Transforming Grid Coordinates to Ground Coordinates w/ Locus Processor and Ashtech Solutions

This document outlines the procedure for computing ground coordinates from grid coordinates based on two separate scenarios. In the first scenario, a ground based coordinates system does not exist in the project area, i.e. no points exist with ground based coordinates established with conventional surveying equipment. In the second scenario, a ground based coordinate system already exists in the project area and at least two of the existing points have been occupied with GPS. Neither scenario requires that known control from a defined grid system (State Plane for example) be included in the survey. The grid coordinates of the grid to ground conversion can be based on a GPS derived autonomous position of one of the points in the project (usually within 25 meters of the true position). The process for computing ground coordinates from grid coordinates for all points in the project will be outlined below for each scenario separately.

The procedures outlined in this document are specific to Locus Processor and Ashtech Solutions v1.2 or higher. If you are running an earlier version, you will need to upgrade.

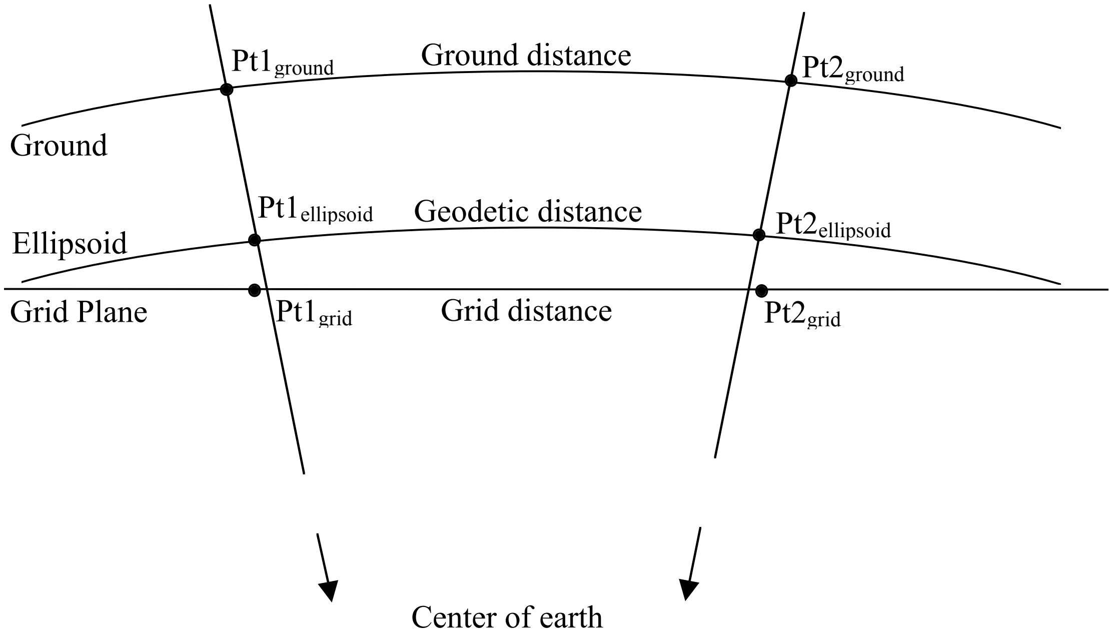
Problem Statement

Locus Processor and Ashtech Solutions allows the user to produce 2-dimensional grid coordinates for surveyed points. A problem arises when a user attempts to utilize these coordinates in the field with conventional surveying equipment. Coordinates computed from a traverse between the points do not correspond with the grid coordinates computed for the points. The problem is due to a scale difference between the grid distances between points and their corresponding ground distances measured. To overcome this problem, grid coordinates can be converted to ground coordinates for all points. With ground coordinates, the scale problem is eliminated and traversing results will be consistent with point coordinates.

Background Information

Grid distance vs Geodetic distance vs Ground distance

The ground distance and grid distance between two points differ in length due to the fact that these distances are determined on different types of surfaces at different distances from the center of the earth. The following diagram helps to illustrate this concept.



In the above diagram can be seen three different surfaces representing the earth in the location of points Pt1 and Pt2; the Ground, the Ellipsoid, and the Grid (Mapping) Plane. On each surface is represented the position of Pt1 and Pt2.

As can be visually seen in the diagram, whenever points Pt1 and Pt2 are 'moved' (transformed) from one surface to another, the distance between the two points change, i.e. the scale changes. When 'moving' points from the grid plane to the ground, one must first pass through the ellipsoid. Therefore, 'moving' points from grid to ground involves first a 'move' to the ellipsoid and then a 'move' to the ground. Each 'move' includes it's own scale change.

The scale value that defines the difference in distance between two points on the grid plane (grid distance) and those same two points on the ellipsoid (geodetic distance) is called the Scale Factor (SF). The scale difference is caused by 'moving' from a flat surface (Grid Plane) to a curved surface (Ellipsoid). Using the Scale Factor, one can determine a geodetic distance from a grid distance, or visa-versa, by using the following relationship:

Geodetic distance = Grid distance / SF

The scale value that defines the difference in distance between two points on the ellipsoid (geodetic distance) and those same two points on the ground (ground distance) is called the Elevation Factor (EF). Scale changes between these two surfaces because the two surfaces are different distances from the center of the earth. Using the Elevation Factor, one can determine a ground distance from a geodetic distance, or visa-versa, by using the following relationship:

Ground distance = Geodetic distance / EF

The most common 'move' is between points on the grid plane and points on the ground. Rather than using a two step process to perform this 'move' (grid to ellipsoid then ellipsoid to ground), it is possible to determine one scale value that will allow a direct 'move' from grid to ground.

This scale value is called the Combination Factor (CF). The Combination Factor is the product of the Scale Factor and the Elevation Factor:

$$CF = SF \times EF$$

Using the Combination Factor, one can determine the ground distance from a grid distance, or visa-versa, by using the following relationship:

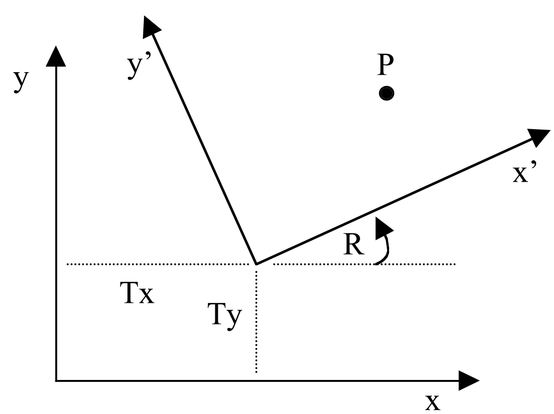
Ground distance = Grid distance / CF

Solution

LOCUS Processor includes a feature that allows the user to define a Local Grid system. This is the feature we will be using to transform grid coordinates to ground coordinates.

The Local Grid feature allows a user to transform from one 2-dimensional coordinate system to another. It utilizes a 4-parameter transformation to perform this task.. The following diagram illustrates three of the four parameters.

The diagram illustrates the relationship between the (x,y) coordinate system and the (x',y') coordinate system. Imagine that the (x,y) coordinate system produces grid coordinates and the (x',y') coordinate system produces ground coordinates. Let's assume you have the coordinates of point P in the (x,y) coordinate system (Grid). To transform these coordinates to the (x',y') coordinate system (ground), you would need to translate the origin of the (x,y) coordinate system by Tx and Ty, and then rotate by the rotation value R. The final parameter, scale (S) now comes into play. After the coordinates are translated and rotated, they are then divided by S to produce the coordinates of point P in the (x',y') coordinate system.



Scenario 1: No existing ground based coordinate system

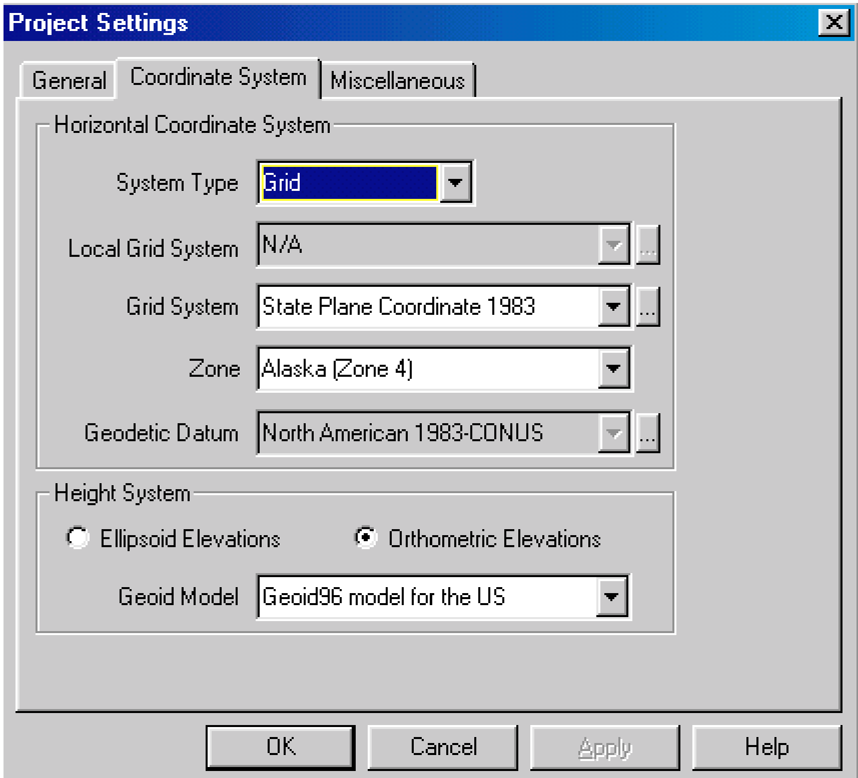
In order to utilize the Local Grid feature to transform all grid coordinates to ground coordinates, we need to have two points that have both grid and ground coordinates. Using the grid coordinates of two points and the Combination Factor (CF) defined above, we will be able to compute the ground coordinates for these two points. Then, using the Local Grid feature, the transformation parameters relating the grid coordinates to ground coordinates will be computed. Finally, these transformation parameters will be applied to all points in the project to produce ground coordinates. The steps for performing this task are outlined below.

Scenario 2: Existing ground based coordinate system

Just as in scenario 1 above, we need at least two points with both grid and ground coordinates to utilize the Local Grid feature to transform all grid coordinates to ground coordinates. Therefore, at least two of the existing points with ground coordinates must have been observed with GPS. Once processed, these points can be used to compute the transformation parameters relating the grid coordinates to the ground coordinates. These transformation parameters will then be applied to all points in the project to produce ground coordinates. The steps for performing this task are also outlined below.

Procedure for Scenario 1: No existing ground based coordinate system
The first task is to process and adjust all data.

1. Load and process all of your data in LOCUS Processor.
2. Perform a minimal constraint adjustment (holding any one point fixed) to ensure the data fits well within itself.
3. If you have not already done so, define a Grid System for your project. You define a Grid System from the Coordinate System tab in the Project Settings dialog box.



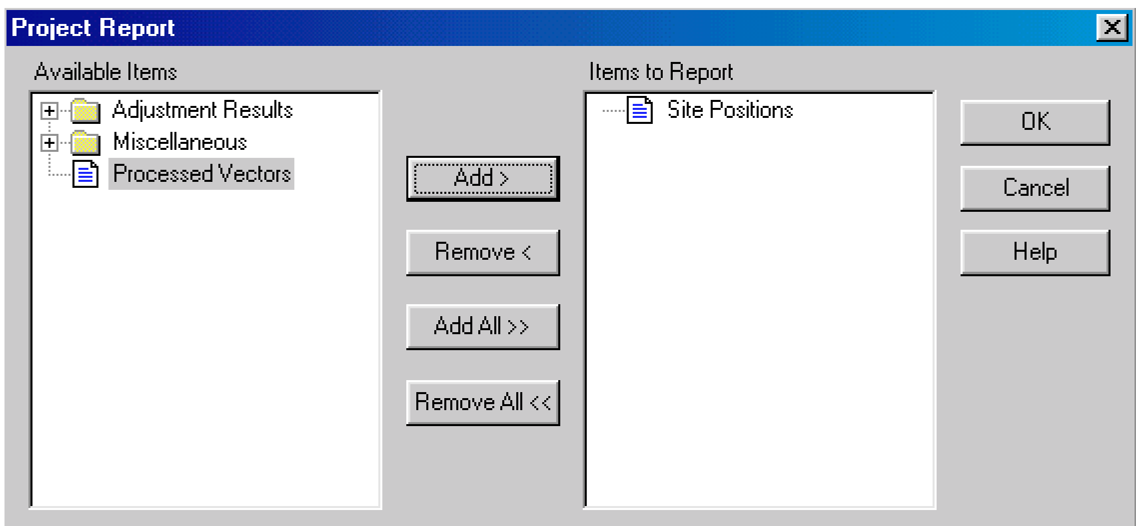
In this example, my Grid System is State Plane Coordinates 1983, Alaska Zone 4. Select which ever Grid System that pertains to your area. Once you have selected the Grid System, press OK to close the dialog box. All of your site positions in your project will have Alaska Zone 4 State Plane Coordinates.

Note: It is not necessary to tie your project to an existing control point with known grid coordinates, i.e. State Plane coordinates for example. Without a known control point, the software will compute grid coordinates based on assumed coordinates at one point (GPS derived autonomous position). All points in the project will be assigned grid coordinates consistent with the assumed coordinate held fixed. This is sufficient for the transformation process defined here. Be aware though that the grid coordinates based on this assumed coordinate will not be consistant with other grid coordinates outside of this project. In other words, if using an assumed coordinate for the bases of the grid system, the transformation from grid to ground will only be good for this specific project. If another project is executed in the same area based again on an assumed coordinate, the transformation process defined here must be followed again. Alternatively, if a control points with known grid coordinates were incorporated into the project, the computed transformation between grid and ground would be consistant for all projects performed in the same area.

Now we will calculate our Combination Factor.

4. Next you must compute an average Combination Factor for your project area. You determine the average Combination Factor by first determining the average Scale Factor and average Elevation Factor from all points in the project area, and then multiplying these averages together to get the average Combination Factor.

   The Scale Factor and Elevation Factor of each point in your projection can be found in the Site Positions Project Report. The Site Positions Project Report can be accessed from the Project Report dialog box.



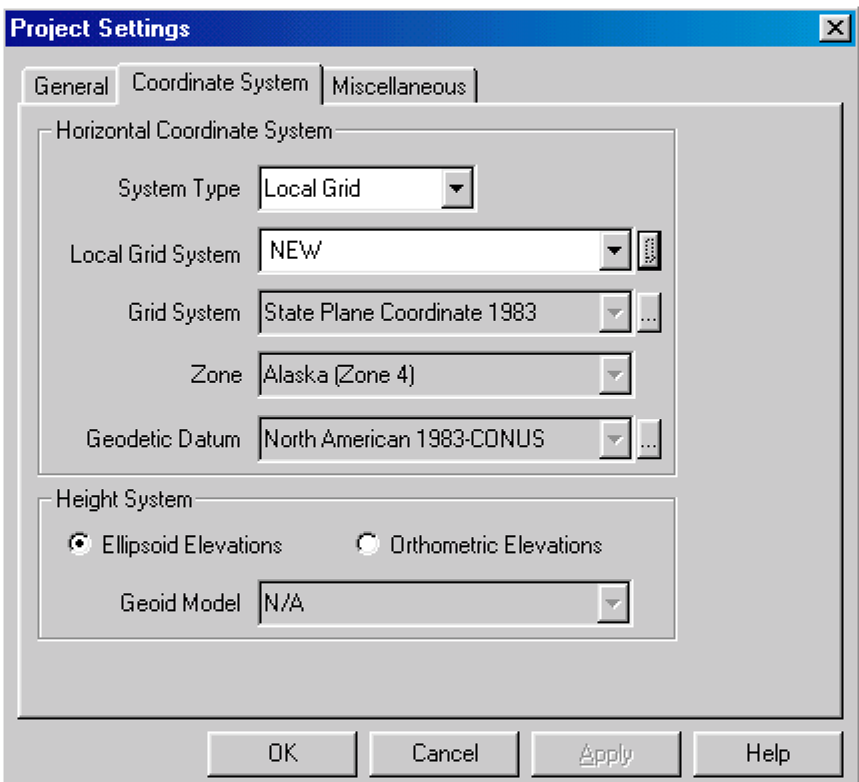
   Add Site Positions to the Items to Report list and press OK. You will then see a report containing site positions. At the bottom of the report, you will find the Scale Factor and Elevation Factor for each point.

	Site ID	Site Name	Convergence	Scale Factor	Elevation Factor
1	**0469**	**SPIKE**	1 25.481	1.000006	0.99995299
2	**0506**	**SPIKE**	1 25.202	1.000005	0.99995037
3	**0312**	**SPIKE**	1 25.302	1.000005	0.99994995
4	**0350**	**LOF-3**	1 24.888	1.000004	0.99994614

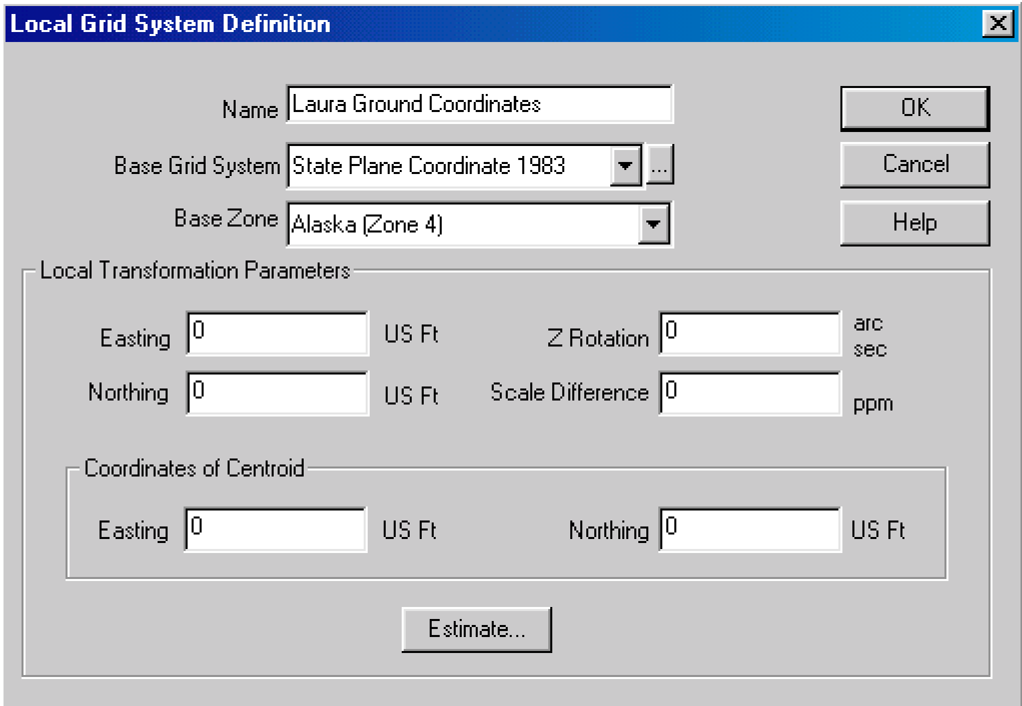
In this example, I would calculate my average Scale Factor by taking the average of the Scale Factor for point 0469 and point 0350 since these two Scale Factors represent the extremes for the project. The average Scale Factor becomes 1.000005. For the average Elevation Factor, I would compute the average of the Elevation Factors for points 0469 and 0350 again. The average Elevation Factor becomes 0.99994956. From these two average values, I calculate my average Combination Factor by multiplying together the average Scale Factor and average Elevation Factor. In this example, my average Combination Factor is 0.99995456. This value defines the scale difference between a grid distance and a ground distance for any two points in the project area.

We will now define a Local Grid system that will transform grid coordinates to ground coordinates.

5. From the Project Settings dialog box, Coordinate System tab, select Local Grid as your System Type, NEW as the Local Grid System, and then press ... to define a new local grid system.

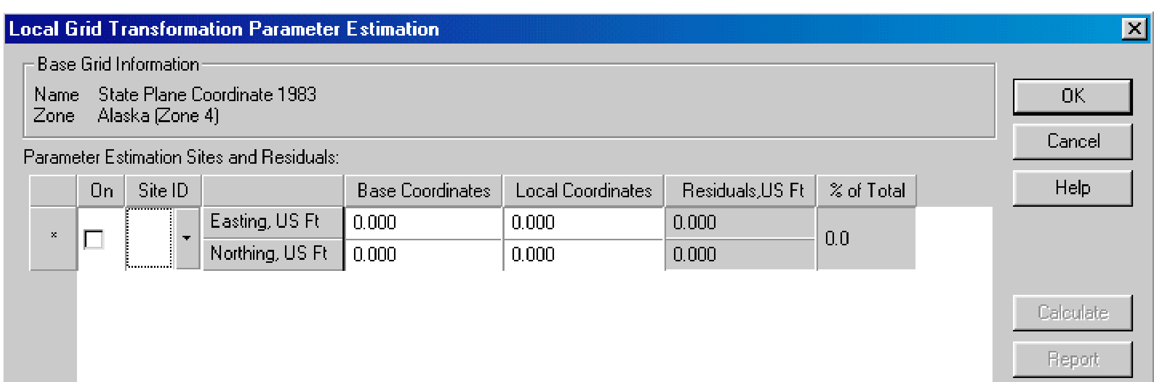


6. The Local Grid System dialog box is now on your screen.



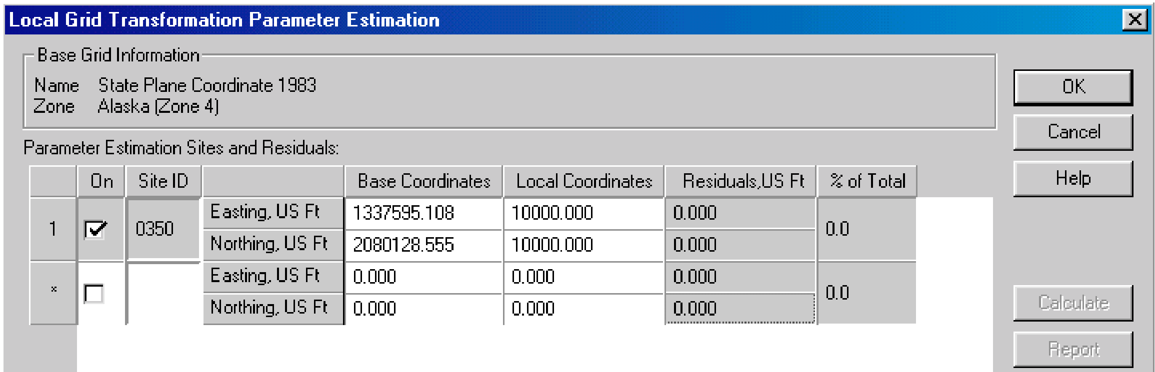
Enter the local grid name in the editable field called Name. The Base Grid System and Base Zone should be the same grid system and zone you defined in step 3 above. Press Estimate… to define the transformation parameters between your new local grid system and the base grid system.

7. The Local Grid Transformation Parameter Estimation dialog box is now on your screen. Now you will calculate the parameters that define the relationship between your base grid system and your new ground system.



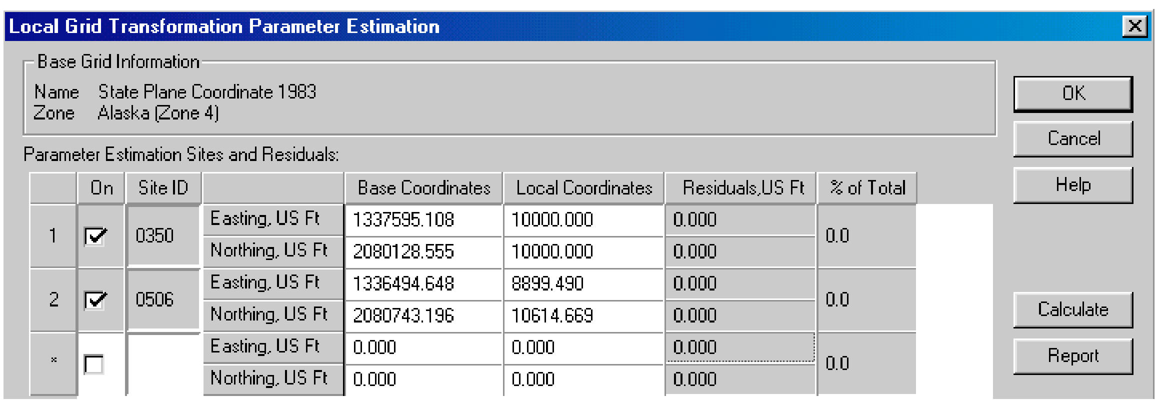
a. Identify any existing project point as the origin of your local grid (ground) coordinate system. Add this point to the Local Grid Transformation Parameter Estimation dialog box by pressing  in the Site ID column and selecting the Site ID for this point.

b. Your selected local grid origin point will appear with coordinates in the Base Coordinate column and 0s in the Local Coordinates column. The Base Coordinates are the grid coordinates of this point in the grid system you chose as the base.



Enter ground coordinates for your origin point in the Local Coordinates column. These can be any values you wish for this point. You may even leave them as 0s.

c. Select a second project point. Do not select a point that is close to the origin point you first selected. Your selected point will appear with base grid coordinates in the Base Coordinates column and 0s in the Local Coordinates column.



You must now calculate the ground coordinates for the second point and enter them in the Local Coordinates column. The ground coordinates are calculated in the following manner:

- Using the grid coordinates found in the Base Coordinates column, compute the grid distance in Northing and Easting between the second point (pt2) and the origin in the following manner:

$$\text{Delta } N_{grid} = \text{Base } N_{pt2} - \text{Base } N_{origin}$$

$$\text{Delta } E_{grid} = \text{Base } E_{pt2} - \text{Base } E_{origin}$$

- Using the average Combination Factor (CF) calculated earlier, compute the ground distance in Northing and Easting between the second point (pt2) and the origin in the following manner:

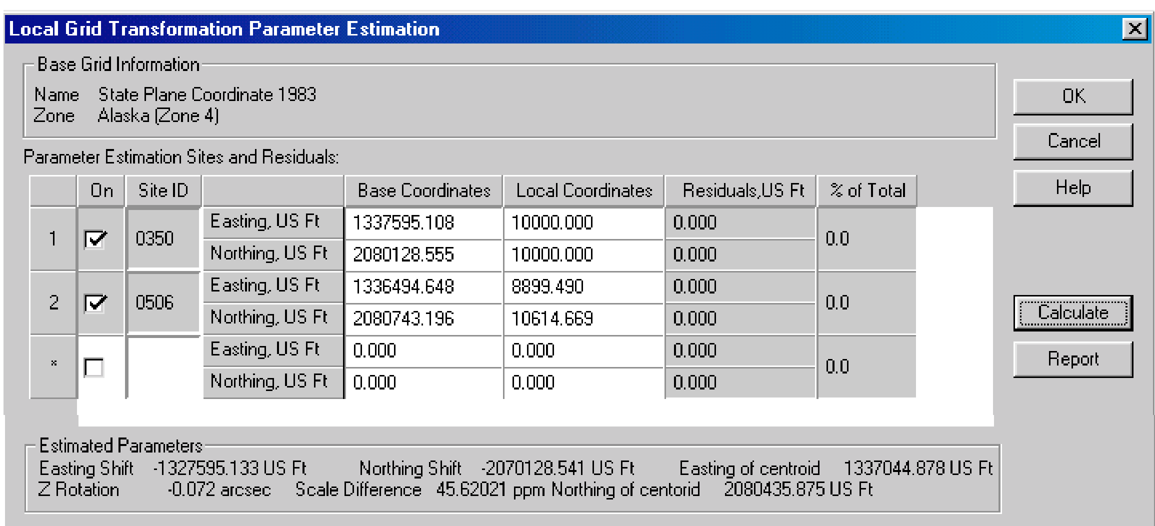
$$\text{Delta } N_{ground} = \text{Delta } N_{grid} / CF$$
$$\text{Delta } E_{ground} = \text{Delta } E_{grid} / CF$$

- Using the ground distances in Northing and Easting between the second point (pt2) and the origin, compute the local (ground) coordinates of the second point (pt2) in the following manner:

$$\text{Local } N_{pt2} = \text{Local } N_{origin} + \text{Delta } N_{ground}$$
$$\text{Local } E_{pt2} = \text{Local } E_{origin} + \text{Delta } E_{ground}$$

Enter these ground coordinates for the second point in the Local Coordinates column of the Local Grid Transformation Parameter Estimation dialog box.

d. You now have two points listed that contain coordinates in both the base grid system and your new ground system. Using these two points, we will now calculate the transformation parameters that relate these two systems.

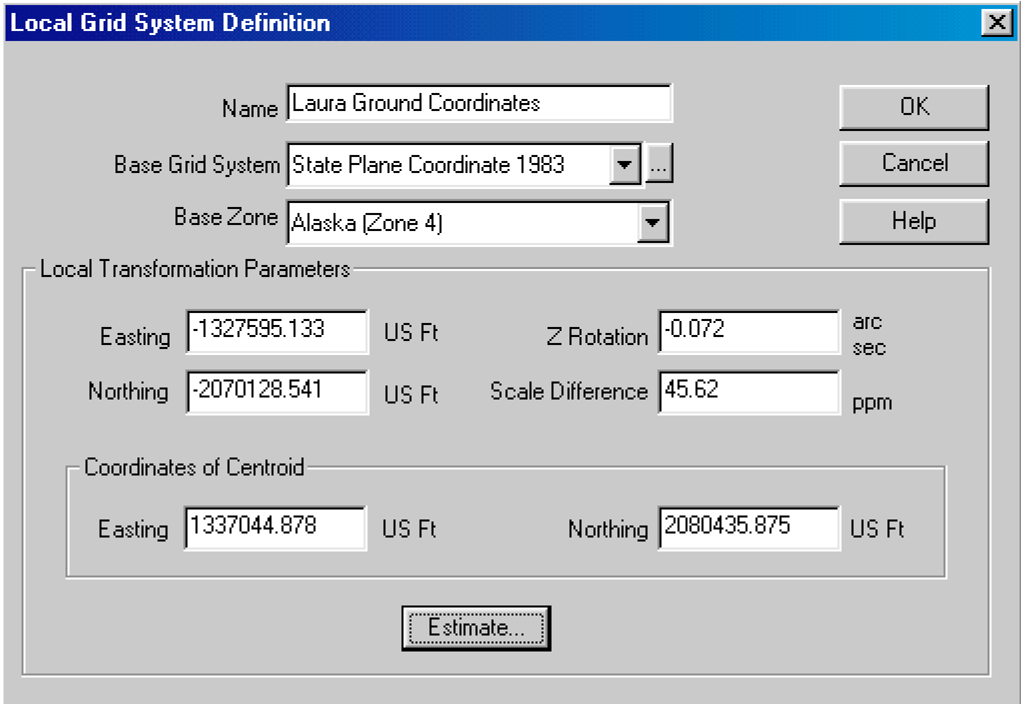


	On	Site ID		Base Coordinates	Local Coordinates	Residuals,US Ft	% of Total
1	☑	0350	Easting, US Ft	1337595.108	10000.000	0.000	0.0
			Northing, US Ft	2080128.555	10000.000	0.000	
2	☑	0506	Easting, US Ft	1336494.648	8899.490	0.000	0.0
			Northing, US Ft	2080743.196	10614.669	0.000	
*	☐		Easting, US Ft	0.000	0.000	0.000	0.0
			Northing, US Ft	0.000	0.000	0.000	

Press the Calculate button to compute the transformation parameters. The computed parameters will appear at the bottom of the dialog box.

Press OK to close the Local Grid Transformation Parameter Estimation dialog box.

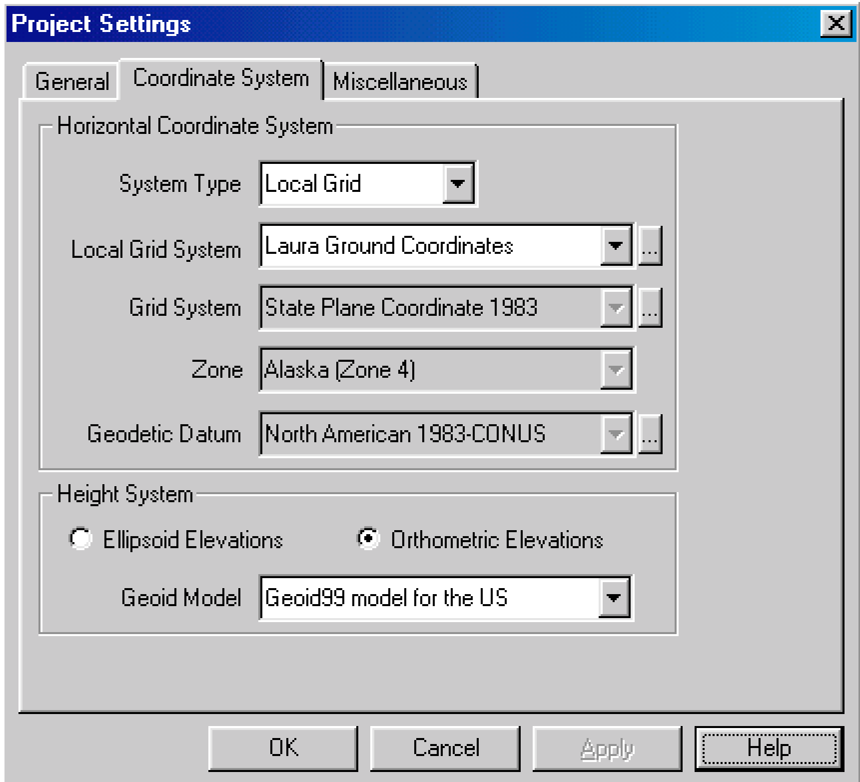
8. The Local Grid System Definition dialog box will have returned to your screen.



The computed transformation parameters will appear under Local Transformation Parameters.

Press OK to accept these parameters.

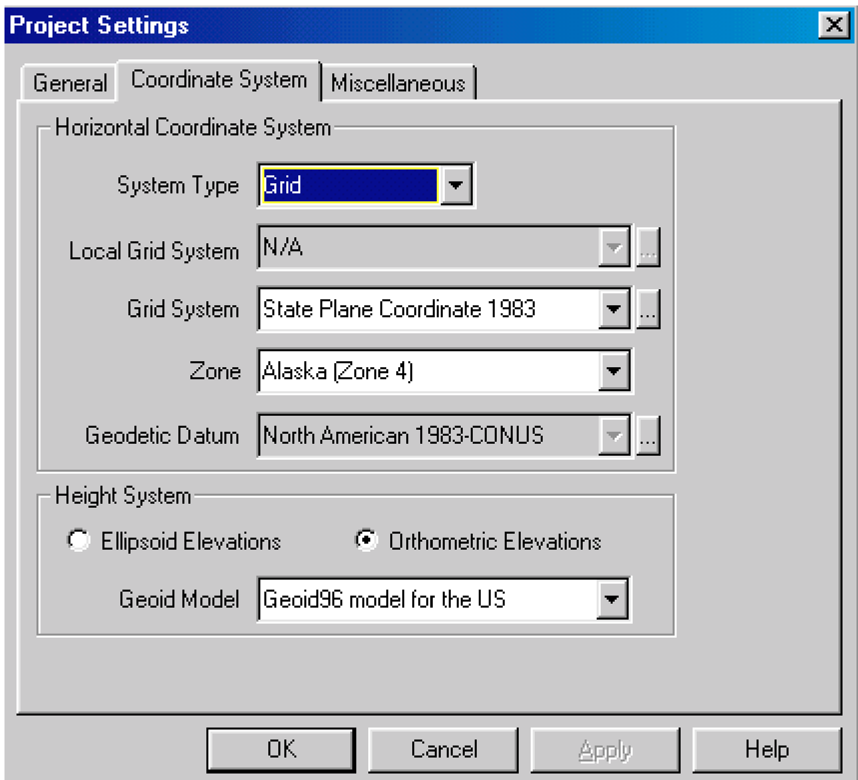
9. The Project Settings dialog box will have returned to your screen.



Your local grid (ground) coordinates system is now defined. Press OK to assign this new ground based coordinate system to all points in the project.

Procedure for Scenario 2: Existing ground based coordinate system
The first task is to process and adjust all data.

1. Load and process all of your data in LOCUS Processor.
2. Perform a minimal constraint adjustment (holding any one point fixed) to ensure the data fits will within itself.
3. If you have not already done so, define a Grid System for your project. You define a Grid System from the Coordinate System tab in the Project Settings dialog box.

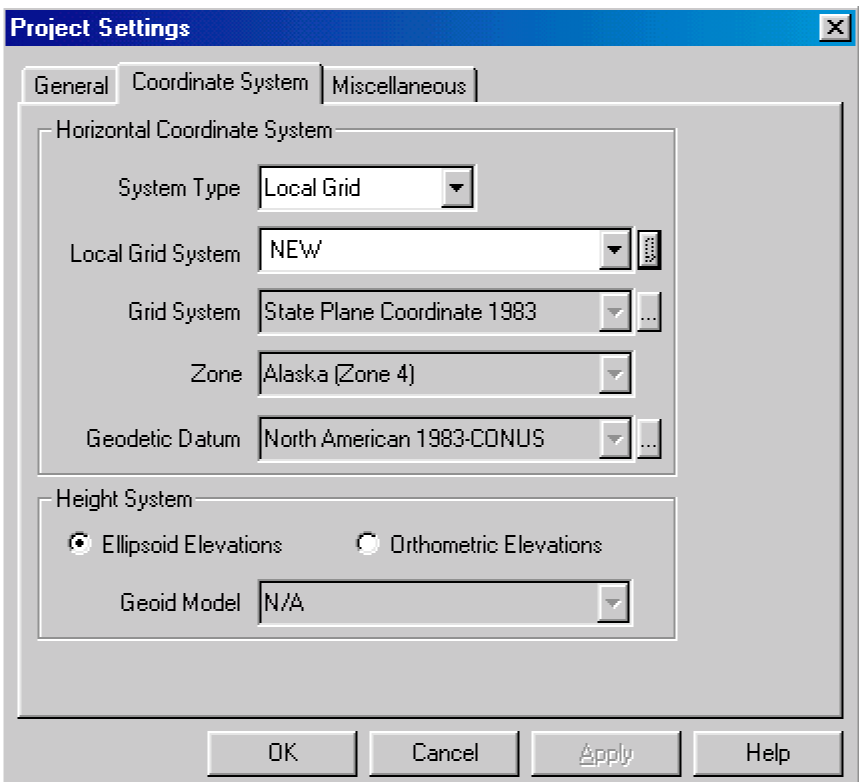


In this example, my Grid System is State Plane Coordinates 1983, Alaska Zone 4. Select which ever Grid System that pertains to your area. Once you have selected the Grid System, press OK to close the dialog box. All of your site positions in your project will have Alaska Zone 4 State Plane Coordinates.

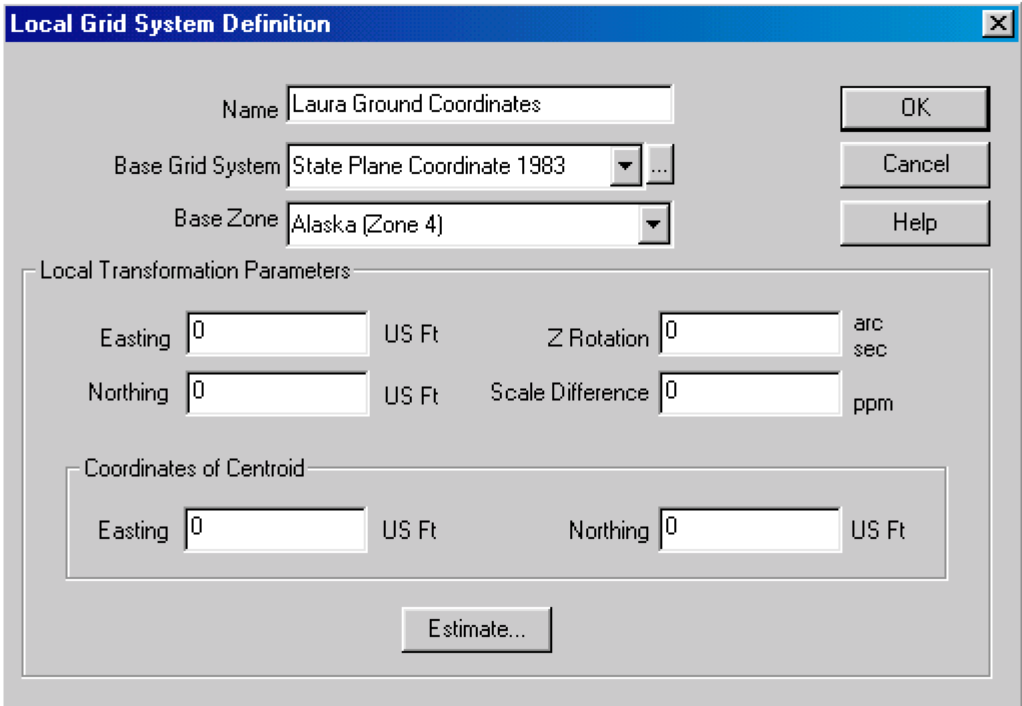
Note: It is not necessary to tie your project to an existing control point with known grid coordinates, i.e. State Plane coordinates for example. Without a known control point, the software will compute grid coordinates based on assumed coordinates at one point (GPS derived autonomous position). All points in the project will be assigned grid coordinates consistent with the assumed coordinate held fixed. This is sufficient for the transformation process defined here. Be aware though that the grid coordinates based on this assumed coordinate will not be consistant with other grid coordinates outside of this project. In other words, if using an assumed coordinate for the bases of the grid system, the transformation from grid to ground will only be good for this specific project. If another project is executed in the same area based again on an assumed coordinate, the transformation process defined here must be followed again. Alternatively, if a control points with known grid coordinates were incorporated into the project, the computed transformation between grid and ground would be consistant for all projects performed in the same area.

We will now define a Local Grid system that will transform grid coordinates to ground coordinates.

4. From the Project Settings dialog box, Coordinate System tab, select Local Grid as your System Type, NEW as the Local Grid System, and then press ... to define a new local grid system.

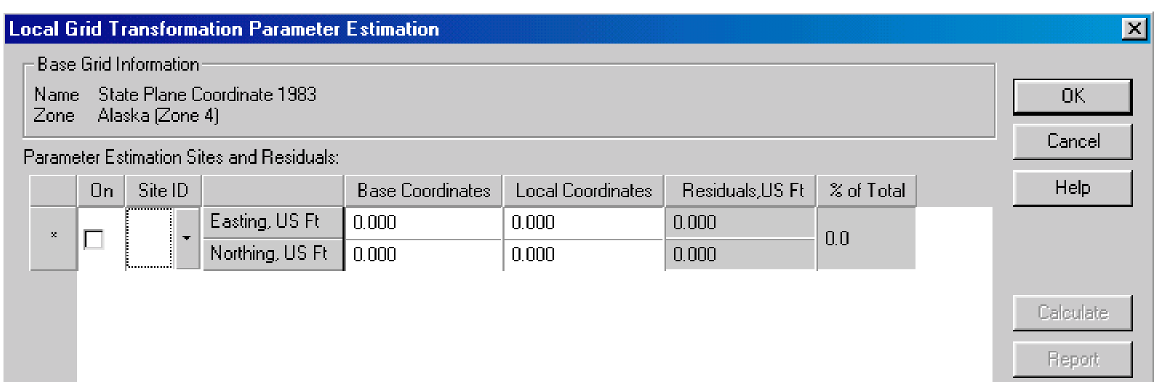


5. The Local Grid System dialog box is now on your screen.



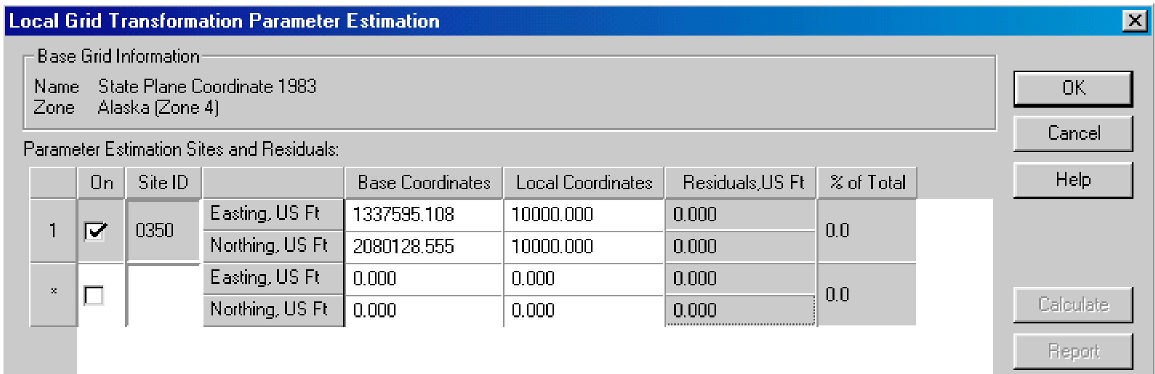
Enter the local grid name in the editable field called Name. The Base Grid System and Base Zone should be the same grid system and zone you defined in step 3 above. Press Estimate… to define the transformation parameters between your new local grid system and the base grid system.

6. The Local Grid Transformation Parameter Estimation dialog box is now on your screen. Now you will calculate the parameters that define the relationship between your base grid system and your new ground system.



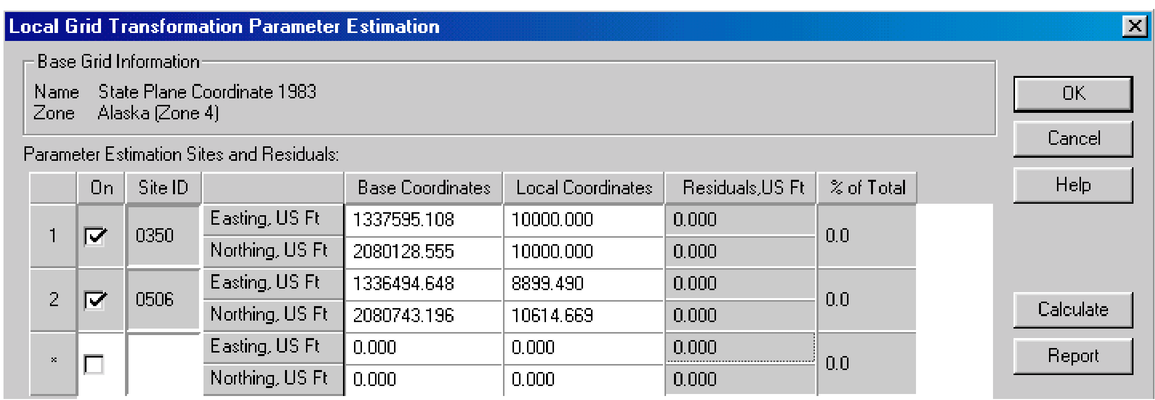
a. Select one of the points having both grid and ground coordinates as the origin of your local grid (ground) coordinate system. Add this point to the Local Grid Transformation Parameter Estimation dialog box by pressing  in the Site ID column and selecting the Site ID for this point.

b. Your selected local grid origin point will appear with coordinates in the Base Coordinate column and 0s in the Local Coordinates column. The Base Coordinates are the grid coordinates of this point in the grid system you chose as the base.



Enter the known ground coordinates for your origin point in the Local Coordinates column.

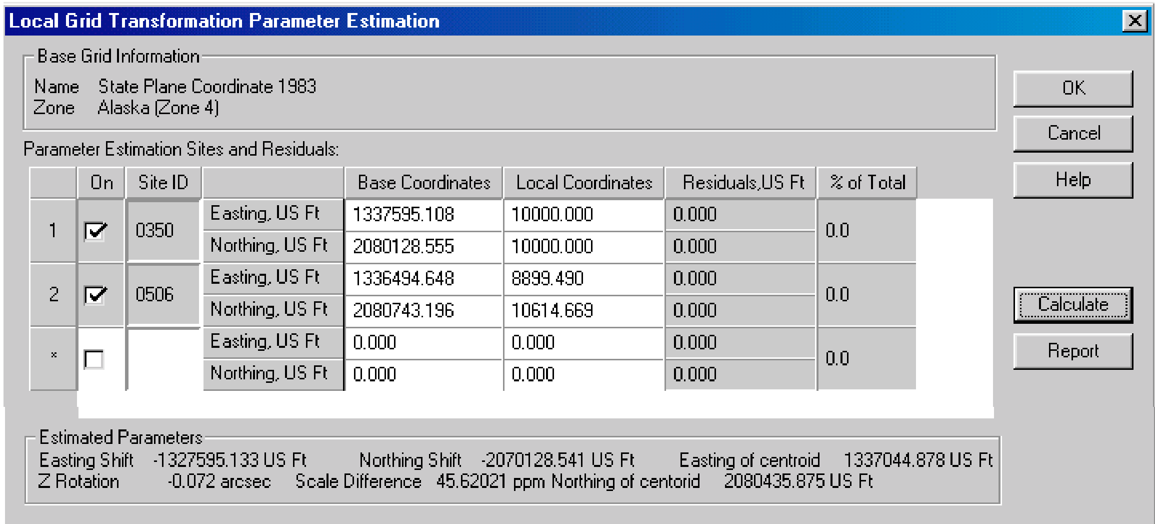
c. Select a second project point having both grid and ground coordinates. Your selected point will appear with base grid coordinates in the Base Coordinates column and 0s in the Local Coordinates column.



Enter the known ground coordinates for this second point in the Local Coordinates column.

d. You now have two points listed that contain coordinates in both the base grid system and your new ground system. Using these two points, we will now calculate the transformation parameters that relate these two systems.

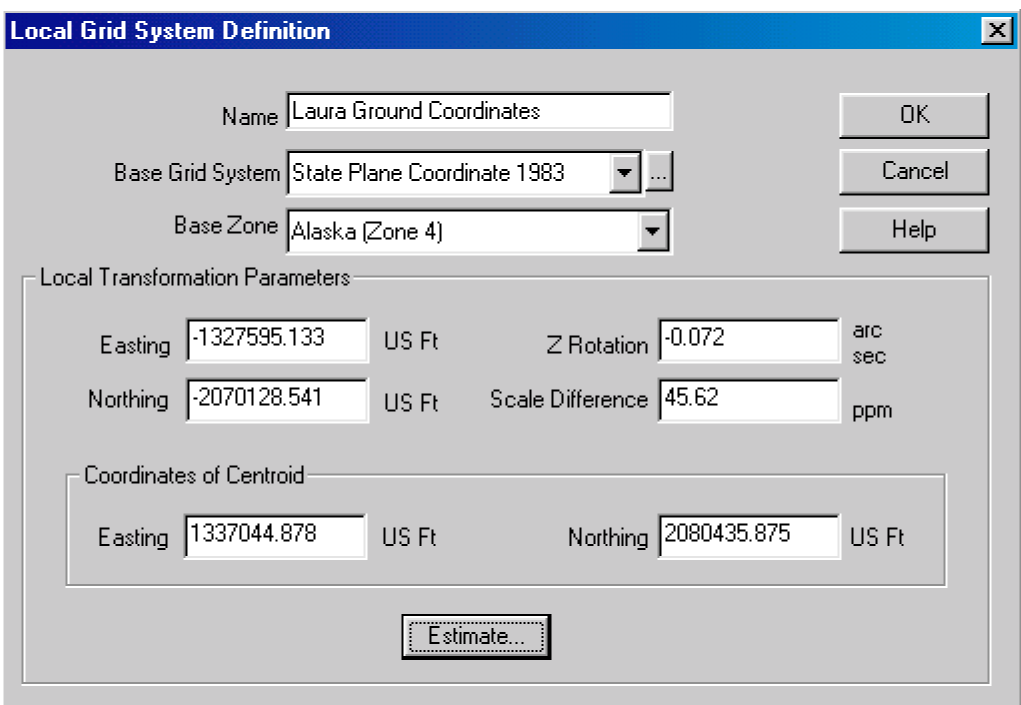
If you have more than two points having both grid and ground coordinates, enter them in. This will give redundancy to the transformation parameter calculation.



Press the Calculate button to compute the transformation parameters. The computed parameters will appear at the bottom of the dialog box.

Press OK to close the Local Grid Transformation Parameter Estimation dialog box.

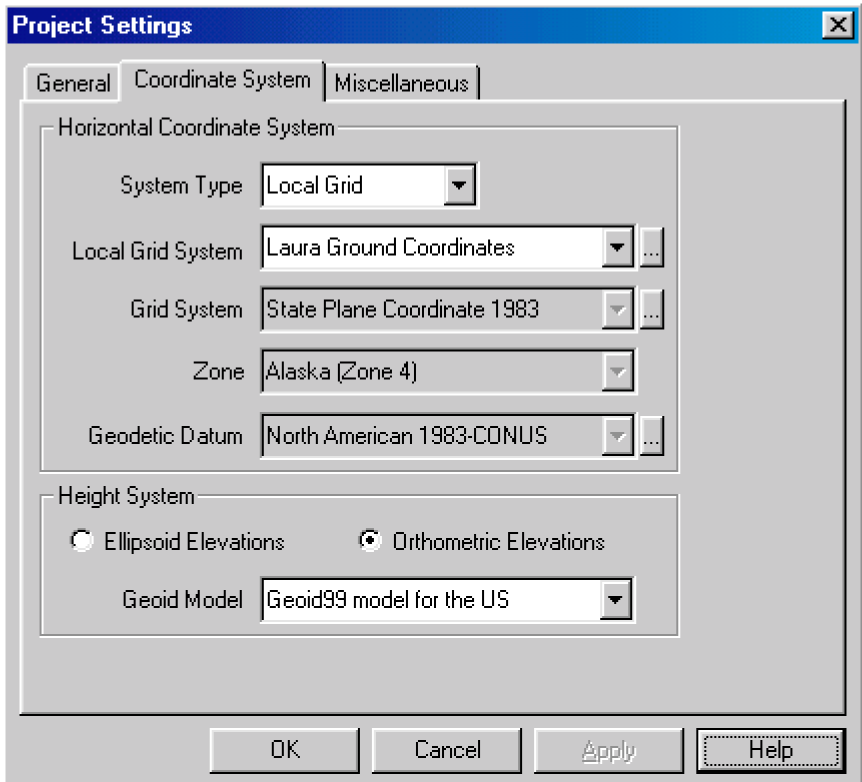
7. The Local Grid System Definition dialog box will have returned to your screen.



The computed transformation parameters will appear under Local Transformation Parameters.

Press OK to accept these parameters.

8. The Project Settings dialog box will have returned to your screen.



Your local grid (ground) coordinates system is now defined. Press OK to assign this new ground based coordinate system to all points in the project.