Procedures for Converting GIS Data from NAD27 to NAD83 in Support of the Washington State Standard on Horizontal Datum and Coordinate System

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Introduction

Prior to performing geographic analysis or mapping, one must accurately determine and reference the geographic locations of the features of interest. The adoption by the State of Washington of a standard Datum and Coordinate System has provided the State with a new foundation for geographic data integration (Washington State Geographic Information Council, 2003). The implementation of this standard will reduce the occurrence of location type errors that often arise when disparate data sources are combined.

The objective of the *Geographic Information Technology Standard - Horizontal Datum and Coordinate System*, adopted by the Washington Information Services Board (ISB) on February 6, 2003, is to provide foundational elements for the integration and reuse of the States' investment in significant geo-datasets. Geodata holdings that are built on common technical standards of registration (datum) and reference (coordinate system) enable or facilitate:

- Emergent data exchange for key datasets,
- Reduction of staff time spent re-projecting from one datum/coordinate system to another,
- On-the-fly integration of distributed and separately maintained geo-datasets and,
- Minimize content distortions and error introduction brought on by multiple re-projections/re-sampling

In support of the above objectives, the standard is intended to apply to existing and new 'significant' geo-datasets maintained by or for the State and specifies that these geo-datasets will be stored in a single datum, and in one of the following coordinate systems.

Datum:
North American Datum 1983 (1991 adjustment) as defined by the National Geodetic Survey. (Also referred to as: NAD83/91)

Coordinate System:
The standard coordinate system shall be Washington Coordinate System of 1983 (Stern, 1989), alternately; Geographic Coordinate System may be used.

The coordinate system standard for significant geo-datasets is Washington Coordinate System of 1983 (WCS 83) zone appropriate for geo-datasets that are maintained within the WCS 83 North zone or, WCS 83 South zone.

The standard is Washington Coordinate System of 1983 South zone if the geo-dataset is maintained as a statewide layer or, a regional layer crossing zones.

Standard unit of measure is US Survey Foot. For agencies that must maintain unit of measure in meters, the standard conversion of coordinates between the meter and the US survey foot shall be based upon the length of the meter being equal to exactly 39.37 inches.

Issue Statement

Washington state agencies have already begun to assess the time and cost associated with converting data to the new projection standard. The software tool that will be used by most state agencies to convert their data will be Environmental Systems Research Institute's (ESRI) ArcGIS or ArcInfo software. During the initial assessment, two issues concerning the use of ArcGIS or ArcInfo for data projection were identified. The two issues are independent of one another. This section will describe each issue, identify who will be impacted, and suggest workarounds to resolve each problem.

Issue 1: Workstation ArcInfo WA/OR Transformation Grid

State plane coordinates in the eastern third of Washington State and Oregon are not getting converted from NAD 1983 to NAD 1983 HARN (HPGN) correctly in ArcInfo Workstation using the PROJECT command. The error is up to approximately 2 feet **(Figure 1)**. Note: this also affects users that are using the "Project Wizard (coverages, grids)" tool available in ArcToolbox for ArcInfo.

Background

High Precision Geodetic Network (HPGN) is the older name and is what is used in ArcInfo workstation. High Accuracy Regional Network (HARN) is the current terminology and is used as part of NAD 1983 HARN to identify data that is referenced to a set of GPS control points, rather than the original NAD 1983 control network.

The transformation method that converts between NAD 1983 state plane coordinates and NAD 1983 HARN coordinates is a file-based method. Sometimes it's also called a grid-based method. Each state or groups of states have two files: one that contains the latitude shifts, while the other contains the longitude shifts. Washington and Oregon use the same files which are called: wohpgn.las and wohpgn.los.

The ArcGIS ArcToolbox "Projection Wizard (shapefiles, geodatabase)" and ArcMap use the individual state(s) HPGN/HARN files directly. Therefore, these tools will project the data appropriately.

In ArcInfo workstation, all HPGN files are combined into a single file, hpgn.dat, which is in a binary format. The hpgn.dat file is indexed by another binary file,

hpgn.def, which lists all the individual files and their extents in a look-up table. The HPGN/HARN files overlap in their extents **(Figure 2)**.

The western Idaho-Montana files (WMHPGN) are first in the hpgn.def look-up table, so any points in the eastern third of Washington and Oregon use the WMHPGN files rather than the WO (Washington-Oregon) files.

Summary of Users Affected

The issue addressed above will not affect everyone. The following is a list of criteria that may impact the results of projecting data:

- Use ArcInfo Workstation to project coordinates from NAD 83 Geographic to NAD 83 HARN*
- Use ArcInfo Workstation to project coordinates from NAD 83 HARN to NAD 83 Geographic*
- One of the above projections is used and all or some of the data is in the eastern half of Washington or Oregon.

* Realize that this may impact other projection scenarios as well; the issue is not limited to the literal projection of NAD 83 Geographic to NAD 83 HARN (or vice versa). For example, when projecting from NAD 27 WA State Plane coordinates directly to NAD 83 HARN WA State Plane coordinates that behind the scenes this is being broken into 4 separate projection steps:

1) NAD 27 WA Stateplane → NAD 27 Geographic
2) NAD 27 Geographic → NAD 83 Geographic
3) * NAD 83 Geographic → NAD 83 HARN Geographic (Projection Issue 1 is at this step)
4) NAD 83 HARN Geographic → NAD 83 HARN WA State Plane

ESRI Solution for Washington and Oregon

Two special HPGN files were compiled to temporarily replace the out of the box workstation HPGN files. Their names are: WO.DAT & WO.DEF.

Steps:

1) Browse to Datum folder found under the ArcHome directory.
2) Copy the WO.DAT and WO.DEF to this location.
3) Rename HPGN.DAT to HPGN-COPY.DAT (or any other name)
4) Rename HPGN.DEF to HPGN-COPY.DEF (or any other name)
5) Rename WO.DAT to HPGN.DAT
6) Rename WO.DEF to HPGN.DEF

7) Now project your data.

Notes:

- Data may need to be projected back to NAD83 from NAD83 HARN to fix the projection issue before swapping files.
- Once all data has been projected correctly, you may want to switch back to the original HPGN files. This is viewed as a temporary fix. If you need to project data that's outside of Washington and Oregon then you will need to switch back to the original files.

Solutions and Use Cases

- **Do nothing:** Of course, this response has to do with the overall quality and scale of the original data. If the intended scale of the original data is 1:24,000, for example, then attempting to correct the error could be a moot point. You can continue to work with the Workstation ArcInfo PROJECT command or the ArcInfo "ArcToolbox Wizard (coverages, grids)" tool and accept the error.
- **Use the ArcGIS Desktop Projection Engine:** Currently ArcToolbox and ArcMap have functions available to project Geodatabase feature classes and Shapefiles. Because the ArcGIS projection engine uses the individual grids, the error won't be propagated in the output. In ArcToolbox, this is performed using the "Project Wizard (Shapefiles, Geodatabase)" tool. If you want to use this tool, coverages would need to be converted into Shapefiles or Geodatabase feature classes. In ArcMap, data can be projected on the fly by setting the Data Frame coordinate system properties and then exported. During the export, the user is prompted to either maintain the original projection or match the output with the data frame properties. This applies only to vector layers.
- **Fix existing data:** This assumes you want to correct for Projection Issue 1. Remember, this problem occurs in both directions: NAD83 to NAD83 HARN or NAD83 HARN back to NAD83. Project the data back to its original coordinate system and use the appropriate solution to reproject the data.
- **Use of the ESRI Fix:** Once all data has been projected back to its original projection (if necessary), all coverages and GRIDs can now be re-projected into HARN using the techniques outlined in the above "ESRI Solution" section. See Steps 1-7, page 5.

Issue 2: Washington Projection Table versus Calculation

Inconsistent results were discovered when projecting from NAD27 WA State Plane South Zone coordinates to NAD27 Geographic in CORPSCON and ESRI software

(using either the ArcGIS Desktop Projection Engine or Workstation ArcInfo. The difference is up to approximately 0.2 feet **(Figure 3)**. Based on research done by both ESRI and WA State agency staff, this difference is due to the fact that ESRI and CORPSCON use different methods of projection (calculation versus table). ESRI and several other 3rd party software packages produce identical results.

Background

Some organizations in Washington use the Washington South zone to map the entire state. This provides positive coordinate values for the entire state. Testing shows increasing differences as the latitude increases reaching to a maximum at the northeastern and northwestern corners of the state. Even at these locations, the differences are less than 0.17 foot.

CORPSCON is a public domain software package originally developed by the US Army Topographic Engineering Center (TEC). It is now available from the National Geodetic Survey (NGS) as well.

CORPSCON uses an NGS-provided source code, which is also available as GPPCGP, a FORTRAN program. When reviewing the GPPCGP program, it was discovered that various values for a state plane zone besides the projection parameters are hard-coded. As it turns out, these hard-coded values are designed to make the results match the original zone projection tables that were created in the 1930s. The projection tables were designed for ease of use when hand-calculating state plane coordinates.

When computers were becoming available, the U.S. Coast and Geodetic Survey (now part of NOAA) published "State Plane Coordinates by Automatic Data Processing" (Claire, 1968). This document also mandates the use of various projection constants for each state plane zone.

In most commercial software packages like the Projection Engine and ArcInfo Workstation, the general projection equations that are used come from John P. Snyder's “Map Projections: A Working Manual” (Snyder, 1987). The only 'hard-coded' values for a particular state plane zone are the projection parameters like central meridian, etc. The projection constants are instead calculated on the fly with much higher precision than those from the original projection tables.

ESRI and WA DNR staff have checked a few other 3rd party software packages (GEOTRANS, Blue Marble Geographic Calculator, Tralaine). GEOTRANS, for example, is a publicly available map projections package from NIMA that makes use of TEC-provided source code. It doesn't support WA State Plane zones per se, but does have the projections that the zones use. It matches the ESRI results. Further, the Blue Marble Geographic Calculator software package supports State Plane with both

the 'standard' table-based solution and an 'exact' calculated solution which matches the ESRI results.

Summary of Users Affected

The issue addressed above will not affect everyone. The following is a list of criteria that may impact the results of projecting data:

- Statewide data is stored all within one zone. This impacts both zones so if all data were stored in the North zone, similar errors to Figure 3 would appear along the southern edges.

Realize that this may have an impact on other projection scenarios as well; the issue is not limited to the literal projection of NAD 27 WA State Plane to NAD 27 Geographic (or vice versa). For example, when projecting from NAD 27 WA State Plane coordinates directly to NAD 83 HARN WA State Plane coordinates that behind the scenes this is being broken into 4 separate steps:

1) * NAD 27 WA State Plane → NAD 27 Geographic (Projection Issue 2)
2) NAD 27 Geographic → NAD 83 Geographic
3) NAD 83 Geographic → NAD 83 HARN Geographic
4) NAD HARN 83 Geographic → NAD 83 HARN WA State Plane

Solutions and Use Cases

- **Do nothing:** Very few GIS users are impacted by a shift 0.2 feet. The calculated coordinates are more accurate.
- **Don't store statewide data in one zone.**
- **Create a new Coordinate system:** create a new official state plane coordinate system with only one zone. This would involve adjusting the north and south parallels.

Summary

On February 6, 2003 the Washington State Information Services Board accepted a new Geographic Information Technology Standard that designated the State's preferred Horizontal Datum and Coordinate Systems. The standard mandates that all significant geographic data sets maintained by executive and judicial branch agencies and educational institutions … must store, or make their data readily available in, the North American Datum 1983 (1991 adjustment)," in addition, the data must be provided in the

Washington Coordinate System of 1983 (a.k.a., Washington State Plane) or in a NAD 83 (1991) based Geographic Coordinate System.

This standard will require that many geographic data sets currently maintained by the State be converted to the NAD 83 (1991) datum. The software tool that will be used by most agencies to convert their data will be ESRI's ArcGIS or ArcInfo software. Unfortunately, two issues were identified with ESRI software that may result in the incorrect projection of the data when converting Coverages, Grids, or Tins to NAD 83 HARN from NAD 27. This paper discussed the two issues, provided estimates of the magnitude of the potential errors, and suggested workarounds to solve or reduce the impact of these issues.

Figure 1:

Issue 1: Difference between CORPSCON and ESRI ArcInfo Workstation in Projecting from NAD 83 (1986) to NAD83 (1991). The units are US Survey Feet. Prepared by Frank Fischer, WADNR, April 29, 2003.

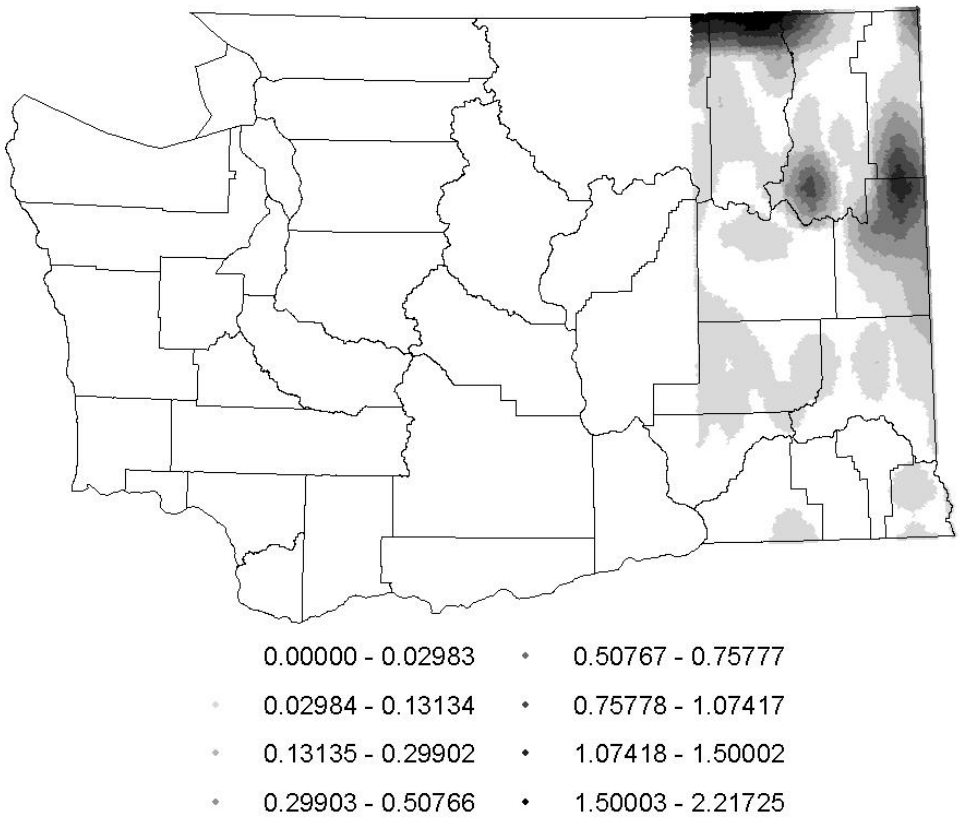


Figure 2:

Issue 1: Areas of overlap between the Washington-Oregon grid and the Idaho-Montana grid. Prepared by Richard Daniels, WADOT, April 29, 2003.

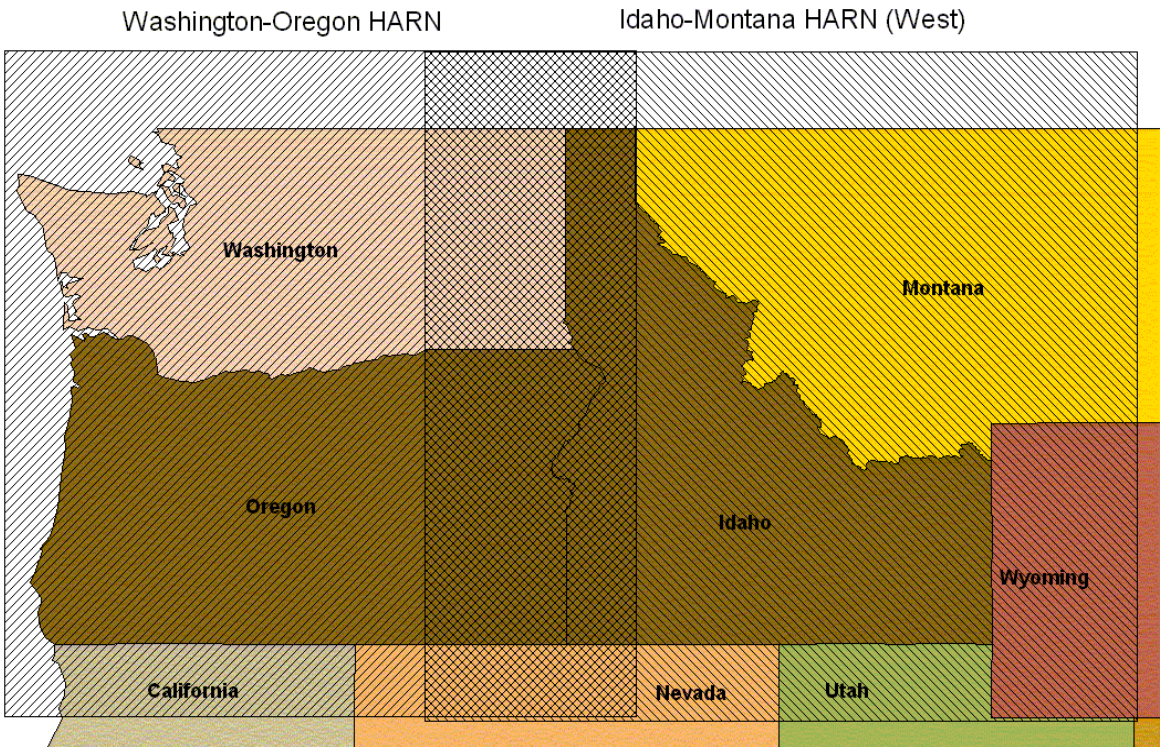
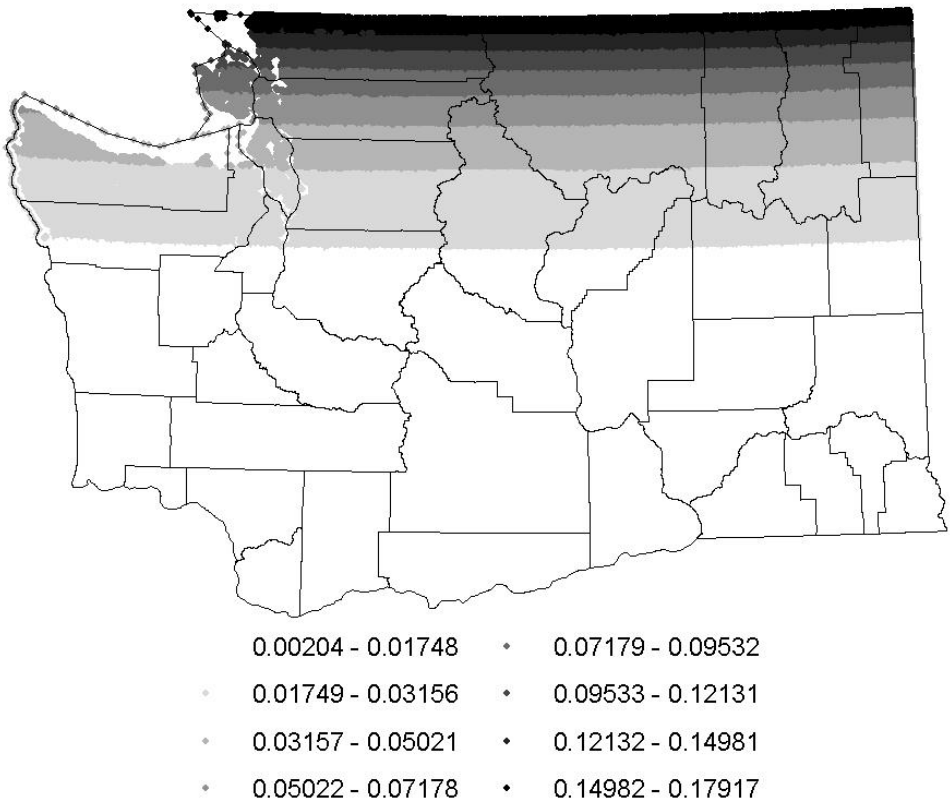


Figure 3:

Issue 2: Difference between CORPSCON and ESRI ArcInfo Workstation in Projecting from Washington State Plane South Zone NAD27 to NAD83 (1986). The Units are US Survey Feet. Prepared by Frank Fischer, WADNR, April 29, 2003



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