

## Summary of Changes

2/28/2025

### ABBREVIATIONS

- 2D – 2 Dimensional
- 3D – 3 Dimensional
- ASCII – American Standard Code for Information Interchange
- ASPRS – American Society of Photogrammetry and Remote Sensing
- AT – Aerial Triangulation or Aerotriangulation
- BEIDOU – Chinese Navigation Satellite System
- BM – Benchmark
- BSM – Bureau of Survey and Mapping
- CADD – Computer Aided Design and Drafting
- CORS – Continuously Operating Reference Station
- CSMO – Central Surveying and Mapping Office
- DEM – Digital Elevation Model
- Department – Florida Department of Transportation
- DMI – Distance Measuring Instrument
- DSMO – District Surveying and Mapping Office
- DTM – Digital Terrain Model
- EOR – Engineer of Record
- F.A.C. – Florida Administrative Code
- FDEP – Florida Department of Environmental Protection
- FDOT – Florida Department of Transportation

- FGDC - Federal Geographic Data Committee
- FHWA – Federal Highway Administration
- FKP - Flächen Korrektur Parameter
- FPRN – Florida Permanent Reference Network
- F.S. – Florida Statutes
- GALILEO – European Navigation Satellite System
- GDOP – Geometric Dilution of Precision
- GLONASS – Russian Navigation Satellite System
- GNSS – Global Navigation Satellite System
- GPS – Global Positioning System
- GSD – Ground Sample Distance
- GVX – GNSS Vector Exchange Format
- iMAC – Individualized Master Auxiliary Concept (iMAX)
- IMU – Inertial Measurement Unit
- INS – Inertial Navigation System
- ISO – International Standard Organization
- KML – Keyhole Markup Language
- KMZ - Keyhole Markup Language zipped
- LiDAR – Light Detection and Ranging
- MOT – Maintenance of Traffic
- MAC – Master Auxiliary Concept (MAX)
- MHWL – Mean High Water Line

- MSTTS – Mobile Survey Tracking System
- NAD – North American Datum
- NAP – North American Profile
- NAVD – North American Vertical Datum
- NCAT – Coordinate Conversion and Transformation Tool
- NDP – Network Design Plan
- NGS – National Geodetic Survey
- NGVD – National Geodetic Vertical Datum
- NSRS – National Spatial Reference System
- NSSDA – National Standard for Spatial Data Accuracy
- OHWL – Ordinary High-Water Line
- OPUS – Online Positioning User Service (NGS Web-based Software)
- OPUS-P – Online Positioning User Service Projects (NGS Web-based Software)
- OPUS-RS – Online Positioning User Service Rapid Static (NGS Web-based Software)
- PC – Point of Curvature
- PDF – Portable Document Format
- PDOP – Positional Dilution of Precision
- PI – Point of Intersection
- POC – Point on Curve
- POT – Point on Tangent
- PPC – Project Primary Control

- PT – Point of Tangency
- PSC – Project Secondary Control
- PSM – Professional Surveyor and Mapper
- PVC – Project Vertical Control
- QA/QC – Quality Assurance/Quality Control
- RF – Radio Frequency
- RINEX – Receiver Independent Exchange Format
- RMS – Root Mean Square
- RMSE – Root Mean Square Error
- RS – Rapid Static GNSS
- RT – Real-Time Kinematic Positioning
- RTN – Real-Time Network Positioning
- R/W – Right of Way
- Scope – Project Scope of Services
- SGSS – State Geodetic Services Supervisor
- SRD – State Road Department
- SUEL – Safe Upland Elevation Line
- TBM – Temporary Benchmark
- TIITF – Trustees of the Internal Improvement Trust Fund
- TRB – Transportation Research Board
- USGS – United States Geological Survey
- VRS – Virtual Reference System

- X,Y,Z – Cartesian Coordinates

## DEFINITIONS

- **Accuracy** – Degree of conformity with a standard or accepted value. Accuracy relates to the quality of a result and is distinguished from precision which relates to the quality of the operation by which the result is obtained.
- **Artifacts** – Erroneous data points that do not correctly depict the scanned area. Objects moving through the scanner’s field of view, temporary obstructions, highly reflective surfaces, and erroneous measurements at edges of artifacts (also known as “edge effects”) can cause artifacts.
- **Axis Test** – Method of calibration in which multiple direct and reverse angular readings are used to correct systematic errors in a total station.
- **Baseline** – Coordinate vector resulting from any station pair.
- **Baseline solution** – Solution from processing a single baseline.
- **Bathymetry** – The art or science of determining ocean depths.
- **Horizontal Geometry** – A 2D featurized CADD object with no inherent elevation (zero elevation in a 3D environment).
- **Image** - A pattern formed by electromagnetic radiation that approximately duplicates the pattern formed by a real object or a physical field detectable by the radiation. This definition is more general than the usual definition because many instruments used for detection operate at other than light frequencies but in ways similar or analogous to those used for forming optical images. The kind of radiation forming an image is usually specified by adding a word that identifies the part of the spectrum involved, e.g., radio image, infrared image, optical image, and X-ray image. However, the terms "radar image" and "X-ray image" are used to refer to optical images of the images formed by radar or X-ray. *Source: National Geodetic Survey: Geodetic Glossary. Library of Congress Catalogue Card Number 86-61105. 1986.*  
  
[http://www.ngs.noaa.gov/CORS-Proxy/Glossary/xml/NGS\\_Glossary.xml](http://www.ngs.noaa.gov/CORS-Proxy/Glossary/xml/NGS_Glossary.xml)
- **Independent baselines** – a baseline that cannot be derived from other baselines in the network and provides unique positioning data; essentially, an independent vector is a non-trivial vector that contributes new information to the solution.
- **LAS** – A binary file standard supported by the American Society of Photogrammetry and Remote Sensing (ASPRS) for storing point location and attribute information primarily used for LiDAR data.

- **LiDAR** – An active optical remote sensing technology which measures the return properties of scattered light to determine range, direction, and other information of a distant line-of-sight object.
- **Linearly dependent (trivial) baselines** – a baseline (the vector between two GNSS receivers) that can be calculated from other existing baselines, meaning it provides no additional independent information and is considered redundant.
- **Localization** – A coordinate transformation from the GNSS reference system to the project specified system as defined by Department approved control.
- **Master Auxiliary Concept (MAC or MAX)** - Transmits all relevant correction data from a CORS network to the rover in a highly compact form by representing ambiguity-levelled observation data as correction differences of dispersive and non-dispersive data for each satellite-receiver pair.
- **Mean High Water (MHW)** – The average height of the high waters over a 19-year period.
- **Mean High Water Line (MHWL)** – The intersection of the tidal plane of mean high water with the shore.
- **Multipath** - A phenomenon in the physics of waves whereby a wave from a source travels to a detector via two or more paths and the two (or more) components of the wave interfere constructively or destructively.
- **Ordinary High Water (OHW)** – The highest reach of a navigable, nontidal waterbody as it usually exists when in its ordinary condition.
- **Ordinary High-Water Line (OHWL)** – The intersection of the plane of ordinary high water with the shore in areas without tidal influence.
- **Orthoimage** - A georeferenced image prepared from a perspective photograph or other remotely-sensed data in which displacement of objects due to sensor orientation and terrain relief have been removed. It has the geometric characteristics of a map and the image qualities of a photograph. (*Source: Federal Enterprise Architecture Geospatial Profile, ver. 2, appendix B (Glossary of terms)(2008).*)
- **Point Cloud** - A relatively precise group of three-dimensional point data collected by a laser scanner from a single observation session. A point cloud may be merged with other point clouds to form a larger composite point cloud.
- **Point Density** - The number of points per unit area; can also be expressed as the average distance between points in a point cloud. National Cooperative Highway Research Program (NCHRP) : Report 748. (2013). *Guidelines for the Use of*

*Mobile LIDAR in Transportation Applications.* Washington D.C.: Transportation Research Board of the National Academy of Sciences.

- **Portable Document Format (PDF)** - a file format that allows users to share and present documents across multiple platforms and software programs.
- **Positional Accuracy** – A statistical estimate of how close the measured position of a point or object is to its true location in a defined spatial system or datum.
- **Precision** – A measure of the uniformity or reproducibility of the result. Precision relates to the quality of the operation by which the result is obtained and is distinguished from accuracy which relates to the quality of the result.
- **Project Specific Datum** – Datum/Realization used for project monumentation (date specific) or specified by the Scope of Services.
- **Session** – An observing period of multiple GNSS receivers.
- **Session adjustment or baseline processing** – 3D least squares adjustment of all possible baseline solutions.
- **Session solution or session processing** – Solution from simultaneous processing of all independent baselines with mathematical correlations between baselines.
- **Space Weather** - the effects of the solar wind, especially on the Earth's magnetosphere, ionosphere, thermosphere, and exosphere. Though physically distinct, space weather is analogous to the terrestrial weather of Earth's atmosphere.
- **Static Survey** - involves the collection of precise code and carrier phase measurements recorded simultaneously at two or more survey control marks and/or CORS using stand-alone GNSS equipment (comprised of a geodetic grade antenna and receiver). Classic Static also typically involves post-processing by the surveyor.
- **Virtual Reference Station (VRS)** - A Global Navigation Satellite System (GNSS) data processing technique that enhances the accuracy of position calculations by using data from multiple reference stations to create a synthetic reference point.
- **Weather** - The state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness.
- **Zippered** - a compressed file that contains one or more files that have been combined and compressed into a single file.

## APPENDIX B – GNSS GUIDELINES

### 1. TYPES OF GNSS SURVEYS

- **Static GNSS (SGNSS)** - Carrier phase differencing technique where the integer ambiguities are resolved from an extended observation period through a change in satellite geometry. (Ionospheric model applied for baselines longer than 15 km)
- **Real-Time GNSS (RT)** – Uses measurements of the phase of the signal's carrier wave, rather than the information content of the signal, and relies on a single reference station to provide real-time corrections.
- **Real-Time Network GNSS (RTN)** – A variation of RT GNSS surveying. Rather than setting up a base station on the project, several permanent and continuously operating base stations are set up providing the augmentation to the basic position as determined at the rover.

### 2. NETWORK DESIGN PLAN (NDP)

Every project that uses GNSS technology will have a NDP submitted, **in open-source format**, and **be** approved by the Department **before** the commencement of work.

#### 2.1. REQUIREMENTS

Every NDP will include:

- Project Description
  - Horizontal Datum to be used
  - Vertical Datum to be used
  - Projection to be applied
  - Geoid Model to be applied
  - Ephemeris to be used
- Types of GNSS survey proposed
  - Sketch showing limits of each type of GNSS survey
- Identification, by make, model, and serial number of equipment to be used
- PPC:
  - Sketch showing project limits with PPC
- PSC:
  - Sketch showing project limits with PSC
- Network Design:
  - Sketch showing overall network design
  - Sketch showing each session design
  - Static session schedule
- Obstruction diagram for each PPC
- Datasheets for control to be used

## 2.2. DELIVERABLES

- Network Design Plan will be submitted in an open-source format, preferably PDF, and delivered electronically.
- A KML or KMZ file, preferably KML, can be delivered electronically to substitute for the required sketches.

## 3. GNSS EQUIPMENT

- Equipment for all GNSS survey activities will be multi-frequency, survey grade, carrier phase, geodetic receivers, and antennas unless prior written approval is obtained from the Department.
- A minimum of 3 GNSS receivers will be used for each session.

## 4. GNSS POINT TYPES

### 4.1. ACCURACY REQUIREMENTS

Accuracy requirements are point-type specific.

GNSS accuracy can be impacted by various error sources including obstructions, multipath, RF interference, and weather conditions, including ionospheric disturbances, tropospheric delays, heavy rain, and snow. GNSS observation times may need to be adjusted depending on error sources.

Manufacturer specific geospatial software can be used for GNSS processing and the final least squares network adjustment. All vectors used in the adjustment will be independent vectors.

See [Appendix C](#) for accuracy requirements for GNSS derived data.

### 4.2. STATEWIDE NETWORK CONTROL (FPRN)

The FPRN will serve as the Statewide Network Control for all Department projects. All newly established control will be constrained to the FPRN.

### 4.3. PROJECT PRIMARY CONTROL (PPC)

Local geodetic control supporting all project geospatial activities. All PPC shall have both Horizontal and Vertical components.

#### 4.3.1. STATIC (SGNSS)

At least 2 Static GNSS observations of 1-hour, minimum, with at least a 2-hour differential is required for all Project Primary Control. Independent vectors shall be observed between newly established Project Primary Control during each session. All

independent vectors shall be occupied at least twice during the totality of sessions. Precise ephemeris shall be used for all processing. Vectors shorter than 800 M may require additional observations to achieve accuracy thresholds.

<b>Observation Method</b>	<b>Constellations</b>	<b>Minimum Occupation Time</b>	<b>Time differential</b>	<b>Minimum Observations</b>
Static GNSS Observations	G	4 hours	4-hours	2
	G/R	2 hours	3-hours	2
	G/E	2 hours	3-hours	2
	G/C	2 hours	3-hours	2
	G/R/E	1.5 hours	2-hours	2
	G/R/C	1.5 hours	2-hours	2
	G/E/C	1.5 hours	2-hours	2
	G/R/E/C	1 hour	2-hours	2

#### **4.3.2. VERTICAL COMPONENT**

- Prior to performing leveling operations, a collimation shall be performed on the digital level and the results saved.
- The vertical component of Project Primary Control must be established using digital differential leveling equipment collecting redundant measurements and observations.

#### **4.3.3. DELIVERABLES**

- Raw data file, for newly established control, converted to RINEX format, open-source, and delivered electronically for each session.
- Raw data file, for FPRN station, converted to RINEX format, open-source, and delivered electronically for each session.
- A Vertical collimation report shall be submitted in an open-source format and delivered electronically for each leveling session.
- The Vertical component of Project Primary Control data sets will be submitted in XML format, open-source, and delivered electronically for each session.

See [Appendix C](#) for accuracy requirements for GNSS derived data.

#### **4.4. PROJECT SECONDARY CONTROL (PSC)**

Local geodetic control supporting all project geospatial activities. All PSC shall have both Horizontal and Vertical components.

##### **4.4.1. STATIC (SGNSS)**

A minimum of 2 Static GNSS observations of 30-minutes with a 2-hour differential is required for all Project Secondary Control. During each session, Independent vectors shall be observed between newly established Project Primary Control. All independent vectors shall be occupied at least twice during the totality of sessions. Precise ephemeris shall be used for all processing.

Table B2				
Observation Method	Constellations	Minimum Occupation Time	Time differential	Minimum Observations
Static GNSS Observations	G	4 hours	4-hours	2
	G/R	2 hours	3-hours	2
	G/E	2 hours	3-hours	2
	G/C	2 hours	3-hours	2
	G/R/E	1.5 hours	2-hours	2
	G/R/C	1.5 hours	2-hours	2
	G/E/C	1.5 hours	2-hours	2
	G/R/E/C	1 hour	2-hours	2

**4.4.2. REAL-TIME (RT)**

RT observations shall be used if the baseline distance (from FPRN Station) is less than 14 KM.

Table B3				
Observation Method	Constellations	Minimum Occupation Time	Time differential	Minimum Observations
Real-Time (RT) GNSS Observations	G	120-epoch (0 to 14 km)	2-hour	2
	G/R	90-epoch (0 to 14 km)	2-hour	2
	G/E	90-epoch (0 to 14 km)	2-hour	2
	G/C	90-epoch (0 to 14 km)	2-hour	2
	G/R/E	60-epoch (0 to 14 km)	2-hour	2
	G/R/C	60-epoch (0 to 14 km)	2-hour	2
	G/E/C	60-epoch (0 to 14 km)	2-hour	2
		G/R/E/C	30-epoch (0 to 14 km)	2-hour

**4.4.3. REAL-TIME NETWORK (RTN)**

- Real-Time Network observations must use the Master Auxiliary Concept (MAX) solution. The Virtual Reference Station (VRS) network solution is not allowed on FDOT Projects.
- RTN observations shall be used if the baseline distance (from FPRN Station) is greater than 14 KM.

<b>Observation Method</b>	<b>Constellations</b>	<b>Minimum Occupation Time</b>	<b>Time differential</b>	<b>Minimum Observations</b>
Real-Time Network (RTN) GNSS Observations	G	120-epoch ( > 14 km)	2-hour	2
	G/R	90-epoch ( > 14 km)	2-hour	2
	G/E	90-epoch ( > 14 km)	2-hour	2
	G/C	90-epoch ( > 14 km)	2-hour	2
	G/R/E	60-epoch ( > 14 km)	2-hour	2
	G/R/C	60-epoch ( > 14 km)	2-hour	2
	G/E/C	60-epoch ( > 14 km)	2-hour	2
	G/R/E/C	30-epoch ( > 14 km)	2-hour	2

#### 4.4.4. VERTICAL COMPONENT

- Prior to performing leveling operations, a collimation shall be performed on the digital level and the results saved.
- The vertical component of Project Secondary Control must be established using digital differential leveling equipment collecting redundant measurements and observations.

#### 4.4.5. DELIVERABLES

- Static raw data file, for newly established control, converted to RINEX format, open-source, and delivered electronically for each session.
- Static raw data file, for FPRN station, converted to RINEX format, open-source, and delivered electronically for each session.
- RT or RTN raw data file, for newly established control, converted to GVX format, open-source, and delivered electronically for each session.
- A Vertical collimation report shall be submitted in an open-source format and delivered electronically for each leveling session.
- The Vertical component of Project Secondary Control data sets will be submitted in XML format, open-source, and delivered electronically for each session.

See [Appendix C](#) for accuracy requirements for GNSS derived data.

### 4.5. PROJECT VERTICAL CONTROL (PVC)

#### 4.5.1. VERTICAL COMPONENT

- Prior to performing leveling operations, a collimation shall be performed on the digital level and the results saved.

- The vertical component of Project Vertical Control must be established using digital differential leveling equipment collecting redundant measurements and observations.

#### 4.5.2. HORIZONTAL COMPONENT

A minimum of 1 observation using RT or RTN, using MAX solution, methods is required for all Project Vertical Control. The Virtual Reference Station (VRS) network solution is not allowed on FDOT Projects.

#### 4.5.3. DELIVERABLES

- A Vertical collimation report shall be submitted in an open-source format and delivered electronically for each leveling session.
- Project Vertical Control data sets will be submitted in XML format, open-source, and delivered in electronic form for each session.
- RT or RTN raw data file, for horizontal portion, converted to GVX format, open-source, and delivered electronically for each session.
- Static raw data file, for FPRN station, converted to RINEX format, open-source, and delivered electronically for each session.

See [Appendix C](#) for accuracy requirements for GNSS derived data.

#### 4.6. LOCATION / TOPOGRAPHY

##### 4.6.1. POINT CHECK-IN

Location and topography data sets using RT or RTN, using the MAX solution, will check into Project Primary Control or Project Secondary Control before beginning each day's data collection, at a minimum of every 2 hours thereafter, and at the conclusion of the day's data collection. The Virtual Reference Station (VRS) network solution is not allowed on FDOT Projects.

##### 4.6.2. OBSERVATIONS

Typical observations are RT or RTN, using the MAX solution, single epoch. This will be the acceptable procedure for both data collection and validation point check-in.

##### 4.6.3. DELIVERABLES

- RT or RTN location and topography data sets shall not exceed 24 hours in length and shall be converted to GVX format, open-source, and delivered electronically for each session.
- Static raw data file, for FPRN station, converted to RINEX format, open-source, and delivered electronically for each session.

See [Appendix C](#) for accuracy requirements for GNSS derived data.

## 5. SGNSS PROCESSING

Session processing is the only acceptable method for PPC Static GNSS processing. Single Point Positioning is not allowed. Independent vectors between newly established PPC must be observed during each session. All independent vectors shall be occupied at least twice during the totality of sessions. Precise ephemeris shall be used for all baseline processing.

### 5.1. SETTINGS

Table B5	
Cut-Off Angle	10°
Sampling Rate	1 second or Use All
Used Satellites	Use All
Ephemeris	Precise
Antenna Calibration	NGS Absolute
Minimum Observations Used	> 80%
Minimum Fixed Ambiguities	> 80%
Solution Type	Phase Fixed
(Tropospheric) Solution Optimization	Automatic
Tropospheric Model	VMF with GPT2 model
Ionospheric Model	Automatic

#### 5.1.1. DELIVERABLES

- Session Processing Reports (1 for each Session)
- Baseline Report (1 for each Session)
- Point Quality Report (1 for each PPC)
- Point History Report (1 for each PPC)
- Network Adjustment Report
- Final Adjusted Coordinates Spreadsheet

## 6. LOCALIZATION / TRANSFORMATION

When using Static observations, after completion of the final least squares adjustment of the PPC a localization / transformation file and report shall be created. The raw GNSS data shall be transformed to the final adjusted coordinates of the PPC. The localization / transformation file shall be saved and applied to all GNSS measurements subsequent to the PPC adjustment. The localization / transformation file and/or the associated report shall be distributed and used by all entities involved with the project through completion.

## 6.1. DELIVERABLES

- The localization / transformation files will be provided in a XML file format and delivered electronically.
- The localization / transformation report will be provided in an open-source format, preferably PDF, and delivered electronically.

## 7. QA/QC

### 7.1. SGNSS

Submit to observation files to OPUS or FPRN Computation Service.

### 7.2. RT or RTN

Observe 20% (at least 3) stations with 30-epoch RT or RTN, using the MAX solution, observations. The Virtual Reference Station (VRS) network solution is not allowed on FDOT Projects.

### 7.3. DELIVERABLES

Comparison spreadsheet showing coordinate differences between final adjusted coordinates and QA/QC coordinates.

## 8. SURVEY REPORT

When GNSS is used on a project, the survey report should contain standard content:

- Manufacturer specific geospatial software programs are acceptable for GNSS processing. When these programs are used, a least squares network adjustment must be applied, and a statistical analysis included in the survey report. See [Section 9](#) and [Appendix E](#) for information on survey reports.