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GPS Pathfinder Office Software or the GPS Analyst Extension for ESRI ArcGIS Software: Resolving the NAD 83 Datum Transformation Issue

Summary

The current realizations of the North American Datum of 1983 (NAD 83) and the World Geodetic System 1984 datum (WGS-84) differ by up to a meter. An error can be introduced by assuming that they are the same. This support note explains how to avoid such “datum shift” errors in Trimble postprocessing software (the GPS Pathfinder® Office software or the Trimble® GPS Analyst™ extension for ESRI ArcGIS software).

Background

The original WGS-84 datum definition was essentially the same as the original NAD 83 datum definition (called NAD 83 (1986)). Over time, both datums have been redefined several times, and they now differ by up to a meter.

The WGS-84 definition has been aligned with the global International Terrestrial Reference Frame (ITRF) definition, to the point where ITRF 2000 and the current realization of WGS-84 differ by only a centimeter worldwide. Therefore, wherever a WGS-84 reference position or datum transformation is required, an ITRF00 reference position or datum transformation can be substituted.

The NAD 83 datum is relevant only to North America, and is used to define the coordinate systems for Canada and the US State Plane systems. The latest realization is called NAD 1983 (CORS 96). Issues that apply to the CORS 96 realization apply similarly to previous realizations such as NAD 1983 (HARN).

Note: For detailed information on NAD 83 realizations and the differences between them, refer to the article titled “Modern Terrestrial Reference Systems Part 2: The Evolution of NAD 83”. This article is available on the National Geodetic Survey (NGS) website at www.ngs.noaa.gov/CORS/Articles.

Issues

Reference Frame

Differentially corrected GPS positions are in terms of the correction source’s reference frame. For example, if you correct against a Continuously Operating Reference Station (CORS) base station using a NAD 83 reference position, then your corrected data is in terms of the NAD 83 datum. Similarly, US Coast Guard beacons provide corrections in terms of the NAD 83 datum, so real-time beacon-corrected positions are in terms of NAD 83.

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In the base station list published by Trimble, ITRF00 reference positions are provided for all CORS, Cooperative CORS, and Scripps Orbit and Permanent Array Center (SOPAC) stations. Other stations' reference positions may be in terms of the NAD 83 datum or other reference frames. To check a base station's reference position, go to the base provider's website.

Trimble postprocessing software assumes that all GPS data is in terms of the current WGS-84 datum. If you have differentially corrected against a correction source whose reference position is not in terms of WGS-84 or ITRF00, then this assumption is false. A datum shift error may be introduced when you export from the GPS Pathfinder Office software to your Geographic Information System (GIS), or when GPS features in the GPS Analyst extension are built into GIS features. If your correction source is in terms of NAD 83 (CORS 96), this error may be up to a meter.

Zero Datum Transformation from WGS-84 to NAD 83

Because WGS-84 and NAD 83 have previously been treated as the same, the coordinate system database (CSD) in the GPS Pathfinder Office software contains a "zero" NAD 83 datum transformation definition, which does not transform coordinates between WGS-84 and NAD 83.

When you export WGS-84 GPS data from the GPS Pathfinder Office software to a GIS that uses a coordinate system based on the NAD 83 datum, no transformation is performed between WGS-84 and NAD 83. This zero transformation may introduce a datum shift error of up to a meter.

Solutions

To ensure that you do not introduce datum shift errors into your data, it is important that you do the following:

- Verify the reference frame of any differential correction source that you use.

This includes real-time correction sources, base providers from the Trimble base station list, and any other base data that you use. To check a base provider's reference position, go to the base provider's website. If necessary, update the reference position for the base provider in your Trimble postprocessing software, so that it is in the required reference frame.

- Apply the correct datum transformation between your GPS data and your GIS.

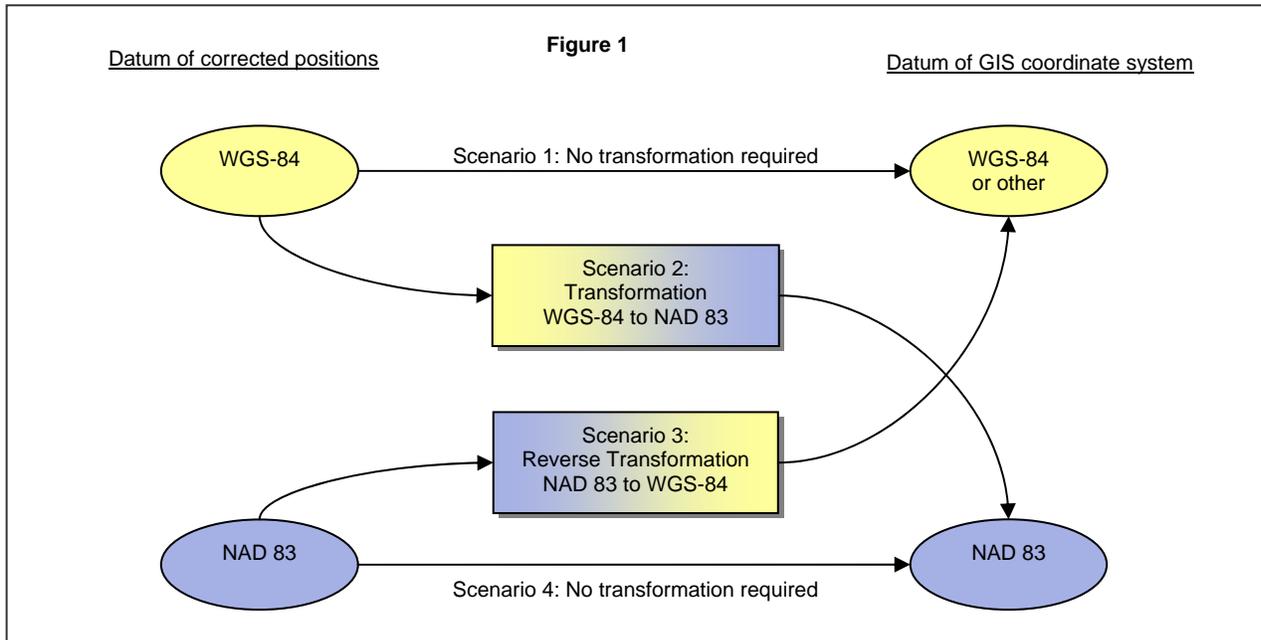
The correct datum transformation depends on the reference frame of the correction source, and on the datum used by the coordinate system in your GIS. If the datums and realizations of the correction source and your GIS match (for example, both are NAD 83 (CORS 96), or both are ITRF00), the best solution is usually to work entirely within the same datum, and to perform no datum transformations in your GPS postprocessing software.

Trimble also recommends that you postprocess GPS data that has been corrected in real time.

Re-correcting real-time positions not only gives you more accurate data, but also eliminates datum shift errors that may have been introduced by real-time correction sources. You can postprocess real-time corrected data only if you have logged SuperCorrect™ or Postprocessable Real-time (PPRT) data in your Trimble field software.

Scenarios

This section describes common user scenarios, lists the problems that can occur, and list the suggested solutions. These are the four basic scenarios:



Scenario 1: Corrected positions in terms of WGS-84, non-NAD 83 in GIS

GPS data is corrected against sources that use WGS-84 or ITRF00 as their reference frame. Examples include real-time Wide Area Augmentation System (WAAS), or a base station with an ITRF reference position.

The GIS uses a coordinate system that is not based on the NAD 83 datum.

GPS Pathfinder Office software

When you export your GPS data from the GPS Pathfinder Office software, the required transformation between WGS-84 and the datum of the export coordinate system is performed. No datum shift error is introduced.

GPS Analyst extension

When you GPS-enable your geodatabase, the GPS Analyst extension prompts you to select a datum transformation. Select the appropriate transformation between WGS-84 and the spatial reference of the geodatabase. Using the correct transformation ensures that no datum shift error is introduced when GPS data is built into GIS feature geometry.

Scenario 2: Corrected positions in terms of WGS-84, NAD 83 in GIS

GPS data is corrected against sources that use WGS-84 or ITRF00 as their reference frame. Examples include real-time WAAS, or a base station with an ITRF reference position.

The GIS uses a coordinate system based on the NAD 83 datum.

GPS Pathfinder Office software

When you export your GPS data from the GPS Pathfinder Office software, the zero WGS-84 to NAD 83 transformation is performed, and a datum shift error of up to 1 meter is introduced.

The solution is to define a new ITRF00 to NAD 83 (CORS 96) transformation in the Coordinate System Manager utility, and use this transformation when exporting data. The section titled *New NAD 83 datum* transformation, on page 6, provides step-by-step instructions for defining and using this new transformation.

GPS Analyst extension

When you GPS-enable your geodatabase, the GPS Analyst extension prompts you to select a datum transformation. Select the transformation named NAD_1983_To_WGS_1984_4. Using this transformation ensures that no datum shift error is introduced when GPS data is built into GIS feature geometry.

For more information, go to the ESRI Support website at

<http://support.esri.com/index.cfm?fa=knowledgebase.techarticles.articleShow&d=21327>.

Note: This is a transformation between NAD 83 (CORS 96) and ITRF96, which is only a few centimeters different from ITRF00. ESRI ArcGIS does not yet provide a NAD 83 (CORS 96) to ITRF00 transformation.

Scenario 3: Corrected positions in terms of NAD 83, non-NAD 83 in GIS

GPS data is corrected against sources that use NAD 83 as their reference frame. Examples include US Coast Guard beacons, or a base station with a NAD 83 reference position.

The GIS uses a coordinate system that is not based on the NAD 83 datum.

GPS Pathfinder Office software

When you export your GPS data, a datum shift error of up to 1 meter is introduced, because the corrected data is in terms of NAD 83 but the software treats it as WGS-84 data. To remove the datum shift error, a reverse transformation (from NAD 83 to WGS-84) would be required in addition to any transformation from WGS-84 to the coordinate system used in the GIS. On export, the software can perform transformations only from WGS-84 to other coordinate systems.

There is no way to remove the error introduced in this scenario. To avoid introducing this error, use a correction source with a reference position defined in terms of WGS-84 or ITRF00. See Scenario 1.

GPS Analyst extension

When GPS data is built into GIS feature geometry, a datum shift of up to 1 meter is introduced, because the corrected data is in terms of NAD 83 but the GPS Analyst extension treats it as WGS-84 data. To remove the datum shift error, a reverse transformation (from NAD 83 to WGS-84) would be required in addition to any transformation from WGS-84 to the spatial reference used in the GIS. The GPS Analyst extension allows you to specify a transformation only from WGS-84 to another spatial reference.

There is no way to remove the error introduced in this scenario. To avoid introducing this error, use a correction source with a reference position defined in terms of WGS-84 or ITRF00. See Scenario 1.

Scenario 4: Corrected positions in terms of NAD 83, NAD 83 in GIS

GPS data is corrected against sources that use NAD 83 as their reference frame. Examples include US Coast Guard beacons, or a base station with a NAD 83 reference position.

The GIS uses a coordinate system that is based on the same realization of the NAD 83 datum.

Note: *If the NAD 83 realizations used by the correction source and the GIS are different, some errors are introduced. The amount of error depends on the realizations used. For example, NAD 83 (HARN) and NAD 83 (CORS 96) differ by only a few centimeters in most US states. However, the original NAD 83 (86) realization is significantly different from these later realizations.*

GPS Pathfinder Office software

When you export your GPS data from the GPS Pathfinder Office software, the zero WGS-84 to NAD 83 transformation is performed. Because the data is already in terms of the required datum (NAD 83), no datum shift error is introduced. No change to your current workflow is required to avoid introducing errors. You do not have to define the new transformation described later in this support note.

GPS Analyst extension

If you select a null transformation when you GPS-enable (either the <null> option, or the transformation named NAD_1983_To_WGS_1984_1), then no transformation is performed between the GPS data and GIS feature geometry. Because the data is already in terms of the required datum (NAD 83), no datum shift error is introduced.

If you select a non-zero WGS-84 to NAD 83 datum transformation when you GPS-enabled your geodatabase, then a datum shift error may be introduced when GPS data is built into GIS feature geometry. The corrected data is in terms of NAD 83 but the GPS Analyst extension treats it as WGS-84 data and applies an additional transformation, which may introduce an error of up to a meter.

New NAD 83 datum transformation for GPS Pathfinder Office software

Note: The instructions in this section **only** apply to Scenario 2 (page 4). Defining or using this new transformation in any other scenario introduces errors into your data.

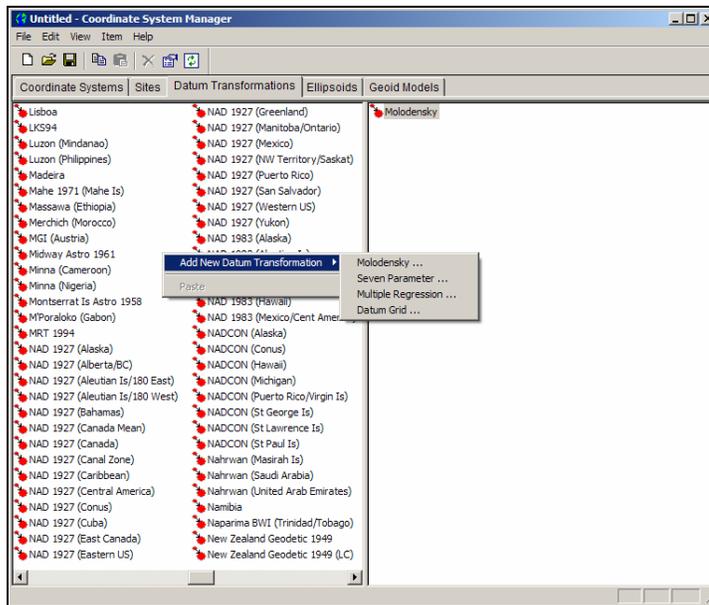
If you have corrected positions in terms of the ITRF00 (or WGS-84) datum, and you want to export to a US State Plane system using the NAD 83 (CORS 96) datum, then you need to perform the following steps to add new definitions to the GPS Pathfinder Office software.

Adding a new NAD 83 datum transformation definition to the coordinate system database

1. Open the GPS Pathfinder Office software.
2. Select *Utilities / Coordinate System Manager*.
3. Select *Datum Transformations*. The window that appears displays the current list of datum transformation definitions within the coordinate system database (CSD).
4. Right-click in the left pane of the *Coordinate System Manager* window.

A pop-up menu appears

5. Select *Add New Datum Transformation / Seven Parameter*:

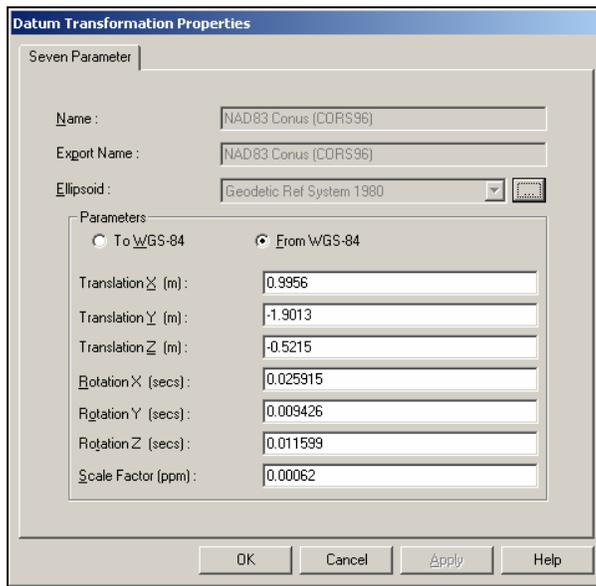


6. Name the new transformation, for example *NAD 1983 (CORS 96)*.
7. Select the *Geodetic Reference System 1980* ellipsoid and then select the *From WGS-84* option.
8. Enter the following parameters:
 - *Translation X (m)*: 0.9956
 - *Translation Y (m)*: -1.9013
 - *Translation Z (m)*: -0.5215

- *Rotation X (secs):* 0.025915
- *Rotation Y (secs):* 0.009426
- *Rotation Z (secs):* 0.011599
- *Scale Factor (ppm):* 0.00062

These are the transformation parameters between ITRF 2000 and NAD 83 (CORS 96), as defined by the National Geodetic Survey (<http://www.ngs.noaa.gov/CORS/coordinates>). For areas outside the continental United States and Canada, where a different NAD 83 realization is used (for example, NAD 83 (PACP00) in Hawaii), different transformation parameters are required. Contact NGS for more information.

The *Datum Transformation Properties* dialog should match the following example:



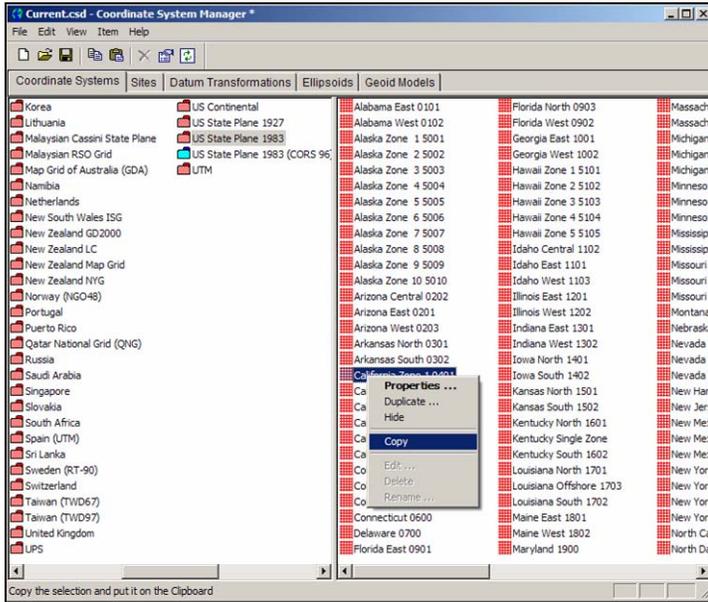
Adding a new US State Plane coordinate system

The US State Plane 1983 coordinate system group listed in the CSD contains a number of zones that reference the original NAD 83 (Conus) datum transformation. Set up a new coordinate system with zones that reference the new ITRF to NAD 83 (CORS 96) transformation. Use this new coordinate system in any part of the GPS Pathfinder Office software where you previously used the US State Plane 1983 coordinate system.

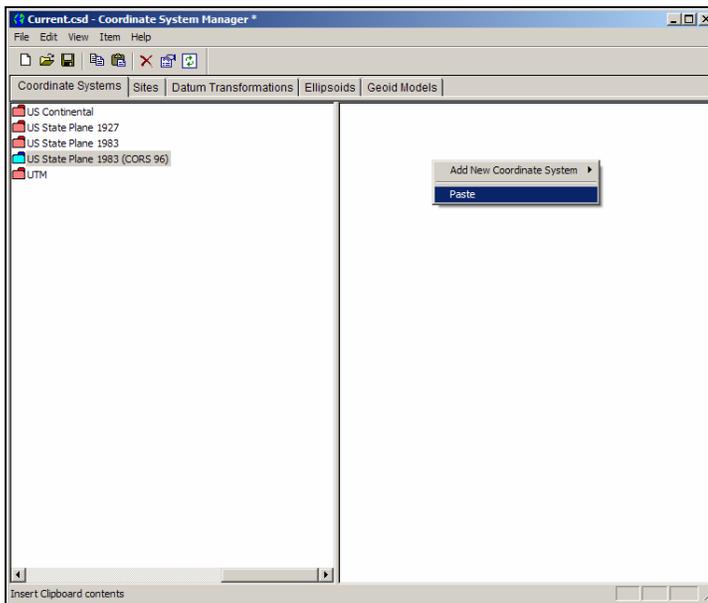
To create a coordinate system that references the new NAD 83 (CORS 96) datum transformation:

1. Select the *Coordinate Systems* tab. The left pane displays the current list of coordinate systems within the CSD.
2. Right-click in the left pane and then select *Add New Coordinate System Group* from the pop-up menu that appears.
3. Create a new coordinate system group named *US State Plane 1983 (CORS 96)*.

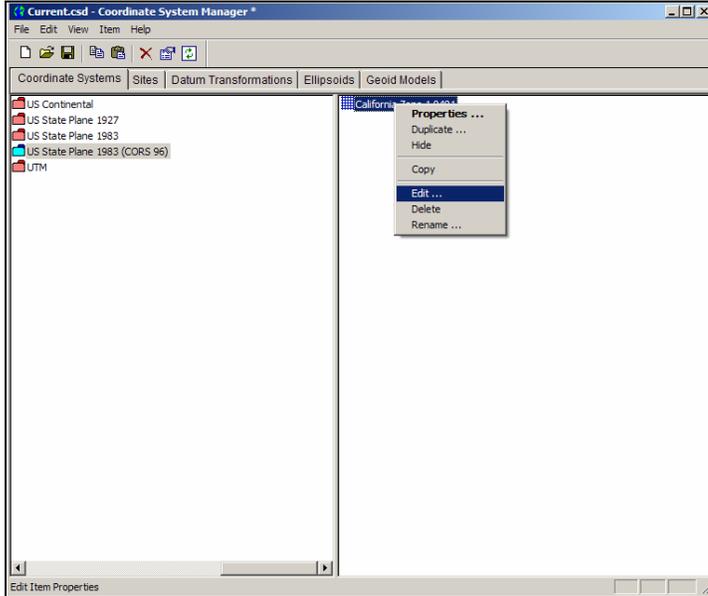
- Select the *US State Plane 1983* group in the left pane and copy an existing zone from the right pane:



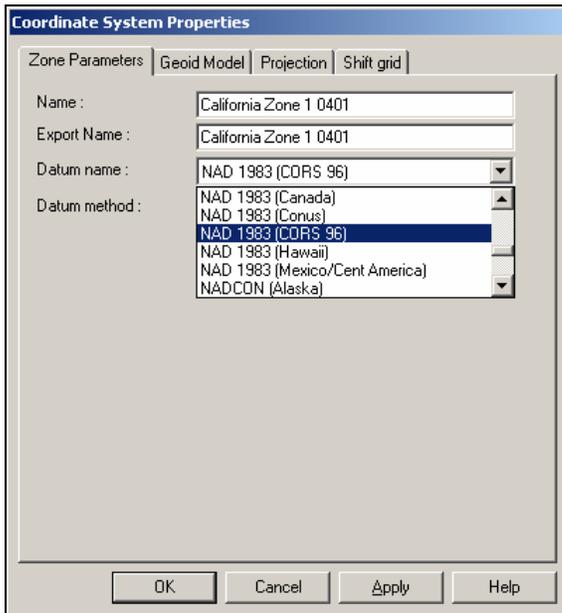
- Select the newly created *US State Plane 1983 (CORS 96)* group in the left pane and paste the zone into the right pane:



- Right-click the zone name and then select *Edit* from the pop-up menu that appears:



- In the dialog that appears, select *NAD 1983 (CORS 96)* from the drop-down menu in the *Datum name* field:

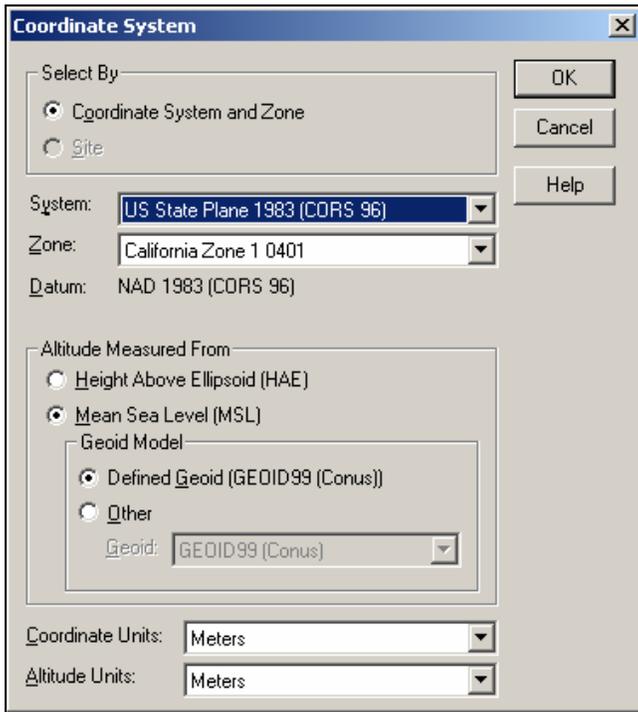


- Click **OK**.
- To save your changes, select *File / Save*.
- Select *File / Exit* to close the Coordinate System Manager utility.

11. To re-load the updated coordinate system database, exit and restart the GPS Pathfinder Office software.

Using the new coordinate system as the current display coordinate system

1. In the main GPS Pathfinder Office software window, select *Options / Coordinate System*. The *Coordinate System* dialog appears.
2. From the *System* list, select the new US State Plane 1983 (CORS 96) system that you have just created.
3. From the *Zone* list, select your local zone. The new NAD 1983 (CORS 96) datum is automatically selected in the *Datum* field:



4. Click **OK**.

Exporting data using the new coordinate system

Whenever you export data from the GPS Pathfinder Office software to your GIS, the export coordinate system must use the new datum transformation.

1. From the main GPS Pathfinder Office software window, select *Utilities / Export*. The *Export* dialog appears.
2. Select the export setup that you want to use, and then click **Properties**. The *Export Setup Properties* dialog appears.
3. Select the *Coordinate System* tab.
4. Do one of the following:
 - If the current display coordinate system uses the new datum transformation, select the *Use Current Display Coordinate System* option.
 - Set the export coordinate system:
 - a. Select the *Use Export Coordinate System* option.
 - b. Click **Change** to open the *Coordinate System* dialog, where you can change the coordinate system used for this export setup.



- c. To change the coordinate system, follow the steps in the previous section.
5. To confirm your changes, click **OK** in the *Export Setup Properties* dialog.