Chapter 9 Total Station System (TSS) Survey Specification

9-01 General

Survey specifications describe the methods and procedures needed to attain the desired survey standard. Specifications in the section are based on Federal Geodetic Control Subcommittee (FGCS) standards and specifications. Except where noted, they have been modified to give results that will meet the standards for various TSS surveys typically performed by WSDOT. For complete standards, refer to Chapter 7, "Accuracy Classifications and Standards".

WSDOT TSS survey specifications are to be used for all WSDOT involved transportation improvement projects, including special-funded projects.

9-02 The TSS Method

The TSS is a system that includes an electronic total station and electronic data collecting system. Conventional survey methods of traverse, network, resection, multiple ties and trigonometric leveling are used with the TSS method. Each WSDOT field survey crew is equipped with a TSS. The basic specifications for the WSDOT TSS are:

- Angle measurement: 6" accuracy, (Standard deviation = 1")

  Distance measurement: +/- (0.01 ft (3 mm) + 3 ppm) in standard mode
- Data Controller: WSDOT standard data controller and with software compatible with WSDOT's design and survey software.
- PC Software: WSDOT's current supported software

The system also includes tripods, tribrachs, prisms, targets and prism poles.

For specific questions about the use of the software, see the programs Manual available on-line or the WSDOT software training manuals.

The specifications included in this Section are based on the basic WSDOT TSS. If other TSS are used, those specifications might not be applicable.

All TSS equipment must be properly maintained and regularly checked for accuracy. Equipment repair, adjustment, and maintenance are covered in Chapter 3, "Equipment."

9-03 General TSS Survey Specifications

9-03.1 Redundancy

When proper procedures are followed, the WSDOT TSS generally can easily meet the accuracy standards for WSDOT second order, third order and general order surveys. For example, the WSDOT TSS instrument specifications indicate that angles observed one time will meet the required accuracy standards, but without redundancy of observations, the possibility of blunders exist. For this reason, a complete set of angles is observed (two pointings to the backsight and two pointings to the foresight, minimum) whenever establishing or tying existing critical points such as control points and cadastral points. Redundant observations such as multiple ties are observed, whenever feasible, to improve the information available from least squares adjustments to strengthen survey networks.

9-03.2 Equipment Checks

Check total station vertical index and horizontal collimation each day.

Systematic errors due to poorly maintained equipment must be eliminated to ensure valid survey adjustments. Regularly check and adjust optical plummets, tribrachs, tripods, and leveling bubbles. For barometers and thermometers, check regularly for accuracy.

9-03.3 Set Up

Height of instrument and target: Measure and enter the H.I. and H.T. into the data controller at the beginning of each set up. It is advisable to check the target and instrument heights at the completion of each set up along with the optical plummet's position over the point.

Temperature and barometric pressure: Measure and enter the appropriate parts per million (ppm) correction into the data controller before work each day for general order and third order surveys. For second order surveys, make temperature and pressure readings and enter ppm correction into the data controller again at midday. Each 34°F (1°C) change in temperature will cause a one-ppm error, if the ppm setting in the data controller is not changed.

Checking: After setting the instrument up, measure the distance to the backsight to provide a check. Observations of other known points are encouraged whenever practical. For general order surveys, it is good practice to observe selected points from two setups as a check. At the conclusion of each setup, re-observe the direction to the backsight. For general order surveys (construction staking, topographic surveys, etc.), where areas are surveyed from two different setups, have common points from the two setups to provide additional checks.

Mode: All distance observations for second order and third order surveys are taken in standard measurement mode on the total station. Distances for general order surveys may be taken in track mode.

9-03.4 Field Notes

Original survey notes, for all TSS observations, are maintained in the data controller and are stored electronically. Data controller headers must be completely filled in. Add comments about observations that might affect data reduction to the data controller file with a text entry. Data for all points that will be used as control and any cadastral monuments must be collected with 2 pointings in the data controller to be incorporated into a least squares adjustment.

Supplement the data controller notes with hand written notes. At a minimum, these notes include setup information (point numbers, codes, measure ups,), sketches, detailed descriptions and/or rubbings of monuments as appropriate and other general comments about the survey. Field notes are not complete unless they contain the date, project name and/or number, page number, and crew names.

9-03.5 Survey Adjustments

All control points used for data gathering and stake out, including photo control, are adjusted by the method of least squares. Control points established by resection methods are adjusted for horizontal position by least squares before they are used in the field.

9-04 Second Order Surveys

9-04.1 Applications

Corridor Control: TSS can be used to perform second order trigonometric leveling surveys for Corridor Control Surveys.

Project Control: TSS can be used for horizontal and vertical Project Control Surveys to densify project control established by GPS.

9-04.2 Horizontal Specifications

Method: Traverse with cross ties. Figure 9-1 lists the specifications required to achieve second order horizontal accuracy.

9-04.3 Vertical Specifications

Method: Trigonometric Leveling, a method by which differences in elevation are determined by measuring vertical angles and slope distances.

Trig leveling is a separate and different procedure than carrying elevations with conventional total station traversing. The total station is setup anywhere convenient just like a level and there is no measure up at the instrument. There is no requirement for balanced sight lengths, and differences in elevation of 60 feet or more between backsight and foresight in one setup are not uncommon in steep terrain. The key to success is redundant elevation differences to fixed height targets.

Figure 9-2 lists the specifications required to achieve second order vertical accuracy.

Specifications	Traverse/Network
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and end each setup
Use optical plummet to check position of target and instrument over points	Begin and end each setup
Measure temperature and pressure and enter ppm correction into total station	First set-up, midday setup
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties to improve least squares adjustment	Required, as feasible
Close all traverses	Required
Horizontal angle observations	3D, 3R (2 set) minimum
Vertical angle observations	3D, 3R (2 set) minimum
Angular rejection limit, i.e., reject angle if difference compared to mean of observations is greater than	5”
Minimum distance measurement	330 ft

Second order (Horizontal) TSS Survey Specifications

Figure 9-1

Specifications	Trigonometric Leveling
Check vertical index error	4 times per day
Use fixed height staff for target	Required
Measure temperature and pressure and enter ppm correction into total station	First setup, midday setup
Vertical angle observations	2 sets of 2D, 2R (See Note)
Angular rejection limit, i.e., reject angle if difference compared to mean of observations is greater than	10”
Measure uncorrected zenith distance	Each pointing
Measure uncorrected slope distance	Each pointing
Difference between two differences in elevation for each setup not to exceed	0.005 ft
Maximum sight length	700 ft
Minimum ground clearance of line of sight	3 ft

Note:

Two sets (eight pointings); each set of observations (2D, 2R) yields an independent difference in elevation between the backsight and foresight.

Second order (Vertical) TSS Survey Specifications

Figure 9-2

9-05 Third Order Surveys (Tertiary)

TSS can be used for both third order horizontal and vertical positioning.

9-05.1 Applications

- Supplemental control surveys for construction and engineering surveys
- Photogrammetric control
- Cadastral Location control
- Monumentation control
- Major structure and interchange staking

Supplemental control points are points that will be used as setup points to gather topographic data, locate monuments, perform Construction Staking and setout other control and right of way monuments.

9-05.2 Specifications

Methods:

- Traverse
- Resection: This method locates the unknown position of a setup point by observing known positions from the unknown point. Generally, points are re sectioned by observing three known points of equal or greater accuracy. Two point resections may be acceptable if the angle between the observed points is less than 135 degrees or greater than 225 degrees. All specifications for third order must be met. Figure 9-3 lists the specifications required to achieve third order accuracy.

Specifications	Traverse/Network Resection Double Tie
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Begin and end each setup
Use optical plummet to check position of target and instrument over points	End of each setup
Measure temperature and pressure and enter ppm correction into total station	First set-up of day
Measure distance to backsight and foresight at each setup	Required
Observe traverse multiple ties to improve least squares adjustment	As feasible
Close all traverses	Required
Number of known points to observe	N/A
Horizontal angle observations	2D, 2R (1 set) minimum
Vertical angle observations	2D, 2R (1 set) minimum
Angular rejection limit, i.e., reject angle if difference compared to mean of observations is greater than	10”
Minimum distance measurement to meet horizontal standard	165 ft
Maximum distance measurement to meet vertical standard	330 ft

Third-Order TSS Survey Specifications

Figure 9-3

9-06 General Order Surveys

9-06.1 Applications

- Engineering survey collected topographical data
- Construction survey, staked points
- GIS surveys
- Environmental surveys

9-06.2 Specifications

The radial survey method is used for all General Order surveys. Data for General Order points are gathered as radial observations in the data controller and are not available for least squares adjustment.

For construction staking, staked positions are rejected, when the difference between the “set” (observed) position and the theoretical design position exceeds the allowable tolerances.

Engineering survey data points are checked by various means including reviewing the digital terrain model, reviewing digital terrain lines in profile, and redundant measurements to some points from more than one setup.

Figure 9-4 lists the specifications required to achieve General Order accuracy.

Specifications	Radial
Check vertical index error	Daily
Check horizontal collimation	Daily
Measure instrument height and target height	Yes
Use optical plummet to check position of target and instrument over points	Begin and end each setup
Measure temperature and pressure and enter ppm correction into total station	First set-up of day
Horizontal angle observations	1D
Vertical angle observations	1D
Minimum distance measurement to meet horizontal standard	65 ft
Maximum distance measurement to meet vertical standard	500 ft

General-Order TSS Survey Specifications
Figure 9-4