Project Control for Highway Projects

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Grid to Ground and State Plane Coordinates

Why do we worry about this?
Ohio Revised Code
157.03 Plane co-ordinates; description

- The plane co-ordinates of a point on the earth’s surface, to be used in expressing the position or location of such point in the appropriate zone of the systems specified in section 157.01 of the Revised Code, shall consist of two distances, expressed in United States survey feet and decimals of a United States survey foot when using the Ohio co-ordinate system of 1927, and expressed in meters and decimals of a meter when using the Ohio co-ordinate system of 1983...

- We find the practice of having Grid coordinates in meters and Ground coordinates in feet a simple and effective way to distinguish between the two systems.
Ohio Revised Code
157.04  Evidence of corner location, purchaser need not rely on system description

Plane co-ordinates, used to reference and describe land boundary corners and made part of the recorded description of such corners, shall be considered adequate evidence of the location of such corners in the absence of original physical monuments or other acceptable controlling evidence of original corner locations. In all instances where reference has been made to such co-ordinates in land surveys, the scale, sea level, and grid factors must also be stated for the survey lines used in computing ground distances and areas.

Nothing in this chapter shall be construed to require a purchaser or mortgagee of real property to rely wholly on a land description, any part of which depends exclusively upon either Ohio co-ordinate system.
Ohio Revised Code
157.09 Distances, bearings, and areas computed indirectly from co-ordinates

Distances, bearings, and areas computed indirectly from co-ordinates shall be considered acceptable measurement evidence for land and other surveys if such co-ordinates have been determined in accordance with sections 157.04, 157.07, and 157.08 of the Revised Code
Atmospheric corrections
Unadjusted equipment
Centering Errors
Combined Scale Factor

The Error Piggy Bank
Don’t feed the Error Pig!

Why introduce unnecessary error?

What errors are acceptable?

You be the Judge.
Don’t feed the Error Pig!

- We eliminate the errors we can by using due diligence in taking our measurements.
- We keep our equipment in proper adjustment.
- We stay conscious of the weather and input the proper atmospheric corrections in our data collectors and total stations to compensate for temperature and pressure.
- We scale all of our jobs to ground coordinates to minimize the effects of the differences between the ellipsoid and ground.
Combined Scale Factors: a case study

<table>
<thead>
<tr>
<th>Latitude</th>
<th>Elevation</th>
<th>Combined Scale Factor</th>
<th>Distance variation in 1000'</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>N 40°-12'-55&quot;</td>
<td>930'</td>
<td>0.99999483</td>
<td>999.99</td>
<td>Delaware South</td>
</tr>
<tr>
<td>N 40°-26'-02&quot;</td>
<td>946'</td>
<td>1.00004223</td>
<td>1000.04</td>
<td>Delaware/Marion</td>
</tr>
<tr>
<td>N 40°-42'-09&quot;</td>
<td>945'</td>
<td>1.00008586</td>
<td>1000.09</td>
<td>Marion/Wyandot</td>
</tr>
<tr>
<td>N 40°-59'-38&quot;</td>
<td>956'</td>
<td>1.00010576</td>
<td>1000.11</td>
<td>Wyandot/Seneca</td>
</tr>
<tr>
<td>N 41°-15'-19&quot;</td>
<td>785'</td>
<td>1.00009271</td>
<td>1000.09</td>
<td>Seneca/Sandusky</td>
</tr>
<tr>
<td>N 41°-27'-14&quot;</td>
<td>574'</td>
<td>1.00006458</td>
<td>1000.06</td>
<td>Sandusky/Ottawa</td>
</tr>
<tr>
<td>N 41°-42'-00&quot;</td>
<td>558'</td>
<td>1.00002343</td>
<td>1000.02</td>
<td>North Bass Island</td>
</tr>
</tbody>
</table>
We got through the “WHY” now let’s focus on the “HOW”
Field Work:
Setting Control, Know your Project Path

Pick Your Path

Tasks have been filtered to remove items that should not typically be included in a project given a certain path. Please note that the Project Manager may determine that it is necessary to include a task based on unique project circumstances.

While an attempt has been made to identify the likelihood that a task is needed for a certain project path, each project must be evaluated to determine if a task is appropriate. If there are questions regarding a task, contact the "responsible office" provided on the task list.

Need a better understanding of what path you should choose? Run through the pages here to get a quick definition of each path and then scroll down to get a more detailed understanding of Path Milestones and a link to the typical tasks associated with the path you choose.
**Field Work: Setting Control**

**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:

<table>
<thead>
<tr>
<th><em>Monument Type</em></th>
<th><strong>Monument Controls</strong></th>
<th><strong>Project Category</strong></th>
<th><em><strong>Positioning Methods</strong></em></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Horizontal &amp; Vertical</td>
<td>Major</td>
<td>Static GNSS</td>
</tr>
<tr>
<td>B</td>
<td>Horizontal with a Separate Temporary Benchmark</td>
<td>Minor and Minimal</td>
<td>++Static GNSS or ODOT VRS</td>
</tr>
</tbody>
</table>

* 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.
Field Work: Setting Control

ODOT Type “A” Monuments

- Path 3 thru Path 5
  - Complex Projects
  - R/W involvement
  - Projects usually span longer time frames

- Setting Control
  - Set a minimum of (3) 8 inch concrete monuments that will survive the project
  - Benchmarks (elevations) established on the concrete monuments
Field Work: Setting Control

ODOT Type “B” Monuments

- Path 1 thru Path 3
  - Simple Projects
  - Little or no R/W involvement
  - Projects usually completed in shorter time frames

- Setting Control
  - Set a minimum of (3) 30” pins that will survive the project
  - Existing control can be used if it meets the specifications

- 3/4” Rebar with 3-1/4” Aluminum Cap
- 5/8” Rebar with Plastic Cap

- Benchmarks
  - Spike in Pole
  - Chiseled “X”
  - Square Cut

502.1 – 502.2.D
Field Work: Measuring Control Points

Initial survey control is collected as grid coordinates in meters.

Grid coordinates are the direct mathematical conversion from WGS 84 (Latitude, Longitude, Ellipsoid) to State Plane Coordinates.
Field Work: Measuring Control Points

- Depending on the size of the job and number of control points to be set, the horizontal positioning of the control normally only takes a few hours.

- Leveling is typically performed on the control points to establish precise elevations.

- We can also start our topographic mapping at this time (before control is formally established). As long as the control points are processed and entered into a Trimble Business Center project as Survey Control before the data collector files are imported, the data automatically adjusts to the control points.
Field Work: Measuring Control Points
Type “A” Monuments

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.
Field Work: Measuring Control Points

- **Eliminate centering error**
  - Take (4) shots, rotating the rod 90 degrees after each observation

- **Eliminate bad initializations**
  - Physically break initialization between sets by turning the antenna upside-down or covering the antenna

- **Eliminate repeat site visits**
  - (3) sets or (12) observations generally provides enough data to satisfy the RMSE requirements
VERTICAL CONTROL
Field Work: Leveling

- GPS does not have a strong vertical component
- Leveling is used to establish precise elevations on all control points and benchmarks
- One project control point is held for elevation, remaining control points and benchmarks are leveled from there
Processing

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

*Check,* = 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:

<table>
<thead>
<tr>
<th>Coordinate Component</th>
<th>Maximum Allowable RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northing</td>
<td>0.029 feet [0.0088 meters]</td>
</tr>
<tr>
<td>Easting</td>
<td>0.029 feet [0.0088 meters]</td>
</tr>
<tr>
<td>Elevation</td>
<td>0.039 feet [0.0119 meters]</td>
</tr>
</tbody>
</table>

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 benchmarks 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).

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 ob
REMEMBER! YOUR MAPPING AND CONTROL IS THE FOUNDATION OF THE PROJECT.

IT IS IMPORTANT INFORMATION!

IT NEEDS TO BE CORRECT!
Contact Information:

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