmitted along a line of sight by radio from satellites.

GPS: Global Position System is a satellite-based radionavigation system owned by the United States government. It is one of the Global Navigation Satellite Systems (GNSS) that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

GPSCOM: This is a program for the combined adjustment of multiple GPS data sets initially processed by the program PAGES. GPSCOM is a simple Helmert Blocking, normal equation processor which combines multiple GPS data sets that have initially been processed by the program PAGES to form and partially reduce normal equations, eliminating numerous nuisance parameters which are not generally of interest in a large global adjustment.

GRP: See "Geometric Reference Point"

Hub: In GNSS network survey design, the hub is a point observed with GNSS which is preferentially selected for inclusion in baseline processing. In other words, an included user mark that is a "hub" is more likely to be connected to other user marks.

Integer Ambiguities: The unknown number of wavelengths spanning the distance between a GNSS satellite when a signal is emitted and a GNSS receiver on the surface of Earth.

Mark: The term OP uses to describe a point observed with GNSS and whose GNSS observations are brought into the project via the OPUS upload page. See also "User Mark."

Multi-Year CORS Solution (**MYCS**): Periodically, new coordinates and velocities are computed for all CORS that are part of the NOAA CORS Network (NCN). This massive computation effort combines data from prior solutions with new CORS data available since then. This processing/reprocessing is made to coincide with the adoption of a new realization of the International Terrestrial Reference Frame (ITRF).

Network Design: A reflection of the choices made in selecting baselines to compute in GNSS-based session processing and network adjustment.

NGS 59: The abbreviated name commonly used to refer to [NOAA Technical Memorandum NOS NGS 59](#), which outlines procedures to obtain orthometric height network accuracies of 5 cm and orthometric height local accuracies of 2 cm or 5 cm using GNSS.

NGS Datasheets ("**Datasheets**"): The expression of the authoritative geodetic control from the NGS database (the Integrated Database, or "IDB") in the form a report containing the published NSRS time dependent, coordinates on a survey mark, as well as subsidiary information and metadata such as superseded coordinates, descriptions and recovery history of the survey mark.

NGS IDB: The NOAA National Geodetic Survey's "Integrated database" containing authoritative, high accuracy positioning on survey marks throughout the nation and its territories. Access to these authoritative information is through [datasheets](#), available online.

NOAA CORS Network: The NOAA CORS Network (**NCN**) is a multi-purpose cooperative network of GNSS stations from over 200 government, academic, and private organizations. Its primary objective is to

enable GNSS users by providing precise positioning relative to the U.S. National Spatial Reference System (NSRS).

PAGE-NT: A Microsoft Windows Graphic User Interface (GUI) that facilitates the running of the PAGES program.

PAGES: An NGS-developed GNSS baseline processing engine that uses double-differencing to solve for geodetic coordinates and uncertainties of unknown marks relative to marks with known coordinates. PAGES can perform simultaneous baseline processing, allowing for determination of correlations between all GNSS receivers during a session. In determining the solutions, PAGES solves for integer ambiguities and determines tropospheric parameters. Output is provided in *S*olution *IN*dependent *EX*change (SINEX) format and as GNSS vectors (used in the ADJUST program). PAGES currently only uses GPS observables, but other GNSS constellations will be added in a future version.

Peak-to-Peak ("**P2P**"): An expression of the range among the different positional solutions coming from OPUS post-processed results. For single OPUS (static) solutions, these numbers express the range among the different positional solutions as a result of post-processing GNSS observations through OPUS (expressing the variability among the different baselines to the CORSs). For OPUS Projects, these numbers express the range among multiple least squares adjustments (e.g. comparisons among the different session processing).

Post-processing: The geodetic computations applied to static GNSS observation data, after the observation files are taken, which take advantage of simultaneous GNSS observations at known reference stations to resolve errors that degrade the precision and accuracy of GNSS-derived positions. OPUS and OPUS Projects are examples of post-processing software.

Project Tracking ID: To gain access to certain capabilities of OP, an NGS-supplied Project Tracking ID must be entered. This ID is provided to you by NGS after we have reviewed the information submitted via the [NGS Survey Project Proposal page](#). For any project you intend to submit to NGS, you must submit the Project Proposal to receive an assigned ID. If you intend to use OP for your own purposes you can utilize the trial ID of "0000" (four zeros). Note that if you initially enter the trial ID with the intent to later enter an assigned ID, you will need to enter your assigned ID before performing any Network Adjustments or you will experience problems with resultant files generated by OP. The most typical reason a user would choose to enter the trial ID is to access the integrated ADJUST software.

Publish: The action of NGS providing to the public the official, National Spatial Reference System (NSRS) time-dependent geodetic coordinates set on a survey mark.

RINEX: The Receiver-INdependent EXchange format is an internationally accepted, ASCII-based GNSS observation file format which enables observations files from many different receiver types to be shared, uploaded, and post-processed.

RMS: Root Mean Square is a computation of error derived on the square root of the sums of squared difference terms.

Serfil: A text file which associates each user mark with both its OPUS 4-character ID and the sequential serial number (SSN) used in the WinDesc description file associated with the project

Session: A group of files associated with nearly simultaneous observations of a group of marks. OP automatically creates sessions based on the start/stop times in the submitted files and the limits selected in Manager's Preferences. A session by itself is not the same as a solution.

Session processing: The post-processing of two or more GNSS data files whose contents were collected with substantial time (observation) overlap to estimate the coordinates of the marks at which the data were collected with respect to one or more marks chosen to act as reference stations.

Share: The act of releasing to NGS the observations (via OPUS), metadata and results of geodetic surveys tied to the NSRS for public dissemination.

Shift: The amount by which a coordinate of a given mark has changed or is different compared to some other coordinate for the same mark. This is a common term when comparing the input coordinates to the output coordinates in an adjustment, or the published coordinates to the adjusted output coordinates.

Sigma: An expression error defined as the sum of squared differences, typically between observations and either the mean of a sample or a (known) parametric value. Sigmas are identified by the greek letter σ.

SINEX: Solution INdependent EXchange format: an internationally recognized data file containing the solutions of GNSS baseline processing. The NGS software PAGES produces SINEX files. For more information, see https://www.iers.org/IERS/EN/Organization/AnalysisCoordinator/SinexFormat/sinex.html

Solution: A solution is the result of a computation based on the observation files in a given session and the processing choices selected by the user. Such user choices include which marks to include or exclude, hub selections, constraints (loose/normal/tight), etc. Therefore, many solutions can be computed from a single session. Each solution can be named. Users should include only one solution per session in a network adjustment.

SSN: Station Serial Number: For the purpose of identifying the station on the observation records in a concise manner, each survey point is assigned a project specific station serial number (SSN) in the range 0001 to 9999.

Submission to NGS: The act of a user releasing to NGS the observations, metadata and results of geodetic surveys tied to the NSRS for the express purpose of NGS evaluating the survey and, if appropriate, including the descriptions and observations in the authoritative national database of survey control, and making the information available through NGS datasheets.

Tropospheric Modeling: Water vapor and the gas components of the dry air cause a delay in the GNSS signals arriving at the receiver. To correct for this delay, tropospheric models are computed, based on a number of tropospheric parameters. Models used by OPUS include a global climatological model (Boehm et al. 2007), a global mapping function for mapping the "dry" component of the tropospheric model (Boehm et al. 2006) and another global mapping function to model the "wet" component of the troposphere (Boehn et al. 2006). Finally, OPUS uses a correction to the "wet" component of the tropospheric model using the GNSS data itself. The estimation of the correction relies on the tropospheric interval.

Tropospheric Parameters: A number of variables are required to model tropospheric delays affecting GNSS signals. Variables include latitude, longitude, height, day-of-year, relative humidity, air temperature, and air pressure.

Tropospheric Interval: The time interval over which tropospheric parameters are interpolated and corrected from model output. OP allows the user to specify not only the time interval, but also the manner in which the interpolation occurs (piecewise linear vs. step-offset.

User Mark: This is the term used throughout this OP user manual to refer to a point observed with GNSS, and whose GNSS observations have been uploaded into the project by the user through the OPUS upload page. Typically, this means a point which was directly observed by the user with GNSS, but it could also refer to a reference point with continuous GNSS observations whose data the user has brought into the project via the OPUS upload page. Within OP, user marks are referred to more simply as "Marks" and are differentiated from "CORS," whose data are brought into the project automatically by OP through CORS selection.

Vertical Sigmas: Vertical uncertainties (sigmas) for vertically constrained marks or CORSs in OP are based on values and relationships established by NGS, according to the source of the height on the datasheet. For an explanation of these values, please see Appendix D.

Appendix A: WinDesc Module for OPUS Projects

A.1 Introduction

Accurate and complete description information is required for geodetic observations to be correctly associated with survey marks in the National Geodetic Survey's authoritative database of survey control – the Integrated Database, or "IDB." This appendix explains how to use the PC executable program, WinDesc, to create, manage, and quality control survey mark descriptions prior to loading into OPUS Projects (OP).

Entering mark descriptive information within the OPUS Projects "Mark Description Summary" will NOT create the description files necessary for submitting the project to NGS. Only WinDesc currently supports this functionality.
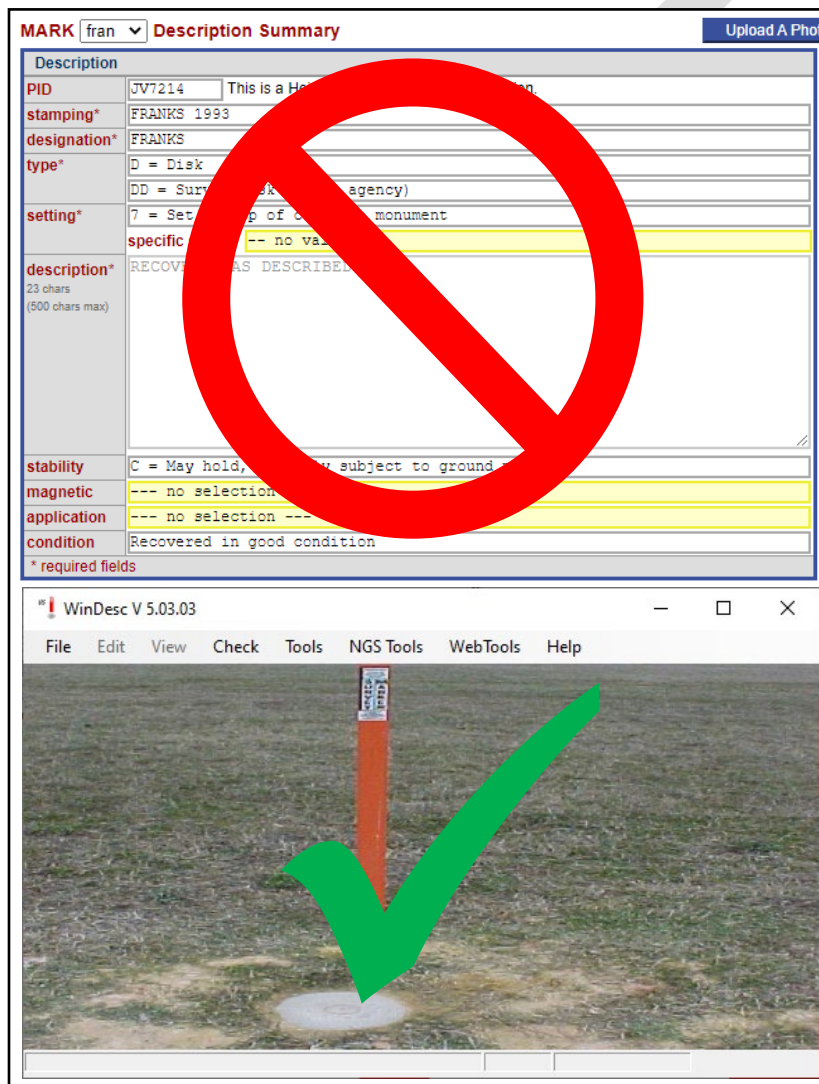
Figure A-1: For submitting a GNSS project to NGS for publication, a complete set of description files are needed. Mark descriptive summary as shown on the Mark Page is not sufficient.

WinDesc enables the creation, editing, and formatting of geodetic control description information in compliance with the National Geodetic Survey's Bluebook Annex P. WinDesc uses scripts that query the NGS database, to ensure consistency.

The software is designed for Microsoft Windows Operating Systems, and has been tested on Windows 7, 8 and 10. Note: The spelling check routine will only work if Microsoft Word is loaded on the PC.

WinDesc is available from the NGS website: www.ngs.noaa.gov/PC_PROD/pc_prod.shtml. Check the website periodically to check for new versions of the program, or navigate to the WebTools→ Update→Program menu. Be sure to uninstall the old version before installing the new one. The program will prompt for intermediate updates periodically. Access to the internet is required to download updates.

Photos are critical pieces of corroborating evidence in mark descriptions, and need to be loaded into OP. Users are directed to the NGS Photo Submission Guidelines for more information. We recommend using the photo editing features within WinDesc, and then uploading photos to OP after all observation files have been loaded.

A.2 Creating a new description file

Select: 'File>New' from the menu or press Ctrl N. Type in the name of the file to be created.
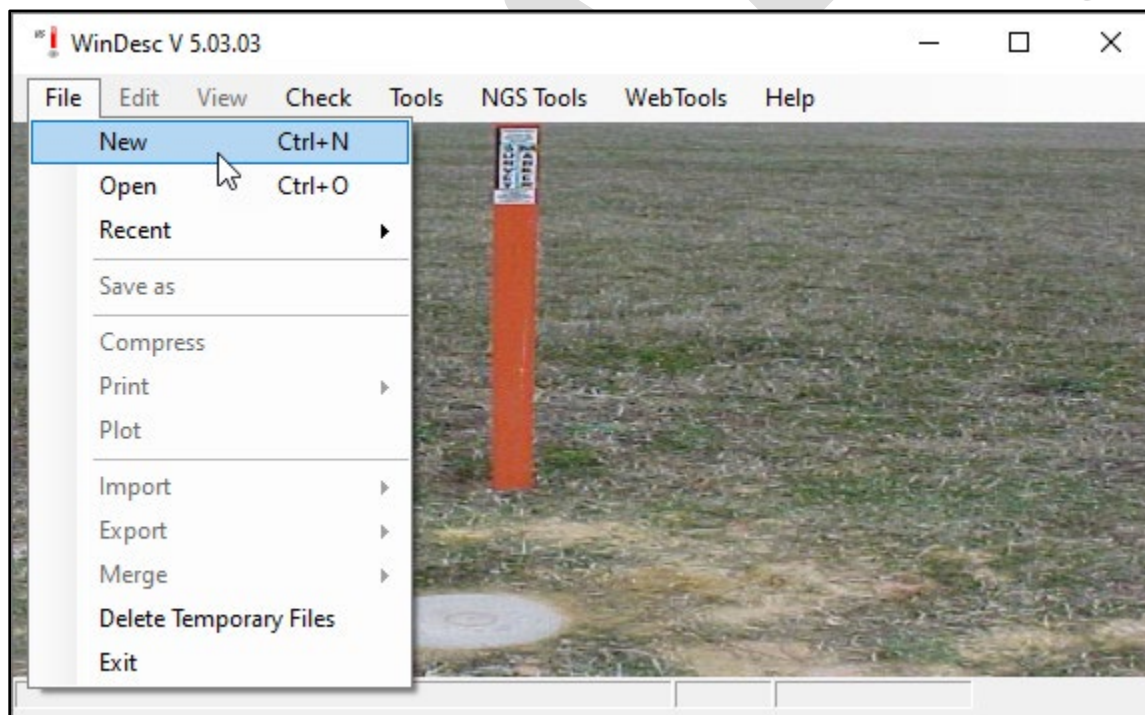
Figure A-2: Home screen WinDesc version 5.03.03, showing the initiation of a new description file

This will create a new *.des file in the directory that you have selected.
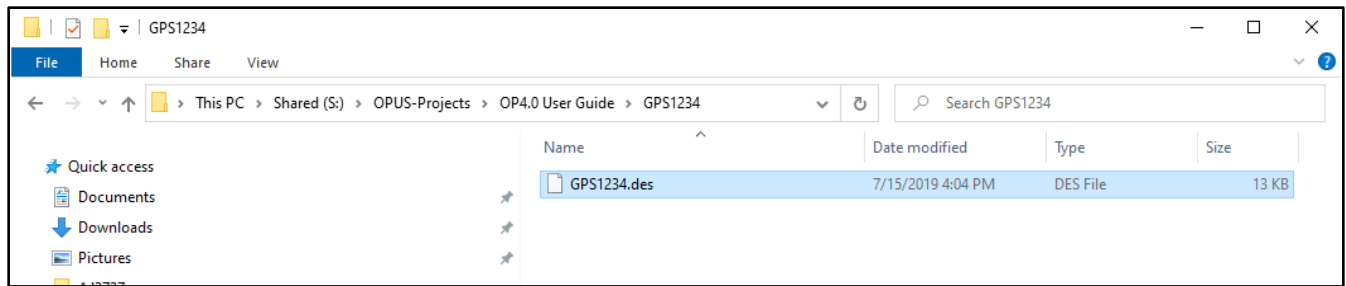
Figure A-3: Sample description file for a fictitious project "GPS1234"

Name your description file with the accession code and number assigned to your project. See below for more information on accession numbers.

A.3 Editing Project Data

To access the project data form, select 'Edit>Project Data' from the main menu.
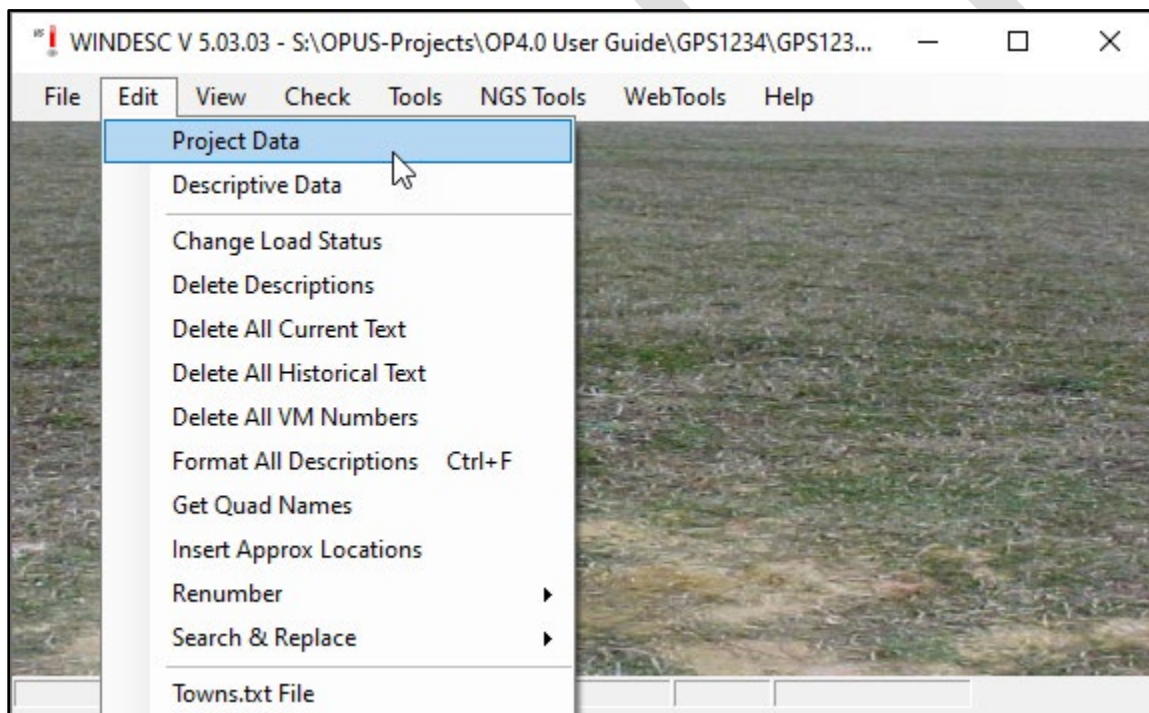
Figure A-4: Accessing Project Data in WinDesc

Figure A-5: Sample WinDesc Project Data screen

Job Code: User-defined, but recommended to always use "AA."

Country: Select appropriate country for project from the drop-down menu

State: Select appropriate state for project from the drop-down menu.

Agcy Cat Code: Drop-down menu; select the appropriate category for you/your agency. The category codes help organize and identify the "agency" assigned to the user for the purpose of submitting information and data to the National Geodetic Survey. Note that a private individual, or "none" as codes can be found under "M - Non-Specific Designators."

Figure A-6: NGS Agency categories drop-down menu

Agcy symb: When the Agency Category Code is selected, the corresponding available Agency Codes are available in the drop-down menu. You can type the Agency Code or scroll to the correct code. Once the code field is entered, the Agency Name will fill in automatically.

If a user is not sure whether their agency has a code they can look it up in the Contrib.dat file (found in the PC's WinDesc folder), or look it up online: (https://www.ngs.noaa.gov/cgi-bin/get_contrib.prl).

If a user cannot find the corresponding agency and would like to register the agency, the user can send an email request to ngs.annexc@noaa.gov.

Accession Code: For any GPS project, accession code is "GPS."

[Accession] No.: Accession numbers are assigned by NGS after a survey project proposal has been reviewed and approved. Please submit your proposal on the Project Proposal website. If not using an accession number, this can be lest blank.

Line/Part: Typically blank for most GPS projects in OP

C.O.P. Name: Enter the Chief of Party name

Initials: Enter the Chief of Party initials

Proj. Title: Enter the name of the project. This should be the same name as the one assigned to the project.

Com.: Comments are optional.

Email: Sharing an email address will allow NGS to contact you if there are any issues or questions about your description files.

Photo Directory: Processing mark descriptions in WinDesc allows the user to correctly format, edit, label, and submit all the required photos for the project. Identifying the directory containing all of the photos simplifies the identification and processing of the photos.

Horizontal/Datum/Order/Class: The default horizontal datum is 83; leave as-is.

Vertical/Datum/Order/Class: The default vertical datum is [NAVD] 88; leave as-is for projects in the Continental USA ("CONUS") and Alaska. For projects outside CONUS, please choose the appropriate datum in the drop-down list (e.g. International Great Lakes Datum, Puerto Rico Vertical Datum, "other," etc.).

Ellipsoid: Leave blank or select GRS-80.

Project Limits: Leave blank

Proj Start and **GPS Start**: Enter the date (yyyymmdd) that the project and GPS observations started.

GPS Comp and **Proj Comp**: Enter the date (yyyymmdd) on which the GPS observations were completed and the project was completed.

Click [OK] to save the project data.

A.4 Editing Descriptive Data

Open the Descriptive Data window by selecting it under the Edit tab:
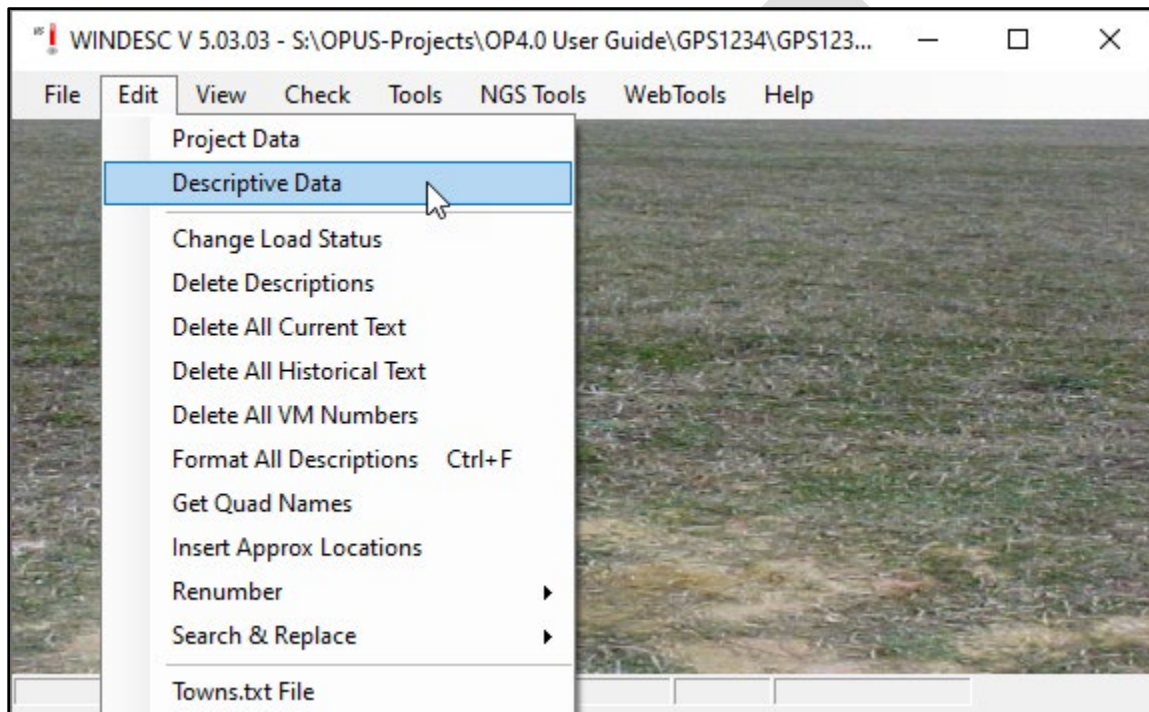
Figure A-7: Accessing the mark Descriptive Data in WinDesc

Figure A-8: Sample mark description for a published mark (information uploaded from the NGS IDB)

SSN (Station Serial Number): Each survey mark is assigned a job-specific station serial number (SSN) in the range 0001 to 9999. Each SSN needs to be unique to each mark observed in the project (<mark>NOT including CORS - no descriptions are required for CORS</mark>).

⚠ The SSNs of the WinDesc file must mach the SSNs in OP

DNR: Describe a new mark (D) or Recover and existing mark (R); N would be used for mark recoveries, if the mark were not found (not typically used for the purposes of building a description file for a survey project)

Figure A-9: Describe, Non-recover, or Recovery a mark options

A.4.1 Recovering an Existing Mark in the NGS IDB

If the mark already exists in the NGS IDB, the user will typically modify (add to) the existing description of a mark in the description file. In rare cases, the user may wish to totally re-describe a mark, if the original description is deemed incorrect.

Rec (Recovery): If an existing mark is recovered (R code, above), then the user can select from the following:

        F: Fully describe a mark not already present in the NGS database (not applicable here, as the mark already exists in the NGS IDB)

        M: Modify (add to) the description of an existing mark in the NGS database

        T: Totally re-describe a mark in the NGS database

If the mark is not in the NGS database, or the user selects the non-recovery of a mark, then the "Rec" option disappears.

Figure A-10: Fully describe, Modify, or Totally re-describe a mark options

Desig (Designation): This is typically a number, an alphanumeric symbol, or a concise, intelligible name which is usually stamped on the disk or access cover of the mark. If the mark already exists in the NGS database, the user should skip this entry and first enter the PID (Permanent Identifier - next entry), and the designation (and other attributes) will automatically be loaded.

PID (Permanent Identifier): This is the unique, six-character code identifying the mark within the NGS IDB. The first two characters are alphabetic, followed by four numeric characters (e.g. "AB1234").

> ⚠️ If the description file will be loaded into OPUS Projects, the PIDs in the WinDesc file must match the PIDs assigned to the marks in the project. Not all marks may have PIDs assigned, but if they do, they must match those in OPUS Projects.

After the PID is entered on the second row of the description entry window, the user can click on the **Dsdata** button to retrieve mark descriptive information already loaded in the NGS IDB. The information will be retrieved from the internet, assuming there is an internet connection; if there is no internet, the user will have to have previously downloaded a datasheet file for each mark in the NGS database.
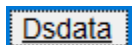
169
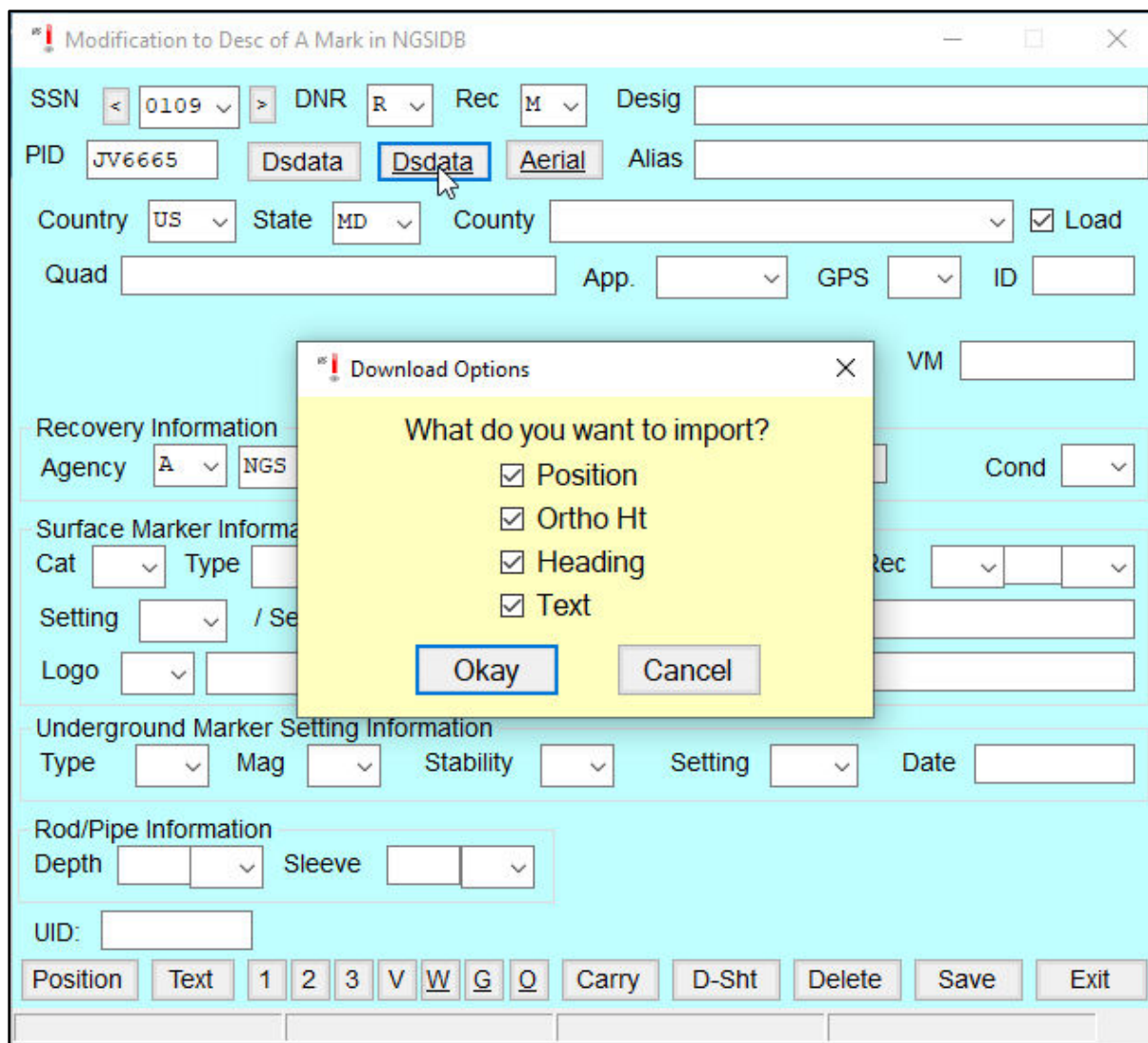
Figure A-11: Pop-up window prompting user to import mark descriptive data from an existing mark in the NGS IDB (using the mark's PID)

Once the description file incorporates the relevant metadata from the NGS database, Windesc adds additional information to the right of the SSN drop-down menu (see below): the first column gives the horizontal order assigned to the mark (all zero-order in the example below); the middle column gives the vertical order (a mixture of First and Second Order in the example); and the right-most column identifies whether the heights are adjusted ("A") or GPS-derived ("G").

The user should verify that the information loaded onto the description pages is correct (including the "Position" and "Text" buttons, explained below).

Figure A-12: Additional mark attributes imported from the NGS IDB

Country/State/County/Quad: Check these attributes (Quad refers to the corresponding USGS 7-minute quadrangle map). These should be correctly imported from the NGS IDB, but it is always prudent to check.

Load: Make sure this is checked so the description file can eventually be loaded into the NGS DIB.

VM: If the mark is a NOAA tidal bench mark, make sure the VM number is listed (available from the Tides & Currents bench mark datasheet pages).

GPS: This describes whether the mark is suitable for GPS observations. For OP, this must be "Y" (Yes, mark is suitable for GPS use).

ID: This is a four-character ID assigned to each observed mark in your GNSS project. The recommendation is to define unique four-character ID's for each mark to be observed in the project, prior to running the survey. In that way, field log sheets can correctly identify the four-character IDs specific to each mark, so there is less chance of confusion when running quality assurance and quality control.

> ⚠ In order for the marks in OP to match the descriptions, the four character ID in the WinDesc file much match the four character IDs for the respective marks in OP

Recovery Information: if the mark is an existing mark, the description file needs information on the agency, date, and Chief of Party associated with the recovery. As before, agency information starts with the agency type code, followed by the specific agency name code (See Bluebook Annex C for more information). The user may also consult the Agency Table, and email ngs.annexc@noaa.gov if a new agency code is required.

Figure A-13: Mark recovery information

Surface Marker Information

For a mark already in the NGS IDB, the surface marker information will have been imported from the database. Occasionally, some information may be missing which the use may be able to provide. It is always recommended to check to make sure all of the information is correct. Any user-changed fields will be reviewed at NGS prior to loading.

Figure A-14: Surface Marker Information

Cat: This is the category of the mark, whether it be a disk, rod mark, landmark, or other.

Type: This is the specific attribute for the mark category. For survey disks, there are a number of types including generic survey disks, tide station disks, vertical control disks, etc. For rod marks, options include flange-encased rod or simply metal rod.

Mag: If the mark is known to have magnetic properties (it can be located with a metal detector), please indicate it here.

Stability: This is the presumed stability (combined horizontal and vertical) of the survey mark. Is the mark subject to disturbance or movement? Please refer to the table below for an explanation of the stability codes.

Table A-1: NGS vertical stability codes

Vertical Stability Code	Definition	Example
A	Marks of the most reliable nature which are expected to hold their position/elevation well	Marks set on outcrops, on foundations of huge structures, or deep rod marks inserted to refusal
B	Marks which probably hold their positions/elevations well	Marks set on foundations of large structures, or deep rod marks
C	Marks which may hold their positions/elevations well, but which are commonly subject to surface ground movements	Marks set in medium structures, including concrete post marks
D	Marks of questionable or unknown reliability	Marks set in light structures (e.g. sidewalks, curbs, etc.)

If a stability code has already been assigned to the mark in the NGS database, only change the stability code if there is proof positive that the original stability is mis-characterized (please provide evidence, such as a photograph).

Fl/Proj/Rec (Flush/Projecting/Recessed): this refers to where the mark is found relative to the surrounding ground. If the mark is not flush with the ground, please provide a measurement of the distance that it is either projecting (P) or recessed (R). Note that either centimeters, inches, or feet are allowed.

Setting: This refers to the structure to which the survey mark is attached. Review for accuracy. If the current setting is currently different than what is indicated in the database, there is either an error in the database, or the mark has been reset. In either case, a note in the text would be warranted.

Setting Phrase: This is a concise (one or several-word) description of the specific setting of the mark. Examples might include "bridge," "abutment," "pier," etc. Review as above, and correct if necessary, adding explanatory text.

Logo: This part of the description relates to the agency that set the mark. Typically a survey mark will have the agency logo stamped onto the disk or mark access cover. Review for accuracy.

Stamp: this refers to the exact stamping seen on the disk or mark access cover. Typically this includes the designation as well as the year the mark was set. Note that the agency logo information is NOT included in the definition of the stamping - only the designation, year, and possibly other text stamped into that particular mark. If there are more than one year stamped on the disk, that is most likely an indication that the original mark has been reset. Review the descriptive information for reference to the mark being a reset.

Underground Marker Setting Information

Traditional horizontal marks set in the 19th and 20th Centuries involved burying the reference mark underground to ensure its preservation. The brass disk or other survey marker on the surface was merely an indicator of where the underground marker lay. In cases where the surface marker may have been damaged or

destroyed, survey parties may attempt to recover the original underground marker (which is itself not to be disturbed). Existing data on the original underground mark description can be found or modified here. Any modifications should also be described in the text portion of the recovery.
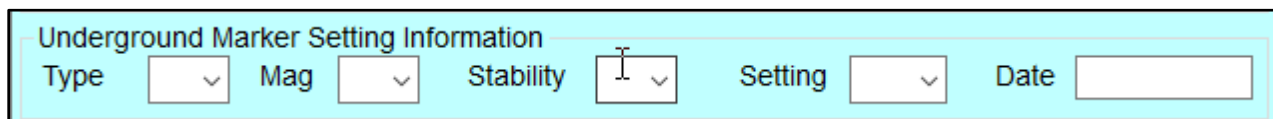
Figure A-15: Underground marker information

Type: This is similar to the mark type seen earlier, and actually has more entries for historical reasons.

Mag: If the mark is known to have magnetic properties (it can be located with a metal detector), this should be indicated here.

Stability: This is assumed stability (combined horizontal and vertical) of the underground survey mark.

Setting: This refers to the structure to which the underground survey mark is attached.

Date: this should be the same as the setting date, if known.

Position: By clicking on the ☐ Position button on the main description data page, a pop-up window will appear which will display positional information for marks already in the NGS database.
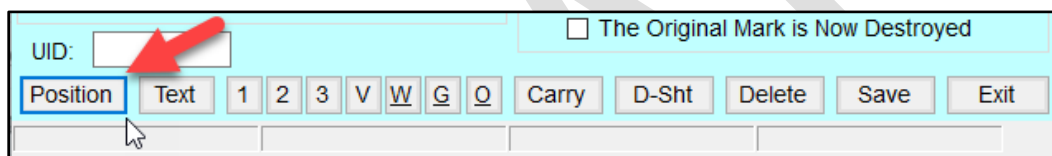
Figure A-16: Location of the "Position" button on the Description Entry Form

Figure A-17: Mark Position data page

A Position page contains the positional information for the mark as stored in the NGS IDB.

An explanation of the data fields is provided below. Review the information presented for completeness.

Lat: Input the latitude for the mark, in the DDMMSS.sssss format.

Lon: Input the longitude for the mark, in the DDMMSS.sssss format.

Source: if the source is already defined from the NGS database, leave as-is. Otherwise, the code would be "O" for "Other."

Datum: select "83" from the list.

Epoch: Do not define or change

Adj. Dt.: Do not define or change

Order: A single OPUS solution is considered Fourth Order.

Class: not required (leave blank)

Technique: Coordinates derived from a single OPUS solution are considered "Hand Held 1" (differential GPS), which means that the horizontal coordinates will be truncated to two decimal places.

Note that these fields (**Source**, **Order**, **Class**, **Technique**) relate to the implied precision and accuracy of the horizontal coordinates, which dictates under which conditions a horizontal position in the NGS database can be superseded. Essentially, if a position in the NGS database is adjusted, anything changed regarding a mark's position in the description file cannot change what is in the database. Any scaled coordinate can be superseded by a position obtained from GNSS. HH1 is a position based on post-processed differential positioning (e.g. an OPUS solution), which will be published to the nearest two decimal places. HH2 is a position based on an autonomous GNSS-based position, either from a hand-held GNSS unit (or smart phone!) or a real-time receiver in autonomous mode. A HH2 position will be published to only one decimal place.

If the precision and accuracy of the horizontal position of a mark is poor (e.g. "scaled"), it is recommended to insert the higher precision Lat/Lon's from an OPUS solution for the corresponding mark. For this reason, it is best to first upload the GPS observation files to your OPUS Project (but not process the session) before creating the description file.

GPS Data/Orthometric Height Data/Ellipsoid Height Data/Geoid Height Data/SPCS Zones/Legacy: not needed in OP - leave as-is or blank.
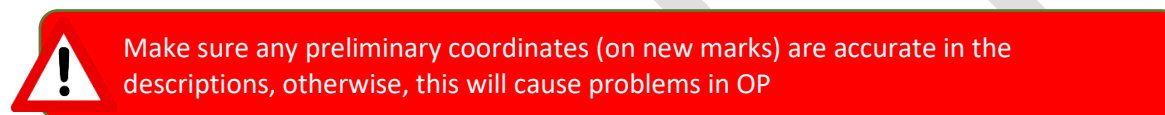
⚠️ Make sure any preliminary coordinates (on new marks) are accurate in the descriptions, otherwise, this will cause problems in OP

Close: Click on this button to bring you back to the Description Entry Form page.

Save: click on this button on the Description Entry Form page to save your Position data.

Figure A-18: Click on the [Save} button to save all mark descriptive information

Text: If the mark is recovered as described and in good condition, there is no need to add any text. However, if there is any important new information to share about a mark's condition or location, then it is recommended to add a description of these changes in the "text" portion of the mark recovery. Examples would include the absence of one or more reference objects, any changes to the mark's projection status, and changes in the area surrounding the mark which may affect the mark's stability or ability to obtain good GNSS signals.

 By clicking on the "Text" button on the main Description Entry Form, a pop-up window will appear in which both historical descriptive text (if available) will appear, as well as a new empty screen for new descriptive text (opened by default).

Figure A-19: Click on the [Text} button to add descriptive text to a mark
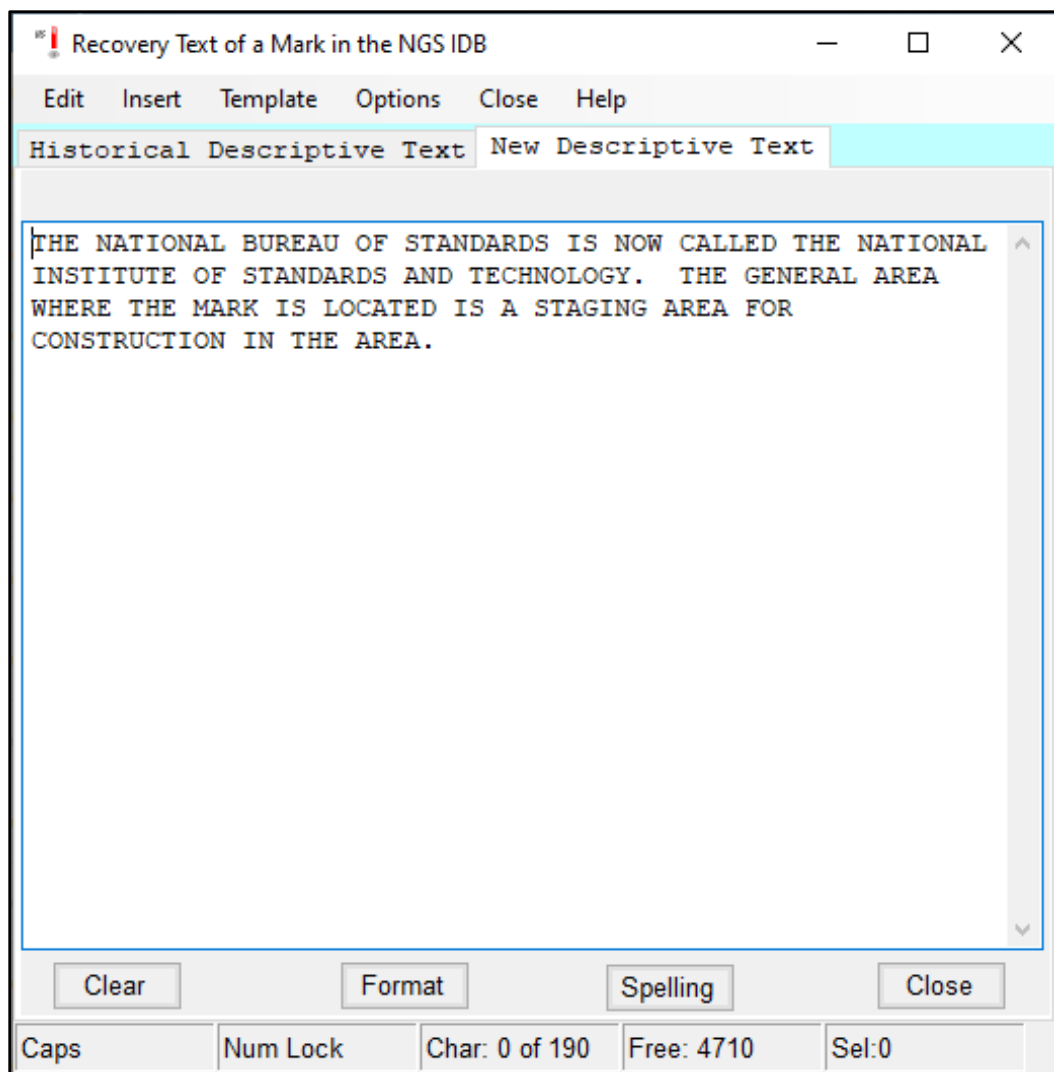
Figure A-20: New descriptive text associated with a mark recovery

Note that the text is entered automatically in ALL CAPS. After entering any new text, click on the [Format] button, which should help format the text appropriately for the datasheet.

For any new text to be loaded successfully, the spell checker will have to be run. Access the spell-checking utility by clicking on the [Spelling] button. This will open the Spell Check window. Click on the [Start] button to begin spell checking.
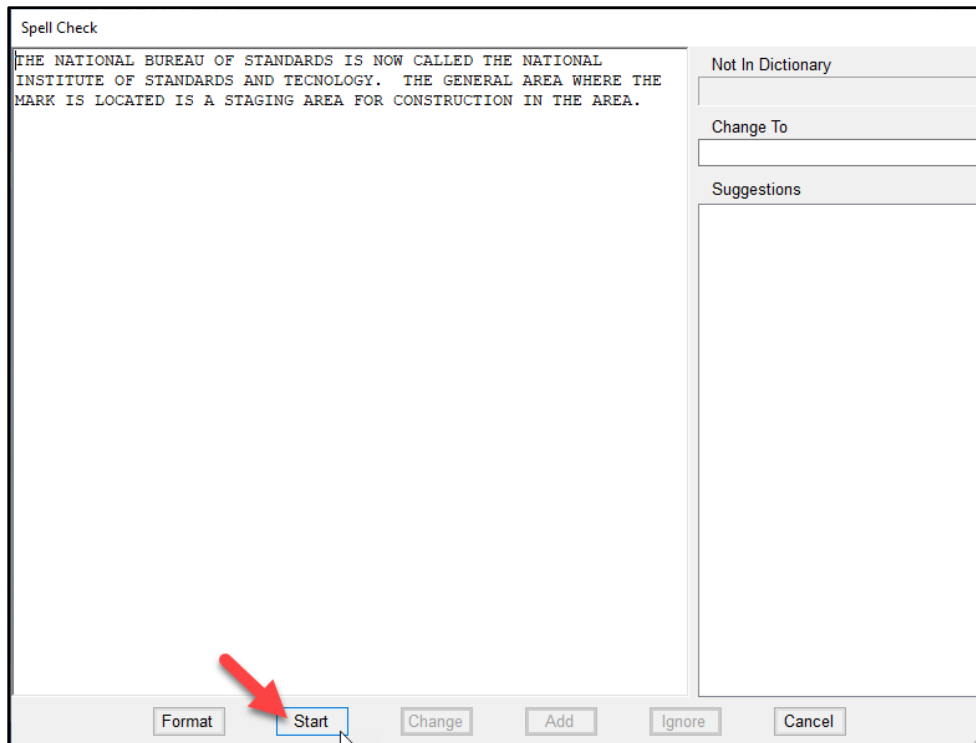
Figure A-21: The WinDesc Spell Check utility

If any misspelled words are found, or there are words not found in the Spell Check library, the user will be prompted to change, add, or ignore the word.
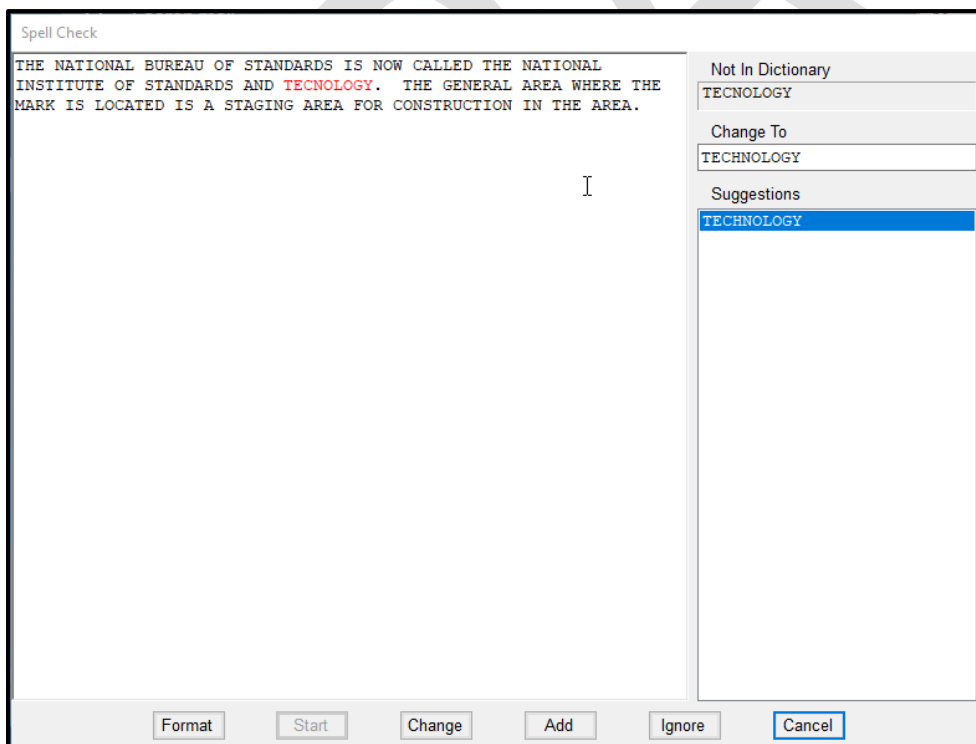
Figure A-22: Example of a misspelled word identified by the WinDesc Spell Check

Once the entire body of the new text is checked, a pop-up window will alert the user that the checking is complete. The Spell Check utility will unload, and the user can then close the window.
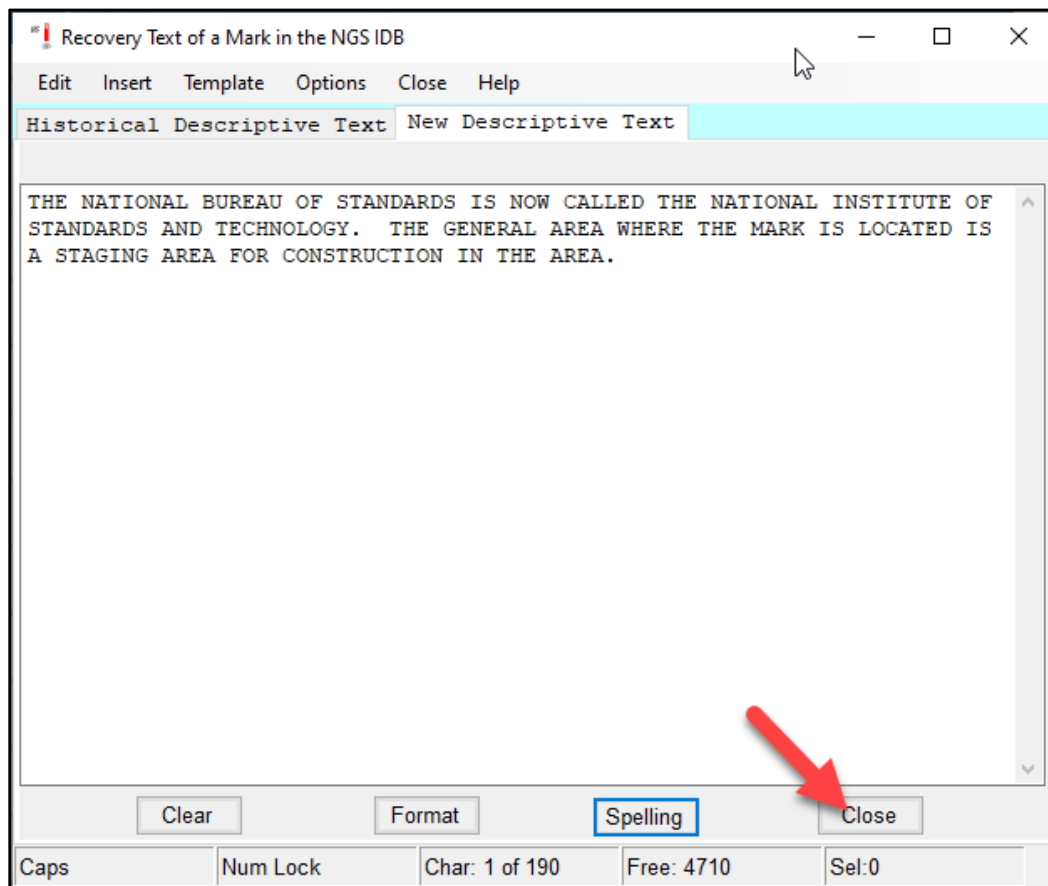
Figure A-23: Closing the WinDesc Spell Check

Since changes have been made to the mark's description, you will need to save your changes before proceeding to the next mark.
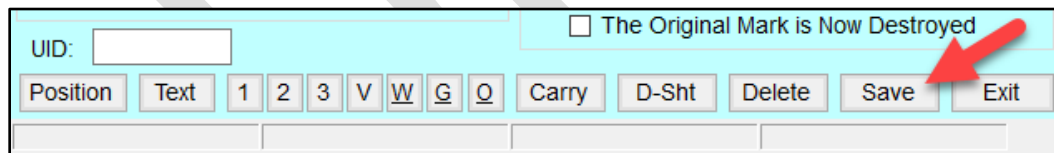
Figure A-24: Save any changes made to the mark description

A.4.2 Describing a New Mark

A new mark is not necessarily a mark that has recently been set. By "new," we mean that it has not yet been described in the NGS IDB. Whereas recovering a mark entails mostly reviewing existing information, describing a new mark means adding all new information. There are some slight changes to the main description entry form described below.

Figure A-25: Original description of a newly set mark in WinDesc

Note that there is no qualifier for the kind of recovery, and the PID field has disappeared.

Desig: This is typically a number, an alphanumeric symbol, or a concise, intelligible name which is usually stamped on the disk or access cover of the mark. Guidelines recommend that the designation be unique to the survey mark at least within the same county, if not the same state, to avoid the probability of mis-identification. Please see Annex D of the Bluebook for additional guidance on designations, especially when dealing with legacy marks. The designation must not exceed 30 alphanumeric characters, including all embedded blanks. When necessary, abbreviate the designation to conform to the 30-character rule.

Alias: This is an optional field to enable the user to add a second name associated with the mark.

Country/State/County/Quad: Enter these attributes. Quad refers to the corresponding USGS 7-minute quadrangle map, and will be automatically entered by WinDesc once the Position information is entered (see below).

Load: Make sure this is checked so the description file can eventually be loaded into the NGS DIB.

App (Application): Identify any special application assigned to the mark from the pull-down menu. This is an optional field that only needs to be specified if there is a special application required. Otherwise leave blank.

Figure A-26: Special application options for a new survey mark

GPS: This describes whether the mark is suitable for GNSS observations. For OP, this must be "Y" (Yes, mark is suitable for GNSS use).

ID: This is a four-character ID assigned to each observed mark in your GPS project. The recommendation is to define unique four-character ID's for each mark to be observed in the project, <u>prior</u> to running the survey. In that way, field log sheets can correctly identify the four-character IDs specific to each mark, so there is less chance of confusion when running quality assurance and quality control.

> ⚠️ In order for the new marks in OP to match the descriptions, the four character ID in the WinDesc file must match the four character IDs for the respective marks in OP
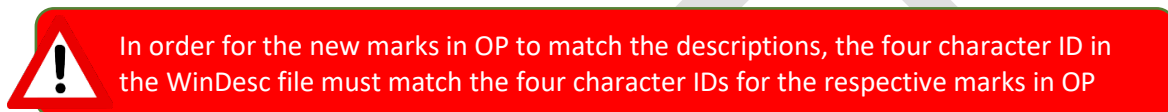
VM: If the mark is a NOAA tidal bench mark, make sure the VM number is listed (available from the Tides & Currents bench mark datasheet pages).

Monumentation Information: if the mark is a not yet in the NGS IDB, the description file needs information specific to the installation of the mark, including the setting agency information, the date the mark was installed, the Chief of Party ("C.O.P."). As before, agency information starts with the agency type code, followed by the specific agency name code (See Bluebook Annex C for more information). The user may also consult the Agency Table, and email ngs.annexc@noaa.gov if a new agency code is required.

Figure A-27: Monumentation information for a newly described mark

Surface Marker Information

Cat: This is the category of the mark, whether it be a disk, rod mark, landmark, or other.

Type: This is the specific attribute for the mark category. For survey disks, there are a number of types including generic survey disks, tide station disks, vertical control disks, etc. For rod marks, options include flange-encased rod or simply metal rod.

Mag: If the mark is known to have magnetic properties (it can be located with a metal detector), please indicate it here.

Stability: This is assumed (combined horizontal and vertical) stability of the survey mark. Is the mark subject to disturbance or movement? See table A-1.

Fl/Proj/Rec (Flush/Projecting/Recessed): this refers to where the mark is found relative to the surrounding ground. If the mark is not flush with the ground, please provide a measurement of the distance that it is either projecting (P) or recessed (R). Note that either centimeters, inches, or feet are allowed.

Setting: This refers to the structure to which the survey mark is attached. Please select the appropriate setting code from the available options. If selecting "00" for "Other," it is recommended to explain the setting in the text portion of the mark description (see below).

Setting Phrase: This is a concise (one or several-word) description of the specific setting of the mark. Examples might include "bridge," "abutment," "pier," etc. Note that the setting phrase is not a repetition of the words used to describe the setting code. By selecting the setting code, the user has already identified the language associated with the code. The Setting Phrase provides the opportunity to add additional explanatory text.

Logo: This part of the description relates to the agency that set the mark. Typically a survey mark will have the agency logo stamped onto the disk or mark access cover. As before, select the agency type, and agency code (See Bluebook Annex C for more information). The user may also consult the Agency Table, and email ngs.annexc@noaa.gov if a new agency code is required.

Stamp: this refers to the exact stamping seen on the disk or mark access cover. Typically this includes the designation as well as the year the mark was set. Note that the agency logo information is NOT included in the definition of the stamping - only the designation, year, and possibly other text stamped into that particular mark.

Underground Marker Setting Information: Newly set marks are surface marks. If describing an underground mark not in the NGS IDB, the Type, Mag, Stability, and Setting fields should be entered. They are similar to those seen in the Surface Marker Information. The Type has more options, however, due to historical reasons.
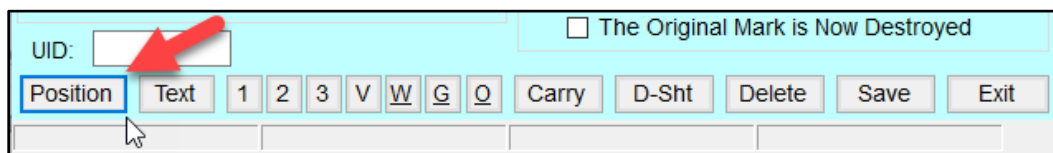
Rod/Pipe Information: If the surface marker is attached to a pipe or rod, the depth needs to be entered in the description, as well as whether or not the rod also has a sleeve (to isolate it from potential movement of the soil surrounding the rod).

Reset Info: If the mark is a reset of an original mark in the NGS IDB, the user can refer to the parent mark here, noting both its PID and designation. Whether the original mark is destroyed or not can also be included.

Figure A-28: Rod/Pipe and Reset information
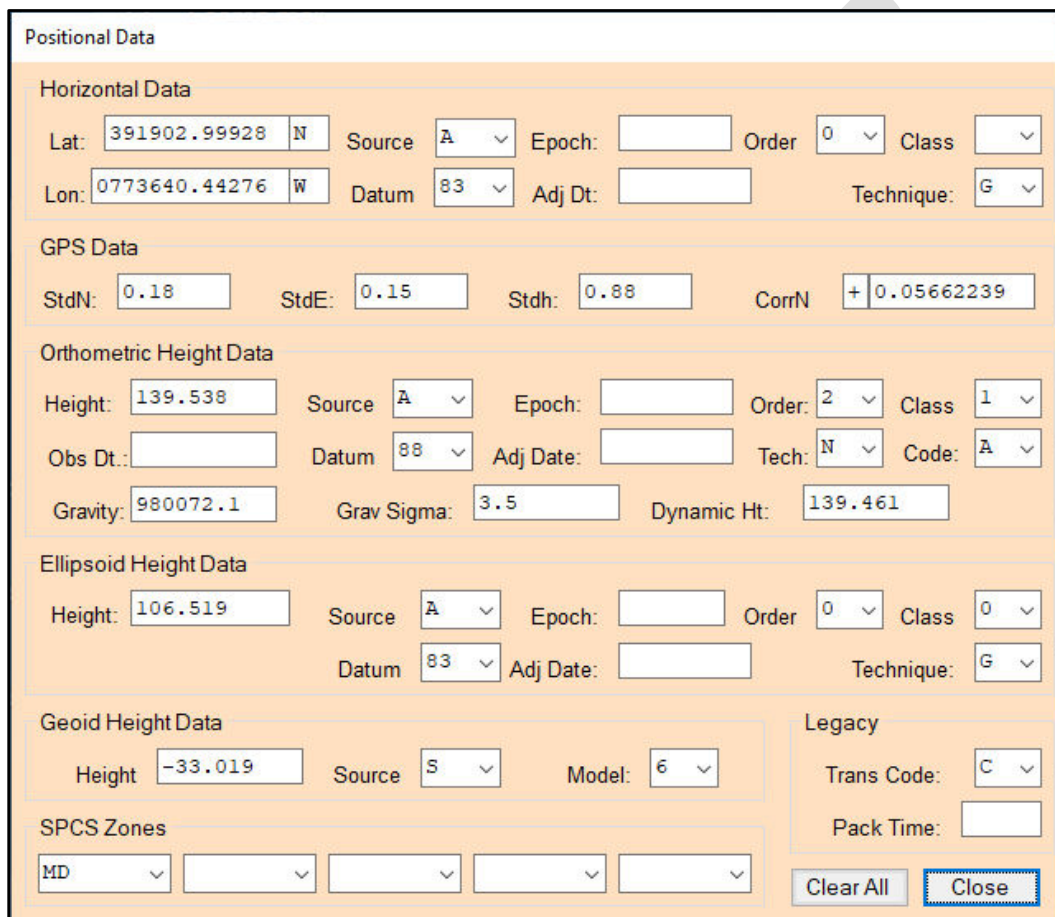
Position: By clicking on the [Position] button on the main description data page, a pop-up window will appear which allow positional information to the entered. Note that if the description file is loaded into OPUS Projects, the positions indicated will not affect the a priori or computed coordinates from any adjustment.

Figure A-29: Location of the "Position" button on the Description Entry Form

Figure A-30: Mark Position data page

For a new mark which part of an OPUS Projects project, it is recommended to enter the position from one of the processed OPUS solutions.

Lat: Input the latitude for the mark, in the DDMMSS.sssss format.

Lon: Input the longitude for the mark, in the DDMMSS.sssss format.

Source: If entering the position from an OPUS solution, this would be "O" for "Other".

Datum: select "83" from the list.

Epoch: not required (leave blank)

Adj. Dt.: not required (leave blank)

Order: A single OPUS solution (or hand-held coordinate) is considered Fourth Order.

Class: not required (leave blank)

Technique: Coordinates derived from a single OPUS solution are considered "Hand Held 1" (differential GPS), which means that the horizontal coordinates will be truncated to two decimal places.

GPS Data/Orthometric Height Data/Ellipsoid Height Data/Geoid Height Data/SPCS Zones/Legacy: this information is not needed to generate a complete description file, so it can be left as-is.
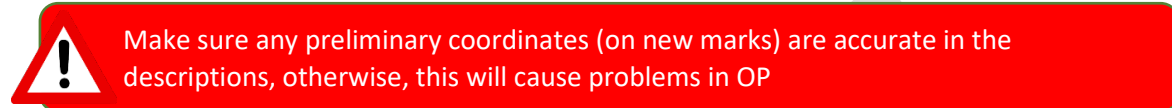
> ⚠ Make sure any preliminary coordinates (on new marks) are accurate in the descriptions, otherwise, this will cause problems in OP

Close: Click on this button to bring you back to the Description Entry Form page.

Save: click on this button on the Description Entry Form page to save your Position data.

Figure A-31: Click on the [Save} button to save all mark descriptive information

New Descriptive Text: A new mark will need a complete descriptive text indicating where the mark is located and how to reach it. A separate text window is accessed by clicking on the `Text` button at the bottom of the Description Entry Form.

Figure A-32: Click on the [Text} button to add descriptive text to a mark

Figure A-33: Example of new descriptive text in the recommended three-paragraph form

A complete, new descriptive text is typically given in a three-paragraph form shown above. The first paragraph identifies where the mark site is located within a general area. Distances to the nearest town center or references to major landmarks are given. The second paragraph describes how to reach the mark site from the nearest road intersections. The third paragraph explains how to find the mark once the site is reached. Measured distances (to the nearest decimal meter) are given to five reference objects, to ensure that the mark can be recovered even if several reference objects disappear over time.

Note that the text is entered automatically in ALL CAPS. After entering new text, click on the Format button, which should help format the text appropriately for the datasheet.

Figure A-34: The [Format] button on the mark descriptive text page

For any new text to be loaded successfully, the spell checker will have to be run. Access the spell-checking utility by clicking on the Spelling button. This will open the Spell Check window. Click on the Start button to begin spell checking.
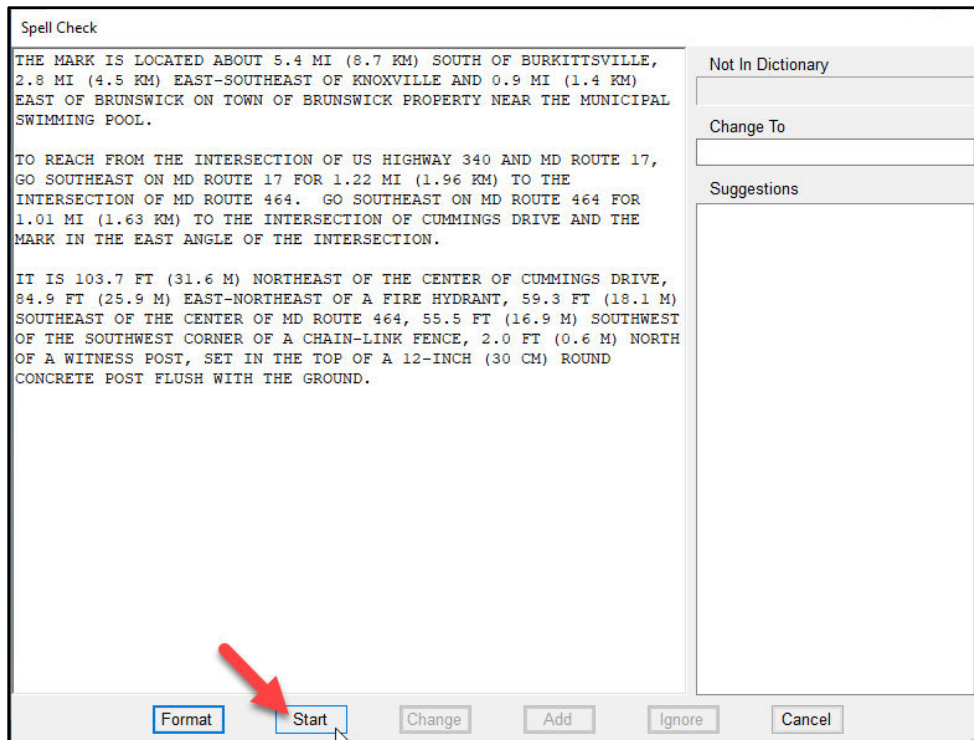
Figure A-35: The WinDesc Spell Check utility

If any misspelled words are found, or there are words not found in the Spell Check library, the user will be prompted to change, add, or ignore the word.
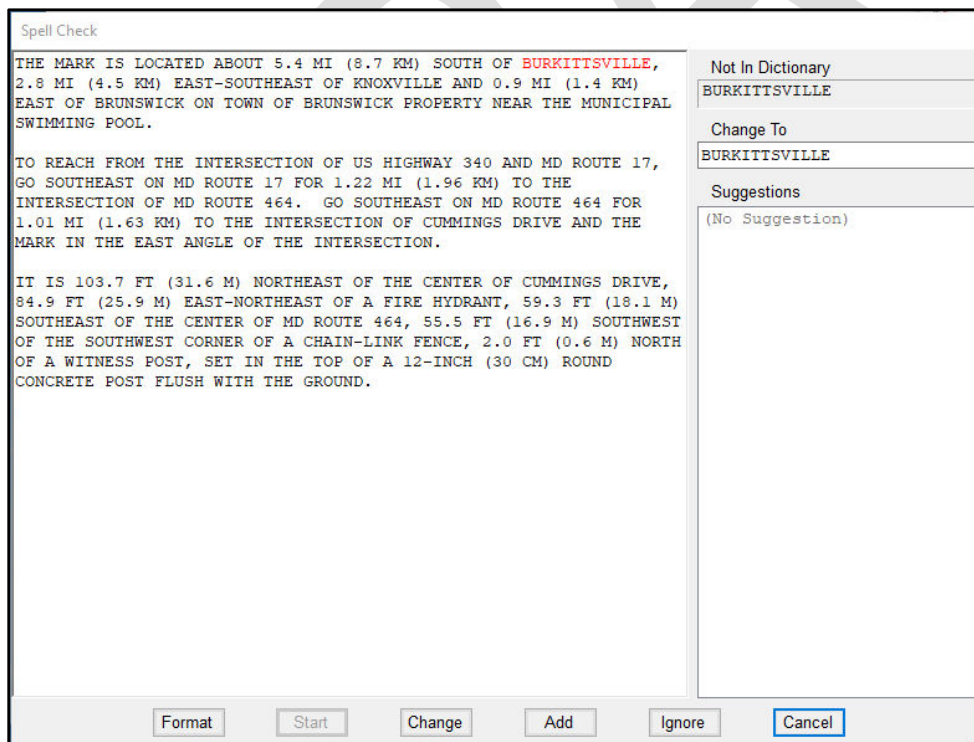
Figure A-36: Example of a misspelled word identified by the WinDesc Spell Check

Once the entire body of the new text is checked, a pop-up window will alert the user that the checking is complete. The Spell Check utility will unload, and the user can then close the window.
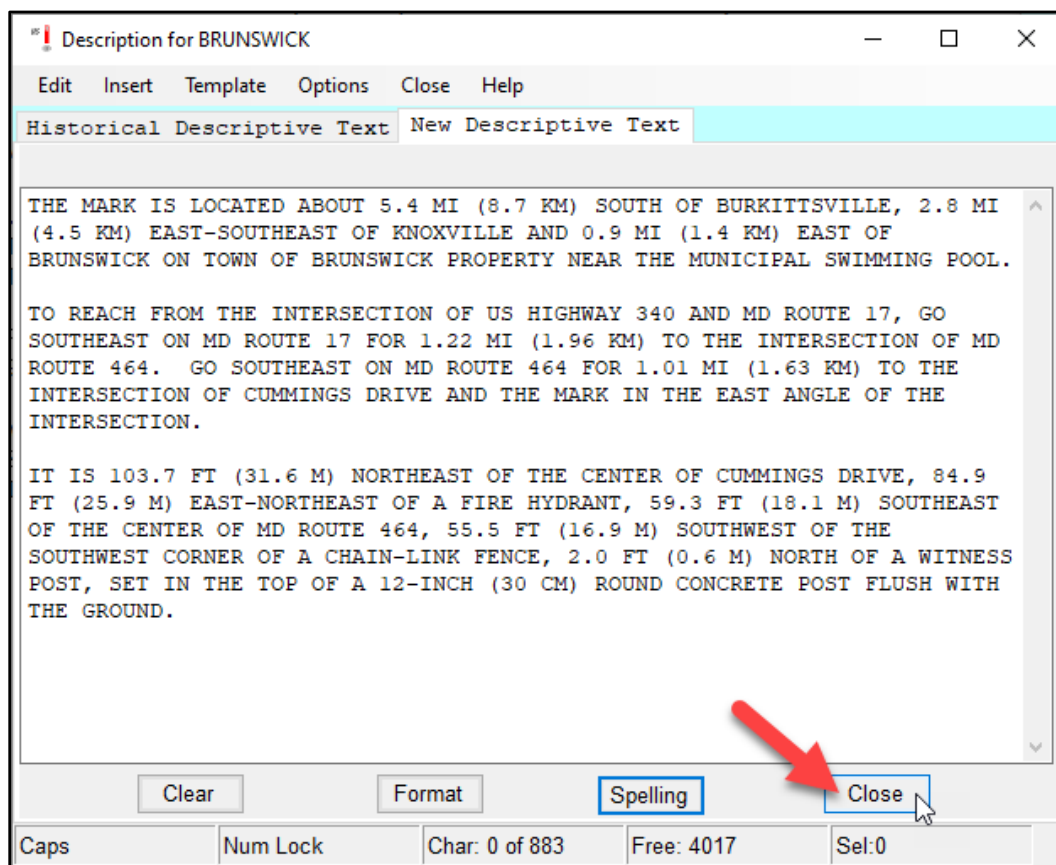
Figure A-37: Closing the WinDesc Spell Check

Since changes have been made to the mark's description, you will need to save your changes before proceeding to the next mark.
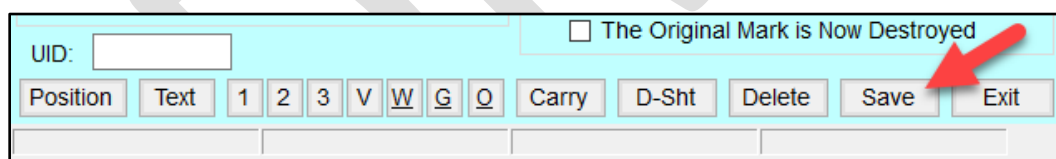
Figure A-38: Save any changes made to the mark description

A.4.3 Photo Editing

Photos are an important part of the mark description, as they provide evidence of the mark itself, as well as its condition. Regardless of whether a mark is newly described, or already exists in the NGS IDB, a set of three photographs are required for submitting a GNSS project to NGS. WinDesc provides easy access to a photo editor which can simplify the process of implementing the NGS Photo Submission Guidelines. If the photo directory has been properly identified under Project Data (Figure A-5), clicking on the <1> <2> and <3> buttons will enable you to select the correct close-up of the mark (Photo #1), eye-level photo of the mark (Photo #2), or horizon view (Photo #3), respectively (see Figure A-39).

Figure A-39: Three buttons at the bottom of the Description Entry Form enable you to properly edit the three required photos for each mark in the project

The WinDesc photo editing features include resizing, cropping the image, rotating, placing a standard (or custom) label on the image, and more.
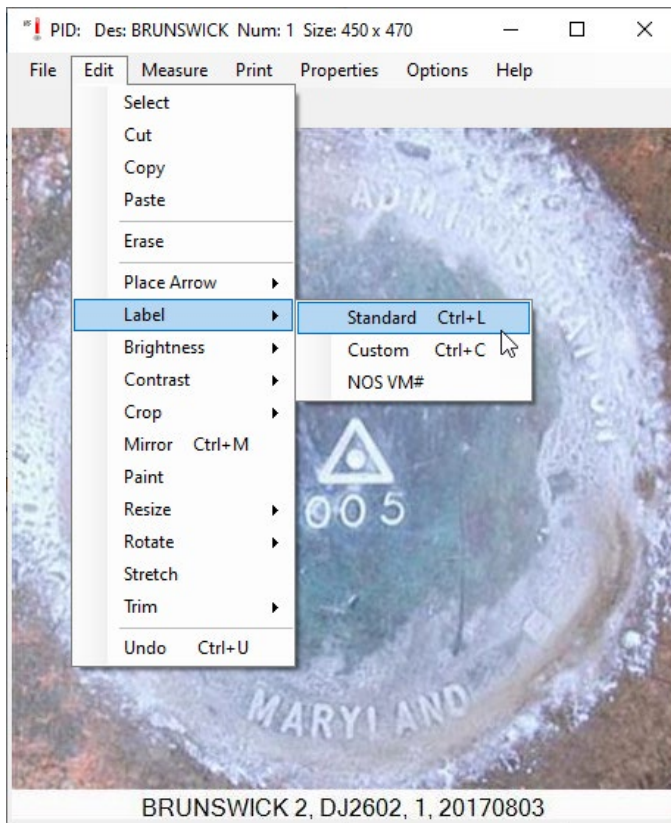
Figure A-40: Example showing the creation of a standard label for a survey mark close-up photograph

With typical high resolution digital cameras, mark photographs are often larger than needed and may also be too large to display properly on a computer terminal. For that reason, NGS recommends a square 400 x 400 pixel size closeup photo (#1) and a 1024 x 768 pixel photo size for photo #2 and #3. WinDesc offers an easy way to resize a photo.

Once the photo has been correctly edited, the user can save and exit the photo editing window to return to the main descriptive entry window.

Once photos have been formatted, edited, and named correctly using WinDesc, they can be loaded into OP. There is no bulk-upload method available at this time, so all photos will need to be uploaded individually. We recommend that photographs be uploaded within OP from within the user mark pages after all RINEX observations have been uploaded (see Section 7.3.7 of the OP User Guide).
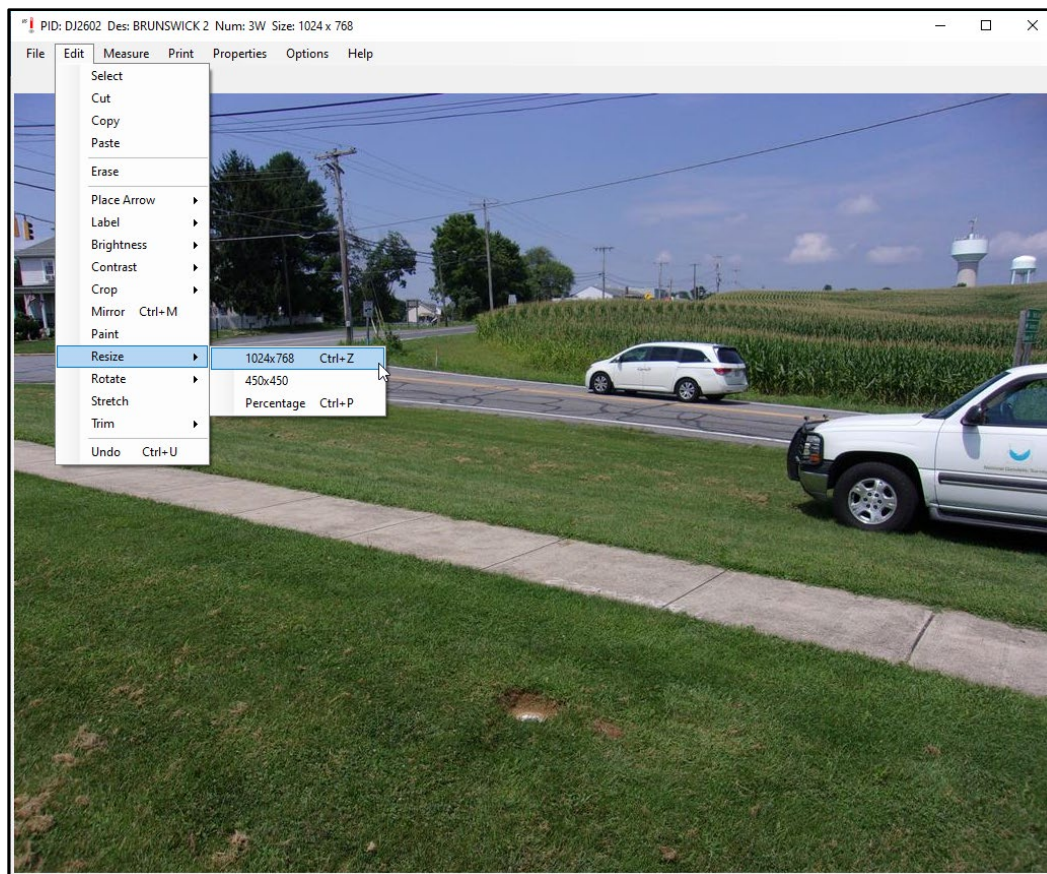
Figure A-41: Using WinDesc to resize a survey mark photo
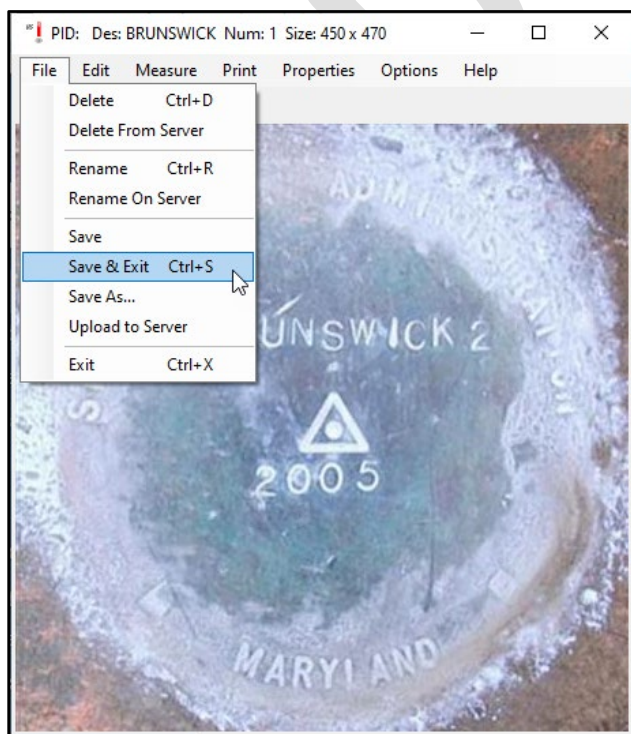
Figure A-42: Saving and exiting the WinDesc photo editing window

> It is recommended to use WinDesc to properly format photos prior to loading into your project

A.4.4 Additional features

WinDesc provides additional features, accessible from the buttons along the bottom of the Description Entry Form. Most of these are typically not required in OP, but are explained below for thoroughness:

V: Use this button to ensure the correct naming of any associated visibility diagram for the mark. Although OP does not support the inclusion of visibility diagrams within the project, certain surveys may require visibility diagrams be submitted (separately) for the project to be accepted by NGS. Please refer to your project instructions regarding whether or not to submit visibility diagrams.

W: Use this button to view the photos previously loaded into the NGS database for this mark.

G: Use this button to check the geocaching website for additional photographic evidence of the mark (note that copyright laws may prohibit you from using geocachers' photos)

O: Use this button to view photos from the OPUS Share database, if available.

Carry: Enables you to carry descriptive information to another mark in your project (may be useful if you are building a large description file of new marks which are similar in numerous mark attributes)

D-SHT: Creates a preliminary datasheet for the mark given the information you have provided.

Delete: deletes this particular description (for the SSN shown at the top of the form) from the description file.

When you have completed your mark description, click on <Save> before proceeding to the next mark in your project.
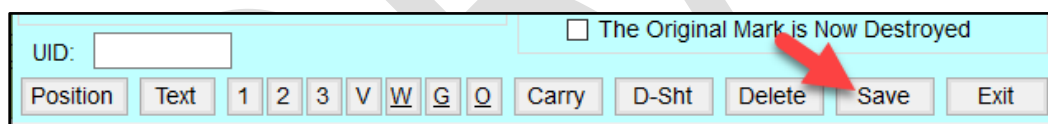
Figure A-43: The [Save] button at the bottom of the Description Entry Form

A.5 Checking the Description File

Once descriptions have been completed for all of the marks in the project, the final step is to run the required checks to ensure successful loading into the NGS database.

A.5.1 Neighbor for all Marks

This check is accessed from the Web Tools tab (see above). Running "neighbors" identifies and lists all marks currently in the NGS database that are within a specified distance from each mark in the description file (based on the position data in each mark's description).
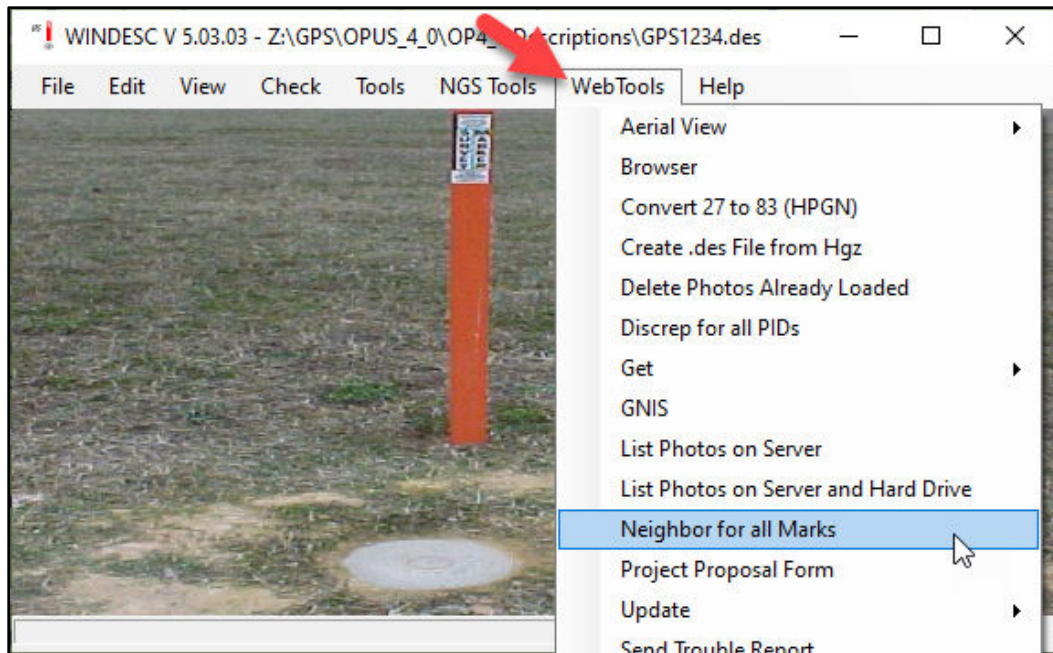
Figure A-44: Accessing the "Neighbor for all Marks" check in WinDesc

Accept the defaults (400 m radius, and do not include temporary bench marks, or TBMs).
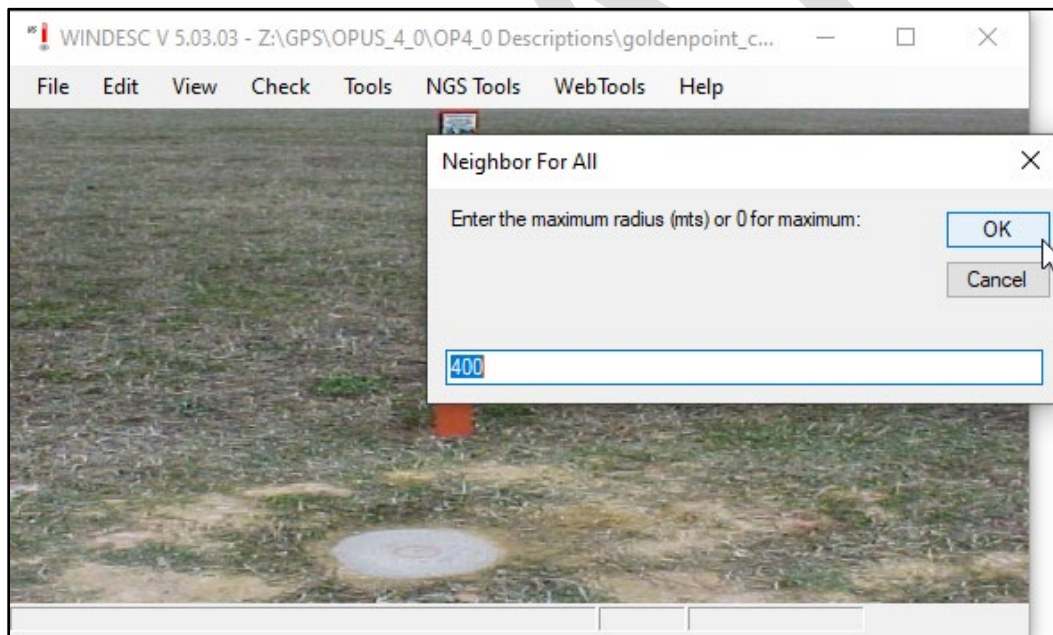
Figure A-45: Default maximum radius for checking neighboring marks in WinDesc
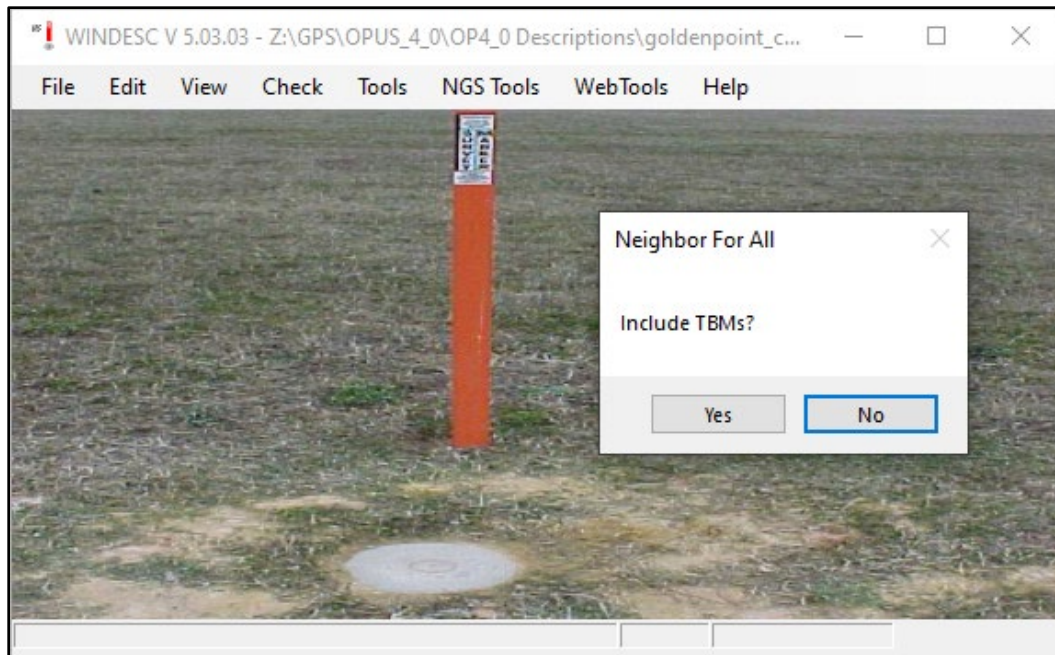
Figure A-46: Option to include TBMs (Temporary Bench Marks) in the WinDesc neighor analysis

The output is a text file (*.nbr) that lists all marks within the specified distance, sorted from nearest to farthest. If the mark already exists in the NGS database, the mark should appear at the top of the list. Note that there can be a slight discrepancy in the distance if the new position is of higher accuracy and precision than what is in the database. This is especially true for marks with scaled coordinates in the database.

Figure A-47: The result of a neighbor analysis in WinDesc

Running neighbors is required to make sure that the user has correctly identified the mark. This is especially important if the mark is part of a set of classical horizontal marks, which may include the horizontal mark itself, as well as reference marks and azimuth marks: all marks in the set may share much of the same designation, which can easily cause confusion and mis-identification (e.g. confusing a reference mark for the horizontal mark itself). Review the information to make sure the correct mark has been included in the description file. The output table is sorted by distance from the input mark's position to the position of nearby marks in the NGS database. The *.nbr file is saved to the same directory as the description file itself.

A.5.2 Discrep for all PIDs

This utility identifies and flags all discrepancies between information in the NGS database and the description file. This ensures that the user is made aware of how the new description file may differ from published datasheets. Common causes for discrepancies include newly identifying the mark as good for satellite observations, or a better source for the horizontal data.
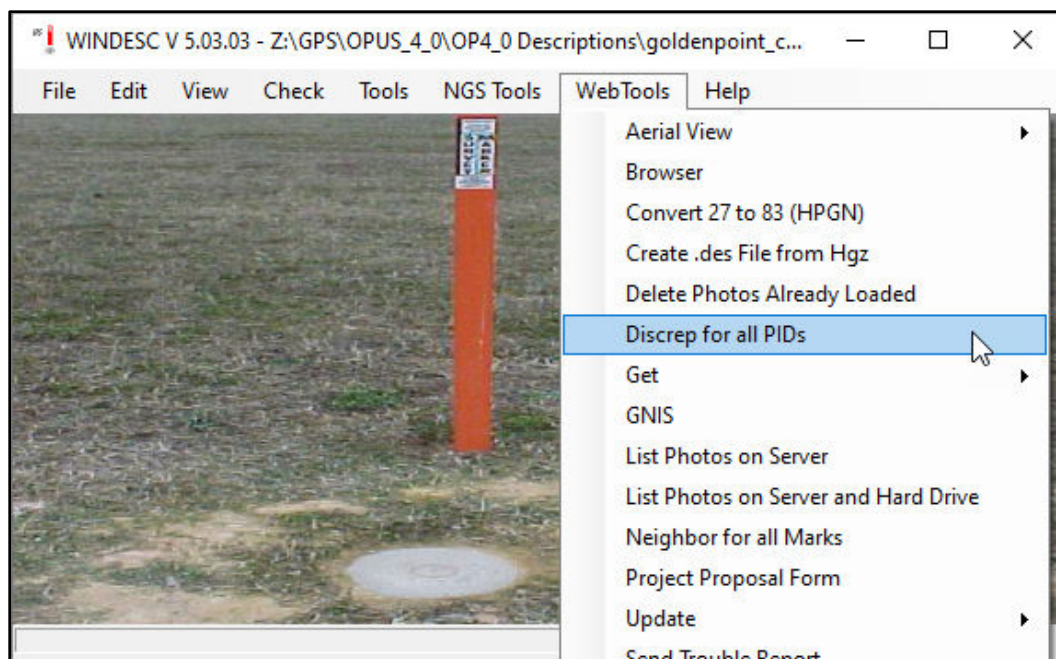
Figure A-48: Accessing the Discrepancy analysis in WinDesc

The output of Discrep is a text file (*.dis) with only those attributes listed that are at variance with the NGS database. The left column is for the new description, the right column is for information currently in the database. In the example, no discrepancies are found for CALVERTON, NBS 102, or BRUNSWICK 2. However, GORF N shows a discrepancy in the designation. Since it's a published mark with a PID, the database designation is correct and the Windesc file's designation is in error and must be corrected. All discrepancies must be considered. Re-run Discrep after all changes, if any, are made.

Remember, a discrepancy is not necessarily an error, but a warning. Your report should indicate that you have run, checked, and verified all discrepancies in the (*.dis) file.

Figure A-49: Sample Discrepancy report showing differences between the description file and information in the NGS IDB

The *.dis file is saved to the same directory as the description file itself.

> ⚠️ Discrepancies do not necessarily mean errors. Verify to make sure any discrepancy is indeed correct.

A.5.3 Recovery Dates for All Marks

Although not required by OP, this is a recommended check to verify that a recovery has not already been loaded for your project, or for another project within the same calendar year. NGS will not publish multiple recoveries within a given calendar year, unless the status of the mark has changed (e.g. from good to poor condition, or from "mark not found" to "found in good condition").
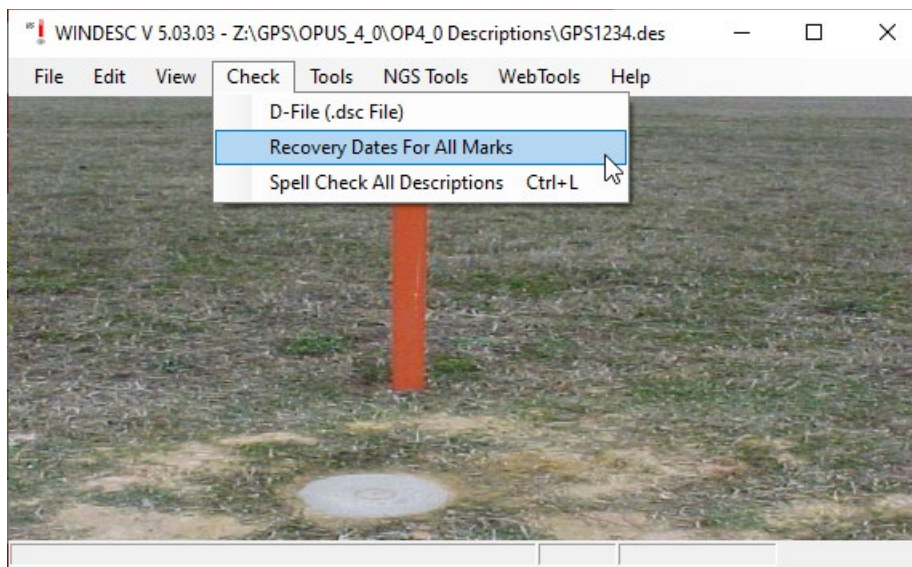
Figure A-50: Checking recovery dates for all marks in the description file

A.5.4 Exporting the Description File and Error Checking

The final steps in preparing the description file involves converting it into a format required for loading into the NGS database, and running a final error check. The export functionality will convert the native WinDesc (*.des) file format into a somewhat reduced file format readable in Linux, so the file can be loaded into the NGS IDB.
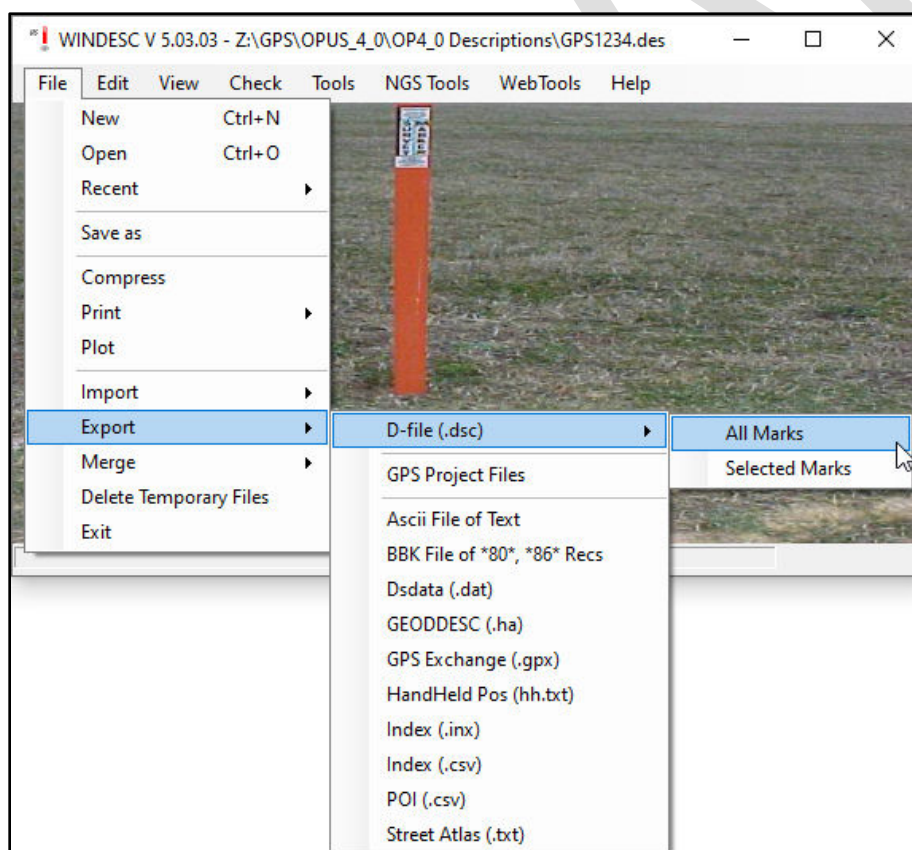
Figure A-51: Exporting the description file

In executing the export script, WinDesc will prompt the user to run a final error check.
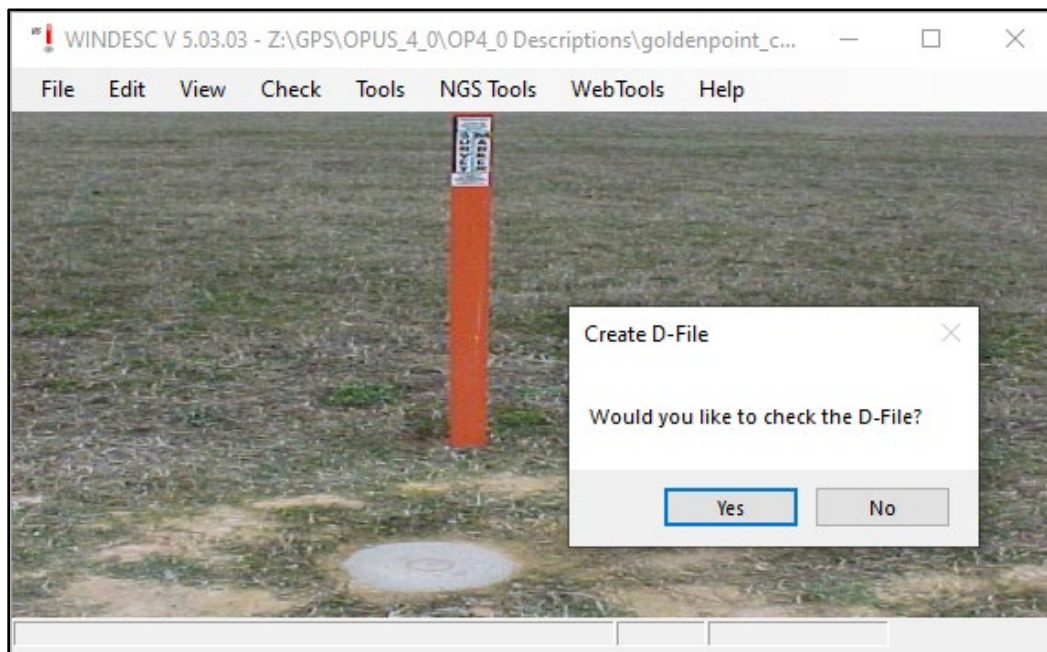
Figure A-52: WinDesc prompts the user to run a final error check after exporting the description file

In the error checking process a *.err file will be created, which lists all the errors found. Typical errors include required stamping information, special characters or other errors in the designation, or additional information required for certain mark setting types. The error checking can detect logical or inconsistency errors in the mark description fields, but it cannot always pinpoint exactly what is wrong. There may therefore be several warnings or errors flagged for a particular mark (identified by its SSN). For submitting the description file to NGS (as part of the OPUS Projects GNSS project), all errors must be resolves (it is permissible to have some warnings, as shown in the example below).

```
Z:\GPS\OPUS_4_0\OP4_0 Descriptions\goldenpoint_corrected.err              —    □    ✕

 File   Search   Tools   Wrap Text

WINDESC CHECK (Version 5.03.03)
LISTING FILE for: z:\gps\opus_4_0\op4_0 descriptions\goldenpoint_corrected.dsc
TYPE OF USER: IN-HOUSE NGS
STARTED: 16:46:18 Mon 31 May 2021
ACCESSION: GPS9056
PROJECT: GOLDEN POINT TEST SURVEY
-------------------------------------------------------------------------------
--(WARNING) Enter FPR code and data if they are available.
        SSN: 0101

--(WARNING) Enter FPR code and data if they are available.
        SSN: 0108


-------------------------------------------------------------------------------
END OF WINDESC CHECK LISTING    DESCRIPTIONS PROCESSED:9
NUMBER OF HEADER (D) RECORDS FOUND:              1      ALLOWED: 1
NUMBER OF PROJ TITLE (A) RECORDS FOUND:          1      ALLOWED: 1
NUMBER OF PROJ COMMENT (B) RECORDS FOUND:        1      ALLOWED: 0-1
NUMBER OF DESC HEADER (@) RECORDS FOUND:         9      ALLOWED: 1-9999
NUMBER OF UNDERGROUND MK (G) RECORDS FOUND:      0      ALLOWED: 0-9999
NUMBER OF RESET (H) RECORDS FOUND:               0      ALLOWED: 0-9999
NUMBER OF BOX SCORE (J) RECORDS FOUND:           0      ALLOWED: 0
NUMBER OF RECOVERY HISTORY (K) RECORDS FOUND:    0      ALLOWED: 0
NUMBER OF POSITION (L) RECORDS FOUND:            9      ALLOWED: 1-9999
NUMBER OF ORTHOMETRIC HEIGHT (M) RECORDS FOUND:  9      ALLOWED: 0-9999
NUMBER OF DESCRIPTIVE TEXT (T) RECORDS FOUND:    8      ALLOWED: 1-9999
NUMBER OF VERTICAL MARK (V) RECORDS FOUND:       0      ALLOWED: 0-9999
ERRORS:0
WARNINGS:2
THE FOLLOWING DESCRIPTIONS ARE MARKED FOR LOADING:
0101 0102 0103 0104 0105 0106 0107 0108 0109
THE FOLLOWING DESCRIPTIONS WILL NOT BE LOADED:

LOAD STATUS: READY
COMPLETED: 16:46:36 Mon 31 May 2021




                    Num Lock                    Insert        DOS          0
```

Figure A-53: Sample error (.err) file*

Warnings often request additional information pertaining to whether the mark is flush with the ground, projecting, or recessed (FPR in the example above). Other warnings might pertain to mark setting codes expecting additional information. Review the warnings to make sure you have provided correct, relevant information.

> ⚠ Any and all errors MUST be resolved prior to loading the description file into OP

A.6 Organizing Files to Upload to OP

As a result of creating, building, checking, and exporting a full description file for your project, you will have five separate files ready to upload to OP:

1) The description file in its native WinDesc format (e.g. GPS9056.des)
2) The description file in a Linux-uploadable, condensed format (e.g. GPS9056.dsc)
3) A listing of neighbors (e.g. GPS9056.nbr)
4) A listing of discrepancies with the NGS database (e.g. GPS9056.dis)
5) The final error checking file (e.g. GPS9056.err)

All five (5) files are required for successfully submitting your OP to NGS for bluebooking.

A.7 Checking Coordinates Prior to Network Adjustments in OP

Prior to running network adjustments in OP, it is important to verify that the geometric coordinates (lat, long, ellipsoid heights), the geometric reference frame, and the height in corresponding vertical datum are correct. This information can be verified using the "Index" file view.
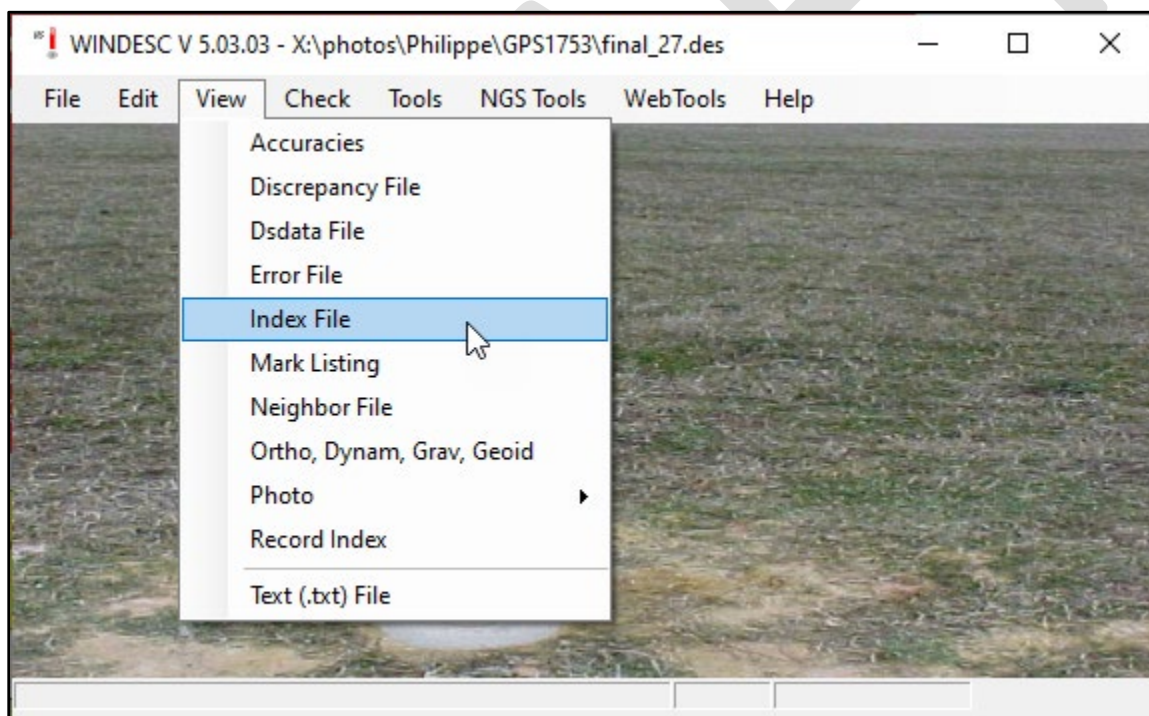
Figure A-54: How to create the WinDesc index file

Figure A-55: An example of a WinDesc index file showing the SSNs, PIDs, Designations,, coordinates, elevations, and other descriptive information

This can be very helpful for larger projects, so one does not have to manually review each individual user mark page. The index file can be saved and imported into a spreadsheet or other software to assist in validation/verification.

WinDesc also provides a utility to display the network *accuracies* of the coordinates if they were based on GNSS. These values are found on the NGS datasheets under "Network accuracy estimates." WinDesc provides an easy way to view them all in tabular form. First, the user must download the data from the NGS IDB using Web Tools → Get → Pos & Acc for GPS PIDs.
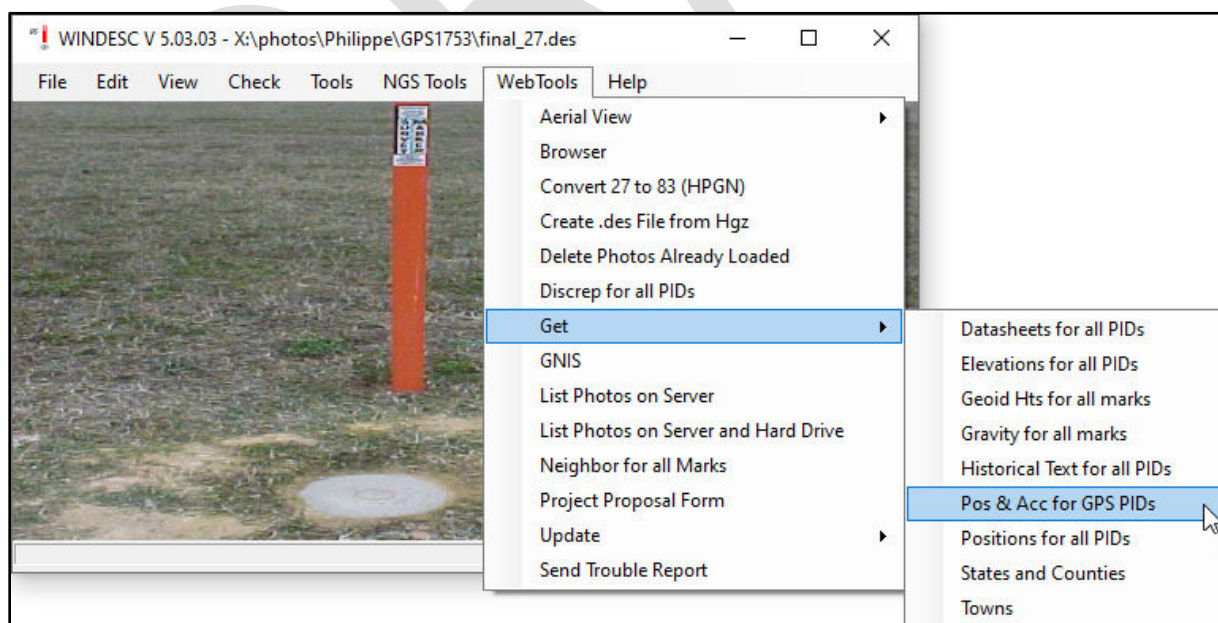
Figure A-56: How to download network accuracies for all marks whose coordinates in the NGS IDB were based on GNSS observations

Next, the user can view the Accuracies file from the View menu.
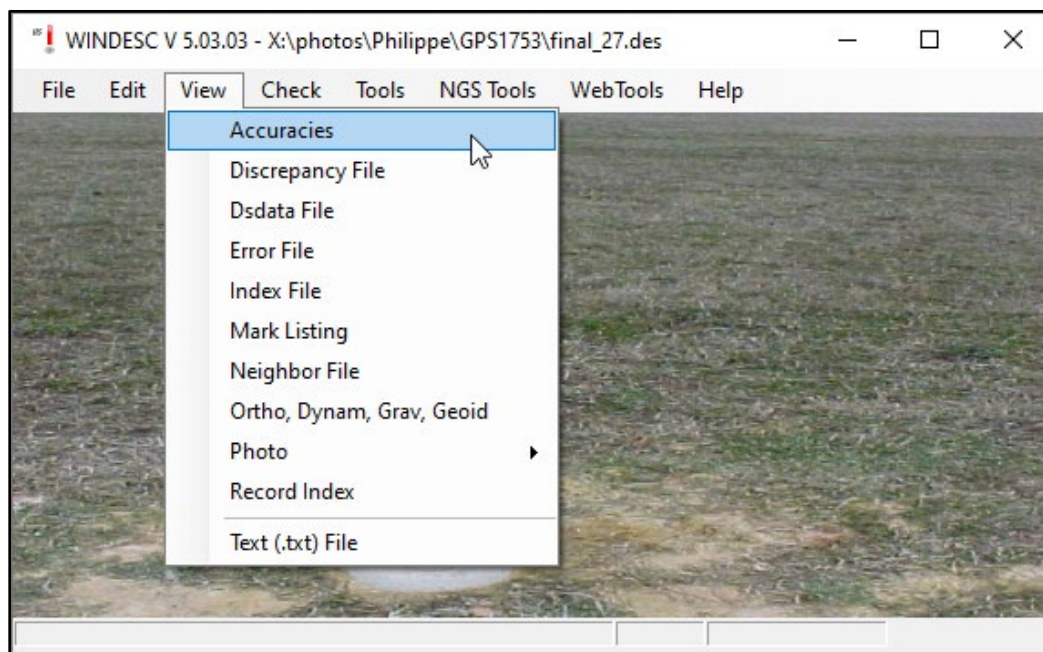
Figure A-57: How to view position accuracies on marks in WinDesc

Figure A-58: Network accuracies and correlations for marks in the description file whose positions in the NGS IDB were determined from GNSS observations

Accuracies can be compared to those given in OP (a priori coordinates and sigmas). The WinDesc Accuracies file can also be saved and imported into a spreadsheet program if desired.

Appendix B: How OP arranges GNSS observations into sessions

OP always attempts to arrange GNSS observations into discrete, repeated sessions. In this appendix, three scenarios are explored as a means to help explain how OP might arrange a user's sessions.

B.1 Scenario 1

In the first scenario, three marks observed twice in one day, and a fourth mark is observed all day long (Figure B-1).

Hours													Marks
6	7	8	9	10	11	12	1	2	3	4	5	6	Marks
		🟩	🟩	🟩	🟩								A, B, C
						🟩	🟩	🟩	🟩				A, B, C
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩		D

Figure B-1: Scenario 1: Three marks observed twice in one day, one mark observed all day long

Marks A, B, and C are observed twice on a given day, in repeated 4-hour sessions: 8 am to 12 noon and then again from 12 noon to 4 pm. However, mark D is observed all day long. To prevent duplication of data/results in the network adjustments and to fulfill the requirements of bluebook, OP will attempt to create two sequential sessions on Day 1. Session A will extend from 6 am to 12:00 noon; Session B will extend from 12:00 noon to 6 pm.

Hours													Marks
6	7	8	9	10	11	12	1	2	3	4	5	6	Marks
		🟩	🟩	🟩	🟩								A, B, C
🟩	🟩	🟩	🟩	🟩	🟩								D

Figure B-2: Session A, from 6 am to 12:00 noon

Hours													Marks
6	7	8	9	10	11	12	1	2	3	4	5	6	Marks
						█	█	█	█				A, B, C
						█	█	█	█	█	█		D

Figure B-3: Session B, from 12:00 noon to 6 pm

The reason OP does not group all of the observations for mark D in, say, Session A is precisely because OP is designed to allow users to deploy temporary GNSS reference stations ("temporary CORS") to serve as local hubs in session and network processing. When OP brings CORS data into the project, it always tries to use the maximum possible data from a CORS in a 1 day (or 2 day) period without re-using observations. The figures below show the same data of Scenario 1, but with the addition of CORS data:

Hours																								Marks
12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
								█	█	█	█													A, B, C
												█	█	█	█	█								A, B, C
					█	█	█	█	█	█	█	█	█	█	█	█	█							D
█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	CORS

Figure B-4: Visualization of GNSS occupations with respect to CORSs 24-hour continuous data

Hours																								Marks
12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
								█	█	█	█	█												A, B, C
						█	█	█	█	█	█													D
█	█	█	█	█	█	█	█	█	█	█	█													CORS

Figure B-5: Session A: 6 am to 12:00 noon

Hours																								Marks
12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
												█	█	█	█									A, B, C
												█	█	█	█	█	█							D
												█	█	█	█	█	█	█	█	█	█	█	█	CORS

Figure B-6: Session B: from 12:00 noon to 6 pm

B.2 Scenario 2

Three marks observed twice in one day, three additional marks observed only once, one last mark observed once all day long.

Hours																								Marks
12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
								■	■	■	■													A, B, C
												■	■	■	■									A, B, C
																■	■	■	■					E, F, G
						■	■	■	■	■	■	■	■	■	■									D
■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	CORS

Figure B-7: Scenario 2: Three marks observed twice in one day, three other marks observed once later in the day, and one mark observed all day

In this scenario, marks E, F and G are different marks (no reoccupation of A, B, C or D). Although the user may attempt to fit marks E, F, and G into their own session, OP will consider them as part of the second session, along with the repeat observations on A, B, and C. Effectively, they are all just observations in the time span of a second session. To put E, F and G in their own session would require either:

1) "splitting" D if it is serving as a temporary CORS and omitting data from E, F and G because of the requirement for mutual visibility from mark - HUB or

2) splitting the CORS data between the B and C sessions which weakens the CORS estimate.

Hours																								Marks
12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
								■	■	■	■													A, B, C
						■	■	■	■	■	■													D
■	■	■	■	■	■	■	■	■	■	■	■													CORS

Figure B-8: Session A from Scenario 2

Hours																								Marks
12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
												■	■	■	■									A, B, C
																■	■	■	■					E, F, G
												■	■	■	■	■	■							D
												■	■	■	■	■	■	■	■	■	■	■	■	CORS

Figure B-9: Session B from Scenario 2

B.3 Scenario 3

One mark observed four different times in one day:

In this example, we'll see how OP splits up the CORS data to match each individual observation session.

12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
								🟩	🟩															A
										🟩	🟩													A
												🟩	🟩											A
														🟩	🟩									A
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	CORS

(Hours)

Figure B-10: Scenario 3: One mark observed at four different times in one day

Since there are four independent sessions, OP will correctly identify the sessions, and use as much independent CORS data as possible for each session. This means that sessions A and D will have more CORS data available compared to sessions B and C.

12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
								🟩	🟩															A
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩															CORS

(Hours)

Figure B-11: Scenario 3 Session A

12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
										🟩	🟩													A
										🟩	🟩													CORS

(Hours)

Figure B-12: Scenario 3 Session B

12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
												🟩	🟩											A
												🟩	🟩											CORS

(Hours)

Figure B-13 Scenario 3 Session C

Hours																							Marks
12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	Marks
																								A
																								CORS

Figure B-14: Scenario 3 Session D

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Appendix C: Coordinate Shifts

There are many places in the various output results of OP where the words SHIFT or COORDINATE SHIFT will appear. In each case the word SHIFT implies from one value to another value. Typically, the "from" value is the output of the prior adjustment, and the "to" value is the output of the current adjustment. If the user is following the sequential adjustment process outlined in Section 12, the coordinate shifts reported in different parts of the output will differ accordingly.

In general, there are 6 major steps in OP where one can expect to see the words "shift" or "coordinate shift:"

1. Session Processing Results
2. Preliminary Adjustment
3. Horizontal Free Adjustment
4. Horizontal Constrained Adjustment
5. Vertical Free Adjustment
6. Vertical Constrained Adjustment

C.1 Session Processing Results

The coordinate shifts from session processing are found in the several places. It is most easily found in the summary results provided within the body of the email sent to the project manager. It is also in the Processing Report. This file can be accessed clicking on the [Show File] button on the Manager's Page and selecting the Processing Report:

Figure C-1: The Show File selection bar providing access to all processing output

It is also the *.txt email attachment. There are two places to examine in the output. The first and most useful is the table of shifts near the top of the output file, called "MARK ESTIMATED - A PRIORI COORDINATE SHIFTS:"

```
MARK  ESTIMATED - A PRIORI COORDINATE SHIFTS
--------------------------------------------------------------------
algo  N:     0.001 m (0.001 m) E:    -0.003 m (0.001 m) H:    -0.002 m (0.001 m)
calv  N:     0.037 m (0.001 m) E:    -0.134 m (0.001 m) H:    -0.038 m (0.001 m)
dene  N:    -0.001 m (0.001 m) E:    -0.002 m (0.001 m) H:    -0.012 m (0.001 m)
fran  N:     0.026 m (0.001 m) E:    -0.110 m (0.001 m) H:    -0.036 m (0.001 m)
gode  N:     0.001 m (0.001 m) E:    -0.001 m (0.001 m) H:     0.000 m (0.001 m)
hnpt  N:    -0.001 m (0.001 m) E:    -0.001 m (0.001 m) H:     0.000 m (0.001 m)
tane  N:     0.030 m (0.001 m) E:    -0.123 m (0.001 m) H:    -0.017 m (0.002 m)
york  N:     0.000 m (0.001 m) E:    -0.001 m (0.001 m) H:    -0.005 m (0.001 m)
```

Figure C-2: Table of coordinate shifts resulting from session processing

The shift is between the estimated (adjusted) coordinate and the a priori coordinate. At this stage in the project, the a priori coordinates can arise from two sources. A priori coordinates for CORS are their published coordinates. The same is true for user marks with published coordinates. User marks that do not have published coordinates will take their a priori coordinates from the first OPUS solution seen by OP once the user

has opened the project. OP automatically sorts all observations sequentially by time, so if all observations are loaded *prior to* opening the project, the a priori coordinates for new marks will effectively come from the first observation. If the user uploads a first observation file for a given user mark (it could be from the very last occupation), and thereupon opens up the project in OP, the a priori coordinates for that mark will come from that very same OPUS solution, regardless of its order in time. Check the Marks page to confirm which OPUS solution has been designated the a-priori.

Note that the mark selected as a constraint should have minimal shift (or as much as is allowed by the constraint preferences). The remaining marks should exhibit small shifts. A larger shift for a given mark can typically arise from three causes, a flawed occupation, a flawed data file, or a flawed a-priori coordinate. The table does not tell which flaw, if any, is present. Another possibility is where most of the shifts are larger than expected. Consider a constrained mark whose published coordinate does not match its actual position on the ground. In such a case, the solution will have large shifts for many marks, all caused by constraining the one flawed coordinate.

Further down in the output after a section called UNCONSTRAINED MARKS, is another section called CONSTRAINED MARKS. In session processing, there is typically only one mark constrained (the hub). The shift indicated here for the constrained mark is the same as was given in the earlier table.


```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINED MARKS              I
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


MARK:      gode (gode  a    4; Washington, UNITED STA)
CONSTRAIN: 3-D NORMAL
     N39:01:18.18974 W076:49:36.57470     15.784m         NAD_83(2011) @ 2010.0000
              0.12cm             0.12cm       0.12cm        NEU SIGMAS
SHIFTS N:    0.001 m (0.001 m) E:   -0.001 m (0.001 m) H:    0.000 m (0.001 m)
```

Figure C-3: Coordinate shifts on a constrained mark shown in the results of session processing

C.2 Preliminary Adjustment

The "MARK ESTIMATED - A PRIORI COORDINATE SHIFTS" table is very similar to session processing, but now the shifts are computed in an adjustment using all the occupations in the several sessions included in the preliminary adjustment setup. As before, the **shift is between the estimated (adjusted) coordinate and the a priori coordinate.**

```
MARK   ESTIMATED - A PRIORI COORDINATE SHIFTS
----------------------------------------------------------------------------
algo  N:   -0.005 m (0.001 m) E:  -0.003 m (0.001 m) H:   -0.006 m (0.001 m)
bell  N:    0.035 m (0.001 m) E:  -0.122 m (0.001 m) H:   -0.035 m (0.001 m)
brun  N:    0.032 m (0.001 m) E:  -0.122 m (0.001 m) H:   -0.038 m (0.001 m)
calv  N:    0.037 m (0.001 m) E:  -0.137 m (0.001 m) H:   -0.026 m (0.001 m)
ded2  N:   -0.003 m (0.001 m) E:  -0.001 m (0.001 m) H:   -0.018 m (0.001 m)
dene  N:   -0.005 m (0.001 m) E:  -0.002 m (0.001 m) H:   -0.009 m (0.001 m)
e087  N:    0.038 m (0.001 m) E:  -0.138 m (0.001 m) H:   -0.028 m (0.001 m)
fran  N:    0.025 m (0.001 m) E:  -0.110 m (0.001 m) H:   -0.033 m (0.001 m)
gode  N:   -0.003 m (0.001 m) E:  -0.004 m (0.001 m) H:    0.000 m (0.001 m)
gorf  N:    0.028 m (0.001 m) E:  -0.124 m (0.001 m) H:   -0.031 m (0.001 m)
hnpt  N:   -0.004 m (0.001 m) E:  -0.004 m (0.001 m) H:   -0.005 m (0.001 m)
n102  N:    0.025 m (0.001 m) E:  -0.128 m (0.001 m) H:   -0.019 m (0.001 m)
pond  N:    0.027 m (0.001 m) E:  -0.119 m (0.001 m) H:   -0.031 m (0.001 m)
tane  N:    0.030 m (0.001 m) E:  -0.123 m (0.001 m) H:   -0.017 m (0.001 m)
york  N:   -0.004 m (0.001 m) E:  -0.004 m (0.001 m) H:   -0.007 m (0.001 m)
```

Figure C-4: Coordinate shifts between the Preliminary Network Adjustment and the a priori coordinates

Shifts should be small. A larger shift for a given mark can arise from three causes (similar to session processing): a flawed occupation in one or more of the sessions, a flawed data file in one or more of the sessions, or a flawed a-priori coordinate for a given mark. The table does not tell which flaw, if any, is present. As before, if larger than expected shifts are seen across many marks, the cause may be th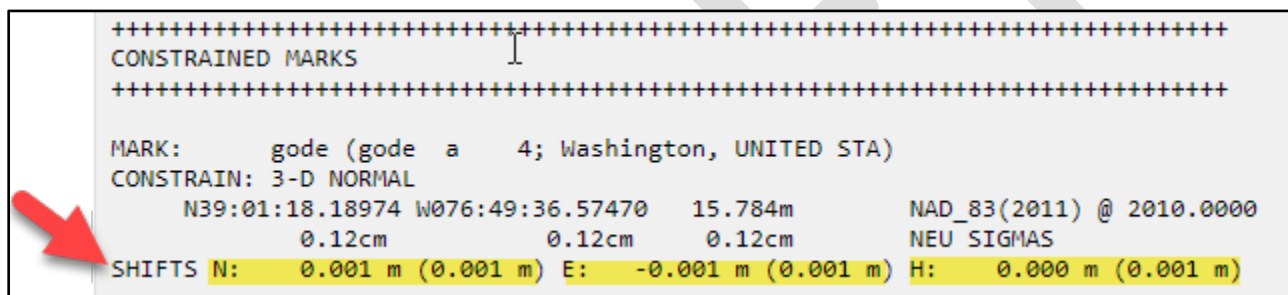e constrained mark's published coordinates not matching well with the observed data. Users will need to consider each possible cause to find the problem. Careful inspection of session-by-session processing results (see Solution Statistics in Section 10.5; pay attention to the P2P values) and session-by-session vector comparison (*.vec email attachments from session processing) may reveal the source of the problem. If the shifts are out of tolerance for the project's specifications, they will not get any better with subsequent adjustments. It is best to find the source of error (an offending observation?) at this stage.

The same shifts are also seen later in the output, in the section called "CONSTRAINED MARKS."

```
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINED MARKS
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

MARK:       gode (gode a  4)
CONSTRAIN: 3-D NORMAL
     N39:01:18.18974 W076:49:36.57470   15.784m        NAD_83(2011) @ 2010.0000
            0.12cm            0.12cm     0.12cm         NEU SIGMAS
SHIFTS N:   -0.003 m (0.001 m) E:   -0.004 m (0.001 m) H:    0.000 m (0.001 m)
```

Figure C-5: Coordinate shifts between the Preliminary Network Adjustment and the a prior coordinates on a constrained mark

C.3 Horizontal Free Adjustment

The Horizontal Free adjustment provides the **shift between the adjusted coordinates from the Horizontal Free adjustment and those from the Preliminary Adjustment:**

```
MARK  ESTIMATED - PRELIMINARY ADJUSTMENT COORDINATE SHIFTS
-----------------------------------------------------------------------
algo  N:    0.001 m (0.003 m) E:    0.003 m (0.003 m) H:    0.037 m (0.008 m)
bell  N:    0.003 m (0.003 m) E:    0.005 m (0.003 m) H:    0.010 m (0.009 m)
brun  N:    0.002 m (0.003 m) E:    0.004 m (0.003 m) H:    0.010 m (0.009 m)
calv  N:    0.002 m (0.003 m) E:    0.005 m (0.003 m) H:    0.008 m (0.009 m)
ded2  N:    0.011 m (0.003 m) E:    0.002 m (0.003 m) H:   -0.009 m (0.008 m)
dene  N:    0.005 m (0.002 m) E:    0.005 m (0.003 m) H:    0.004 m (0.008 m)
e087  N:    0.002 m (0.002 m) E:    0.004 m (0.003 m) H:    0.009 m (0.008 m)
fran  N:    0.002 m (0.003 m) E:    0.005 m (0.003 m) H:    0.011 m (0.009 m)
gode  N:    0.004 m (0.002 m) E:    0.005 m (0.002 m) H:    0.000 m (0.008 m)
gorf  N:    0.002 m (0.003 m) E:    0.005 m (0.003 m) H:    0.011 m (0.009 m)
hnpt  N:    0.005 m (0.002 m) E:    0.002 m (0.003 m) H:   -0.009 m (0.008 m)
n102  N:    0.003 m (0.003 m) E:    0.005 m (0.003 m) H:    0.011 m (0.009 m)
pond  N:    0.002 m (0.003 m) E:    0.004 m (0.003 m) H:    0.010 m (0.009 m)
tane  N:    0.001 m (0.003 m) E:    0.004 m (0.003 m) H:    0.011 m (0.009 m)
york  N:    0.005 m (0.002 m) E:    0.007 m (0.003 m) H:    0.004 m (0.008 m)
```

Figure C-6: Coordinate shifts between the Horizontal Free and the Preliminary Network Adjustments

The shifts should be small. A larger shift for a given mark can arise from the same three causes explained earlier (flawed occupation, data file, or a priori coordinate). Also, if the user selects a different constraint in the Horizontal Free Adjustment than was used in the Preliminary Adjustment, it is logical to expect a shift from the a priori coordinates. Another possible case is where most of the shifts are larger than expected. Consider a constrained CORS or user mark whose published coordinate does not match its observed position on the ground. In such a case, the solution will have large shifts for many marks, all caused by constraining the one flawed coordinate. Users will need to consider each possible cause to find the problem. As before, careful inspection of session-by-session processing results or session-by-session vector comparison may reveal the source of the problem.

Further down in theProcessing Report (*.txt attachment) is a section on CONSTRAINED MARKS (there should only be one such mark in the Horizontal Free adjustment). As before, these shifts are between the Horizontal Free adjustment and the Preliminary Adjustment.

```
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINED MARKS
+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

MARK:      gode (0003; AF9647; GODDARD SFC CORS MONUMENT)
CONSTRAIN: 3-D NORMAL
      N39:01:18.18974 W076:49:36.57470    15.784m        NAD_83(2011) @ 2010.0000
            0.17cm              0.23cm      0.77cm        NEU SIGMAS
SHIFTS N:    0.004 m (0.002 m) E:    0.005 m (0.002 m) H:    0.000 m (0.008 m)
```

Figure C-7: Coordinate shifts on a constrained mark shown in the results of the Horizontal Free Network Adjustment

C.4 Horizontal Constrained Adjustment

In the Processing Report for the Horizontal Constrained adjustment, **two** different types of shifts are given: shifts between the adjusted coordinates from the Horizontal Constrained Adjustment and the Horizontal Free Adjustment, and between the adjusted coordinates from the Horizontal Constrained Adjustment and the published coordinates.

C.4.1 Shifts between the adjusted coordinates from the Horizontal Constrained Adjustment and those from the Horizontal Free Adjustment

```
MARK  ESTIMATED - HORIZONTAL-FREE ADJUSTMENT COORDINATE SHIFTS
----------------------------------------------------------------------------
algo  N:   -0.004 m (0.002 m)  E:    0.002 m (0.001 m)  H:    0.016 m (0.004 m)
bell  N:   -0.003 m (0.002 m)  E:    0.003 m (0.002 m)  H:    0.019 m (0.004 m)
brun  N:   -0.001 m (0.002 m)  E:    0.002 m (0.002 m)  H:    0.016 m (0.005 m)
calv  N:   -0.001 m (0.002 m)  E:    0.002 m (0.002 m)  H:    0.016 m (0.005 m)
ded2  N:   -0.002 m (0.002 m)  E:    0.001 m (0.001 m)  H:    0.017 m (0.004 m)
dene  N:   -0.001 m (0.001 m)  E:    0.001 m (0.001 m)  H:    0.015 m (0.004 m)
e087  N:   -0.002 m (0.002 m)  E:    0.002 m (0.001 m)  H:    0.016 m (0.004 m)
fran  N:   -0.001 m (0.002 m)  E:    0.002 m (0.002 m)  H:    0.015 m (0.005 m)
gode  N:   -0.001 m (0.001 m)  E:    0.001 m (0.001 m)  H:    0.015 m (0.003 m)
gorf  N:   -0.001 m (0.001 m)  E:    0.004 m (0.001 m)  H:    0.017 m (0.003 m)
hnpt  N:   -0.001 m (0.001 m)  E:    0.001 m (0.001 m)  H:    0.015 m (0.003 m)
n102  N:   -0.001 m (0.002 m)  E:    0.002 m (0.002 m)  H:    0.015 m (0.005 m)
pond  N:   -0.001 m (0.002 m)  E:    0.002 m (0.002 m)  H:    0.015 m (0.005 m)
tane  N:   -0.002 m (0.002 m)  E:    0.002 m (0.002 m)  H:    0.015 m (0.005 m)
york  N:   -0.002 m (0.001 m)  E:    0.000 m (0.001 m)  H:    0.015 m (0.004 m)
```

Figure C-8: Coordinate shifts between the Horizontal Constrained and the Horizontal Free Network Adjustments

At this stage in the sequential adjustment process, a larger shift for a given mark can arise from two causes: a flawed a-priori coordinate from the Horizontal Free adjustment, or a flawed constrained coordinate for a given mark. The table does not tell which flaw if any is present. The Horizontal Constrained Adjustment will almost always have several constraints, so it is logical to expect a shift from the Horizontal Free coordinates. A possible case may arise where most of the shifts are larger than expected. Consider a constrained CORS or user mark whose published coordinate does not match its observed position on the ground. In such a case, the solution will have large shifts for many marks, all caused by constraining the one flawed coordinate. Users will need to consider each possible cause to find the problem. Careful inspection of session-by-session processing results or session-by-session vector comparison may reveal the source of the problem.

C.4.2 Shifts between the adjusted coordinates from the Horizontal Constrained Adjustment and the published coordinates:

```
MARK  ESTIMATED - PUBLISHED HORIZONTAL COORDINATE SHIFTS
----------------------------------------------------------------------------
algo N: -0.007 m (0.002 m)  E:   0.001 m (0.001 m)  U:   0.044 m (0.004 m) CORS
bell N:  0.003 m (0.002 m)  E:  -0.002 m (0.002 m)  U:  -0.006 m (0.004 m) OPUS
ded2 N:  0.006 m (0.002 m)  E:   0.002 m (0.001 m)  U:  -0.010 m (0.004 m) CORS
dene N: -0.001 m (0.001 m)  E:   0.003 m (0.001 m)  U:   0.009 m (0.004 m) CORS
e087 N:  0.008 m (0.002 m)  E:  -0.018 m (0.001 m)  U:  -0.001 m (0.004 m) OPUS
gode N: -0.001 m (0.001 m)  E:   0.001 m (0.001 m)  U:   0.015 m (0.003 m) CORS
gorf N: -0.001 m (0.001 m)  E:  -0.002 m (0.001 m)  U:  -0.002 m (0.003 m) OPUS
hnpt N: -0.000 m (0.001 m)  E:  -0.001 m (0.001 m)  U:   0.003 m (0.003 m) CORS
york N: -0.000 m (0.001 m)  E:   0.004 m (0.001 m)  U:   0.012 m (0.004 m) CORS
```

Figure C-9: Coordinate shifts between the Horizontal Constrained Adjustment and published positions

Large shifts here are often indicative of suspect Input constraints.

C.5 Vertical Free Adjustment

In the Vertical Free adjustment, coordinate **shifts are between the Horizontal Constrained adjustment and the Vertical Free adjustment**:

```
 MARK   ESTIMATED - HORIZONTAL-CONSTRAINED ADJUSTMENT COORDINATE SHIFTS
--------------------------------------------------------------------------
 algo  N:    0.003 m (0.003 m) E:   -0.002 m (0.003 m) H:   -0.016 m (0.008 m)
 bell  N:    0.007 m (0.003 m) E:   -0.005 m (0.003 m) H:   -0.019 m (0.009 m)
 brun  N:    0.001 m (0.002 m) E:   -0.002 m (0.003 m) H:   -0.016 m (0.008 m)
 calv  N:    0.001 m (0.002 m) E:   -0.002 m (0.003 m) H:   -0.016 m (0.008 m)
 ded2  N:    0.008 m (0.002 m) E:    0.001 m (0.003 m) H:   -0.017 m (0.008 m)
 dene  N:    0.000 m (0.002 m) E:    0.002 m (0.003 m) H:   -0.015 m (0.008 m)
 e087  N:    0.010 m (0.002 m) E:   -0.021 m (0.003 m) H:   -0.016 m (0.007 m)
 fran  N:    0.001 m (0.002 m) E:   -0.002 m (0.003 m) H:   -0.015 m (0.008 m)
 gode  N:    0.000 m (0.001 m) E:    0.000 m (0.002 m) H:   -0.015 m (0.008 m)
 gorf  N:    0.000 m (0.002 m) E:   -0.007 m (0.003 m) H:   -0.017 m (0.008 m)
 hnpt  N:    0.001 m (0.002 m) E:   -0.002 m (0.003 m) H:   -0.015 m (0.008 m)
 n102  N:    0.001 m (0.002 m) E:   -0.002 m (0.003 m) H:   -0.015 m (0.008 m)
 pond  N:    0.002 m (0.003 m) E:   -0.002 m (0.003 m) H:   -0.015 m (0.009 m)
 tane  N:    0.001 m (0.002 m) E:   -0.002 m (0.003 m) H:   -0.015 m (0.008 m)
 york  N:    0.001 m (0.002 m) E:    0.003 m (0.003 m) H:   -0.015 m (0.008 m)
```

Figure C-10: Coordinate shifts between the Vertical Free and the Horizontal Constrained Network Adjustments

At this stage in the sequential adjustment process, a larger shift for a given mark can arise from two causes: a flawed a-priori coordinate from the Horizontal Constrained adjustment, or a flawed vertical constraint. The table does not tell which flaw if any is present. The vertical shifts are often similar in magnitude and sign even if they are small. This is because the Vertical Free Adjustment is constraining a single Orthometric Height, rather than several Ellipsoid Heights. A few centimeters is to be expected. Another possible case is where most of the vertical shifts are larger than expected. Consider a constrained mark whose published orthometric height does not match its actual position on the ground. In such a case, the solution will have large shifts for many marks, all caused by constraining the one flawed height. Users will need to consider each possible cause to find the problem. Careful inspection of session-by-session processing results or session-by-session vector comparison may reveal the source of the problem.

Further down in the Processing Report is the section on CONSTRAINED MARKS. The shifts indicated here are between the Vertical Free adjustment and the Horizontal Constrained adjustment, but only for the coordinates constrained in the Vertical Free adjustment.

Note that the mark "e087" was constrained vertically, so the shift is only given in the vertical dimension (orthometric height).

Figure C-11: Shift in the vertical dimension (orthometric height) shown for the mark held vertically constrained in the Vertical Free Network Adjustment

Similarly, the shifts in the mark "gode" are only given in the horizontal dimension, as the mark was constrained horizontal-only.

Figure C-12: Shifts in the horizontal dimension shown for the mark held constrained horizontally in the Vertical Free Network Adjustment

C.6 Vertical Constrained Adjustment

Similar to the horizontal constrained adjustment, **two** tables of coordinate shifts are provided in the Processing Report (and in the email) for the Vertical Constrained adjustment. The first table provides the geometric (3D) coordinate shifts between the vertical constrained and the vertical free network adjustment. The second table provides the shifts in the orthometric heights between the vertical constrained and vertical free network adjustments.

C.6.1 Shifts between the adjusted coordinates from the Vertical Constrained Adjustment and those from the Vertical Free Adjustment:

```
MARK  ESTIMATED - VERTICAL-FREE ADJUSTMENT COORDINATE SHIFTS
-------------------------------------------------------------------------------
algo  N:  -0.001 m (0.003 m) E:   0.000 m (0.003 m) H:   0.010 m (0.005 m)
bell  N:   0.000 m (0.003 m) E:   0.000 m (0.003 m) H:   0.009 m (0.006 m)
brun  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.010 m (0.005 m)
calv  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.009 m (0.005 m)
ded2  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.010 m (0.005 m)
dene  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.009 m (0.004 m)
e087  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.008 m (0.004 m)
fran  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.009 m (0.005 m)
gode  N:   0.000 m (0.001 m) E:   0.000 m (0.002 m) H:   0.009 m (0.004 m)
gorf  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.013 m (0.005 m)
hnpt  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.010 m (0.005 m)
n102  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.009 m (0.005 m)
pond  N:   0.000 m (0.003 m) E:   0.000 m (0.003 m) H:   0.009 m (0.006 m)
tane  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.009 m (0.005 m)
york  N:   0.000 m (0.002 m) E:   0.000 m (0.003 m) H:   0.009 m (0.005 m)
```

Figure C-13: Coordinate shifts between the Vertical Constrained and Vertical Free Network Adjustments

At this stage in the sequential adjustment process, the horizontal shifts should be small. Ideally, the vertical shifts should also be small. A few centimeters is to be expected. If most of the vertical shifts are larger and in the same direction than expected, this could be due to a bias in the published heights for one or more vertically constrained marks.

C.6.2 Shifts between the adjusted coordinates from the Vertical Constrained Adjustment and the published coordinates:

```
MARK  ESTIMATED - PUBLISHED VERTICAL COORDINATE SHIFTS
-------------------------------------------------------------------------------
bell: ORTHO HGT: -0.026 m (0.006 m) AJ7978 FGCS LEVELING IN NGSIDB
brun: ORTHO HGT: -0.019 m (0.005 m) DJ2602 FGCS LEVELING IN NGSIDB
calv: ORTHO HGT:  0.006 m (0.005 m) AJ7981 FGCS LEVELING IN NGSIDB
ded2: ORTHO HGT: -0.002 m (0.005 m) DO7623 GPS HEIGHTS: 2CM/5CM STANDARDS
dene: ORTHO HGT:  0.010 m (0.004 m) DK4426 GPS HEIGHTS: 2CM/5CM STANDARDS
e087: ORTHO HGT:  0.008 m (0.004 m) JV2551 FGCS LEVELING IN NGSIDB
fran: ORTHO HGT:  0.003 m (0.005 m) JV7214 GPS HEIGHTS: 2CM/5CM STANDARDS
gode: ORTHO HGT:  0.003 m (0.004 m) AF9647 GPS HEIGHTS: 2CM/5CM STANDARDS
gorf: ORTHO HGT: -0.013 m (0.005 m) JV6895 FGCS LEVELING IN NGSIDB
n102: ORTHO HGT: -0.009 m (0.005 m) JV2194 FGCS LEVELING IN NGSIDB
pond: ORTHO HGT:  0.016 m (0.006 m) JV6666 FGCS LEVELING IN NGSIDB
tane: ORTHO HGT:  0.018 m (0.005 m) JV6665 FGCS LEVELING IN NGSIDB
```

Figure C-14: Shifts in Orthometric Heights between the Vertical Free and Vertical Constrained Network Adjustments

The shifts specifically refer to orthometric heights, and the source of the published heights are given to the right of the shifts. See the table above for several examples, including "FGCS LEVELING IN NGSIDB," "GPS HEIGHTS: 2CM/5CM STANDARDS," and "FGCS LEVELING NOT IN NGSIDB."

Further down in the Processing Report is the section on CONSTRAINED MARKS. The shifts indicated here include all of the vertical constraints, as well as the horizontal constraint. The values presented here are between the Vertical Constrained adjustment and the Vertical Free adjustment.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
CONSTRAINED MARKS
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


MARK:      bell  (108; AJ7978; BELL)
CONSTRAIN: VER-ONLY NORMAL
                                    113.549m  ORTHO NAVD 88
                                      0.70cm        U SIGMA
SHIFTS                                         OH:   -0.019 m (0.004 m)
```

Figure C-15: Orthometric Height shift for a mark held constrained vertically in the Vertical Constrained Network Adjustment

```
MARK:      brun (0103; DJ2602; BRUNSWICK 2)
CONSTRAIN: 3-D NORMAL
    N39:19:02.99928 W077:36:40.44276  139.538m  ORTHO NAD_83(2011) @ 2010.0000
            0.18cm            0.15cm     0.70cm       NEU SIGMAS
                             SHIFTS N:   0.000 m (0.002 m) E:   0.000 m (0.002 m) H:   -0.014 m (0.004 m)
```

Figure C-16: Geometric (3D) coordinate shifts for a mark held constrained geometrically in the Vertical Constrained Network Adjustment

Note that in the case of the mark bell, only the vertical shift is given, since the mark was only constrained vertically. In the case of the mark "brun," the mark was constrained 3D, so shifts in all three coordinates are given.

Appendix D: How OP assigns sigmas on constrained marks

In both session processing and network adjustments, realistic estimates of a CORS or user mark's positional uncertainties are very important in deriving an accurate solution. In this appendix, we present additional information on the sources of these uncertainties within OPUS Projects .

D.1 Source of Uncertainties for Session Processing

The uncertainties associated with each coordinate are used to construct constraints in session processing. The uncertainties come from four possible sources:

1. Unpublished user uploaded marks: the coordinate uncertainties come from the source OPUS-S solution used for the mark's a priori NAD 83 and ITRF2014 coordinates. The reported OPUS-S peak-to-peak uncertainties are scaled by 1.6929 (Schwarz 2006) thereby estimating one sigma uncertainties. The uncertainty is never allowed to be smaller than 0.001 m.
    The mark's velocity comes from the HTDP program and given 0.01 cm / yr uncertainties.

2. Published user uploaded marks: the NAD 83 coordinates and uncertainties are taken from the datasheet for a mark (created from information in the NGS database) when the PID for that mark is associated with the mark in the project. From these coordinates, ITRF2014 coordinates are computed using HTDP. The NAD 83 coordinate uncertainties are transferred to the ITRF2014 coordinates without modification.
    The mark's velocity comes from the HTDP program and given 0.01 cm /yr uncertainties.

3. CORS: a database of ITRF2014 coordinates, velocities and uncertainties derived from the latest **Multi-Year CORS Solution** (MYCS; see Glossary) adjustment are kept by the CORS data center and used in OP. Occasionally, a CORS's coordinates are updated because of divergence seen in daily NCN monitoring. In these cases, the coordinates and/or velocity are updated, the coordinates are given 0.1 cm uncertainties; the velocity 0.01 cm / yr uncertainties.

4. Users can change user mark coordinates and uncertainties (i.e., sigmas) from their defaults (the sources given above) for unpublished marks from the individual mark web pages (not published marks or CORS). In addition, users can change constraint coordinates on the session processing form, but cannot change constrained coordinate sigmas from that form (again, not published marks or CORS).

In addition, a scaling factor specified by the user is applied to those uncertainties in session processing. Labeled the "Constraint Weights" on the session processing setup form, the options are: LOOSE, NORMAL or TIGHT. LOOSE scales constraint uncertainties to be approximately 1 m in magnitude; NORMAL scaled them to be approximately 0.01 m; and TIGHT scales them to be approximately 0.0001 m.

D.2 Source of Uncertainties for Network Adjustments

OP assigns uncertainties to all coordinates that are constrained by the user during a network adjustment. The Preliminary adjustment is best thought of as an extension to the session processing. Uncertainties are assigned to the constrained coordinates the same as in session processing, as explained above.

Geometric coordinates (e.g., latitude, longitude, ellipsoid height) constrained in the horizontal-free, horizontal-constrained, vertical-free and vertical-constrained coordinate constraints follow the guidelines required for submission to NGS:

1. Unpublished user marks can be constrained (but this is not recommended). By default, OP will constrain the a priori coordinates of an unpublished mark and will assign uncertainties for these coordinates the same as in session processing, as noted above. Users can change the constraint coordinates and/or their sigmas from the mark web page.
2. Published user marks will be constrained to their published coordinates and uncertainties, taken from the datasheet for a mark.
3. CORS will be constrained to their published, NCN coordinates. However, the coordinates' uncertainties are set to equal the root-mean-square (RMS) error values computed from network monitoring results around the time of the project[5]. For examples of the most recent RMS values, see the CORS short-term plots. Adjustments using CORS outside of those monitored by the NCN are not allowed.
4. There are circumstances where published mark or CORS constrained coordinates can appear to be modifiable by the user, but in these cases the marks are treated as unpublished user marks with 0.10 cm coordinate uncertainties.

OP suggests only constraining orthometric heights in the vertical-free and vertical-constrained adjustments following the guidelines required for submission to NGS. All orthometric height uncertainties are computed according to Table D-1, below.

- For constrained marks with published orthometric heights determined by leveling, uncertainties are based upon the vertical source type and the order and class descriptions in the datasheets as noted in the table above.

- For constrained marks or CORS with GPS-derived, published orthometric heights that meet height modernization standards (i.e., procedures outlined in NGS-59), constraints are derived from the ellipsoid and geoid height uncertainties appropriately computed using error propagation per the equation in the table above. For these marks or CORS, the datasheet will have a vertical source equal to GPS OBS, and HT_MOD will be listed at the top of the datasheet. Note that the same equation will be used to estimate uncertainties for GPS-derived orthometric heights constrained by the user that do not meet height modernization standards (although such constraints are not recommended).

---

[5] If possible, OP uses a 90-day interval centered at the midpoint of the survey to compute RMS. If processing a recent survey, OP will use the nearest 90 days to the midpoint of the survey.

- For constrained, unpublished marks labeled as "LEVELING NOT PUBLISHED" in the adjustment setup form, uncertainties are treated as third order leveling . This option allows users to constrain leveling-derived orthometric heights that have not yet been published.

Table D-1: Vertical uncertainties (sigmas) assigned in OP based on the source of the published orthometric height

Vertical Source on Datasheet	Vertical Sigma (cm)
ADJUSTED or ADJ UNCH*	
VERT ORDER – FIRST CLASS 0	0.2
VERT ORDER – FIRST CLASS I	0.3
VERT ORDER – FIRST CLASS II	0.5
VERT ORDER – SECOND CLASS I	0.7
VERT ORDER – SECOND CLASS II	0.9
VERT ORDER – SECOND CLASS 0	0.9
VERT ORDER – THIRD	1.3
RESET or N-HEIGHT	1.3
POSTED or GPSONLV	1.5
GPS OBS and Height Modernization Station (as indicated by HT_MOD special category at the top of the datasheet)	$\sqrt{SD\_h^2 + 1}$ where *SD_h* is ellipsoid standard deviation

No additional scaling of constraint uncertainties is applied for these adjustments.

Literature Cited:

Schwarz, C. R. 2006, "Statistics of Range of a Set of Normally Distributed Numbers", "CORS and OPUS for Engineers", ed. T. Soler, American Society of Civil Engineers, Reston, VA, USA, pp. 41-45

Appendix E: FAA Airport Surveys

The National Geodetic Survey, in accordance with a series of interagency agreements with the Federal Aviation Administration (FAA), provides airport geodetic control, as well as runway, navigational aid, obstruction, and other aeronautical data that is critical to the operation of the National Airspace System. Most of these data are source information obtained using field survey and photogrammetric methods. These data are used to develop runway approach procedures and obstruction charts.

NGS contracts survey work for Area Navigation Approach (ANA) charts to the private sector on a funds available basis. Survey specifications are provided in AC No: 150/5300-16B(2019) and the older "FAA No. 405, Standards for Aeronautical Surveys and Related Products," 4th edition, September, 1996; and "General Specifications for Aeronautical Surveys, Vol. I. Establishment of Geodetic Control on Airports." Funding for these surveys is provided to NGS by the FAA. This latest version of OPUS Projects (OP) fully supports the bluebooking process for FAA surveys by producing a b-file and g-file, and automatically invokes ADJUST in the required series of network adjustments. All files required for a successful submission of an airport survey to NGS are fully supported by OP.

E.1 NEW PACS/SACS

When PACS/SACS are established as "New" there should be very little deviation from the recommended style of processing in OP. Observations for **new PACS/SACS** must meet all required observation criteria as defined in the AC 150/5300-16B to include, but not limited to:

a. Two 4-hour or more simultaneous observation sessions are required on the PACS, HARN, and NAVD 88 bench marks involved in the survey, with a 30-60 minute break between. Observations must be simultaneous with the PACS.
b. Two 2-hour or more observations on the SACS with a 30-60 minute break between sessions is required. Observations must be simultaneous with the PACS.
c. The operator must reset the tripod (take down - set up) between the sessions and document the same.
d. Start times on subsequent days must be at least 2.5 hours different from the previous start times to incorporate a different satellite geometry.
e. If the OPUS solution report is "bad" (low % obs or low % ambiguities fixed or high overall RMS or any uncertainties > 4 cm), the mark must be reoccupied (no exceptions). OP can, on occasion, "recover" data that OPUS could not initially process as successfully as we might like, but if OPUS struggles in its initial solution, chances are significantly higher that OP will struggle as well. The initial OPUS solution is your first quality control stage: use it.
f. Remember that OPUS will not allow less than 2 hrs of usable data.
g. NGS recommends collecting and processing GNSS data at a 10° elevation mask.

E.2 Existing PACS/SACS

The following example provides guidance for those FAA surveys where the existing PACS is found to be in good condition at an airport, but either one or more SACS are destroyed. The existing PACS may serve as passive control to position new SACS so long as the existing PACS meets the AC 150/5300-16B Section 7.7.3 Accuracy Standards. The PACS and SACS (including both new and existing SACS) must be observed. Observation criteria is similar to a new PACS/SACS survey, except additional HARN and NAVD88 bench mark ties are not a requirement.

a. Two 4-hour or more observation sessions on the PACS with a 30-60 minute break between sessions is required.
b. Two 2-hour or more observations on the SACS with a 30-60 minute break between sessions is required. Observations must be simultaneous with the PACS.
c. The operator must reset the tripod (take down - set up) between the sessions and document the same.
d. Start times on subsequent days must be at least 2.5 hours different from the previous start times to incorporate a different satellite geometry.
e. If the OPUS solution report is "bad" (low % obs or low % ambiguities fixed or high overall RMS or any uncertainties > 4 cm) the mark must be reoccupied (no exceptions). OP can, on occasion, "recover" data that OPUS could not initially process as successfully as we might like, but if OPUS struggles in its initial solution, chances are significantly higher that OP will struggle as well. The initial OPUS solution is your first quality control stage: use it.

f. Remember that OPUS will not allow less than 2 hrs of usable data.
g. NGS recommends collecting and processing GNSS data at a 10° elevation mask.

E.3 Example of Recovering an Existing PACS

PACS station PIH FAA (AA3682) was recovered and observed in 2 sessions spanning 4 hours or more. The observations were uploaded into OP.

a. The two PACS initial OPUS solutions are compared to ensure consistency among the redundant observations (see section 7.1.4.6 of this document). The two horizontal coordinates are verified to be within 3 cm of each other. The ellipsoid heights are verified to be within 5 cm of each other. Failure to meet this requirement would mean re-observing the mark.

```
First  Station : FAA PIH A Session A
----------------
X =   -1797612.8291 m  LAT =  42 54 47.03861 North
Y =   -4320473.1246 m  LON = 112 35 26.36466 West
Z =    4321349.1331 m  EHT =      1344.5860  Meters


Second Station : FAA PIH A Session B
----------------
X =   -1797612.8432 m  LAT =  42 54 47.03832 North
Y =   -4320473.1396 m  LON = 112 35 26.36498 West
Z =    4321349.1388 m  EHT =      1344.6040  Meters


Forward azimuth          FAZ = 219  2 40.1632 From North
Back azimuth             BAZ =  39  2 40.1631 From North
Ellipsoidal distance      S =         0.0115 m
Delta height             dh =         0.0180 m
Mark-to-mark distance     D =         0.0214 m


DX =        -0.0141 m   DN =        -0.0090 m
DY =        -0.0150 m   DE =        -0.0073 m
DZ =         0.0057 m   DU =         0.0180 m


Zenith (mk-to-mk)        ZD =  32 37 49.17
Apparent zenith distance    =  32 37 49.17
```

Figure E-1: Example using INVERS3D to compare two OPUS solutions from redundant observations

B. Once the initial OPUS solutions are checked for consistency, the results can be verified with the NGS published coordinates for this station. The observed vs. published values must meet the AC 150/5300-16B requirement of 3 cm horizontal, 5 cm ellipsoid, 5 cm orthometric. If the PACS does not meet this requirement in the initial OPUS solution stage, this station may need to be redetermined in accordance with the AC 150/5300-16B, Section 7. A revised geodetic control plan will need to be submitted for review.

```
First  Station : FAA PIH A OPUS-S
----------------
X =   -1797612.8291 m  LAT =  42 54 47.03861 North
Y =   -4320473.1246 m  LON = 112 35 26.36466 West
Z =    4321349.1331 m  EHT =      1344.5860  Meters


Second Station : FAA PIH A Published
----------------
X =   -1797612.8308 m  LAT =  42 54 47.03909 North
Y =   -4320473.1305 m  LON = 112 35 26.36463 West
Z =    4321349.1589 m  EHT =      1344.6080  Meters


Forward azimuth           FAZ =   2 37 49.0266 From North
Back azimuth              BAZ = 182 37 49.0266 From North
Ellipsoidal distance       S =          0.0148 m
Delta height              dh =          0.0220 m
Mark-to-mark distance      D =          0.0265 m


DX =        -0.0017 m   DN =          0.0148 m
DY =        -0.0058 m   DE =          0.0007 m
DZ =         0.0258 m   DU =          0.0220 m


Zenith (mk-to-mk)         ZD =  33 59  6.54
Apparent zenith distance     =  33 59  6.54
```

Figure E-2: Example using INVERS3D to compare an initial OPUS solution to the published coordinates

C. Following the OPUS solution verification of the PACS, the additional observations may be uploaded into the project.

MARKS	Sessions 2020-021 A	2020-021 B	MARKS
piha	🟢	🟢	piha
pihc	🟢	🟢	pihc
pihn	🟢	🟢	pihn
brew	🔺	🔺	brew
gtrg	🔺	🔺	gtrg
idif	🔺	🔺	idif
idnl	🔺	🔺	idnl
idpo	🔺	🔺	idpo
p675	🔺	🔺	p675

Figure E-3: Two, same-day sessions loaded into OPUS Projects (2020-021A and 2020-021B)

D. Review Project Preferences as described in Section 4 of this User Guide. Do not edit or modify the Data and Solution Quality Thresholds.

E. Add the NGS-Assigned Tracking ID
    a. Following the approval of the Geodetic Control Plan (GCP), NGS will assign a Project Tracking ID. This number will be at the header of the NGS review.
    b. Use the assigned Project Tracking ID as described in Section 7.1.4.5 of this document to enter into the appropriate field. Complete all other necessary information in this window.
F. Upload Description files (*.dsc, *.des, *.err, *.dis, *.nbr) for all marks searched for or recovered during this survey. This operation will associate published and non-published marks with the observed marks.
G. Upload Field Logs as described in section 7.1.4.9.
    a. GNSS Observation Logs
    b. Station Location Sketch and Visibility Diagrams
    c. Recovery Logs (Optional)
H. Add mark photos (Close-up, Eye-level, and Horizon View) as described in section 7.3, Individual Mark Web Pages (7.3.7). Ensure proper captions and filenames are applied prior to upload.
I. Confirm the information for the mark occupations (Data File, Span, Antenna/Receiver Hardware, Antenna/Receiver Serial Number, ARP Height, and Receiver Firmware version) as described in section 7.3. This information must match the GNSS Observation Logs.
J. Evaluate and select CORSs to be used in the project as described in section 9.
K. Add a distant CORS to de-correlate the tropospheric parameters as described in section 9.2.2.
L. Remove any unused CORS(s) to reduce clutter.
M. Perform the first session processing as described in section 10 and evaluate results. Carefully review the *a priori* shifts of all stations given in the Processing Report (*.txt). Keep in mind the *a priori* coordinates can vary from a mark with a published PID (eg. existing PACS) or an OPUS solution for a mark with an unpublished PID (eg. new SACS being established).

```
MARK   ESTIMATED - A PRIORI COORDINATE SHIFTS
-------------------------------------------------------------------------------
brew  N:    -0.003 m (0.001 m) E:    0.004 m (0.001 m) H:    -0.013 m (0.001 m)
gtrg  N:     0.003 m (0.001 m) E:    0.006 m (0.001 m) H:    -0.024 m (0.001 m)
idif  N:     0.003 m (0.001 m) E:    0.000 m (0.001 m) H:    -0.014 m (0.001 m)
idnl  N:    -0.006 m (0.001 m) E:    0.000 m (0.001 m) H:    -0.010 m (0.001 m)
idpo  N:     0.000 m (0.001 m) E:    0.001 m (0.001 m) H:     0.000 m (0.001 m)
p675  N:    -0.002 m (0.001 m) E:    0.003 m (0.001 m) H:    -0.011 m (0.001 m)
piha  N:    -0.027 m (0.001 m) E:   -0.002 m (0.001 m) H:    -0.021 m (0.002 m)
pihc  N:    -0.005 m (0.001 m) E:    0.005 m (0.001 m) H:    -0.011 m (0.002 m)
pihn  N:    -0.028 m (0.001 m) E:   -0.010 m (0.001 m) H:     0.014 m (0.002 m)
```

Figure E-4: Coordinate shifts between a priori estimates and OP session processing for session 2020-021-A

N. Once results are acceptable for the first session, perform session processing on the next sequential session and evaluate results.
O. Once two sessions have been processed, evaluate the peak-to-peak errors from the Solution Statistics selection in the pull-down menu above the "Marks and Sessions" table (section 10.5.5). Ensure that no user marks have errors that exceed 1 cm for North or East and 3 cm for UP as required by the AC-16B (Section 7.7.4.3)

MARKS	occupations count	occupations used	solutions count	Obs Used	Obs Used(%)	AMB Fixed(%)	North P2P(cm)	East P2P(cm)	Up P2P(cm)	MARKS
piha	2	2	2	7062	98.3	100.0	0.3	0.3	0.9	piha
pihc	2	2	2	5417	98.9	100.0	0.1	0.1	0.6	pihc
pihn	2	2	2	5131	96.7	100.0	0.2	0.2	0.5	pihn
brew	1	1	2	34721	96.3	100.0	0.24	0.32	0.92	brew
gtrg	1	1	2	37213	96.7	100.0	0.19	0.31	0.94	gtrg
idif	1	1	2	37446	96.6	99.1	0.02	0.25	0.62	idif
idnl	1	1	2	38287	98.9	97.3	0.08	0.25	0.51	idnl
idpo	1	1	2	203913	97.7	99.2	0	0.06	0	idpo
p675	1	1	2	38636	99.6	99.4	0.19	0.32	0.31	p675

Figure E-5: Solution Statistics for all sessions

If P2P errors exceed these values, common causes that should be investigated can include:
   a. Incorrect ARP height calculated/entered (height error).
   b. Incorrect antenna type selected (horizontal and/or vertical error).
   c. Tripod out of calibration (horizontal and/or vertical error).
   d. Improper tripod equipment (horizontal and/or vertical error).
   e. Insufficient dataset
   f. Limited CORS availability
P. Process additional sessions if there are any and evaluate results.
Q. Set up Adjustment
   a. Run the preliminary network adjustment as described in section 11 with a single HUB CORS as the 3D constraint and evaluate solution quality. Using the Processing Report (*.txt), verify a priori coordinate shift for the PACS still the accuracy requirement of 3 cm Horizontal, 5 cm Ellipsoid. For those marks with PIDs, this will be the initial Minimally Constrained Adjusted vs. Published comparison using GPSCOM.

```
MARK   ESTIMATED - A PRIORI COORDINATE SHIFTS
---------------------------------------------------------------------------
brew  N:   -0.002 m (0.001 m) E:    0.005 m (0.001 m) H:   -0.008 m (0.001 m)
gtrg  N:    0.004 m (0.001 m) E:    0.008 m (0.001 m) H:   -0.019 m (0.001 m)
idif  N:    0.003 m (0.001 m) E:    0.001 m (0.001 m) H:   -0.011 m (0.001 m)
idnl  N:   -0.005 m (0.001 m) E:    0.001 m (0.001 m) H:   -0.007 m (0.001 m)
idpo  N:    0.000 m (0.001 m) E:    0.000 m (0.001 m) H:    0.000 m (0.001 m)
p675  N:   -0.001 m (0.001 m) E:    0.005 m (0.001 m) H:   -0.010 m (0.001 m)
piha  N:   -0.025 m (0.001 m) E:    0.000 m (0.001 m) H:   -0.017 m (0.001 m)
pihc  N:   -0.006 m (0.001 m) E:    0.005 m (0.001 m) H:   -0.013 m (0.001 m)
pihn  N:   -0.028 m (0.001 m) E:   -0.009 m (0.001 m) H:    0.015 m (0.001 m)
```

Figure E-6: Coordinate shifts between a priori estimates and minimally constrained preliminary network adjustment

   b. Set up Adjustment to run the **Horizontal Free** as described in Section 11.7.2. Hold the HUB CORS as the only 3D constraint. Un-constrain all other Marks and CORS.

Figure E-7: Setting up the Horizontal Free network adjustment

Evaluate solution quality. The a priori shifts of the CORSs may be a bit higher in this solution due to holding the PACS as the only constraint. You may notice that the N E H shifts are closely related to the N E U Free vs. Published inverse output for the PACS in the solution above.

```
MARK   ESTIMATED - PRELIMINARY ADJUSTMENT COORDINATE SHIFTS
--------------------------------------------------------------------------------
brew  N:    0.002 m (0.003 m) E:    0.003 m (0.005 m) H:    0.004 m (0.007 m)
gtrg  N:    0.005 m (0.002 m) E:   -0.008 m (0.004 m) H:    0.008 m (0.007 m)
idif  N:    0.000 m (0.002 m) E:   -0.009 m (0.004 m) H:    0.003 m (0.007 m)
idnl  N:    0.012 m (0.002 m) E:    0.003 m (0.004 m) H:    0.009 m (0.007 m)
idpo  N:    0.000 m (0.002 m) E:    0.000 m (0.004 m) H:    0.000 m (0.007 m)
p675  N:    0.005 m (0.002 m) E:   -0.002 m (0.004 m) H:    0.010 m (0.007 m)
piha  N:    0.011 m (0.003 m) E:    0.003 m (0.005 m) H:    0.008 m (0.008 m)
pihc  N:    0.012 m (0.003 m) E:    0.003 m (0.005 m) H:    0.009 m (0.009 m)
pihn  N:    0.011 m (0.003 m) E:    0.003 m (0.005 m) H:    0.010 m (0.009 m)
```

Figure E-8: Coordinate shifts between horizontal free and preliminary network adjustments

c. Set up Adjustment to run **Horizontal Constrained** as described in Section 12.3. In this case, FAA PIH A, PIH N and all CORSs are selected as 3D Constraints. **DO NOT** modify any of these a priori coordinates. This is a good time to check coordinate constraints vs. the published datasheets. In all cases, remove the distant CORS as a constraint. Constrain all other CORSs in 3D.

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Figure E-9: Setting up the horizontal constrained network adjustment

Evaluate the results of the Constrained Adjustment starting with the F-test as described in section 11.7.3.2. A failed F-Test will likely result in an unsuccessful project submission. Evaluate the mark estimated - horizontal-free adjustment coordinate shifts, mark estimated - published horizontal coordinate shifts, and residuals.

Figure E-10: Output from the Processing Report of the Horizontal Constrained network adjustment showing the result of the F-test

```
MARK   ESTIMATED - HORIZONTAL-FREE ADJUSTMENT COORDINATE SHIFTS
------------------------------------------------------------------------
brew  N:    0.000 m (0.002 m) E:    0.001 m (0.002 m) H:   -0.002 m (0.007 m)
gtrg  N:    0.000 m (0.002 m) E:    0.001 m (0.002 m) H:   -0.002 m (0.006 m)
idif  N:    0.000 m (0.002 m) E:    0.002 m (0.002 m) H:   -0.001 m (0.006 m)
idnl  N:   -0.001 m (0.002 m) E:    0.001 m (0.002 m) H:   -0.002 m (0.006 m)
idpo  N:    0.000 m (0.002 m) E:    0.001 m (0.002 m) H:   -0.002 m (0.006 m)
p675  N:    0.000 m (0.002 m) E:    0.001 m (0.002 m) H:   -0.002 m (0.006 m)
piha  N:    0.003 m (0.003 m) E:    0.001 m (0.002 m) H:    0.000 m (0.007 m)
pihc  N:    0.001 m (0.003 m) E:    0.001 m (0.003 m) H:   -0.002 m (0.009 m)
pihn  N:    0.004 m (0.003 m) E:    0.002 m (0.002 m) H:   -0.009 m (0.007 m)
```

Figure E-11: Shifts between Horizontal Constrained and Horizontal Free adjusted coordinates

```
MARK   ESTIMATED - PUBLISHED HORIZONTAL COORDINATE SHIFTS
------------------------------------------------------------------------------
brew N:  0.002 m (0.002 m) E:   0.010 m (0.002 m) U: -0.007 m (0.007 m) CORS
gtrg N:  0.008 m (0.002 m) E:   0.001 m (0.002 m) U: -0.012 m (0.006 m) CORS
idif N:  0.002 m (0.002 m) E:  -0.006 m (0.002 m) U: -0.009 m (0.006 m) CORS
idnl N:  0.006 m (0.002 m) E:   0.005 m (0.002 m) U: -0.001 m (0.006 m) CORS
idpo N: -0.000 m (0.002 m) E:   0.001 m (0.002 m) U: -0.002 m (0.006 m) CORS
p675 N:  0.003 m (0.002 m) E:   0.005 m (0.002 m) U: -0.001 m (0.006 m) CORS
piha N: -0.011 m (0.003 m) E:   0.004 m (0.002 m) U: -0.009 m (0.007 m) OPUS
pihn N: -0.013 m (0.003 m) E:  -0.004 m (0.002 m) U:  0.016 m (0.007 m) OPUS
```

Figure E-12: Shifts between the Horizontal Constrained adjusted and Published coordinates

```
network-final-horizontal-constrained.preplt2 created: 2020-09-17 12:29 UTC downloaded: 2021-06-09 16:19 UTC
      Residual Components(m)  Rej  Baseline  FROM:                              TO:
Obs#    DN       DE       DU        (m)     SSN   Designation              SSN    Designation
  22  -0.0047  -0.0011  -0.0066   14016.0026 ( 0001) FAA PIH A             ( 0014) POCATELLO CORS ARP
  25  -0.0003  -0.0009   0.0028   12804.9158 ( 0002) PIH C                 ( 0014) POCATELLO CORS ARP
  28  -0.0036  -0.0024   0.0045   14215.7979 ( 0003) PIH N                 ( 0014) POCATELLO CORS ARP
  31  -0.0015  -0.0018  -0.0050  813536.2311 ( 0016) BREWSTER VLBA 40473M001 ( 0014) POCATELLO CORS ARP
  34  -0.0008  -0.0019  -0.0050   78229.1154 ( 0011) GTRG_EBRY_ID1998 CORS ARP ( 0014) POCATELLO CORS ARP
  37   0.0003  -0.0019  -0.0033   78859.7661 ( 0012) IDAHO FALLS CORS ARP  ( 0014) POCATELLO CORS ARP
  40  -0.0001  -0.0016  -0.0025   89193.9122 ( 0013) IDAHO NAT LAB CORS ARP ( 0014) POCATELLO CORS ARP
  43  -0.0009  -0.0019  -0.0015   76327.4604 ( 0015) HOLBROOK__ID2006 CORS MON ( 0014) POCATELLO CORS ARP
  46  -0.0013   0.0019   0.0023   14016.0026 ( 0001) FAA PIH A             ( 0014) POCATELLO CORS ARP
  49  -0.0012   0.0001  -0.0033   12804.9158 ( 0002) PIH C                 ( 0014) POCATELLO CORS ARP
  52  -0.0056   0.0002   0.0090   14215.7979 ( 0003) PIH N                 ( 0014) POCATELLO CORS ARP
  55   0.0013   0.0016   0.0043  813536.2311 ( 0016) BREWSTER VLBA 40473M001 ( 0014) POCATELLO CORS ARP
  58   0.0012   0.0017   0.0045   78229.1154 ( 0011) GTRG_EBRY_ID1998 CORS ARP ( 0014) POCATELLO CORS ARP
  61   0.0001   0.0012   0.0028   78859.7661 ( 0012) IDAHO FALLS CORS ARP  ( 0014) POCATELLO CORS ARP
  64   0.0007   0.0014   0.0024   89193.9122 ( 0013) IDAHO NAT LAB CORS ARP ( 0014) POCATELLO CORS ARP
  67   0.0011   0.0019   0.0016   76327.4604 ( 0015) HOLBROOK__ID2006 CORS MON ( 0014) POCATELLO CORS ARP
network-final-horizontal-constrained.preplt2 created: 2020-09-17 12:29 UTC downloaded: 2021-06-09 16:19 UTC
```

Figure E-13: Output from Preplt2 showing the residuals from the Horizontal Constrained adjustment

d. Set up Adjustment to perform a **Vertical Free** as described in Section 12.4. Constrain the PACS only in Vertical, Constrain the HUB CORS in HOR-only. Do not modify any of these a priori coordinates. This is a good time to check coordinate constraints vs. published.

Figure E-14: Setting up the Vertical Free network adjustment

Evaluate output. The a priori coordinate shifts may appear higher than normal due to holding only a single passive control mark as the vertical constraint.

```
MARK   ESTIMATED - HORIZONTAL-CONSTRAINED ADJUSTMENT COORDINATE SHIFTS
------------------------------------------------------------------------------
brew   N:   -0.002 m (0.003 m) E:    0.001 m (0.005 m) H:    0.023 m (0.025 m)
gtrg   N:    0.009 m (0.002 m) E:    0.000 m (0.004 m) H:    0.023 m (0.025 m)
idif   N:    0.002 m (0.002 m) E:   -0.008 m (0.004 m) H:    0.022 m (0.025 m)
idnl   N:    0.006 m (0.002 m) E:    0.004 m (0.004 m) H:    0.023 m (0.025 m)
idpo   N:    0.000 m (0.002 m) E:    0.000 m (0.004 m) H:    0.022 m (0.025 m)
p675   N:    0.004 m (0.002 m) E:    0.004 m (0.004 m) H:    0.022 m (0.025 m)
piha   N:   -0.014 m (0.003 m) E:    0.002 m (0.005 m) H:    0.020 m (0.024 m)
pihc   N:   -0.001 m (0.003 m) E:   -0.001 m (0.005 m) H:    0.023 m (0.025 m)
pihn   N:   -0.017 m (0.003 m) E:   -0.006 m (0.005 m) H:    0.029 m (0.025 m)
```

Figure E-15: Shifts between the Horizontal Constrained and Vertical Free coordinates

e. Set up Adjustment to perform a **Vertical Constrained** as discussed in Section 12.5. Constrain the PACS vertical and in cases where the existing SACS meet all Horizontal, Ellipsoid and Vertical requirements, constrain the Vertical as well. Constrain the HUB CORS in 2D only.

Figure E-16: Setting up the Vertical Constrained network adjustment

f. Evaluate output. Take note if the adjustment passed the F-Test. Evaluate mark estimated - vertical free adjustment coordinate shifts, mark estimated - published vertical coordinate shifts, and residuals.

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```
network-final-vertical-constrained.txt created: 2020-09-17 13:28 UTC downloaded: 2021-06-09 19:42 UTC
             NGS BETA OPUS-Projects 2.03 NETWORK ADJUSTMENT REPORT
             ======================================================

All coordinate accuracies reported here are 1x the formal
uncertainties from the solution. For additional information:
geodesy.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy

These positions were computed without any knowledge by the National
Geodetic Survey regarding the equipment or field operating procedures used.

SUBMITTED BY:                  kevin.jordan
SOLUTION FILE NAME:            network-final-vertical-constrained.sum
SOLUTION SOFTWARE:             ADJUST(6.4.3)
SOLUTION DATE:                 2020-09-17T09:27:52 UTC
STANDARD ERROR OF UNIT WEIGHT: 1.009
F STATISTIC TEST:              PASS (1.02 < 2.95 F CRITICAL @ 99% CONFIDENCE)
TOTAL NUMBER OF OBSERVATIONS:  203913
TOTAL NUMBER OF MARKS:         9
CONSTRAINED MARKS:             1 HORIZONTAL, 2 VERTICAL
idpo N42:51:55.99536 W112:25:54.28751                NAD_83(2011) @ 2010.0000
idpo       0.21cm              0.44cm                NE SIGMAS
piha                                   1357.66m  ORTHO NAVD 88
piha                                      2.43cm         U SIGMA
pihn                                   1353.26m  ORTHO NAVD 88
pihn                                      2.45cm         U SIGMA
```

Figure E-17: Processing Report (.txt) from Vertical Constrained network adjustment highlighting the result of the F-test*


```
MARK   ESTIMATED - VERTICAL-FREE ADJUSTMENT COORDINATE SHIFTS
-----------------------------------------------------------------------------
brew  N:    0.002 m (0.003 m) E:   -0.002 m (0.005 m) H:   -0.021 m (0.018 m)
gtrg  N:    0.000 m (0.002 m) E:    0.000 m (0.004 m) H:   -0.021 m (0.018 m)
idif  N:    0.000 m (0.002 m) E:    0.000 m (0.004 m) H:   -0.021 m (0.018 m)
idnl  N:    0.000 m (0.002 m) E:    0.000 m (0.004 m) H:   -0.021 m (0.018 m)
idpo  N:    0.000 m (0.002 m) E:    0.000 m (0.004 m) H:   -0.020 m (0.018 m)
p675  N:    0.000 m (0.002 m) E:    0.000 m (0.004 m) H:   -0.020 m (0.018 m)
piha  N:    0.000 m (0.003 m) E:    0.000 m (0.005 m) H:   -0.020 m (0.018 m)
pihc  N:    0.000 m (0.003 m) E:    0.000 m (0.005 m) H:   -0.021 m (0.018 m)
pihn  N:    0.000 m (0.003 m) E:    0.000 m (0.005 m) H:   -0.021 m (0.018 m)
```

Figure E-18: Shifts between Vertical Free and Vertical Constrained adjusted coordinates


```
MARK   ESTIMATED - PUBLISHED VERTICAL COORDINATE SHIFTS
-----------------------------------------------------------------------------
brew: ORTHO HGT:   0.007 m (0.018 m) DK4090 GPS HEIGHTS: 2CM/5CM STANDARDS
piha: ORTHO HGT:  -0.020 m (0.018 m) AA3682 GPS HEIGHTS: DECIMETER ACCURACY
pihn: ORTHO HGT:   0.021 m (0.018 m) AB8163 GPS HEIGHTS: DECIMETER ACCURACY
```

Figure E-19: Shifts between Vertical Constrained and published orthometric heights

In this case, BREW is the distant CORS and was unconstrained in the adjustment. The output for this CORS may be ignored.

g. Follow OP guidance to Review and Submit to NGS as described in Section 11.7.6. Additional notification on the FAA Airports GIS portal as well as supplemental documents, including the OPUS Projects ID, NGS Tracking ID and date submitted will be required.

Appendix F: Tying a Real-Time Network to the NSRS

OP may be used for tying coordinates of real-time network control stations to the NSRS. A more formal NGS NSRS validation process/service may be available in the future.

The following is an outline of general 'best practices' for tying an RTN to the NSRS, mostly concatenated from current general guidelines outlined in Section V. of Henning et al (2013) "NGS Guidelines for Real Time GNSS Networks."

F.1 Determining RTN Station Coordinates using OPUS Projects

It is recommended that the RTN Administrator follow the procedures outlined in this manual (especially Sections 10 and 11) to perform the sequential network adjustments on simultaneous observations from the real-time base stations as required for submitting the project to NGS. Following these procedures, the coordinates derived for the real-time base stations will be properly tied to the NSRS.

> NGS accepts survey project proposals intended to tie RTN base stations to the NSRS via OP: a NGS Project Tracking ID will be issued as with any other GNSS survey project designed to be submitted to NGS

For this task, it is recommended that a minimum of five (5) twenty-four (24) hour data sets be used for each base station that is not a CORS in the network adjustment. The corresponding 24-hour data files are uploaded into the project through the regular OPUS data file upload page, noting that the antenna heights would be set to zero (0.0000 m).

> For connecting RTN base stations to the NSRS, only RTN base station data (24-hour files) need to be downloaded from the network and uploaded to OP; there is no need to download/upload CORS data

F.2 MON vs. GRP vs. ARP

Published CORS coordinates are automatically seeded into OP projects when RTN active station data is uploaded through OPUS to an OP project. In many cases, the published height at a CORS is with respect to the ARP, or "antenna reference point." It may also be published with respect to the **GRP**, or "**geometric reference point**," which is virtually the same as the ARP. In some cases, however, the published height is attributed to the MON, or "monument." OPUS keeps track of any MON/GRP/ARP vertical offsets (even if it is 0.000m) but will always only report the MON ellipsoid height for CORS, if available. This distinction is typically unimportant for most projects, but in the case of an RTN project where CORS may also be part of the RTN, the project manager must be aware of this MON vs ARP distinction. The difference between coordinates for the MON vs. GRP vs. ARP may cause confusion, as RTN network software typically expects the ellipsoid heights at the ARP to be entered for all stations. .
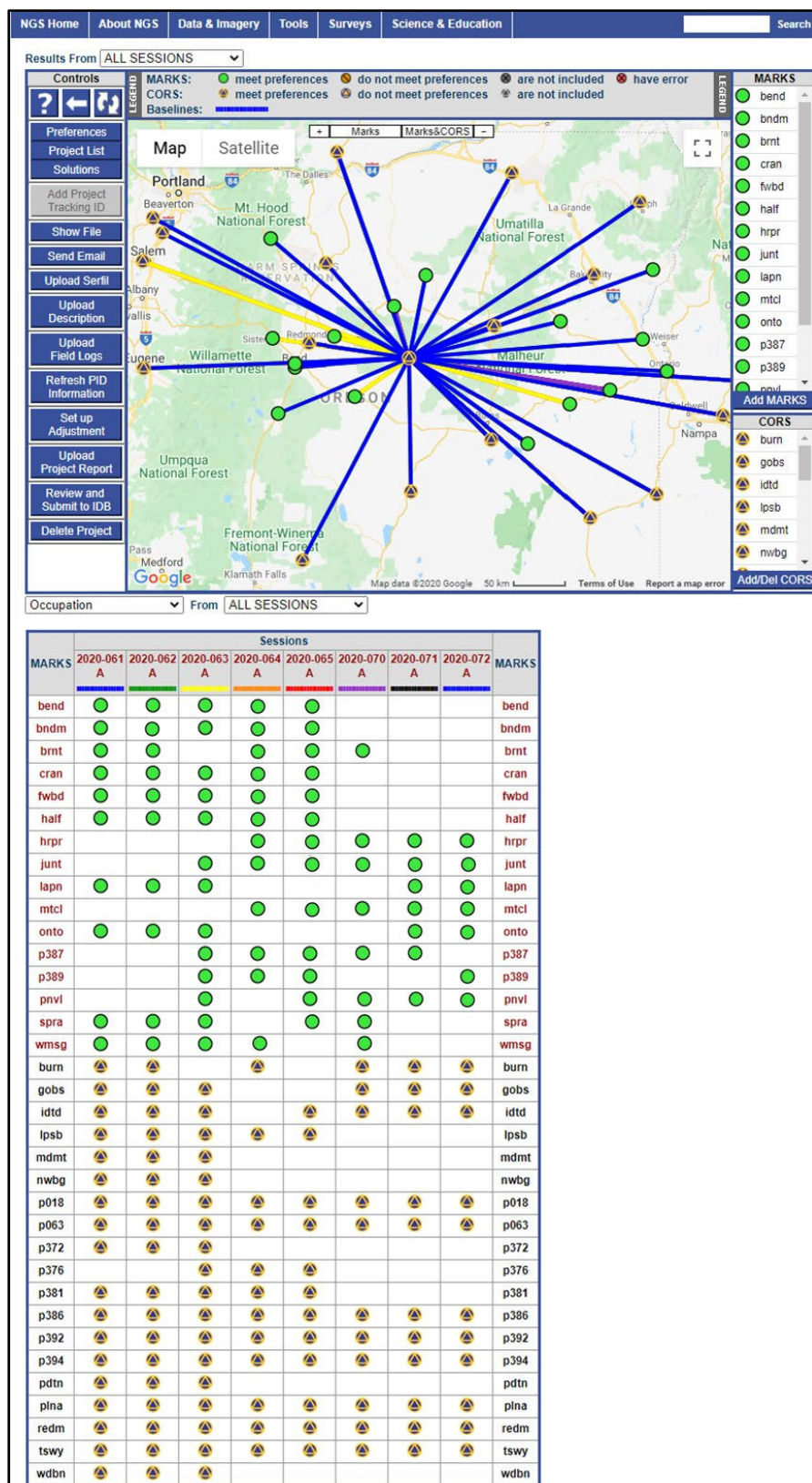
Figure F-1: Example project which includes RTN base stations as user marks in OP

Large real-time networks can be completed sequentially in OP by creating multiple projects containing RTN clusters that overlap each other providing the ability to check the same station coordinates in different projects. Each cluster project must use identical constraining CORS. While this multi-project technique produces good results, adjusting the entire RTN as one project produces the best results.

F.3 Use the Latest Absolute Antenna Calibrations

Since 2011, NGS has been using Absolute Antenna calibrations in the definition of the national reference frames. The latest absolute antenna patterns are automatically used in OPUS and thus OP as well. Within each antenna calibration file there are north and east orientation values. For best results, therefore, each antenna's North Reference Point (NRP) should be aligned to true north. Normally all CORS are orientated to north when they are installed. The NGS maintains an antenna calibration web page where absolute calibrations are provided for most geodetic GNSS antennas currently on the market.

F.4 Collect Station Data During Optimal Weather Conditions

Typically, the errors remaining in GNSS after modeled effects are removed result from signals going through the troposphere. It is therefore recommended to collect RTN station data (to use in processing) during a dry weather period when high pressure may dominate the entire RTN coverage area and tropospheric conditions are uniformly stable. Care should also be exercised not to use data taken during periods of high ionospheric disturbance. The National Weather Service Space Weather Prediction Center provides information and warnings of these periods; see https://www.swpc.noaa.gov/.

F.5 Tie RTN Stations to the NSRS Using Select CORSs

It is recommended that the RTN be tied to the NOAA CORS Network (NCN). This is very easy to achieve within OP as the access to the entire NCN is available within the program. At least 10% or a minimum of three (whichever is greater) of the RTN active reference stations should be part of the NCN. This provides a continuous real-time network tie to the NCN, the NSRS, and the geometric datum. The NCN sites to be constrained in the network should be distributed as uniformly as possible throughout the RTN service area. For the best tie, use CORS that have proven themselves to be reliable and stable over time, and have up to date log files with photos. Verify that the antenna and radome in the log file are the ones actually on the mount during the time the data are downloaded. Include constraining to one or more IGS CORS sites and refer to the IGS website for more information on the IGS site locations: http://igscb.jpl.nasa.gov/network/netindex.html

⚠ OP lists both NCN and IGS Stations (not in the NCN) as "CORS." Clicking on the individual CORS for more information will reveal which kind of station it is.

F.6 Coordination

Real-time networks that are adjacent to one another may want to consider coordinating their efforts to position their networks such that rover operators may cross RTN borders and expect to work effectively with common, homogeneous coordinates. Thorough testing of the network correctors, supported by empirical data, may provide some assurance of common coordinates corroborated by independent OPUS Static solutions.

F.7 Field Tests

RTN Administrators may elect to occupy a subset of passive marks with rovers to compare RTN derived positions with the NGS national adjustment positions in the same reference frame. However, the correctors any given RTN provides may yield coordinates for an RTN rover, at passive control, that disagree with NAD 83(2011)2010.00 coordinates. Note that the processed vectors used in the national adjustment of 2011 (NA2011, which yielded NAD 83(2011)) are from surveys spanning nearly 20 years and therefore based on equipment and software used at the time of the original survey. Additionally the adjustment will not account for possible mark disturbance or movement since the observation date. Western states' passive marks may be subject to significant tectonic plate motion which complicates efforts to assign long-lasting, stable coordinate positions. In fact, even in the most "stable" part of the North American Continent, residual interplate motions are known to exist. For checking the validity of RTN correctors after tying the network to the NSRS, it is recommended to perform a static GNSS occupation on the passive mark, and compare the new independent OPUS solution to the RTN-rover-based coordinate value. This method uses the identical survey epoch (with similar atmospheric conditions) and hardware, with the only difference being the method of computation (OPUS vs. RTN).

F.8 Monitoring RTN Station Coordinates

After a successful submission of the RTN project to NGS, NSRS coordinates will be published for the RTN base stations (not part of the NCN). The RTN Administrator should plan to monitor the positions of all RTN stations to ensure that their coordinates do not deviate more than expected from these newly published values. Administrators should provide quality assurance to users that the positions do not vary by more than an expected amount for any given day of RTN operation. How much variance or movement in position is acceptable? What are the seasonal effects on station positions? Each RTN should determine acceptable normal limits and beyond those limits consider re-positioning the station. For consistency, consider adopting procedures for updating the station's coordinates and/or velocity if coordinate differences in excess of 2 cm in either horizontal dimension and/or 4 cm in ellipsoid height persist over a period of several days.

After completing a new RTN adjustment or updating individual station coordinates the RTN Administrator should consider publishing each station's position on the RTN website. Include metadata about the adopted coordinates and relative positioning network accuracies for the RTN stations based on the assumption that CORS are errorless. Network accuracies should be published for each station so that users may include those errors when performing local project static network adjustments using the RTN stations. Thus local project network error will include the RTN network error. The network error should be normally reported at the 95% (2) confidence level.

F.9 Literature Cited:

Henning, W., D. Martin, G. Schrock, G. Thompson, R. Snay. 2013. National Geodetic Survey Guidelines for Real Time Networks. Accessed online on November 16, 2020: https://www.ngs.noaa.gov/PUBS_LIB/NGSGuidelinesForRealTimeGNSSNetworksV2.2.pdf. 64pp.