

ASSOCIATION OF NOVA SCOTIA LAND SURVEYORS

Nova Scotia Coordinate Referencing System

User Guide

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List of Acronyms

| | |
|----------------|--|
| ATS77 | Average Terrestrial System of 1977 |
| CGVD28 | Canadian Geodetic Vertical Datum of 1928 |
| CGVD2013 | Canadian Geodetic Vertical Datum of 2013 |
| CSF | Combined Scale Factor |
| CSRS | Canadian Spatial Referencing System |
| GNSS | Global Navigation Satellite System |
| MTM | Modified Transverse Mercator |
| NAD27 | North American Datum of 1927 |
| NAD83 | North American Datum of 1983 |
| NRCan | Natural Resources Canada |
| NRTK | Network Real Time Kinematic |
| NSACS | Nova Scotia Active Control Stations |
| NSCCS | Nova Scotia Coordinate Control System |
| NSCM | Nova Scotia Control Monument |
| NSCRS | Nova Scotia Coordinate Referencing Systems |
| NSHPN | Nova Scotia High Precision Network |
| PPP | Precise Point Positioning |
| RTK | Real Time Kinematic |

1 Introduction

The purpose of this user guide is to help members of the Association of Nova Scotia Land Surveyors (ANSLS) use and integrate the North American Datum of 1983 (NAD83) Canadian Spatial Referencing System (CSRS) into their daily work. The NAD83(CSRS) reference system has been available to surveyors within the province since the late 1990s. The Nova Scotia High Precision Network (NSHPN) monuments were observed using Global Navigation Satellite Systems (GNSS) and coordinates were made available to users at that time. Until recently, the system did not receive much uptake in survey work due to the distance between the monuments (~20 km) and the lack of GNSS users. Many provincial government data layers were migrated from the Average Terrestrial System of 1977 (ATS77) to NAD83(CSRS) at this time.

Since 2012, the Province of Nova Scotia has began installing permanent Active Control Stations throughout the province, forming the Nova Scotia Active Control Stations (NSACS) network. These stations combined with a denser NSHPN have reinvigorated the migration of survey work to NAD83(CSRS) in the province. One of the main purposes of this infrastructure has been to address ongoing accessibility needs to the Nova Scotia Coordinate Referencing System (NSCRS).

The use of GNSS has revolutionized the way land surveyors and other users perform their daily work. The issue with the Nova Scotia Coordinate Control System (NSCCS) based on ATS77 is that it is not compatible with GNSS. The NSCCS was established using terrestrial (conventional) based methods. With the widespread use of GNSS, and specifically Real Time Kinematic (RTK) technology, errors have been observed throughout the NSCCS.

As with any industry, the adaptation to new technologies is the key to success and growth. With the NSACS and expanded NSHPN infrastructure in place, the switch from ATS77 to NAD83(CSRS) has been made possible to surveyors and other users of the system. The purpose of this guide is to provide some direction on how to implement and utilize the NSCRS in surveying workflows and how to best bring forward ATS77 based surveys in NAD83(CSRS).

2 Defining the NSCRS - Spatial Reference Standard

This chapter will explain the components of the NSCRS program and its newly adopted spatial reference standards. The NSCRS is the underlying infrastructure that allows all geographic information in Nova Scotia to be represented in a coordinate reference system that is relatable globally. The NSCRS develops and maintains a spatial reference standard and provides the framework for the provincial mapping base.

This chapter will explain the rationale in switching from ATS77 to NAD83(CSRS). It is realized that for nearly 35 years, surveyors in the province have been tying their surveys to the NSCCS, based on ATS77. When the NSCCS was rolled out to supersede the North American Datum of 1927 (NAD27) apprehension also existed. At that time, some individuals felt that a compass was the only tool needed to reference a bearing and that using "control monuments" meant more time in the field, more effort and more cost for the client.

No one can disagree that tying a survey to control does require more effort, but the benefits gained by the profession far exceed the added work. Today, all surveys in the province are required to be tied into the Nova Scotia Coordinate Referencing System (NSCRS).

2.1 NAD83(CSRS)

The North American Datum of 1983 is not unique to Nova Scotia. All provinces and territories in Canada have adopted NAD83(CSRS). The current adopted version of NAD83(CSRS) in Nova Scotia is specifically known as NAD83(CSRS) epoch 2010.0. Previous versions of the datum like NAD83(Original) were again based on terrestrial observations, much like ATS77. The Canadian Spatial Referencing System (CSRS) is compatible with and supports new technologies.

NAD83(CSRS) is endorsed by the Canadian Council of Geomatics and is the best choice when conducting GNSS surveying.

The epoch of the datum is also important. Due to the fact that a GNSS receiver provides positions based on a global scale, tectonic plate movements can now be quantified. As the plates move over time, monuments set in the ground also move with them. The global coordinates of these monuments will change as time passes. The purpose of noting the epoch provides a time stamp on a monument as where it was positioned on the Earth's surface at a particular time.

Currently the NSACS broadcasts coordinates in epoch 2010.0. For more details regarding NAD83(CSRS) please visit NSCRS Tech Support at: <http://geonova.novascotia.ca/coordinate-referencing-technical-support>.

2.2 Velocity Model and Epoch

Our planet is constantly experiencing tectonic motion. When implementing national and international coordinate referencing systems, one must choose between a.) a dynamic system which follows Earth's movements (like the International Terrestrial Reference System (ITRS) or b.) a plate-fixed system which moves with a tectonic plate. NAD83(CSRS) is fixed to the North American Plate.

In Canada, the NAD83 reference frame is chosen to align with the International Terrestrial Reference Frame (ITRF) at a particular epoch. Currently this is January 01, 2010. This is the only moment where GNSS derived coordinates (based on the ITRF) would match NAD83(CSRS) coordinates. To transform GNSS coordinates measured before or after that time, a model is needed to account for the movement of the North American Plate.

Permanently tracking GNSS stations (like the NSACS) is used to determine plate movement. The more stations that are used, generally the more accurate the model will be. Over time, the model evolves to reflect information that new stations provide. Although the stations are moving at a very slow rate, (millimetres or centimetres per year) the model is referred to as a velocity model since it reflects the change in position over time. Velocities vary across the country according to regions and local geophysical phenomenon. Consequently, a standard transformation model will not work.

The longer the period over which a velocity model must be applied, the greater the uncertainty will be in a set of coordinates. Over time, Canadian Geodetic Survey updates the reference system to align with the ITRF at a more recent epoch. Additionally, the velocity model is updated to reflect better information about the movement of the North American Plate. The relatively dense spacing of the NSACS will help to ensure that updates to the velocity model should have minimal impact in Nova Scotia. The adoption of a new alignment epoch will, however, change coordinate values noticeably.

The current version of the velocity model adopted by Nova Scotia is version 6 (v6). Velocity models improve over time when new sample points (Active Control Stations) are added to the velocity model calculations. In general, it takes about 5 years for an Active Control Station to add value to the velocity model. Consequently, the benefits of the NSACS may soon be realized for Nova Scotia modeling. Previous models relied upon 5 Canadian Base Network Stations and 1 Canadian Active Control Station. Version 7 (v7) of the velocity model was recently released (<https://webapp.geod.nrcan.gc.ca/geod/tools-outils/nad83-docs.php>) but has not been implemented in Nova Scotia. Initial analyses suggest that v6 and v7 agree at millimetre level in

Nova Scotia. It is important to keep consistent or make note of which velocity model is used, as the difference between model versions will increase over time. Future velocity model versions may have significant differences compared to past models. When these differences exceed the acceptable tolerance accuracies of a GNSS system (i.e. 0.030m in the three-dimensional position), the Province should then move to the most current velocity model adopted by Natural Resources Canada (NRCan).

Currently the NSACS broadcasts coordinates in epoch 2010.0 and is aligned with the federal standard. Some provinces use other epochs from previous standards. For more details regarding NAD83(CSRS) please visit NSCRS Tech Support at: <http://geonova.novascotia.ca/coordinate-referencing-technical-support>.

2.3 Modified Transverse Mercator Mapping Projection

The most common surveying mapping projection used in Nova Scotia is the 3^o Modified Transverse Mercator Projection (MTM). Throughout Nova Scotia, this projection is divided into 2 zones which cover the majority of the province (Zone 4 & Zone 5). The mapping projection dictates bearings illustrated on survey plans. The MTM projection has been in use in Nova Scotia since the implementation of the NSCCS. With the transition to NAD83, the MTM mapping projection can still be used and is recommended for survey work. This will enable a direct comparison of bearings shown on ATS77 plans versus new NAD83 plans. For more details regarding mapping projections used in the province please visit NSCRS Tech Support at: <http://geonova.novascotia.ca/coordinate-referencing-technical-support>.

2.4 Vertical Reference System

A vertical reference system is simply the height reference used when illustrating elevations on an engineering or survey plan. The previous standard vertical reference system used throughout the province was the Canadian Geodetic Vertical Datum of 1928 (CGVD28). This vertical datum was established in 1935 as the official height referencing system in Canada. NSCCS heights were based upon CGVD28 derived from levelling and trigonometric heighting. Since the implementation of the NSCCS, elevations used in engineering and surveying plans were usually derived from a specific NSCM's published elevation.

In 2013, the Canadian Geodetic Vertical Datum of 2013 (CGVD2013) was adopted as the official height referencing system in Canada. The difference between CGVD28 and CGVD2013 is approximately 0.64 metres throughout the majority of the Province but is dependant on your geographic location. CGVD2013 is based on satellite gravimetric observations whereas CGVD28 was based on leveling techniques as noted above. CGVD2013 works seamlessly with the new NSHPN.

Since being adopted by the NSCRS, all new work completed in the province is recommended to be conducted using the new CGVD2013 vertical datum. Since the difference is relatively close, care must be taken to ensure the proper vertical datum is being used. For more details vertical reference systems used in the province please visit NSCRS Tech Support at:

<http://geonova.novascotia.ca/coordinate-referencing-technical-support>.

3 NAD83(CSRS) Project Preparation

This chapter will explain how to setup up your project before heading out to the field. There are a multitude of variations on how surveyors can do this. This chapter will focus on GNSS controller setup, coordinating an ATS77 plan (worksheet) and NSHPN monument reconnaissance using the NSCRS Viewer.

3.1 Controller Setup

One of the most important factors in completing a NAD83(CSRS) survey is to have your GNSS controller setup properly. There are many brands of controllers and receivers, all having specific data inputs regarding datums, mapping projections and vertical reference frames. If the user feels confident setting up their own templates for NAD83(CSRS) within their controller, it is recommended to conduct a field test ensuring the results are favourable. This would simply be an observation on 2 or more existing NSHPN monuments with favourable results. If a user does not feel confident, it is recommended to contact your service provider or distributor to have them prepare a template for you.

3.2 Coordinating an ATS77 Plan

This section will detail the process to perform coordinate transformations from ATS77 to NAD83(CSRS)2010.0 v6 using the available tools from NRCan which are supported by the NSCRS. The recommended methodology to coordinate a previously surveyed ATS77 legal plan to NAD83(CSRS)2010.0 v6 is to collect GNSS observations on NSCMs which are referenced in the legal plan. This can be done using a variety of methods which range from Static GNSS, NRTK observations and Precise Point Positioning (PPP). However, if these options are not available and a coordinate transformation of both horizontal and vertical coordinates is required,

please follow the below instructions to complete these calculations. Additional information can be found in the Geomatica publication Migrating from ATS77 to NAD83(CSRS) in Nova Scotia (https://geonova.novascotia.ca/sites/default/files/resource-library/c_Bond_126_712.pdf).

3.2.1 NTV2: Convert ATS77 to NAD83(CSRS)

In order to perform coordinate transformations from ATS77 to NAD83(CSRS)2010.0 v6 the calculation tool NTV2 will be required. This program can be found on the NRCan website in both a stand-alone desktop application or online web-based tool. Please visit the following URL to either download the stand-alone version or access the web application,

<https://www.nrcan.gc.ca/maps-tools-publications/maps/tools-applications/10925>.

Since there is no absolute transformation between ATS77 and NAD83(CSRS) 2010.0 v6, a grid shift file is required to perform this calculation. To download the grid shift files required for use in the NTV2 desktop application, please use the following URL for the Nova Scotia Provincial Data Directory, <https://nsgi.novascotia.ca/gdd> and download the file titled “Nova Scotia Grid Shift Files”. Once downloaded, please unzip/extract the data onto your local machine. The next two sections will provide instructions on how to use both versions of the NTV2 software to perform datum transformations from ATS77 to NAD83(CSRS) 2010.0 v6.

Please note that it is not recommended to rely on converted coordinates of NSCMs from ATS77 to NAD83(CSRS) 2010.0 v6 due to the inherent risks associated with grid shift files. It is recommended that coordinates for NSCMs that do not have published NAD83(CSRS) 2010.0 v6 coordinates should only be calculated using GNSS observations following the procedure outlined by the NSCRS.

3.2.1.1 NTV2 Stand-Alone Software

Once NTV2 is installed on your PC, the first step is to load the correct grid shift file into the program. Open NTV2 and select “Grid File ...” in the top left corner of the program.

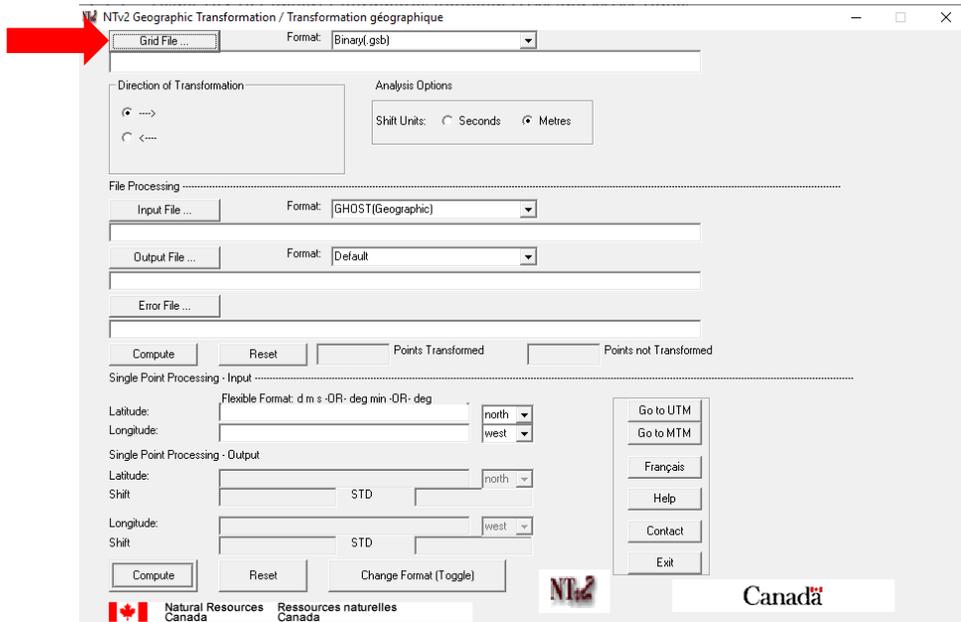


Fig. 3.1 - NTV2: Grid Shift File

You will now be prompted to navigate and select the grid shift file (.gsb) used in the datum transformation. If you downloaded and extracted the previously mentioned grid shift files in Section 3.2.1, please navigate to the following directory
\\LOC_NS_Gridshift_Files\Gridshifts\canada withing the downloaded file and select the “NS778302.gsb” grid shift file”. NTV2 should now indicate in the “Direction of Transformation” section that a transformation between ATS77 and NAD83 can occur in both directions. Select the direction which your transformation is required.

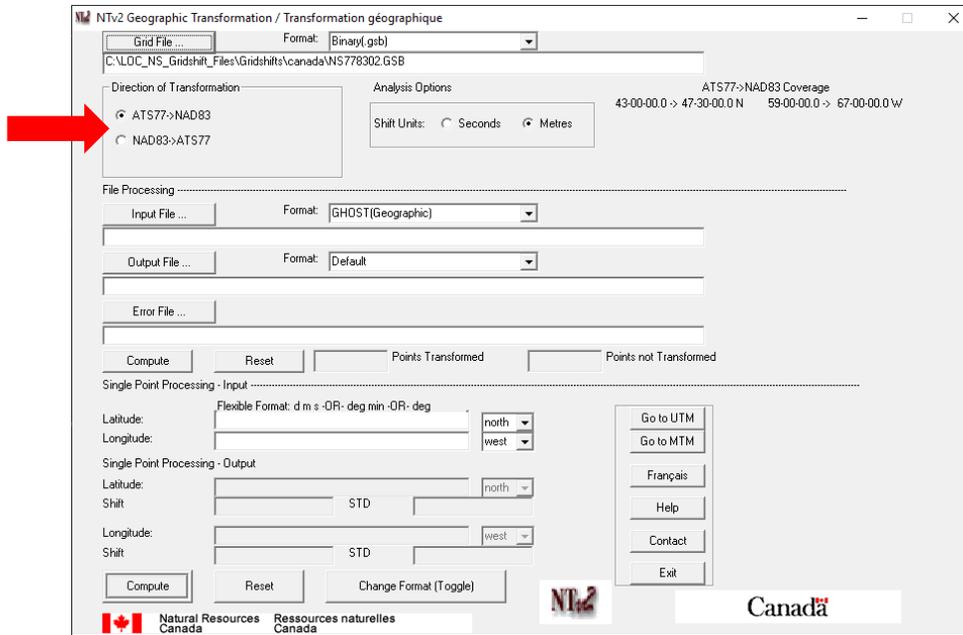


Fig. 3.2 - NTV2: Direction of Transformation

Coordinates can now be entered into the software by first selecting the direction the user requires to complete the transformation (ex. ATS77 to NAD83(CSRS)2010.0 v6). Coordinates can be entered and transformed individually, or a batch transformation can be completed. Coordinates can be entered individually into the program in Geographic, MTM and UTM format by toggling the highlighted buttons.

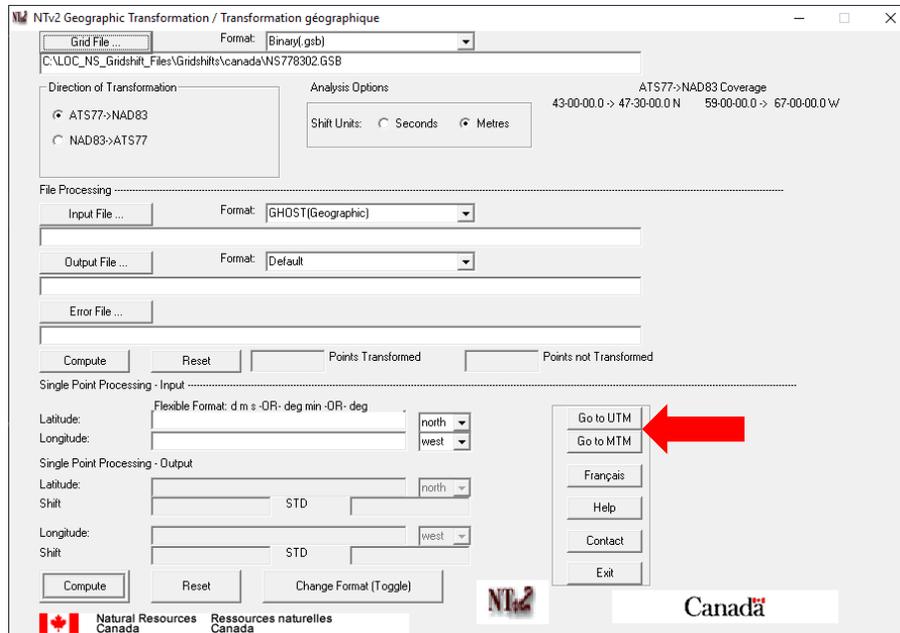


Fig. 3.3 - NTV2: Transverse Mercator

When entering coordinates as either UTM or MTM, ensure that the correct zone width is selected. For further information regarding batch processing formats please consult the help button on the lower right corner of the program.

It is recommended that a test coordinate transformation is completed using the desired settings before completing final calculations. Test coordinates can be found using the Coordinate Referencing Viewer, <https://gis8.nsgc.gov.ns.ca/NSCRS> and selecting an HPN that has both a published ATS77 and NAD83(CSRS)2010.0 v6 coordinate. For batch processing it is recommended that the test coordinate be included in the batch file and confirmed following the transformation.

3.2.1.2 NTV2 Online Computation Tool

This version of the software requires an internet connection to use and it is recommended to be used on a desktop/laptop PC. Go to the following link to access the NTV2 Online Computation Tool, <https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ntv2.php>.

You are required to select the correct grid shift file. Click the “Select Grid” hyperlink to bring you to the page listing all the available grid shift files.

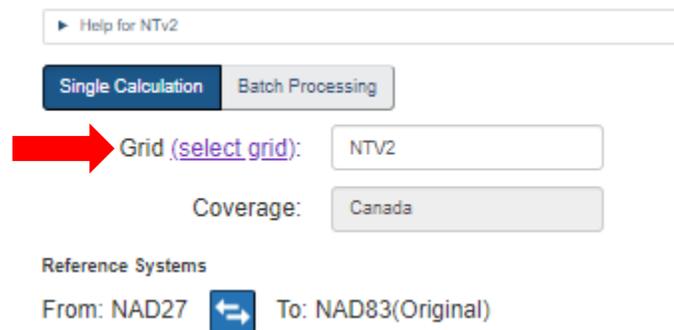


Fig. 3.4 - NTV2 Online: Grid Shift Selection

The page will display all available grid shift files available in the NTV2 Online Computation Tool. Select the hyperlink called “NS778302” which is the name of the grid shift file for transformations from ATS77 to NAD83(CSRS) 2010.0 v6. By clicking on the hyperlink, you should be directed back to the main NTV2 Online Computation Tool page. Once the correct grid shift file has been loaded into the tool, you should be able to view and toggle the direction of the transformation.

For single point calculations the user will be required to select the “Origin” and “Destination” format for their coordinates. By default, the tool selects Geographic coordinates, to change coordinate type to UTM or MTM for the “Origin” coordinate, select the “UTM/MTM/Stereo”

tab. To change the coordinate type to UTM or MTM for the “Destination” coordinate, select “UTM/MTM/Stereo” in the “Coordinates” drop down box.

The next step will be to select what UTM/MTM Zone both the “Origin” and/or “Destination” coordinates are located within. Click on the “select zone” hyperlink and select what Zones correspond to both the “Origin” and “Destination” coordinates.

The screenshot shows the 'Single Calculation' interface. At the top, there is a checkbox for 'Longitude Positive West' which is checked. Below this, the 'Origin (ATS77)' section has two tabs: 'Geographic' and 'UTM/MTM/Stereo'. The 'UTM/MTM/Stereo' tab is active, and a red arrow points to the 'Zone (select zone)' dropdown menu. Below the tabs are three input fields for 'Easting (metres)' and 'Northing (metres)'. The 'Destination (NAD83(CSRs) 2010)' section has a 'Coordinates' dropdown menu set to 'UTM/MTM/Stereo' and a 'Zone (select zone)' dropdown menu set to 'UTM'. A red arrow points to the 'Zone (select zone)' dropdown menu. At the bottom left, there is a 'Calculate' button.

Fig. 3.5 - NTv2 Online: UTM/MTM Zones

You will be directed to another page which displays all available UTM and MTM Zones for Canada. The appropriate UTM Zones for Nova Scotia are UTM19, UTM20 and UTM21.

For MTM Zones with coordinates in ATS77 use either “NS-ATS77-4” or “NS-AST77-5”, where 4 and 5 denote the MTM Zone. For coordinates in NAD83(CSRs)2010.0 v6, use either “NS-NAD83-2010-4” and “NS-NAD83-2010-5”, where 4 and 5 denote the MTM Zone.

Coordinates can now be entered into their corresponding text boxes using the appropriate formatting and transformations completed using the “Calculate” button. For more information regarding coordinate formatting please select the “Help for NTv2” link.

Batch processing can be performed using the Online Computation Tool. Batch files are loaded into the Online Computation using the “Choose File” button and the user must select the “Destination” format for the desired output coordinates. Formatting information and sample batch files can be found by clicking the “Help for NTV2” link.

It is recommended that a test coordinate transformation is completed using the desired settings before completing final calculations. Test coordinates can be found using the Coordinate Referencing Viewer (<https://gis8.nsgc.gov.ns.ca/NSCRS>) and selecting an HPN that has both a published ATS77 and NAD83(CSRS)2010.0 v6 coordinate. For batch processing it is recommended that the test coordinate be included in the batch file and confirmed following the transformation.

3.2.2 Grid Shift File in Survey Software

Depending on the type of surveying software a particular organization uses, often the provincial grid shift file can be implemented directly into a software package. Most survey controllers and survey grade desktop software can use the provincial grid shift file to implement approximate transformations between ATS77 and NAD83. It is recommended that a user contact their software supplier for details about integrating the grid shift file. For more details regarding Grid Shift Files please visit NSCRS Tech Support at: <http://geonova.novascotia.ca/coordinate-referencing-technical-support>.

3.3 NSCRS Viewer

The Nova Scotia Coordinate Referencing System Viewer is the only certified source for acquiring coordinate values for NSCCS and NSCRS monuments throughout the province. The

NSCRS viewer can be found at <https://gis8.nsgc.gov.ns.ca/NSCRS>. This tool enables the user to view NSHPN coordinate values, heights, sketches, photos, and notes pertaining to each specific monument. This tool also provides users with historical data regarding the NSCCS monuments. Please note that by default the Nova Scotia Coordinate Referencing System Viewer only displays NSHPNs on the home screen. To toggle on NSCCS and NSACS locations, click on the checkbox on the desired source. Up to date representations of property boundaries, 2K and 10K aerial imagery/orthophotos can also be toggled in this viewer to provide more detail.

This tool should be used every time a surveyor is conducting a survey in NAD83(CSRS)2010.0 v6. Once the surveyor is prepared to enter the field, this tool should be used to locate the nearest NSHPN monument to their site of survey. Prior to the surveyor setting control at a site, it is recommended to perform a check measure observation on the nearest NSHPN monument. This observation will ensure that the user's GNSS controller is setup properly and that the GNSS corrections being received using the nearest NSACS station are working. Checking into an NSHPN monument that is not near the project site will not validate local performance. If the local NSACS is offline or the service provider has an incorrect setting for the NSACS, these issues will remain hidden without performing a local check. Regardless of the type of GNSS system being used (Static, RTK, NRTK), the NSHPN monument is your direct physical connection to the provincial system.

3.4 GPS-H: Convert CGVD28 to CGVD2013

In order to perform height transformations from CGVD28 to CGVD2013 the calculation tool GPS-H will be required. This program can be found on the NRCan website in both a stand-alone desktop application or online web-based tool. Please visit the following URL to either download

the stand-alone version or access the web application (<https://www.nrcan.gc.ca/maps-tools-publications/tools/geodetic-reference-systems-tools/tools-applications/1092>).

3.4.1 GPS-H Stand-Alone Software

Once GPS-H is installed on your PC, open the software to the home screen. You will need to select the correct geoid model. For conversions from CGVD28 to CGVSD2013 you will need to select the “HT2_1997_CGG2013a [Conversion]” geoid model. Depending on the version of the GPS-H, it may be labelled “HT2_0_CGG2013a [Conversion]”, which is simply a renamed version of the geoid model conversion.

You will need to select the correct projection for your project. You may need to create a custom “My MTM” under the projections dropdown (arrow) for NAD83(CSRS) 2010.0 MTM. For more details regarding NAD83(CSRS) 2010.0 MTM projection values, please visit NSCRS Tech Support at: <http://geonova.novascotia.ca/coordinate-referencing-technical-support>. To proceed with the conversion input the station name, Easting, Northing (or geographic coordinates) and CGVD28 height. Once entered, the CGVD2013 height will automatically be calculated.

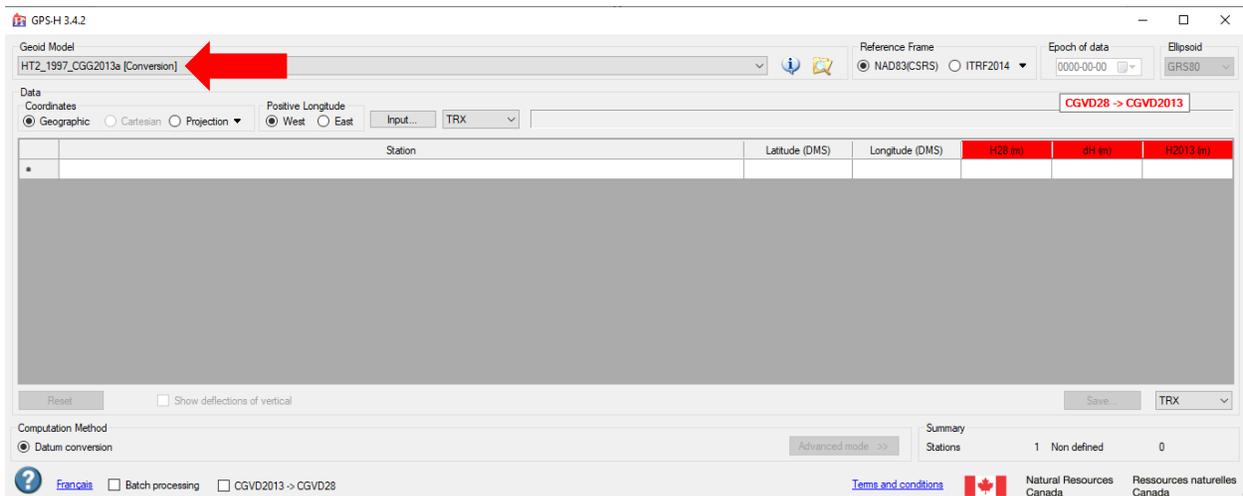


Fig. 3.6 - GPS-H: Geoid Model

To perform a batch calculation, click the “Batch processing” checkbox in the bottom left corner of the program. A batch file in the correct format will need to be loaded into GPS-H in either GHOST, GeoLab or UNICSV format.



Fig. 3.7 - GPS-H: Batch Processing

For more information on batch file formatting and other technical items please click on the “Help” button located in the bottom left corner.

It is recommended that a test height transformation is completed using the desired settings before completing final calculations. Test heights can be found using the Coordinate Referencing Viewer (<https://gis8.nsgc.gov.ns.ca/NSCRS>) and selecting an NSHPN monument that has both a published CGVD28 and CGVD2013 height. For batch processing it is recommended that the test height be included in the batch file and confirmed following the transformation. Please note that test heights will not match exactly published heights due to the errors associated with CGVD28 heights.

3.4.2 GPS-H Online Tool

This version of the software requires an internet connection to use and it is recommended to be used on a desktop/laptop PC. Go to the following link to access the GPS-H Online Computation Tool (<https://webapp.geod.nrcan.gc.ca/geod/tools-outils/gpsh.php>). You will first need to select the “Convert” checkbox and then select the “HT2_1997_to_CGG2013a” conversion drop down box.

Fig. 3.8 - GPS-H Online: Geoid Model

Enter the geographic coordinates and CGVD28 height of the point you wish to convert. Once completed click on the “Calculate” button. Your results will then be presented to you in the bottom of the screen in the “H2013” textbox.

To perform a batch calculation, click on the “Batch Processing” tab at the top of the screen. Use the settings discussed earlier in this section to define the conversion. A batch file in the correct format will need to be loaded into GPS-H in either GHOST, GeoLab or UNICSV format by selecting the “Choose File” button.

Fig. 3.9 - GPS-H Online: Batch Processing

For more information on batch file formatting, sample files and other technical items please click on the “Help for GPS-H” button.

It is recommended that a test height transformation is completed using the desired settings before completing final calculations. Test heights can be found using the Coordinate Referencing Viewer (<https://gis8.nsgc.gov.ns.ca/NSCRS>) and selecting an NSHPN monument that has both a published CGVD28 and CGVD2013 height. For batch processing it is recommended that the test height be included in the batch file and confirmed following the transformation. Please note that test heights will not exactly match published heights due to the errors associated with CGVD28 heights.

4 NAD83(CSRS) GNSS Surveying Types

This chapter will detail the main variations of GNSS surveying types and how to implement NAD83(CSRS) while conducting a survey in the province. Depending on the land surveyor or firm, field techniques can vary widely from one end of the province to the other. This chapter is not intended to detail best practices with regards to fieldwork, rather how to implement NSHPN monuments and the NSACS network when conducting a NAD83(CSRS) based survey.

Additional information can be found in the Geomatica publication Modernization of The Nova Scotia Coordinate Referencing System Through Active Control Technology

(https://geonova.novascotia.ca/sites/default/files/resource-library/Bond_modernization_Geoamtica694_Dec2015.pdf).

4.1 NSACS Network

The 40 GNSS stations comprising the NSACS network were completely installed in Nova Scotia in 2015. Since that time, users have been able to access a sub-centimeter GNSS network with only the use of one GNSS receiver, survey controller and a mobile network signal (cell phone signal). This system, unlike any other, provides the user with real time coordinates without the limitation of a radio link or base station setup.

This system is based on NAD83(CSRS) v6 epoch 2010.0. For a surveyor to use the system to complete a survey in NAD83(CSRS), the first step is to ensure that their survey controller is setup correctly. With the project open, the user simply connects to the NSACS Network through their service provider. Please note, that some service providers are currently using velocity model v7. Care should be taken to ensure the proper velocity model is used and the proper notation is used for any deliverables produced. Providing this information will allow a surveyor

in the future to translate a coordinate based on a historical velocity model, to the current model being utilized.

Once connected, the user should begin receiving corrections from the NSACS Network. With the project running, it is recommended for the user to perform a check measure observation on the nearest NSHPN monument to their site of survey. Results may vary, but a residual of 0.02 metres (horizontal and vertical) should be expected.

At this point the user is receiving corrections from the NSACS network and they have ensured that the project is set up correctly on their survey controller as the observation on the NSHPN monument returned favorable results. At this time, the user can continue to the site to begin to survey. As the corrections received are based on the NSACS Network, there is no need for localization (site calibration). It is recommended that control at the site of survey is set so that checks can be made at the site in subsequent visits, without the need to return to the NSHPN monument.

It is recommended that the user conduct periodic observations on their control set at the site of survey to ensure the NSACS Network is providing adequate results throughout the day. If high confidence is required in vertical measurements (i.e. inverts, pipelines, etc.), the user should complete a repeat pass on the same topographic points to confirm the results (check-measure). After conducting a survey, visiting the GNSS Service Provider's website will enable the user to verify the uptime of the nearest NSACS during the time of survey. This is useful as it indicates whether the nearest NSACS to the site of survey was functioning properly. If the nearest NSACS was not operating during the survey period, results will likely be less precise due to the longer baseline lengths to the next nearest NSACS stations.

When using the NSACS network, it is important to remember that the NSHPN monument is your only physical link to the NSCRS. Once you have confirmed the system is working and you are receiving real time corrections from the network, you can provide real time coordinates in NAD83(CSRS) to features located in the field.

4.2 Base/Rover RTK

To conduct a survey in NAD83(CSRS) epoch 2010.0, a user needs only to locate a NSHPN monument near their site of survey. These monuments are generally spaced 10 kilometres apart providing a NSHPN monument within 5 kilometres, more or less, of any site of survey.

The user will to setup a GNSS base receiver directly over the NSHPN monument. If radio range to the site of survey can not be maintained, the "leapfrog" method can be utilized. It is also possible to deploy a base and radio link anywhere near the job site, and post process using freely available NSACS data.

If post processing software is not available, NRCAN's PPP service can also be used to obtain coordinates for a base station at an arbitrary location. This program can be found on the NRCAN website in both a stand-alone desktop application or online web-based tool. Please visit the following URL to either download the stand-alone version or access the web application, <https://www.nrcan.gc.ca/maps-tools-publications/maps/tools-applications/10925>. When using PPP, it is important to make sure that NAD83(CSRS)2010.0 settings are chosen. Although v7 of the velocity model is currently used online, differences will only be at millimetre level compared with v6. A v6 solution can be obtained using the PPP Direct desktop application. Additional

details regarding PPP can be found at: [https://www.ansls.ca/files/Precise Point Positioning Presentation Oct 2020.pptx](https://www.ansls.ca/files/Precise%20Point%20Positioning%20Presentation%20Oct%202020.pptx).

4.3 Static

Surveyors in the province have been performing static surveys since the implementation of GNSS in the surveying industry. A static survey by today's standards would typically be used in remote locations, where no mobile network service is available, or radio link range is limited. The methodology is no different than before, with the exception of having GNSS receivers located at NSHPN monuments rather than AT577 LRIS monuments.

Users of the NSACS network have an advantage as they do not require their own multiple GNSS receivers running at one time during a static survey. The user would need to only setup their GNSS receiver at the site of survey for approximately 20 to 30 minutes to acquire centimeter level accuracy. This is due to the fact that there are multiple Nova Scotia Active Control Stations running throughout the province 24 hours a day. The user can simply download from their service provider a RINEX file (GNSS raw data) during their observation time from multiple stations or a virtual reference station near their site of survey. Using their GNSS software, a user can post process a static network using this supplied data to position NAD83(CSRS) control at their site of survey.

Precise Point Positioning (PPP) is provided to the public through Natural Resources Canada and enables surveyors to set NAD83(CSRS) control at their site. PPP is simply a standalone system (Absolute GNSS – no reference station required) that enables users to submit a raw GNSS RINEX file and receive post processed results of their data within 24 hours. The only draw back

from this system is that it can require lengthy observations to provide centimeter level accuracy. In general the expected accuracies are approximately 1 hour of observation equates to 3 cm, and 3 hours equates to 1 cm, but is site dependent.

5 Plan Preparation

This chapter will provide suggestions regarding the making of surveys using NAD83(CSRS). As no one survey plan is the same, variations of information regarding datum and mapping projections can differ from one surveyor to another. The purpose of this chapter is to provide some input as to a suggested minimum standard of what should be shown on a plan.

5.1 Grid vs. Ground

Grid distances and ground distances are a common concern when conducting GNSS surveys. Regardless of datum, the differences between grid and ground distances in the province are often substantial. The majority of GNSS receivers measure along the grid, while total stations (terrestrial observations) measure along the ground. However, current technologies allow GNSS to generate ground measurements and total stations to generate grid measurements. The important point is to understand what you are measuring and how it may influence your survey.

Most surveys completed in the province illustrate measurements as being ground distances. This is usually due to the fact that total stations have been used to measure around a site of survey. If a GNSS system was used to set control at a site, grid measurements would have been used to establish a control tie from a base point, typically a monument within the NSCRS.

As many surveyors are using both GNSS observations and terrestrial observations, the Combined Scale Factor (CSF) at the site must be implemented. The CSF at the site of survey should be used to reduce or enlarge (depending on location) grid measurements (GNSS) to ground measurements (terrestrial). In most cases, the only grid distance shown on a survey plan is the control tie from the NSCRS monument used. All other measurements, typically the boundary dimensions, are illustrated as ground measurements. Grid distances are determined by multiplying the combined scale factor at a site by the ground distance (i.e. $\text{Grid} = \text{Ground} \times \text{CSF}$). Ground distances derived from GNSS measurements are determined by multiplying the reciprocal of the combined scale factor ($1/\text{CSF}$) at a site by the grid distance (i.e. $\text{Ground} = \text{Grid} \times 1/\text{CSF}$). Additional information can be found in the GeoNOVA NSCRS technical support document (<https://geonova.novascotia.ca/nscrs-tech-support-ts0006-scale-factors>).

5.2 Combined Scale Factor

To determine the CSF, there are a multitude of methods that can be utilized for a during or after the survey. Traditionally the scale factor was calculated by interpolating between the published NSCSS scale factors to the project area centroid. This method can be utilized with the NSHPNs in areas where the spacing is close but is not the preferred method. Additionally, the various GNSS software packages will typically be able to calculate the CSF for each observation, within the GNSS controller or with GNSS survey software.

Surveys with large elevation changes, or where there is large distance between the NSHPN monuments can cause a significant difference in the actual CSF and an interpolated CSF. In order to calculate the CSF for any point within a project area, the calculation tool TRX will be required. TRX is used to convert between reference frames, coordinate types, projections and

epochs. This program can be found on the NRCAN website in both a stand-alone desktop application or online web-based tool. Please visit the following URL to either download the stand-alone version or access the web application, <https://www.nrcan.gc.ca/maps-tools-publications/maps/tools-applications/10925>.

5.2.1 TRX Stand-Alone Software

Once TRX is installed on your PC, open the software to the home screen. You will need to select the correct projection for your project. You may need to create a custom “My MTM” under the projections dropdown (arrow) for NAD83(CSRS) 2010.0 MTM. For more details regarding NAD83(CSRS) 2010.0 MTM projection values, please visit NSCRS Tech Support at: <http://geonova.novascotia.ca/coordinate-referencing-technical-support>.

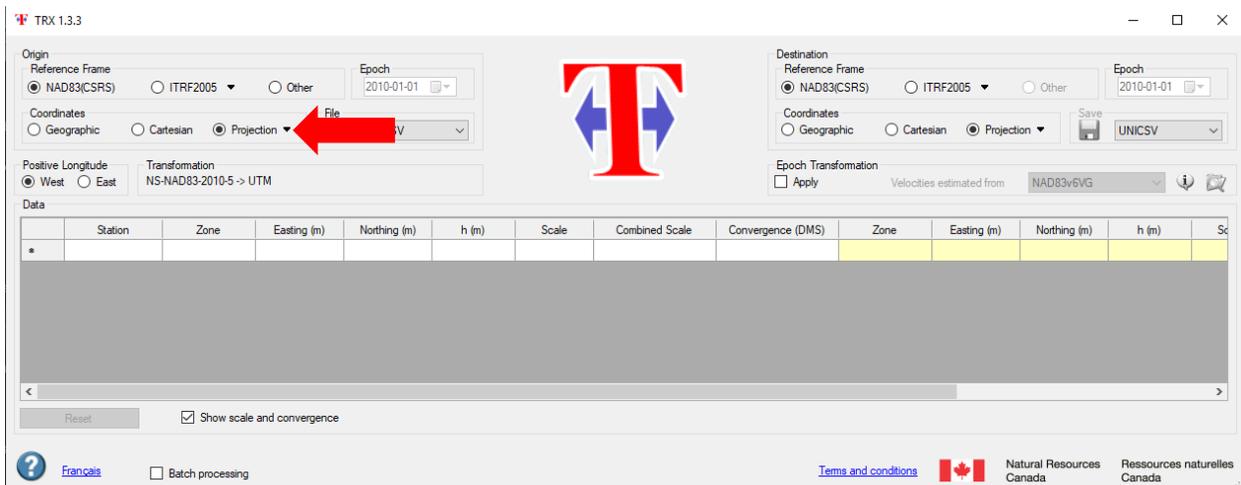


Fig. 5.1 - TRX: Projections

Once the correct projection is selected, ensure the “Show scale and convergence” box is checked. To calculate the CSF, enter the easting, northing and ellipsoidal height (h) into the origin coordinates and the (MTM) zone will be calculated automatically.

To perform a batch calculation, click the “Batch processing” checkbox in the bottom left corner of the program. A batch file in the correct format will need to be loaded into TRX in either GHOST, GeoLab or UNICSV format.

5.2.2 GPS-H: Ellipsoidal Height

For the CSF to be calculated properly in TRX, the ellipsoidal height must be used. To calculate the ellipsoidal height, the NRCan software GPS-H is to be used. This program can be found on the NRCan website in both a stand-alone desktop application or online web-based tool. Please visit the following URL to either download the stand-alone version or access the web application, <https://www.nrcan.gc.ca/maps-tools-publications/maps/tools-applications/10925>. Once GPS-H is installed on your PC, open the software to the home screen. You will need to select the correct geoid model. Selecting the “CGG2013an83 [Geoid Height]” geoid model and then select the “h=H+N” checkbox option.

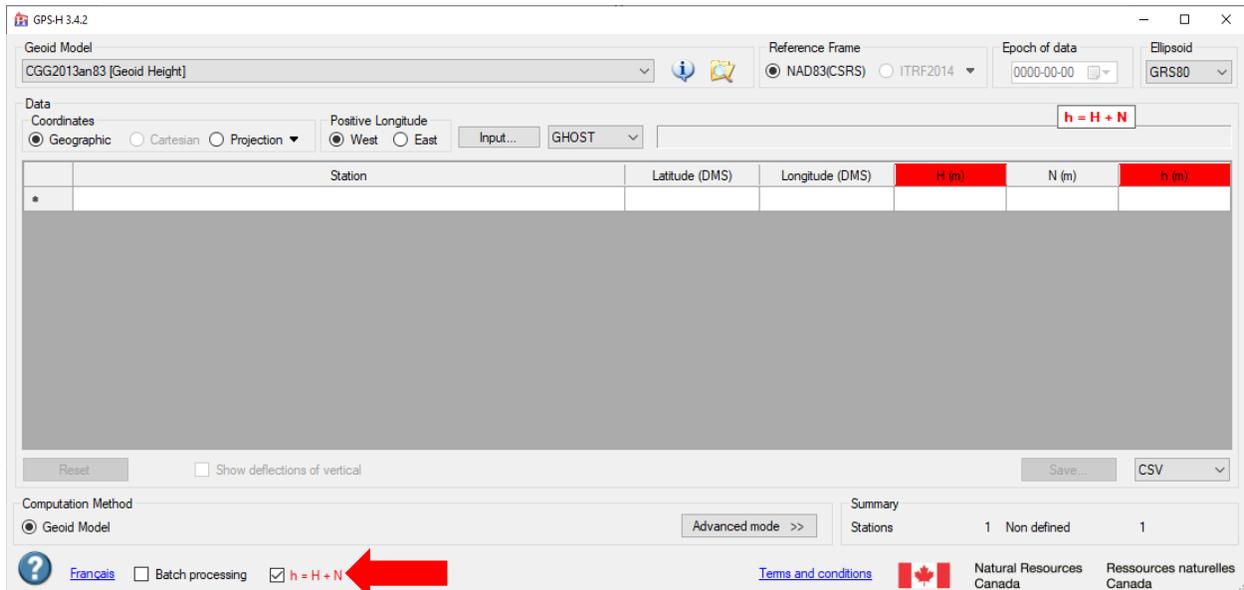


Fig. 5.2- GPS-H: Ellipsoidal Height

The online version of the software requires an internet connection to use and it is recommended to be used on a desktop/laptop PC. Go to the following link to access the GPS-H Online Computation Tool (<https://webapp.geod.nrcan.gc.ca/geod/tools-outils/gpsh.php>). The GPS-H online tool will compute the ellipsoidal height when the “Convert” checkbox is deselected and the checkbox “Input H” is selected.

The screenshot shows the 'Single Calculation' interface of the GPS-H Online tool. At the top, there are three checkboxes: 'Convert' (unchecked), 'Longitude Positive West' (checked), and 'Input H' (checked). Two red arrows point to the 'Convert' and 'Input H' checkboxes. Below the checkboxes are four dropdown menus: 'Vertical Datum' (CGVD2013), 'Geoid' (CGG2013a), 'Reference Frame' (NAD83(CSRS)), and 'Epoch (YYYY-MM-DD)' (2010-01-01). There are three tabs: 'Geographic', 'Cartesian', and 'UTM/MTM/Stereo'. The 'Cartesian' tab is selected. Below the tabs are four input fields: 'Zone (select zone)', 'Easting (metres)', 'Northing (metres)', and 'H (metres)'. A 'Calculate' button is located at the bottom left of the form.

Fig. 5.3 - GPS-H Online: Ellipsoidal Height

To proceed with the conversion input the station name, Easting, Northing (or geographic coordinates) and CGVD2013 orthometric height. Once completed click on the “Calculate” button. Your results will then be presented to you in the bottom of the screen in the “h” textbox.

It is recommended that a test height transformation is completed using the desired settings before completing final calculations. Test heights can be found using the Coordinate Referencing Viewer (<https://gis8.nsgc.gov.ns.ca/NSCRS>) and selecting an NSHPN monument that has both a published CGVD28 and CGVD2013 height. For batch processing it is recommended that the test height be included in the batch file and confirmed following the transformation. Please note that test heights will not match exactly published heights due to the errors associated with CGVD28 heights.

5.3 Control Tie

The control tie has been the standard method of coordinating survey plans since the implementation of the NSCCS. The control tie typically illustrated a calculated (published) bearing and distance between 2 monuments and a measured bearing and distance from one of the monuments into the site of survey. Up until the late 1990's, it was apparent that all control ties were ground distances. Since the implementation of GNSS, control ties can be either ground or grid as noted earlier.

The control tie still has a relevant place in a NAD83(CSRS) survey. The control tie should be from a NSHPN monument. In the case of a Base/Rover RTK or Static survey, the control tie should be illustrated from the NSHPN monument observed and held fixed during the course of the survey. In the case of a NSACS Network survey, the tie can be shown from the published values of the NSHPN monument checked into during the initial phase of the project. This will enable other surveyors that review your plan the opportunity to duplicate your control tie if necessary. This control tie should always be illustrated as a grid distance, as the distance from the NSHPN monument to the site may be in excess of 5 kilometres. The current standard of practice is the control tie is shown as a bearing to the nearest 1 second. Since control tie distances can be significantly larger than the NSCCS plans, it is suggested that control ties to the NSHPN be shown to the nearest 0.1 second. The error over distance is shown in the chart below for both rounding to 1 or 0.1 second, highlighting the importance of the rounding as the control tie distance increases. Ideally coordinate values on at least one survey marker on the site would remove any rounding errors caused by the rounding in the coordinate tie bearing.

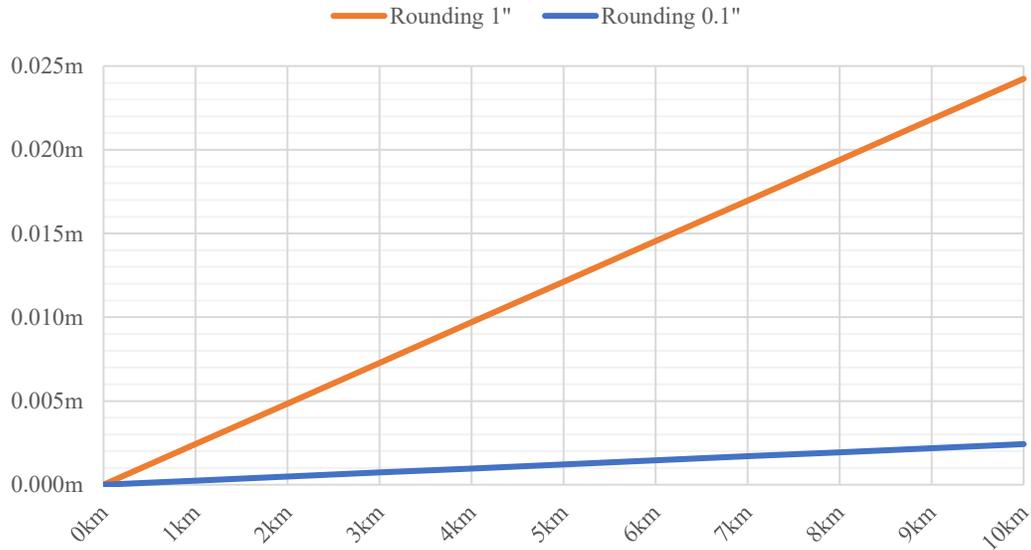


Fig. 5.4 - Control Tie: Bearing Rounding Error

The NSHPN tie also helps to verify that the NSACS network is functioning properly in the survey area. It is not sufficient to observe a NSHPN monument near the survey office (away from the site of survey) as it may not reflect NSACS conditions at the site of survey. If a control tie is to be illustrated on the plan, published coordinates of the NSHPN monument used should be shown, its horizontal reference frame, published coordinate date and its epoch of adjustment.

5.4 Coordinate Table

A coordinate table is recommended when preparing a survey plan using NAD83(CSRS). The coordinate table allows another surveyor to quickly differentiate the grid coordinates of a survey marker versus the ground distances illustrated on the plan. As noted in section 5.1, the control tie is typically illustrated showing a grid distance, while boundary dimensions can be illustrated using ground distances.

The coordinate table should list the grid coordinates of a main corner(s) of a property or terminal point(s) along a boundary. This enables another surveyor using a GNSS receiver to observe the

actual grid coordinates of a survey marker in real time, rather than computing the grid coordinates from the plan. Providing coordinates for at least one survey marker at the site of survey will also eliminate rounding errors from a long control tie (i.e. 1" over 20km = 0.097m).

| Grid Coordinate Table (metric) | | | | |
|---------------------------------------|-----------------|----------------|------------------|--------------------|
| Point | Northing | Easting | Elevation | Description |
| A | 4526365.215 | 2565231.214 | 30.256 | SM (Pl) |
| B | 4526456.263 | 2565592.325 | 41.568 | SM (Pl) |
| C | 4526299.692 | 2565219.589 | 32.635 | SM (Fd) #378 |
| 225879 | 4527125.632 | 2565917.532 | 29.645 | NSHPN (Published) |

Fig. 5.5 - Example Grid Coordinate Table

5.5 Notes on Plan

The notes on a NAD83(CSRS) survey plan should reflect what was done during the course of the survey and how coordinates were attained. If published values of a NSHPN monument are shown on a plan, the published date is to be noted. This is best identified by noting the “Adjustment ID” and coordinate date, listed in the NSHPN station report. The Adjustment ID value identifies the year, which iteration and who performed the network adjustment for the published NSHPN value. This is important to note as over time NSHPN values can change, due to disturbances or coordinate system updates.

As noted earlier in this guide, there are many different types of GNSS survey methods that can provide NAD83(CSRS) coordinate values. For these reasons, a table is recommended to be shown on the plan to identify the GNSS survey type, the horizontal and vertical datum used, their corresponding epoch, and the mapping projection used. Shown below are examples of tables that are recommended.

| | | | |
|--|-------------|--|-----------|
| GNSS Survey Type: | NRTK | Source: | CanNet |
| Coordinate System Information | | | |
| Horizontal Datum: | NAD83(CSRS) | Epoch: | 2010.0 |
| Velocity Model: | Version 6 | Projection: | 3° MTM |
| Central Meridian: | -64°30' | Zone: | 5 |
| Vertical Datum: | CGVD2013 | Calculated Offset Between CGVD28 to CGVD2013: -0.64m | |
| Combined Scale Factor at the Site of Survey: | | | 1.0002354 |

Fig. 5.6 - Example of NAD83 MTM Survey Using NSACS Network

| | | | |
|--|-------------|--|------------|
| GNSS Survey Type: | PPP | Source: | NRCan |
| Coordinate System Information | | | |
| Horizontal Datum: | NAD83(CSRS) | Epoch: | 2010.0 |
| Velocity Model: | Version 6 | Projection: | 6° UTM |
| Central Meridian: | -63° | Zone: | 20N |
| Vertical Datum: | CGVD2013 | Calculated Offset Between CGVD28 to CGVD2013: -0.64m | |
| Combined Scale Factor at the Site of Survey: | | | 0.99961235 |

Fig. 5.7 - Example of NAD83 UTM Survey Using PPP

| | | | |
|--|-------------|--|------------|
| GNSS Survey Type: | Static | Source: | NSCRS |
| Coordinate System Information | | | |
| Horizontal Datum: | NAD83(CSRS) | Epoch: | 2010.0 |
| Velocity Model: | Version 6 | Projection: | 3° MTM |
| Central Meridian: | -61°30' | Zone: | 4 |
| Vertical Datum: | CGVD2013 | Calculated Offset Between CGVD28 to CGVD2013: -0.64m | |
| Combined Scale Factor at the Site of Survey: | | | 0.99998563 |

Fig. 5.8 - Example of NAD83 MTM Survey Using Static

Survey plans should always indicate whether ground or grid distances are being illustrated and how they are obtained (i.e. GNSS or Total Station). The combined scale factor at the site of survey should always be noted on the plan and how it was applied. Examples of notes regarding the use of a combined scale factor could resemble:

"Distances shown on this plan are grid distances as derived from GNSS observations."

"Distances shown on this plan are ground distances derived from grid distances using the indicated combined scale factor."

"Distances shown on the plan are ground distances measured using a total station."

"Distances shown on the plan are ground distances using a combination of total station measurements and derived GNSS ground distances."

The former use of "scale factors applied" or "scale factors not applied" is no longer sufficient with the multitude of surveying methods available today. It is important for the surveyor to realize the values their equipment is providing and how to illustrate those values clearly on a plan of survey. This will enable the next surveyor with a clear understanding of how the measurements illustrated on a plan were derived.