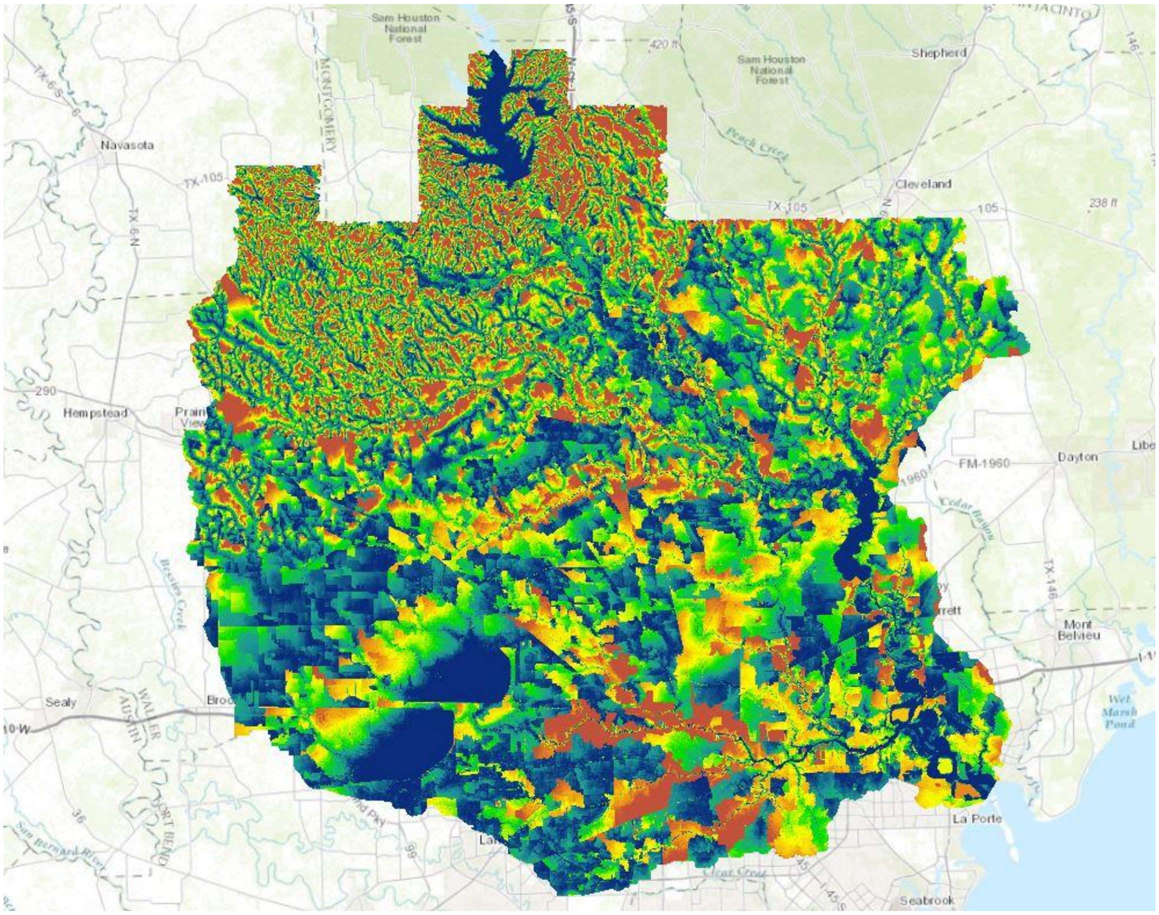

Height Above Nearest Drainage in Houston

THE UNIVERSITY OF TEXAS AT AUSTIN

Jeff Yuanhe Zheng | GIS in Water Resources | December 2nd, 2016

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1.0 Introduction

Floods are one of the most deadly natural disasters in the U.S. From flash floods and inland flooding to storm surges and coastal floods, the primary effects of floods include loss of life, damage to homes and businesses, and crippled infrastructures. Although different flood events vary in terms of magnitude, frequency, and distribution (spatial and temporal), it remains important to predict and understand the risks that are associated with flooding, especially in areas with greater urban development (higher associated risks). As such, flood mapping is an incredibly vital practice that generates images with an abundance of useful information, such as levels of flood risk for a given area. Flood maps can provide communities with valuable, actionable knowledge, which serves to educate and better prepare them for the possible risks associated with such natural disasters.

Efforts to inform and educate the populace on varying levels of flood risks with flood/inundation maps should be made a top priority. Although, it is likely as important (as providers of such incredibly powerful pieces of information) to improve upon the quality of information that is used to generate such flood/inundation maps. As such, efforts were placed on analyzing terrain using a model called Height Above Nearest Drainage (HAND) to generate inundation maps as a result. HAND is a terrain model that normalizes input national elevation datasets (NED) according to the local relative elevations/heights found along a drainage network [2]. Furthermore, HAND results depict nearest drainage maps that are based on the vertical distance of each unit cell/pixel (each cell contains a value representing information such as elevation) to the nearest stream cell it drains into. A flowchart for the HAND model (courtesy of Xing Zheng, a PhD student) is provided in the Appendix (**Figure A3**).

This project employs HAND specifically for the greater Houston area. The relatively flat topography of the Houston make for extremely interesting and important inundation mapping analyses. Furthermore, with the availability of Geographic Information Systems (GIS) and associated hydrological tools, we are able to model the topographical, hydrological and hydraulic conditions of an area of interest at a local, national, or even global scale. Therefore, coupling GIS with the HAND model may further water investigations, such as on the hydrological response of a particular watershed after a large rain event or even the inundation extent of certain stream networks.

2.0 Project Objective

The main objective of this project is to look into high resolution (1:24,000-scale or better) NHDPlus and 3-meter NED terrain data for the Houston area. Additionally, it is important to confirm that the overall model is coherent and meaningful in a manner that allows us as well as the non-scientific community to interpret the information effectively. It is important to note that the initial project scope considers the geography surrounding Houston. Although, for purposes in understanding how HAND handles areas with relatively flat topography, in addition to time constraints, only portions of Houston – scaled down to appropriate sample studies – were extensively analyzed for this report. The results and corresponding remarks on HAND for Houston are reported in this paper. Future work regarding the area encompassing Galveston is mentioned in the Conclusions and Future Work section of this report.

3.0 Data and Methods

Early stages of this project were to familiarize myself with NHD-HAND. This was achieved through reading materials on HAND and working through sample data (provided by Xing Zheng) in order to have a better grasp of the model. In terms of data resources, NHDPlus flowlines at medium and high resolution as well as national elevation datasets of Houston at 10-meter and 3-meter were provided by Yan Liu and Dr. Maidment. Additionally, a HAND raster file of Houston (using 3-meter NED and high resolution NHD flowlines) was already generated by Yan Liu (Appendix, **Figure A1**). The complications that exist for the greater Houston area prompts efforts to investigate underlying factors that contribute to the model's failure to depict drainage networks and inundation extents cohesively. It is worth noting that the original HAND file emphasizes the need to improve the quality of terrain data and provide coherent and meaningful information for local communities. The HAND data for Houston also serves to justify the approaches adopted for this project to examine the terrain data and the capabilities of HAND to model largely concentrated and relatively flat urban areas.

The initial approach to analyzing the Houston-HAND data is to examine areas where the method accurately depicts drainage networks/inundation extents (characterized as dendritic structures) as well as portions that appear rather inconsistent/incoherent in representing drainage networks. Part of this approach requires investigating the input features (terrain data and flowlines) that are essential to generating HAND models in order to validate the accuracy of the datasets by comparing spatial discrepancies and noting degrees of success in representing topographical features relative to ground truth. Due to large input datasets, a much smaller scale analysis is adopted in order to facilitate efforts to obtain appropriate sample study results. Thus, the sample areas of interest include three [clipped] small-scale catchments: 1) Kachel Lake, 2) Spring Creek, and 3) Cane Island Branch. These catchments were chosen based on the spatial distribution of the terrain data (3-meter DEM) as well as the nearest drainage results (original HAND data). Subsequent approach in examining these catchments is to overlay the 3-meter DEM dataset with high resolution flowlines and note the closeness of fit between the features. Additionally, another method called GeoNet is used to supplement the HAND analysis.

GeoNet is an open source computational tool, developed by Paola Passalacqua and her team, which uses high resolution topography data (lidar) to automatically extract channel networks, channel heads, and channel morphology. The method includes three important elements: 1) nonlinear filtering - removes small-scale variability (i.e., bumpiness of the ground) to enhance features of interest such as channel banks, 2) statistical analysis of curvature – identifies likely channelized pixels (skeleton), and 3) geodesic minimization principles – extracts channel heads and centerlines [1]. For a complete description of GeoNet, please refer to Passalacqua et al., 2010a; 2010b; 2012; Sangireddy et al., 2016.

For this project, GeoNet was used with MATLAB, though it is also developed for Python. The extracted channel network from GeoNet is coupled with 3-meter national elevation dataset and compared to the NHDPlus flowlines. The generated maps with GeoNet extracted channels, NHDPlus flowlines, 3-meter elevation data, as well as HAND data are presented in section 4.0 Results and Discussion.

4.0 Results and Discussion

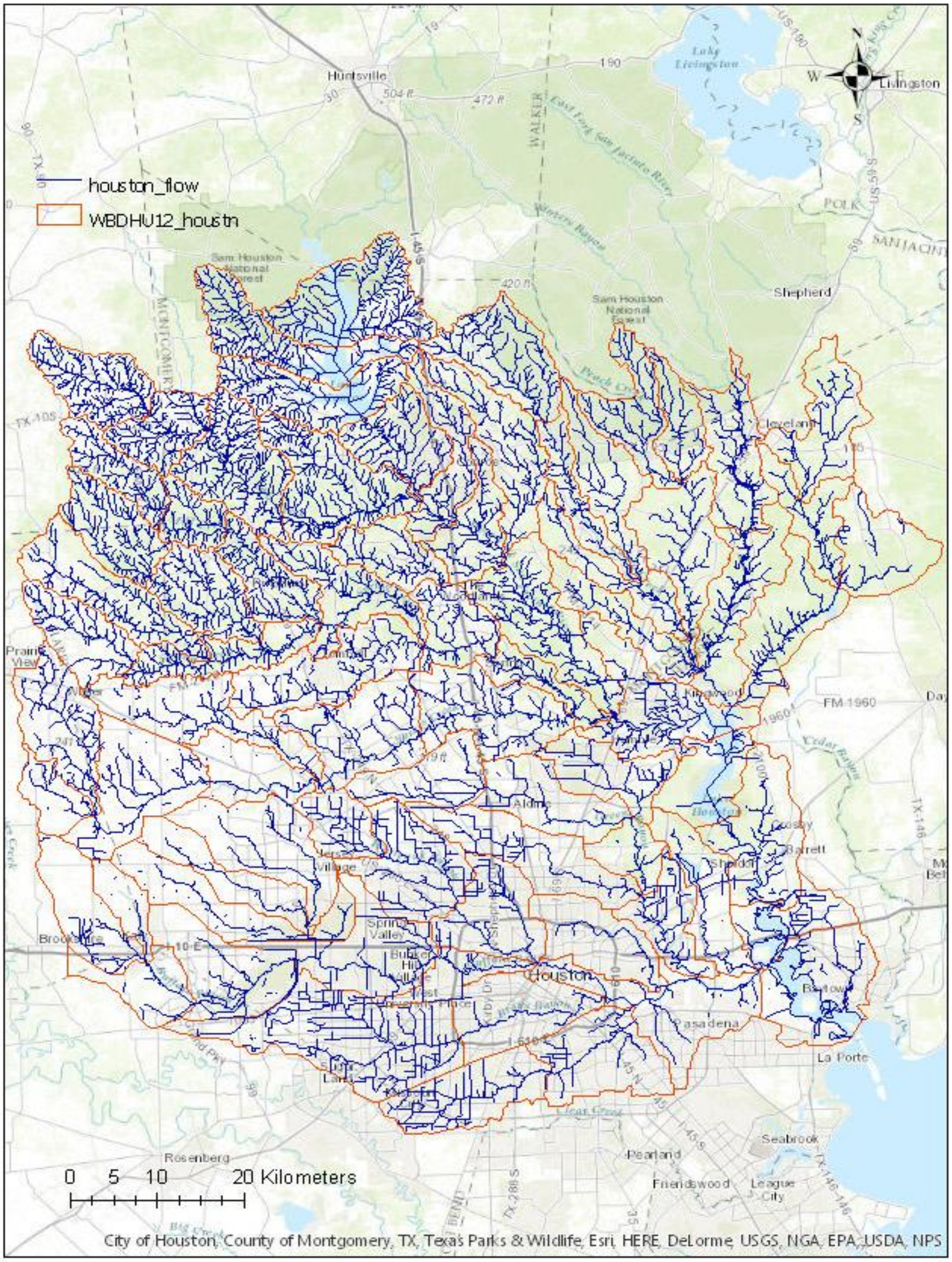


Figure 1. Delineated HUC12 catchments for the greater Houston area coupled with NHDPlus flowlines (blue).

Figure 1 served as a basis on which smaller scale catchments containing flowlines were delineated and examined. Additional description of chosen catchments are presented in the following pages.

4.1 KACHEL LAKE CATCHMENT

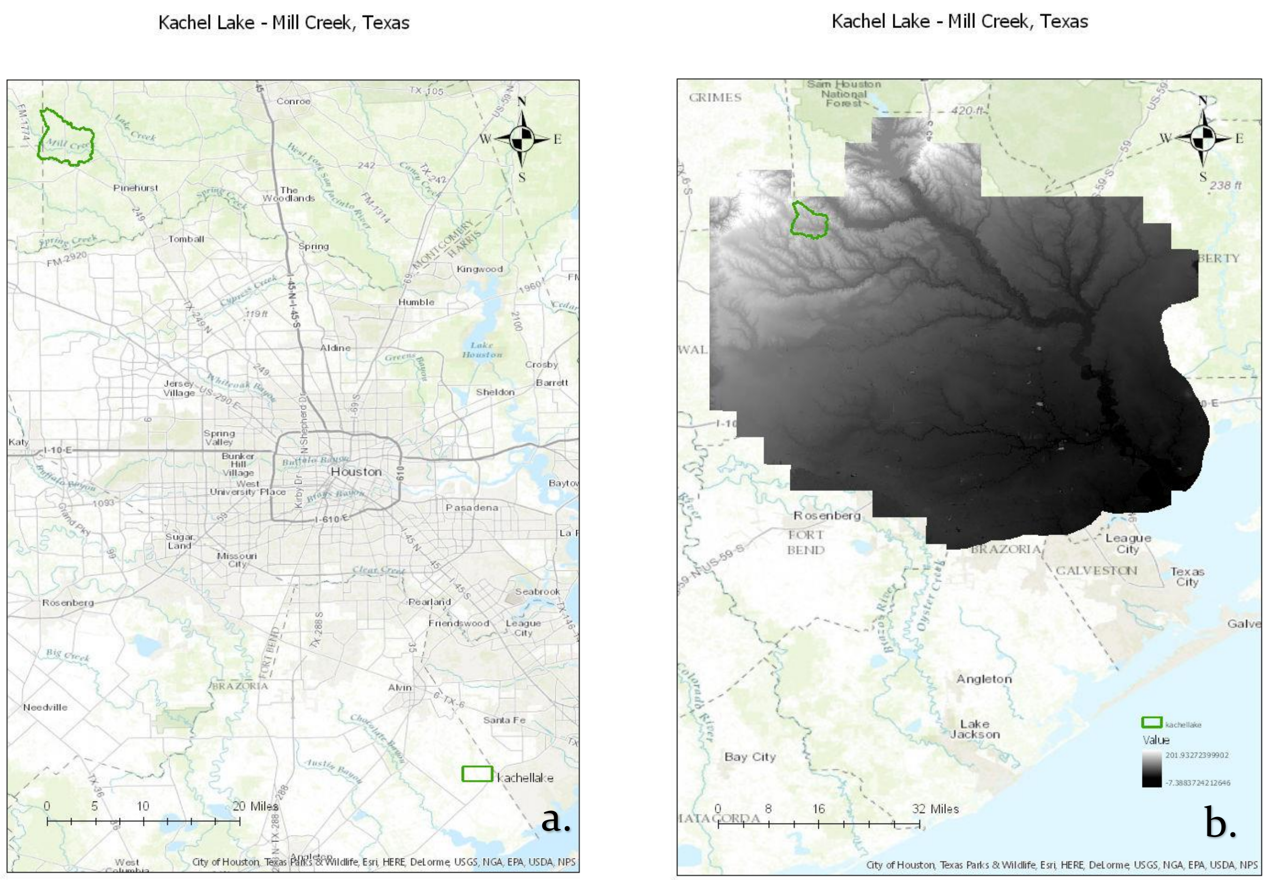


Figure 2. a) Location of chosen catchment near Houston. b) Location of catchment coupled with 3-meter DEM.

Table 1. Kachel Lake Attributes

Kachel Lake Catchment - Attributes	
Area (km^2)	48.24
HUC12	120401020207
HUType	Standard
Kachel Lake 3-Meter DEM	
Columns	2529
Rows	3045
Cell size (m)	3 by 3
Max DEM value	93.84
Min DEM value	66.23

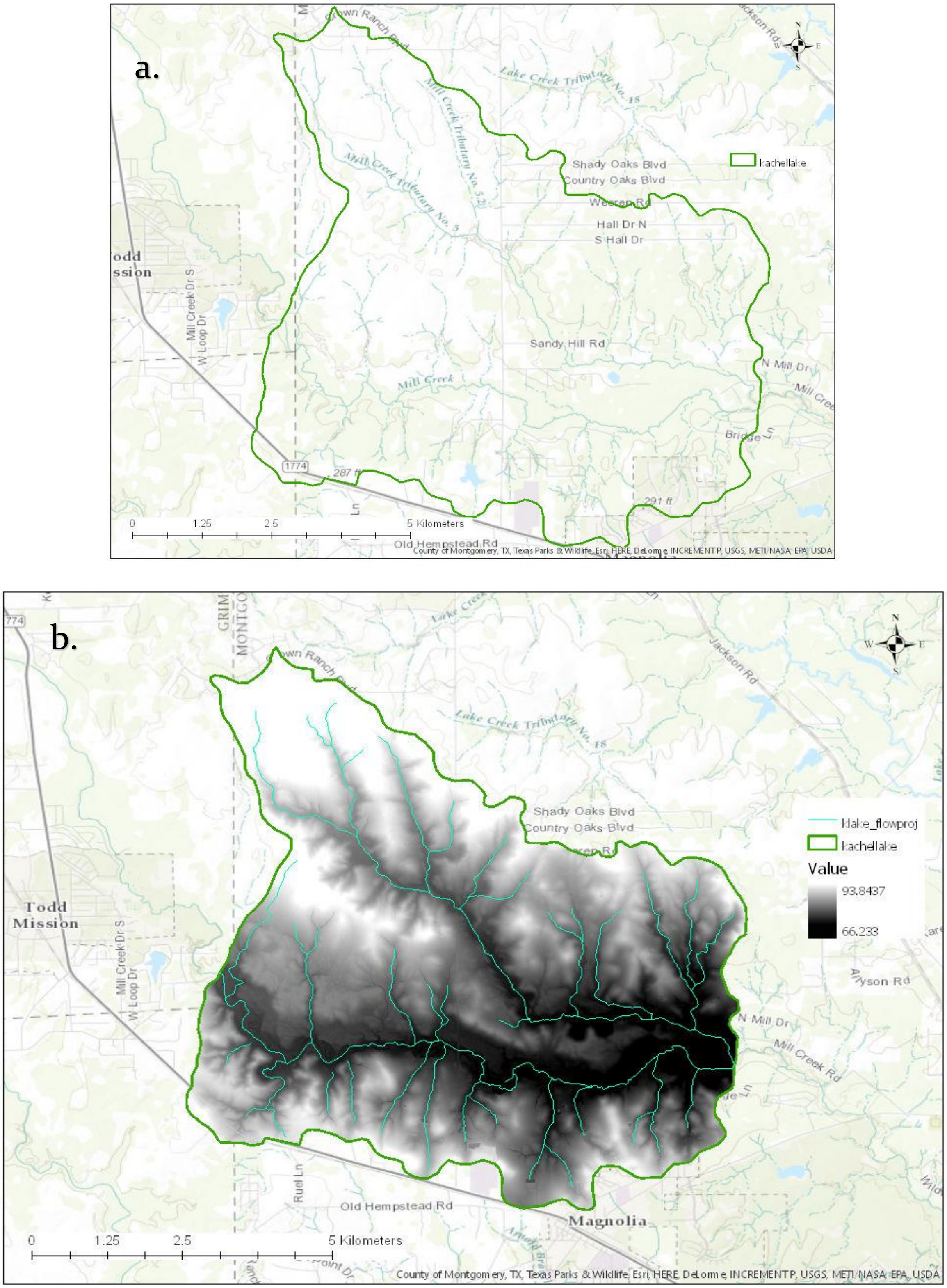


Figure 3. a) Kachel lake catchment with topographic base-map layer. b) Kachel Lake catchment with 3-meter DEM and NHDPlus flowlines (light blue).

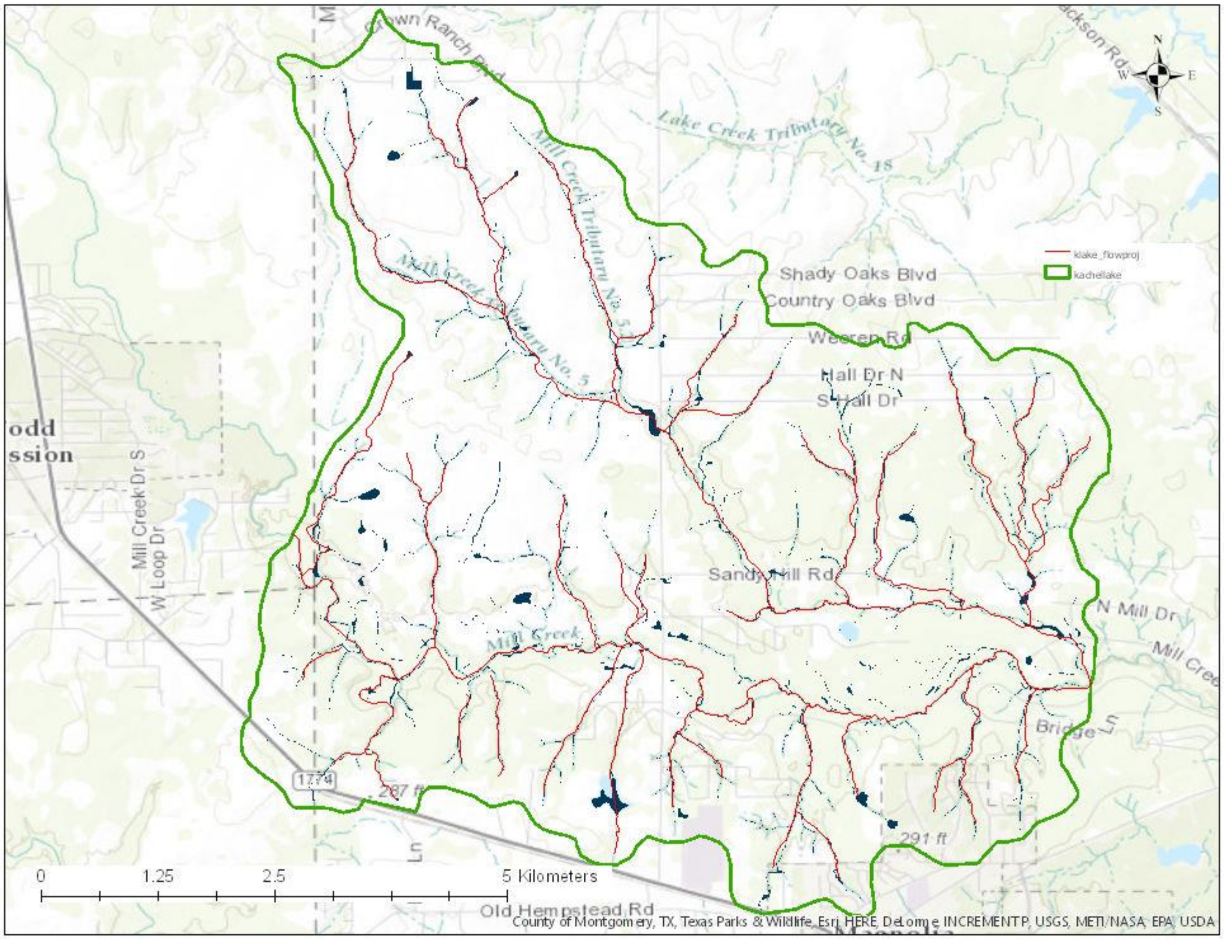
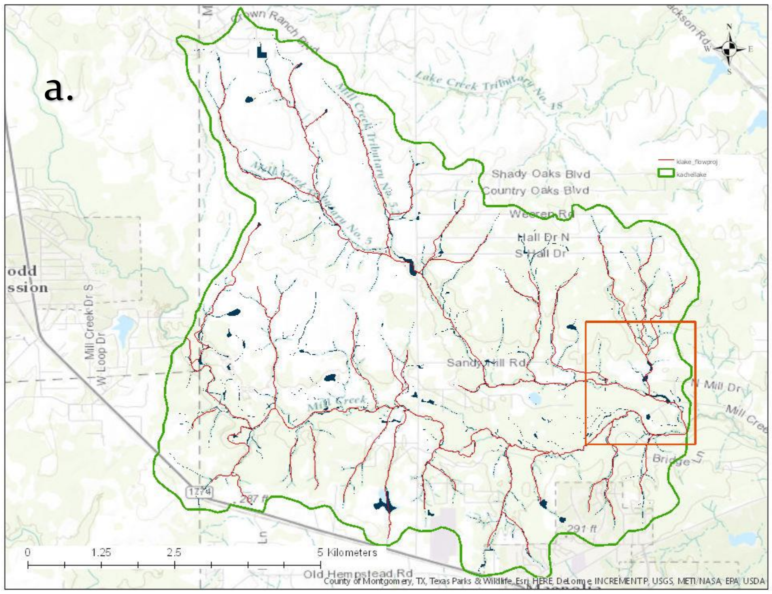


Figure 4. NHDPlus flowlines (red) overlaid with GeoNet extracted likely channelized pixels (blue).

Figure 4 details drainage network comparisons between NHDPlus and GeoNet extracted results. It is apparent that the likely channelized flowlines from GeoNet more closely follow the topographic base-map channel lines (**Figure** 3a). A closer comparison of the drainage networks is made near the outlet of the catchment.



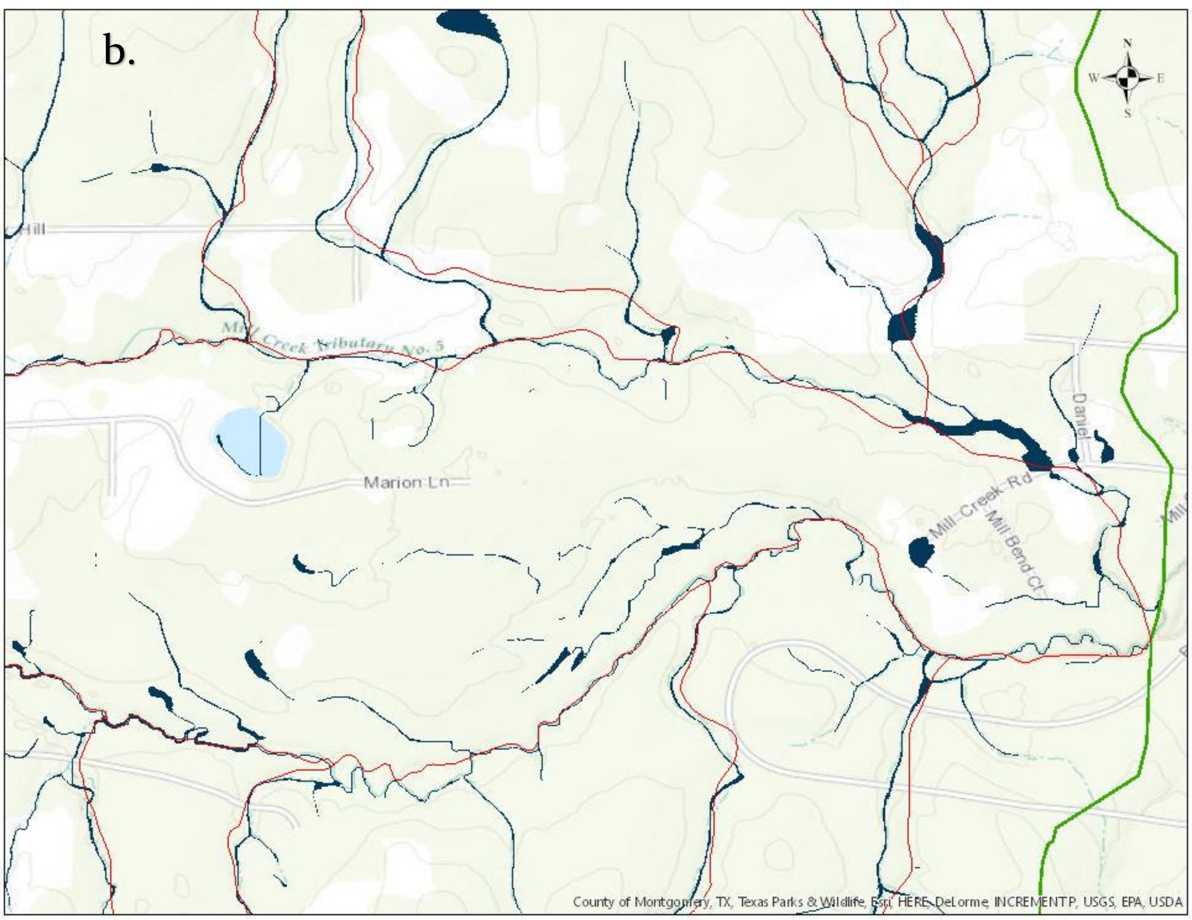


Figure 5. a & b) A closer look at the drainage patterns for NHDPlus flowlines (red) and GeoNet extracted results (blue).

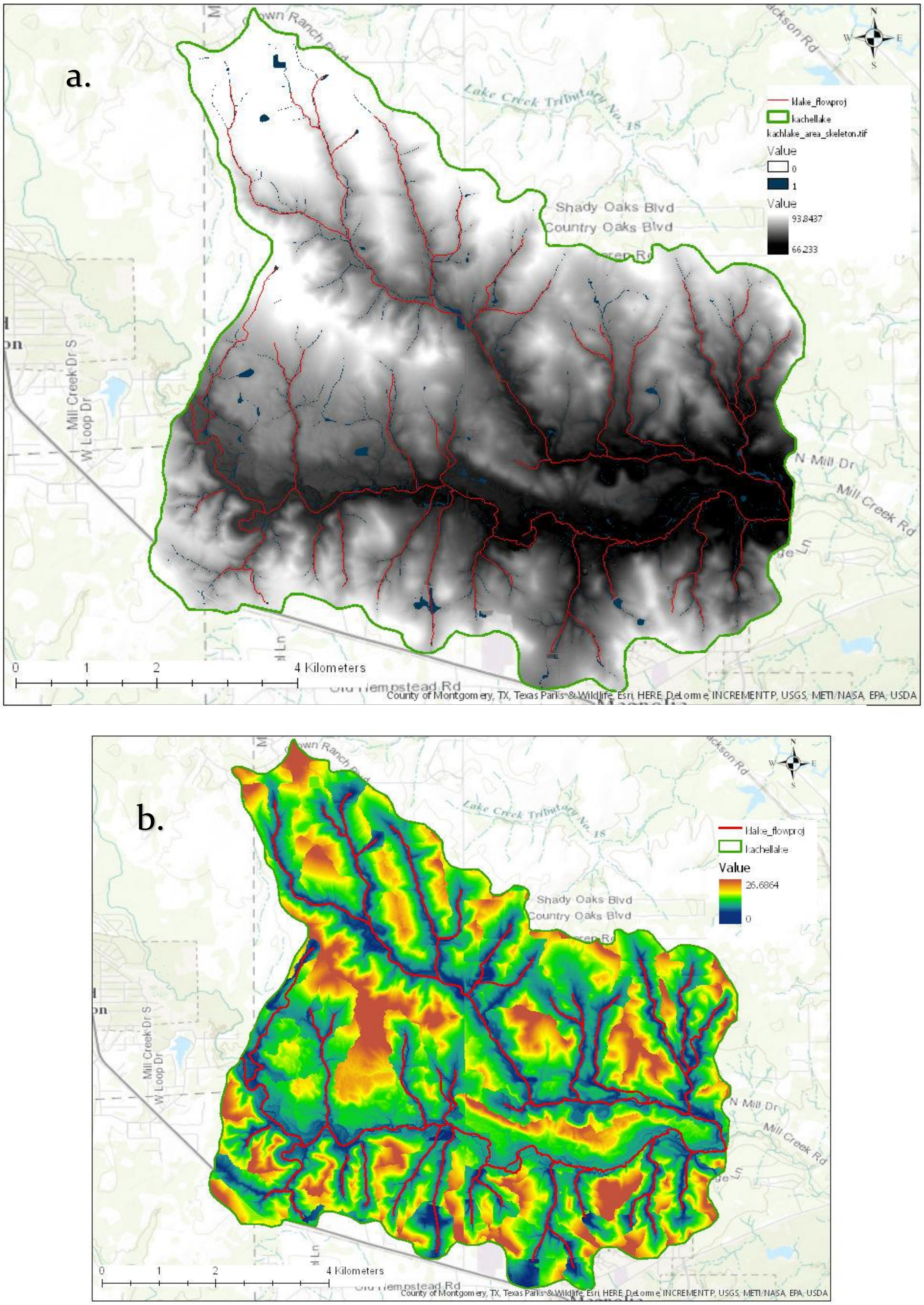


Figure 6. a) 3-meter DEM layer overlaid with NHDPlus flowlines (red) and GeoNet likely channelized pixels (blue). b) Original HAND overlaid with NHDPlus flowlines (red).

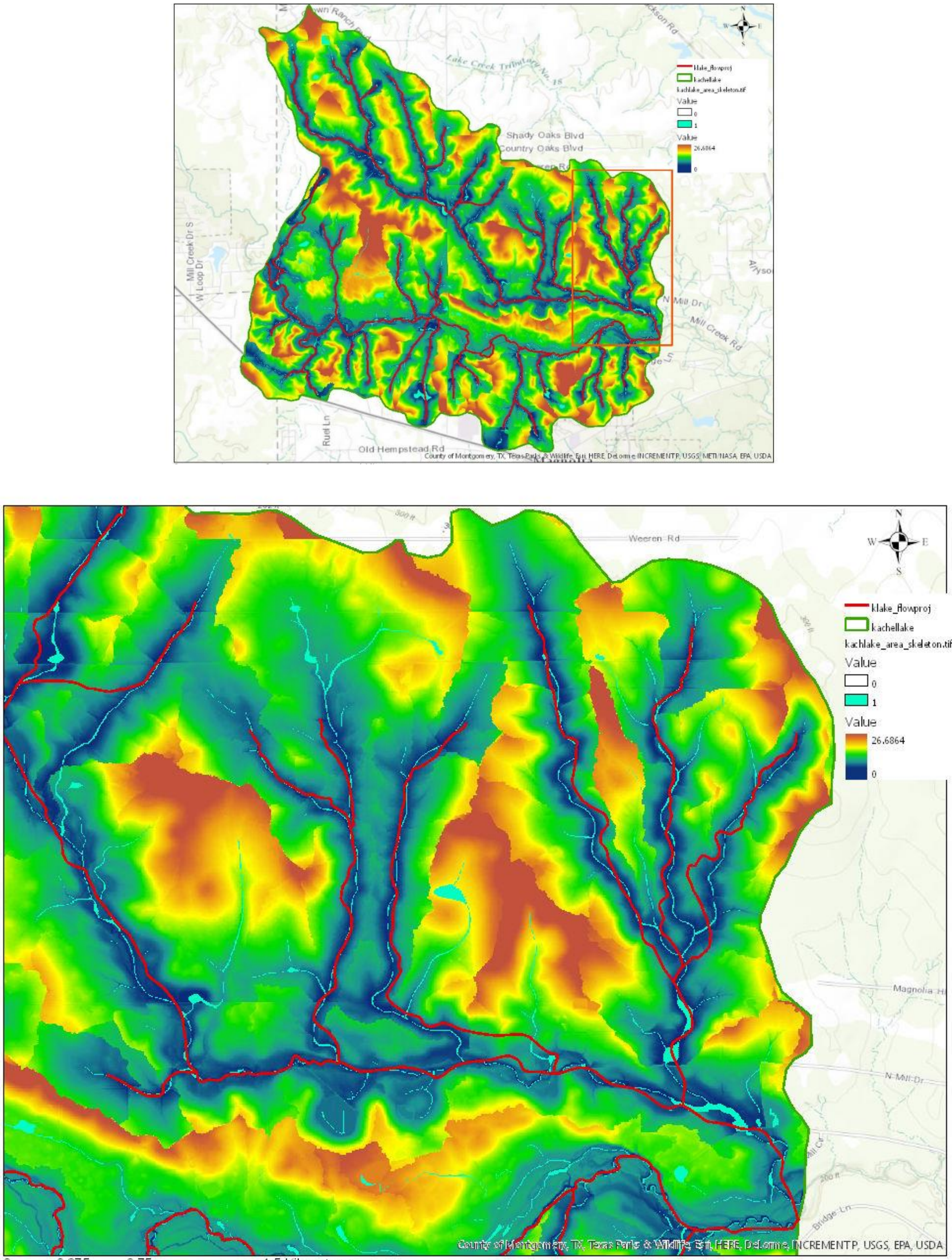


Figure 7. Original HAND layer overlaid with NHDPlus flowlines (red) and GeoNet extracted likely channelized pixel (cyan).

Recall that the original HAND dataset was generated with 3-meter elevation data and high resolution NHDPlus flowlines. **Figure 7** compares the closeness of fit between the two drainage networks with the HAND data. It is apparent that the GeoNet extracted results more closely resembles the nearest drainage results calculated from HAND whereas the NHD flowlines are somewhat off in regards to closeness of fit with HAND results. **Figure 7** is a good indicator of the potential for GeoNet extracted channels to be used as flowlines for generating more accurate and detailed HAND data.

4.2 SPRING CREEK CATCHMENT

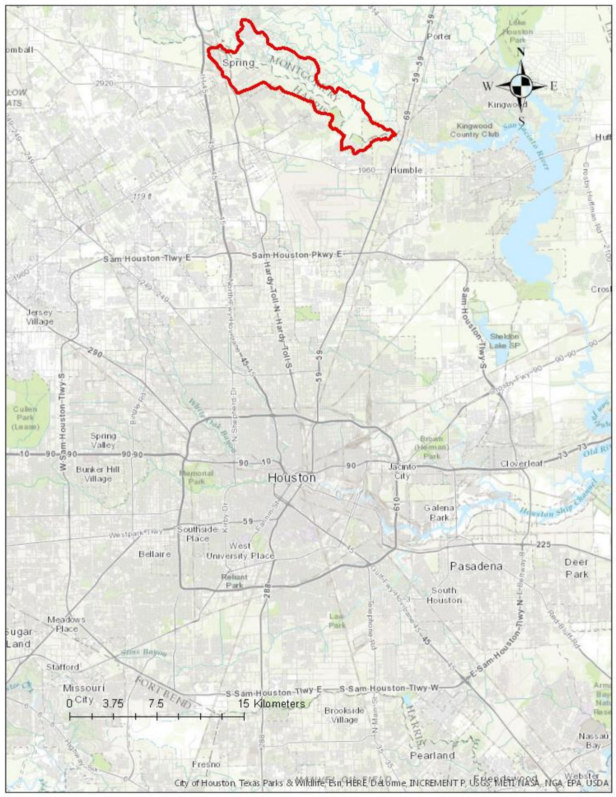


Figure 8. Location of Spring Creek Catchment

Table 2. Spring Creek catchment attributes

Spring Creek Catchment - Attributes	
Area (km^2)	52.65
HUC12	120401010501
HUType	Standard
Spring Creek 3-Meter DEM	
Columns	5389
Rows	3916
Cell size (m)	3 by 3
Max DEM value	33.875
Min DEM value	16.589

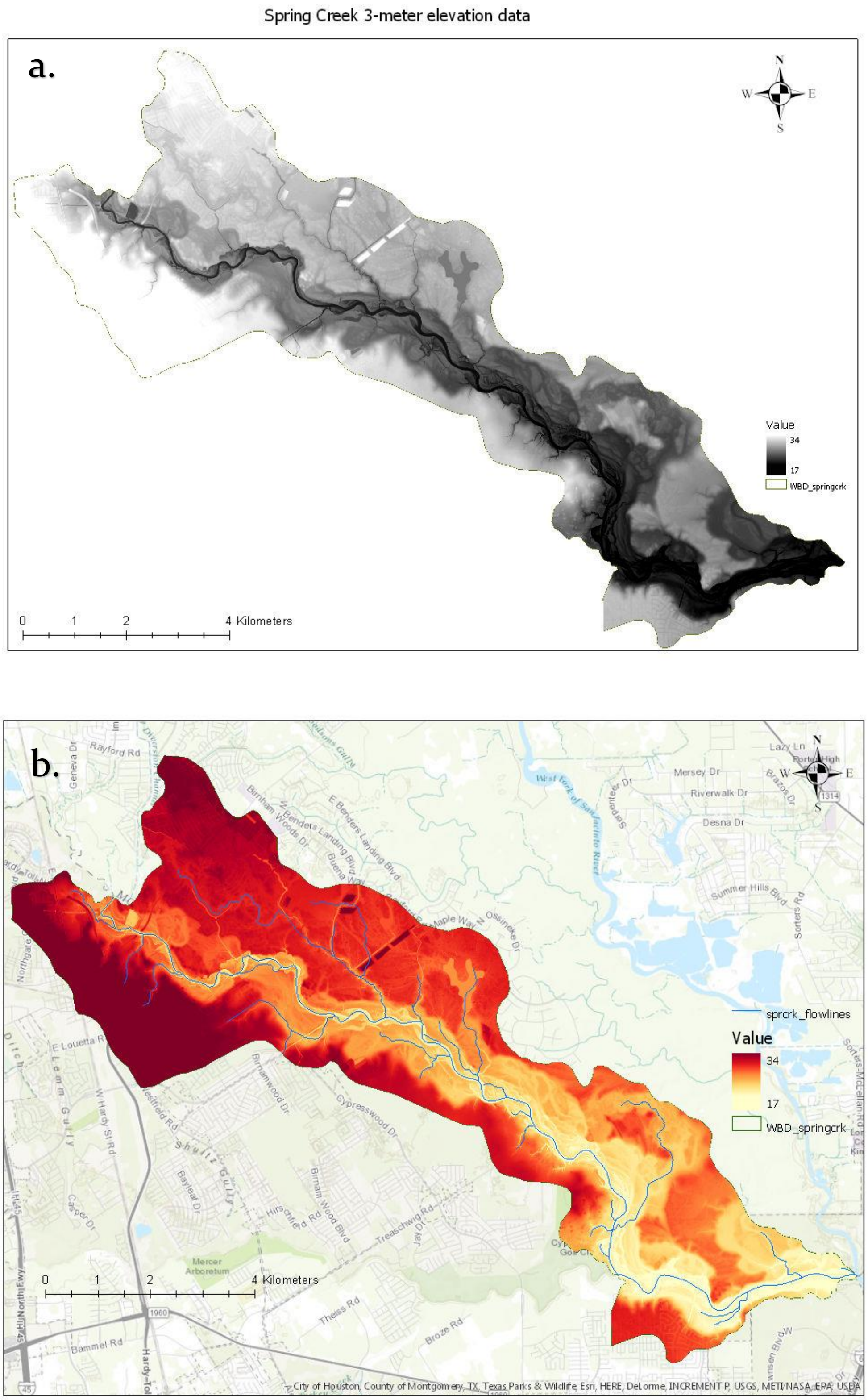


Figure 9. a) 3-meter DEM of Spring Creek. b) 3-meter dem overlaid with NHDPlus flowlines (blue).

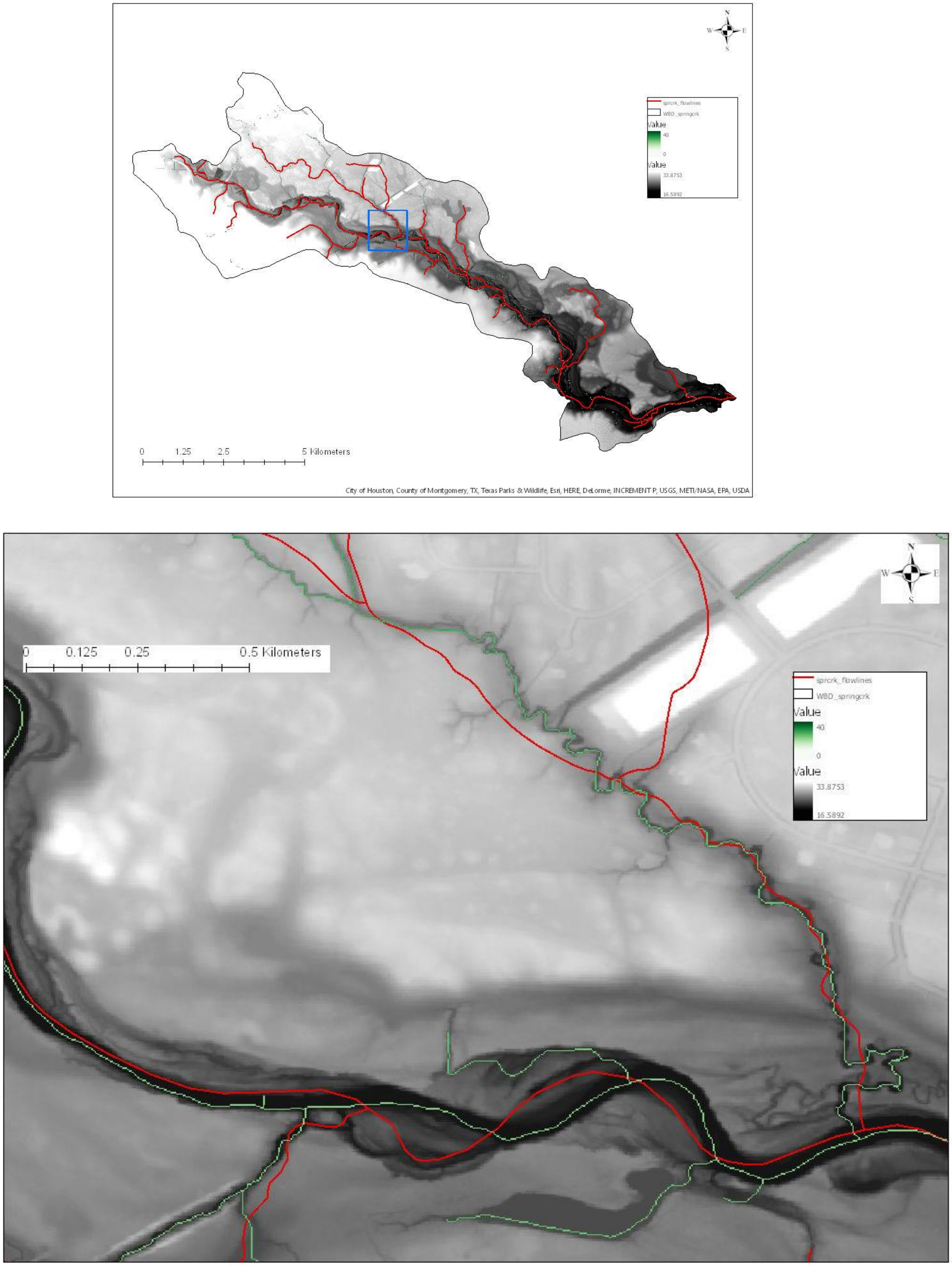


Figure 10. 3-meter DEM with NHDPlus flowlines (red) and GeoNet extracted channel (green).

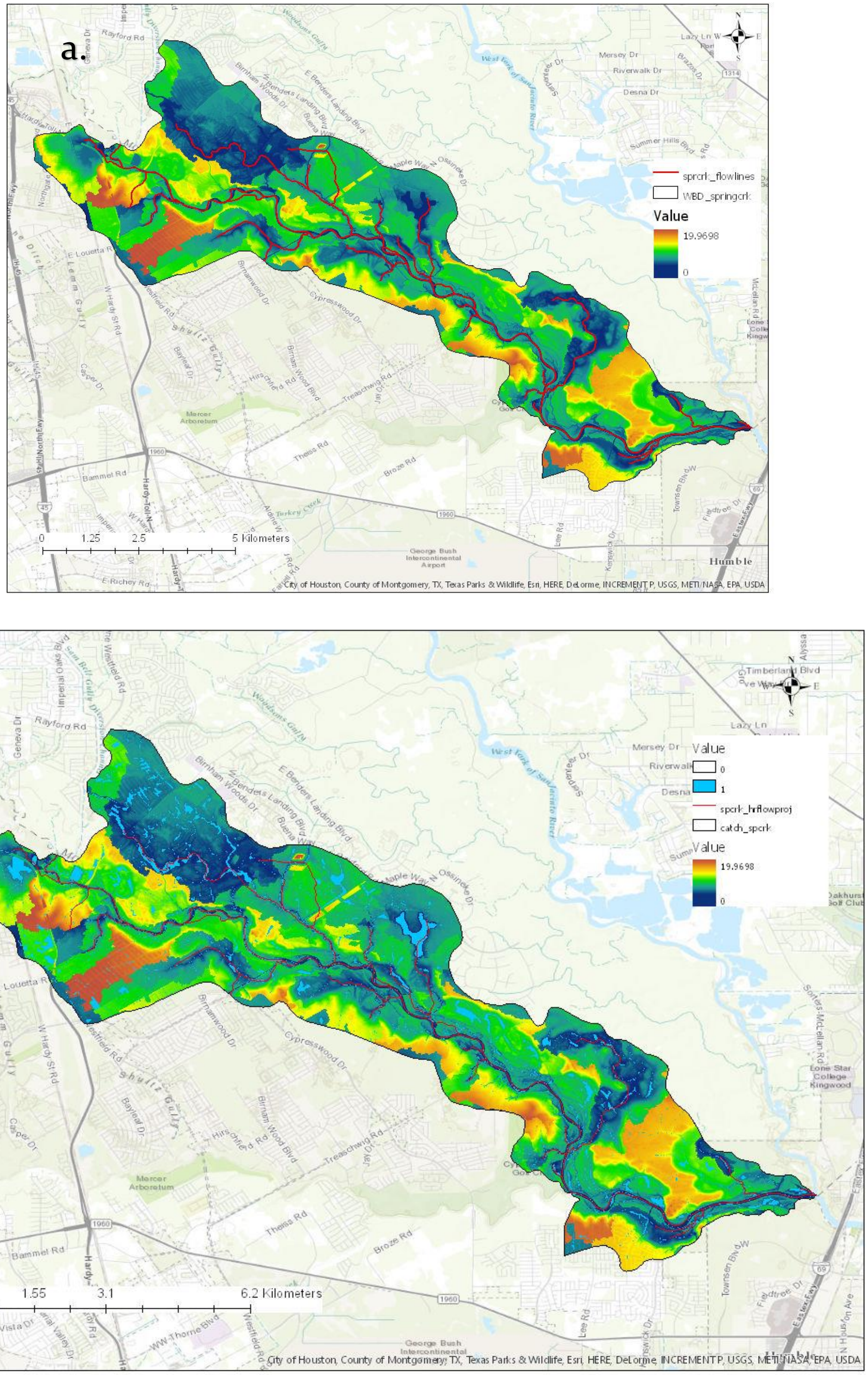


Figure 11. a) Clipped original HAND overlaid with NHDPlus flowlines. b) Original HAND with NHDPlus flowlines (red) and GeoNet extracted likely channelized pixels (light blue).

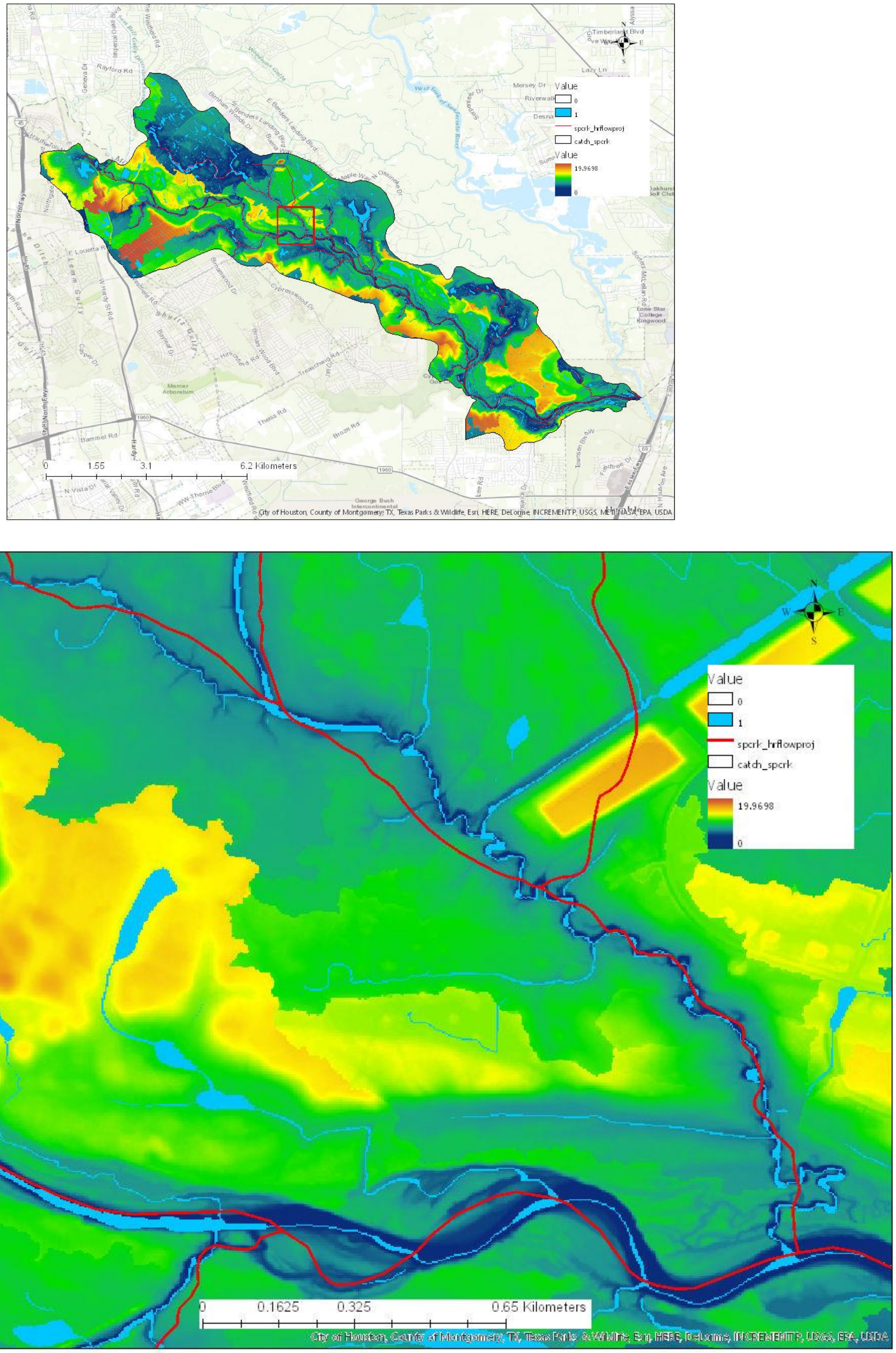


Figure 12. Closer look at the closeness of fit between NHDPlus flowlines (red) and GeoNet extracted skeleton with HAND (light blue).

4.3 CANE ISLAND BRANCH CATCHMENT

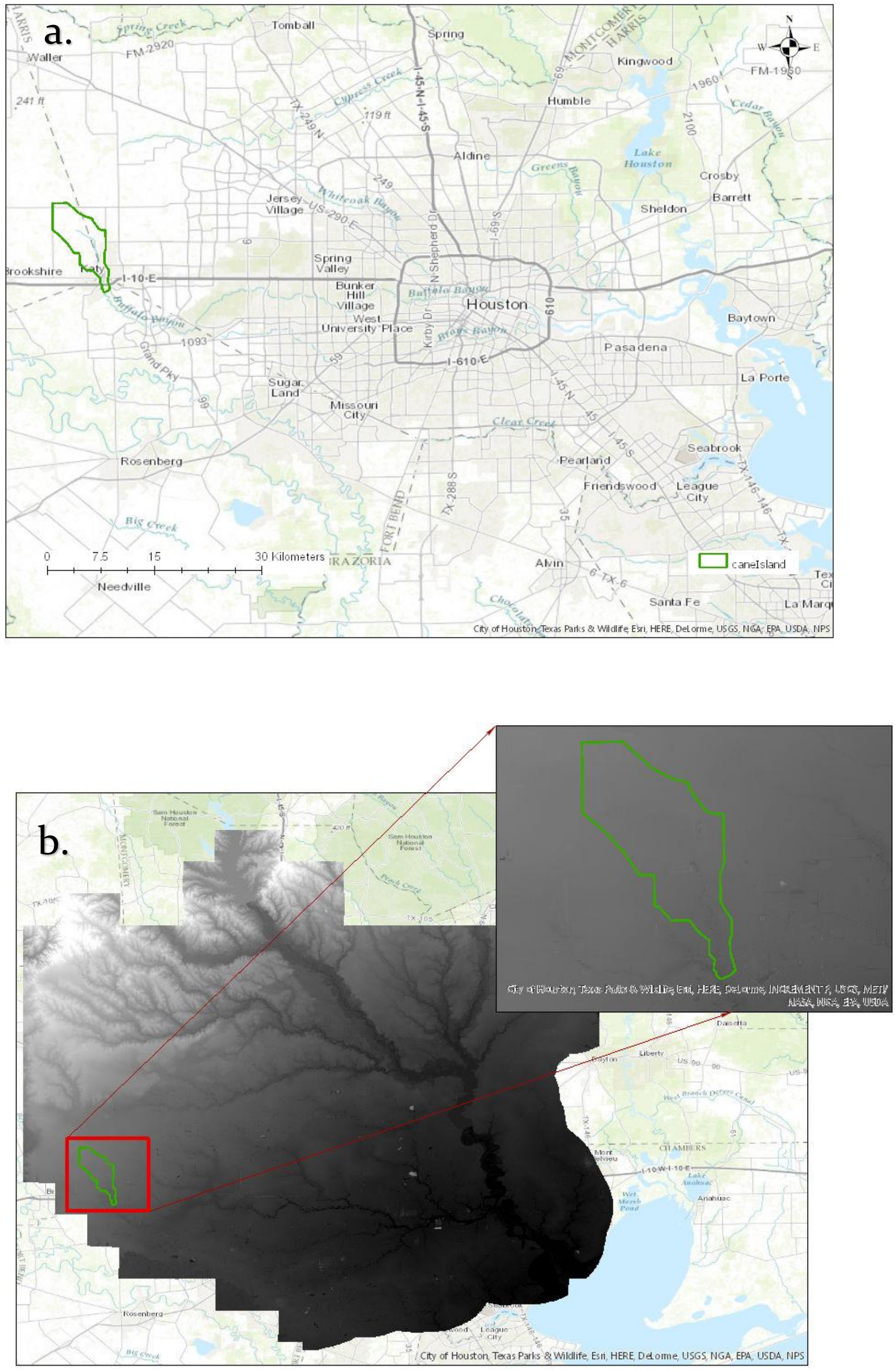


Figure 13. a) Location of Cane Island catchment. b) Closer look at Cane Island with 3-meter DEM.

Table 3. Cane Island catchment attributes

Cane Island Branch Catchment - Attributes	
Area (km^2)	41.18
HUC12	120401040102
HUType	Multiple Outlet
Cane Island Branch 3-Meter DEM	
Columns	2200
Rows	3880
Cell size (m)	3 by 3
Max DEM value	54.66
Min DEM value	42.75

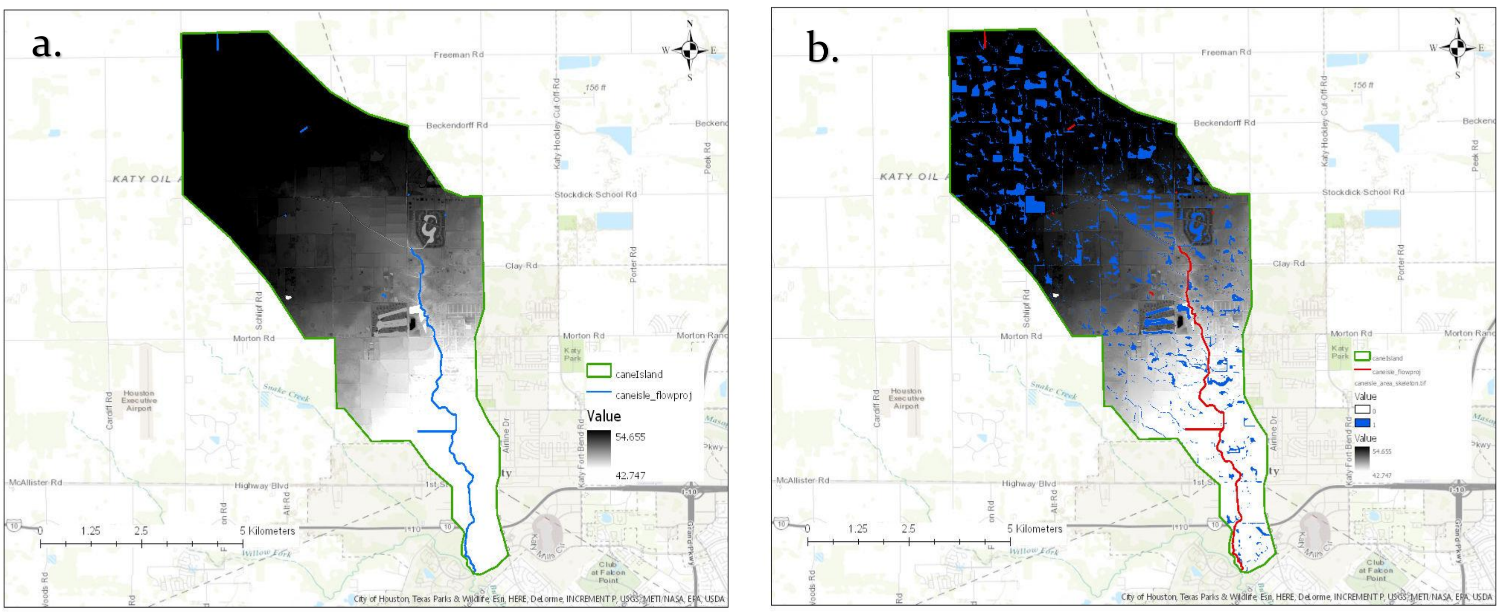


Figure 14. a) 3-meter elevation data overlaid with NHDPlus flowline (blue). b) 3-meter DEM with NHDPlus flowline (red) and GeoNet extracted likely channelized pixels (blue).

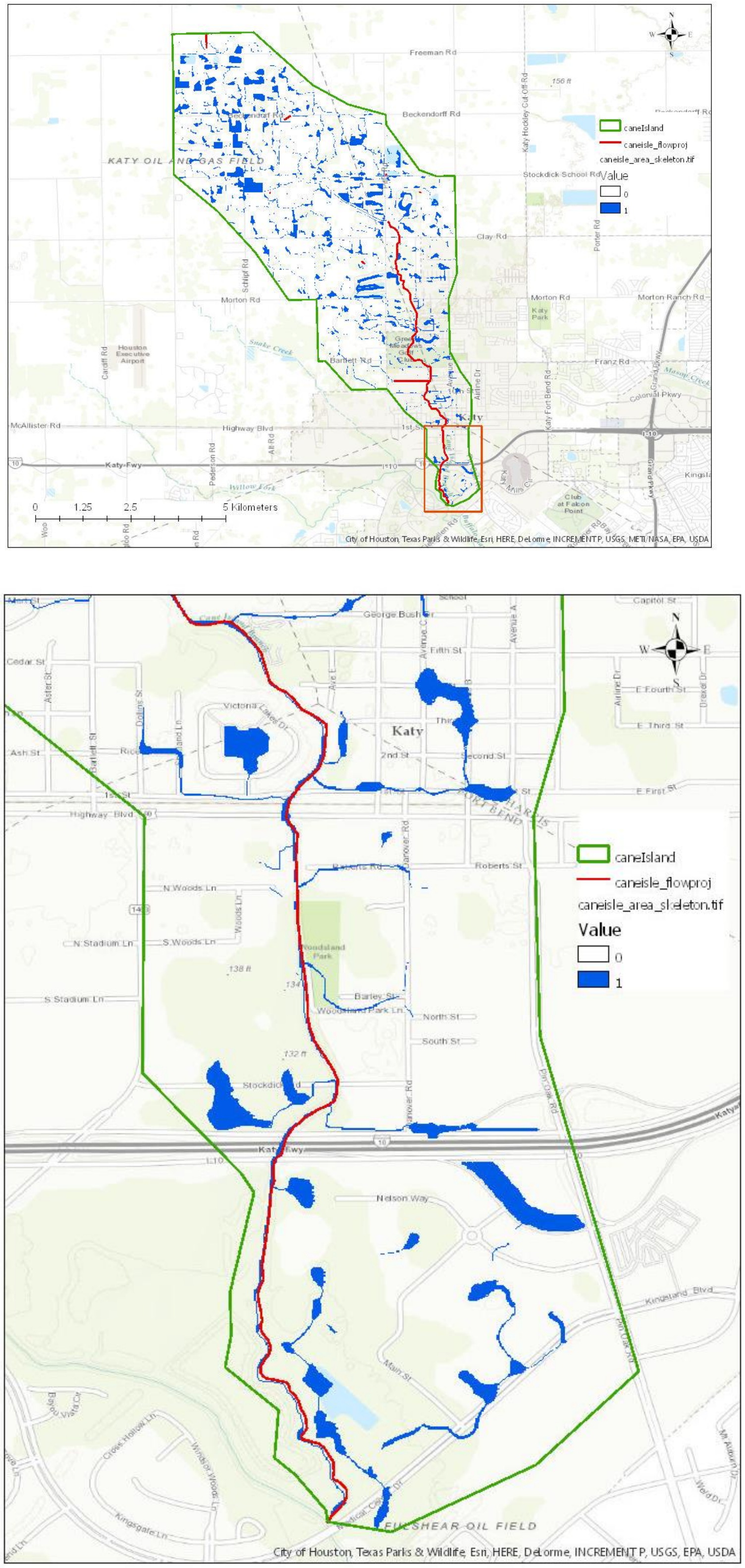


Figure 15. Closer look at NHDPlus flowline (red) and GeoNet extracted skeleton (blue) near the catchment outlet.

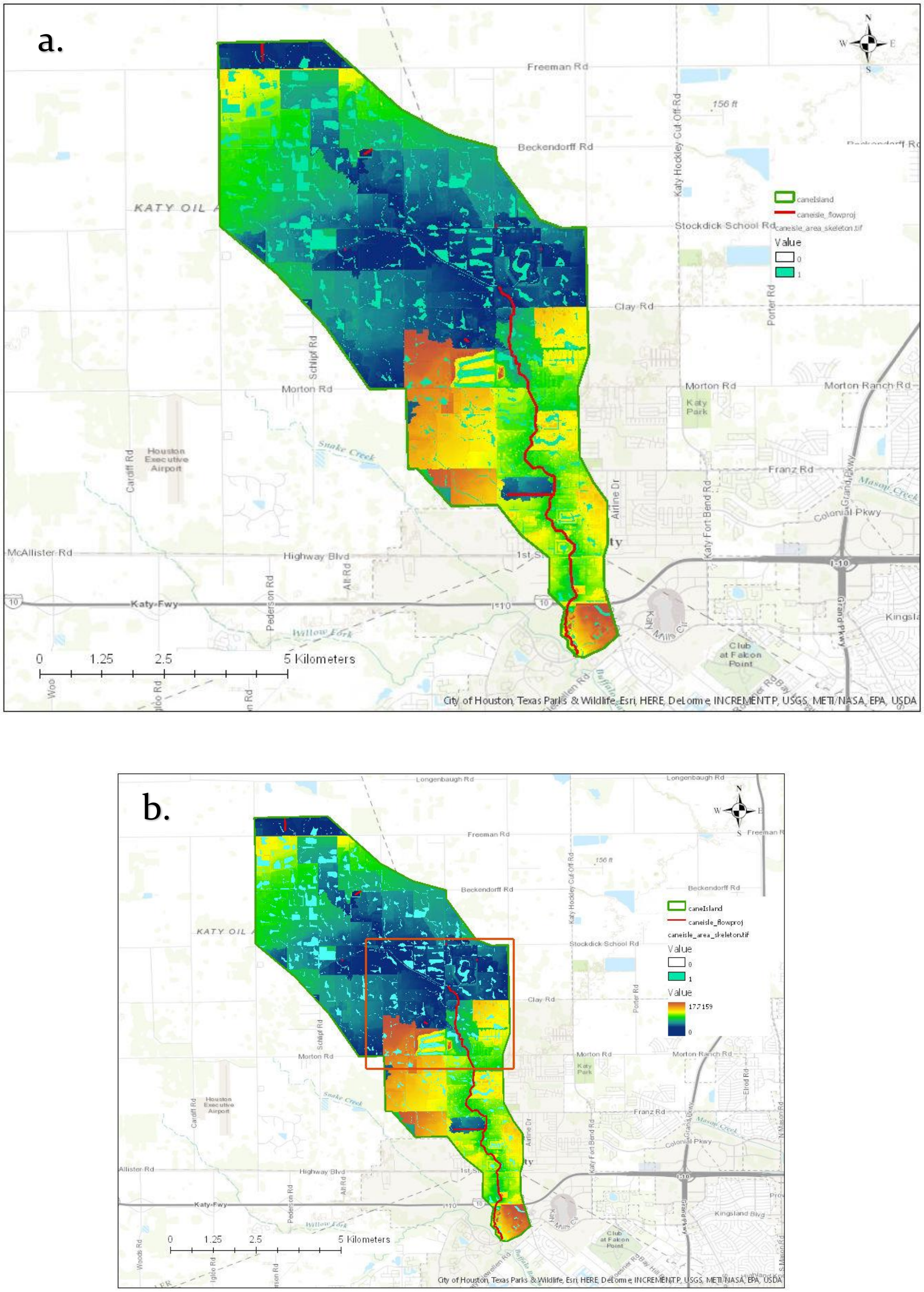


Figure 16. a) Clipped original HAND with NHDPlus flowline (red) and GeoNet extracted skeleton (light blue). b) Closer comparison between the two drainage networks with HAND.

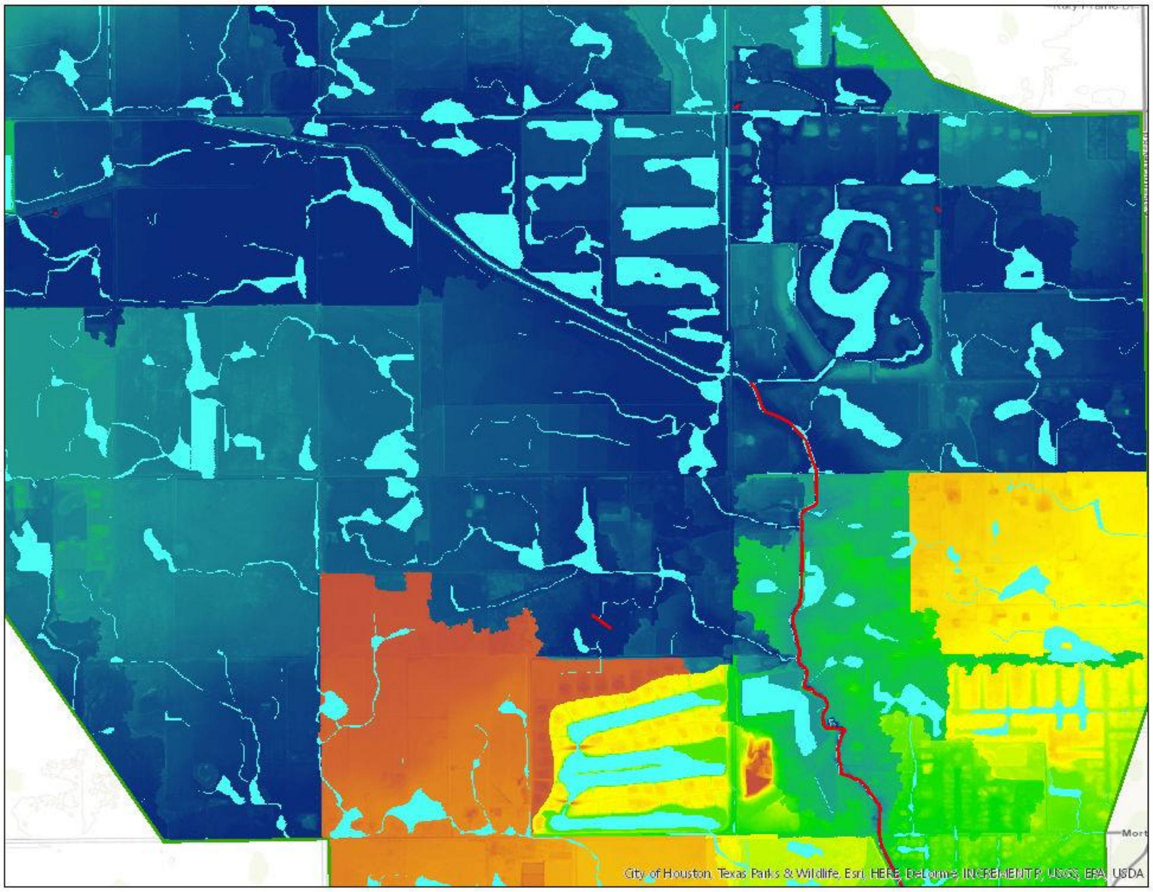


Figure 17. Closer look at NHDPlus flowlines (red) and GeoNet extracted likely channelized pixels (light blue).

For **Figure 12**, a closer look at GeoNet extracted skeleton (light blue) and NHDPlus flowlines (red) with HAND suggests that GeoNet fits closer to the actual HAND data than NHD flowlines. Again, this is a strong indicator of the potential for GeoNet to supplement the high resolution flowlines to improve the HAND data.

For **Figure 17,** in comparing NHDPlus flowlines with GeoNet results, it is interesting to see that both features (from different sources) have difficulty in generating smooth drainage networks for relatively flat and urbanized areas. Although, there is potential to improve the output results from GeoNet by looking into the lines of code to adjust some parameters (e.g. skeleton thinning parameter) in order to further enhance certain channel features and generate better-defined drainage patterns. Overall, **Figure 17** emphasizes the complicated nature of terrain data and the need to find better alternatives to model such complexities; especially with the ever increasing human population, there is a greater necessity to generate higher resolution data.

It is important to note that for catchments Kachel Lake and Cane Island Branch, GeoNet extracted drainage networks were not available because a MATLAB extension tool called mapping toolbox* is required to generate such features (as shapefiles). As such, the extracted network skeletons (likely channelized pixels) for both catchments were employed instead as likely channels to facilitate the HAND analysis. Future results will incorporate these extracted drainage networks.

*This is currently an ongoing administrative/commercial licensing issue. Additionally, Spring Creek drainage network was obtained using a trial version of the mapping toolbox (since expired).

5.0 Conclusions and Future Work

The initial objective of this project was to look into HAND for 3-meter elevation data and high resolution NHDPlus flowlines for Houston. From examining the HAND raster of Houston (generated from 3-meter DEM and high resolution flowlines), it becomes apparent that the effort to model HAND in this relatively flat and urbanized area with current data sources is rather challenging due to the natural complexities in dealing with flat terrain, defining natural and artificial networks, as well as maintaining the smooth transition of channel networks from rural to urban areas. Comparing elevation data with NHDPlus high resolution flowlines were shown to be not as reliable as expected; therefore, alternative methods should be assessed in order to improve the accuracy of the HAND results. An obvious issue from the results is that NHDPlus flowlines from all three catchments have difficulty fitting accurately to the channelized elevation data. Perhaps, as a future work, it might be beneficial to look into improving the NHD flowlines by possibly manually fitting (or coding) the flowlines to the high resolution DEM. Another possible option for future work is employing the GeoNet extracted skeleton as a sort of channel buffer feature that allows for the creation of more accurate channel lines that follow the actual DEM of the catchments. Due to time constraints, HAND analysis for Galveston was not considered in this project; however, future work will consider applying an improved HAND method to this area.

Lastly, as a concluding remark, this project (and this class) has demonstrated that maps in general are extremely effective in communicating complicated pieces of information in a simple yet meaningful way. As such, emphasis should be placed on the advancement of such methods of communication to further research goals.

References

[1] Sangireddy, H., C.P. Stark, A. Kladzyk, Passalacqua, P. (2016). GeoNet: An open source software for the automatic and objective extraction of channel heads, channel network, and channel morphology from high resolution topography data, Environmental Modeling and Software, 83, 58-73.

[2] Nobre, A. D., et al. "Height Above the Nearest Drainage–a hydrologically relevant new terrain model." Journal of Hydrology 404.1 (2011): 13-29.

Appendix

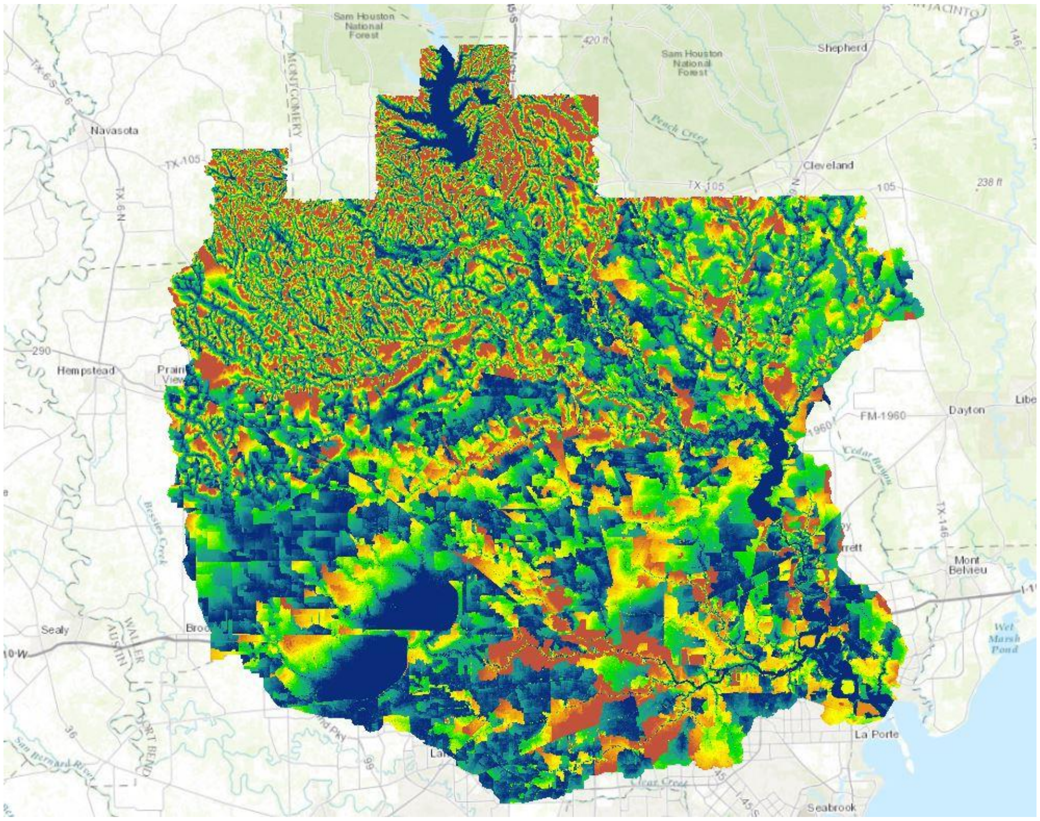
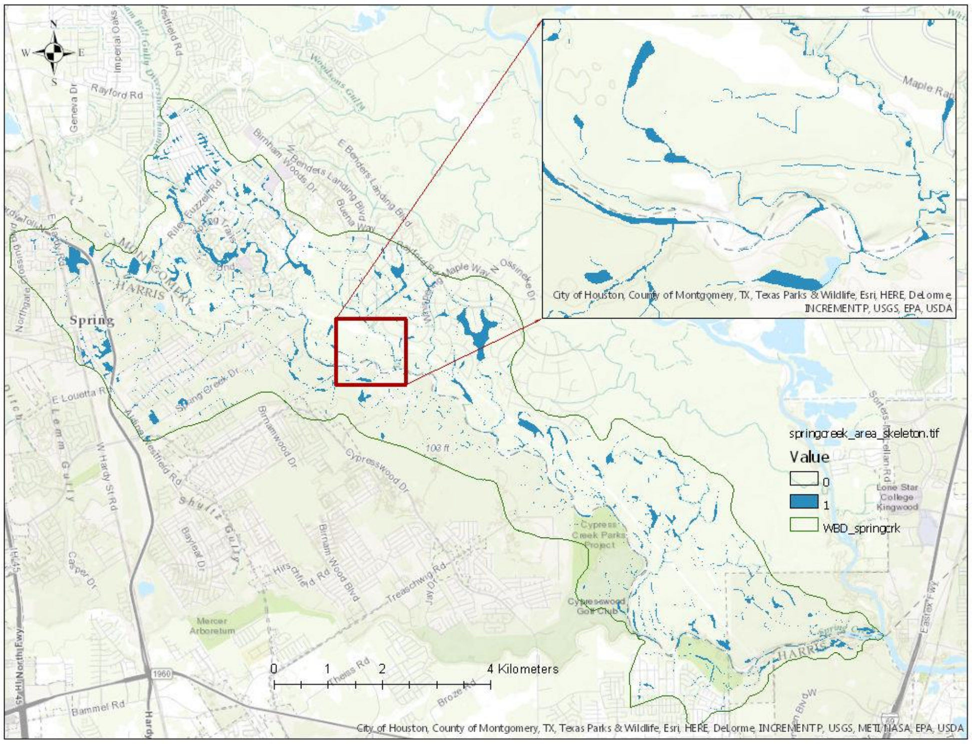


Figure A 1. HAND raster of greater Houston area



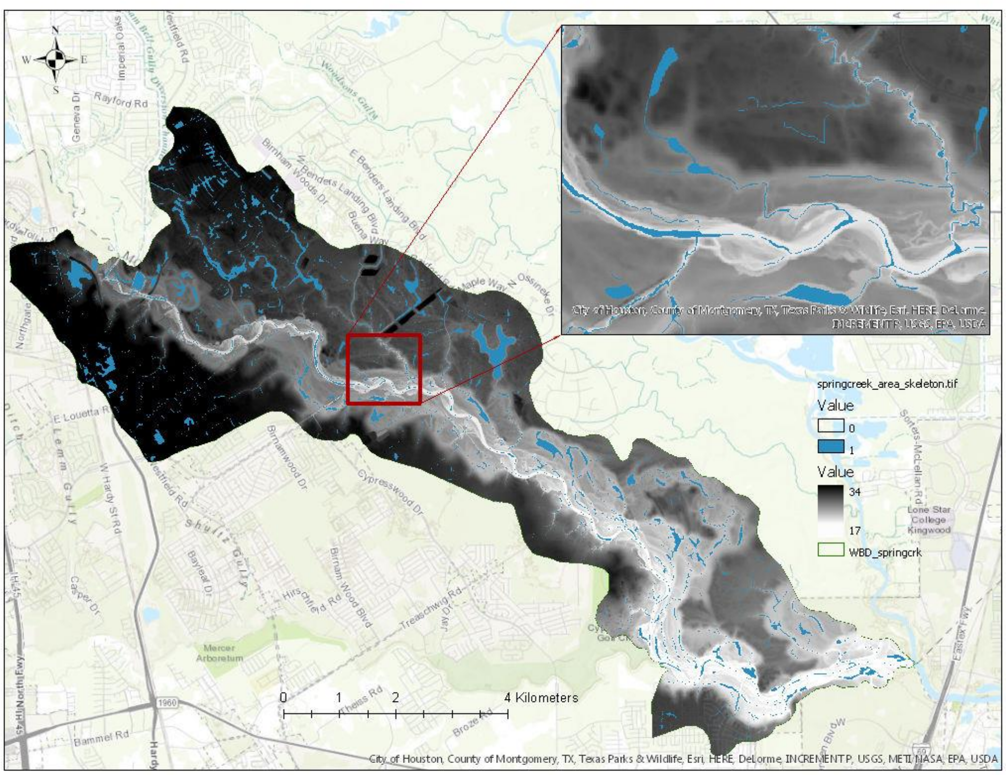


Figure A 2. a) Spring Creek – GeoNet extracted skeleton with topographic base map. b) GeoNet extracted skeleton with 3-meter DEM.

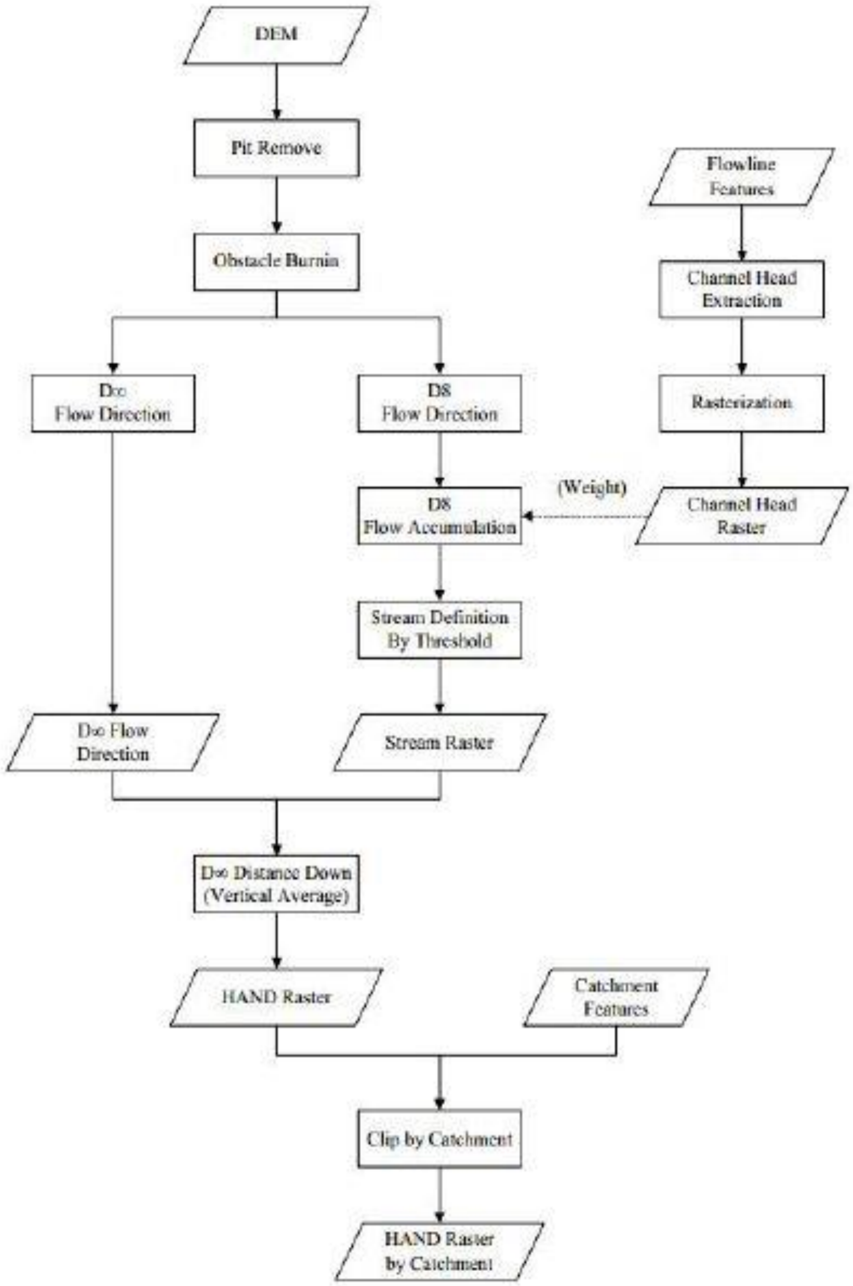


Figure A 3. HAND processing flow chart