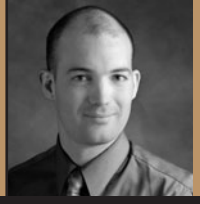

By Landon Blake, LS

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Best Practices for Very Large Boundary Surveys

Coordinate Reference Systems

In the March 2012 installment of Footsteps we outlined best practices for research and data management on very large boundary surveys. In this installment, we will return to the topic of very large boundary surveys, but this time we are going to discuss best practices for selecting and using coordinate reference systems.

What is a coordinate reference system?

We will provide a very simple definition of coordinate reference system that will serve us for the remainder of this article: A coordinate reference system is used to identify the position of geographic features.

In the case of a very large boundary survey, we use coordinate reference systems to identify the position of property corners, property corner monuments, and other elements of our boundary survey. In most cases, we will be using a coordinate reference system that includes a map projection. A map projection is a geometric construct used to "project" the location of features on the curved surface of the earth onto a plane, or flat surface that is more useful for mapping.

Why is it important to think about the coordinate reference system used for your very large boundary survey?

It is important to consider the coordinate reference system for your very large boundary system for two (2) reasons:

- Over large areas the shape of the earth distorts your surveying measurements and calculations.
- The distortions that impact your measurements and calculations can result in the improper location of property corners and boundaries.

Consider the following four (4) best practices for selecting and using a coordinate reference system on your very large boundary survey.

Best Practice #1: Know how your measurements are affected.

On a very large boundary survey you need to understand how the shape of the earth, and your use of a coordinate reference system, can impact your measurements and calculations. This distortion can occur in at least four (4) ways:

- Distortion of distances. Distances can be shorter or longer on the grid or plane used in many map projections. A scale factor is used to convert distances between the grid or plane and "ground", or the earth's surface. The scale factor used can vary with the location and elevation of the project. Significant change in elevation within a project can also distort distances.
- Distortions of directions and angles. Directions and angles can also be distorted by the shape of the earth over large areas. Meridians converge as you move towards the poles, spherical excess results in the misclosure of

KNOW HOW YOUR MEASUREMENTS ARE AFFECTED

1. Distortions of distances.
2. Distortions of directions and angles.
3. Distortions of area.
4. Distortions of shape.

CHARACTERISTICS THAT IMPACT DISTORTION SIZE

1. The size (area) of your very large boundary survey.
2. The size (length) of your very large boundary survey.
3. The location of your very large boundary survey in relation to the selected coordinate reference system.
4. The type of CRS (and map projection) selected for your very large boundary survey.
5. The elevation of points in your very large boundary survey.

large traverses, and lines on the latitudinal curve have a constantly changing bearing.

- Distortions of area. Areas of parcels are also distorted over large areas, and in the use of map projections. Like distances, areas can be larger or smaller on the grid or plane, depending on the parcel location and the type of projection used.
- Distortions in shape. The shapes of parcels and lines can also be distorted over large areas, and in the use of map projections.

Best Practice #2: Know How Big is Big Enough to Matter

The four (4) types of distortions listed above will not be significant in all boundary surveys. One task for the boundary survey is to understand when the errors are big enough to matter. The following characteristics of your very large boundary survey can impact the size of the distortions:

- The size (area) of the very large boundary survey.
- The size (length) of the very large boundary survey.
- The location of the very large boundary survey in relation to the coordinate reference system.
- The type of coordinate reference system (and map projection) selected for the very large boundary survey.
- The elevation of points in the very large boundary survey.

Consider some brief examples: The larger the area of a very large boundary survey, the greater the spherical excess. In many cases, as the distance increases between your very large boundary survey and elements of the map projection, the angular distortions (mapping angle) and scale factor distortions increase. Scale factor, or the difference between grid distances and ground distances can increase with elevation.

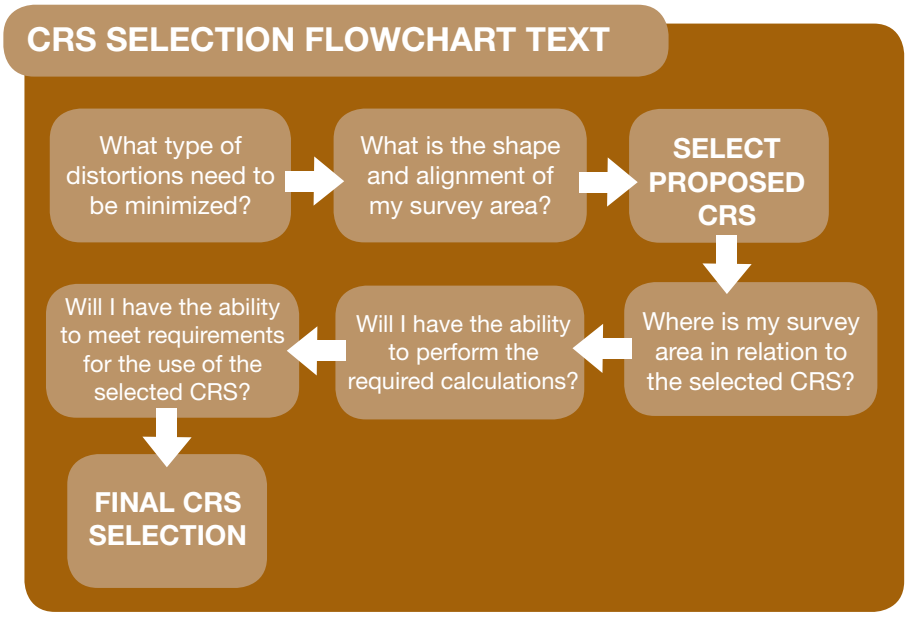
Best Practice #3: Select an appropriate CRS for your very large boundary survey.

It is important to select the appropriate coordinate reference system for your very large boundary survey. Many surveyors choose to work on their local state plane coordinate system. Almost all boundary surveys at the surveying company I work for are done on state plane coordinates. However, I know I'm guilty of using the state plane coordinate system by default. Don't make this same mistake. Understand how your particular state plane coordinate system distorts measurements and make a good professional judgment on whether it is the best choice for the very large boundary survey under consideration. You can view a list of map projection types from the USGS at http://egsc.usgs.gov/isb/pubs/MapProjections/projections.html.

What are some factors you may want to consider when selecting a coordinate reference system for your very large boundary survey? They include the following:

- The elements for which you want to minimize distortion on your survey. These are the elements listed in Best Practice #1. For example: If doing large scale work for a tax assessment, it may be more important to minimize errors to area than the other elements.
- The shape and alignment of your project. For example: Some map projections work well for projects with a large east-west extent, while others work better for projects with a large north-south extent.
- The location of your project within the map projection used by your CRS. If your CRS uses a map projection that places your project location near the edge, or across the edge, of a map projection zone, it may be a poor choice.
- Your ability to perform calculations that move between your surveyed positions on the surface of the earth and the map projection plane or grid. For example: NGS makes available software online that can be used to convert between latitude/longitude positions and state plane coordinates.
- Local laws and regulations may require the use of specific coordinate reference systems for specific types of projects. For example: Many jurisdictions now require boundary surveys to be referenced to the state plane coordinate system.

> **"The shape of the Earth distorts your surveying measurements and calculations."**



Best Practice #4: Include appropriate coordinate reference system data on your filed survey.

In many jurisdictions you are required by law to file a survey in the public record if your survey hits certain triggers. It is important to include detailed information about the coordinate reference system used for your survey, especially if coordinate values are shown. (I provide coordinate values on all of the property corner monuments shown on my filed surveys.) This allows retracing surveyor's to understand how your work was completed and preserves the value of the work that is reflected on your filed survey map.

What information needs to be shown about the coordinate reference system you selected for your very large boundary survey? It should show, at a minimum, the following elements:

- The identity (name) of the coordinate reference system.
- The identity (name) of the horizontal and vertical datum used in the coordinate reference system.
- The scale factor used to move distances and areas between the surface of the earth and the plane (or grid).
- The mapping angle used to move directions and angles between the surface of the earth and the plane (or grid).
- Identity (name) and published coordinates for the control points used to establish the coordinate reference system for the very large boundary survey.

Remember that some jurisdictions have requirements you must meet of you use certain coordinate reference systems, or if you use them in a particular way. For example: California requires that you show ties to control monuments and other information on your filed survey map if you show California state plane coordinates. You have to meet additional requirements if you list accuracies for these coordinates.

Conclusion

I'm certainly not a geodesist. There is a great deal I still have to learn about geodesy and its application to land surveying. Many boundary surveyors share that challenge with me. However, especially when working on very large boundary surveys, knowledge of geodesy and of coordinate reference systems becomes more important. Hopefully this article will get some of my readers to think about the issues involved, and to learn more, as I plan to do. I hope I can look closer at some of the items we discussed in this article, as they relate to boundary surveys, in future Footsteps articles. The relationship between geodesy and the PLSS is especially interesting, as I've been learning during my CFEDS training this summer. If you have comments or questions about geodesy as it applies to boundary surveying, please don't hesitate to contact me. Perhaps our conversations can serve as the starting place for future articles.