Water Supply System in Ntisaw, Cameroon

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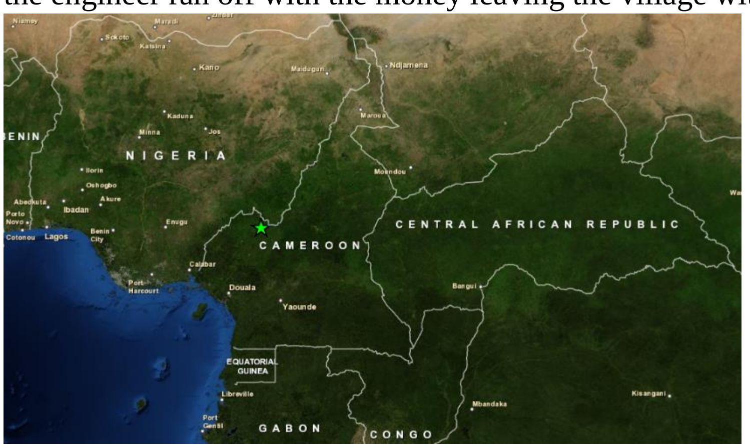
Project Background

Cameroon is a country located on west coast of Africa officially known as the Republic of Cameroon. Compared to other countries within this region of Africa Cameroon has a relatively stable political landscape which has allowed it advance in the construction of many modern conveniences such as roads, railways, and a petroleum industry. Cameroon has a diverse landscape including beaches, deserts, mountains, rainforests, and savannas.

During the winter of 2010/2011 the remote village of Ntisaw in Cameroon with a population of 1000 was supplied with a water distribution pipeline as part of an Engineers without Borders (EWB) project. However, the process to getting the water pipeline was not a smooth one. In 1994, the village put together money to hire a local engineer to build a water distribution system. After building a spring box near a local water source to supply water, the engineer ran off with the money leaving the village without a water system. Once again leaving the burden on the women and children from the village to gather water. The location of Ntisaw is shown by a green start on the image to the left.



Engineers without borders with the University of Illinois-Urbana Champaign designed and built the gravity fed distribution system to supply water from the spring box build in 1994. By building and supplying materials for 6.5 kilometers of pipeline, 4 stone storage tanks and 14 tap stands water was able to be supplied throughout the village.

The system which was designed and built by EWB however does have some limitations. While it feeds water throughout the village at the tapstands via a gravity driven system there is very limited head for the system. This leads to added difficulty when wanting to expand upon the system. The system operates on a very narrow head margin which is leading to difficulty now that a filtration system is attempting to be added to the system. The water system is fed by an underground spring which is subject to contamination from runoff by nearby farms so a filter would greatly benefit the inhabitants of the village alleviating the need to boil water before use.

To design a filter the hydraulic profile of the pipeline needs to be determined to see what design constraints there are. The goal of this GIS project will be to determine the elevation profile of the pipeline as well as the hydraulics of the system to aid in the design of a sand and charcoal filter.

Available and Required Data

As part of the work done by EWB during the installation of the pipeline a survey of a portion of the ground leading toward the first tank from the spring box was done. This survey data is available for analysis along with latitude and longitude points where the pipeline was laid. However, no elevation data from the GPS used for mapping the pipeline was recorded and is thus needed. Elevation data from the USGS digital elevation model SRTM and ASTER at 3 arc second can provide for elevation profiles within the area.

Methodology

The first step in this project was to compile all of the data for the systems in Ntisaw into files that could be imported into excel files. These files were then converted into decimal degrees so they could be input into the GIS system using the World Geodetic System of 1988. This included mapping the tapstands, pipelines, springbox, and storage tanks. The pipelines were then separated into different lines corresponding with size and where it was supplying water too. After adding the components of the water system into the GIS system and connecting all the points in the pipeline to form vectors, basemaps were added to visually inspect that everything was added correctly. **Figure 1** below shows the results of adding all the components to the GIS system. Labeling was then added to assist in making sense of the location of everything.

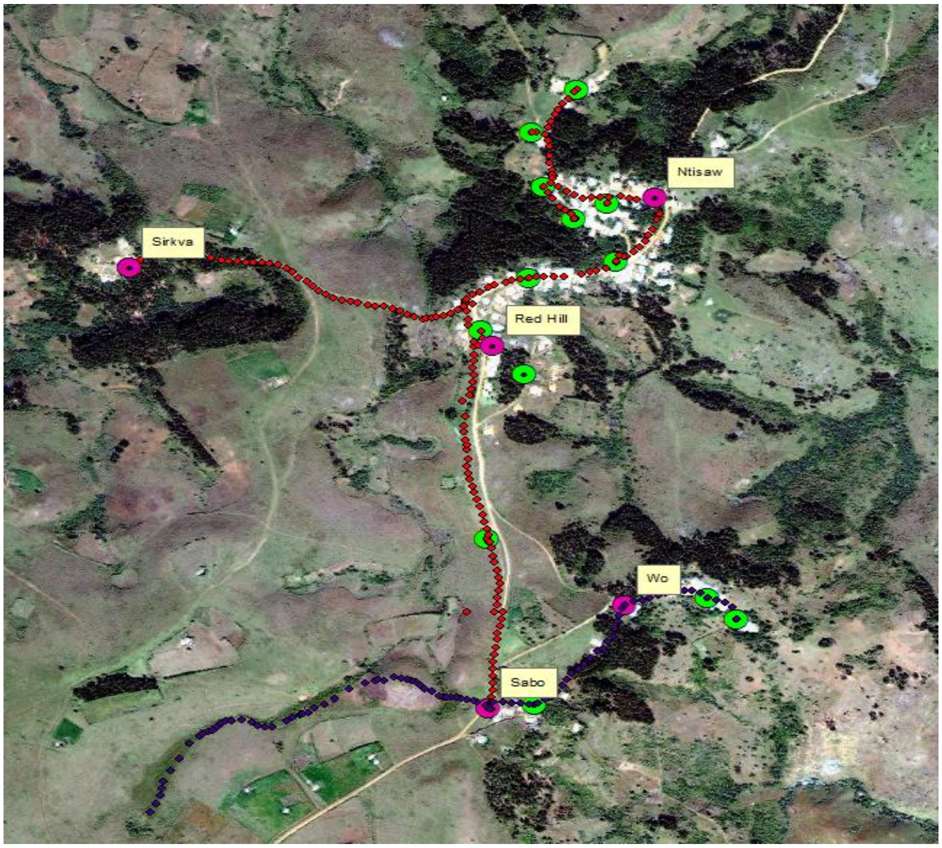


Figure 1 Results of adding components to GIS system

After importing all the necessary information into the GIS system the digital elevation models needed to be downloaded from the USGS website. SRTM and ASTER at 3 arc second were downloaded from the USGS website to provide elevation profiles for the pipelines. Importing the SRTM and ASTER DEM's into GIS created the following elevation models as shown in **Figure 2**.

Figure 2 ASTER & SRTM Digital Elevation Models

Once the digital elevation model was put into the GIS system the latitude and longitude of each point needed to be combined with the elevation corresponding to that cell space. The GIS tool ‘Extract Muli Values to Point’ was used for giving an elevation value to the latitude and longitude points. Unfortunately when working with elevations in a 30m x 30m cell space oftentimes multiple latitude and longitude points fell within a single space and thus were assigned the same elevation value. This created problems which will be shown further into the report. The profile from combing the STRM and ASTER data to the to the pipeline data leading to the first tank aka. Sabo tank are shown in **Figure 3**.

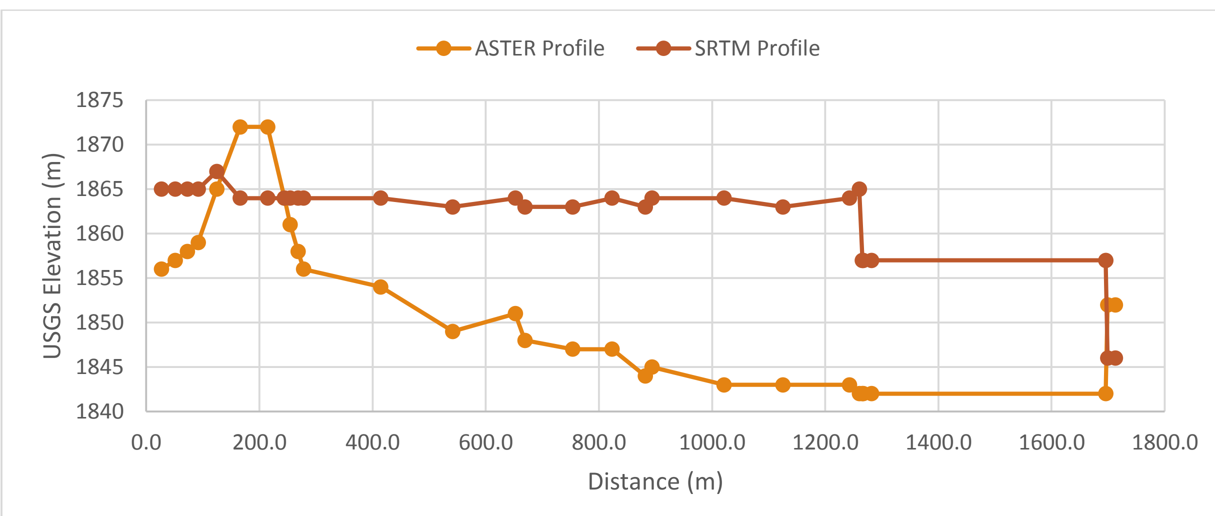


Figure 3 Elevation Profile to Sabo Tank

Since there was survey data leading to Sabo tank it could be compared to the elevation profiles shown in **Figure 3** to see whether or not this method was adequate for creating a profile all the way to the Ntisaw tank located near the town another 2 kilometers away. The results of plotting the surface profiles of the USGS data and the survey are presented in **Figure 4**.

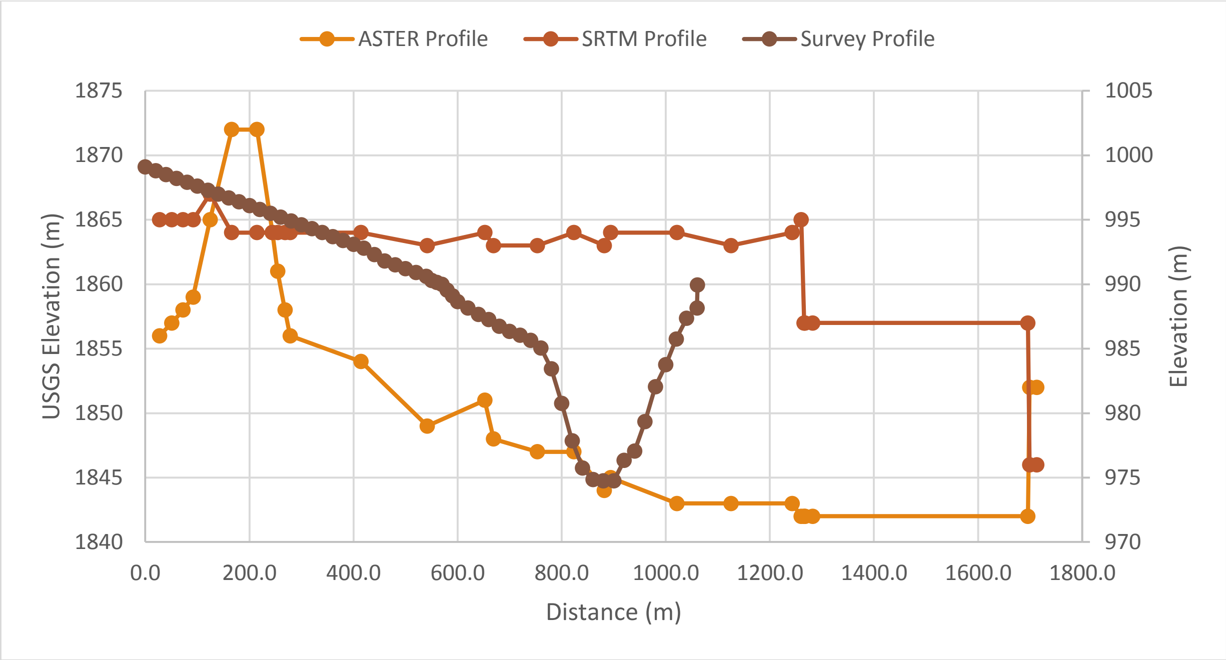


Figure 4 USGS elevations and Survey elevations

The actual elevation on earth for the start of the survey was unknown so the profile is just showing the difference in elevation from a set start elevation while the USGS data is using a believed known elevation from sea-level. This is why there are two elevations on the y axis in **Figure 4**. Regardless of the starting elevation it can be seen that neither of the USGS data sets when combined with point data provide very good elevation profiles nor do they have similar distance for the pipeline. Thus a new technique needed to be utilized for determining the elevation profile and hydraulic profile.

It was recognized that each points elevation needed to be interpolated based off surrounding elevations and that just broadly applying elevations to points based of their being within 30m grid cells was inaccurate. To account for this need for more elevation profiles the a toll within the 3D analyst toolbox was used called 'Interpolate Line.' This tool interpolates the elevation of points on a DEM providing for more accurate profiling. The results of applying the interpolation tool the profile leading to Sabo tank are shown in **Figure 5** compared to the survey results.

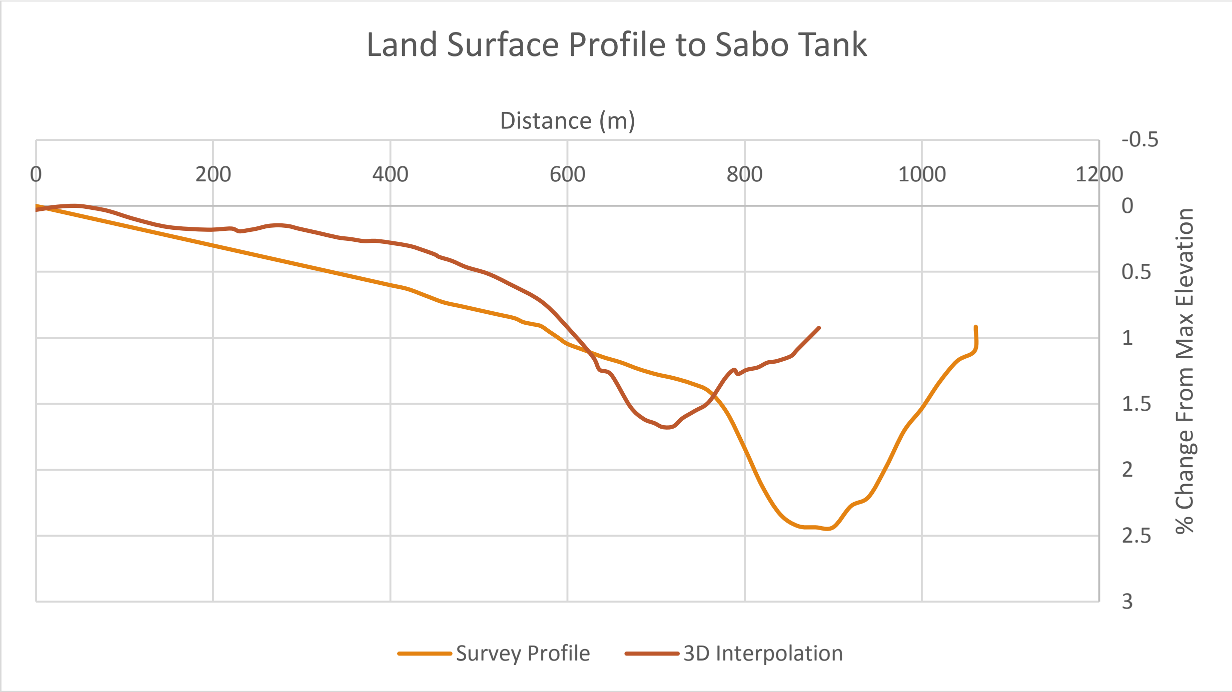


Figure 5 Elevation Interpolation and Survey Results

These results were much better and you can see that the survey and interpolation profiles are much closer however the total distance of pipeline is still different. This time however the predicted length for the pipeline is shorter than the actual length. The difference from the max elevation is nearly identical at the end point which would be much more ideal for developing a hydraulic profile.

Applying the interpolation method to the pipeline leading to the main village of Ntisaw produces the results shown **Figure 6** below.

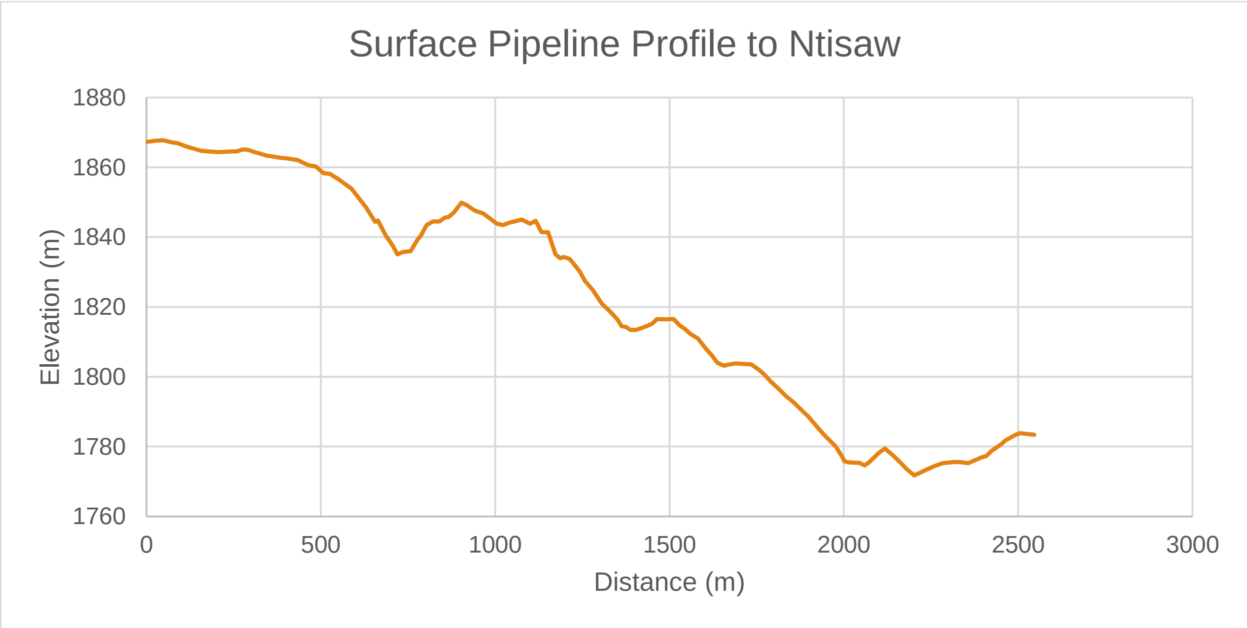


Figure 6 Surface Profile to Ntisaw Tank

The elevation profile leading to Ntisaw is promising and thus it would be worthwhile to create a hydraulic profile leading to Ntisaw using this elevation profile. This will be done by creating a profile during peak flow. Previous studies have indicated that the peak flow through the pipe is near 1 liter/sec which will also be assumed to not be open channel flow as the pipes are very small (25mm -50mm) and solving an open channel system in such small pipes would be extremely difficult. Assuming a full pipe system the Hazen-Williams formula can be used to solve for the head losses throughout the system as well as account for minor losses caused by elbows, tees, and other appurtenances. The results of the hydraulic analysis are shown in **Figure 7** below.

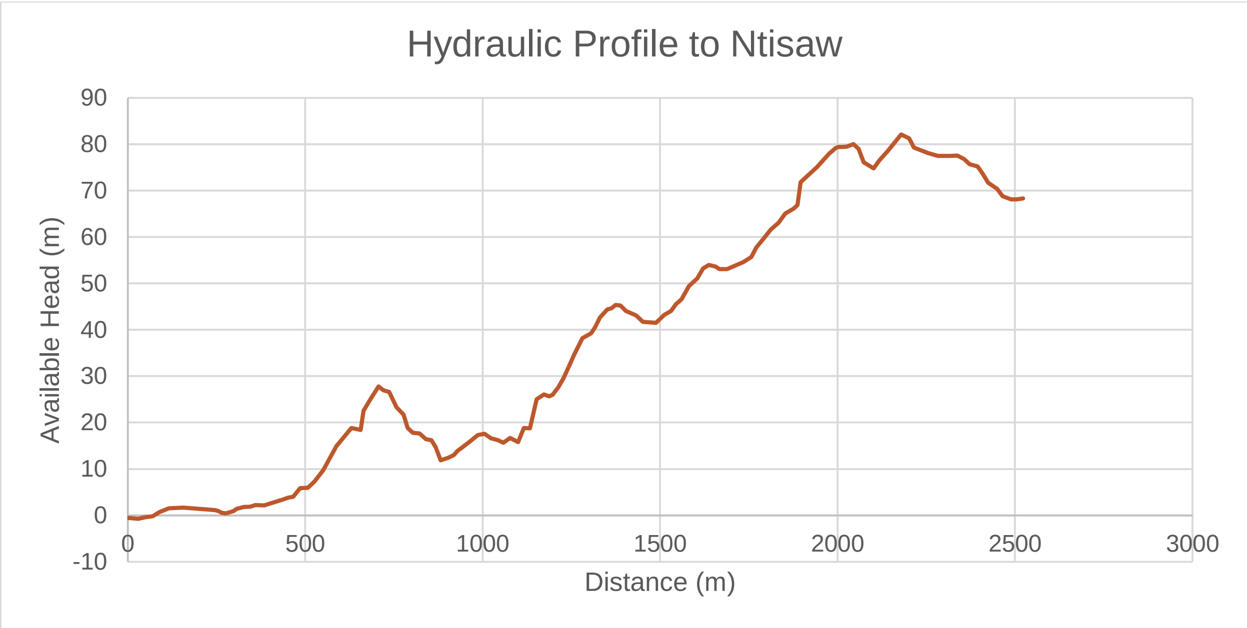


Figure 7 Hydraulic Profile to Ntisaw Tank

Further discussion of the impact of these results in presented in the following section.

Results

The results of the hydraulic analysis shown in Figure 7 indicate that there would be enough excess hydraulic head to provide a filter as long as it were placed in the correct place. The first 500m of pipe would not be an ideal place for the filter as there is insufficient head to maintain gravity flow after the loss of head from the filter. The best place to put the filter would be somewhere after 1200m as this is where the most excess head is available as well as the greatest increases in potential head due to elevation.

From this project it can be concluded that for a pipeline that is only 2500m the method of combing elevation onto latitude and longitude values is insufficient. A spatial combining within cells does not provide good estimates. However, using a 3D interpolation methods much better profiles can be made and used with greater confidence.

Future work

To further expand on the work done in this project it would be beneficial to solve for a head loss profile assuming open channel flow. This could be done by using EPA SWMM or other runoff modeling software and inputting the pipe diameters. It would also be beneficial to look at headloss curves at different flow rates below the peak flow. Since the goal of this project was to look at applications of GIS these hydraulics questions will be answered privately.

Sources

https://www.google.com/maps

http://nationalmap.gov/viewer.html