OREGON DEPARTMENT OF TRANSPORTATION

Delivery and Operations Division

Engineering and Technical Services Branch

Engineering Automation Section

CONSTRUCTION SURVEYING MANUAL FOR CONTRACTORS

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This companion manual to Standard Specification 00305 provides detailed information on performing construction survey work for highways, bridges, signs, signals, illumination and associated work.

Revision History

For previous version revision history, please see past versions which are available from the ODOT Engineering Automation Section.

Seventh Release - January 15, 2021

- Removed previous version Revision History.

Chapter 1.3 - Revised timing of Pre-Survey Conference to match Pre-Construction Conference.

Chapter 4.6 - Clarified Culvert/Pipe Data Sheet requirements.

Chapter 8.1.1 - Added data format requirement for Grade Verification points.

Chapter 9.4 - Added final Vertical Clearance measurement instructions.

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CHAPTER 1 - GENERAL INFORMATION

1.1 Scope - This work consists of all surveying activities necessary to control the many phases of work required to construct a Project to the lines and grades as shown, specified, or established.

Make all supporting computations and field notes required for control of the work and as necessary to establish the exact position, orientation, and elevation of the work from control stations, including furnishing and setting construction stakes and marks, reference marks, and additional control stations.

Plans, specifications and other data necessary to lay out the work will be available for inspection at the Engineers office.

1.2 Definitions:

3D Engineered Model - The Agency prepared electronic file(s) that identify northing, easting, and elevation to represent the Work to be performed. The 3D Engineered Model may include the surface model(s) or other designed Work elements and is an electronic representation of the line, grade, and cross section applicable to the project.

3D Construction Model - Supplemental unstamped 3D Model, not furnished by the Agency, that the Contractor is required to submit to the Engineer.

Automated Machine Guidance (AMG) - AMG is the computerized guidance of construction equipment to follow the line and grade of the engineered design. Guidance is either by direct control of the machinery or through visual and/or audible signals to the operator. Operation is based on digital input from positioning systems, and typically produces an increased level of precision, speed, and accuracy.

Confidence Points - Random points measured in the field within the boundary of a digital terrain model (DTM), the purposes of which are to verify the accuracy of the DTM and to provide evidence just prior to construction that the DTM is a reasonable representation of the original ground for computation of volumes and pay quantities. For constructed Grade Verification see Chapter 8 “Line and Grade Verification.”

Confidence point locations follow these guidelines:

- Randomly selected without regard for the location of DTM points or triangles
- Evenly distributed over the entire DTM area to be validated
- Proportionately distributed between confidence point types as applicable
- At a density sufficient to validate the surface, generally ten per instrument location as used in collecting DTM data or if not applicable, as in LIDAR data, 2% of DTM points

Control Network - An array of control stations either established by the Contractor or provided by the Agency.

Control Station - Any item identified in the Project records as having a position and elevation on the Project datum and intended to be used to control the many phases of the construction work.

Digital Terrain Model (DTM) - An electronic computer model of the shape of the ground.

Grade Verification Points - Points measured in the field used to verify that a constructed grade has been built according to the line and grade of the design.

Reference Stakes - Stakes set away from but with information relating back to the intended location and grade.

Slope Catch - The location where a design slope intersects the existing ground and where excavation or embankment work should begin to provide the intended earthwork.

Slope Staking - The process of using measurements and calculations in the field to determine the slope catch. Slope staking shall normally include setting stakes to mark the slope catch and setting a reference stake for every catch stake.

Stakes - Stakes, nails, marks, string lines, or other devices or mechanisms set or established for the purpose of indicating or controlling the location, orientation, or grade of any feature intended for construction, or for the purpose of limiting or influencing the construction work.

Staking - The act of placing stakes.

Subgrade Area - The area of Subgrade from Subgrade shoulder to Subgrade shoulder.

Survey Marker - Any survey monument, control station, or stake.

Survey Monument - Any natural or man-made item specified or identified in a property deed, boundary survey, government document, or other instrument of public record, when the purpose of said item is to mark or reference a property boundary, geographical location, elevation, or other position.

Surveyor - The individual designated by the Contractor and licensed in the state of Oregon as a Professional Land Surveyor and placed in "responsible charge" of the survey work as defined in ORS 672.002(6)(b).

Temporary Bench Mark (TBM) - A control station established for the purpose of providing vertical control for the Project. A TBM may or may not have an established horizontal position.

1.3 Mandatory Pre-Survey Conference - The prime Contractor, subcontractors, Surveyor, survey crew leader, and all surveying personnel who are to be involved in the survey work shall

meet with the Engineer at or near the time of the pre-Construction Conference, which shall occur prior to beginning survey work. The purpose of this meeting will be to discuss methods and practices of accomplishing required survey work.

1.4 Review by the Engineer - The Engineer may periodically review the notes, calculations and layout work, including field locations, for compliance with these specifications. Survey work that does not meet the tolerances in Chapter 4.1 of this manual may be rejected, and the work redone at the Contractors expense to meet the tolerances.

Review by the Engineer does not constitute approval or acceptance of the work, nor does it relieve the Contractor of responsibility for performing work in conformance with the plans and specifications.

1.5 Agency Responsibilities:

- Perform a Pre-Construction Survey in accordance with Chapter 7 of this manual.
- Provide copies of plans and specifications.
- Establish initial horizontal and vertical control stations in the proximity of the Project.
- Provide horizontal and vertical alignment data.
- Provide cross section grade elevations to establish lines, grades, slopes, cross sections, and curve superelevations for each phase of roadwork. When available, provide 3D Engineered Models.
- Evaluate grade for acceptance at each course of material.
- Perform measurements and calculations for pay quantities.
- Perform final "as constructed" measurements.

1.6 Contractor Responsibilities - Perform or provide the following items of work:

- Make calculations, field notes and survey drawings for the layout and control of the work as are necessary to construct the Project as specified.
- Provide original or copies of notes, calculations and drawings as requested.
- Preserve survey monuments and control stations according to Chapter 6.2 of this manual and as governed by applicable law.
- Replace and augment control stations as necessary to control the Project.
- Establish additional control stations as necessary to control the Project.

- Remove and dispose of all flagging, lath, stakes and other temporary staking material after the Project is completed.
- Collect Grade Verification points according to Chapter 8.2 of this manual.
- Complete Vertical Clearance requirements according to Chapter 9 of this manual.

Non-AMG controlled Work:

- Set stakes to define construction centerline, centerline offsets, detour lines, or other lines necessary for control of the Project work.
- Set stakes to define and control the work, that may include but is not limited to the following:

    - Roadway location and grade.
    - Fences and gates.
    - Guardrail, barrier, barricades, and associated features.
    - Traffic delineators, reflectors, and guide devices.
    - Temporary and permanent pavement striping and pavement marking devices.
    - Temporary and permanent signing.*
    - Poles and footings, cabinets, junction boxes, sensors, and other features associated with illumination and signal facilities.*
    - Curbs, walks, ADA ramps, stairs, walls, mailboxes, and other miscellaneous structures.*
    - Pipes, manholes, inlets, weirs, settlement basins and other drainage and water quality structures and facilities.*

        *This includes field verification of fit and functionality or as instructed by the Engineer.
    - Landscaping items.
    - Earthwork features including guardrail flares, berms, and mounds
    - Buildings and other structures and facilities.
    - Environmental impact mitigation features.

AMG controlled Work:

- For work being controlled by a 3D Model, as required by the Contract Section 00305.05, provide unstamped 3D Construction Models according to the Contract Section 00150.35 which include the following:
    - A Narrative outlining any changes made to the Agency prepared 3D Engineered Models in the creation of the 3D Construction Models.
    - A copy of the 3D Construction Models that will be used by the Contractor's equipment for machine guidance or verification, which include and represent the Agency prepared 3D Engineered Models with changes identified in the Narrative. Provide files in LandXML format or as directed.
    - A written AMG work plan as required in Chapter 1.8 of this manual.

Bridge Work:

- Supply survey drawings depicting the location and elevations of the elements of substructure and superstructure and place stakes for features including but not limited to the following:

Substructure:

- Piling
- Footings
- Columns, walls, and abutments
- Pile caps and cross beams
- Bearing pads or devices

Superstructure:

- Horizontal alignment and deck edges
- Soffit grades
- Seismic restraints
- Wing walls and retaining walls
- Bridge end panels
- Deck elevations

- Railings
- Deck drains and other bridge drainage facilities

- Set reference stakes and elevations in the vicinity of the structure work, as are necessary for the Engineer to check the layout. This may include establishment of a control network.

1.7 Survey Methods - Survey procedures shall be appropriate for the equipment being used and be according to current Agency practices, which can be found in the current version of the ODOT Survey Policy and Procedure Manual available here: http://www.oregon.gov/ODOT/ETA/Documents_Geometronics/Survey-Policy-Procedure-Manual.pdf

New survey procedures that are not according to current Agency practices shall be submitted to the Engineer for review 21 days prior to conducting the work. The surveyor may be required to demonstrate the capabilities, accuracy, and reliability of the intended procedure. The Engineer will evaluate the procedure and intended application and provide approval or rejection within 21 days. Work may proceed immediately upon approval of procedures by the Engineer.

Test and adjust survey equipment according to Agency's procedures and maintain records of test results and submit copies to the Engineer upon request. Information on Agency test procedures may be obtained from the Engineer.

1.8 Automated Machine Guidance (AMG) - In lieu of setting stakes, the Contractor may use AMG.

- Inform and gain approval from the Engineer prior to the use of AMG on a project.
- Submit a plan in writing addressing the use of AMG on the project. The plan shall be submitted 10 days prior to the Pre-Construction meeting or 21 days prior to use of AMG. The plan shall include but not be limited to the following items:
    - Narrative outlining the overall AMG plan, including;
        - Processes and procedures used with AMG equipment.
        - Survey control procedures (verification and augmentation).
        - Machine positioning technology method (GNSS, total station, laser, etc.).
        - Data validation and data conversion process.
    - List of pay items that will be constructed with AMG procedure for constructing each type of construction material, including;
        - Construction equipment being used.
        - Personnel being used & their experience using AMG.

        - Survey equipment, GNSS, & sensors being used with each piece of equipment.
    - Procedure for collecting Grade Verification points on each type of material.
    - Identify the Registered Professional Land Surveyor in charge of the survey activities

- Demonstrate capabilities, accuracy, and reliability of the intended AMG procedure if required by the Engineer.

- Perform any supplemental staking as directed by the Engineer.

1.9 Survey Work Records - Contractor's survey personnel shall maintain a Project daily record of work performed by the survey crew. The daily record shall contain the date, crew names, type and location of work, and work accomplished. Upon request, furnish a copy of diary entries to the Engineer. Furnish a final copy of the diary when the Project is complete.

Contractor's survey personnel shall make all field notes and calculations in a manner consistent with current Agency practices and on forms provided or approved by the Engineer. Computations, survey notes and other records necessary to accomplish the work shall be neat, legible and complete. Furnish copies of computations, notes and other records when requested by the Engineer.

For bridges, furnish all computations, layout notes, and drawings of the structure to the Engineer for review 7 Calendar Days before beginning construction.

Upon completion of construction staking and prior to final acceptance of the Contract, furnish to the Engineer, computations, survey notes, Project records and other data used to accomplish the work. Include an itemized list of the data.

All data and original documentation associated with the Project will become the property of the Agency.

1.10 Communication With the Surveyor - The Engineer has the right to communicate directly with the surveyor.

CHAPTER 2 - ELECTRONIC DATA

2.1 General - The Engineer will not be responsible for any data translations. Compressed data provided by the Engineer or the Contractor will be in a "self-expanding executable" format. The method of exchange of electronic data will be mutually agreed upon at the pre-survey conference.

2.2 File Formats For Digital Data Exchange - Below are the preferred formats for data exchanged between the Agency and the Contractor. Other formats may be used, but must be pre-approved by the Engineer.

- **Alignments (Horizontal and Vertical)** – LandXML alignments.
- **CAD (graphics)** - MicroStation Design File (.dgn).
- **Coordinates (1D, 2D, and 3D)** – LandXML coordinates.
- **Digital Terrain Model (DTM)** – LandXML surface.

2.3 Other Documents - Adobe Acrobat Portable Document Format (pdf) is the preferred format for exchanging documents such as reports, drawings, maps.

CHAPTER 3 - MATERIALS, EQUIPMENT, AND LABOR

3.1 Materials - Furnish all materials including supplies, clothing, and incidentals required to accomplish the work. Use materials of good quality and suitable for the purpose intended. Stakes and hubs are to be of sufficient length to provide a solid set in the ground. Mark the stakes in such a way as to remain legible for the intended duration. Provide and use safety equipment required by State and federal regulations.

3.2 Survey Equipment - Furnish survey equipment required to accomplish the work that meets the following requirements:

- Components designed to work together.
- Suitable for the purpose intended.
- Capable of achieving the necessary accuracy and precision appropriate for the work.
- In good operating condition.
- Maintained to meet manufacturers specifications.
- Kept in proper adjustment throughout the duration of the Project.

Submit documentation on survey equipment that is new to the industry, to the Engineer for review 21 days prior to its use. The Engineer will evaluate the equipment and intended application and provide approval or rejection within 21 days. Equipment may be used immediately upon approval by the Engineer.

3.3 Personnel - Provide technically qualified personnel capable of performing required tasks in a timely and accurate manner. Perform work under the direction and review of the Surveyor.

The Surveyor is responsible for:

- Maintaining registration as a Professional Land Surveyor in the State of Oregon.
- Performing or validating requirements for procedures and testing of equipment.
- Maintaining familiarity with the site conditions and progress of the Project.
- Becoming familiar with the plans and specifications.
- Determining notes and documentation required for types of survey work.
- Determining the accuracy required for each survey stake.
- Using appropriate equipment and methods.
- Maintaining close communication with the Project inspector(s), Engineer, and Agency survey crews working on the Project.

- Being familiar with varying construction survey requirements of each aspect of the Project, including various bridge construction techniques when applicable.
- Notifying the Project inspector of conflicts and changes necessary due to utilities, match point variations, design revisions, or other variables.
- Ensure survey personnel's adherence to the Prime Contractors on site personal protective equipment rules

The survey crew leader is responsible for:

- Becoming familiar with the plans and specifications.
- Keeping close communication with the Project inspector(s), Engineer, and Agency survey crews working on the Project.
- Notifying the Project inspector of conflicts and changes necessary due to utilities, match point variations, design revisions, or other variables.

CHAPTER 4 - CONSTRUCTION STAKING

4.1 Construction Staking Tolerances - Set stakes or other devices at an adequate frequency and within the following tolerances. The Engineer may check the stakes in accordance with Chapter 1.4.

Item	Horizontal	Vertical
Box Culverts	+/- 0.10 ft.	+/- 0.05 ft.
Bridge Substructures	+/- 0.03 ft.	+/- 0.03 ft.
Bridge Superstructures	+/- 0.02 ft.	+/- 0.02 ft.
Clearing and Grubbing Stakes	+/- 1.00 ft.	n/a
Construction Centerline Control Points	+/- 0.05 ft.	n/a
Construction Centerline Station Points	+/- 0.10 ft.	n/a
Curbs, Walks, and Bike Paths	+/- 0.03 ft.	+/- 0.02 ft.
Engineering Stationing	+/- 1.00 ft.	n/a
Grade Stakes - Roadway Subgrade	+/- 0.20 ft.	+/- 0.05 ft.
Grade Stakes - Top of Rock	+/- 0.20 ft.	+/- 0.03 ft.
All ACP Courses	+/- 0.10 ft.	+/- 0.02 ft.
Manholes, Inlets, and Culverts	+/- 0.10 ft.	+/- 0.03 ft.
PCC Pavement	+/- 0.10 ft.	+/- 0.02 ft.
Slope Stakes and References	+/- 0.30 ft.	+/- 0.10 ft.
Traffic Markings	+/- 0.20 ft.	n/a
Walls - Retaining, MSE, Sound, etc.	+/- 0.10 ft.	+/- 0.05 ft.
Wetland Mitigation Control Stakes	+/- 0.20 ft.	+/- 0.20 ft.
Luminaire and Signal Poles (incl. footings)	+/- 0.20 ft.	+/- 0.03 ft.

Stakes for miscellaneous items not listed above will have a horizontal and vertical tolerance of 0.20 foot, unless otherwise directed. Features that are to be constructed flush to another surface should take on the same tolerance as that surface.

Staking tolerances for special circumstances will be discussed at the pre-survey meeting.

4.2 Slope Stakes and References - When slope staking is performed by the Contractor, set slope stakes and references on both sides of centerline at 50 foot stations and at terrain breaks and changes in the typical section. Establish slope stakes in the field at the actual point of intersection of the design roadway slope with the existing ground line. Direct staking of the theoretical (computer generated) slope stake catch point requires prior approval of the Engineer.

Set slope stake references farther out from centerline than the actual catch point. Include all reference point and slope stake information on the reference stakes.

Record the actual as staked (three dimensional) position of the slope and reference stakes. Prepare field notes showing slope stake and reference information, and provide to the Engineer.

4.3 Clearing Limits - When clearing limits are to be established by the Contractor, set clearing limit stakes according to the Oregon Standard Specifications for Construction, Section 00320. Space clearing limit stakes at intervals not greater than 50 feet or as directed.

4.4 Grade Stakes - Set grade stakes or other control for grade elevation and horizontal alignment. Set grade stakes at each grade break line. Set additional points at intervals, as necessary, not to exceed the width of the grading equipment, or as approved by the Engineer. Set these rows at 50 foot stations or as required in special situations, as in road connections and other areas where conditions require tighter spacing of grade stakes to assure grade and alignment.

4.5 Walls - Set stakes or other devices to control the location and elevation of walls, including retaining walls, geotextile walls, wing walls, sound walls and other walls as specified. Provide horizontal and vertical control for elements of wall(s) including but not limited to footings, leveling pads, batter slope and direction, and top elevation. Stake drainage facilities, electrical conduits, water pipes and other items shown or identified that are to be integrated into the construction of the wall(s).

4.6 Pipes and Culverts - Stake pipes and culverts to fit field conditions. Their location may be different from the plans. Perform the following:

- Determine the roadbed slope catch points at the inlet and outlet of pipes and culverts.
- Set reference point offsets to pipes and culverts. Set a minimum of three reference stakes per pipe run or culvert. Record information necessary to determine structure length and end treatments.
- Stake ditches or grade to make pipes and culverts functional.
- Complete a Culvert/Pipe Data Sheet (Form 734-3247) of the as constructed conditions according to Agency standards.
- Submit a copy of the field notes as directed by the Engineer by the next working day following completion of the staking work.

4.7 Box Culverts - Set stakes or other devices to control the location and elevation of box culverts as specified. Provide horizontal and vertical control for elements of the box culvert(s) including but not limited to footings, side walls, wing walls, weirs, fish ladders, aprons and top elevation. Stake other drainage facilities, electrical conduits, water pipes, and other items shown or identified that are to be integrated into the construction of the box culvert(s). Stake ditches to make the box culvert(s) functional.

4.8 Manholes and Inlets - Determine the location of manholes, inlets, siphon boxes, slope protectors, and other similar structures. This may require an approved field adjustment to the

planned location in order to avoid obstacles or assure placement at the low point. Determine the elevation of the center of the grate.

Set a stake referencing the center of the structure. Set a guard stake with the following information written on it:

- Type of structure
- Centerline station
- Centerline offset
- Reference distance
- Cut or fill to top of structure
- Center of structure elevation
- All invert elevations within the structure

Establish a reference line to control the alignment of the structure. Record data on the Culvert/Pipe Data Sheet (Form 734-3247) containing staking information for the outlet pipe from the specific drainage structure.

4.9 Stockpile Sites - Perform the work necessary for the initial layout and measurement of the stockpile site by one of the following methods:

4.9.1 Cross Section Method - Establish a reference baseline, site limits, and clearing limits. Survey and record original ground cross sections prior to placement of stockpile material. Take cross-sections at maximum 25 foot intervals, grade breaks in the existing ground, and at locations anticipated to be grade breaks in the completed stockpiled. Survey and record final cross sections after completion of the stockpile. Take cross sections at all previous locations plus any additional locations necessary to accurately reflect size and shape of stockpile.

4.9.2 Digital Terrain Model (DTM) Method - Establish instrument control stations, site limits, and clearing limits. Survey and record original ground measurements. Use the proper placement of breaklines and regular terrain points. Record a minimum of 10 confidence points. Verify instrument setup by recording elevation and backsight checks.

Survey and record the stockpile surface measurements. Use the proper placement of breaklines and regular terrain points. Record a minimum of 10 confidence points. Verify instrument setup by recording elevation and backsight checks.

4.10 Engineering Stationing – When required, establish engineering stationing at the required intervals, or at a greater interval as agreed upon, for the length of the project along the shoulder of the highway. The stationing shall be visible and maintained throughout the construction of the project.

CHAPTER 5 - HORIZONTAL AND VERTICAL CONTROL AND LAYOUT

5.1 Horizontal Control - Establish horizontal control stations using Terrestrial (Total Station) network or static GNSS techniques. Least squares adjustments shall be applied to either method. The use of traverses will be permitted only if approved by the Engineer.

Preserve all Agency provided and Contractor established horizontal control stations for the life of the Project. If the horizontal control network cannot be preserved in its original position during construction or if the Agency provided control stations are not of adequate quantity or location, establish a secondary horizontal control network using the original control as a basis. This secondary control network may then be used by the Contractor to layout all construction items and may be used by the Agency for right-of-way monumentation and for other purposes.

5.1.1 General Specifications - Horizontal control networks shall conform to these general requirements in addition to Terrestrial or GNSS specifications to follow.

5.1.1.1 Equipment:

- Use tripods for all occupations with Total Station, target, or GNSS antenna.
- Test all components and adjust according to manufacturer specifications.

5.1.1.2 Procedures:

- Include in field notes a detailed point description and vicinity sketch for each control station and survey monument established or used.
- Perform a minimally and fully constrained Least Squares adjustment.
- The line used for the basis of bearing shall be greater than 1,000 feet unless approved by the Engineer.
- Prior to using 2 points for the basis of bearing, perform an analysis to verify that the points are actually those indicated in the record.
- Control station monuments shall conform to the requirements of the ODOT Survey Policy and Procedure Manual.
- If available, include at least three existing control stations in establishing any control network.
- Establish a point identifier for each control point within the range of 1 - 399. Alphanumeric point identifiers up to eight characters may be used. Inscribe the point identifier on the monument.

5.1.1.3 Acceptance Standards - A least squares adjustment shall be accepted based on the following criteria for all specified tolerances:

- Two-thirds of all values shall be within the total tolerance.
- 100% of all values shall be within 3 times the total tolerance.
- Tolerance for confidence regions at the 95% level is 0.05 feet + 50 ppm based on the shortest distance to the nearest unadjusted control station.

5.1.1.4 Data Requirements:

- Field notes containing a detailed point description and vicinity sketch for each control station and survey monument established or used.
- Minimally and fully constrained least squares adjustment reports.

5.1.2 Terrestrial Networks:

5.1.2.1 Equipment:

- Use Total Stations with a maximum angular standard of error no greater than +/- 6 seconds.
- Use Total Stations with a maximum distance standard error no greater than +/- 0.02 feet +/- 5 ppm.
- All components shall be of compatible accuracy and designed to be used together.

5.1.2.2 Field Procedures:

- Include distance measurements with all observations unless impractical.
- Have at least one redundant observation for every point in the network.
- Triangulation, trilateration, and resection methods are acceptable.

5.1.2.3 Acceptance Tolerances:

- Tolerance for angle residuals is +/- 3 seconds.
- Tolerance for distance residuals is +/- 0.02 feet +/- 2 ppm.

5.1.2.4 Data Requirements - Provide the following to the Engineer for each network or circuit established:

- **Raw Data Files** - These are electronic data files containing original measurements produced by the Total Station (or data collector). The file shall contain:
  - Observation data for each measurement, including:
    - point identifier

- direction, plate reading, or horizontal angle
- vertical or zenith angle
- slope distance

- Supplemental measurement data, including:

  - distance units recorded
  - angular units recorded
  - curvature and refraction correction applied
  - atmospheric correction applied
  - prism correction applied

- Codes or instructions to the processing software on how to process the data.
- Atmospheric conditions at the time of the survey.
- Angular and distance units recorded, and whether the distance has been corrected for curvature and refraction and atmospheric conditions.

- **Set Reduction Report** - This report summarizes the reduction of the angle sets and mean distances.
- **Least Squares Adjustment Reports** - These reports contain details of the least squares adjustment, including a list of all angular and distance residuals, confidence region values at a 95% confidence level, and final adjusted coordinates.

5.1.3 GNSS Networks:

5.1.3.1 Equipment:

- GNSS receivers shall be dual frequency geodetic receivers with a manufacturer specified accuracy of +/- 0.02 feet +/- 1 ppm or better.
- All components shall be of compatible accuracy and designed to be used together.

5.1.3.2 Field Procedures:

- Ensure that satellite geometry during the field observation phase is sufficient to produce accurate results. The position dilution of precision (PDOP) shall not be greater than 6.
- The number of healthy satellites being observed at any time shall be four or more.
- The elevation mask shall be not less than 10 degrees.

- Horizontal survey measurements, once completed, shall form a closed figure, and shall be connected to at least two existing horizontal control stations.
- Network shall be comprised entirely of independent baselines.
- Adjacent stations shall have direct connections.
- Every station shall be connected to two or more stations.
- Receiver documentation shall be followed for observation times and epoch intervals.
- Each control station shall be occupied no less than twice, of which two occupations shall be separated from each other by time. Separation shall be measured start-time to start-time. Separation shall be 45 minutes or more from initial occupation. Additional occupations beyond two are not subject to time restrictions.
- Stations closer together than 1,500 feet shall be connected with terrestrial observations.
- Inter-visible stations closer together than 3,000 feet shall be connected with terrestrial observations.

5.1.3.3 Acceptance Tolerances:

- Tolerance for linear residuals in latitude, longitude, and elevation is +/- 0.05 feet.

5.1.3.4 Data Requirements - Provide the following to the Engineer for each network established:

- **Receiver Independent Exchange (RINEX) Data Files** - These are industry-standard non-proprietary electronic data files containing original data collected by the receiver. The provided files shall contain all data supported by both the RINEX file format and the equipment and software employed in the survey. Files provided shall include as a minimum:
  - GNSS observation data file
  - GNSS navigation message file
- **Observation Log Sheet** - This log includes, for each observation, start and stop times, and antenna height including measurement procedure.
- **Least Squares Adjustment Reports** - These reports contain details of the least squares adjustment, including a list of all latitude, longitude, and height residuals, confidence region values at a 95% confidence level, and final adjusted coordinates.

5.1.4 Traverses:

5.1.4.1 Equipment:

- Identical to requirements for Terrestrial networks.

5.1.4.2 Field Procedures:

- Include distance measurements with all observations unless impractical.
- Close both traverse for angle and distance.

5.1.4.3 Acceptance Standards:

Closure shall be a minimum of 1:20,000 after angular adjustment and prior to coordinate adjustment.

5.1.4.4 Data Requirements - Provide the following to the Engineer for each traverse established:

- **Adjustment Report** - This report contains details of the traverse adjustment, including adjusted coordinates.
- **Other Reports** - All data required for Terrestrial networks except least squares adjustment report.

5.2 Vertical Control - Establish vertical control stations using differential leveling and third order or better equipment and techniques. The development of vertical control by techniques other than differential leveling must be approved by the Engineer. A least squares adjustment shall be applied to each network of acceptable level circuits.

The Agency provided and Contractor established vertical control stations shall be preserved for the life of the Project. If the vertical control network cannot be preserved in its original position during construction or if the Agency provided control stations are not of adequate quantity or location, establish a secondary vertical control network using the original control as a basis. This secondary control network would then be used to layout all construction items and may be used by the Agency for other purposes.

5.2.1 Field Procedures:

- Use a compensated (or "automatic") optical level or compensated digital level.
- Use precise non-adjustable rod(s) unless otherwise directed.
- Use a rod level with each rod.
- Include a minimum of two published bench marks in each circuit unless otherwise directed.

- If the circuit between benches does not close within the tolerance stated below, close circuit back to the starting point.
- If the use of one benchmark is approved, close circuit back to the starting point.
- Select turning points that are firm, solid objects with a defined high point. Set a nail, spike, or stake if no existing items are acceptable. Turning plates with a weight of not less than 4.5 pounds may be used.
- Balance backsight and foresight distances to within 30 feet on each setup and to within 30 feet on the entire circuit.
- Make a record of the rod reading(s) and the observation distance on each sighting
- Set TBM's near significant construction items (bridges, intersections, and other locations where elevations will be needed) and not more than 1,000 feet apart throughout the Project.
- Select TBM monuments that are firm, solid objects with a defined high point, not likely to be moved by human or natural influences, readily identifiable, and out of the path of construction. Do not use fire hydrants, guardrails, highway signs, or nails or spikes in utility poles or fence posts.
- Include detailed point descriptions and vicinity sketch in field notes.
- Take field notes when recording measurements electronically. Include data and information not electronically measured and recorded.
- Apply a vertical least squares adjustment to allowable errors. The use of proportional distribution of error may be used if approved by the Engineer.

5.2.2 Acceptance Standards - Each leveling circuit shall be accepted based on the "point-to-point" or "closed-loop" limits described below. A single least squares adjustment shall be applied to the observations in the leveling circuits meeting the acceptance standards

- Accept point to point circuit based on the following. Error of closure shall be no greater than:

$$\text{Allowable Error} = 0.05 \text{ ft.} \sqrt{D}$$

D = Shortest level line distance in miles

- If a closed loop, the error of closure shall be no greater than:

$$\text{Allowable Error} = 0.035 \text{ ft.} \sqrt{E}$$

E = Perimeter of level loop in miles

5.2.3 Data Requirements - Provide the following to the Engineer for each network or circuit established:

- **Raw Data** - These are hand written field notes or hand written field notes accompanied by electronic data files containing original measurements produced by the level. The file shall contain:

    - Data for each measurement, including a:

        - point identifier (within a range of 400 - 499 and also inscribed on the monument)
        - rod reading
        - observation distance

    - Supplemental measurement data, including:

        - distance units recorded
        - curvature and refraction correction applied

- **Level Computation Report** - This report contains the computation of unadjusted elevations, observation distance imbalances, computer allowable error, and closure error.

- **Level Adjustment Report** - This report contains the adjustment details, including residual values, adjusted elevations and standard errors.

- Point Elevation Data File

5.3 Bridges - Set stakes, nails, or other devices to control the location and elevation of the various parts of bridges and progressive phases of construction. Provide horizontal and vertical control for all elements of bridge construction. Stake drainage facilities, electrical conduits, water and sewer pipes, pedestrian and bicycle facilities, traffic signal and sign supports, illumination devices, and other items shown or identified that are to be integrated into the construction of the bridge.

Identify marks or provide field notes or reports to the Engineer. Such provision of information shall be adequate for the Engineer to review the location and elevation of the mark for the intended purpose prior to incorporating material that is based on the mark.

5.3.1 Bridge Survey Control Stations - Use the smallest number of original Project control stations as is practical for establishing positions and reference points for bridge construction on one bridge. Use of multiple control stations will increase the probability of incorporating error into the construction. Use control stations that are as closely related mathematically as practical. The Contractor may establish additional control stations as necessary to complete the survey work. Additional control stations shall be established in such a manner as to provide the accuracy needed to meet the tolerances in Chapter 4.1 of this manual.

Original Project control stations shall be used only after the following evaluation is completed for each bridge:

- Supply a list of original Project horizontal and vertical control stations intended by the Contractor to be used in establishing positions on a given bridge.
- Measure relative positions of original Project horizontal control stations intended to be used.
- Measure elevation differences between original Project vertical control stations intended to be used.
- Supply horizontal and vertical measurement data to the Engineer.
- Compare measured values with those computed from original horizontal network coordinates and vertical network elevations.
- Any discrepancy of concern to either the Contractor or the Engineer will be resolved before that combination of control stations is used.

5.3.2 Layout Marks and Reference Points:

5.3.2.1 Substructure - Stake, reference, or otherwise identify locations, orientations, and elevations necessary for placement of substructure components, including but not limited to cofferdams, pilings (including batter), drilled shafts, footings, columns, abutments, caps, cross beams, bearing devices, temporary supports or falsework, and excavations and embankments associated with any of the above. Excavations and embankments are subject to Grade Verification per Section 8.2

Verify and document the locations, elevations and spatial relationships with adjacent substructure components. On bridges where prefabricated beams will be used, measure and document span lengths between bearing devices at each beam location as soon as practical. Supply a copy of such documentation to the Engineer for review before the next stage of construction.

Compute the final elevations after studying the plans, specifications, and shop drawings. Adjust the grades as needed to compensate for camber of prefabricated beams, chording of beams across the low side of super-elevations, width of flat beams on super-elevated surfaces, and any other factor resulting from design or construction methods.

5.3.2.2 Superstructure - Stake, reference or otherwise identify locations, orientations, and elevations necessary for placement of superstructure components including but not limited to beams, girders, diaphragms, earthquake restraints, deck, rails, structure mounted traffic control and illumination devices, and concrete forms, temporary supports and falsework associated with any of the above.

Stake alignment of structure as needed at each stage of construction. Stake alignment of poured-in-place items at 10 foot stations or as established by the Engineer. Stake alignment for the following items as needed to maintain the horizontal tolerance defined in Chapter 4.1 of this manual:

- Outside edge of girder(s).
- Face(s) or centerline(s) of internal girders or stem walls.
- Edge of deck.
- Alignment of grade breaks.
- Pedestrian and bicycle facilities.
- Rails and railings.

Stake grades at each stage of construction. Stake grade of poured-in-place items at 10 foot stations, or as established by the Engineer. Apply corrections to design grades based on the dynamics of the evolving structure. Corrections that may be required depend upon the design of the bridge and the construction methods employed. Provide correction values to the Engineer at least 15 working days prior to incorporating into the structure. The following list is examples of possible corrections:

- Design camber (upward adjustment to compensate for anticipated deflection).
- Structural deflection (deflection of the bridge under its own increasing weight).
- Post tensioning lift (upward movement of the bridge under post tensioning forces).
- Structural shifting (dynamics of the bridge under eccentric loading).
- Falsework deflection (deflection of falsework beams under increasing weight).
- Falsework crush (compression of falsework supports under increasing weight).
- Form crush (compression of forms under increasing weight).
- Equipment deflection (deflection of deck finishing machine or deck rails).
- Other adjustments to staked value to achieve the design grade.

5.3.3 Bridge Deck Grades - Set stakes or other devices to control the deck grade elevations. The exact process will depend upon the type of deck and the equipment being used.

5.3.3.1 Portland Cement Concrete Deck - The surveyor and survey crew leader shall attend the first of the two deck pre-placement conferences, described in the Oregon Standard Specifications for Construction, subsection 00540.02(a), required for each deck placement.

Control of a PCC deck may involve significant work with the deck placement crew to establish control for a deck finishing machine. Rails for supporting the deck finishing machine are generally set up on either side of the deck. Each rail is held up by adjustable supports every 5 feet. Adjust the rail at each support to the desired grade while the rail is supporting the weight of the finishing machine. Corrections may need to be applied as listed in Chapter 5.3.2.2 of this manual.

5.3.3.2 Asphaltic Concrete Deck - Control of an AC deck will not generally involve as many variables as PCC. An AC deck serves as a wearing surface, but not a structural component. Asphaltic concrete will frequently be used as filler to create the desired superelevation when flat beams form the superstructure. Stake control of the finish grade like any asphalt finish grade. Under some circumstances, design camber and structural deflection may need to be considered.

5.4 Pavements - Set stakes or other control devices to control the location and elevation of asphalt and PCC pavement as shown. Provide surveying or survey-related activity necessary to control grade, thickness, and smoothness as required.

5.5 Signs, Signals, Illumination and Fabricated Items - Determine the exact location and their relative location to roadway and bridge features as appropriate such as edge of pavement, curbs, islands, sidewalks, sidewalk ramps, lane lines, bridge columns, bridge decks, and other existing features for the following items:

- Posts and poles including foundations.
- Cabinets.
- Junction boxes.
- Detectors.
- Other similar sign, signal, and illumination appurtenances.
- New fabricated items.

Provide the following documentation to the Engineer before submitting working drawings:

- Field verified length of poles, posts, mast arms, and tenon locations.
- Field verified orientation of triangular bases for poles.
- Field verified measurements of all existing features including orientation and relationship to all other new appurtenances and new fabricated items.
- Plan, elevation, and side views.
- Identification of all obstacles.

Field adjustment to the planned location may be required in order to avoid obstacles and to ensure its placement in a functional location. Do not submit working drawings until the Engineer returns the field verified documents. The Engineer will return field verified documents within 21 calendar days after receipt of the documents.

Set a stake referencing the center of the item. Set a guard stake with the following information written on it:

- Description of item (by plan number if applicable).
- Centerline station.
- Centerline offset distance.
- Cut or fill from reference point (and what point the cut or fill is to).
- Intended elevation.

If the orientation of the item is significant and is not clear, establish a reference line for the skew of the item.

Have bridge layout and roadway layout features staked, including referencing, no more than seven calendar days before submitting field verification documents.

CHAPTER 6 - TEMPORARY PROTECTION, PRESERVATION, AND MONUMENTATION

6.1 Temporary Protection and Direction of Traffic - For survey activities outside of the projects traffic control plan and lasting 3 days or less, provide work zone traffic control according to ODOT's "Oregon Temporary Traffic Control Handbook".

For survey activities outside of the projects traffic control plan and lasting longer than 3 days, provide work zone traffic control according to Oregon Standard Specifications for Construction Section 00225.

6.2 Preservation of Survey Markers:

(a) Project Control Points Established by the Engineer - Maintain, relocate or replace existing survey monuments, control points, and stakes, as determined by the Engineer. Perform the work to produce the same level of accuracy as the original monument(s) in a timely manner, and at no additional cost to the Agency.

(b) Monuments of Record - Preserve survey monuments according to the Oregon Standard Specifications for Construction, subsection 00170.82(c), ORS 209.140, and ORS 209.150. If such monuments are to be disturbed or destroyed, comply with requirements of these ORS at no additional cost to the Agency.

6.3 Project Monumentation - The Contractor will not be responsible for performing right-of-way monumentation.

CHAPTER 7 - THE PRE-CONSTRUCTION SURVEY

7.1 Scope - A Pre-Construction Survey is a series of tasks performed by the Agency or its agents just prior to the Contractor starting work on the project.

The purpose of this survey is to:

Verify that the horizontal and vertical control monuments established during the project development phase still exist in their original positions.

Verify that the original ground digital terrain model still represents the terrain.

Recover any record monuments set after the project development record of survey.

If necessary, assist in pre-construction utility relocation work.

7.2 Timing - A Pre-Construction Survey should be conducted by the Agency at, or near, the Bid Letting date to confirm that preparation for construction is complete.

7.3 Tasks - A Pre-Construction Survey consists of the following tasks.

7.3.1 Gather Data

Project plans

Control data – Horizontal and Vertical.

Alignments – Horizontal and Vertical.

Original Ground DTM.

R/W Maps.

Standard Specifications

Special Provision 00305 and 00150.

7.3.2 Check Control

Recover all existing horizontal and vertical control.

Replace and augment control stations as necessary to control the project.

Perform checks of the horizontal control network by measuring arbitrary cross ties. Compare measured values to the record.

Check the vertical control.

7.3.3 Check the DTM

Measure confidence points to validate and check the original ground DTM.

Densify or replace portions of the original ground DTM that have changed.

7.3.4 Search For and Tie New Monuments

Check county records for private surveys conducted along the project corridor since the filed recovery survey.

Tie any new monuments.

File a monumentation recovery survey.

7.3.5 Utility Relocation - If necessary provide field layout of specific roadway features to assist in pre-construction utility relocation work.

7.3.6 Document Results

Write a narrative discussing the results of the Pre-Construction Survey.

Submit narrative to the Engineer.

Submit revised Survey Data Control plan sheet to the Engineer if there are any changes made to survey control.

CHAPTER 8 - LINE AND GRADE VERIFICATION

8.1 General - Grade Verification points are to be collected such that they provide a reasonable record of the grade as constructed. Provide Grade Verification points in the approved file format to the Engineer for analysis. The Engineer may request additional Grade Verification points as needed.

Grade Verification points are to be collected on courses of material where the Agency has provided grade information. Grade Verification points are to be collected at the completion of each course of material. Do not begin placement of the next course of material until the Engineer has evaluated the grade and approval is given to proceed. Additional Grade Verifications as a result of failing reports will be at no additional cost to the Agency.

Grade Verification points are not the same as confidence points nor do they utilize the construction staking tolerances listed in 4.1.

8.1.1 Submittal Format - Grade Verification Points shall be submitted in a file format and manner as directed by the Engineer and agreed upon in the Pre-Survey Conference/Pre-Construction Meeting.

8.2 Collection of Grade Verification Points - Collect Grade Verification points with a Total Station. Alternative survey equipment (GNSS) may be used with approval of The Engineer. The Engineer may require validation of the accuracy of the selected collection method.

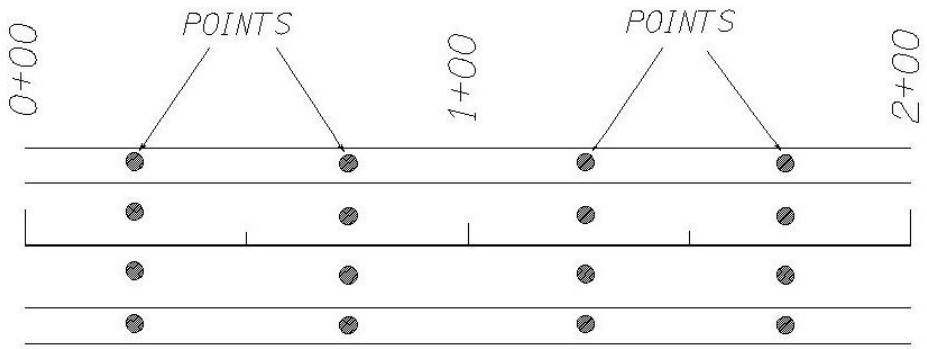
If hubs/stakes are used to control the grade for construction, Grade Verification points shall be taken no closer than 5 feet from any grade control hub/stake.

8.2.1 Outside Subgrade Area - Measure and record Grade Verification points upon completion of trimmed and finished areas outside of the Subgrade area (I.E. ditches, waterway channels, roadbed side slopes, embankment areas and other areas). Location and spacing of these Grade Verification points shall be such that they provide a reasonable record of the constructed surface and placed at a nominal rate of one point for every 1,000 square feet.

On large embankments or slope excavation with limited post construction grading accessibility (due to slope, material, location or any combination), consider the slope area covered by each 10 foot change in vertical elevation as one course of material for Grade Verification purposes only. Submit grade verification points for these 10 foot elevation changes to the Engineer for evaluation before the next 5 foot change in elevation has occurred

8.2.2 Within Subgrade Area - Measure and record Grade Verification points upon completion of each course (subgrade, base, cold plane removal, ACP leveling, ACP and PCC surfaces, or other course of material) and prior to the placement of the next course. Location and spacing of these Grade Verification points shall be such that they provide a reasonable record of the grade as constructed and placed at either a nominal rate of one point for every 500 square feet of grade or placed in a cross section layout with one shot per 10 feet of cross

section width across the grade, spaced at +/- 50 feet along the grade as shown in the example below.



Sample Grade Verification point layout using cross section method on a +/- 40 foot wide section

8.3 Construction Tolerances – In constructing the work, the Contractor shall meet the appropriate construction tolerances for the material as specified in the Contract, regardless of any surveying or staking tolerances, specific to the work item.

8.3.1 Areas with Specified Tolerance values - For areas with specified tolerance values the Contractor shall meet said tolerances when constructing the work.

Specification	Material	Tolerance
00330.70	subgrade	± 0.06’
00344.46	treated subgrade	± 0.06’
00370.40	subgrade	± 0.06’
00640.44	aggregate	± 0.04’
00641.45	aggregate	± 0.04’

2021 Standard Specification Tolerances

The table above is not intended to be an exhaustive list of construction tolerances, nor does it supersede any Specifications, plans, details, etc.

8.3.2 Areas without Specified Tolerance values - For areas outside of the Subgrade area (ditches, side slopes, detention ponds, etc.) with a tolerance specified as “line and grade”, “line, grade, and cross section” or no defined numeric tolerance given by the Specifications, the Engineer will hold work to a tolerance based on the design requirements, material size, construction method, or other factors as determined by the Engineer.

8.4 Evaluation - The Engineer will evaluate the grade using the method described in Chapter 12D of the ODOT Construction Manual or any industry-standard technique or method. The Engineer will verify or reject the grade before the end of the first business day following receipt of the Grade Verification point data. The Contractor may submit an alternate plan due to shift work or similar

circumstance for approval by the Engineer. Do not begin placement of the next course until the Engineer has verified the grade and approval is given to proceed.

CHAPTER 9 – VERTICAL CLEARANCE

9.1 General – Maintaining accurate Vertical Clearance records on ODOT bridges and structures is a critical component in ensuring safe mobility for the traveling public. During construction projects it is critical to document and provide notice of any changes in Vertical Clearance.

Vertical clearance can be affected by changes to the bridge or structure, changes to the roadway surface, or changes to the alignment of the roadway under the bridge or structure.

9.2 Temporary Reduction – When a Project will temporarily restrict any vertical clearances, complete and submit to the Engineer a Temporary Vertical Clearance form (Form No. 734-2614a) 30 days before the restriction takes effect.

9.3 Permanent Reduction - When a Project affects any permanent change to vertical clearances within the traveled way, complete and submit to the Engineer a Standard Vertical Clearance form (Form No. 734-2614) 30 days prior to the actual reduction in vertical clearance.

9.4 Final Vertical Clearance Measurements – Upon completion of Project work that may have affected vertical clearance, the Agency will make the final measurements to confirm that the minimum vertical clearance has been meet per the contract plans. If corrective action is need the Engineer shall notify the contractor.