Flood Hazard Zone Modeling for Regulation Development

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Abstract

The desire to blend current digital information with government permitting procedures, coupled with refinements in geospatial modeling, has led to an increasing need for data revisions to match the compounding complexity of today's development regulations. Flood data sets, comprised of both vertical and horizontal buffering elements, and developed in conjunction with the surface water department in Pierce County, Washington, were created using digital terrain models along with ArcView Spatial and 3D Analyst. This process translates paper regulations into visual and quantitative models to facilitate efficient land use decisions and improved customer service.

Introduction

The Water Programs division of Pierce County Public Works requested the assistance of the GIS division in the production of digital flood data layers to support the introduction and enforcement of a new chapter in local flood hazard awareness. The data creation and rule induction process was driven by the following purposes:

1. Protect human life and health
2. Minimize expenditure of public money on costly flood control projects
3. Minimize the need for rescue and relief efforts associated with flooding events
4. Minimize prolonged business interruptions
5. Minimize damage to public infrastructure, facilities, and utilities
6. Minimize damage to critical fish and wildlife habitat areas
7. Minimize net loss of ecological functions of floodplains
8. Ensure that potential buyers are notified that property is in a flood hazard area
9. Ensure that those who occupy flood hazard areas assume responsibility for their actions
10. Further qualify Pierce County for participation in the National Flood Insurance Program, thereby giving the citizens of Pierce County the opportunity to purchase flood insurance with particular emphasis to those in flood hazard areas.

Background

New information products were required as part of the critical areas ordinance for use as a trigger in permitting based on proximity to hydrologic features. The Water Programs division currently uses the

Federal Emergency Management Agency firm maps for hydrologic zones. The limitations on present information include a lack of accurately delineated flood polygon boundaries for numbered A zones (major streams) and a reliance on vertical measures only for minimum building finished floor height. The unnumbered A zones (small streams/natural watercourses) had very little detail mapping, lacked maintenance and are largely 20+ years outdated. The coverage for unnumbered A zones was also spatially limited. Hydrologic B zones (lakes and other still water bodies) were largely ignored by existing regulating data sources. All existing sources lack convenient analytical triggers for effective regulation and customer service.

As is common in the field of GIS, the original client data request did not completely fit the client goals but further demonstration of possible roadblocks was much more visually impactful than verbally or descriptively. The requested data included a five foot vertical flood model to aid a preconceived five foot flood level stream regulation. Other basic data products based on horizontal feature buffers were also requested to add flexibility to implementation.

Methodology

The digital delineation of vertical and horizontal potential flood hazards involves the application of two constraints to extract meaningful and accurate models of potential flood impact areas. If performed by hand, this procedure would be extremely time consuming and difficult if not impossible to replicate. The use of Geographic Information Systems and Digital Terrain Models from high accuracy elevation data can automate the delineation procedure and increase repeatability.

Pierce County acquired highly accurate elevation data from orthophoto flights for about one third of the county (figure 1). In the urban areas there are two foot contours, while in the rural area, five foot contours exist. In addition to contours, a series of other features collected during the orthophoto process were used to build DTMs. These included hydro features, breaklines, mass points, and roads.

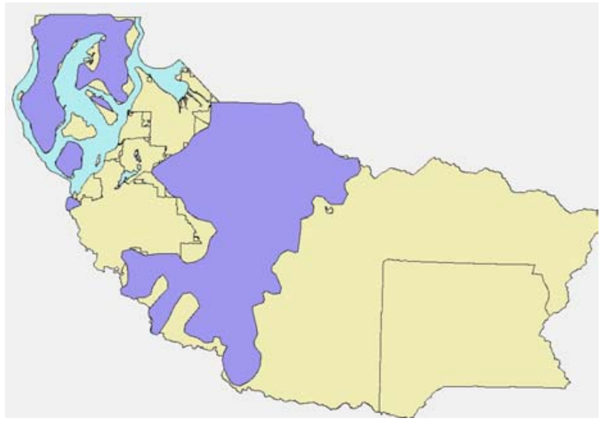

Figure 1

The digital delineation of potential vertical and horizontal flood hazards consists of several steps all conducted in ArcView 3.x software using Spatial Analyst and 3D Analyst. A customized ArcView user interface was built which consists of a series of buttons that trigger a series of sixteen Avenue scripts. (figure 2)

Figure 2

The study area is examined to find hydro lines not currently covered with regulatory boundaries. A DTM or elevation surface is created around the selected hydro features. Next, the hydro line itself is densified (split every two feet) and buffered by feet of elevation using numerous grid functions. Finally, the resulting potential flood hazard polygon boundary is inspected and if applicable, added to a master flood hazard shapefile.

Inspection

The hydro line features from the orthophoto DXFs are used as the projects central component. These are the features to which the vertical buffering will be applied. First, a hydro line without an existing one hundred year flood plain (figure 3) is identified. The orthophotos and contours are then inspected to determine if the hydro line is in fact a naturally draining geomorphic feature. (figure 4)

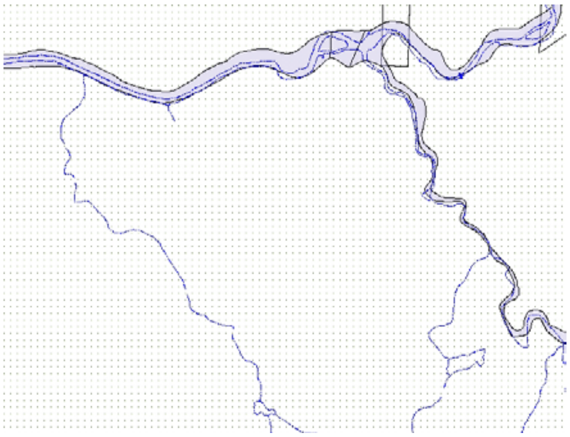

Figure3

Figure 4

Building the Elevation Surface

The second step is to build the elevation surface or DTM for the area surrounding the hydro feature. An Avenue script applies buffers to the selected hydro features and pulls in the contour data needed to build the terrain model. (figure 5)

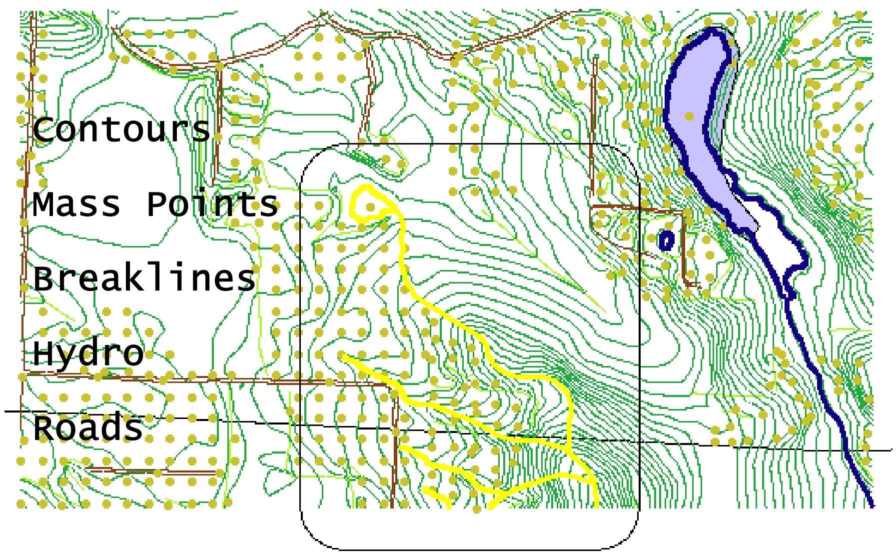

Figure 5

These features are then added to a TIN. Contours and mass points are added as mass points while breaklines, hydro, and road layers are added a breaklines. Orthophoto DXF breaklines are added with z values. The TIN is then converted into a grid using a 2 foot cell size. (figure 6)

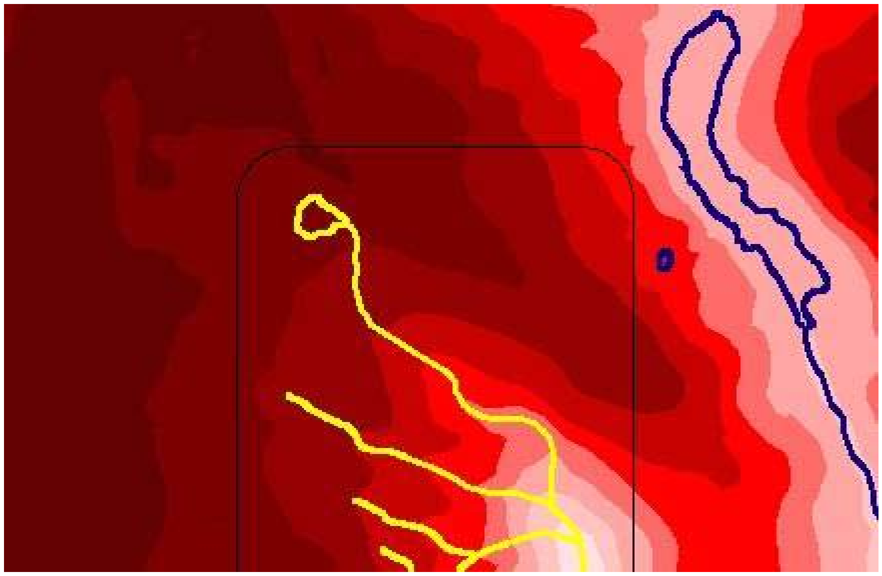

Figure 6

Buffer by Elevation

To buffer by elevation, the hydro lines must first be converted into a grid and assigned elevation values based on the elevation surface. With each line segment of the hydro feature having an assigned single elevation value, it is necessary to densify the nodes of each line. The next step effectively splits the hydro line every 2 feet which matches the contour interval distance of the DTM. (figure 7) The feature is now ready to be converted into a grid. This hydro grid is assigned elevation values from the DTM. (figure 8)

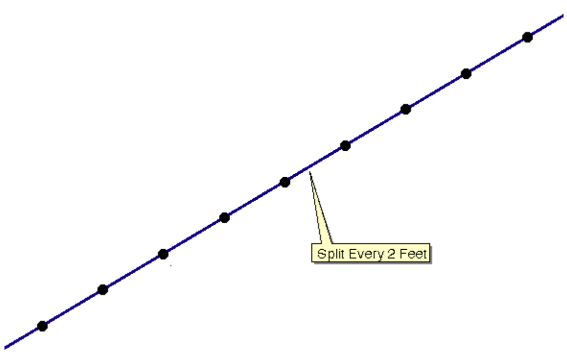

Figure 7

Figure 8

A Euclidean distance allocation grid is then created.(figure 9) This procedure is applied to the hydro grid with elevation values for each null cell based on the nearest non-null cell. In effect, a grid version of the familiar Thiessen polygons used to create TINs is constructed.

Figure 9

With the Euclidean distance allocation grid applying the hydro elevation to surrounding cells, we can now subtract the Euclidean distance allocation grid from the elevation with an elevation change grid as a result. (figure 10)

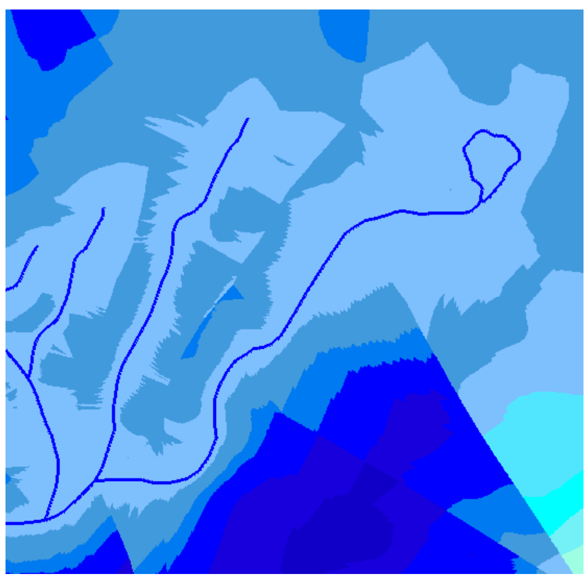

Figure 10

To complete the process, we simply select those cells with values less that or equal to our elevation measure. If the resulting elevation grid has coarse outlines, a boundary clean algorithm is used to quickly smooth away much of the coarseness. The elevation change grid is then converted to a shapefile for the creation of the new flood hazard area. (figures 11,12,13)

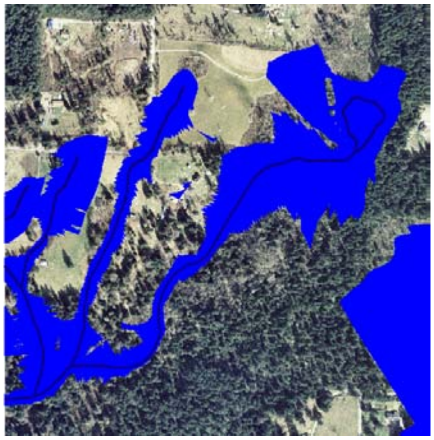

Figure 11
(Raw)

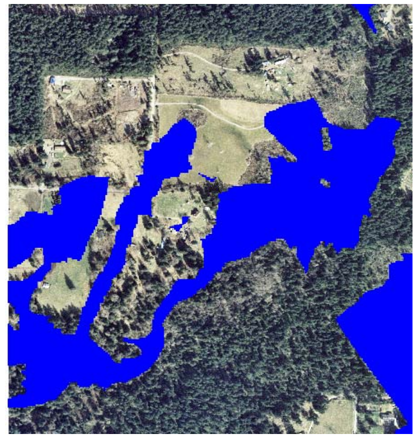

Figure 12
(Cleaned)

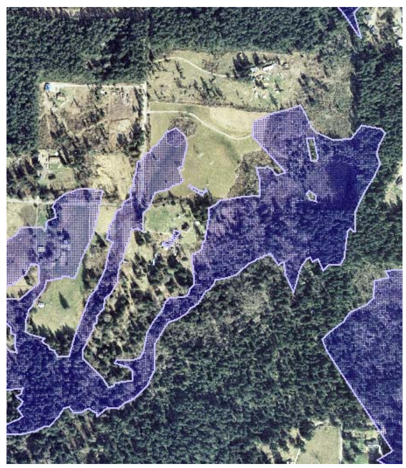

Figure 13

Summary

This was the methodology used by Pierce County for digital delineation of potential flood hazards around small streams and other hydrologic features. TINs and grids were used to model these flood hazard areas by buffering hydro-geomorphic features by a 5 foot elevation. The use of Geographic Information Systems and Digital Terrain Models from high accuracy elevation data can automate the delineation procedure, increase process repeatiblility, and accelerate data production. The following are some interesting statistics of the project results.

547 miles of stream channel were assigned flood dimensions

1306 acres of land associated with unnumbered A zones were saved from over-regulation based on the more precise vertical/horizontal analysis when compared to basic horizontal buffering techniques used in many flood polygon delineations

8+ square miles of land were flooded by the new modeling efforts

Various data types were requested for flexibility in implementation. The data products produced in this effort included:

1. Detailed study streams flooded 5 feet vertically and clipped horizontally by 300 feet
2. A 300 foot horizontal stream buffer built upon existing FEMA floodzones
3. Detailed study lakes flooded 5 feet vertically from lake orthophoto edge elevation clipped horizontally by 300 feet
4. A 300 foot horizontal lake buffer built from FEMA floodzones
5. A 300 foot horizontal wetland buffer built from FEMA floodzones
6. Small natural watercourses flooded 5 feet vertically and clipped horizontally by 65 feet
7. A 300 foot horizontal small natural watercourse buffer built from stream centerlines
8. A 65 foot buffer of small natural watercourses built from stream centerlines

Upon adoption of the new flood hazard regulation document, the data products are envisioned to be directly implemented in the following ways:
--Research and analysis use by Water Programs division staff
--Visual reference based advising at the Planning department public service desk
--In web based public access products for developer use
--In printed book/atlas form for focused public distribution

Conclusion

The Federal Emergency Management Agency dubs the new regulations and supporting products as a very positive and proactive move. If adopted, this would be one of the model plans in the nation. Approval of the new regulations would lower Pierce County's Community Ratings System (CRS) class from five to three. This would result in a ten percent reduction in flood insurance rates for Pierce County residents.

The new chapter in Pierce County flood hazard regulation has gone through the County planning commission and is set to go before the Pierce County council in July 2003.

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