Patch Analysis:

After you have generated a corridor polygon that connects two habitat blocks, the next step is to evaluate how well that corridor serves the species of interest. This Patch Analysis tool is intended for cases where you feel that some habitat within the corridor may be of poor quality, and therefore the species will have to move through some amount of unsuitable habitat as it makes its way through the corridor.

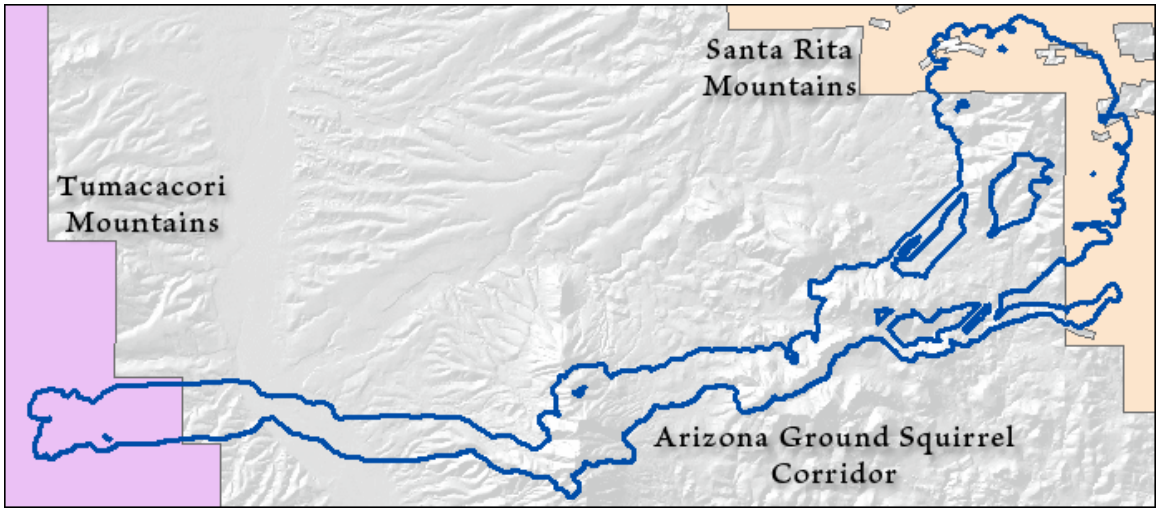
Presumably you have some idea of the largest distance of unsuitable habitat that the species could move through. This distance value may be based on your knowledge of typical foraging movement patterns of that species, or possibly juvenile dispersal distances. If your corridor polygon contains patches of good habitat, then these patches may serve as stepping stones for the species as it moves through the corridor, and potentially reduce the expanse of unsuitable habitat that a species must cross at any one time.

This Patch Analysis tool identifies the path through the corridor that minimizes the distance between patches of high-quality habitat. If no patches are available, then it will simply calculate the minimum distance necessary to move from one habitat block to the other, while staying within the corridor.

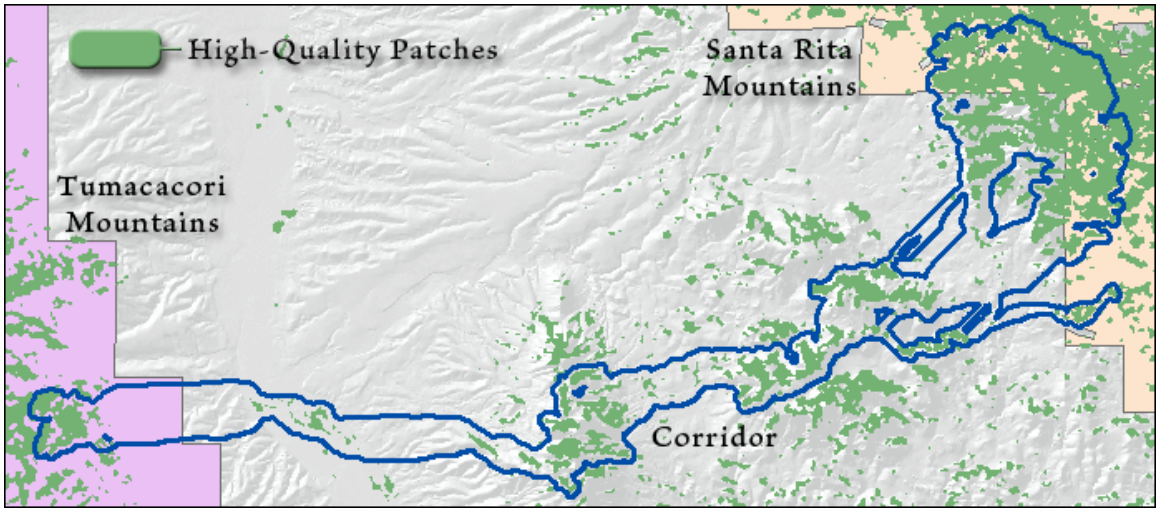
NOTE: This tool accomplishes its purpose reasonably well, but it can take a very long time to work depending on the shape of the corridor and the number of patches available. For example, the analysis illustrated in the example below took 1 hour and 22 minutes to complete. The problem is that the tool occasionally calls upon Spatial Analyst-based least-cost-path functions which dramatically increase the processing time. We are looking into alternatives to these Spatial Analyst functions, which we believe should speed up the analysis, but we do not know when or if we will be able to successfully implement these alternatives. In the meantime, if you wish to get a quick and rough estimate of the maximum patch-to-patch distance necessary to get through the corridor without using this Patch Analysis tool, you may use the standard ArcGIS Measure tool  to simply draw a line over what you visually determine to be the longest gap the species will have to cross.

USING THE PATCH ANALYSIS TOOL:

As an example, suppose that we have previously generated a corridor for Arizona ground squirrels that connects the Santa Rita Mountains to the Tumacacori Mountains in southern Arizona:

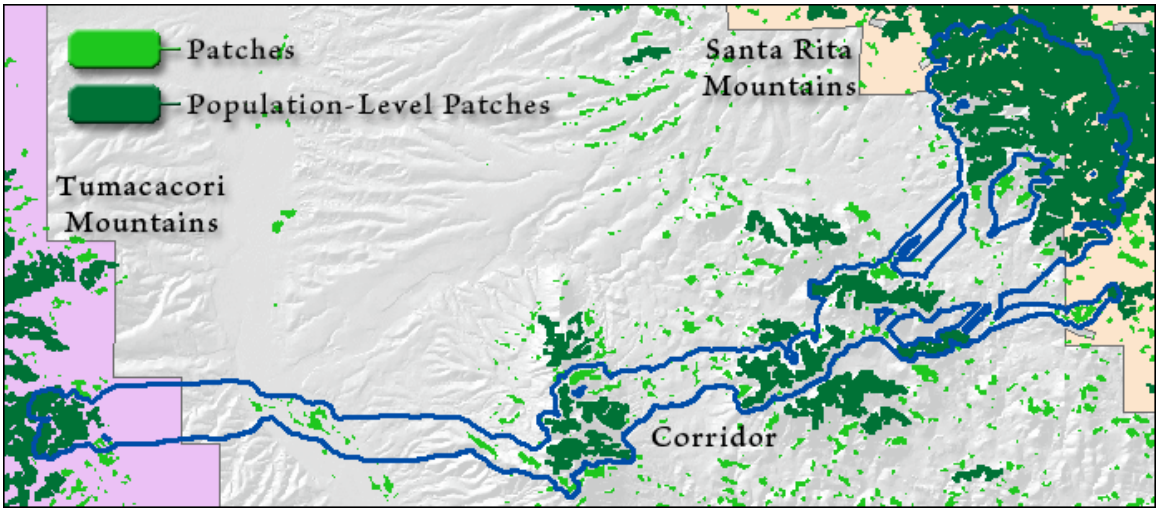


The corridor itself is quite long, at about 22 km. There are also a fairly large number of high-quality habitat patches within the corridor:

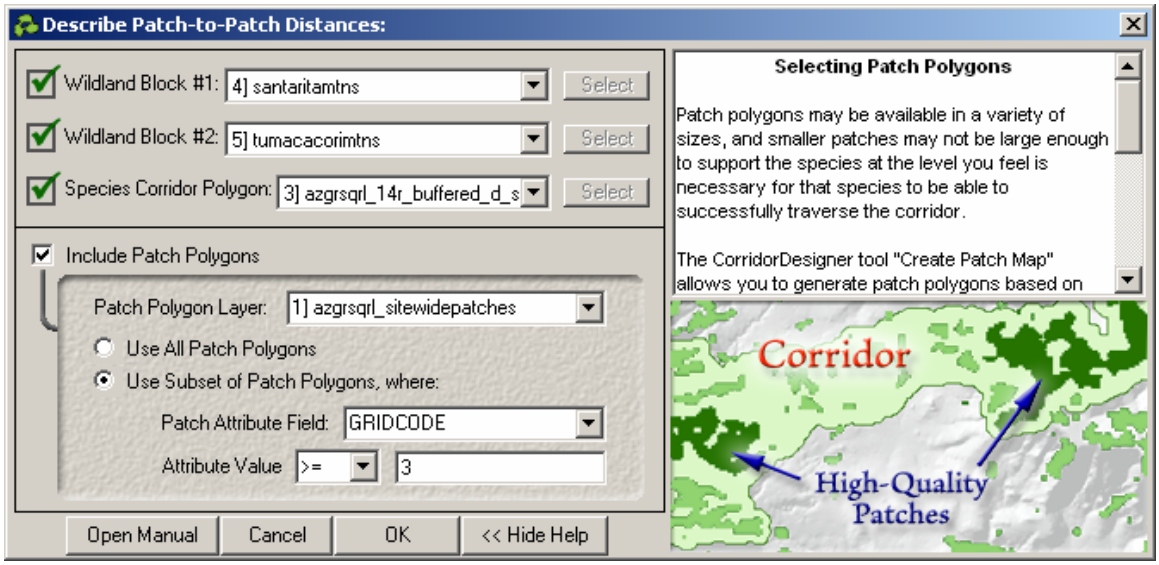


For Arizona ground squirrels, we may feel that they will require a fairly long time to cross this corridor. Therefore we may only want to consider patches that are large enough to support the species for multiple generations.

If we generated these patches using the Corridor Designer "Create Patch Map" tool, then we may have specified a size threshold which would support a sustainable population over multiple generations. In this case we can easily identify these polygons using the "Gridcode" attribute in the Patch polygon layer: In this example, population-level patches are identified with a Gridcode value = 3.

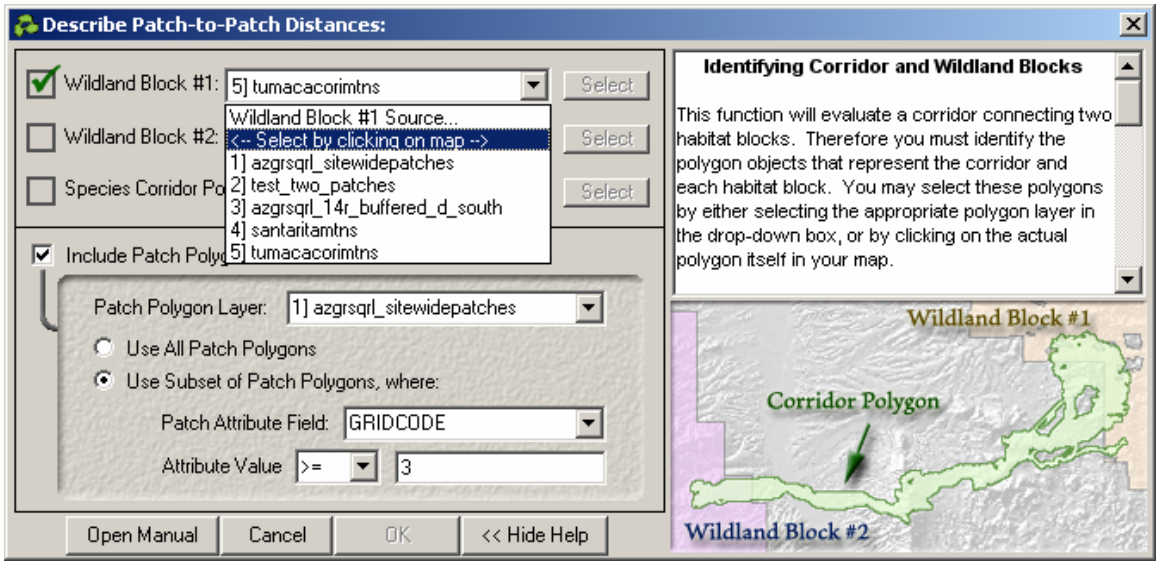


Click the Patch Analysis button  to open the analysis parameter dialog:



Select the polygons that correspond to your corridor and habitat blocks. You may only select a single polygon for each object, although that polygon may be a multi-part polygon. If you have a polygon layer containing only a single feature, then you may simply select that layer from the list in the dropdown box. If you wish to select a single polygon from an existing layer, or if you wish to select or draw a graphic polygon, then click the second item in the drop-down list "Select by clicking on map":

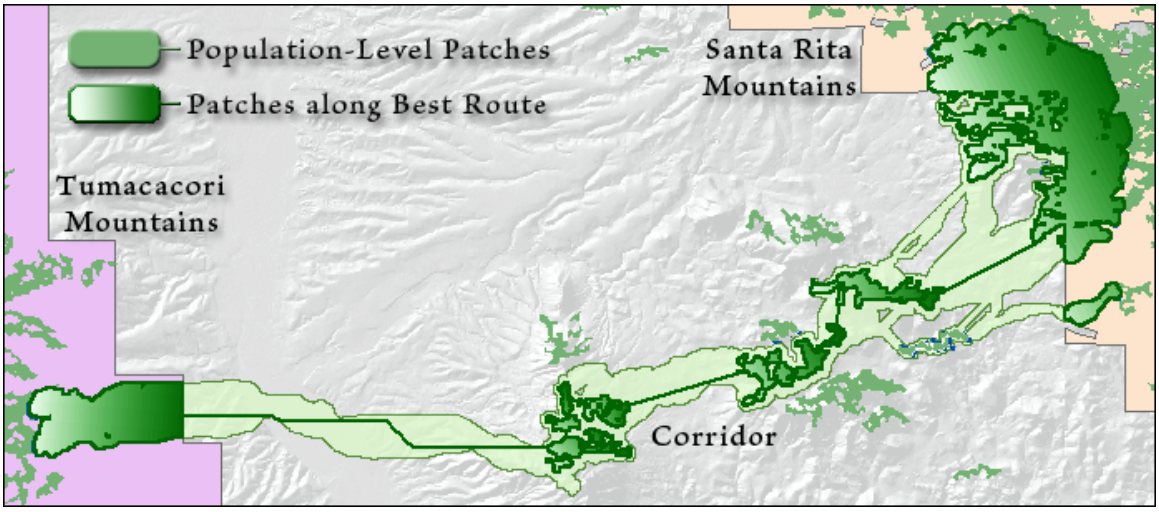
NOTE: This tool will not let you use several separate polygons as a single "wildland block" or "corridor" object. If you wish to use several polygons for this purpose, you will need to combine them into a single entity first. We have a separate stand-alone tool available which will do this function, available for free download at http://www.jennessent.com/arcgis/shapes_graphics.htm (see especially the discussion of the "Combine Features" tool).

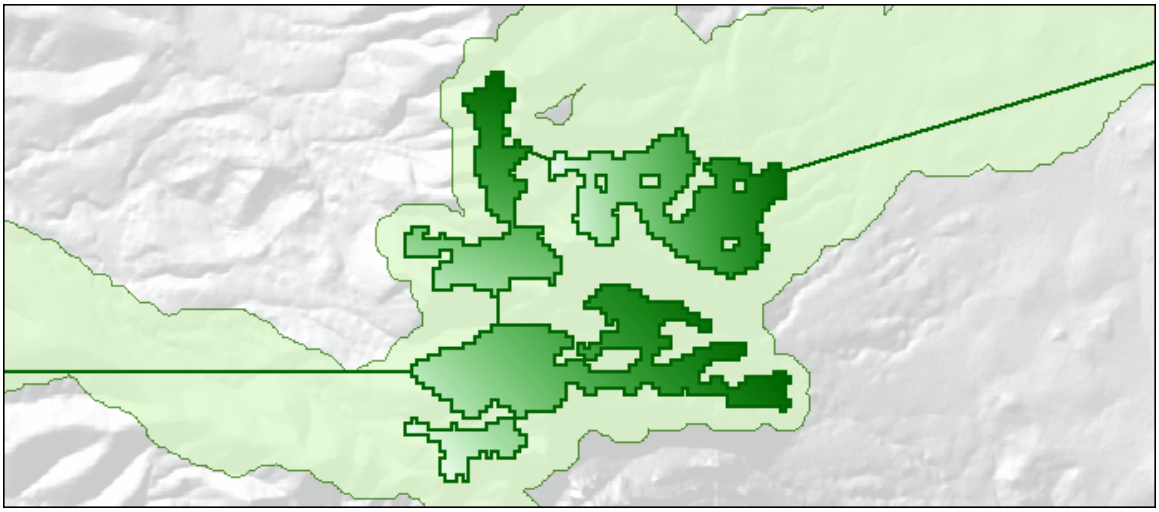


This will enable the "Select" button just to the right of the drop-down list. Click the "Select" button to open the "Selecting or Drawing Polygons" function (see Selecting or Drawing Polygons [p. 7] for details on this on using this tool).

After identifying your corridor and habitat blocks, specify whether you are using patch polygons in this analysis. In the example above, we are using patches from the polygon layer "azgrsqrl_sitewidepatches", and we are only considering those patches with a GRIDCODE value ≥ 3.

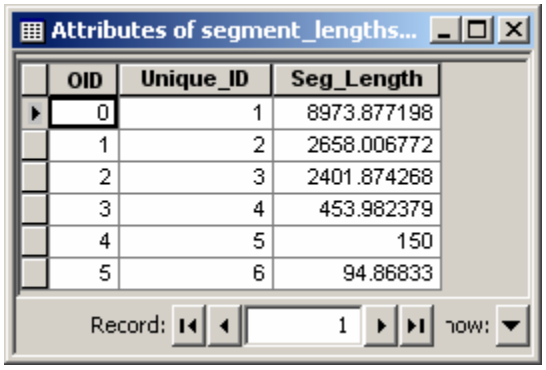
Click 'OK' and wait for a potentially very long time for it to finish. Upon completion, the tool will add graphic connector lines and graphic patch polygons indicating the route through the corridor that minimizes the patch-to-patch distances:



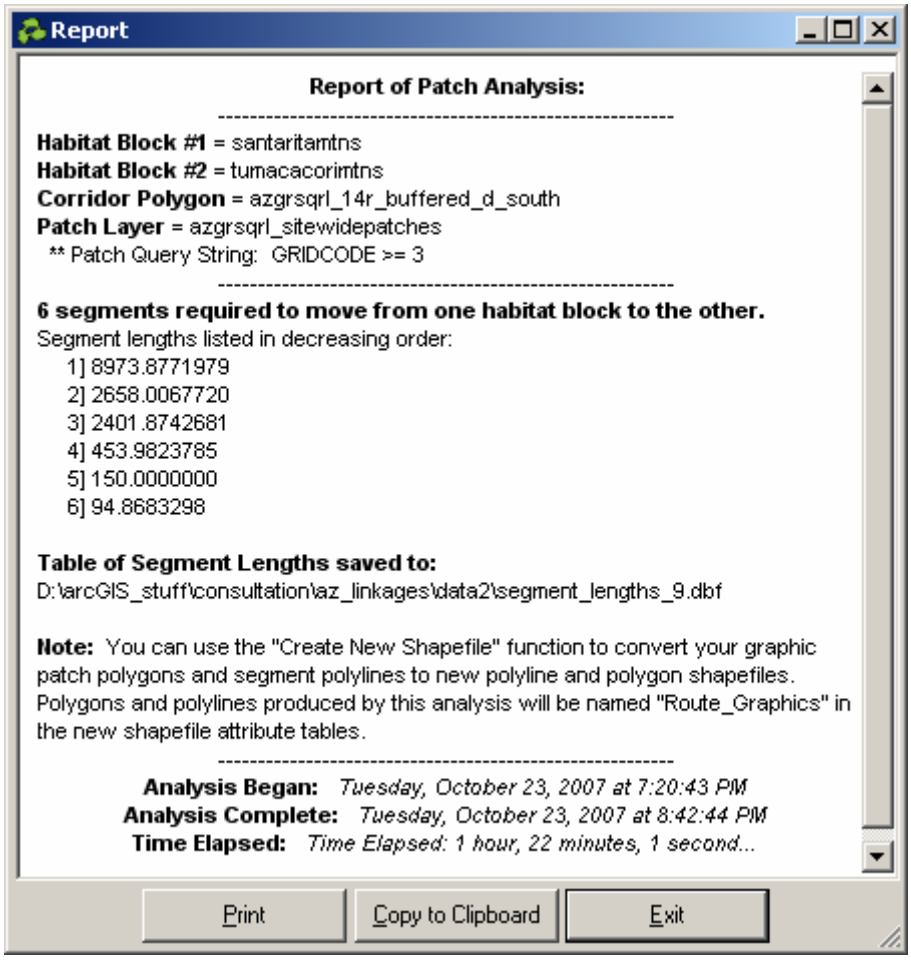


These are only graphics on the screen and can be easily deleted using the "Delete Corridor Designer Graphics" tool (see p. 11). You may also convert them to permanent polyline and polygon shapefiles using the "Create New Shapefile" tool (see p. 12).

The tool will also generate a table of all the connector lengths, listed in decreasing order, and add it as a standalone table to your map document. Remember that all standalone tables are available by clicking the "Source" tab at the bottom of the Table of Contents window:



Finally, the tool will generate a report detailing the analysis and results:



Note that in this example, Arizona ground squirrels will have to cross a gap of almost 9km in order to make it from one habitat block to the other.

TECHNICAL DETAILS: For those interested in the methods used by this function, the basic algorithm works as follows:

1) *Step 1: General Error-Checking:* Just makes sure that corridor and habitat block polygons are valid polygons, and that the corridor actually connects them. This step also confirms that the two habitat blocks are not already connected (or are possibly referring to the same polygon), in which case no corridor would be needed.

2) *Prepare the Corridor, Habitat Block and Patch Polygons:* This includes extracting only the outermost ring of the habitat block polygons so that any internal holes are ignored. The tool only intends to connect the outermost edges of the habitat block polygons and therefore internal holes are irrelevant to the analysis. This step also involves clipping the habitat polygons to the general extent of the corridor polygon and checking to see if any sub-polygons of possibly multi-part habitat polygons can be excluded from the analysis. Finally, all patch polygons are clipped to the corridor polygon. All polygons are set to the projection of the corridor polygon.

3) *Generate a Raster Analysis Environment:* This function will likely require some Spatial Analyst processes, and therefore generates a raster analysis environment based on the extent of the corridor polygon +5% on all sides. The cell size is calculated as the longer of the height vs. width of the analysis extent, divided by 600.

4) *Generate Distance Matrix of all patches and habitat polygons.* This reflects the distance between polygons when constrained to the interior of the corridor polygon, and therefore the connection segments may bend around corners. If patches cannot be connected (such as if they lie within different corridor strands), then no distance is calculated.

   NOTE: This step is exactly why this function takes so long. It is not difficult to calculate the absolute Euclidian distances between polygons but it takes a long time to calculate the distance around corners. This step first generates a connection line that connects the closest points on each polygon, and then checks whether that connection line extends outside the corridor boundary. If so, then the tool resorts to Spatial Analyst least-cost-path functions to recreate that connection line.

5) *Identify Path that Minimizes Patch-to-Patch Distances:* This step utilizes a concept called a Minimum Spanning Tree (MST), which is a method of connecting all nodes in a graph while using the shortest overall accumulated connection segments. The patches and habitat blocks are treated as nodes, and the method is modified a bit because the goal is not to connect all patches but rather to connect the origin habitat block with the destination habitat block. Therefore the origin habitat block can only have outgoing connections and the destination habitat block can only have incoming connections, and the analysis is complete when the habitat blocks are connected, not when all polygons are connected in a complete MST.

   This function implements a variation on *Kruskall's Algorithm* to generate the modified MST. Please refer to p. 174-177 of O'Rourke[1] for additional information on MSTs and Kruskall's Algorithm. In simple terms, this algorithm does the following:

   a. Sorts all possible polygon-to-polygon connection segments by length.

   b. Starting with the shortest segment, progressively builds an MST graph by adding each successively longer segment to the graph.

   c. After adding each segment, the function checks for two conditions:

      i. If the two polygons directly connected by the new segment have already been connected by some series of shorter segments, then this new segment is rejected. This is referred to as testing for *acyclicity*.

      ii. If this new segment forms the last link in a continuous connection path between the two habitat blocks, then the goal has been achieved and the algorithm is suspended.

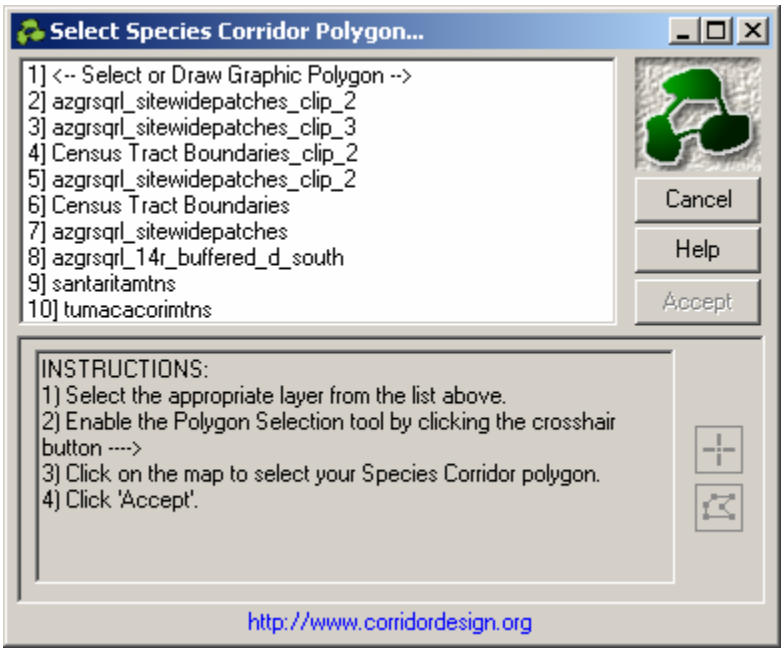
6) At this point we have an abbreviated MST that connects the habitat blocks, plus probably has a few extraneous branches that are irrelevant to the analysis. Therefore the final step is to prune the extraneous branches, leaving only the single route.

Selecting or Drawing Polygons:

Four functions allow the user to do something based on a selected polygon graphic or polygon feature, and therefore all three tools needed a way to select or draw that polygon. The Patch

[1] O'Rourke, J. 2000. Computation Geometry in C, 2nd Ed. Cambridge University Press, Cambridge, United Kingdom. 376 pp.

Analysis, Bottleneck Analysis, Cross-Tabulation Table and Clip tools all provide access to the following dialog:

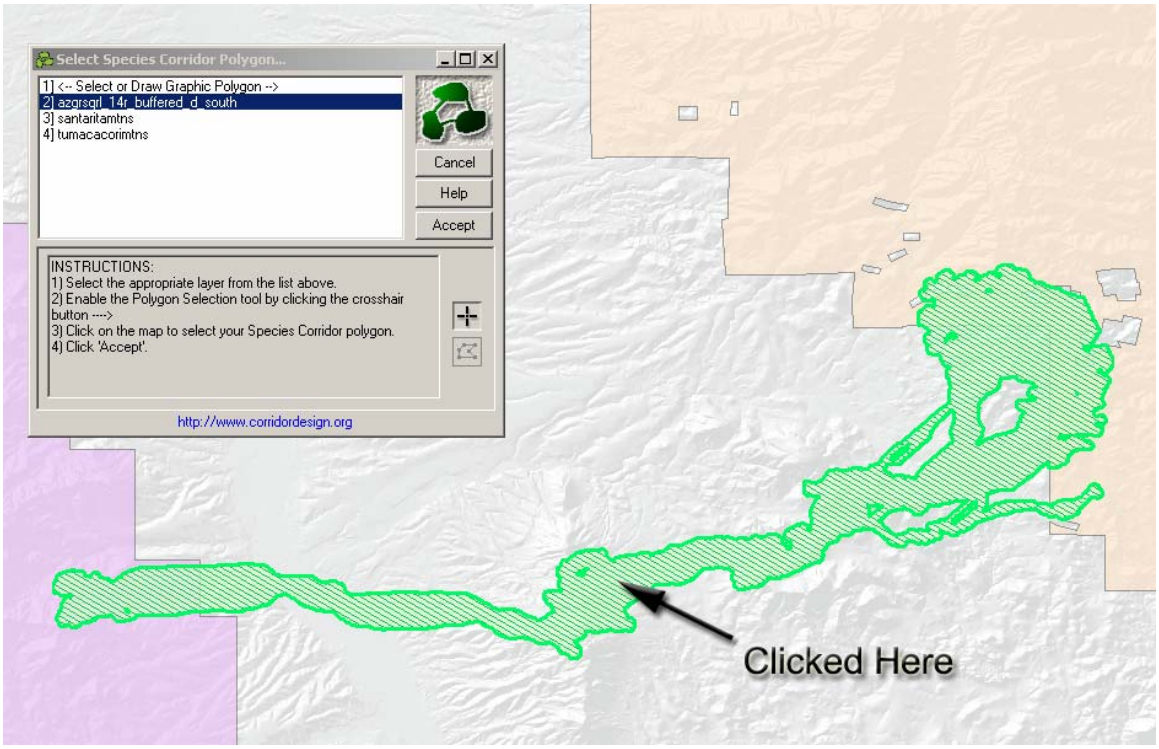


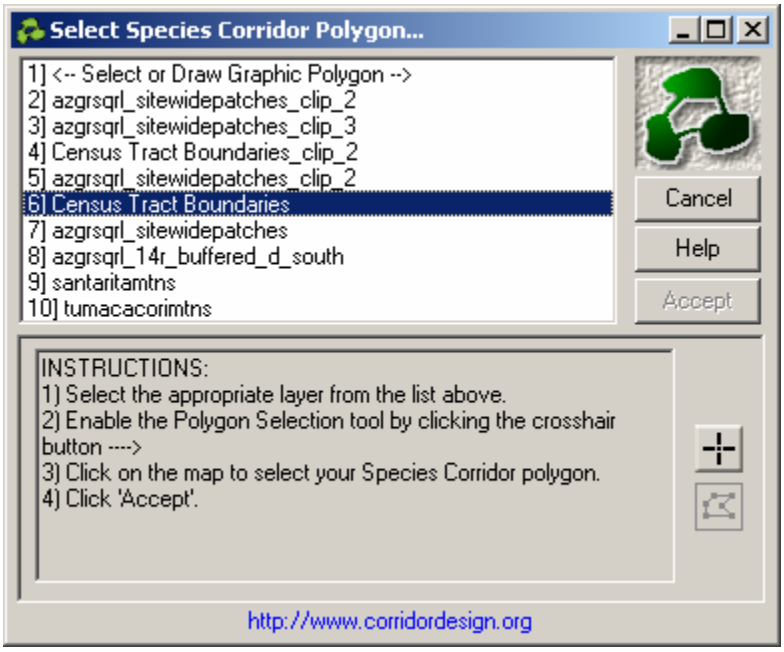
NOTE: The title of this dialog will change depending on whether the user is searching for a corridor polygon or a wildland block.

This dialog allows you to:

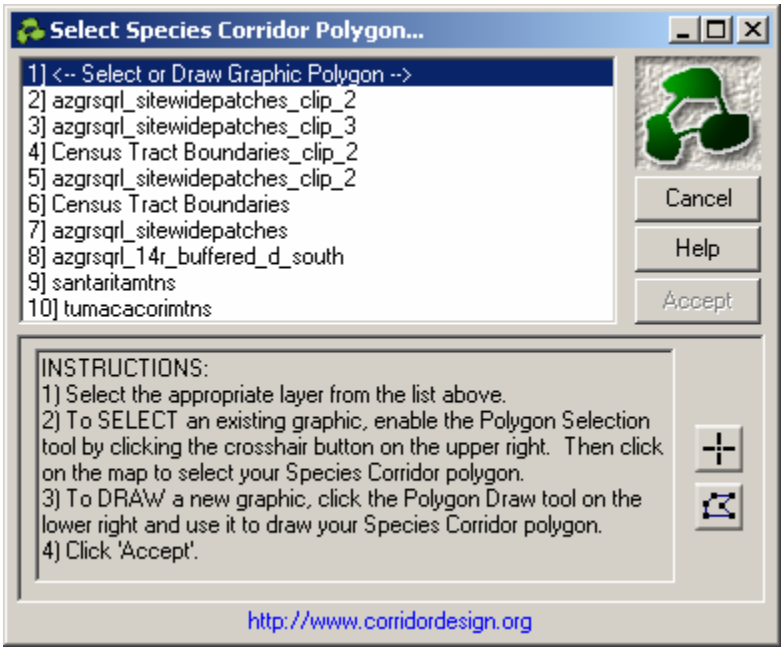
1. Select a single polygon from a polygon feature layer, or
2. Select a single graphic polygon, or
3. Manually draw a graphic polygon on the screen.

If you select a polygon theme from the list at the top of the dialog, then the "Select Polygon" button  will become enabled and the corresponding tool will become enabled on the Corridor Designer toolbar. Click this button and then select a polygon from the theme. After you click on a polygon, it will turn a green color with a crosshatch fill:



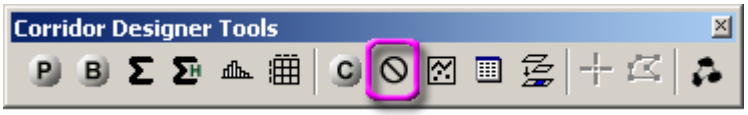


You may also select or draw graphic polygons, rather than selecting polygons from a polygon layer. If you select the first item in the list, "Draw or select graphic polygon", then both the "Select Polygon"  and "Draw Polygon"  buttons will become enabled. Use the appropriate button to either select or draw a graphic polygon. Note that the instructions change if you select this option:

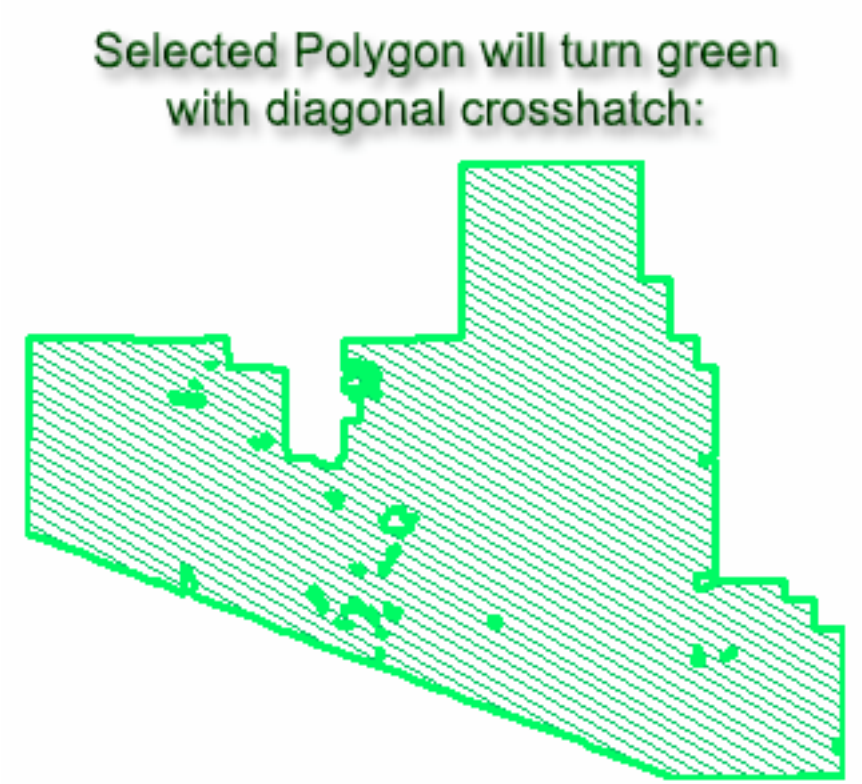


In all cases, selected polygons will be shaded green with a crosshatch pattern. If any of these graphics remain in your view after you no longer need them, you can quickly clear them out using the "Delete Corridor Designer Graphics" tool (p. 11). You may also convert any graphics to a shapefile using the "Create Shapefile" tool (p. 12).

Delete Corridor Designer Graphics:



Several of the Corridor Designer Evaluation functions create graphics on the screen. For example, the Clip tool and the Polygon Selection tool both produce polygons with a particular fill pattern:



The bottleneck and patch distance tools will also produce distinctive graphics.

This button simply clears out any CorridorDesigner-produced graphics, leaving any other user-created graphics untouched.

Create New Shapefile:

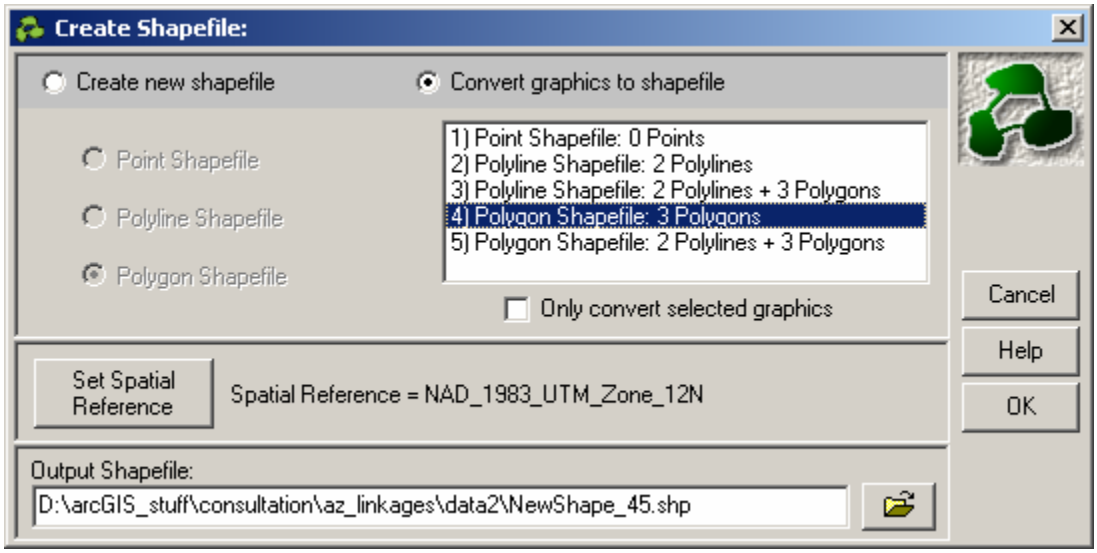
This function allows you to either create a new empty shapefile or convert graphic shapes to a shapefile. You may create either point, polyline or polygon shapefiles with this tool.

- Polygon shapefiles will include attribute fields for [Unique_ID] and [Area].
- Polyline shapefiles will include attribute fields for [Unique_ID] and [Length]
- Point shapefiles will include attribute fields for [Unique_ID], [X_Coord] and [Y_Coord].

NOTE: If you are converting graphics to a shapefile, and if those graphics have names (right-click the graphic and check the properties to see if it has a name), then these names will also be added to the attribute table in a [Name] field.

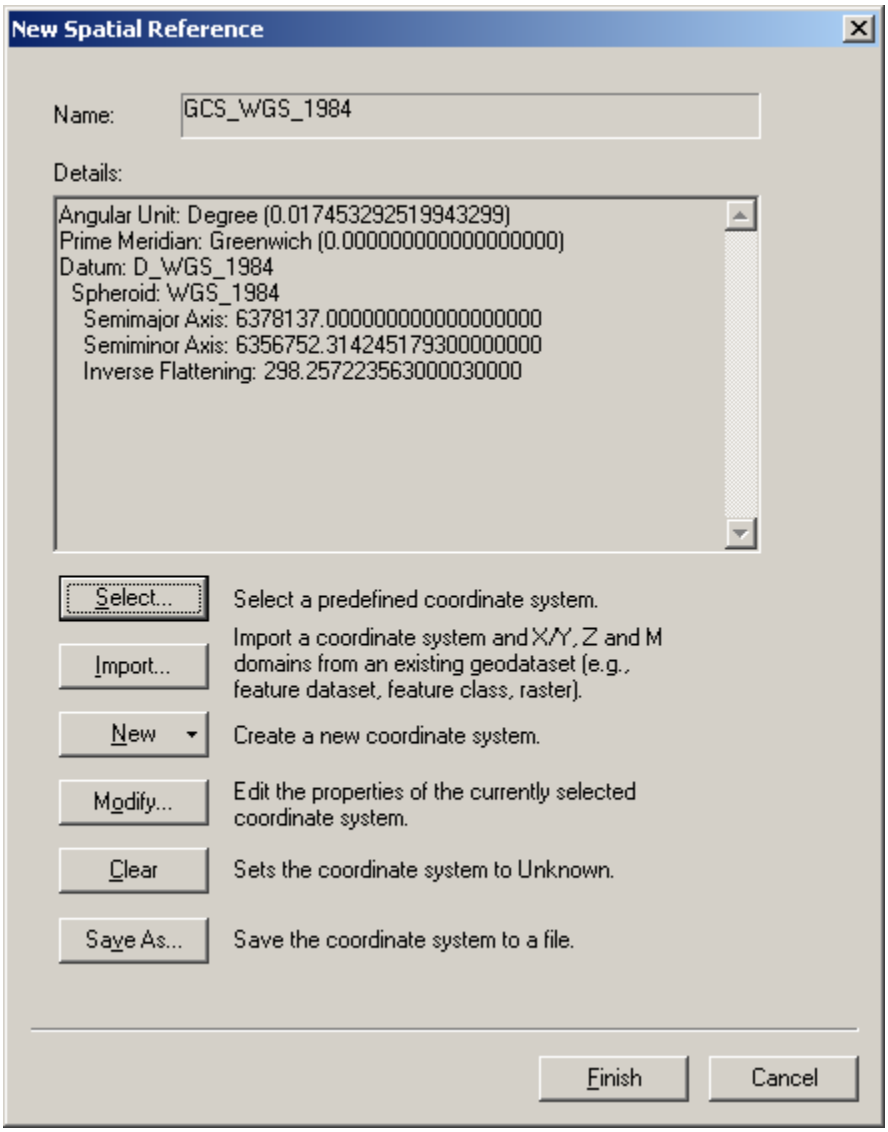
This function also allows you to convert polyline graphics to polygons, or polygon graphics to polylines, if you wish. When opened, the tool will examine your map to see how many point, polyline or polygon graphics are available, and whether any of them are selected. The tool will show you how many of each type are available to convert. If you attempt to create a shapefile from existing graphics when there are no graphics to convert, you will be notified of this and asked if you would like to try a different shape type.

NOTE: Certain linear or areal graphic shapes are not technically polylines or polygons. Polygons that are defined by a circle or elliptic arc are not really "polygons" in the sense that they are not composed of a series of straight-line segments. This is also true for linear features that are constructed of Bezier curves. It is not possible to add true curves such as circles, ellipses or Bezier curves to a polyline or polygon shapefile, so this function will convert these shapes to standard polygons or polylines before adding them to the shapefile. It does this by generating 200 evenly-spaced points along the length or perimeter of the curve, and connecting these points with straight segments. Therefore, if the original graphic feature is composed of true curves, then the actual shape in the shapefile will be slightly different than the original feature.



You must set a spatial reference for the new shapefile. If your map has a spatial reference set, then the map spatial reference will be the default value. You may easily change the spatial

reference by clicking the “Set Spatial Reference” button and identifying the spatial reference you want:



NOTE: This function adds the new shapefile to map, but does not delete existing graphics so you may not see the new shapefile when the shapes lie behind the graphics.