Is ArcGIS the right tool? Analysis of a Water Distribution Pipeline in Tuni Grande, Peru

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GIS in Water Resources Term Project
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Introduction

A water improvement project located in Tuni Grande, in southwestern Peru, has an inefficient distribution system for which students at Utah State University wish to design a better system. The pipeline currently includes several hundred feet of unnecessary pipe which increases friction losses. Water is piped into the system at a location which reduces the equality of water distribution. Engineers Without Borders-USU is beginning the process of rerouting the main waterline so that it more directly enters the distribution system, reducing the excessive pipe length and creating a more equal distribution of water. Engineers Without Borders requires that existing water pipelines be modeled prior to implementing a water improvement project. This prevents implementation of a design which would inadvertently make an existing problem even worse.

Use of software is required for EWB-USU as they analyze Tuni Grande's water system and recommend improvements to the system. Water distribution systems are often analyzed in EPANET. The inputs required to create a model include length or distance of pipe and the change in elevation from one node to another. This must be determined outside of EPANET.

This term project assesses the use of ArcGIS as the preliminary tool to using EPANET and analyzing the water system in Tuni Grande. Included in this report are the project objectives, methods, results, discussion and conclusion. The project objectives include the goal of the project and how ArcGIS will be used to facilitate analysis of the system. The data used are described along with the methods and ArcMap tools used to transform the data into a useful map document. A final map of the community is illustrated in the results section, prefaced by the learning curve experienced in manipulaton of the data to develop a working model of the system. The discussion section reflects on difficulties encountered in the project and the positive aspects of using ArcGIS in such an exercise. The work performed for this project is summarized and restated in the concluding section of the report.

Project Objectives

The goal of EWB-USU is to obtain the parameters required for the use of EPANET and create a map of all the important features in the community's distribution system. If ArcGIS can deliver the other calculations necessary for EPANET, it would seem an efficient use of time to use ArcGIS both to transform the data and create a map. The objectives of this project then, are two-fold:

1- Determine if ArcMap is a suitable tool for measuring the components in a distribution system.
2- Produce a map of the water distribution system in Tuni Grande, Peru.

The system components requiring measurement include distances and elevation differences between nodes. This can be performed in Excel, but developing a map cannot be readily accomplished using Excel. It seems sensible to use mapping software such as ArcMap to develop the map, in the second objective.

Data and Methods

The EWB-USU team gathered GPS coordinate data in August, 2011. The team used a handheld GPS device to gather latitude and longitude coordinates in degrees and decimal minutes. Elevation differences were measured using a level and rod. They measured relative elevation only for spigots and valves, but not for joints or bends where water was not removed from the system. These data were entered into Excel and changed to units of decimal degrees and feet elevation.

Data was imported into ArcGIS using the Add XY data feature. The Geographic Coordinate System was specified as the WGS 1984 projection. The xy data was exported to a new layer for editing.

A flaw was noted in the data as it had been entered into Excel. South America is located in the southern and western hemispheres, so its coordinates should both be preceded by a negative sign, denoting west and south. The negative sign was missing on the southern coordinates, so the orientation of the data points was incorrect. Editing the data in Excel and importing the edited data flipped the point to shown the correct orientation of the distribution system, as shown below in Figures 1 and 2.

Figure 1 Incorrect Layout of Tuni Grande's Distribution System. Both x and y coordinates should be negative to represent a west and southern location.

Figure 2 Corrected layout of Tuni Grande's Distribution System.

Data manipulation of the imported points layer was extensive. Adding polylines to the map required use of a script entitled "Points to Line". This tool resulted in the creation of a single polyline feature, shown below in Figure 3. The points are connected in the order that the data had been entered into the spreadsheet.

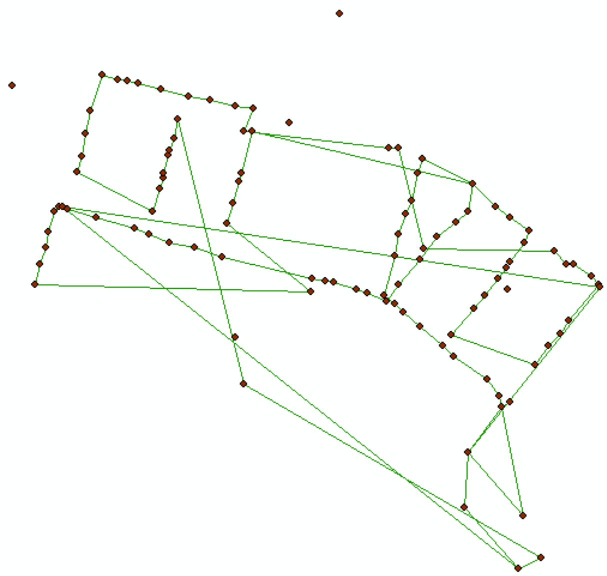

Figure 3 Results of initial "Points to Line" Script. Single polyline feature connected in order of data point collection.

This script connects the dots in order that the data is ordered in the dataset provided to ArcGIS. Thus GPS coordinates taken out of order caused the polyline to be distorted and not follow the path of the distribution line. ArcGIS has the option to create the line based on a sort order which can be specified by a column in the attribute table of the data.

Determining the order of the points consumed a significant amount of time. Adding the sort order improved the appearance of the pipeline, however, as shown below in Figure 4.

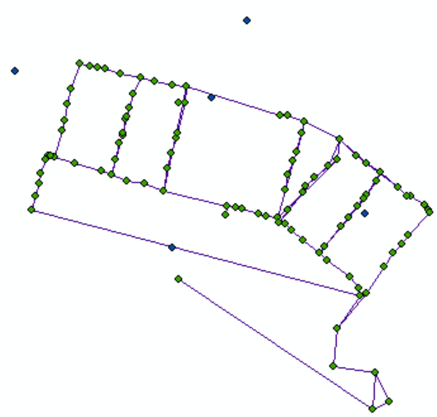

Figure 4 "Points to Line" Script, with data points ordered according to pipeline layout

The resulting line feature of this script contained only one object: a single connected polyline, as shown below in Figure 5.

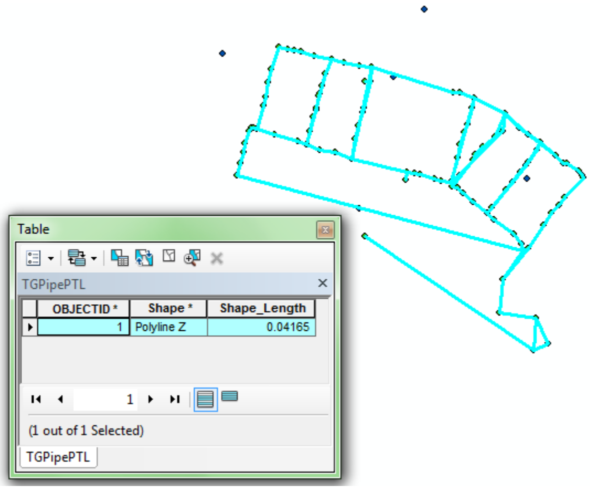

Figure 5 "Points to Layer" resulted in single polyline; examination of the attribute table confirmed only one object had been created.

The objective of this project is to determine distances between each point, so the polyline needed to be disaggregated. A tool entitled "Split Line At Vertices" was used to break the single polyline into many line features, each one representing the distance between two points. This resulted in many smaller lines, each with an attribute labeled Shape_Length. The units were unclear, as the sum of all the shape lengths was only 0.04165, as shown below in Figure 6.

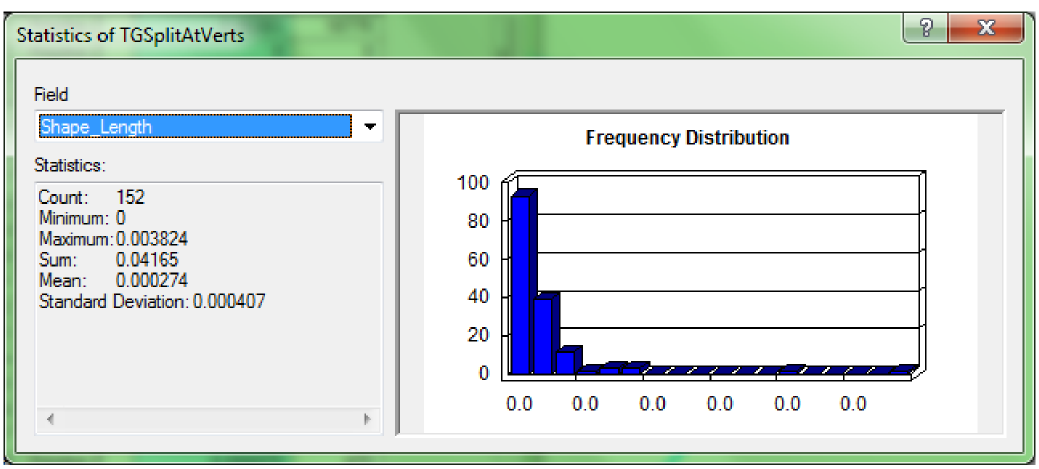

Figure 6 Statistics of pipeline. Total shape length equal to 0.04165.

The chosen Geographic Coordinate System listed angular units in degrees, but no linear measurement units were defined.

A UTM projection was applied to the data layer containing the lines with shape lengths. The “Project” tool was used, and the South American projection for this area in southern Peru was determined to be represented by UTM Zone 18S. This projection allowed distance measurements to be calculated in linear units. The meter is the distance unit for this projection.

Data Source

Projected Coordinate System:	WGS_1984_UTM_Zone_18S
Projection:	Transverse_Mercator
False_Easting:	500000.00000000
False_Northing:	10000000.00000000
Central_Meridian:	-75.00000000
Scale_Factor:	0.99960000
Latitude_Of_Origin:	0.00000000
Linear Unit:	Meter

Figure 7 Projected Coordinate System for southern Peru. Linear distances measured inmeters.

The resulting attribute table contained an attribute named Shape_Length, measured in meters. These shape lengths closely matched the distance values calculated using the curved earth distance formula:

$$\textbf{Curved Earth Distance} = R\cos^{-1}[\sin\phi_a \sin\phi_b + \cos\phi_a \cos\phi_b \cos(\lambda_a - \lambda_b)] \quad \text{(Equ 1).}$$

The EWB-USU team provided a Google Maps Image of Tuni Grande, which was added to ArcGIS as a backdrop for the mapped data points. This was accomplished by editing a control point layer based on the projected layers and georeferencing the raster image of Tuni Grande with the control points layer. This final map is shown in Figure 8 on the next page.

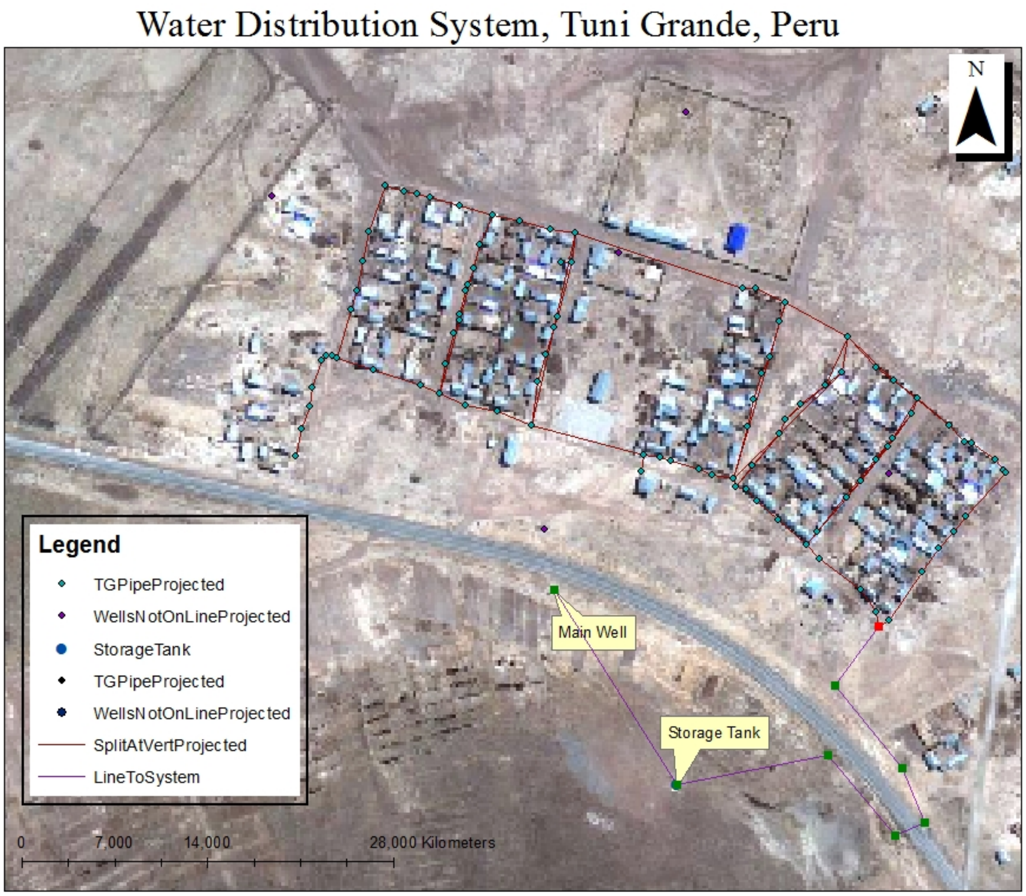

Figure 8 Map of Tuni Grande and Distribution System

Results

The shape lengths finally calculated in ArcGIS are the distances sought in fulfilling the first objective. However, vertical differences were not calculated, so the objective is only partially met by the use of ArcGIS.

The second objective of developing a map showing the pipeline layout of Tuni Grande was met using ArcGIS, as shown in the map in Figure 8, above. The distribution system was overlaid on a Google Map Image of Tuni Grande and the main well and storage tank were denoted. Points along the distribution system are shown in blue dots to represent the pipeline and wells are designated by purple dots. Only one well feeds the water distribution system. The line from the well to the storage tank to the system is denoted by a purple line, and measurement points along that line are denoted by green squares.

Discussion

One purpose of this exercise was to determine if ArcGIS might be a simple way to use GPS coordinates to find parameters of a distribution system for future use in analysis of a pipeline. Unfortunately, the real-life data acquired from the EWB-USU team was not in a form easily used by ArcGIS. Data manipulation of the GPS coordinates was extensive to accomplish relatively simple tasks such as creating lines between data points. The data manipulation likely needed to make this data compatible for Schematic Processing and Network Analysis must be overwhelming, so it wasn't even attempted.

The objectives of the project were met with only moderate success. Distance between data points was determined, and a map was developed for the community pipeline. However elevation distances between points in the system were not shown by ArcGIS.

Conclusion

Mapping tools such as ArcGIS may or may not be practical in the application of determining water distribution system components based on GPS data points collected in the field. A team of students from USU travelled to Tuni Grande, Peru, to collect GPS locations and relative elevation for points along a water distribution system. The coordinates were imported into ArcMap. Data manipulation and transformation and projection changes were required to determine distances between data points and produce a reasonable map. ArcGIS is a useful tool for mapping GPS coordinates and creating a map, however, it is not an efficient tool to analyze components of a water distribution system.

References

Google Maps. (2011). (14°58’52.74”S, 70°24’39.06”W) to (14°59’8.58”S, 70°24’24.6”W) Accessed 2 December 2011.