Optimizing DEM Resolutions for Terrain and Hydrologic Analyses in Browns Canyon Wash

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SSCI581- Concepts for Spatial Thinking

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1. Introduction

This project examines the influence of spatial resolution on terrain and hydrologic analyses within Browns Canyon Wash, utilizing Digital Elevation Models (DEMs) at 1m, 10m, and 30m resolutions. By applying a suite of GIS tools, this study aims to ensure the optimal DEM resolution that balances analytical precision with computational efficiency for environmental studies. Also, terrain analyses encompass the generation of Hillshade, Alope, and Aspect maps, while hydrologic analyses focus on stream flow identification and watershed delineation.

2. Study Area Description

As illustrated in Figure 1, the Santa Susana Mountains near Los Angeles are home to Browns Canyon Wash; also, this sub-watershed of the Los Angeles River is essential for regional hydrology, supporting a variety of ecological systems. According to region, the research area is marked by a bounding rectangle that includes both natural as well as developed areas which impact water flow and terrain structure.

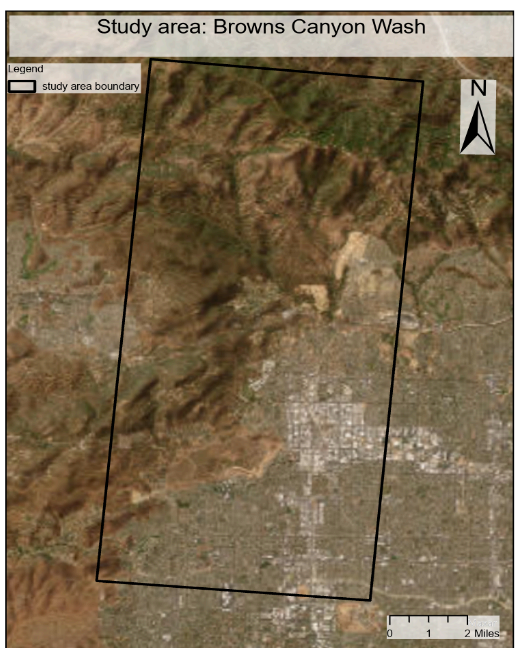

Figure1. Boundary of Study Area

3. Data Table

Dataset Description	Usage in Analysis	Data Source
Bounding Rectangle of Study Area	DEM extraction mask	USC Spatial Science Institute
DEM datasets (1m, 10m, 30m resolutions)	Terrain and hydrology analysis	USGS 3D Elevation Program
USGS-defined Browns Canyon Wash Boundary	Watershed boundary comparison	USGS Watershed Boundary Dataset

Table 1: Data Sources and Uses for Browns Canyon Wash Analysis

4. Method

4.1 Data Preparation

To prepare for an study of 1m and 30m Digital Elevation Models (DEMs), the initial step involved importing the original dataset, which consists of a grid of cells measuring 30m by 30m. Furthermore, given the necessity for accuracy and the ability to compare across different scales, both of the (1m and 30m) DEMs were mapped into “NAD 1983 UTM Zone 11N”, similar to the 10m DEM utilized for reference purposes. Besides, this projection was selected to minimize distortion across the study area. To tailor the dataset specifically to the area of interest, a masking technique employing a bounding rectangle feature was used. However, this was important to focus an study and ensure consistency in terrain analysis across different resolutions.

4.2 Terrain Analysis

the topographic analysis began with the application of the "Hillshade" tool on the (1m and 30m) DEMs as shown in Figure 2 and Figure 3. Initial runs were performed using default parameters to establish baseline Hillshade models for each resolution.

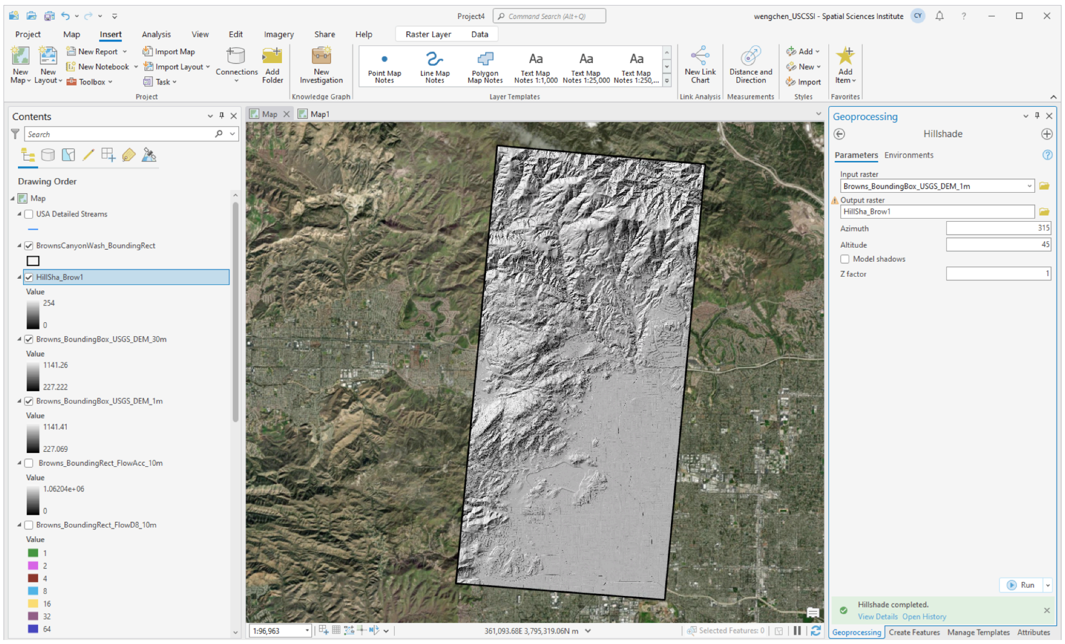

Figure 2. The “Hillshade” Surface with (1m) Resolution

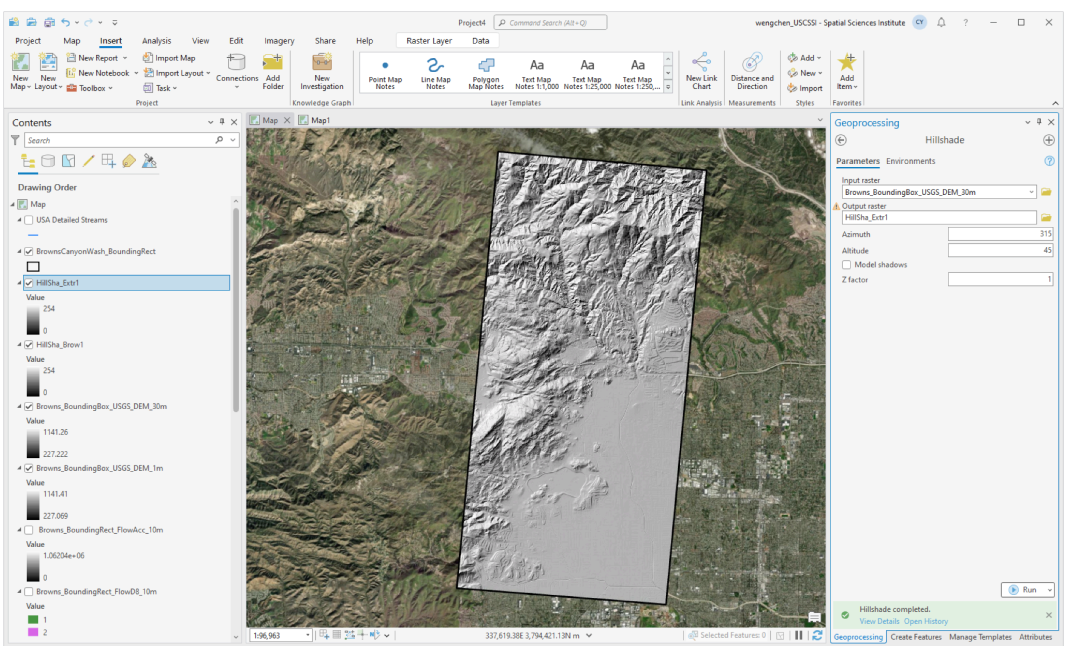

Figure 3. The “Hillshade” Surface with (30m) Resolution

To investigate how the impacts of sunlight angle on terrain visualization, the altitude parameter was adjusted from 45 to 80 degrees in subsequent iterations for the 30m DEM as shown in Figure 4. This adjustment aimed to simulate different sunlight conditions and enhance the visualization of terrain features, based on the understanding that sunlight angle can significantly affect the perception of topographical depth and relief.

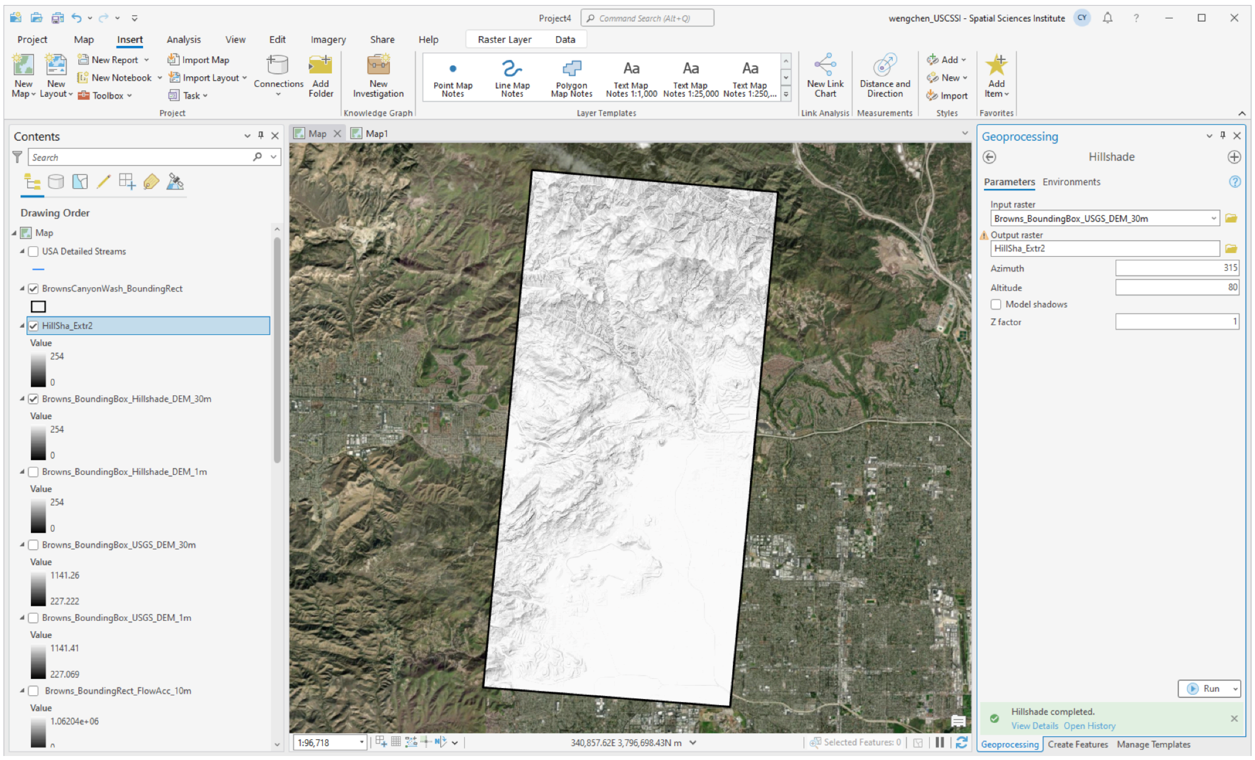

Figure 4. The “Hillshade” Surface Resolution with Increased Altitude Variable (30m)

Moreover, in an attempt to enhance the visual representation of hills and valleys, the Z factor was increased from 1 to 10 for the 30m DEM; also, this variation is depicted in Figure 5. The change was inspired by the view that height exaggeration may be helpful in understanding of scenery features, particularly in places with subtle topographic differences.

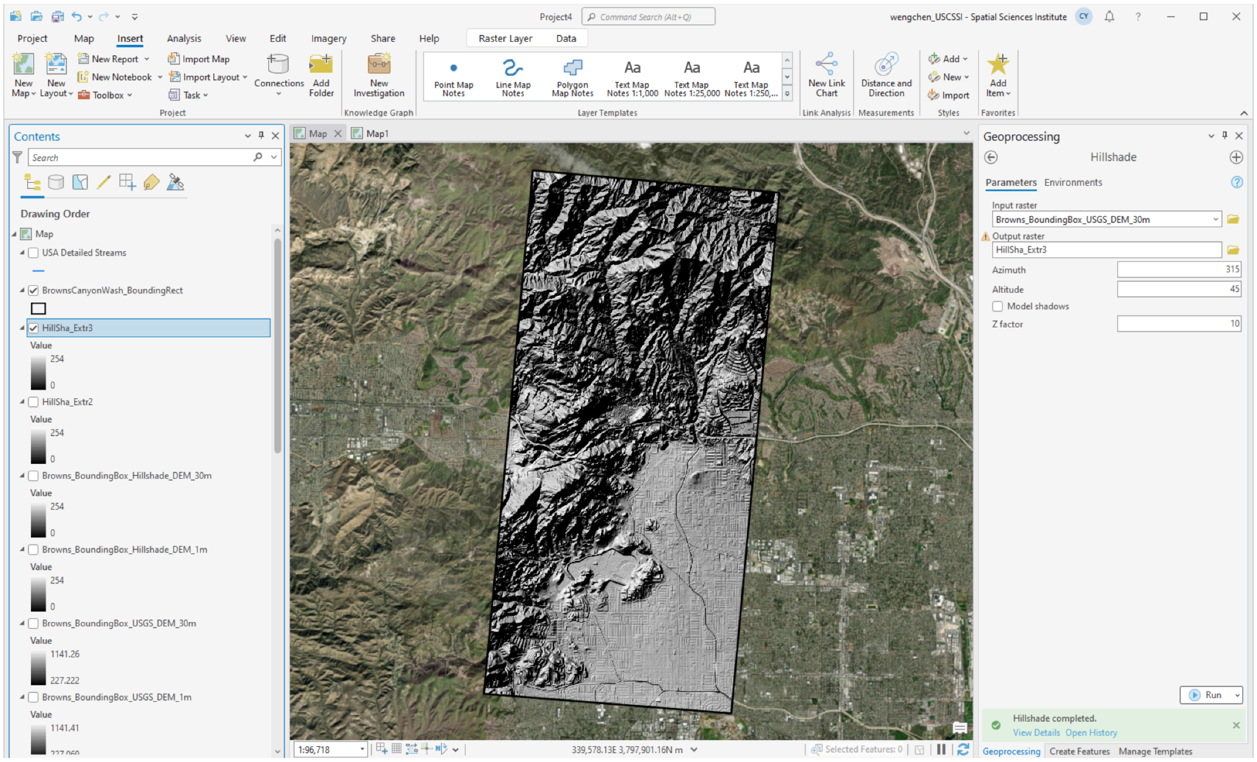

Figure 5. Elevated Z Factor Amplified “Hillshade” Surface Resolution (30m)

The "Slope" tool was then employed to calculate the terrain's gradient. Initial analyses used default settings to generate slope maps regarding the DEMs (1m and 30m) as shown in Figure 6, and Figure 7. These maps underwent naming conventions for organization and ease of reference. Close inspection of the generated slope maps revealed differences in terrain detail visibility between resolutions, prompting further examination of specific areas to assess the data's granularity and the slope's representation accuracy.

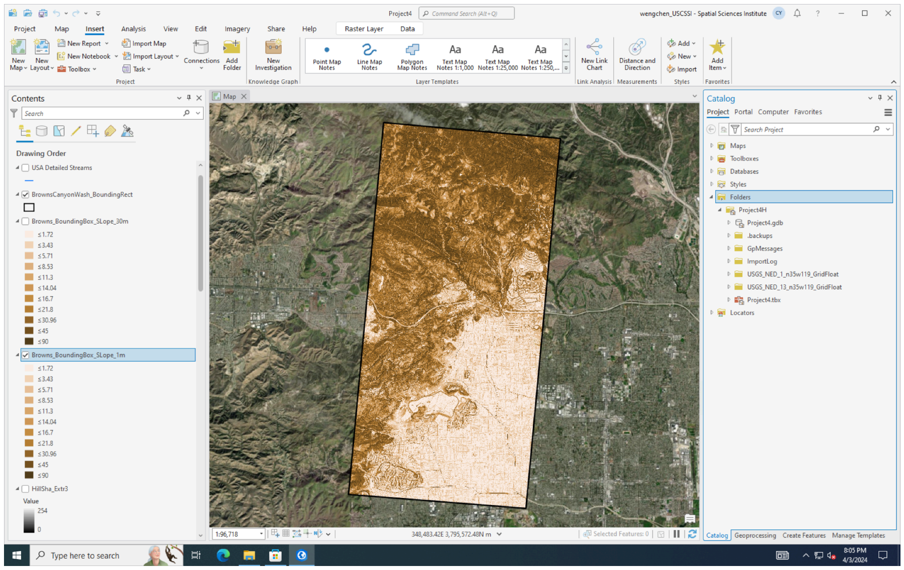

Figure 6.The “Slope” Surface with a Resolution (1m)

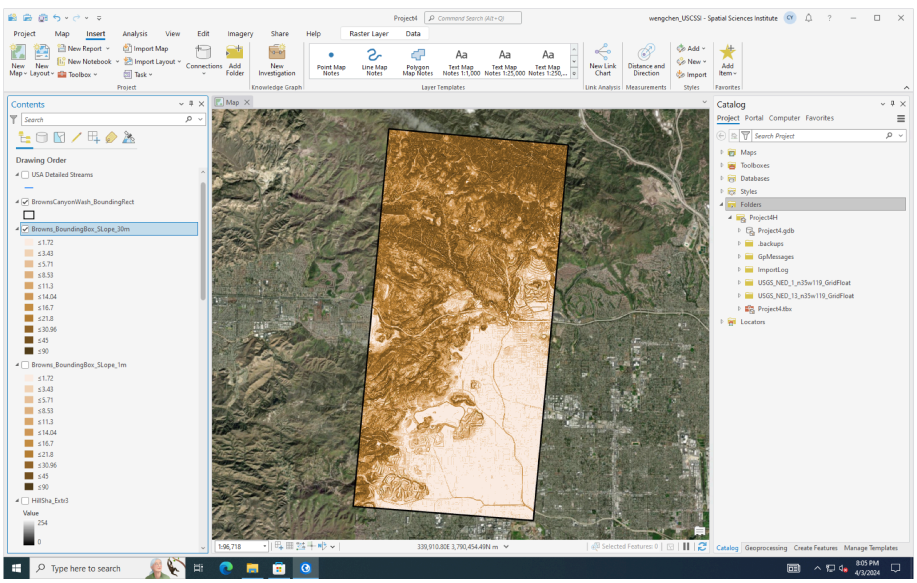

Figure 7. The “Slope” Surface with a Resolution (30m)

At first glance, “Slope” surfaces across various resolutions appear remarkably similar. However, upon closer inspection, by zooming into the map, the 1m map reveals greater detail as shown in Figure 8, whereas the 30m map exhibits a more vague representation as shown in Figure 9.

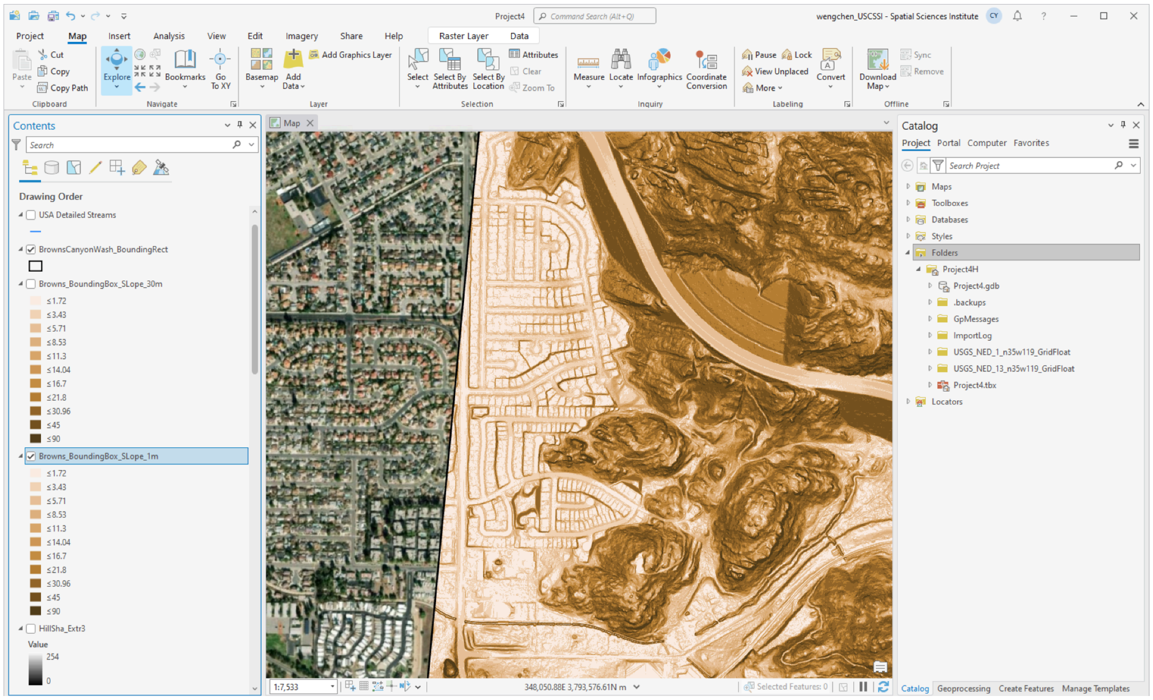

Figure 8. An Overview of “Slope” Surface Resolution in Detail (1m)

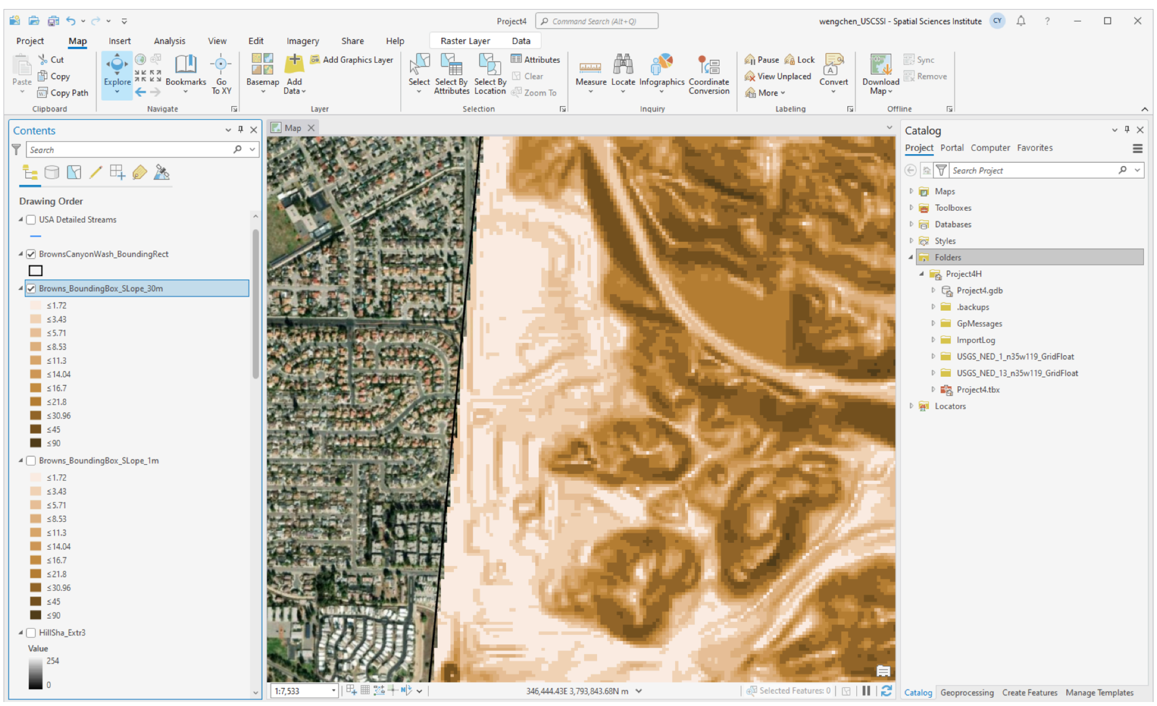

Figure 9. An Overview of “Slope” Surface Resolution in Detail (30m)

Aspect maps were generated using the "Aspect" tool for both resolutions, with an interest in comparing how directional slopes are depicted across the varying scales. Aspect analysis, good for understanding watershed drainage patterns and solar exposure, was performed to elucidate the methodological impacts of DEM resolution on capturing terrain orientation as shown in Figure 10, and Figure 11.

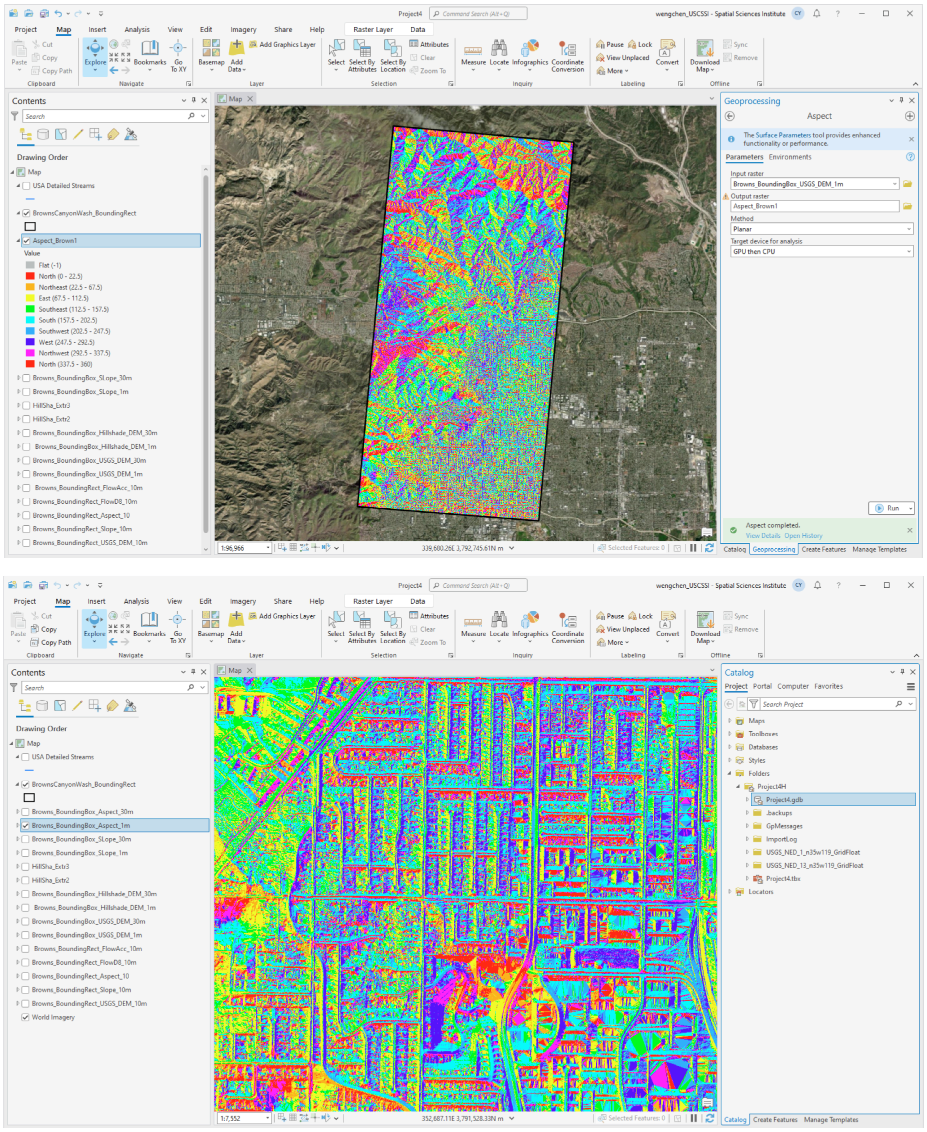

Figure 10. The Aspect Surface at 1m Upon Closer Inspection

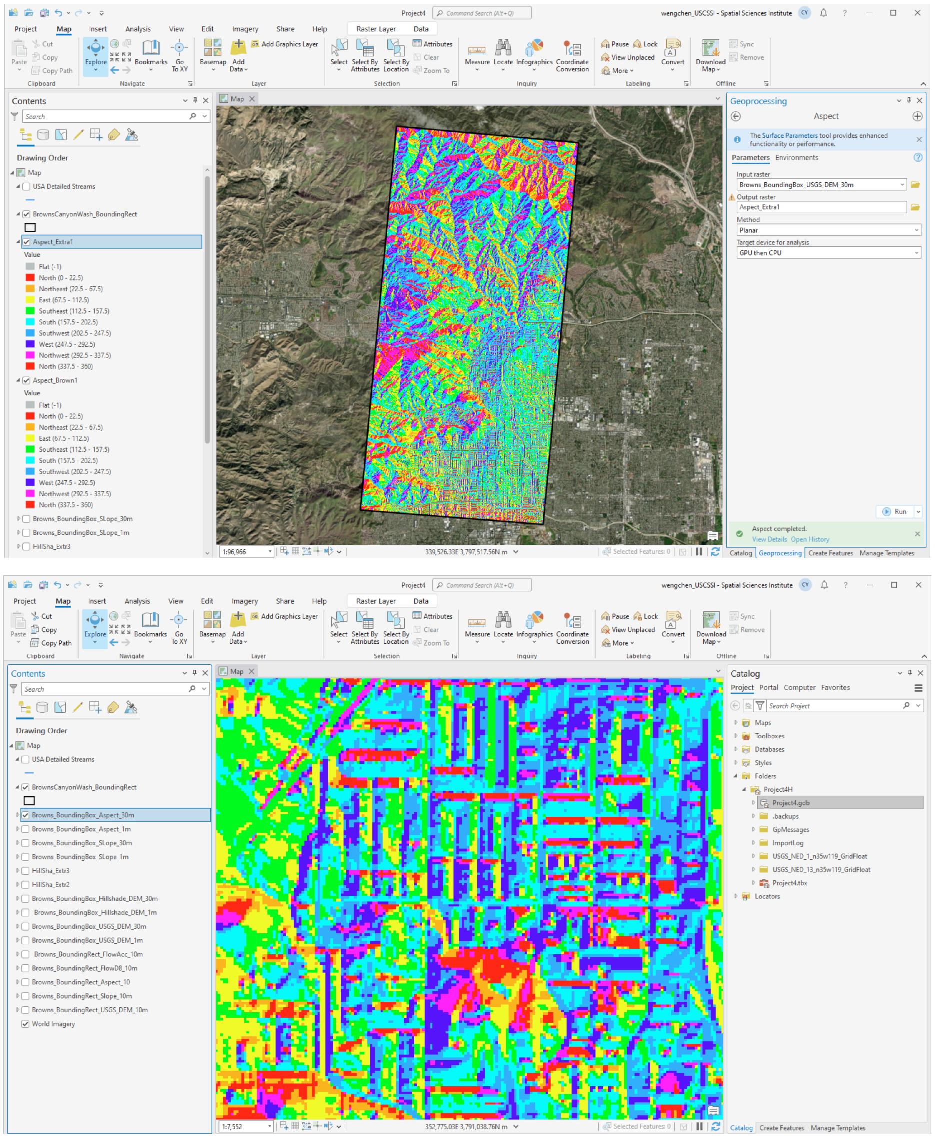

Figure 11. The Aspect Surface at 30m Upon Closer Inspection

4.3 Analysis of Stream Flow

The hydrologic analysis commenced with the application of the "Fill" tool to both DEMs to eliminate data voids that could interrupt water flow simulation as shown in Figure 12. This step ensured a continuous elevation surface, vital for accurate downstream flow direction modeling.

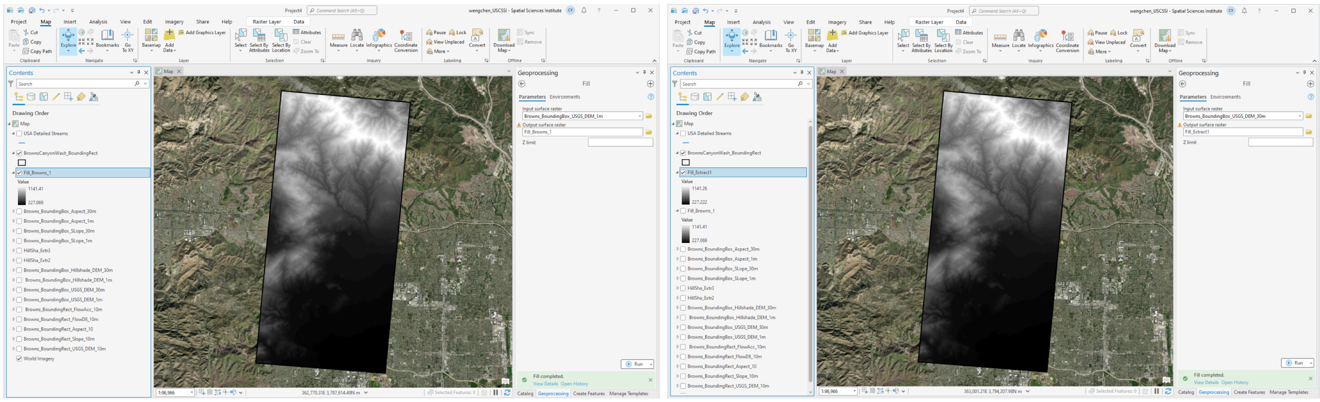

Figure 14. The application of the "Fill" tool to both DEMs (1m, 30m)

was measured for the (1m and 30m) DEMs using the "Flow Direction" tool with the default D8 algorithm selected, as Figure 13 illustrates. Moreover, this algorithm was selected for its ability to model water flow from each cell to its steepest downslope neighbor, a method widely accepted for its simplicity and effectiveness in hydrologic modeling.

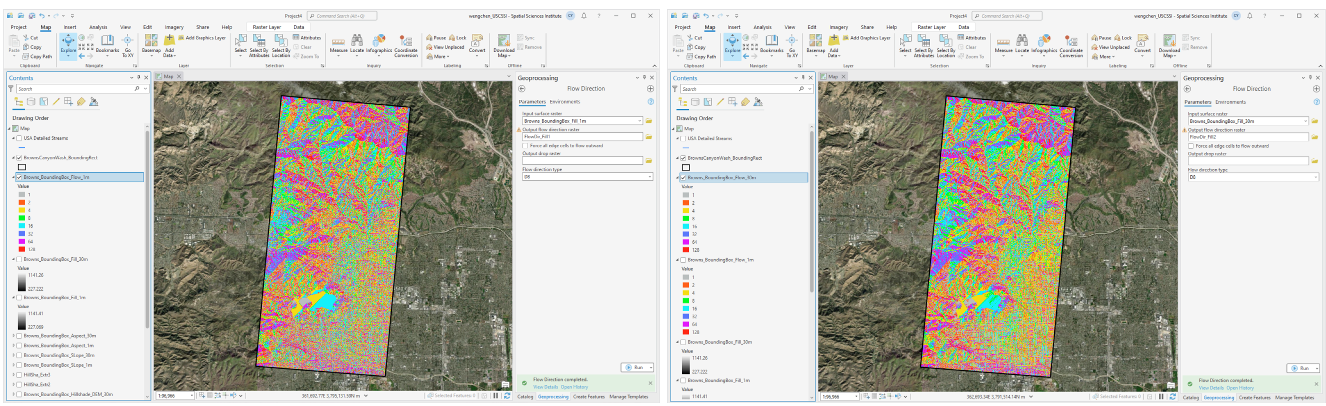

Figure 13. The application of the "Flow Direction" tool to both DEMs (1m, 30m)

The next step involved the computation of accumulated flow.This was achieved by employing the “Flow Accumulation” tool, which, as Figure 14 illustrates, shows the sum of the weight of all cells which contribute to each downslope cell in the output raster.

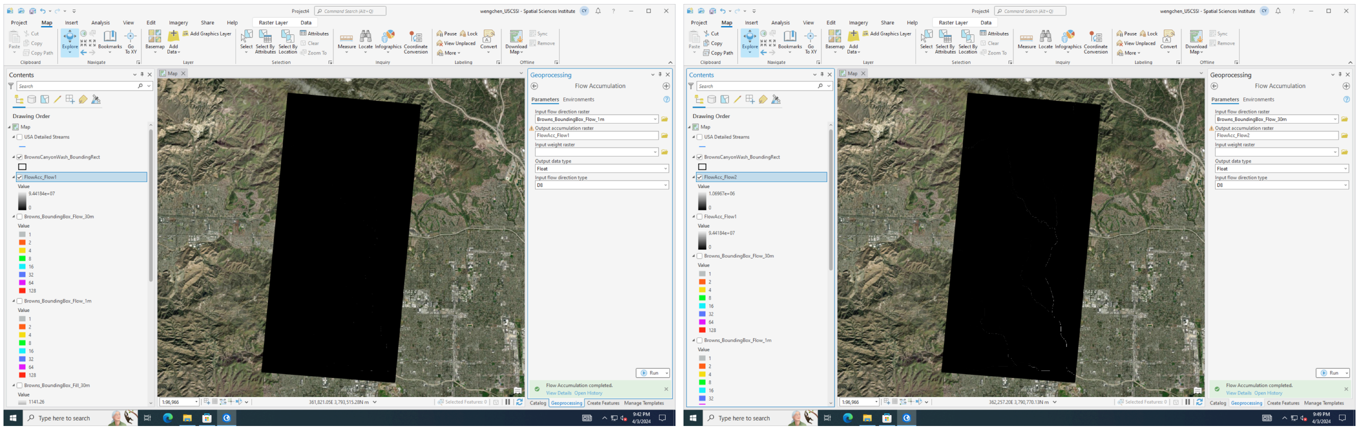

Figure 14. The application of the "Flow Accumulation" tool to both DEMs (1m, 30m)

Upon obtaining the flow accumulation layer, the primary symbology was altered to "Classify" to facilitate the visualization of streams. A closer examination of the flow accumulation layer with (1m) resolution revealed the presence of straight lines resembling streams. These lines, however, represented streets that intercepted some of the water flow, potentially complicating the identification of actual streams. To mitigate these discrepancies, various cutoffs for the symbology were tested, including 100, 1000, and 10000. Additionally, the “US Detailed Streams” layer was was turned on in order to identify the valley's principal streams and do a comparison study in the (1m flow) “Accumulation” layer. It was observed that higher cutoff values corresponded with fewer red lines, indicating a clearer distinction of stream paths. Consequently, a cutoff of 10000 was selected for the 1m accumulation layer’s symbology, as it aligned more accurately with the main streams in the valley, as depicted in Figure 15. A similar approach was applied to the 30m accumulation layer, with the determination that a 1000 cutoff value offered a clearer representation of the terrain, illustrated in Figure 16.

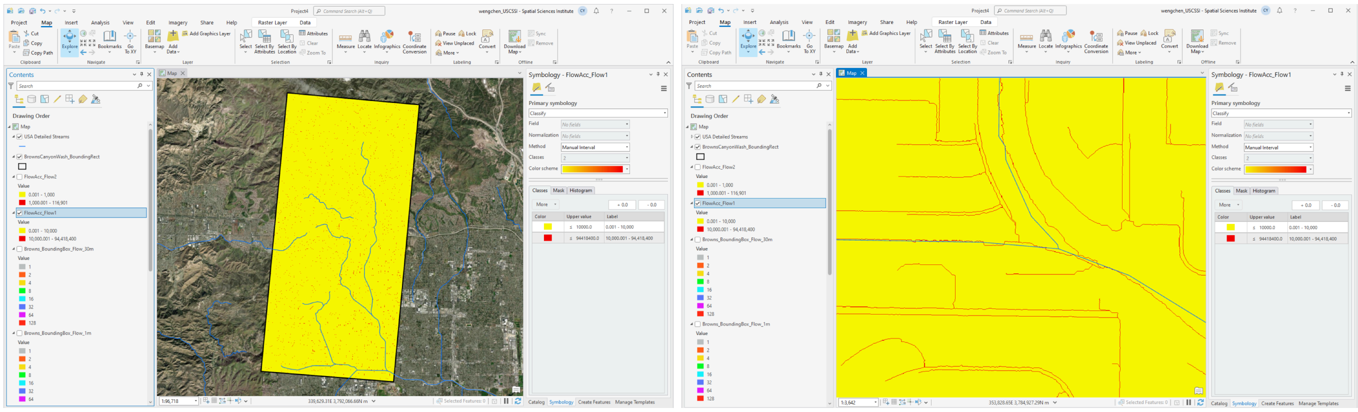

Figure 15. 1m Flow Accumulation Displayed in Two Categories Using a 10000 Cutoff Value

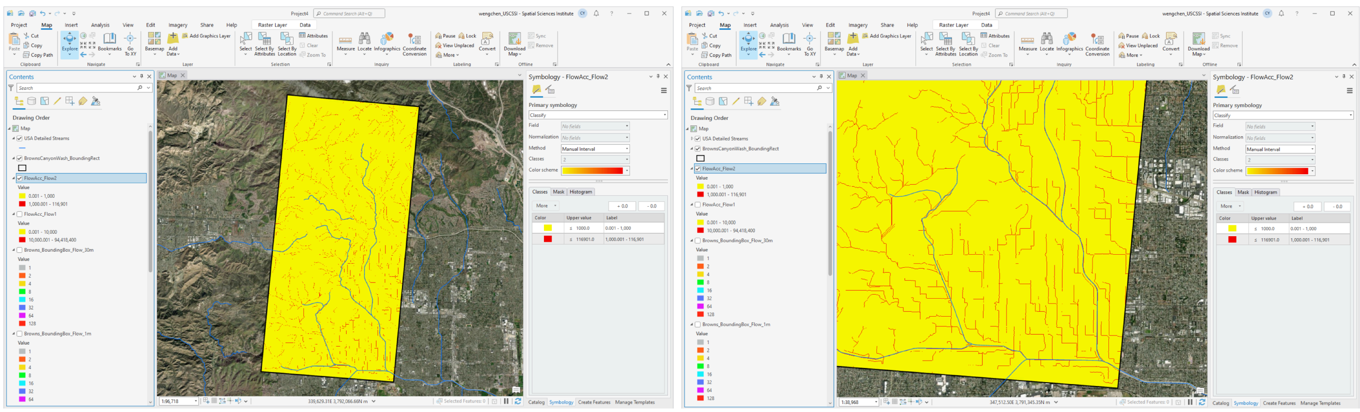

Figure 16. 30m Flow Accumulation Displayed in Two Categories Using a 1000 Cutoff Value

4.4 Land Area Calculation

Identifying the precise pixel where Brown Canyon Creek joins the Los Angeles River was critical for accurately calculating the land area draining into the creek. This pinpointing process, illustrated in Figures 17 and 18, underscores the meticulous attention to detail necessary in geographic analysis. The calculation of land area based on pixel value and resolution highlights the intersection of spatial data and mathematical principles in environmental analysis.

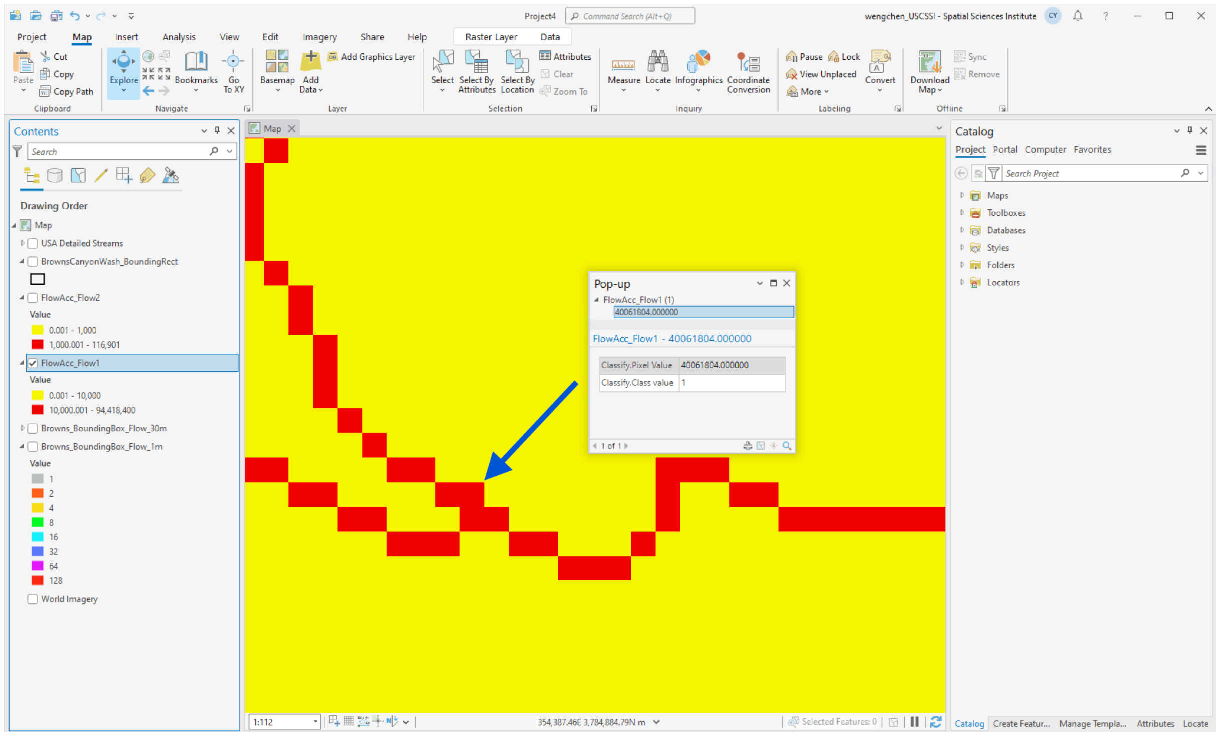

Figure 17: Accumulation at Creek-River Join (1m)

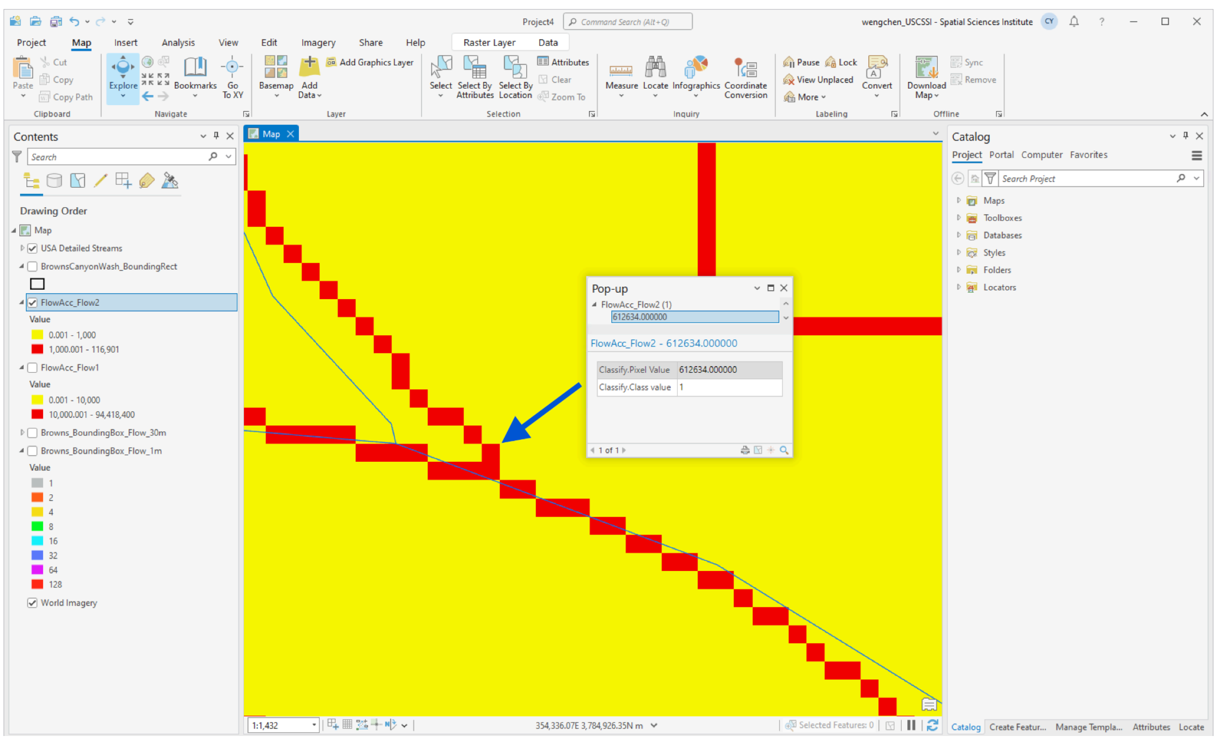

Figure 18: Accumulation at Creek-River Intersection (30m)

The identified pixel for the 1m DEM has a value of 40061800, which translates to a land area of 40.0618 km^2 when calculated as 400618001/1000000. For the 30m DEM, the identified pixel value of 612634 results in a land area calculation of 551.3706 km^2, using the formula 61263430*30/1000000.

for the selected pixel to construct and edit a point; also, this point acted as the reference for further procedures to define the Browns Canyon Creek watershed boundary. The Watershed tool was then applied, along with the flow direction and reference point layers at (1m, 10m, and 30m) resolutions, to produce the watershed boundary outlines for "Browns Canyon Wash", revealing the contrast in detail at each resolution.

4.5 Create Finished Map

The creation of the final map layout involved synthesizing the analytical findings with visual elements like legends, scale bars, and north arrows to communicate the results effectively. This process not only demanded technical skill in GIS tools but also an understanding of cartographic principles to produce a map that is both informative and visually appealing.

5. Results

In the findings, focus was placed on examining terrain and hydrological features across three distinct DEM resolutions: 1m, 10m, and 30m, within Browns Canyon Wash. The terrain analysis conducted unveiled significant differences in the depiction of terrain features such as elevation, slope, and aspect across these resolutions, highlighting the impact of spatial resolution on the perception of physical geography. This comparative analysis is visually summarized in Figure 19, illustrating the variations in terrain features observed at the 1m, 10m, and 30m DEM resolutions.

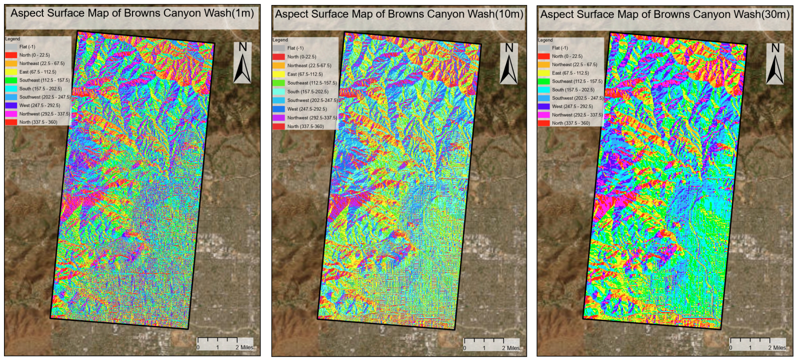

Figure 19. Browns Canyon Creek 30m Aspect Surface Map (1m, 10m, 30m)

Similarly, in the hydrologic analysis, attempt was dedicated to delineating the watershed boundaries for each resolution, comparing the findings with the USGS-defined boundary to gauge accuracy. This part of the work yielded essential insights into how the choice of DEM resolution influences watershed modeling and the precise identification of hydrological flow paths. Figure 20 presents watershed boundary delineations for the 1m, 10m, and 30m DEMs, respectively, offering a clear visual comparison against the established USGS boundary. These figures underscore the challenges posed by the resolution of space in environmental modeling, emphasizing the importance of selecting an appropriate scale for accurate terrain and hydrologic analyses.

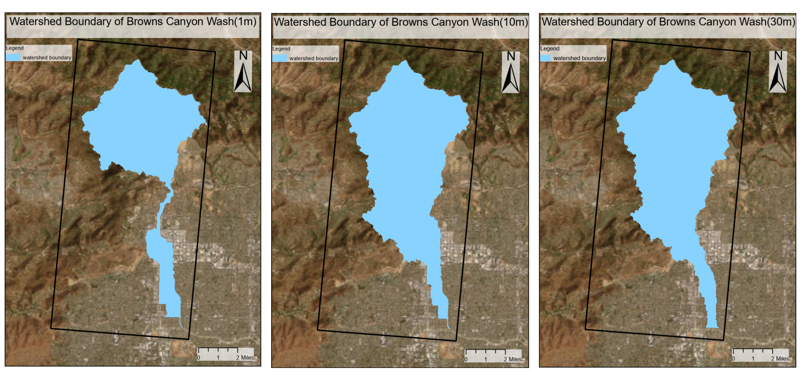

Figure 20. Completed Map of Browns Canyon Creek Watershed Boundary (1m, 10m, 30m)

6. Discussion

6.1 Terrain Analysis

For terrain analysis in Browns Canyon Wash, the **(10m) DEM scale** is the most appropriate for topographical analysis. It captures the ideal balance between data handling and detail, capturing essential terrain features without overwhelming computational resources. This scale minimizes the impact of the Modifiable Areal Unit Problem, reducing the risk of overemphasizing minor details or oversimplifying the landscape, which aligns with our goal of accurately representing terrain characteristics necessary for medium scale environmental assessments.

6.2 Hydrologic analysis

In contrast, for hydrologic analysis, the **(30m) DEM scale** is preferred because of its coarser resolution effectively captures the natural watershed boundary, offering a more accurate representation for regional scale studies. This choice adeptly addresses the MAUP by prioritizing natural hydrologic patterns over detailed anthropogenic features, which are less critical for broad watershed analyses. However, the 30m scale's focus on essential hydrologic features aligns with the requirement for a resolution that mirrors the spatial scale of the processes being examined.

MAUP considerations guide the selection process with the aim of minimizing scale related distortions in interpretation. Choosing scales that align with analysis goals, specifically 10m for terrain analysis and 30m for hydrologic analysis, helps to mitigate the influence of MAUP. This approach ensures the methods used yield relevant and accurate insights for each analysis type, enhancing the validity and applicability of the findings to the environmental issues encountered in Browns Canyon Wash.