THE OHIO DEPARTMENT OF TRANSPORTATION

Survey and Mapping Specifications

January 17, 2020

Prepared by ODOT CADD & Mapping Services

Ohio Department of Transportation

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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.

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 accuracy of the TIN.

Combined Scale Factor: A conversion factor that uses the combination of the Grid Scale factor and the Elevation Scale Factor of a point to reduce horizontal ground distances to grid distances.

Department: The Department of Transportation, State of Ohio.

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.

Dz: Mathematical difference between elevations from the Check Points and elevations produced from the TIN (created from the Survey Points) at the same horizontal location.

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

Elevation Scale Factor: A multiplier used to change horizontal ground distances to geodetic (ellipsoid) distances.

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.

OPUS Static: The National Geodetic Survey's On-Line Positioning User Service (OPUS). OPUS accepts a user's GPS tracking data and uses corresponding data from the U.S. Continuously Operating Reference Station (CORS) Network to compute 3 dimensional positional coordinates of the user's submitted data. OPUS processes a 3-dimensional coordinate with an accuracy of a few centimeters for data sets spanning 2 hours or more.

OPUS-RS: A rapid static form of the National Geodetic Survey's On-Line Positioning User Service (OPUS). OPUS-RS accepts a user's GPS tracking data and uses corresponding data from the U.S. Continuously Operating Reference Station (CORS) Network to compute 3 dimensional positional coordinates of the user's submitted data. OPUS-RS can process a 3-dimensional coordinate with an accuracy of a few centimeters for data sets spanning as little as 15 minutes.

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).

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.

Planimetric Accuracy Detail Class: The required number of detailed features to be collected. The mapping is assigned an accuracy detail class by the District Survey Operations Manager.

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

Project Development Process (PDP): The process used by The Ohio Department of Transportation to develop and manage construction projects. ODOT projects are categorized by 5 Paths, Path 1 being the simplest ODOT project to Path 4 and Path 5 being ODOT's most complex projects.

Project Adjustment (scale) Factor: The inverse of the Combined Scale factor (1/Combined Scale Factor) used to convert grid distances and coordinates to ground distances and coordinates

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.

Root Mean Square Error (RMSE): Mathematical calculation that is used to describe the vertical mapping accuracy encompassing both random and systematic errors.

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/

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 Audiences

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.

104 Quality Control Report

Ensure a Survey and Mapping Quality Control Report (see examples in Appendix C & D) is submitted to the District Survey Operations Manager for review and comments PRIOR to submission of Stage 1 engineering plans.

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 OHIO811 (the Ohio Utilities Protection Service) (OUPS), at least 48 hours but no more than 10 working days (excluding weekends and legal holidays) before beginning any excavation work, construction of Control Monuments, or driving of pins. For more information, visit www.OHIO811.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 Datum's, Coordinate Systems, and Positioning Parameters

As of the publication date of this specification all project control and mapping will be surveyed and mapped on NAD83 (2011) & Geoid 18.

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:

- Orthometric Height Datum – NAVD88
- Geoid Model – Geoid 18

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

302 Horizontal Positioning

Furnish horizontal positions using the following:

- Coordinate System – Ohio State Plane:
    - North or South Zone as appropriate
    - Project Adjustment Factor (1/Combined Scale Factor) from grid to ground as appropriate (Refer to Section 502.2k)
        - Use 0,0 for the origin of the coordinate system
        - North Zone Latitude/Longitude origin point: Lat,Long = 0,0
            - N 39º 27' 01.76097"/W 89º 28' 32.98476"
        - South Zone Lat/Long origin point: Lat,Long = 0,0
            - N 37º 47' 45.30621"/W 89º 19' 00.02517"
- Map Projection – Lambert Conformal Conic 2 Standard Parallel
- Reference Frame – NAD83(2011) (epoch 2010.0)
- Ellipsoid – GRS80

400 Units of Measurement

401 U.S. Survey Foot Definition

The U.S. Survey foot is defined as 1 meter = 39.37 inches. Use the following conversion factor: 1 meter = 3937/1200 U.S. Survey feet.

402 Distance

Furnish units in U.S. Survey Feet. Provide distances to the nearest hundredth (i.e. 0.01) of a foot.

403 Angles

Furnish angles in degrees-minutes-seconds to the nearest second (i.e. 01º01’01”).

404 Direction

Furnish directions as bearings in degrees-minutes-seconds to the nearest second (i.e. N 01º01’01” E).

405 Area

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

406 Volume

Furnish volumes to the nearest cubic yard unless otherwise stated.

407 Horizontal/Vertical Positions

Furnish state plane coordinates for all survey control points, Right-of-Way, Centerline, and Boundary monuments that will be shown on any recorded documents and scaled using a project adjustment factor or in an ODOT approved alternate projection in both metric and U.S. survey feet. Meters shall be shown to the nearest thousandth (i.e. 0.001) of a meter. U.S. survey feet shall be shown to the nearest thousandth (I.e. 0.001) of a foot. The format for reporting all Horizontal and Vertical positions in state plane or scaled shall be: Point Number/Northing coordinate/Easting coordinate/Elevation/Code/Attribute (if applicable) (P,N,E,Z,D,A1).

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 may be 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 (e.g. northings, eastings, and elevations) on strategically located monuments to govern all survey work that follows.

502.2 Project Control

502.2a General

Project Control, the purpose of a geodetic/primary control survey is to establish a network of physically monumented coordinate points in and along a highway corridor that provide a common horizontal and vertical datum for the entire project. The geodetic control survey provides the means for tying all the geographic features and design elements of a project to one common horizontal and vertical reference system. The geodetic/primary control survey is performed at a higher level of accuracy than the aerial control survey, as such the aerial control survey shall be considered secondary control.

For projects where no ODOT geodetic/primary control survey has been completed, the District Survey Operations Manager shall be contacted, and a determination made if a geodetic/primary control survey is to be completed prior to the aerial control survey. ODOT discourages the practice of performing any aerial control survey without a previously established geodetic/primary control survey already in place, as this causes accuracy and coordinate conversion problems later in the progression of the project.

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

502.2b Geodetic Control (for path 4 or 5 projects)

Geodetic Control will govern the positioning for all ODOT path 4 or 5 projects that require aerial mapping tying them to the National Spatial Reference System (NSRS). Geodetic Control monuments should be set prior to the establishment of any aerial photo or lidar control. All ODOT projects will be positioned based on the most current horizontal and vertical datums established by the National Geodetic Survey (NGS) or as scoped. Path 4 & 5 projects greater than 1 mile in length but less than 5 miles in length shall have a minimum of 5 Geodetic Control monuments that are separate of the Primary Project Control. Additional Geodetic Control monuments will be required for projects greater than 5 miles long. All Path 1 thru 3 projects and Path 4 & 5 projects less than 1 mile in length will not require Geodetic Control monuments.

Geodetic Control monuments shall be set approximately ½ mile outside of and encompassing the project limits. One Geodetic Control monument will be set near the center of, but outside of, the area where construction activity is expected to take place. This monument will be used to calculate the Project Adjustment Factor as well as serve as the primary benchmark for all leveling (see following diagram for example).

Geodetic Control monuments should be of sufficient design, material, and construction to maintain their horizontal and vertical position throughout the life span of the project. The project surveyor may use existing monuments (e.g. NGS horizontal control or benchmarks, County Geodetic Control monuments or PLSS monuments) or set their own type A monuments if no other options are available.

502.2c Primary Project Control (for all projects)

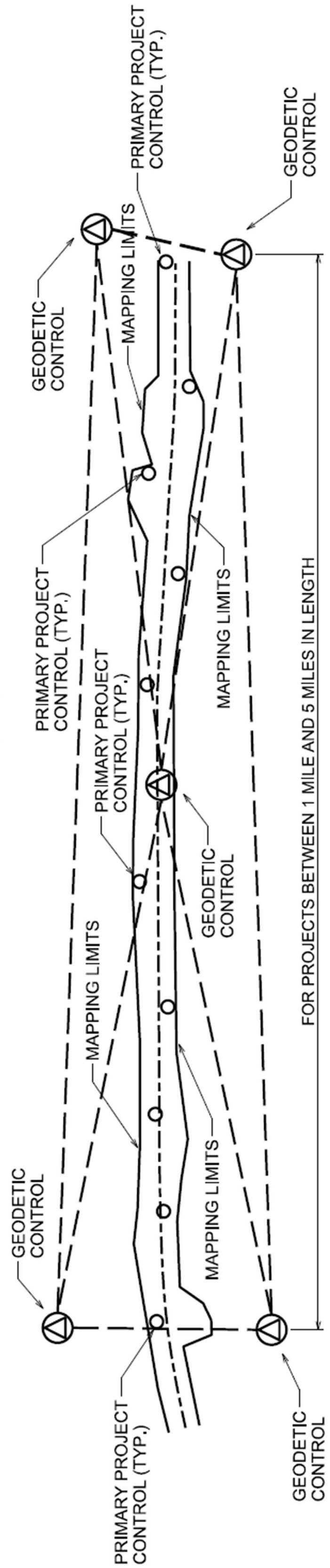
Primary Project Control Monuments are monuments set along the project corridor that are used exclusively to collect topographic, boundary, and utility data as well as control construction activities. Primary Project Control should be established with a minimum of three monuments set outside the construction limits of the project. Primary project control shall be constructed to remain stable and last the duration of the project. Primary Project Control shall be set and positioned based on the Geodetic Control, if used, or by methods outlined in 502.2e. Ensure all topographic, boundary, and utility data is collected and adjusted relative to the established Primary Control Monuments. Construct Primary Project Control Monuments flush to the ground according to details shown in Appendix H. Preferably, Primary Project Control Monuments should be positioned to have a clear view of the sky and to reduce the potential for GNSS multipath signals. Placement of Primary Project Control Monuments is dependent upon the project length. Furnish Primary Project Control Monuments per the following table:

Geodetic/Primary Project Control Monument Placement Criteria

Project Category**	Type of Control	Monument Type*	Monument Controls	Horizontal Positioning Methods***	Vertical Positioning Methods
Path 4 & 5	Geodetic > 1 mile Primary	A	Horizontal &Vertical	Static GNSS, PPK, Conventional Traverse	+Differential Leveling
Path 1-3++	Primary Only	A or B	Horizontal only on type B Separate Vertical	Static GNSS, PPK, ODOT VRS, RTK Conventional Traverse	+Differential Leveling
	* 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. See 502.2d for positioning methods. + See Section 502.3 ++Consider using type A monuments for Path 1-3 projects that may expect to be delayed in project development.				

Primary Project Control Monument Placement				
Project Length	**Beginning & End of Project Limits (Excluding MOT)**	**Approx. Interval Distance along Alignment**	**At locations Specified by District**	**Minimum # of Monuments Required**
< 1mile	X	0.5 Miles	X	3
≥1mile	X	0.5 Miles	X	4
*See diagrams below for examples of project control monument placement				

PATH 4 AND 5 PROJECTS
CONTROL REQUIREMENTS FOR PROJECTS REQUIRING AERIAL MAPPING GREATER THAN 1 MILE IN LENGTH



GEODETIC CONTROL: TYPE"A" MONUMENTS OR EXISTING PERMANENT CONTROL SUCH AS EXISTING NGS MARKS OR COUNTY CONTROL

PRIMARY PROJECT CONTROL: TYPE "A" OR "B" MONUMENTS AS APPROPRIATE OR SCOPED BY DISTRICT SURVEY OPERATIONS MANAGER

502.2d Observation Methods to Establish Geodetic Control on Path 4 and 5 projects

- Static GNSS Surveys [Required on Path 4 and 5 projects, Recommended on Path 3 projects] All control points need a minimum of 3 GNSS sessions observed on 3 separate days within a 4-week period. Use survey grade GNSS receivers and antennas in accordance with Section 600. Use one of the following methods:
-
    - OPUS Solution for all Control Points
        - Collect a minimum of 3 sessions of static GNSS data following NGS requirements for an OPUS static session for each Geodetic 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, etc.
    - Base Receiver Setup/CORS with Rover unit collecting PPK data
        - Establish a base receiver by collecting the Geodetic Control Monument near the center of the project using a minimum of 3 static GNSS sessions as described above or use a nearby CORS as a base. Simultaneously collect the remaining Geodetic Control and/or Primary Control points using a GNSS rover collecting fast-static data. Collect 3 individual sessions on each Geodetic Control and/or Primary Control point using fast-static data for a minimum of 20 minutes plus 1 minute per kilometer over 15 kilometers of baseline between the occupied control points.
- Traversing
    - Conduct a conventional survey traverse using an Electronic Total Station defined in 602.2. A minimum of 2 direct/2 reverse angles and 5 distance measurements shall be observed and averaged for the final observation of each control point.
    - Closed loop traverses or ties to known control points at the beginning and end of each project should be used to adjust the traverse for errors.
      Note: at least two monuments need to be tied to the NSRS and the traverse transformed and adjusted to their positions.

502.2e Observation Methods to Establish Control on Path 1 thru 3 projects

- ODOT VRS Surveys [For use on Path 1-3 projects only, not to be used on Path 4 or 5 projects]
    - For use on Path 1-3 projects only collect the Northing, Easting, and Elevation coordinates using 5 second observations at a 1 second epoch rate. Collect a minimum of 12 observations for each project control monument. *Note: If more than 20 observations are needed to meet the minimum RMSE requirements consider changing location of control and contact district Survey Operations Manager*. Collect 4 observations rotating the rod 90 degrees between each observation, remove the rod and break initialization, repeat observation procedures until 12 positions have been recorded. Consider the following when planning and performing VRS surveys: positional dilution of precision (PDOP), number of satellites, mask angle, multipath, solar activity, etc. A minimum of 9 observations are required to be included in the RMSE calculations that meet the required accuracy.
- RTK Surveys [For use on Path 1-3 projects only, not to be used on Path 4 or 5 projects]

  - Establish a base receiver by collecting 3, 4-hour static sessions on one control point. While the receiver is collecting static data perform an RTK survey on the remaining control points. Repeat with each static data collection session so every control point has a minimum of 3 RTK/static positions.
- Traversing
  - Conduct a conventional survey traverse using an Electronic Total Station defined in section 602.2. A minimum of 2 direct/2 reverse angles and 5 distant measurements shall be observed and averaged for the final observation of each control point.
  - Closed loop traverses or ties to known control points at the beginning and end of each project should be used to adjust the traverse for errors.
    Note: at least two monuments need to be tied to the NSRS and the traverse transformed and adjusted to their positions.

502.2f Static GNSS Data Processing

- OPUS Solution for all Control Points
  - 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 nearest CORS base stations and standard logging rates when processing a primary project control point in OPUS. The user must manually select the CORSs to be used in the OPUS processing.
- Base Receiver Setup with Rover unit collecting PPK data
  - Establish the base station coordinates to post process GNSS baselines by submitting the GNSS data RINEX files to OPUS as described for OPUS Static solutions. Process the collected GNSS data by importing into a GNSS post processing software such as Trimble Business Center, Leica Infinity, or MAGNET, post process the GNSS baselines thru the appropriate post processing software. Calculate the positions of three observations per point and calculate the RMSE value to insure the control point meets the ODOT Survey and Mapping Specifications for a type A monument.
- CORS with Rover unit collecting PPK data
  - Use the published coordinate values of the nearest CORS to post process GNSS baselines from. Process the collected GNSS data by importing into a GNSS post processing software such as Trimble Business Center, Leica Infinity, or MAGNET. Post process the GNSS baselines thru the appropriate post processing software. Calculate the positions of three observations per point and calculate the RMSE value to insure the control point meets the ODOT Survey and Mapping Specifications for a type A monument.

502.2g Coordinate Statistical Analysis

Calculate the Root Mean Square Error (RMSE) for each coordinate component (Northing, Easting, and Elevation) at each Primary Project Control Monument as shown in Appendix D:

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]

See Appendix D for RMSE calculation

502.2h Geodetic/Primary Project Control Monument Horizontal Coordinates

The Northing and Easting of the Geodetic/Primary Project Control Monument coordinates are determined by taking the average of each coordinate component from the solutions that meet the RMSE requirements as specified in Section 502.2g.

502.2i Geodetic/Primary Project Control Monument Vertical Coordinates

Establish the elevations of Geodetic/Primary Project Control Monuments or their associated project benchmarks by differential leveling. Refer to section 502.5 for leveling procedures. Differential leveling for Geodetic/Primary Project Control Monuments and project benchmarks will originate from, and close on, the Geodetic Control Monument (Path 4 or 5) at the center of the project or the Primary Project Control Monument (Path 1-3) with the lowest Elevation RMSE value nearest to the center of the project. Level through all Geodetic and/or Primary Project Control Monuments as well as project benchmarks. Hold the elevation values established by differential leveling for all Geodetic and Primary Project Control Monuments. As a check, compare the leveled elevations to the GNSS determined elevations from Section 502.2g. Highlight any differences that exceed 0.10 U.S. Survey Foot.

502.2j Intermediate Project Control

Intermediate project control for surveying purposes are to be positioned relative to the Geodetic/Primary Project Control.

502.2k Project Adjustment Factor (Grid to Ground multiplier)

- The Project Adjustment Factor shall be documented and used for all work on the project. The Project Adjustment Factor shall be calculated by taking the inverse of the combined scale factor (1/(coordinate scale factor x ellipsoid height scale factor)). Scale the project about the origin of the Zone of the State Plane Coordinate system (0, 0). Provide Project Adjustment Factor to the 8^{th} decimal place. If a Project Adjustment Factor is required, use one of the following methods for establishing the combined scale factor:
    - The Latitude of the center Geodetic Control Monument or Primary Project Control Monument closest to the center of the project shall be used to calculate the Project Adjustment Factor for all projects regardless of the method used to locate the monument or method used to determine the Project Adjustment Factor. An ellipsoid height that is a good representation of the average height of the project site shall be used to calculate the ellipsoid height scale factor.
    - Project Adjustment Factor may be derived by other means with approval of the District Survey Operations Manager (i.e. Data Collector solution, TBC, Infinity, Magnet tools) based on GNSS data collected for any individual point. The control point used should meet the RMSE requirements.
    - As reported by OPUS or OPUS-RS

502.2l Site Calibration

- Site Calibration: Use a minimum of 4 points to calculate a horizontal site calibration and 5 control points to establish a vertical site calibration. The entire project should lie within the control point network. Hold the initial scale of the site calibration fixed at 1 to determine if the horizontal and vertical residuals of the control points are within the current RMSE tolerances. If one or more control points are out of the current RMSE tolerances it can be discarded, and another point added to the calibration. If you are performing a Site Calibration on the Grid Coordinates, the GNSS observed Site Calibration Coordinates and the Horizontal and Vertical Residuals, shall be included in the final deliverables to the Survey Operations Manager. Consult the Survey Operations Manager regarding Site Calibrations that need to be performed on ODOT projects.

502.2m Deliverables

Furnish the following deliverables as soon as possible prior to the Beginning of Design:

- Surveyor's Certification Statement (See Appendix F).
- A table that includes geodetic/primary project control coordinates. Include the following in the table:
    - Point Number
    - Point Description
    - Monument Type
    - Positioning Method
    - State Plane Coordinates (Grid)
        - Northing (meters) and U.S. Survey Feet
        - Easting (meters) and U.S. Survey Feet
        - Ortho Height (meters) and U.S. Survey Feet
    - If applicable, Scaled Coordinates (Ground)
        - Northing (U.S. survey feet)
        - Easting (U.S. survey feet)
        - Ortho Height (U.S. survey feet)
    - If applicable, the Project Adjustment Factor, associated monument and average ellipsoidal height
    - Type A primary geodetic/project control orthometric heights (U.S. survey feet)
    - Project Benchmark number, description, and orthometric height listed with each Type B primary control monument
- NGS OPUS data sheets if used in the solutions
- Statistical analysis for each Geodetic/Primary Project Control Monument *(See example, Appendix D)*
- Native survey data files in Trimble RAW or RINEX format
- A general map of the entire project with the control monuments identified in PDF, .dgn (version according to ODOT CADD Engineering Standards Manual), or any standard raster format
- All field notes, sketches, and adjustment calculations
- All differential leveling deliverables as specified in Section 502.3f.
- Documentation confirming the calibration of all survey equipment used.
- Copies of Ohio Utility Protection Service (OUPS) Tickets

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 after 10 working days. 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 geodetic and primary project control.

502.3 Differential Leveling

502.3a General

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

502.3b Project Benchmarks

Construct or identify project benchmarks in conjunction with Type B Primary Project Control Monuments. Construct project benchmarks as required to complete project related tasks or where dictated by the District Survey Operations Manager. Ensure project benchmarks are of a stable nature. Furnish project 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 project benchmarks with the deliverables. Ensure station/offset and descriptions are included. Commence and close all leveling for project benchmarks from an established geodetic/primary control point monument as specified in Section 502.2.

502.3c 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 requirements.

502.3d Closure Requirements

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

0.04 feet x ($\sqrt{E}$)

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.

Consult district Survey Operations Manager if site conditions make it difficult to meet the published closure requirements.

502.3e 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.

502.3f Deliverables

- Surveyor's Certification Statement
- Report of all geodetic/primary project control, and Project benchmark elevations established. Include the following as a minimum: point name, elevation, description of the mark and a sketch defining its location
- Field notes for all leveling work
- Listing of all field crew members/titles
- Details of misclosures, calculations and adjustments
- Make, model, serial numbers and firmware versions of all equipment used
- Post-processing software used with version number (where applicable)
- Show the difference between leveled and GNSS derived elevations for all Type A Geodetic/Primary Project Control Monuments or Project benchmarks for Type B monuments.
- 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 Boundary Surveys
Boundary 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. All boundary surveys shall be tied to the Geodetic and/or Primary Project Control.

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. All Right-of-Way and Highway Centerline surveys shall be tied to the Geodetic and/or Primary Project Control.

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, hydrographic surveys, Aerial mapping surveys, Mobile mapping surveys, etc.

Any mapping survey must be accurately tied to ground control and meet the DTM accuracy as set forth in this document. All ground control work shall be directly supervised and certified by a professional surveyor licensed in the State of Ohio.

504.2 Accuracies
All mapping surveys are required to abide by the following accuracy classes outlined in the sections below:

504.2a DTM Accuracy
Check points to verify remotely sensed mapping products should be dispersed throughout the entire project. To determine the minimum amount of check points, use the following formula:

Minimum Number of Class A points = 20+2*x at 5 foot spacing in two or more locations

AND

Minimum Number of Class B, C or D points = 20+2*x at 5 foot spacing in two or more locations

Note: X is equal to the distance of project in miles

DTM Accuracy Class	Classification Area	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	± 1.00	1.00

See Appendix B DTM accuracy testing procedure.

504.2b Horizontal Planimetric Accuracy

This specification covers collection of existing planimetric features and all known underground utilities. Remote sensing products are included with this specification and may be required in the scope of services. Ensure positioning is performed relative to geodetic/primary project control.

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). Check points should be dispersed throughout the entire project. To determine the minimum amount of check points, use the following formula and table:

Number of Planimetric check points = 20+2*x, where x is equal to the distance of project in miles

Planimetric Features	**Maximum Allowable Horizontal RMSE (ft.)**
Planimetric features listed in Appendix A	0.30

See Appendix B for horizontal planimetric feature accuracy testing procedure.

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.

504.3 Ground Control

Collect coordinates and elevations at the center of the aerial target or selected picture point. All ground control (Targets and Photo Points) shall be furnished with a survey nail except on private property. Ensure all photo control is positioned relative to the Geodetic Control and meets the RMSE tolerances as set forth in 502.2g. A professional surveyor licensed in the State of Ohio will document the accuracies, survey procedures and methods used.

If a geodetic/primary control survey will not be performed, all aerial control horizontal surveys shall be referenced to and tied into the National Spatial Reference System (NSRS) as defined by the National Geodetic Survey (NGS) or through the project scoping process.

504.4 Deliverables

Furnish deliverables to the District Survey Operations Manager prior to performing any engineering design work. Deliverables may be sent in combination with Section 502.2 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. Include the following as applicable:

504.4a Surveyor's Certification Statement

Any control established and verification of a mapping survey must be done under the direct supervision of a professional surveyor licensed in the State of Ohio (i.e. Primary Control, Ground Control Points etc.).

See Appendix F for a template of a Surveyor's Certification Statement.

504.4b Quality Control Report

See Appendix C for an example of a completed quality control report.

When applicable the following is required:

- DTM Accuracy Report
- Horizontal Planimetric Accuracy Report
- Aero Triangulation Report
- Control Report (Survey Master Sheet)

504.4c Equipment Calibration/Certifications

Any equipment used in the creation of project deliverables must meet the calibration requirements as specified in section 600. Include the following as applicable:

- Boresight alignment calibration parameters for any airborne sensors utilized for mapping
- Camera calibration certificate
- GNSS/INS system lever arms for any airborne sensors
- Documentation confirming the calibration of all survey equipment used
- Any calibration/certificates for equipment required to adjust the data set

504.4d Imagery Deliverables

- Raw and Processed images in digital format
- Aero Triangulation Solution
- Orthomosaic TIFF referenced in project coordinate system
  - 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. 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.

504.4e Basemap Design Files

Provide all basemap design files produced for mapping survey (i.e. BK, BA, FB, etc.). See CADD Engineering Standards Manual for proper design file standards.

504.4f LandXML

All existing surfaces and alignments (if applicable) shall be submitted in LandXML format or as otherwise scoped.

600 Survey and Mapping 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:

- Internal compensator/auto-level.
- 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:

- Compensated with a dual axis compensator.
- Horizontal and vertical angular accuracy of $\geq$ 5 seconds.
- 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:

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

602.4 Remote Sensing Systems

Remote sensing systems are required to be survey grade and meet the accuracy standards set forth in section 500. Remote Sensing Systems include but are not limited to: LiDAR Systems, Digital Cameras, etc.

603 Equipment Calibration and Maintenance

Ensure all surveying and mapping 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:

Every 3 Months:

- Clean and inspect optics, electrical contacts, instrument body, and instrument case
- Check and adjust level vials
- 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:

Every 3 Months:

- Clean and inspect optics, electrical contacts, instrument body, and instrument case
- Check and adjust level vials
- Check and adjust vertical plummet
- Check horizontal and vertical circle collimation and adjust as needed

Every 6 Months:

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

603.3 Tripods, Tribrach's, Prism Rods, and RTK Rods

Perform maintenance and care according to the following schedule:

Every 3 Months:

- Clean and inspect
- Adjust level vials

- Adjust the optical plummet
- Tighten all clamps, locks, feet and screws to the proper specification

Appendix A -Planimetric Collection

Standard Mapping Collection Features

(Within Project Limits affected by design)

1. Edge of pavement (i.e.: paint line)
2. Edge of treated shoulder
3. Curb (field collected)
4. Curb Ramps (field collected)
5. Sidewalks
6. ADA Ramps (field collected)
7. Driveways
8. Bikeways
9. Parking Lots
10. Bridge Deck
11. Streams, Rivers, Ponds, Lakes, Wetlands
12. Highway barriers
13. Walls (retaining, headwalls, etc.)
14. Fences
15. Buildings
16. Mailbox (specify number of mailboxes in survey notes)
17. Utilities
    a. Power Poles
    b. Manholes
    c. Light Pole
    d. Telecommunication poles
    e. Unknown poles
    f. Fire Hydrants
    g. Catch Basins
    h. Underground utilities (field collected)
18. Above Ground Tanks (oil/gas)
19. Cemeteries
    a. Roads
    b. Buildings
    c. Estimated Cemetery boundary
    d. Any headstones within Road Right-of-Way
20. Swimming pools
21. Towers
    a. Cell phone
    b. Etc.
22. Culverts
23. Railroads
24. Utility boxes
25. Survey Control Points for AT solution
26. 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.

Additional Aerial Mapping Collection Features

(Outside Project Limits affected by design)

1. Edge of pavement (i.e.: 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.

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

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

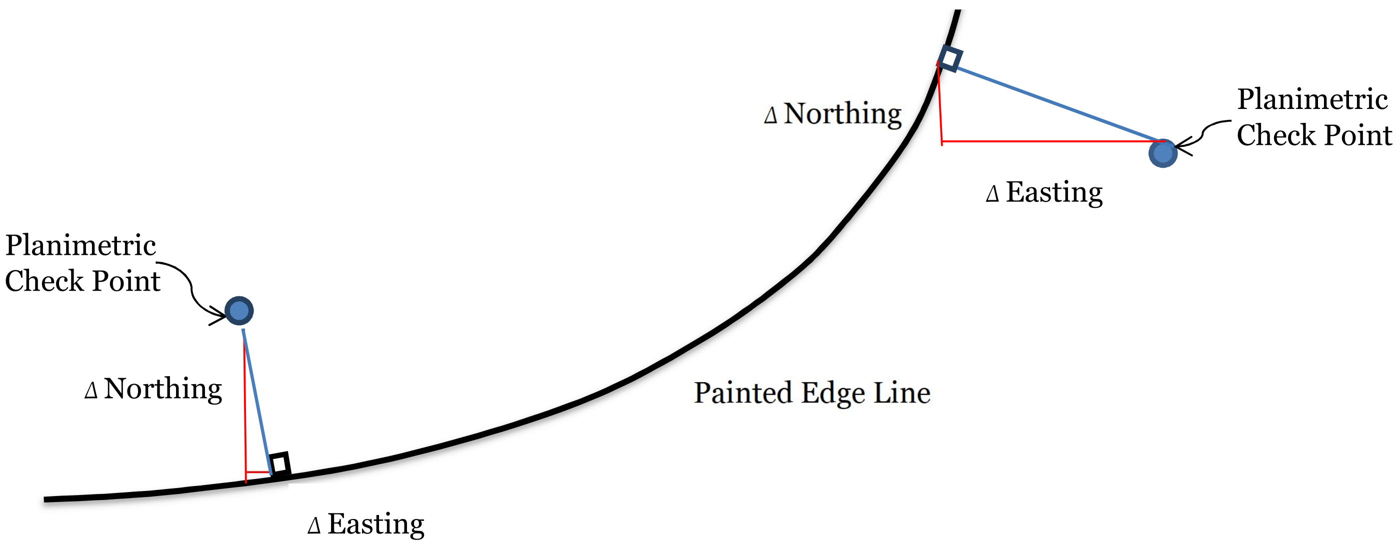
Planimetric Feature = Edge of pavement paint line

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

$$RMSE Easting = \sqrt{\frac{1.262}{31}} = 0.202'$$

$$RMSE Northing = \sqrt{\frac{0.786}{31}} = 0.159'$$

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.

Appendix C -Example Mapping Quality Control Report

Mapping & Survey Quality Control Report for:

TUS-800-25.65
PID #101531

Report Submitted by:
CADD and Mapping Services Staff

Mapping Performed by:
CADD and Mapping Services Staff

Mapping Checked by:
CADD and Mapping Services Staff

Surveying Performed by:
District Survey

Survey Checked by:
District Survey

The above parties certify the mapping furnished with this project meets the requirements of the ODOT Mapping Specifications, dated **January 1, 2020**.

General Comments

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

The mapping was compiled for design engineering use.

Project control is not included with this report.

Hard Surface is only accurate from date of flight (03/07/2016)

Datum and Coordinate Systems

Vertical

Orthometric Height Datum: NAVD88
Geoid Model: GEOID18

Horizontal

Coordinate System: Ohio State Plane, North Zone
Map Projection: Lambert Conformal Conic
Reference Frame: NAD83 (2011)
Ellipsoid: GRS80
Combined Scale Factor: 1.0000000000
Project Adjustment 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 an Airborne LiDAR sensor with GPS/IMU navigation system.

The entire DTM was vertically adjusted to the Check Points by: -0.5760 feet

DTM Accuracy Class A – Paved Surfaces

Average Dz:	0.00‘
RMSE	0.07‘

DTM Accuracy Class B – Vegetated Surfaces

Average Dz:	0.07‘
RMSE:	0.17‘

Data Used for Statistical Analysis is attached.

Additional DTM Notes:

- Project is mapped for DTM Accuracy Class A on the pavement and DTM Accuracy Class B off 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 existing surface model.
- Retaining walls and bridges 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 digital camera with a GPS/IMU navigation system, aerotriangulation, and Photogrammetric 3D stereo planimetric collection.

Additional Digital Mapping Notes:

- Project is mapped for Planimetric Accuracy Class I.
- All subsurface utilities require field collection.

DTM Accuracy Class A Survey Points & Check Points

Survey Check Point	Point Easting	Point Northing	Survey Check Point Elevation	LiDAR Elevation	Dz
5115	2266388.2720	321624.0200	888.2200	888.0700	-0.1500
5116	2266386.8250	321620.3860	888.2360	888.1300	-0.1060
5117	2266384.6450	321615.9720	888.2540	888.1700	-0.0840
5118	2266383.0260	321612.1420	888.3330	888.1900	-0.1430
5119	2266381.3230	321608.3530	888.3810	888.2100	-0.1710
5120	2266379.6140	321604.5600	888.2320	888.2200	-0.0120
5121	2266378.0230	321601.1590	888.2470	888.2400	-0.0070
5122	2266376.5960	321598.2000	888.2240	888.2600	0.0360
5123	2266374.4810	321593.7000	888.2360	888.2700	0.0340
5124	2266372.7070	321589.4730	888.1900	888.2700	0.0800
5125	2266371.5650	321586.7920	888.3490	888.2500	-0.0990
5126	2266368.8750	321581.5420	888.2840	888.2400	-0.0440
5127	2266367.3320	321577.3920	888.2110	888.2300	0.0190
5128	2266365.2840	321573.2760	888.3180	888.2000	-0.1180
5129	2266363.2800	321568.9120	888.3800	888.1900	-0.1900
5130	2266361.4990	321565.1320	888.1710	888.2000	0.0290
5131	2266359.8700	321561.4170	888.2640	888.1900	-0.0740
5132	2266358.0910	321557.4940	888.1870	888.1900	0.0030
5133	2266355.9490	321552.9720	888.2040	888.1500	-0.0540
5134	2266354.3490	321549.2420	888.1390	888.0900	-0.0490
5135	2266352.5040	321545.3360	888.0790	888.0400	-0.0390
5136	2266350.8110	321541.7220	887.9890	888.0000	0.0110
5137	2266349.1390	321538.0810	887.8690	887.9700	0.1010
5138	2266347.2680	321534.3920	887.9390	887.9400	0.0010
5139	2266345.8280	321530.9360	887.8890	887.9900	0.1010
5140	2266344.0950	321527.3840	887.9210	887.8700	-0.0510

5141	2266342.5380	321524.1660	887.7710	887.8300	0.0590
5142	2266340.8160	321520.3870	887.7380	887.7300	-0.0080
5143	2266339.3420	321517.2530	887.7290	887.6700	-0.0590
5144	2266319.9080	321530.3120	888.1170	888.1700	0.0530
5145	2266321.6540	321534.1680	888.1480	888.2400	0.0920
5146	2266323.4410	321537.8070	888.3940	888.3100	-0.0840
5147	2266325.2170	321541.9610	888.3260	888.4100	0.0840
5148	2266327.2730	321546.3720	888.4240	888.4800	0.0560
5149	2266329.7700	321551.5850	888.6640	888.5700	-0.0940
5150	2266331.4040	321555.2140	888.6100	888.6100	0.0000
5151	2266333.2360	321559.1410	888.6770	888.6500	-0.0270
5152	2266335.5170	321564.0080	888.8300	888.7100	-0.1200
5153	2266337.1980	321567.7920	888.7310	888.7300	-0.0010
5154	2266338.9030	321571.3290	888.8740	888.7800	-0.0940
5155	2266340.5390	321574.7320	888.8100	888.8000	-0.0100
5156	2266342.8980	321579.9650	888.8660	888.8200	-0.0460
5157	2266342.8410	321579.9090	888.8800	888.8200	-0.0600
5158	2266344.5620	321583.9990	888.8020	888.8500	0.0480
5159	2266346.4540	321587.7430	888.8330	888.8700	0.0370
5160	2266348.5360	321591.8890	888.9440	888.9000	-0.0440
5161	2266349.8800	321595.3360	888.9000	888.9100	0.0100
5162	2266351.3160	321598.5450	888.9450	888.9400	-0.0050
5163	2266352.9250	321602.0250	888.9640	888.9500	-0.0140
5164	2266354.9580	321606.2390	888.9260	888.9900	0.0640
5165	2266356.6340	321610.2080	889.0780	889.0000	-0.0780
5166	2266358.3290	321614.1940	889.0480	888.9700	-0.0780
5167	2266360.2180	321618.2270	888.9840	888.9100	-0.0740
5168	2266362.1290	321622.8230	888.9260	888.8700	-0.0560
5169	2266364.2060	321627.3000	888.8370	888.8500	0.0130
5170	2266365.9940	321631.1960	888.7710	888.8200	0.0490
5171	2266376.2450	321625.4850	888.7420	888.7100	-0.0320
5172	2266374.1660	321620.8530	888.8000	888.7700	-0.0300
5173	2266371.7240	321615.9020	888.7600	888.8200	0.0600
5174	2266369.5160	321610.7450	888.8320	888.8300	-0.0020
5175	2266367.2450	321605.6170	888.9790	888.8400	-0.1390
5176	2266364.8370	321600.4150	888.9280	888.8400	-0.0880
5177	2266362.9060	321595.9000	888.8080	888.8400	0.0320
5178	2266361.0890	321591.9630	888.7990	888.8400	0.0410
5179	2266359.3020	321588.1730	888.8260	888.8500	0.0240
5180	2266357.4460	321583.9180	888.7480	888.8300	0.0820
5181	2266355.0020	321578.6970	888.7020	888.7900	0.0880
5182	2266353.7440	321575.2010	888.7810	888.7600	-0.0210

5183	2266350.5340	321567.9750	888.7330	888.7200	-0.0130
5184	2266348.2460	321563.8590	888.6210	888.6600	0.0390
5185	2266346.2860	321559.5090	888.5570	888.6100	0.0530
5186	2266344.1370	321554.9160	888.5700	888.5700	0.0000
5187	2266342.4020	321551.0210	888.5430	888.5200	-0.0230
5188	2266340.1680	321546.4280	888.4140	888.4400	0.0260
5189	2266338.0470	321541.9760	888.4570	888.3800	-0.0770
5190	2266335.0230	321535.5230	888.2290	888.3300	0.1010
5191	2266332.7590	321530.3070	888.0920	888.2500	0.1580
5192	2266330.4820	321525.1320	888.0490	888.1500	0.1010
5198	2266318.1050	321526.4610	888.0080	888.0800	0.0720
5199	2266323.0720	321523.5340	887.9990	888.0700	0.0710
5200	2266328.5570	321520.9910	887.9450	888.0500	0.1050
5201	2266333.3810	321518.6140	887.7310	887.9100	0.1790
5202	2266338.8220	321515.8730	887.5150	887.6300	0.1150
5212	2266362.7740	321567.3820	888.2010	888.1800	-0.0210
5213	2266356.8380	321570.3690	888.5100	888.5500	0.0400
5214	2266352.2450	321572.2160	888.7830	888.7400	-0.0430
5215	2266347.7750	321575.1100	888.8580	888.8300	-0.0280
5216	2266341.9430	321577.8030	888.7700	888.8100	0.0400
5229	2266367.1110	321633.6810	888.7130	888.7900	0.0770
5230	2266372.7890	321630.7920	888.7250	888.7300	0.0050
5231	2266377.6360	321628.5440	888.6950	888.6700	-0.0250
5232	2266382.6870	321626.4460	888.3910	888.4500	0.0590
5233	2266388.3100	321624.0390	888.1020	888.0700	-0.0320

DTM Accuracy Class B Survey Points & Check Points

Survey Check Point	Point Easting	Point Northing	Survey Check Point Elevation	LiDAR Elevation	Dz
5193	2266303.7340	321533.2410	888.9270	888.7000	-0.2270
5194	2266308.2230	321531.2340	888.1540	888.3500	0.1960
5195	2266312.2140	321529.2320	887.6940	887.9400	0.2460
5196	2266314.7660	321528.0110	887.9020	888.1000	0.1980
5197	2266316.2720	321527.3640	888.0210	887.9500	-0.0710
5203	2266339.7330	321515.4600	887.6160	887.5400	-0.0760
5204	2266341.8880	321514.6280	887.5860	887.3500	-0.2360
5205	2266344.1800	321513.6090	887.2160	887.1400	-0.0760
5206	2266349.3230	321511.1300	886.1680	886.6100	0.4420
5207	2266402.1580	321553.0060	885.5810	885.7100	0.1290
5208	2266390.9690	321557.0530	886.5600	886.5500	-0.0100
5209	2266378.7290	321561.6070	887.1680	887.2300	0.0620
5210	2266366.8000	321565.9080	887.6080	887.6300	0.0220
5211	2266365.4590	321566.2910	887.8070	887.8600	0.0530
5217	2266339.9970	321578.6500	888.6960	888.7400	0.0440
5218	2266336.8000	321579.7710	888.6620	888.6800	0.0180
5219	2266334.0060	321581.0680	888.6110	888.8900	0.2790
5220	2266333.2750	321581.6290	889.0100	888.9800	-0.0300
5221	2266327.9050	321584.7190	889.7800	889.8300	0.0500
5222	2266323.2240	321586.9280	890.7070	890.8800	0.1730
5223	2266352.8460	321638.8890	889.3650	889.3400	-0.0250
5224	2266355.8450	321637.6880	888.5620	888.6600	0.0980
5225	2266358.9030	321636.1490	888.4130	888.7000	0.2870
5226	2266359.8550	321635.8710	888.6250	888.7000	0.0750
5227	2266362.1680	321635.3980	888.6620	888.7100	0.0480
5228	2266365.1220	321634.4700	888.7110	888.7400	0.0290
5234	2266391.5700	321622.9280	887.8920	887.8000	-0.0920
5235	2266395.2050	321621.7100	887.2840	887.2900	0.0060
5236	2266400.1050	321620.1450	886.5770	886.8600	0.2830
5237	2266413.4590	321613.6570	885.7320	886.0500	0.3180

Appendix D – Example Static GNSS Coordinate Statistical Analysis

VRS GNSS Project Control Monument Coordinate Analysis

PROJECT:	RIC-039-24.73								REPORT DATE:	11/15/2013
PID:	87695								PREPARED BY:	J. Keller
MONUMENT NUMBER:		CP01	NUMBER OF SESSIONS:		12				CHECKED BY:	J. Keller

SESSION #	Point	Observation Date	Start Time	Northing(m)	Easting(m)	Height(m)	Δ Northing(m)	Δ Easting(m)	Δ Height(m)	Include in Solution?
1	CP01	11.14.2013	10:11:58 AM	116107.06410	609689.50720	362.55740	0.01280	-0.00795	0.01785	☑
2	CP01	11.14.2013	10:13:14 AM	116107.07550	609689.51180	362.55180	0.00140	-0.01255	0.02345	☐ FALSE
3	CP01	11.14.2013	10:13:48 AM	116107.07510	609689.50370	362.57220	0.00180	-0.00445	0.00305	☑
4	CP01	11.14.2013	10:14:11 AM	116107.06330	609689.49700	362.59260	0.01360	0.00225	-0.01735	☐ FALSE
5	CP01	11.14.2013	10:15:17 AM	116107.07620	609689.48920	362.58540	0.00070	0.01005	-0.01015	☑
6	CP01	11.14.2013	10:15:40 AM	116107.07700	609689.48670	362.59100	-0.00010	0.01255	-0.01575	☑
7	CP01	11.14.2013	10:16:12 AM	116107.09600	609689.48740	362.59220	-0.01910	0.01185	-0.01695	☐ FALSE
8	CP01	11.14.2013	10:16:37 AM	116107.08800	609689.48190	362.59530	-0.01110	0.01735	-0.02005	☐ FALSE
9	CP01	11.14.2013	10:17:41 AM	116107.10300	609689.49490	362.56990	-0.02610	0.00435	0.00535	☐ FALSE
10	CP01	11.14.2013	10:18:16 AM	116107.08550	609689.50060	362.56870	-0.00860	-0.00135	0.00655	☑
11	CP01	11.14.2013	10:18:41 AM	116107.08660	609689.50670	362.55570	-0.00970	-0.00745	0.01955	☐ FALSE
12	CP01	11.14.2013	10:19:17 AM	116107.08350	609689.50810	362.57680	-0.00660	-0.00885	-0.00155	☑
13	0	0:00:00	12:00:00 AM	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	☐ FALSE
14	0	0:00:00	12:00:00 AM	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	☐ FALSE
15	0	0:00:00	12:00:00 AM	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	☐ FALSE
			AVERAGE	116107.07690	609689.49925	362.57525	RMSE:	RMSE:	RMSE:	
						RMSE IN METRIC:	0.00689	0.00838	0.01099	
		ENGLISH TO METRIC CONVERSION	3.280833333			RMSE IN US SURVEY FEET:	0.0226	0.0275	0.0360	
		UNITLESS GRID TO GROUND MULTIPLIER	1.000090872				PASS	PASS	PASS	

AVERAGED GPS-DERIVED POSITION

MONUMENT COORDINATES	NORTHING	EASTING	ORTHO HEIGHT
METERS (GRID)	116107.0769	609689.4993	362.5753

LEVELED ELEVATION

US SURVEY FEET	1189.549	(Type the leveled elevation or N/A if no leveled elevation is available)
MONUMENT HELD	CP01	(Type the monument name from which leveling originated)
LEVLED ELEVATION - GPS DERIVED ELEVATION =		0.000

FINAL MONUMENT COORDINATES

MONUMENT COORDINATES	NORTHING	EASTING	ELEVATION	FEATURE CODE
US SURVEY FEET (GRID)	380927.968	2000289.632	1189.549	IPINS
US SURVEY FEET (GROUND)	380962.584	2000471.403	1189.549	IPINS

Notes:
3/4" rebar with 3" aluminum disk marked "Ohio Department of Transportation" set

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

Mask Angle: 13°

For a copy of the Survey Master spreadsheet go to:

(http://www.dot.state.oh.us/Divisions/Engineering/CaddMapping/Pages/SurveyandMappingSpec.aspx)

Appendix E - Example OPUS Report

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)]
```

EPHEMERIS

ORTHOMETRIC HEIGHT/ELEVATION
Convert to US Survey Feet

```
                                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)
```

NORTHING & EASTING
Convert to US Survey Feet

COMBINED
SCALE
FACTOR

```
                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
DK3322 KYTF KY HWY DIST 6 CORS ARP          N390240.928 W0843436.884    49759.0
DI1082 OHPR PREBLE COUNTY CORS ARP          N394426.665 W0843429.075    42586.8
DI2232 OHDT CITY OF DAYTON CORS ARP         N394553.062 W0841050.335    38155.4
```

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

Appendix F – Surveyor's Certification Statement

<u>Surveyor's Certification for Project Control</u>

I, (Surveyor's Name) do hereby certify that the (Geodetic and/or Primary Project Control depending on project path) for (name of project) was constructed and established in accordance with the Ohio Department of Transportation's Survey and Mapping Specifications, dated (last revision date) for a (Path 1 thru 5) project and meet the accuracy requirements as set forth by these specifications. I also certify that all ground control points to control aerial mapping have been set and meet the accuracy requirements as set forth herein (if applicable). 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

Appendix G – Property Owner Notification

(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)

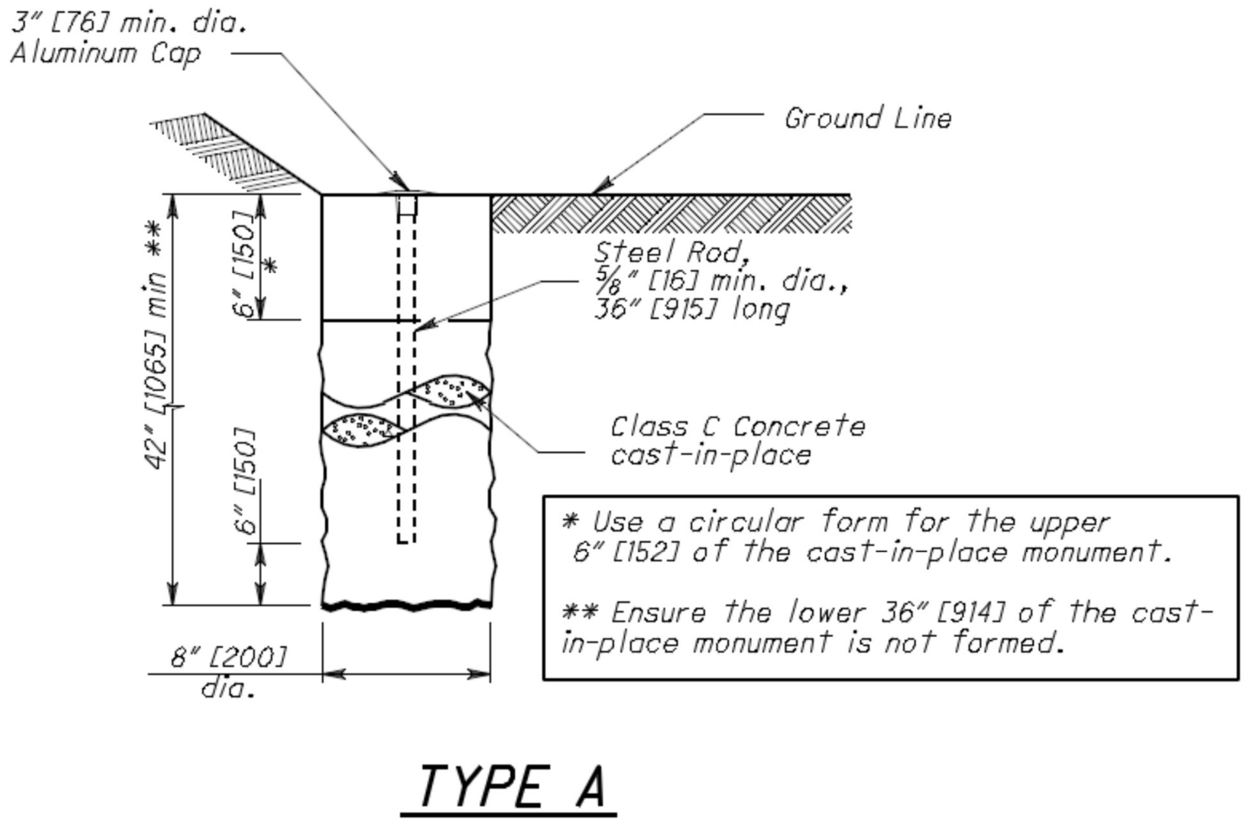
Please note that our survey personnel will not be able to give any information or answers to your questions. The survey staff will simply be collecting data to complete the surveying or specific mapping work. Should the ultimate design of the project affect your property or lands, a representative of 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, <u>(Surveyor Name and Title)</u>

Appendix H – Geodetic/Project Control Monuments

Geodetic and Primary Project Control Monument, Type A



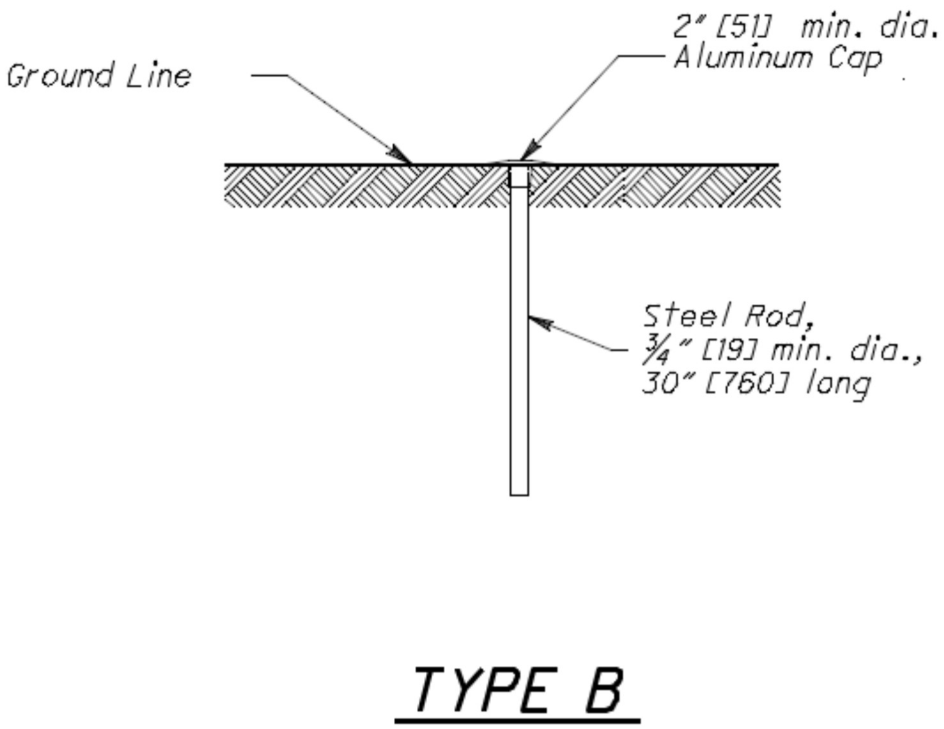
<u>Notes:</u>

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



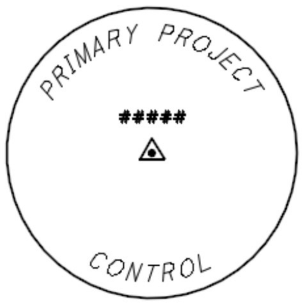
Notes:

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



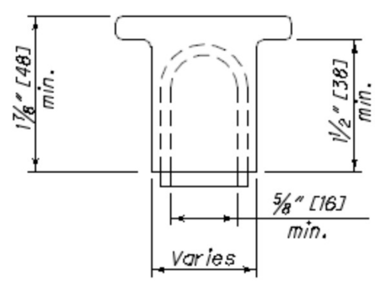
DESIGN 1

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

Appendix I – L & D Manual G105 Survey Parameters

G105 – SURVEYING PARAMETERS

Designer Note:

Use note G105, unless otherwise directed by the District Survey Operations Manager. Projects should have utilized the Department's **Survey and Mapping Specification** which can be found on the **Office of CADD and Mapping Services**' website. Specify primary project control parameters and provide a table in the plans with the following information for primary project control monuments, including azimuth marks and temporary benchmarks: Point Number, Grid Coordinates (Northing, Easting), Scaled Coordinates (Northing, Easting), Elevation, and Description of Monument. At a minimum, the Description of Monument in the table shall indicate the type of monument (i.e. iron pin, concrete monument, etc.) and whether the monument is for project control or traverse purposes. If a Monument, Type B, is used for project control, do not provide an elevation in the Elevation column of the table. Use of a Monument, Type B, establishes horizontal control only. A separate vertical benchmark (i.e. aluminum disc on bridge abutment) will need to be included in the table. Project control is typically established prior to construction. If the designer determines that the location of the monuments associated with project control may be disturbed by the Contractor's construction activities, provide quantities for resetting the monuments in the plans according to CMS 623. Standard Construction Drawing RM-1.1 and the Department's **Survey and Mapping Specification** provide further information regarding project control.

G105

PRIMARY PROJECT CONTROL MONUMENTS GOVERN ALL POSITIONING ON ODOT PROJECTS. SEE SHEET ___ OF THE PLANS FOR A TABLE CONTAINING PROJECT CONTROL INFORMATION.

USE THE FOLLOWING PROJECT CONTROL, VERTICAL POSITIONING, AND HORIZONTAL POSITIONING PARAMETERS FOR ALL SURVEYING:

PROJECT CONTROL

POSITIONING METHOD: ______________________________
MONUMENT TYPE: ______________________________

VERTICAL POSITIONING

ORTHOMETRIC HEIGHT DATUM: ______________________________
GEOID: ______________________________

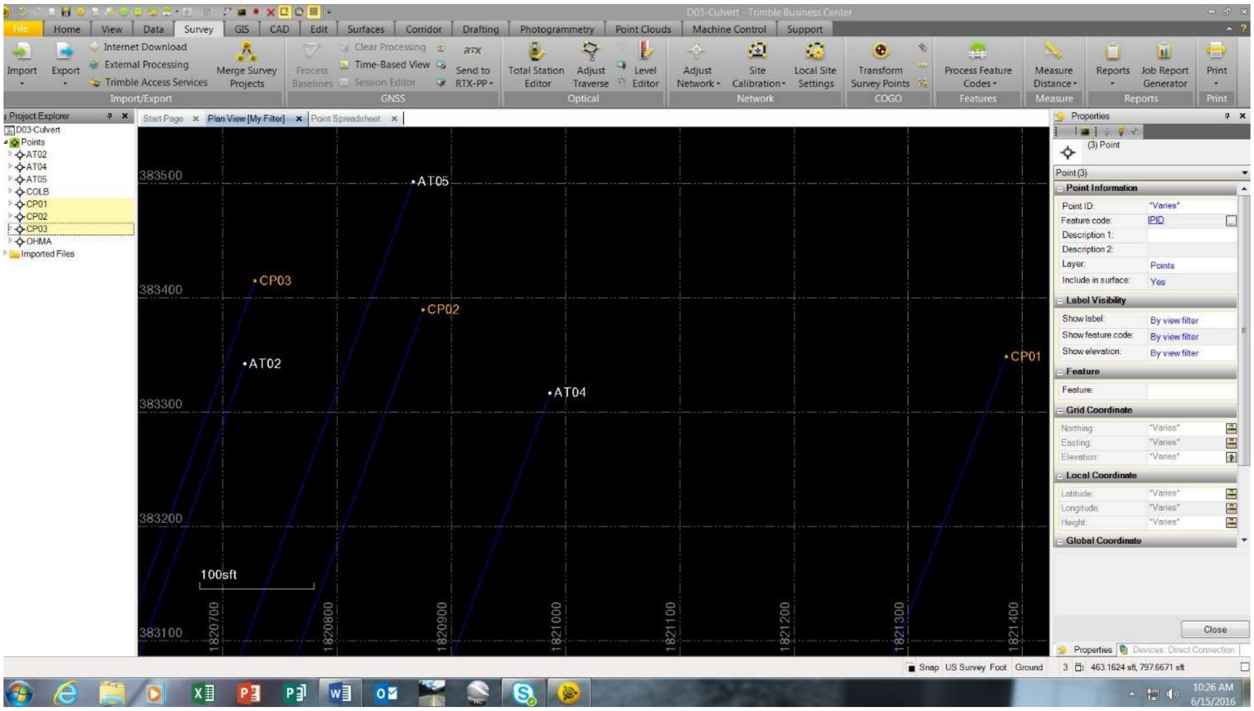
HORIZONTAL POSITIONING

REFERENCE FRAME: ______________________________
ELLIPSOID: ______________________________
MAP PROJECTION: ______________________________
COORDINATE SYSTEM: ______________________________
COMBINED SCALE FACTOR: ______________________________
ORIGIN OF COORDINATE SYSTEM: ______________________________

USE THE POSITIONING METHODS AND MONUMENT TYPE USED IN THE ORIGINAL SURVEY TO RESTORE ALL MONUMENTS RELATED TO PRIMARY PROJECT CONTROL THAT ARE DAMAGED OR DESTROYED BY CONSTRUCTION ACTIVITIES. RESTORE THE DAMAGED OR DESTROYED MONUMENTS IN ACCORDANCE WITH CMS 623.

Appendix J – Project Scale Factor Calculations

Step 1.) **Import control points into Trimble Business Center or other compatible Survey Processing Software.**



Step 2.) **Select points that are to be used to calculate the Project Scale Factor. Points selected should represent a good overall elevation (high, low, mean elevation) of the project.**

Step 3.) **Open a point spreadsheet to determine the projection scale factor and height scale factor of the points selected. Use the Projection Scale Factor of the control point near the center of the project (0.9999576958). Average the Height Scale Factor of any and all points used to determine an elevation that is representative of the project.**

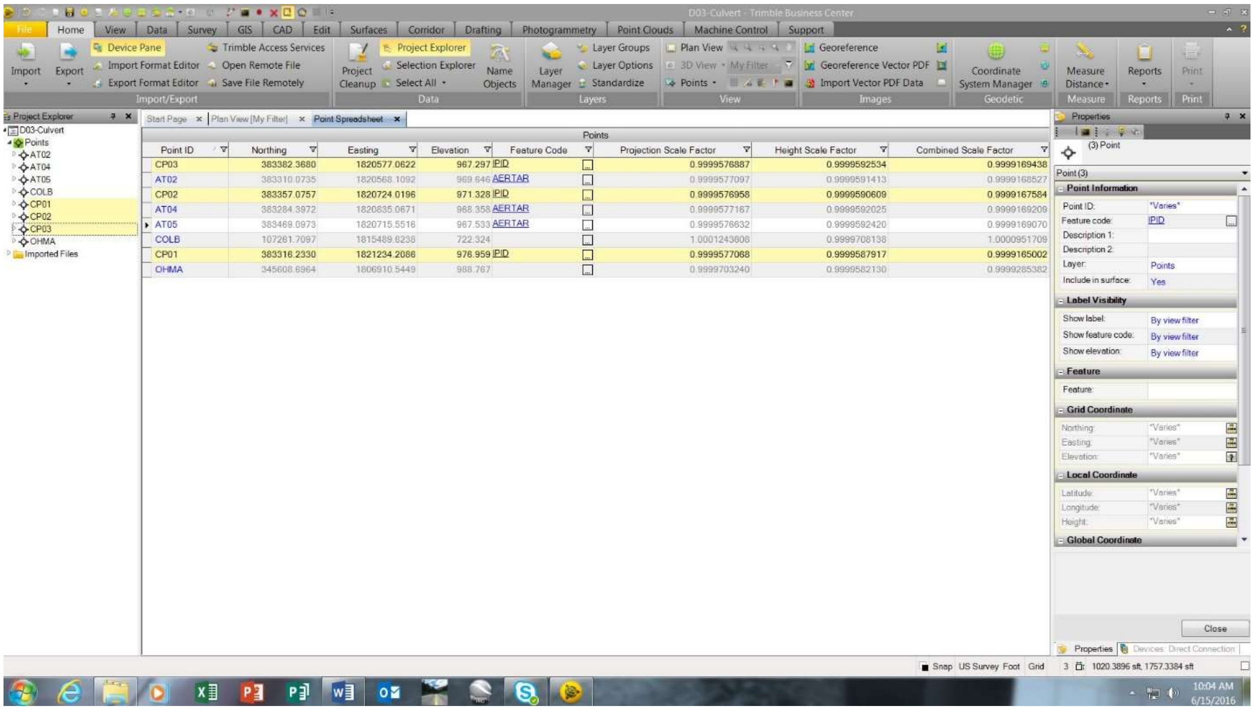
(0.9999587917 + 0.9999590609 + 0.9999592534)/3 = 0.99995916

Step 4.) **Multiply Projection Scale factor by average Height Scale Factor**

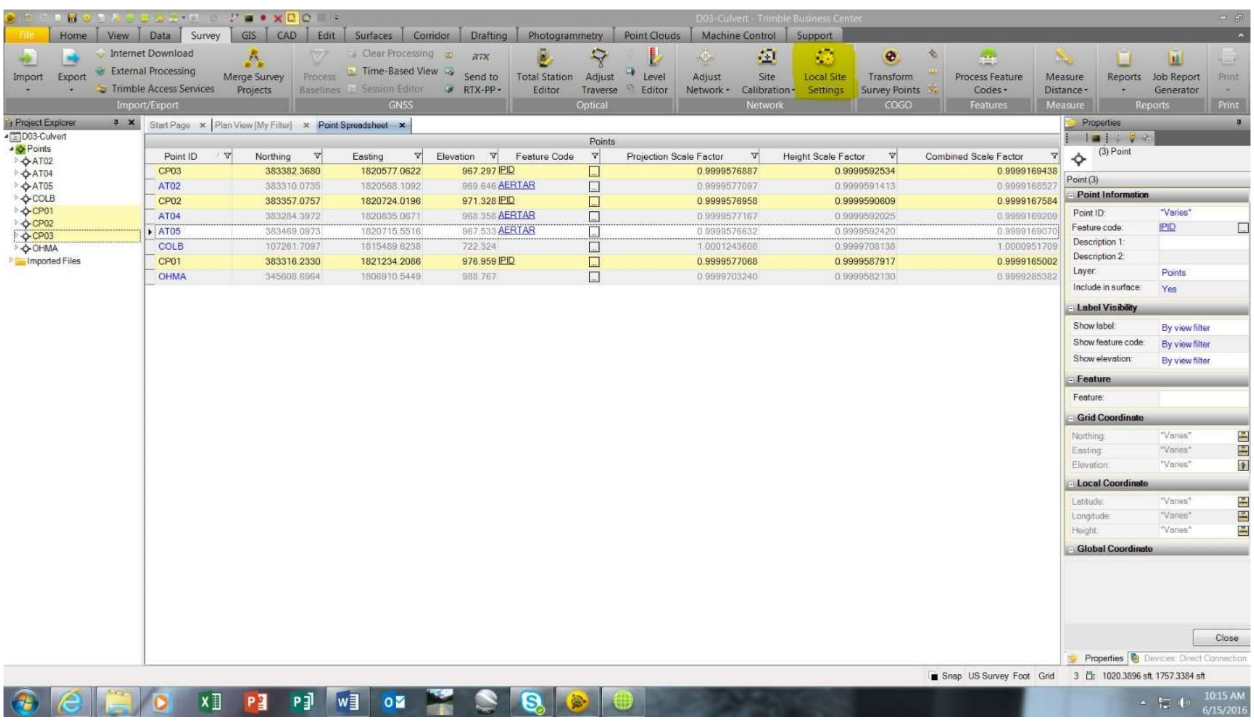
0.99999576958 * 0.99995916 = 0.99991686

Step 5.) **Take the inverse of your answer in Step 4 1/.99991686 = 1.00008315**

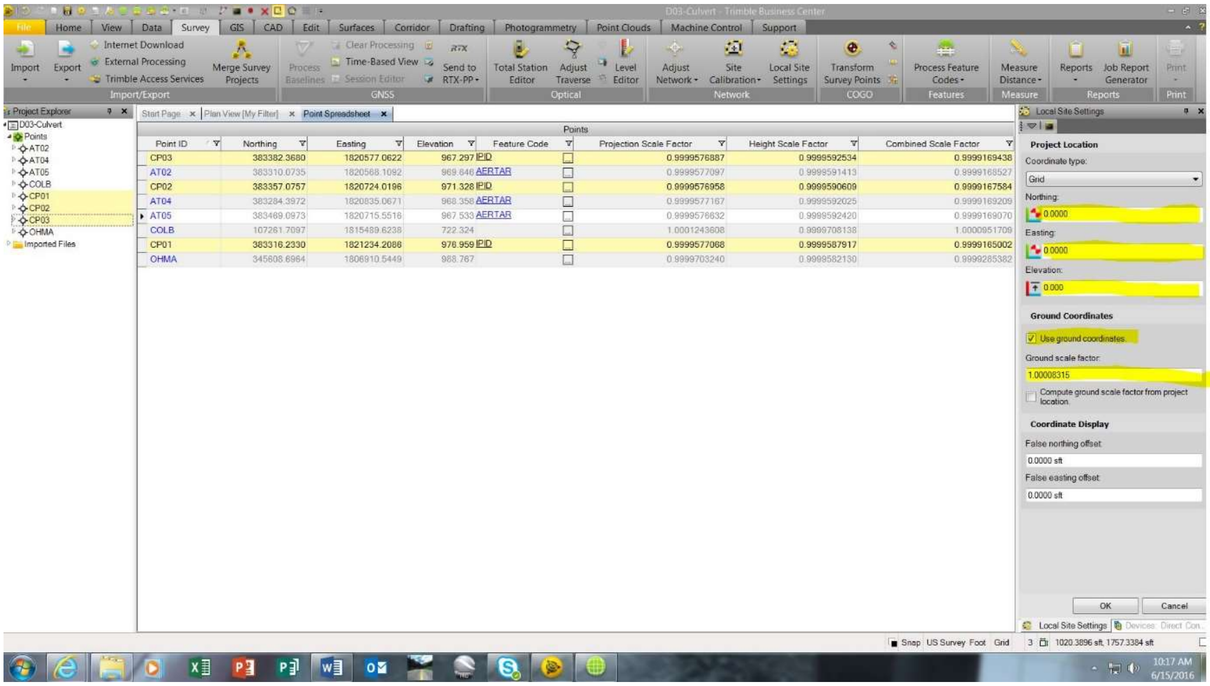
<u>This is your Project Scale Factor</u>



Step 6.) **Select Local Site Settings to enter the Project Scale Factor and project the site to Ground Coordinates**



Step 7.) **Enter origin point (0,0) elevation (0) and Project Scale Factor. Select use Ground Coordinates and click OK.**



Step 8.) When completed Combined Scale Factor for the points used should change to numbers close to 1.00000000.