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Modernizing Floodplain Map Production with GIS
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Abstract

A cornerstone of the FEMA's (Federal Emergency Management Agency) National Flood Insurance Program (NFIP) is Map Modernization. One of this program's main goals is to produce timely digital updates of flood hazard maps for the entire nation. But while Map Modernization strives to improve map production, much of the data development relies on tedious manual engineering techniques. Given formidable time constraints and a lack of accurate digital data for some projects, procedures to streamline these manual techniques were developed using GIS technology, producing significant time savings. These procedures created and enabled data to be utilized by several different applications, while reducing the need to pass hard-copy maps with markups and comments between engineering and GIS staff. Manual techniques that would normally take one week to complete were reduced in some cases to eight hours. This paper will describe several of the procedures that were used to complete such a project in FEMA Region V.

Introduction

Map Modernization strives to significantly reduce the time it takes to produce Digital Flood Insurance Rate Maps (DFIRMs). The turn-around time from Scoping to Map Publication should be as little as 24 months[1]. With such a limited timeframe in place, it is critical for FEMA Mapping Partners to devise streamlined and innovative processes to produce timely map updates.

There are many examples of automated map production tools that are used once the hydrologic and hydraulic engineering work is complete. This paper will focus on two methods devised to automate or at least, significantly streamline the typically manual processes involved in floodplain delineation modeling and adjustments.

Examples shown are for a restudy of Lac Qui Parle County, Minnesota, which is located in the west-central portion of the state. Lac Qui Parle County occupies an area of 774 square miles and had a population of 9,067 as of the 2000 Census.[2] The focus will be on County Ditch No. 5, a stream located on the western boundary the County.

Floodplain Delineation

Redelineation of effective flooding is done to improve the overall match between the floodplain elevations and the best available topography. Automated hydrology and hydraulics packages such as HEC-RAS, HEC-GeoRAS and Watershed Analyst are used to produce the tabular and spatial data needed to produce generalized, draft polygons of floodplains. These packages rely on elevation data in the form of digital contours or Digital Elevation Models (DEMs) that meet FEMA's standards for spatial accuracy.[3]

What happens when the only available elevation data falls short of these standards? This problem was encountered recently in the restudy of Lac Qui Parle County. Over 100 miles of streams were to be restudied, and the available digital elevation data for the area were United States Geological Survey (USGS) 30 Meter DEMs. In order to meet FEMA specifications, 10 Meter DEMs would be required. The only suitable elevation data that existed for this area were United States Army Corps of Engineers (USACE) georeferenced images of contour maps with 4-foot intervals, derived from aerial photography. The only other data provided was digitized cross sections and tabular HEC-RAS output containing cross section station distances and flood top width measurements. This would eliminate the use of automated methods to delineate digital floodplains. The imagery obtained from the Corps of Engineers, while spatially accurate, was very difficult to read.

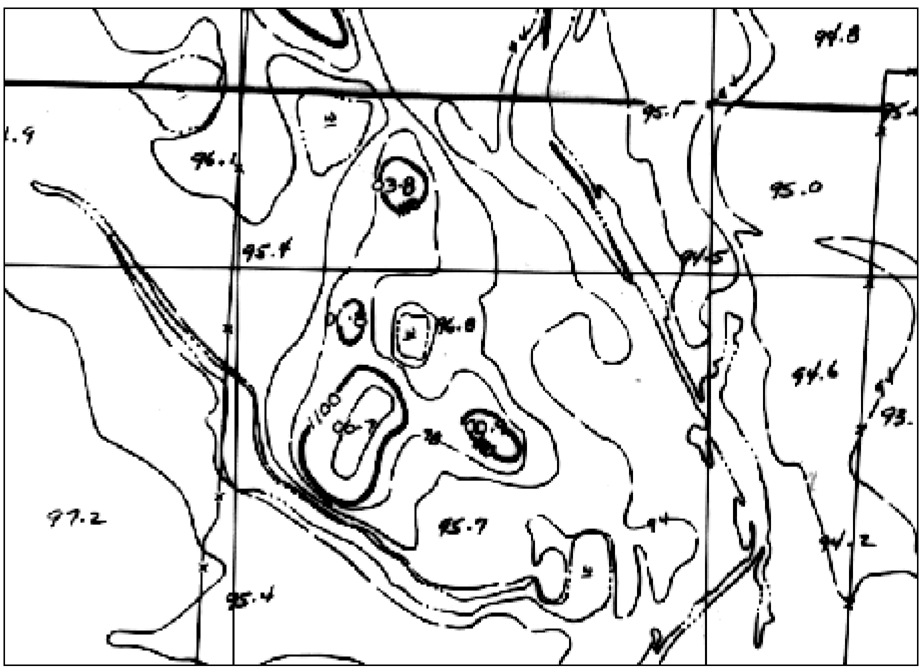


Figure 1: Close-up illustrating visual quality of available topographic map

One option for creating elevation data called for digitizing and attributing contour lines. Most analysts know that this is difficult under the best of circumstances, and with visual quality of the contour maps being so poor, digitizing thousands of square miles of floodplain area was certain to be a tedious and potentially mistake ridden process. Another option required hand drawing the flood plains based on the flood top widths produced by HEC-RAS, but given the spacing between cross sections, this also promised to be a less than optimal solution.

An innovative and cost effective method was devised to automate large portions of delineation by exporting floodplain top width and flood elevation data directly from hydraulic models into table form. Digitized cross sections were attributed with this information and a simple first-cut delineation connecting the attributed cross sections was devised. Instead of having to manually delineate, GIS analysts and scientists were instead able to merely correct the draft delineation, saving hundreds of hours.

Through ArcObjects and Visual Basic programming, a tool was devised to assist in delineation. The tool calculated and created points to mark the 100-year and 500-year flood top widths along each cross section. By obtaining these points, generalized arcs and polygon features could be constructed to provide the basic shape of the floodplain. These features would then be reshaped to the match the corresponding contour lines. The points acted as "guideposts" to ensure that polygon reshaping remained on course throughout the process. Comparing cross section water surface elevations to the contour lines was efficiently managed by simply turning on labels marking those spots. Having these visual references available made floodplain delineation far more accurate and efficient than by simply digitizing contours or drawing the floodplain by hand.

Materials

The materials required for the delineation tool to run included the following:

1. HEC-RAS modeling data that included cross section identifiers, top width left and right overbank distances for 100-year and 500-year flood events, and corresponding water surface elevations at each cross section. This tabular data was then converted into GIS compatible DBF files
2. Digitized cross sections obtained from USACE workmaps
3. Digitized profile baseline, also obtained from USACE workmaps
4. A Geodatabase created for each stream that includes polygon, arc and point feature classes necessary to run the delineation tool
5. ArcMap, where most of the processes run

Data Preparation

The first step was to convert the HEC-RAS tabular model into a GIS compatible database file. This database file was then joined with the cross section feature class to provide the required attributes for further calculation. Next, the cross section arcs were intersected with the profile baseline, which split the cross sections and created nodes at each intersection. Additional fields were added to the cross section feature class and populated to identify the left and right sides, depending on the direction of the stream flow. The nodes and modified cross sections form the basis for the remaining processes.

SECTION_	STREAM_ID	PROFILE	SIDE	TW_R_METER	TW_L_METER	W_S__ELEV_
UC5-4	CD5	100-year	L	34.445448	271.192752	1115.21
5-20	CD5	100-year	L	1313.054016	420.7764	1102.17
UC5-4	CD5	100-year	R	34.445448	271.192752	1115.21
5-19	CD5	100-year	L	297.18	446.532	1102.17

Figure 2. Cross Section table showing attributes used to create100-year flood top widths

Methodology

Once the data was prepared the delineation tool was ready for use. The next step was to load the cross section and empty point feature classes from the Geodatabase into ArcMap.

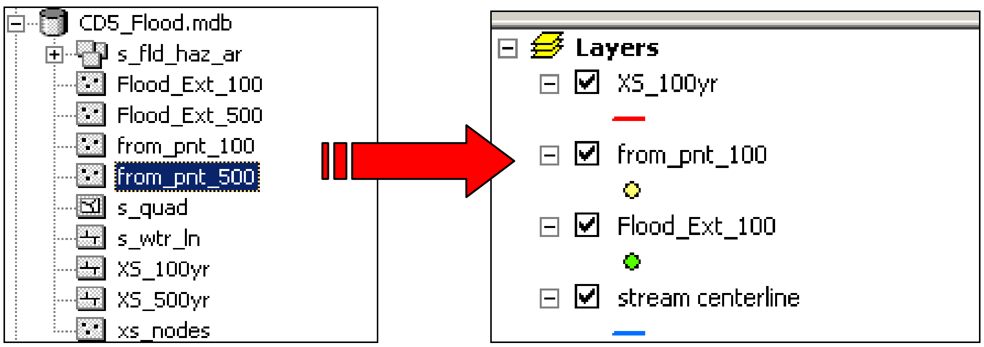


Figure 3: feature classes are loaded in a specific order necessary for the delineation tool to run

A customized toolbar added to ArcMap provided the functions required to create top width points along cross sections. Enacting the first sub routine, points were created at the beginning and endpoints of each cross section and placed in the from_pt_100 feature class, which provided reference for the second sub routine, which placed points on each cross section corresponding to the left and right top width values in the XS_100yr table.

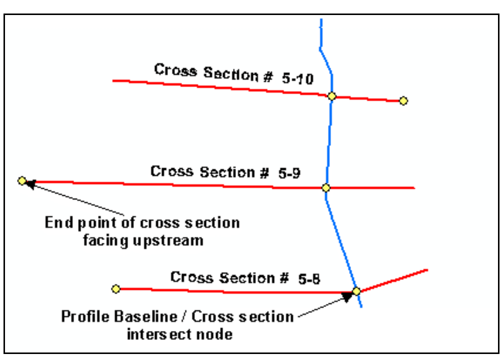


Figure 4: Positioning of points created by the first sub routine

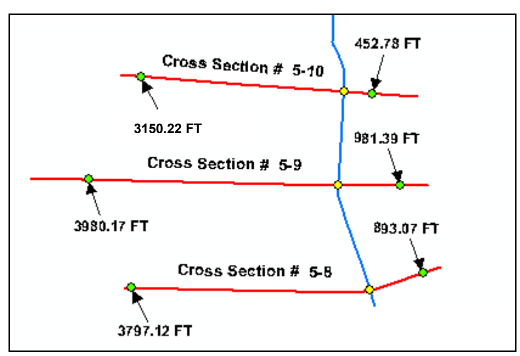
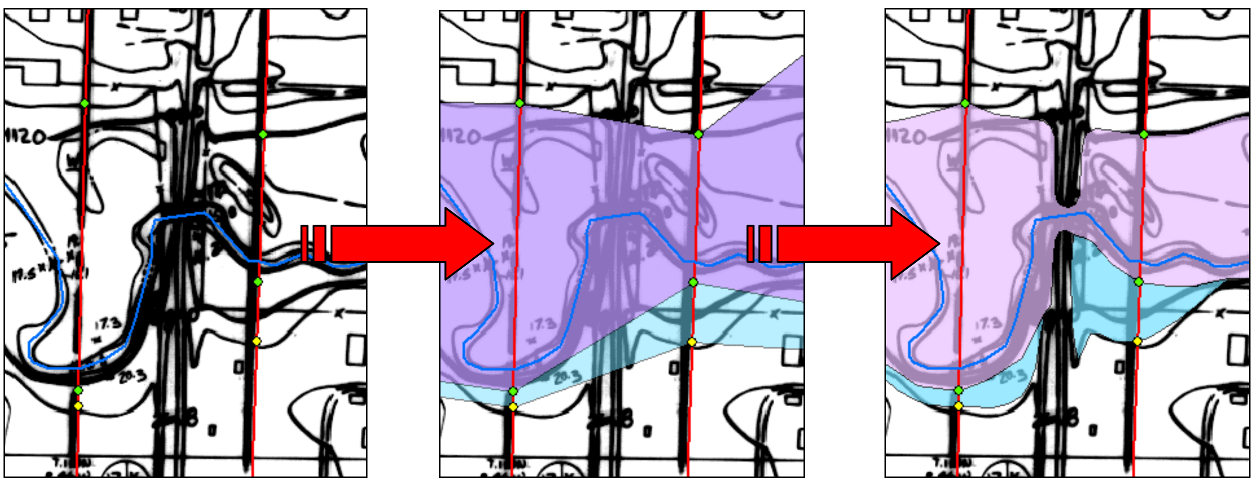


Figure 5: Positioning of 100-year top width points created by the second sub routine

The generated top width points were then used to construct flood arcs and polygons. XTools Pro, a third party extension, converted the points into polylines. It should be noted here that an additional attribute, DRAW_ORDER, was added to the cross section feature class. This attribute tells the tool the drawing order of the points, allowing XTools Pro to properly construct arcs between the points.

Next, the polylines were imported into the S_FLD_HAZ_LN feature class of a Standard DFIRM database. The required topology was enabled and polygons created. This methodology was then repeated for the 500-year floodplain.



(a) (b) (c)

Figure 6: This illustration reveals the delineation process – (a) shows the profile baseline, cross sections and 100-year top width points (green) and 500-year top width points (yellow), prior to running the tool. (b) shows the rough-cut polygons created from the top width points. (c) shows the reshaped flood zones, matching both the top width points and contour lines.

Once all streams were completed, quality control reviews conducted by both GIS analysts and floodplain scientists confirmed accuracy of the method, as only a few adjustments were needed for the delineations.

Redlining Data

While FEMA Mapping Partners have created many innovations in the way DFIRMs are produced, the use of paper workmaps are still very much part of the process. Floodplain engineering still involves traditional instruments to perform measurements on maps. Study workflow involves the passing of workmaps back and forth between GIS analysts and Floodplain scientists and engineers.

The process usually begins with preliminary flood data, political boundaries, and DOQs assembled together on paper plots at DFIRM panel scale. The paper plots are then reviewed floodplain scientists/engineers, who will make adjustments to the flooding data and plot Base

Flood Elevations (BFEs). Adjustments can be erased, crossed out and redone, making them difficult for GIS analysts to see and increasing chances of missing call corrections. Notes are often included, either written directly on the plot or by attached sticky note.

Plots marked up by engineers are returned to GIS staff, and are scanned and rectified. A typical countywide study will have 80-100 DFIRM map panels, so this process can take a great deal of time. Scanned maps also require a lot of disk space for storage.

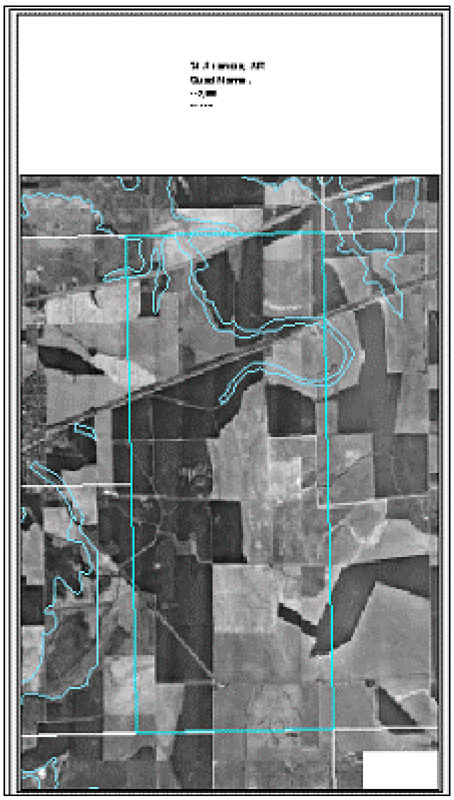


Figure 7: Sample of a Paper Workmap

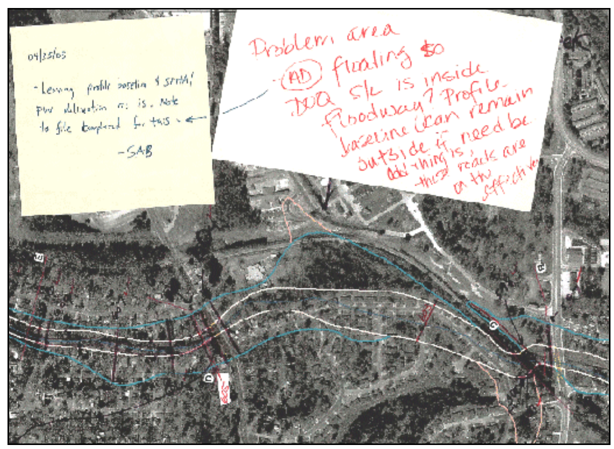


Figure 8: close-up of a Paper Workmap

While paper maps cannot be completely eliminated, the use of GIS based Redline data provides engineering staff with precision data, eliminating the need for most manual measurements of things such as distances between cross sections, and floodway, 100-year and 500-year floodplain top width distances. The precise distances from GIS data increase accuracy over manual measurements gathered using a scale or wheel. Engineering models can be exported to table form and easily compared to onscreen, labeled attributes from the data. Advantages include clearer base map information, the ability to zoom in and out, adding new data such as contour lines, and labeling data as desired. Adjustments to be made are clearly marked, BFEs can be plotted onscreen and the Arcmap callout tool makes notations easier to see.

For GIS analysts, there is no need for scanning and georeferencing. Flood adjustments are easy to see and understand.

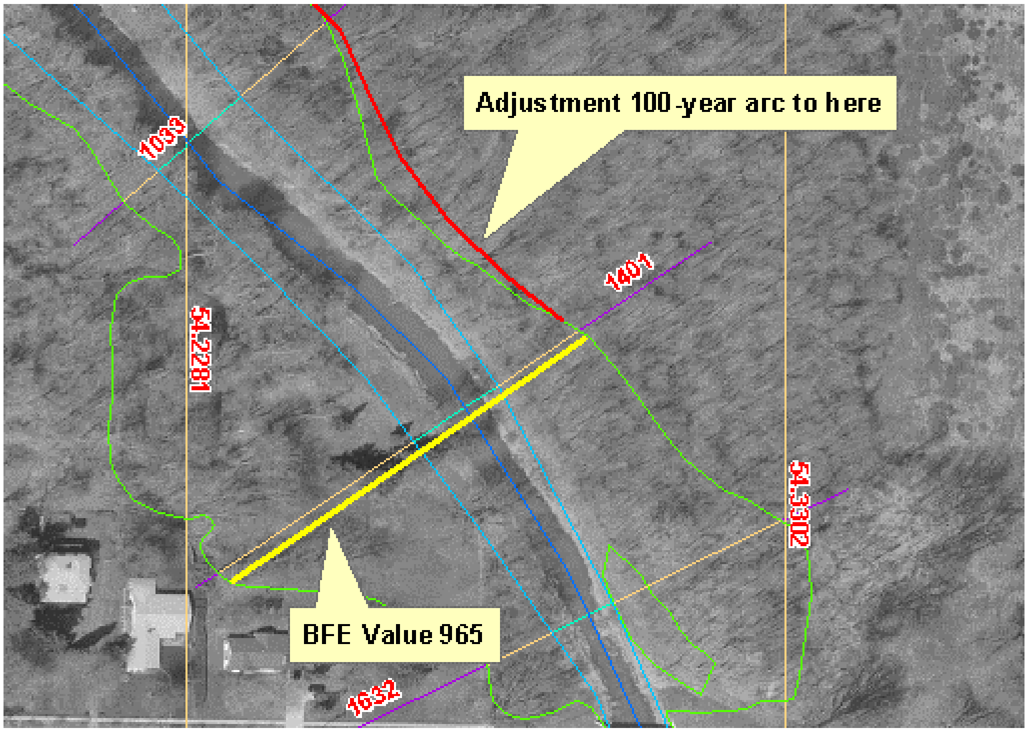


Figure 9: Example of Redlining Data.

Figure 9 shows Redlining data in action. The flood arcs are clearly visible and are symbolized to represent the floodway and 100-year floodplain. The cross sections are intersected with the flood arcs to provide data to verify top widths for each flood zone. The profile baseline is intersected with cross sections to determine station distances. The flood adjustment is marked in red and corresponding notes are visible. BFEs are plotted and attributed. All data created by this methodology exists in table form, which can be copied to other formats, such as engineering spreadsheets.

Conclusion

Due to an increasing workload for FEMAs Map Modernization initiative, it is critical to use GIS to work more intelligently and efficiently. The innovative tools and methodology discussed in this paper allow us to gradually move away from time-consuming paper-intensive workflow to an integrated, technology-based environment, which speeds workflow between team members.

Acknowledgments

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Key Definitions

100-Year Flood - "100-year" frequency flood refers to a flood discharge of a magnitude likely to occur on the average of once every 100 years or, more properly, has a 1 percent chance of being exceeded in any year.

500-Year Flood - "500-year" frequency flood refers to a flood discharge of a magnitude likely to occur on the average of once every 500 years or, more properly, has a 0.2 percent chance of being exceeded in any year.

Base Flood Elevation (BFE) – The height of floodwaters reached during the base flood.

Cross Section - A surveyed plot of ground elevation across a floodplain, usually along a line perpendicular to the stream or direction of flow.

Flood Top Width - The water surface elevation extended out along a cross section to a maximum defined distance.

Profile Baseline – The map representation of a flood profile.

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Author Biography

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Endnotes

[1] Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A, FEMA [April 2003]

[2] Preliminary Flood Insurance Study (FIS) for Lac Qui Parle County, Minnesota, FEMA [July 2004]

[3] Guidelines and Specifications for Flood Hazard Mapping Partners, Introduction, FEMA [April 2003]