10. PHOTOGRAMMETRIC CONTROL SURVEYS

PHOTOGRAMMETRIC CONTROL

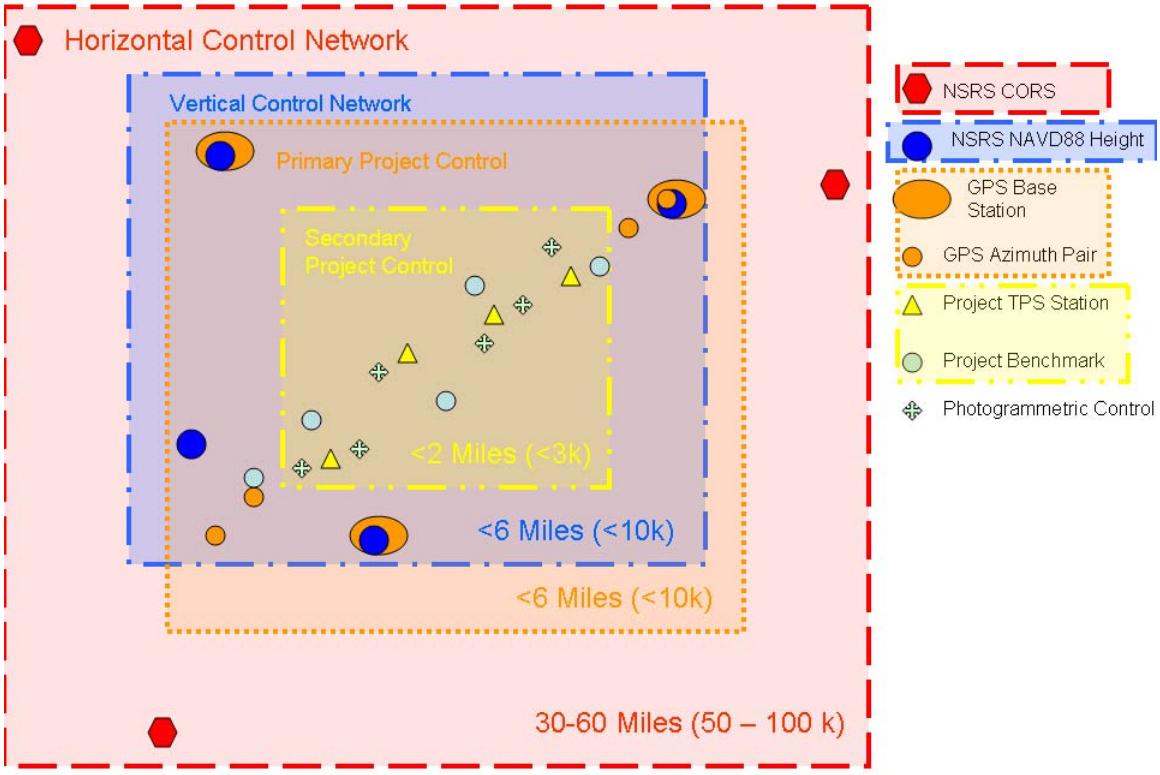
10.1 INTRODUCTION

The purpose of this chapter is to specify the minimum standards and describe procedures for establishing photogrammetric control on NYSDOT capital projects.

When the term *photogrammetric control* is used in this manual it refers to the ground control targets or photo identifiable points occurring within the area of a project. The photo control can be selected before (pre-marking, e.g. targets), or after (post-marking, e.g. photo-identifiable points) the aerial photography flight. Whenever possible, targets should be used. Photo control is used to control the photogrammetric mapping and DTMs required for a project. Points established under these standards and procedures are generally within the work limits of the project and are assumed to be expendable.

Photogrammetric control traverses, level runs, and GPS networks should begin and end on at least secondary project control stations.

FIGURE X. Photogrammetric Control



Not to Scale

10.2 MONUMENTATION

Aerial photo targets shall be placed in the field, to be used as photogrammetric control points. The targets shall be placed in accordance with the NYSDOT targeting diagram and "Targeting Guidelines". Refer to the Photogrammetry Section's targeting guidelines for proper placement of targets and other information.

Targets are considered to be expendable. Some temporary method of monumentation such as PK Nails or Spikes should be used in case there is a lapse in time between the photogrammetric flight and the control survey. Effort should be made to perform the survey as close to the aerial flight as possible, in order to minimize the loss of targets. Target placement shall consider survey method. If GPS method is going to be used, target obstructions shall be considered in order to be able to achieve a position using GPS techniques.

10.3 MINIMUM STANDARDS

Photogrammetric Horizontal Control shall be established using GPS or TPS techniques, to establish horizontal photo control in support of surveying and mapping operations at the project site.

10.3.1 Photogrammetric Horizontal Control Standards

10.3.1.1 GPS Techniques

All GPS surveys for photogrammetric control shall meet the standards of at least order C2-II as defined in *GEOMETRIC GEODETIC ACCURACY STANDARDS AND SPECIFICATIONS FOR USING GPS RELATIVE POSITIONING TECHNIQUES*, Federal Geodetic Control committee (FGCC), August, 1989. http://www.ngs.noaa.gov/FGCS/tech_pub/GeomGeod.pdf

10.3.1.2 TPS Techniques

Photogrammetric Horizontal Control Points can be located from a secondary control traverse or sub traverses, using a total station. Traverses shall meet the standards of at least 2nd Order Class II as defined in *Standards and Specifications for Geodetic Control Networks*, Federal Geodetic Control Committee (FGCC), September, 1984

10.3.2 Photogrammetric Vertical Control Standards

10.3.2.1 Differential Levelling Techniques

Photogrammetric Vertical Control Points can be located from a secondary control level run using a level. Vertical Control Points shall be incorporated as turning points, in a level loop.

Level line errors, expressed in **feet**, for level runs which include V.P.'s as turning points shall not exceed .03 ft$\sqrt{D}$ where D is the length of the level line in miles (shall not exceed 8mm$\sqrt{D}$ where D is equal to the length of the level line in kilometers).

10.3.2.2 TPS Techniques

Photogrammetric Vertical Control Points can be located from secondary vertical control, by trigonometric leveling, using a total station. Sub traverses which incorporate Vertical Control Points shall meet the standards of at least 2nd Order Class II as defined in

Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee (FGCC), September, 1984 and reflect a precision of at least 1:20,000.

Level line errors, expressed in feet, for traverses which include V.P.'s as turning points, shall not exceed .03 ft $\sqrt{D}$ where D is the length of the level line in miles (shall not exceed 8mm $\sqrt{D}$ where D is equal to the length of the level line in kilometers).

10.3.2.3 GPS Techniques

GPS surveys for photogrammetric control shall meet the standards of at least order C2-II as defined in *GEOMETRIC GEODETIC ACCURACY STANDARDS AND SPECIFICATIONS FOR USING GPS RELATIVE POSITIONING TECHNIQUES*, Federal Geodetic Control Committee (FGCC), August, 1989. http://www.ngs.noaa.gov/FGCS/tech_pub/GeomGeod.pdf

10.4 PROCEDURES

Photogrammetric control surveys can be conducted before or after aerial photography flights.

Photo control surveys conducted before flying should include the horizontal and/or vertical coordinates of *targeted points* (HPs & VPs). Aerial photo targets shall be placed in the field, to be used as photogrammetric control points. The targets shall be placed in accordance with the NYSDOT targeting diagram and "Targeting Guidelines". A hand-held GPS receiver shall be used to determine the approximate coordinates of the actual target locations, and a text file with the approximate coordinates shall be submitted. Refer to the Photogrammetry Section's targeting guidelines for proper placement of targets and other information.
http://intradot/design/dsb/photo/at/guideline2000.pdf

Target placement should also take in to consideration the survey method to be used for locating the target.

Photo control surveys conducted after flying should include the horizontal and/or vertical coordinates of HPs and VPs (photo identifiable points), which were found by the photogrammetrist to be readily and discretely identifiable on aerial photos. Photo control points that are relocated in the field need to be communicated to the photogrammetrist.

The coordinates of H.P.'s and V.P.'s should be determined by inclusion in a GPS Network, a closed subtraverse or run of levels respectively. When located as sideshots from a traverse or as RTK GPS observations, an appropriate method of redundant observations should be employed.

RTK GPS has become the preferred method of surveying photogrammetric control, based on accuracy and efficiency. In particular the use of RTK GPS and the NYSNet CORS RTN is being used successfully to survey photogrammetric control. Other survey methods may still be acceptable, but RTK has been found to be the most efficient method. Consult with the Regional Land Surveyor for approval to use other survey methods.

10.4.1 Horizontal

10.4.1.1 GPS Techniques

Equipment

PHOTOGRAMMETRIC CONTROL

Surveyors shall employ dual frequency GPS receivers. Not less than two GPS receivers shall be employed during an observation session, at least one reference base station receiver and one rover receiver. When using the NYSNet RTN, using just one rover receiver meets this requirement. Fixed height tripods should be used at GPS base stations. Fixed height tripods or a bipod/GPS pole should be used at target locations.

Techniques

Static or Dynamic (Fast Static, Kinematic) techniques may be employed. Real Time Kinematic (RTK) using primary project control base stations (Local RTK) or Network RTK (NRTK) using the NYSNet RTN (Real Time Network) can be used.

Minimum of 15 second epochs will be collected for static techniques.
Minimum of 5 second epochs will be collected for fast static or kinematic techniques.
1 second epochs should be used for RTK techniques.
Tracking elevation mask angle should be 10 deg.
Post-processing of simultaneous static field observations or RTK shall be used.

Network Design

GPS surveys for Photogrammetric Control should be configured as networks of redundant vectors. Photogrammetric control, including targets and photo identifiable points, shall have two independent observations. Redundant vectors are accomplished only by completely independent occupations of stations. Independent occupations require that the tripod or stand be reset and replumbed between sessions. So-called spaghetti, radial, or traverse survey schemes shall not be used on NYSDOT capital projects.

At least three horizontal control stations, being in different quadrants shall be incorporated into the network design (i.e. azimuth pair stations/base stations that meet the required standards for C1 order, or NRTK using the NYSNet RTN).

All photo control points observed shall have two independent occupations. Each of these two occupations will be made at a time of day separated by a minimum of 20 minutes sidereal time displacement (start time to next start time). ~~Each of these two occupations will be tied to two different base stations.~~ The baselines that were used to establish the Primary Control Base Stations should be enabled for the photo control network processing so that only independent baselines are used for loop closures and adjustment.

Network statistics shall meet the requirements for order C2-II as defined in *GEOMETRIC GEODETIC ACCURACY STANDARDS AND SPECIFICATIONS FOR USING GPS RELATIVE POSITIONING TECHNIQUES*, Federal Geodetic Control Committee, August, 1989. http://www.ngs.noaa.gov/FGCS/tech_pub/GeomGeod.pdf

100% of new stations shall be included in a loop. Loops shall include baselines from at least two different sessions. Loops may contain up to a maximum of 10 legs.

Planning

Proper planning and network design shall be used in GPS surveys for photogrammetric control.

PHOTOGRAMMETRIC CONTROL

Base stations used should be as unobstructed as possible. Target locations should be placed in consideration of sky visibility and obstructions. Refer to the Photogrammetry Section's targeting guidelines for proper placement of targets and other information.
http://intradot/design/dsb/photo/at/guideline2000.pdf

Field reconnaissance and pre-mission observation planning will be accomplished for all surveys. Analysis should consider the number of available satellites and PDOP.
At least four healthy satellites shall be observed in common at all simultaneously occupied stations.

The PDOP should not exceed 7 during any GPS survey observations.

Final choice of observation session lengths shall also consider site obstructions, predicted PDOP, number of satellites available, network configuration, and manufacturer guidelines.

Field Observations

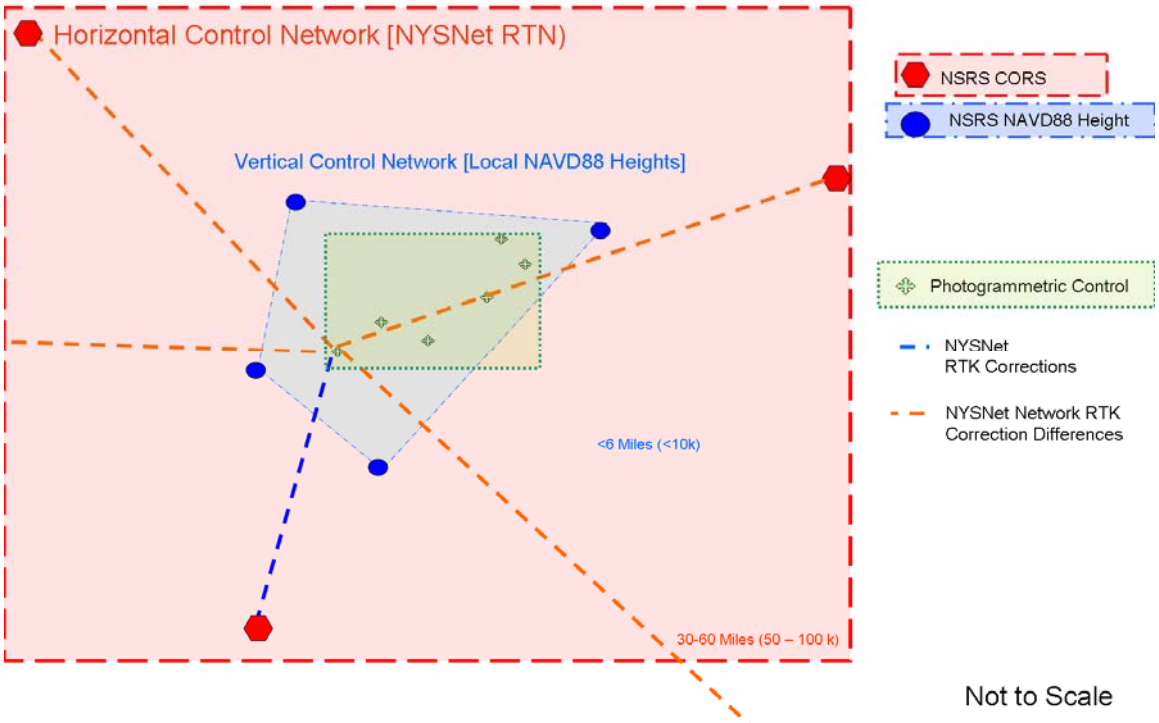
GPS antennas should be set up over the base stations and photo control points using fixed-height antenna tripods or a pole with bipod.

Vehicles should be parked away from or below the GPS antenna to minimize the chances of causing multipath signals.

Great care shall be taken in measuring and recording antenna heights. When using standard tripods, the antenna slope-height will be measured multiple times (per manufacturer's directions) and the average recorded.

NYSDOT experience has found the following RTK or Fast Static procedures will provide assurance that a photogrammetric control survey will be completed successfully without the need for return trips to the field:

FIGURE XI. NRTK Photogrammetric Control Survey



Network RTK (NRTK)

Network RTK corrections, from the NYSNet Real Time Network (RTN), shall be used.
NAVD88 heights should be localized by either:

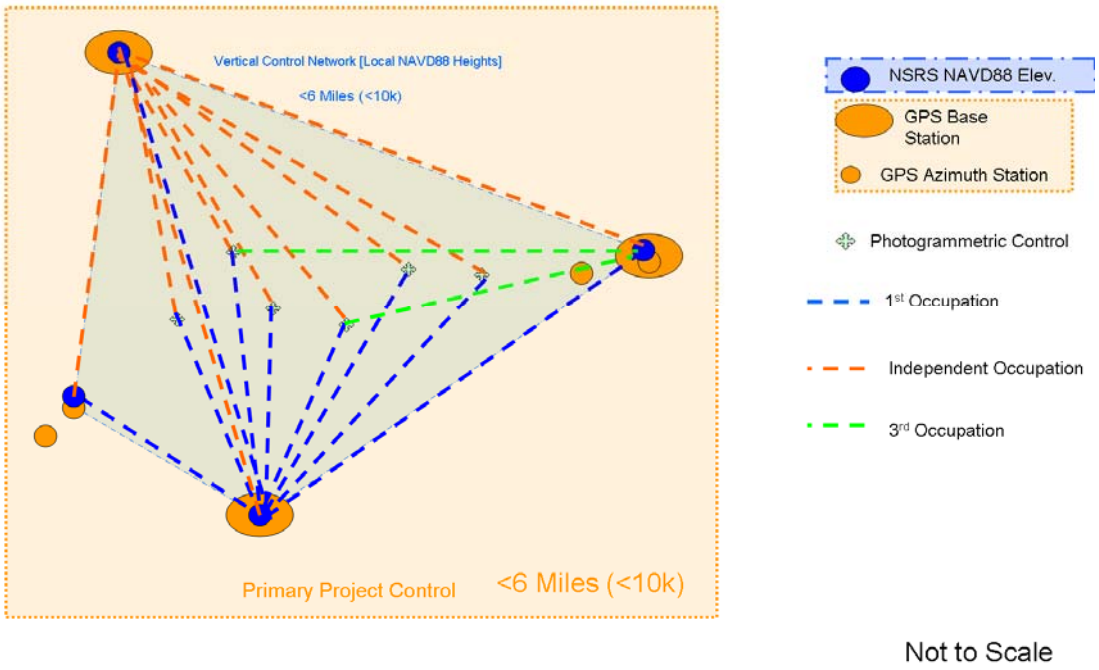
- Confirming heights produced from a GEOID model are consistent with NAVD88 Heights at the project.
- Computing local transformation parameters to 4 valid NAVD88 Heights surrounding the project. The maximum residual for control stations used to determine these transformation parameters shall be 0.1 feet (3 cm).
- Computing a 1 point mean shift transformation to an NAVD88 height, and leveling through project to confirm GPS derived heights.
- Computing a 2 point mean shift transformation to 2 valid NAVD88 heights on the project.

Use of a 3 point transformation to local NAVD88 heights may introduce a tilt to the transformation parameters and shall not be used.

Transformation parameters, for a local coordinate system may have to determined if the project coordinate system datum is different from the NYSNet RTN coordinate system datum. If this is required, the maximum residual for control stations used to determine these transformation parameters shall be 0.06 feet (2 cm).
After determining local height transformation parameters, and applying them at the rover, check shots on other project control stations, should be observed to assure transformation parameters are correct.
Observations should only be started once ambiguities have been fixed. Some method of checking the integrity of the ambiguity resolution shall be used.
1 Second Observation Epochs or less shall be used for RTK.
At least 6 one second epochs shall be collected per occupation.

A position quality of 0.03 feet (1cm) and height quality of 0.06 feet (2cm) shall be achieved; otherwise, additional epochs shall be collected until these are achieved. If this cannot be achieved, other survey methods should be used.
Targets shall have 2 independent occupations at a time of day separated by a minimum of 20 minutes sidereal time displacement (start time to next start time).
Independent occupations shall agree within 0.07 feet (2 cm) horizontal, and .10 feet (3cm) vertical. Occupations that do not meet this criterion shall be reobserved. The averaged position, using these independent occupations, meeting these criteria, shall be reported as the surveyed target position.

FIGURE XII. Local RTK Photogrammetric Control Survey

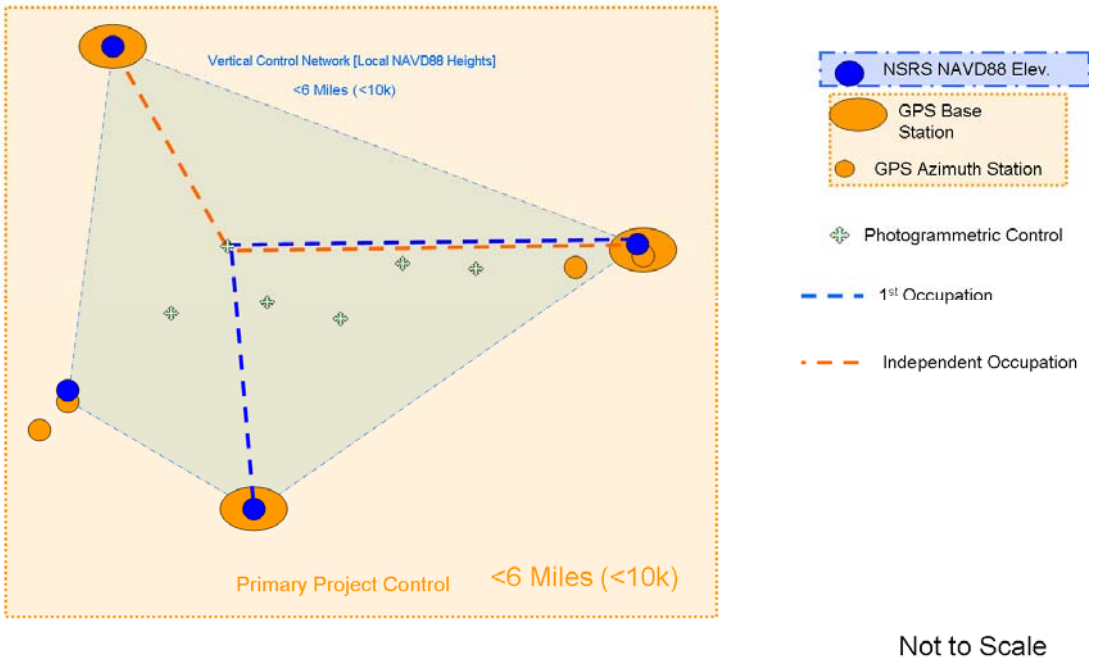


Local RTK (LRTK)

Observations should only be started once ambiguities have been fixed. Some method of checking the integrity of the ambiguity resolution shall be used.
1 Second Observation Epochs or less shall be used for RTK.
At least 6 one second epochs shall be collected per occupation.
A position quality of .03 feet (1cm) and height quality of .06 feet (2cm) shall be achieved; otherwise, additional epochs shall be collected until these are achieved. If this cannot be achieved, other survey methods should be used.
At least four local control stations, with valid NAVD88 heights should be incorporated into the real time network. Targets shall have 2 independent occupations at a time of day separated by a minimum of 20 minutes sidereal time displacement (start time to next start time).The second observation must be from a second base station. 20 percent of the targets should be occupied a third time, using a third base station. During each session, observations should be made from the session base station, to the other base stations in the real time network.
Independent occupations shall agree within .07 feet (2 cm) horizontal, and .10 feet (3cm) vertical. Occupations that do not meet this criterion shall be reobserved. The averaged

position, using these independent occupations, meeting this criteria, shall be reported as the surveyed target position.

FIGURE XIII. Fast Static Photogrammetric Control Survey



Not to Scale

Fast Static

At least three primary horizontal project control stations, being in different quadrants shall be incorporated into the network design (i.e. azimuth pair stations or base stations surveyed to primary project control GPS Base Station Standards). NYSDOT experience has found the following procedure will provide assurance that a photogrammetric control survey will be completed successfully without the need for return trips to the field: Occupy two primary project control stations as base stations, rove through the targets, move one base station to a third primary project control station, in a different quadrant, rove to the targets again with two base stations running.

10.4.1.2 TPS Technique

Network Geometry

Photogrammetric HP's can be located directly from a secondary project control baseline station or can be incorporated in a sub-traverse. When locating from a secondary project control survey baseline station as a sideshot, some method of redundant observations shall be employed. The HP shall be located from another secondary project control baseline station, or multiple observations shall be recorded to the target. When incorporating an HP in a sub-traverse the traverse shall begin and end on a secondary project control baseline station, with the required azimuth and position closures.

PHOTOGRAMMETRIC CONTROL

Equipment

The total station used for photogrammetric project control shall be at least a one-second (angle) and **0.003 ft. (1 mm)** (distance) least-count instrument with Dual-Axis Compensation. The total station used should have a minimum DIN accuracy of two seconds (angle) and **0.006 f**t. (2 mm) +2ppm (distance). The total station, tribrachs, prism targets, prism poles, tripods, etc. used for control surveys shall be adjusted properly and maintained in good condition

Techniques

When traversing for photogrammetric control the standards and procedures for secondary project control shall be followed.

When locating a target from a secondary project control traverse, the following procedures shall be followed:

Observe temperature and atmospheric pressure and enter this data into the total station to correct the slope distance for atmospheric affects.

Account for prism offset in all distance measurements in the instrument settings.

A backsight of known azimuth shall be used. Backsight targets should be tripod mounted.

The foresight target should be tripod mounted or mounted on a prism pole with bipod.

Measure horizontal angles one time in a set of direct and reverse attitudes (1 D&R). The suggested procedure is to:

1. sight the backsight with telescope direct
2. turn the angle right to the foresight
3. plunge the telescope and re-sight the foresight with the scope reversed
4. turn the angle right to the backsight

This is one D&R.

The sum of the direct and reversed horizontal angles of a single set of angles should not deviate from 360° by more than 5.0 seconds. Re-observe, rejecting sets until the two sets agree within this tolerance.

For total station instruments that include the capability, the vertical indexing initialization procedure should be checked at the beginning of each day.

Measure zenith angles used to reduce slope distance to its horizontal component in both the direct and reversed attitudes.

The sum of the direct and reversed vertical angles of a single set of angles should not deviate from 360° by more than 10.0 seconds. Observe, once again, the rejected sets until the set agrees within this tolerance. Measure all distances electronically in both direct and reverse attitudes.

10.4.2 Vertical

10.4.2.1 Differential Leveling Technique

Network Geometry

Level runs shall begin and end on primary or secondary project control stations.

Equipment

Use only automatic levels or digital levels. With digital levels a sectional composite or invar bar-code staff should be used

Field Procedures

Expend reasonable effort when balancing backsights and foresights. Use subsequent set-ups to make up for deficiencies in balancing. Difference in forward and backward sight lengths should never exceed **30 ft**. (10 meters) per setup or **30 ft. (10 meters)** per section. Maximum sight length should not exceed **230 ft. (70 meters)** Minimum ground clearance of line of sight should be **2 ft. (0.5 meters)**

Photogrammetry Targets or photo identifiable points shall be incorporated as turning points in a sub loop.

10.4.2.2 TPS Technique

Photogrammetric Vertical Control Points can be located from a secondary project control baseline, using secondary project control TPS trigonometric leveling techniques.

Trigonometric Level line errors, expressed in **feet**, for level runs which include V.P.'s as turning points, shall not exceed .03 ft $\sqrt{D}$ where D is the length of the level line in miles (shall not exceed 8mm $\sqrt{D}$ where D is equal to the length of the level line in kilometers).

10.4.2.3 GPS Technique

Techniques in Section 10.4.1.1 Horizontal Photogrammetric Control GPS Techniques can be followed to establish elevations on vertical photogrammetric control targets or PIPs. The primary project control stations incorporated in the vertical GPS Network, as base stations, shall be Primary Vertical Control Stations established in accordance with Section 8.4.2 Primary Vertical Project Control.

10.5 DATA PROCESSING

10.5.1 Horizontal

10.5.1.1 GPS

GPS survey observations for capital projects may be post processed with the broadcast ephemeris.

Process baselines using a default elevation mask of 15 degrees. Alter elevation mask when necessary.

The quality of baselines shall be checked according to the software manufacturer's guidelines.

Loop closures should be analyzed. In any component (X,Y,Z), "maximum" misclosure, not to exceed **2 ft**. **(50 cm)** In any component (X,Y,Z), "maximum" misclosure, in terms of loop length, not to exceed 60 ppm. In any component (X,Y,Z), "average" misclosure, in terms of loop length, not to exceed 40 ppm.

Repeat Baselines should be analyzed. In any component (X,Y,Z), "maximum" not to exceed 50 ppm.

A minimal constrained adjustment should be performed holding one primary project control base station fixed in X, Y, and Ellipsoid Height. Adjustment residuals shall be analyzed for outliers. Once internal network accuracy is proven a fully constrained adjustment shall be performed. Adjustment residuals shall be analyzed. Outliers, if any, shall be identified, and coordinate differences shall be reported to the Regional Land Surveyor.

Expected setup errors shall be accounted for in the least squares adjustment program. For photogrammetric control, using a bipod to locate targets, an expected setup error of **0.02 ft (0.5 cm)** should be used.

See Section 8.5.1 Primary Horizontal Project Control Data Processing for least squares adjustment guidelines.

10.5.1.2 TPS

Follow Section 9.5.1.2 Secondary Project Control Data Processing procedures when incorporating traversing into photogrammetric control

When observing targets or photo identifiable points with a total station, the combined factor shall be applied to slope distances.

10.5.2 Vertical

10.5.2.1 Differential Leveling

To qualify for adjustment, level line error shall not exceed .03 ft $\sqrt{D}$ where D is the length of the level line in miles (shall not exceed 8mm $\sqrt{D}$ where D is equal to the length of the level line in kilometers).

Differential level lines should be adjusted according to the number of turns between bench marks.

10.5.2.2 TPS

When incorporating targets in a traverse, follow 9.5.1.2 Secondary Project Control Data Processing guidelines.

When locating targets as sideshots from a secondary project control traverse, observation sets shall be meaned.

10.5.2.3 GPS

Processing guidelines for establishing secondary project control with GPS in section 9.5.1.1 should be followed.

10.6 QUALITY CONTROL

The land surveyor in charge of the survey shall be responsible for the integrity and quality control of all survey data produced.

10.7 REPORTING

10.7.1 Field Notes

10.7.1.1 Horizontal

GPS

Raw data files along with RINEX files shall be submitted for secondary horizontal control surveys.

TPS

Raw data files shall be submitted which indicate the setup information, traverse observations, sideshot observations, closure error between observation sets, and meaned observations.

10.7.1.2 Vertical

Raw Data and processed files shall be submitted for secondary vertical project control surveys.

10.7.2 Survey Reports

The Survey Report for Photogrammetric Control, in addition to the information required below, requires a Survey Submission Memo as specified by the Photogrammetry Section.
http://axim22.nysdot.private:7779/pls/portal/docs/PAGE/WCC_PG/DESIGN_DIVISION/PHOTOGRAMMETRY_SECTION/AEROTRIANGULATION_UNIT/RF99.PDF
The survey submission memo requires target locations be submitted in digital form.
A comma delimited ascii text file of target coordinates shall include
A header listing:
Coordinate System, Datums, Units, GEOID Model and Combined project scale factor
The body of the report shall include:
Point ID, Northing, Easting, Orthometric Height, Standard Deviation in N, E, Height.

10.7.2.1 Horizontal

GPS

See section 8.7.2.1 for primary project control reporting requirements.

TPS

See section 9.7.2.1 TPS section for secondary project control reporting requirements.

10.7.2.2 Vertical

Differential Leveling

See section 9.7.2.2 for secondary project control.

TPS

See section 9.7.2.2 for secondary project control.

GPS

See section 8.7.2.1 for primary project control.

10.8 REFERENCES

1Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, FGCC, 1989
http://www.ngs.noaa.gov/FGCS/tech_pub/GeomGeod.pdf
2. Survey Submission Memo" as specified by the Photogrammetry Section.
http://intradot/design/dsb/photo/at/rf99.pdf
3. Targeting guidelines for proper placement of targets.
http://axim22.nysdot.private:7779/pls/portal/docs/PAGE/WCC_PG/DESIGN_DIVISION/PHOTOGRAMMETRY_SECTION/AEROTRIANGULATION_UNIT/TARGET2005.PDF