NJDEP GPS Data Collection Standards for GIS Data Development

Bureau of Geographic Information Systems
Office of Information Resource Management
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1.0 Introduction

The New Jersey Department of Environmental Protection (NJDEP) maintains a Geographic Information System (GIS) for use by the Department for the storage and analysis of cartographic and related environmental scientific and regulatory database information. The data in the Department's GIS database has been used by NJDEP staff for over twenty years for environmental decision and policy making. The NJDEP makes the data in its GIS database available to the public via a data downloads page on its web site (http://www.nj.gov/dep/gis). The major aspect that makes the NJDEP data valuable to so many is that the geographic data produced by and for the NJDEP must adhere to guidelines set forth by NJDEP's ***Mapping and Digital Data Standards***. Further, a key requirement is that the data must be documented with ***Federal Geographic Data Committee (FGDC) standard metadata***.

There are many methods by which data in a GIS database can be generated. The use of Global Positioning System (GPS) receivers for accurately and efficiently collecting and storing mapped feature locations and descriptive attributes has become a widely accepted method for capturing data for GIS applications. With continuing declining costs in GPS hardware that provide greater locational accuracies, users today now have the ability to use this technology to cost-effectively collect highly accurate GIS data. GPS technology has been widely embraced by other applications ranging from basic navigation to precision surveys. There are many different models of GPS receivers on the market, each designed to serve a particular niche or user community. Each user community has particular needs from a GPS receiver. Not all GPS receivers are designed for GIS data collection applications. Because of this fact, it is imperative that NJDEP adopt GPS data collection standards to insure data quality and consistency. This document provides both NJDEP staff and the private sector, standards and guidelines for collecting GIS data with GPS for the Department's GIS.

The procedures outlined in this document must be applied to GPS work performed by or for NJDEP. GPS can be used to provide the locational accuracy from a few centimeters to tens of meters. **NJDEP's horizontal accuracy standard for locations determined through the use of GPS is within 5 meters of truth, with a 95% level of confidence.** The standards and procedures in this document have been developed to meet or, in most cases, exceed this accuracy standard. This accuracy standard will meet the requirements for most GIS mapping applications such as point generation (wellheads, environmental sampling locations, point pollution sources), line generation (roads, streams, forest trails), and polygon generation (area boundaries). Specific projects undertaken for NJDEP may have more stringent accuracy requirements that may require significant modifications to the procedures outlined.

2.0 GPS Receiver Hardware and Data Processing Software Requirements

To insure that the appropriate type of GPS receiver is matched to the mapping application, an understanding of receiver capabilities and limitations is required. There are three classes of GPS receivers: Recreation Grade (Sports Receivers), Mapping Receivers (Resource Grade), and Geodetic Grade (Carrier Phase).

Recreation Grade or Sports Receivers - This receiver is **not** designed for mapping and GIS applications, but more for basic navigation use by drivers of automobiles, boaters, hikers, etc. Generally, these do not have data collection capabilities beyond the storing of waypoints (points you wish to navigate to) and routes (also called tracks - sets of linked waypoints). With this class of receiver, users can expect determined position fixes to be accurate to within 10 meters with a 95% confidence under ideal conditions (GPS signals of sufficient strength, and favorable satellite geometry). Under more typical field conditions where a user has to contend with tree cover and other objects that block portions of the sky, with less than favorable GPS satellite geometry, users can expect the accuracy of these determined positions to be potentially much worse - perhaps as high as within 40 meters. Most GPS receivers in this category have WAAS (Wide Area Augmentation System) correction capabilities. While the WAAS correction can increase accuracy to within 5 meters, the WAAS correction signal is not always available. Often in the field, landscape and man-made features can block WAAS signals, preventing a WAAS correction. **Data collected with recreation grade receivers is inappropriate for NJDEP's GIS as it will not always meet NJDEP's 5 meter or better accuracy standard**.

Resource Grade or Mapping Receivers -These are specifically designed for storing mapped features that include feature coordinates and attributes. Positions determined by these receivers are generally in the 1 to 5 meter accuracy range after differential correction, though more advanced receivers are capable of sub-meter and sub-foot accuracies. These receivers generally perform better in less GPS friendly environments. These receivers can operate in real time differential correction mode using WAAS, or other real time differential correction solutions (that usually require additional hardware and/or service subscriptions). These receivers have significant data storage capacity, providing users the ability to easily capture a full day's worth of field data. Some of these receivers combine the GPS receiver and GPS configuration/logging software on the handheld device, while others integrate a GPS receiver on a Windows Mobile device and allow the user the option of installing one of several GPS configuration/logging software applications on the device. GPS data post processing software is necessary in order to perform differential corrections and other data processing tasks. The GPS data differential correction software includes utilities to enable GPS field data file transfer to a PC, perform differential corrections, allow analysis/edit of data, and enable the export of collected data to a GIS file format. **The mapping grade GPS receiver is the most acceptable grade for GIS data collection within the NJDEP.**

Geodetic Grade or Carrier Phase - Designed for applications that require extremely high accuracy. Positions determined by these receivers can be accurate to within less than a centimeter. These receivers are more sensitive to surrounding environmental conditions that cause signal blockage than mapping grade receivers. In GIS applications, these receivers are used most often for establishing the geodetic control base for study areas, and for data collection projects that require higher accuracies. Users of this system require additional technical knowledge and training, levels beyond what mapping grade users require.

A-GPS: The standards in this document are meant for GPS, not assisted GPS (A-GPS) data collection. GPS receivers determine coordinate locations based on signals received from GPS satellites. Mapping grade GPS receivers measure the time it takes the GPS signal to travel from the satellite to the GPS receiver, then trilaterates the receiver's position based on simultaneous

measurements from at least four GPS satellites. This method can be extremely accurate when best practices are performed correctly with mapping grade receivers. A-GPS is a technology solution for determining locations, that uses GPS in mobile devices that are communicating with cellular networks, most often through a user's smart phone. A smart phone communicates with a cellular network through cell towers. Most cell towers have linked GPS receivers that track and download GPS satellite information. This data can be communicated to a user's cell phone quickly because the relevant satellites for fixing the user's location have already been identified, and all the GPS computations have been handled by servers associated with the cellular network. Although the length of time to acquire a fix for the location is much faster, the accuracy is not as reliable. The configuration of the A-GPS chip and controlling software varies from phone to phone, and the chip functionality varies from carrier to carrier. Consequently, the accuracy of A-GPS data collection cannot be documented with certainty. **Therefore, the Department does not allow A-GPS for data collection unless the data is error checked through other means (e.g. overlay with aerial photography) before publishing**.

2.1 GPS Receiver Requirements

The mapping grade GPS receivers used for GIS data collection for NJDEP must adhere to the following requirements:

- The GPS receiver must routinely achieve 5 meter or better horizontal accuracy, using with the assistance of post-processing correction and real time correction whenever possible.
- The GPS receiver must operate in a 3D mode, where the receiver requires signals from a minimum of four satellites to determine a 3D (latitude, longitude, and elevation) location (a fix). Fixes determined by calculations based on fewer than 4 satellites (2D or 2D/3D) are not permitted.
- The GPS receiver must allow the storage of position fixes for features that are being mapped. When mapping point features, the receiver must be able to store a sample of position fixes (the minimum number depending on the quality of the receiver) for the feature. The receiver must have enough data storage capacity for a typical day's worth of data collection.

2.2 GPS Processing Software Requirements

The GPS data processing software must adhere to the following requirements:

- Post-processing software must be capable of performing differential corrections.

- The GPS processing software will provide quality control information about, or summary reports on, satellite residuals, standard deviations of point features, Dilution of Precision (DOP), files processed, critical receiver setting parameters (collection mode, elevation mask, Position Dilution of Precision (PDOP) mask, signal to noise ratio mas, etc.) The ability to detect and remove bad satellite data or positions is also preferable.

- The GPS processing software must be capable of exporting data to a GIS or CAD file format. Final submission to NJDEP must be consistent with the approved export formats, coordinate system, datum, and units as specified in NJDEP's *Mapping and Digital Data Standards*).

3.0 GPS Field Data Collection

GPS field work must be performed by staff that has had training in the operation of a GPS receiver and GIS or has a surveying or mapping background. Field staff must have a thorough understanding of GPS basic concepts, and receiver operation. How a receiver's critical parameter settings affect data collection must be very well understood. The staff must also have familiarity with the types of features to be located, and must be able to recognize/interpret features in the field. To achieve the NJDEP's target accuracy, all collected GPS data must be differentially corrected, either in real time or in a post process step.

3.1 GPS Collection Parameter Settings

To be consistent with NJDEP's GPS collection guidelines, the following critical receiver parameters should be set accordingly:

Standard GPS Collection Parameter Settings

Position Mode	All position fixes must be determined with 4 or more satellites. 2D fixes (using only 3 satellites) are **not** acceptable. 3D positions generated from 2D fixes supplemented with user entered elevations are also **not** acceptable.
Elevation Mask	15 degrees above horizon.
PDOP Mask	If this parameter setting exists, set it to the manufacturer's recommendation that would, at a minimum, allow the GPS data collected to achieve NJDEP's 5 meter standard.
Signal to Noise Ratio Mask (SNR)	If this parameter setting exists, set it to the manufacturer's recommendation that would, at a minimum, allow the GPS data collected to achieve NJDEP's 5 meter standard. The more noise in a signal, the less reliable the signal will be for accurate position determination.
Minimum Positions for Point Features	If this parameter setting exists, set it to the manufacturer's recommendation that would, at a minimum, allow the GPS data collected to achieve NJDEP's 5 meter standard. Solutions based on a single fix are not acceptable.
Logging Intervals	Intervals for point features will be 1 or 5 seconds. Intervals for line and area features depend on the velocity at which the receiver will be traveling and the nature of the feature and the operating environment. Under normal circumstances (i.e., when the user is walking with the receiver) the interval for line and area features will be set to 5 seconds.
Logging of DOP	If the receiver allows, this parameter setting will be set to allow the logging of DOP data along with position fixes.

3.2 Field Notes

Field notes must be maintained for each feature collected. The notes should document the following:

Project name	Date of collection
Site name	Feature number (permit #, well #, etc.)
Feature description	GPS file name
Begin data logging time	End data logging time
PDOP value	Number of position fixes
Name of receiver operator	Difficulties/Comments
Brand & Model of GPS receiver	Any additional hardware (if applicable)

Depending on the project, additional project specific information may also be recorded. If the GPS antenna is not positioned directly over the feature to be captured, and an offset measuring device is not being used, the GPS operator should also sketch a diagram showing the antenna's location with respect to the feature location. On the diagram, the distance (in decimal feet) and direction (forward azimuth from true north) from the antenna to the feature must be noted. The diagram will also depict landmarks (that will be labeled) such as building structures, streets, water features, etc., and have a north arrow.

4.0 Processing of GPS Field Data

All GPS data collected for NJDEP must undergo post processing steps using GPS processing software before the data can be used to generate a GIS layer. The GPS processing software must be able to download GPS data files from the GPS receiver, and perform differential corrections. In addition, it must allow exporting the corrected data to a NJDEP approved export GIS formats, specified in NJDEP's *Mapping and Digital Data Standards*, in the correct coordinate system (New Jersey State Plane), in the correct horizontal geodetic datum (NAD83), and in the correct units (US Survey Feet).

4.1 GPS Base Stations for Differential Corrections

For post processed differential corrections, several resources exist for GPS base station data in New Jersey. This base data is typically freely available via the web. Differential correction routines in GPS data post processing software can often identify what time frame correction files are necessary and provide the user the ability to select the files from a preferred base station (usually closest to the field data site). Users requiring Receiver INdependent EXchange (RINEX) format may obtain base data collected by the network of CORS stations. For the latest on CORS GPS base data availability in and around New Jersey, check the NGS web site at http://www.ngs.noaa.gov/CORS.

4.2 Analysis and Edit

The fact that GPS field data is differentially corrected does not necessarily mean that it is of high quality. It must be inspected for errors and analyzed for precision. For point features, at least 95% of the position fixes making up the feature should be within 5 meters horizontally of the feature's true position. Outlier fixes that are obviously in error may be edited (deleted) from the sample of position fixes for a point feature. For line and area features, the standard is the same. At least 95% of the fixes making up a line feature or area boundary should be within 5 meters (perpendicular) of truth. Fixes that show significant deviation from what should be a relatively straight or smooth line or curve may be deleted.

4.3 Export to GIS

As stated previously, NJDEP prefers GIS data submittals to be consistent with the NJDEP approved GIS formats, as specified in the NJDEP's *Mapping and Digital Data Standards*. Coordinate data must be in the New Jersey State Plane Coordinate System (NJSPCS) in the North American Datum of 1983 (NAD83) horizontal geodetic datum. The preferred unit of measure is the US Survey Feet, though meters is also acceptable.

In addition to feature coordinate and field entered attribute data, some GPS processing software packages are capable of automatically generating metadata for exported features. This metadata can provide users of the GIS data an indication as to the quality of the GPS position fixes that were used to generate the features. If the GPS processing software allows, the following generated attributes must be produced as metadata for exported features:

Automatically Generated Metadata Attributes

All Features	Point Features	Line and Area Features
Maximum PDOP	Everything in All Features plus:	Everything in All Features plus:
Receiver type	Standard deviation	Average horizontal precision
Correction status	Horizontal Precision	Worst horizontal precision
Date of collection	*Elevation (MSL in feet)	*Average vertical precision
Time of collection	*Vertical Precision	*Worst vertical precision
Data file name		
Total positions		
Filtered positions		

* Only necessary if elevation data is required by project

4.4 Elevation Data

If elevation data is required by the project, it will be referenced to the North American Vertical Datum of 1988 (NAVD 88) vertical geodetic datum. Elevations must be generated as orthometric heights (relative to mean sea level) determined using the GEOID03 (CONUS) or later geoid conversion model.

5.0 Deliverables

The following are guidelines for acceptable GPS data collected by an outside agency.

5.1 GPS and GIS Data Files

Final deliverables to NJDEP must be consistent with the approved formats, as specified in NJDEP's *Mapping and Digital Data Standards*, and will include the following GPS and GIS files:

1) All GPS field data files, both uncorrected and corrected versions, must be submitted. If field data was collected in real time differential mode, then there will not be uncorrected files, and only the real time corrected files are necessary. If edits are made to corrected files (i.e., fixes deleted or offset), copies of both edited and unedited are to be submitted.

2) All GPS to GIS export files (using New Jersey State Plane Coordinates, in the NAD 83 horizontal geodetic datum, in US survey feet units).

3) All GPS processing log files pertaining to differential correction and GIS export (if produced by the GPS processing software).

4) GPS Data dictionary files, defined for project attribute storage.

5) GIS coverage files.

These files should all be in a compressed format and be organized into a logical directory structure. For example, the files could be organized by date of data collection, and then into subdirectories for *Data* and *Export*. Uncorrected, corrected field data files, post process differential correction log files, and data dictionary files would reside in the *Data* subdirectory. GIS export files and associated export log files would reside in the *Export* subdirectory. Final GIS coverage files would reside in a separate GIS directory.

5.2 Project Report

The contractor must submit a project report that includes the following information:

1) An introduction describing the project. This would include the project name, the names of NJDEP programs involved, the purpose and goals of the project, the project's study area, and data collection (including accuracy) requirements.

2) A project time line depicting significant milestones or achievements during the course of the project. Examples might include: awarding of contract, meetings with NJDEP staff, GPS field data collection/processing phase, significant delays, interim deliverables and status reports, final deliverables and status report; etc.).

3) Profiles on contractor staff performing project work, including level of education, degrees held, GPS qualifications and/or certifications, and prior GPS work experience.

4) A list of GPS hardware and processing software used for the GPS data collection/processing phase of the project. The hardware listing will include GPS receiver models (including firmware version), data loggers, antennas, external sensors, laser offset measuring devices, etc. The GPS processing software, mapping software, and any related data management software will be listed, along with version number.

5) A list of GPS base stations used for the project. If local base stations (stations other than US EPA, or CORS) were used, the setup procedure must be described in detail, along with the operation, collection parameter settings, and what steps were used to establish the reference position.

6) A project overview documenting the plan for carrying out the field data collection, the methods and techniques used for the GPS field data collection, how the data was processed. The handling of special circumstances and problems must also be documented.

7) A description of the deliverables including naming conventions, file formats, media, etc.

8) A listing of all of the project's mapped features, organized by date of collection.

9) A copy of all field notes in either hard copy or digital form.

6.0 Useful Links:

New Jersey Department of Environmental Protection, Mapping and Digital Data Standards:
http://www.nj.gov/dep/gis/assets/NJDEP_GIS_Spatial_Data_Standards_2013.pdf

Federal Geographic Data Committee Standard Metadata:
https://www.fgdc.gov/metadata/geospatial-metadata-standards

Content Standard for Digital Geospatial Metadata Workbook
https://www.fgdc.gov/metadata/documents/workbook_0501_bmk.pdf