

6. NYSDOT COORDINATE SYSTEMS AND DATUMS

NYSDOT COORDINATE SYSTEMS AND DATUMS

6.1 INTRODUCTION

Surveys are performed on the irregular surface of the earth, and are then transformed into a plane rectangular coordinate system for ease of use in engineering and surveying computations. In a state as large as New York, there is a need for a consistent, accurate, and documented system so that surveys performed for NYSDOT are related in a standardized system. This requires a well-defined coordinate system and datums, which NGS has developed and NYS has adopted. This coordinate system and datums will provide NYSDOT with a consistent, accurate, and reproducible system, which will protect the interests of the People of the State of New York.

There may be exceptions to the standards specified below. The coordinate system and datums for each project should be reviewed with the Regional Land Surveyor.

6.2 REFERENCE SYSTEM

Surveys for NYSDOT shall be connected to the NYS Spatial Reference Network (NYSNet). NYSNet is a network of continuously operating Global Positioning System (GPS), reference stations (CORS) throughout NYS that can be used for differential GPS applications. NYSNet is part of the National Spatial Reference System (NSRS), maintained by the National Geodetic Survey.

The National Spatial Reference System (NSRS) is a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States, and how these values change with time. NSRS comprises:

- 1) A consistent, accurate, and up-to-date national shoreline;
- 2.) A set of Global Positioning System (GPS) Continuously Operating Reference Stations (CORS) meeting NOAA standards for installation, operation, and data distribution;
- 3.) A network of permanently marked points including the Federal Base Network (FBN), and Cooperative Base Network (CBN), commonly called the High Accuracy Reference Network (HARN), User Densification Network; and a set of accurate models describing dynamic geophysical processes that affect spatial measurements.

NSRS provides a highly accurate, precise, consistent geographic framework throughout the United States. It is the foundation for the National Spatial Data Infrastructure, a critical component of the information superhighway. NSRS is a significant national resource - one whose value far exceeds its intended purpose.

6.3 COORDINATE SYSTEM

Because of the complexity of performing the calculations for geodetic surveying and the limited extent of most surveying projects, most surveyors generally use plane surveying techniques. For local projects of limited extent, plane surveying yields accurate results, but for large projects locally administered plane surveying systems may not be adequate. Not only can locally administered plane coordinate systems be inaccurate over large areas, but they cannot be easily related to other local systems.

NYSDOT COORDINATE SYSTEMS AND DATUMS

In response to the needs of local surveyors for an accurate plane surveying coordinate system useful over relatively large areas, the U. S. Coast and Geodetic Survey (the predecessor of NGS) developed the State Plane Coordinate System in 1934.

The State Plane Coordinate System was established to provide a means for transferring the geodetic positions of monumented points to plane coordinates that would permit the use of these monuments in plane surveying over relatively large areas without introducing significant error.

A plane-rectangular coordinate system is by definition a flat surface. Geodetic positions on the curved surface of the earth must be “projected” to their corresponding plane coordinate positions. Projecting the curved surface onto a plane requires some form of deformation. Imagine the stretching and tearing necessary to flatten a piece of orange peel.

Survey data for use on NYSDOT projects will be coordinated and reported in the New York State Plane Coordinate System (NYSPCS) of 1983 (with specified adjustment date) as established in Chapter 605 of the 1995 Laws of the State of New York amending Chapter 605 of the 1938 Laws of the State of New York. Chapter 605 of the 1938 Laws of the State of New York authorized the Department of Public Works (Predecessor of NYSDOT) as administrative agency in connection with the NYSPCS.

NYSDOT COORDINATE SYSTEMS AND DATUMS

6.4 NYSPCS ZONES

NYSPCS is made up of 4 zones: West, Central, East and Long Island.

FIGURE I. NYSPCS ZONES



For a definition of these zones refer to Chapter 605 of the 1995 Laws of the State of New York. Coordinates are specific to each zone. Coordinates can be projected from one zone to another accurately. Most Surveying, GPS, and Geographic Information System (GIS) software include projection tools to convert state plane coordinates from one zone to another. NYSDOT Projects that extend from one zone to another should use NYSPCS coordinates based only in one zone.

6.5 HORIZONTAL DATUM

An ellipsoid is a mathematically defined, regular surface (with specific dimensions) most closely approximating the shape of the earth. It is a biaxial ellipse rotated about its minor (shorter) axis. It's like a flattened sphere because the earth is in fact flattened slightly at the poles and bulges somewhat at the equator.

A geodetic datum is a mathematical model that consists of an ellipsoid and an initial point of reference. Once a datum is adopted, it provides the surface to which ground control measurements are referred. A horizontal datum forms the basis for the computations of horizontal control surveys in which the curvature of the earth is considered. The two horizontal datums normally concerned with in mapping are the North American Datum of 1927 (NAD27) and the North American Datum of 1983 (NAD83). Problems with NAD27 included measurement errors and intentional distortions. The datum was redefined and recomputed, resulting in NAD83, which is more accurate. Two of the important parameters that define a datum are the reference ellipsoid selected for the computations and the location of an initial point of reference, or origin. NAD83's reference ellipsoid is Geodetic Reference System 1980 (GRS80). GPS

NYS DOT COORDINATE SYSTEMS AND DATUMS

uses the World Geodetic System 1984 (WGS-84) reference ellipsoid (an earth-centered ellipsoid whose origin is the center of the earth's mass). The differences between WGS-84 and GRS80 are very small and for most GPS applications these ellipsoids can be considered equal (the difference is to the 9th decimal place).

Horizontal coordinates shall be reported in the North American Datum of 1983 (NAD83) as defined in NOAA Manual NOS NGS 5 "State Plane Coordinate System of 1983".

The CORS adjustment of NAD83 coordinates, available from NGS, shall be used. The most recent CORS adjustment shall be used, currently NAD83 (CORS96). The most recent EPOCH date shall be used, currently EPOCH 2002.

To assure the most current data is used, coordinates for these stations shall be obtained from the [NGS database](http://www.ngs.noaa.gov/cgi-bin/datasheet.prl) at: <http://www.ngs.noaa.gov/cgi-bin/datasheet.prl>

The physical reference network (the ground control stations) for the NAD83 (CORS) datum shall be any CORS station that is part of the [NYS Spatial Reference Network \(NYSNet CORS/RTN\)](#). When necessary, National CORS surrounding NYS may also be included in the control survey.

When including other CORS stations their data availability and stability should be considered.

NYS DOT COORDINATE SYSTEMS AND DATUMS

6.6 VERTICAL DATUM

A vertical datum is a surface to which elevations are referred. Elevations (Orthometric Heights) shall be reported in the North American Vertical Datum of 1988 (NAVD88). The physical reference network (the ground control stations) for NAVD88 shall include any station listed in the NGS database for which the orthometric height was determined by differential leveling techniques, adjusted to the NAVD88 datum, and has the appropriate accuracy classification for the survey. To assure the most current data is used; orthometric heights for these stations shall be obtained from the [NGS database](http://www.ngs.noaa.gov/cgi-bin/datasheet.prl) at: <http://www.ngs.noaa.gov/cgi-bin/datasheet.prl>

The NYSNet CORS/RTN is not directly connected to the North American Vertical Datum of 1988 (NAVD88). Depending upon required survey accuracy, the user must determine the appropriate connections to local vertical datums, including NAVD88. Possible connection methods when using the NYSNet CORS/RTN:

- 1) Use of GPS observations and a GEOID model.
- 2) Use of GPS observations, a GEOID model, and mean shift transformation to local benchmarks.
- 3) Use of GPS observations and a transformation to at least 4 local benchmarks surrounding the project area. Benchmarks must be checked for accuracy and integrity. For project areas larger than 10k or where there is significant undulation in the GEOID through the project area, a GEOID model should also be used.

The regional land surveyor shall be consulted when determining methods for connecting to NAVD88.

When working with old contract plans that are in US Customary Units you must take into account the difference in the Vertical Datums before incorporating the information into current Record Plans.

6.7 UNITS OF LENGTH

Survey distance measurements will be collected and reported in **feet (ft) or meters**, as specified in [Section 1.2](#). To convert **between feet and metric** dimensions they will be converted based on the U.S. Survey foot definition, by **using** the result of 39.37/12, which is 3.28083333333 (to no less than twelve significant figures).

6.8 COORDINATE CONVERSIONS

GPS works in an earth centered coordinate system. The projection to a state plane coordinate system is usually handled by GPS processing software. The GPS processing software will also calculate convergence angles and combined factors. Combined factor = (grid scale factor x ellipsoidal reduction factor).

Though convergence angles will differ from point to point, if the procedures outlined in this manual for establishing project control are followed, the effect of the change in convergence angle will have a minimal effect on the accuracy of the survey.

Though combined factors will differ from point to point based on distance from reference meridian or elevation, as a general rule a mean combined factor should be used for each

NYSDOT COORDINATE SYSTEMS AND DATUMS

project. This policy will usually cause no appreciable loss in accuracy and will eliminate confusion caused by multiple combined factors. However, where elevations of stations vary significantly, or for projects extending away from the reference meridian, applying more than one combined factor may be necessary to achieve required position and [azimuth](#) closure standards. If proper field procedures are followed, and the application of a meaned combined factor does not achieve azimuth and position closure standards, the regional land surveyor should be consulted on use of multiple combined factors.

NYSDOT COORDINATE SYSTEMS AND DATUMS

6.9 DISTANCE CONVERSIONS

When processing survey data from a total station traverse the combined factor must be applied to distances so that required traverse closure accuracy in the NYSPCS is achieved. The combined factor is the resulting product of the grid scale factor multiplied by the ellipsoidal reduction factor. Combined factor = (grid scale factor x ellipsoidal reduction factor).

When staking out survey points in the field using a total station for a survey on the NYSPCS the inverse of the combined factor (1/combined factor) should be applied to distances in order to convert NYSPCS grid distances back to ground distances.

6.10 DATUM TRANSFORMATIONS

There are coordinate transformation programs available to transform coordinates from one datum to another such as [CORPSCON](http://crunch.tec.army.mil/software/corpscon/corpscon.html).

<http://crunch.tec.army.mil/software/corpscon/corpscon.html>

CORPSCON incorporates NGS programs such as [NADCON](http://www.ngs.noaa.gov/TOOLS/Nadcon/Nadcon.html)

<http://www.ngs.noaa.gov/TOOLS/Nadcon/Nadcon.html>

and [VERTCON](http://www.ngs.noaa.gov/FORMS_PROCESSING/Vertcon/vertcon.html)

http://www.ngs.noaa.gov/FORMS_PROCESSING/Vertcon/vertcon.html

to compute transformations between datums. NADCON and VERTCON transformations between datums are based on a model of over 250,000 common stations. Therefore, conversions are approximate and accuracy can vary depending on location and proximity to common stations.

NADCON

The accuracy of the transformations should be viewed with some caution. At the 68 percent (1 sigma) confidence level, this method introduces approximately 0.15 meter uncertainty within the conterminous United States between NAD27 and the initial adjustment of NAD83 published in 1986 and referenced as NAD83(1986).

Transformations between NAD83 (1986) and HARNs introduce approximately 0.05 meter uncertainty.

VERTCON

The VERTCON 2.0 model was computed on May 5, 1994 using 381,833 datum difference values. A key part of the computation procedure was the development of the predictable, physical components of the differences between the NAVD 88 and the National Geodetic Vertical Datum of 1929 (NGVD 29) datums. This included models of refraction effects on geodetic leveling, and gravity and elevation influences on the new NAVD 88 datum. Tests of the predictive capability of the physical model show a 2.0 cm RMS agreement at the 381,833 data points. For this reason, the VERTCON 2.0 model can be considered accurate at the 2 cm (1 sigma) level.

NYS DOT COORDINATE SYSTEMS AND DATUMS

These programs only model shifts between datums, they are not based solely on a mathematical formula. While these transformations may be adequate for most mapping, low-accuracy surveying, or navigation applications, they are usually not accurate enough for survey control. Therefore, if the scope of a project requires tying in to a previous project on a different datum, either:

1. control stations from the previous project must be reobserved in the current survey. A minimum of 5 , well distributed control stations should be incorporated into the current survey, or
2. original observations from connected stations can be readjusted in the new datum.

6.11 DOCUMENTATION

The survey field notes and/or control report shall identify:

- 1) The coordinate system (NYSPCS), zone (EAST, CENTRAL, WEST, or LONG ISLAND), and datum (NAD83).
- 2) The date of the datum adjustment (NAD83/96).
- 3) The name and coordinates of horizontal control stations used to establish such coordinates. The NGS PID (Point Identifier).
- 4) The agency establishing those coordinates (NGS).
- 5) The combined factor, ellipsoidal reduction factor, and grid scale factor.
- 6) Units of Length.
- 7) The geoid model used.

The Licensed Land Surveyor responsible for such work shall certify on or within such documents that the survey connections to the control stations meet or exceed the minimum accuracy standards.

6.12 REFERENCES

1. Chapter 605 of the Laws of 1995 of the State of New York. Refer to this for the definition of NYSPCS zones.
2. [State Plane Coordinate System of 1983, NOAA Manual NOS NGS 5;](http://www.ngs.noaa.gov/PUBS_LIB/ManualNOSNGS5.pdf)
http://www.ngs.noaa.gov/PUBS_LIB/ManualNOSNGS5.pdf Refer to this document for definitions and computations required for working in the NYSPCS.
3. [National Imagery and Mapping Agency, Technical Report TR8350.2 "World Geodetic System 1984, Its Definition and Relationship with Local Geodetic Systems."](http://earth-info.nga.mil/GandG/publications/tr8350.2/wgs84fin.pdf)
<http://earth-info.nga.mil/GandG/publications/tr8350.2/wgs84fin.pdf>
4. [Federal Register Notice, Vol 54. No. 113, June 14, 1989 "Affirmation of Datum for Surveying and Mapping Activities."](http://www.ngs.noaa.gov/PUBS_LIB/FedRegister/FRdoc90-18809.pdf)
http://www.ngs.noaa.gov/PUBS_LIB/FedRegister/FRdoc90-18809.pdf
5. [Federal Register Notice, Vol 58. No. 120, June 24, 1993 "Affirmation of Vertical Datum for Surveying and Mapping Activities."](http://www.ngs.noaa.gov/PUBS_LIB/FedRegister/FRdoc93-14922.pdf)
http://www.ngs.noaa.gov/PUBS_LIB/FedRegister/FRdoc93-14922.pdf
6. [Federal Register Notice, Vol 55. No. 155, August 10, 1990 "Notice to Adopt Standard Method for Mathematical Horizontal Datum Transformation."](http://www.ngs.noaa.gov/PUBS_LIB/FedRegister/FRdoc90-18809.pdf)
http://www.ngs.noaa.gov/PUBS_LIB/FedRegister/FRdoc90-18809.pdf

Refer to the remaining chapters of this manual for standards and procedures consistent with working in the NYSPCS.

