

Modifying projection zones to incorporate a “datum-adjustment factor”

This Technical Tip provides instructions for creating “modified” projection zones that match the scaled or “surface” state-plane coordinates used by some organizations.

An example of interest to many Inland GPS customers is the process used by the Wyoming Department of Transportation (WY DoT) that applies a datum-adjustment factor (DAF) to produce so-called “surface coordinates”.

When you have the results of a good control survey and are told or can otherwise determine how the coordinates were modified, this approach is faster, easier, and more accurate than trying to perform an in-field calibration.

This document concentrates on the horizontal component, but if you are provided good ellipsoid heights and elevations for an appropriate number of the control points you can perform a vertical-only calibration before you even leave the office. That will refine and improve the vertical accuracy of your GPS measurements. If you do a vertical-only calibration, make sure that the ellipsoid heights and elevations used in the calibration are truly independent values – not simply a result of applying the separation obtained from the geoid model.

You should definitely check the control in the field by measuring to the control points as they are available, but if the control network was properly done to begin with there will be little or nothing gained by making additional field measurements for calibration.

WY DoT generates what they refer to as “surface coordinates” by multiplying state-plane coordinates by a DAF that is the inverse of a more-or-less representative combined factor (the multiplication product of the grid scale factor and the elevation factor) for a project area. This method scales coordinates from 0.00 northing and 0.00 easting.

It is important to realize that the positions of grid points in a TGO project can change if the coordinate-system definition of the project is changed after the grid points are imported into the project. (This is the same feature that lets the user easily reproject data into any desired coordinate system.) Therefore, this procedure establishes the necessary coordinate-system-definition details before the grid points are imported into the project.

The easy way -

The easy way is to simply enter the “datum-adjustment factor” or “surface-adjustment factor” into the appropriate field in Trimble Geomatics Office. This works for either Transverse Mercator or Two-Parallel Lambert zones.

1. Start Trimble Geomatics Office (TGO) and start a new project in the appropriate units and zone (Wyoming West Central 4903, for example). Go to File | Project Properties and click the Coordinate System tab. Make certain the Coordinate-system settings are correct so far. The GEOID99 geoid model will be used in most if not all cases, which is fine. You could just as well use GEOID03 if you prefer.
2. Now you need to tell the software that you want the coordinates scaled per the DAF. Click the Change button in the Local-site settings (lower) part of the window and the Local-site settings dialog will appear.
3. In those cases where the scaling is done simply by multiplying northings and eastings by the DAF (this is almost always the case and this is how Wyoming DoT does it) you are scaling from 0.00 northing, 0.00 easting. In the portion of the screen labeled Project location make certain the Grid radio button is dotted and enter zeros for the northing and easting. Leave the question mark in the elevation field.
4. Moving down the screen, check the Use ground coordinates box. Enter the DAF in the Ground scale factor field.
5. This window also gives you the option of shifting or truncating these modified coordinates so they do not look exactly like real state-plane coordinates, but we have only seen a few organizations do this. It is a good idea to do so as it can prevent problems arising from misinterpretation of the coordinates.

6. Click OK to exit the Local-site settings dialog. The bottom line of the Coordinate-system window will now show Ground coordinates. Click OK to exit the Project Properties window.
7. Now the coordinate-system details are set. Bring the coordinates into the TGO project. This can be done by importing an ASCII file, by hand-entering the coordinate values, or any other reasonable method.
8. Always confirm what you have done by doing appropriate checks on the coordinates. Add more points to the TGO project, either as grid or geographic coordinates, and make certain everything matches up.

One of the best tests to determine if you have achieved “surface coordinates” is to examine the combined scale factors of points in the project. To do this in TGO, simply label all points with the “Combined Scale Factor” from the View | Point Labels command. The combined factors should be very close to unity. Ideally, some will be slightly above one and others will be slightly less than one. Remember that every ppm difference from unity in the combined scale factor represents approximately 21 feet vertical separation from the projection surface.

Another good check is to inverse between pairs of far-apart points and compare the grid and ground distances. Remember that ultimately it is impossible to perfectly flatten a round and lumpy world onto a flat projection surface. Recognize and live with the inherent limitations.

Important – Use different names for the geographic position you use to start the base receiver and for the GPS measurements to the control points having the grid coordinates entered above. Example- if the control point is named ABCD7, you could name the grid point ABCD7_NEE, with the suffix representing Northing Easting Elevation.

The less-easy way -

The less-easy way is to use the Coordinate System Manager that is part of the Trimble software to create a project-specific projection zone that match the scaled or “surface” state-plane coordinates. The advantage to using this approach is that some software may not have the ground-coordinate features of Trimble Geomatics Office. If you determine the projection-zone parameters this way they can be used in any geodetic software.

WY DoT generates what they refer to as “surface coordinates” by multiplying state-plane coordinates by a DAF that is the inverse of a more-or-less representative combined factor (the multiplication product of the grid scale factor and the elevation factor) for a project area. This method scales coordinates from 0.00 northing and 0.00 easting.

The procedure to create a Transverse Mercator projection zone that incorporates the DAF is as follows:

1. Start Coordinate System Manager. Click the Coordinate Systems tab, and select US State Plane 1983 in the left pane. (Note - of the 49 or so coordinate-system groups that appear, the typical user in the United States is probably interested in no more than three. Select the unneeded coordinate-system groups, right click, and select Hide to get them out of the way. If needed, they may be instantly summoned by toggling the Hidden Records option under the View menu.)
2. In the right pane, find the correct zone (Wyoming West 4904, for example.) Right click the zone, and select the Duplicate option. You will be prompted for a name and an export name, suggest you use something logical such as “Wyoming West DAF <Name>”, where <Name> is a meaningful name for the situation, perhaps the WY DoT job number. Suggest using the same name in both fields, the software encourages this by automatically duplicating in the right window what you type into the left window.
3. Coordinate System Manager will open a dialog that allows you to change the coordinate system properties. Click on the Projection tab and you will see the projection parameters. Multiply the false northing, false easting, and scale factor by the DAF. Preserve precision by entering false northing and false easting to six decimal places, scale factor to twelve decimal places. Click the OK button, and you have created a new zone. Save, and then close Coordinate System Manager.
4. To use this new zone, select it through the “Select Coordinate System” dialog. Select New System, click Next, select Coordinate System and Zone, click Next, select the US State Plane 1983 coordinate-system

group, then your new zone will be available for selection from the right pane. Highlight and click Next. Confirm the geoid model to be used (should be GEOID99 (Conus)), click Finish.

5. Now the coordinate-system details are set. Bring the coordinates into the TGO project. This can be done by importing an ASCII file, by hand-entering the coordinate values, or any other reasonable method.
6. As always, confirm by doing appropriate checks of coordinates. One of the best tests to determine if you have achieved “surface coordinates” to examine the combined factors of points in the project. To do this in TGO, simply label all points with the “Combined Scale Factor” from the View | Point Labels command. The combined factors should be very close to unity. Ideally, some will be slightly above one and others will be slightly less than one.

The same results can be achieved by modifying the projection parameters in the Trimble Survey Controller software used in the data collector, it is all fairly simple mathematics.

Lambert conic zones -

You can do a similar thing in a Lambert conic zones, such as are used in Montana, Nebraska, Colorado, South Dakota, North Dakota, and Utah, but it is a little more complicated. In such cases, you will need to change from the commonly used two-parallel Lambert projection to a one-parallel Lambert, then apply the DAF.

The conversion to the one-parallel Lambert projection is necessary because the projection parameters for the two-parallel Lambert do not include a scale factor. The cone is secant to the ellipsoid at the north and south parallels and a scale factor is not required to define the projection.

1. Start Coordinate System Manager. Click the Coordinate Systems tab, right click in the left pane, and select Add New Coordinate System Group. You will be prompted for a name for this coordinate-system group, suggest something like “State Plane Lambert DAF,” click OK.
2. Select the new coordinate-system group in the left pane, right click in the right pane, select Add New Coordinate System, then click on Lambert Conformal Conic 1 Parallel.
3. You will now be prompted for a name for the new zone, suggest using something like “Montana DAF<Name>”, where <Name> is a meaningful name for the situation, perhaps your project name. Set Datum name to NAD 1983 (Conus) and click Next.
4. In the Geoid Model dialog, set Method to Geoid Grid Model, select GEOID99 (Conus) as the Model, then click Next.
5. Now you will be at the Projection dialog. Here you will need to enter the parameters for your zone. First, determine the parameters for the one-parallel Lambert zone that is equivalent to the standard two-parallel Lambert zone.

One place to find these parameters is in Appendix C to NOS NGS 5 - State Plane Coordinate System of 1983 by James E. Stem. This publication may be purchased from the National Geodetic Survey, or downloaded from the NGS Web site at http://www.ngs.noaa.gov/PUBS_LIB/ManualNOSNGS5.pdf.

The parameters requested by Coordinate System Manager and the corresponding defining and computed constants in NOS NGS 5 are as follows:

Central latitude	Bo	Notice this is provided in decimal degrees, you must convert to degrees minutes seconds before you key into the field in Coordinate System Manager..
Central longitude	Lo	Provided in degrees and minutes, enter as published. Notice that NOS NGS provides this as a positive number. In Coordinate System Manager make certain this is shown as West longitude or entered as a negative number.
False northing	No	Notice that this is in meters, which is what Coordinate System Manager wants anyway. Multiply the number from NOS NGS 5 by

		the DAF and insert in this field. Suggest carrying to at least four decimal places.
False easting	Eo	Again, multiply by the DAF. Suggest carrying to at least four decimal places.
Scale factor	ko	Note that Coordinate System Manager automatically puts a "1" in this field, this is wrong. Multiply ko from NOS NGS 5 by the DAF and insert in this field. Suggest carrying to at least nine decimal places.

- Click Finish after filling in all five fields, and you have created a new zone. Save, and then close Coordinate System Manager.
- To use this new zone, select it through the "Select Coordinate System" dialog. Select New System, click Next, select Coordinate System and Zone, and click Next. Then you select the coordinate-system group you created in Step 1 above and your new new zone will be available for selection from the right pane. Highlight the correct zone and click Next. Confirm the geoid model to be used (probably should be GEOID99 (Conus)), click Finish.
- Again, always confirm by doing appropriate checks of coordinates.

If you must do this in the field -

As mentioned under section headed "The less-easy way --" above, you can certainly calculate modified projection parameters and key them into the Survey Controller job. Survey Controller software versions 10 and up for the Trimble ACU and Trimble TSCe offer another way that is similar to the recommended method using Trimble Geomatics Office (TGO). At this time this discussion will be focused toward the WY DoT situation and Survey Controller Ver 10 and higher.

- Start Survey Controller and create a new job. Assign a name to this job, then go to the Properties section. Select the desired units for the job in the "Units (Dist.)" field.
- Click on the "Coord. sys." field of the Properties section, select the "Select from library" option, then press Next. Select the System (most likely US State Plane 1983) and Zone (Wyoming East 4901, for example). Datum will remain at NAD 1983 (Conus) Mol. We strongly recommend you use the latest and best geoid information available, which is GEOID03 as of this writing.

If you even think about using US State Plane 1927 coordinates or datum grids you had better know what you are doing. Do not expect a lot of sympathy if you go down that path and end up in a huge train wreck.

- Now you need to tell the software that you want the coordinates scaled per the Surface DAF provided by WY DoT. In the "Coordinates" field select "Ground (keyed in scale factor)". In the field named "Ground scale factor:" enter the DAF.
- In those cases where the scaling is done simply by multiplying northings and eastings by the DAF (this is almost always the case and this is how Wyoming DoT does it) you are scaling from 0.00 northing, 0.00 easting. In Trimble Geomatics Office this is real easy because all you have to do is enter zeros in the northing and easting fields. Survey Controller only accepts geographic coordinates for the scaling origin.

The scaling origins for the four Wyoming state-plane zones are as follows:

Zone	Latitude	Longitude
Wyoming East 4901	40° 28' 33.33824" N	107° 31' 30.90937" W
Wyoming East Central 4902	39° 30' 22.33951" N	111° 59' 00.57724" W
Wyoming West Central 4903	40° 17' 03.67568" N	115° 48' 11.29019" W
Wyoming West 4904	39° 13' 45.72520" N	119° 20' 27.34769" W

If you do not have this list with you in the field when setting up a job, you can simply key in a point with grid coordinates 0.00 N, 0.00 E and use "Review current job" to see what the geographic coordinates are for that point.

Remember that this scaling-origin point will probably be outside the area covered by your geoid subgrid, so it would be advisable to set up a dummy job that does not use the geoid model for determining the scaling-origin point.

Enter the scaling-origin coordinates in the Latitude and Longitude fields of the “Project location” section. Enter a representative value in the Height field if one is not there already.

5. Survey Controller also gives you the option of shifting these modified coordinates so they do not look exactly like real state-plane coordinates, but we have only seen a few organizations do this. It is a good idea to do so as it can prevent problems arising from misinterpretation of the coordinates. Because WY DoT simply scales the coordinates, make sure the “False northing offset:” and “False easting offset:” fields contain zeros.
6. Click Store to accept the coordinate settings. Click Accept to exit the “Job properties” window.
7. Always confirm what you have done by doing appropriate checks on the coordinates. Add more points to the TGO project, either as grid or geographic coordinates, and make certain everything matches up.

When you do this in the field you cannot examine the combined scale factors of points in the project like you can in TGO.

One check you can do is to set a GPS receiver on or very near one of the control points and use the “Navigate to point” feature to see if you are within autonomous-accuracy distance of the control point.

Another good check is to inverse between pairs of far-apart points and compare the grid and ground distances. Remember that ultimately it is impossible to perfectly flatten a round and lumpy world onto a flat projection surface. Recognize and live with the inherent limitations.

Important – Use different names for the geographic position you use to start the base receiver and for the GPS measurements to the control points having the grid coordinates entered above. Example- if the control point is named ABCD7, you could name the grid point ABCD7_NEE, with the suffix representing Northing Easting Elevation.