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CVEN 658 Civil Engineering Applications of GIS
Using ArcGIS, HEC-GeoHMS and HEC-HMS to Model Ticky Creek Watershed
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Abstract

This report contains the methods and results from a watershed modeling of Ticky Creek. Ticky Creek is a watershed approximately 20 square miles in size and located northeast of Dallas within Colin County. It drains into what is now Lavon Lake and contains a variety of land uses. ArcGIS, Hydrologic Engineering Center’s Geospatial Hydrologic Modeling (HEC-GeoHMS) and Hydrologic Engineering Center’s Hydrologic Modeling System (HEC-HMS) were the three computer software tools used in this project to model the watershed. HEC-GeoHMS uses the ArcGIS component ArcView and the Spatial Analyst extension to develop hydrologic inputs for watershed modeling in HEC-HMS. The storm chosen to model the watershed was a 50 year 2 hour storm with a 2 hour intensity. The end result was hydrograph created within HEC-HMS of the outlet point during the selected storm. The peak runoff from the storm turned out to be approximately 14,900 cfs 3 hours after the storm began. The primary purpose of this project was to gain a familiarity and understanding of HEC-GeoHMS and how it can be applied within ArcGIS to create the hydrologic modeling inputs for HEC-HMS.
Introduction

This project uses ArcGIS and HEC Geo-HMS in order to create hydrologic inputs into HEC-HMS which then models the selected watershed. The project area chosen was Ticky Creek watershed, located north of Lavon Lake in Colin County. This location was chosen because it is in an area that has a mixed land use and where the necessary data was available. The watershed was modeled under a 50 year 2 hour storm with a 2 hour intensity. This provided a hydrograph of volumetric flow over a period of time representing the outlet point of the watershed. This quantitative information obtained from the HEC-HMS model can then be used to design desired structures such as a channel, culvert, detention structure, etc. In this case, a reservoir has been constructed at a point south of the outlet point which Ticky Creek watershed contributes to. Originally designed and constructed in 1948, Lavon Lake was built with the primary purpose of flood control, followed by water storage and recreation. Lavon Lake provides flood protection to the East Fork of the Trinity River.

The importance of this project is to get familiar with ArcGIS and HEC Geo-HMS so that future work using these tools can be done. HEC Geo-HMS is a valuable tool in modeling watersheds. It can effectively provide hydrologic inputs for HEC-HMS in a timely manner for watersheds of all sizes. Familiarity with these tools is vitally important for a Water Resource Engineer interested in Hydrologic design. With these tools an engineer is equipped with the ability to effectively and efficiently model a watershed.
Literature Review

Watershed modeling is a fundamental task in Water Resources Engineering. Originally watersheds had to be delineated using a paper map and modeled using hand calculations. HEC-HMS was developed by the Hydrologic Engineering Center under the U.S. Army Corps of Engineers to assist in modeling precipitation-runoff in watersheds. The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC) was formed in 1964 to institutionalize the technical expertise that subsequently became known as hydrologic engineering. (HEC History) There have been multiple versions of HEC-HMS developed but the one used for this project was HEC-HMS 3.5. It has only been recently that ArcGIS and HEC Geo-HMS have been used to assist in providing the inputs for HEC HMS. HEC-GeoHMS uses ArcView and the Spatial Analyst extension to develop a number of hydrologic modeling inputs for HEC-HMS. (HEC-GeoHMS) With these inputs, HEC-HMS can then be used to model any type of watershed.

Environmental Systems Research Institute, Inc. (Esri) was developed in 1969 to develop geographic information system technology. Esri developers began formulating the concepts that ultimately led to the release in 1982 of ARC/INFO, the first commercial GIS. (Esri History) From this first ARC software, multiple versions have been developed up to the ArcGIS 10 used today which includes ArcView, ArcEditor, and ArcInfo. The first tool developed to delineate streams and watersheds and build hydrologic model structures for HEC-HMS was PrePro, a predecessor to HEC-GeoHMS. HEC-GeoHMS Version 1.0 was then developed to use the readily available digital geospatial information to construct hydrologic models expediently. (HEC-GeoHMS, 2009) The most recent version and the version used in this project is HEC-GeoHMS 4.2. Much work has been done in the past involving ArcGIS, HEC Geo-HMS, and HEC-HMS. They are tools which are commonly used by engineering firms in modeling watersheds.

This project is not novel in that all of the tools used and the project location have been modeled before. However, because of increasing urbanization the Curve Number and percent impervious of the watershed have changed since the Lakes construction in the early 1950’s. When it was constructed this Lake was designed to handle a 35 year flood event. It has since been modified and in 1975 the level of the lake was increased 12 feet to meet an increasing demand for water supply in the region. (Lake Information)
Methodology

First an ArcGIS project was created and the relevant data added to the data frame. The data needed to for this project included National Elevation Dataset (NED), Impervious Surfaces, Land Cover, and Hydrography data. After adding the data, the next steps were the terrain preprocessing tools which prepare the data for analysis in Geo-HMS.

The first step in the terrain reconditioning was DEM Reconditioning. This lowers grid cells along line features and outputs a reconditioned grid as shown in Figure 1. (HEC-GeoHMS, 2009)

![Figure 1: DEM Reconditioning](image)

The Terrain Preprocessing functions were the next steps taken to prepare the data. With terrain preprocessing, a terrain model is used as an input to derive eight additional datasets that collectively describe the drainage pattern of the watershed and allow for stream and subbasin delineation. (HEC-GeoHMS, 2009)
The first function was Fill Sinks which is a tool to remove sinks or depressions created by the reconditioning process. The next step was Flow Direction which defines a flow direction for each cell in the DEM represented in Figure 2. The numbers in the legend represent the following directions: 1 = east, 2 = southeast, 4 = south, 8 = southwest, 16 = west, 32 = northwest, 64 = north, 128 = northeast.

Figure 2: Flow Direction
The next step uses the Flow Accumulation operation which determines the contributing area to each cell in the map. (HEC-GeoHMS, 2009) The flow accumulation grid is shown in Figure 3.

Figure 3: Flow Accumulation
The Stream Definition editor was then used in order to classify all cells belonging to the stream network. This tool uses the information from the flow accumulation data to determine what cells belong to a stream network. The flow accumulation for a particular cell must exceed a user-defined threshold to be considered in the stream. (HEC-GeoHMS, 2009) The default of 1% of the largest drainage area in the entire DEM was used for this project. An output of the stream network is shown in Figure 4.
The next step was to use the Stream Segmentation operator which divides the stream produced by stream definition into separate sections. The stream segments are the sections of a stream that connect two successive junctions, a junction and an outlet, or a junction and a drainage divide. (HEC-GeoHMS, 2009) An illustration of the stream segments is shown in Figure 5.
The next step was Catchment Grid Delineation which delineates a subbasin for every stream segment created in Stream Segmentation. (HEC-GeoHMS, 2009) An illustration of all the subbasins that were created from the Catchment Grid Delineation is shown in Figure 6.

Figure 6: Catchment Grid Delineation

Catchment Polygon Processing was the next step taken, which created a vector layer of subbasins with the subbasins created in Catchment Grid Delineation. (HEC-GeoHMS, 2009) The red outlines of the subbasins in Figure 7 illustrate the polygons created from the Catchment Polygon Processing Function.
Figure 7: Catchment Polygon Processing

Drainage Line Processing was the next step which created a vector stream coverage. (HEC-GeoHMS, 2009) The light blue lines illustrated below in Figure 8 represent the vector stream coverage.

Figure 8: Drainage Line Processing
The final step in the Terrain Preprocessing was Watershed Aggregation which aggregates the upstream subbasins at every stream confluence. This is a required step and is performed to improve computational performance for interactively delineating subbasins and to enhance data extraction. (HEC-GeoHMS, 2009)

With all of the Terrain Reconditioning and Terrain Preprocessing finished the HMS Project Setup began. The Terrain Reconditioning and Terrain Preprocessing prepared the terrain data in a way that the HEC-GeoHMS tools could use. The HMS Project Setup menu is responsible for extracting data that will be used to develop the necessary information to create a HEC-HMS project. (HEC-GeoHMS, 2009) The first step was to start the new project and select the outlet point for the project. The exact coordinates of the outlet point were found using the USGS EarthExplorer. Using these coordinates the outlet point of the Ticky Creek watershed was set in ArcMap. This created the project point, as well as the project area shown below in Figure 9.

![Figure 9: Project Area](image-url)
The next step was to create a river profile, shown below in Figure 10. The river profile tool was found under the Basin Processing menu. The purpose of the river profile is to illustrate the elevation changes and breaks in the river.

![River Profile](image)

**Figure 10: River Profile**

The next steps were to obtain stream and subbasin characteristics using HEC-GeoHMS. These tools extract the topographic characteristics of streams and subbasins and are available from the Basin Characteristics menu on the HEC-GeoHMS Project View toolbar. (HEC-GeoHMS, 2009)

The first step in this process was to use the function River Length which adds a field named “RivLen” with the length of the river within the basin in the attribute table of the river. The River Slope function was then used to calculate the river slope of the river within the project area. It added the values for “ElevUP”, “ElevDS” and “Slp” in the attribute table of the river shown in Table 1 below.

<table>
<thead>
<tr>
<th>Table 1: River Attribute Table</th>
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Next the Basin Slope function was used to determine the average basin slope in the watershed. It adds a field in the subbasins attribute table called “BasinSlope”, which is the average slope of the subbasin. The basin slope is illustrated below in Figure 11.

![Figure 11: Basin Slope](image)

Next, the Longest Flow Path tool was used to compute the longest path a drop of water can take to contribute to the outlet in the watershed. The Longest Flow Path tool created the longest flow length, upstream elevation, downstream elevation, and slope between the endpoints. The attribute table for the Longest Flow Path layer can be seen below in Table 2. The Longest Flow Path layer in the project area is illustrated as well in Figure 12.

![Table 2: Longest Flow Path Attribute Table](image)
The next step was to use the Basin Centroid tool to find the centroid of the subbasins. The center of gravity method was used to find the centroid because this would represent an adequate centroid location for the subbasins. The center of gravity method computes the centroid as the center of gravity of the subbasin. (HEC-GeoHMS, 2009) The center of gravity of the subbasins can be seen in Figure 13.
Next, the Centroid Elevation tool was used to compute the elevation of each centroid point. After that the Centroidal Flow Path tool was used to compute the flow path of the centroid by projecting it onto the longest flow path. The centroidal flow path is then measured from the projected point onto the longest flow path to the subbasin outlet. (HEC-GeoHMS, 2009)

The Hydrologic Parameter Estimation tools were used next to estimate some of the hydrologic parameters. The first tool used was Subbasin Parameters From Raster. This tool operates on a raster layer and computes the average hydrologic parameters for each subbasin. (HEC-GeoHMS, 2009) Using the land cover data and impervious surfaces data from USGS, the Curve Number and Percent Impervious for each subbasin were determined respectively. An image of land cover data within the subbasin is shown in Figure 14 and an image of the impervious surfaces data is shown in Figure 15.
Next the Select HMS Process tool was used to select the methods to be used by HEC-HMS to analyze the watershed. The SCS method was chosen for both the Loss and the Transform Method, and Lag was chosen for the Route Method. Then the River Auto Name and Basin Auto Name tools were used to assign names to the river reaches and subbasins.
After that, the hydrologic inputs for HEC-HMS were developed. The first tool used was Map to HMS Units. This converts the physical characteristics of reaches and subbasins into SI or English units. (HEC-GeoHMS, 2009) English units were chosen for this project.

The HMS Data Check tool was used next to check the datasets for inconsistencies. This tool checks the datasets for consistency in describing the hydrologic structure of the model. (HEC-GeoHMS, 2009) No errors were found in this step.

HEC-HMS Basin Schematic was then used to create the GIS representation of the HEC-HMS model. This tool builds a simple hydrologic network that contains HEC-HMS model elements and shows their connectivity. (HEC-GeoHMS, 2009) After creating the HEC-HMS Schematic, the HMS Legend tool was used to input HEC-HMS icons to represent point and line features as shown below in Figure 16.

![HEC-HMS Basin Schematic](image)

**Figure 16: HEC-HMS Basin Schematic**

The Add Coordinates tool was used next which added coordinates to the HMS Nodes and HMS Link layers. Then the Prepare Data for Model Export tool was used. This tool gathers parameter data stored in the attribute tables for the subbasin and river layers and prepares it for export to the HEC-HMS basin model file. (HEC-GeoHMS, 2009) Next, the Background Map tool was used to create the
background map layers. There are two options to choose from, either the Map File or Shape File, the Shape file was chosen for this project. Finally the Basin File tool was used which captures the hydrologic elements, their connectivity, and related geographic information in an ASCII text file that can be loaded into an HEC-HMS project. (HEC-GeoHMS, 2009)

**Application Results and Discussion**

The study area considered is the Ticky Creek Watershed. This watershed is located northeast of Dallas in Colin County. The runoff from Ticky Creek Watershed drains directly into Levon Lake. Lavon Lake is a U.S. Army Corps of Engineers Reservoir. Its construction was completed in 1954 and was built primarily to prevent flooding on the Trinity River. (Lake Information)

![Google Earth Image of Ticky Creek Watershed](image)

**Figure 17: Google Earth Image of Ticky Creek Watershed**

All of the Data that I obtained came from the USGS National Map Viewer from the USGS website. I obtained National Elevation Dataset (NED) data, land cover and impervious surfaces within the National Landcover Database 2001, and Hydrography data.
This watershed was modeled for a 50-yr 2 hr storm with an intensity of 2 hrs. Rainfall data was obtained from TP-40 (Technical Paper – 40). TP-40 is a rainfall atlas of the United States and is provided by the Weather Bureau within the U.S. Department of Commerce. The rainfall for a 50 year 2 hour storm for Colin County was 4.5 inches. (Hershfield, 1963) The hydrograph obtained from the HEC-HMS results showed a peak flow of 14,908 CFS. A summary of the storm is displayed in Figure 18, and the Hydrograph is shown in Figure 19.

Figure 18: Summary Results of HEC-HMS Model

Figure 19: Hydrograph from HEC-HMS Model
These results indicate a significant amount of flow will reach the outlet point. However, after four hours it appears that the flow will cease. This information of volumetric flow over time and peak flow can be used by engineers to design a number of features. In the case of Ticky Creek watershed, the flow rates are used to design the reservoir for flood control and water supply.
Conclusions

HEC Geo-HMS is a valuable tool in modeling watersheds. Watersheds of large size can be analyzed and hydrologic modeling inputs can be created for HEC-HMS. Determining the hydrologic inputs computationally from ArcGIS is significantly faster than determining them by hand. I am very glad that I became familiar with how to use HEC-GeoHMS because it is a tool that I expect I will use in the future as a Water Resources Engineer.

Had I done this project again, I would have changed my project area to the entire watershed of Lavon Lake. I then would have determined if the Lake had the flood storage capacity to hold the peak flow of the original storm that it was originally designed for. However, with this being my first time using HEC-GeoHMS, Ticky Creek watershed was a reasonable and manageable size. This project allowed me to gain a significant depth of understanding in how to use the software and because of that I found this project to be highly beneficial.
Bibliography


