OHIO DEPARTMENT OF TRANSPORTATION

Survey & Mapping Specifications

Office of Aerial Engineering

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Glossary of Terms

Azimuth Mark: A Type 'A' or Type 'B' project control monument set at the end points of the project for use as a 'backsight' point.

Benchmark: A relatively permanent object, natural or artificial, bearing a marked point whose elevation is above or below a referenced datum with a known published elevation.

Department: The Department of Transportation, State of Ohio.

Differential Leveling: Determining the difference in elevation between two points by the sum of incremental vertical displacements of a graduated rod.

Geodetic Datum:

1. "A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating the coordinates of points on the Earth."
2. "The datum, as defined in (1), together with the coordinate system and the set of all points and lines whose coordinates, lengths, and directions have been determined by measurement or calculation."

Global Navigation Satellite System (GNSS): Any satellite system which can be used to determine a precise location on the surface of the Earth. The US system is known as NAVSTAR Global Positioning System (GPS). The Russian system is known as the Global'naya Navigatsionnaya Sputnikovaya Sistema or GLONASS. The European Space Agency system is known as GALILEO.

Hydrographic Survey: A survey having for its principal purpose the determination of data relating to bodies of water, and which may consist of the determination of one or several of the following classes of data; depth of water and configuration of bottom; directions and force of current; heights, times and water stages; and location of fixed objects for survey and navigation purposes.

Multipath (Multipath Error): The error that results when a reflected GNSS signal is received. When the signal reaches the receiver by two or more different paths, the reflected paths are longer and cause incorrect pseudoranges or carrier phase measurements and subsequent positioning errors. Multipath is mitigated with various preventive antenna designs and filtering algorithms.

Position Dilution of Precision (PDOP): A numerical representation of the predicted accuracy of a geodetic position determined from GNSS satellites. The term represents the quality of the satellite geometry with respect to the receiver location. A PDOP of 3 or less will generally insure accuracy of the highest survey quality.

Real Time Kinematic (RTK) GNSS Survey: A method of determining relative positions between known control and unknown positions using carrier phase measurements. A base station at the known point transmits corrections to the roving receiver offering high accuracy positions in real time.

Right of Way Survey: A survey performed for the purpose of laying out an acceptable route for an easement or right of way for a road, pipeline, utility, or transmission line. This survey would include the establishment of all boundary lines and road crossings along the route.

Static GNSS Survey: A geodetic survey that uses survey grade satellite receivers to collect satellite data on a fixed point requiring post processing to determine position.

Temporary Benchmark: A vertical position transferred from a primary project control monument for use on a specific project.

VRS GNSS Survey: A real time geodetic survey that uses multiple survey grade satellite receivers at surrounding CORS stations to determine an accurate "rover" position. The CORS station data along with the rover location are sent to a remote server where specialized software generates correctors. The correctors are then streamed via various communications technologies to the rover to yield enhanced three dimensional positions. VRS derived positions can be categorized as a "network" solution.

Reference Documents

Ohio Department of Transportation. Real Estate Policies and Procedures Manual: Right of Way Plans. Office of Production. http://www.dot.state.oh.us/drrc/Pages/default.aspx

National Geodetic Survey (NGS). Online Positioning Service (OPUS). http://www.ngs.noaa.gov/OPUS/

Ohio Department of Transportation. Supplemental Specification 823. http://www.dot.state.oh.us/drrc/Pages/default.aspx

100 Introduction

101 Purpose

These requirements and specifications have been developed for all surveying and mapping work performed for The Ohio Department of Transportation. This document is neither a textbook nor a substitute for knowledge, experience, or judgment. It is intended to provide uniform procedures for surveying and mapping to assure quality and continuity in the design and construction of the transportation infrastructure within Ohio. Ensure all work is in accordance with *O.A.C. 4733* & *O.R.C. 4733*.

102 Audience

This document is intended for use by anyone performing surveying and/or mapping for The Ohio Department of Transportation.

103 Scope of Work

Ensure the District Survey Operations Manager is consulted during the scoping of projects that involve surveying and mapping. The Department will provide a scope of work document outlining the surveying and mapping work to be performed.

200 Safety

201 General

Ensure safe practices are utilized while performing all surveying and mapping work for ODOT. Follow safe practices according to **Standard Procedure 220-006(SP) Ohio Department of Transportation Safety & Health Standard Operating Procedure**.

202 Public Utilities

In accordance with Ohio Revised Code 3781.25 to 3781.32, everyone must contact the Ohio Utilities Protection Service (OUPS), 1-800-362-2764 or 8-1-1, at least 48 hours but no more than 10 working days (excluding weekends and legal holidays) before beginning any excavation work or driving of pins. For more information, visit www.oups.org.

203 Traffic Control

Ensure safe standards are followed according to the *Ohio Manual of Uniform Traffic Control Devices (OMUTCD), Part 6. Temporary Traffic Control*.

204 Construction Site Safety

Ensure safe practices are followed according to *Federal Occupational Safety & Health Standards 29CFR1926, et seq.*

205 Confined Space Entry

Ensure safe practices are followed for confined space entry according to *Federal Occupational Safety & Health Standards 29CFR1910.146 Permit-required confined spaces* and the Ohio Department of Transportation Culvert Management Manual.

300 Datums, Coordinate Systems, and Positioning Parameters

Ensure all project control and mapping performed for ODOT meets the following positioning parameters unless otherwise directed by the District Survey Operations Manager.

301 Vertical Positioning

Furnish vertical positions using the following:

A. Orthometric Height Datum – NAVD88
B. Geoid Model – GEOID09

For purposes of this document, the term "elevation" refers to the orthometric height.

302 Horizontal Positioning

Furnish horizontal positions using the following:

A. Coordinate System – Ohio State Plane:
    1. North or South Zone as appropriate
    2. Combined Scale Factor from ground to grid as appropriate (Refer to Section 502.2 M)
        i. Use 0,0 for the origin of the coordinate system
B. Map Projection – Lambert Conformal Conic
C. Reference Frame – NAD83(CORS96)
D. Ellipsoid – GRS80

400 Units of Measurement

401 Distance

Furnish units in U.S. Survey Feet. Use the following conversion factor: 1 meter = 3.280833333 U.S. survey feet. Provide distances to the nearest hundredth (i.e. 0.01) of a foot.

402 Angles

Furnish angles in degrees-minutes-seconds to the nearest second (i.e. $01^{o}01'01''$).

403 Direction

Furnish directions as bearings in degrees-minutes-seconds to the nearest second (i.e. N $01^{o}01'01''$ E).

404 Area

Furnish units in square feet to the nearest square foot, in acres to the nearest thousandth (i.e. 0.001) of an acre.

405 Volume

Furnish volumes to the nearest cubic yard unless otherwise stated.

406 Horizontal Coordinates

Furnish all horizontal coordinates in northing and easting to the nearest thousandth (i.e. 0.001) of a U.S. survey foot. Report Primary Project Control in both U.S. survey feet and meters to the nearest ten-thousandth (i.e. 0.0001) of a meter.

407 Elevation/Orthometric height

Furnish units in U.S. survey feet to the nearest hundredth (i.e. 0.01) of a foot.

500 Types of Surveys

501 General

The following survey types are those most commonly performed by ODOT. There are specialty surveys which may not fall into these categories. The requirements for these specialty surveys will be determined on a project-by-project basis and implemented through the scope of services.

501.1 Property Owner Notification of Entry

Survey crews performing work for the Department are granted access to private land per *O.R.C.163.03* & *O.R.C. 5517.01*. Property owner notification is required at least 48 hours in advance. A standard property owner notification form is included in Appendix G. Both ODOT and consultant surveyors are responsible for any damage to the property of others incurred during the process of their work. Should any damages occur; the survey crew chief will document the damage and deliver a report to the District.

502 Control Surveys

502.1 General

Control Surveys consist of establishing positions (northings, eastings, and elevations) on strategically located monuments to govern all survey work that follows.

502.2 Project Control

A. General

Position all monuments in accordance with this specification. Previously established monuments may be used if those monuments were constructed, positioned, and checked according to this specification. Ensure existing monuments are in good repair and stable.

B. Primary Project Control

Primary Project Control will govern the positioning for all ODOT projects. After establishing the coordinates for primary project control, ensure all survey work is adjusted relative to the established control monuments.

C. Primary Project Control Type

Primary Project Control consists of two available monument types and two positioning methods. Use one of the following monument types and positioning methods unless otherwise specified by the Department:

*Monument Type	Monument Controls	**Project Category	***Positioning Methods
A	Horizontal &Vertical	Major	Static GNSS
B	Horizontal with a Separate Temporary Benchmark	Minor and Minimal	++Static GNSS or ODOT VRS

* If site geology or site conditions do not permit placement of the monument, contact the District Survey Operations Manager.

** Project Category is defined in the Project Development Process Manual.

*** Contact the District Survey Operations Manager if GNSS positioning is not feasible due to site conditions.

++ Use only one positioning method for project control on a single project. Do not combine Static GNSS and ODOT VRS for project control.

D. Primary Project Control Monuments

Construct primary project control monuments flush to the ground according to details shown in appendix H. Locate primary project control monuments inside the public right-of-way, within the vicinity of the project, and outside of the construction work limits. Contact the District Survey Operations Manager if placement is not possible as noted above. Placement of primary project control monuments are dependent upon the project length. Furnish primary project control monuments per the following table:

Primary Project Control Monument Placement					
Project Length	**Beginning & End of Alignment**	**Approx. Interval Distance along Alignment**	**At locations Specified by District**	**Minimum # of Monuments Required**	**Minimum # of Azimuth Marks**
< 1mile			x	1	1
≥1mile	X	1 mile	x	2	2

Establish a Type A azimuth mark for the Type A primary project control monuments at the beginning and end of the project. Use a cap identifying the point as "azimuth mark" in accordance with details shown in appendix H. Place the azimuth mark a minimum distance of 500 feet from the primary project control monument. Determine the horizontal and vertical position of the azimuth mark using the same positioning method, coordinate statistical analysis, and coordinate determination as the primary project control monuments. Ensure there is a clear line of sight from the primary project control monument to the azimuth mark. Contact the District Survey Operations Manager if the distance of 500 feet is not feasible due to site characteristics.

Establish a Type B azimuth mark for the Type B primary project control monuments at the beginning and end of the project. Determine the horizontal position of the azimuth mark using the same positioning method, coordinate statistical analysis, and coordinate determination as the primary project control monument. Each Type B primary project control monument will have a corresponding temporary benchmark, except Type B azimuth marks. Ensure temporary benchmarks are of a stable and permanent nature. Locate temporary benchmarks within a clear line of sight to the primary project control monument, outside of construction areas, clear of traffic, and within a public right of way or easement. Transfer the elevation of the Type B primary project control monument to the temporary benchmark using differential leveling in accordance with Section 502.4. Determine the vertical difference between the primary project control monument and the temporary benchmark within 3 days of the last GNSS observation on the primary project control monument. Contact the District Survey Operations Manager if the distance of 500 feet is not feasible due to site characteristics.

Ensure primary project control monuments are placed to have a clear view of the sky and to reduce the potential for GNSS multipath signals.

E. Survey Equipment

Use survey grade GNSS receivers and antennas in accordance with Section 600.

F. Static GNSS Data Collection

Collect a minimum of 3 sessions of static GNSS data consisting of at least 4 hours per session for each primary project control monument. Ensure the survey equipment is removed and reinstalled over the monument between sessions. Ensure proper GNSS survey planning to achieve the required data quality as outlined in this specification. Consider the following when planning the GNSS survey: positional dilution of precision (PDOP), number of satellites, mask angle, collection rate, multipath, solar activity, etcetera.

G. Static GNSS Data Processing

Process the collected data to determine the Northing, Easting, and Elevation (Orthometric Height) for each session using National Geodetic Survey's OPUS (Online Positioning User Service). Use the rapid or precise ephemeris only. Ensure the correct antenna height, make, and model are utilized. Use the same three base stations when processing a primary project control point in OPUS. The user must manually select the base stations to be used in the OPUS processing.

H. ODOT VRS Data Collection

Collect the Northing, Easting, and Elevation coordinates using 5 second observations at a 1 second epoch rate. Collect a minimum of 5 observations for each project control monument. *Note: More than 5 observations may be required to meet the minimum RMSE requirements specified below.* Ensure the survey equipment is removed and reinstalled over the monument between sessions. Consider the following when planning and performing VRS surveys: positional dilution of precision (PDOP), number of satellites, mask angle, multipath, solar activity, etcetera.

I. Coordinate Statistical Analysis

1. Calculate the Root Mean Square Error (RMSE) for each coordinate component (Northing, Easting, and Elevation) at each primary project control monument using the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} [Average_i - Check_i]^2}{N}}$$

$Average_i$ = Average position of the Northing, Easting, or Elevation value at a primary project control monument

$Check_i$ = Northing, Easting, or Elevation value from each individual GNSS static session at a project control monument or ODOT VRS observation at a primary project control monument

N = Number of sessions at a primary project control monument

An example calculation is included in Appendix D.

2. Ensure the RMSE for the Northing, Easting, and Elevation components do not exceed the maximum allowable RMSE for all project control monuments according to the following:

Coordinate Component	Maximum Allowable RMSE
Northing	0.029 feet [0.0088 meters]
Easting	0.029 feet [0.0088 meters]
Elevation	0.039 feet [0.0119 meters]

3. Perform additional observations as required to meet the maximum allowable RMSE. Any combination of observations may be used to achieve the required RMSE, provided all coordinate components (Northing, Easting, and Elevation) are used in the solution.

J. Primary Project Control Monument Horizontal Coordinates

The Northing and Easting primary project control monument coordinates are determined by taking the average of each coordinate component from the OPUS or ODOT VRS solutions that meet the RMSE requirements as specified in Section 502.2 I.

K. Primary Project Control Monument Vertical Coordinates

Establish the elevations of primary project control monuments or their associated temporary bench marks by differential leveling. Refer to section 502.4 for leveling procedures. Differential leveling for primary project control monuments and temporary bench marks will originate from, and close on, the primary project control monument closest to the center of the project.

Hold the elevation calculated from the vertical component of the OPUS or ODOT VRS solutions for the primary project control monument closest to the center of the project. Ensure the elevations for the primary control monument meet the RMSE requirements as specified in Section 502.2 I. As a check, compare the leveled elevations to the GNSS determined elevations from Section 502.2 I. Highlight any differences that exceed 0.10 U.S. Survey Foot and contact the District Survey Operations Manager immediately to determine a course of action prior to performing any additional work.

L. Secondary and Temporary Project Control

Secondary and Temporary project control for surveying or construction purposes are to be positioned relative to the primary project control. Establish a monument type sufficient to ensure stability for the anticipated duration of project or task to be performed. Establish secondary and temporary project control at an accuracy to ensure conformance to the project plans.

M. Project Scale Factor

If a project scale factor is required, use the following method for establishing the combined scale factor:

1. If Static GNSS is used to determine the positions for primary project control monuments, use the average of the OPUS calculated combined scale factors for the monument closest to the center of the project. Ensure the scale factor is calculated from OPUS solutions that meet the RMSE requirements. Scale the project about the origin of the coordinate system (0,0).
2. If VRS is used to position primary project control monuments, perform a 20 minute static observation on the monument closest to the center of the project. Submit the static session to OPUS-RS to obtain the combined scale factor. Scale the project about the origin of the coordinate system (0,0) using the combined scale factor. Ensure coordinates and elevations obtained from OPUS-RS are not utilized.

N. Deliverables

Furnish the following deliverables:

1. Surveyor's Certification Statement. A standard form is included in Appendix F.
2. A table that includes primary project control coordinates and azimuth mark coordinates. Include the following in the table:
   a. Point Number
   b. Point Description
   c. Monument Type
   d. Positioning Method
   e. Grid Coordinates
      a. Northing (meters)
      b. Easting (meters)
   f. If applicable, Scaled Coordinates
      a. Northing (U.S. survey feet)
      b. Easting (U.S. survey feet)
   g. If applicable, the Project Combined Scale Factor and associated monument
   h. Type A primary project control orthometric heights (U.S. survey feet)
   i. Temporary Benchmark number, description, and orthometric height listed with each Type B primary control monument
3. NGS OPUS data sheets if used in the solutions
4. NGS OPUS-RS data sheets if used to obtain a scale factor
5. Statistical analysis for each primary project control monument and azimuth mark(s). (See example, Appendix D)
6. Native survey data files in Trimble RAW or RINEX 2.0 format

7. A general map of the entire project with the project control monuments identified in PDF, MicroStation (version according to ODOT CADD Engineering Standards Manual), or any standard raster format
8. All field notes, sketches, and adjustment calculations
9. All differential leveling deliverables as specified in Section 502.4 F.
10. Documentation confirming the calibration of all survey equipment used.

Ensure all deliverables are on the same datum and coordinate system as specified in Section 300. Furnish deliverables to the District Survey Operations Manager prior to performing any additional work indicated in this specification. Allow 10 working days for review. Consultant may proceed at their own discretion if comments are not received. A licensed Professional Surveyor registered in the State of Ohio will sign, seal, and certify that all work performed meets or exceeds the requirements of this specification for primary project control.

502.3 Aerial Photo Control

A. General

Aerial photo control is used to georeference images produced from aerial photography. Ensure adequate aerial photo control is used to correctly position images and subsequent products relative to the primary project control. Ensure the required DTM and Planimetric Accuracy Classes are met.

B. Aerial Targets

Place aerial targets at locations easily identified in aerial photographs. When possible, place all targets within the public right-of-way. Obtain permission prior to placing targets on private property.

The preferred target for aerial photography is a 4 foot by 4 foot cross, 8 inches in width. Use white thermoplastic material thoroughly adhered to the pavement. Other target sizes, shapes, or material may be utilized provided they are clearly visible in aerial photographs. Furnish a PK nail driven flush to the ground at the center of the target.

Use a temporary cloth aerial target for non-pavement applications. Ensure the surface is relatively level. Pull the cloth target tight and securely stake the target to the ground.

C. Picture Points

Furnish picture point positions if aerial targets are not utilized. Select picture points that can easily be identified on the aerial photographs. Ensure the selected position is not obscured by shadows or directly adjacent to an object extending above the ground by more than 6 inches. Acceptable picture points include, but are not limited to the following:

1. Sidewalk corners
2. Stop bar pavement markings
3. Tip of pavement marking arrows
4. Concrete pad corners
5. Parking lot pavement markings
6. Top of grate corner for catch basins

Furnish a sketch of each picture point feature. Indicate the location of the surveyed point on the sketch.

D. Aerial Photo Control Surveys

Collect coordinates and elevations at the center of the cross (aerial target) or at the selected picture point. Ensure all photo control is positioned relative to the primary project control. Document the survey procedures and methods used.

E. Survey Feature Codes

Use the following survey feature codes when collecting aerial photo control:

Description	Feature Code
Aerial Target	AERTAR
Aerial Target - Picture Point	AERPP

502.4 Differential Leveling

A. General

Perform differential leveling to determine the orthometric height of primary project control monuments, temporary benchmarks, and other benchmarks. Differential leveling may also be performed to establish elevations of secondary and temporary control points as needed.

B. Temporary Benchmarks

Construct temporary benchmarks in conjunction with Type B primary project control monuments. Construct temporary benchmarks as required to complete project related tasks or where dictated by the District Survey Operations Manager. Ensure temporary benchmarks are of a stable nature. Furnish temporary benchmarks that are easily accessible, located outside of anticipated construction areas, clear of traffic, and within a public right of way or easement. Include a list of temporary benchmarks with the deliverables. Ensure station/offset and descriptions are included. Commence and close all leveling for temporary benchmarks from an established primary control point monument.

C. Differential Leveling Surveys

Complete leveling surveys to an accuracy required in this specification. Higher accuracy leveling may be required for certain projects or when specified by the District Survey Operations Manager. Ensure proper leveling procedures are followed to obtain the required accuracy. Consider balancing foresights and backsights, sight length limitations, and multiple rod readings to increase accuracy as needed. Use equipment meeting Section 600.

D. Closure Requirements

The maximum allowable misclosure for all level loops is defined by the following equation:

$$\textbf{0.04 feet} \times (\sqrt{E})$$

E = Length of loop in miles (loop is defined as a series of setups closing on the starting point).

Re-level all level loops whose misclosure exceeds this closure requirement.

E. Leveling adjustments

Adjust level loop misclosures that fall within given closure requirements. Corrections for the closing error will be prorated equally to each turning point and benchmark between the controlling monument(s) for the length of the level loop.

F. Deliverables

1. Surveyor’s Certification Statement

2. Report of all primary project control, andtemporary benchmark elevations established. Include the following as a minimum: point name, elevation, description of the mark and a sketch defining its location
3. Field notes for all leveling work
4. Listing of all field crew members/titles
5. Details of misclosures, calculations and adjustments
6. Make, model, serial numbers and firmware versions of all equipment used
7. Post-processing software used with version number (where applicable)
8. A spreadsheet showing the differences between leveled and GNSS derived elevations for all Type A primary project control monuments or temporary bench marks for Type B monuments.
9. Documentation confirming the calibration of applicable survey equipment used.

503 Boundary Surveys

503.1 General

ODOT surveying and mapping projects may require the location, retracement and establishment of boundaries including: private and public properties, federal, state, county and municipal boundaries, public land subdivisions, highway alignments, easements, etcetera. Ensure all ODOT boundary surveys originate from monumentation constructed and/or positioned according to this specification. Ensure conformance to all county, municipal and jurisdictional survey requirements for the project location. Complete all boundary work in accordance to O.A.C. 4733 & O.R.C. 4733 and the ODOT Right-of-Way Plan Manual.

503.2 Property Surveys

Property surveys are required for all parcels that may be legally affected, altered or transferred, either temporarily or permanently, as part of an ODOT project. Refer to the project scope of services or the District Survey Operations Manager for further project specific information.

503.3 Right of Way & Highway Centerline Surveys

All Right-of-Way and Highway Centerline surveys are governed by the Ohio Department of Transportation Right-of-Way Plan Manual, Sections 3103 and 3104.

504 Mapping Surveys

504.1 General

A mapping survey is the collection of points to define the features (natural, man-made, or both) of a physical surface. Examples may include topographic surveys, bridge surveys, hydrographic surveys, etcetera.

504.2 Topographic Surveys

A topographic survey is the collection of points and attributes to define the shape of the Earth's surface, including natural and man-made features.

A. Digital Terrain Model (DTM)

This specification covers Digital Terrain Models (DTMs) provided for ODOT projects. Ensure all deliverables use the same datum, coordinate system, and units specified in Sections 300 & 400, respectively. Ensure positioning is performed relative to primary project control.

B. Definitions

Use the following definitions:

1. Survey Points – 3-dimensional positions collected with traditional ground surveying, Real Time Kinematic GNSS surveying, Static GNSS, Photogrammetry, or Light Detection and Ranging (LiDAR). Survey Points are used to create the Triangulated Irregular Network (TIN).
2. Check Points – 3-dimensional positions obtained independently of Survey Points by traditional ground surveying, Real Time Kinematic GNSS surveying or Static GNSS. Check Points are used to verify the vertical accuracy of the TIN.
3. Dz – Mathematical difference between elevations from the Check Points and elevations produced from the TIN at the same horizontal location.
4. Root Mean Square Error (RMSE) – Mathematical calculation that is used to describe the vertical mapping accuracy encompassing both random and systematic errors.
5. DTM Accuracy Class – A specific area within the mapping limits that has an assigned maximum allowable Dz and RMSE. The number of areas and the DTM accuracy class for each area is assigned by the District Survey Operations Manager.

The following accuracy classes are used in this specification:

DTM Accuracy Class	Recommended Use	Maximum Allowable Average Dz (feet)	Maximum Allowable RMSE (feet)
Class A	Paved areas	± 0.07	0.16
Class B	Vegetated areas outside of pavement that are maintained at a minimum biannual frequency (i.e.: farm fields, residential yards, roadside R/W, etcetera)	± 0.25	0.32
Class C	Vegetated areas that are not maintained	± 0.50	0.50
Class D	Areas where vertical accuracy is not critical or warranted (i.e.: planning engineering projects)	± 1.00	1.00

C. Triangulated Irregular Network (TIN)

Create a TIN using Survey Points to obtain a DTM that meets the required Average Dz and RMSE for each DTM accuracy class. Ensure a sufficient number of Survey Points and break lines are collected to meet the required DTM Accuracy Class specified by the Department for each project. Remove vegetation, buildings, bridges, and other points that do not represent the ground. Ensure voids are placed within the TIN to prevent triangulation through water bodies and bridges. The TIN may be adjusted vertically to ensure it meets the maximum allowable average Dz for the DTM accuracy class of the paved roadway surface. Ensure the vertical adjustment is applied uniformly to the entire DTM.

D. Vertical TIN Accuracy Testing Procedure

Collect Check Points per the following:

1. Collect cross sections perpendicular to the roadway alignment from proposed Right-of-Way to proposed Right-of-Way near the beginning and end of the alignment(s) and at an interval of approximately every 1 mile. Ensure the cross sections have sufficient points to clearly define the existing surface.
2. Collect a profile that is parallel to the roadway alignment along the painted pavement edge line for a minimum distance of 100 feet with Check Points spaced at approximately 5-foot intervals at each cross section area collected above.
3. Collect additional Check Points at locations specified by the District Survey Operations Manager.

Perform an RMSE calculation using the elevation values of the Check Points and the TIN at the same horizontal location for each area of accuracy class. Use all Check Points in the RMSE calculation for each area of accuracy class. Major errors or blunders in the Check Points may be eliminated if the rationale is well documented and submitted in the deliverables. Calculate the RMSE with the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} [Checkpoint_i - TinElevation_i]^2}{N}}$$

$TinElevation_i$ = Elevation generated from the ground surface TIN (feet).

$CheckPoint_i$ = Elevation value from the Check Point (feet)

N = Total number of Check Points for each accuracy class area. Ensure enough Check Points are collected to represent different terrain and vegetation conditions for statistical validity.

An example calculation is included in Appendix B.

The Department may collect Check Points for an independent verification of the TIN anywhere within the project. Check Point locations will be determined by the Department. If the Department finds any area of the TIN to exceed the Maximum Allowable Average Dz or the Maximum Allowable RMSE for the specified DTM Accuracy Class, the consultant will perform any corrective work necessary to meet this specification at no additional cost to the Department within a time frame agreed upon by the Department and the consultant.

E. Deliverables

Furnish deliverables to the District Survey Operations Manager prior to performing any engineering design work. Deliverables may be sent in combination with Section 504.3 deliverables. Allow 10 working days for review. Consultant may proceed at their own discretion if comments are not received. Ensure all CADD drawings conform to the ODOT CADD Engineering Standards Manual and are in units of U.S. survey feet. Ensure finished products use the same datum and coordinate system of Section 300.

Include the following deliverables as applicable:

1. Completed quality control report (example shown in Appendix C).
2. Identify all Check Points that were omitted in the analysis and the rationale for their removal.
3. GNSS/INS system lever arms for any airborne sensors utilized for the digital mapping.
4. Flight Log for any airborne sensors. Include the following information:
    a. GNSS Base Station(s) used
    b. Date of flight
    c. Flight Altitude (AGL)
    d. Aircraft make and model
    e. Weather conditions
    f. Crew
5. DTM for existing ground in GEOPAK Binary TIN format including any breaklines collected. Ensure individual files are less than or equal to 130MB in size.
6. Aerotriangulation solution if applicable to the method of Survey Point collection.
7. Classified LiDAR Point Cloud in a LAS format if applicable to the data collection methodology.
8. A MicroStation (version according to ODOT CADD Engineering Standards Manual) CADD drawing of the entire project that includes the triangles of the existing TIN, and the location of all Survey and Check Points. Include contours at a 1 foot interval.
    a. Ensure there is a title block that contains the following items:
        a. North Arrow
        b. Project Name
        c. Project PID
        d. Delivered Date
        e. Date of raw data collection (LiDAR, Photogrammetry, etc.)
        f. Coordinate System
        g. Datum
        h. Mapping Projection
        i. Geoid
        j. Combined Scale Factor
        k. Units (US Survey Feet)
9. Documentation confirming the calibration of all survey equipment used.

504.3 Planimetric Features

A. Description

This specification covers collection of existing planimetric features and all known underground utilities. Aerial orthophotos are included with this specification and may be required in the scope of services. Ensure all deliverables use the same datum, coordinate system, and units specified in Sections 300 & 400, respectively. Ensure positioning is performed relative to primary project control.

B. Definitions

For the purposes of this specification use the following definitions:

1. Planimetric Features – Existing 2-dimensional features collected with traditional ground surveying, Real Time Kinematic GNSS surveying, or Photogrammetry for use in engineering projects (example: existing pavement edge line).
2. Planimetric Check Points – 2-dimensional positions that are obtained independently of the planimetric feature data collection. Use traditional ground surveying or Real Time Kinematic GNSS surveying.
3. Planimetric Accuracy Class – The required horizontal accuracy for all existing planimetric features in the mapping. The mapping is assigned an accuracy class by the District Survey Operations Manager.

   The planimetric accuracy classes with the corresponding maximum allowable RMSE are provided below:

Planimetric Accuracy Class	Recommended Use	Maximum Allowable RMSE (ft)
Class I	Projects that require Class I planimetric features listed in Appendix A to be identified and mapped (ie: design engineering projects)	0.30
Class II	Projects that require Class II planimetric features listed in Appendix A to be identified and mapped (ie: planning studies)	1.00

C. Horizontal Planimetric Feature Accuracy Testing Procedure

Use the following procedure to test the horizontal planimetric features (see Appendix B for an example):

1. Collect Planimetric Check Points along well defined planimetric features shown in the delivered mapping. Check points collected for the vertical DTM accuracy test may be utilized if they are on a planimetric feature (example: painted edge line). Collect Planimetric Check Points at each of the following locations:
   a. Near the beginning of the roadway alignment(s).
   b. Near the ending of the roadway alignment(s).
   c. At an interval of approximately 1 mile along the roadway alignment(s).
   d. At locations specified by the District Survey Operations Manager.
2. Measure the Northing and Easting distances to the Planimetric Check Point using a perpendicular line from the planimetric feature to the Planimetric Check Point.
3. Perform an RMSE calculation using the Northing and Easting distance values. Use all Planimetric Check Points in the RMSE calculation. Major errors or blunders in the Planimetric Check Points may be eliminated if the rationale is well documented and submitted in the deliverables. Calculate the RMSE for both the Northing and Easting directions with the following equations:

$$RMSE\ Northing = \sqrt{\frac{\sum_{i=1}^{N} [NorthingDist]^2}{N}} \qquad RMSE\ Easting = \sqrt{\frac{\sum_{i=1}^{N} [EastingDist]^2}{N}}$$

NorthingDist = Distance in the Northing direction for a line drawn perpendicular from the planimetric feature to the Planimetric Check Point (feet).

EastingDist = Distance in the Easting direction for a line drawn perpendicular from the planimetric feature to the Planimetric Check Point (feet).

N = Number of Planimetric Check Points used in analysis. Ensure sufficient Planimetric Check Points are collected to represent different terrain conditions for statistical validity. An example calculation is included in Appendix B.

The Department may collect Planimetric Check Points for an independent verification of the planimetric feature accuracies anywhere within the project. If the Department finds any planimetrics that exceed the maximum allowable RMSE, the Consultant will perform any corrective work necessary to meet this specification at no additional cost to the Department within a time frame agreed upon by the Department and the Consultant.

D. Orthophoto

Create an orthorectified image using a digital terrain model. Ensure the orthophoto is color, free of visible image smear, free of noticeable seam lines, free of artifacts, has a uniform tone and brightness, and is free of misalignment errors. Furnish an orthophoto that is rectified to the ground and bridge deck surfaces. "True orthophotos" of buildings, utilities, or other items (exclusive of bridge deck surfaces) that are 4 feet or more above the existing ground surface are not required. Ensure the pixel size of the orthophoto is less than or equal to 6 inches and the file size is less than 400MB.

E. Deliverables

Furnish deliverables to the District Survey Operations Manager prior to performing any engineering design work. Deliverables may be sent in combination with Section 504.2 deliverables. Allow 10 working days for review. Consultant may proceed at their own discretion if comments are not received. Ensure all CADD drawings conform to the ODOT CADD Engineering Standards Manual and are in units of U.S. survey feet. Ensure finished products use the same datum and coordinate system of section 300.

Include the following as applicable:

1. Completed quality control report (example shown in Appendix C).
2. Boresight alignment calibration parameters for any airborne sensors utilized for mapping.
3. Camera calibration certificate if a camera sensor was utilized.
4. Film negatives if a film camera was utilized
5. Individual processed digital images if a digital camera was utilized
6. GNSS/INS system lever arms for any airborne sensors utilized for the digital mapping.
7. Flight Log for any airborne sensors with the following information:
   a. GNSS Base Station Used.
   b. Date of flight.
   c. Height AGL.
   d. Aircraft make and model.
   e. Weather conditions.
   f. Crew.
8. Aerotriangulation solution if applicable to the method of planimetric feature collection.
9. List of all underground utilities that were notified. Include contact names, telephone numbers, and addresses.
10. Include sketches of underground utility structures. Indicate conduit type, size, invert elevations, and direction of flow (if applicable) in the sketch.
11. Georeferenced Orthophoto in a TIFF format.
12. A Microstation CADD (version according to ODOT CADD Engineering Standards Manual) drawing of the entire project that includes planimetric features and planimetric check points. Use a scale of 1 to 1 with the model annotation scale for existing planimetric features set at 1 inch=50 feet. Ensure the planimetric features use the same datum and coordinate system of section 300. Include all planimetrics required for the specified planimetric accuracy class (see appendix A). Ensure there is a block that contains the following items:
    a. North Arrow
    b. Project Name
    c. Project PID
    d. Delivered Date

e. Date of raw data collection (Lidar, Photogrammetry, etc.)
f. Coordinate System
g. Datum
h. Mapping Projection
i. Geoid
j. Combined Scale Factor
k. Units (US Survey Feet)

13. Documentation confirming the calibration of all survey equipment used.

504.4 Bridge

Bridge survey information is dependent upon the structure type and anticipated type of work. The Project Engineer should direct the survey crew in accordance to the needs of the project. Typical items included in a bridge survey may include one or more of the following: bearing seat elevations, dimension and shape of piers, profile of crown of pavement on bridge deck, profile of edge of pavement along bridge deck, profile of crown of pavement and both edges of pavement leading up to and away from bridge, bottom of beam profile for all beams, distance between the backwall and the edge of all beams, vertical clearance at crown of pavement, and all painted edge lines or changes in section grade.

Additional items may be required if the bridge spans a water course, such as: The Ordinary High Water Mark (OHWM), cross sections of the watercourse upstream and downstream, or the watercourse bottom measured radially from each pier.

Ensure all profiles include sufficient survey density to accurately depict each item. Include the coordinate location and orthometric height of all surveyed items.

504.5 Hydrographic

Hydrographic surveys may be required for particular projects that require information such as: depth of water, topography of the bottom, direction of currents, and locations of fixed objects. This type of survey is unique and requires the combination of various surveying technologies to perform. Contact the District if this type of survey is required.

505 Construction

505.1 General

Construction surveys are performed in order to construct the project in accordance with the plans. Regardless of the methodology for constructing the project, a minimum amount of construction staking must be furnished for the Department to verify conformance to the design plans.

505.2 Construction Staking

Staking along the mainline is covered under Supplemental Specification 823. Staking at other significant items such as structures, utilities, earthwork, etc. is required throughout the project at sufficient density to ensure the Department can verify the work performed by the Contractor. Contact the Project Engineer to ensure adequate construction staking is furnished.

Furnish all staking information to the Project Engineer. Include the following staking information for points established: station with offset and direction, feature description, elevation, cut/fill, and any other information as requested by the Project Engineer.

505.3 Machine Control

The construction industry continues to develop innovative equipment and methodologies that allow the use of "machine control" to improve performance and productivity. Machine control is typically defined as the automatic control of a machine or portions of a machine to achieve the desired results. Operations involving machine control may be based on one or more of a variety of technologies such as rotating lasers, total stations, proximity sensors, GNSS, INS, etcetera. If a contractor elects to use any type of machine control, they are responsible to ensure that the selected technology and operations meet the project requirements. The contractor will not be granted an extension to the completion date (intermediate or final) due to machine control related issues or problems.

600 Survey Equipment

601 Equipment Care and Maintenance

Proper handling and servicing of all surveying equipment is essential to achieving the accuracy and precision required for ODOT projects. Careful handling of high accuracy instrumentation such as total stations, levels, GNSS receivers and other components is critical. Replace or repair broken, faulty, or inaccurate equipment prior to performing ODOT survey work.

602 Equipment Types and Specifications

602.1 Levels

Optical and digital levels are acceptable for leveling operations. Leveling rods are to be single section or multi-section fiberglass, wood, or metal. Leveling instruments are required to meet the following minimum manufacturer specifications:

1. Internal compensator/auto-level.
2. Height accuracy of ± 1.5mm standard deviation for 1km double run leveling.

602.2 Total Stations

Total Stations are to be capable of measuring horizontal angles, vertical angles and distances electronically in a single unit. Total stations are required to meet the following minimum manufacturer specifications:

1. Compensated with a dual axis compensator.
2. Horizontal and vertical angular accuracy of 5 seconds.
3. EDM accuracy of ±(3mm + 3ppm) to a reflective prism.

602.3 GNSS Receivers

GNSS receivers are to be survey grade units and are required to meet the following minimum specifications as provided by the manufacturer:

1. Capable of tracking L1 and L2 frequency signals.
2. Static positioning accuracy of 5mm+1ppm horizontal/6mm+1ppm vertical (post processed).
3. Kinematic positioning accuracy of 10mm+1ppm horizontal/20mm+1ppm vertical.

603 Equipment Calibration and Maintenance

Ensure all surveying equipment is calibrated and adjusted in accordance with the manufacturer's recommendations. Documentation of all equipment adjustments and calibrations shall be kept and made available to ODOT upon request. Refer to the following criteria as a minimum for equipment maintenance:

603.1 Levels

Ensure professional calibration and servicing is performed per the manufacturer's specifications.

In addition, perform maintenance and care according to the following schedule:

<u>Every 3 Months:</u>

1. Clean and inspect optics, electrical contacts, instrument body, and instrument case
2. Check and adjust level vials
3. Peg test the level and adjust as needed

603.2 Total Stations

Ensure professional calibration and servicing is performed per the manufacturer's specifications.

In addition, perform maintenance and care according to the following schedule:

<u>Every 3 Months:</u>

1. Clean and inspect optics, electrical contacts, instrument body, and instrument case
2. Check and adjust level vials
3. Check and adjust vertical plummet
4. Check horizontal and vertical circle collimation and adjust as needed

<u>Every 6 Months:</u>

1. Check calibration of E.D.M. on a baseline and adjust as needed

603.3 Tripods, Tribrachs, Prism Rods, and RTK Rods

Perform maintenance and care according to the following schedule:

<u>Every 3 Months:</u>

1. Clean and inspect
2. Adjust level vials
3. Adjust the optical plummet
4. Tighten all clamps, locks, feet and screws to the proper specification

Appendix A –Planimetric Collection

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Planimetric accuracy Class I projects require more detail than planimetric accuracy Class II projects. Include the following planimetric features according to the accuracy class specified by the Scope of Work:

Class I Planimetric Features

1. Edge of pavement (ie: paint line)
2. Edge of treated shoulder
3. Edge of graded shoulder
4. Driveways
5. Bikeways
6. Parking Lots
7. Bridge Deck
8. Streams, Rivers, Ponds, Lakes, Wetlands
9. Sidewalks
10. Highway barriers
11. Walls (retaining, headwalls, etc.)
12. Buildings
13. Utilities
    a. Power Poles
    b. Manholes
    c. Light Pole
    d. Telecommunication poles
    e. Unknown poles
    f. Fire Hydrants
    g. Catch Basins
    h. Underground utilities from field collection
14. Traffic Signs (specify number of posts, sign size, and sign message in survey notes)
15. Above Ground Tanks (oil/gas)
16. Large piles (junk yard, stockpiles of material, etc.)
17. Above Ground Pumps
18. Mailbox (specify number of mailboxes in survey notes)
19. Cemeteries
    a. Roads
    b. Buildings
    c. Estimated Cemetery boundary
20. Yard Lights
21. Airport Lights
22. Airport Windsock
23. Basket Ball Hoops
24. Flag Poles
25. Landscaping
    a. Bushes (individual and lines)
    b. Rocks (Boulders)
    c. Flower Beds
    d. Trees (individual sizes according CMS Item 201)
        i. Evergreen
        ii. Deciduous

        iii. Stumps
    e. Shrubs (individual)
26. Golf Course greens
27. School Playgrounds (Equipment not itemized)
28. Swimming pools
29. Ground based/mounted satellite dishes
30. Towers
    a. Cell phone
    b. Etc
31. Fences
32. Guardrail
33. Bird houses (unknown post)
34. Traffic Mast arms
35. Culverts
36. Trails (dirt roads)
37. Railroads
38. Billboards
39. Utility boxes
40. Survey Control Points for AT solution
41. Any other item(s) that will be significant to the cost of an engineering project or that have been identified by the District Survey Operations Manager that are not listed above. These items may require a higher order of accuracy as specified by the District Survey Operations Manager.

Class II Planimetric Features

1. Edge of pavement (ie: paint line)
2. Edge of treated shoulder
3. Driveways
4. Bikeways
5. Parking Lots
6. Bridge Deck
7. Streams, Rivers, Ponds, Lakes, Wetlands
8. Highway barriers
9. Walls (retaining, headwalls, etc.)
10. Buildings
11. Utilities
    a. Power Poles
    b. Manholes
    c. Light Pole
    d. Telecommunication poles
    e. Unknown poles
    f. Fire Hydrants
    g. Catch Basins
    h. Underground utilities from field collection
12. Above Ground Tanks (oil/gas)
13. Cemeteries
    a. Roads

   b. Buildings
   c. Estimated Cemetery boundry
14. Swimming pools
15. Towers
   a. Cell phone
   b. Etc
16. Culverts
17. Railroads
18. Utility boxes
19. Survey Control Points for AT solution
20. Any other item(s) that will be significant to the cost of a planning project or that have been identified by the District Survey Operations Manager that are not listed above.

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Appendix B –Example RMSE Calculation for Vertical TIN & Horizontal Planimetric Features

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Vertical TIN Accuracy Test

Example Survey Check Shot Data Compared to TIN for Accuracy Class A (Units in U.S. Survey Feet)

Number	Easting	Northing	Check Z	TIN Z	Dz	Dz^2
SV100	1916349.000	784522.400	1148.453	1148.740	0.287	0.082
SV101	1916343.000	784531.300	1148.361	1148.590	0.229	0.052
SV102	1916337.000	784539.400	1148.580	1148.340	-0.240	0.058
SV103	1916330.000	784548.200	1147.800	1148.250	0.450	0.203
SV104	1916324.000	784556.200	1147.688	1147.670	-0.018	0.000
SV105	1916317.000	784565.300	1147.463	1147.430	-0.033	0.001
SV106	1916311.000	784574.100	1147.236	1147.230	-0.006	0.000
SV107	1916304.000	784583.300	1147.109	1147.080	-0.029	0.001
SV108	1916296.000	784594.200	1146.849	1146.930	0.081	0.007
SV109	1916290.000	784602.200	1146.779	1146.760	-0.019	0.000
SV110	1916282.000	784612.300	1146.618	1146.640	0.022	0.000
SV111	1916275.000	784621.900	1146.589	1146.510	-0.079	0.006
SV112	1916268.000	784631.200	1146.308	1146.350	0.042	0.002
SV113	1916263.000	784639.300	1146.184	1146.230	0.046	0.002
SV114	1916255.000	784648.800	1146.000	1146.080	0.080	0.006
SV115	1916248.000	784659.600	1145.778	1145.810	0.032	0.001
SV116	1916239.000	784670.700	1145.682	1145.840	0.158	0.025
SV117	1916232.000	784681.100	1145.947	1146.040	0.093	0.009
SV118	1916224.000	784691.100	1146.438	1146.310	-0.128	0.016
SV119	1916217.000	784701.300	1146.700	1146.560	-0.140	0.020
SV123	1916221.000	784704.400	1146.537	1146.480	-0.057	0.003
SV124	1916221.000	784704.500	1146.293	1146.480	0.187	0.035
SV125	1916230.000	784709.400	1146.307	1146.330	0.023	0.001
SV126	1916237.000	784715.700	1145.967	1146.080	0.113	0.013
				Sum Dz=	1.094	
				Sum Dz^2=		0.543
				N=	24	

$$Average\_Dz = \frac{1.094}{24} = 0.046'$$

$$RMSE = \sqrt{\frac{0.543}{24}} = 0.150'$$

Horizontal Planimetric Feature Accuracy Test

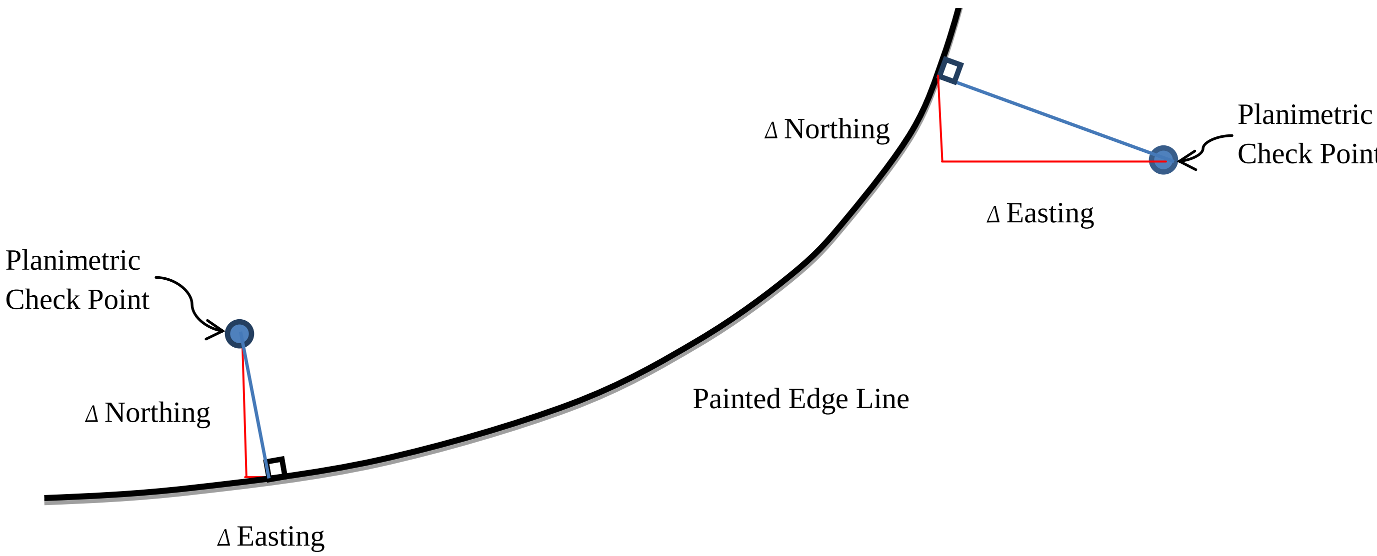
Planimetric Feature = Edge of pavement paint line

Survey Point #	Δ Easting	(Δ Easting)^2	Δ Northing	(Δ Northing)^2
100	0.131	0.017	0.104	0.011
101	0.148	0.022	0.117	0.014
102	0.138	0.019	0.109	0.012
103	0.149	0.022	0.118	0.014
104	0.202	0.041	0.157	0.025
105	0.186	0.035	0.145	0.021
106	0.171	0.029	0.133	0.018
107	0.227	0.052	0.176	0.031
108	0.243	0.059	0.189	0.036
109	0.238	0.057	0.185	0.034
110	0.221	0.049	0.171	0.029
111	0.278	0.077	0.216	0.047
112	0.196	0.038	0.152	0.023
113	0.282	0.080	0.219	0.048
114	0.116	0.013	0.091	0.008
115	0.256	0.066	0.200	0.040
116	0.216	0.047	0.169	0.029
117	0.287	0.082	0.224	0.050
118	0.226	0.051	0.177	0.031
119	0.259	0.067	0.202	0.041
120	0.217	0.047	0.169	0.029
121	0.219	0.048	0.168	0.028
122	0.171	0.029	0.132	0.017
123	0.252	0.064	0.194	0.038
124	0.201	0.040	0.155	0.024
125	0.126	0.016	0.097	0.009
126	0.200	0.040	0.154	0.024
127	0.034	0.001	0.027	0.001
128	0.139	0.019	0.108	0.012
129	0.164	0.027	0.128	0.016
130	0.090	0.008	0.161	0.026
	Sum=	1.262	Sum=	0.786

$$RMSEEasting = \sqrt{\frac{1.262}{31}} = 0.202'$$

$$RMSENorthing = \sqrt{\frac{0.786}{31}} = 0.159'$$

Graphic of Horizontal Planimetric Feature Test on Painted Edge Line



Measurements are taken perpendicular to the center of the painted edge line. Determine the Δ Northing and Δ Easting components for use in Horizontal Planimetric Feature Accuracy Test.

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Appendix C –Example Mapping Quality Control Report

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Mapping & Survey Quality Control Report for:

GEA 422 2.76

Report Submitted by: ODOT/Office of Aerial Engineering
08.06.2010

Mapping Performed by: Kyle Brandon, E.I.
Shawn Richardson
08.05.2010

Mapping Checked by: Rachel Lewis, P.E.
08.06.2010

Surveying Performed by: Kevin Pore
06.09.2010

Surveying Checked by: Scott Hawkins, P.S.
06.09.2010

The above parties certify the mapping furnished with this project meets the requirements of the ODOT Survey & Mapping Specifications, dated **April 15, 2011**

General Comments

Attached is the quality control report for the provided mapping and survey work for this project.

The mapping was compiled for design engineering projects.

Project Control was not included in this QC report.

Datum and Coordinate Systems

Vertical

Orthometric Height Datum: NAVD88
Geoid Model: GEOID03

Horizontal

Coordinate System: Ohio State Plane, North Zone
Map Projection: Lambert Conformal Conic
Reference Frame: NAD83(CORS96)
Ellipsoid: GRS80
Combined Scale Factor: 1.0000000000

Units

All units are US Survey Feet.

Digital Terrain Model

Methodology & Equipment Used
Check points were collected using ODOT VRS.
Survey points were collected using Airborne LiDAR sensor with GPS/IMU navigation system.

The entire DTM was vertically adjusted to the Check Points by: -0.245 feet

DTM Vertical Accuracy Class A – Paved Surfaces
Average Dz: 0.006’
RMSE: 0.014’

DTM Vertical Accuracy Class B – Vegetated Surfaces
Average Dz: 0.155’
RMSE: 0.203’

Data Used for Statistical Analysis is attached.

Additional DTM Notes:

- LiDAR was acquired by Consultant and processed by the Office of Aerial Engineering.
- Project is mapped for Accuracy Class A on the pavement and Accuracy Class B off of the pavement.
- All subsurface drainage, ditch inverts, or channel inverts require field collection and inclusion into the furnished existing surface model.
- Areas with dense brush or heavy vegetation require field collection and inclusion into the furnished existing surface model.
- Retaining walls require field collection and inclusion into the existing surface model.

Digital Mapping

Methodology & Equipment Used

Check points were collected using RTK ODOT VRS.
Survey points were collected using large format Airborne film camera with a GPS/IMU navigation system, aerotriangulation, and Photogrammetric 3D stereo planimetric collection.

Planimetric Horizontal Accuracy Class I

RMSE Easting: 0.008’
RMSE Northing: 0.169’

Aerotriangulation Solution

Check Point Id	Computed:		Given:		Residuals:	
	Easting (feet)	*Northing(feet)*	*Easting(feet)*	*Northing (feet)*	*Easting(feet)*	*Northing(feet)*
410	2286688.718	629628.325	2286688.690	629628.273	0.028	0.052
409	2286801.914	628498.059	2286801.937	628498.043	-0.023	0.016
408	2295471.118	628314.636	2295471.092	628314.639	0.026	-0.003
407	2295453.635	627389.720	2295453.638	627389.698	-0.003	0.022
405	2304760.448	627465.599	2304760.453	627465.660	-0.005	-0.061
406	2304726.031	626294.629	2304726.008	626294.778	0.023	-0.149
403	2312518.751	628140.634	2312518.800	628140.600	-0.049	0.034
404	2312551.051	627470.851	2312551.078	627470.809	-0.027	0.042
402	2320671.558	628731.138	2320671.599	628731.065	-0.041	0.073
401	2320511.516	627422.058	2320511.446	627422.085	0.070	-0.027

Data Used for Statistical Analysis is attached.

Additional Digital Mapping Notes:

N/A

Data (before vertical adjustment):

DTM Class A Survey Points & Check Points (in survey feet)					
Point ID	Point Easting	Point Northing	Check Point Elevation	Survey Point Elevation	Dz
LC30	2320871.370	628034.997	1194.725	1194.530	-0.195
LC29	2320865.568	628033.832	1194.654	1194.560	-0.094
LC28	2320859.752	628032.681	1194.849	1194.660	-0.189
LC27	2320853.382	628031.508	1194.965	1194.690	-0.275
LC26	2320846.920	628030.264	1194.897	1194.800	-0.097
LC25	2320839.600	628028.777	1194.961	1194.870	-0.091
LC24	2320831.251	628027.297	1195.105	1194.930	-0.175
LC23	2320824.158	628025.857	1195.271	1195.080	-0.191
LC22	2320815.891	628024.224	1195.433	1195.140	-0.293
LC21	2320808.377	628022.700	1195.650	1195.280	-0.370
LC20	2320799.636	628021.068	1195.770	1195.380	-0.390
LC19	2320791.654	628019.501	1195.788	1195.490	-0.298
LC18	2320783.406	628017.830	1195.939	1195.640	-0.299
LC17	2320775.569	628016.330	1195.974	1195.780	-0.194
LC16	2320765.627	628014.379	1196.000	1195.960	-0.040
LC15	2320756.632	628012.522	1196.419	1196.130	-0.289
LC14	2320746.097	628010.487	1196.361	1196.360	-0.001
LC13	2320736.033	628008.519	1196.932	1196.610	-0.322
LC12	2320725.223	628006.552	1197.211	1196.830	-0.381
LC11	2320714.442	628004.417	1197.328	1197.050	-0.278
LC10	2320703.682	628002.352	1197.637	1197.230	-0.407
LC09	2320693.309	628000.285	1197.599	1197.400	-0.199
LC08	2320682.596	627998.183	1197.848	1197.540	-0.308
LC07	2320671.344	627995.981	1198.231	1197.720	-0.511
				sum Dz=	-5.887
				N=	24
				Avg Dz=	-0.245

Data shown is for demonstration purposes only. Actual projects will have enough data to satisfy the requirements of the Survey and Mapping Specifications.

$$Average\_Dz = \frac{-5.887}{24} = -0.245'$$

Data (after vertical adjustment):

DTM Class A Survey Points & Check Points (in survey feet)						
Point ID	Point Easting	Point Northing	Check Point Elevation	Survey Point Elevation	Dz	Dz^2
LC30	2320871.370	628034.997	1194.525	1194.530	0.005	0.000
LC29	2320865.568	628033.832	1194.554	1194.560	0.006	0.000
LC28	2320859.752	628032.681	1194.649	1194.660	0.011	0.000
LC27	2320853.382	628031.508	1194.665	1194.690	0.025	0.001
LC26	2320846.920	628030.264	1194.777	1194.800	0.023	0.001
LC25	2320839.600	628028.777	1194.861	1194.870	0.009	0.000
LC24	2320831.251	628027.297	1194.925	1194.930	0.005	0.000
LC23	2320824.158	628025.857	1195.071	1195.080	0.009	0.000
LC22	2320815.891	628024.224	1195.133	1195.140	0.007	0.000
LC21	2320808.377	628022.700	1195.250	1195.280	0.030	0.001
LC20	2320799.636	628021.068	1195.370	1195.380	0.010	0.000
LC19	2320791.654	628019.501	1195.488	1195.490	0.002	0.000
LC18	2320783.406	628017.830	1195.639	1195.640	0.001	0.000
LC17	2320775.569	628016.330	1195.774	1195.780	0.006	0.000
LC16	2320765.627	628014.379	1195.934	1195.960	0.026	0.001
LC15	2320756.632	628012.522	1196.119	1196.130	0.011	0.000
LC14	2320746.097	628010.487	1196.361	1196.360	-0.001	0.000
LC13	2320736.033	628008.519	1196.632	1196.610	-0.022	0.000
LC12	2320725.223	628006.552	1196.853	1196.830	-0.023	0.001
LC11	2320714.442	628004.417	1197.028	1197.050	0.022	0.000
LC10	2320703.682	628002.352	1197.237	1197.230	-0.007	0.000
LC09	2320693.309	628000.285	1197.399	1197.400	0.001	0.000
LC08	2320682.596	627998.183	1197.548	1197.540	-0.008	0.000
LC07	2320671.344	627995.981	1197.731	1197.720	-0.011	0.000
				Sum Dz=	0.137	
				Sum Dz^2=		0.005
				N=	24	

Data shown is for demonstration purposes only. Actual projects will have enough data to satisfy the requirements of the Survey and Mapping Specifications.

$$Average\_Dz = \frac{0.137}{24} = 0.006'$$

$$RMSE = \sqrt{\frac{0.005}{24}} = 0.014'$$

DTM Class B Survey Points & Check Points (in survey feet)						
Point ID	Point Easting	Point Northing	Check Point Elevation	Survey Point Elevation	Dz	Dz^2
LC39	2320857.248	628100.573	1188.761	1189.090	0.329	0.108
LC40	2320855.030	628111.969	1191.050	1191.350	0.300	0.090
LC38	2320858.827	628092.885	1188.180	1188.460	0.280	0.078
LC37	2320860.588	628085.028	1188.642	1188.950	0.308	0.095
LC36	2320861.117	628079.936	1189.718	1189.900	0.182	0.033
LC35	2320862.126	628074.986	1190.770	1191.080	0.310	0.096
LC34	2320862.808	628070.550	1191.955	1192.120	0.165	0.027
LC33	2320863.709	628064.540	1193.122	1193.340	0.218	0.048
LC32	2320864.129	628057.234	1194.207	1194.370	0.163	0.027
LC31	2320865.110	628052.792	1194.777	1194.730	-0.047	0.002
LC41	2320728.523	628076.425	1194.174	1194.430	0.256	0.066
LC42	2320728.016	628070.949	1193.967	1194.140	0.173	0.030
LC43	2320728.150	628063.416	1193.752	1193.820	0.068	0.005
LC44	2320728.338	628055.294	1193.202	1193.590	0.388	0.151
LC45	2320729.306	628046.829	1194.207	1194.330	0.123	0.015
LC46	2320729.618	628040.327	1194.989	1195.130	0.141	0.020
LC48	2320730.385	628026.733	1196.788	1196.640	-0.148	0.022
LC47	2320729.812	628032.990	1196.099	1196.120	0.021	0.000
LC80	2312514.424	628350.857	1241.897	1241.950	0.053	0.003
LC81	2312508.546	628350.647	1241.684	1241.710	0.026	0.001
LC82	2312502.206	628350.124	1242.433	1242.460	0.027	0.001
LC83	2312497.166	628349.474	1243.982	1244.30	0.318	0.101
LC84	2312492.126	628349.120	1244.439	1244.440	0.001	0.000
LC85	2312515.681	628274.740	1245.019	1245.140	0.121	0.015
LC86	2312509.182	628274.038	1244.853	1245.040	0.187	0.035
LC87	2312501.233	628273.856	1245.061	1245.130	0.069	0.005
				Sum Dz=	4.032	
				Sum Dz^2=		1.074
				N=	26	

Data shown is for demonstration purposes only. Actual projects will have enough data to satisfy the requirements of the Survey and Mapping Specifications.

$$Average\_Dz = \frac{4.032}{26} = 0.155'$$

$$RMSE = \sqrt{\frac{1.074}{26}} = 0.203'$$

	Class I Planimetric Features Compared to Check Points (in survey feet)							
ID	Check Point Easting	Check Point Northing	Planimetric Easting	Planimetric Northing	Residual Easting	Residual Easting^2	Residual Northing	Residual Northing^2
LC01	2320618.027	627979.852	2320618.058	627979.745	0.031	0.001	-0.107	0.011
LC02	2320624.225	627982.744	2320624.217	627982.773	-0.008	0.000	0.029	0.001
LC03	2320632.449	627986.119	2320632.466	627986.005	0.017	0.000	-0.114	0.013
LC04	2320640.732	627988.776	2320640.750	627988.680	0.018	0.000	-0.096	0.009
LC05	2320650.920	627991.540	2320650.927	627991.490	0.007	0.000	-0.050	0.003
LC06	2320660.696	627993.751	2320660.714	627993.579	0.018	0.000	-0.172	0.030
LC07	2320671.344	627995.981	2320671.358	627995.851	0.014	0.000	-0.130	0.017
LC08	2320682.596	627998.183	2320682.600	627998.150	0.004	0.000	-0.033	0.001
LC09	2320693.309	628000.285	2320693.311	628000.271	0.002	0.000	-0.014	0.000
LC10	2320703.682	628002.352	2320703.685	628002.325	0.003	0.000	-0.027	0.001
LC11	2320714.442	628004.417	2320714.438	628004.453	-0.004	0.000	0.036	0.001
LC12	2320725.223	628006.552	2320725.221	628006.582	-0.002	0.000	0.030	0.001
LC13	2320736.033	628008.519	2320736.018	628008.683	-0.015	0.000	0.164	0.027
LC14	2320746.097	628010.487	2320746.082	628010.642	-0.015	0.000	0.155	0.024
LC15	2320756.632	628012.522	2320756.614	628012.691	-0.018	0.000	0.169	0.029
LC16	2320765.627	628014.379	2320765.620	628014.444	-0.007	0.000	0.065	0.004
LC17	2320775.569	628016.330	2320775.564	628016.379	-0.005	0.000	0.049	0.002
LC18	2320783.406	628017.830	2320783.402	628017.904	-0.004	0.000	0.074	0.005
LC19	2320791.654	628019.501	2320791.653	628019.511	-0.001	0.000	0.010	0.000
LC20	2320799.636	628021.068	2320799.636	628021.064	0.000	0.000	-0.004	0.000
LC21	2320808.377	628022.700	2320808.372	628022.765	-0.005	0.000	0.065	0.004
LC22	2320815.891	628024.224	2320815.891	628024.228	0.000	0.000	0.004	0.000
LC23	2320824.158	628025.857	2320824.159	628025.037	0.001	0.000	-0.820	0.672
LC24	2320831.251	628027.297	2320831.258	628027.215	0.007	0.000	-0.082	0.007
LC25	2320839.600	628028.777	2320839.594	628028.834	-0.006	0.000	0.057	0.003
LC26	2320846.920	628030.264	2320846.921	628030.257	0.001	0.000	-0.007	0.000
LC27	2320853.382	628031.508	2320853.382	628031.512	0.000	0.000	0.004	0.000
LC28	2320859.752	628032.681	2320859.744	628032.747	-0.008	0.000	0.066	0.004
LC29	2320865.568	628033.832	2320865.565	628033.878	-0.003	0.000	0.046	0.002
LC30	2320871.370	628034.997	2320871.369	628035.006	-0.001	0.000	0.009	0.000
LC200	2286404.019	629080.661	2286403.981	629080.550	-0.038	0.001	-0.111	0.012
					Sum of Residual^2=	0.002		0.883
					N=	31		

Data shown is for demonstration purposes only. Actual projects will have enough data to satisfy the requirements of the Survey and Mapping Specifications.

$$RMSEEasting = \sqrt{\frac{0.002}{31}} = 0.008' \qquad RMSENorthing = \sqrt{\frac{0.883}{31}} = 0.169'$$

Appendix D – Example Static GNSS Coordinate Statistical Analysis

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Static GNSS Project Control Monument Coordinate Analysis

PROJECT: ***XXX-XXX-XXXX*** | *REPORT DATE:*
PID: ***XXXXX*** | *PREPARED BY:*
MONUMENT NUMBER: ***XXXXX*** | *CHECKED BY:*

SESSION #	Observation Date	Start Time (GMT)	End Time (GMT)	Northing(m)	Easting(m)	Height(m)	Δ Northing(m)	Δ Easting(m)	Δ Height(m)	Include in Solution? (Y/N)
~~1~~	~~2010-06-21~~	~~12:50:00~~	~~16:57:00~~	~~235,289.65300~~	~~452,974.23300~~	~~268.31900~~	~~-0.00250~~	~~0.00800~~	~~-0.04650~~	N
2	2010-06-24	12:23:00	17:03:30	235,289.65100	452,974.24200	268.28400	-0.00050	-0.00100	-0.01150	Y
3	2010-06-28	13:26:00	17:49:00	235,289.65200	452,974.23200	268.28000	-0.00150	0.00900	-0.00750	Y
4	2010-07-06	13:24:00	18:06:00	235,289.65000	452,974.24400	268.26900	0.00050	-0.00300	0.00350	Y
5	2010-07-21	13:02:00	18:35:00	235,289.64900	452,974.24600	268.25700	0.00150	-0.00500	0.01550	Y
6				0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
			AVERAGE	235,289.65050	452,974.24100	268.27250	RMSE:	RMSE:	RMSE:	
						RMSE IN METRIC:	0.00112	0.00539	0.01050	
						RMSE IN US SURVEY FEET:	0.0037	0.0177	0.0344	
							PASS	PASS	PASS	

FINAL MONUMENT COORDINATES			
MONUMENT COORDINATES	NORTHING	EASTING	ORTHO HEIGHT
METERS (GRID)	***235289.6505***	***452974.2410***	***268.2725***
US SURVEY FEET (GRID)	***771946.128***	***1486132.989***	***880.157***
US SURVEY FEET (GROUND)	***771946.128***	***1486132.989***	***880.157***

ENGLISH TO METRIC CONVERSION	3.280833333
GRID TO GROUND MULTIPLIER(SCALE FACTOR)	1.000000000

Notes:

CORS BASE STATIONS USED FOR OPUS:

OHDR SIDN OHCL

MASK ANGLE: 13°

Δ North, Δ East, and Δ Ht. are the difference between the average northing, easting, and height and the OPUS solution for each session.

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Appendix E – Example OPUS Report

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opus <opus@ngs.noaa.gov>
03/02/2011 04:18 PM
Please respond to ngs.opus@noaa.gov

To scott.hawkins@dot.state.oh.us
cc
bcc
Subject OPUS solution : 87531451.10o 000172697

```
FILE: 87531451.10o 000172697

                         NGS OPUS SOLUTION REPORT
                         ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.html#accuracy

      USER: scott.hawkins@dot.state.oh.us             DATE: March 02, 2011
RINEX FILE: 8753145o.10o                              TIME: 21:18:22 UTC


 SOFTWARE: page5  1009.28 master23.pl 121510      START: 2010/05/25  14:49:00
 EPHEMERIS: igs15852.eph [precise]                 STOP: 2010/05/25  18:51:00
 NAV FILE: brdc1450.10n                        OBS USED:  8221 /  9340   :
88%
 ANT NAME: TRM_R8             NONE              # FIXED AMB:    64 /    66   :
97%
ARP HEIGHT: 2.0                                 OVERALL RMS: 0.016(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)              ITRF00
(EPOCH:2010.3964)

         X:       491394.221(m)   0.013(m)          491393.478(m)   0.013(m)
         Y:     -4908754.046(m)   0.018(m)        -4908752.637(m)   0.018(m)
         Z:      4029480.538(m)   0.015(m)         4029480.415(m)   0.015(m)

       LAT:   39 25 49.48958      0.012(m)      39 25 49.51690      0.012(m)
     E LON:  275 42 59.71978      0.011(m)     275 42 59.69473      0.011(m)
     W LON:   84 17  0.28022      0.011(m)      84 17  0.30527      0.011(m)
    EL HGT:         222.617(m)    0.020(m)              221.399(m)  0.020(m)
  ORTHO HGT:        256.276(m)    0.041(m) [NAVD88 (Computed using GEOID09)]

                           UTM COORDINATES    STATE PLANE COORDINATES
                            UTM (Zone 16)         SPC (3402 OH S)
Northing (Y) [meters]        4368063.931          160311.154
Easting (X)  [meters]         733819.472          446469.633
Convergence  [degrees]        1.72619684         -1.13160925
Point Scale                   1.00027318          0.99993623
Combined Factor               1.00023825          0.99990131

US NATIONAL GRID DESIGNATOR: 16SGJ3381968063(NAD 83)


                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DK3322 KYTF KY HWY DIST 6 CORS ARP      N390240.928 W0843436.884    49759.0
DI1[illegible]82 OHPR PREBLE COUNTY CORS ARP      N394426.665 W0843429.075    42586.8
DI2232 OHDT CITY OF DAYTON CORS ARP     N394553.062 W0841050.335    38155.4
```

EPHEMERIS

ORTHOMETRIC HEIGHT/ELEVATION
Convert to US Survey Feet

NORTHING & EASTING
Convert to US Survey Feet

COMBINED SCALE FACTOR

Specify the same three base stations for positioning primary project control monuments

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Appendix F – Surveyor's Certification Statement

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<u>Surveyor’s Certification for Primary Project Control</u>

I, (Surveyor’s Name) do hereby certify that the Primary Project Control for (name of project) were constructed and established in accordance with the Ohio Department of Transportation’s Survey and Mapping Specifications, dated (last revision date) for a (major or minor and minimal) project and meet the accuracy requirements as set forth therein. All observation data and RMSE calculations are on file and available at the request of the Ohio Department of Transportation.

____________________________ ___________

Signature Date Surveyor’s Seal

Surveyor’s Printed Name

And Registration Number

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Appendix G – Property Owner Notification

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(Date)

Property Owners along (Project)

Dear Property Owner:

The Ohio Department of Transportation intends to improve portions of (Project Name), to better serve the needs of the traveling public.

Accordingly, we wish to advise you that it will be necessary for our survey personnel to enter upon your property in the next several days to obtain certain field data needed in connection with this highway project. Sections 5517.01 and 163.03 of the Ohio Revised Code authorize such entries but also require that reimbursement be made for any actual damage resulting from such work. Our survey personnel are aware of the desire to preserve private property and public lands. In the event that any valuable vegetation must be cleared in order to accomplish our work, you will be so notified and informed as to the procedure to follow in preparing a claim for reimbursement. In all cases, however, removal of vegetation as well as other damage will be held to a minimum. If at any time you feel that our representatives have not given proper attention to private property, please notify this office at the following address:

Ohio Department of Transportation

(District Office or Consultant Name)

(Surveyor Name and Title)

(Address)

(Phone)

Please note that our survey personnel will not be able to give any information or answers to your questions. The survey staff will simply be collecting data to complete the surveying or specific mapping work. Should the ultimate design of the project affect your property or lands, a representative of the Ohio Department of Transportation (ODOT) will contact you regarding the details.

We sincerely appreciate your cooperation and assistance so that this worthwhile project can be completed at the earliest possible date.

Sincerely,

(Surveyor Name and Title)

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Appendix H – Project Control Monuments

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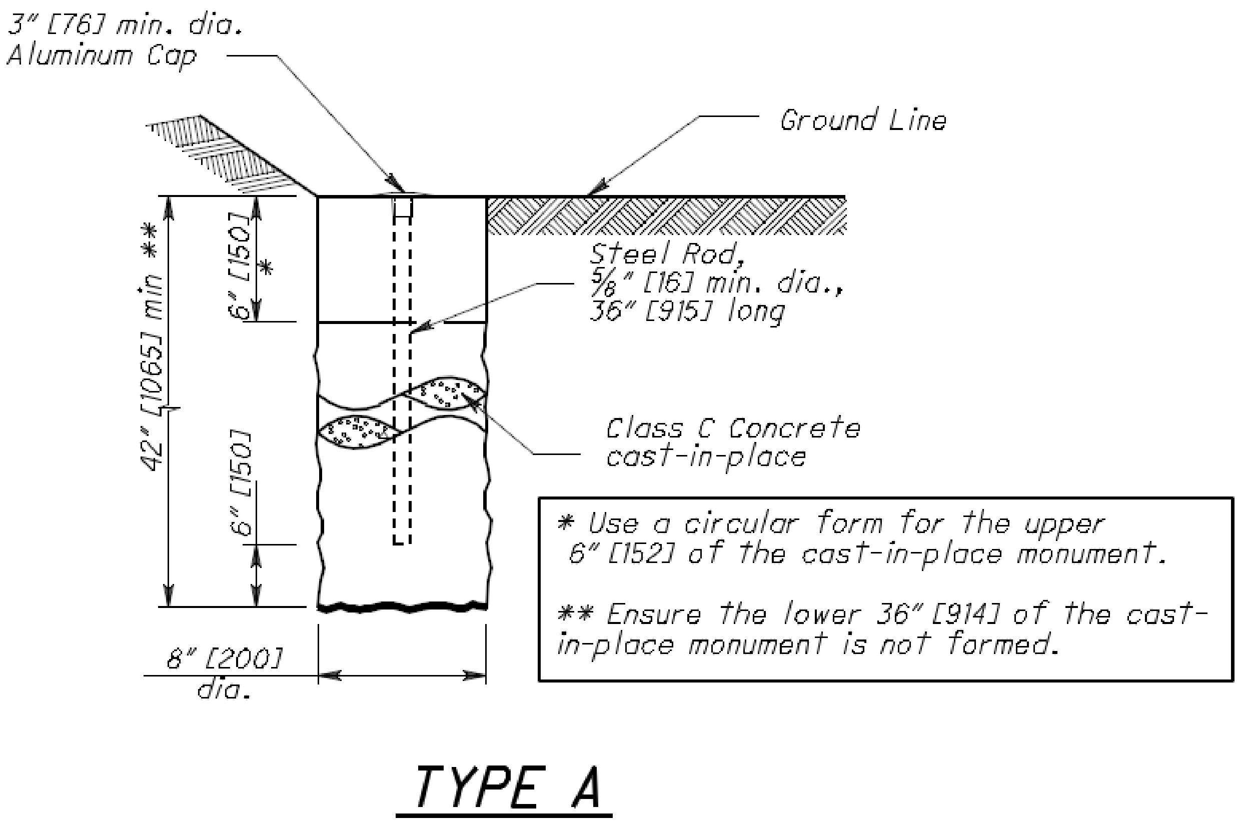
Primary Project Control Monument, Type A



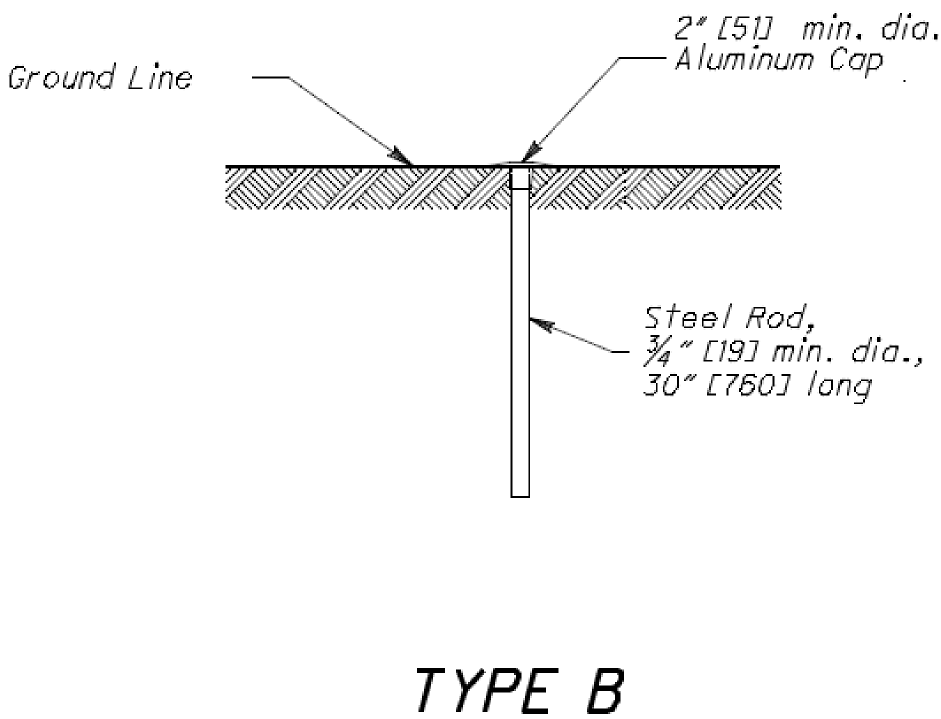
<u>Notes:</u>

Use Cap Design 1 for Primary Project Control Monuments

Use Cap Design 2 for Primary Project Control Monuments to be used as Azimuth Marks

See page 63 for Cap Designs

Primary Project Control Monument, Type B



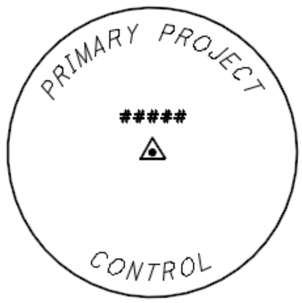
<u>Notes:</u>

Use Cap Design 1 for Primary Project Control Monuments

Use Cap Design 2 for Primary Project Control Monuments to be used as Azimuth Marks

See page 63 for Cap Designs

Cap Designs



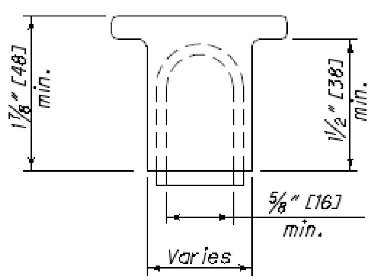
DESIGN 1

2" [51] or
3" [76] MIN. DIA.
ALUMINUM CAP
PLAN VIEW

DESIGN 2

2" [51] or
3" [76] MIN. DIA.
ALUMINUM CAP
PLAN VIEW

Place point number associated with the monument.



SIDE VIEW OF CAP