Term Project Final Submission

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Subject: Channel Identification in the Guadalupe Delta System, TX

The following report presents the work done throughout the semester on identifying an automated method for extracting water surfaces covered in vegetation from an aerial lidar dataset. As the no complete method was ever achieved, the results are more an exploration of various methodologies. The report depends heavily on maps and images presented in full page for clarity attached at the end of the document in an appendix. Because of this and the limitation of submitting a single document, it is strongly recommended that the reader open two instances of the document and follow along through the Figure appendix while reading the document.

Channel Identification in the Guadalupe Delta System, TX

CE 394K: GIS in Water Resources

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1 Introduction

Using remotely sensed data to identify and digitize landscape features provides significant obvious advantages to fieldwork, but these techniques often require extensive manual manipulation, and as a result, are difficult to standardize. The human eye can readily determine landscape features and characteristics whose identification is difficult to code for, hence the problem of manual manipulation. Furthermore, human opinion is difficult codify, resulting the latter of the two problems mentioned previously. This study attempts to circumvent these issues by developing an automated or semi-automated technique for identifying water surfaces from 1 m^2 resolution airborne lidar digital elevation model (DEM) of the Lower Guadalupe Delta and estuary system in southeastern Texas.

2 Study area and difficulty

The study area is a highly diffuse (flat) and remote landscape about 35 miles south of Victoria, TX. The entire lidar DEM is about 400 km^2, but this study will focus on a much smaller portion primarily surrounding the Guadalupe Delta Wildlife Management Area. Figure 1 provides a larger section of the DEM for context while Figure 2 shows the central study area.

Looking at Figure 2, there are a few noticeable characteristics. As is the case with lidar, water is identified by no data, seen as white. Simply put, airborne lidar data is gathered by spraying a landscape with laser from an airplane or helicopter. Based on how long it takes the light to return to the aircraft, the land elevation can be calculated and modeled. However, the light from the laser is not reflected cleanly off water, so no data is returned. Returning to Figure 2, the Guadalupe River in the southwest corner in the lake in the middle show how water returns no signal. This characteristic makes the water very easy to represent as a polygon. Unfortunately, the Guadalupe Delta is often infested with the invasive species, water hyacinth. The hyacinth forms a thick mat that floats atop the water and shows up as land in the lidar DEM. Figure 3 shows this effect on the dataset, while Figure 4 shows aerial view of this same transition.

The difficulty of this study is digitizing the channels of the Guadalupe Delta covered in vegetation. While the channels may be apparent in the DEM to the human eye, manually drawing channels is time consuming, highly dependent on subjectivity, and would be necessary to do again given a different dataset. A standardized automated or semi-automated method would ameliorate or solve entirely these problems.

3 Methods

The following methods represent the bulk of work in extracting the channels of the Guadalupe Delta due primarily to their effectiveness. Other methods have been but with little success

3.1 NHD dataset

The National Hydrography Dataset[1] (NHD) is a collection of digitized vector representations of water bodies, water areas, and flow lines in the United States. The dataset has been previously updated with new data and recompiled as the NHDPlus[2]. As these two feature datasets are widely used in variety of studies and applications, they provide a convenient starting point for isolating the channels through the Guadalupe River Delta. Considering that the NHDPlus is an update to the original NHD, it would make sense to use this newer dataset. However, with regards to area in question, the original NHD provides a more accurate representation of water surfaces, vegetated or not.

The red in Figure 5 shows a combination of these NHD features. The channel flowing north to south along the western edge is Schwing's Bayou, the channel flowing generally from west to east is Hog bayou, and the large water body towards the center of the figure is Alligator Slide Lake. Looking at Figure 5, it is apparent that the water bodies and water areas from the NHD dataset provide a good representation of the major water surfaces for the majority of the area. At times, the NHD misses the channel edges by over 10 meters. Unfortunately, the NHD flow lines provide little information more than the connectivity of the system. They indicate that there is indeed a channel present put give no indication to its width and thus provide no means of establishing a polygon for the water surface. Furthermore, in some cases, the lines are just incorrect. These issues can be seen in Figure 6. Finally, large branches of the bayou channels are not even recognized in the dataset. So, while the NHD provides significant coverage of system channels with varying degrees of accuracy, the data is insufficient.

3.2 Elevation, slope, and curvature thresholding

In some systems, it is possible to identify channels by a variety of thresholding techniques applied to the original DEM elevations or the calculated slopes and curvatures. Assuming that the lowest sections in landscape will be the conduits for water, elevation thresholds applied intelligently should produce a raster in which the pixels represent the channels. In many areas of the Delta, this is exactly what happens despite the presence of the hyacinth atop the water.

Figure 7 shows a progression of increasing thresholds applied to the region of the Delta seen previously in Figure 5. Paying attention the Schwing's bayou in the southwestern corner, the channels are clearly isolated by the 0.5 m threshold and have a fair definition with just a 0.25 m threshold. While this elevation may work for Schwing's bayou, it fails

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[1] http://nhd.usgs.gov/
[2] http://www.horizon-systems.com/nhdplus/

entirely with Hog bayou running across the northern edge to Alligator Slide Lake and beyond.

Hog bayou receives a greater flow than Schwing's due to a series of diversions from the Guadalupe River. It carries more sediment, and when overtopped, this sediment deposits around the channel. Over the years, the bayou has developed natural levees that raise the water surface above there surrounding land. Because of this process, an elevation threshold of even 0.75 m fails to clearly identify the main channel of the bayou. Furthermore, with this threshold the raster extraction begins to isolate more and more of the lower lands leading to a sort of raster "bleed".

As with elevation, thresholds can be applied to the slope and curvature rasters calculated from the DEM. The idea behind this technique is that the highest slopes in the diffuse landscape would be located at the channel banks and the highest curvature would occur at the initiation and conclusion of the slopes along the channel banks. With either of these features isolated, channels would effectively be outlined and thus easily combined into water surface polygons. Unfortunately, this technique fails too as thresholds have difficult times with gentle sloping point bars along the inside of bends.

3.3 TerEX terrace extraction toolbox

With similar aspirations as with this project, Dr. Patrick Belmont of Utah State University along with others developed an ArcGIS toolbox, TerEX[3], for the semi-automated extraction of terraces, along river channels. With the hopes that the toolbox would recognize the reasonably flat surface of the water hyacinth as a terrace and therefore extract the channel, the TerEX toolbox is applied to the section of Schwing's bayou readily identified by the elevation thresholding technique, Figure 8. As is apparent by the red identified terraces, the toolbox exhibits excessive bleed and fails to even fully locate the center channel. This is not wholly surprising, however, as the toolbox was not intended for such landscapes.

3.4 GeoNet2.0 geomorphic feature extraction toolbox

Continuing with the idea that channel banks would represent areas of high slope and curvature from the thresholding method, a portion of the GeoNet2.0[4] MATLAB code developed by Dr. Paola Passalacqua and others is used to strike cross sections across a stream centerline and determine the likely banks based on the slope and curvature characteristics across the cross section profile. With this series of likely bank locations for the left and right banks, bank edges can be drawn automatically and connected with minimal additional work creating a stream polygon.

Figure 9 shows a zoomed in version of Hog Bayou from the north center page of Figure 5. A custom set of stream centerlines was developed based on an edited version of the NHD for use with this technique. In Figure 9, the custom stream line is seen with a transect of the stream with the north to south transect seen in the profile view as left to right. In the profile, the bank edges are clearly visible.

[3] http://www.cnr.usu.edu/htm/facstaff/belmont-hydrology-and-fine-sediment-lab/belmont-lab-resources
[4] https://sites.google.com/site/geonethome/home

Exporting the stream centerline and DEM as tiff files to MATLAB, GeoNet2.0 strikes cross sections of user defined lengths at user defined intervals, Figure 10. The code then identifies the left and right bank locations that were then exported back to ArcGIS. As seen in Figure 11, code does an excellent job of locating the stream banks. However, anomalies are already apparent in that the bank sides (left and right) spontaneously jump back and forth in certain areas. Connecting the bank lines, Figure 12, a more significant problem is apparent. For much of the reach, the code does well to define the stream banks and connect them as edges. However, in the sinuous middle section of the reach the bank edges appear to jump around causing the lines to connect erratically.

The problem stems from use of the tiff format for importing the stream centerlines. GeoNet2.0 was originally written to import shapefiles by using the MATLAB mapping toolbox. With the vector data, exact coordinates could be passed along to the code along with other information such a sequential order. The tiff raster format provides neither sequential order nor specific coordinates. Instead, it represents a simply grid of streamline or non-streamline cells. GeoNet2.0 processes this by scanning the data systematically, Figure 13. As such, cells encountered sequentially may not actually be adjacent cells. This represents significant problems when the code is counting sequential cells and basing cross section angle off cells on either side of the cross section.

As with TerEX, it should be said that there are many reasons why this technique failed when adopting the program for this particular application. In an effort to discontinue the need for the costly MATLAB mapping toolbox, GeoNet2.0 was rewritten to be able to handle tiff files. Normally, the code produces its own vector centerline itself and thus has sequential exact coordinates to process. However, the code was modified for this use in order to read in an artificial stream centerline. It is in this aspect that the program runs into trouble.

3.5 HEC-GeoRAS and HEC-RAS

In an effort to avoid the coding required to correct the issues using GeoNet2.0, the HEC-GeoRAS toolbox is used to strike cross sections along an artificial centerline. These initial steps are seen in Figure 14, overlain across at Triangular Irregular Network (TIN) of the DEM necessary for the toolbox. This geometry is exported to HEC-RAS where bank locations are manually approximated using the cross section profile editor. This process requires significant manual work, and identifying the bank locations by eye provides no reliable standard. These points are hitherto moot, however, as the export of the geometry back from HEC-RAS to HEC-GeoRAS has also resulted in errors.

4 Conclusions and future work

The automated extraction of stream centerlines from remotely sensed data of highly diffuse landscapes can cause significant problems. Combining this with the requirement of determining transverse channel geometry creates a whole new level of difficulty. In the case of this project however, the pervasive presence of aquatic vegetation requires just such a technique to approximate the water surfaces. Were the vegetation not present, the water would be evident by the lack of data returns.

While many techniques are explored in this study, the by far the most automated and least subjective is the use of GeoNet2.0. Despite the problems involving the processing of artificial streamlines, the code identified channel banks with a great degree of success and without human subjectivity. It is for this reason that the thrust of the future work with this data will involve continuing work with GeoNet2.0.

Appendix: Figures

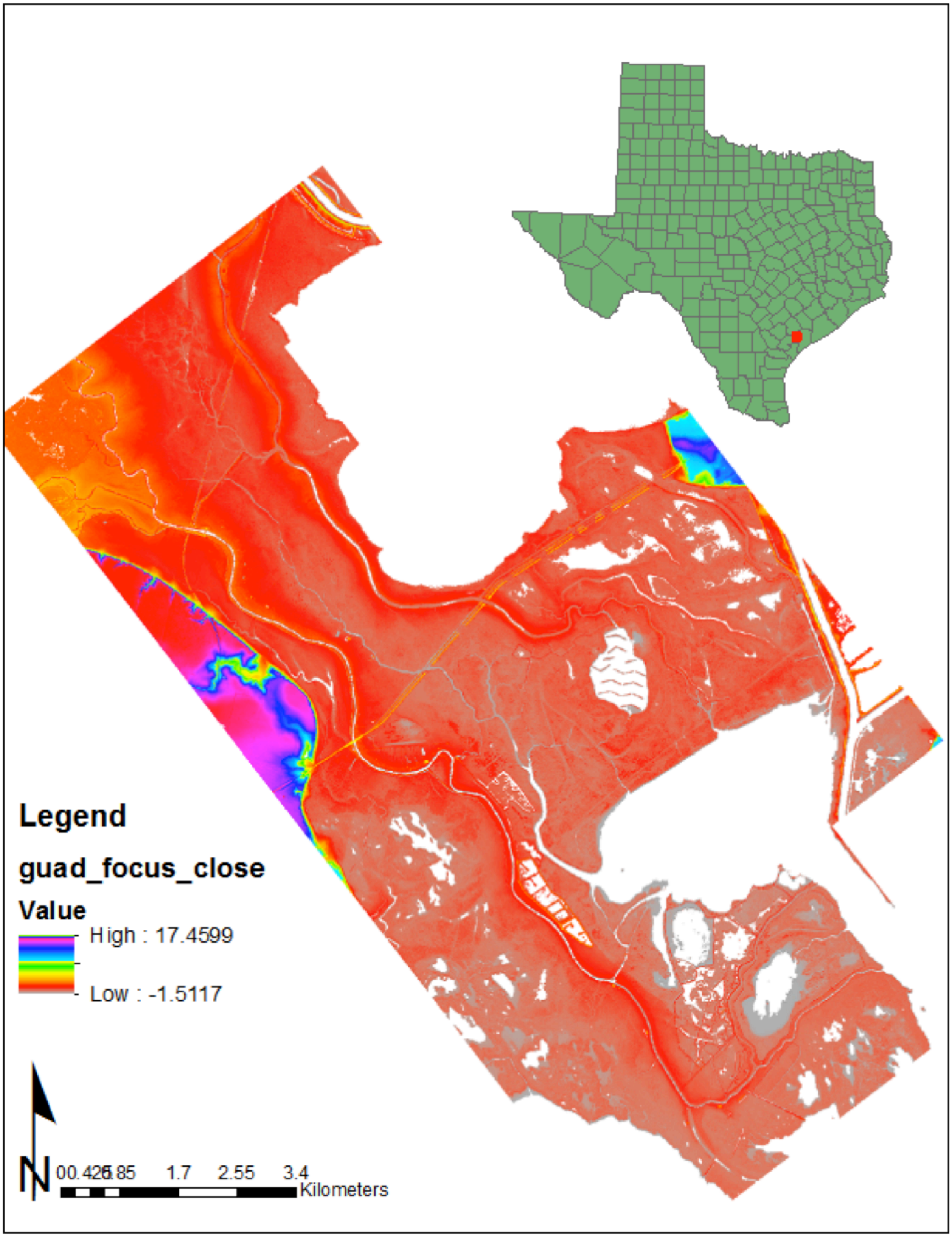

Figure 1. General study area of the lower Guadalupe

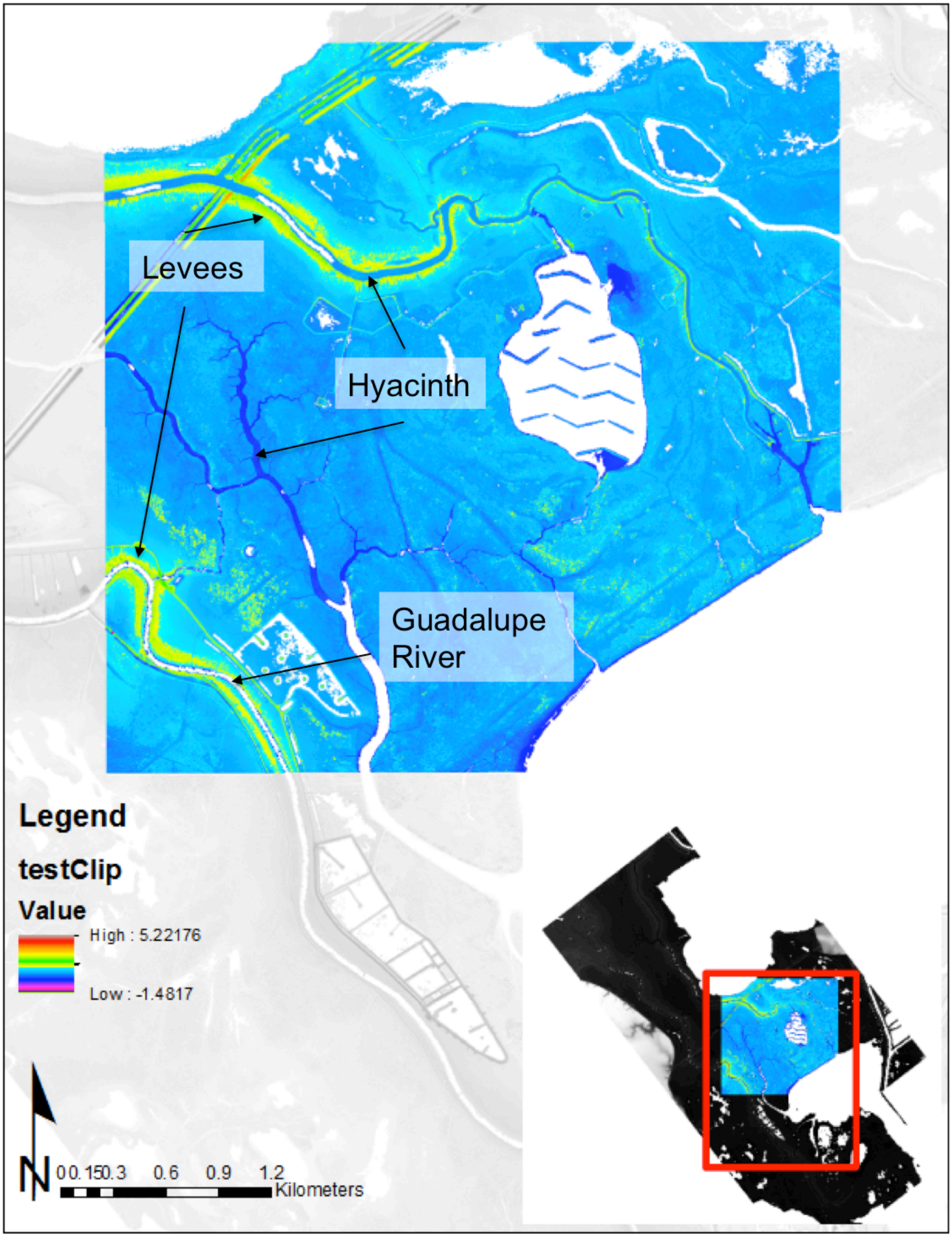

Figure 2. General study areas. Visible are the problematic hyacinth, the Guadalupe River, and the levees supporting the River and Hog bayou

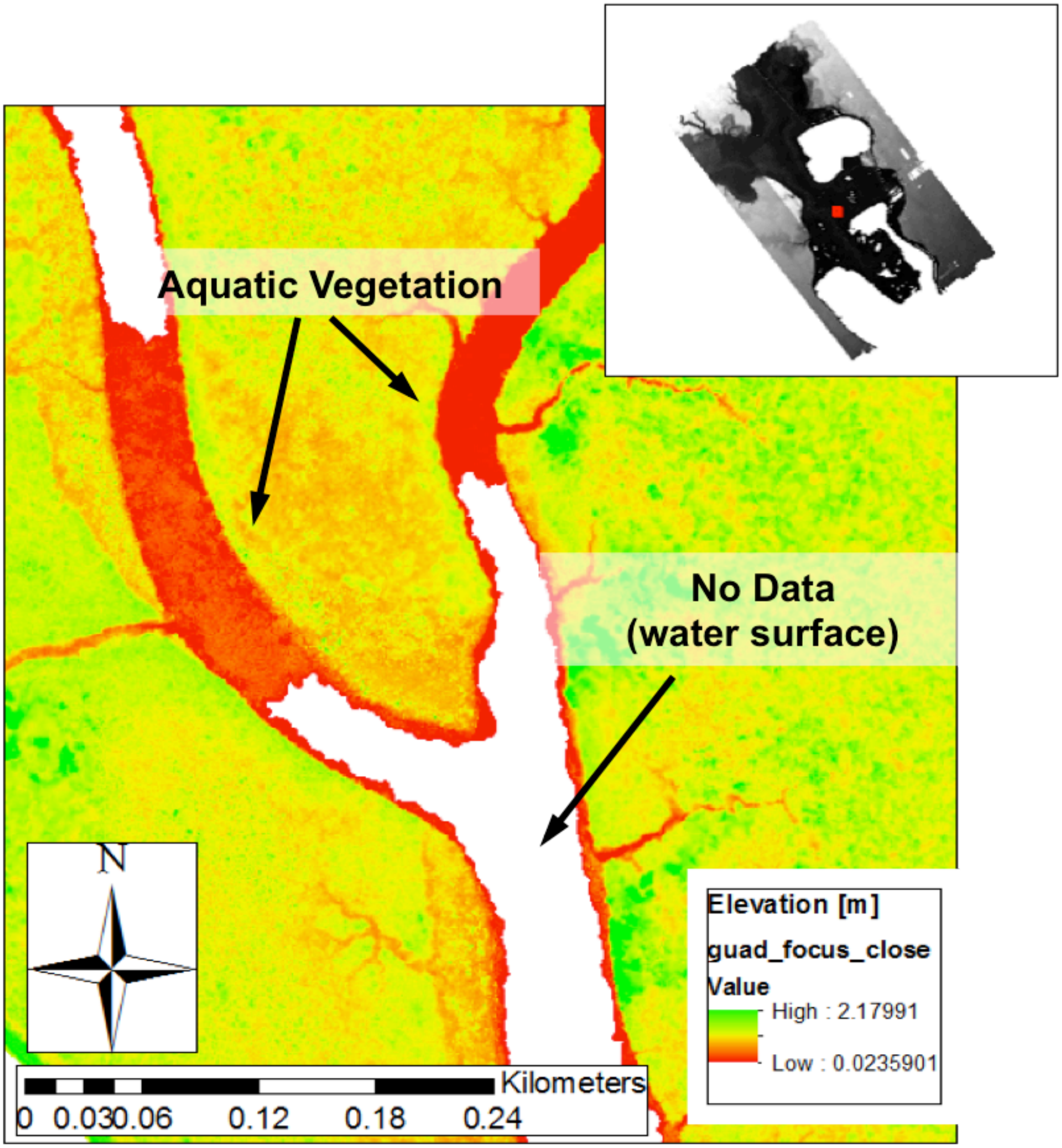

Figure 3. DEM of a fork of Schwing's bayou. Visible are the problematic hyacinth and the transition between vegetation and water.

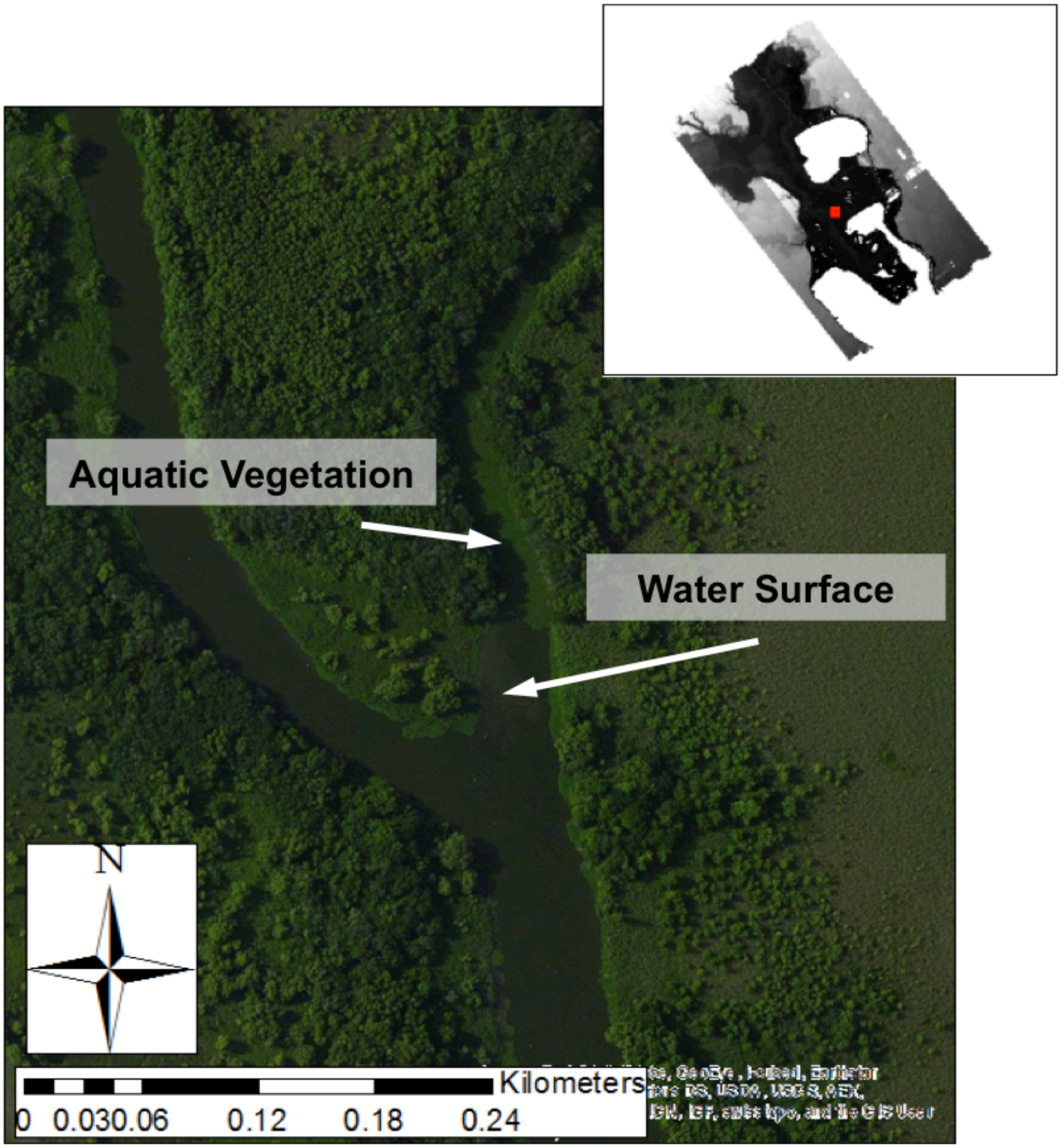

Figure 4. Aerial view of a fork of Schwing's bayou. Visible are the problematic hyacinth and the transition between vegetation and water.

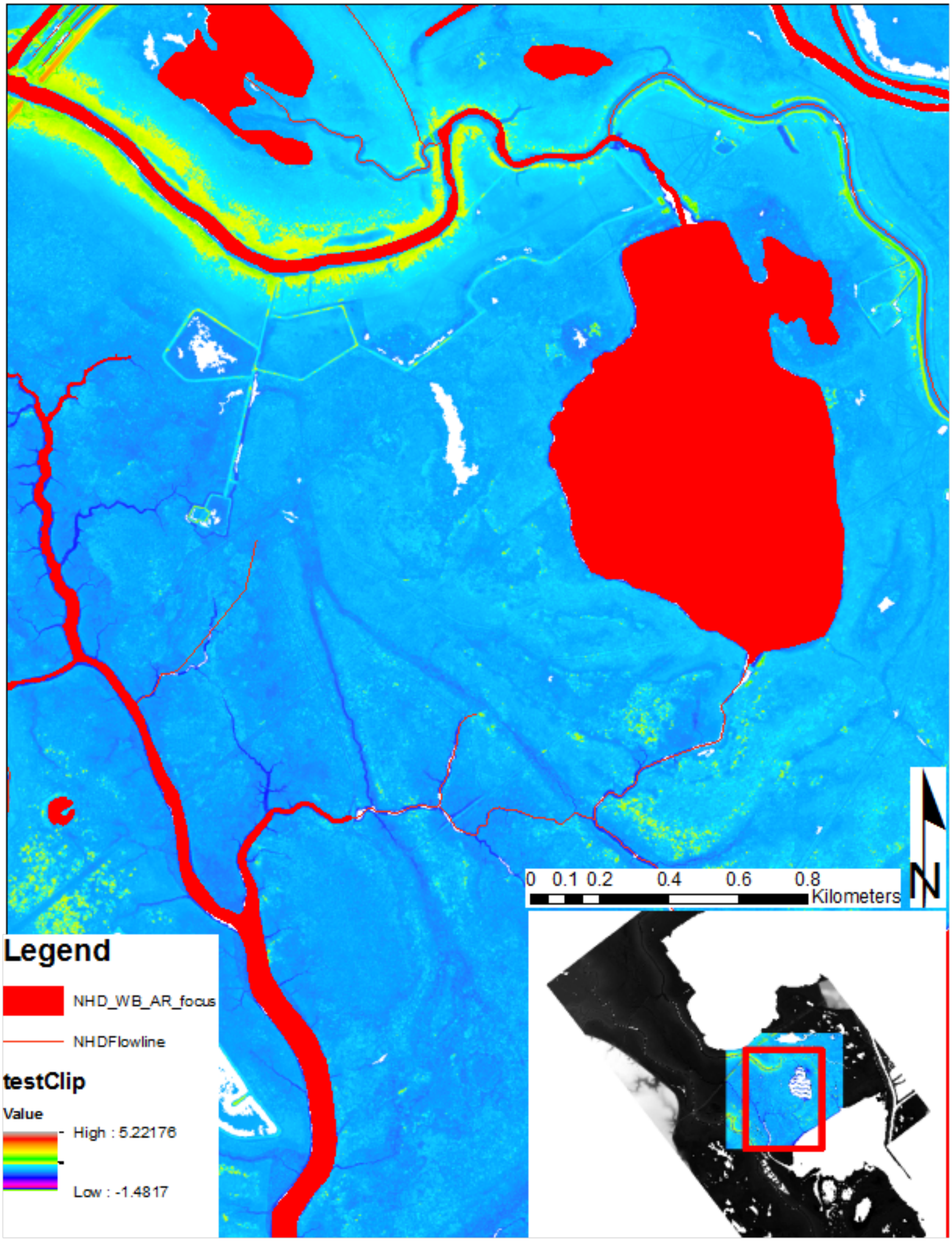

Figure 5. NHD flow lines and water bodies.

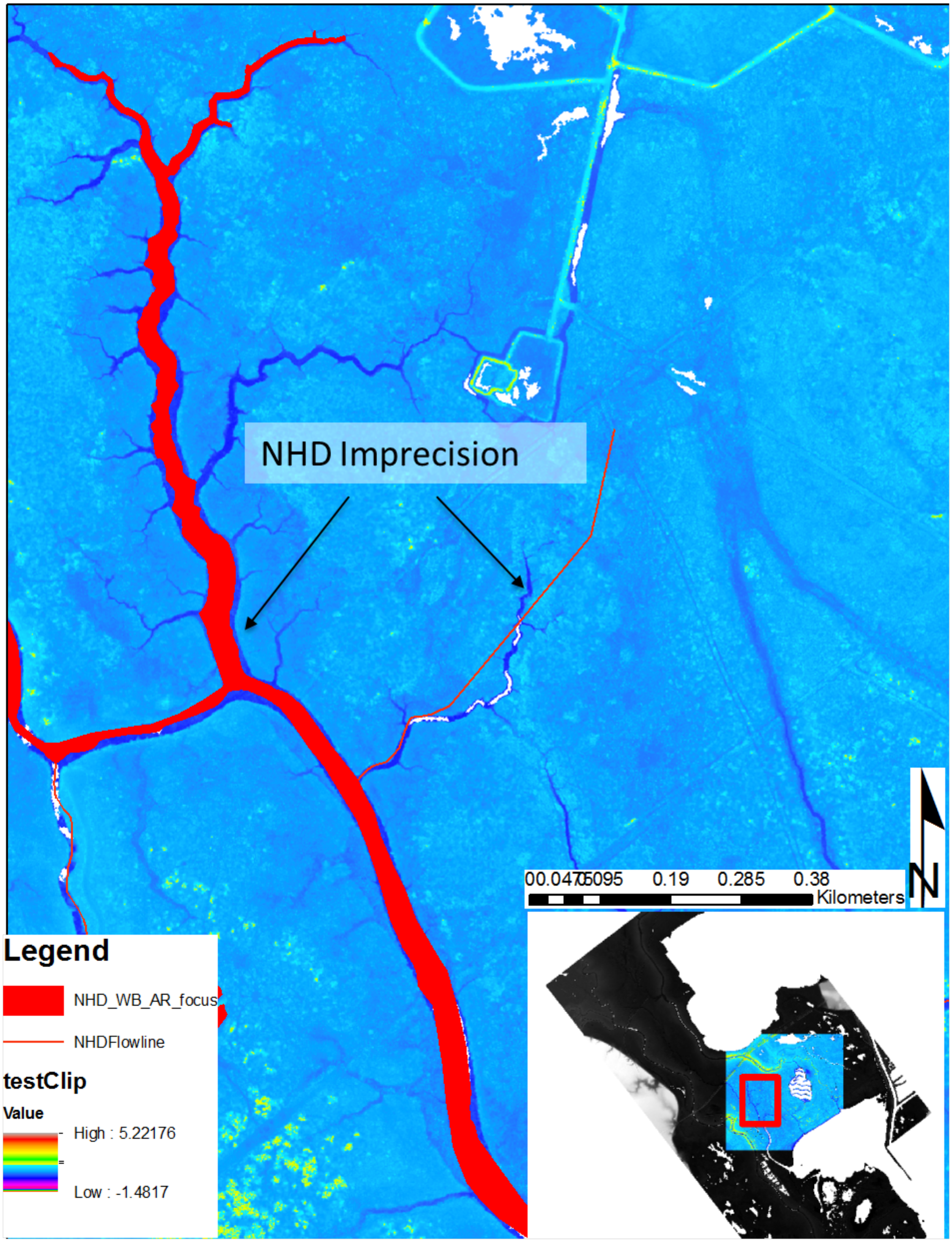

Figure 6. Enlarged NHD flow lines and water bodies.

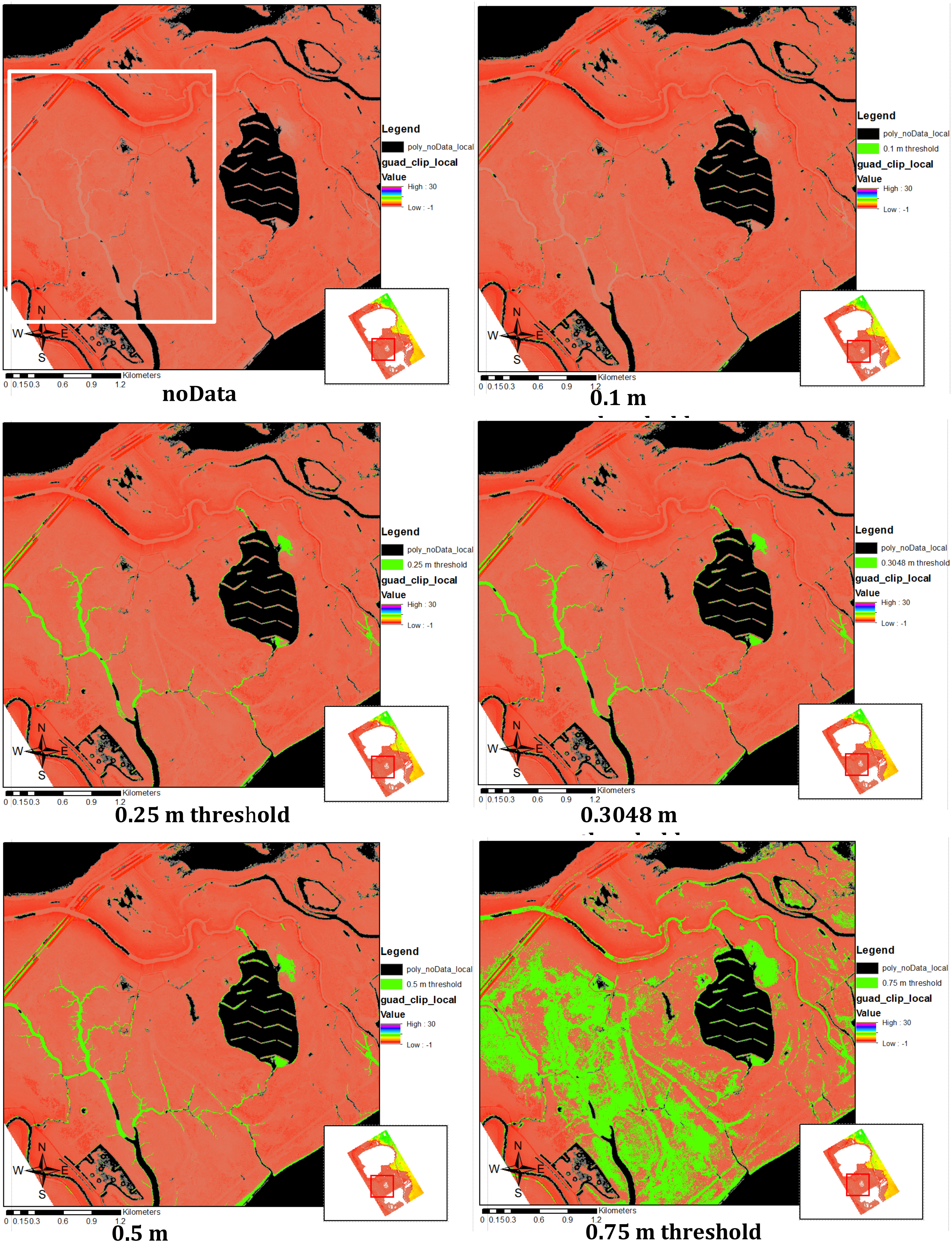

Figure 7. Increasing channel network clarity (and noise) with increasing elevation threshold.

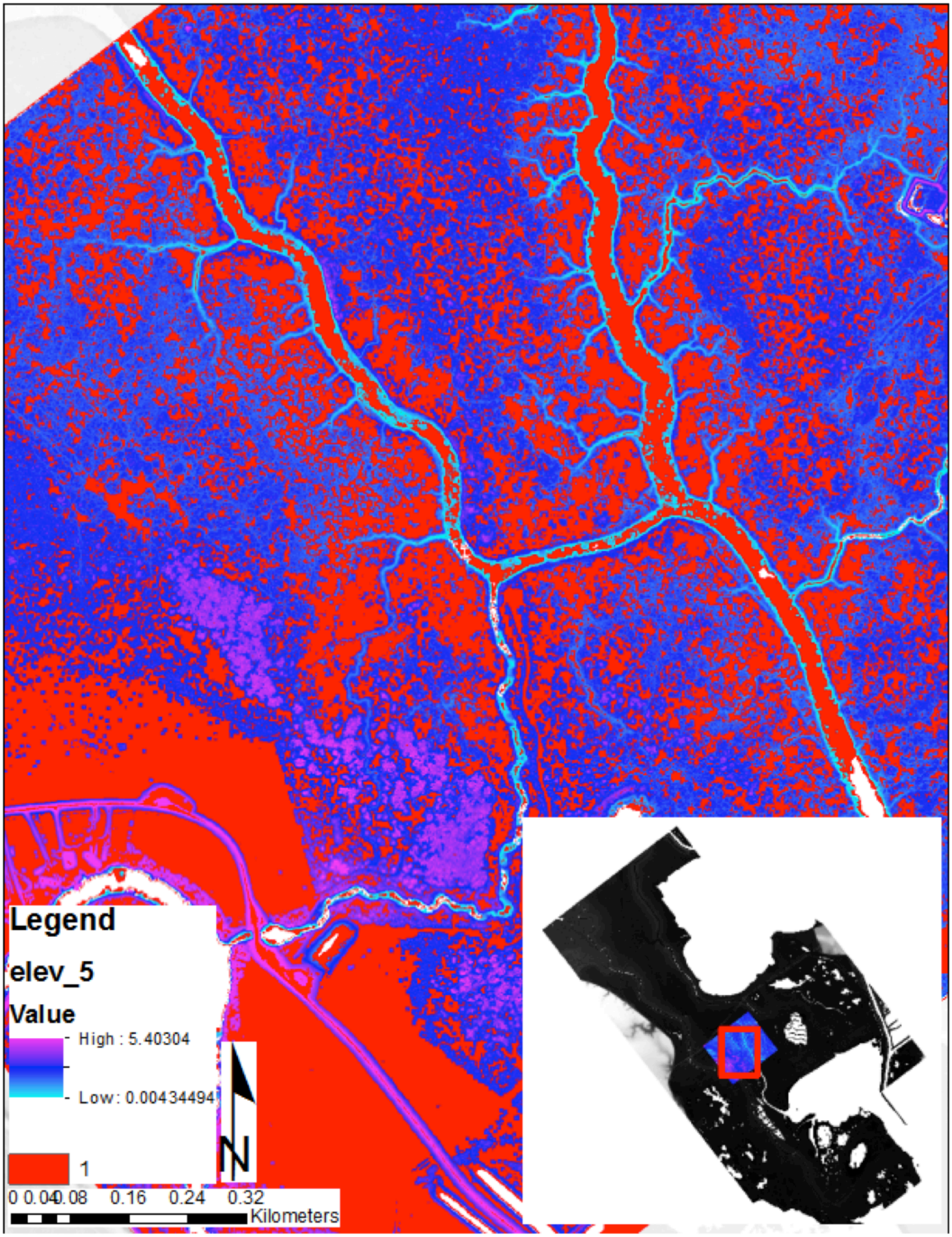

Figure 8. TerEx terrace extraction tool output seen in red.

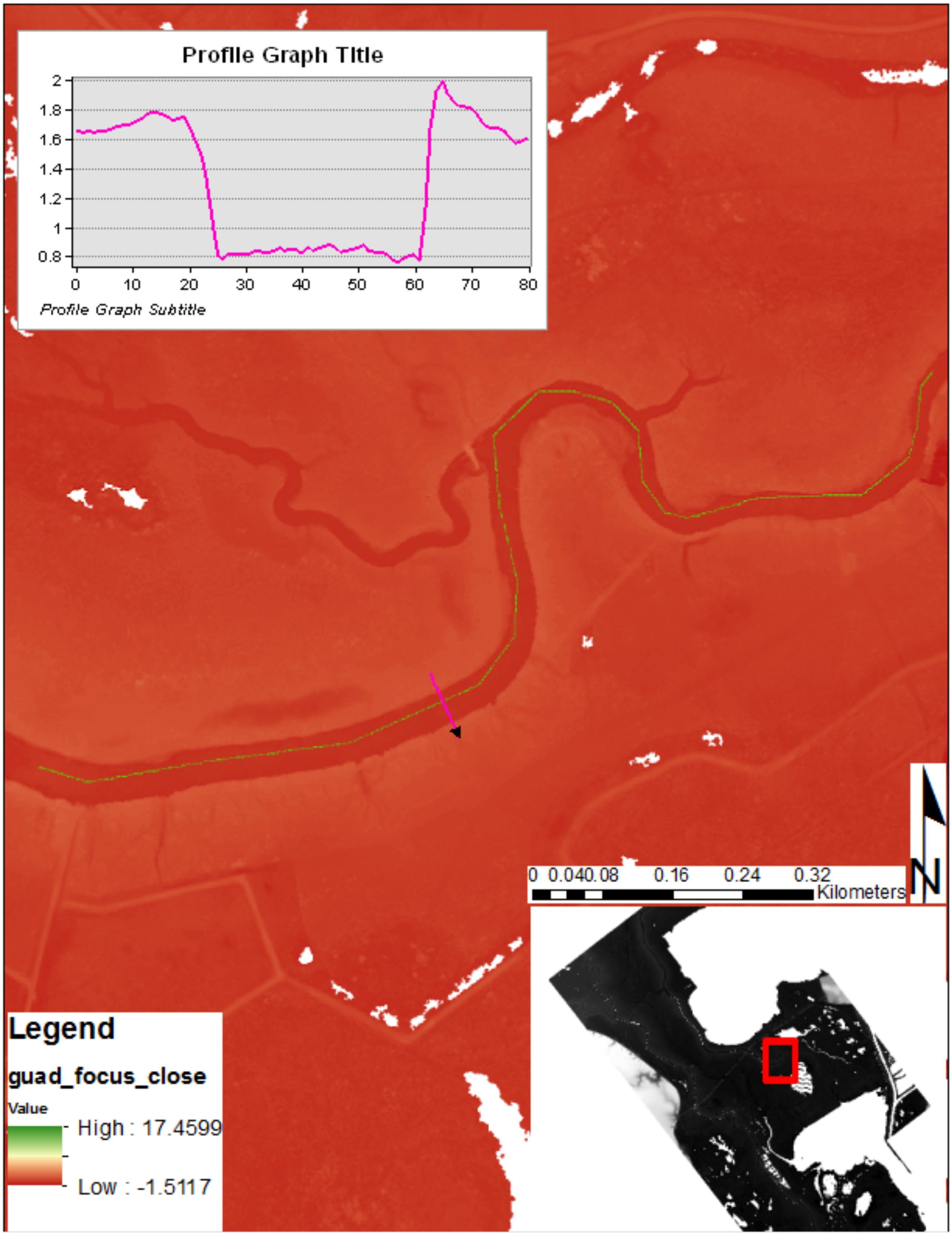

Figure 9. Artificial flowline used for GeoNet2.0 analysis. Profile view seen left to right as arrow transects flow

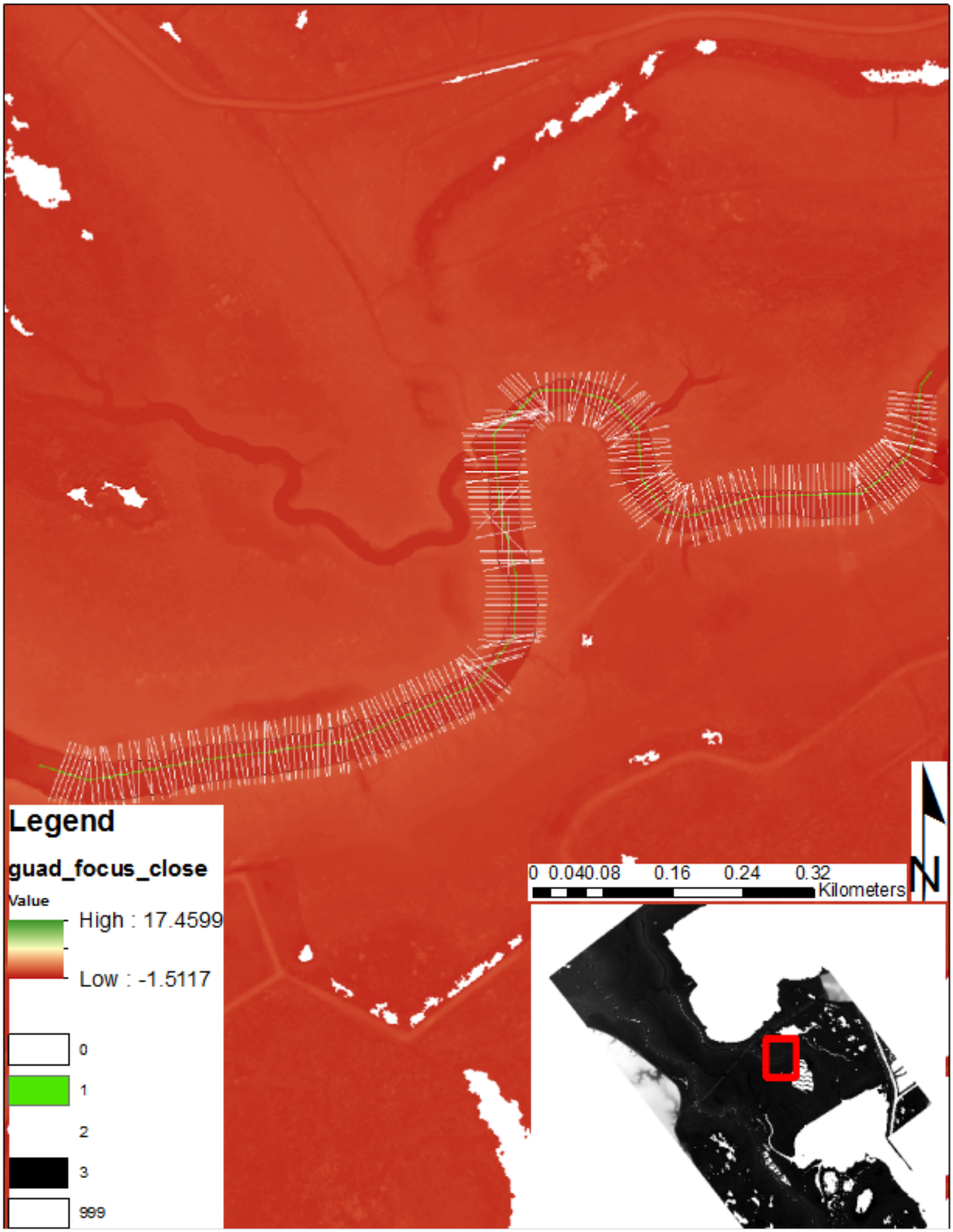

Figure 10. Cross sections generated by GeoNet2.0 code

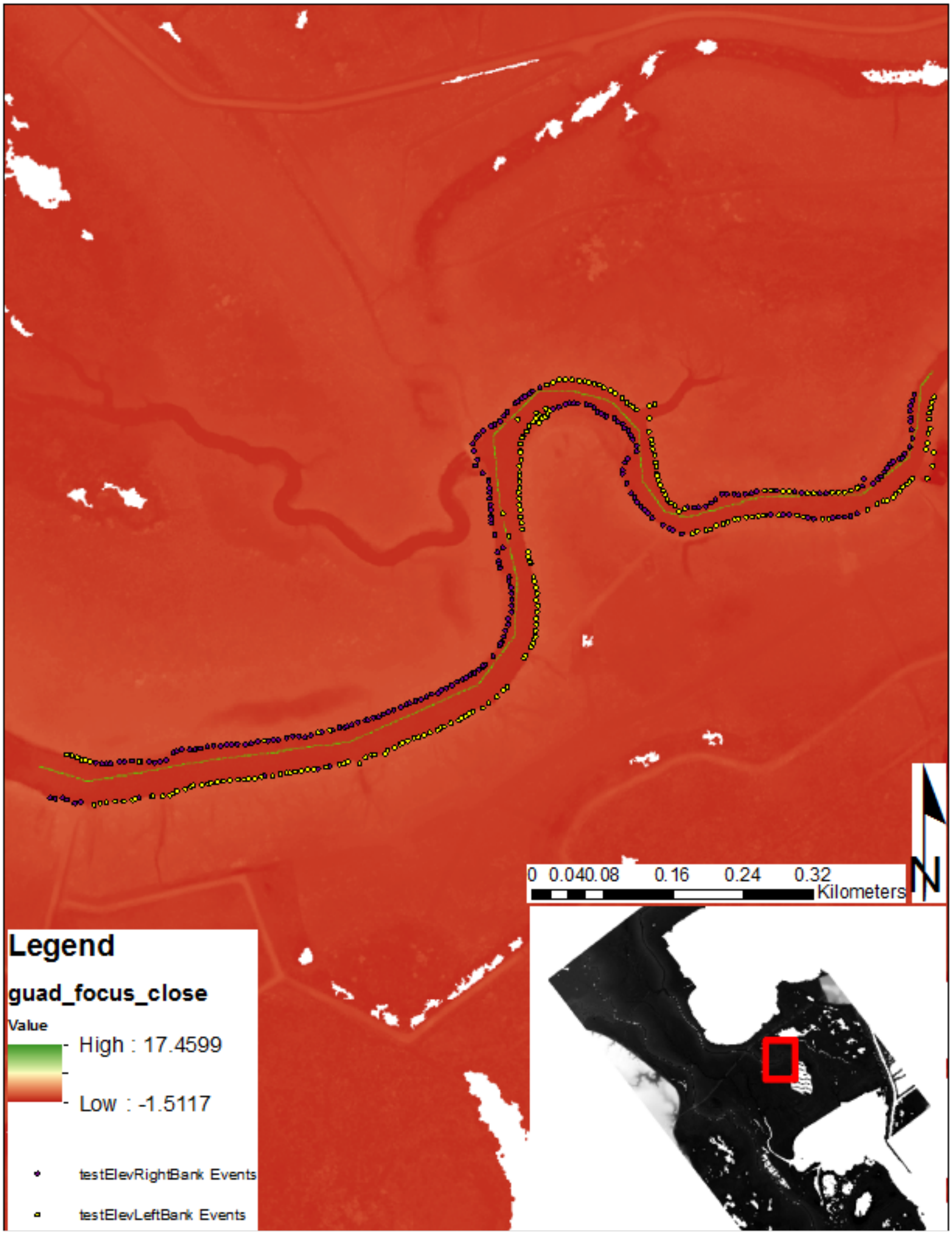

Figure 11. Left and right banks as identified by GeoNet2.0. Note the switching of bank sides by left and right banks

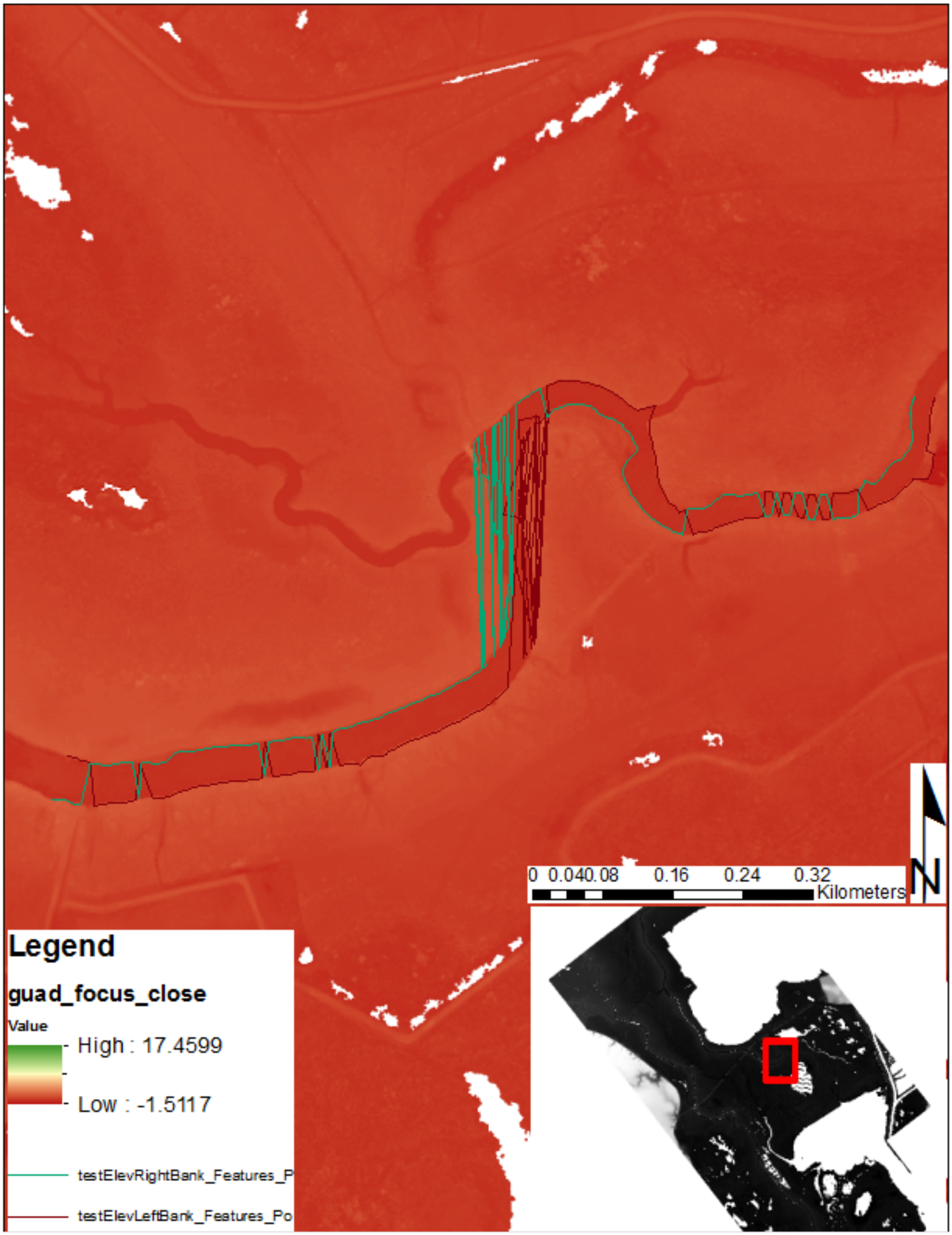

Figure 12. Bank edges determined by bank locations from GeoNet2.0. Note the large irregularities in the center

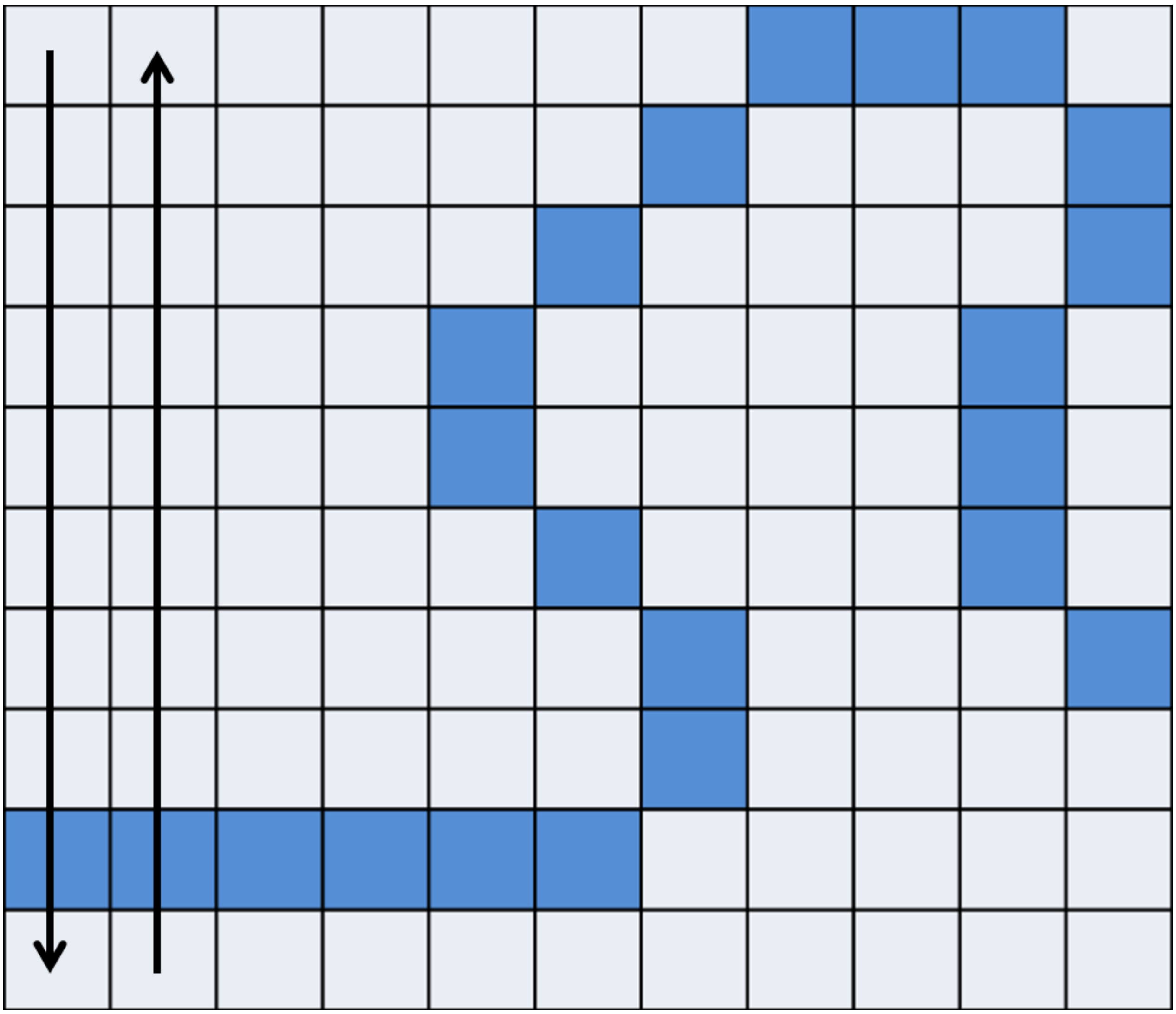

Figure 13. GeoNet2.0 interpretation of rasterized stream lines

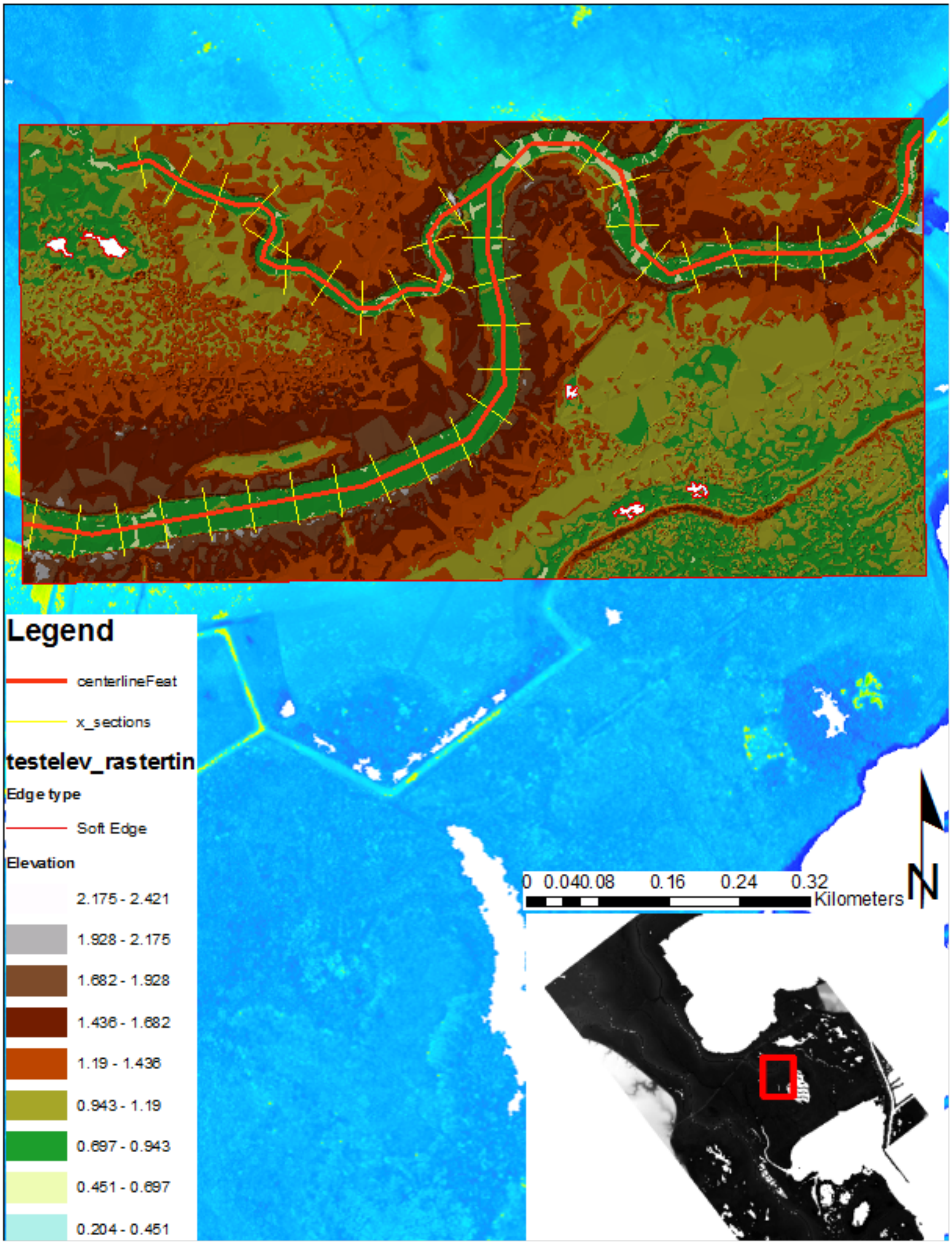

Figure 14. Cross sections generated by HEC-GeoRAS atop TIN of DEM