AUTOMATING "ETHINGTON TRANSECTIONS":

A NEW VISUALIZATION TOOL

by

Anne Jeanene (AJ) Bengoa

A Thesis Presented to the
FACULTY OF THE USC GRADUATE SCHOOL
UNIVERSITY OF SOUTHERN CALIFORNIA
In Partial Fulfillment of the
Requirements for the Degree
MASTER OF SCIENCE
(GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY)

August 2016

DEDICATION

I dedicate this document to all my family for their constant support; my loving husband, 2 amazing kids, my encouraging parents and my ever helpful aunts.

ACKNOWLEDGMENTS

I will be forever grateful; to my amazing professor and friend—Dr. Swift, for Dr. Ethington's remarkable ideas and continuous support, and to Dr. Vos for his valuable input to this project both at its launch and terminus. Thank you also to my family and friends, without whom I could not have made it this far.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ESI	Environmental Sensitivity Index
ETT	Ethington Transection Toolbox
GDB	Geodatabase
GIS	Geographic Information System
HGIS	Historical Geographic Information System
ICW	Intercoastal Waterway
MAUP	Modifiable Areal Unit Problem
SSI	Spatial Sciences Institute
USC	University of Southern California

ABSTRACT

The goal of this project is to develop an Ethington Transection Toolbox (ETT) to automate, increase the efficiency, and improve the efficacy of creating "Ethington Transections." Ethington presents these hybrid charts/maps to visualize social change in space and time, along urban streets in his forthcoming book, *Ghost Metropolis: A Global History of Los Angeles since 13,000*. A new technique for visualizing the act of moving through the landscape over time, "Ethington Transections" are defined as a cross-sectional sample of data from polygons to simulate a single, directional line of transit. The objective of this thesis is to streamline the creation of transections resulting from the input of common polygon-distributed data, and to share such a tool so that others may benefit from increased efficiencies. The final result is a custom toolbox in Esri's ArcGIS ModelBuilder of seven custom models with contextual help, written documentation and video walkthroughs. This series of models creates an editable map and graph layout and an organized geodatabase of intermediate outputs that can be reused for additional analyses or presentations. The ETT shortens the time to complete an "Ethington Transection" from 8 hours to slightly less than 1 hour. The previously tedious and time intensive task of creating transections was automated and made accessible to a wider range of researchers, facilitating new perspectives and interpretations of data. Therefore this toolbox should enhance the analytic skills of those looking to study how changes occur through space and time along any linear sample of data to simulate a transit in polygonal datasets.

CHAPTER 1: INTRODUCTION

There are many ways in which human beings struggle to understand their place in the world. By looking back, we often better understand where we are, and illuminate better paths forward. Since the beginning of recorded history the idea of place has been important (Bodenhammer 2013). In order to fully understand the historical picture the essential question of "Where?" had to be answered (Bodenhammer 2013). Over time tools have been developed to help us "see" our human story in different ways. Maps were developed to convey just such spatial information. With the growth in computers, and specifically the field of Geographic Information Systems (GIS), the story teller, or modern researcher, could go beyond the map in the ability to analyze relationships over time in a place.

Transections are a GIS technique developed by Dr. Philip Ethington (Forthcoming) in order to visualize the act of moving through the landscape over time. Transections can be defined as a cross-section sample of data from polygons to simulate a single line of transit (Ethington Forthcoming). The objective of this thesis was to streamline the creation of Ethington Transections resulting from the input of basic polygon-distributed data, and to be able to share such a tool so that others may benefit from the increased efficiencies. This thesis project devised a method to automate the process, thus hastening time to data visualization. The final result is a custom toolbox in Esri's ArcGIS ModelBuilder of seven custom models with contextual help, written documentation and video walkthroughs called the Ethington Transection Toolbox (ETT). This series of models creates an editable map and graph layout and an organized geodatabase of intermediate outputs that can be reused for additional analyses or presentations. The ETT can enhance the analytical skills of researchers studying how changes in almost any kind of spatial data occur through space and time along any linear sample of data to simulate a transit in polygonal datasets.

The ETT is delivered with all the requisite templates and geoprocessing steps. The operation of the ETT does not necessitate the distribution of any particular data as it utilizes only data inputs from the user. However a sample geodatabase (GDB) is made available which enables a new user to run through the tutorial explained in the accompanying User's Manual. This project also utilized both a previously compiled GDB and publicly available data sources (U.S. Census, NOAA, DCGISopendata, and FWC-FWRI) in order to test the effectiveness of the ETT. Automation enables researchers to increase the number of transection visualizations derived and allow for easier comparisons within and between datasets.

Current manual methods call for the data from all the desired variables and data layers for visualization to be apportioned to a single geographic areal unit configuration. Then, the areal units along the line being selected are outputted to a drawing program for cartographic presentation. Next, the data on a variable of interest from those areal units are output to a spreadsheet program and charted variables of interest, afterward the charts are also moved to a drawing program to align the chart data to the geographic information for presentation. Then manual methods are employed to visually align the data points of the graphs with the geography of the polygons. This manual method is cumbersome and time consuming.

The goals of this project were to provide a toolset and technique to all those looking for alternative methods of linear visualization, and to broaden the scope of the Ethington Transection beyond its present usage in urban spatial history. This project automated the above steps for the creation of Ethington Transections by developing a custom desktop Esri ArcMap Python toolbox (Esri 2015). Producing a desktop ArcMap Python toolbox worked well to automate transection creation because they are easily produced, distributed, and integrated in to the ArcGIS application. These ArcMap Python tools are well supported by Esri and widely used by ArcGIS users of all skill levels., and therefore makes a great platform for the application of the is project.

Other applications have been created to ease processing challenges within ArcGIS and other GIS software (Bell 2004; Dilts, Yang and Weisberg 2010; Pratt 2000; Rattan, Campese and Eden 2012; Reed, Boggs and Mann 2012; Reiser 2014; Silva and Taborada 2013; Spalding 2000; Wheaton et. al. 2012). Geoprocessing tools are developed primarily to simplify or reduce the completion time of a GIS-based computational task that can be run multiple times, and then they can be shared with others so that they too may benefit from the efficiencies of the tool (Allen 2011). The development of this tool allows researchers to utilize the advantages of task-specific, customized GIS data processing tools.

The previously tedious and time intensive task of creating Ethington Transections is automated and made more accessible to a wider range of scholars. Topics such as ethnic diversification, gentrification, and economic shifts can be visualized using transections by examining demographic variables like population by ethnicity, population by age, unemployment, buying power, and average household size. Alternatively, in the ecological research sphere, changes in wildlife land use, invasive species distribution patterns, or oceanic catch densities could also be evaluated with an Ethington Transection.

The structure of the remainder of thesis document: first describes the context of the project; then reviews the literature on spatial linear analysis, HGIS automation, and GIS tool development; then confers in detail the specifics of the ETT and its development; next delivers the results of using the ETT in multiple scenarios; and lastly discusses considerations, limitations, and possible future work for the ETT.

1.1 Topic Definition

In order to adequately define the topic of this project a brief account of some alternate spatial data visualization methods is presented herein, along with a closer look into what are Ethington Transections and how they differ from more traditional approaches. Additionally a look into the application development solutions chosen for this project will be discussed.

1.1.1 Visualizing Historical Data of Place

The role of geography is to distill spatial information so that ideas and patterns become readily apparent (Montello 2001). The very act of creating a map requires a distortion of reality, where only a "selective, incomplete view" can be represented on the scaled down two-dimensional surface at hand (Monmonier 1996). One role of a geographer is deciding what story needs to be told and then how best to visualize it. This can become more challenging when trying to relate information that includes time (Gregory and Ell 2007).

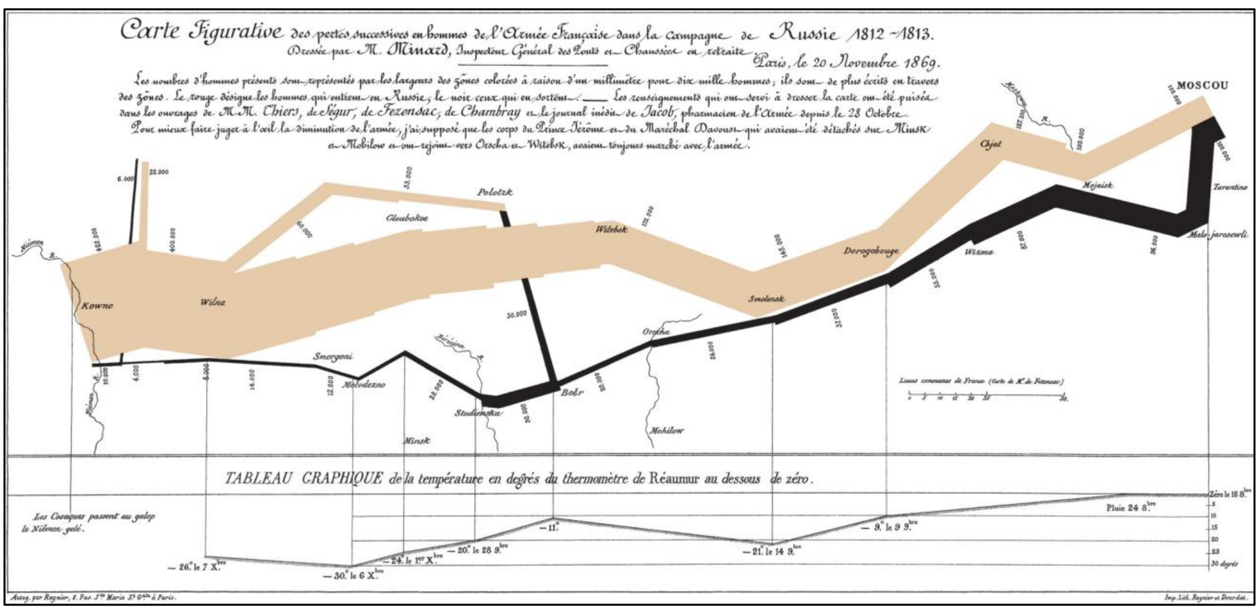


Figure 1. Charles Minard's Napoleon's March to Moscow in the War of 1812.

One of the most highly acclaimed spatial visualizations throughout history is Charles Minard's depiction of Napoleon's March to Moscow during the War of 1812 as reproduced in

Figure 1 (Wikimedia Commons 2105). It goes beyond a simple map or graph and endeavors to deliver large amounts of information allowing for multiple comparisons and true “graphical excellence.” Edward Tufte (2001, 51) posits, “graphical excellence is that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.” To truly deliver an impactful message all modern scholars should struggle to do the same.

The story of a place can be told in many ways in order to synthesize and illuminate different facets of the complex web of information experienced at that location. Just as altering the angle, zoom or aperture of a camera readily changes the image it is shooting, so can altering the tools, data, and perspectives of a story change our “image” of a place. When GIS is employed to tell this story, “innovative ways to collect, manage, model, analyze, interpret, and display geographic information” (Offen 2013, 568) are developed. HGIS becomes the tool to facilitate this shifting perspective by incorporating the essential added dimension of time (Raymond 2011). However no matter the quantity of visualizations GIS and “big data” tools can deliver, “there are few that can assemble the data collected by Minard and create a more sophisticated representation” (Plummer 2014, “How modern visualizations” para 1).

One of the most common ways researchers use GIS outputs to represent pattern distribution in a place is with a series of choropleth maps that view the panorama from a typical map scale delivered as a series of small multiples. In the example of this formula seen in Figure 2, climate conditions of California are shown in six small multiples (Slocum, et al. 2009). The top ones are in a continuous raster format, while the bottom indicates the results distributed by county. This arrangement allows the viewer to draw conclusions about the relationship between temperature and precipitation in the state, as well as to illustrate the Modifiable Areal Unit Problem (MAUP) (Peterson 2011). In the small multiple, three or more maps or images are used in a sequence to display different data from the same geographic space (Tufte 1990). This composition allows all the maps to be viewed semi-simultaneously in order to draw conclusions by discerning inter-map similarities and differences (Peterson 2012). This gives the viewer the impression they are watching the polygons on the ground shifting colors as if viewed from a stationary point in orbit above the Earth (at for instance 10,000 feet). These visualizations have proven useful and are able to reveal patterns in the changes of numerous variables (ethnicity, economic status, land cover, rainfall, etc.) (Slocum, et al. 2009).

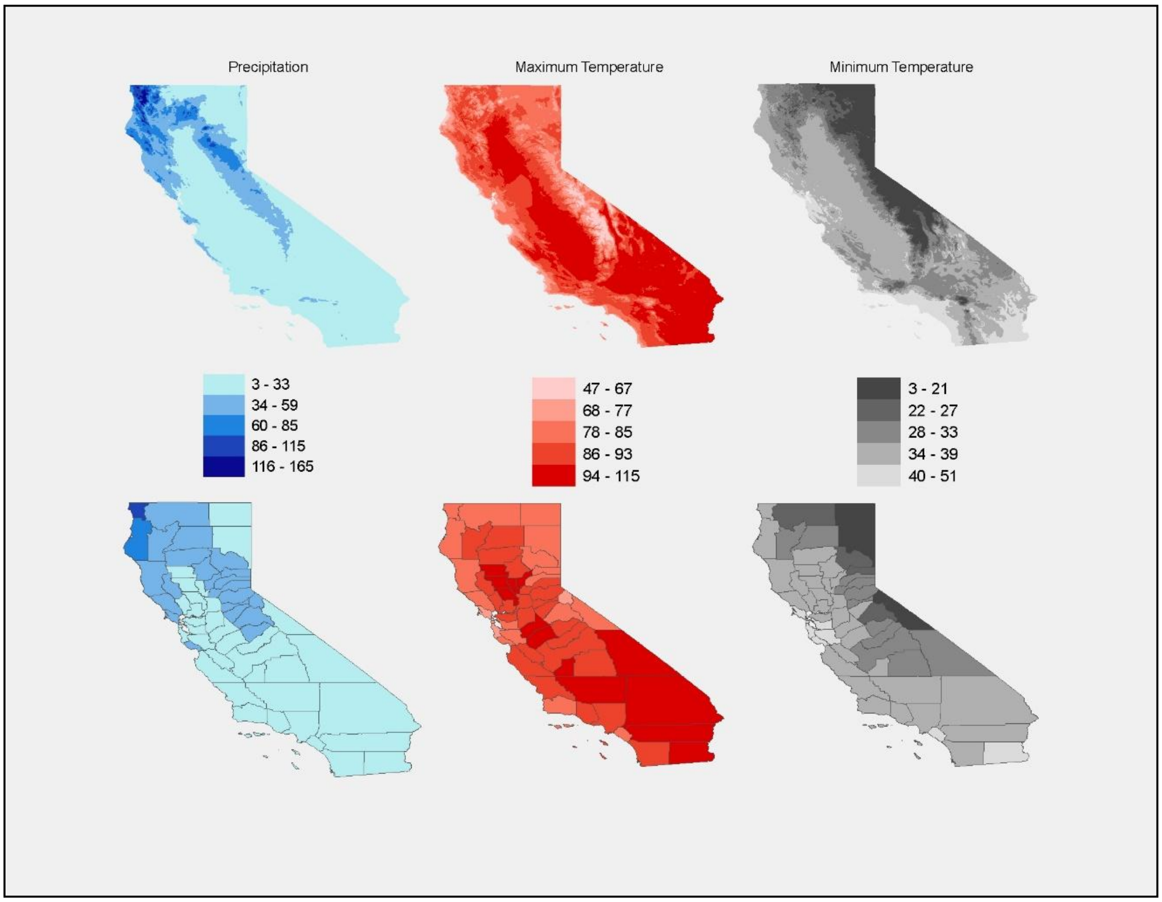


Figure 2. Example of a small multiple map set (Slocum, et al. 2009).

As useful as this method is, Ethington supposed that it did not adequately reflect the differing human experiences of place (Forthcoming). A person does not acquire a city's character solely from the sum total of statistical facts over time (Lynch 1960). And one certainly does not receive this data in an instant, as if downloaded directly to our psyche. Also, one does not typically experience the urban landscape from a bird's eye view.

Instead, the observer of a city creates a relationship with it and attempts to understand it. We have to interact with the landscape in a spatially ordered manner. The most common way that people experience a place is by moving through it (Lynch 1960). This is exemplified when driving down a street, walking along a river bank, or riding on a train. At the beginning of this process, only the small piece of the puzzle in which a person stands can be visualized. Over time, the known puzzle pieces come together to create a distinct picture of a city. Just as someone working a puzzle can imagine what the form of the missing pieces should be, the city wanderer can work similar strategies on their mental urban image. Even if we don't have all the pieces—have not experienced every part of the city—we know what the pieces should contain to complete the image. Thus we have the confidence to navigate the "in between spaces" that were previously blank in our knowledge base. Lynch (1960) famously termed this property of cities "imageability".

1.1.2 What are Transections?

In order to visualize the act of moving through the landscape Ethington drew inspiration from the likes of Minard and Tufte to develop a new spatial data visualization technique—the transection (Forthcoming). He defined it as "a cross-section of the metropolis on a single line of transit". By creating a transection based on popular thoroughfares one can experience both the impression of a commute and of transits between segregated spaces. This transection technique capitalizes on the advantage of using GIS—the opportunity to develop new analytical techniques to best represent spatial data (Gregory and Ell 2007).

The first step to creating an Ethington Transections is to select a significant transit through the region (Ethington Forthcoming). It is desirable to choose arteries or paths that have permanent relationships with the landscape. Then all the areal units that touch that path are queried for their data. The data are then organized in the direction of the path. Next a variable such as % white non-Hispanic, median household value, or the like, is plotted as a standard line graph. Graphs can be repeatedly generated on different variables for simultaneous display and cross comparison. The plots are standardized such that the distance between the data points corresponds to the physical/spatial distance traveled along the path represented in the transection. An example of this process can be seen in Figure 3, “Pico-Whittier Transection” from “The Spacetime Transection: Pico-Whittier, Lakewood-Rosemead, and Sepulveda” in Ghost Metropolis: Los Angeles Since 13,000 BP (Ethington forthcoming).

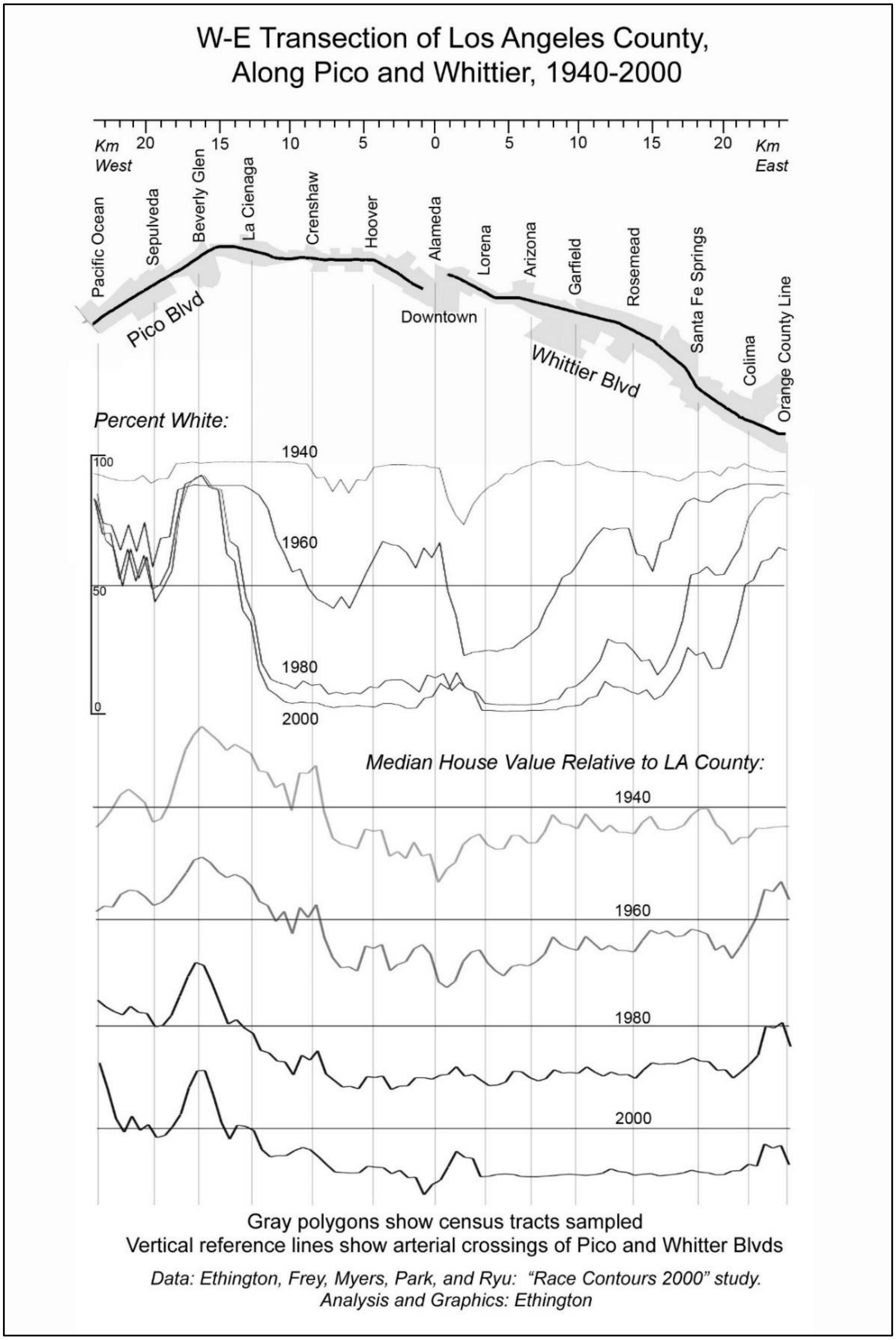


Figure 3. "Pico-Whittier Transection" (Ethington forthcoming).

Ethington presents the first charts made along his unique street-derived transections in *Ghost Metropolis: Los Angeles Since 13,000 BP* (Forthcoming). These transections plot ethnicity and economic data for 1940, 1960, 1980 and 2000. Transections were chosen along the east-west streets following Pico Blvd and Whittier Blvd, the north-south oriented Lakewood Drive and Rosemead Avenue, and the meandering Sepulveda Blvd. The Pico-Whittier Transection can be seen in Figure 3 as an example of the technique. Graphs from these transections reveal that property value patterns tended to be more stable over time than the still relatively stable pattern representing the percentage of white residents (Ethington Forthcoming).

1.1.4 What is Inscription?

Inscriptions are conceptual imprints left on a landscape from the past political and cultural activities (Ethington Forthcoming). One example would be how the initial delineation of ranchos in LA was based on previous indigenous settlements, and whose pattern can still be seen in the major centers of population today .In an effort to discover and convey these theories, one of Ethington's goals is to find and visualize these inscriptions; principally for Los Angeles, but ultimately for other cities and social spaces as well. Ethington Transections grew out of this particular objective.

By examining the institutional inscriptions left by the changing Spanish, British, Spanish (again), and American governmental controls, Baldwin was able to use transections to visualize the remarkable persistence of land usage in in St. Augustine, Florida, especially as it related to attributes of the parcel geometry (2014). Transections were used to visualize the parcel geometry shifts of this area (Baldwin 2014). The Minorcan Quarter showed a persistent style of cultural, economic and government usage patterns that was difficult to explain at first with other methods (Baldwin 2014).

1.1.3 Finding patterns in the history of Los Angeles

The large and complex network of communities making up Los Angeles is an ever-enticing, ever-ambivalent, and increasingly multicultural megalopolis (Brook 2013). Los Angeles represents a diverse quilt of people living within the landscape that have evolved through history (Ethington Forthcoming). The landscape and sense of place are key. This makes Los Angeles an interesting and rich source for historical research. As Ethington explains:

> What holds it together in the imagination (which is always partly visual) are mental images of a whole city, imaginary illusions of a whole to cover the actual reality of a million separate parts. What holds it together functionally is the state, the institutions of civil society, and the infinite daily practices of its millions of residents. (Ethington Forthcoming)

Pulido, Barraclough and Cheng assert that Los Angles is made of just more than its people, but also its ghosts (2012). These ghosts of the past can be felt by exploring the historical places and moments that still haunt Los Angeles today. Ethington's forthcoming book *Ghost Metropolis: Los Angeles Since 13,000 BP* delves into the history of Los Angeles County with data rich cartographic visualizations. The themes explored—demographic patterns, institutional inscriptions, and transections—strive to unearth and visualize the relationships of these ghosts of the past to the current Los Angeles landscape (Ethington Forthcoming). All of his presented work showed unique and powerful methods for analyzing Ethington's primary interest, "historical change over time and space"—in its current context of Los Angeles County. The book is an attempt to tell Los Angeles's history of the "inscription of institutional forms into the landscape." Ethington argues that such inscriptions give this area its unique character, and more precisely, created the spaces that shaped and continues to shape the lives of all Angelenos.

1.2 Motivation

It was decided that this particular visualization technique (transection) produces valuable insights to the study of how changes occur through space and time and thus would be desirous for multiple uses across many fields of spatial inquiry. However the current method for conducting the Ethington Transection visualization (detailed in the next section) is long, cumbersome and prohibitively difficult for use by researchers lacking a professional level knowledge of GIS software. Therefore the primary motivation for automating a visualization using transections is to broaden the use of transections by the research community.

1.2.1 How to perform Ethington Transection visualization without the tool

In order to properly understand the scope of the project and to accurately compare the manual method of creating transections to that of the automation procedure, the step by step instructions for a manual Ethington Transection visualization are sketched out in this section.

Prior to creating a transection, the initial data must be assembled to standardize the areal units. The specific data assembly for Los Angeles was described by Ethington in his analyses of the ethnic shift between 1940 and 2000 (Forthcoming).

First, assemble all the data of interest of a given visualization. There may be situations when this data occurs in different geographic units in different time periods or data sets and therefore must be standardized to a specific/chosen set of areal units. Then, all the data across the variables must be fitted to the chosen geography by area apportionment. Data from the U.S. Census Bureau acquired at the census tract level is an example, while custom geographic areal units can be devised to meet research needs. For instance, a study area can be divided based on school districts, watersheds, or parcels. In creating any level of areal unit, any inconsistencies must be reconciled, such as population occurring in unincorporated areas or multiple polygons in fragmented zones.

Second, all the variables required for the visualization need to be reported using the same criteria and codes. Any variations in criteria or coding schemes must be reconciled and well documented.

After the communities are designated and each contained within a polygon, a transection can be generated following the steps listed in Ethington (Forthcoming). For example:

1) In a GIS, a line is created that will define the transection along which the areal units will be sampled.
2) Every census tract (any polygon) adjacent to the transection is selected, sampled, and the data is exported in a tabular format (ex. Excel spreadsheet).
3) The selected polygons (census tracts), their labels, and the transection line vector are exported to a graphics format (such as Adobe Illustrator's vector based encapsulated post-script [EPS]) to create a map and spatial reference for the transection's final graphic.
4) The attribute data tables associated with the selected, adjacent polygons are then arranged in an orderly E-W or N-S directional order, whichever is most representative of the transection selection.
5) Data from any selected variable along that sequence is plotted on a line graph. A separate line graph is created for all desired variables.
6) All the line graphs are imported into an image editor such as Adobe Illustrator so that the layout and format is adjusted to the scale and position of the map data.

7) Appropriate map elements are added to the graphic are made such as a legend, scale bar, labels, and title.

Despite this standard recipe for conducting an Ethington Transection visualization, there are still assumptions and choices that must be made while assembling the final product. One such decision is what to do if polygonal bounded data sits along the line/path in irregular ways such as overlapping the line, or occurring just above or below it; should all these polygons be included or only certain ones? Decisions must also be made as to how the polygons and their associated data shall be ordered in the map and corresponding line graphs.

The information gleaned from the transections paints a picture of Los Angeles that is difficult to acquire elsewhere. It represents a unique and relevant view of a place that is linear, sequential and directional. It is a vision worthy of exploring further and implementing in other metropolises, or even in other realms of inquiry all together.

The current methods of Ethington Transection visualization are time consuming, tedious and difficult to implement. Although it would be possible for others to create transections using the current methods, the daunting workload would deter all but the most ardent researcher with extensive GIS skills. Consequently this project proposes to devise a method to automate, increase the efficiency, and prove the efficacy of Ethington Transection visualization. By creating a tool to use within a GIS environment, the time to data visualization is shortened and the technique is available to be shared amongst other researchers (Allen 2011).

Whereas transections have already been applied to examine the issues of ethnic segregation, median household values, and parcel geometry (Baldwin 2014, Ethington Forthcoming), additional specific aspects of urban history such as blight, gentrification, architectural structure (building height), immigration integration, drug use, crime trends, and loss of green space could also be evaluated. Urban historians who maintain a database of information about their metropolises of interest could add this tool to their "analysis toolbox", particularly when a metropolis maintains a strong connection to distinct corridors that shaped the changes of their development. For example the Ohio River through Cincinnati, OH which acts as both a physical and governmental demarcation between the states of Ohio and Kentucky which has led to drastically different settlement patterns on either side through history, especially as the influence of the river as a transportation hub waned in the late 20th century. To discover how this path has led to differential establishment of race, economic classes, and land use along the river course would be interesting. Another example is the development of South Florida's "Gold Coast" which initially followed the Intercoastal Waterway, then later shifted to Flagler's influential railway, then shifted again to street based transportation. The influx of various migrant groups to the area and the different cultural connections that they brought with them could be visualized against ethnic integration, economic indicators and land use.

It is also foreseen that this technique would appeal to researchers beyond urban historians. For example, environmental managers could show how the density of trees along a logging road has changed over time, how ecological classifications have changed along an ever more utilized highway corridor, how dominant flora change seasonally on a hiking trail or how fish densities have changed within a river throughout various management practices. Any researcher that is looking for alternative linear visualization techniques to examine their geographically distributed data might be able to utilize the ETT.

1.3 General Objective of Proposed Application

The potential users of the tool are researchers that are interested in illuminating a characteristic (i.e., population, land usage, species count, etc.) along a representative track from their areas of interest. The tool was designed so that minimal GIS and graphic design technique are required to achieve visually appealing results that allow for effective analytic comparisons. The tool was initially tested on data from the Los Angeles area to make it comparable to previously performed transects as described Chapter 4. The automation was accomplished by creating numbered tools, which run from a custom toolbox in ArcMap that starts from a blank map (**Error! Reference source not found.**).

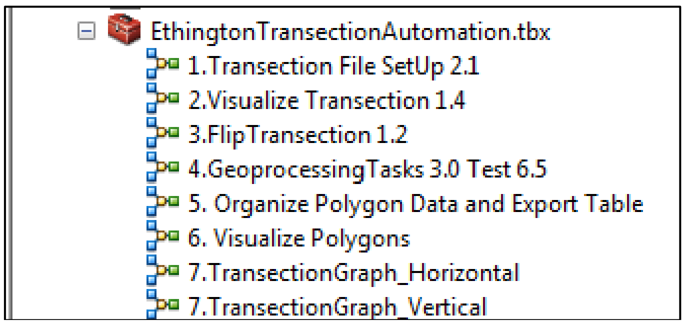


Figure 4. The numbered models in the custom toolbox for the Ethington Transection Toolbox.

CHAPTER 2: LITERATURE REVIEW

In order to put this project in perspective, this chapter reviews the literature about previous similar GIS programming efforts. Acknowledging the derivations of transections in the HGIS community and simultaneously looking towards its use in the broader research community for spatial visualizations, the topics proceed from linear visualization and analysis techniques to basic tool development, while briefly discussing previous HGIS efforts and a review of GIS tools previously made available to the public for use by the GIS community. To close chapter, the distinctions that make this project unique are discussed.

2.1 A Survey of Linear Visualization and Analysis References

Research into the literature revealed that generally linear analysis techniques create an equation model of line pattern or graphs data, often employing statistics. If any visual spatial reference is given at all it is a map juxtaposed with the graph. It is then left for the reader to make the connection between the spatial relationship and that of the distance on the graph. Articles that exemplify slight variations on this strategy in different fields are described next.

Mishra, Parida and Rangnekar quantify and analyze the traffic noise emissions along a bus rapid transit corridor in Delhi (2010). Field measurements were carried out to understand and assess various aspects of the impact of the bus rapid transit system corridor on land use and the social lives of residents and road users. The presentation of some of this data is seen in Figure 5 where the horizontal line graph is juxtaposed with a map in a characteristic arrangement. The remainder of the data presentations—of noise level, indicators of resident health, and additional traffic flow—are line or bar graphs. This particular dataset would be well-suited to visualize in an Ethington Transection as it of a transit path through varying sectors of the urban landscape.

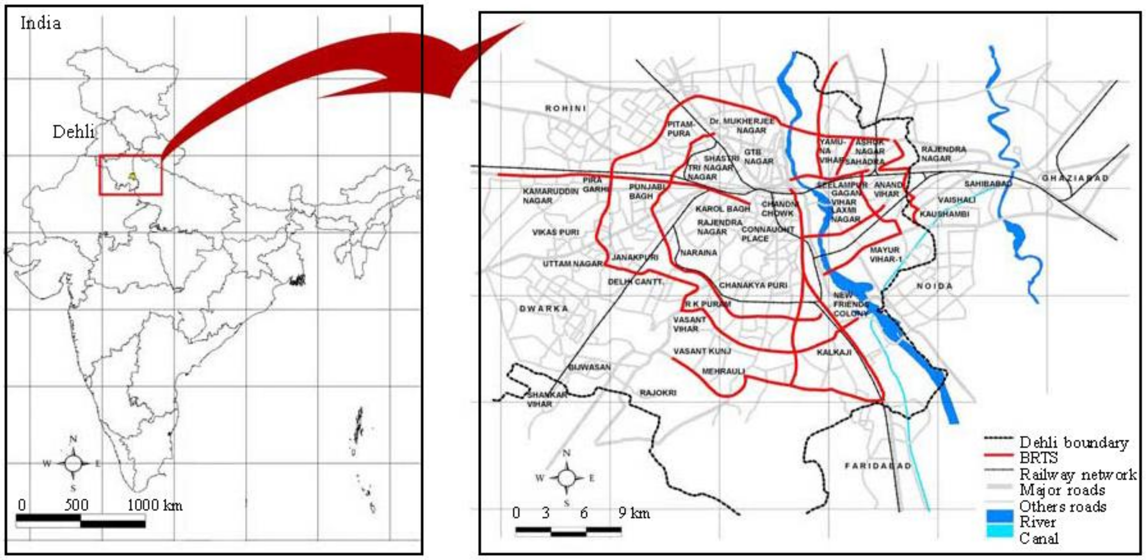


Fig. 1: Bus rapid transit system network of Delhi

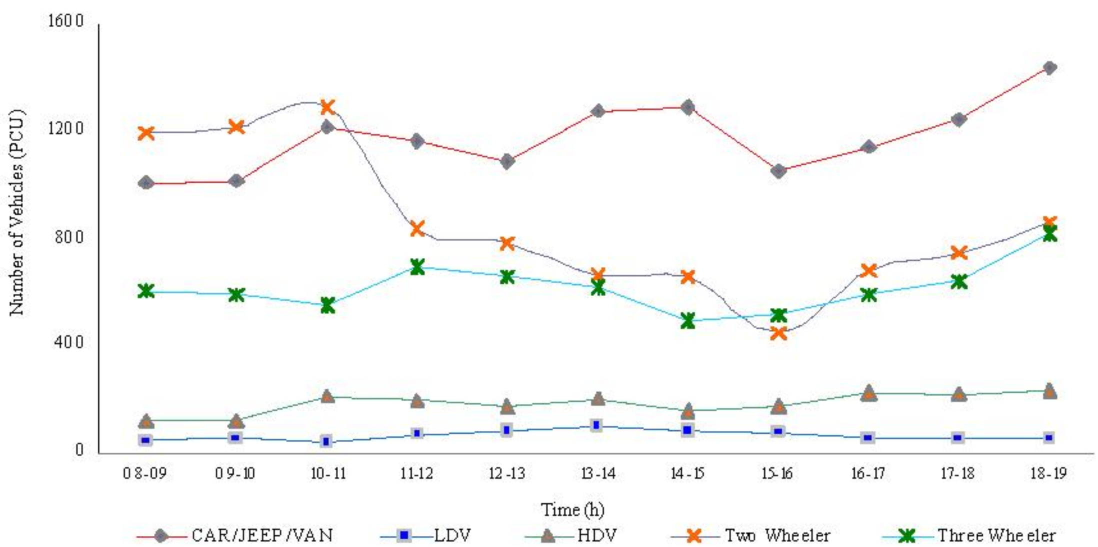


Fig. 2: Hourly traffic flow towards Moolchand at BRTS corridor

Figure 5. Traffic flows on Delhi bus routes (Mishra, Parida and Rangnekar 2010).

Investigating a different set of parameters associated with well-traveled roadway, Alexander and Waters monitored wildlife movement across and adjacent to the Trans-Canada Highway (2000). The annual average daily traffic rate of the Trans-Canada Highway is 14,000, and the adjacent Highway 1A is 3000 as they traverse Banf National Park, in Alberta, Canada. Animal tracks were observed crossing roadways and on transects adjacent to roads for wolves, cougar, lynx, wolverine, marten, elk, deer, sheep, hare, and red squirrel relative to road types, and it was determined that the highway was indeed a barrier to movement for all species. The figure most connected to the spirit and purpose of an Ethington Transection can be seen in **Error! Reference source not found.**, where the map is labeled and two small horizontal line graphs of wildlife movement are inset. The remainder of the article depends on tables of data and summary statistics to make its case. Again this seems a perfect candidate for an Ethington Transection whereas this research actually used a well-established transit path as its locational determinant for data collection, only failing to make the leap to visually connect the data to the spatial distribution.

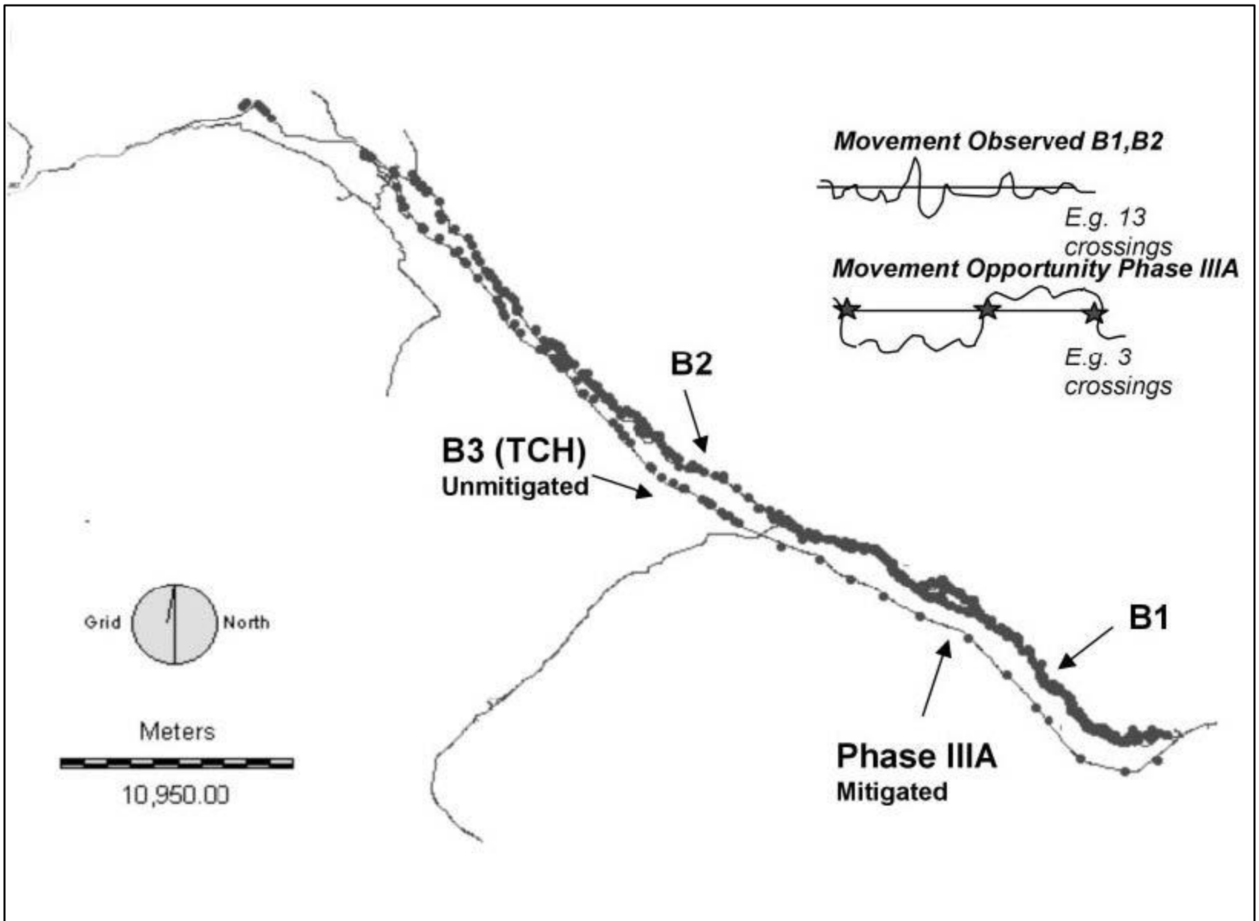


Figure 6. Wildlife movement on Trans-Canada Highway (Alexander and Waters 2000).

Some other studies investigated how to model water infiltration through bedrock and identify steep concentration gradients (Maier, Flegr, Rügner, and Grathwohl 2013), and the yearly seasonal depth distribution patterns of an invasive macroalga via a transect through a typical Sargassum bed in Limfjorden (Thomsen, Wernberg, Stæhr, and Pedersen 2006). This second example contains one graph series showing variables such as species richness, % coverage, and % substrate mapped against distance from shore. At least this representation is scaled to match the landscape, though again the final step of connecting the spatial visually to the data is missed.

A particularly entertaining study mapped seasonal distributions of elephant dung with transects (Vanleeuwe 2010). A selected number of line-transect were used to collect data on elephant dung piles that were then analyzed using the generalized linear model. The results of the analysis was used to build explanatory models and distribution maps (heat maps) which became powerful tools for patrol planning and land-use management by locating the areas of high elephant density and the habitats they move between. Here the data collected on a line was used to interpolate results to the larger geographic area of Mount Kenya National Reserve that encircles Mount Kenya National Park. Because of the rugged terrain and inaccessibility it was near impossible to distribute transects evenly over the entire habitat as would typically be done, instead walkable transects were created that were as similar in nature as possible in length and relationship to natural features (such as rivers), but that managed to traverse the diversity of the possible habitats in the reserve. Consequently these transects take on more of the feel of transection. However as the purpose of a transection is to display polygonally distributed data in a linear format, the purpose of this transect was the inverse—to interpolate the linearly collected data to a larger geographic area that was visualized as heat map distributions for the entire Reserve (Figure 7).

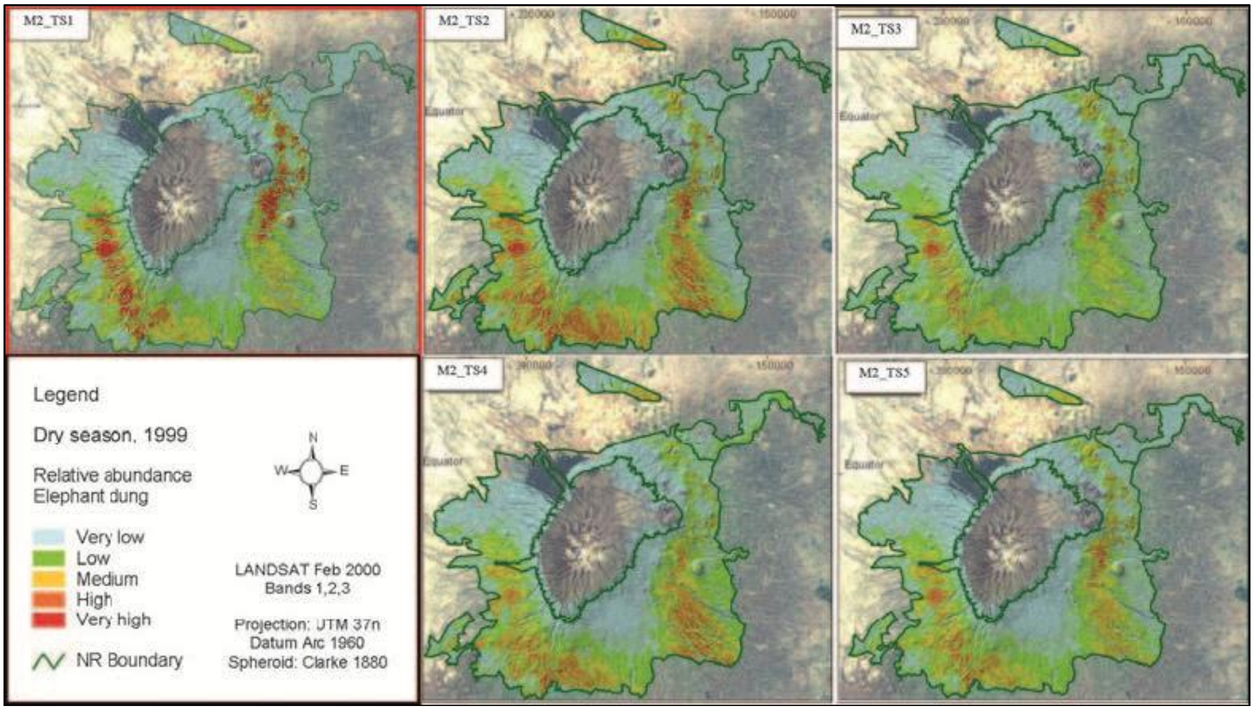


Figure 7. Elephant density as determined by dung piles at Mount Kenya (Vanleeuwe 2010).

One final mention of a study using linear techniques. Just as Ethington created transections to visualize the patterns he wanted to explore in urban historical data, Watson and Pauly created 'catch transects,' a novel intuitive approach for the representation of fisheries catches within profiles perpendicular to the coast (2014). These 'catch transects' show where catch is extracted in the water column on plots of bathymetry versus distance offshore and thus allow for spatial representation of the catch density of pelagic and benthic fisheries in heat maps (Figure 8). Hence, they allow direct visual comparison of the intensity of fishing through time and space, very much in the spirit of an Ethington Transection.

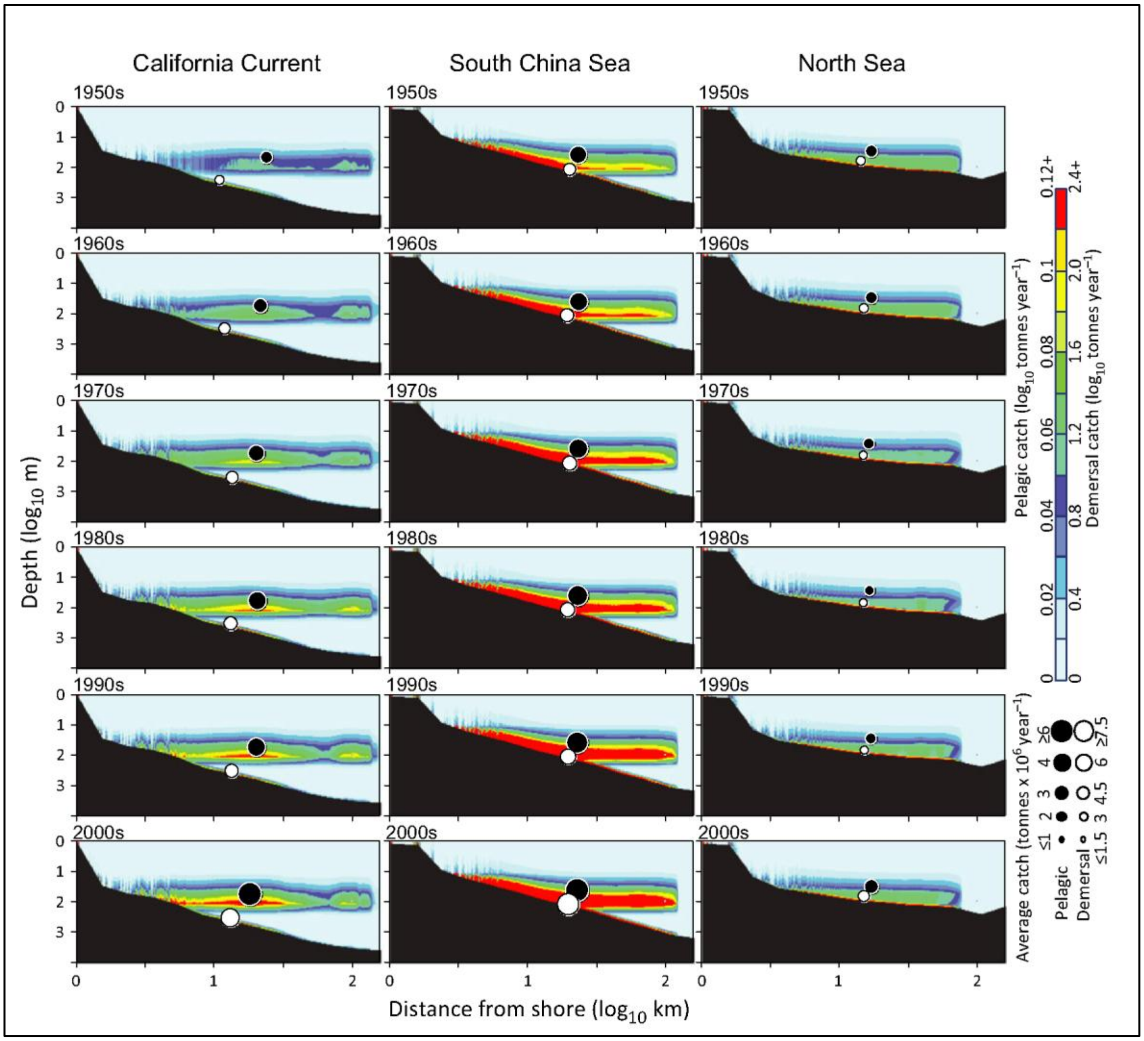


Figure 8. Catch Transects for multiple years in 3 locations (Watson and Pauly 2014).

2.1.1 Transects vs. Transections

The search term "transect" yielded 22,694 results just from the general search engine employed by the USC library system, and thus it would be impossible to assert a thorough understanding of them all. Therefore with the awareness that no search can ever be claimed to be thoroughly exhaustive, and after sampling several hundred articles on the subject of transects and spatial linear analysis and visualizations, it will be stated here that no exact replicate of the Ethington Transection technique has been found reported in the literature. Therefore it will be instructive to discuss the differences between and Ethington Transection and traditional transects a summary of which can be evaluated in Table 1.

By its very nature, an Ethington Transection is linear, sequential and directional. Most uses of transects only call on their linear quality and fail to incorporate any sequential or directional information, particularly in their data display. Transections make use of a pre-existing human path of travel over the landscape that has purpose and meaning, and very likely repeatable, versus a random or systematic line that is conjured solely for the use in the study. Other data displays do not typically align with cartography even though admirable examples of this concept have been historically available such as the previously mentioned Minard's visualization of Napoleon's Russian campaign (Figure 1; 1869). Instead the map and graph are simply set beside each other with the left to reader to ponder the spatial relationship, unlike transections which make the effort to graph data that is spatially aligned and scaled to match map.

The purpose of Ethington Transections are to visualize how data density drawn from a polygonal distribution changes as you move along a previously defined path through the landscape versus that of transects which are to define probable density distribution of an area by sampling a "representative" linear path through that landscape. These hint at the differing underlying assumptions of the two techniques; transects use point data collected along a line to interpolate to a broader geographic area, whereas transections visualize polygon distributed data along a specific path of transit.

Table 1. Comparison of Transects and Transections.

Transects	Transections
Uses point data collected along a line to interpolate to a broader geographic area such a polygon	Uses polygon distributed data to visualize a specific linear path of transit
Novel path; A line randomly or systematically generated in the landscape that is irrelevant to repeated measures and generally only defined and meaningful within the bounds of the study	Pre-existing path; A path of travel through the landscape that has purpose and meaning and likely repeatable (i.e. streets, rivers, railroads)
Cartography separate: Graph and map are set proximate to each other without regard to scale and visual alignment	Integrated with cartography: Graphed data is spatially coordinated, aligned and scaled to match map
Purpose is to define probable density distribution of an area by sampling a "representative" linear path through that landscape	Purpose is to visualize how data density drawn from a polygonal distribution changes as you move along a previously defined path through the landscape

2.2 GIS Tool development efforts in the Literature

Other similar computing tool development projects, outside of linear analysis and visualization, have also been reported in the literature. A shorter term (30 year) time series of the sea ice benefited from the development of a Java-based tool to ease access and visualization of the National Ice Center's (NIC) abundant data (Tang and Wong 2005). These tools were developed to facilitate the analysis and statistical visualization of the NIC dataset via the web. An HGIS tool for urban planning decisions, iCity, utilized irregular cellular automata modeling and was a user-friendly tool designed to be embedded for use within a GIS desktop application (Stevens, Dragicevic, and Rothley 2007). CHaMP is a similarly webpage embedded tool to transform environmental monitoring survey data that was created as an ArcGIS Add-In with a user-friendly interactive interface (Wheaton et. al. 2012). The Florida Panther Habitat Estimator tool automates the geo-processing tasks used to apply a Mahalanobis distance (D 2) statistical habitat model to quantify the effects of land-use changes on panther habitat, and was designed for use by persons with only modest GIS familiarity (Murrow et. al. 2013). The System for the Prediction of Acoustic Detectability GIS tool (SPreAD-GIS) is implemented as a toolbox in ArcGIS that was written in Python in order to model noise propagation in natural habitats by using commonly available datasets on land cover, topography, and weather conditions (Reed, Boggs and Mann 2012). The Beach Morphodynamic Model tool (BeachMM) integrated two prediction models for coastal processes— Simulating Waves Nearshore (SWAN; SWAN 2015) and XBeach (Roelnivik et al. 2009; Roelnivik 2010)—into one Python script for use within ArcGIS (Silva and Taborada 2013). BeachMM was shown to greatly simplify dataflow effort, reduce human error, and provide a dynamic visualization of these coastal prediction models.

A highly ambitious project developed a set of geoprocessing tools for integration of several platforms to aid in marine geospatial analyses. From within ArcGIS ecologists can utilize the Marine Geospatial Ecology Tools (MGET) that provide user-friendly access to the advanced analytic methods available in ArcGIS, Python, R, MATLAB, and C++ which are extensible, powerful, easy-to-use, and open-source (Roberts et. al 2010). The aim of these tools was to put the techniques in the hands of the average marine ecologist so that they did not have to perform the programming or learn every software package to accomplish the analyses.

A very similar approach to the one taken for this project can be seen implemented for the analysis of walkability in Canada (Rattan, Campese and Eden 2012). The complete walkability analysis workflow can easily be repeated due to automation provided by ArcGIS ModelBuilder which was delivered in a custom toolbox. As data are updated, only simple changes in input parameters are required to run through the four models and perform new analyses. The parallels to HGIS continue with its use of ArcMap's geocoding tools and the Esri Network Analyst extension (Esri 2015a). The automation of the first four steps of the workflow reduced the necessary time, effort and technical GIS skill required to conduct the analysis.

Additionally *ArcUser* magazine, over the last 15 years, has featured many uses of ModelBuilder to automate workflows varying from transportation networks, fire hazards, flood heights (Bell 2004; Dilts, Yang and Weisberg 2010; Pratt 2000; Spalding 2000). All these articles showcase how ArcGIS ModelBuilder can streamline the analysis process to reduce time, effort and skill level required, which is the goal of this particular thesis project.

2.3 Previous HGIS efforts

Technical work in history research in the GIS field has involved the creation of projects that digitize historical documents and create maps to allow for spatial analysis. Just such an example is in the HGIS of the Southern Great Plains created to digitize the erosion maps from 1936-1937 (Cunfer 2011). Another example is where the urban historians gathered data on the single tradesmen of Victoria, BC's building boom circa 1891. This case study combined qualitative and quantitative data on 2,000 urban working men to create a spatial database as a research tool for labor historians (Dunae et. al. 2013). And yet another HGIS was created based on the European railways during 1830-2010 in order to analyze the relationship between population distribution and railway development (Morillas-Torné 2012). A case study in Seattle, WA on the effects of the removal of the 245-foot Denny Hill in 1906 and 1935 developed an HGIS by digitizing the study site evidence between 1893 and 2008 (Raymond 2011).

In addition to the development of HGIS, there has been work in tools developed to facilitate HGIS analyses. Audisio, Nigrelli, and Lollino (2009) created a new HGIS tool implementing a systematic strategy for analyzing historic geologic instability processes that utilizes the framework of a tool fashioned for swift and methodical ingestion of records into a

GIS. This tool adds the ability to ingest visual information (such as maps and aerial photos), and allows the analysis of instability phenomena to include the effects of intense rainfall events. The new information gathered with their HGIS tool allowed the researchers to conclude that the amount of catastrophic events was increasing over time and thus inform policy makers so that they could properly prepare for future situations.

2.4 Available tools in on-line repositories

A slightly different execution can be seen in some of the apps available in the ArcGIS Online Marketplace. In particular, Esri Insights operates ways that parallel this proposed tool. A user can generate info-graphics of demographic data by placing a pin (with buffer), drawing a line (with buffer), or delimiting an area using a simple configurable and interactive web-based tool (Esri 2014).

At the time of this writing, a search of GitHub's ArcGIS repositories yields 1,626 results, 296 of which are Python based (GitHub, Inc. 2015b). Tools (and toolboxes) can be found that range from making it easier to work with NASA remote sensing data, to acquiring Tweets within a radius of individuals features, to just making it easier to batch move files in ArcCatalog. Of note is the ArcGISCensusDownload Python toolbox which automatically downloads relevant Census data based on a user's specified area of interest (Reiser 2014). This particular tool would be helpful preparing data for areal reapportionment prior to running the Ethington Transection Toolbox.

2.5 Novelty of proposed project

The proposed project is similar to previous linear analysis and visualization efforts in that data for analysis are acquired along a linear path. Although this one differs in that the line is drawn along a transit path versus other random or systematic style transects, and aligning the data points to locations on a coordinating map further enhances the technique's visualization. Additionally the use of ArcGIS ModelBuilder to automate workflows has been well documented in the scientific literature and trade journals as a method to increase efficiency and broaden the audience of available users for particular analysis and visualization techniques. This project is the first attempt at a user-friendly, interactive automation tool for linear visualizations specifically for creating Ethington Transections at the time this project was conducted. The creation of this toolbox is truly a synthesis of techniques and theory that has not been achieved before.

CHAPTER 3: METHODOLOGY

The spatial analysis and mapping technology currently available are continuously evolving. In general, a spatial analysis which consisted of hundreds of steps and took days to complete, from theory to process to final graphics, is now automated for ease of use. In this study, the primary goal of this thesis project was to employ available GIS technology to simplify and automate an existing lengthy set of procedures originally being executed in Adobe Illustrator, Microsoft Excel and Esri ArcGIS. The Ethington Transection (Ethington Forthcoming) has been developed from a basic theory of visualization for "how a human travels through space" approach of a geographically distributed variable into a compact digital spatial visualization and mapping methodology which is described in this chapter. Since the foundational steps of the process were already being performed using Esri, a popular GIS industry standard, and since ArcGIS has additional powerful automation tools built-in, this was deemed the perfect technology to implement this thesis project.

3.1 Programming Objectives

The primary programming objective for this project was to design a desktop application that can be executed from within Esri ArcGIS that dramatically simplifies and shortens the time required to perform an original Ethington Transection (Ethington Forthcoming). The objective is to allow users to easily select a path through a geographic area and to create an Ethington Transection graphic (map and line graphs in a standard layout) and decrease the time it takes to perform these tasks. To meet this objective, the intent was to code and implement this desktop application with a user-friendly interface that does not necessitate additional software requirements of the user beyond Esri's ArcMap.

An important motivation for this effort is to put the Ethington Transection visualization technique into the hands of more users, so that others can better understand the variable within the spatial context as they change across a landscape. Ensuring that the Ethington Transection Toolbox is user-friendly and timesaving, increases its appeal to a broader audience. Removing requirements to install and license additional software other than Esri to perform the visualization should also reduce barriers to its use.

Thus for the purposes of this study, a custom toolbox within ArcGIS 10.3 was created using ArcGIS ModelBuilder to allow for easy sharing of application within the ArcGIS user and developer communities. The tool also requires ArcGIS Network Analyst extension version 10.0 or higher for sequencing geoprocessing tasks along a user-selected spatial path or transect. The Ethington Transection visualization variables were exposed so that each tool user can easily introduce unique input data for which transections could be created. This means that the tool can be used anywhere (where input data is available), thus is independent of location.

3.2 Technology: Software Choices and Programming Considerations

Esri ModelBuilder allows the developer to connect a long string of geoprocessing tasks into a single tool, or step for the tool user. By laying out blocks resembling a flowchart within the ModelBuilder interface, a developer can visually connect the tasks that represent the underlying code (Allen 2011). The ETT was divided into seven ArcMap models to allow for user modifications between steps, and multiple runs of the same data while changing selected variables (see Figure 4).

Historically, Ethington Transections were created using Adobe Illustrator for creating map layouts and Microsoft Excel for generating graphs of results. Illustrator is similar to ArcMap only in regards to map creation or layout functionality. Conveniently, the ETT developed for this thesis allows users to export results to file formats suitable for graphics and presentation programs such as Illustrator and Microsoft PowerPoint. The graphing previously done using Microsoft Excel is now accomplished through ArcMap graphing tools, where again users also have the option of exporting the results to other charting or graphics software for further refinement.

3.3 Application Development

Figure 9 provides an overview of the Ethington Transection Toolbox application development process. The general tasks are listed down the center in order performed. The itemized goals of each task are detailed immediately to the right of each task. The Application Development functionality used to accomplish the enumerated tasks are listed on the left of each task in a font color that coordinates with the task numbers. The creation of the ETT Evaluation (4), Documentation (5), Zip ETT for Delivery (6) and ETT Efficacy Test (7) are listed as the last three steps of the process in the diagram, however behind-the-scenes these processes continuously occur until the completion of the project.

The tasks in Figure 9 are ordered so that the majority of the tool's creation progress is completed early on in the application development process. This allowed for the maximum amount of time to be devoted to testing and validation of the results of running the tool. In hindsight this was a good move, considering the challenges in coding the beginning and ending models as a series of geoprocessing tasks.

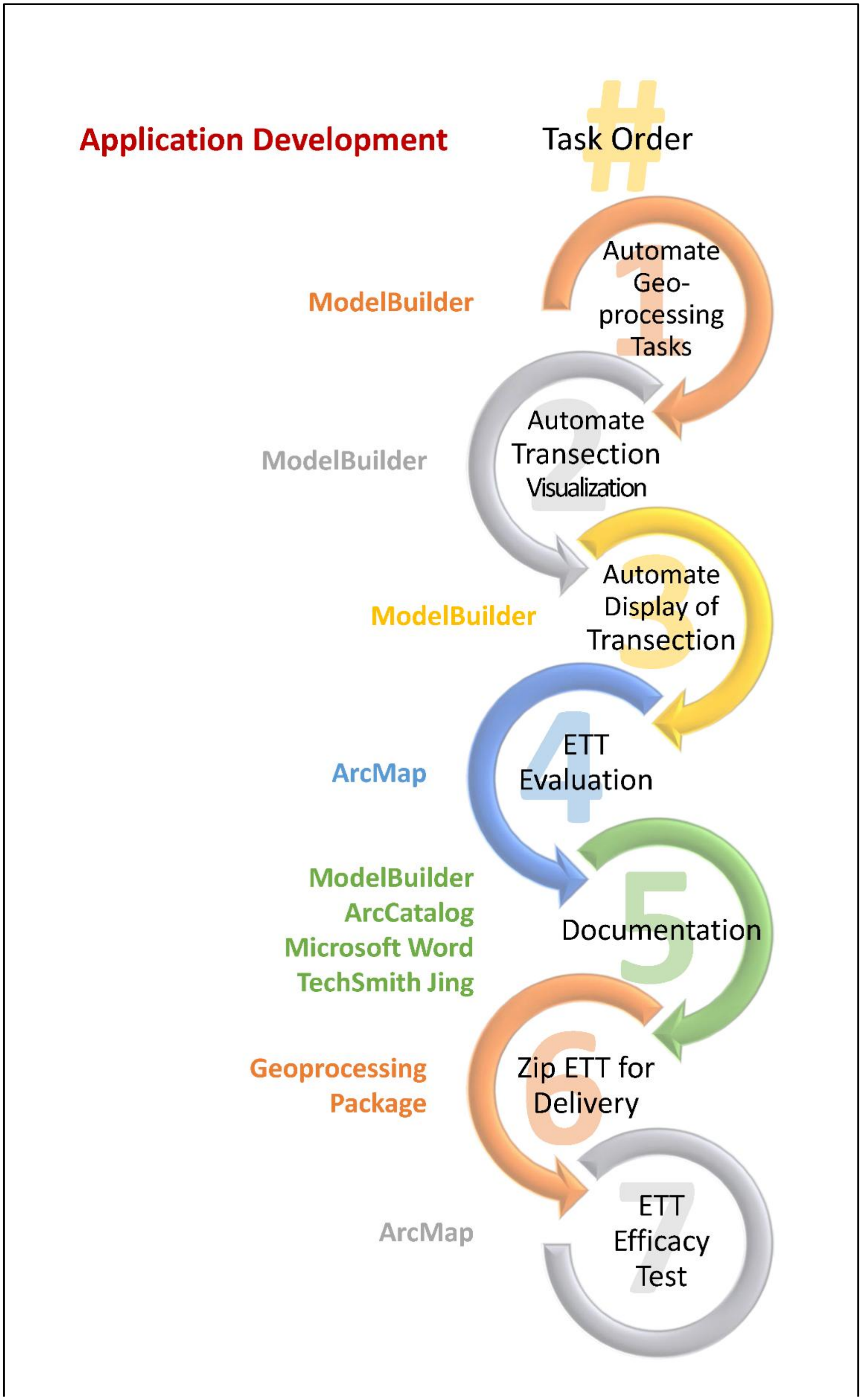


Figure 9. Flow chart for the development of the Ethington Transection Toolbox.

3.3.1 Task Goals Detailed

The individual goals are detailed next in order to better understand the specifics of each task in the Application Development Flow Chart (Figure 9). For the first task, “Automate Geo-processing Tasks,” the goals were to: establish a geodatabase workspace; select the transection line, measure its length, and export as feature class; select adjacent areal units, export them as a feature class, assign an order to polygons, and establish geographic centers along transect line; and select the columns (variables) of interest and extract all relevant data to a feature class and exported table. The goals of the second task, “Automate Transection Visualization,” were to: establish a virtual transection line as a straight line space for graphing; assign areal unit centers along a virtual line, and get measurements of position along that line; and plot the desired data. “Automate Display of Transection” was the third task whose goals were to: display data plots with labels and predefined symbology; add transection and areal unit selections map with labels and predefined symbology; and add a title and brief explanation. For the fourth task, “ETT Evaluation,” the goals were to have the: developer test the entire workflow of ETT with different data scenarios; developer refine the ETT as issues arise from testing; developer’s committee members test the entire workflow of the ETT; and developer refine the ETT based on comments from committee. The fifth task’s goals, “Documentation,” were to: label major steps within each model diagram; construct context sensitive help (Appendix A); create a “User’s Manual” with step by step instructions (Appendix B); and produce short instructional “how to” videos (links available in Appendix B). The goals of the sixth task, “Zip ETT for Delivery,” were to: collect all seven modules in one custom toolbox; create a Geoprocessing Package within ArcMap of all necessary supporting files; and create a compressed folder (zipped) of ETT file for cloud/ web-based delivery (Figure 19). Lastly the two goals for the seventh task, “ETT Efficacy Test,” were to test the ETT on current Los Angeles data, and then to test it on two other data types from public data sources. One was visualizing Washington DC's population characteristics along the Orange Metro Line, while the other was plotting the species diversity of the Environmental Sensitivity Index along the FL Intercoastal Waterway.

3.4 The Ethington Transection Toolbox Models

The seven tools within the ETT are detailed next. Each numbered tool narrative contains a description of its function, the necessary user inputs and a listing of its outputs. The numbers following the tool's name indicate version numbers of that particular component. These designations were necessary during application development to maintain organization while testing multiple programming strategies. All actions are executed in ArcMap unless otherwise indicated in the narrative. All seven help documents detailing parameter input criteria can be found in Appendix A.

3.4.1. Transection File SetUp 2.1

This model will help collect all the files and create the beginning file structures necessary to create the Ethington Transection illustrations (Figure 10). This model will run from the catalog window starting with a new blank map open in the map window. Each time this model runs a unique set of names for the folder must be entered, otherwise errors will be generated proclaiming that the file already exists. In order to run this tool a second time with same names, the user must delete the files created during the first iteration of this tool. The two inputs for this model are; a polygon file (shapefile or feature class) of the areal units containing data on the variable desirous of analysis, and a file (shapefile or feature class) containing the line feature to be used as a transection. The outputs generated are a new file geodatabase with one dataset and two feature classes. The feature classes are copies of the two inputs. The two feature classes are placed as layer files in the previously blank map and projected according to the coordinate system designated in one of the parameters.

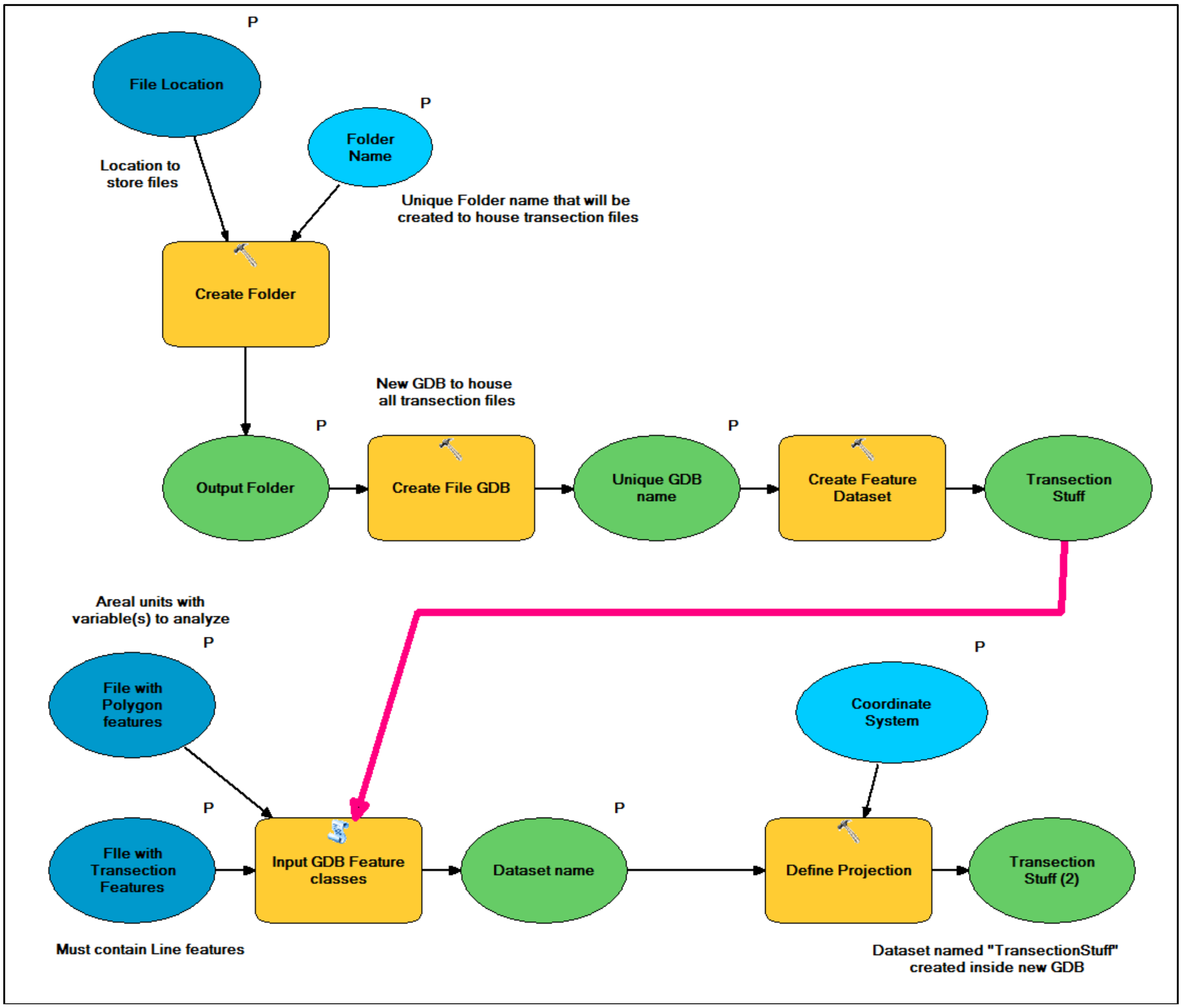


Figure 10. ModelBuilder view of Model 1.

3.4.2. Visualize Transection 1.4

This model is intended to visualize the direction of the transection and isolate all files necessary for transection visualization (Figure 11). This step should not be skipped in order to ensure proper directionality of transection visualization. The two inputs for this model are; the transection's layer file, and a symbology layer (included in the ETT zipped folder) to correctly designate the direction of travel along the transection. The outputs generated are a new layer file of the visualized transection and a new feature class for the transection with additional fields containing directional information for the creation of the network route in Model 4.

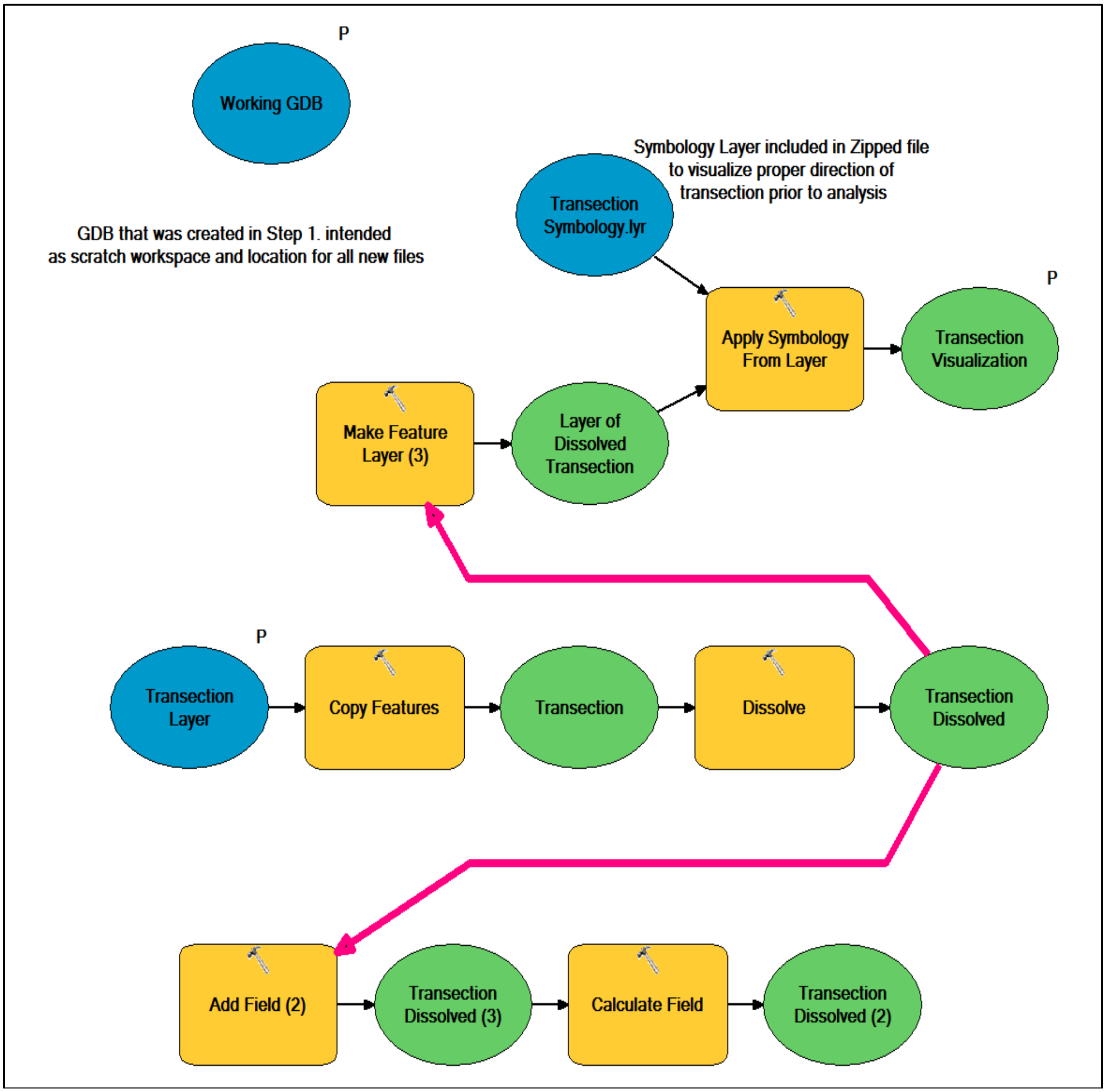


Figure 11. ModelBuilder view of Model 2.

3.4.3. FlipTransection 1.2

This model is used to reverse the direction of the transection after it is visualized in step 2 of the Ethington Transection Toolbox (Figure 12). This step is optional and only required if the user desires the order of the polygons to go in the opposite direction as those visualized in step 2. This model may run any multiple of times without complications, however as it only switches the direction back and forth, this should not be necessary. If the direction of the line is already correct proceed to step 4. The two inputs for this model are; the transection's layer file, and a symbology layer (included in the ETT zipped folder) to correctly designate the direction of travel along the transection. The outputs generated are a revised layer file of the visualized transection.

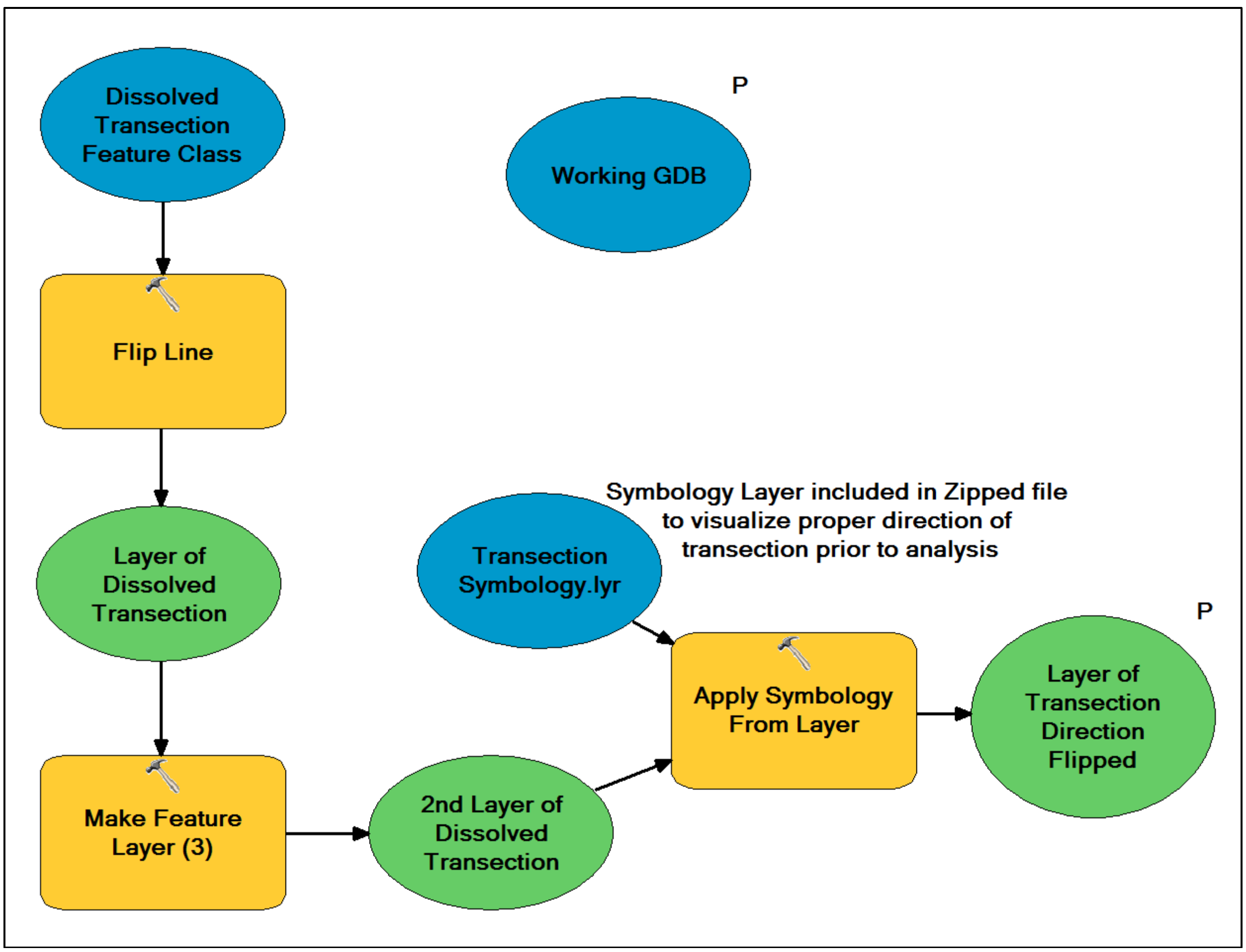


Figure 12. ModelBuilder view of Model 3

3.4.4. GeoprocessingTasks 3.0 Test 6.5

Reported herein are the primary geoprocessing tasks to automate the creation of Ethington Transections within ArcMap (Figure 13a & b). This model performs a selection of polygons adjacent to the transection and exports them to a new polygon feature class in the geodatabase. Then the transection is divided into segments at the junctions with the polygons in order to determine relative distances traveled along the transection within each polygon. Then center point along the transection segment within each polygon is determined. Using a network dataset, a new one-way network route is calculated which numbers the transection segment centroids according to their order along the transection. Next the new polygon feature class of adjacent areal units is spatially joined with the ordered transection segments. Lastly, the order of the polygons is visualized as a layer file. This step requires the use of the ArcGIS Network Analyst extension version 10.0 or higher, in order to determine the correct polygon sequence. The inputs for this model are; the transection's feature class, the polygon feature class, and a symbology layer (included in the ETT zipped folder) to visualize the order of the polygons. The outputs generated are a new layer file of the visualized polygon order and additional columns in the polygon feature class designating their order along the transection and relative distances traveled within the polygons along the transect.

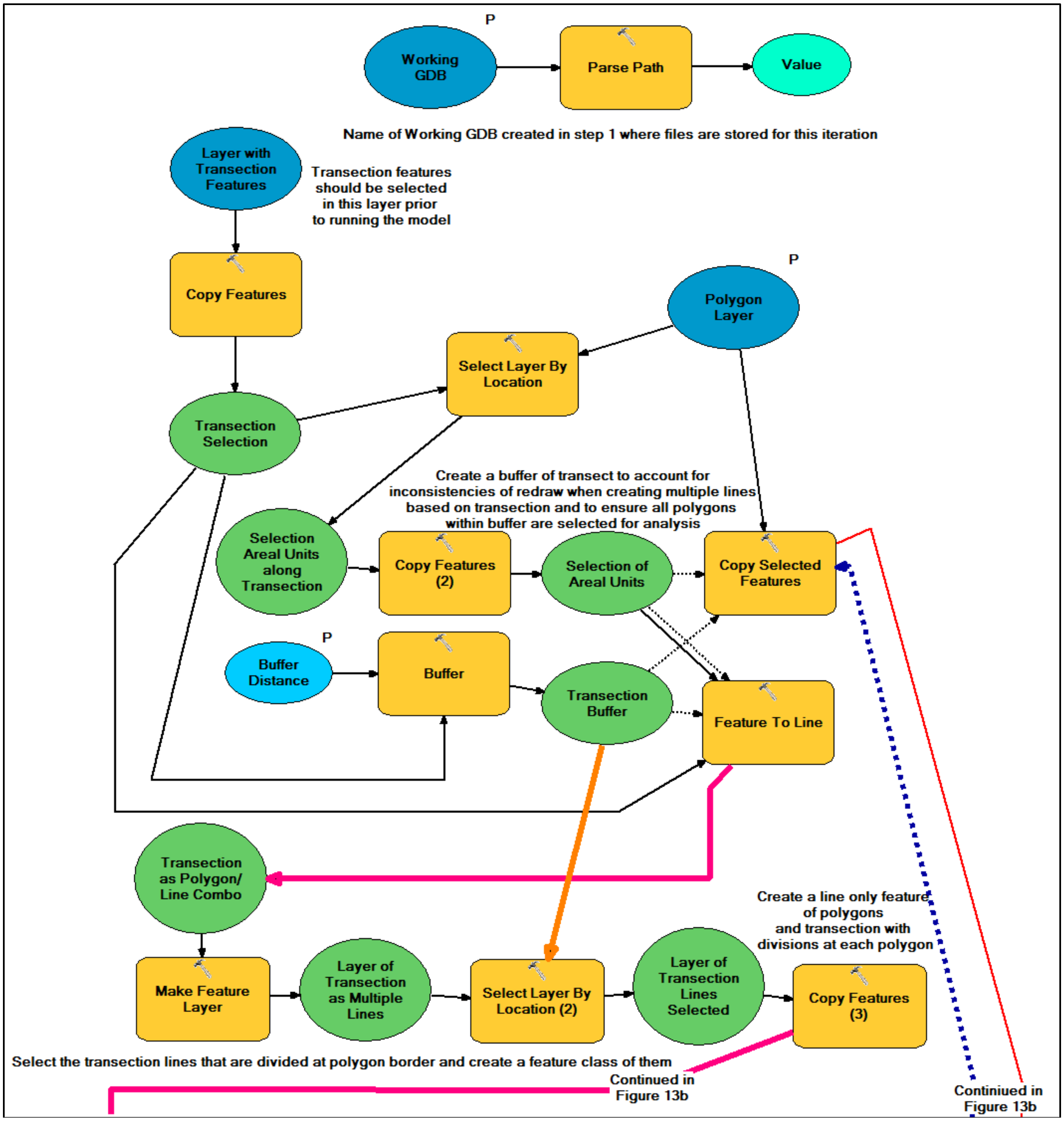


Figure 13a. ModelBuilder view of Model 4.

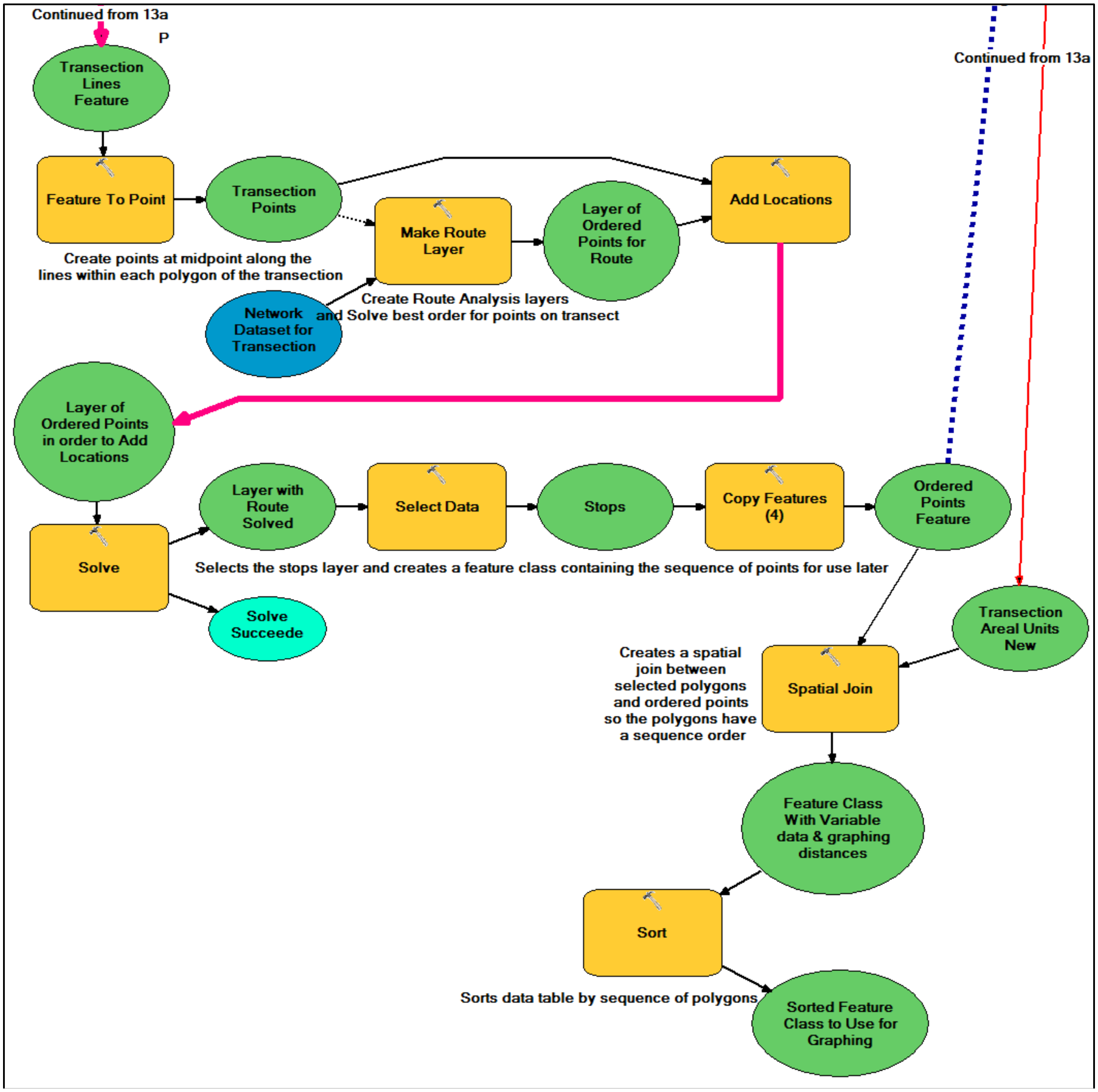


Figure 14b. ModelBuilder view of Model 4.

3.4.5. Organize Polygon Data and Export Table

This model organizes the polygon data generated in “4. Geoprocessing Tasks 3.0 test 6.5” for export to Excel and graphing in ArcGIS (Figure 15). This allows for quick visualization of the data in subsequent models. The only input for this model is the joined polygon feature class. The outputs generated are a revised polygon feature class and an Excel table of the joined polygon data.

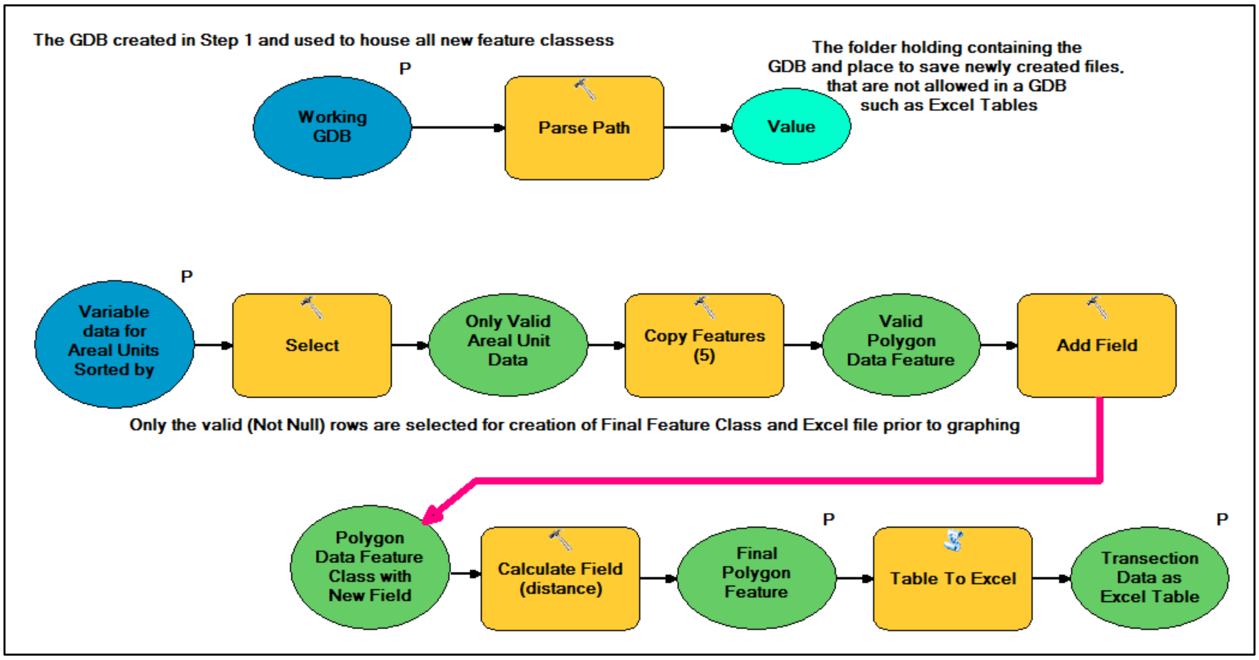


Figure 15. ModelBuilder view of Model 5.

3.4.6. Visualize Polygons

Step 6 of the Ethington Transection Toolbox. This tool is intended to show the sequence order of the polygons to ensure proper placement prior to graphing the data (Figure 16). The two inputs for this model are; the polygon feature class, and a symbology layer (included in the ETT zipped folder) to correctly designate the order of the polygons along the transection. The outputs generated are a new layer file visualizing the polygon sequence via labeling using the "Order" variable.

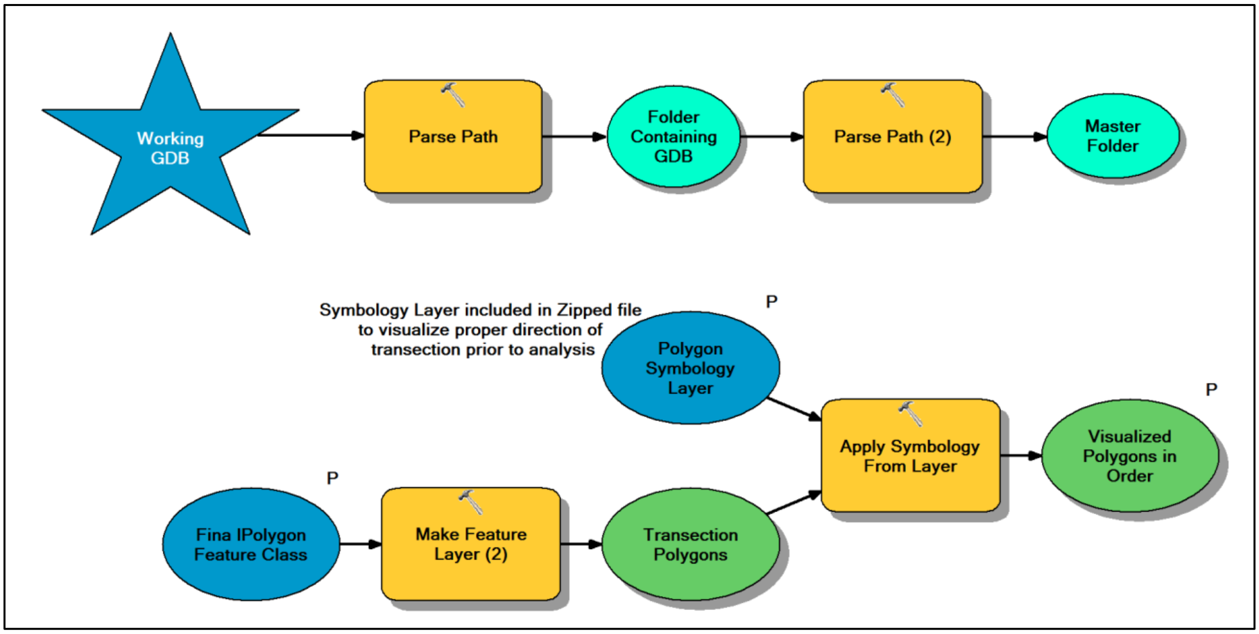


Figure 16. ModelBuilder view of Model 6.

3.4.7. Transection Graph_Horizontal (or _Vertical)

This model is to create a line graph of the data from the execution of previous steps in the Ethington Transection Toolbox and exports that graph in a designated format. There are two versions of this tool. The first one shown in Figure 17 will display a graph oriented in the horizontal direction. However if the orientation of the chosen geographic data is more vertical, the alternate version "7. TransectionGraph_Vertical" should be utilized. The orientation of the graph directs the choice of plot type chosen to create the template for the model, therefore a separate template was needed for each graph orientation. Only one template can be specified at a time in a model, therefore two separate models were needed to allow for both directional eventualities. The two inputs for this model are; polygon feature class, and a graph template (included in the ETT zipped folder) to visualize the data plot in a similar style to that of the manually created Ethington Transections. The output generated is a new graph file.

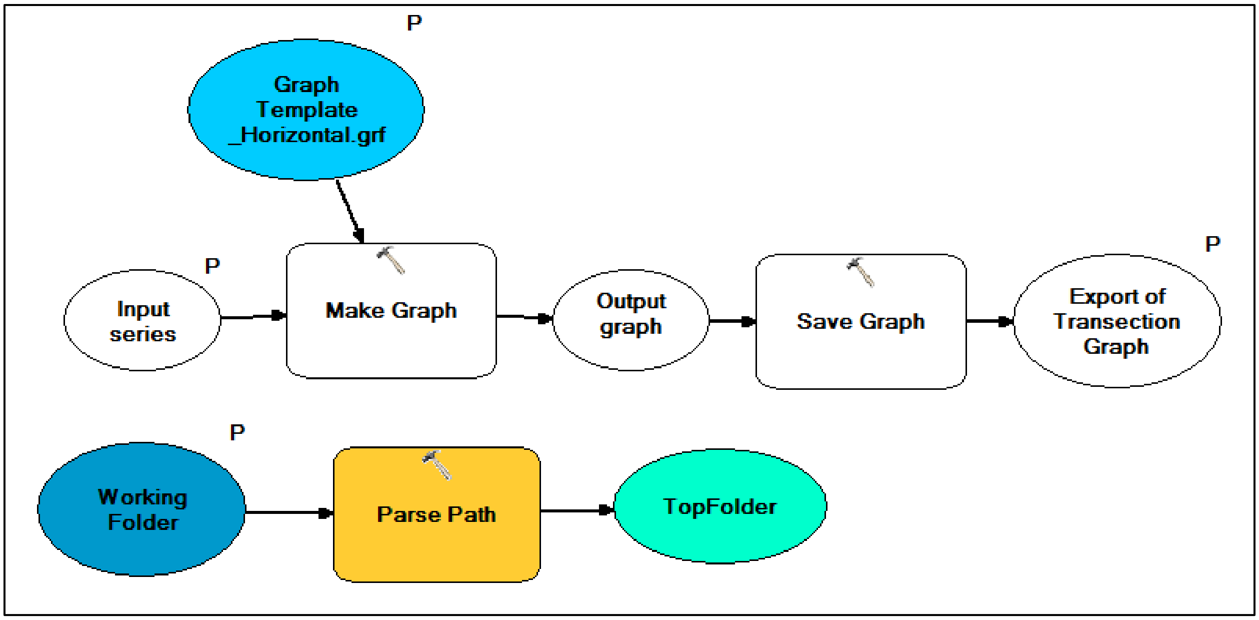


Figure 17. ModelBuilder view of 7. TransectionGraph_Horizontal

In summary, the final version of the ETT only requires two novel data inputs from the user. All other parameters set by the user while running the ETT are required decisions being made by the user in order to customize the end result. The primary output as the end result is a layout consisting of a graphically stylized map and a line graph.

3.5 Documentation

The documentation process occurred throughout application development in order to maintain an organized experience for both the developer's programming and the end user's visualization. The general methods of documentation are listed in Figure 9 but are discussed in greater detail here. The first means of documentation was within each model diagram to label major steps and to identify the specifics of each parameter inside ModelBuilder's edit window (Figure 10 through Figure 17). This aided in application development as modules were moved and edited in order to fine tune the results of the model. The second means of documentation was to construct context sensitive help that appears during the running of the model if the help window is open. A summary entry was written for each model and then for each parameter from ArcCatalog's information edit dialog. Each of these documents have been saved as PDFs and can be reviewed in Appendix A. Next, a User's Manual was created in Microsoft Word and exported as a PDF for cross-platform capability (Appendix B). This document contains step-by-step instructions for the entire process, especially emphasizing steps needed in between the running of the sequential models. In order to supplement the User's Manual and create the most straight forward user's experience, short instructional "how to" videos corresponding to each model were produced. These are video screen captures of the models being run along with narration describing the steps and parameter settings to use the tool effectively. The videos were generated with TechSmith Jing and their hyperlinks were integrated into the User's Manual (Appendix B).

3.6 ETT Evaluation

During the course of the coding process, all models were periodically evaluated for individual effectiveness by running the ETT multiple times using different transections whose intermediate data outputs had been previously determined manually. The tests were all run on the same data that rendered the initial Ethington Transections compiled manually. This data was stored in a file geodatabase that was amended during the testing phase to include the sample transections and intermediate outputs. There were three different transections (**Error! Reference source not ound.**) that were created as tests and all were line features in one feature class called "Sample Transections" that were selected by various methods (select by attribute, select by geometry and using the ArcMap interactive selection tool) between Model 1 and Model 2. The three test transections used to evaluate tool performance during ETT application development (SimpleLine, Spiral Track and Tracks) can be seen in Figure 18 along with the feature classes visible in the catalog window on the right side of the figure within the labeled dataset. The ETT generated outputs were then compared to the expected outcomes. When discrepancies occurred the programming was altered until an adequate solution was achieved ("debugged").

Figure 18. The three test transections used to evaluate model performance.

Three times during the programming process, two members of the thesis committee also evaluated the ETT for ease of use and generation of understandable outputs. One committee member would be considered an expert/experienced Esri ArcGIS user, who teaches graduate classes in the spatial sciences that often utilize ArcGIS. The other member is a professor outside of spatial sciences, but who utilizes ArcGIS in his work and would be considered an intermediate level user. These two differing levels of experience helped to evaluate the functionality and ease of use of the ETT. The models were distributed to the committee in compressed folders via a cloud-based based file sharing and storage platform that was then downloaded for testing onto their ArcGIS system. In general, to successfully guide the committee members in running the most current versions of the models, the developer relied on creating context sensitive help (that were also output as standalone pdf documents; Appendix A), detailed user's documents (Appendix B) at each step of testing, along with run-through videos detailing each step of the process to be tested. Occasionally the developer met with the committee members and/or Esri tech support in a virtual web conference room to go through and discuss pending concerns. All of this valuable feedback was then used to further refine the ETT. However, the committee members did not compare these outputs to expected results.

3.7 ETT Efficacy Test

In order to evaluate the efficacy of the ETT three different tests were performed. The first was to compare the outputs of the ETT to the same visualizations Ethington (Forthcoming) created of streets through Los Angeles County using the historical manual process. The next test was also performed in urban environment on a different means of transportation—Washington DC's Metro. And the final test endeavored to broaden the scope of the ETT beyond urban history by evaluating shifts in the Environmental Sensitivity Index (ESI) as one travel's through the Florida Intercoastal Waterway (ICW).

3.7.1 Old vs. New: Comparison of Pico-Whittier Transections

The ETT was run using the same original geodatabase Ethington that generated Figure 3. This particular transection was chosen because it was deemed as the most appropriate prototype for the first iteration of the ETT and thus was deemed the most applicable first test. One input was the polygon feature class that contained the percent of whites per census tract in Los Angeles County for years 1940, 1960, 1980 and 2000, while the other was the street line feature class. The geographic data is oriented in the horizontal, therefore it was chosen direction for the final model. The tool was run once through for models one to six, however model seven was run four different times to generate the graphs based on four distinct time periods. All graphs were saved and then added to the layout from the graph manager.

3.7.2 Washington DC Orange Metrorail

The next transection created was of the Washington DC's Orange Metrorail as it traverses the census tracts of the city. The ETT was run using the data acquired from the District of Columbia Open Data Catalog (DCGISopendata 2015a, DCGISopendata 2015b). This particular transection was chosen because it was similar in nature to the original Ethington transections by being both a well-defined urban environment and of a means of transportation, however it was a slightly different take on both of these components. The public availability of the data was also a benefit for the project to allow for easy acquisition at no cost. The Orange line was chosen because of its primarily horizontal orientation and the percentage of the line that occurs inside the borders of Washington DC as opposed to neighboring VA or MD which is beyond the bounds of the visualization. One input was the polygon shapefile that contained the demographics of race and median household income per census tract in Washington DC for 2000 and change since 1990, while the other was the Metrorail line shapefile. The horizontal graph was chosen for the final model. The ETT was run once through for models one to six, however model seven was run three different times to generate the graphs based on three different variables. All graphs were saved and then added to the layout from the graph manager.

3.7.3 Environmental Sensitivity Index along the Intercoastal Waterway

The last transection created was by analyzing how the ESI changes along the course of the eastern Florida ICW. The ETT was run using the ICW data acquired from the Florida Fish and Wildlife Conservation Commission (FWC-FWRI 2001) and ESI data from the National Oceanic and Atmospheric Administration (NOAA 1996). In particular the polygon feature class representing the number of monitored rare species of reptiles was chosen due to the nature of the polygons in additional categories that will be discussed further in Chapters 4 and 5. This particular transection was chosen because it was so different from the first two, and to showcase the broad application of this technique beyond that of the urban historian. The public availability of the data was also a benefit for the project to allow for easy acquisition at no cost. The vertical orientation of ICW along Florida's eastern coast is also an opportunity to display a contrasting vertical transection. One input was the polygon geodatabase (GDB) that contained the ESI values for all of peninsular Florida in 1996, while the other was the Eastern Florida ICW line shapefile (FWC-FWRI 2001). The vertical graph was chosen for the final model. The ETT was run once through for all models. The graph was saved and then added to the layout from the graph manager.

3.8 Application Development Issues Encountered

Several issues were encountered during development of the Ethington Transection Toolbox. Early in the process of creating sample transections, it was discovered that paths that "turned back on" themselves could not render geographies that line up visually with the graphed data. Although this is a logical conclusion in retrospect, it made for some interesting investigations into how to handle this particular situation. In the end, the decision was to accept this limitation and document it in the usage of the ETT.

In the first model it was discovered that even though the coordinate system was defined for the feature classes copied into the newly created feature dataset, the feature data set's coordinate system was not defined. This is contrary to Esri documentation. An Esri support personnel was questioned and unaware of the discrepancy. Esri made note of it for future exploration. Consequently a "Define Projection" module was added and exposed as a parameter to ensure that a proper coordinate system and projection is defined from the outset for the feature dataset and its future feature classes.

It became apparent that the direction of the transection could not always be predicted from an inspection of the data and that the user needed to be aware of and have control over the direction of data display and polygon order. Most graphs are either interpreted from left to right or top to bottom and if the polygon order was in fact opposite of this convention the data would not align with the geography. Therefore; a way to visually inspect the direction of travel along the transection was needed. Model 2was created for this purpose. All line features in ArcMap contain directional information that is utilized in network analysis, but it is not a data attribute that is accessible under normal circumstances. A symbology layer with arrows denoting the directionality of the line was created and applied to a feature layer based on the transection feature class, and a field is added to the attribute table indicating the direction of travel. This attribute can then be inspected and altered later if needed. The user has the option of accepting the current direction of transection or to run Model 3 to reverse the transection's direction. The modules would not visualize properly when combined with Model 1 and thus remained in a standalone model. This addresses the most pervasive issue of ETT's application development.

The most challenging issue arose due to the size and complexity of the primary model (mostly encompassed in Model 4). As additional functionality was added to the model and the amount of modules increased, certain necessary intermediate outputs were not generated, nor added to the map despite their designations as parameters and the selection of "add to display" options. This turned into a recurring phenomenon throughout the programming process. For instance once the buffer process was added to the model the polygons would no longer appear on the map and the labels for the order were not being applied from the symbology layer. Additionally when the visualization modules were run concurrently with the export of the table to Excel, neither worked successfully. Both of these steps became separate models (5 and 6).

When these geoprocessing tasks were run outside ModelBuilder the visualizations were as expected. However copying the geoprocessing tasks from the results window and creating a new model resulted in lack of visualization again. Breaking the model apart and running the pieces separately worked. Combining them back together did not. Esri support was contacted and they worked to combine the models and to generate the intermediate outputs, but were also unsuccessful. The recurring solution was to break the model apart into more models. Consequently the tool was divided into seven models, rather than only three models

Another issue was discovered when the selection of the polygons along the transection first occurred as many adjacent polygons were not included in the selection. The precision of the selection tool and that of the copy was not as fine as expected. Therefore a buffer was used to ensure that all desired polygons were included in the selections. The size of the buffer is a parameter in the model and can be user adjusted to an appropriate size for the scale of the visualization. The same buffer was also necessary to select all the transection lines divided at the polygon borders. It seems that once the lines were divided they did not always fall directly on the original transection. However, at the scale of Los Angeles County this buffer was only 10 m wide and therefore sufficient to include the appropriate line pieces without selecting additional pieces.

There was no way to automate the creation of a new network dataset based on the transection. This particular issue was well documented by Esri. The only concession to this particular issue was to ensure that the steps necessary to create the network data set were well documented in the User's Manual and the corresponding videos. Additionally due to the nature of network datasets and the creation of routes, it was discovered that the line features utilized for the transection have to be contiguous (no gaps) for a successful run.

The last model of the ETT was not without its challenges either. It turns out that although the creation of graphs can be automated in ModelBuilder (or Python) the placing of graphs onto the layout cannot. Therefore the last steps of the process are well documented in the User's Manual and videos.

In summary, although there were several issues encountered during the application development process, solutions were implemented as best as possible. The primary responses turned out to be splitting the models into smaller components and increasing the level of documentation associated with that process.

CHAPTER 4: RESULTS

The primary results of this project are the ETT itself and the outputs generated from running the models. The functionality of the ETT was previously discussed in "Chapter 3. Methodology," thus this chapter will be devoted to discussing the different outputs produced throughout the process and then the results of the various efficacy tests.

4.1 Running the ETT

The actual step by step process of going through using the ETT is documented in detail in the context sensitive help (Appendix A) and in the User's Manual (Appendix B), which is the main documentation provided for the ETT, developed as part of this thesis work. A summary of the procedures for using the ETT is provided in this chapter. The ETT comes packaged in zipped folder along with supporting files and sample data (Figure 19). Once these files are copied into the desired working folder the ETT can be opened up in the Catalog window of ArcMap (Figure 4).

EthingtonGDB	6/27/2015 5:57 PM	File folder	
EthingtonTransectionAutomation	6/27/2015 5:09 PM	ArcGIS Toolbox	1,998 KB
Graph Template_Horizontal.grf	5/7/2015 4:42 PM	GRF File	24 KB
Graph_Template_Vertical.grf	6/27/2015 4:31 PM	GRF File	24 KB
Poly_to_OPoints_join_FC	5/7/2015 4:42 PM	ArcGIS Layer	21 KB
TransectionArealUnits	5/7/2015 4:42 PM	ArcGIS Layer	19 KB
TransectionSymbology	5/7/2015 4:42 PM	ArcGIS Layer	8 KB

Figure 19. Contents of Zipped folder for delivery of the ETT.

In order to start a visualization, ArcMap is opened to a blank map with the Catalog window open to the ETT. All of the ETT models, except for "6. Visualize Transection," are run by double clicking on the model's icon in the Catalog window. After running the first model the ArcMap windows will look similar to Figure 20, where the polygon and line data is added to the map after being copied into a new feature dataset inside a new file geodatabase inside a new folder (indicated in the red box in the catalog window on the right).

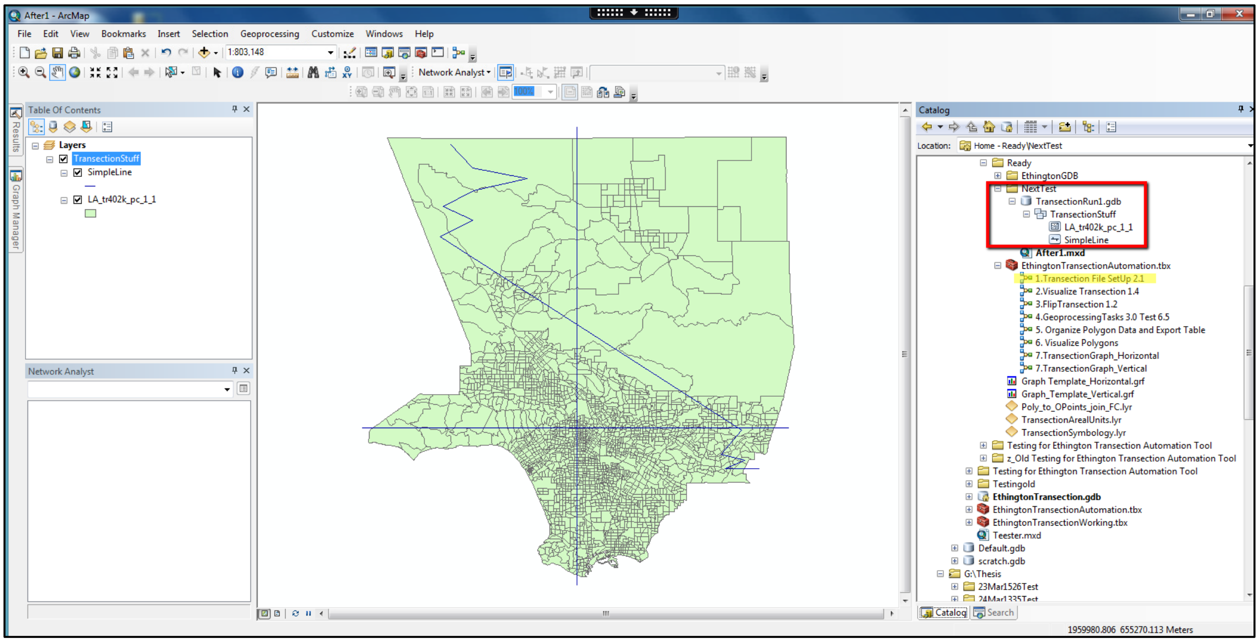


Figure 20. ArcMap after model "1. Transection File Set Up" runs.

The next model isolates the contiguous line features for the transection and then visualizes the direction of travel along the line (Figure 21). For example, a new feature class entitled "Transection_Dissolve" is created and stored in the GDB.

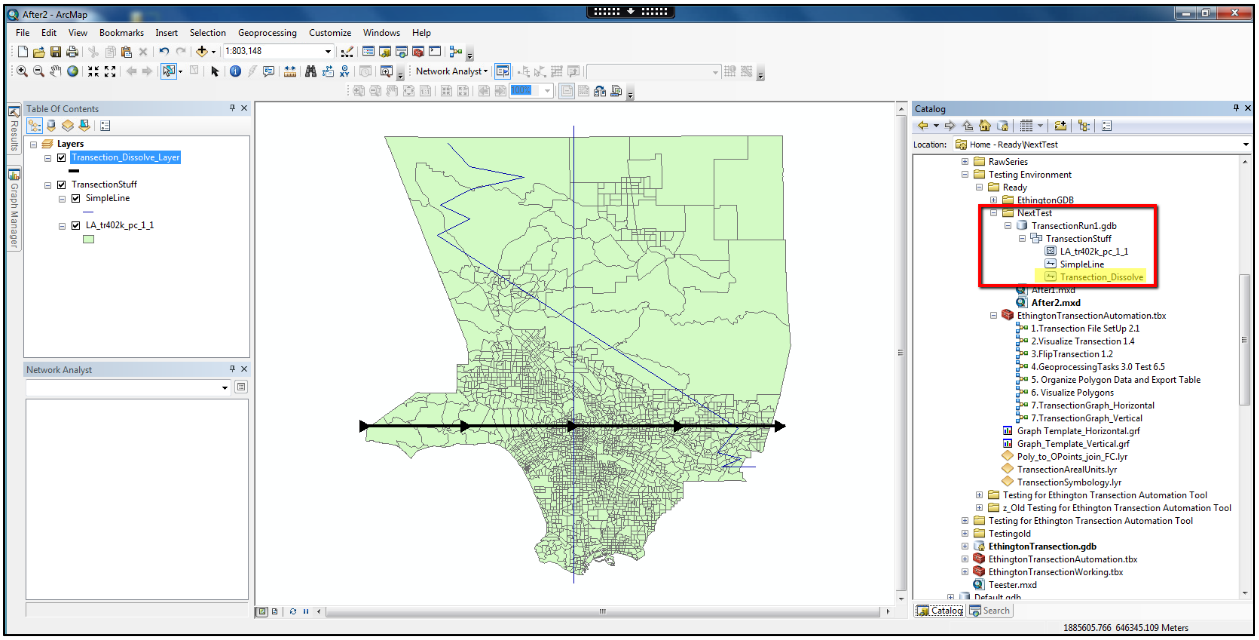


Figure 21. ArcMap after Model 2 runs.

The only visible change after running Model 3 is that the direction of the arrows has flipped (Figure 22). However since this is not the desired direction for graphing, the tool is run again to flip the direction back again to a West to East orientation before proceeding in the sequence. In general most graphs are produced and read with the starting point on the left-hand side. This recognition pattern correlates with a path that travels from the left to the right instead of the right to left orientation of Figure 21. After the network dataset was created, prior to running model 4, and can be seen in Figure 23.

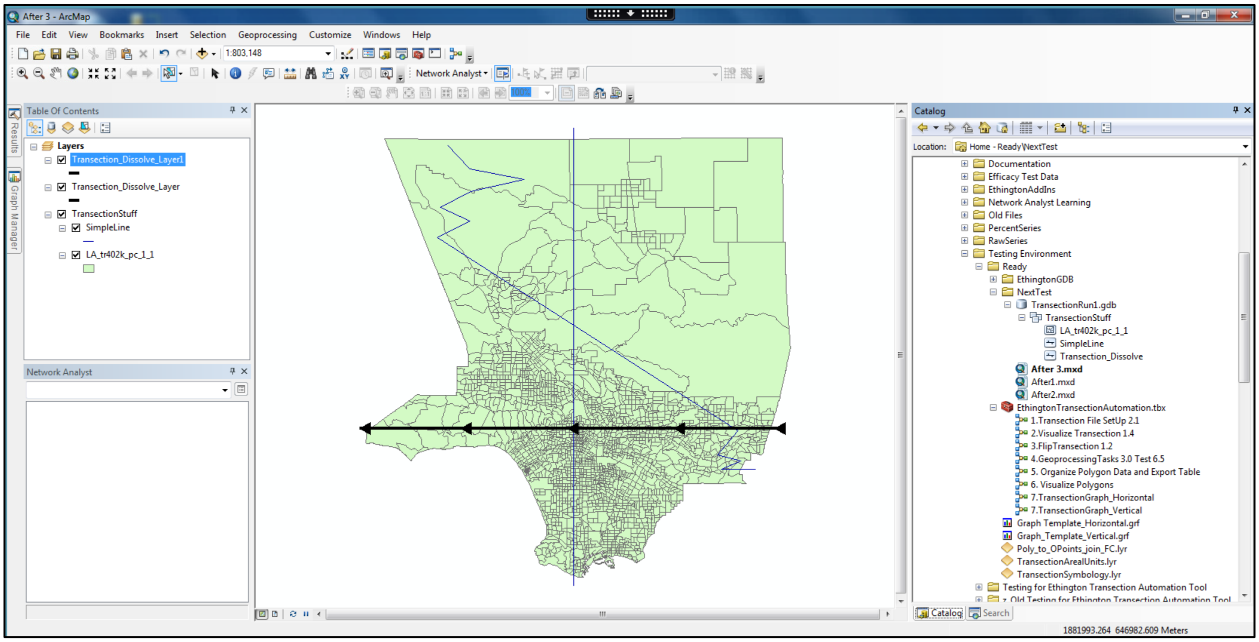


Figure 22. ArcMap after Model 3 runs.

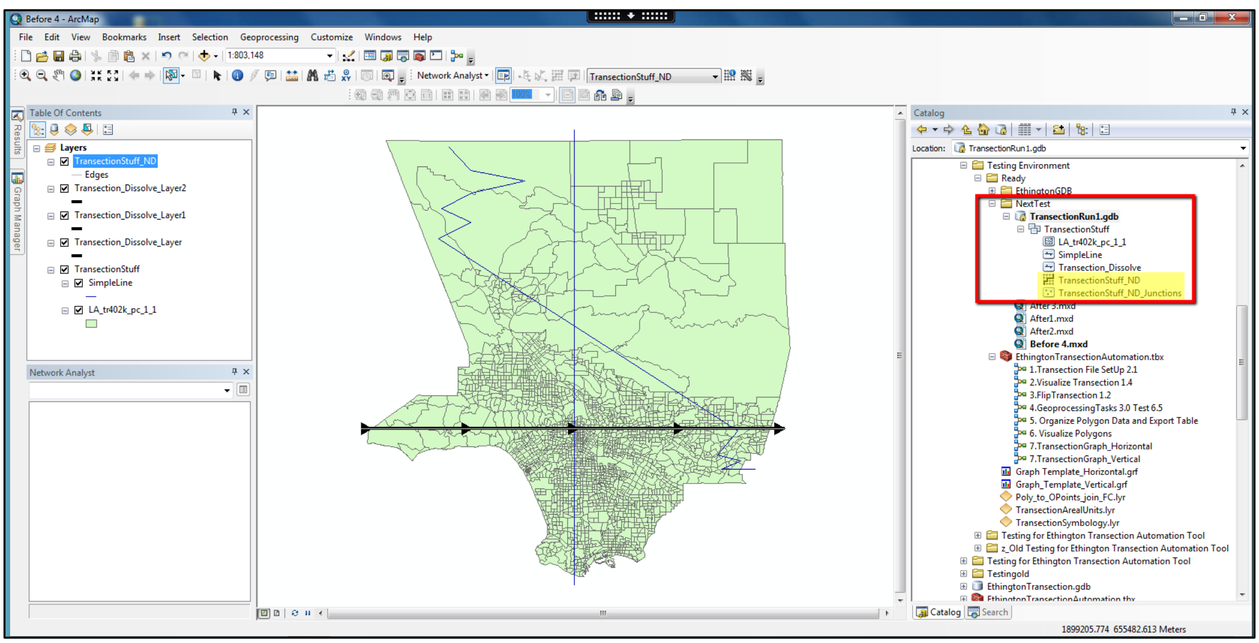


Figure 23. Example of how the ArcMap windows prior to running Model 4.

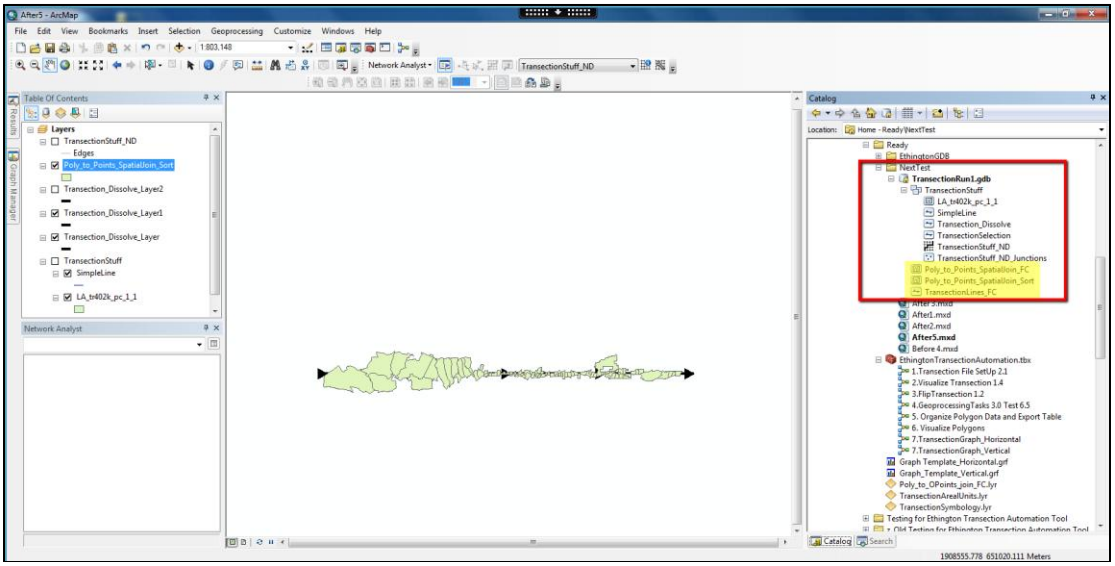


Figure 24. An example of ArcMap after Model 4 runs.

As the sequence continues the polygons are selected and saved as a new feature class (Figure 24). These polygons have the information for the variables of interest as well as the sequential designations along the transection. These new files highlighted in the catalog window by the red box. And running model 5 generates an Excel table from the joined polygon attribute table as seen indicated by the red box in the catalog window in Figure 25.

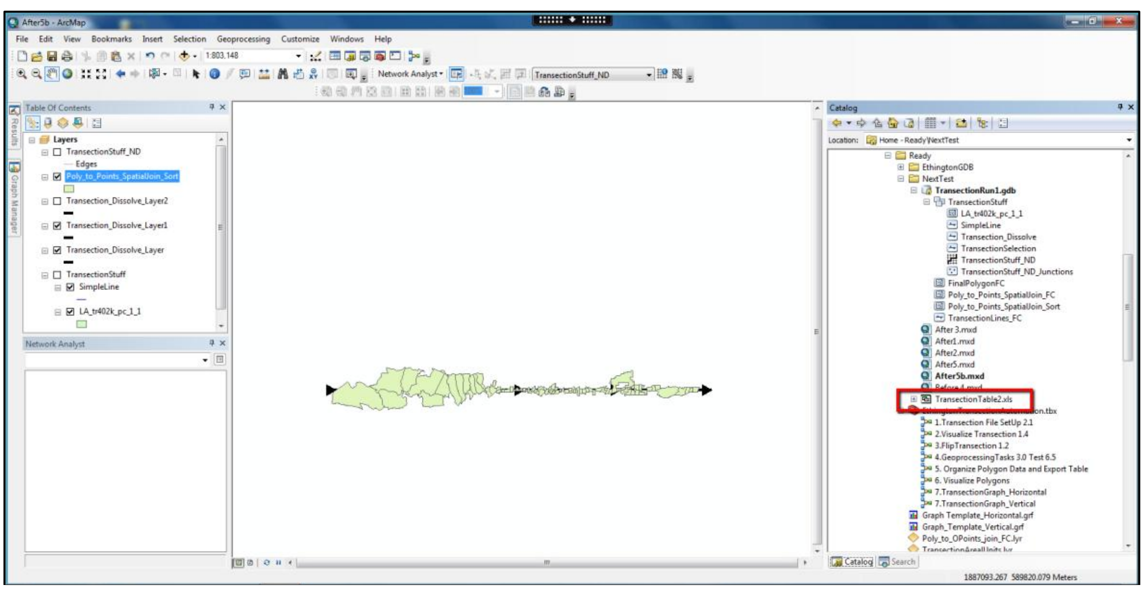


Figure 25. An example of ArcMap after Model 5 runs.

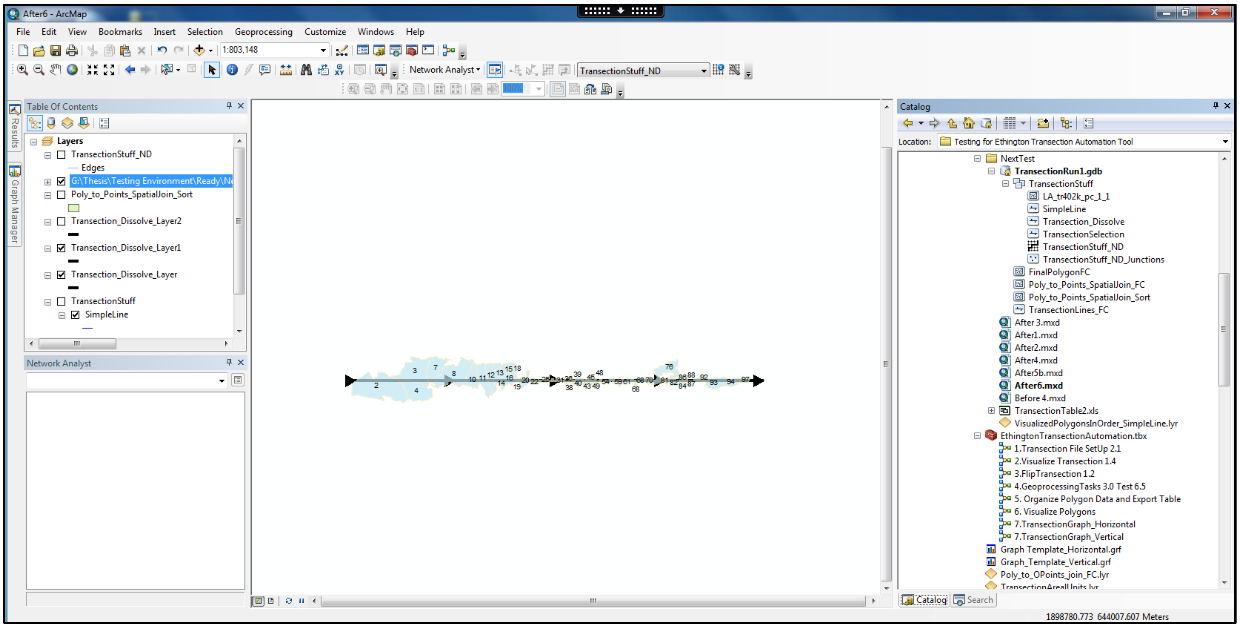


Figure 26. An example of ArcMap after Model 6 runs.

In the last few steps the final the transection visualization is accomplished. In model 6 the geography is labeled and situated with respect to the transection (Figure 26). And finally the graph is produced and placed within the layout, and sized to match the length of the geometry (Figure 27).

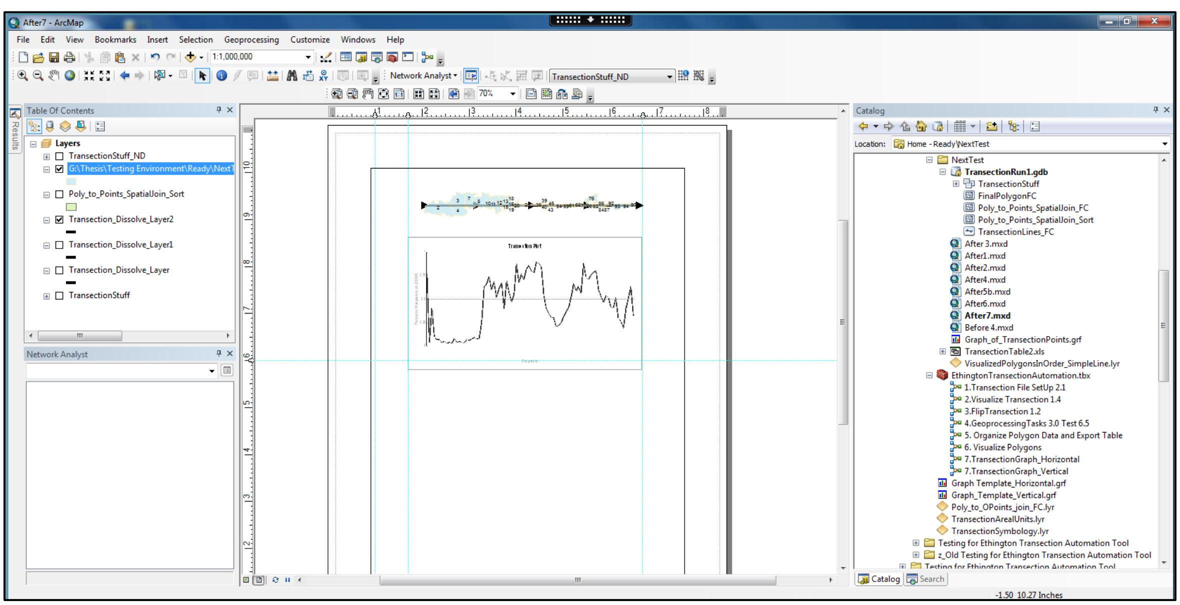


Figure 27. An example of a final layout view for a sample ETT run.

The total time completely run through the ETT is between 30 and 45 minutes depending on how much time is spent in between running the models making adjustments or saving intermediate data.

4.2 ETT Efficacy Test Results

The Efficacy tests on the ETT allowed for comparisons with known "Ethington Transections" as well as a chance to showcase new possible applications. While these goals were accomplished, each new test also managed to illustrate some of the limitations of the current version. These limitations are detailed below with coordinating figures to best explain the necessary assumptions of the ETT's use and how the user can navigate these particular speed bumps while running it.

4.2.1 Old vs. New: Comparison of Pico-Whittier Transections

Two things became readily apparent when attempting to run a replica of the Pico-Whittier Transection in Figure 3. The first was that there was a large break between the two streets as they did not meet exactly in the middle. Since a primary requirement of using the ETT is that the transection be contiguous, the two sides could not be run simultaneously. Pico Blvd. was chosen as the first half of the graph. Once Pico Blvd. was isolated and the used as the transection for the first two tools, a second issue presented itself as can be seen in Figure 28—Pico Blvd is actually shown as going two directions at the same time. This dual directionality would not produce a valid route in Model 4, and therefore was investigated visually by zooming in on one of the conflicting areas (Figure 29).

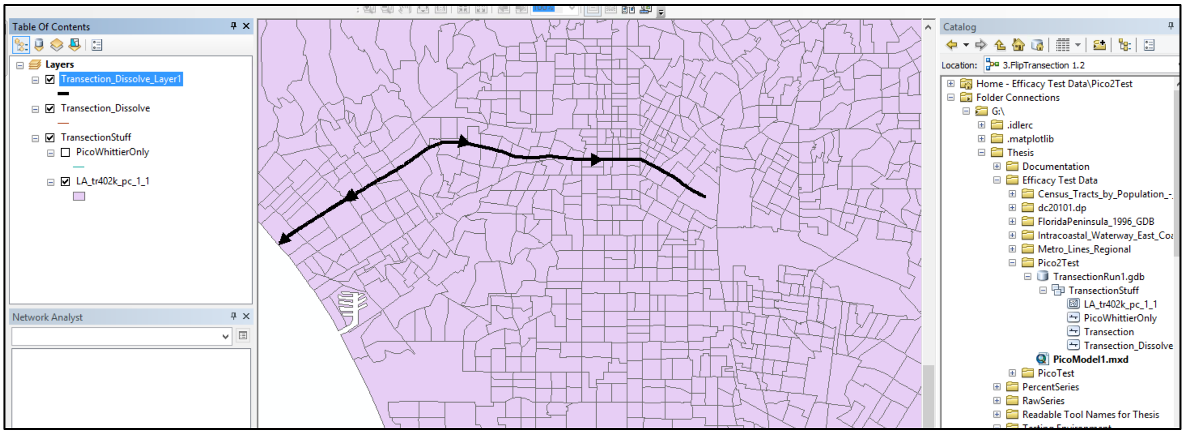


Figure 28. Pico Blvd. transection shown going in 2 different directions.

This smaller scale revealed that the line feature class used for Pico Blvd occasionally split in two, presumably to represent a median or other split roadway situation (Figure 29). Similar "surprise" situations are likely to occur when using new data sources for the first time with the ETT. This spilt line was remedied by editing a copy of the line feature class that only contained Pico Blvd to remove the southern portions of the double lines. The southern portions were chosen because it was evident that Pico Blvd. ran between adjacent polygons and was coincident with many of the boundary edges, but in general the line feature class tended run slightly to the south of the demarcation. It was hoped that maintaining the northern path would allow for more generous polygon inclusion during the selection process.

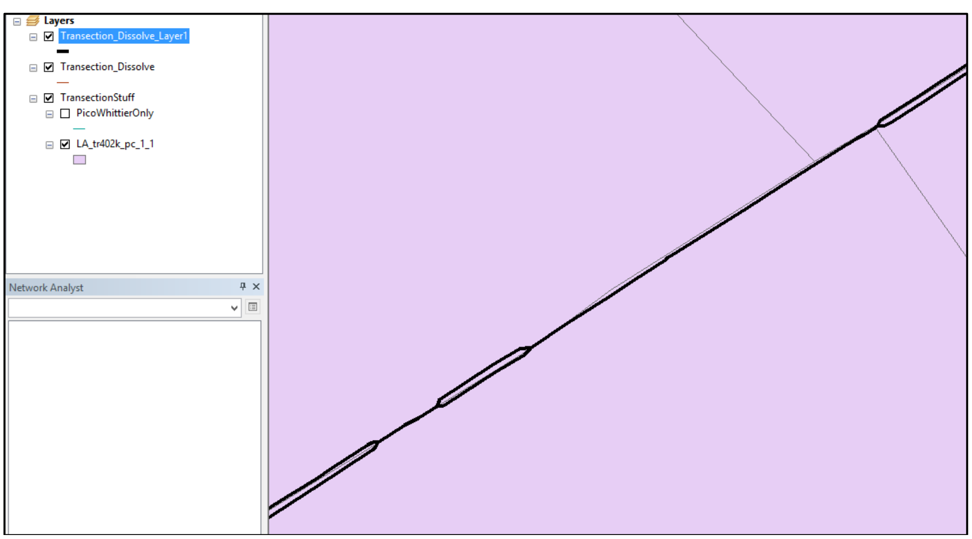


Figure 29. Zooming in on Pico Blvd. to reveal split lanes along travel path.

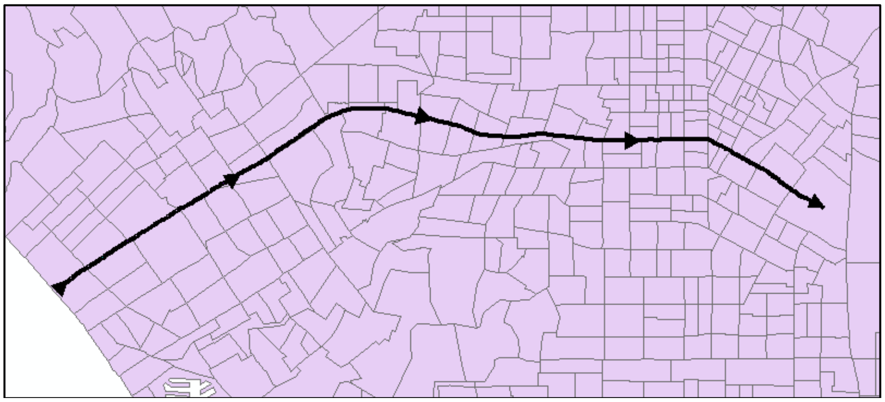


Figure 30. Pico Blvd. Transection in only one direction.

After the editing of the Pico Blvd. feature class, the first entire ETT was run through yielding a single directionality visualized after Model 2 in Figure 30, and the polygon selection in peach shown in Figure 31. This visualization yielded far too few polygons in comparison to the original transection. As alluded to previously, the boundary of many of the polygons was coincident with Pico Blvd as can be seen more clearly the small scale map on the right in Figure 31. The solution to this issue was to enlarge the buffer used in Model 4 from the default 20 meters to 100 meters. This incorporated the additional green polygons in Figure 31's left pane.

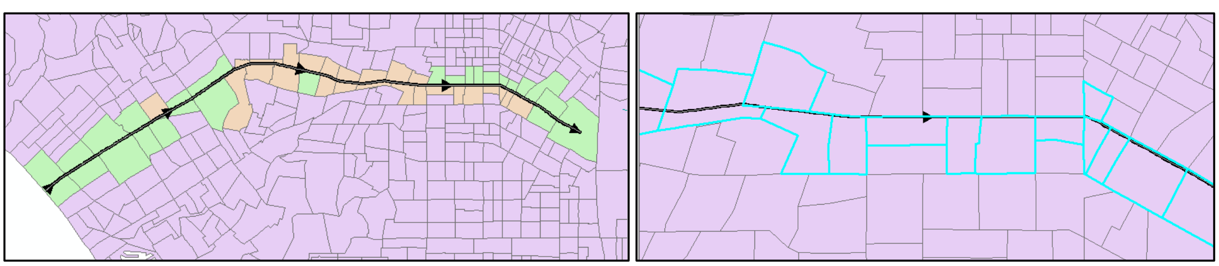


Figure 31. The two alternate polygon selections of Pico Blvd. with a portion in small scale.

After ensuring the proper polygons were incorporated in the final polygon feature class, the final visualizations were produced in two map documents (Figure C- 1 and Figure C- 2). The graphs for the percentage of whites in the total population in 1940 and 1960 are on one layout, while the 1980 and 2000 are on another. The graphs that result from using the default actions of the ETT are stacked and aligned as best as possible according to the directions in the User's Manual.

4.2.2 Washington DC Orange Metro Line

Using the ETT to create an Ethington Transection of the Washington DC Orange Metro Line had some similar issues to the Pico Blvd. test, along with a few novel realizations arising from utilizing this data set. One similar conundrum was from the phenomenon when there are coincident polygon boundaries. The selected polygons and paired ordered stops are displayed in Figure 32, where the transection can be seen traveling on top of adjacent polygon boundaries. This results in some of the stops along the route being placed in approximately the same plane (stops 10-13, 18 &19, 29 & 30 and 33 & 34) for the graph. The solved route still distinguishes a sequential order, however the distance between the grouped values on the graph is small (0 m, 99 m, 5 m, 104 m) relative to the total length of 14,620 m.

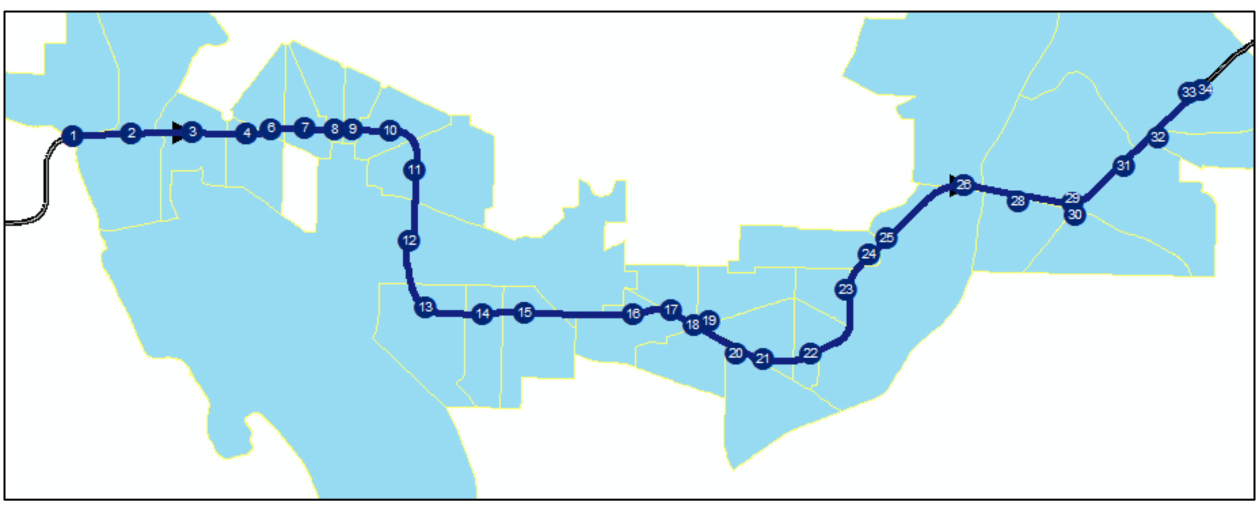


Figure 32. The ordered stops displayed along with the selected polygons for the DC test.

An additional evaluation of stops 10 through 13 illustrate what happens when the transection takes a 90° turn and the logical sequential order no longer is represented adequately by the ETT generated distance on the graph (actually places stop 11 and 12 in the same location because the distance to the graphing line between them is negative which defaults to zero to avoid errors). Next a whole can be observed under stop 7, where a polygon completely surrounded by selected polygons remains unselected since the transection does not course through it. And further note that several polygons are actually crossed by the transection in multiple places which may also yield unexpected polygon sequences.

A novel realization occurred upon discovery of the fact that even if both source data sets were in the same coordinate system and it was specified in the "define projection" parameter the ETT would yield no results if this was not a projected coordinate system. Both the Metro Line and 2000 Census Tract feature classes, seen in Figure 33, shared the WGS 1984 geographic coordinate system. This was discovered when the outputs from Model 4 appeared as new feature classes within the GDB, but were not seen in the map. Upon "zooming to layer" the Transection Points were seen in a completely shifted part of the world. The coordinate system was now designated as "NAD_1983_State_Plane_California_V_FIPS_0405." This is contrary to Esri's documentation that specifically says "when you specify the coordinate system, the network can be accurately reprojected to match the projection of other map layers that might be displayed in a common view" (Esri 2015d, "More Information para 1).

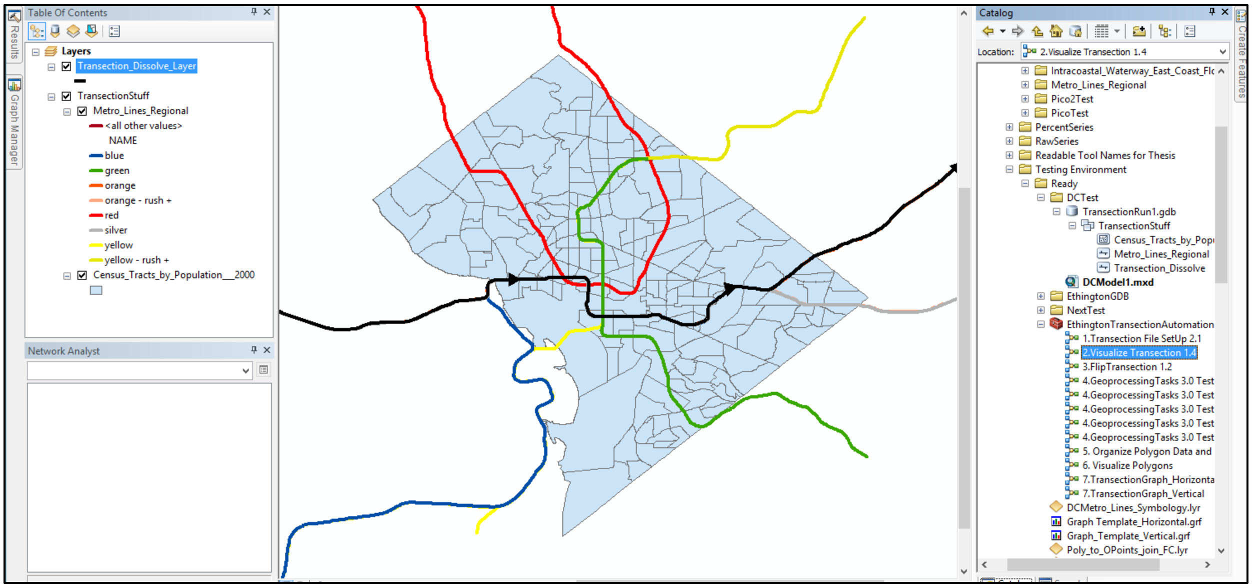


Figure 33. The DC Metro Line and 2000 Census Tract data.

It is presumed that California State Plane projection was chosen either because it was listed as the first choice in the favorites list, or because it was the last projection coordinate system used (with the Los Angeles County data for the Pico test). To alleviate the issue, the two initial data sources were both projected to WGS_1984_UTM_Zone 18N prior to running the tool again. No further complications arose due to this oddity during the remainder of the test.

The final layout of this Ethington Transection can be seen in Figure C- 3. Just as with the DC test Transection, two graphs were stacked below the map in accordance with the User's Manual instructions. The two variables that were graphed, Percent of Total Population Under 17 and Percent of Owner Occupied Homes, were chosen because the normalized values had been already calculated in the source data and so were the most efficient choices for the visualization.

4.2.3 Environmental Sensitivity Index along the Intercoastal Waterway

Executing the ETT on the ICW and ESI proved again to be a circumstance where the transection data source had to be altered prior to a successful run. Although the ICW feature class was a line type as required, the visualization in Model 2 revealed a discontinuous multi-directional split path. When inspected in a smaller scale, as in Figure 34, it could be determined that the line features were shaped as the edges of a long thin polygon defining the two edges of the navigable channel as the ICW snakes its way along the coast. Furthermore there were two instances where the polyline feature endpoints were not adjacent, resulting in a broken topology. Editing a copy of the source file remedied the situation.

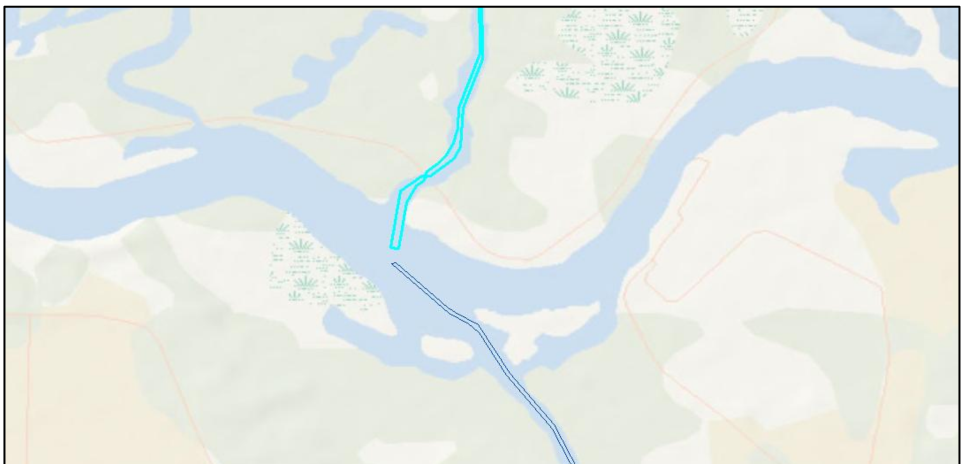


Figure 34. The initial line feature class of the ICW.

The ESI GDB contains several possible categorical feature classes giving counts the numbers of rare species found in certain polygonal areas that were candidates for using with the ETT. However before using the ETT, these feature classes were visually inspected with regards to their spatial and attribute qualities. Several different polygon arrangements were discovered that required some consideration; overlapping features, multi-part features, a discontinuous polygonal fabric, polygons crossed by the transection multiple times, and corridors narrowly sheathing the transection or inversely creating an exclusionary buffer around the transection (all of which are represented with further explanation in Table 3). The reptile feature class proved to be the most readily appropriate for running the ETT and it can be seen mapped along with the southward flowing ICW in Figure 35.

The final Transection can be seen in Figure C- 4 where the north-to-south orientation of the layout necessitated the vertical graphing template. Both orientations of graphing template were created with the expectation of normalized percent data and so the scale was set to range from 0 to 1 with a grid line indicating the 0.5 mid-point. Since these data were raw species counts the initial graph rendered a seemingly bizarre set of lines that went to zero and off the edge of the graph again. Adjustments to the scale were then made to display the full range of values by accessing the graph's properties while it was open in the graph window prior to adding it to the map layout. Even with scalar modifications, the large shifts in species counts between polygons (from 0 to 285 in some cases) and a preponderance of zero values still gives a stochastic, rather than a fluid feel to the Transection.

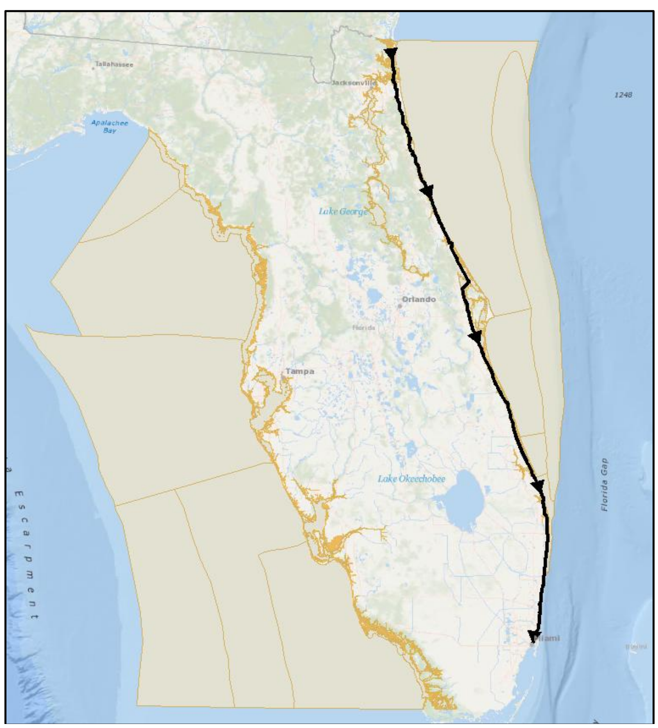


Figure 35. The reptile feature class of the ESI with the Floridian ICW.

CHAPTER 5: CONCLUSIONS AND DISCUSSION

The goal of this project was to create a more efficient and user-friendly way to conduct an Ethington Transection visualization. By comparing the time required to historically conduct the visualization (8-10 hours) to that of using the ETT (30-45 minutes) it can be concluded that the ETT is more efficient. However there are several considerations and limitations in the use of the ETT, and they are detailed in this chapter. And although some limitations may eventually prove to be permanent constraints, it is supposed that in the future, some solutions to these limitations may be found and incorporated into the ETT. Additionally, there is still a great deal of room for improvement to make the ETT more user-friendly and visually appealing.

5.1 Considerations for Using the ETT

There are some considerations for employing the current version of the ETT stemming primarily from three things; the nature of an Ethington Transection, the limits and inconsistencies of ArcGIS, and the constraints on the developer's time and abilities as undertaken for this thesis project. Some are discussed here to assist future users in their decision making efforts before and during the use of the ETT.

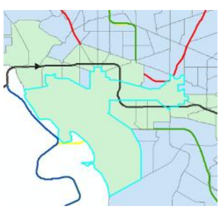
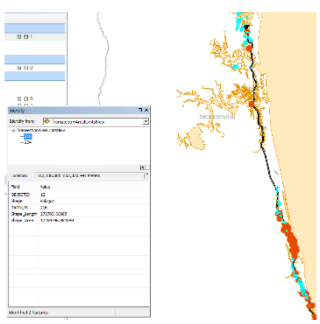
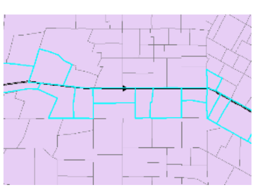
One of the fist items a user must consider is the nature of the transection they are planning to use. Certain line feature class qualities make the use of the ETT problematic or impossible; such as when a transection is discontinuous, bi-directional, or coincident with polygon borders. A further elucidation occurs in Table 2 of figures elsewhere in the document that illustrate this concept, the situations when these might occur, what current work-arounds enable their use as Ethington Transections and whether they can still be used with the ETT as a transection (column **ETT OK?**).

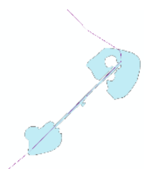
Table 2. Qualities of a line feature Class that warrant consideration when using the ETT.

Quality	Situation it occurs	Current work around	ETT OK?
Discontinuous network (topology error) **Figure 34**	When the line feature class is supposed to be continuous but drawing errors produced unintentional gaps	Repair the topology of the network by editing out the gaps in the source data	Yes, if fixed
Discontinuous network (by design) **Figure 3**	Where two intentionally separate lines are desired to be combined in the visualization to represent one transection, such as in Ethington's original Pico-Whittier Transection	Visualize the different sections separately and then unite in final layout or combine the exported tables to create a combined graph with the data and create one map for faster version than if done by hand	Not really, but ETT can still speed time to visualization by automating many of the key steps
Bi-directional **Figure 28, Figure 29 & Figure 34**	When two parallel lines are used to represent some quality in the transection, such as medians in the Pico Blvd. or the channel edges of the ICW	Edit the source data such that only one continuous line remains, the tool will resolve any directional inconsistencies	Yes, if fixed
Coincident with Polygon Boundaries **Figure 31**	When the boundaries of the polygons used correlates with the transection in some way and results in both following the same path	Ensure buffer is sufficient to include both "sides" of the transection and may need to make decisions about data placement along the graph line	Yes
Contains Angles approaching 90° or less **Figure 33**	When the line bends to such an extent that the angle approaches 90° it can causes multiple stops on originating in different polygons along the transection to pile up on area of the graph line; acute angles can cause the sequence of the stops to actually visualize in a reverse order	For angles approaching 90° sometimes stop points can be manually moved to provide a measure of visible distance between graphed values, but this becomes less available at 90° and less, the only available strategy would be to average the values of all "stacked" points and display on one point along the graph line	Minimally for angles greater than 90°, but less so without manual recalculations for acute angles

After the transection, it is wise to consider the nature of the polygons. Table 3 organizes the primary polygon qualities of concern along with figurative examples and brief descriptions of the matching considerations. For instance, sometimes census data uses your "transection" (i.e. street, river, or railroad) to demarcate the boundary for the tract polygons. This can make for challenges in determining the proper way to visualize polygon data that co-occur on either side of the transection. Are the two values averaged and displayed as one point on the graph? Or possibly is one of the points (stops) assigned to the polygons manually moved "up or down" along the transection so they are visualized as distinct values? (Consequently these same possible strategies can be employed when transection angles are 90 degrees or less, or overlapping polygons occur.)

Table 3. Qualities of polygons that warrant consideration when using the ETT.

Figurative Example	Quality	Necessary Considerations
	Transection passes through boundaries multiple times	ETT will designate more than one location for this polygon which must be deleted prior to graphing once the user determines which location is the most appropriate for plotting the data
	Overlapping polygons	May make interpreting transection difficult as full extent of all polygons will not be visible in the map portion and so relating data to location becomes problematic
	Discontinuous polygonal fabric	Any data gaps are not indicated in the graph as all data points are connected via a continuous plot line; the separated polygons in the graph will appear as the data seamlessly transitions between them although actual values are unknown
	Polygons have coincident boundaries with Transection	User will need to decide to what extent to incorporate "both sides" of the transection and if these values will be plotted as an average, two slightly separated values with an artificial distance, or some other mechanism when the center locations along the transection are coincident

Figurative Example	Quality	Necessary Considerations
	Multipart polygon features	ETT will plot same value in multiple locations along the transection; these values may truly represent identical situations in alternate locations or the value may be an average of all parts; a user may decide to leave these results as the default, plotted at only one location or to separate them based on their knowledge of the data's distribution.
	Polygon creates ensheathing corridor around Transection	ETT handles this expected though it may appear as if there is a gap in the polygons at the large scale of the map graphic; only caution is to not interpret data values beyond the corridor, which is the case for all Ethington Transections
	An polygonal exclusionary buffer exists as a corridor around Transection	No polygons would be selected and no data plotted unless the buffer was made large enough to account for this phenomenon; care must be made when inferring that the conditions of the buffered polygons accurately represents the reality inside the corridor

There is no right or wrong choice of strategy in any given situation, but the user must confront the challenge and make knowledgeable decisions about how to proceed. There indeed may not be a one-size fits all solution to these challenges, or even a "correct" consistent strategy employed to address the same quality challenge in subsequent visualizations. It is simply that these things must be carefully considered and actively addressed during the Ethington Transection creation process and in particular if employing the ETT.

The next consideration applies to the buffer employed in Model 4 to effect the number of polygons included in the visualization. The buffering step was originally added to the model to account for inconsistencies in ArcMap's drawing of the individual line pieces of transection inside each polygon. The center point of each of these lines is used to locate each stop in the sequence and thus determine the order and relative distance on the graph. However once testing of the ETT began, an insidious use was discovered. The raising of the value beyond the level needed to account for redraw inconsistencies included not merely adjacent polygons, but ones that were only nearby and within the buffer's range.

These polygons would not automatically be included in the final visualization if the transection does not pass through them and the User's Manual instructions were followed exactly, however by manually entering an appropriate sequence number for these additional polygons, and editing the original polygonal attributes in kind, the tool could be wrought to maintain them in the final visualization. This workaround is surprisingly simple to include additional polygons. The removal of any unwanted polygons from the increased buffer selection is even easier. Just delete these features from the resultant attribute table at the same point in the ETT, between Models 4 and 5. The reverse cannot be said. Manually adding any unselected polygons at this point involves hunting down the entire records in the original attribute table and copying and pasting feature by feature. This procedure is cumbersome, time-consuming and fiddly. Therefore it would seem wise to err on the side of polygon over-inclusion in the first iterations of any visualizations with the ETT. Consequently manipulation of the buffer can be used to address the MAUP of Ethington Transections.

5.1.1 How the MAUP applies to Ethington Transections

The Modifiable Areal Unit Problem (MAUP) presents itself in Ethington Transections and when using the ETT. MAUP arises because the data is displayed at an aggregation level greater than that at which the data was collected and often "arbitrary with respect to phenomenon under investigation" (O'Sullivan and Unwin 2010, 37). The whole point generating an Ethington Transection is to change the spatial reference frame, which in so doing O'Sullivan and Unwin (2010, 38) imply becomes "itself a significant determinant of the …patterns we observe." The primary consideration here is the duality whereby the data plotted from the transection line may not accurately represent the qualities of the whole polygon area shown in the map (a MAUP typical of most polygon data distributions), or conversely the aggregated data of the whole polygon may not represent the realities experienced while traveling along the narrowed corridor of the transection in a “street side view.” It follows then that the MAUP is inherent in any Ethington Transection, so no matter good the automation of future ETT versions gets, the MAUP will persist. Users should utilize their knowledge of the subject to evaluate how the phenomenon they are trying to visualize may be influenced by any aggregation that occurred compiling the candidate polygons and how increasing or decreasing the number of polygons included in the process may skew representations of the data. The quantity of included polygons can be most effectively manipulated via the buffer designation in Model 4 of the ETT. The goal of any user should be to minimize the extent of the MAUP as much as possible when creating Ethington Transections and acknowledge it during any discussion during their presentation.

5.2 Limitations of Current ETT

One of the first encountered limitations was that the path or line used for a transection cannot deviate more than 90 degrees along its course, or to turn back in on itself, in order for the geography to line up with the data in the graph. The ETT can still be used in this circumstance but will create a graph where the data will be spaced along the axis such that it represents the distance traveled along the transection. This was deemed an appropriate compromise and is likely to remain a constraint in the future.

As briefly discussed previously, another limitation is that the line feature used as the transection must be contiguous. This is due to the fact that the polygon sequential order is determined by creating a route using the Esri Network Analyst extension. And although this is a quick and accessible solution, it is speculated that an alternative may present itself in the future to allow for gaps in the transection and the corresponding graph in future versions of Network Analyst. Since this was already handled elegantly in Ethington's visualization of Pico and Whittier (Figure 3), it is surmised that in future this limitation could be removed from the ETT.

A further limitation imposed by utilizing the network analyst extension is the necessity to create the network dataset outside the ETT in between models. Whereas this was addressed by providing detailed documentation for creating the particular network dataset utilized by model 4, it would be far more elegant a solution if this was also automated. If an alternative method of sequencing the polygons could be determined, it is likely that these three limitations imposed by its use could be removed.

The complicated graphing capabilities of ArcMap also presented a challenge to the development of a user-friendly ETT. There is a great deal of power and flexibility in the graphing modules of ArcGIS, but they are exposed in such a limited way during the automation process. All orientation and design decisions (including scale) must be built into the graph templates and creating a plethora of templates to anticipate all transection graphing eventualities proved difficult and cumbersome. Ultimately only one horizontal and one vertical template were provided. The flexibility in the data used for creation of the graph is delivered by exposing the graphing options as a parameter. However, this parameter appears as one large scrollable table that can be described as dense at best and opaque to many (Figure 36). The ETT would benefit from a more simplified parameter, or even a stepped response approach (such as employed in the graphing "wizard."

Once the graph is created, there was still no ability to "add to layout" and thus further steps outside of the ETT were documented to ensure an even remotely comparable transection visualization could be achieved. The graphs can be altered after creation, but this is tedious and be best handled by allowing graphing options to be available to future programming efforts. It is desirous in future that more of the graphing functionality could be accessed via programming not just the creation of multiple templates and a one –size fits all input series.

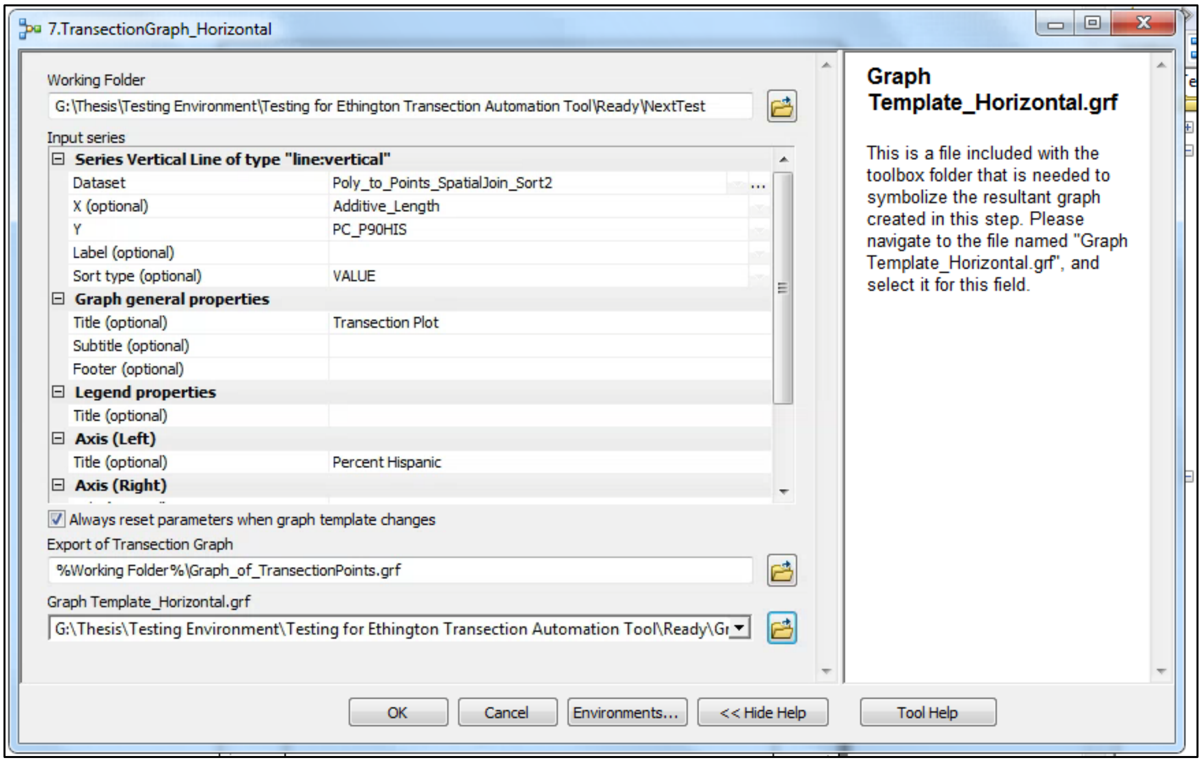


Figure 36. The Input Series for creating a graph via an exposed parameter in a model 7.

Although the ETT does generate a matched graph and geographic image, it is far from the elegant and refined transections originally produced “manually” by Dr. Ethington. It would require a great deal of time to fine-tune the final layouts. As the graphing and feature manipulation in ArcGIS continues to improve, hopefully the quality of transections produced by future versions of the ETT will improve as well.

The limitations above speak to specific steps in the ETT, however one over-arching goal of the project was not met and remains a constraint on possible users—that was to make the ETT truly easy to use and available to those with only a minimal GIS skill level. The multitude of models and bits and pieces that still necessitate manual completion by the user clearly put the ETT out of the reach of the novice. It has been determined that an appropriate user would be considered of an “Intermediate” level. Minimally a user would require knowledge of: using a ModelBuilder toolbox from both the Catalog and Model Editing window; managing geodatabases; employing extensions; and utilizing the Catalog window heavily for managing folders, copying files, interpreting GDB contents, and placing items in the map window. Lastly users must be able to review all the required parameter inputs and understand the file types and definitions and how they are applied. The ability to edit input data sources when potential issues are discovered when using the ETT is also beneficial. It would certainly be desirous to lower the current skill level needed in the future.

5.2 Addressing Current Issues in Future Work

Part of the reason there was such a rigorous approach to documentation was to counterbalance the complexity and number of steps necessitated in the final version of ETT. The goal was to create an easy to use and efficient ETT, but this proved problematic with current programming constraints. Consequently increased effort went into documenting how a user walks through the use of the tool in the most straight-forward manner. The addition of the Jing videos integrated into the User’s Manual proved to be an effective means of achieving this goal. However in future the ETT would benefit from refinement and a reduction in the total number of models needed to accomplish the visualization.

In the future this issue should be solved so that the number of steps or models required to run the tool can be reduced. This could be accomplished simply by combining several of the models. For example models one and two would combine yielding the new GDB and the proposed transection and direction visualized. Model three should be left separate as an option when the direction of the transection should be flipped, but models four through six should be able to be combined in future work with the addition of model seven as well if future Arc GIS ModelBuilder parameters allow alternate choices of graph templates. This would render only two or three final models and the optional model three “Flip Transection.”

An additional annoying consequence of breaking the ETT into so many pieces is having to designate the newly created GDB again in every model, even though it is the same each time. Additional programming efforts and strategies (such as converting the models to Python) could fix this issue in future work.

Another future work prospect would be to build-in an ability of the toolbox to batch process and automatically combine transections based discontinuous networks by design. Automating this potential situation would increase the potential scope of possible transections available to the ETT, and further the goal of the developer to be able to generate Ethington Transections comparable to those of the model “Pico-Whittier Transection” seen in Figure 3.

In order to facilitate future development and use of the ETT, an entire geoprocessing package is being made available via a public GitHub repository labeled identical to the title of this thesis. The custom toolbox with all the models, a sample data set, the User’s Manual and tutorial video files are all offered free to all GitHub users. It is hoped that future versions of the ETT will benefit from its availability on the web for in the spirit of “open source is the idea that by sharing code, we can make better, more reliable software" (GitHub 2015a, "Use someone else's project" para 1).

5.3 Additional Future Work

The original vision of the developer was curtailed by the issues and time constraints of this project. The future iterations of the ETT would benefit from implementing some of the strategies originally envisioned. The current models could be converted to Python and additional streamlining by the use of variables could reduce the number of parameter entries necessary. However this alone might actually raise the difficulty level of running the ETT, depending entirely on the user's familiarity with using Python code.

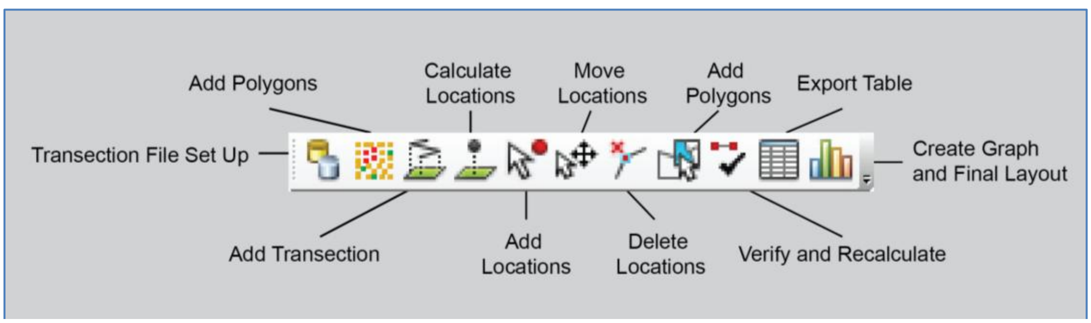


Figure 37. Mock-up of possible future ETT distributed as a Python add-in toolbar.

But if the Python code was then packaged as an ArcGIS add-in, the ETT could begin to become the interactive easy to use visualization desired. A Python add-in is a customization to an ArcGIS for Desktop application (that is, ArcMap, ArcCatalog, ArcGlobe, and ArcScene), for instance a collection of custom tools on a toolbar offering additional functionality (Esri 2015c). A Python add-in is a single compressed file with an .esriaddin extension delivered with all the required files necessary for it to work. Add-ins are easy to share between users and plugged into a desktop application by copying the file to a well-known folder, or simply removed by deleting it from this same folder. The ETT could then be distributed as a toolbar with buttons, menus and interactive tools that guide the user through the visualization like what is seen in Figure 37. Because add-ins are also able to make a customization that performs an action in response to an event, or requires the use of the mouse to interact with the display, additional functionality and user customization could be incorporated into the ETT. An example might be a tool that allows the user to interactively click and drag a custom transection path over a map to define an area of interest, or to limit the visualization area with a drawing tool. Another example might be the ability to interactively add and subtract polygons from the selection, or alter polygonal sequence order. A future iteration of the ETT could function as illustrated in Figure 38. All of these features would greatly enhance the ETT and assist in lowering the skill level requisite for its use.

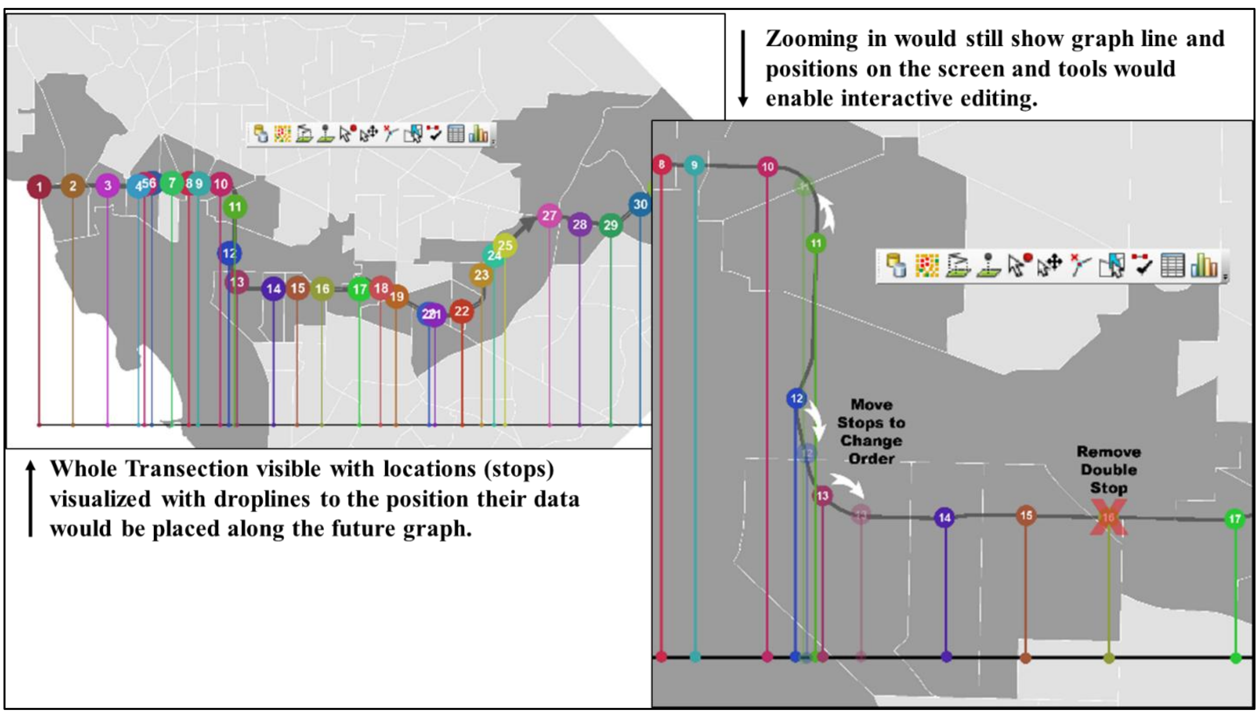


Figure 38. Mock-up of screen shots while using future versions of the ETT.

5.4 Conclusion

This thesis project devised a new method to automate, increase the efficiency, and improve the efficacy of creating Ethington Transections (Forthcoming), thus hastening time to data visualization. The final result is custom toolbox called the Ethington Transection Toolbox (ETT). The previously tedious and time intensive task of manually creating transections was automated using Esri's ArcMap, Modelbuilder and Network Analyst, and is now accessible to a wider range of scholars that will only need a minimal familiarity with ArcGIS to perform this Ethington Transection visualization. Therefore the ETT should enhance the analytic skills of those with an interest in urban spatial studies, or other fields, such as environmental studies, that seek to visualize polygonal data along linear, sequential paths. Automation will enable researchers to increase the number of transection analyses derived and allow for easier comparisons within and between places. It is also hoped that other scientific fields will embrace this new visualization tool for their own purposes and consequently expand the range of ETT users.

REFERENCES

Allen, D. W. 2011. *Getting to Know ArcGIS ModelBuilder*. Esri Press.

Alexander, S., and N. Waters. 2000. The effects of highway transportation corridors on wildlife: A case study of Banff National Park. *Transportation Research Part C: Emerging Technologies* 8 (1–6) (0): 307-20.

Arctur, D., and M. Zeiler. 2010. *Designing Geodatabases: Case studies in GIS data modeling.* Second ed. Redlands, CA: ESRI, Inc.

Audisio, C., G. Nigrelli, and G. Lollino. 2009. A GIS tool for historical instability processes data entry: An approach to hazard management in two Italian alpine river basins. *Computers and Geosciences* 35 (8): 1735-47.

Baldwin, S. M. 2014.“Institutional Inscription in the Minorcan Quarter of Saint Augustine, Florida.” MS thesis, University of Southern California, 2014.

Bell, K. 2004. Automating Work Flows With ModelBuilder at Salt Lake City's Transportation Division. *ArcUser* 7(4). Accessed May 7, 2015. http://www.esri.com/news/arcuser/1104/trafficount.html

Bodenhammer, D. J. 2013. “Beyond GIS: Geospatial Technologies and the Future of History,” In *History and GIS: Epistemologies, considerations and reflections*. Eds. von Lünen, Alexander, and Charles Travis Dordrecht, 1-12; Netherlands: Springer.

Brook, V. 2013. *Land of Smoke and Mirrors: A Cultural History of Los Angeles*. New Brunswick, NJ: Rutgers University Press.

Cunfer, G. 2011. The southern Great Plains wind erosion maps of 1936-1937. *Agricultural History* 85 (4): 540.

DCGISopendata 2015a. Census Tracts by Population – 2000 Last accessed 16 August 2015 http://opendata.dc.gov/datasets/0efdf1f78d4f40e3ba111feadac48553_18

——— 2015b. Metro Lines Last accessed 16 August 2015 http://opendata.dc.gov/datasets/a29b9dbb2f00459db2b0c3c56faca297_106

Dilts, T. E., J. Yang and P. J. Weisberg. 2010. Mapping Riparian Vegetation with Lidar Data: predicting plat community distribution using height above river and flood height. *ArcUser* 14(4): 18-21. Accessed May 7, 2015. http://www.esri.com/news/arcuser/0110/files/mapping-with-lidar.pdf.

Dunae, P. A., D. J. Lafreniere, J. A. Gilliland, and John S. Lutz. 2013. Dwelling places and social spaces: Revealing the environments of urban workers in Victoria using historical GIS. *Labour/Le Travail* (72): 37.

Esri. 2014. "Esri Insights: Quickly get the facts & demographics for any area." Esri. Accessed April 26, 2014. http://marketplace.arcgis.com/listing.html?id=fef73db0214f4ab9b98b06e645b962f9 and http://la.arcgis.com/insights/#

———. 2105a. "What is the ArcGIS Network Analyst Extension?" Esri. Accessed August 20, 2015. http://desktop.arcgis.com/en/desktop/latest/guide-books/extensions/network-analyst/what-is-network-analyst-.htm

———. 2015b. "What is ModelBuilder?" Esri. Accessed August 15, 2015. http://desktop.arcgis.com/en/desktop/latest/analyze/modelbuilder/what-is-modelbuilder.htm

———. 2015c. “What is a Python add-in?” Esri. Accessed September 5, 2015. http://desktop.arcgis.com/en/desktop/latest/guide-books/python-addins/what-is-a-python-add-in.htm

———. 2015d. “24014: The network dataset has an unknown coordinate system.” Esri. Accessed September 6, 2015. http://desktop.arcgis.com/en/desktop/latest/guide-books/extensions/network-analyst/24014-unknown-coordinate-system.htm

Ethington, P. J. (Forthcoming). *Ghost Metropolis: Los Angeles Since 13,000 BP*.

FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute) as the data source, and FIND (Florida Inland Navigation District) as the originator 2001. Intracoastal Waterway East Coast Florida. Last accessed 16 August 2015 at http://geodata.myfwc.com/datasets/facfb0c2903e4c6d89b878b32b3ca610_8

GitHub, Inc. 2015a. “GitHub Help: Fork a Repo” GitHub, Inc. Accessed September 7, 2015. https://help.github.com/articles/fork-a-repo/

——— 2015b. “Search Results: ArcGIS; Python.” GitHub, Inc. Accessed September 5, 2015. https://github.com/search?utf8=%E2%9C%93&q=ArcGIS

Gregory, I. and P. S. Ell. 2007. *Historical GIS: Technologies, methodologies and scholarship*. Vol. 39. Cambridge, UK: Cambridge University Press.

Lynch, K. 1960. “The image of the environment”. In *The image of the city*. 11: 1-13. Cambridge, MA: MIT Press.

Maier, U., M. Flegr, H. Rügner, and P. Grathwohl. 2013. Long-term solute transport and geochemical equilibria in seepage water and groundwater in a catchment cross section. *Environmental Earth Sciences* 69, (2): 429-441.

Mishra, R. K., M. Parida, and S. Rangnekar. 2010. Evaluation and analysis of traffic noise along bus rapid transit system corridor. *International Journal of Environmental Science & Technology* 7, (4): 737-750.

Morillas-Torné, M. 2012. Creation of a geo-spatial database to analyse railways in Europe (1830-2010). A historical GIS approach. *Journal of Geographic Information System* 4 (2): 176-87.

Monmonier, M. S. 1996. *How to lie with maps*. Chicago: University of Chicago Press.

Montello, D. R. 2001. "Scale in Geography". In *International Encyclopedia of the Social & Behavioral Sciences*, eds N.J. Smelser and P.B. Baltes, 13501-13504. Pergamon Press.

Murrow, J. L., C. A. Thatcher, F. T. van Manen, and J. D. Clark. 2013. A data-based conservation planning tool for Florida panthers. *Environmental Modeling & Assessment* 18 (2): 159-70.

NOAA (National Oceanic and Atmospheric Administration) 1996. Last accessed on 16 August 2015 at http://response.restoration.noaa.gov/maps-and-spatial-data/download-esi-maps-and-gis-data.html#TOC

Offen, K. 2012. Historical geography II: Digital imaginations. *Progress in Human Geography* 37 (4): 564-577.

O'Sullivan, D. and D. Unwin. 2010. *Geographic Information Analysis.* 2nd ed. Hoboken, NJ: John Wiley & Sons.

Pratt, M. 2000. Modeling Fire Hazard. *ArcUser* 3(3): Special 1-5 Accessed May 7, 2015. http://www.esri.com/news/arcuser/0700/files/firemodel.pdf.

Peterson, G. 2011. Small Multiples: March 30th, 2011 blog post. A Cartographer's Toolkit: map making tips, tricks and inspiration. Accessed 15 August 2015. http://www.gretchenpeterson.com/blog/small-multiples/

———. 2012. *Cartographer's Toolkit: Color, typography, patterns*. Fort Collins, CO: PetersonGIS.

Plummer, B. 2014. Data visualization: past vs. present; Blog posted by Ben Plummer October 07, 2014. DataWatch Accessed September 9, 2015. http://www.datawatch.com/data-visualization-past-vs-present/.

Pulido, L., L. Barraclough and W. Cheng. 2012. *A People's Guide to Los Angeles*. Los Angeles: University of California Press.

Rattan, A., A. Campese and C. Eden. 2012. Modeling Walkability *ArcUser* 15 (4): 30-33 Accessed May 7, 2015. http://www.esri.com/news/arcuser/0112/files/walkability.pdf.

Raymond, A. 2011. Denny Regrade, 1893-2008: A case study in historical GIS. *Social Science History* 35 (4): 571-97.

Reed, S. E., J. L. Boggs, and J. P. Mann. 2012. A GIS tool for modeling anthropogenic noise propagation in natural ecosystems. *Environmental Modelling and Software* 37: 1.

Reiser, J. 2014. "Census download tools for ArcGIS". Accessed April 26, 2014. https://github.com/RowanGeolab/ArcGISCensusDownload

Roelvink D., A. Reniers, A. van Dongeren, J. van Tiel de Vries, R. McCall, J. Lescinski. 2009. Modeling storm impacts on beaches, dunes and barrier islands. *Coast Engineering* 56(11–12):1133–1152

Roelvink D., A. Reniers, A. van Dongeren, J. van Tiel de Vries, J. Lescinski, R. McCall. 2010. *XBeach Model description and Manual*. UNESCO-IHE Institute for Water Education, Deltares and Delft University of Tecnhology. Report June, 21 2010 version 6

Silva, A. M. A. N., and R. P. M. Taborda. 2013. Integration of beach hydrodynamic and morphodynamic modelling in a GIS environment. *Journal of Coastal Conservation* 17 (2): 201-10.

Slocum, T. A., R. B. McMaster, F. C. Kessler, and H. H. Howard. 2009. *Thematic cartography and geovisualization*. Third ed. Upper Saddle River, New Jersey: Pearson-Prentice Hall.

Spalding, V. 2000. Automating Spatial Processes. *ArcUser* 3(3). Accessed May 7, 2015. http://www.esri.com/news/arcuser/0700/mbover.html.

Stevens, D., S. Dragicevic, and K. Rothley. 2007. iCity: A GIS–CA modelling tool for urban planning and decision making. *Environmental Modelling and Software* 22 (6): 761-73.

SWAN. 2015. Scientific and technical documentation SWAN Cycle III version 41.01A. Delft University of Technology, Environmental Fluid Mechanics Section. Accessed August 18, 2015 http://swanmodel.sourceforge.net/online_doc/swantech/swantech.html

Tufte, E. R. 1990. *Envisioning Information*. Cheshire, CT: Graphics Press.

———. 2001. *The Visual Display of Quantitative Information*. Cheshire, CT: Graphics Press

Tang, Y., and D. W. Wong. 2006. Exploring and visualizing sea ice chart data using java-based GIS tools. *Computers and Geosciences* 32 (6): 846-58.

Thomsen, M., T. Wernberg, Peter A. Stæhr, and Morten F. Pedersen. 2006. Spatio-temporal distribution patterns of the invasive macroalga *sargassum muticum* within a Danish sargassum-bed. *Helgoland Marine Research* 60 (1): 50-8.

Vanleeuwe, H. 2010. Predictive mapping of season distributions of large mammals using GIS: An application to elephants on Mount Kenya. *Methods in Ecology and Evolution* 1 (2): 212-20.

Watson, R, and D. Pauly. 2014. Coastal catch transects as a tool for studying global fisheries. *Fish and Fisheries* 15 (3): 445-55.

Wikimedia Commons 2015. File:Minards chart Napoleons Russian campaign of 1812 made in 1869.jpg. Wikimedia. Accessed September 8, 2015. https://commons.wikimedia.org/wiki/File:Minards_chart_Napoleons_Russian_campaign_of_1812_made_in_1869.jpg

Wheaton, Joseph M., Chris Garrard, Kelly Whitehead, and Carol J. Volk. 2012. A simple, interactive GIS tool for transforming assumed total station surveys to real world coordinates – the CHaMP transformation tool. *Computers and Geosciences* 42 : 28-36.

Zandbergen, P. A. 2013. *Python Scripting for ArcGIS*. Redlands, CA: ESRI, Inc.

Zeiler, M. 1999. *Modeling our world: The ESRI guide to geodatabase design*. Vol. 40 Redlands, CA: ESRI, Inc.

APPENDIX A: CONTEXT SENSITIVE HELP DOCUMENTS FROM MODELS

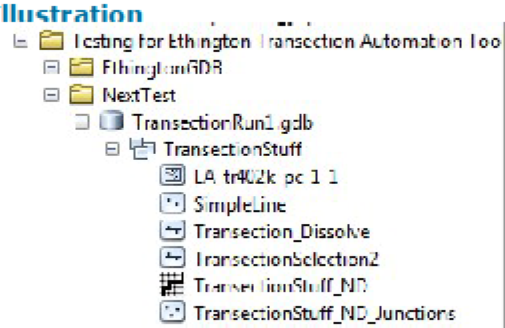
1.Transection File SetUp 2.1

Title 1.Transection File SetUp 2.1

Summary

This model will help collect all the files and create the beginning file structures neccessary to create the Ethington Transection illustrations. Run this tool from the catalog window with a new blank map open in the map window. Each time you run this tool you must enter a unique set of names for the folder, otherwise errors will be generated proclaimimg that the file already exists. In order to run this tool a second time with same names, the user must delete the files created the first iteration of this tool.

Illustration



Usage

There is no usage for this tool.

Syntax

BeginningHousekeeping2 (File_Location, Folder_Name, FIle_with_Transection_Features, File_with_Polygon_features, Coordinate_System)

Parameter	Explanation	Data Type
File_Location	**Dialog Reference** Please select the general location you would like to store all the transection files that will be created while running these tools. This should be a folder location. The next step would be to name a folder that will be created to store this particular transection run. There is no python reference for this parameter.	Folder
Folder_Name	**Dialog Reference** Please type in the unique name of a new folder that will be created to store this iteration of transection creation. There is no python reference for this parameter.	String
FIle_with_Transection_Features	**Dialog Reference** Please select the line file containing the features desired to use as the transection. It can be a feature class, shapefile or layer, but it must contain the transection features as a line. Individual features from this file may be selected after this tool runs to specify the transection. There is no python reference for this parameter.	Feature Layer

File_with_Polygon_features	**Dialog Reference** Please select the spatial file containing the polygon information desired to analyze with the transection technique. It can be a feature class, shapefile or layer, but it must contain only polygon features. There is no python reference for this parameter.	Feature Layer
Coordinate_System	**Dialog Reference** Please specify the coordinate system of the polygon feature dataset if known. If not leave as the default "Unknown." There is no python reference for this parameter.	Coordinate System

Code Samples
There are no code samples for this tool.

Tags
Transection, workspace creation, Ethington, Bengoa

Credits
A.J. Bengoa and Dr. Phil Ethington

Use limitations
There are no use limitations for this item.

2.Visualize Transection 1.4

Title 2.Visualize Transection 1.4

Summary

This tool is intended to visualize the direction of the transection and isolate all files neccessary for transection analysis. DO NOT SKIP THIS STEP!!! If the direction of the line is correct proceed to step 4. If it is neccessary to flip/reverse the direction of the line then proceed to step 3.

Usage

There is no usage for this tool.

Syntax

Model2222 (Working_GDB, Transection_Layer, Transection_Visualization)

Parameter	Explanation	Data Type
Working_GDB	**Dialog Reference** Please select the geodatabase created in step 1. of Ethington Transection Analysis where all the files will contiue to be placed during the analysis. There is no python reference for this parameter.	Workspace
Transection_Layer	**Dialog Reference** Please use the drop down list to select the layer containing the features desired for the transection. The drop down list should contain all layers curently in the map's table of contents (TOC). If you ran step 1 with a new blank map the TOC will only contian two layers; the one containing the transection , and the one containing the polygons for analysis. If only certain features are desired for the transection then ensure they are selected prior to running this tool. All features in this layer will be used to create the transection if there are no selctions in this layer (**all selected features must be of line type**). All selected features should be of the line type and should be contiguous (meaning that all end points must join with next line feature end point without gaps). There is no python reference for this parameter.	Feature Layer or Raster Catalog Layer
Transection_Visualization	**Dialog Reference** **Leave the default.** \No need to change this input. It is exposed as a prameter in order to place the output in the blank map for visualization. There is no python reference for this parameter.	Feature Layer

Code Samples

There are no code samples for this tool.

Tags

transection, direction visualization, Bengoa, Ethington

Credits

Dr. Phil Ethington, A.J. Bengoa

Use limitations

There are no use limitations for this item.

3.FlipTransection 1.2

Title 3.FlipTransection 1.2

Summary

This tool is used to reverse the direction of the transection after it is visualized in step 2 of the Ethington Transection Analysis. This step is optional and only required if the user desires the order of the polygons to go in the opposite direction as those visualized in step 2. You may run this tool any multiple of times without complications, however as it only switches the direction back and forth this should not be necessary.

Usage

There is no usage for this tool.

Syntax

3.FlipTransection2 (Working_GDB, Layer_of_Transection_Direction_Flipped)

Parameter	Explanation	Data Type
Working_GDB	**Dialog Reference** Please select the working GDB containing the latest iteration the Ethington Transection Analysis. It should be the GDB created in step 1. There is no python reference for this parameter.	Workspace
Layer_of_Transection_Direction_Flipped	**Dialog Reference** **Leave default.** No user input neccessary. This parameter is exposed to ensure that the layer is added to the map so that the user may verify that the direction of travel has indeed been reversed and indicates the desired direction. There is no python reference for this parameter.	Feature Layer

Code Samples

There are no code samples for this tool.

Tags

transection, ethington, bengoa, flip line, reverse direction

Credits

Dr. Phil Ethington, A.J. Bengoa

Use limitations

There are no use limitations for this item.

4.GeoprocessingTasks 3.0 Test 6.5

Title 4.GeoprocessingTasks 3.0 Test 6.5

Summary

The initial geoprocessing tasks in a model to automate the creation of Ethington Transections within ArcMap.

Usage

There is no usage for this tool.

Syntax

InitGeoProc282522 (Working_GDB, Polygon_Layer, Transection_Lines_Feature_Class, Buffer_Distance)

Parameter	Explanation	Data Type
Working_GDB	**Dialog Reference** Please select the working GDB that was created in step 1 of this iteration of the Ethinton Transection Analysis. This is where all your files are being and will be stored in the future. There is no python reference for this parameter.	Workspace
Polygon_Layer	**Dialog Reference** The polygon layer from the map that conatins the data to be analyzed in the Ethington Transection Analysis. Should be in the dropdown menu. There is no python reference for this parameter.	Feature Layer or Raster Catalog Layer or Mosaic Layer
Transection_Lines_Feature_Class	**Dialog Reference** No user input required or desired. Please leave as is. It is exposed as a parameter to ensure that the result is placed in the new map. There is no python reference for this parameter.	Feature Class
Buffer_Distance	**Dialog Reference** This is the buffer distance you want to invoke for the selection of polygons. If you only want to select polygons that are absolutely touching the line it should be set to 0. The default setting is 20 m which for city wide distances is still small but allows for some additional inclusion for polygons that are proximate though possibly not touching. Set this distance to a meanigful relative distance for your project's purposes. There is no python reference for this parameter.	Linear unit or Field

Code Samples

There are no code samples for this tool.

Tags

transection, HGIS, linear analysis

Credits

Philip J. Ethington and AJ McCoy Bengoa

Use limitations

There are no use limitations for this item.

5. Organize Polygon Data and Export Table

Title 5. Organize Polygon Data and Export Table

Summary

This tool organizes the polygon data generated in tool 4 for export to Excel and graphing in ArcGIS. This allows for quick visualization of the data in a simple transection layout (tools 6 & 7).

Usage

There is no usage for this tool.

Syntax

Model2 (Working_GDB, Final_Polygon_Feature_Class, Transection_Data_as_Excel_Table, Variable_data_for_Areal_Units_Sorted_by_Sequence)

Parameter	Explanation	Data Type
Working_GDB	**Dialog Reference** Please select the working GDB containing the latest iteration the Ethington Transection Analysis. It should be the GDB created in step 1. There is no python reference for this parameter.	Workspace
Final_Polygon_Feature_Class	**Dialog Reference** **Leave as default.** No user input required or desired. Please leave as is. It is exposed as a parameter to ensure that the result is placed in the new map. If you have run this tool before and want to run again you must change the name of this feature class, otherwise an error will occur. (i.e. Final PolygonFC2) There is no python reference for this parameter.	Feature Class
Transection_Data_as_Excel_Table	**Dialog Reference** This is the name of the Excel table that will be exported with all the relevant data if further analysis is desired in this program. For many people it will be desirable to create multiple iterations of the charts in Excel due to its more familiar interface and interoperability with presentation software, rather than using ArcMap. There is no python reference for this parameter.	File
Variable_data_for_Areal_Units_Sorted_by_Sequence	**Dialog Reference** This is the input for this tool which should be the output from Tool 4 you just placed on the map. **Leave as default.** No user input required or desired. Please leave as is. It is exposed as a parameter in case your feature class was changed from teh default in tool 4. There is no python reference for this parameter.	Feature Layer

Code Samples

There are no code samples for this tool.

Tags
Ethington Transection, HGIS, linear analysis

Credits
There are no credits for this item.

Use limitations
There are no use limitations for this item.

6. Visualize Polygons

Title 6. Visualize Polygons

Summary
Step 6 of the Ethington Transection Automation. This tool is intended to show the sequence order of the polygons to ensure proper placement prior to graphing the data.

Usage
There is no usage for this tool.

Syntax
Model12 (Visualized_Polygons_in_Order, Working_GDB, Polygon_Symbology_Layer, Fina_lPolygon_Feature_Class)

Parameter	Explanation	Data Type
Visualized_Polygons_in_Order	**Dialog Reference** The final feature layer name. You may change name if desired. Exposed as a parameter to ensure it is added to the map. There is no python reference for this parameter.	Feature Layer
Working_GDB	**Dialog Reference** Please select the geodatabase created in step 1. of Ethington Transection Analysis where all the files to be used can be found and new feature classes will continue to be placed during the analysis. There is no python reference for this parameter.	Workspace
Polygon_Symbology_Layer	**Dialog Reference** This is a symbology layer included in the folder with the Ethington Transection Automation tool box. If you have not moved the files and have placed the Working GDB in the same Master folder as the Ethington Transection Automation Toolbox then you should be able to leave this as the default. However, if an error message occurrs at this paramter input, please locate this layer file in order to symbolize the polygons correctly. There is no python reference for this parameter.	Layer
Fina_lPolygon_Feature_Class	**Dialog Reference** **Leave as default**. No user input required or desired. Please leave as is, unless you changed the feature class name in the output of tool 5. This is the tool's input and contains all the final data neccessary for graphing and plotting transections and was the final output feature class dereived from running tool 5 of the Ethington Transection Automation toolbox. There is no python reference for this parameter.	Feature Layer

Code Samples
There are no code samples for this tool.

Tags
Ethington transection, hgis, linear analysis

Credits
There are no credits for this item.

Use limitations
There are no use limitations for this item.

7.TransectionGraph_Horizontal

Title 7.TransectionGraph_Horizontal

Summary

This tool is to create a line graph of the data from the execution of the Ethington Transection Analysis tools 1-4 and allows you to export that graph to the format of your choice.

Usage

There is no usage for this tool.

Syntax

5.TransectionGraph2 (Working_Folder, Input_series, Export_of_Transection_Graph, Graph_Template__Horizontal_grf)

Parameter	Explanation	Data Type
Working_Folder	**Dialog Reference** Input the folder that you have been working in which contains your GDB, the toolbox and all the working files. This will be the folder to which the graphs will be saved. There is no python reference for this parameter.	Workspace
Input_series	**Dialog Reference** These are the variables available for adjustment in the creation of this graph. *If for some reason this looks blank, ensure the graph template file parameter is designated. This will cause it populate.* **Series Vertical Line of type "line:vertical"** Dataset: *Poly_to_Points_SpatialJoin_Sort2*. Don't change this. This should be the file containing the data you want to graph X (optional): *Additive_Length*. Don't change this. This is the field to plot the relative distances of the polygons along the transection. Y: Please choose the column heading that you would like to graph from the data. (examples include percent Hispanic, Median home values, number of trees, etc.) Label (optional): If you have a column of alternate labels for the Y axis select it here. Sort type (optional): *VALUE*Don't change this. **Graph General Properties** Title (optional): *Transection Plot*. Input the name you would like to appear above this particular graph. Subtitle (optional): Input a subtitle if desired. Footer (optional): Input a footer if desired. **Legend Properties** Title (optional): This graph template does not contain a legend but you may enter a legend title here in this spot. **Axis (Left)** Title: *Percent Hispanic*. Enter the Title/label that describes the data plotted on the y axis.	Graph Data Table

	Axis (Right) Title: Input a title for the left axis if desired. **Axis (Bottom)** Title: Input a title for the bottom axis if desired. **Axis (Top)** Title: Input a title for the top axis if desired. There is no python reference for this parameter.	
Export_of_Transection_Graph	**Dialog Reference** The location automatically indicates the folder selected above. Type the file name desired for the saved graph after the "%Working Folder%\" and select the format desired from the list below. **Output file:** The output image, vector, or graph file (.grf). *The additional supported image and vector formats are:* Windows Bitmap (.bmp) GIF(.gif) JPEG (.jpg) Portable Network Graphic (.png) Paintbrush (.pcx) Scalable Vector Graphics (.svg) Adobe Acrobat PDF (.pdf) Encapsulated PostsScript (.eps) Enhanced Metafile (.emf) Windows Metafile (.wmf) There is no python reference for this parameter.	File
Graph_Template__Horizontal_grf	**Dialog Reference** This is a file included with the toolbox folder that is needed to symbolize the resultant graph created in this step. Please navigate to the file named "Graph Template_Horizontal.grf", and select it for this field. There is no python reference for this parameter.	Graph or File

Code Samples
There are no code samples for this tool.

Tags
Ethington, Transection, line graph

Credits
There are no credits for this item.

Use limitations
There are no use limitations for this item.

7.TransectionGraph_Vertical

Title 7.TransectionGraph_Vertical

Summary

This tool is to create a line graph of the data from the execution of the Ethington Transection Analysis tools 1-4 and allows you to export that graph to the format of your choice.

Usage

There is no usage for this tool.

Syntax

5.TransectionGraph22 (Working_Folder, Input_series, Export_of_Transection_Graph, Graph_Template__Vertical_grf)

Parameter	Explanation	Data Type
Working_Folder	**Dialog Reference** Input the folder to which you want the graphs saved. I would suggest the same folder as your GDB but it really is up to you. There is no python reference for this parameter.	Workspace
Input_series	**Dialog Reference** These are the variables available for adjustment in the creation of this graph. **Series Vertical Line of type "line:vertical"** Dataset: *Poly_to_Points_SpatialJoin_Sort2*. Don't change this. This should be the file containing the data you want to graph X (optional): *Additive_Length*. Don't change this. This is the field to plot the relative distances of the polygons along the transection. Y: Please choose the column heading that you would like to graph from the data. (examples include percent Hispanic, Median home values, number of trees, etc.) Label (optional): If you have a column of alternate labels for the Y axis select it here. Sort type (optional): *VALUE*Don't change this. **Graph General Properties** Title (optional): *Transection Plot*. Input the name you would like to appear above this particular graph. Subtitle (optional): Input a subtitle if desired. Footer (optional): Input a footer if desired. **Legend Properties** Title (optional): This graph template does not contain a legend but you may enter a legend title here in this spot. **Axis (Left)** Title: *Percent Hispanic*. Enter the Title/label that describes the data plotted on the y axis. **Axis (Right)** Title: Input a title for the left axis if desired.	Graph Data Table

	Axis (Bottom) Title: Input a title for the bottom axis if desired. **Axis (Top)** Title: Input a title for the top axis if desired. There is no python reference for this parameter.	
Export_of_Transection_Graph	**Dialog Reference** The location automatically indicates the folder selected above. Type the file name desired for the saved graph after the "%Working Folder%\" and select the format desired from the list below. **Output file:** The output image, vector, or graph file (.grf). *The supported image and vector formats are:* Windows Bitmap (.bmp) GIF(.gif) JPEG (.jpg) Portable Network Graphic (.png) Paintbrush (.pcx) Scalable Vector Graphics (.svg) Adobe Acrobat PDF (.pdf) Encapsulated PostsScript (.eps) Enhanced Metafile (.emf) Windows Metafile (.wmf) There is no python reference for this parameter.	File
Graph_Template__Vertical_grf	**Dialog Reference** This is a file included with the toolbox folder that is needed to symbolize the resultant graph created in this step. Please navigate to the file named "Graph of Poly_to_Points_SpatialJoin_Sort2.grf", and select it for this field. There is no python reference for this parameter.	Graph or File

Code Samples
There are no code samples for this tool.

Tags
Ethington, Transection, line graph

Credits
There are no credits for this item.

Use limitations
There are no use limitations for this item.

APPENDIX B: USER'S MANUAL FOR THE ETHINGTON TRANSECTION TOOLBOX (ETT)

User Instructions for Ethington Transection Automation Toolbox

1. See "Step1Instructions" video (http://screencast.com/t/pTwBQCJ6kDXy). Copy the zipped folder "Testing for Ethington Transection Automation Tool", containing a custom toolbox and all supporting template layer and graph files, to your computer where you would like to run the transection automation. (This also includes a copy of the "EthingtonTransection.gdb" for sample files). You should then unzip the folder where you want to conduct your analyses.

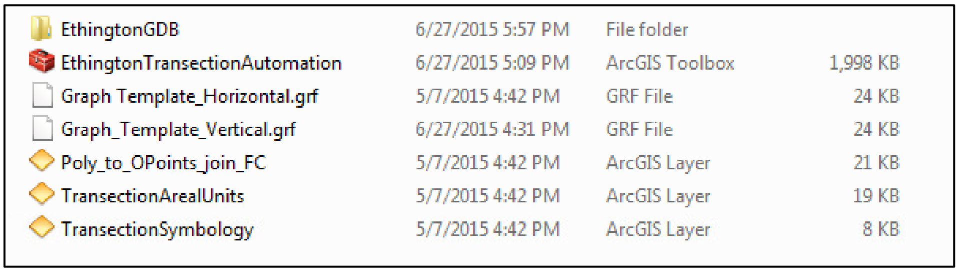


Figure 39. List of all files included in the zipped to run Ethington Transection Automation Tools.

2. Open ArcMap to a Blank Map and choose a default geodatabase. (The choice of default geodatabase is irrelevant to use of the tool as the first steps will establish a new empty geodatabase to house all the new files created while running the transection automation.)

3. Open the Catalog window and "pin it" open by pressing the pushpin in the top right corner till it faces down so the catalog window stays open. Navigate to the folder containing the copied "Ethington Transection Toolbox" and open it so it reveals Tools 1-7 as below.

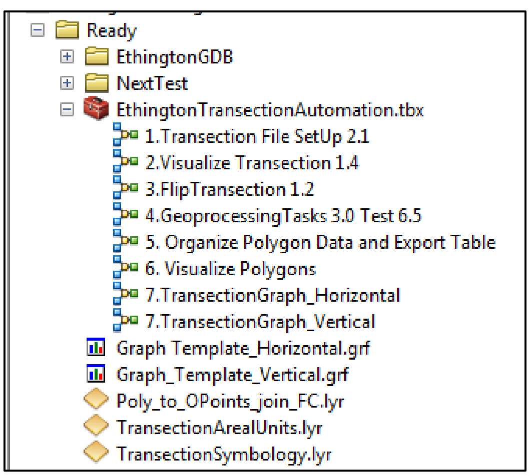


Figure 40. Catalog window in ArcMap showing the contents of the toolbox and the supporting files for running the Ethington Transection Automation.

4. Turn on the Network Analyst Extension by going to Customize/Extensions in ArcMap. Click the check box for "Network Analyst" (this will be used in Tool 4 and is easier to turn on now rather than at that time). For the same later use ensure that the Network Analyst toolbar is turned on by going to Customize/Toolbars/Network Analyst.

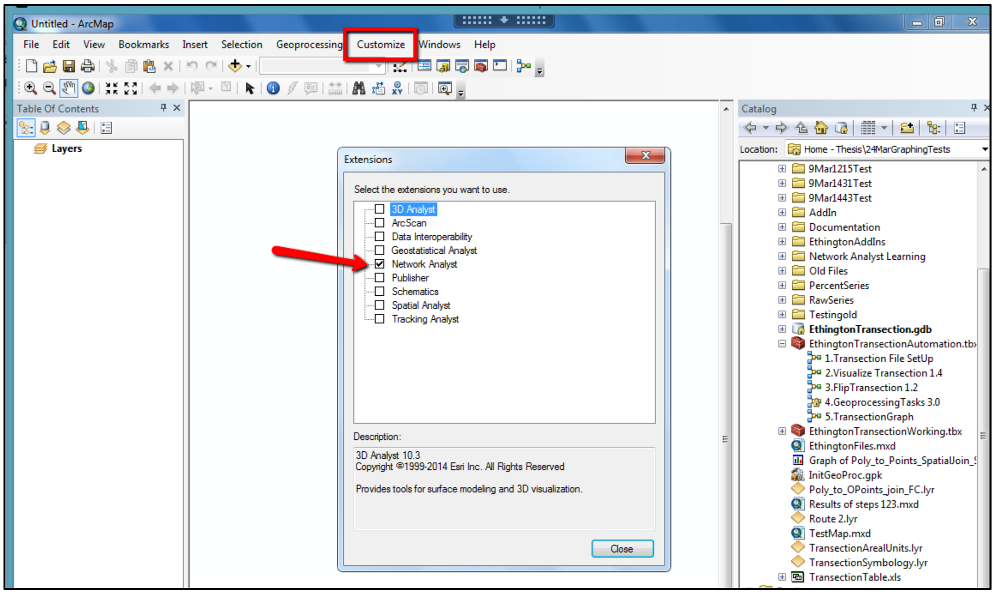


Figure 41. Extension Manager in ArcMap to Turn on Network Analyst.

5. Double click the tool labeled "1.Transection File SetUp". When the Tool opens please ensure the Help is visible by toggling the "Show/Hide Help" button until it is visible to the left of the parameter input window. Clicking in in each parameter field will change the context sensitive help messages at the left. By utilizing the information in the help window please make the appropriate choices for the four parameters and then press OK to run the tool.

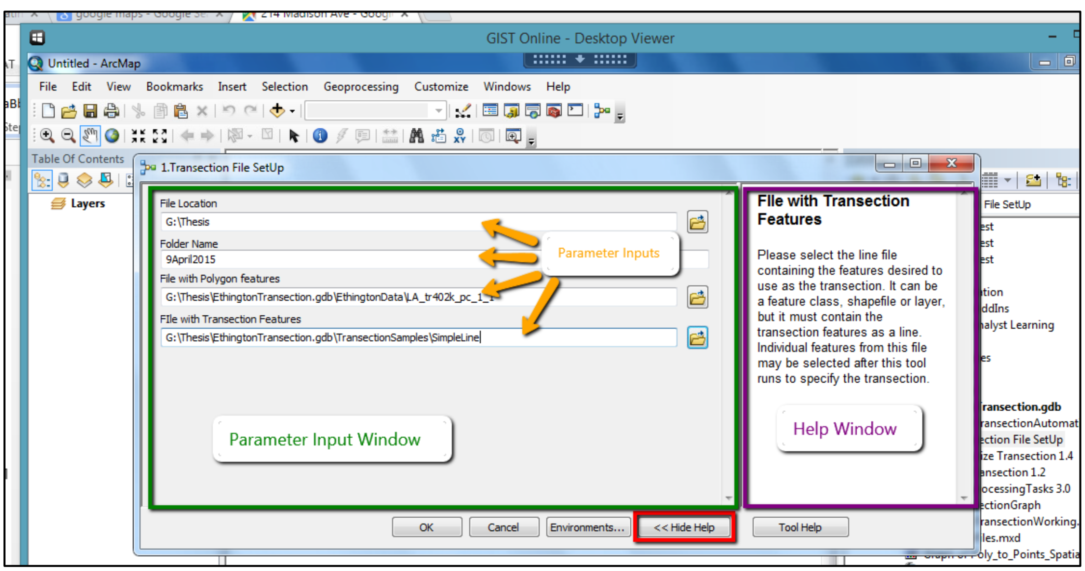


Figure 42. The view of Tool 1 prior to running it with parts labeled.

6. Save the Map file to a location of your choice, if you want to come back to this point at a later date. At this time you should notice that the line and polygon files you selected have been added to the map and that a new folder, file geodatabase, and dataset with the two files you

selected have been added in the catalog window. You will also have to reopen the toolbox at this time to see the next tool.

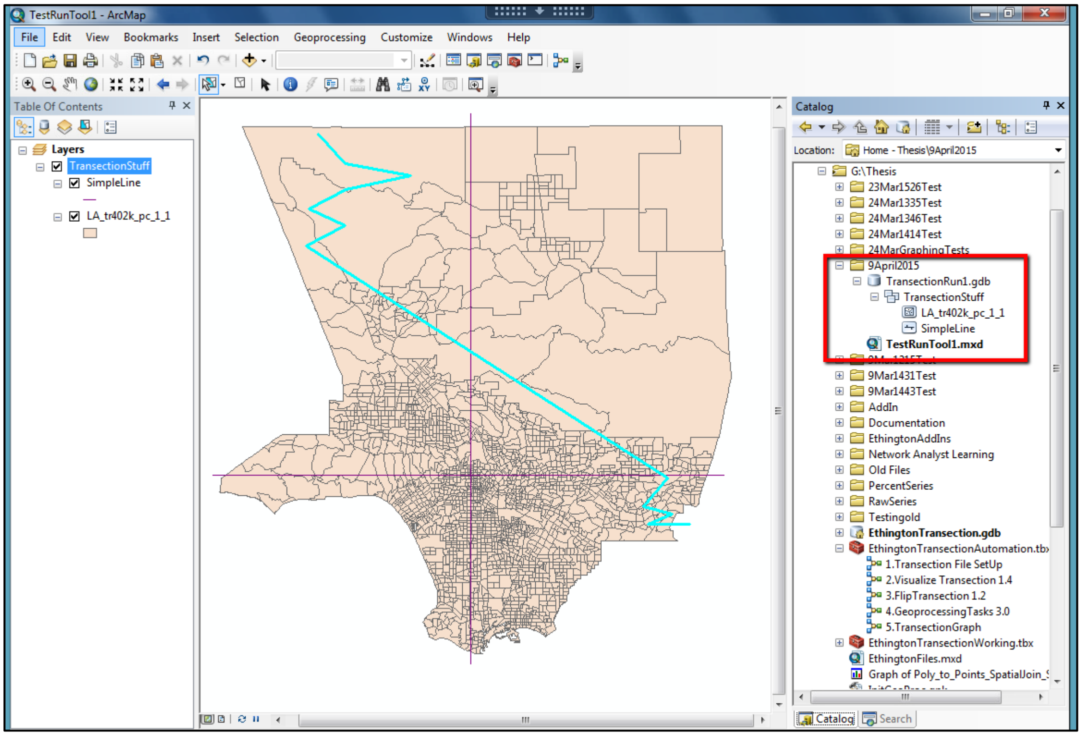


Figure 43. ArcMap after Tool 1 runs with the new files indicated in the catalog window.

7. See "Step2Instructions_Alternate" video (http://screencast.com/t/RJDKALGGdUC). Select the contiguous line features that you want to designate as the transection by using any of ArcMap's selection tools (an example selection of four features in one contiguous line selection is shown in *Figure 43*). If nothing is selected all features in the line file will be used to create the transection. If these are not contiguous line features there will be an error in the next step and when running Tool 4.

8. Run Tool 2 by double-clicking it, reading the help menu items for the tool and each parameter, filling out the parameter inputs with the appropriate data, and clicking OK.

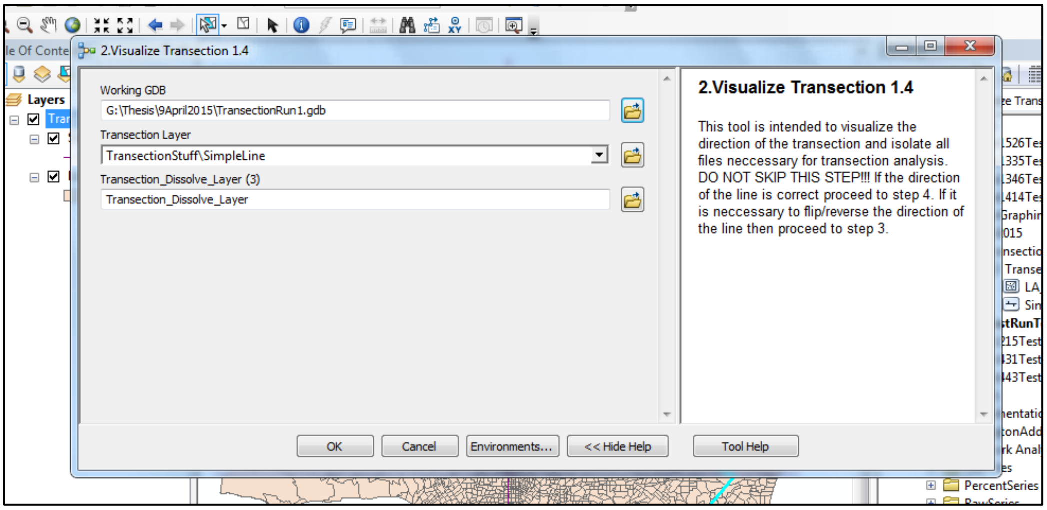


Figure 44. Tool 2 when open showing suggested parameter inputs and help.

9. Save the Map file again and evaluate the direction of the transection indicated in the map window. The direction of the black arrowheads indicates the direction of travel along the transection and will indicate the order that the polygon data will be recorded. In general the direction of travel should be left to right or down to up to coincide with the direction of default graph reading, but as this can all be customized later it is up to user's choice. If the current direction is correct, skip the next step and do not use Tool 3.

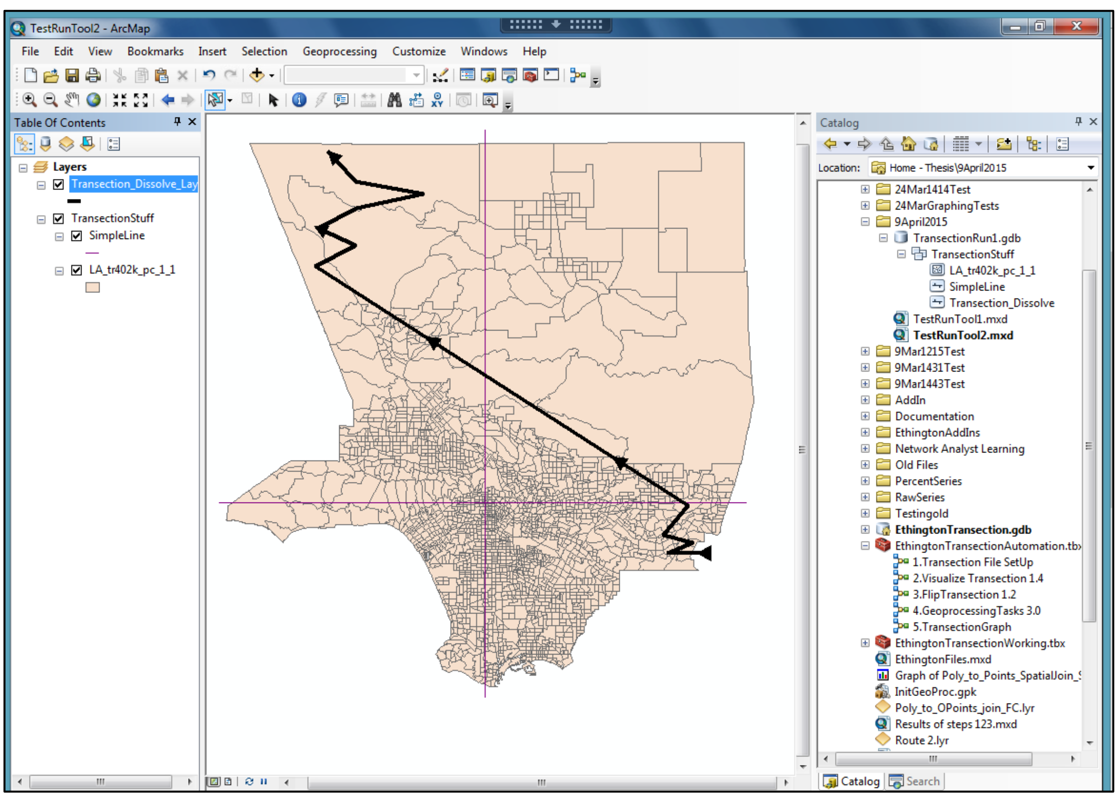


Figure 45. ArcMap windows after running Tool 2 with the black arrows indicating the direction of travel along the transection.

10. See “Step3Instructions” video (http://screencast.com/t/t7QqNo8rdaNT).Run Tool 3 if you want to switch the transection’s direction of travel. Follow the directions in the help and enter the appropriate parameters.

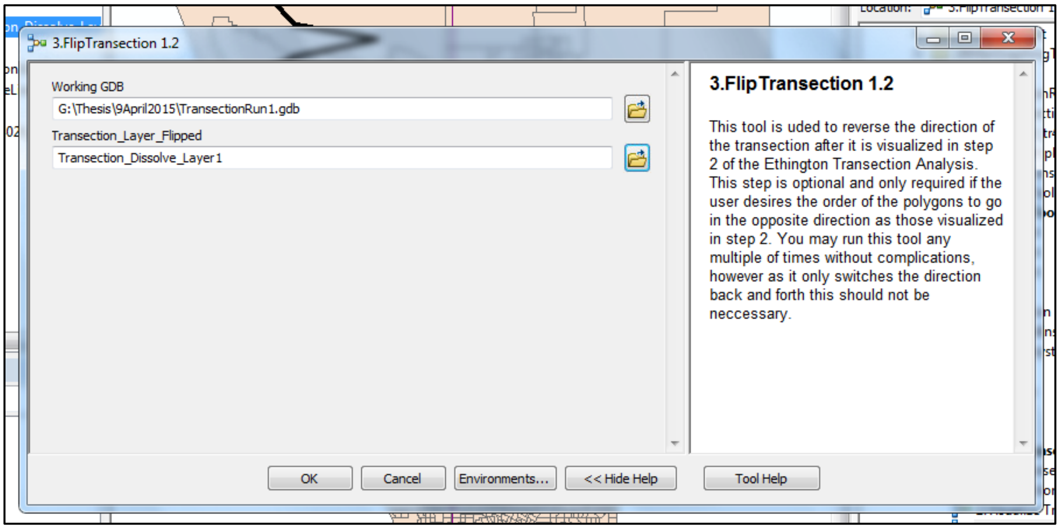


Figure 46. Dialog of parameter window and help window of Tool 3 with example entries.

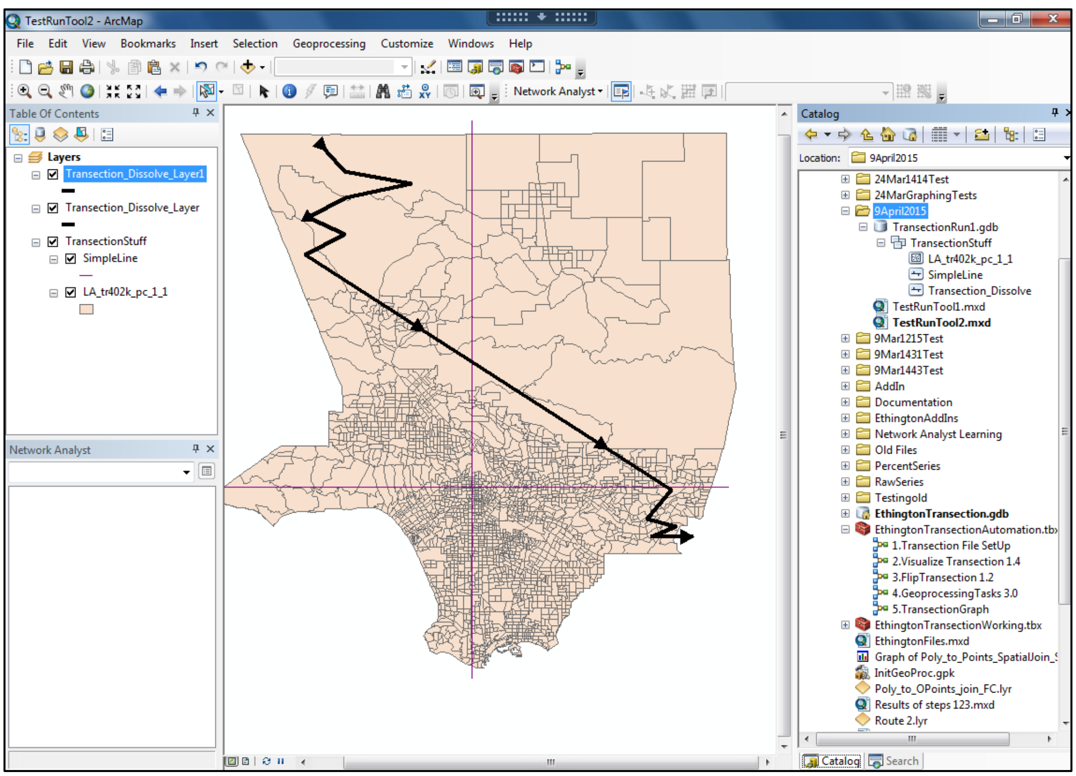


Figure 47. ArcMap after running Tool 3 to flip the direction of travel for the transection (notice that the arrows are pointing the opposite direction than in Figure 45.

11. See “Step4InstructionsBefore” (http://screencast.com/t/xXZ5FrzNOVSe).Create a network route with the transection. First ensure that the Network Analyst window is open by clicking the

button on the Network Analyst toolbar. Move/dock this window where you can access it but it does not impede the map, catalog or TOC windows.

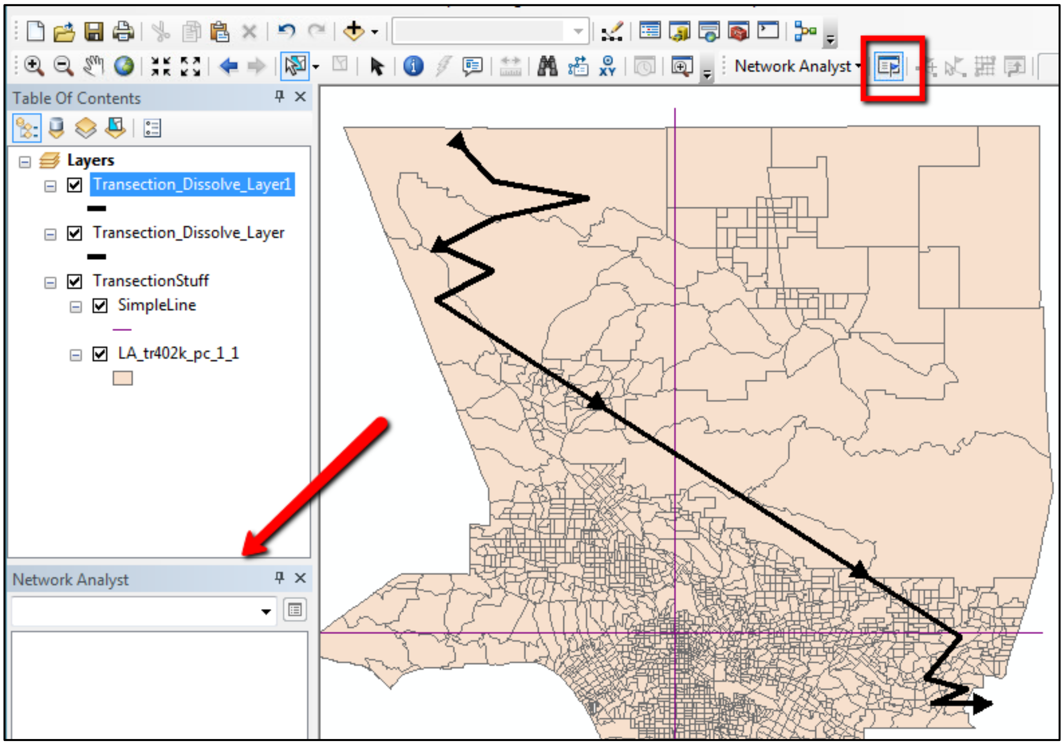


Figure 48. ArcMap with the Network Analyst window and button indicated.

In the catalog window, right-click the dataset and Select a New/Network Dataset as indicated in *Figure 49*.

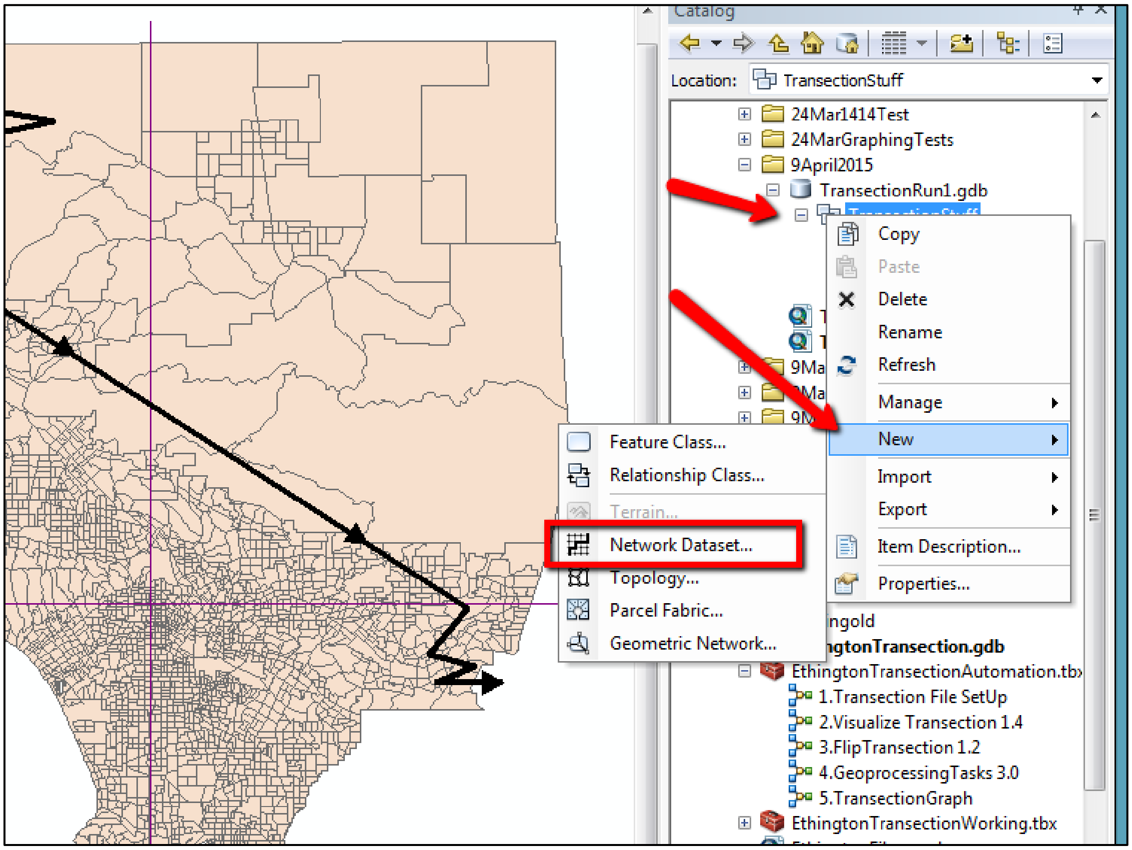


Figure 49. Selecting to create a New Network Dataset by right-clicking on the database in the catalog window.

When the Network Dataset wizard begins, enter a name for the dataset (the default is fine), and press Next. Select only the feature class “Transection_Dissolve” which contains the transection, and press Next. Answer “No” for “Do you want to model turns in this network?” and press Next. Leave the Connectivity settings as is and just press Next again. Choose “None” for elevation models and press Next. The attributes of the dataset should appear as in *Figure 50* where you can optionally set the units of the length attribute (if they do not appear by default) by clicking on the field at the cross section of “Units and Length”. At the Travel Mode Screen click the + sign next to the drop down menu as indicated in and Enter any word (I suggest “Going”) and enter. Then Choose “Not Allowed” from the U-Turns at Junction field. Then press Next. Select “No” to the question “Do you want to establish driving directions settings for this network dataset?” and click Next. Leave the “Build Service Area Index” unchecked and click Next. The last screen is the Summary page and Click “Finish” to create the Network Dataset. Once the wizard runs click “Yes” when asked if you would like to build the dataset now, but “No” When asked if you want to add all the elements to the map (lack of spatial references can be ignored). The Network Dataset files should now be added to the dataset and look similar to *Figure 52*.

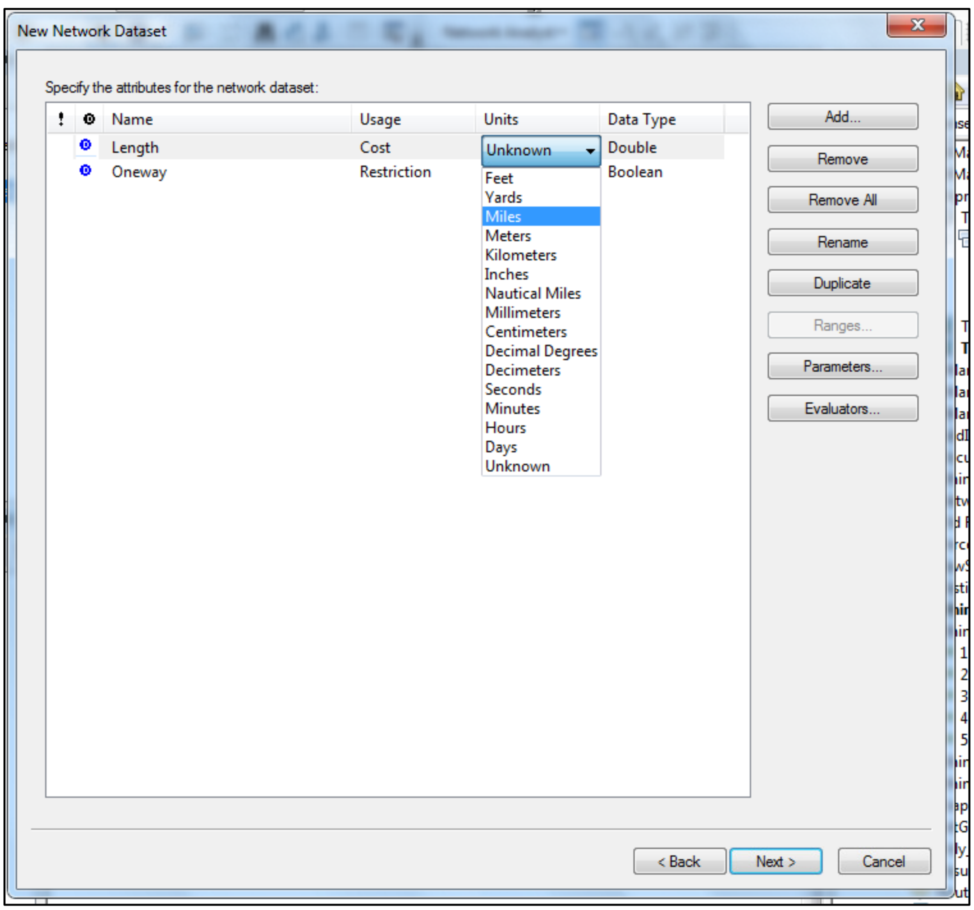


Figure 50. Network Dataset Wizard on attribute screen, with optional setting of units open.

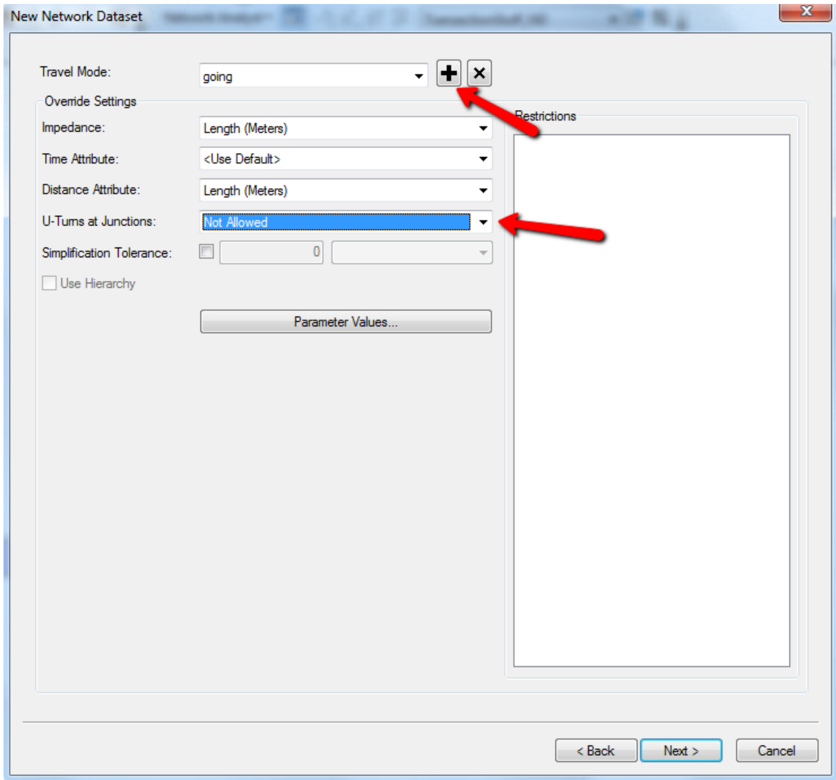


Figure 51. Travel Window for creation of new Network Dataset with the two items that must be changed indicated with red arrows.

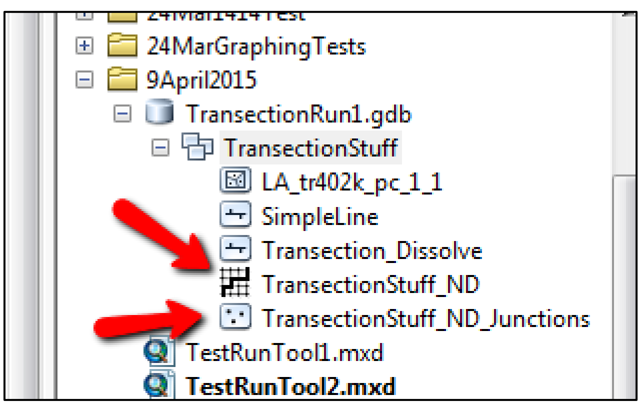


Figure 52. Network Dataset Elements identified in the catalog window.

12. See “Step4bInstructions” video (http://screencast.com/t/ch9yrqX1). Run Tool 4 by double-clicking it and following the help directions for the parameters’ input. This may take a few minutes to complete.

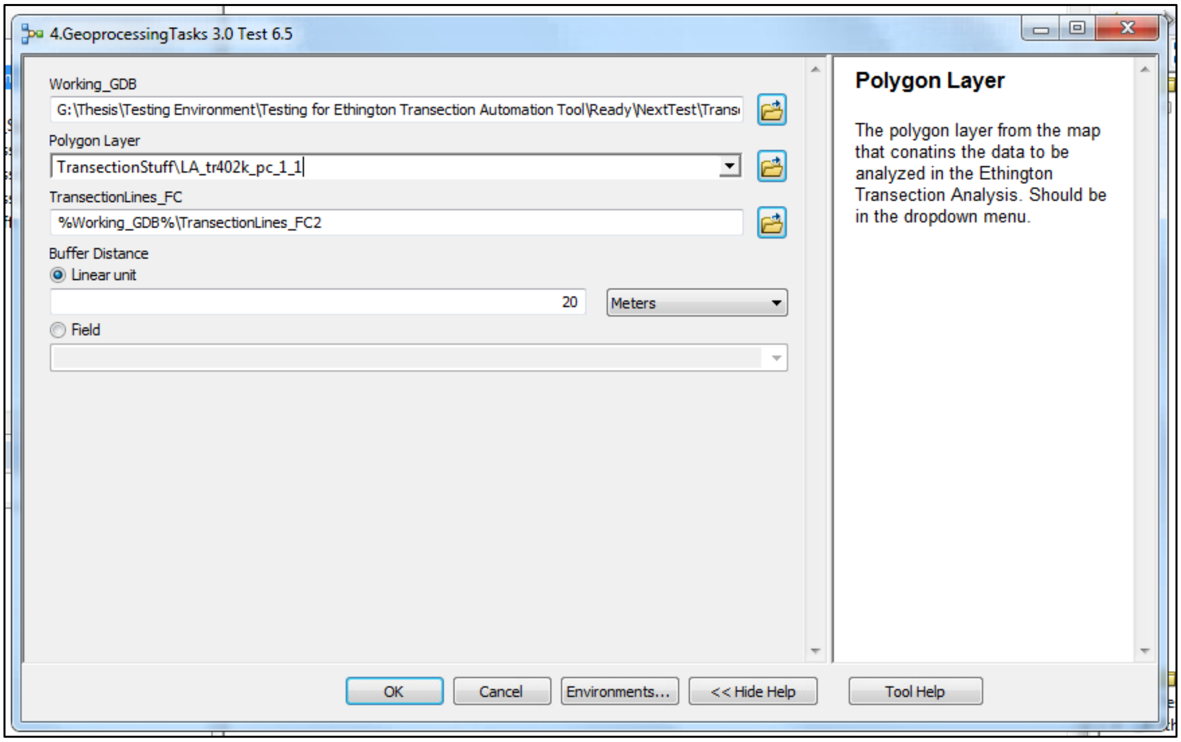


Figure 53. Parameter Entry Window and Help for Tool 4.

13. Add the “Poly_to_Points_SpatialJoin_Sort” feature class from the catalog to the Table of Contents by dragging the feature class from the catalog window to the TOC window.

14. See “Step5Instructions” video (http://screencast.com/t/uNt4JvZdtl). Designate the Working GDB in the first parameter input and leave the rest of the parameters as the default (*Figure 54*).

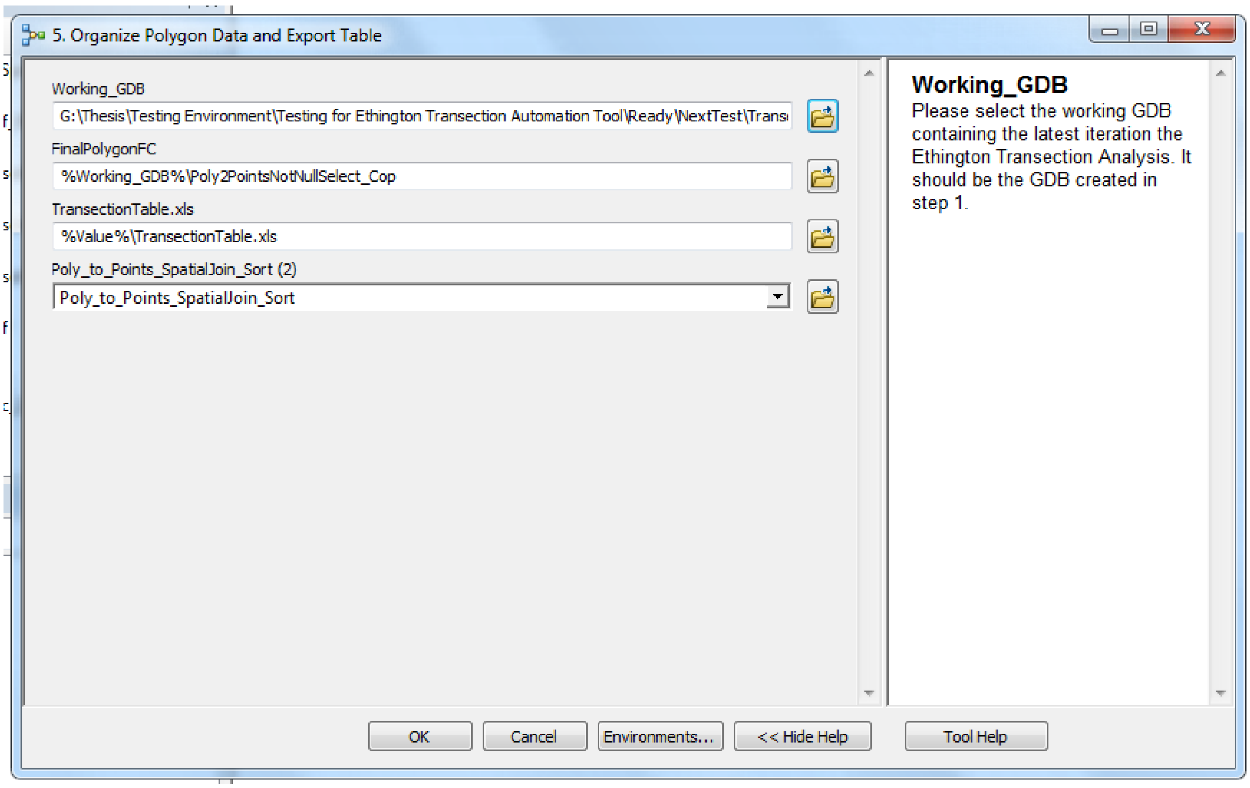


Figure 54. The Parameter Entry Window for Tool 5.

15. See “Step6Instructions” video (http://screencast.com/t/cKTDyoVDT). Run this tool from the ModelBuilder window by right clicking the tool and choosing “Edit” (*Figure 55*). The only parameter input is selected by double-clicking the star at the beginning of the flow diagram (*Figure 56*). This should point to the same Working GDB used with all the other tools. Then validate the tool by clicking the check mark in the upper right hand corner. And run the tool by clicking the small right facing green triangle in the upper right hand corner. After the tool runs the labels must be designated. Right click the layer added to the map and select “Properties” (*Figure 57*). Select the “Labels” tab and ensure the “Label features in this layer” box is checked, and that “Sequence” is the designated label field (*Figure 58*).

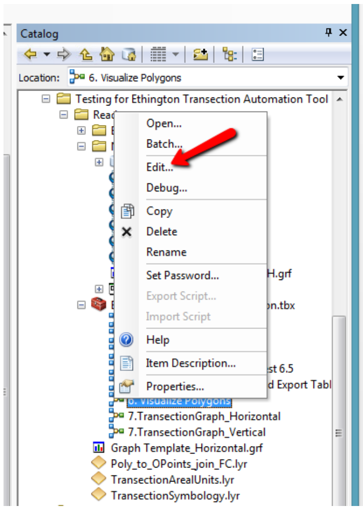


Figure 55. Selecting the Edit option from the right-click drop-down menu for Tool 6 in order to run the tool in the ModelBuilder window.

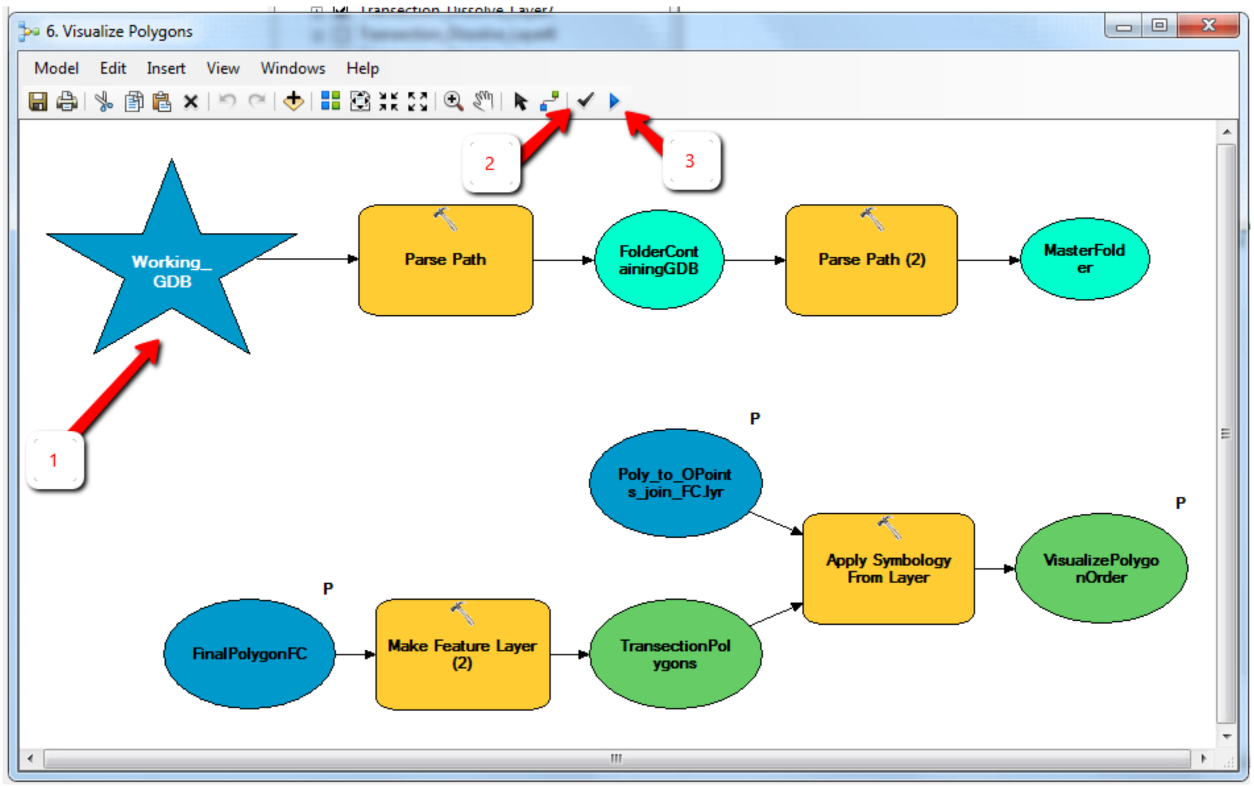


Figure 56. The ModelBuilder window with the steps to run Tool 6 designated in sequential order.

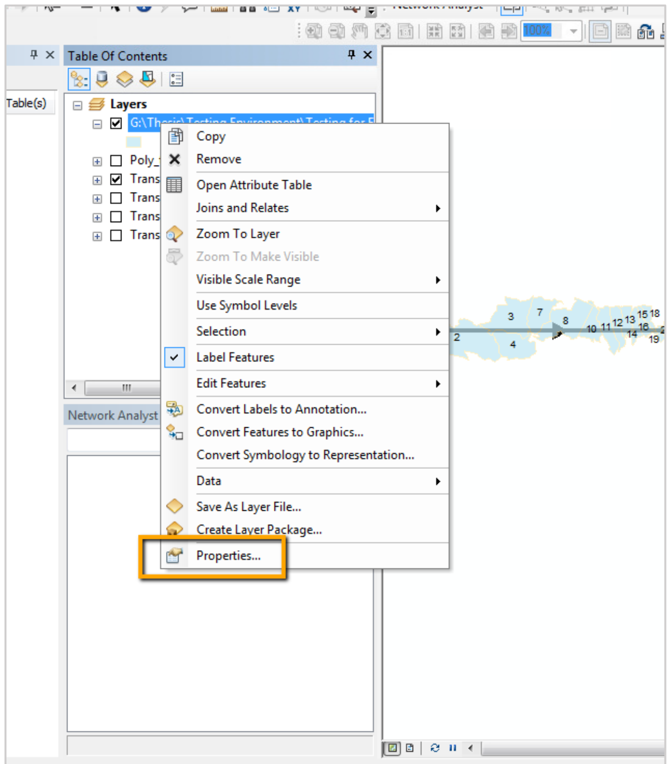


Figure 57. Highlighting the Properties option while right-clicking the newly created layer after running Tool 6.

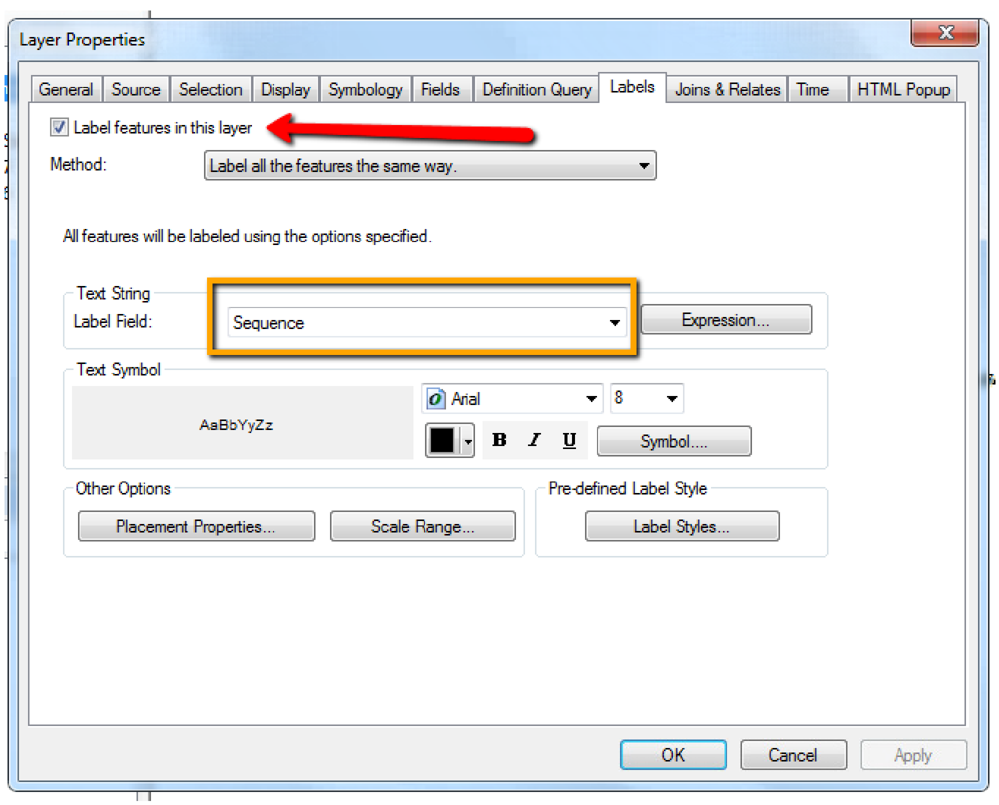


Figure 58. The Labels tab for the Layer's Properties wIndow indicating the correct inputs for properly labeled transection polygons resulting from running Tool 6.

16. See “Step7Instructions” video (http://screencast.com/t/8EFdTML6w). First change to the “Layout View” (*Figure 59*). Run Tool 7 in order to generate a scaled graph based on the values of your transection polygons. First determine whether your map is primarily running in the horizontal or vertical direction and select the appropriate tool to coordinate. The parameters necessary for entry are primarily contained in the Input Series table for the graph’s options. Please use the tool’s context sensitive help to set the desired parameters to generate the graph (*Figure 60*).

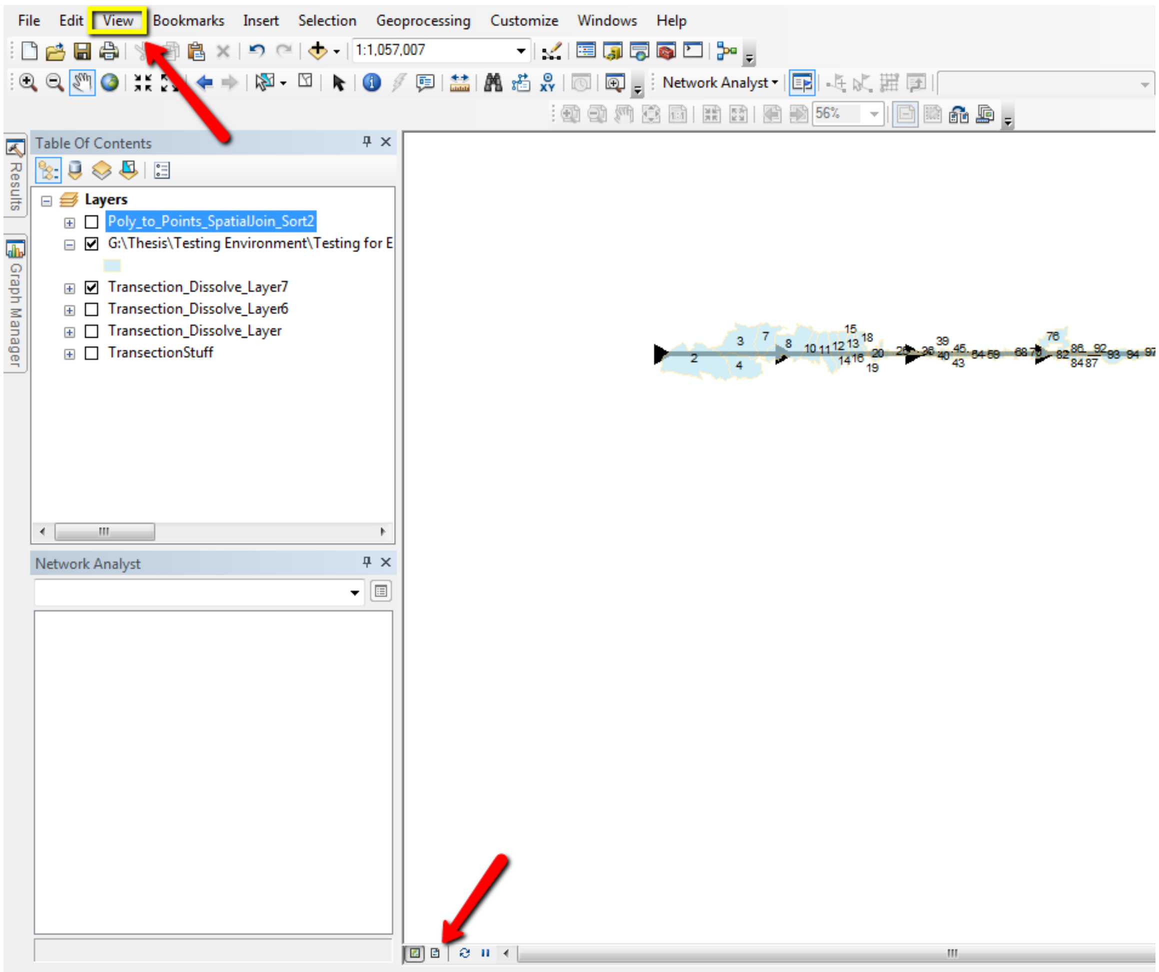


Figure 59. The two methods to select the "Layout View" prior to running Tool 7.

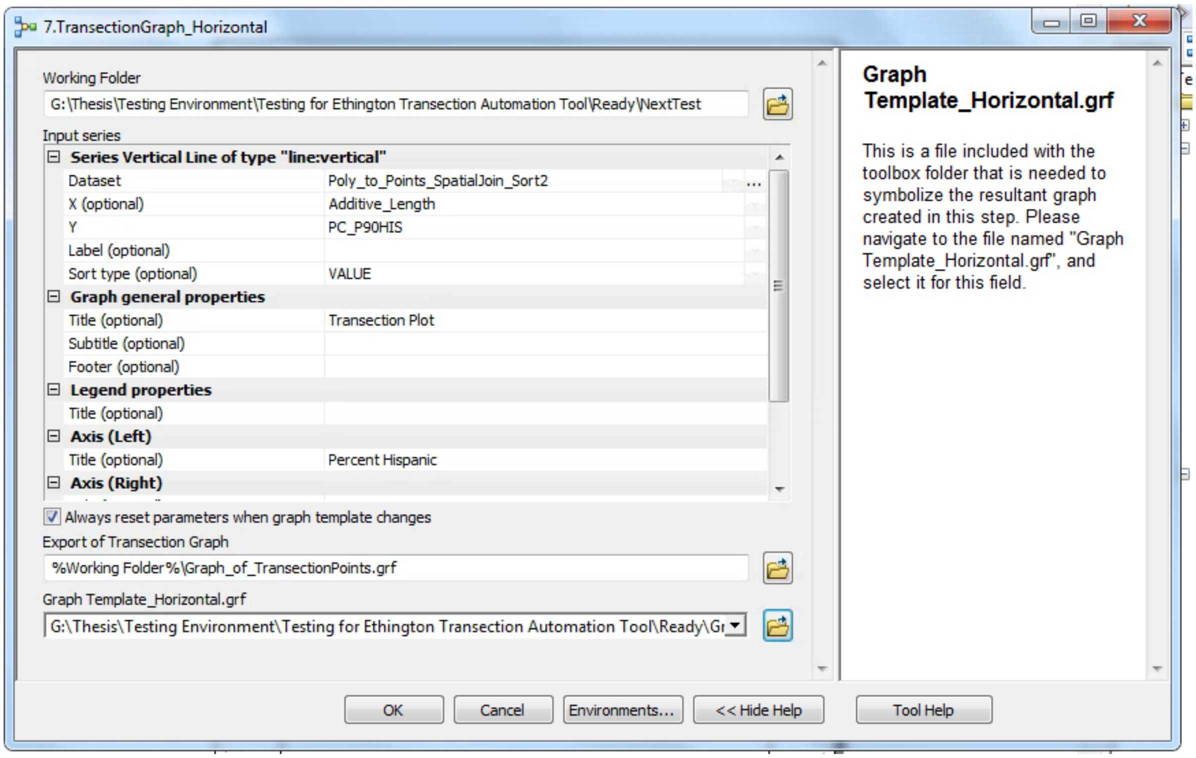


Figure 60. The parameter entry window for tool 7, most of which is taken up by the Input Series for the creation of the graph.

After running Tool 7 you should view your graph by going to the “View menu” indicated in *Figure 59* and selecting “Graphs>Load Graph”. Then navigate to the recently saved graph file, select it and press “Open” (*Figure 61*). This will open a new window with a graph simply symbolized such as in *Figure 62*.

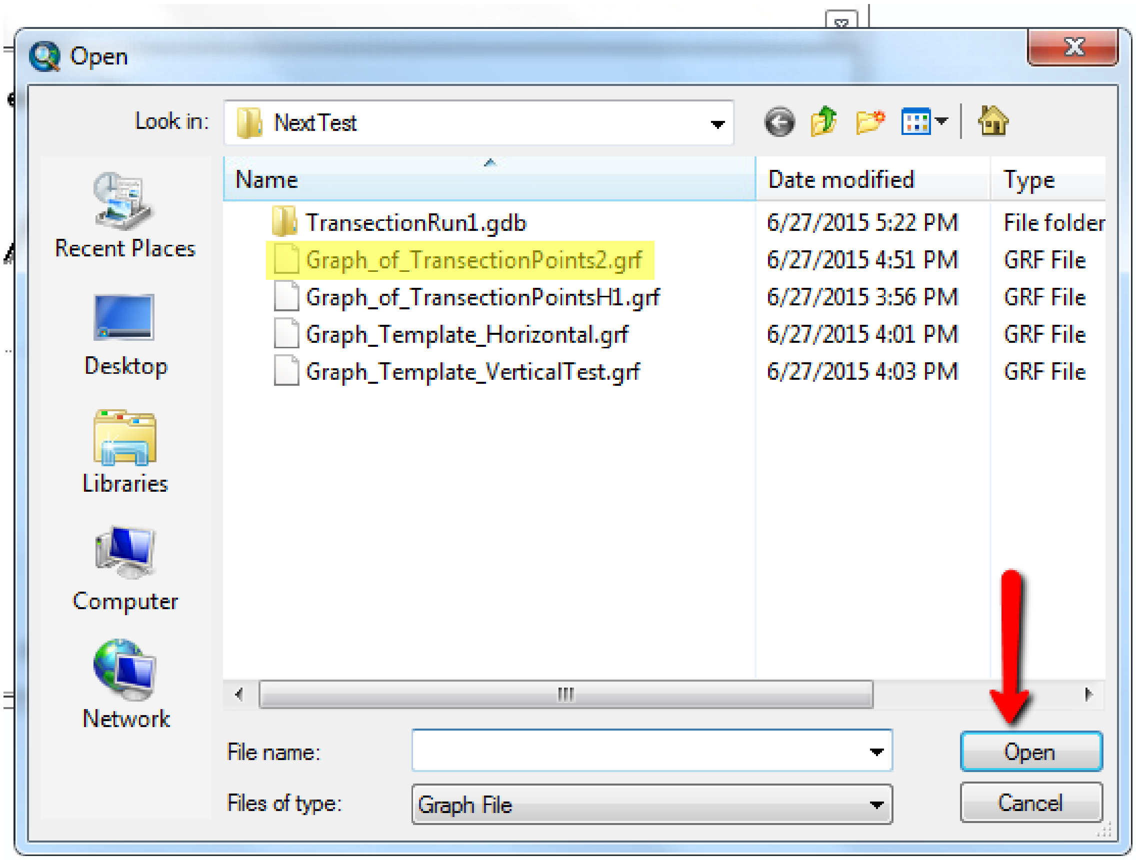


Figure 61. Open menu for loading recently saved graphs to the viewing window.

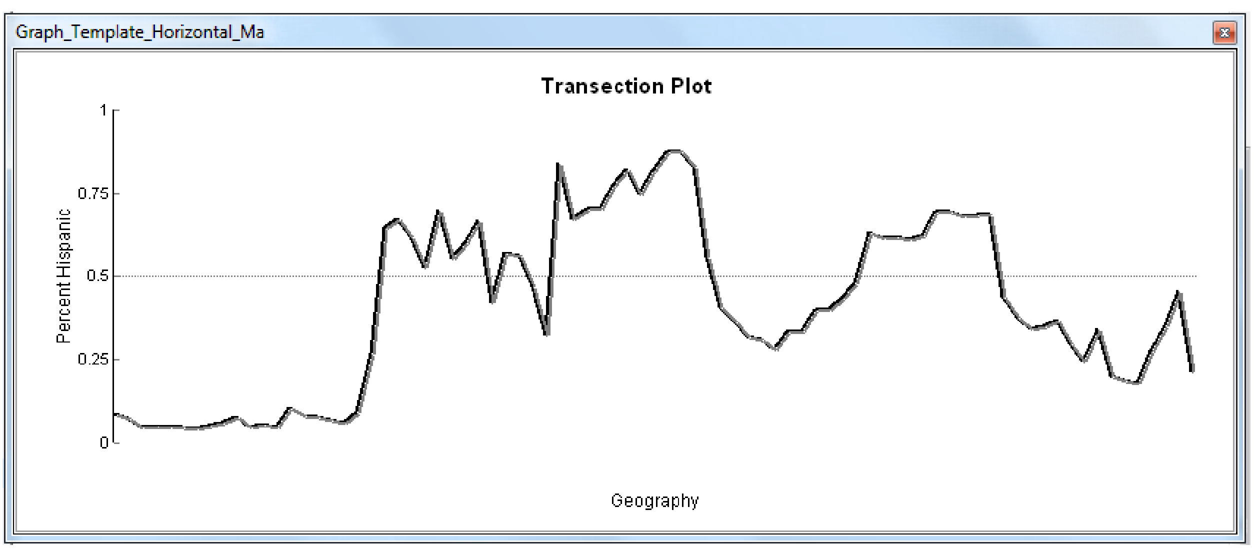


Figure 62. An example of graph created after running Tool 7, horizontal version.

17. The final step is to right-click the graph and choose "Add to Layout" from the menu (*Figure 63*). Once the graph appears in the layout view, you must resize the graph bounding box to the same width as the geography and this will align the results of the graph to the center points of the polygons to which they correspond. At this point you may generate additional graphs, export the graphic to a graphics editor for further refinement, or generate your final output from the layout view (*Figure 64*).

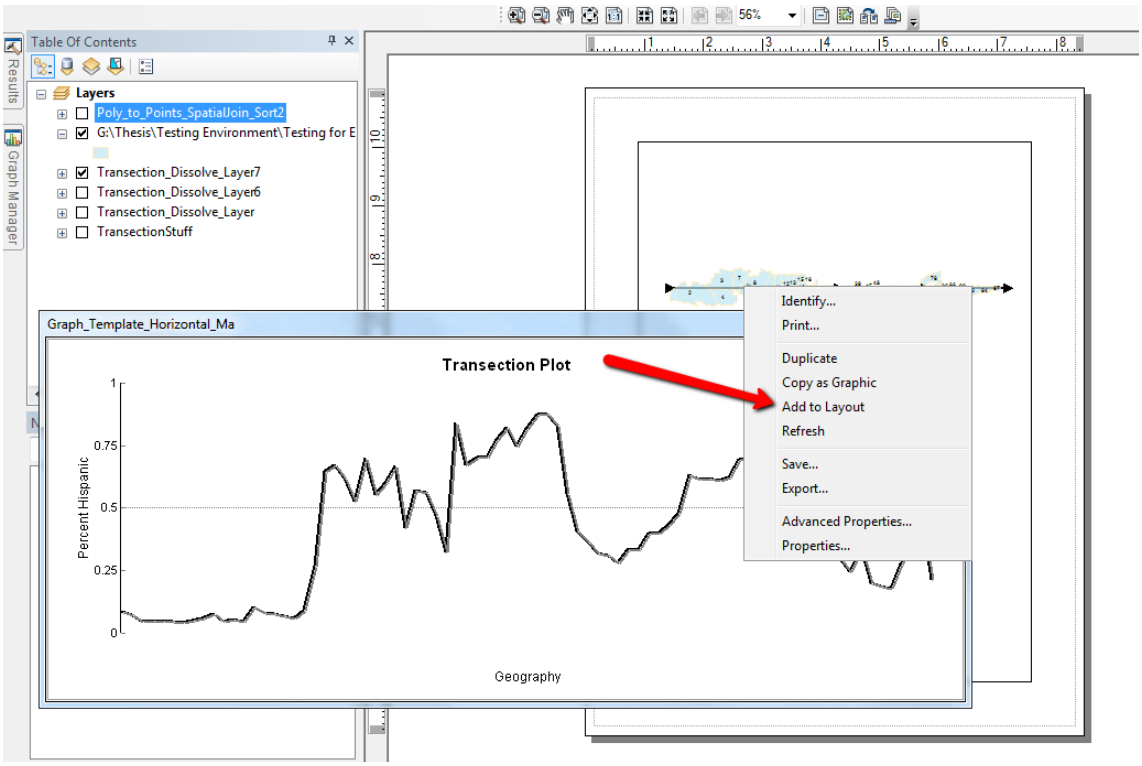


Figure 63. When right-clicking the graph window a context sensitive menu appears. The "Add to Layout" option is indicated by the red arrow.

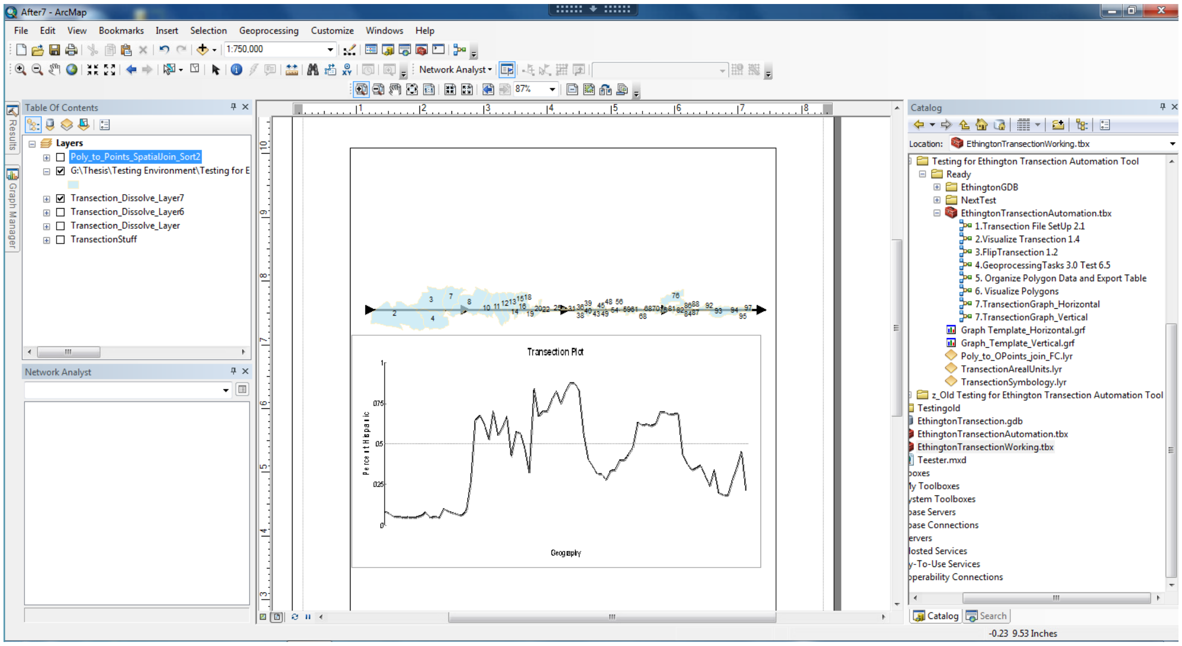


Figure 64. An example of the end result of following these instructions for using the Ethington Transection Automation Toolbox.

APPENDIX C: MAP DOCUMENTS PRODUCED DURING EFFICACY TESTS

Figure C- 1. Pico Blvd. Transections for Percent White in 1940 and 1960

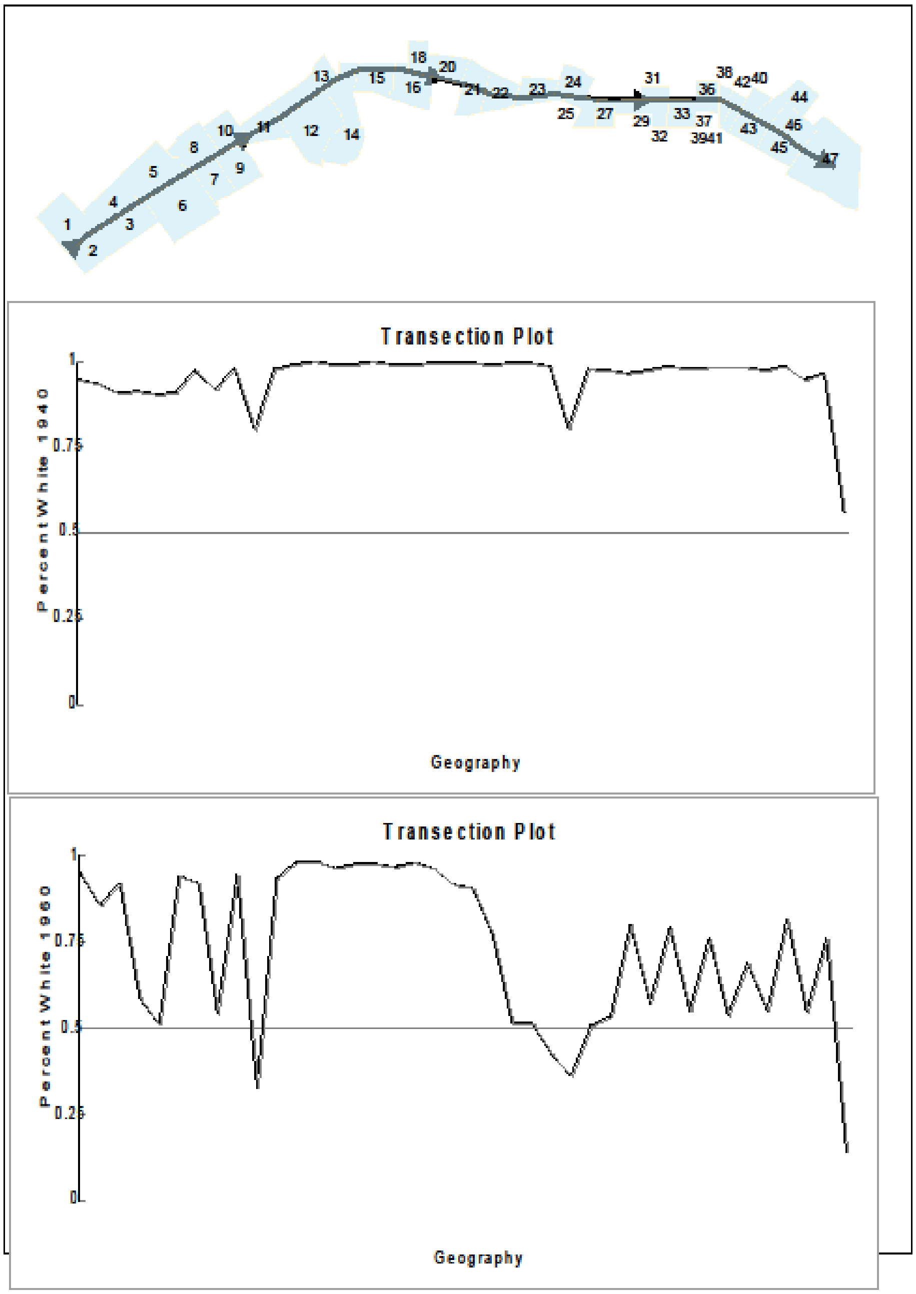


Figure C- 2. Pico Blvd. Transections for Percent White in 1980 and 2000

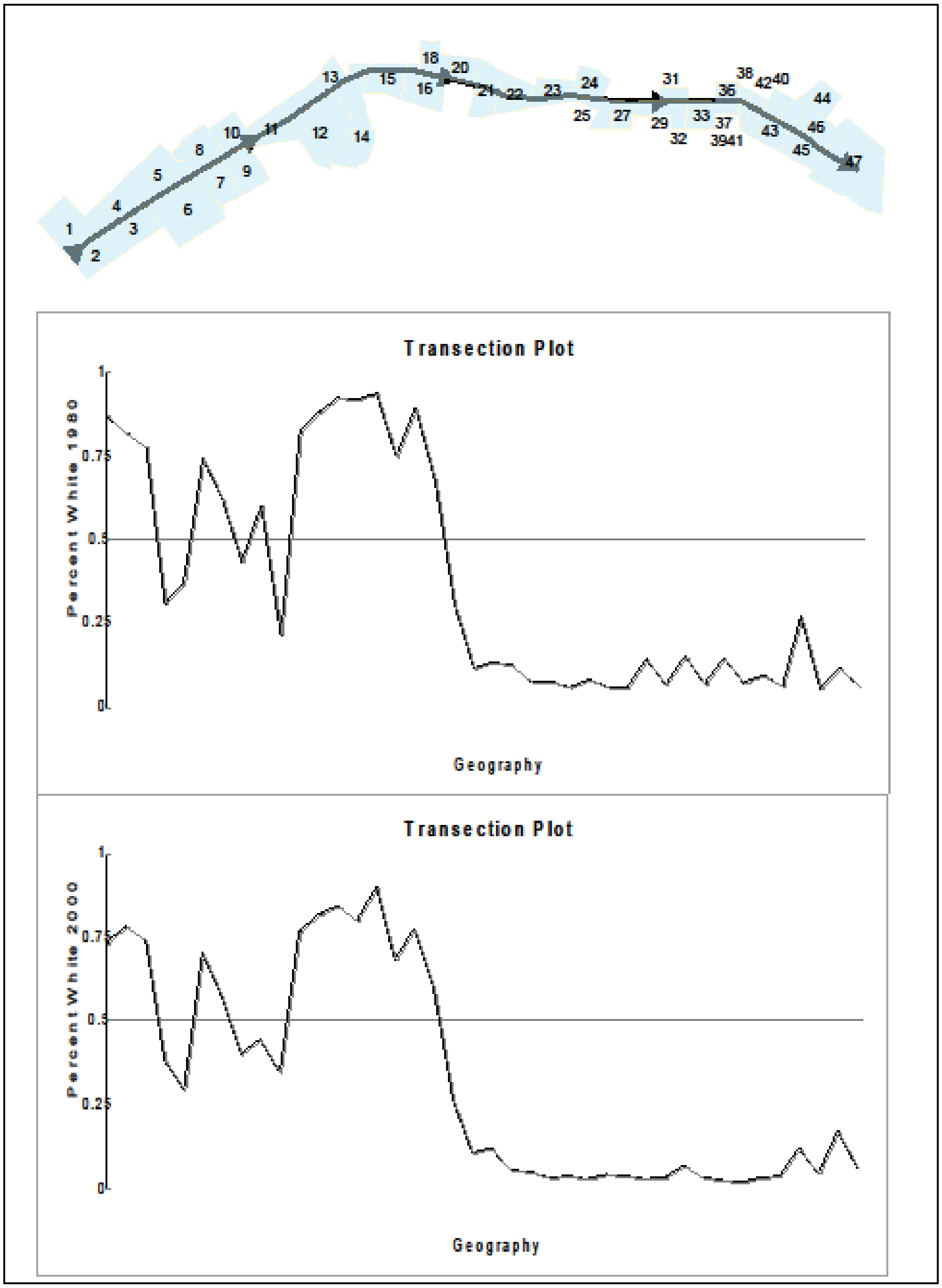


Figure C- 3. DC Orange Line Metro Transection for Percent <17 and Home Ownership.

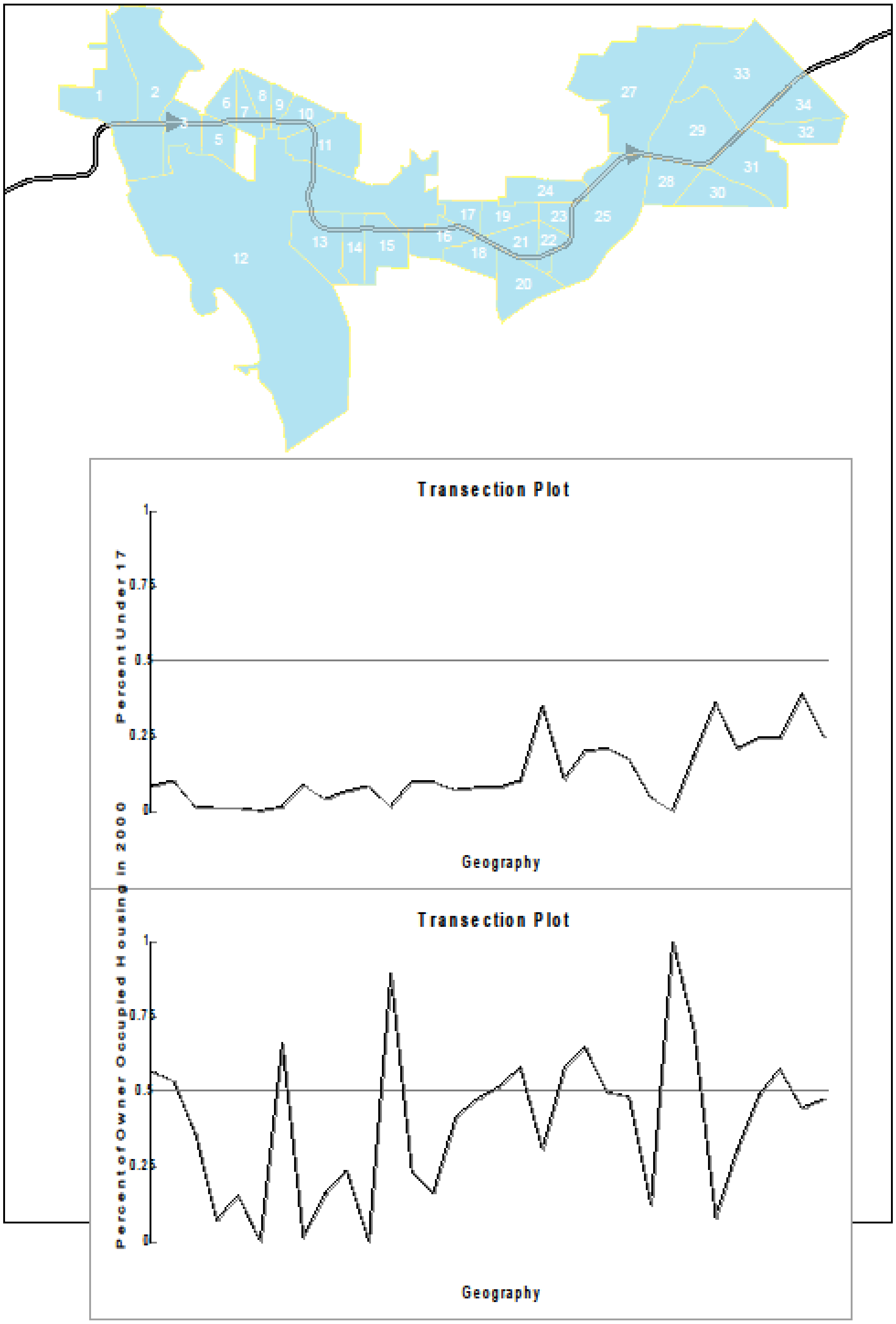


Figure C- 4. Florida ICW Transections for Counts of Reptiles of Special Concern