Coordinate Systems, Datums, and Map Projections

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Our business is dependent on coordinate data, whether for locating wells, seismic data, land ownership, or other cartographic applications. Failure to consider the proper datum can result in errors in location that may not be identified until significant problems arise. This article introduces some of the basic concepts of datums for the oil and gas professional.

DATUMS AND ELLIPSOIDS

Coordinate data are based on geodetic datums. A geodetic datum, or simply "datum," is a set of reference points on the Earth's surface relative to which position measurements are made.

Currently, in the fields of cartography and land-use, there are two horizontal datums in use in North America. These are the North American Datum of 1927 ("NAD27") and the North American Datum of 1983 ("NAD83"). Both are geodetic reference systems based on ellipsoids. Ellipsoids are mathematical shapes that approximate the geoid, the geoid being the equipotential surface of the earth's gravity field that approximates mean sea level. Ellipsoids are defined by major and minor axes, flattening, and eccentricity parameters.

NAD27 is based on the Clarke Ellipsoid of 1866. It is derived from land-based surveys with a geodetic center at Meades Ranch in Kansas. NAD27 is defined by the latitude and longitude of its geodetic center, the direction of a line between this point and a specified second point, and two dimensions that define the ellipsoid. NAD83 is based on the GRS80 ellipsoid, an ellipsoid derived from satellite geodesy. GRS80 is an Earth-centered datum having no initial point or initial direction.

The oil industry in North America primarily uses NAD27. Government and regulatory bodies are in the process of converting to NAD83. Most other industries are already using NAD83.

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It is important to note the difference in horizontal location that results from application of one or the other of these datums. In Texas, a point having a given latitude and longitude in NAD27 is displaced anywhere from 70 to 170 feet from a point having the identical latitude and longitude in NAD83 (**Figure 1**).

PROJECTIONS

Projections convert spherical coordinates (latitude-longitude) to planar coordinates so that they can be displayed on a flat surface. These projections create distortions of shape, area, and distance. The different projections that we use in different parts of the United States have been designed to minimize the collective distortions that they produce within those given areas. There are three fundamental types of projections:

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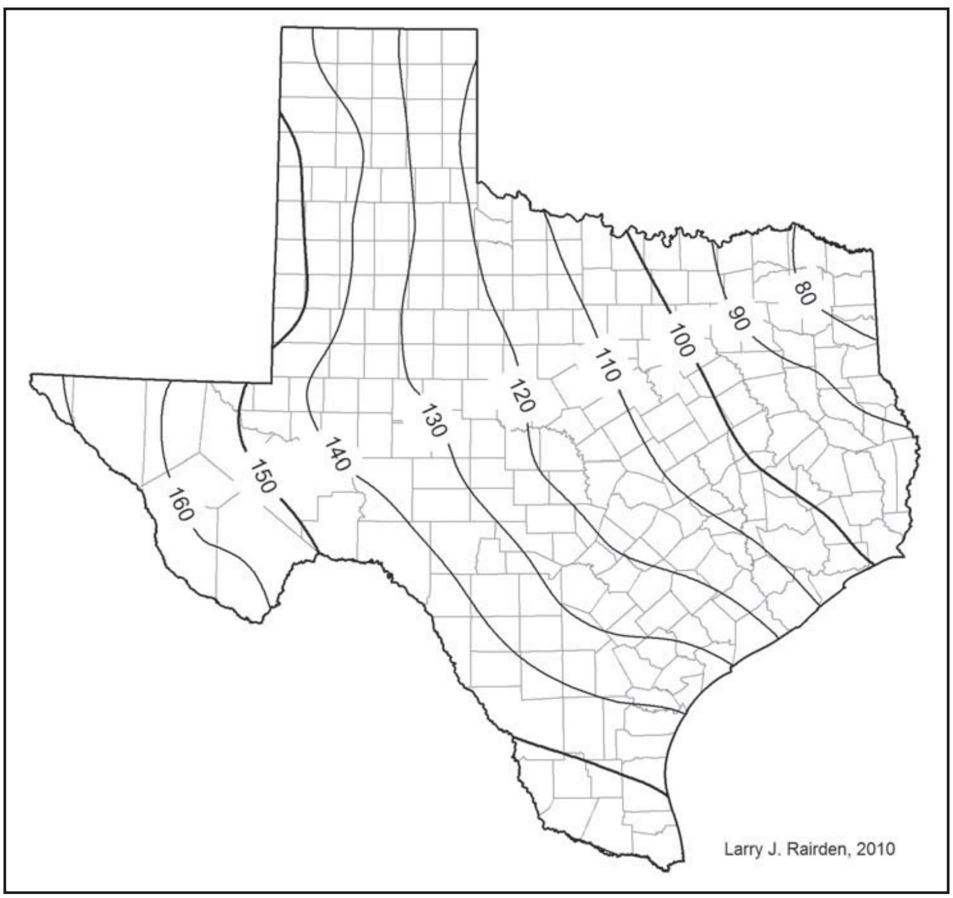

Figure 1. Magnitude of horizontal datum shift, in feet, between NAD27 and NAD83.

- Azimuthal, where points on the ellipsoid are projected onto a planar surface
- Conic, where points are projected onto a cone which is then unrolled to a plane (**Figure 2**)
- Cylindrical, where points on the ellipsoid are projected onto a cylinder which is then unrolled to a plane (**Figure 3**)

Lambert Conformal Conic projections are used for rectangular zones with a larger east-west than north-south extent. Transverse Mercator (cylindrical) projections are used to define zones with a larger north-south extent.

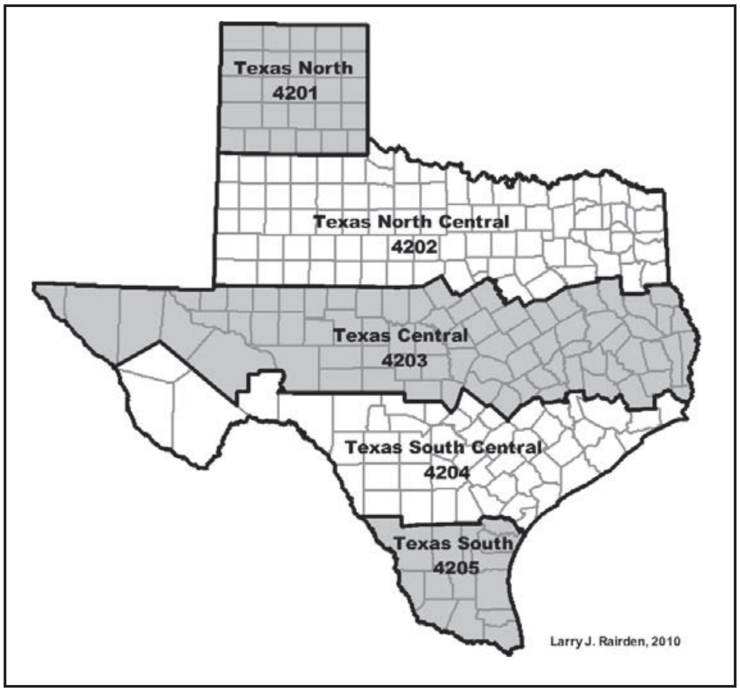

Figure 4. Texas is composed of five State Plane Coordinate System (SPCS) zones.

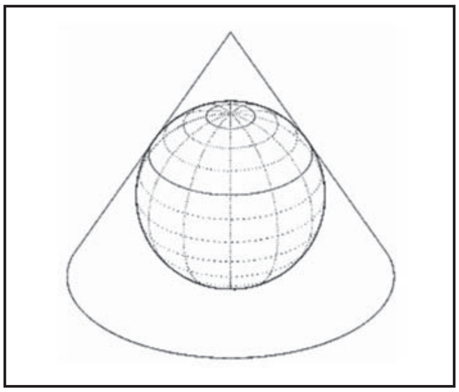

Figure 2. Lambert conformal conic. The cone is tangent to the surface of the ellipsoid at a particular latitude. When points are projected onto the cone and the cone is unwrapped to a plane, distortions are minimized in the vicinity of this particular latitude.

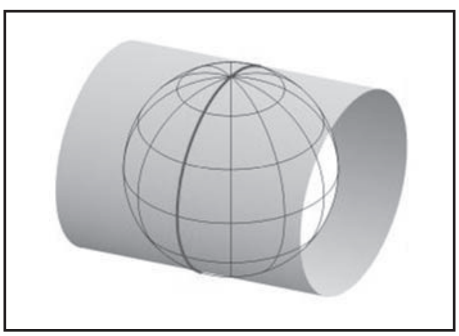

Figure 3. Transverse Mercator. The cylinder is tangent to the surface of the ellipsoid at a particular meridian of longitude. When points are projected onto the cylinder and the cylinder is unwrapped to a plane, distortions are minimized in the vicinity of this particular meridian.

STATE PLANE COORDINATE SYSTEM

Because surveys are performed on the curved surface of the earth and at different elevations, measurements from different starting points will not mesh nor will the lines be rectilinear. In order to seamlessly connect survey work over greater distances, we use a working plane with a rectangular grid. For domestic oil and gas applications, the State Plane Coordinate System (SPCS) is most common. The Universal Transverse Mercator (UTM) coordinate system is also fairly common.

The State Plane Coordinate System was developed in the United States in the 1930s and was originally based on the NAD27 datum. This system divides the United States into more than a hundred distinct grid surfaces ("zones"). Each state plane zone is based on either a Transverse Mercator projection or a Lambert conformal conic projection. The choice between the two map projections is based on the shape of the state and its zones. States that are long in the east-west direction are typically divided into zones that are also long east-west. These zones use the Lambert conformal conic projection because it is good at maintaining accuracy along an east-west axis. Zones that are long in the north-south direction use the Transverse Mercator projection because it is better at maintaining accuracy along a north-south axis. Some smaller states use a single state plane. Larger states are divided into several zones, with state plane zone boundaries often following county boundaries.

In Texas, the Lambert conformal conic projection is used to project from the earth's curved surface to a planer surface. Five planer coordinate projection zones divide the state into east-west bands of counties surrounding five particular latitudes. These are the North (TX4201), North Central (TX4202), Central (TX4203), South Central (TX4204) and South (TX4205) SPCS zones (**Figure 4**).

The 1983 State Plane Coordinate System is based on NAD83. NAD83 coordinates are based on the meter while NAD27 coordinates are based on U.S. Survey Feet. The U.S. Survey

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Foot, it should be noted, is two parts per million longer than the International Foot, the former being 0.3048006 meters while the latter is 0.3048 meters. Coordinates from NAD27 and NAD83 do not resemble each other at all, though, even when NAD83 coordinates have been converted to U.S. Survey Feet. Different false eastings and false northings have been assigned to the two datums to prevent confusion between coordinates computed on each. While NAD27 has been superseded by NAD83 for many applications such as geodetic surveying, maps in the NAD27 State Plane Coordinate System are still the standard for oil and gas mapping activities.

UNIVERSAL TRANSVERSE MERCATOR (UTM) COORDINATE SYSTEMS

The UTM system employs a series of sixty zones worldwide, each 6° of longitude in width and centered on a meridian of longitude. Eastings are measured from the central meridian (with a 500 km false easting to insure positive coordinates). Northings are measured from the equator (with a 10,000 km false northing for positions south of the equator). UTM Zones are numbered from 1 to 60. Zone 1 is bounded by longitude 180° to 174° W and is centered on the 177th West meridian. Zone numbering increases in an easterly direction. The continental United States spans ten UTM zones, from UTM Zone 10 to UTM Zone 19 (**Figure 5**). The UTM coordinate system is based on the WGS84 ellipsoid.

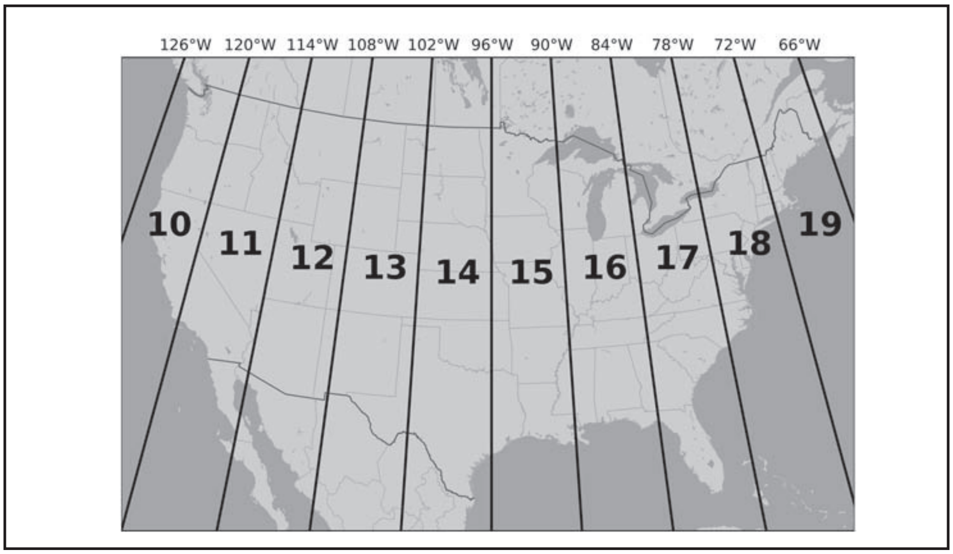

Figure 5. UTM zones spanning the continental United States.

DATA INTERCHANGE AND DATUM TRANSFORMATION

When combining spatially referenced data from different sources, such as different vendors or partners, the datum of the data must be correctly identified and the mapping system must be able to handle datum transformations as needed. NAD27 is the standard for oil and gas data in the United States and vendor data is commonly supplied conforming to this datum. Survey and culture shapefiles, on the other hand, often come with NAD83 datum and require conversion upon import into the oil and gas mapping system. Mapping software should be able to handle such conversions. GIS utilities are available to perform these transforms if your favorite workstation is not up to the task.

The bottom line is this: know the datums of your data and apply appropriate coordinate transformations in your mapping workflow. Coordinates of proposed targets should be thoroughly checked. Don't wait until you are rigging up or have already drilled a non-legal location to find out that you applied the wrong datum transformation to critical data!

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