Chapter 7

Tools *(updated September 7, 2009)*

Tools

The TOOLS module offers additional computational options for inversing, traversing, coordinate transformations, coordinate exporting and more. Within this module, data in the current project can be accessed and manipulated in a variety of ways.

For most of the topics in this chapter, we use our BIGBASIN.TXT network described in the GETTING STARTED chapter.

Most report contain multiple columns of data. You can sort the report by any column (toggling between ascending and descending order) by simply clicking on a column header. To sort by the absolute value of a numeric column, change the VIEW - SORT BY ABSOLUTE VALUE menu item to a checked state.

You can resize the width of any column by grabbing the applicable column separator with the mouse and moving it left or right. Using this technique, you can hide the contents of a column by simply making that column very narrow. This will enhance your ability to look at only the data in which you are interested.

For most tools, all project data (stations and observations) must be entered (or loaded) into COLUMBUS. There are a variety of ways to get your data into COLUMBUS. Consult the FILE MANAGEMENT and DATA chapters of this manual for more information.

To write the results from any tool to a report file, click on the **REPORT** button and COLUMBUS will prompt you for the name of a report file. You can create a new report file or appended to an existing file.

Before continuing, please review the General Discussion section of Chapter 3 - Views.

Coordinate Geometry

The Coordinate Geometry tools allow you to compute inverses and traverses between two or more stations. A traverse can begin and end at different stations, or form a loop that closes upon itself. This feature is very useful when looking for observation blunders.

If the main project graphical view is active, the inverse and traverse results are based on the station coordinates for the project. If the network adjustment graphical view is active, the inverse and traverse results are based on the current adjusted station coordinates.

COLUMBUS currently can performs six inverse types between stations:

Height Difference:	Height inverse.
2D Mean Bearing:	2D mean bearing inverse.
2D Geodetic:	2D geodetic inverse on the ellipsoidal surface.
3D Local NEU:	3D local horizon plane north, east and up inverse.
3D ECEF XYZ:	3D ECEF (earth centered earth fixed) XYZ inverse.
3D Astro Geodetic:	3D astro geodetic inverse.

COLUMBUS supports nine traversing types between two or more stations:

1D Vertical:	1D vertical traverse.
2D Geodetic:	2D geodetic traverse at a fixed height using latitude and longitude.
3D Geodetic:	3D geodetic traverse using latitude, longitude and height.
2D State Plane:	2D State Plane traverse using NE at a fixed orthometric height.
3D State Plane:	3D State Plane traverse using NEE.
2D UTM:	2D UTM traverse using NE at a fixed orthometric height.
3D UTM:	3D UTM traverse using NEE.
2D Local Horizon NE:	2D Local Horizon Plane traverse using NE at a fixed orthometric height.
3D Local Horizon NEE:	3D Local Horizon Plane traverse using NEE.

When performing 3D geodetic inverses or 3D geodetic traverse computations, you can use either the orthometric height field or the ellipsoidal height field to control the vertical. To compute 3D geodetic inverses and 3D geodetic traverses based on orthometric height, enter the OPTIONS - GLOBAL SETTINGS dialog and set the 3D Geodetic Height to Orthometric Height. To use Ellipsoidal height within your computations, set this option to Ellipsoidal Height.

3D State Plane, 3D UTM, and 3D Local Horizon Plane traverses are based on the orthometric height (elevation) value entered for the known starting station.

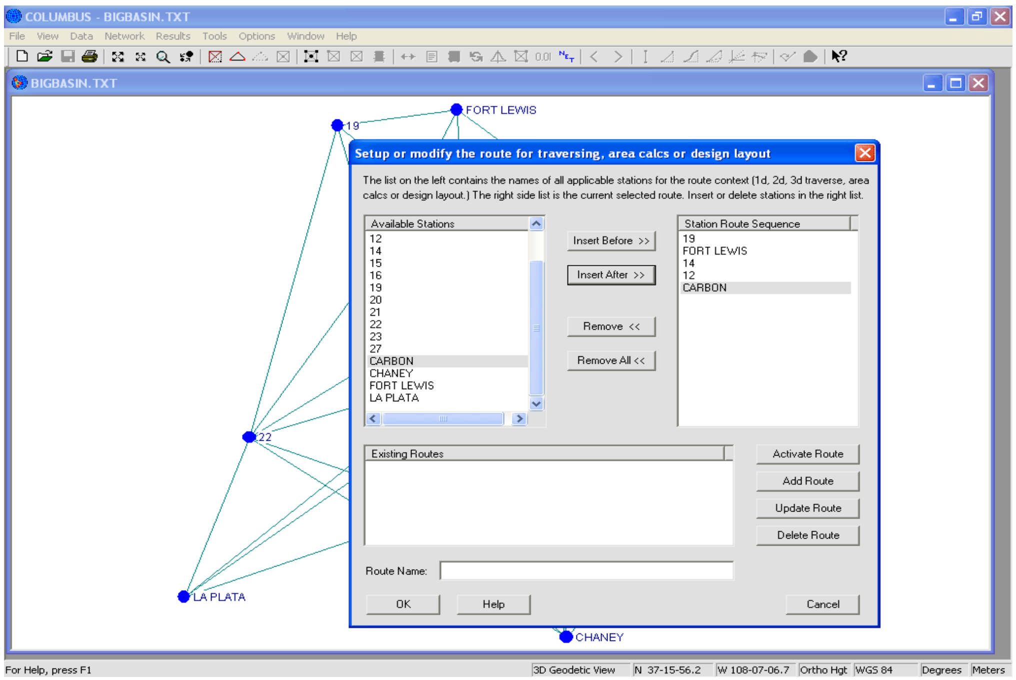
1D vertical results in this chapter were computed from the station and observation data contained in the VERTICAL.TXT sample file shipped with COLUMBUS. To duplicate our results, open this file and set the OPTIONS - UNITS option to meters.

Most other results in this chapter were computed from the station and observation data contained in the BIGBASIN.TXT file. To duplicate our results, open this file and set the OPTIONS - GLOBAL SETTINGS - 3D Geodetic Height option to Ellipsoidal Height. Set the OPTIONS - UNITS - Linear Units to Meters.

For 2D/3D State Plane, 2D/3D UTM and 2D/3D Plane traverses, the demo files STATEPLANE_TRAV.TXT, UTM_TRAV.TXT and NEE_TRAV.TXT were used (respectively).

Computing an Inverse Between Stations

To compute an inverse between two or more stations, you must first define the inverse route. Using the right mouse button, click on the desired stations in succession. As each new station is selected, a line will be drawn from the previous selected station to the current selected station. If no lines are visible, check the COGO color setting in the OPTIONS - COLORS dialog. As each station is selected, the station symbol color should change as well.



You can also define the inverse route using the VIEW - SETUP COGO/DESIGN ROUTE dialog. See the Views chapter for more information on using this method of route creation and route editing.

After selecting a route, enter the TOOLS - COGO submenu and choose from any of the enabled inverse menu commands to compute the results. The menu options available are dependent on the active view. For example, you cannot perform a 3D Astro Geodetic Inverse if the 1D Vertical view is active.

Each of the inverse options can also be accessed using the applicable toolbar button.

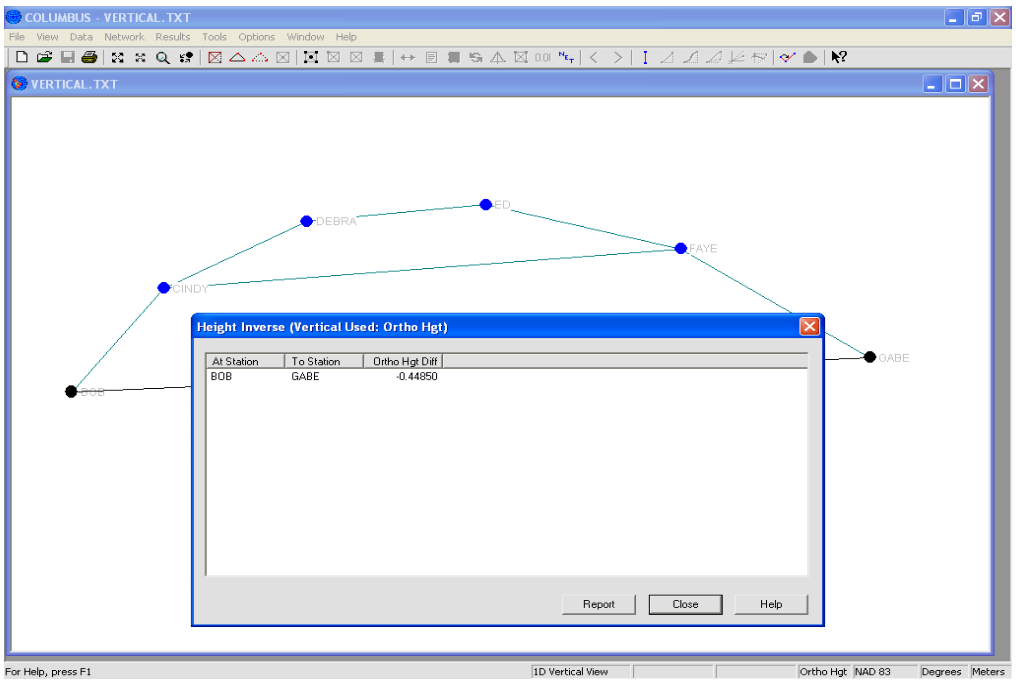
The next several sections describe the results for each inverse option.

Height Difference Inverse

The Height Difference Inverse can be computed when either the 1D Vertical or 3D Geodetic view is active.

For the 1D Vertical view, the Height type station data is used. This station type is commonly used when constructing 1D vertical (levelling) networks.

For the 3D Geodetic view, the geodetic height component (i.e., orthometric or ellipsoidal height) is used. The height component used for each station (orthometric or ellipsoidal) is dependent on the OPTIONS - GLOBAL SETTINGS - 3D Geodetic Height setting.

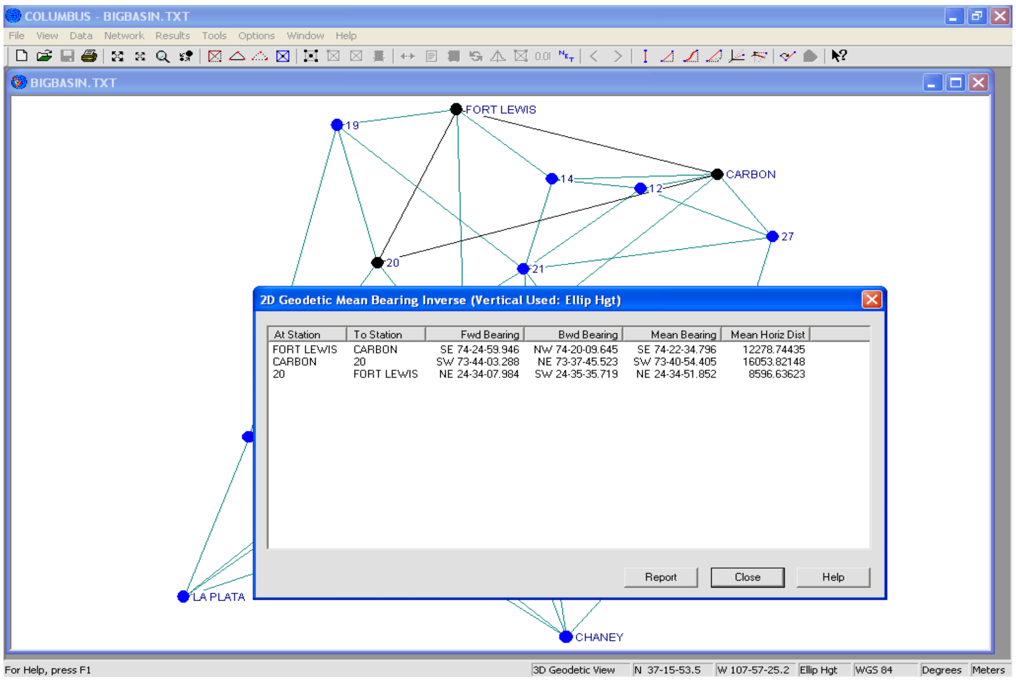


This dialog box above shows the results for a height difference inverse between station BOB and station GABE. The linear results are in meters. The height difference is shown as an ellipsoidal height difference due to the 3D Geodetic Height setting within the OPTIONS - GLOBAL SETTINGS dialog.

The height difference is displayed in the order in which the route was defined.

2D Mean Bearing Inverse

The 2D Mean Bearing Inverse can be computed when either the 2D Geodetic or 3D Geodetic view is active.



This inverse is similar to the 3D Local NEU inverse in its basic concept (see the diagram for 3D Local NEU inverse). However, the Up component is dropped, leaving the Local North and East (forward and backward) to compute the mean bearing and mean horizontal distance.

$$\sqrt{(local\ fwd\ north^2 + local\ fwd\ east^2)} = forward\ horizontal\ distance$$

$$\sqrt{(local\ bwd\ north^2 + local\ bwd\ east^2)} = backward\ horizontal\ distance$$

The mean of the above is the mean horizontal distance.

As paired stations occur further apart or as the elevation difference increase, so too will the difference between the forward and backward horizontal distance. Each is based on a different tangent plane orientation. Both tangent planes are perpendicular to the ellipsoidal normal, which closely approximates the direction of gravity. The forward horizontal distance is computed using the height at the AT station. The backward horizontal distance is computed using the height at the TO station.

The distance is presented in the active linear units. The mean bearing is based on the average of the forward and backward bearings between the two stations.

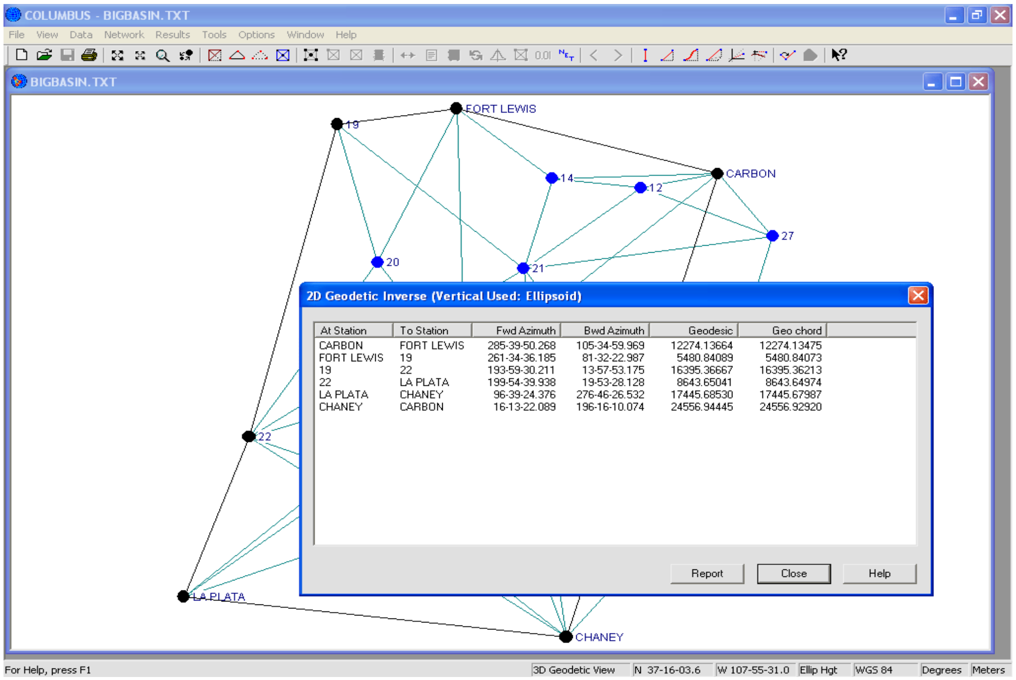
In this example, the ellipsoidal height was used for the vertical portion of the computation for each geodetic station. To use orthometric height, select Orthometric Height in the OPTIONS - GLOBAL SETTINGS - 3D Geodetic Height selection. The results are displayed in the order the route was defined.

If the View mode is set to 2D geodetic, the 2D Height (average height) set up in the OPTIONS - GLOBAL SETTINGS dialog will be used for each station.

The results shown above show the mean bearing inverse between stations FORT LEWIS, CARBON, 20 then back to FORT LEWIS.

2D Geodetic Inverse

The 2D Geodetic Inverse can be computed when either the 2D Geodetic or 3D Geodetic view is active. The geodetic inverse is computed as if the stations were located directly on the ellipsoid surface, at an ellipsoidal height of zero. The data used at each station are latitude and longitude.

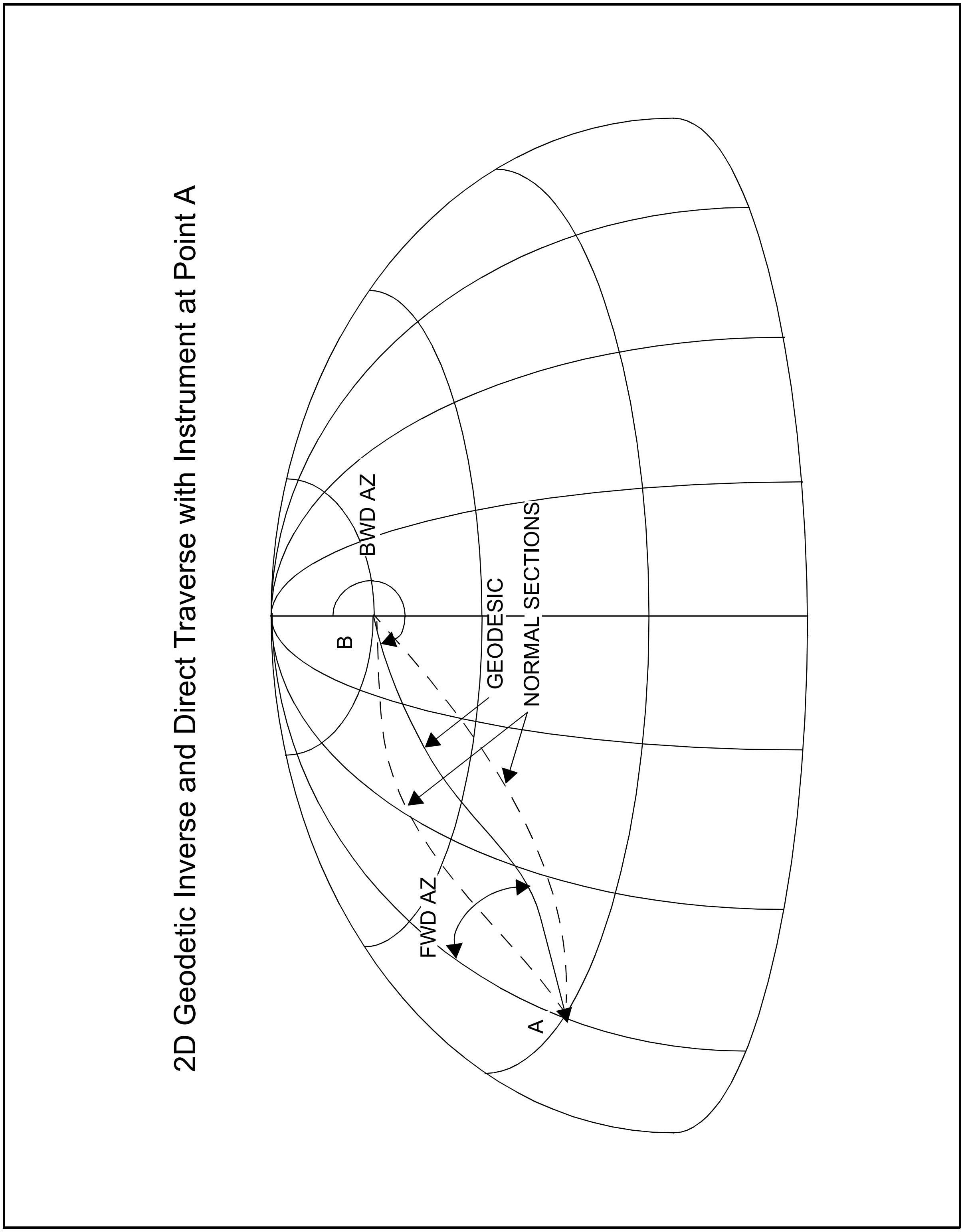


At Station	To Station	Fwd Azimuth	Bwd Azimuth	Geodesic	Geo chord
CARBON	FORT LEWIS	285-39-50.268	105-34-59.969	12274.13664	12274.13475
FORT LEWIS	19	261-34-36.185	81-32-22.987	5480.84089	5480.84073
19	22	193-59-30.211	13-57-53.175	16395.36667	16395.36213
22	LA PLATA	199-54-39.938	19-53-28.128	8643.65041	8643.64974
LA PLATA	CHANEY	96-39-24.376	276-46-26.532	17445.68530	17445.67987
CHANEY	CARBON	16-13-22.089	196-16-10.074	24556.94445	24556.92920

The results above show the geodetic inverse between stations CARBON, FORT LEWIS, 19, 22, LA PLATA, CHANEY, then back to CARBON.

The figure below depicts the 2D geodetic inverse. The 2D geodetic inverse results in a chord distance and a geodesic distance. Because the computations are based at an ellipsoidal height of zero, the chord distance actually cuts through the ellipsoidal surface. The geodesic distance is the shortest distance between the two stations as measured along the curved ellipsoidal surface.

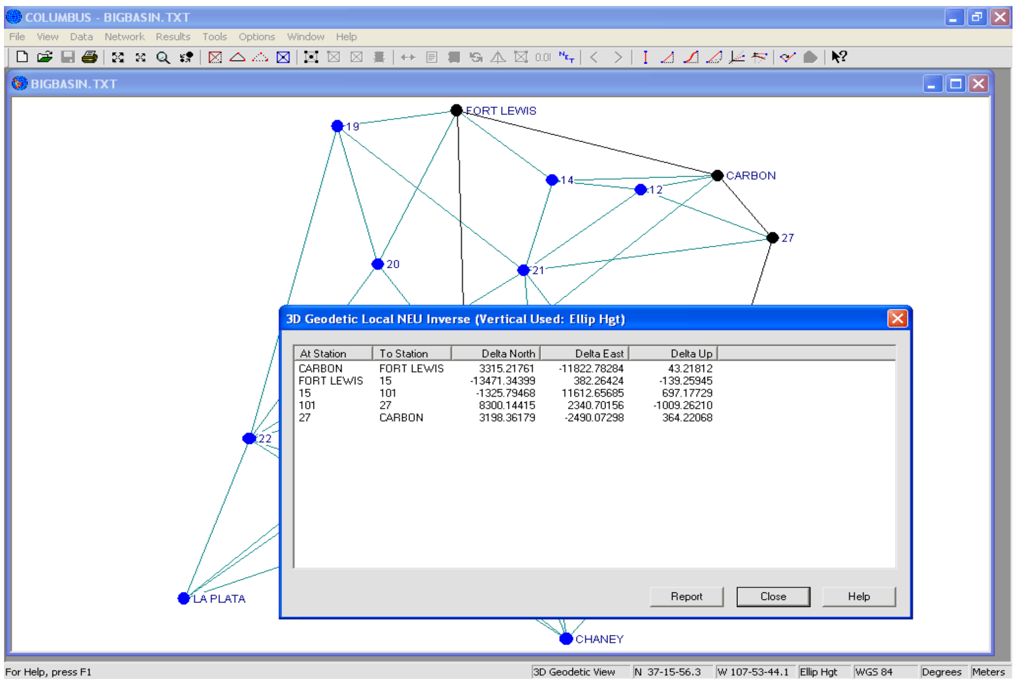
The geodesic distance can be computed to within 0.001 meters for stations up to 20,000 km apart. The geodetic chord distance accuracy is only limited by the accuracy of the AT and TO station coordinates. It is simply a vector in space.


2D Geodetic Inverse and Direct Traverse with Instrument at Point A
BWD AZ
B
GEODESIC
NORMAL SECTIONS
FWD AZ
A

3D Local NEU Inverse

The 3D Geodetic Local Horizon NEU (North, East, Up) Inverse can be computed when the 3D Geodetic view is active. This inverse is based on a tangent plane surface, which forms a Local Horizon NEU (North, East and Up) mathematical system. The tangent plane is perpendicular to the ellipsoidal normal and closely approximates the direction of gravity. The figure at the end of this section depicts this inverse type.

Below are the results for an inverse between stations CARBON, FORT LEWIS, 15, 101, 27, then back to CARBON.



The chord distance between two stations is equal to:

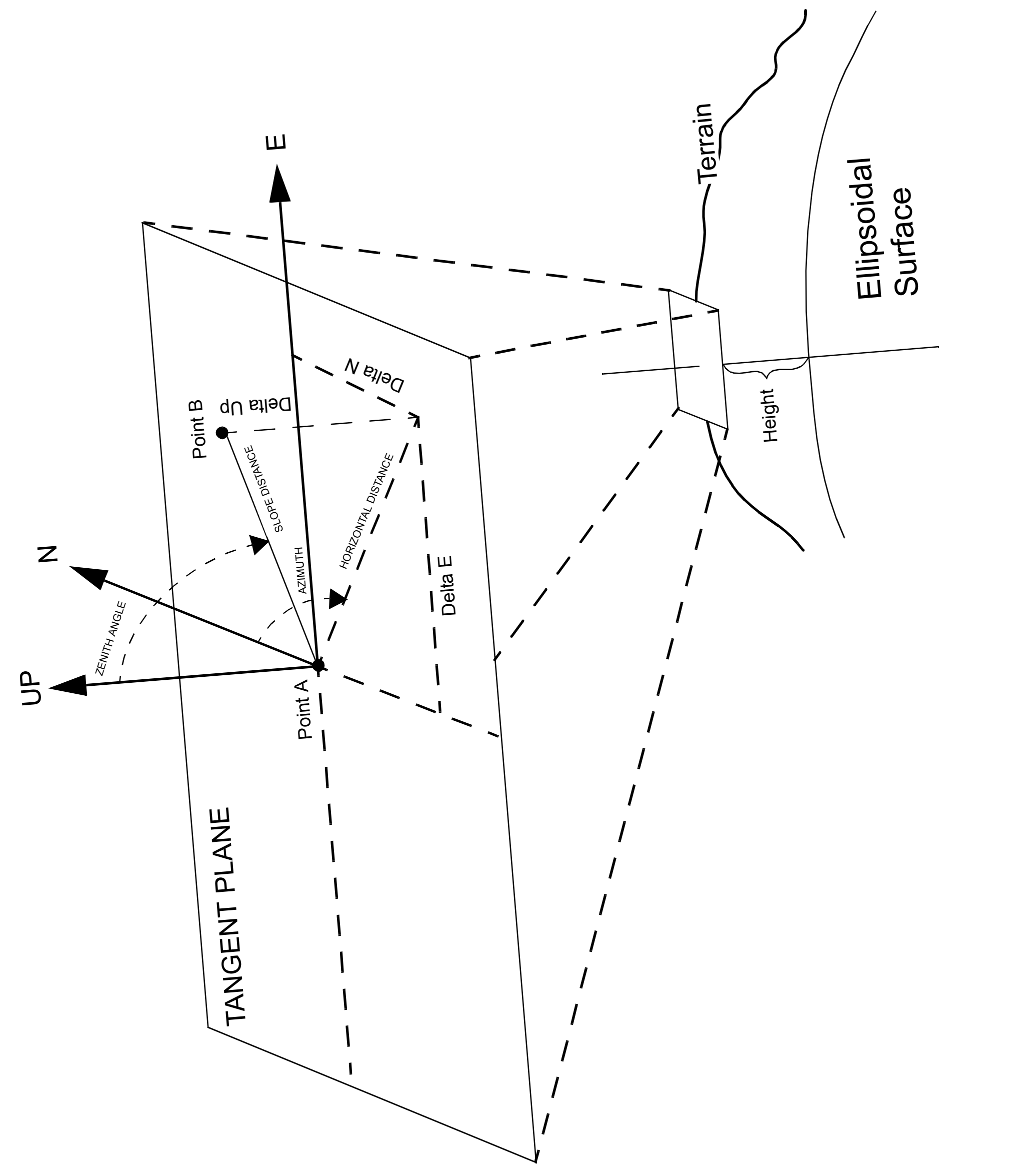
$$\sqrt{(fwd\ delta\ north^2 + fwd\ delta\ east^2 + fwd\ delta\ up^2)}$$

If you were to compute the inverse in the reverse order you would notice that the magnitude of the forward and backward vectors (dN, dE, dUP) are the same; however, the orientation of these vectors is different. This is due to the ellipsoidal nature of the Earth's surface. Within a limited distance, the orientation will be similar, as would occur on a flat surface. As your stations are moved farther apart, the orientation changes markedly.

The data used at each station includes latitude, longitude and height (orthometric or ellipsoidal). All vector components are presented in the active linear units.

In this example, the ellipsoidal height was used as the vertical portion of the computation. To use orthometric height, enable the Orthometric Height option by changing the 3D Geodetic Height setting in the OPTIONS - GLOBAL SETTINGS dialog. The results are displayed in the order in which the route was defined.

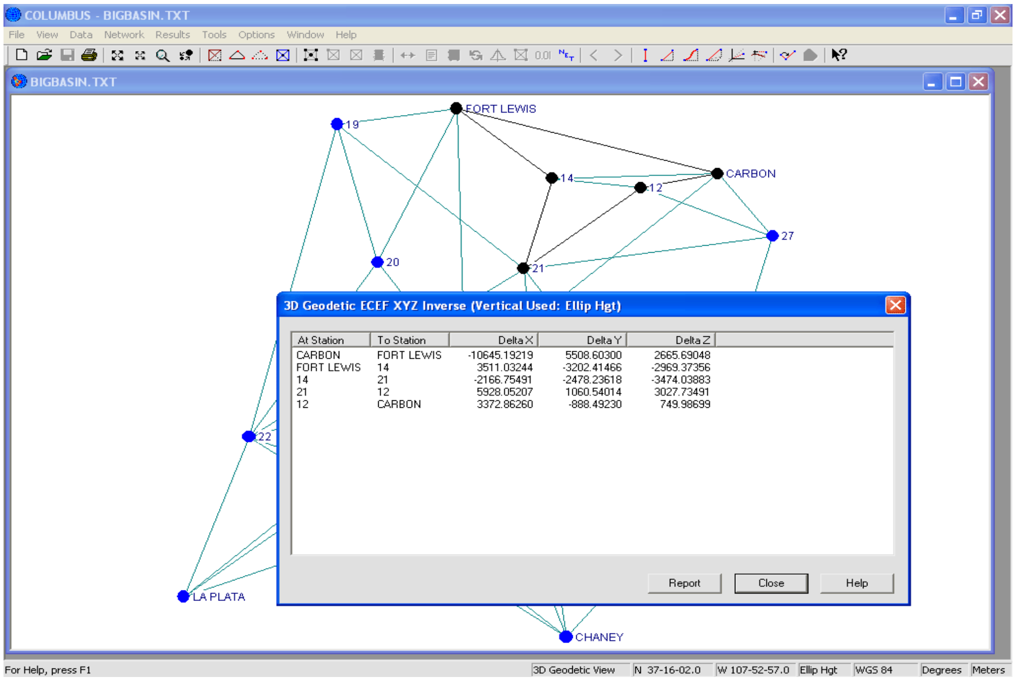
3D Local Inverse and Local Direct Traverse with Instrument at Point A



3D ECEF XYZ Inverse

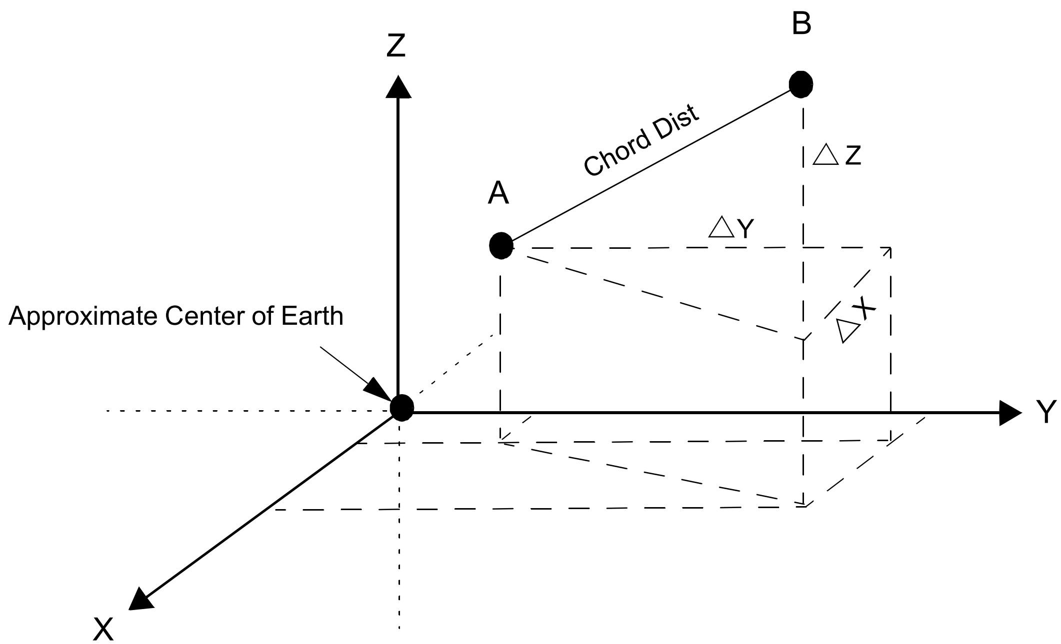
The 3D ECEF Inverse can be computed when the 3D Geodetic view is active. This inverse (Earth Centered Earth Fixed delta X, Y and Z vector) is analogous to a baseline measured using differential GPS positioning. Since these are vectors in 3D space, the magnitude of each vector component between the AT and TO station is the same in either direction. Only the sign (±) will differ if the AT and TO stations are reversed. The data used at each station includes latitude, longitude and height. All vector components are presented in the active linear units.

Below are the results for an inverse between stations CARBON, FORT LEWIS, 14, 21, 12, then back to CARBON.



In this example, the ellipsoidal height was used as the vertical portion of the computation. To use orthometric height, enable the Orthometric Height option by changing the 3D Geodetic Height setting in the OPTIONS - GLOBAL SETTINGS dialog. The results are displayed in the order in which the route was defined.

3D ECEF XYZ Inverse and Direct Traverse with Instrument at Point A

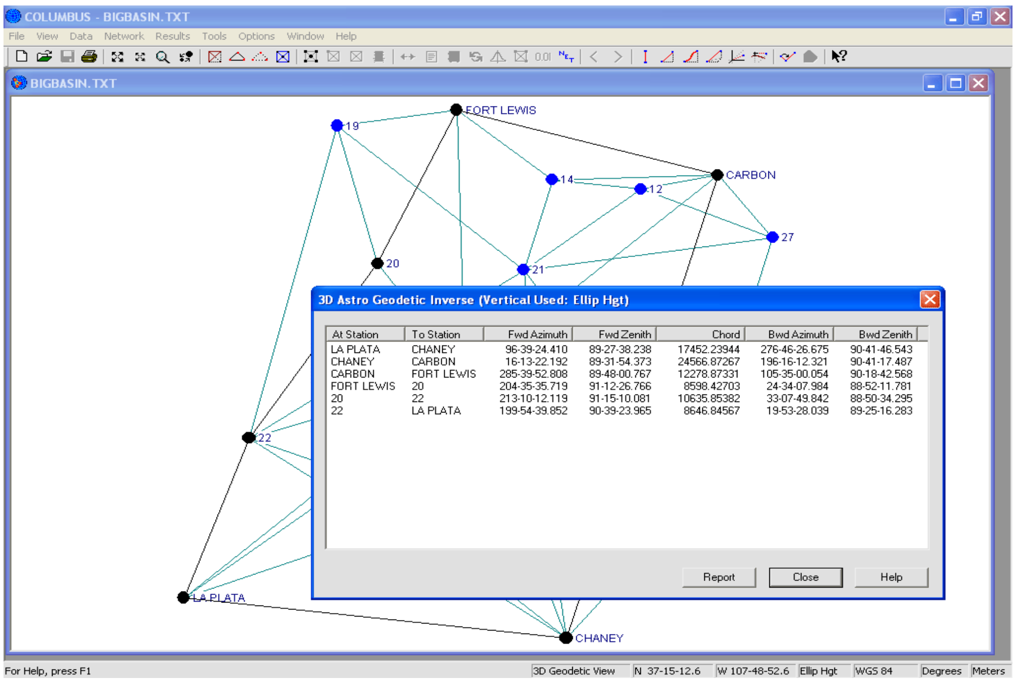


$$\text{Chord Dist} = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

3D Astro Geodetic Inverse

The 3D Astro Geodetic Inverse can be computed when the 3D Geodetic view is active. This inverse computes results as they would be observed in the field (mark to mark) on the geoid (Earth's surface), provided the deflections of the vertical are known at each station. In other words, the geodetic inverse observations are computed then corrected to Astronomic observations. The data used at each station includes latitude, longitude, height and the deflections of the vertical (if available).

Below are the results for an inverse between stations LA PLATA, CHANEY, CARBON, FORT LEWIS, 20, 22, then back to LA PLATA.

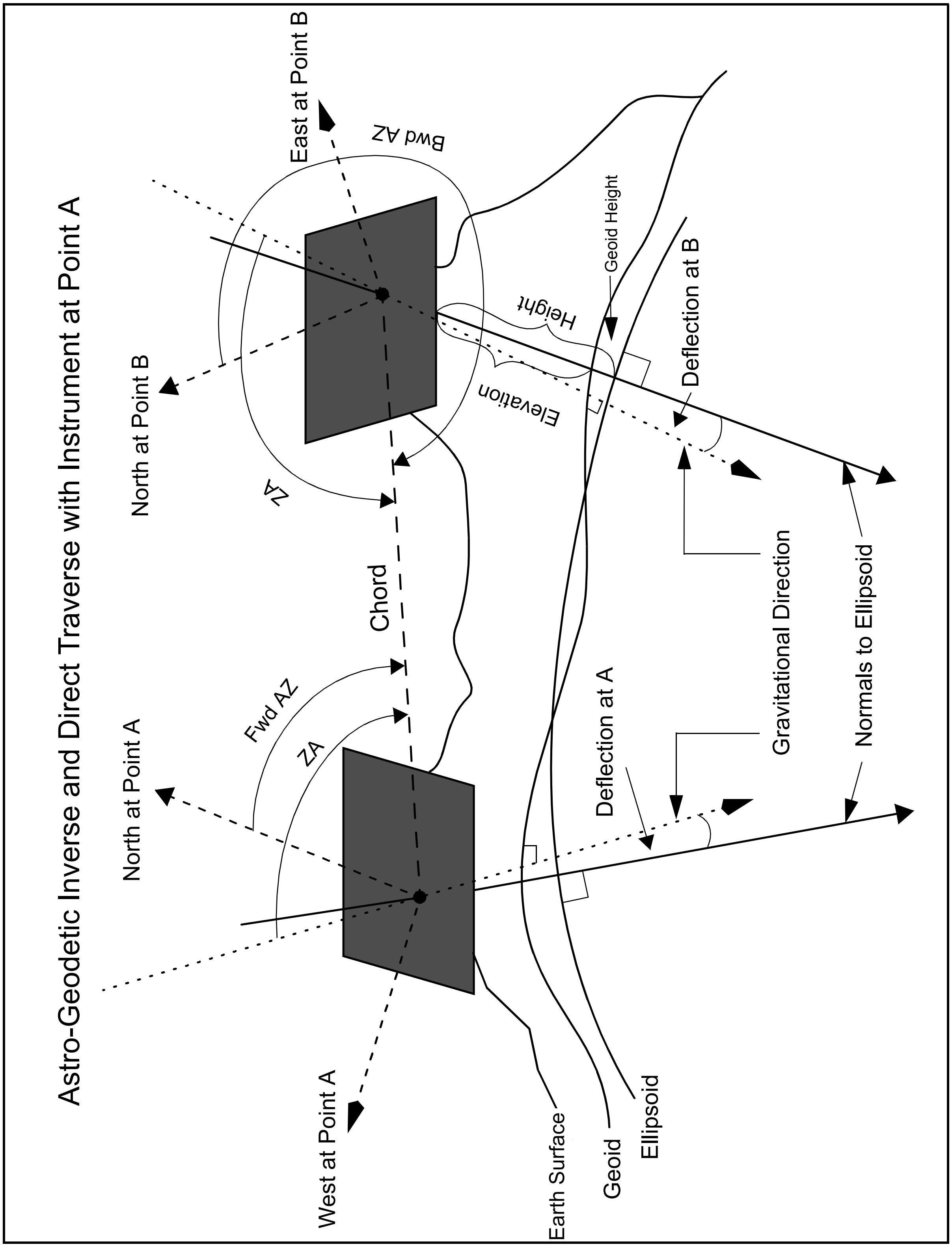


The Astro Geodetic inverse is based upon a three-dimensional geometry. The figure shown at the end of this section depicts Astro Geodetic measurements. The forward azimuth and zenith angles are computed in relation to a plane tangent to the Earth's surface at the AT station. Likewise, backward azimuth and zenith angles are computed in relation to a plane tangent to the Earth's surface at the TO station. The chord represents the straight-line distance between the two stations. This is analogous to a slope distance measurement between the stations at monument level (mark-to-mark). Notice that a chord distance is measured in 3D space. It is not influenced by deflections of the vertical or geoidal height separations (i.e., the difference between orthometric height and ellipsoidal height).

COLUMBUS allows you to enter deflections of the vertical for geodetic stations in the DATA -STATIONS - GEODETIC grid. This value is the angular difference (in seconds of latitude and longitude) between a normal (perpendicular) vector to the ellipsoid and a normal (perpendicular) vector to the geoid (the direction of gravity). Traditional surveying instruments measure angles in reference to the local gravitational field (perpendicular to the geoid). The value of the deflection varies with your location on the Earth's surface.

If deflection angles are entered as zero, the computations are performed as though the normal to the ellipsoid and the local gravitational field (perpendicular to the geoid) are the same. In other words, no correction is applied and the Geodetic results are equivalent to Astronomic results. In general, the zenith angle receives the greatest correction when deflections of the vertical are known.

In this example, the ellipsoidal height was used as the vertical portion of the computation. To use orthometric height, enable the Orthometric Height option by changing the 3D Geodetic Height setting in the OPTIONS - GLOBAL SETTINGS dialog. The results are displayed in the order in which the route was defined.


Astro-Geodetic Inverse and Direct Traverse with Instrument at Point A
East at Point B
Bwd AZ
North at Point B
Geoid Height
Height
Elevation
Deflection at B
ZA
Chord
Fwd AZ
ZA
North at Point A
Deflection at A
Gravitational Direction
Normals to Ellipsoid
West at Point A
Earth Surface
Geoid
Ellipsoid

Computing A Traverse Or Loop Closure

The traverse tools allow you to compute an on-the-fly open or closed (loop) traverse using station and observation data from the current project. By selecting the route (ordering of the stations for the traverse), you can quickly compute the position of all stations along the traverse.

The traverse methods available in COLUMBUS include 1D, 2D and 3D variations: **For 3D traverses, you must provide instrument and target heights to compute accurate forward positions (unless of course your observations are already mark to mark).**

1D Vertical traverses are commonly performed from differential levelling observations.

2D Geodetic, 2D State Plane, 2D UTM and 2D Local Horizon Plane traverses are computed at an average project height.

3D Geodetic, 3D State Plane, 3D UTM and 3D Local Horizon Plane traverses are used when you intend to compute forward ellipsoidal or orthometric heights at each station.

COLUMBUS allows you to use any number of redundant observations when computing forward positions. After selecting your route, then invoking one of the traverse options, COLUMBUS will present you with a list containing all the applicable observations for the traverse. You can de-select individual observations or simply use all of them in the traverse computation. When redundant observations are used, COLUMBUS uses the same least squares weighting strategy used in network adjustments to weight each observation.

Suppose you created a route that starts at station A, then goes to station B, and ends at station C (open traverse). You then compute the 3D geodetic traverse to determine the positions of station B and C (where station A is your known station). If you then performed a network adjustment using these three stations, holding station A fixed in 3D, you would get the same results as those from the traverse computation. In this scenario, your network is minimally constrained and open ended, resulting in the same coordinates (assuming you use exactly the same observations).

To compute a traverse containing multiple stations, you first define the traverse route. You can either define the route by successive right mouse clicks on the desired stations or you can use the route creation and editing tool found in the VIEW - SETUP COGO/DESIGN ROUTE dialog.

When using the mouse, as each station is selected, a line will be drawn from the previous selected station to the current selected station. If no lines are visible, check the COGO color setting in the OPTIONS - COLORS dialog. As each station is selected, the station symbol color will also change.

Example:

For the example that follows, we computed a 3D Geodetic Traverse starting at station A (backsight to station F), and continuing through station B, C, D, E, then back to station F. There are measured observations between all station pairs. Between some station pairs, there are more observations than necessary to compute the forward position (there is redundancy). Here is what you would do to compute this traverse:

1. Prepare a data file (or add the station and observation data using the Data Management Grids) similar to the demo file GEO_TRAV.TXT (or simply use this project file as given). Load the project into COLUMBUS and change the view to 3D Geodetic. Also study demo files NEE_TRAV.TXT, STATEPLANE_TRAV.TXT or UTM_TRAV.TXT to compute a Local NEE, State Plane, or UTM

traverse respectively.

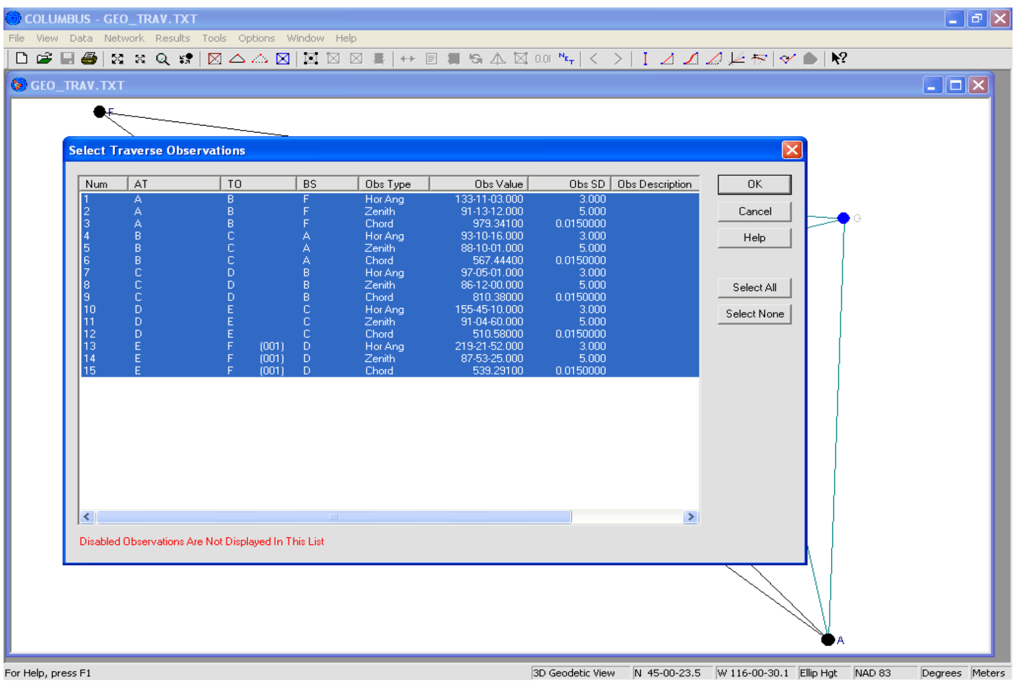
2. Define the route by first right clicking on station F followed by station A, B, C, D, E, then F again.

3. Invoke the TOOLS - COGO - 3D GEODETIC TRAVERSE command or the toolbar button (with tip entitled **Compute 1D, 2D, or 3D Traverse**).

   If the traverse has a valid starting horizontal angle or starting direction set pointing into (or back at) the first station, you would be prompted with a dialog asking you if the first station selected should be treated as a backsight only. The dialog explains the rest.

   For this hypothetical example, a valid starting horizontal angle is one that either backsights or foresights station F. The other end of the angle must point to station B. The angle is measured from station A.

   A valid starting direction set (or partial set) is one that is measured at station A and points to station F. There must also be a second direction that is measured at station A and points to station B. Furthermore, both directions must have the same direction set number.



4. You are then presented with a list of all applicable observations for the entire traverse. Select or deselect any observations you want/don't want, then press **Ok** to begin the traverse computation. Since some station pairs have redundant observations between them, a weighted average of these observations will be used for these legs of the traverse. The weight applied is identical to that used in a 3D Geodetic Network Adjustment. The estimated errors of these observations (standard deviations) will be used to weight these legs.

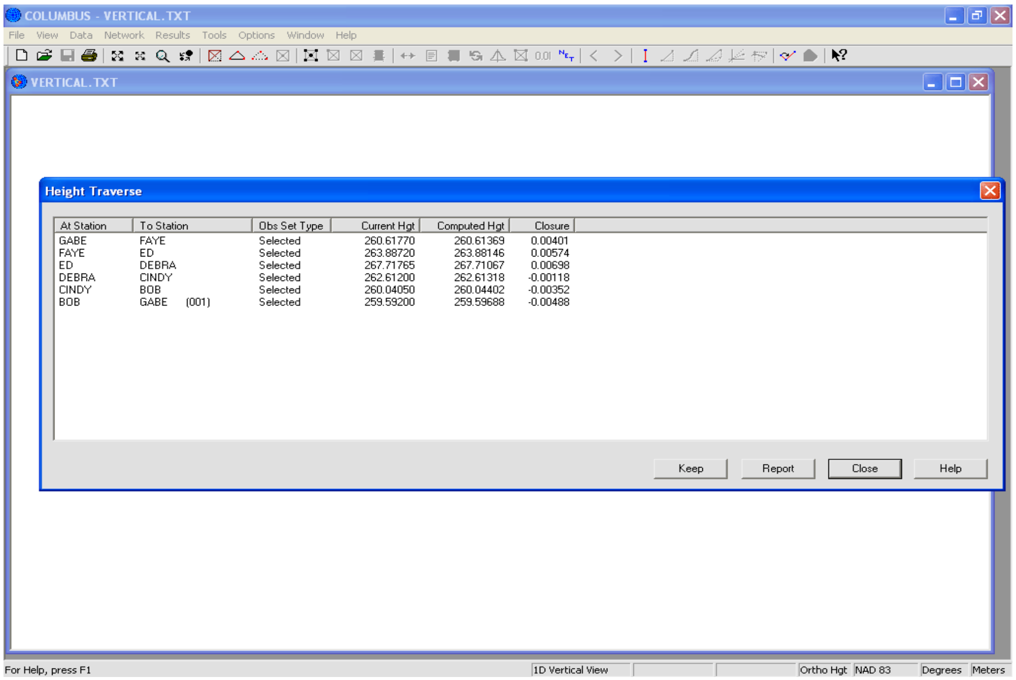
   The initial station F and final station F are the same point on the ground. For the purposes of using unique names for every leg of the traverse, the second reference to station F (i.e., the end of the traverse) will be called "F (001)". This is only a temporary work station that is destroyed when exiting the results dialog.

5. The traverse results are then displayed in the results dialog. For this example, station "F (001)" would appear last, since it is the last station in the traverse.

6. To keep the newly computed positions, invoke the Keep button. The station names appear in a list ordered by the route of the traverse. If you choose to keep the coordinate for station "F (001)", it will actually be kept into station F as expected. The main graphical view is immediately updated to reflect any new coordinates Kept to memory.

1D Vertical Traverse

The 1D VERTICAL TRAVERSE tool facilitates the computation of a vertical traverse. Valid observations include height difference and local delta Up observation types. This option is available when the 1D Vertical view is active. For the 1D Vertical view, Height type station data are used.



Before computing a 1D Vertical Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 1D VERTICAL TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project VERTICAL.TXT and chose a LOOP Traverse originating and terminating at Station GABE. The ordering of the traverse is GABE, FAYE, ED, DEBRA, CINDY, BOB, then back to GABE.

To compute the traverse closure, COLUMBUS compares the known height, for each station, with the computed height for the station. Since GABE is the originating and terminating station, its computed value at the end of the loop is compared to its known value (originating traverse value within the project). All results are presented in the active linear units.

The Closure is computed for each station by taking the difference between the known value for the station and its computed value:

$$Closure \ = \ known\ value - computed\ value$$

KEEP

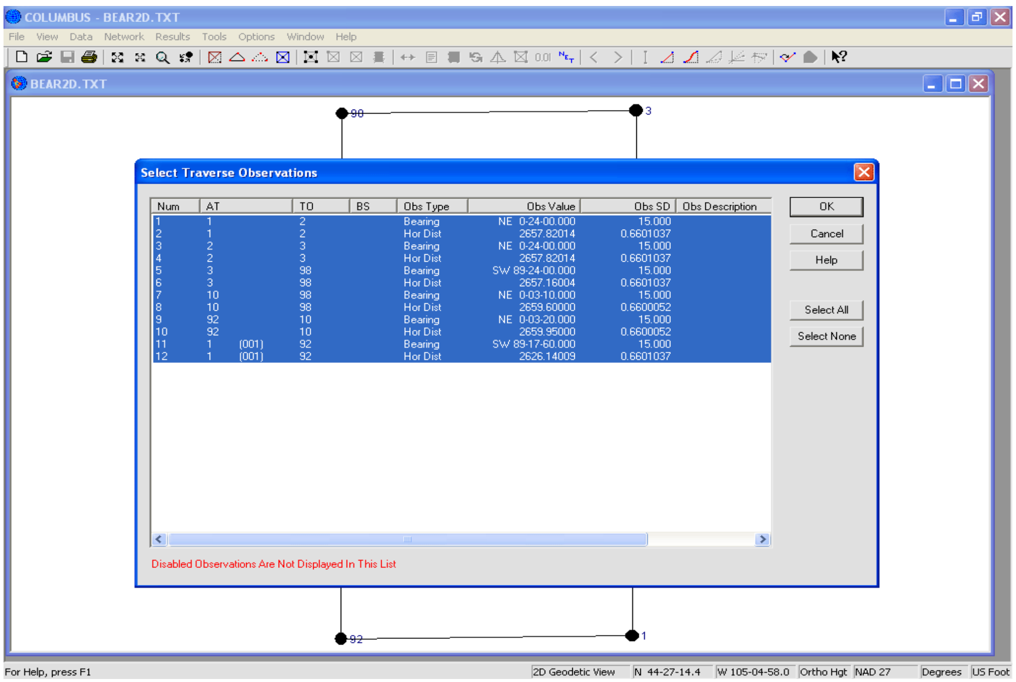
Invoke the **KEEP** button to Keep the computed heights into the current project, thus overriding the current height value for each selected Height type station. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE or FILE - SAVE AS command to save the results to a project file.

The 1D VERTICAL TRAVERSE option provides an excellent tool for computing vertical traverses or loop closures. This option helps you isolate trouble spots within complex 1D vertical networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed.

2D Geodetic Traverse

The 2D GEODETIC TRAVERSE option facilitates the computation of 2D geodetic traverses at a fixed project height. This option is available when the 2D Geodetic view is active. For the 2D Geodetic view, the geodetic station data are used.

Valid observations for a 2D geodetic traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, and local delta east observations.



The project height is established by entering the OPTIONS - GLOBAL SETTINGS dialog and entering the 2D Height in the active linear units.

The Zenith angle is only used to correct a paired chord distance to a horizontal distance. The zenith angle and chord distance must belong to the same observation set in order to pair them correctly. If the zenith angle is not present, COLUMBUS assumes the chord distance has already been corrected to a horizontal distance and hence no further correction is applied.

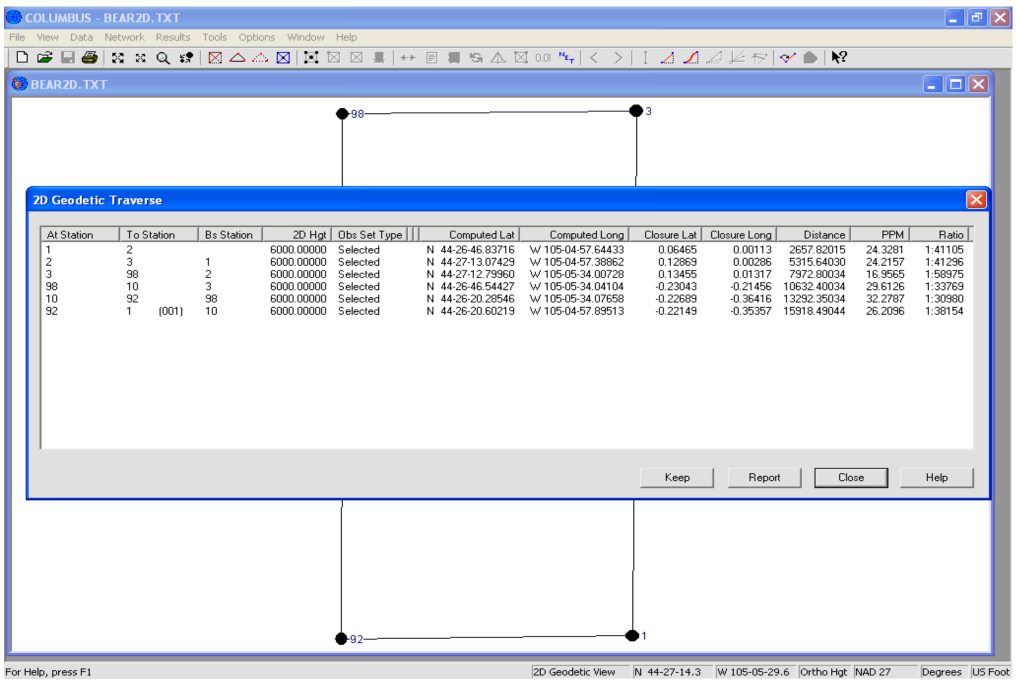
No corrections due to deflection of the vertical, refraction, or mark-to-mark reductions are made, since their impact would be minimal on a 2D geodetic traverse of this type. If these corrections are desired, or if you want the best traverse results possible, we recommend you use the 3D Geodetic Traverse option.

Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observations can be freely mixed with the other observations. When one is encountered, their effect is based on the height of the ellipsoidal surface (zero).

Before computing a 2D Geodetic Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 2D GEODETIC TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project BEAR2D.TXT and chose a LOOP Traverse originating and terminating at Station 1. The ordering of the traverse is 1, 2, 3, 98, 10, 92, then back to 1. We also set the average project height to 6000.0 feet and turned on Rotate Bearings. This traverse winds around one half of a section from a township.



To compute the traverse closure, COLUMBUS compares the known position, for each station, with the computed position for the station. Since Station 1 was the originating and terminating station, its known value is compared to its computed value (at the end of the loop).

Latitude and longitude closures are shown in the active linear units. The PPM and ratio are computed from the 2D closure and the current length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(-0.22149)^2 + (-0.35357)^2}}{Distance} \times 1,000,000.0$$

The ratio is then:

$$\frac{1,000,000}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

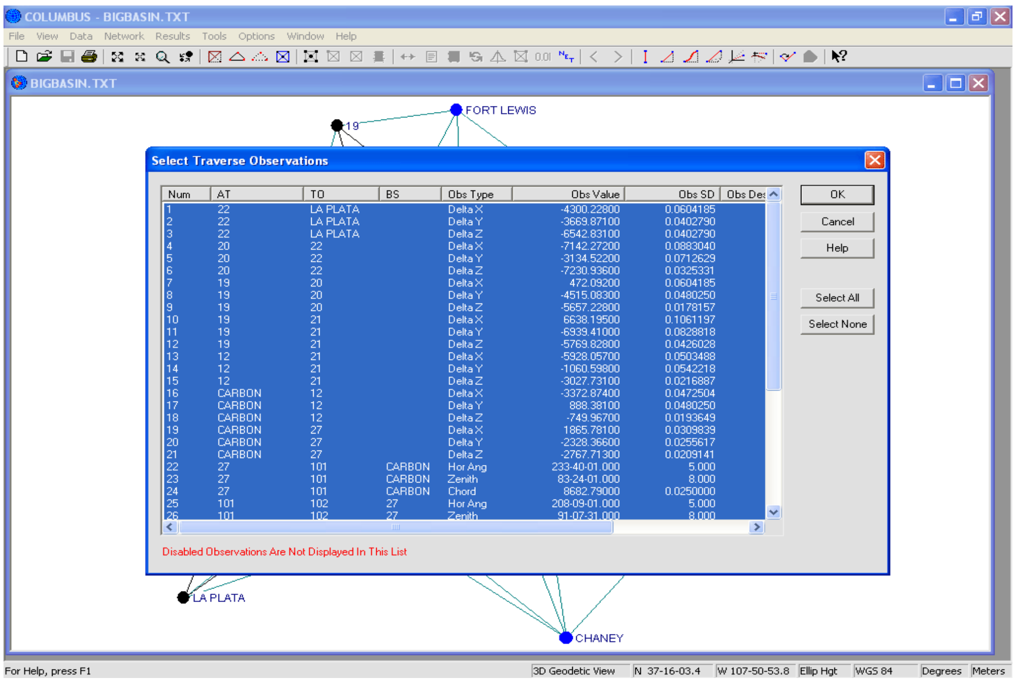
Invoke the **KEEP** button to Keep the computed latitude, longitude and 2D project height coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can the FILE - SAVE or FILE - SAVE AS command to save the results to a data file.

The 2D GEODETIC TRAVERSE option provides an excellent tool for computing 2D geodetic traverses or loop closures. This option helps you isolate trouble spots within complex 2D geodetic networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed. Try experimenting with different project heights if the terrain varies greatly. Adopt an average project height or use different average project heights for different areas of the survey.

3D Geodetic Traverse

The 3D GEODETIC TRAVERSE module facilitates the computation of 3D geodetic traverses. This option is available when the 3D Geodetic view is active. For the 3D Geodetic view, the geodetic station data are used.

When observations are carefully measured, including instrument and target heights, excellent results can be achieved. Valid observations for a 3D geodetic traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, local delta east, local delta up, height difference, and GPS dX, dY, dZ observations.



Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observation sets can be freely mixed with the other observations. When one is encountered, their effect is based on the height of the ellipsoidal surface (zero).

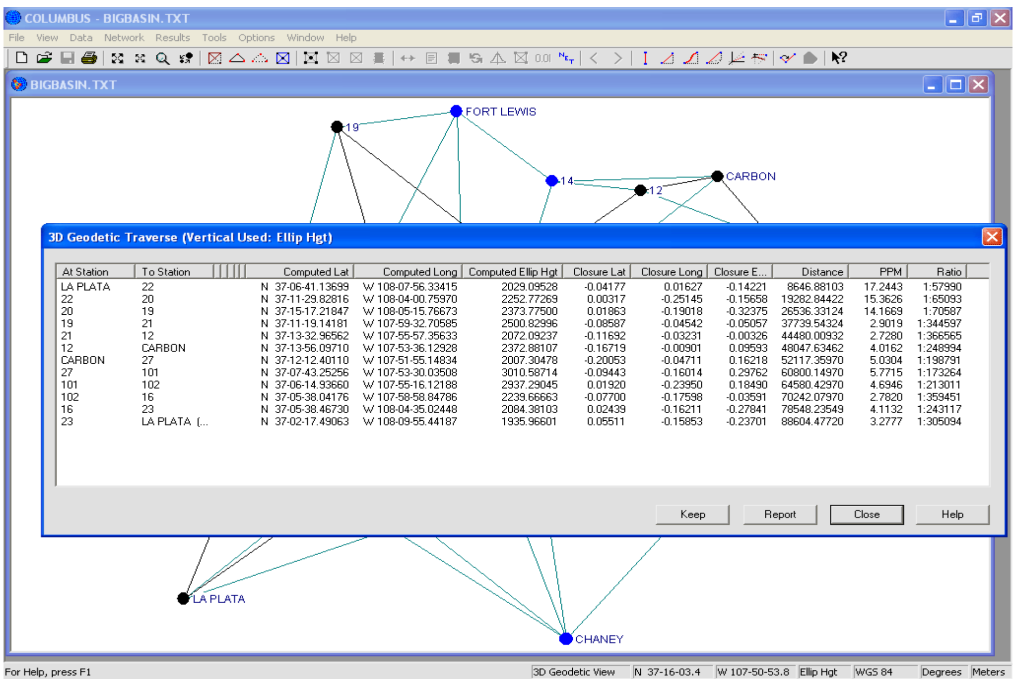
If the deflections of the vertical are known at the current AT station, COLUMBUS will correct the measured applicable Astro-Geodetic observations (azimuth, direction, horizontal angle and zenith angle) to geodetic form (i.e., leveled in the direction of the ellipsoidal normal). If the deflections of the vertical are not known (i.e., entered as zero), no corrections are made and the observed observations (levelled in the direction of gravity) are assumed to be geodetic observations (levelled in the direction of the ellipsoidal normal). This will introduce a very small systematic error in the coordinates for each forward station. Deflection of the vertical corrections have their largest impact on zenith angle observations. **All deflection of the vertical**

corrections can be turned off (if desired) from within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog.

Zenith angles will also be corrected for refraction, if a correction has been set up in the OPTIONS - GLOBAL SETTINGS dialog.

Before computing a 3D Geodetic Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 3D GEODETIC TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project BIGBASIN.TXT and chose a LOOP Traverse originating and terminating at Station LA PLATA. The ordering of the traverse is LA PLATA, 22, 20, 19, 21, 12, CARBON, 27, 101, 102, 16, 23, then back to LA PLATA. This traverse winds through a portion of the BIGBASIN.TXT network using GPS and conventional observation data.



At Station	To Station	Computed Lat	Computed Long	Computed Ellip Hgt	Closure Lat	Closure Long	Closure E...	Distance	PPM	Ratio
LA PLATA	22	N 37-06-41.13699	W 108-07-56.33415	2029.09528	-0.04177	0.01627	-0.14221	8646.88103	17.2443	1:57990
22	20	N 37-11-29.82816	W 108-04-00.75970	2252.77269	0.00317	-0.25145	-0.15658	19282.84422	15.3626	1:65093
20	19	N 37-15-17.21847	W 108-05-15.76673	2373.77500	0.01863	-0.19018	-0.32375	26536.33124	14.1669	1:70587
19	21	N 37-11-19.14181	W 107-59-32.70585	2500.82996	-0.08587	-0.04542	-0.05057	37739.54324	2.9019	1:344597
21	12	N 37-13-32.96562	W 107-55-57.35633	2072.09237	-0.11692	-0.03231	-0.00326	44480.00932	2.7280	1:366565
12	CARBON	N 37-13-56.09710	W 107-53-36.12928	2372.88107	-0.16719	-0.00901	0.09593	48047.63462	4.0162	1:248994
CARBON	27	N 37-12-12.40110	W 107-51-55.14834	2007.30478	-0.20053	-0.04711	0.16218	52117.35970	5.0304	1:198791
27	101	N 37-07-43.25256	W 107-53-30.03508	3010.58714	-0.09443	-0.16014	0.29762	60800.14970	5.7715	1:173264
101	102	N 37-06-14.93660	W 107-55-16.12188	2937.29045	0.01920	-0.23950	0.18490	64580.42970	4.6946	1:213011
102	16	N 37-05-38.04176	W 107-58-58.84786	2239.66663	-0.07700	-0.17598	-0.03591	70242.07970	2.7820	1:359451
16	23	N 37-05-38.46730	W 108-04-35.02448	2084.38103	0.02439	-0.16211	-0.27841	78548.23549	4.1132	1:243117
23	LA PLATA (...	N 37-02-17.49063	W 108-09-55.44187	1935.96601	0.05511	-0.15853	-0.23701	88604.47720	3.2777	1:305094

To compute the traverse closure, COLUMBUS compares the known position, for each station, with the computed position for the station. Since Station LA PLATA was the originating and terminating station, its known value is compared to its computed value (at the end of the loop).

Latitude, longitude and height (ellipsoidal or orthometric) closures are in the active linear units (meters in this example). The PPM and ratio are computed from the 3D closure and the length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(0.05511)^2 + (-0.15853)^2 + (-0.23701)^2}}{Distance} \times 1,000,000.0$$

The ratio is then:

$$\frac{1,000,000.0}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

Invoke the **KEEP** button to Keep the computed latitude, longitude and height coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE of FILE - SAVE AS command to save the results to a data file.

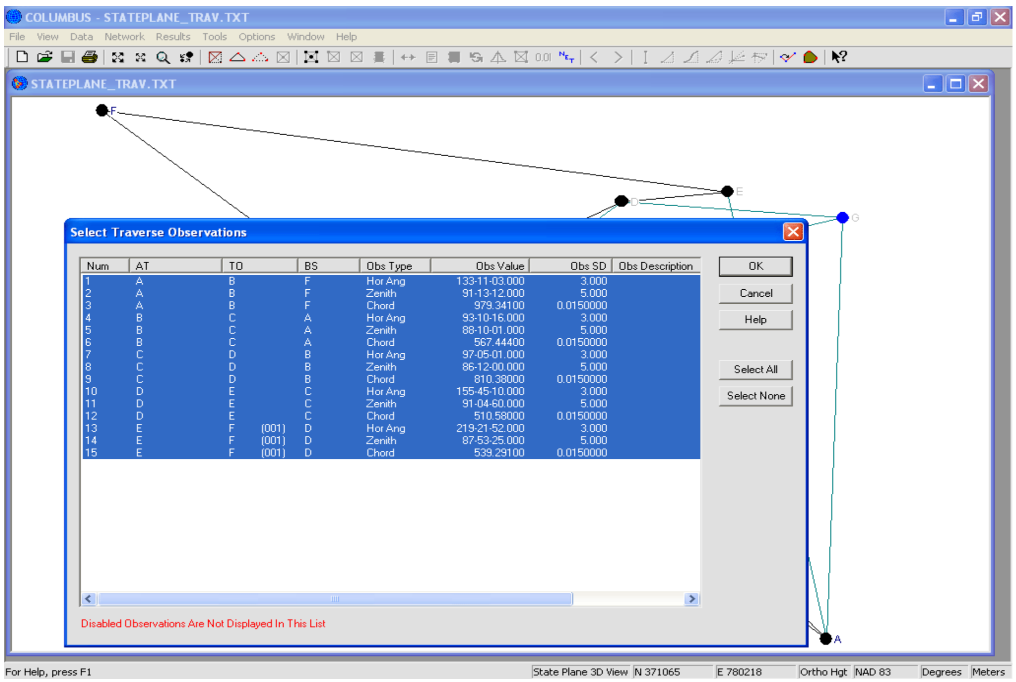
The 3D GEODETIC TRAVERSE option provides an excellent tool for computing 3D geodetic traverses or loop closures. This option helps you isolate trouble spots within complex 3D geodetic networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed.

When using this option, try experimenting with orthometric height as the vertical and then with ellipsoidal height as the vertical (toggle the option by changing the 3D Geodetic Height in the OPTIONS - GLOBAL SETTINGS dialog). For GPS observations, using ellipsoidal height is more appropriate. If the geoidal separation is uniform in the project area, both vertical types (orthometric or ellipsoidal) will deliver excellent results for all observation types.

2D State Plane Traverse

The 2D STATE PLANE TRAVERSE option facilitates the computation of 2D State Plane traverses at a fixed project elevation. This option is available when the State Plane (2D) view is active. For the State Plane (2D) view, the State Plane station data are used.

Valid observations for a 2D State Plane traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, and local delta east observations.



The project elevation is established by entering the OPTIONS - GLOBAL SETTINGS dialog and entering the 2D Height in the active linear units.

The Zenith angle is only used to correct a paired chord distance to a horizontal distance. The zenith angle and chord distance must belong to the same observation set in order to pair them correctly. If the zenith angle is not present, COLUMBUS assumes the chord distance has already been corrected to a horizontal distance and hence no further correction is applied.

No corrections due to deflection of the vertical, refraction, or mark-to-mark reductions are made, since their impact would be minimal on a 2D State Plane traverse of this type.

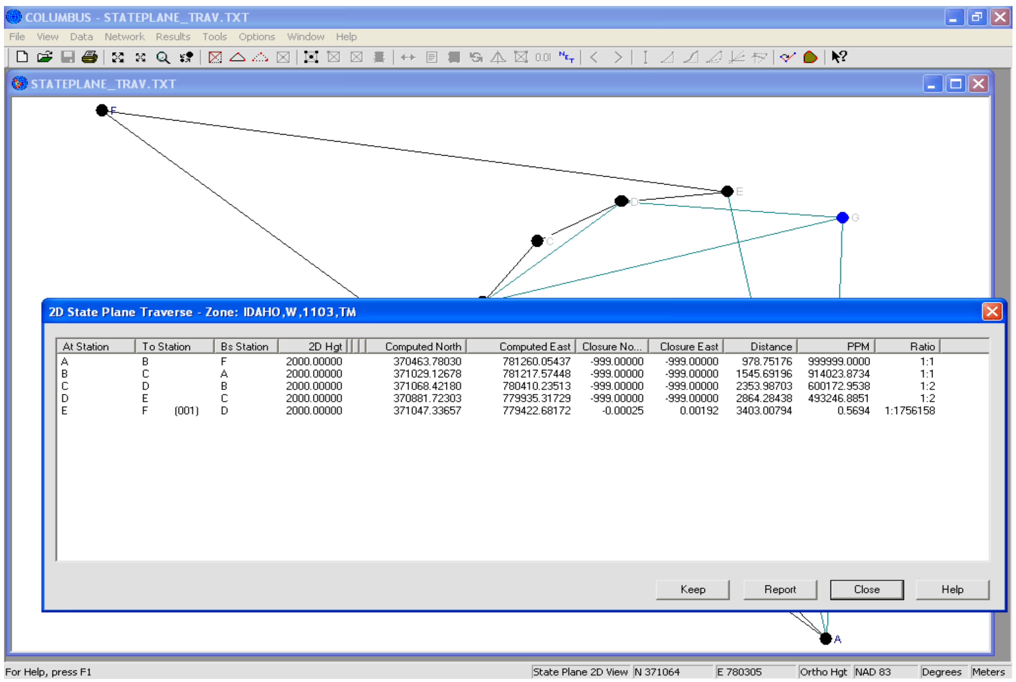
Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observations can be freely mixed with the other observations. When one is encountered, their effect is

based on the height of the ellipsoidal surface (zero).

Before computing a 2D State Plane Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 2D STATE PLANE TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project STATEPLANE_TRAV.TXT and chose a traverse originating at station A (with backsight to station F) and terminating at Station F. The ordering of the traverse is F, A, B, C, D, E, then back to F. We also set the average project elevation to 2000.0 meters.



To compute the traverse closure, COLUMBUS compares the known position, for each station, with the computed position for the station. Since Station A was the originating station and station F was the terminating station, their known values are compared to their computed values.

Grid North and East closures are shown in the active linear units. The PPM and ratio are computed from the 2D closure and the current grid length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(-0.00025)^2 + (0.00192)^2}}{Distance} \times 1,000,000.0$$

The ratio denominator is then:

$$\frac{1,000,000}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

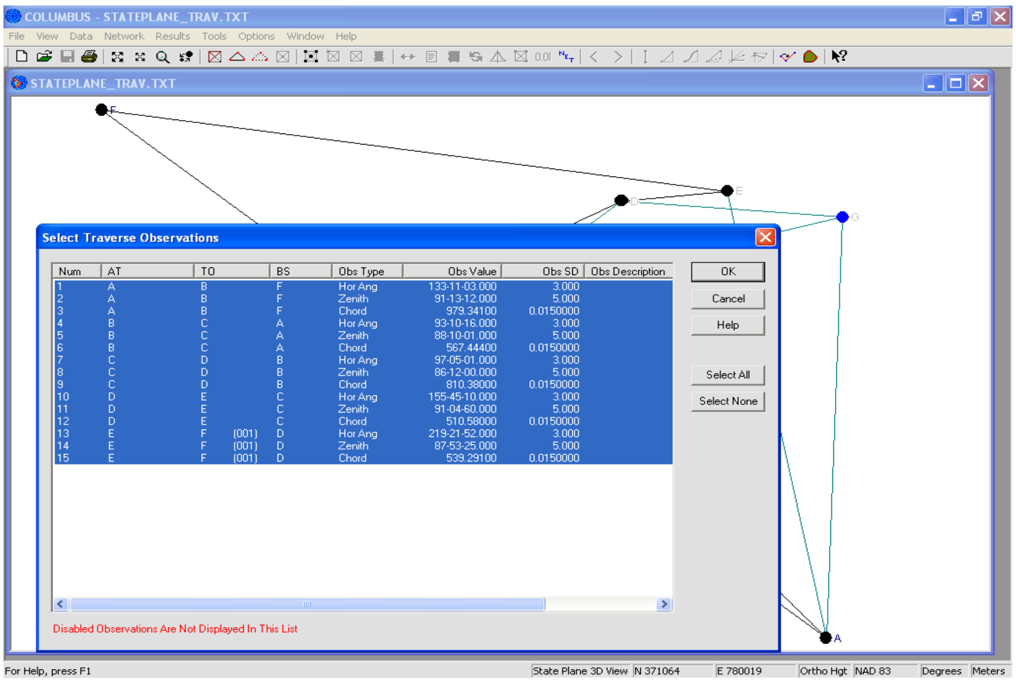
Invoke the **KEEP** button to Keep the computed North, East and 2D project elevation coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE of FILE - SAVE AS command to save the results to a data file.

The 2D STATE PLANE TRAVERSE option provides an excellent tool for computing 2D State Plane traverses or loop closures. This option helps you isolate trouble spots within complex 2D State Plane networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed. Try experimenting with different project elevations if the terrain varies greatly. Adopt an average project elevation or use different average project elevations for different areas of the survey.

3D State Plane Traverse

The 3D STATE PLANE TRAVERSE module facilitates the computation of 3D State Plane traverses. This option is available when the State Plane (3D) view is active. For the State Plane (3D) view, the State Plane station data are used.

When observations are carefully measured, including instrument and target heights, excellent results can be achieved. Valid observations for a 3D State Plane traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, local delta east, local delta up, height difference, and GPS dX, dY, dZ observations.



Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

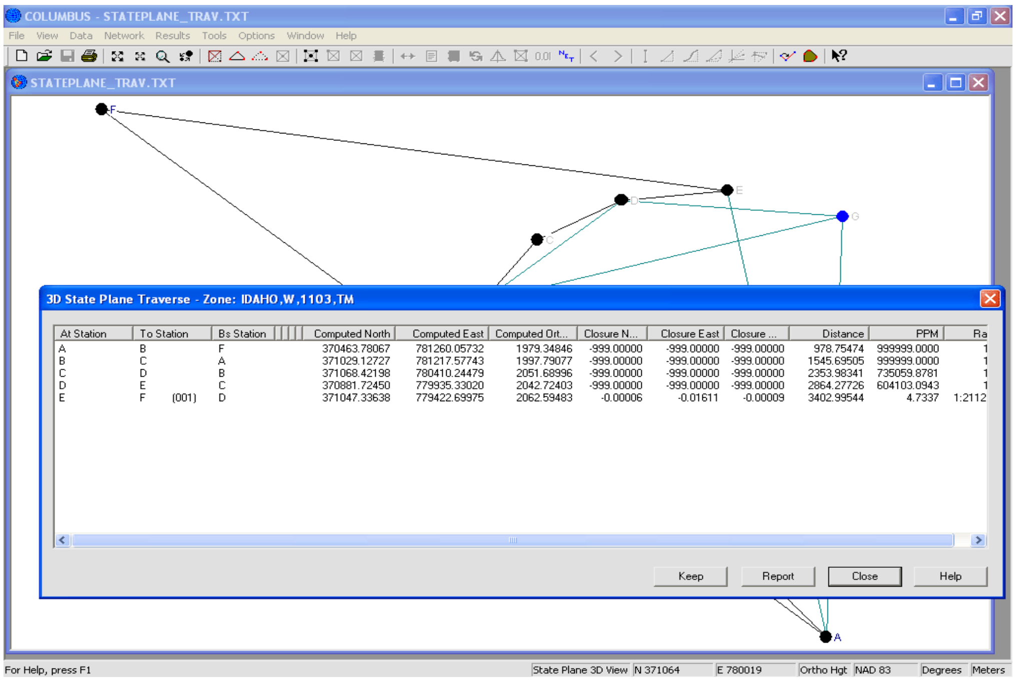
The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observation sets can be freely mixed with the other observations. When one is encountered, their effect is based on the height of the ellipsoidal surface (zero).

Since 3D State Plane traverses are based on elevation, observations measured in the field should not be corrected for deflection of the vertical. Deflection of the vertical corrections should only be used when performing traverses (or adjustments) based on ellipsoidal height.

Zenith angles will be corrected for refraction, if a correction has been set up in the OPTIONS - GLOBAL SETTINGS dialog.

Before computing a 3D State Plane Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 3D STATE PLANE TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project STATEPLANE_TRAV.TXT and chose a traverse originating at station A (with backsight to station F) and terminating at Station F. The ordering of the traverse is F, A, B, C, D, E, then back to F.



To compute the traverse closure, COLUMBUS compares the known position, for each station, with the computed position for the station. Since Station A was the originating station and station F was the terminating station, their known values are compared to their computed values.

Grid North, East and Elevation closures are in the active linear units (meters in this example). The PPM and ratio are computed from the 3D closure and the grid length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(-0.00006)^2 + (-0.01611)^2 + (-0.00009)^2}}{Distance} \times 1,000,000.0$$

The ratio is then:

$$\frac{1,000,000.0}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

Invoke the **KEEP** button to Keep the computed North, East and Elevation coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE or FILE - SAVE AS command to save the results to a data file.

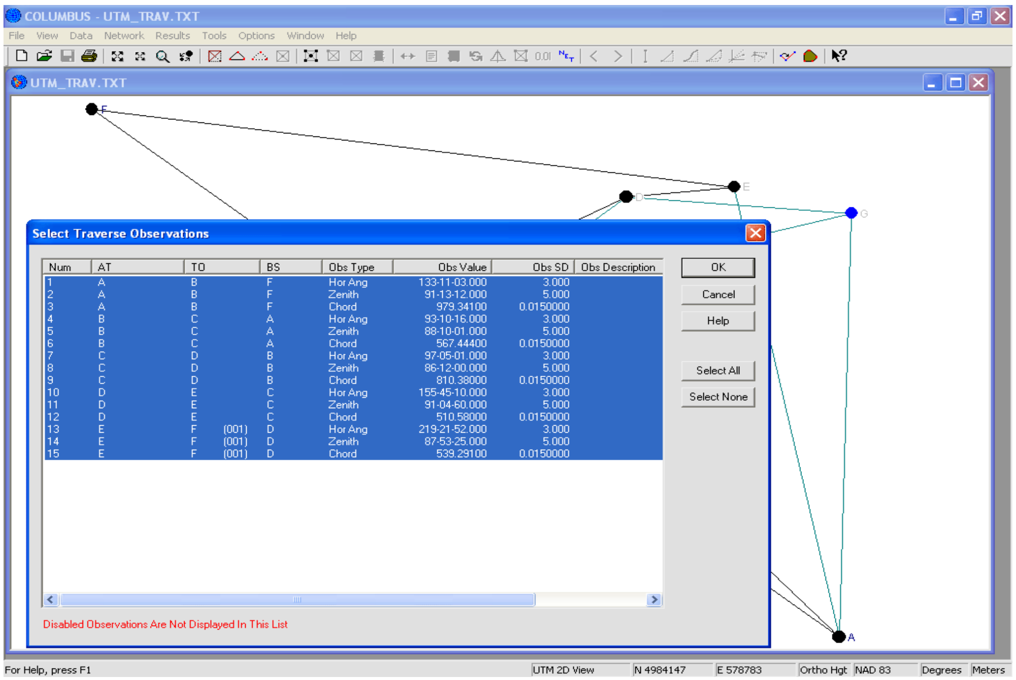
The 3D STATE PLANE TRAVERSE option provides an excellent tool for computing 3D State Plane traverses or loop closures. This option helps you isolate trouble spots within complex 3D State Plane networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed.

If you need to use ellipsoidal height as the vertical, change each known station elevation field (A and F in this example) to the corresponding ellipsoidal height. For GPS observations, using ellipsoidal height is more appropriate. If the geoidal separation is uniform in the project area, both vertical types (orthometric or ellipsoidal) will deliver excellent results for all observation types.

2D UTM Traverse

The 2D UTM TRAVERSE option facilitates the computation of 2D UTM traverses at a fixed project elevation. This option is available when the UTM (2D) view is active. For the UTM (2D) view, the UTM station data are used.

Valid observations for a 2D UTM traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, and local delta east observations.



The project elevation is established by entering the OPTIONS - GLOBAL SETTINGS dialog and entering the 2D Height in the active linear units.

The Zenith angle is only used to correct a paired chord distance to a horizontal distance. The zenith angle and chord distance must belong to the same observation set in order to pair them correctly. If the zenith angle is not present, COLUMBUS assumes the chord distance has already been corrected to a horizontal distance and hence no further correction is applied.

No corrections due to deflection of the vertical, refraction, or mark-to-mark reductions are made, since their impact would be minimal on a 2D UTM traverse of this type.

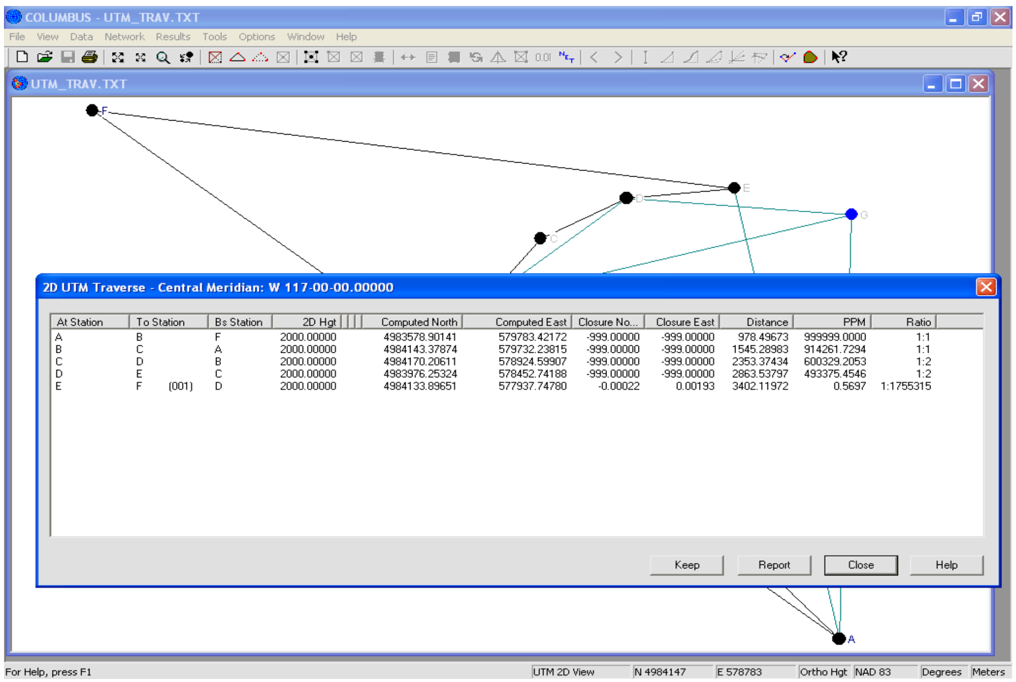
Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observations can be freely mixed with the other observations. When one is encountered, their effect is

based on the height of the ellipsoidal surface (zero).

Before computing a 2D UTM Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 2D UTM TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project UTM_TRAV.TXT and chose a traverse originating at station A (with backsight to station F) and terminating at Station F. The ordering of the traverse is F, A, B, C, D, E, then back to F. We also set the average project elevation to 2000.0 meters.



To compute the traverse closure, COLUMBUS compares the known position, if any (within the project), for each station with the computed position for the station. Since Station A was the originating station and station F was the terminating station, their known values (originating values) are compared to their computed values.

Grid North and East closures are shown in the active linear units. The PPM and ratio are computed from the 2D closure and the current grid length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(-0.00022)^2 + (0.00193)^2}}{Distance} \times 1,000,000.0$$

The ratio denominator is then:

$$\frac{1,000,000}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

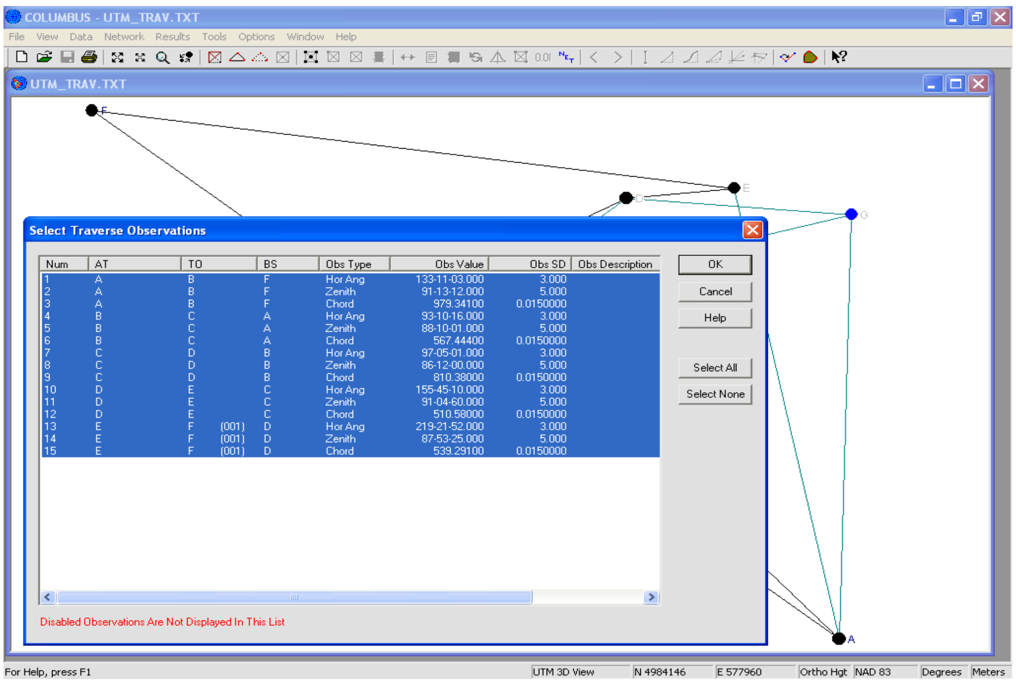
Invoke the **KEEP** button to Keep the computed North, East and 2D project elevation coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE or FILE - SAVE AS command to save the results to a data file.

The 2D UTM TRAVERSE option provides an excellent tool for computing 2D UTM traverses or loop closures. This option helps you isolate trouble spots within complex 2D UTM networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed. Try experimenting with different project elevations if the terrain varies greatly. Adopt an average project elevation or use different average elevations for different areas of the survey.

3D UTM Traverse

The 3D UTM TRAVERSE module facilitates the computation of 3D UTM traverses. This option is available when the UTM (3D) view is active. For the UTM (3D) view, the UTM station data are used.

When observations are carefully measured, including instrument and target heights, excellent results can be achieved. Valid observations for a 3D UTM traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, local delta east, local delta up, height difference, and GPS dX, dY, dZ observations.



Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

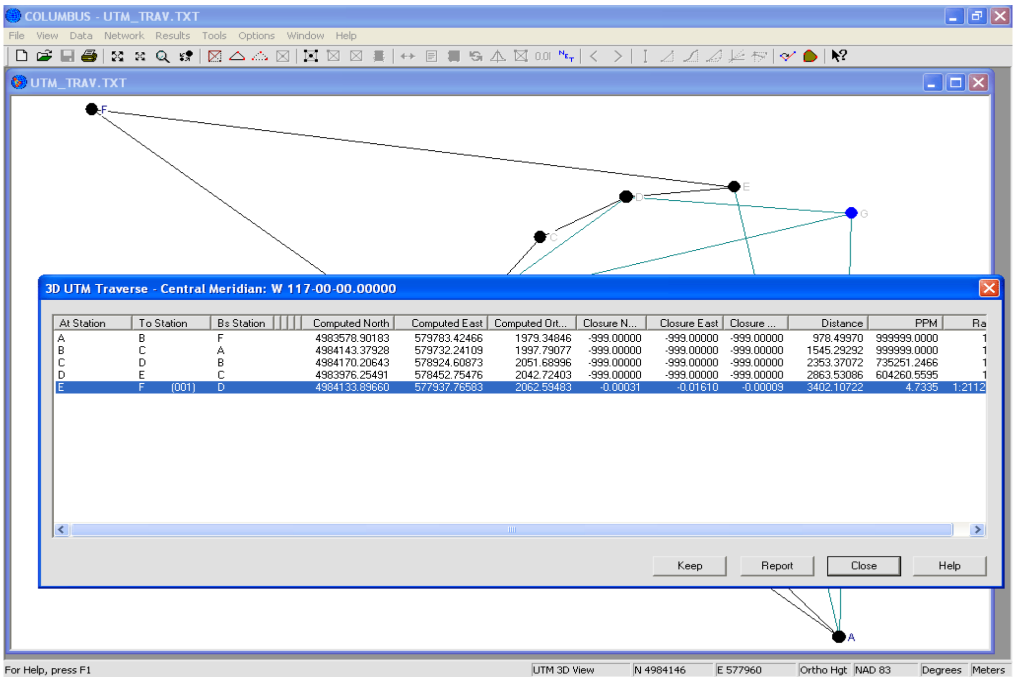
The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observation sets can be freely mixed with the other observations. When one is encountered, their effect is based on the height of the ellipsoidal surface (zero).

Since 3D UTM traverses are based on elevation, observations measured in the field should not be corrected for deflection of the vertical. Deflection of the vertical corrections should only be used when performing traverses (or adjustments) based on ellipsoidal height.

Zenith angles will also be corrected for refraction, if a correction has been set up in the OPTIONS - GLOBAL SETTINGS dialog.

Before computing a 3D UTM Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 3D UTM TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project UTM_TRAV.TXT and chose a traverse originating at station A (with backsight to station F) and terminating at Station F. The ordering of the traverse is F, A, B, C, D, E, then back to F.



To compute the traverse closure, COLUMBUS compares the known position, for each station, with the computed position for the station. Since Station A was the originating station and station F was the terminating station, their known values are compared to their computed values.

Grid North, East and Elevation closures are in the active linear units (meters in this example). The PPM and ratio are computed from the 3D closure and the grid length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(-0.00031)^2 + (-0.01610)^2 + (-0.00009)^2}}{Distance} \times 1,000,000.0$$

The ratio is then:

$$\frac{1,000,000.0}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

Invoke the **KEEP** button to Keep the computed North, East and Elevation coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE or FILE - SAVE AS command to save the results to a data file.

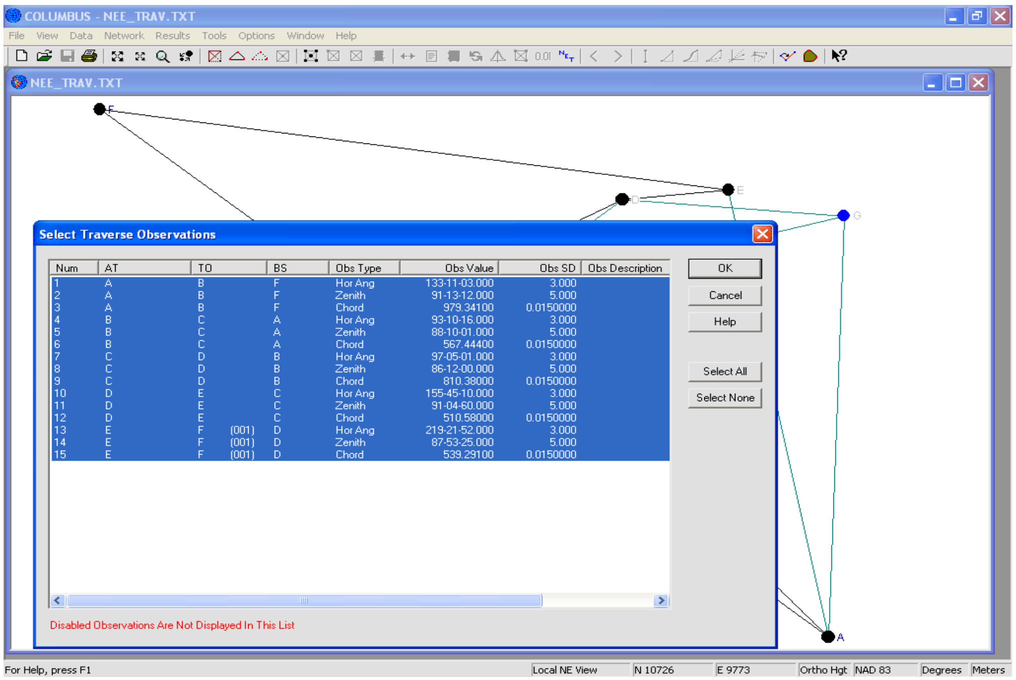
The 3D UTM TRAVERSE option provides an excellent tool for computing 3D UTM traverses or loop closures. This option helps you isolate trouble spots within complex 3D UTM networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed.

If you need to use ellipsoidal height as the vertical, change each known station elevation field (A and F in this example) to the corresponding ellipsoidal height. For GPS observations, using ellipsoidal height is more appropriate. If the geoidal separation is uniform in the project area, both vertical types (orthometric or ellipsoidal) will deliver excellent results for all observation types.

2D Local Horizon Plane Traverse

The 2D LOCAL HORIZON PLANE TRAVERSE option facilitates the computation of 2D Local Horizon Plane traverses at a fixed project elevation. This option is available when the Local NE (2D) view is active. For the Local NE (2D) view, the Local NEE station data are used.

Valid observations for a 2D Local Horizon Plane traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, and local delta east observations.



The project elevation is established by entering the OPTIONS - GLOBAL SETTINGS dialog and entering the 2D Height in the active linear units.

The Zenith angle is only used to correct a paired chord distance to a horizontal distance. The zenith angle and chord distance must belong to the same observation set in order to pair them correctly. If the zenith angle is not present, COLUMBUS assumes the chord distance has already been corrected to a horizontal distance and hence no further correction is applied.

No corrections due to deflection of the vertical, refraction, or mark-to-mark reductions are made, since their impact would be minimal on a 2D Local Horizon Plane traverse of this type.

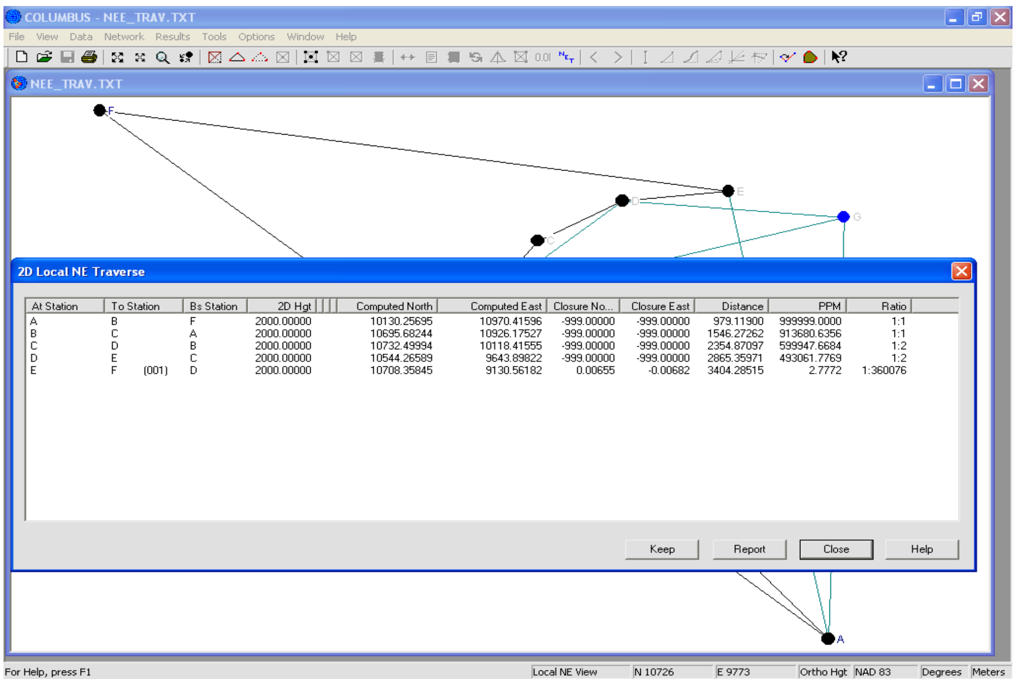
Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observations can be freely mixed with the other observations. When one is encountered, their effect is

based on the height of the ellipsoidal surface (zero).

Before computing a 2D Local Horizon Plane Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 2D LOCAL NE TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project NEE_TRAV.TXT and chose a traverse originating at station A (with backsight to station F) and terminating at Station F. The ordering of the traverse is F, A, B, C, D, E, then back to F. We also set the average project elevation to 2000.0 meters.



To compute the traverse closure, COLUMBUS compares the known position, for each station, with the computed position for the station. Since Station A was the originating station and station F was the terminating station, their known value are compared to their computed values.

Local North and East closures (based on the ground elevation) are shown in the active linear units. The PPM and ratio are computed from the 2D closure and the current ground length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(0.00655)^2 + (-0.00682)^2}}{Distance} \times 1,000,000.0$$

The ratio denominator is then:

$$\frac{1,000,000}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

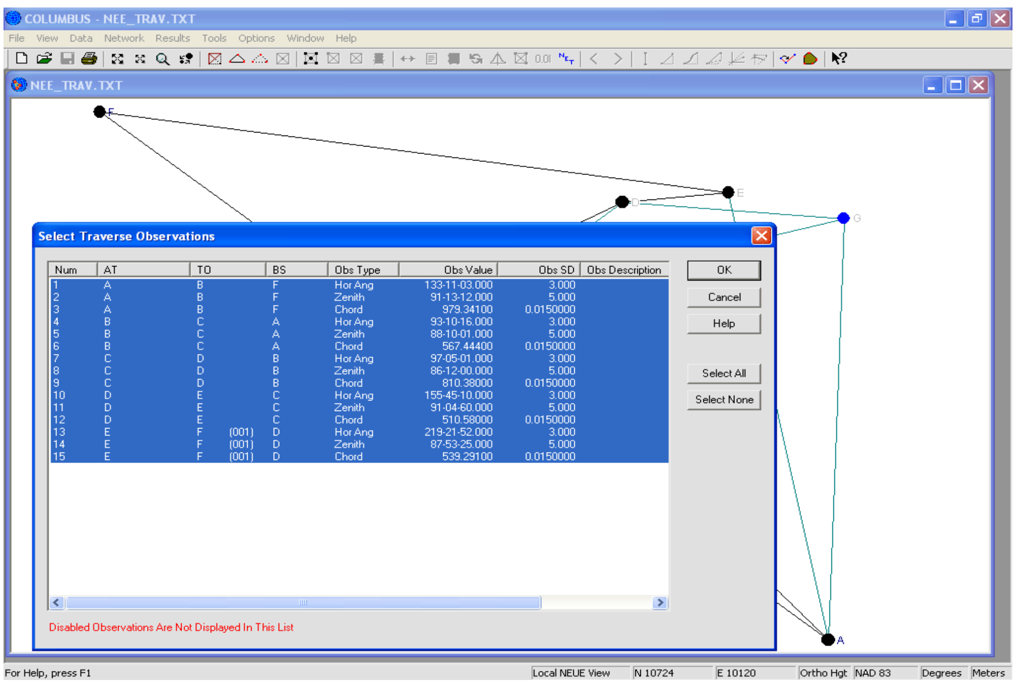
Invoke the **KEEP** button to Keep the computed North, East and 2D project elevation coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE of FILE - SAVE AS command to save the results to a data file.

The 2D LOCAL HORIZON PLANE TRAVERSE option provides an excellent tool for computing 2D Local NE traverses or loop closures. This option helps you isolate trouble spots within complex 2D Local NE networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed. Try experimenting with different project elevations if the terrain varies greatly. Adopt an average project elevation or use different average project elevation for different areas of the survey.

3D Local Horizon Plane Traverse

The 3D LOCAL HORIZON PLANE TRAVERSE module facilitates the computation of 3D Local Horizon Plane traverses. This option is available when the Local NEE (3D) view is active. For the Local NEE (3D) view, the Local NEE station data are used.

When observations are carefully measured, including instrument and target heights, excellent results can be achieved. Valid observations for a 3D Local NEE traverse include: azimuth, zenith angle, direction, bearing, horizontal angle, chord distance, horizontal distance, geodesic distance, geo chord, local delta north, local delta east, local delta up, height difference, and GPS dX, dY, dZ observations.



Bearing observations can be treated as azimuths, or they can be treated as mean bearings between each station pair (as is commonly found on P.L.S.S. plats). If you are using a mean bearing observation type, you should enable the Rotate Bearings option within the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. COLUMBUS will rotate all (mean) bearings by 1/2 the convergency, determined at both the AT and TO station, to correct each to a forward azimuth prior to forward computation.

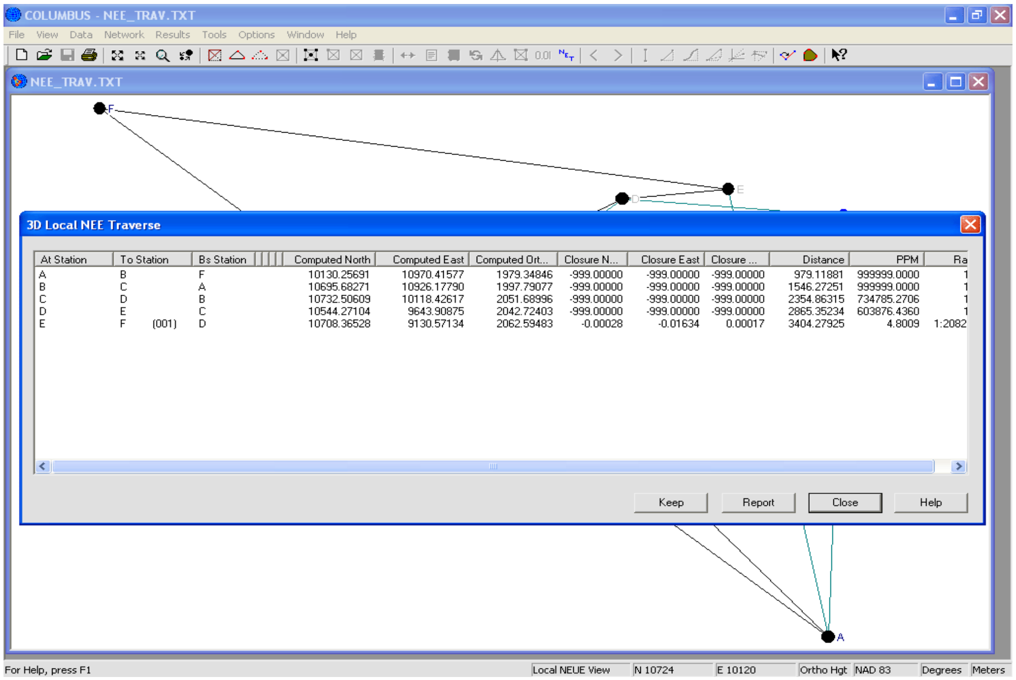
The geodesic distance and geo chord observations are based on the ellipsoidal surface. These observation sets can be freely mixed with the other observations. When one is encountered, their effect is based on the height of the ellipsoidal surface (zero).

Since Local Horizon Plane traverses are based on elevation, observations measured in the field should not be corrected for deflection of the vertical. Deflection of the vertical corrections should only be used when performing traverses (or adjustments) based on ellipsoidal height.

Zenith angles will also be corrected for refraction, if a correction has been set up in the OPTIONS - GLOBAL SETTINGS dialog.

Before computing a 3D Local NEE Traverse, you must first define the traverse route. After you have selected your route, invoke the TOOLS - COGO - 3D LOCAL NEE TRAVERSE command (or the 1D, 2D, 3D traverse toolbar button).

In this example, we loaded the project NEE_TRAV.TXT and chose a traverse originating at station A (with backsight to station F) and terminating at Station F. The ordering of the traverse is F, A, B, C, D, E, then back to F.



To compute the traverse closure, COLUMBUS compares the known position, if any (within the project), for each station with the computed position for the station. Since Station A was the originating station and station F was the terminating station, their known values (originating values) are compared to their computed value.

North, East and Elevation closures (based on the ground elevation) are in the active linear units (meters in this example). The PPM and ratio are computed from the 3D closure and the ground length of the traverse. For the example shown above, the PPM is:

$$\frac{\sqrt{(-0.00028)^2 + (-0.01634)^2 + (0.00017)^2}}{Distance} \times 1,000,000.0$$

The ratio denominator is then:

$$\frac{1,000,000.0}{PPM}$$

The Closure is computed for each station by taking the difference between the known coordinates and the computed coordinates:

$$Closure = known\ coordinates - computed\ coordinates$$

KEEP

Invoke the **KEEP** button to Keep the computed North, East and Elevation coordinate components into the current project, thus overriding the current values. Select the stations to Keep and click on the **OK** button. Once Kept to the project, you can invoke the FILE - SAVE or FILE - SAVE AS command to save the results to a data file.

The 3D LOCAL NEE TRAVERSE option provides an excellent tool for computing 3D Local NEE traverses or loop closures. This option helps you isolate trouble spots within complex 3D Local NEE networks. By computing multiple loop closures, poor observations can be identified and then remeasured or removed.

If you need to use ellipsoidal height as the vertical, change each known station elevation field (A and F in this example) to the corresponding ellipsoidal height. For GPS observations, using ellipsoidal height is more appropriate. If the geoidal separation is uniform in the project area, both vertical types (orthometric or ellipsoidal) will deliver excellent results for all observation types.

Transformation

The TOOLS - TRANSFORMATION options provides tools for transforming geodetic coordinates to and from other coordinate systems. This module compliments the NETWORK ADJUSTMENT module or can be used as a stand-alone tool. Survey projects can be adjusted using the accurate geodetic model, then transformed to simpler coordinate systems for other purposes (mapping, local survey, GIS, etc.).

Transformations from one non-geodetic system (State Plane, UTM, Local NEU) to another non-geodetic system can be accomplished by transforming the positions to geodetic coordinates, then transforming them to any other supported coordinate system.

For example, to transform UTM coordinates to State Plane coordinates, first transform the UTM coordinates to geodetic coordinates. Then, the geodetic coordinates can be transformed to State Plane coordinates. In a similar manner, coordinates can be transformed from one State Plane coordinate system to another State Plane coordinate system, or from one Local Horizon NEU system to another Local Horizon NEU system.

When transforming coordinates from one mathematical system to another (except Geodetic to Geodetic), both coordinate systems must be based on the same datum. If geodetic coordinates are based on the NAD 83 datum, transforming them to State Plane will produce NAD 83 State Plane coordinates.

To transform SPCS 83 coordinates (State Plane Coordinate System of 1983) to SPCS 27 (State Plane Coordinate System of 1927), first transform the SPCS 83 coordinates to NAD 83 geodetic coordinates. Next, the NAD 83 geodetic coordinates are then transformed to NAD 27 geodetic coordinates using one of the GEODETIC <--> GEODETIC transformation methods. Finally, the NAD 27 geodetic coordinates can be transformed to SPCS 27 coordinates.

For each of the options described in this chapter, we use the results contained within the BIGBASIN.TXT data file shipped with COLUMBUS (described in the GETTING STARTED chapter of this manual). We have included the adjusted positions and all transformed coordinates in this file so you may use the data in any module, without requiring you to first adjust the network. The adjusted coordinates are based on the WGS 84 datum.

In this section, we will transform the WGS 84 adjusted geodetic coordinates to: WGS 84 Cartesian coordinates, WGS 84 and NAD 27 State Plane coordinates, WGS 84 UTM coordinates, and Local Horizon NEU coordinates. Each of these transformations are accomplished in one step, except the WGS 84 geodetic to NAD 27 State Plane transformation, which requires two steps. In order to transform WGS 84 geodetic coordinates to NAD 27 State Plane coordinates, the WGS 84 geodetic coordinates must first be transformed to NAD 27 geodetic coordinates. The NAD 27 geodetic coordinates can then be directly transformed to NAD 27 State Plane coordinates.

For our BIGBASIN.TXT example, we could compute the adjustment on the NAD 27 datum to generate NAD 27 geodetic coordinates directly. While there can be problems with this approach (since our GPS baselines are based on the WGS 84 datum), many people use this approach on a regular basis. However, for the BIGBASIN.TXT network, the deflections of the vertical (which are used to correct Astronomic terrestrial observations to Geodetic observations) are based on the WGS 84 datum and not the NAD 27 datum. Therefore, if you prefer to do the adjustment based on the NAD 27 datum, you should first zero out the deflection of the vertical fields for all geodetic stations.

Geodetic <--> Geodetic Transformation

The **GEODETIC <--> GEODETIC** options provide tools to transform geodetic coordinates based on one datum (NAD 83, WGS 84, etc.) to geodetic coordinates based on a second datum (NAD 27, Bessel, etc.). Because there is no perfect relationship between any two ellipsoidal models (due to localized errors in the known control for both systems), accurate transformation between two datums is non-trivial. Therefore, there a variety of transformation models that utilize a different number of parameters to describe the relationship between any two datums.

Background

The primary goal of the geodesist is to mathematically describe the shape of the Earth. Although no perfect model exists (because the Earth is irregularly shaped), geodesists recognize various ellipsoids (ellipses rotated about their minor axes) to be the best mathematical figures for describing the Earth's shape.

These ellipsoidal models vary in size and origin, to conform to different regions of the world. In fact, many countries have developed their own ellipsoidal models to better fit their locality. These are local datums, meaning they were developed to fit a portion of the Earth's surface well, but not the entire surface. In the United States, NAD 83 (North American Datum of 1983) was designed to replace the NAD 27 datum. Other ellipsoidal models were designed for global use. They attempt to fit the entire Earth relatively well, but are not designed for any specific area. WGS 84 is an example of a global datum.

Because, so many different datums exist, it is sometimes necessary to transform coordinates from a global datum to a local datum or to transform geodetic coordinates between two local datums. Because geodetic control stations have their own inherent error (relative to each other), there are no perfect mathematical models for transforming between two geodetic datums. In our example, we need to express the WGS 84 geodetic coordinates in NAD 27 State Plane form. To do this, we need to first transform the WGS 84 geodetic coordinates to NAD 27 geodetic coordinates, then transform these coordinates to NAD 27 State Plane coordinates.

Transformation Models

There are three transformation models (three, four, and seven parameter) and two primary methods (Bursa-Wolf and Molodensky-Badekas) available in COLUMBUS. The difference between the models is in the numbers of parameters used to describe the relationship between the datums for a given area. The three transformation models are presented as follows:

MODEL	PARAMETERS USED
Three Parameter Model	delta X, delta Y, delta Z
Four Parameter Model	delta X, delta Y, delta Z, scale factor
Seven Parameter Model	delta X, delta Y, delta Z, scale factor, rotation X, rotation Y, rotation Z

With the **Three Parameter Model,** COLUMBUS uses Earth Centered Earth Fixed delta X, Y and Z translation differences between each datum to relate the origins of the two ellipsoidal systems. Geodetic coordinates (latitude, longitude and height) for the BEG DATUM are transformed to Earth Centered Earth Fixed X, Y and Z coordinates. The translation parameters (dX, dY and dZ) are added to these coordinates to attain X, Y and Z coordinates based on the END DATUM. These Cartesian coordinates are then converted back to geodetic coordinates on the END DATUM. Although the three parameter model is the easiest to understand and compute, this technique can be very accurate in areas where the delta X, Y and Z translations between the two datums are constant.

The **Four Parameter Model** and **Seven Parameter Model** are improved variations of the three parameter model. In the four parameter model, a scale parameter is introduced to account for any difference in scale between the two systems. The seven parameter method includes three rotation parameters. The three rotation parameters (one around each of the coordinate axis), relate the orientation of the two systems.

Transformation Methods

COLUMBUS implements two methods for transformations: the Bursa-Wolf Method and the Molodensky-Badekas Method. Each utilizes different transformation strategies. Each of the models can use any of the three transformation models (three, four, or seven parameter) previously discussed.

Bursa-Wolf Method

The Bursa-Wolf Method is well suited for the transformation between two global datums. It is not very well suited for transformations between global and local datums due to high correlations between the parameters. In other words, over a limited area, it is hard to distinguish between offsets due to translation (delta X, Y and Z) and those due to rotation (about X, Y and Z). COLUMBUS does not compute the Bursa-Wolf parameters. These parameters are based on the origins of both coordinate systems and are published for various localities throughout the world. If you have no published parameters, you must use the Molodensky-Badekas Method.

Molodensky-Badekas Method

The Molodensky-Badekas Method allows you to compute parameters from known control stations near the project area. The Molodensky-Badekas (four and seven parameter) model overcomes the correlation problem by relating the scale and rotation parameters to some fundamental point, M, and working with differences from this point. Point M is computed as the average local position of the common control points in the project area (average latitude, longitude and height for all control stations). The parameters for the Molodensky-Badekas model are solved using least squares fitting techniques.

This method uses stations with coordinates in both datums (control stations) along with their estimated standard deviations to derive the least squares estimate of the parameters. The Molodensky-Badekas three parameter model computes parameters in a similar way, but they are based on Point M, being the origin of the BEG DATUM X, Y and Z axis. Once the parameters have been determined using the Molodensky-Badekas Method, you can easily transform dozens of positions (within the area) from the BEG DATUM to the END DATUM.

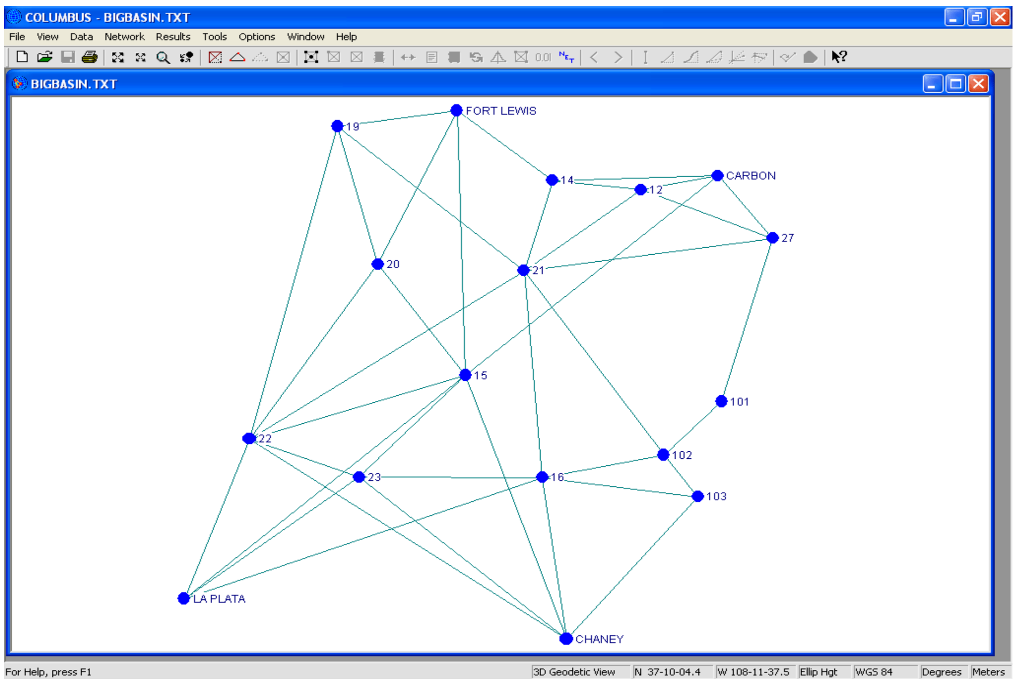
The Molodensky-Badekas Method works very well in the area bounded by your control stations. The higher the quality of your control stations (i.e., first-order, second-order, etc.), the greater likelihood your computed parameters will accurately model the area. If you use the three parameter method, you make the assumption that within this area, there is little or no rotation or scale changes between the two mathematical systems.

In two error-free systems (two datums), it would be possible to derive an error-free seven parameter transformation model, since the seven parameters account for all possible systematic differences in the definition of two datums (translations, rotations and scale). However, no two mathematical systems have control stations which are error free. Therefore, when using the Molodensky-Badekas Method, you should experiment with all three methods to see which delivers the best results for your project area.

Summary

There are three transformation models available (three, four, and seven parameter). Each can be used with one of two methods (Bursa-Wolfe or Molodensy-Badekas). If the transformation parameters are known and based on the origins of each datum, then the Bursa-Wolfe method should be used. If these parameters are not known, then you must use the Molodensky-Badekas method to compute the parameters.

It is worth pointing out that you always have the option of exporting your coordinates from COLUMBUS and using a third party coordinate transformation tool to move your coordinates from one mathematical system to another. You can also make use of the TOOLS - CREATE NGS NADCON FILE tool (discussed later) when working in North America.



Transformation Parameters Known

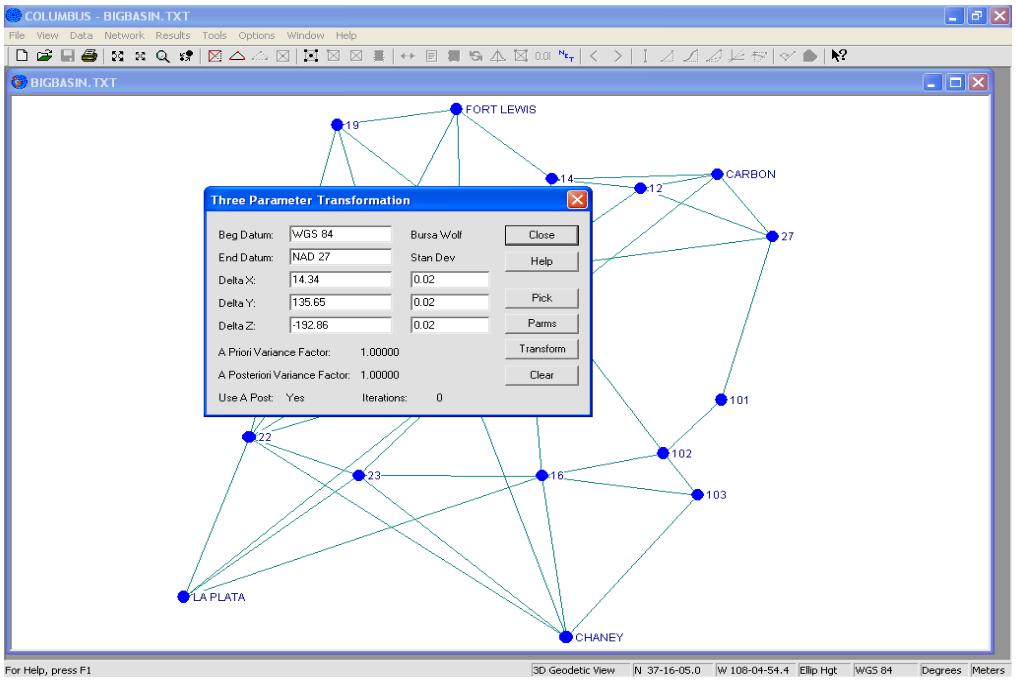
The Bursa-Wolf Method requires known transformation parameters. COLUMBUS allows you to enter these values.

Transformation Parameters Unknown

The Molodensky-Badekas Method allows you to compute transformation parameters. This method utilizes a least squares approach to compute transformation parameters based upon the relationship between common control stations expressed in both datums.

Case 1: Transformation Parameters Known (Bursa-Wolf Method)

This method is generally used to perform transformations between two global datums (i.e., WGS 84 to WGS 72). These parameters must be based on the origins of both coordinate systems. For all practical purposes, the Bursa-Wolf three parameter and Molodensky-Badekas three parameter methods use similar translation parameters (i.e., dX, dY, and dZ). **This is not the case for the four and seven parameter transformation methods.**



We have developed hypothetical parameters (dX, dY dZ) for our BIGBASIN.TXT network to demonstrate the three parameter Bursa-Wolf Method. In many cases, you will not know the parameters and you will need to use the Molodensky-Badekas Method. Always keep in mind, the quality of your transformed coordinates are only as good as your originating coordinates and the transformation parameters.

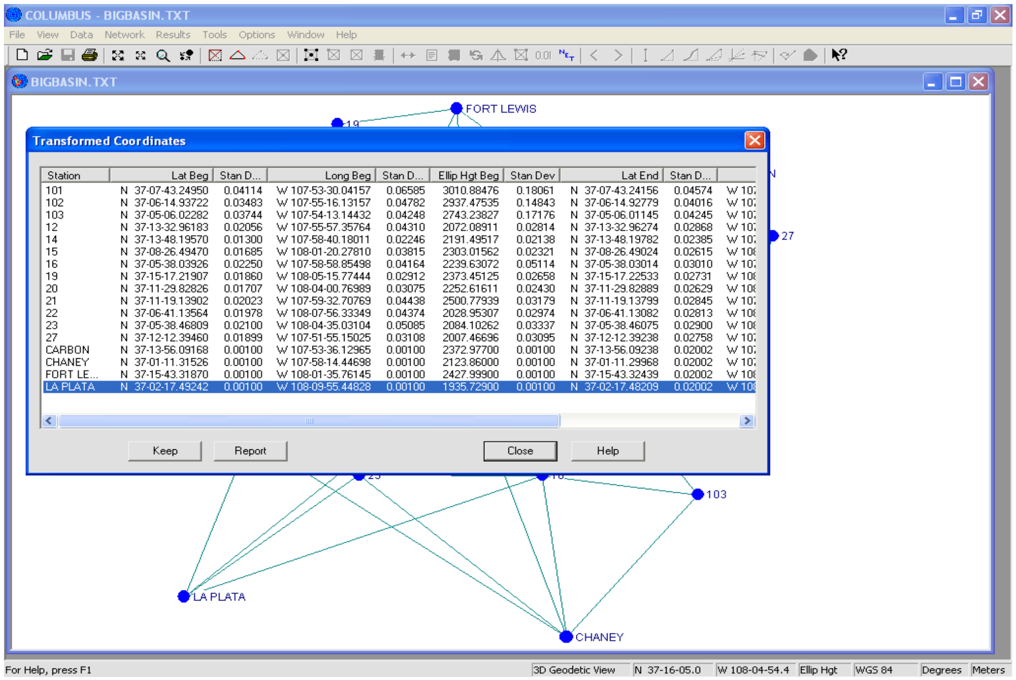
1. First, load the BIGBASIN.TXT file into COLUMBUS within the FILE - OPEN command. This file contains adjusted coordinates based on the WGS 84 datum.

2. Enter the TOOLS - TRANSFORMATION - GEO <--> GEO - THREE PARM dialog. Enter the BEG datum name (WGS 84) or select this datum using the **PICK** button. Enter the END datum name (NAD 27) in a similar manner.

3. Enter the parameters shown in the screen above (i.e., dx = 14.34, dxSD = 0.02, dy = -135.65, dySD = 0.02, dz = -192.86, dzSD = 0.02 all in meters). For this example, we developed these parameters to demonstrate the Bursa-Wolf Method. They should **not** be used for any real project. They are provided for demonstration only. The standard deviation for each parameter are also artificial. They are used to propagate the standard deviations for each station on the BEG datum (WGS 84) to standard deviations for the computed stations on the END datum (NAD 27).

4. Transform the WGS 84 positions to NAD 27 positions by clicking on the **TRANSFORM** button. COLUMBUS will display a candidate list of all geodetic stations associated with the BEG datum. Click on the **SELECT ALL** button to highlight every station in the list, then click on the **OK** button.

COLUMBUS will then compute the transformed NAD 27 coordinate for each station.



Station	Lat Beg	Stan D...	Long Beg	Stan D...	Ellip Hgt Beg	Stan Dev	Lat End	Stan D...
101	N 37-07-43.24950	0.04114	W 107-53-30.04157	0.06585	3010.88476	0.18061	N 37-07-43.24156	0.04574
102	N 37-06-14.93722	0.03483	W 107-55-16.13157	0.04782	2937.47535	0.14843	N 37-06-14.92779	0.04016
103	N 37-05-06.02282	0.03744	W 107-54-13.14432	0.04248	2743.23827	0.17176	N 37-05-06.01145	0.04245
12	N 37-13-32.96183	0.02056	W 107-55-57.35764	0.04310	2072.08911	0.02814	N 37-13-32.96274	0.02868
14	N 37-13-48.19570	0.01300	W 107-58-40.18011	0.02246	2191.49517	0.02138	N 37-13-48.19782	0.02385
15	N 37-08-26.49470	0.01685	W 108-01-20.27810	0.03815	2303.01562	0.02321	N 37-08-26.49024	0.02615
16	N 37-05-38.03926	0.02250	W 107-58-58.85498	0.04164	2239.63072	0.05114	N 37-05-38.03014	0.03010
19	N 37-15-17.21907	0.01860	W 108-05-15.77444	0.02912	2373.45125	0.02658	N 37-15-17.22533	0.02731
20	N 37-11-29.82826	0.01707	W 108-04-00.76989	0.03075	2252.61611	0.02430	N 37-11-29.82889	0.02629
21	N 37-11-19.13902	0.02023	W 107-59-32.70769	0.04438	2500.77939	0.03179	N 37-11-19.13799	0.02845
22	N 37-06-41.13564	0.01978	W 108-07-56.33349	0.04374	2028.95307	0.02974	N 37-06-41.13082	0.02813
23	N 37-05-38.46809	0.02100	W 108-04-35.03104	0.05085	2084.10262	0.03337	N 37-05-38.46075	0.02900
27	N 37-12-12.39460	0.01899	W 107-51-55.15025	0.03108	2007.46696	0.03095	N 37-12-12.39238	0.02758
CARBON	N 37-13-56.09168	0.00100	W 107-53-36.12965	0.00100	2372.97700	0.00100	N 37-13-56.09238	0.02002
CHANEY	N 37-01-11.31526	0.00100	W 107-58-14.44698	0.00100	2123.86000	0.00100	N 37-01-11.29968	0.02002
FORT LE...	N 37-15-43.31870	0.00100	W 108-01-35.76145	0.00100	2427.99900	0.00100	N 37-15-43.32439	0.02002
LA PLATA	N 37-02-17.49242	0.00100	W 108-09-55.44828	0.00100	1935.72900	0.00100	N 37-02-17.48209	0.02002

5. To Keep the results into the project for use in other modules, click on the **KEEP** button. You will be prompted with a list of transformed stations to select. Click on the **SELECT ALL** button, followed by the **OK** button. To access the newly computed NAD 27 geodetic coordinates, you will eventually need to enter the OPTIONS - DATUMS dialog and make the NAD 27 datum active (currently, the WGS 84 datum is active).

6. To write the results to a report file, click on the **REPORT** button. COLUMBUS will prompt you for the name of a report file. You can create a new report file or append to an existing file.

If you use the three parameter transformation model, you are making the assumption that the affects due to scale and rotation in the area are negligible. Put another way, you are implying the translation (delta X, Y and Z) parameters completely model the relationship between the two systems in the project area. In most cases, you will be forced to use the method for which you have known parameters.

Case 2: Transformation Parameters Computed (Molodensky-Badekas Method)

If you need to transform geodetic coordinates between two datums, but the parameters are not known, they can be computed using a least squares approach. To do this, you must have one or more known control stations. Control stations are those for which you have known latitude, longitude and height defined in both datums. From the known control stations, a mathematical relationship (transformation parameters) can be computed that map the coordinates from the beginning datum to the end datum.

If you only have one control station, the parameters are computed by examining the set of coordinates at that station (WGS 84 set and the NAD 27 set for our example). If this is the case, only the three parameter model can be used. If several control stations exist, a least squares fitting technique can be applied which results in a solution (for the parameters) that best fits all the control stations. This least squares fitting technique is weighted by the estimated accuracy of each control station coordinate pair. The estimated accuracy is the standard deviation in latitude, longitude and height for each station coordinate pair for each datum.

There are a minimum number of station pairs required to compute parameters using the Molodensky-Badekas Method.

Three Parameter Model	requires ONE or more 3D control station pairs
Four Parameter Model	requires TWO or more 3D control station pairs
Seven Parameter Model	requires THREE or more 3D control station pairs

Each control station must have a known latitude, longitude and height component. A common mistake is to use orthometric height instead of ellipsoidal height at each station. In some cases this may be desirable, but it can lead to unpredictable results (unless the geoid undulation is uniform in the project area). Remember, orthometric height is the vertical distance above the geoid. It is the same for any datum, since orthometric height is based on the geoid, not the reference ellipsoid. The ellipsoidal height is the vertical distance above the reference ellipsoidal surface. **Caution:** Do not mix the two height types.

To use orthometric height and not ellipsoidal height when computing transformation parameters, change the 3D Geodetic Height option in the OPTIONS - GLOBAL SETTINGS dialog to Orthometric Height. If you know the orthometric height and ellipsoidal height at each control station, you might try using both separately to see which gives better results. **In most cases, ellipsoidal height should be used.**

It is important that your control stations are of the highest quality possible. Your resulting transformation parameters will only be as good as the control stations you select. With excellent control, you can often attain transformation results better than ± 10 cm.

For this example, we again refer to our example network BIGBASIN.TXT. This network was adjusted using the WGS 84 datum. Now we need to compute NAD 27 State Plane coordinates for each adjusted station.

To do this, we must first transform the WGS 84 geodetic coordinates to NAD 27 geodetic coordinates. Then, we can easily transform the NAD 27 geodetic positions to NAD 27 State Plane positions using the TOOLS - TRANSFORMATION - STATE PLANE <--> GEODETIC option.

In our network, we used four control stations (CARBON, CHANEY, FORT LEWIS and LA PLATA). These four stations were tied directly to our network. However, we also have known geodetic coordinates available for three additional stations in the area (LINE, GLO 15 RM1, and SECS 33 34 SC), bringing the total number of control stations to seven. For each control station, we have the known latitude and longitude expressed as WGS 84 and NAD 27 coordinates.

For the four stations used in the network, we also have their WGS 84 ellipsoidal height. Unfortunately (as is often the case), we do not know what their NAD 27 ellipsoidal heights are. Consequently, we are forced to compute the transformation using an ellipsoidal height of zero for all seven stations (both WGS 84 and NAD 27 coordinates). This will work because we only require NAD 27 latitudes and longitudes (not height) to compute NAD 27 State Plane coordinates.

In our example, we use all seven stations to compute the transformation parameters. Any time you have more control stations than the minimum required, you should experiment with different station combinations to see which deliver the best results. In the steps described below, we will use the seven parameter transformation method.

1. Load the BIGBASIN.TXT file into COLUMBUS within the FILE - OPEN dialog. The WGS 84 datum becomes the active datum since it is the only datum defined in the file.

2. Make the 3D Geodetic view active by selecting it from the VIEW menu.

3. Enter the remaining control station data. We could edit the BIGBASIN.TXT file, but let's leave this file untouched so we can use it in other examples in this manual. Enter the DATA - STATIONS - GEODETIC grid. Since the WGS 84 datum is active, we can access all WGS 84 data or add new WGS 84 data. For each control station currently in the current project (CARBON, CHANEY, FORT LEWIS and LA PLATA), change the orthometric height, geoid height and ellipsoidal height fields to zero. Next, enter the three additional WGS 84 control station coordinates (latitude north, longitude west, orthometric height, geoid height and ellipsoidal height of zero).

Station	Latitude	Stan Dev	Longitude	Stan Dev	Ellip Hgt	Stan Dev
CARBON	37-13-56.09168	0.001	107-53-36.12965	0.001	0.0	0.001
CHANEY	37-01-11.31526	0.001	107-58-14.44698	0.001	0.0	0.001
FORT LEWIS	37-15-43.3187	0.001	108-01-35.76145	0.001	0.0	0.001
LA PLATA	37-02-17.49242	0.001	108-09-55.44828	0.001	0.0	0.001
GLO 15 RM1	37-03-15.73126	0.002	108-09-00.36236	0.002	0.0	0.002
LINE	37-00-32.24879	0.003	107-53-13.40419	0.003	0.0	0.003
SECS 33 34 SC	37-03-14.30301	0.005	108-08-47.21627	0.005	0.0	0.005

Be sure to enter the standard deviation for each component. The standard deviation is used to weight the least squares computation of the parameters. Stations with smaller standard deviations for their components will have a greater weight (influence) in the adjustment (i.e., the computed parameters will tend to fit them better).

4. Enter the NAD 27 geodetic coordinate for each of the seven WGS 84 control stations. To do this, enter the OPTIONS - DATUMS dialog and change the active datum to NAD 27. Return to the DATA - STATIONS - GEODETIC grid and enter the following coordinate and standard deviation for each station (latitude north, longitude west, orthometric height, geoid height and ellipsoidal height to zero).

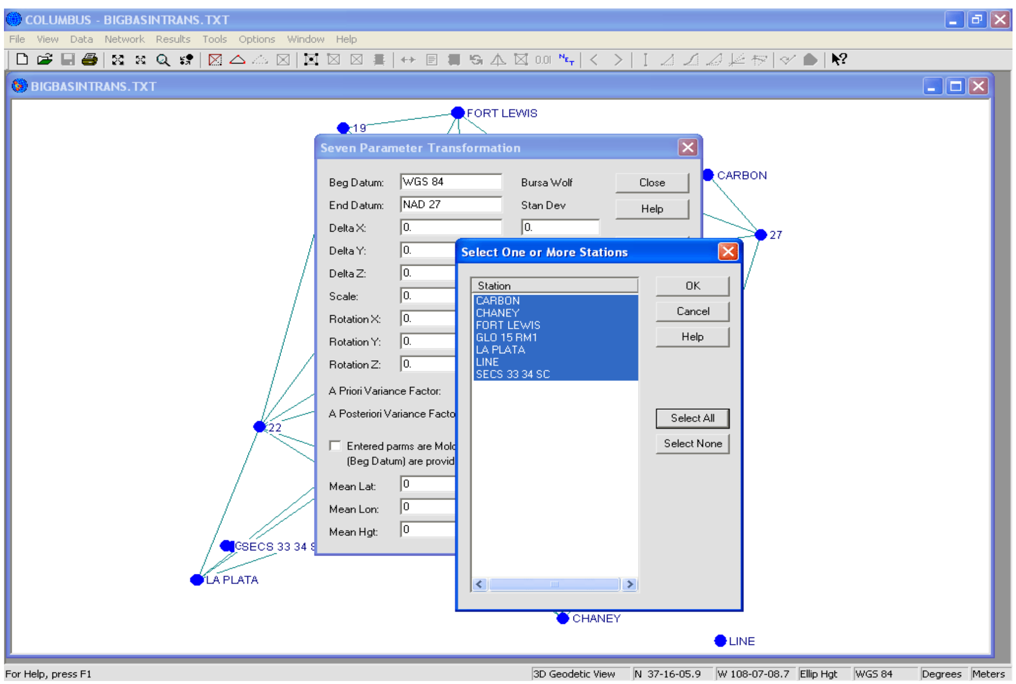
Station	Latitude	Stan Dev	Longitude	Stan Dev	Ellip Hgt	Stan Dev
CARBON	37-13-56.084	0.007	107-53-33.880	0.007	0.0	0.007
CHANEY	37-01-11.309	0.008	107-58-12.206	0.008	0.0	0.008
FORT LEWIS	37-15-43.314	0.010	108-01-33.505	0.010	0.0	0.010
LA PLATA	37-02-17.492	0.009	108-09-53.187	0.009	0.0	0.009
GLO 15 RM1	37-03-15.728	0.012	108-08-58.095	0.012	0.0	0.012
LINE	37-00-32.237	0.014	107-53-11.162	0.014	0.0	0.014

SECS 33 34 SC	37-03-14.300	0.020	108-08-44.950	0.020	0.0	0.020

At this point, you have entered quite a bit of new data. You should save this data to a COLUMBUS ASCII (Text) file so you can recover the complete data set from disk in the event of a system failure. Save the contents of the project to a file called BIGBASINTRANS.TXT using the FILE - SAVE AS command. Then, move to the FILE - STATION/OBSERVATION SUMMARY option to view the current contents of the project.

5. Enter the TOOLS - TRANSFORMATION - GEO <--> GEO - SEVEN PARM dialog. Enter the BEG datum name (WGS 84) or select this datum by clicking on the **PICK** button. Enter the END datum name (NAD 27) in a similar manner.

6. Click on the **PARMS** button to bring up a list of the matching geodetic control stations entered above. When you invoke the **PARMS** button, COLUMBUS examines all the station names associated with both datums. Matching station names are added to a common list. You should see seven stations (see screen below). If you do not see all the stations in the list, you may have misspelled one or more of the station names. The control station names for each datum must be spelled identically, since COLUMBUS is case-sensitive.



Select all the stations by clicking on the **SELECT ALL** button. Click on the **OK** button to compute the least squares best-fit parameters for the BIGBASIN.TXT project. COLUMBUS uses an iterative least squares process to determine the transformation parameters. At the conclusion of the computation, the transformation summary results are presented.

Delta X, Y and Z are based on the difference in the origins between the two datums. They are presented in the active linear units. The scale parameter is in PPM (parts per million). A more familiar interpretation can be examined by the following formula:

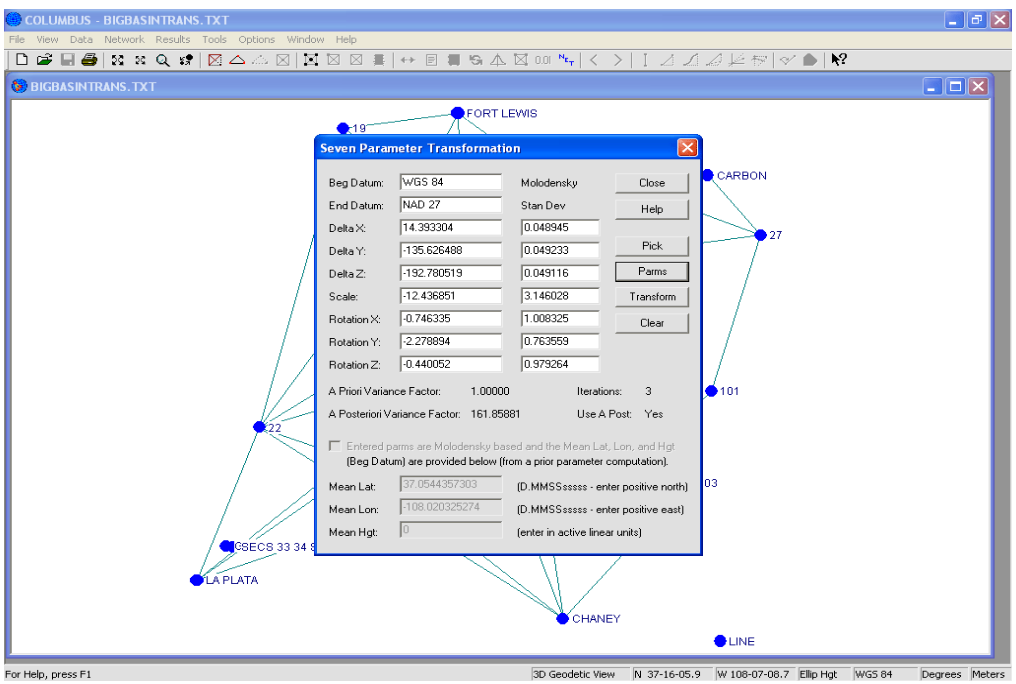
$$\frac{scale}{1,000,000.0} + 1.0$$

(in this case, (-12.436767 / 1,000,000) + 1.0 or roughly 0.99998756). Rotations in X, Y and Z are based on a mean point M (determined from the BEG Datum control stations). Rotations are in seconds of arc. The mean point M is shown at the bottom of the dialog. **The rotation is not based on the geocentric origin of the BEG datum as it is when using the Bursa-Wolf Method.**

7. Click on the **TRANSFORM** button to transform the WGS 84 stations to NAD 27 stations using the newly computed transformation parameters. COLUMBUS will display a candidate list of all geodetic stations associated with the BEG datum. Click on the **SELECT ALL** button, then click on the **OK** button to compute the transformed NAD 27 coordinate for each station. Since we were unable to model the height components for this computation (we used zeros for both datums), the computed NAD 27 height results are meaningless. However, the latitude and longitude are modeled well.

8. To Keep the results into the project for use in other modules, click on the **KEEP** button. In order to access these NAD 27 coordinates in other modules, you must return to the OPTIONS - DATUMS dialog and change the active datum to NAD 27.

9. To write the results to a report file, click on the **REPORT** button. COLUMBUS will prompt you for the name of a report file. You can create a new report file or append the results to an existing file.

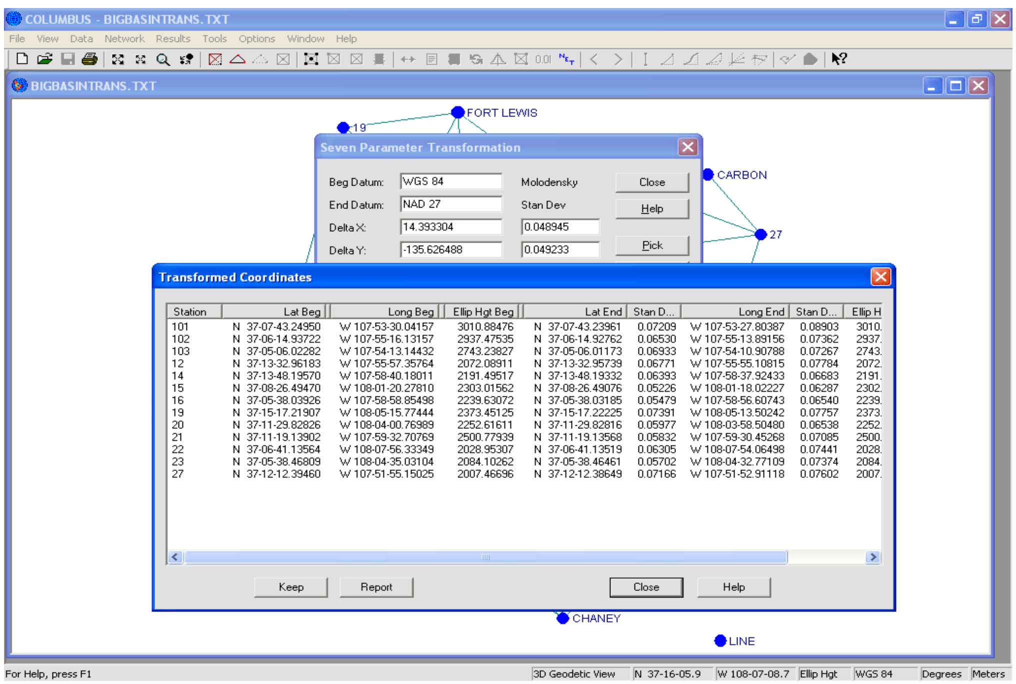


Now, you can transform the new NAD 27 geodetic coordinates to NAD 27 State Plane coordinates using the STATE PLANE <--> GEODETIC option described later in this chapter.

When you have a surplus of control stations, you should experiment with the many combinations available for computing the parameters. You might try using a subset of the control stations. Also try using all three models (three, four and seven parameter). By transforming the control stations, you can compare the known NAD 27 control coordinates with their transformed (from WGS 84) positions. Look for a combination that yields the most favorable results.

The Bursa-Wolf and Molodensky-Badekas methods are not compatible. Each uses a different point of reference for the parameters (except the three parameter model). The Bursa-Wolf Method uses the center of the Earth, whereas the Molodensky-Badekas Method uses the center of the Earth and a central point in the project area. Because of this, it is **not** possible to compute the parameters once (Molodensky-Badekas), then manually enter them (Bursa-Wolf) again whenever they are needed (unless you are using the three parameter model).

You can also use previously computed Molodensky-Badekas parameters by selecting the same model that you computed them within (three parameter, four parameter, or seven parameter) and entering the parameters in the dialog. You must also enter the geodetic position for the point M at the bottom of the dialog. Finally enable the check box labeled "Entered parms are Molodensky based...". Below are the transformed stations (NAD 27 geodetic positions). Ignore the height components for this example.



Both methods (Bursa-Wolfe or Molodensky-Badekas) provide excellent results, depending on the quality of known parameters or control coordinates in the project area.

Cartesian <--> Geodetic Transformation

This tool allows you to transform geodetic coordinates (latitude, longitude and height) to Earth Centered Earth Fixed cartesian coordinates (X, Y and Z) and the reverse. When transforming from geodetic to cartesian, the geodetic latitude, longitude and height components are transformed to Earth Centered Earth Fixed cartesian X, Y and Z components. When transforming from cartesian to geodetic, the Earth Centered Earth Fixed cartesian X, Y and Z components are changed to latitude, longitude and height. All transformations are based on the active datum.

The direction of the transformation is dependent on the active view (selected from the VIEW menu). For example, if the 3D Geodetic view is active, the context is to transform from geodetic to cartesian. If the Cartesian view is active, the context is to transform from cartesian to geodetic. In either case, the data used are from the current project. Additionally, when transforming from 3D geodetic to cartesian, you can use either the orthometric height or ellipsoidal height component for each geodetic station. To use ellipsoidal height (**most common**), set the OPTIONS - GLOBAL SETTINGS - 3D Geodetic Height setting to Ellipsoidal Height. To use orthometric height, change this setting to Orthometric Height.

If you have just performed a 3D geodetic adjustment and the Adjusted Network Graphical View is active, the transformation is from geodetic to cartesian, using the adjusted geodetic coordinates.

Transformation from Cartesian Coordinates to Geodetic Coordinates

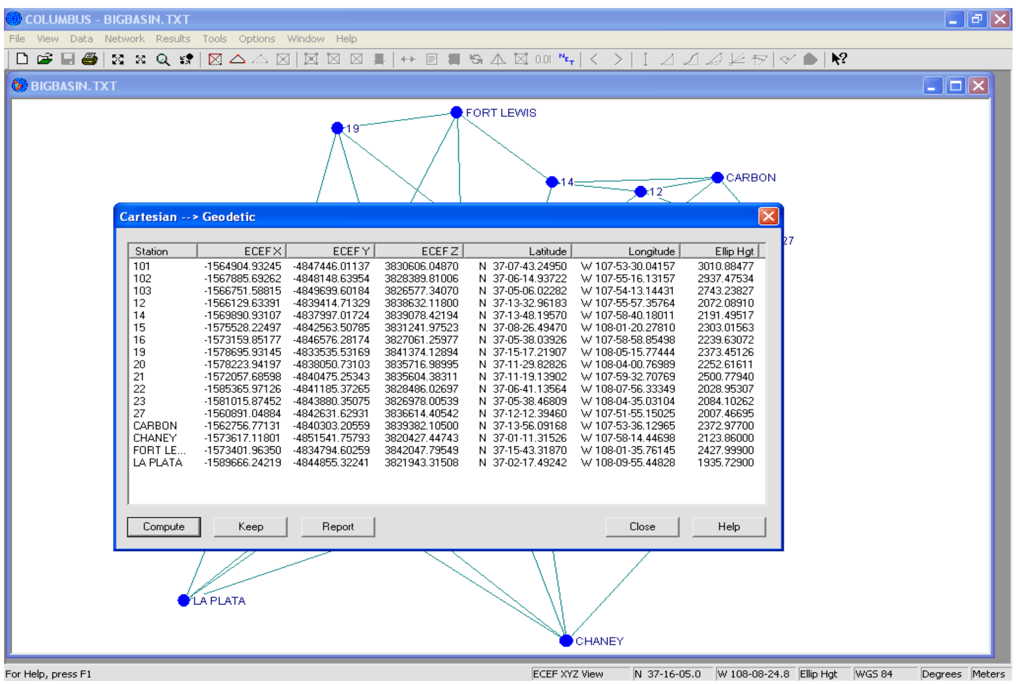
1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and Earth Centered Earth Fixed (ECEF) cartesian coordinates.

2. Change the project view to Cartesian XYZ from the VIEW menu.

3. Enter the TOOLS - TRANSFORMATION - CARTESIAN <--> GEODETIC dialog. Notice the direction of transformation in the title bar (Cartesian to Geodetic).

4. Click on the **COMPUTE** button to generate a list of stations with cartesian coordinates.

5. Click on the **SELECT ALL** button followed by the **OK** button to transform the stations to geodetic coordinates.



6. To Keep the geodetic coordinates into the project, click on the **KEEP** button and select the station to keep.

7. To write the results to a report file, click on the **REPORT** button and COLUMBUS will prompt you for the name of a report file. You can create a new report file or appended to an existing file.

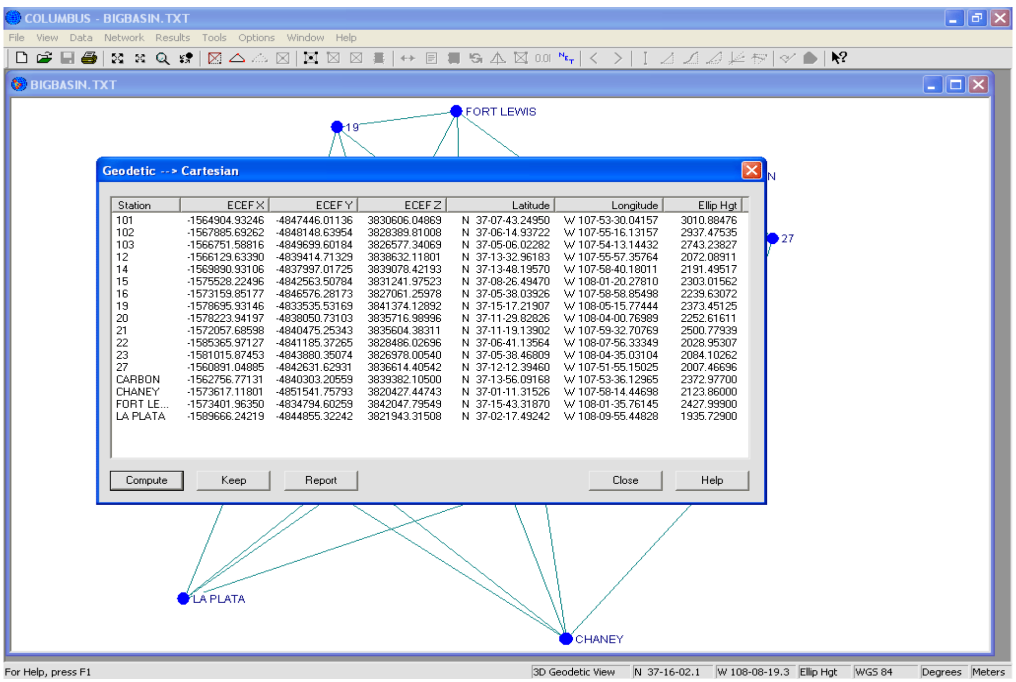
Transformation from Geodetic Coordinates to Cartesian Coordinates

1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and ECEF cartesian coordinates.

2. Change the project view to 3D Geodetic from the VIEW menu.

3. Enter the TOOLS - TRANSFORMATION - CARTESIAN <--> GEODETIC dialog. Notice the direction of transformation in the title bar (Geodetic to Cartesian).

4. Click on the **COMPUTE** button to generate a list of stations with geodetic coordinates. Click on the **SELECT ALL** button followed by the **OK** button to transform the stations to cartesian coordinates.



5. To Keep the cartesian coordinates into the project, click on the **KEEP** button and select the stations to keep.

6. To write the results to a report file, click on the **REPORT** button and COLUMBUS will prompt you for the name of a report file. You can create a new report file or appended to an existing file.

If the transformed coordinates are Kept, they can be used within any other applicable computational module. They can also be exported to an external data file in the TOOLS - USER DEFINED XPORT tool.

State Plane <--> Geodetic Transformation

This tool allows you to transform geodetic coordinates to State Plane coordinates and the reverse. When transforming from geodetic to State Plane, the geodetic latitude and longitude components are transformed to State Plane north and east coordinates. When transforming from State Plane to geodetic, the State Plane north and east components are transformed to latitude and longitude. All transformations are based on the active datum.

COLUMBUS supports most of the projection zones used within the United States that conform to the Lambert (single and double parallel), Transverse Mercator or Azimuthal Equidistant projections. COLUMBUS also supports zones outside the United States which are based on these projections. If you cannot find your projection zone in our supported list, you can enter the projection zone parameters directly. For more information on entering your own parameters, please see the OPTIONS - PROJECTION ZONES - STATE PLANE ZONES discussion in the OPTIONS chapter.

The direction of the transformation is dependent on the active view (selected from the VIEW menu). If the 2D or 3D Geodetic view is active, the context of this tool is from geodetic to State Plane. If the 2D or 3D State Plane view is active, the context of this tool is from State Plane to geodetic. In any case, the data used are from the current project.

If you have just performed a 2D or 3D geodetic adjustment and the Adjusted Network Graphical View is active, the transformation is from geodetic to State Plane, using the adjusted geodetic coordinates.

When computing State Plane coordinates, there are three scale factors that are generated. They are the GSF (grid scale factor), HSF (height scale factor) and CSF (combined scale factor) where:

Ellipsoidal Distance = Ground Distance * HSF

Grid Distance = Ellipsoidal Distance * GSF

Grid Distance = Ground Distance * CSF

If orthometric height is the active height, you can (or should except for NAD 27) add an approximate geoid height to each orthometric height to generate an approximate ellipsoidal height. This approximate ellipsoidal height is then used when computing HSF and CSF. See the OPTIONS - GLOBAL SETTINGS dialog to enter an approximate geoidal height for COLUMBUS.

If you want to compute scale factors and inverses based on a mean project height, set the view to 2D Geodetic (or 2D State Plane) and enter the mean project height in the OPTIONS - GLOBAL SETTINGS - 2D Height field.

In the example that follows, we use the results from our BIGBASIN.TXT network described in the GETTING STARTED chapter. All computed positions are based on the WGS 84 datum. If you have read through the GEODETIC <--> GEODETIC section, you now know how to transform WGS 84 geodetic coordinates to NAD 27 geodetic coordinates. In this example, however, we will transform our WGS 84 geodetic coordinates to and from WGS 84 State Plane coordinates.

Transformation from State Plane Coordinates to Geodetic Coordinates

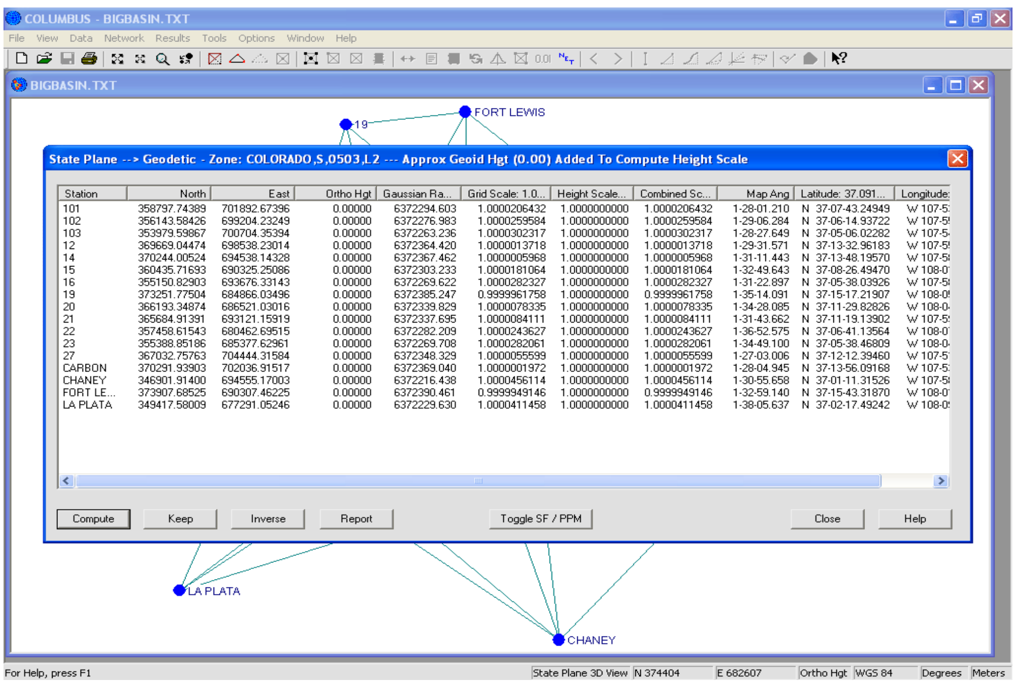
1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and State Plane coordinates.

2. Change the project view to 2D or 3D State Plane from the VIEW menu.

3. Enter the OPTIONS - PROJECTION ZONES - STATE PLANE ZONES dialog and change the Projection Zone to COLORADO 0503.

4. Enter the TOOLS - TRANSFORMATION - STATE PLANE <--> GEODETIC dialog. Notice the direction of the transformation in the title bar (State Plane to Geodetic).

5. Click on the **COMPUTE** button to generate a list of stations with State Plane coordinates. Click on the **SELECT ALL** button followed by the **OK** button to transform the stations to geodetic coordinates.



6. All State Plane coordinates are grid coordinates. The GSF (grid scale factor), HSF (height scale factor) and CSF (combined scale factor) are also presented. To toggle between scale factor and PPM, click on the **Toggle SF / PPM** button. The average scale factor (or PPM) for each applicable column is shown in the column headers.

7. To view the grid, ellipsoidal, and ground distance between each station pair, click on the **INVERSE** button. **The ground distance is based on the mean elevation shown for each station pair**. The ground distance is not a horizontal distance; it is a curved surface distance that more accurately reflects the true ground distance between the stations.

8. To Keep the geodetic coordinates into the project, click on the **KEEP** button and select the stations to keep.

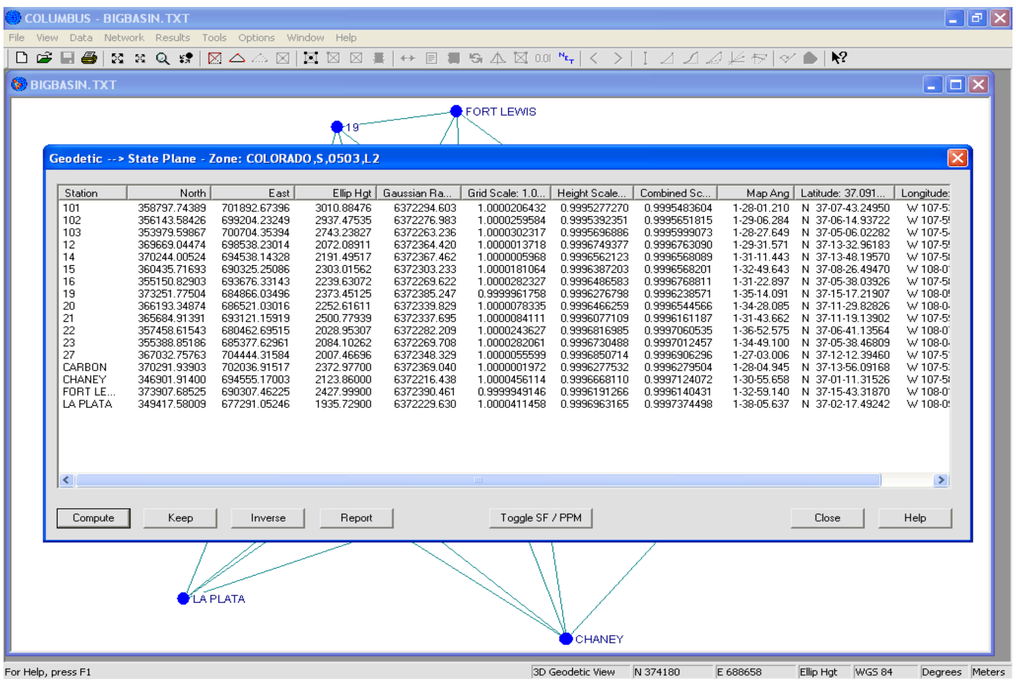
Transformation from Geodetic Coordinates to State Plane Coordinates

1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and State Plane coordinates.

2. Change the project view to 2D or 3D geodetic from the VIEW menu.

3. Enter the OPTIONS - PROJECTIONS ZONES - STATE PLANE ZONES dialog and change the Projection Zone to COLORADO 0503.

4. Enter the TOOLS - TRANSFORMATION - STATE PLANE <--> GEODETIC dialog. Notice the direction of the transformation in the title bar (Geodetic to State Plane).



5. Click on the **COMPUTE** button to generate a list of stations with geodetic coordinates. Click on the **SELECT ALL** button followed by the **OK** button to transform the stations to State Plane coordinates.

6. All State Plane coordinates are grid coordinates. The GSF (grid scale factor), HSF (height scale factor) and CSF (combined scale factor) are also presented. To toggle between scale factor and PPM, click on the **Toggle SF / PPM** button. The average scale factor (or PPM) for each applicable column is shown in the column headers.

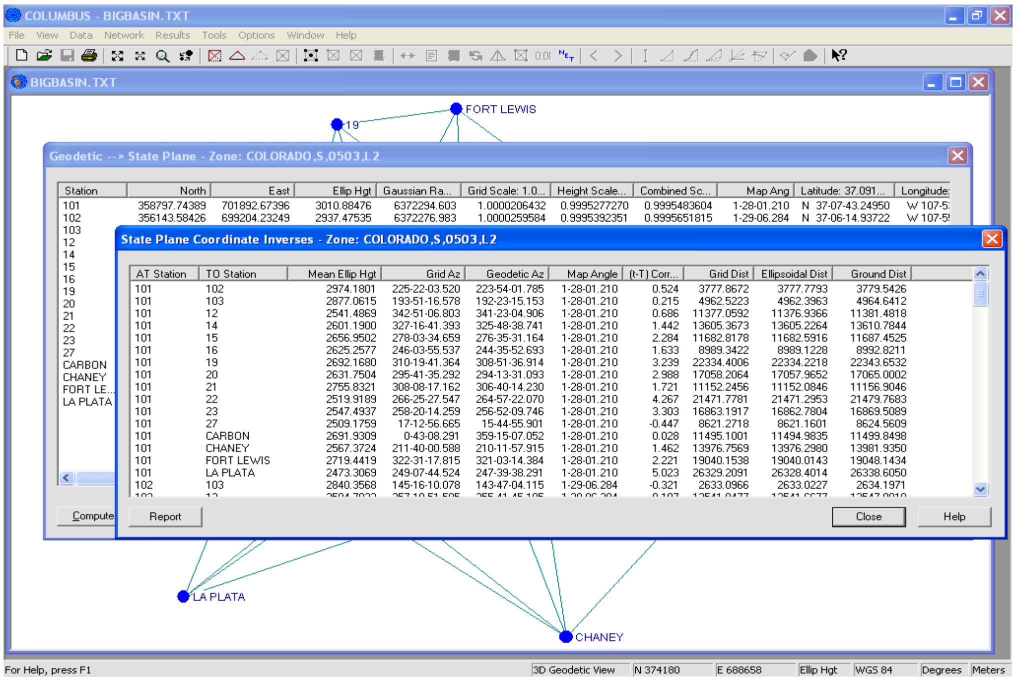
7. To view the grid, ellipsoidal, and ground distance between each station pair, click on the **INVERSE** button. **The ground distance is based on the mean elevation shown for each station pair**. The ground distance is not a horizontal distance; it is a curved surface distance that more accurately reflects the true ground distance between the stations.

8. To Keep the State Plane coordinates into the project, click on the **KEEP** button and select the stations to keep.

If you want to transform State Plane coordinates to UTM, a two-step approach can be used:

1. Transform the State Plane positions to geodetic and Keep them into the project.

2. Enter the geodetic to UTM option (see next section) and convert these geodetic positions to UTM.



The above screen shows the inverse results between station pairs. The ground distance is based on the average elevation for each station pair.

UTM <--> Geodetic Transformation

This tool allows you to transform geodetic coordinates to UTM (Universal Transverse Mercator) coordinates and the reverse. When transforming from geodetic to UTM, the geodetic latitude and longitude components are transformed to UTM north and east coordinates. When transforming from UTM to geodetic, the UTM north and east components are transformed to latitude and longitude. All transformations are based on the active datum.

COLUMBUS supports any Transverse Mercator type zone (UTM, TM, 3TM, etc.) that has its North-South origin at the equator. The zone parameters can be set up in the OPTIONS - PROJECTION ZONES - UTM ZONE SETUP dialog. For more information on entering your own parameters, please see the OPTIONS - PROJECTIONS ZONES - UTM ZONE discussion in the OPTIONS chapter.

The direction of the transformation is dependent on the active view (selected from the VIEW menu). If the 2D or 3D Geodetic view is active, the context of this tool is from geodetic to UTM. If the UTM view is active, the context of this tool is from UTM to geodetic. In either case, the data used are from the current project.

If you have just performed a 2D or 3D geodetic adjustment and the Adjusted Network Graphical View is active, the transformation is from geodetic to UTM, using the adjusted geodetic coordinates.

When computing UTM coordinates, there are three scale factors that are generated. They are the GSF (grid scale factor), HSF (height scale factor) and CSF (combined scale factor) where:

Ellipsoidal Distance = Ground Distance * HSF

Grid Distance = Ellipsoidal Distance * GSF

Grid Distance = Ground Distance * CSF

If orthometric height is the active height, you can (or should except for NAD 27) add an approximate geoid height to each orthometric height to generate an approximate ellipsoidal height. This approximate ellipsoidal height is then used when computing HSF and CSF. See the OPTIONS - GLOBAL SETTINGS dialog to enter an approximate geoidal height for COLUMBUS.

If you want to compute scale factors and inverses based on a mean project height, set the view to 2D Geodetic (or 2D UTM) and enter the mean project height in the OPTIONS - GLOBAL SETTINGS - 2D Height field.

In the example that follows, we use the results from our BIGBASIN.TXT network described in the GETTING STARTED chapter. All computed positions are based on the WGS 84 datum.

Transformation from UTM Coordinates to Geodetic Coordinates

1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and UTM coordinates.

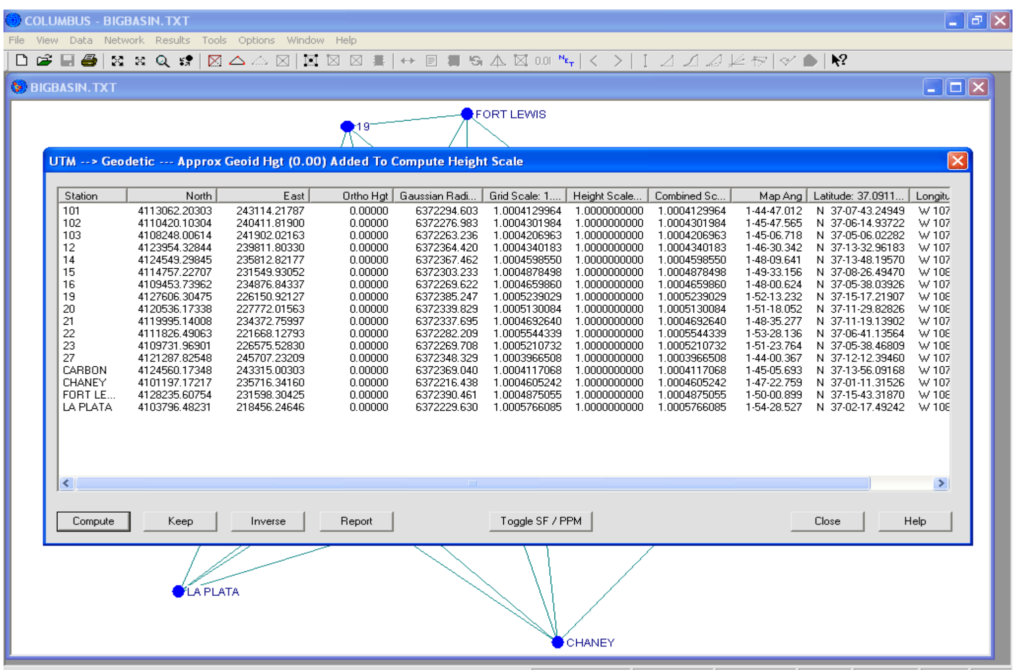
2. Change the project view to 2D or 3D UTM from the VIEW menu.

3. Enter the OPTIONS - PROJECTION ZONES - UTM ZONES dialog to enter the zone parameters.

Central Meridian	-105.0000 (negative in Western Hemisphere)
Scale Factor	0.9996
False Easting	500000.0000 meters
False Northing	0.0000 meters

4. Enter the TOOLS - TRANSFORMATION - UTM <--> GEODETIC dialog. Notice the direction of the transformation in the title bar (UTM to Geodetic).

5. Click on the **COMPUTE** button to generate a list of stations with UTM coordinates. Click on the **SELECT ALL** button followed by the **OK** button to transform the stations to geodetic coordinates.



6. All UTM coordinates are grid coordinates. The GSF (grid scale factor), HSF (height scale factor) and CSF (combined scale factor) are also presented. To toggle between scale factor and PPM, click on the **Toggle SF / PPM** button. The average scale factor (or PPM) for each applicable column is shown in the column headers.

7. To view the grid, ellipsoidal, and ground distance between each station pair, click on the **INVERSE** button. **The ground distance is based on the mean elevation shown for each station pair.** The ground distance is not a horizontal distance; it is a curved surface distance that more accurately reflects the true ground distance between the stations.

8. To Keep geodetic coordinates into the project, click the **KEEP** button and select the stations to keep.

Transformation from Geodetic Coordinates to UTM Coordinates

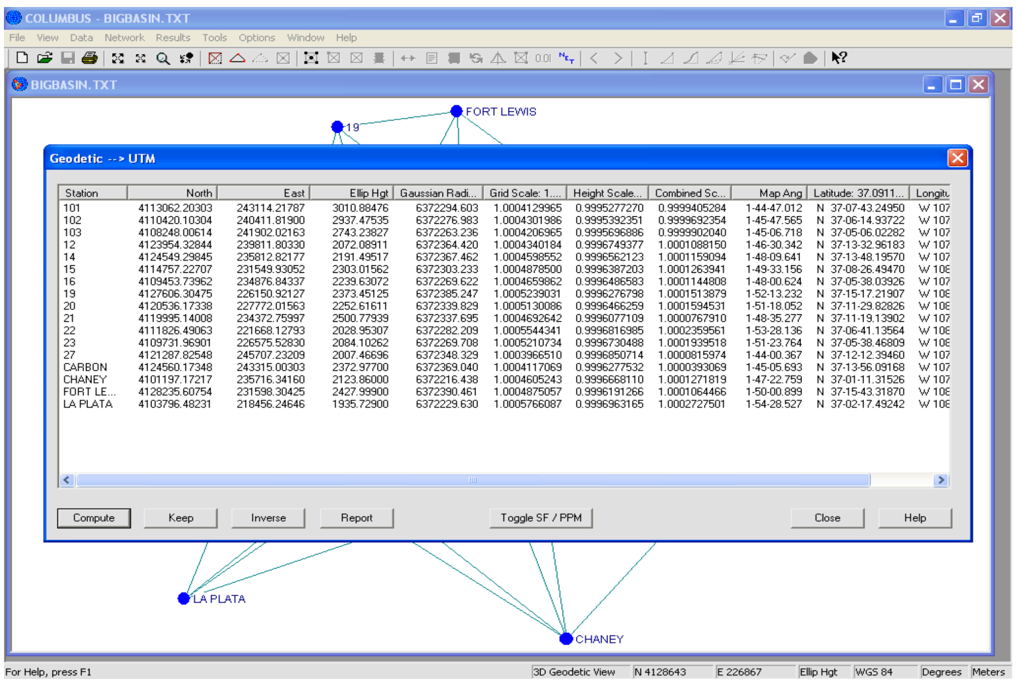
1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and UTM coordinates.

2. Change the project view to 2D or 3D Geodetic from the VIEW menu.

3. Enter the OPTIONS - PROJECTION ZONES - UTM ZONES dialog to enter the zone parameters.

Central Meridian	-105.0000 (negative in Western Hemisphere)
Scale Factor	0.9996
False Easting	500000.0000 meters
False Northing	0.0000 meters

4. Enter the TOOLS - TRANSFORMATION - UTM <--> GEODETIC dialog. Notice the direction of the transformation in the title bar (Geodetic to UTM).



5. Click on the **COMPUTE** button to generate a list of stations with geodetic coordinates. Click on the **SELECT ALL** button followed by the **OK** button to transform the stations to UTM coordinates.

6. All UTM coordinates are grid coordinates. The GSF (grid scale factor), HSF (height scale factor) and CSF (combined scale factor) are also presented. To toggle between scale factor and PPM, click on the **Toggle SF / PPM** button. The average scale factor (or PPM) for each applicable column is shown in the column headers.

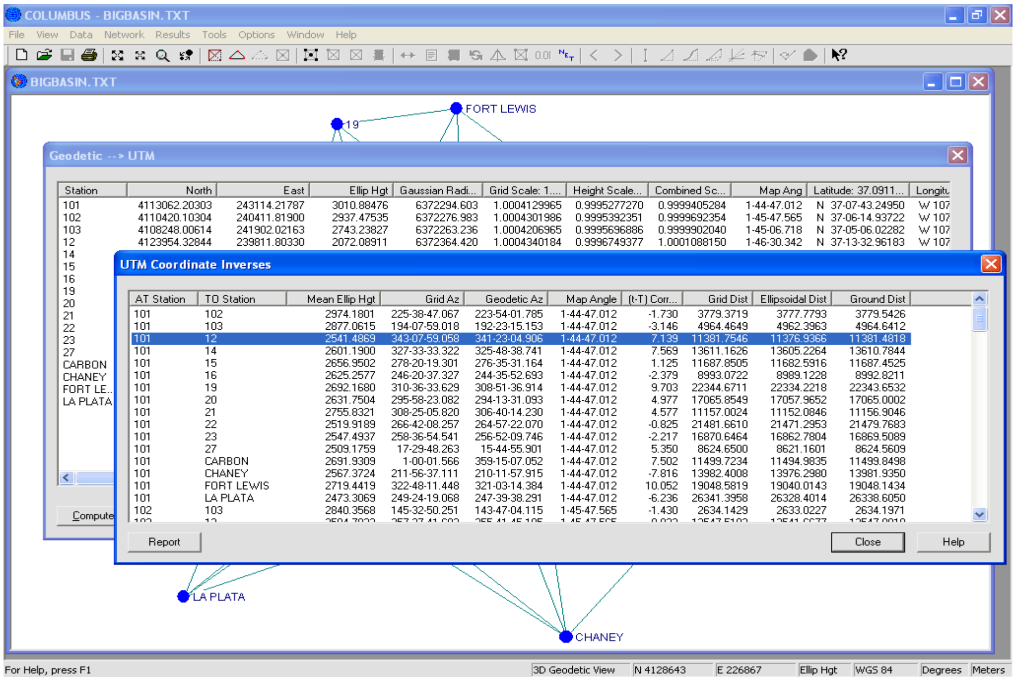
7. To view the grid, ellipsoidal, and ground distance between each station pair, click on the **INVERSE** button. **The ground distance is based on the mean elevation shown for each station pair.** The ground distance is not a horizontal distance; it is a curved surface distance that more accurately reflects the true ground distance between the stations.

8. To Keep UTM coordinates into the project, click the **KEEP** button and select the stations to keep.

If you want to transform UTM coordinates to State Plane, a two step approach can be used:

1. Transform the UTM positions to geodetic and Keep them into the project.

2. Enter the geodetic to State Plane option (see previous section) and convert these geodetic positions to State Plane.



The above screen shows the inverse results between station pairs. The ground distance is based on the average elevation for each station pair.

Local Horizon NEU <--> Geodetic Transformation

This tool allows you to transform geodetic coordinates to a Local Horizon NEU (North, East and Up) tangent (or secant) plane coordinate system and the reverse. COLUMBUS allows you complete flexibility in selecting the point of tangency for the Local NEU plane in relation to the ellipsoidal surface. This is particularly useful when a control portion of a survey is performed on the geodetic model, but the interior of the project will be handled on a simplified Local NEU system. Alternately, a project may be completed on a Local NEU system, then transformed and reported in geodetic form. All references to Local NEU coordinate systems within COLUMBUS refer to coordinate systems where the north component is true north at the point of tangency with the Earth's surface.

The direction of the transformation is dependent on the active view. If the 3D Geodetic view is active, the context of this module is to transform from geodetic to Local NEU. If the Local NEUE view is active, the context of this module is to transform from Local NEU to geodetic.

If you have just performed a 3D geodetic adjustment and the Adjusted Network Graphical View is active, the transformation is from geodetic to Local NEU, using the adjusted 3D geodetic coordinates.

When transforming geodetic coordinates to a Local Horizon NEU system or the reverse, a common point of origin must be established between the two mathematical systems (geodetic and Local NEU). That is, a point (station) must be selected that has both a known geodetic position and an assigned or known Local NEU coordinate. This point establishes the orientation of the Local NEU plane onto the ellipsoid. Once this station has been defined, all remaining geodetic or Local NEU coordinates (depending on direction of transformation) can be transformed to Local NEU or geodetic positions.

The point of origin can also be based on a mean location for the project area. Suppose you have several geodetic positions scattered throughout a ONE by ONE km square parcel of land. You may wish to establish the reference point in the center of the project to minimize the projection distortions. You can compute a mean position from some or all geodetic stations within the project area. This location can then be assigned Local NEU coordinates. This type of projection would then be based on a secant plane (intersecting the ellipsoidal surface at an infinite number of points) in the project area.

In the example that follows, we use the results from our BIGBASIN.TXT network described in the GETTING STARTED chapter. Within the BIGBASIN.TXT file are the results from a 3D geodetic network adjustment. Each station has a computed geodetic coordinate position. Selected stations also have a Local NEU coordinate position (Stations CARBON, 27, 21, 12 and 14). We wish to give the results from part of this survey to the local subdivision firm, Company XYZ. Company XYZ needs to subdivide a portion of the area bounded by Stations CARBON, 27, 21 and 14. Since they do not work with geodetic coordinates, we will establish a Local Horizon NEU system in this area and compute relative Local NEU coordinates for the above mentioned stations and Station 12. Company XYZ can then use these five stations for control in their subdivision work.

Finally, after the subdivision is complete, they will give us back the new stations they established within the region. We will then transform these Local NEU positions back to geodetic.

In actuality, the area covered by these points is too large to be accurately represented by a local NEU coordinate system. The area should be no larger than ONE km by ONE km. However, the same logic described below is correct for any size project.

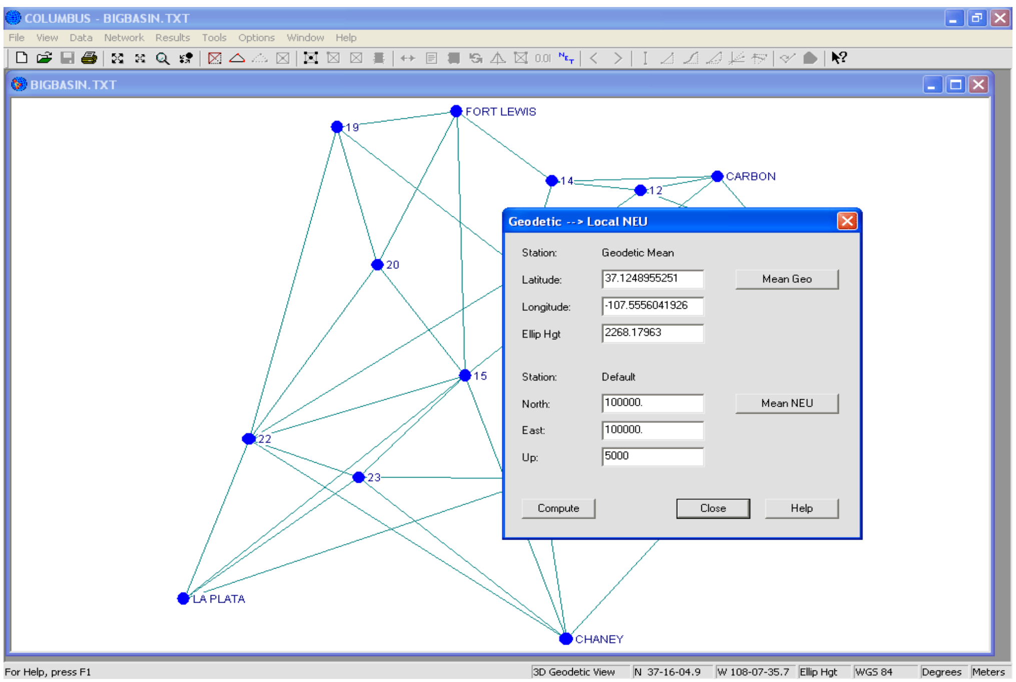
Transformation from Geodetic Coordinates to Local NEU Coordinates

1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and Local NEU coordinates.

2. Change the project view to 3D Geodetic from the VIEW menu.

3. Enter the TOOLS - TRANSFORMATION - LOCAL NEU <--> GEODETIC dialog. Notice the direction of the transformation in the title bar (Geodetic to Local NEU).

4. Set up the Local NEU plane orientation about the ellipsoid. There are two options for selecting the geodetic origin:



A. Make the Local NEU plane tangent to the ellipsoid (approximate Earth's surface) at a specific geodetic station by clicking on the **MEAN GEO** button to generate a list of geodetic stations. Select one station to be used as the origin by clicking on the station name. Click on the **OK** button; COLUMBUS will display the geodetic position for that station. This option results in the Local NEU plane intersecting the ellipsoidal surface at one point (the selected station).

B. Select from several geodetic stations to compute a mean geodetic origin by clicking on the **MEAN GEO** button to generate a list of all geodetic stations. Select each applicable station name. Click on the **OK** button; COLUMBUS will display the mean geodetic position for the stations selected. This option results in the Local NEU plane being placed tangent to the average position of the selected geodetic stations. In effect, a secant plane is established for the project which intersects the ellipsoidal surface at an infinite number of points.

When performing the Geodetic to Local NEU or Local NEU to Geodetic transformation, the orthometric or ellipsoidal height can be used. The option can be selected by enabling either the

Orthometric Height or Ellipsoidal Height choice for the 3D Geodetic Height option in the OPTIONS - GLOBAL SETTINGS dialog. For our example, we use ellipsoidal height.

For our example, we are only interested in the area bounded by Stations CARBON, 27, 21 and 14. Follow Step 5B to compute the mean geodetic origin from these four stations. The position you compute will be near the center of this polygon. The screen above shows the mean geodetic origin.

5. Select or enter (the coordinates) for the Local NEU station which will serve as the local origin for the point selected in the previous step. When the projection is calculated, all computed Local NEU coordinates will be translated about this point. There are three options for this selection:

   A. Select the Local NEU station from a list generated with the **MEAN NEU** button. This results in the projected Local NEU coordinates to be translated about the selected station. In other words, the coordinates of the selected station will not change. Select one station to be used as the origin by clicking on the station name. Click on the **OK** button; COLUMBUS will display the Local NEU position for that station.

   B. Select from several Local NEU stations to compute a mean Local NEU origin by clicking on the **MEAN NEU** button to generate a list of all Local NEU stations. Using the mouse, click on each applicable station name. Click on the **OK** button; COLUMBUS will display the mean Local NEU position for the stations selected.

   C. Enter the coordinates directly or use the default values.

   For our example, use option 5C and enter the NEU values of 100000.0, 100000.0, 5000.0 respectively.

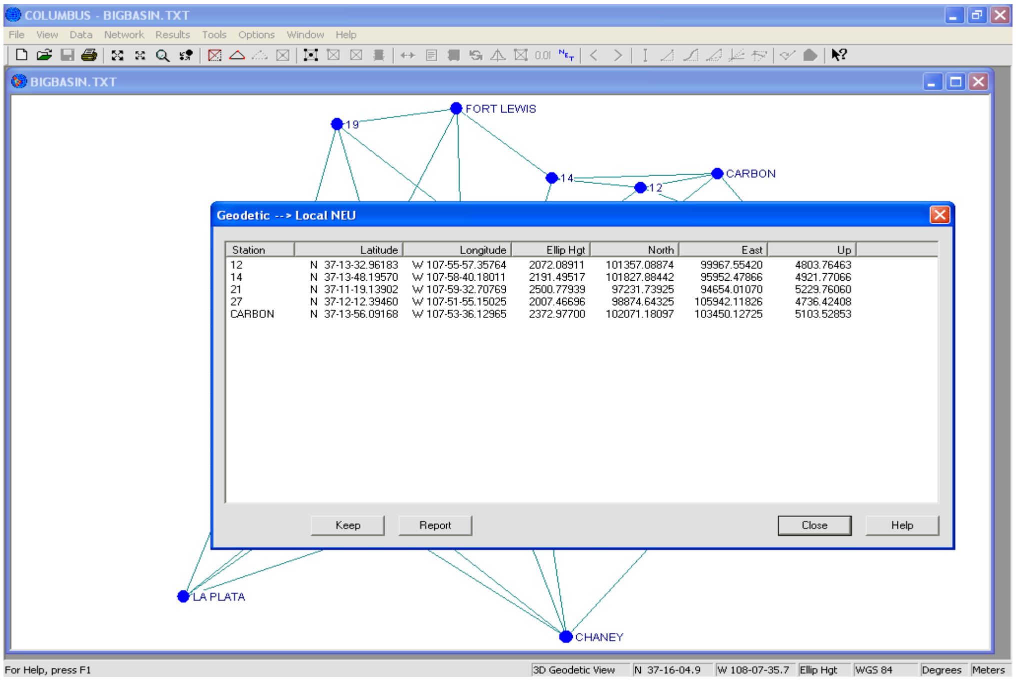
   To summarize: In this example, our origin is located at N 37-12-48.95525, W 107-55-56.04193, Hgt 2268.17963m. We have assigned this point the Local origin of N = 100000.0^{m}, E = 100000.0^{m} and Up = 5000.0^{m}.

6. Compute the Local NEU coordinates from the geodetic stations by clicking on the **COMPUTE** button. This will generate a list of all geodetic stations that can be transformed. Select Stations CARBON, 27, 21, 14 and 12 by tagging each as described earlier. Click on the **OK** button and COLUMBUS will transform these positions to Local NEU coordinates.

7. To Keep the Local NEU coordinates into the project, click on the **KEEP** button and select the stations to keep.

8. To write the results to a report file, click on the **REPORT** button and COLUMBUS will prompt you for the name of a report file. You can create a new report file or append to an existing file.

Once the transformed coordinates are Kept into the project, they can be used within any other applicable computational module. They can also be exported to an external data file in the TOOLS - USER DEFINED XPORT module. If you need to scale your Local NEU coordinates, this can be accomplished in the TOOLS - SCALE COORDINATES module.



Now wait a few weeks until Company XYZ has finished their subdivision work in this area. Obtain the additional Local NEU positions established by them and proceed to the next section to transform these positions back to geodetic.

Transformation from Local NEU Coordinates to Geodetic Coordinates

1. Load the BIGBASIN.TXT network file using the FILE - OPEN command. This file contains several adjusted stations with already computed geodetic and Local NEU coordinates.

2. Change the project view to Local NEUE from the VIEW menu.

3. Enter the DATA - STATIONS - LOCAL NEUE dialog and enter the new subdivision coordinates established by Company XYZ. The station names and their Local NEU coordinates are shown below (in meters).

Station	North	East	Up
AAAA	100000.0	95000.0	4800.0
BBBB	99000.0	103000.0	4500.0
CCCC	101000.0	97000.0	5000.0
CENTER	100000.0	100000.0	5000.0

Using this tool we will transform these Local NEU positions back to geodetic.

4. Enter the TOOLS - TRANSFORMATION - LOCAL NEU <--> GEODETIC dialog. Notice the direction of the transformation in the title bar (Local NEU to Geodetic).

5. Set up the Local NEU plane orientation about the ellipsoid. There are two options for selecting the geodetic origin:

   A. Make the Local NEU plane tangent to the ellipsoid (approximate Earth’s surface) at a specific geodetic station by clicking on the **MEAN GEO** button to generate a list of geodetic stations. Select one station to be used as the origin by clicking on the station name. Click on the **OK** button and COLUMBUS will display the geodetic position for that station. This option results in the Local NEU plane intersecting the ellipsoidal surface at one point (the selected station).

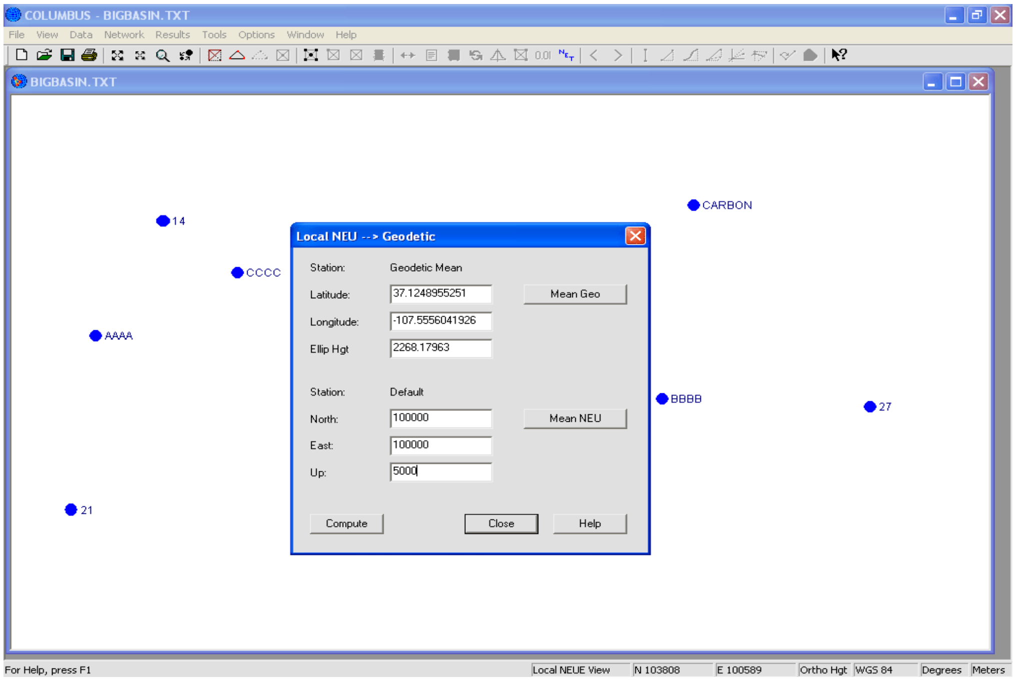
   B. Select from several geodetic stations to compute a mean geodetic origin by clicking on the **MEAN GEO** button to generate a list of all geodetic stations. Using the mouse, click on each applicable station name. Click on the **OK** button and COLUMBUS will display the mean geodetic position for the stations selected. This option results in the Local NEU plane being placed tangent to the average position of the selected geodetic stations. In effect, a secant plane is established for the project which intersects the ellipsoidal surface at an infinite number of points.

      When performing the Geodetic to Local NEU or Local NEU to Geodetic transformation, the orthometric or ellipsoidal height can be used. The option can be selected by enabling either the Orthometric Height or Ellipsoidal Height choice for the 3D Network Type option in the OPTIONS - NETWORK OPTIONS - NETWORK SETTINGS dialog. For our example, we use ellipsoidal height.

   For our example, we are only interested in the area bounded by Stations CARBON, 27, 21 and 14. Furthermore, we need to reverse the process from the previous section in order to get the correct transformed results (i.e., use the same origin). Follow option 5B and compute the mean geodetic origin from these four stations. The position you compute will be near the center of this polygon. The screen above shows the mean geodetic origin.

6. Select the Local NEU station which will serve as the local origin for the point selected in the previous step. When the projection is calculated, all computed Local NEU coordinates will be translated about

this point. There are three options for this selection:



A. Select the Local NEU station from a list generated with the **MEAN NEU** button. This results in the projected Local NEU coordinates to be translated about the selected station. In other words, the coordinates of the selected station will not change. Select one station to be used as the origin by clicking on the station name. Click on the **OK** button and COLUMBUS will display the Local NEU position for that station.

B. Select from several Local NEU stations to compute a mean Local NEU origin by clicking on the **MEAN NEU** button to generate a list of all Local NEU stations. Using the mouse, click on each applicable station name. Click on the **OK** button; COLUMBUS will display the mean Local NEU position for the stations selected.

C. Select no Local NEU station. The local coordinates of the geodetic origin will be 0, 0, 0 (North, East, Up) by default.

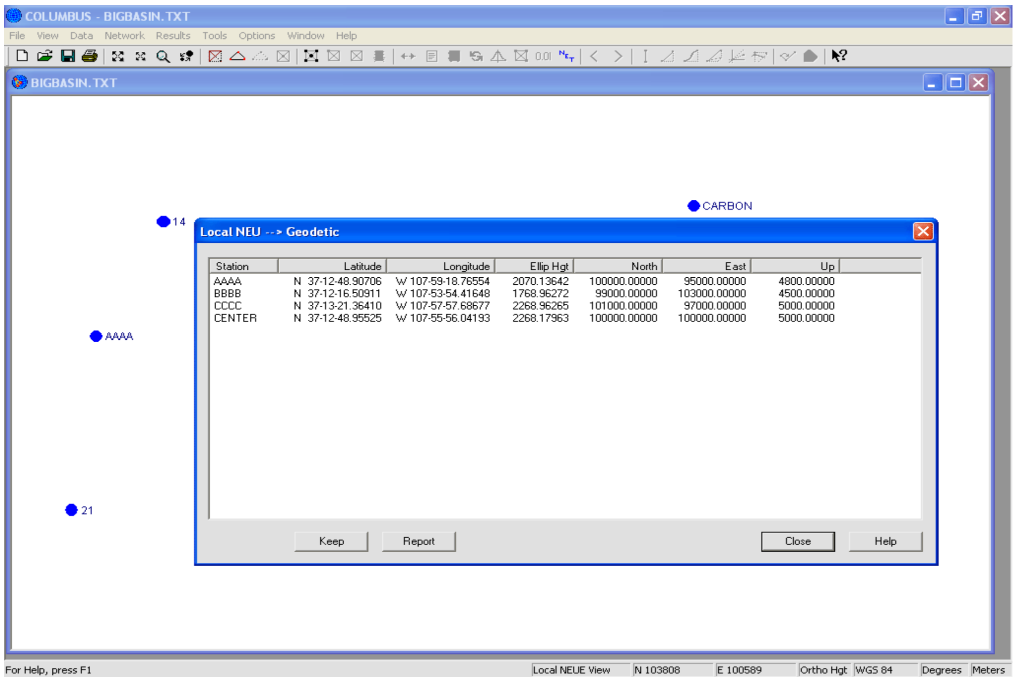
For our example, use option 6A and select Station CENTER as the Local NEU origin. This is the same Local NEU origin we set up in the geodetic to Local NEU transformation. All transformed Local NEU stations will be translated about this station.

To summarize: In this example, our origin is located at N 37-12-48.95525, W 107-55-56.04193, Hgt 2268.17963m. We have assigned this point the Local origin of N = 100000.0m, E = 100000.0m and Up = 5000.0m.

7. Compute the geodetic coordinates from the Local NEU stations by clicking on the **COMPUTE** button. This will generate a list all Local NEU stations in the project which can be transformed. Select Stations AAAA, BBBB, CCCC and CENTER by tagging each as described earlier. Click on the **OK** button; COLUMBUS will transform these positions to geodetic coordinates. Notice Station CENTER has the

same geodetic coordinates as the geodetic origin.

8. To Keep the geodetic coordinates into the project, click on the **KEEP** button and select the stations to keep.



9. To write the results to a report file, click on the **REPORT** button and COLUMBUS will prompt you for the name of a report file. You can create a new report file or appended to an existing file.

Once the transformed coordinates are Kept into the project, they can be used within any other applicable computational module. They can also be exported to an external data file in the TOOLS - USER DEFINED XPORT module.

If you want to transform Local NEU coordinates to State Plane, a two step approach can be used:

1. Transform the Local NEU positions to geodetic and Keep them into the project.

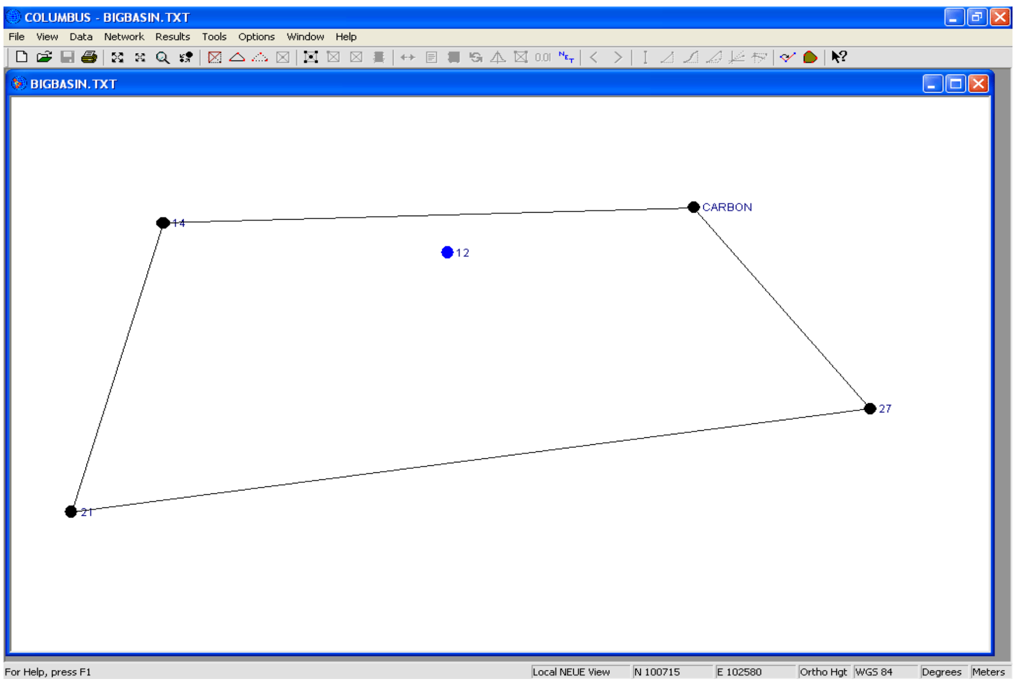
2. Enter the geodetic to State Plane option and transform these geodetic positions to State Plane. Be sure the proper Projection zone has been established in the OPTIONS module.

Compute Area

The COMPUTE AREA tool allows you to calculate areas from State Plane, UTM or Local NEU (North, East and Up) coordinates. These coordinate types can be entered directly in the applicable DATA - STATIONS tabbed grids, loaded from an ASCII (Text) file, or computed and Kept into the project within one of the TOOLS - TRANSFORMATION options.

Because COLUMBUS is an integrated system, you can perform a COGO traverse or network adjustment, Keep the results to the project, transform them to one of these three coordinate systems, Keep those positions into the project, then compute areas bounded by the selected stations.

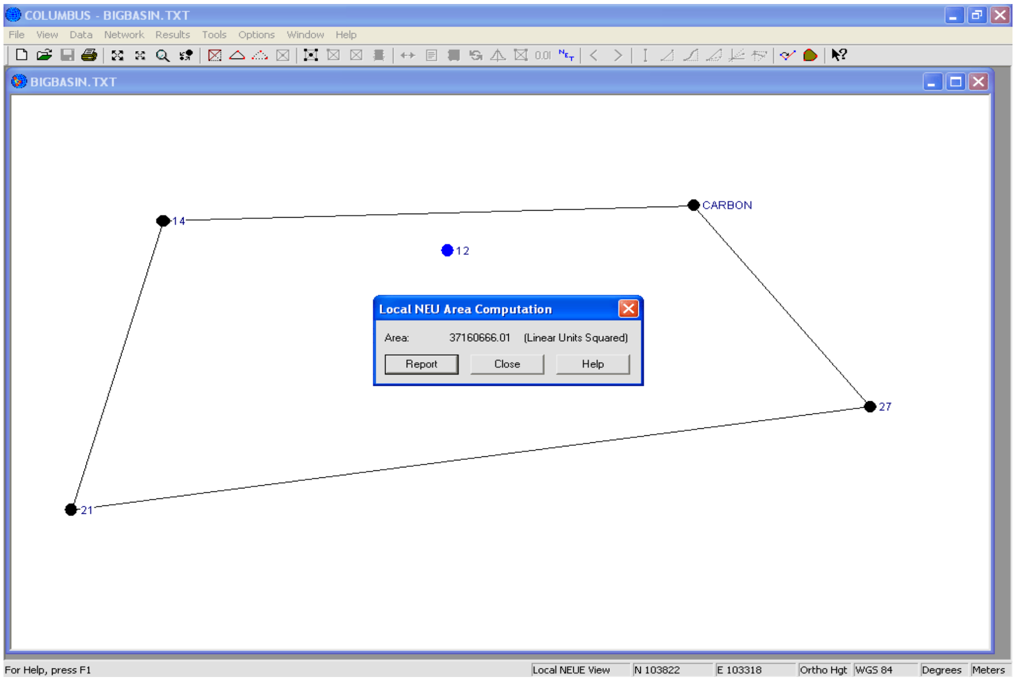
To compute an area, you must have one of the applicable State Plane, UTM or Local NEUE views active.



1. Load the BIGBASIN.TXT file using the FILE - OPEN command. Within this file are Local NEU coordinates derived from the adjusted geodetic stations. Change the view to Local NEUE. This file also contains State Plane and UTM positions for the same stations.

2. Define the polygon for the area to be computed. Using the right mouse button, click on the following stations in successive order: CARBON, 27, 21, 14 and back to CARBON. As you click on each station, the polygon lines will become visible. If no lines are visible, check the COGO, Area, or Design Course color option in the OPTIONS - COLORS dialog. As each station is selected, the station symbol color should also change. You can also select or edit the route using the VIEW - SETUP COGO/DESIGN ROUTE dialog.

3. Invoke the TOOLS - COMPUTE AREA command to compute the area. Notice the context is "Local NEU" in the dialog title bar, since the Local NEUE view is active. The area is presented in the active linear units squared.



4. Click on the **REPORT** button to write the results (including the polygon order) to a report file. You can create a new report file or append to an existing file.

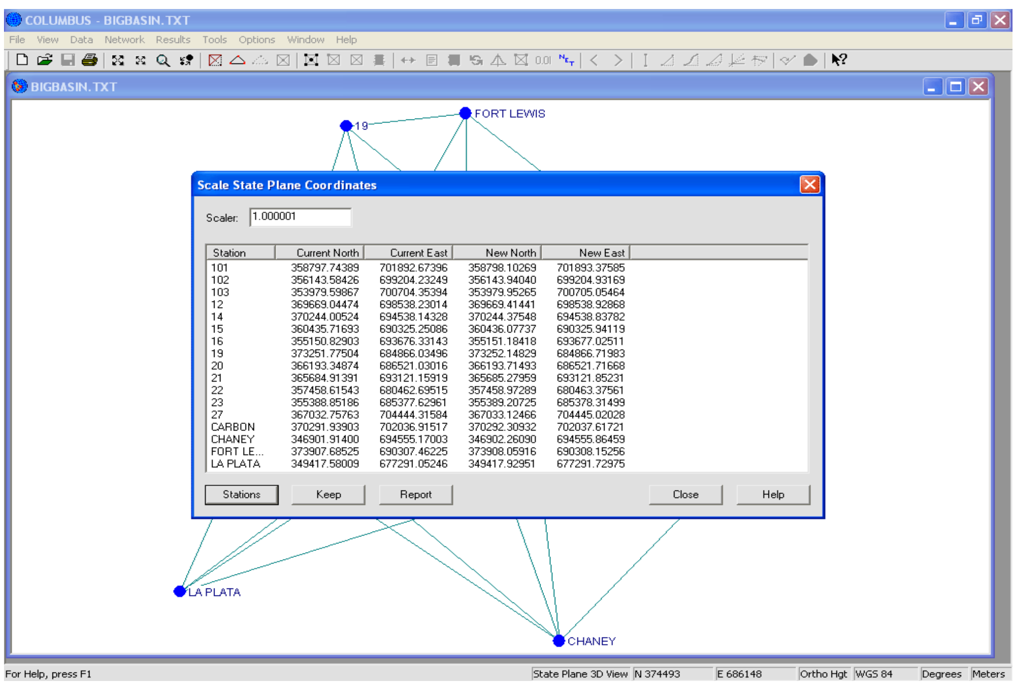
Scale Coordinates

This tool allows you to scale State Plane, UTM and Local NEU coordinates in the active project. It was originally developed to facilitate the Scaling of State Plane coordinates from the grid to some average elevation. It is still commonly used for this purpose; however, you must provide your own scale factor.

1. Load the BIGBASIN.TXT file within the FILE - OPEN command. This file contains the results from our 3D geodetic network adjustment. Each station also has an adjusted State Plane coordinate position. Change the active project view to 2D or 3D State Plane to display all the stations with State Plane coordinates.

2. Enter the TOOLS - SCALE COORDINATES dialog and enter a scale factor of 1.000001. The scale factor is always multiplied by the current coordinate values. Notice the context in the dialog title bar is to scale State Plane coordinates.

3. Click on the **STATIONS** button and COLUMBUS will present a list of all the State Plane stations in the project (for the active datum). Click on the **ALL** button to select all stations shown, then click on the **OK** button to scale the selected station State Plane coordinates.



4. COLUMBUS displays the current and newly scaled coordinates for each station.

5. To keep the newly scaled coordinates into the project, click on the **KEEP** button and select the stations to keep. The current coordinate values will then be replaced with the new scaled coordinate values.

6. To write the results to a report file, click on the **REPORT** button. You can either create a new report file or append the results to an existing file.

Geoid Modeling

This tool allows you to determine geoidal heights from geoidal height grid files. NGS grid files are based on the NAD 83 ellipsoid (WGS 84 ellipsoid will work too). Geoidal Height results are valid for these two datums only.

COLUMBUS also supports the Canadian HT2_0 (and .BYN formats) and EGM 96 geoid models. EGM 96 is a worldwide GEOID model. Using EGM 96, you can determine the geoidal height for any position on the ground throughout the world.

Geodetic coordinates have three height components; orthometric height (elevation), geoidal height, and ellipsoidal height. Given any two, you can directly compute the third by applying the following relationship:

$$\textit{ellipsoidal height} = \textit{orthometric height} + \textit{geoidal height}$$

If we know the ellipsoidal height for a geodetic station and then we compute the geoidal height for that station, we can determine its orthometric height. Alternatively, if we know the orthometric height and geoidal height for a station, we can compute the ellipsoidal height.

Since GPS observations are based on ellipsoidal height (not orthometric height), many network adjustments are computed using latitude, longitude, and ellipsoidal height. If we need to determine the orthometric height for these stations, we need to determine the geoidal height at each station. This option facilitates this process.

To compute geoidal heights from grid files, the geodetic coordinates (latitude and longitude) for each station must be known. Using the geodetic coordinates, COLUMBUS reads the appropriate grid file and interpolates the geoidal height from the grid of geoidal heights within the file. The grid file can be set up in the OPTIONS - DIRECTORIES dialog or within this dialog directly.

When you use this option, COLUMBUS will either compute the orthometric height from the derived geoidal height and known ellipsoidal height, or COLUMBUS will compute the ellipsoidal height from the known orthometric height and the derived geoidal height.

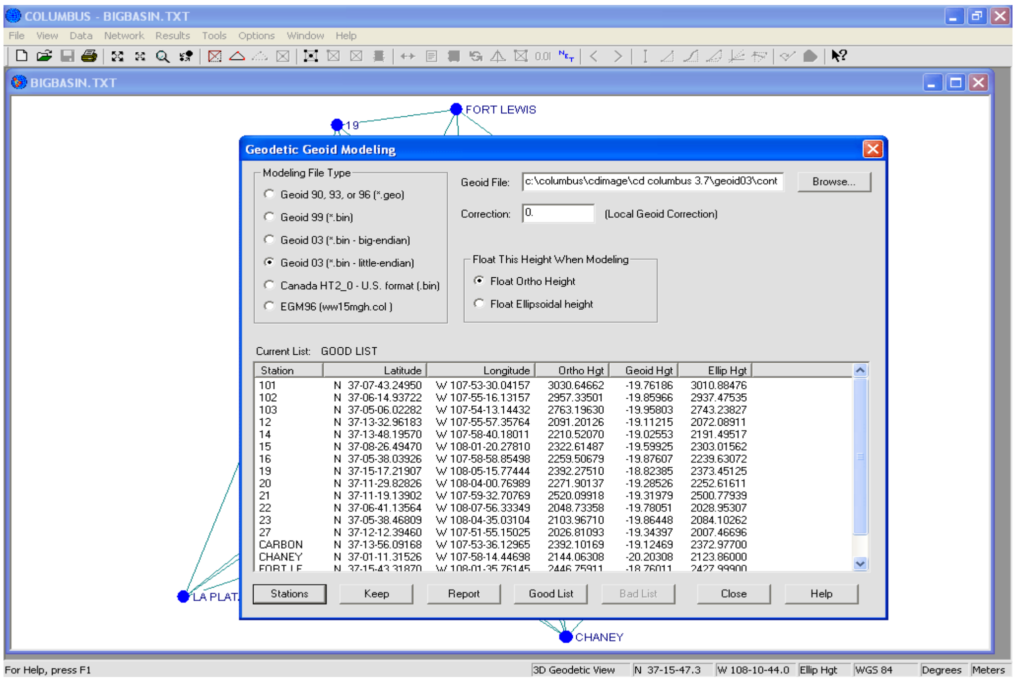
1. Load the BIGBASIN.TXT network file, described in the GETTING STARTED chapter, using the FILE - OPEN command. Change the view to 3D Geodetic (selected from the VIEW menu). **To duplicate our results, you must have the NGS geoid03 grid file G2003006.BIN installed on your system.** The location and grid file name must be defined in the OPTIONS - DIRECTORIES dialog or locally within this dialog. You must also select Geoid 03 as the Modeling File Type.

2. Enter the TOOLS - GEOID MODELING dialog and click on the **STATIONS** button and select the height component to float. This will bring up a list of all geodetic stations associated with the active datum (remember, geoid modeling is only valid for geodetic coordinates based on the WGS 84 or NAD 83 datum). Click on the **SELECT ALL** button to tag all stations, then click on the **OK** button to compute the geoidal heights.

3. Click on the **KEEP** button to Keep the new height fields into the project. Select the stations to keep and click on the **OK** button. Each of the three height fields (Orthometric Height, Geoid Height and Ellipsoidal Height) will be updated for each station Kept. For station 102, the resulting geoid height was determined to be -19.72233 meters. The Height was held fixed at 2937.47535 meters. The Orthometric Height was computed from the Ellipsoidal Height and Geoid Height (i.e., 2937.47535 minus 19.72233). **Although the height components are reported here to the fifth decimal place,**

the geoidal height can only be estimated to within a few centimeters under favorable conditions.

4. Click on the **BADLST** button to examine any stations which were not computable, because their geodetic coordinates were not within the range supported by the active geoid grid file. Likewise, the **GOODLST** button will produce a list of those stations for which computations were successful.



5. Click on the **REPORT** button to write the results to a report file. COLUMBUS will prompt you for the name of a report file. You can create a new report file or append to an existing file.

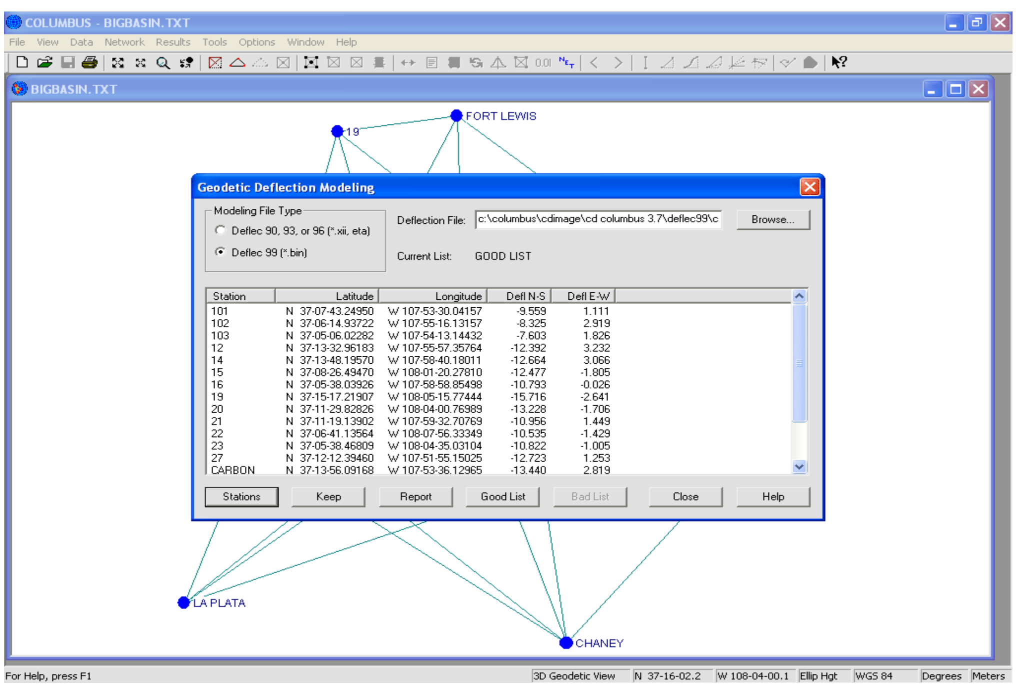
In this example, the quality of the computed orthometric heights are a function of the quality of the known ellipsoidal heights and the modeled geoidal heights. Some users report computed orthometric heights to be within 1-2 cm of their known orthometric height (derived using differential leveling). You results will vary with your location. The grid files cannot deliver the same level of accuracy in all regions covered. In general, the more uniform the geoidal height in your area (i.e., the more uniform the difference between the orthometric height and the ellipsoidal height in the project area), the better results you will obtain.

Deflection Modeling

This tool allows you to determine deflection of the vertical values (in the N-S and E-W directions) for geodetic stations using grid files created by NGS (National Geodetic Survey, U.S.A.). The NGS grid files are based on the NAD 83 ellipsoid (WGS 84 ellipsoid will work too). The modeled deflections of the vertical results are valid for these two datums only.

The Deflection of the vertical is used to correct Astronomic Observations (terrestrial observations measured in the field) to Geodetic observations (terrestrial observations based on the NAD 83 or WGS 84 ellipsoid) for 3D Geodetic Traverses and 3D Geodetic Network adjustment computations. The deflections of the verticals (N-S and E-W) are expressed in seconds of latitude and longitude between Astronomic geodetic coordinates and Ellipsoidal geodetic coordinates (Ellipsoidal geodetic coordinates are used in the surveying community).

To compute the deflection of the vertical (N-S and E-W) for each station from the NGS grid files, the geodetic coordinates (latitude and longitude) for each station must be known. Using the geodetic coordinates, COLUMBUS reads the appropriate grid files and interpolates the deflection of the vertical from the grid of vertical deflections within the file (using a method defined by NGS). Two grid files are required for each region. One contains the N-S results (XII file), the other contains the E-W results (ETA file). The grid files can be set up in the OPTIONS -DIRECTORIES dialog or within this dialog directly.



1. Load the BIGBASIN.TXT network file, described in the GETTING STARTED chapter, using the FILE - OPEN command. Change the view to 2D or 3D Geodetic (selected from the VIEW menu). **To duplicate our results, you must have the NGS Deflec99 grid files E1999U06.BIN and N1999U06.BIN installed on your system.** The location and grid file names (without the extension) must be defined in the OPTIONS - DIRECTORIES dialog or locally within this dialog. You only need to specify one of the files, not both. You must also select Deflec 99 as the Modeling File Type.

2. Enter the TOOLS - DEFLECTION MODELING dialog and click on the **STATIONS** button. This will

bring up a list of all geodetic stations associated with the active datum (remember, deflection modeling is only valid for geodetic coordinates based on the WGS 84 or NAD 83 datum). Click on the **SELECT ALL** button to tag all stations, then click on the **OK** button to compute the vertical deflection values.

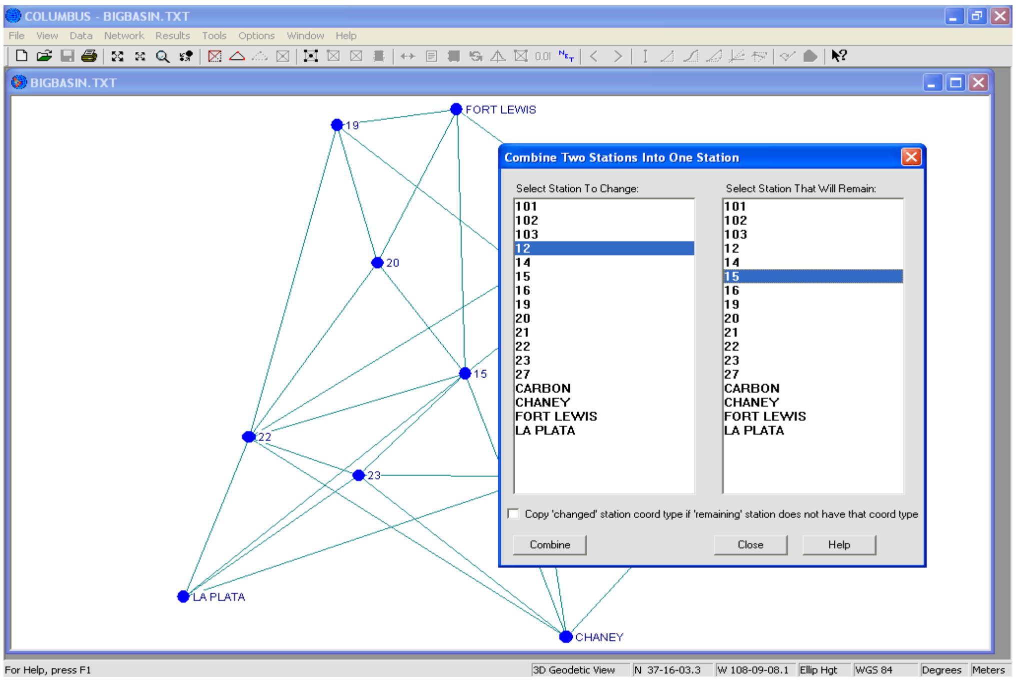
3. Click on the **KEEP** button to Keep the new deflection of the vertical fields into the project for each geodetic station. Select the stations to keep and click on the **OK** button. In the example above, the deflection of the vertical in the N-S and E-W for station 102 are: -8.325 and 2.919 respectively. **Although the deflection values are reported to three decimal places, the actual accuracy is closer to one decimal place.**

4. Click on the **BADLST** button to examine any stations which were not computable, because their geodetic coordinates were not within the range supported by the active deflection grid file. Likewise, the **GOODLST** button will produce a list of those stations for which computations were successful.

5. Click on the **REPORT** button to write the results to a report file. COLUMBUS will prompt you for the name of a report file. You can create a new report file or append to an existing file.

Combine Two Stations

The COMBINE TWO STATIONS tool allows you to combine two station names into one station name. Use this tool when you have mistakenly given the same point on the ground two or more different station names.



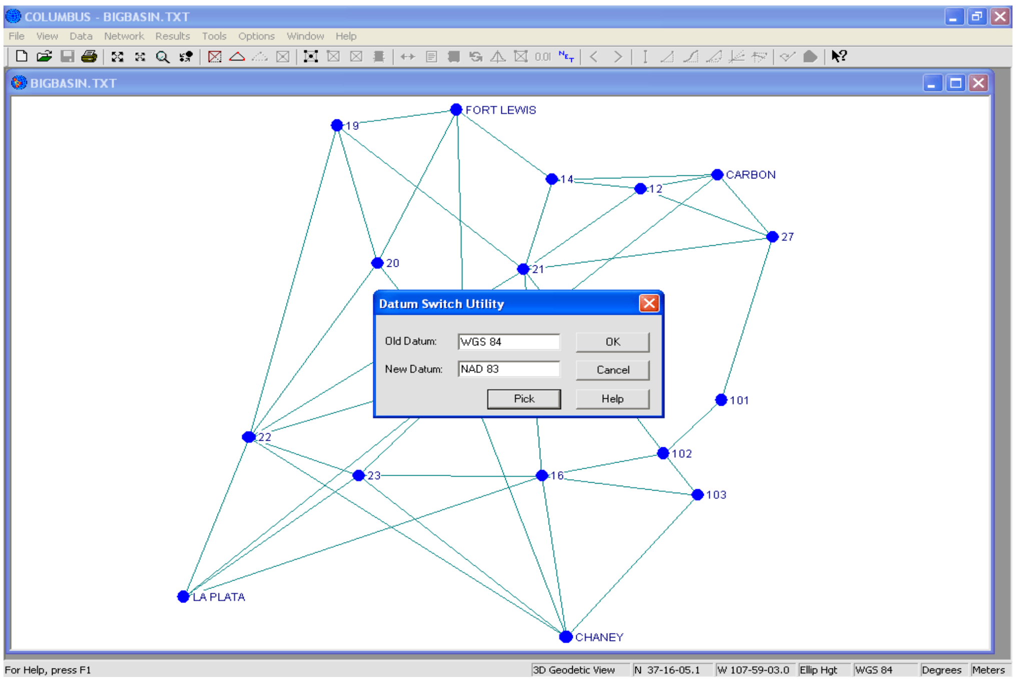
Simply select the station to merge in the left-side list, then select the correct station name in the right-side list. Click on the Combine button and all observations and data will be moved to the station selected in the right-side list. **If the correct station is not shown in the right side list, then simply rename the incorrect station (station 12 in this example) within one of the DATA - STATIONS tabbed grids.**

In the screen above, station 12 would be renamed (and therefore merged) to station 15. All observations referencing station 12 would then reference station 15. This is only a hypothetical example. For the project BIGBASIN.TXT, station 12 and station 15 are completely different points on the ground.

Another way to combine station names is by saving the project to an ASCII (Text) file using the FILE - SAVE or FILE - SAVE AS command. The resulting file can be loaded into a text editor and station name changes can be made using the Search and Replace command (if available in your text editor).

Datum Switch

The DATUM SWITCH tool allows you to switch your internal project data from one datum to another datum. All data within COLUMBUS is associated with a datum. A common mistake users make is to enter data, while the desired datum is not active. If data is currently associated with WGS 84, but needs to be associated with NAD 83, this tool can be used to switch the data to NAD 83. To perform a switch, it is not necessary to have data connected to each datum.



Enter the Old Datum name for the datum your data is currently linked. Enter the New Datum name for the datum your data should be linked. You can either type in the datum names or click on the **DATUM** button after highlighting the applicable Datum name edit box (i.e., Old Datum or New Datum).

Click on the **OK** button and all data linked to each datum will be switched. In the above example, any data linked to WGS 84 will become linked to NAD 83. Any data linked to NAD 83 will become linked to WGS 84.

After switching data from one datum to another, use the FILE - SAVE or FILE - SAVE AS command to save the contents of the project into a new project file. The next time you load this data, the data will be associated with the correct datum.

Note: This tool does NOT transform coordinates from one datum to the other.

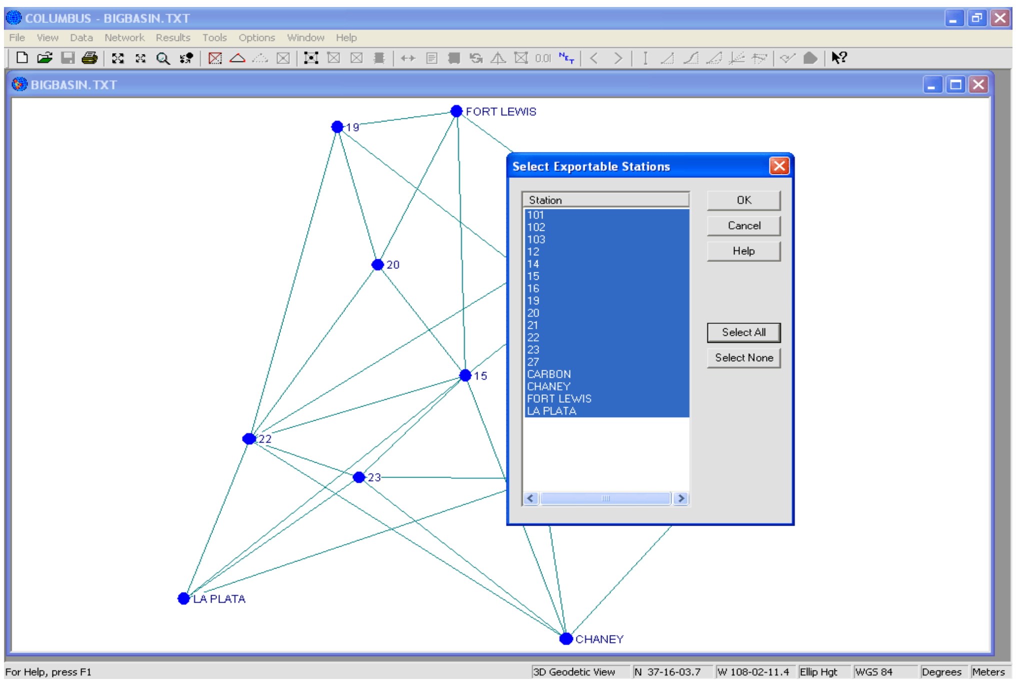
Exporting Station Data

These tools allow you to export coordinate data to an ASCII (Text) data file or to a DXF (drawing exchange format) file. COLUMBUS allows you to export the coordinate results from any computation to a customized data file. This is particularly handy for plotting projects or further processing by third party software systems. **The DXF options allow you to use your preferred coordinate type (State Plane, UTM or Local NEU) when creating the DXF file.**

User-Defined Format

COLUMBUS provides a template in the OPTIONS - EXPORT FILE SETUP - USER DEFINED dialog that allows you to setup which coordinate data types to export. Individual fields (latitude, longitude, X, Y, Z, State Plane north, east, etc.) can be selected and arranged in any order. If you attempt to export a coordinate field which does not exist (for a particular station), COLUMBUS will export the text ###### for that field.

Please Note: *COLUMBUS also supports the automatic creation of comma delimited result files (.CSV) for every report generated by COLUMBUS. These are ASCII (Text) files that contain all data relevant to the report you are generating - not just coordinate data. To activate this feature, see the OPTIONS - REPORT HEADINGS dialog.*



1. Load the BIGBASIN.TXT file using the FILE - OPEN command. This file contains results from a 3D Geodetic Network adjustment referenced throughout this manual. Each station has an adjusted State Plane position. We wish to export the station name and its State Plane north and east coordinate components to an ASCII (Text) data file.

2. Enter the OPTIONS - EXPORT FILE SETUP - USER DEFINED dialog and setup the exporting template for the station name and its State Plane north and east coordinate components. For information on setting up the export template, please see the OPTIONS chapter.

3. Enter the TOOLS - USER DEFINED XPORT dialog. COLUMBUS will present a list of all stations in the project for the active datum. Select the stations to export that have State Plane coordinates (click on the **SELECT ALL** button in this example), then click on the **OK** button.

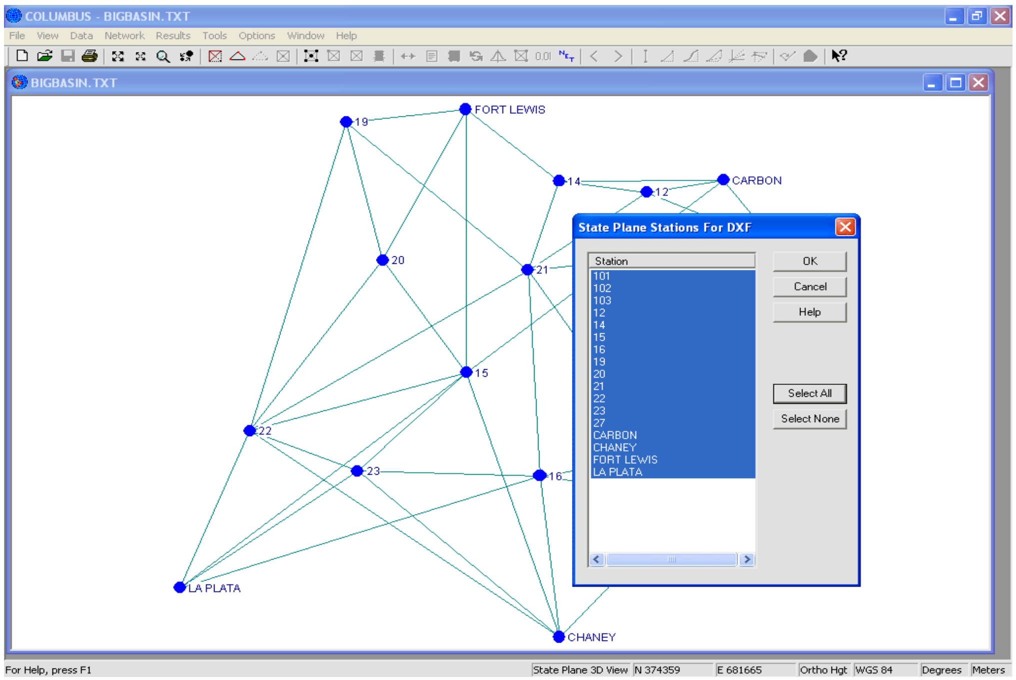
4. COLUMBUS will prompt you for the name of the export file. You can either declare a new file or

append to an existing file.

5. Either print out the resulting ASCII (Text) file or view it through your favorite text editor. This file can then be read by many third party software packages.

DXF Defined Format

This option allows you to export data in the project (stations and observation connections) to a CAD compatible DXF drawing file. All the DXF options described in the OPTIONS chapter are available except error ellipses. These are not available in the TOOLS module (error ellipses are applicable to the creation of a DXF file from the NETWORK - CREATE NETWORK DXF command).



You can create a DXF file from your adjusted (or analyzed) 2D or 3D network in the NETWORK module.

1. Load the BIGBASIN.TXT file using the FILE - OPEN command. Change the view to State Plane. This file contains results from the 3D Geodetic Network adjustment detailed throughout this manual. Each station has an adjusted State Plane position. We wish to export the State Plane station coordinates and connecting observation types into a DXF file for further use in your CAD package.

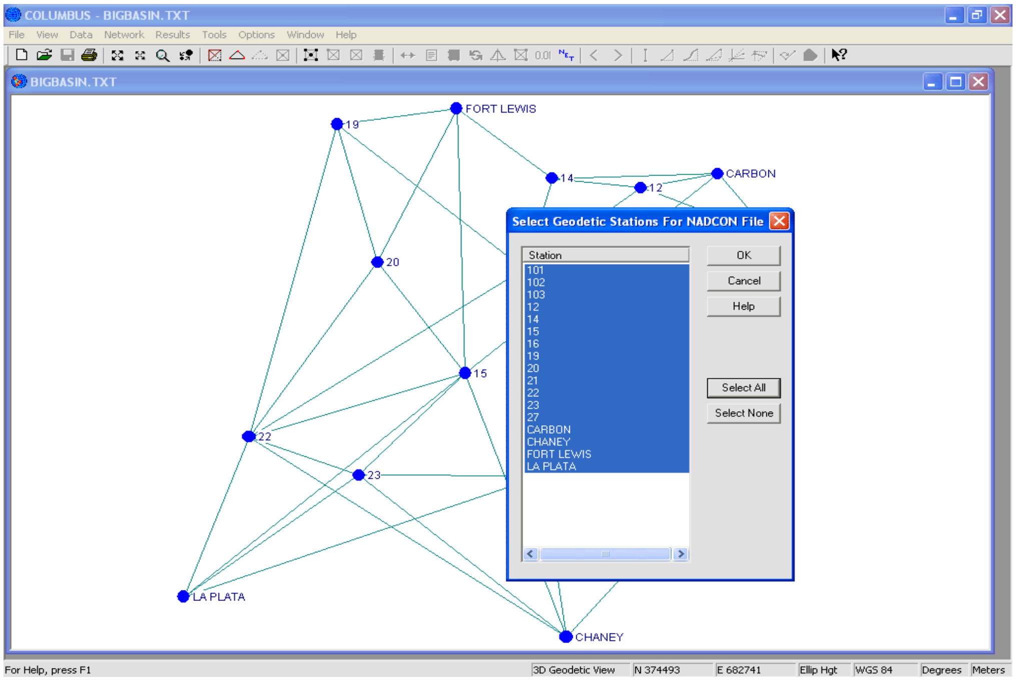
2. Enter the OPTIONS - EXPORT FILE SETUP - DXF dialog and setup the DXF template. For information on setting up the DXF template, please see the OPTIONS chapter.

3. Enter the TOOLS - CREATE DXF FILE dialog. Notice the context is "State Plane" in the dialog title bar. COLUMBUS will gather up all State Plane stations in the project for the active datum. Select the stations to export (click on the **SELECT ALL** button in this example), then click on the **OK** button.

4. COLUMBUS will prompt you for the name of an output DXF file. If your CAD package requires the DXF extension, you must explicitly enter it at this time. The resulting DXF file can then be loaded into your CAD system.

Create NGS NADCON File

This tool allows you to create a NGS NADCON compatible input file. The file format created is Type 2 (DD MM SS.sssss format) for each geodetic station. The resulting file can be loaded directly into the NADCON online program found on the NGS web site.



1. Load the BIGBASIN.TXT file using the FILE - OPEN command. Change the view to 2D or 3D Geodetic.

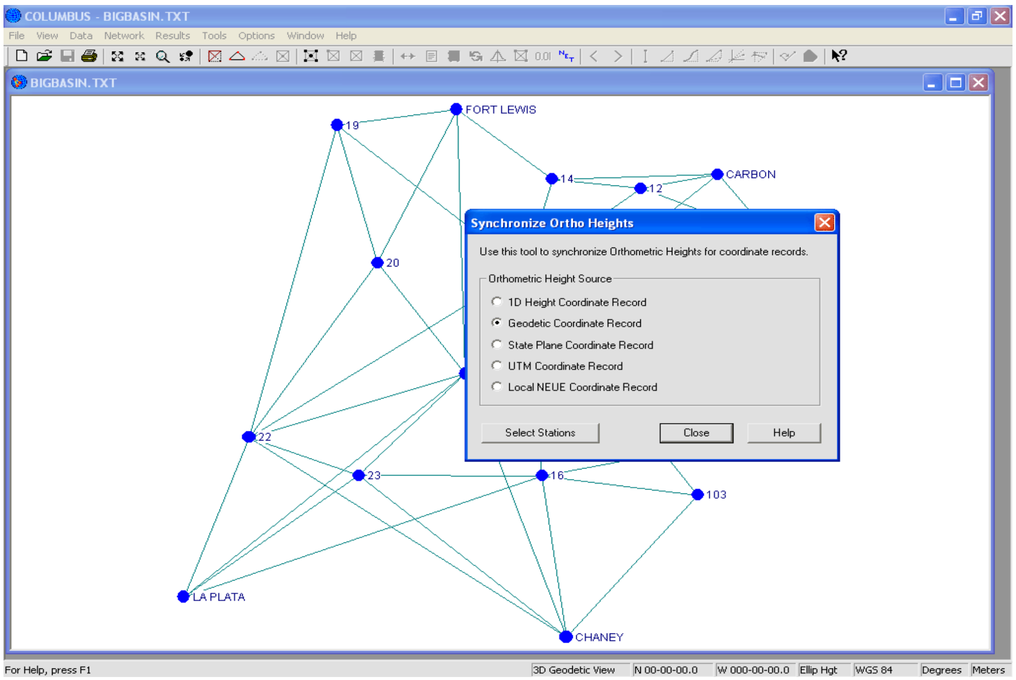
2. Enter the TOOLS - CREATE NGS NADCON FILE dialog. A list of all geodetic stations in the project for the active datum will be displayed. Select the stations to write to the NADCON compatible file (click on the **SELECT ALL** button in this example), then click on the **OK** button.

3. COLUMBUS will prompt you for the name of an output NADCON file. The resulting NADCON file can then be used by the NADCON coordinate conversion program.

Synchronize Ortho Height

The SYNCHRONIZE ORTHO HEIGHT tool allows you to set all Orthometric height fields (for each selected station) to be the same value.

There are five station coordinate types (for each station) that support an orthometric height entry; 1D height coordinate type, geodetic coordinate type, State Plane coordinate type, UTM coordinate type and local NEUE coordinate type.



To set all these coordinate types to the same value (synchronize all orthometric heights for each station), select the Source Orthometric coordinate type, then select the stations to synchronize.

For example, if you select the source height as **1D Height Coordinate**, then select station LA PLATA, all orthometric height fields for station LA PLATA will be set to the current value of the 1D Height field for station LA PLATA. If you had also selected station 20, all orthometric height fields for station 20 would be synchronized to the current 1D Height field for station 20.

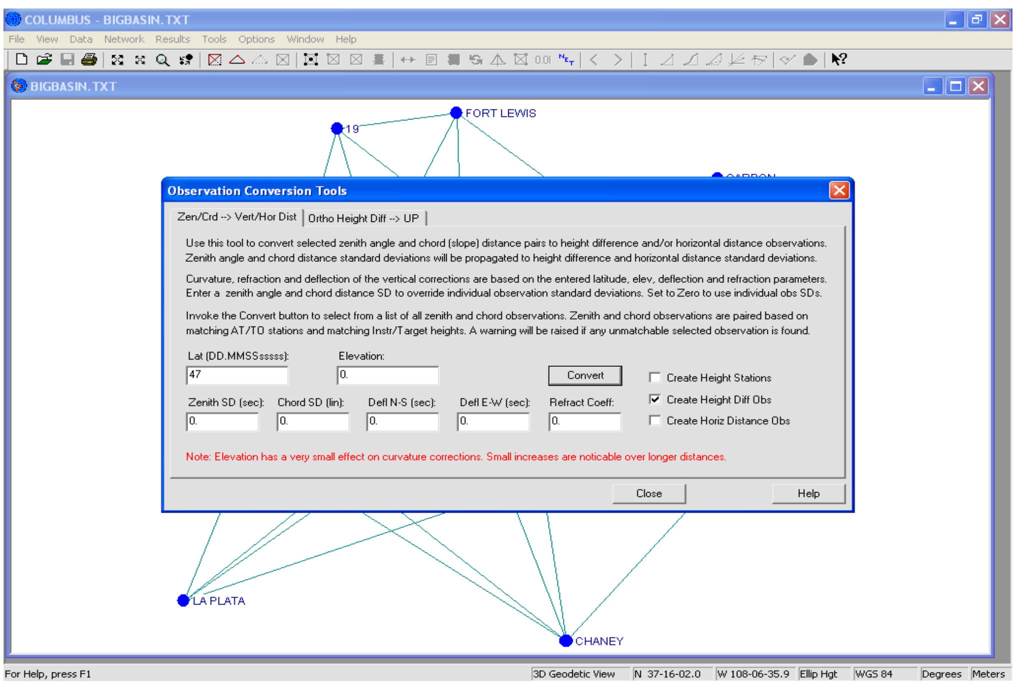
Convert Data

This tool allows you to convert observations from one type to another type. There are times when you may collect enough data for a full 3D geodetic adjustment, but may chose to use the data for a 1D or 2D adjustment instead. This may require converting the observations to a different observation type.

Zenith/Chord to Height Difference/Horizontal Distance

This tool can be used to convert Zenith Angles and Chord (slope) Distances to Height Differences and/or Horizontal Distances. Standard deviations from zenith angles and chord distances are automatically propagated to height difference and horizontal distance standard deviations.

One application for this tool is Trig Leveling. In the field you measure zenith angles and slope distance observations, then use this tool to convert them to 1D height differences for vertical adjustments or traversing.



One approach to trig leveling is to set up at an arbitrary position ('Temp1' for example) between a starting benchmark (e.g., 'AA' with known elevation) and the forward station ('BB'). Using the SAME TARGET HEIGHT at station 'AA' and 'BB', you then measure the zenith angle and slope distance to both 'AA' and 'BB' during the same setup at 'Temp1'. Instrument and target heights are not measured, since we are not interested in the elevation of 'Temp1'. Next, you move the instrument to a new arbitrary position between station 'BB' and the next station ('CC' for example) and repeat the process (measure to 'BB', then to 'CC').

This data can be entered into a COLUMBUS compatible ASCII (Text) input file then loaded into COLUMBUS (or loaded from the sample file TRIGLEVEL.TXT). Below is a sample set of data for a small Trig Leveling project consisting of a loop traverse. The starting and ending station is 'AA'. Station 'AA' has a known elevation of 170.0 U.S. feet. The elevation for station 'BB', 'CC', and 'DD' are to be determined by the survey.

Station 'Temp1', 'Temp2', 'Temp3', and 'Temp4' are the arbitrary instrument setup positions. We are not interested in the elevations of these Temp locations. A Fixed Height target is used on station 'AA', 'BB', 'CC', and 'DD'.

This same data can be found in the demo file: TRIGLEVEL.TXT

```
! ***** BEGIN PROJECT DATA *****
!
!SAMPLE PROJECT FILE FOR THIS SURVEY
!
! The exact datum used is only important if you are measuring long distances, otherwise just about
! any datum will do.
! NAD 83 parameters
$DATUM
 NAD 83
 6378137.000000
 298.257222101

! Linear units in file are in U.S. feet (U, use M if linear units are in meters)
$UNITS
 U
 D
 1

! Opens view in 1D Vertical mode and creates height stations for any stations not defined by
! the $HEIGHT_COMPACT record below.
$STATION_TYPE_FOR_OBS
 1D_VERT

! Station Names can be a maximum of 15 characters in length
! Station Name; Height; Height SD
$HEIGHT_COMPACT; AA; 170.0; 0.00000

! Global standard deviation for Zenith Angles. This value will override any zenith angle standard deviations
! found in the $AZ_COMPACT records below. Remove, comment out, or set to ZERO to disable.
$G_ZEN_SD
3.0

! Global standard deviation for Chord (slope) Distances. This value will override any chord deviation found
! in the $AZ_COMPACT records below. Remove, comment out, or set to ZERO to disable.
$G_CRD_SD
0.010


! AT Station Name; TO Station Name; Azimuth; Azimuth SD; Zenith; Zenith SD;
! Chord (Slope Dist); Chord SD; Instr Hgt; Targ Hgt
$AZ_COMPACT; Temp1; AA; NOOBS; NOOBS; 85.4930; 5.0; 1100.10; 0.015; 0; 0
$AZ_COMPACT; Temp1; BB; NOOBS; NOOBS; 87.1000; 5.0; 1200.30; 0.015; 0; 0
$AZ_COMPACT; Temp2; BB; NOOBS; NOOBS; 86.3015; 5.0; 825.20; 0.015; 0; 0
$AZ_COMPACT; Temp2; CC; NOOBS; NOOBS; 87.4217; 5.0; 965.15; 0.015; 0; 0
$AZ_COMPACT; Temp3; CC; NOOBS; NOOBS; 91.0030; 5.0; 500.10; 0.015; 0; 0
```

$AZ_COMPACT; Temp3; DD; NOOBS; NOOBS; 93.4320; 5.0; 400.10; 0.015; 0; 0
$AZ_COMPACT; Temp4; DD; NOOBS; NOOBS; 89.3030; 5.0; 650.10; 0.015; 0; 0
$AZ_COMPACT; Temp4; AA; NOOBS; NOOBS; 79.3100; 5.0; 304.25; 0.015; 0; 0

! ***** END PROJECT DATA *****

For the above example, the Instrument and Target heights have been set to ZERO. This is due to the fact that a fixed target height was used at station 'AA', 'BB', 'CC', and 'DD'. We don't care about the resulting verticals for the Temp1, Temp2, Temp3 or Temp4 stations, so we do not need their Instrument Heights. The azimuth and azimuth standard deviation have been set to NOOBS (meaning no observation)

If you did not follow this procedure, you would need to provide an Instrument and Target Height for each set of observations (zenith angle and chord distance). For example, You might have begun your survey by setting up on station 'AA', then measured to station 'BB', then moving forward to 'BB' and measuring to station 'CC', etc. In this scenario, instrument an target heights for all setups must be carefully measured and entered (not set to zero) into $AZ_COMPACT records.

Converting Observations

After loading your observations into COLUMBUS, enter the TOOLS - CONVERT OBSERVATIONS - ZenCrd --> Vert/Hor Dist Tabbed dialog.

Enter the approximate latitude for the project area (47.0 for this example). The Latitude is used to accurately determine corrections due to curvature and deflection of the vertical (if average deflection values are provided). An approximate value (+- several minutes) will suffice for most projects.

For long distances, different elevations will influence the results. For most projects, a value of 0.0 is fine.

If you want zenith observations corrected for deflection of the vertical, enter the deflection values in seconds. Leaving them set to zero results in no correction. Normally, you will only do this when trying to compute ellipsoidal heights.

If you wish to correct the zenith angle for refraction, enter the zenith angle refraction coefficient. For information on how refraction is calculated from this coefficient, please refer to the Options chapter of the COLUMBUS user manual.

If you want to provide a common Standard Deviation for all zenith angles and/or chord distances (different from what you provided in your input data or have globally defaulted in COLUMBUS) then supply a Zenith SD and/or Chord SD. The measured observation SD's (chord and zenith angle) are propagated to the equivalent Hgt Diff and Hor Dist SD's during computation.

Check the "Create Height Diff Obs" checkbox. This Tells COLUMBUS to create this new observation type from the measured observations. Click on the Convert Button and COLUMBUS will present you with a list of all the Zenith Angle and Chord Distances for the current active Datum in the project.

Note: Your active view should be "1D Vertical". No observation lines (zenith and chord) are shown, because these are not 1D observations types.

Select the observations to convert, then click the OK Button. The Height Difference observations will be created and added to the current project.

Note: The computed height difference observations are now visible in the view. A height difference observation is a valid 1D observation type.

At this point you are now ready to use the new height difference observations for a 1D vertical adjustment or a 1D vertical traverse.

Adjustment

To perform the adjustment, using the observations derived from the data set above, do the following:

1. Enter the **Select Network Stations** dialog and select all the stations to be included in the adjustment.

2. Enter the **Select Fixed Stations** dialog and select station 'AA' to be fixed in 1D.

3. Enter the **Select Obs** dialog and select ALL height difference observations.

4. Click on the **Start Adjustment** toolbar icon.

5. View the adjusted results by entering the various Results views. NOTE: keep the Network Processing Summary view open.

The adjusted height (elevation) for station 'CC' should be **137.4376 U.S. Feet.**

If U.S. Feet is not the active linear units setting, simply enter the Options - Units dialog and change the linear units to U.S. Feet. The adjusted coordinate view will automatically be updated.

Final Notes:

1. The results above are based on the following input values when converting the observations to height difference.

Latitude:	47.0000 (positive north)	
Elevation:	0.0	
Zenith SD:	0.0	(ignore and use those from input file)
Chord SD:	0.0	(ignore and use those from input file)
Defl N-S	0.0	(apply no correction)
Defl E-W	0.0	(apply no correction)
Refrac Coeff	0.0	(apply no correction)

2. Computed height difference observations are automatically corrected for curvature (based on the underlying geodetic model).

3. The computed height difference observations are automatically added to your current project. They have not been saved to disk. To save them to disk with the current project data, invoke the FILE - SAVE or FILE - SAVE AS command.

4. The orginal Zenith and Chord Distances are still in your project.

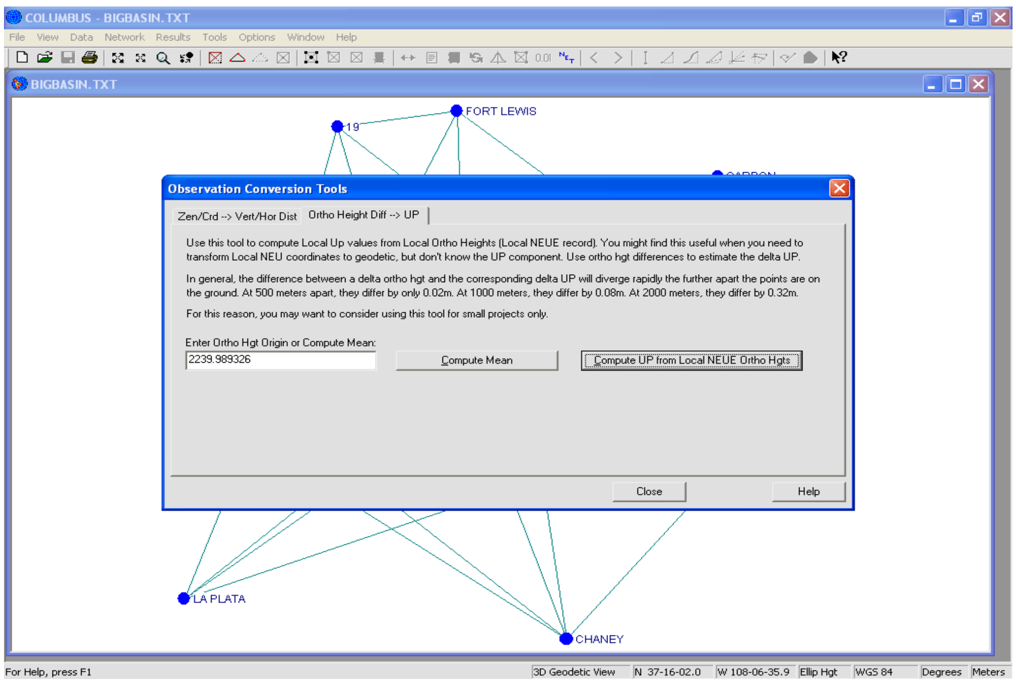
5. To quickly delete the newly added height difference observations (perhaps you want to try adding a refraction correction), enter the Data - Delete Observation dialog, sort the observations by type, then select the observations to delete. Perform the observation conversion again.

Orthometric Height Difference to UP

These tool allows you to convert an orthometric height difference (between two stations) to UP coordinate components for each station. If you have two or more Local NEUE stations, but don't have (or know) the UP component for some of these stations, you can compute the UP component.

For example:

Suppose you have three Local NEUE stations and you need to convert them to 3D geodetic coordinates. You don't have an UP value for any of these stations, but you do have an elevation for each. To transform the Local NEU coordinates to 3D geodetic, you need a Local Horizon Plane N, E and UP value for each station.



To generate the UP value for each Local NEUE station, do the following:

Select one of these stations to be the origin for the Local NEU system (station AA for example). This is usually the station that will be the Local NEU origin when using the TOOLS - TRANSFORMATION - LOCAL NEU --> GEODETIC tool. Invoke the **Compute Mean** button and select station AA. The orthometric height for this station will be displayed. Invoke the **Compute UP from Local NEUE Ortho Hgts** button and select all the Local NEUE stations for which you want to compute an UP. Include station AA in this selection. Select OK and UP values will be computed for all stations by subtracting the elevation of station AA from each station selected. You are now ready to transform your Local NEU coordinate to geodetic using station AA as the origin.

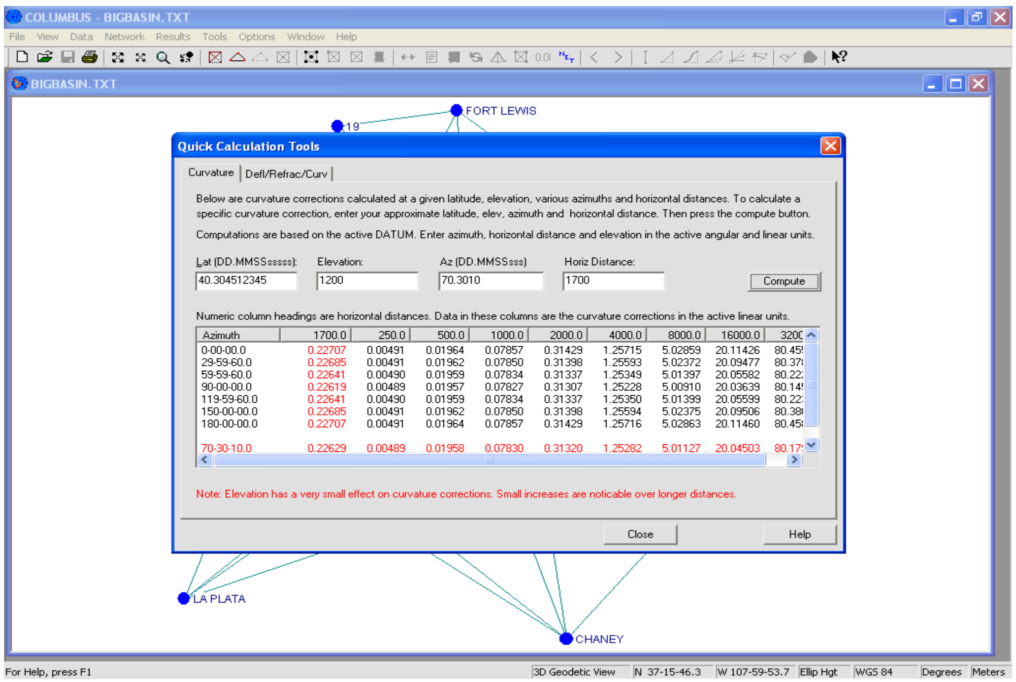
Note: This method will only provide an accurate UP component for stations close together (a few hundred meters or less). However, for less accurate UP components, you can still generate accurate 2D geodetic coordinates.

Quick Calculations

Curvature Correction

Enter your approximate latitude, elevation, azimuth and horizontal distance. Click on the Compute Button to calculate the curvature correction. The horizontal distance is the value that would be computed by multiplying the SINE of the zenith angle by the slope distance. It is a tangent plane (local horizon) distance.

This Quick Calculation is based on the Active Datum. Results are presented in a tabular format to give you curvature corrections based on your data as well as other azimuth and horizontal distance data. Your results will be displayed in a different color.



Example:

Datum: WGS 84
Lat: 40-30-45.12345 (entered as 40.304512345)
Elev: 1200.0 meters
Azimuth 70-30-10 (entered as 70.3010)
Hor Dist: 1700.0 meters
Curvature correction: 0.22629m

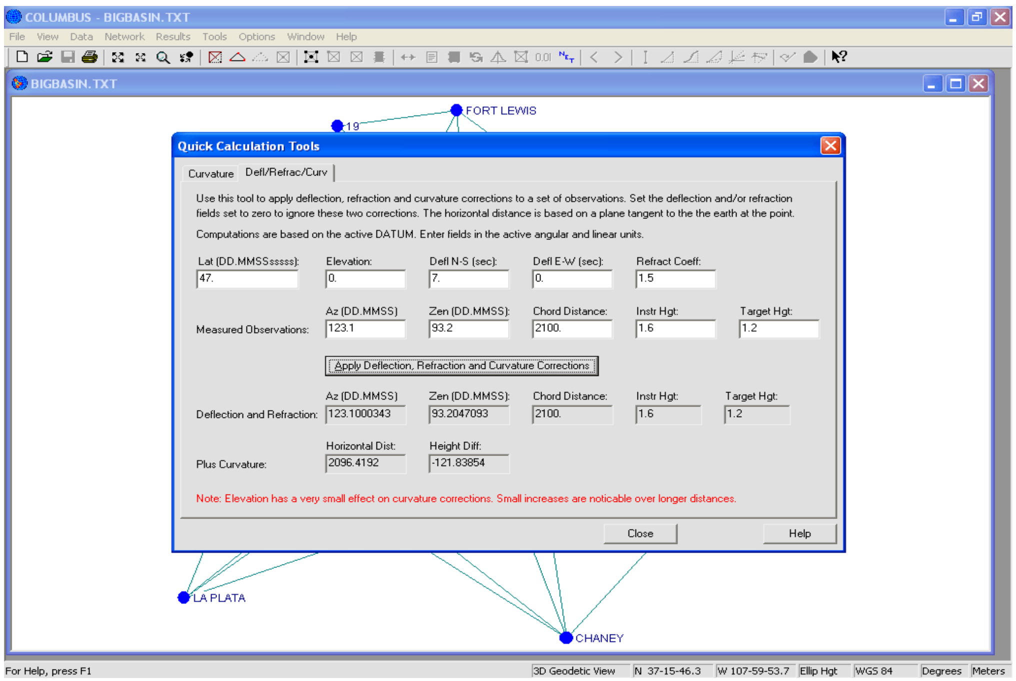
Try altering the latitude, elevation and azimuth and notice any small changes.

Deflection, Refraction and Curvature Correction

Enter your approximate latitude, elevation, vertical deflections (in seconds), and the refraction coefficient. If you don't want to correct your observations for deflection and/or refraction, leave these fields set to zero.

Enter the azimuth, zenith angle, chord (slope) distance, instrument and target heights in the active angular and linear units. The azimuth value can be very approximate. Curvature varies slightly with azimuth, but for most conventional measurements it is not much of a factor (unless the slope distances are long).

Click on the **Apply Deflection, Refraction...** Button to compute the corrected observations (based on deflection and refraction) and the resulting Horizontal Distance and Height Difference.



The Horizontal Distance is the distance on a plane tangent to the earth's surface at the AT station location. It is a local horizon distance.

The Height Difference includes the correction for curvature, corrected observations (due to deflections and refraction if applicable), and the instrument/target heights. It is the mark to mark height difference between the AT station and the hypothetical TO station.