**City of Knoxville Survey Control Network**
**May 2002**
*(minor revision – January 2003)*

This is a brief overview of the development of the City of Knoxville's survey control network, and an explanation of how to use the control data provided.

**Important:**
**Most of Knoxville's survey control added since September 1999 has been established by GPS measurements, and many new ties have been made directly to the Tennessee Geodetic Reference Network (TGRN), which is maintained by the Tennessee Department of Transportation (TDOT) as part of a nationwide High Accuracy Reference Network (HARN). For this reason, Knoxville's control system has been readjusted to insure a best-fit relationship with the TGRN. As a result, some coordinate values will differ slightly from those published through March 2001.**

The TGRN is an order B (1 PPM) Global Positioning System **(GPS)** network developed as a joint effort of TDOT and the National Geodetic Survey **(NGS)**. It is based on the 1995 readjustment of the North American Datum of 1983 **(NAD 83)**. Three TGRN points were used to fix the positions of the City's original 50 first-order (10 PPM) GPS points, so that a consistency between state and local coordinates would be maintained. *GPS, conventional traverse, and differential leveling are now being used to accomplish densification of the original 50-point network. Equipment, methods used, and resulting closures meet or exceed second-order specifications. (text added in January 2003)*

The control data provided for each point includes state plane coordinates, latitudes and longitudes, elevations, scale factors, convergence values and intervisible points. Other information includes point descriptions and "to reach" instructions. All linear units are expressed in U.S. Survey Feet.

The projection employed to calculate the state plane coordinates **(SPC)** used in the State of Tennessee is the **Lambert Conformal Conic Projection**, which projects ground positions onto an imaginary cone, the axis of which coincides with the earth's polar axis.

**Use of geodetic and grid data supplied in this publication:**

When using the City of Knoxville control system, it should be kept in mind that there are two factors that affect the relationship between distances inversed from SPC and distances measured in the field. One is the **sea level factor**, and the other is the **scale factor**.

The sea level factor **(SLF)** uses the elevations of the points involved, and the mean radius of the earth to reduce surface measurements to a common datum, which approximates sea level. This is not a precise reduction to the ellipsoid used to develop state plane coordinates, but it suffices for general surveying applications. It may be easily calculated by using the mean elevation of the survey line and the mean radius of the earth:

$$\mathbf{SLF} = \mathbf{R} \div (\mathbf{R} + \mathbf{h})$$

where **R** = 20,906,000 ft (mean radius of the earth)
**h** = elevation above sea level in feet

For small surveys, the average elevation of the area surveyed is completely adequate for reducing the entire survey to sea level. If a higher degree of precision is needed, however, large surveys over uneven terrain should have each line reduced individually by using the mean elevation of its end points.

The scale factor **(SF)** is used to correct distortions of the sea level distances occurring because measurements made on the curved surface of the earth are being projected onto a plane. In the Lambert projection, scale varies with latitude, but is unaffected by longitude. As with the **SLF**, small surveys may be corrected with an average factor for the area. Corrections for individual lines are unnecessary, except in high-precision surveys. For the surveyor who needs the information, exact scale factors are being published for each point in the control network.

The SLF and SF are normally multiplied to derive the **combined grid factor (GF)**, which may then be used to reduce distances to the grid with one operation.

**GF** = **SLF** × **SF**

**Grid distance** = **GF** × **horizontal** distance at ground

Anywhere in the Knoxville area, a **local grid factor** of **.99990000** may be used with acceptable precision for most surveys. This is based on a scale factor for the approximate middle latitude of the City, and a mean elevation for the local area.

For example, using the SPC supplied by Aero Services (the original GPS contractor in 1988), the **grid distance** inversed between GPS 0018 and GPS 0019 is **1979.539** feet. An Engineering Department survey crew checked this line, measuring a horizontal distance of **1979.714** feet at the instrument elevation. Below is a comparison of the results obtained by reducing the field measurement using both the local grid factor, and an approximate, but more precise method using the average scale factors of the two end points of the line. An **exact reduction** exists, but it is beyond the scope of this manual. It is more trouble to apply, and will not give significantly different results from the approximate method until the line is several miles in length.

**Approximate reduction:**

**GPS 0018:** elevation = 972.34
scale factor = .99995117

**GPS 0019:** elevation = 958.24
scale factor = .99995139

**Mean elevation** = (972.34 + 958.24) ÷ 2 = 965.29

**SLF** = 20,906,000 ÷ (20,906,000 + 965.29) = .99995383

**Mean SF** = (.99995117 + .99995139) ÷ 2 = .99995128

**GF** = .99995383 × .99995128 = .99990511

**Grid Distance** = 1979.714 × .99990511 = 1979.526 **(reduced measurement)**

1979.526 - 1979.539 **(inversed grid distance)** = -0.013 (precision ratio =1:152,000)

**Local reduction:**

**Grid Distance** = 1979.714 × .9999 = 1979.516 **(reduced measurement)**

1979.516 - 1979.539 **(inversed grid distance)** = -0.023 (precision ratio =1:86,000)

As can be seen here, the local factor gives satisfactory results for anything other than large control surveys. Depending on the location and elevation of a given survey, the agreement between the approximate and local reduction may be better or worse than in the above examples.

**Convergence angle:**

The **convergence angle**, also known as **mapping angle** or **theta** ($\theta$), is the difference between the grid and geodetic azimuth at a given point. Geodetic azimuths may be determined by geodetic inverse (using latitudes and longitudes), or by Laplace-corrected astronomic observations. They differ from grid azimuths because lines of longitude converge toward the earth's poles.

**Grid azimuth** = geodetic azimuth - $\theta$ + (T-t)

The second term (T-t), which is a small curvature correction applied to horizontal angles, may be ignored for all lines of less than 5 miles - it is shown here for completeness only.

**Elevations:**

As of May 2002, elevations will be published both on the National Geodetic Vertical Datum of 1929 **(NGVD 29) and** the North American Vertical Datum of 1988 **(NAVD 88).** This will help minimize confusion as the City transitions to NAVD 88, expected to be used by virtually all government agencies. Since NAVD 88 uses an improved gravity model, the relationship between the two datums is not constant, varying with location. In the Knoxville control system, the NAVD 88 elevation of a point is, on average, 0.43 foot less than its NGVD 29 elevation, ranging from a minimum value of -0.37 foot to a maximum value of -0.47 foot.

Beginning with this publication (May 2002), elevations will be categorized by the method used to determine them, i.e., direct leveling, trigonometric, or GPS. Leveled elevations are determined by differential leveling using second-order equipment. The NGS gravity model **GEOID99** is being used to compute elevations from GPS observations. These elevations agree closely with those determined by direct leveling. Results of both procedures are published to the nearest hundredth (0.01) of a foot. Trigonometric elevations are determined by traditional means, and are published to the nearest tenth (0.1) of a foot.