Civil Engineering 394K:

Topic 3

Geographic Information Systems (GIS) in Water Resources Engineering

TERM PROJECT REPORT

Reinvestigation of the Halloween Flood and Hydrologic Modeling of the Onion Creek Watershed

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Written By: Juhn-Yuan Su (js56859), M.S. Student in EWRE

Instructor: Dr. D. R. Maidment (University of Texas at Austin)

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Background

The Onion Creek Watershed is located near central Texas and covers some portions of Austin, particularly Travis County. Onion Creek exhibits a gradually growing population since the 1850s, which this region enters Austin City Limits by 2000 (Jasinski, 2010). Figure 1 displays the Onion Creek Watershed relative to Austin, with the indicated 12-digit Hydrologic Unit Codes.

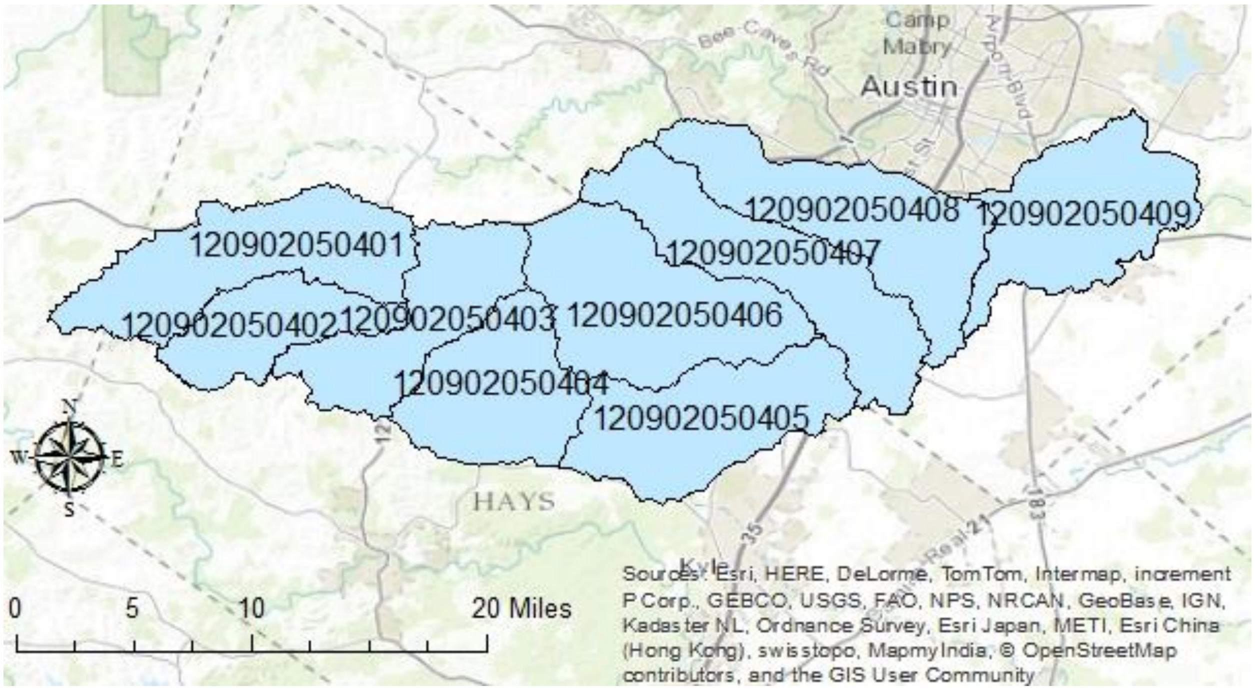

Figure 1: Onion Creek Watershed with HUC 12 Basins relative to Austin

The Onion Creek Watershed, including the 9 HUC 12 sub-watersheds as displayed in Figure 1, constitutes approximately 941 square kilometers. Onion Creek meets with Carlson Creek at the effluent of the Onion Creek Watershed (at the outlet of HUC 12 Sub-watershed 120902050409). Then, Onion Creek empties into the Colorado River at the outlet of the watershed.

On October 31, 2013, a major flood broke out in the Onion Creek Watershed, which this event has been denoted as the *Halloween Flood*. During this event, water flowed into neighborhoods at approximately 5:00 AM and intensified until 10:00 AM on the same day (Jervis, 2013), destroying at least 1200 homes and killing at least 4 people. This event poses a major challenge to the hydraulic and hydrologic analysis of this watershed, which investigations are needed to develop an emergency response that may warn civilians about floods that may occur.

Project Analysis

This project revisits the Halloween Flood and investigates factors that may have contributed to this major event. ArcGIS is employed through ArcHydro to generate the watershed catchments and drainage lines. HEC-GeoHMS (Hydrologic Engineering Corps: Geospatial Hydrologic Modeling Systems) is used to incorporate the watershed into HEC-HMS to generate a HMS model for analysis. Then, the analysis is conducted in HEC-HMS to determine the peak streamflow and the time for this to occur. Assumptions have been made to simplify this project to a small-scale revisit of the Halloween Flood for calculating the peak streamflow.

Analysis of Previous Studies

Much research has been conducted toward predicting streamflow from given precipitation data for a watershed. Much of the general parameters are needed for calculating streamflow from precipitation data, involving the storage over time, the evapotranspiration of the watershed, and the infiltration into the land. However, while these variables (evapotranspiration, infiltration, and storage) are fundamental for determining the streamflow for the watershed, such parameters are affected by the surrounding environment. For instance, increasing temperature over northern regions pose significant concern on whether the streamflow for the region increases, such as Northern Russia (Adam & Lettenmaider, 2008). GIS is also employed for incorporating groundwater recharge for a mountain river for calculating streamflow in Taiwan (Yeh, et al., 2014). Landuse and geological information are integrated into the watershed and then processed by GIS to develop a groundwater potential zone map (Yeh, et al., 2014), which can then be used to determine the streamflow through the watershed. Meanwhile, Tobin and Bennett (2014) incorporated two models, the Soil and Water Assessment Tool with the Gridded Surface and Subsurface Hydrologic Analysis, toward predicting streamflow from the given precipitation data. The complexity of the models are tested to understand the impacts upon streamflow calculations for varying precipitation data (Tobin & Bennett, 2014).

Approaches for calculating streamflow from given precipitation data are researched based on previous journal articles and studies. For instance, a conceptual model that divides streamflow into baseflow, interflow (between surface and underground), and surface flow is used for analyzing precipitation data for a watershed (Rimmer & Salingar, 2006). On the other hand, Patterson et al. (2012) analyzed streamflow changes in the southeastern United States region over time. A regression analysis was developed to relate streamflow changes with precipitation in response to droughts during the late 1900s (Patterson, Lutz, & Doyle, 2012). Han (2010) performed a small-scale analysis of streamflow prediction incorporating sets of precipitation time series data based on distinct moisture conditions. Both GIS and HEC-GeoHMS were incorporated to compute streamflow for the generated subbasins of the San Antonio River Watershed (Han, 2010). At the same time, another study involves the incorporation of GIS into studying subbasin and reach lag time for streamflow calculation (Costache, 2014). These investigations have been analyzed to understand a general procedure for predicting streamflow from precipitation data for the Onion Creek Watershed.

Project Approach

The Onion Creek Watershed has been extracted from the ArcMap package provided by Dr. David Tarboton at the University of North Carolina at Chapel Hill, as shown in Figure 1 above. The following approaches are generally employed for this project:

ArcHydro Preprocessing

The general Digital Elevation Model (N30m) provided by the United States Geological Survey (USGS) is used for the ArcHydro Preprocessing portion, and the DEM is then extracted over the watershed buffer. ArcHydro and HEC-GeoHMS are used to generate the watershed basins and the drainage lines that are then imported into HEC-HMS for analysis. The following procedures are employed for processing the Digital Elevation Model of the Onion Creek Watershed:

1) **Filling the DEM:** All the pits in the watershed are filled using the general fill geoprocessing tool studied in class. Figure 2 corresponds to the Filled DEM for the Onion Creek Watershed.

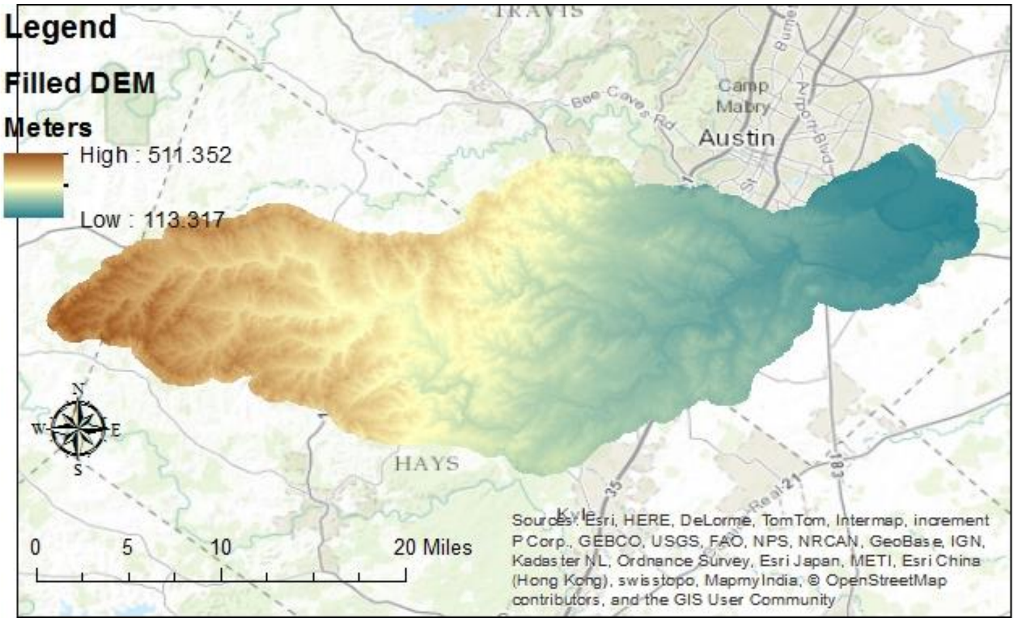

Figure 2: Filled DEM over the Onion Creek Watershed

2) **Flow Direction:** The Eight-Point Model has been used to determine the flow direction over the watershed, as displayed in Figure 3.

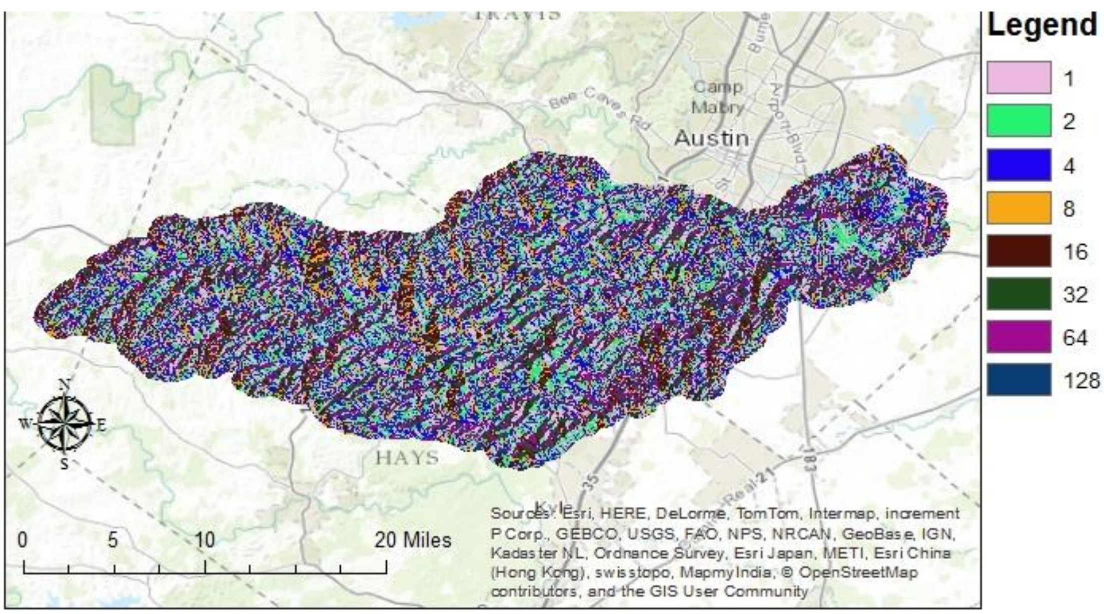

Figure 3: Flow Direction Raster Dataset

3) **Flow Accumulation:** The flow accumulation geoprocessing tool is employed to determine the cumulative area flowing into a particular grid using the flow direction feature class generated from step 2. Figure 4 displays the flow accumulation grid.

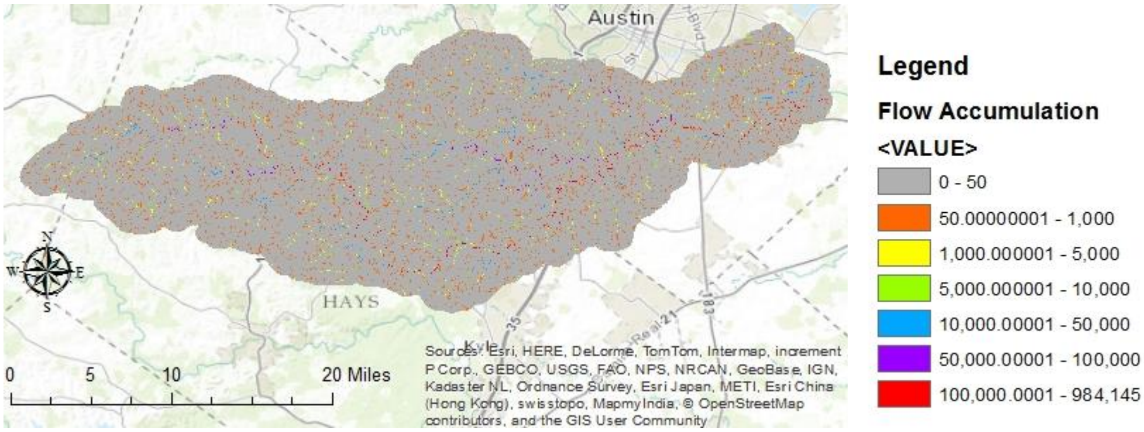

Figure 4: Flow Accumulation Grid

4) **Stream Definition:** Due to a complex flow accumulation network, the raster calculator geoprocessing tool is employed to define streams along the Onion Creek Watershed. For this project, a flow accumulation that is greater than 20,000 grids is used to define a stream, as shown in Figure 5. Figure 6 displays the resulting stream definition grid.

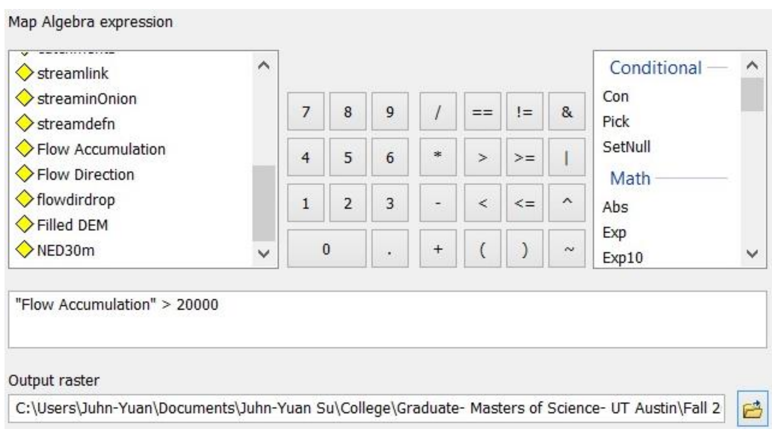

Figure 5: Stream Definition Generated from Flow Accumulation through Raster Calculator

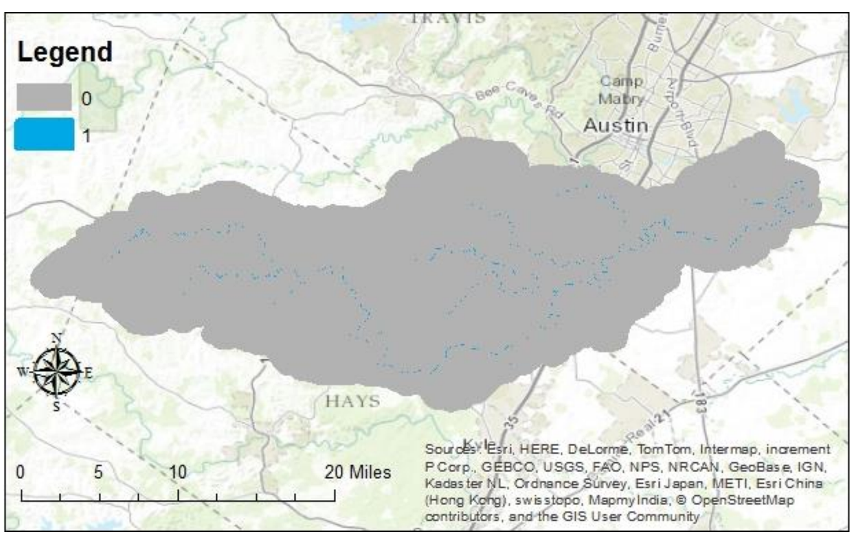

Figure 6: Stream Definition Grid

5) **Stream Link:** The flow direction and the stream definition feature classes are combined to generate stream links through the geoprocessing tools studied in class.
6) **Watershed:** The Watershed Spatial Analyst geoprocessing tool is then used to generate catchments based on the streams. Figure 7 displays the stream link grid with catchments over the Onion Creek Watershed, with 23 subbasins generated (with each subbasin and stream having a unique color). For this project, one sub-catchment at the effluent of the watershed has been treated as the outlet itself, resulting into **22 sub-catchments** for the project.

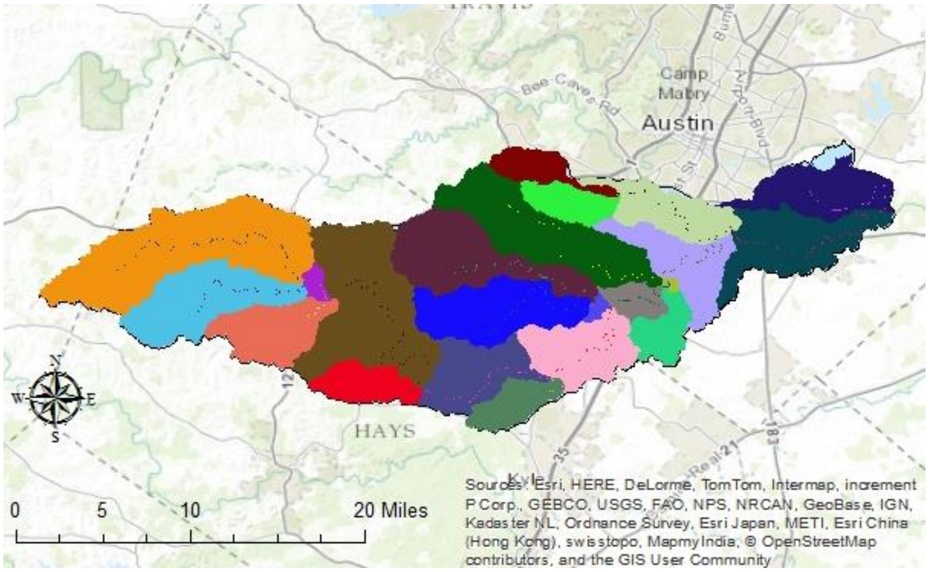

Figure 7: Stream Link and Catchment Grid

7) **Raster to Features:** As Steps 1-6 involves the Digital Elevation Model that is a raster, or gridded, model, the catchments and the stream links are converted into vector feature classes as catchment polygons and drainage lines, respectively, as shown in Figure 8.

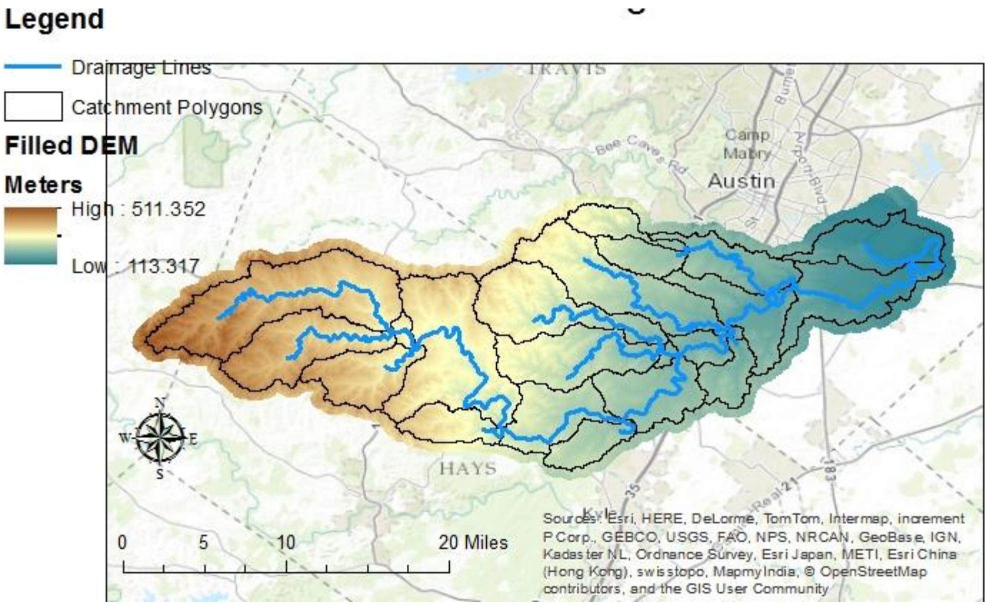

Figure 8: Drainage Lines and Catchment Polygons over Onion Creek

8) **Adjoint Catchment Processing:** The catchment polygons and the stream links that are converted into vector feature classes are then aggregated, with the catchment polygons dissolved into a single subbasin using the HEC-GeoHMS preprocessing tools.

The catchment polygons and the drainage lines are then used by HEC-GeoHMS to generate a new HMS project for further analysis.

Soil and Land Use

Soil data has been gathered through the Soil Survey Geographic (SSURGO) service for Travis County, including information related to the hydrologic soil group that classifies soils based on their properties, such as the general infiltration rate. Land Use data has been gathered through the National Land Cover Database (NLCD), which the 2011 version has been used. The following procedures are implemented for determining a **curve number grid**, which is essential for calculating excess precipitation over the watershed:

1) **Extract by Mask and Intersect:** The land use data, a raster dataset, covers the entire United States and are hence extracted for the Onion Creek Watershed. Soil data over Travis County, a vector feature class, is intersected with the adjoint Onion Creek Watershed to yield soil information over this watershed only rather than the entire county.
2) **Combine Land Use and Soil Data:** Both the land use and soil data that are extracted for the Onion Creek Watershed are then intersected to determine the corresponding land use and soil type for a given area.
3) **Curve Number Lookup Table:** Using the TR-55 Reference Manual (Cronshey, et al., 1986) and a general guide that approximates curve numbers for forests and agricultural purposes (Merwade, 2012), a curve number table has been developed based on the land use and soil type.
   a) *Soil Type:* Soils are identified as Type A, B, C, and/or D. Type A soils have the quickest infiltration rates, and the infiltration rate decreases as one goes from A to B to C to D, with Group D soils having the *slowest* infiltration rates. Figure 9 displays the hydrologic group for the Onion Creek Watershed, which seems to be dominated by group D soils.

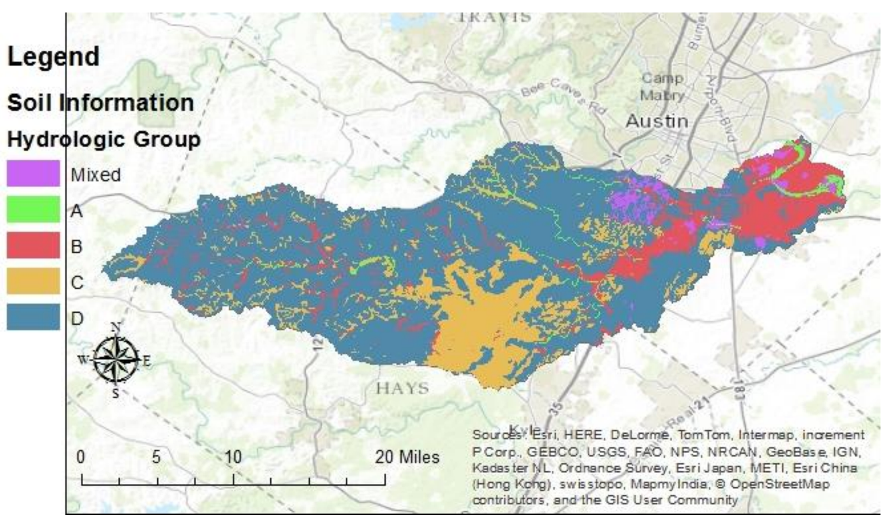

Figure 9: Soil Hydrologic Groups in the Onion Creek Watershed

As shown in Figure 9, there are regions where the soil type is rather unknown. For this project, a grid with a given soil type is identified as 100% of that type (e.g., soil identified as “A” will be “100% Type A”). On the other hand, the soil type that is undefined is assumed to be an *equal* mix of all the groups (25% Type A, 25% Type B, 25% Type C, and 25% Type D). Therefore, four columns are generated in the Soil Type Attribute Table with “PctA”, “PctB”, “PctC”, and “PctD” (which are required fields for the curve number grid). Using field calculator, a short Python Code is implemented, which is shown for “PctB” as follows (into the source block, with HG as the hydrologic group):

```
def reclass(HG):
 if HG = = “B”:
  return 100
 elif HG = = “ ”:
  return 25
 else:
  return 0
```

Figure 10 displays the code input into the field calculator for the soil type attribute table over the Onion Creek Watershed.

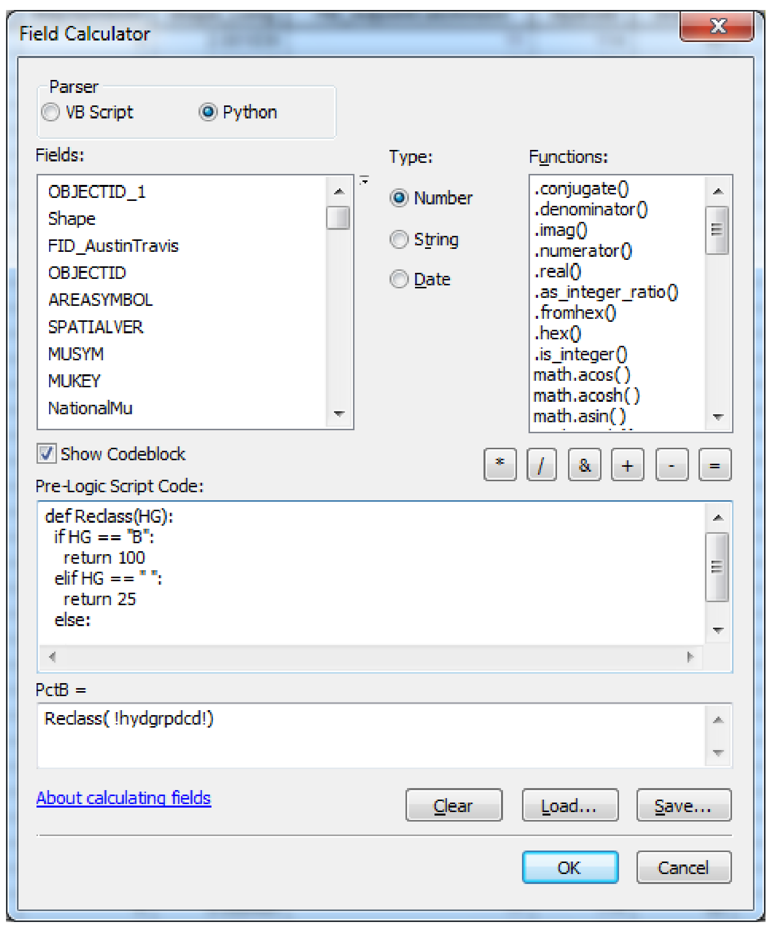

Figure 10: Coding of PctB over the Onion Creek Watershed

b) *Soil Type and Land Use Curve Number Lookup Grid:* TR-55 and Merwade (2012) are referenced for determining the curve number for a given land use and soil hydrologic group. Table 1 displays the curve number lookup table and the land use definitions based on the values (“LUValue”) shown.

Table 1: Curve Number Lookup Table for Land Use and Soil Type

LUValue	Land Use	A	B	C	D
11	Open Water (assumed water)	98	98	98	98
21	Developed; assumed 12% Impervious	46	65	77	82
22	Developed; assumed 38% Impervious	61	75	83	87
23	Developed; assumed 65% Impervious	77	85	90	92
24	Developed; assumed 85% Impervious	89	92	94	95
31	Barren Soil, Rock, and Gravel	77	86	91	94
41	Forest (Deciduous)	30	58	71	78
42	Forest (Evergreen)	30	58	71	78
43	Forest (Mixed)	30	58	71	78
52	Shrub and Scrub (assumed Agricultural)	67	77	83	87
71	Grassland (assumed Agricultural)	67	77	83	87
81	Pasture/Hay	49	69	79	84
82	Cultivated Crops	67	77	83	87
90	Woody Wetlands (assumed water)	98	98	98	98
95	Emergent Wetlands (assumed water)	98	98	98	98

c) *Land Use:* For the Curve Number Grid, the parameter PctImp (Percent Impervious) is required but not defined in the land use data. The PctImp is programmed similarly as the PctA (and the other soil groups) for a given land use (written as LU for the code) value (only LUValue of 21, 22, 23, and 24 exhibit % impervious for this project):

Pre-Logic Code (Python)

```
def reclass(LU):
  if LU = = 21:
    return 12
  elif LU = = 22:
    return 38
  elif LU = = 23:
    return 65
  elif LU = = 24:
    return 85
  else:
    return 0
```

PctImp = Reclass(LUValue)

4) **Curve Number Grid:** Using HEC-GeoHMS processing capabilities, a curve number grid is generated over the Onion Creek Watershed based on the lookup table developed in Step 3 and the combined land data (land use + soil data). The generated curve number grid is a raster layer that can be analyzed over the sub-catchments of the Onion Creek Watershed.

Generating the curve number grid seems to be a decently long process, which takes approximately 22 hours total for the entire Onion Creek Watershed. Figure 11 displays the curve number grid over the watershed.

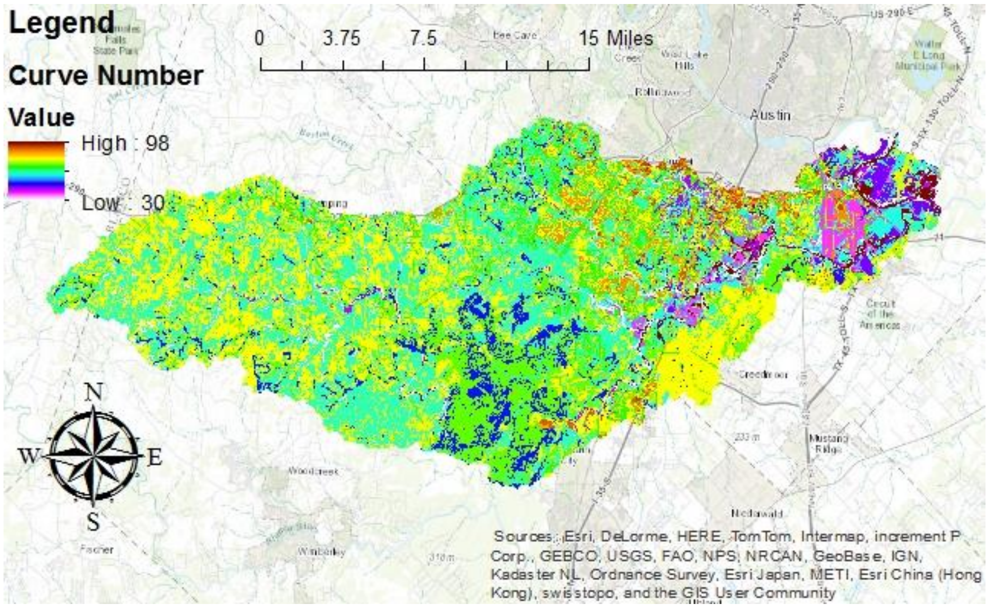

Figure 11: Curve Number Grid over Onion Creek Watershed

5) **Percent Impervious Grid:** Using the land use data and the definitions, approximations are made related to the percent impervious based on the developed land use types. The percent impervious grid is then generated over the Onion Creek Watershed using these definitions (for percent impervious versus the developed land use type). Figure 12 displays the percent impervious grid for the watershed.

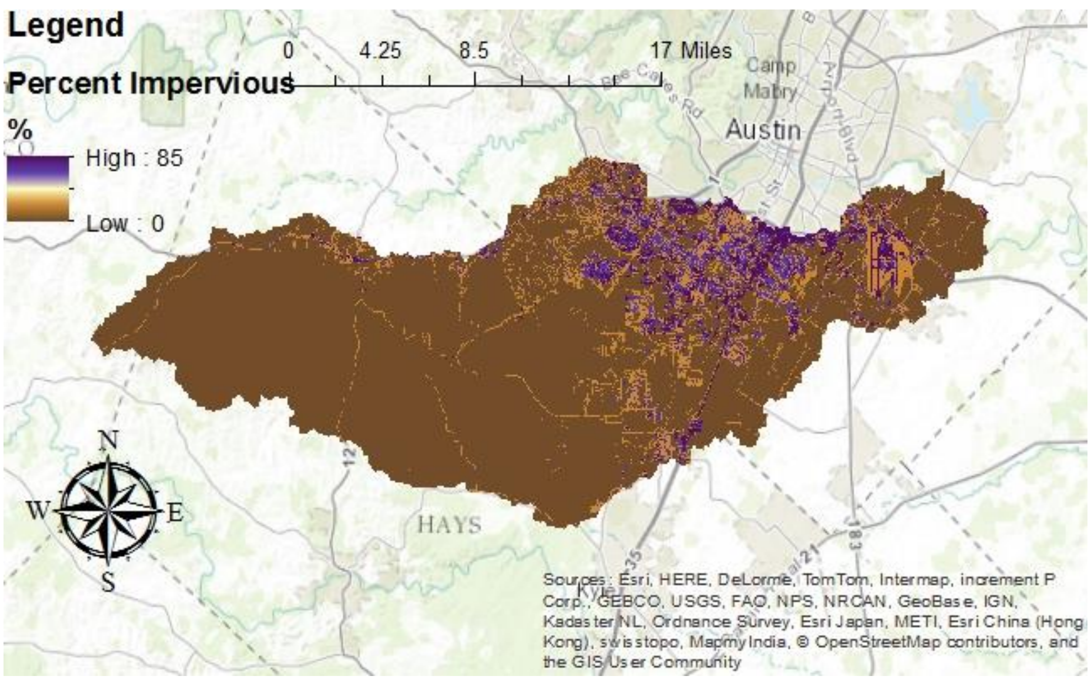

Figure 12: Percent Impervious Grid over Onion Creek Watershed

The curve number and percent impervious grids are then incorporated into the ArcHydro Catchment model for subsequent analysis.

HEC-GeoHMS Processing: Basin and River

After the preprocessing from ArcHydro and the grid generation from Land Data, the two results are then combined to develop a HMS model. The following procedures are employed for calculating the parameters needed for generating the HMS model files using HEC-GeoHMS:

1) **New Project:** A new HMS project has been defined and generated using the required ArcHydro preprocessed datasets (filled DEM, flow direction, flow accumulation, drainage lines, catchment polygons, adjoint catchment polygons). The subbasin and river feature classes based on a selected project point has been generated through this process.
2) **River Length:** The length of the drainage lines through the sub-catchments generated by ArcHydro are calculated.
3) **River Slope:** The Raw Digital Elevation Model (the DEM model before the Fill Tool) is combined with drainage line feature class to determine the average slope of the river for each sub-catchment.
4) **Catchment Slope:** The slope geoprocessing tool by ArcHydro is used to generate a raster dataset that calculates the slope along the Onion Creek Watershed.
5) **Basin Slope:** The slope raster dataset is combined with the subbasin feature class to calculate the average subbasin slope over the sub-catchments.
6) **Longest Flowpath:** The raw Digital Elevation Model (Raw DEM), the flow direction grid, and the subbasin feature classes are then combined, using the zonal statistics geoprocessing tool, to generate the longest flowpath feature class.
7) **Basin Centroid:** Using the method of center of gravity (the default option for HEC-GeoHMS), a centroid feature class is generated and gives the centroid for each sub-catchment over the Onion Creek Watershed.
8) **Centroid Elevation:** The raw DEM and the centroid feature classes are combined to yield a feature class that gives the elevation of the centroid for each sub-catchment.
9) **Centroidal Longest Flowpath:** The subbasin, centroid, and the longest flowpath feature classes are combined to determine the centroidal longest flowpath feature class.

The feature classes generated in this portion constitute part of the required parameters for creating the files for the HMS model.

HEC-GeoHMS Processing: Flows and Grid Cells

The HEC-GeoHMS tool is then used to describe the properties of the Onion Creek Watershed sub-catchments that are generated from the ArcHydro Preprocessing steps. This portion involves describing the reach parameters, including the routing and loss methods to be used for the analysis. For this project, the Soil Conservation Service (SCS) method is employed for excess rainfall calculation. The SCS Unit Hydrograph is employed as the routing method for subbasins that converts the excess precipitation to streamflow. The Muskingum Cunge method is used as the routing method for the river feature class, assuming that the river is a *trapezoidal channel* with Manning's coefficient *n* as 0.035 and a side slope of 3 horizontal to one vertical. Since the Raw Digital Elevation Model has been taken from the N30m grid from the ArcGIS services, a bottom width of 30 meters is used for the river throughout the watershed. For this project, all these parameters are assumed to be constant throughout the reach. The following processes are used to generate the grid cell intersect feature class needed for the project:

1) **HMS Processes:** The processes for the loss and transform methods for subbasins, along with the routing method for rivers, have been defined at the beginning of this sub-section.
2) **River Auto Name:** HEC-GeoHMS defines the sub-catchment reaches using a unique identifier that is used in HMS.
3) **Basin Auto Name:** HEC-GeoHMS defines the sub-catchments in the Onion Creek Watershed with unique identifiers.
4) **Subbasin Parameters from Raster:** The percent impervious and curve number grids are combined with the subbasin feature class to determine the average percent impervious and average curve number for each sub-catchment. For this project, normal conditions (antecedent moisture condition II) has been used for the curve numbers.
5) **Muskingum Cunge and Kinematic Wave Parameters:** Properties of the reach, such as the Manning's *n* and the side slopes, are defined and applied to all reaches in the Onion Creek Watershed.
6) **Curve Number Lag:** The lag time for each subbasin has been calculated in HEC-GeoHMS using the slope of each sub-catchment and the average curve number. The lag time for each subbasin can be calculated as follows (DHI, 2009):
$$t_{Lag} = \frac{L^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1900Y^{0.5}}$$
The parameter t_{Lag} is the lag time in hours while CN is the average curve number for a subbasin. The parameter L is the hydraulic length of the catchment in feet while the variable Y is the average slope of the subbasin in percent. HEC-GeoHMS uses this method for calculating the CN Lag for the subbasins.
7) **TR 55 Flow Path Segments and Parameters:** The flow direction raster dataset is combined with the longest flow path and the subbasin feature classes to generate break points and segments that are used to generate the HMS subbasin model.
8) **Grid Cell Processing:** A grid cell feature class is generated using the Standard Hydrologic Grid (SHG) for this project. The flow direction dataset is combined with the subbasin feature class (with the curve number and the percent impervious defined) to generate a grid cell intersect feature class that is used for generating the HMS model files. Figure 13 displays the Grid Cell Intersect class over the Onion Creek Watershed.

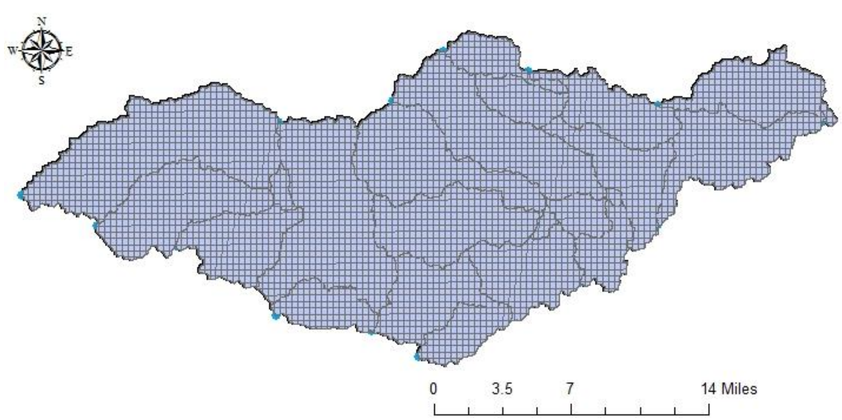

Figure 13: Grid Cell Intersect Class from Grid Cell Processing

The outputs from this process involve the flow path segments and the grid cell feature class that are employed for generating the HMS basin model file.

Exporting the Files onto HMS

The files needed for the HMS model involve the BASIN file (the subbasin), the Meteorology File (for the precipitation gages), and the GAGE file generated from the meteorology file. The following processes are employed for generating these files into HMS, which are used for setting up a model for computing the streamflows:

1) **Map to HMS Units:** This process is needed for converting the model into the appropriate units that HMS uses for simulating a run. Figure 13 displays the required files to complete this process.

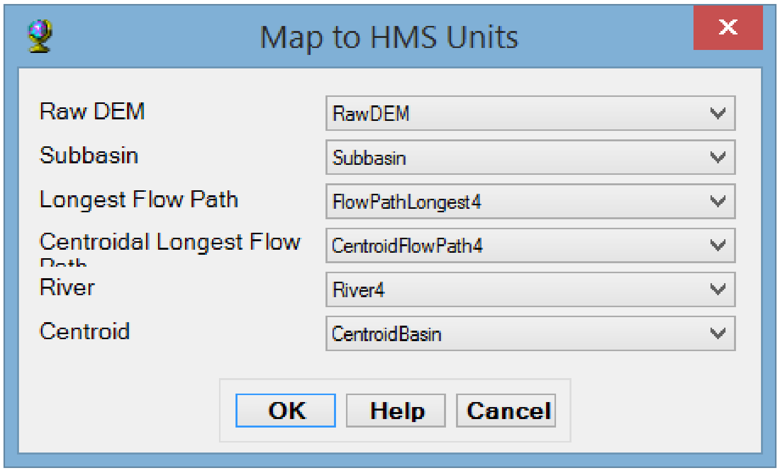

Figure 14: Required Files for Map to HMS Units

2) **HMS Schematic:** The TR 55 flow path segments, the subbasin, and the river features are combined to generate the HMS model for the watershed. Figure 3 displays the HMS model schematic created for the Onion Creek Watershed.

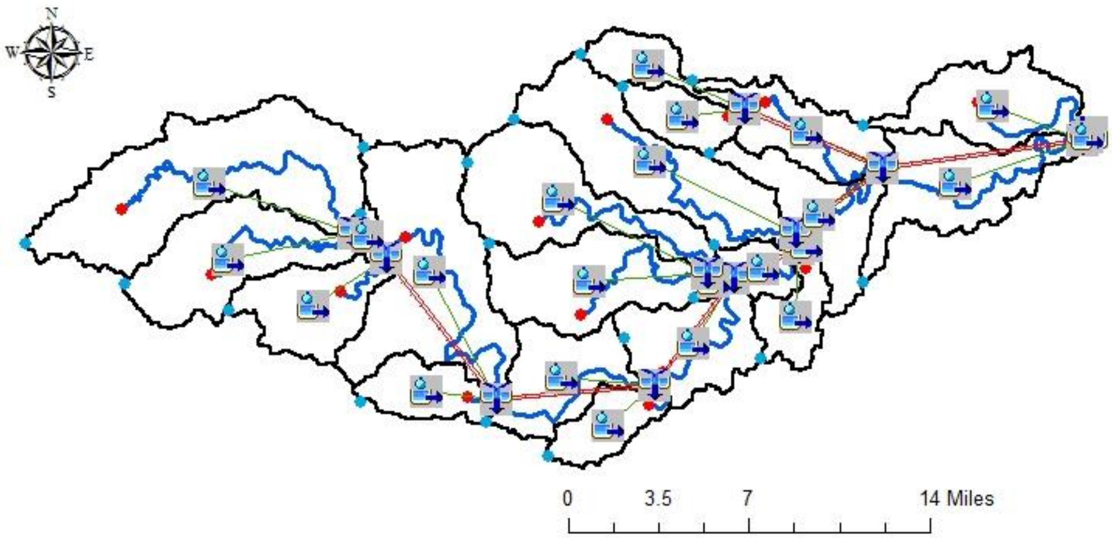

Figure 15: HMS Schematic for Onion Creek Watershed

3) **Prepare Data for Model Export:** The longest flow path, the centroidal longest flow path, the subbasin, and the river feature classes are combined to generate the needed files for the HMS model.
4) **Basin Model File:** Using the parameters from Steps 2 and 3, a basin model file has been generated and gives the subbasins, junctions, and reaches needed for the HMS project.
5) **Grid Cell File:** The grid cell intersect feature class from the Grid Cell Processing step is exported into a MOD file that is needed for the HMS project.
6) **Thiessen Polygon:** Using the precipitation data gathered from the National Oceanic and Atmospheric Administration (NOAA) for October 31, 2013, Thiessen Polygons are employed to determine the representative precipitation areas over the watershed. For this project, evapotranspiration has been neglected and assumed to be already accounted for the precipitation data. Figures 16 and 17 display the precipitation map on October 31, 2013 and the Thiessen Polygons generated over the Onion Creek Watershed, respectively.

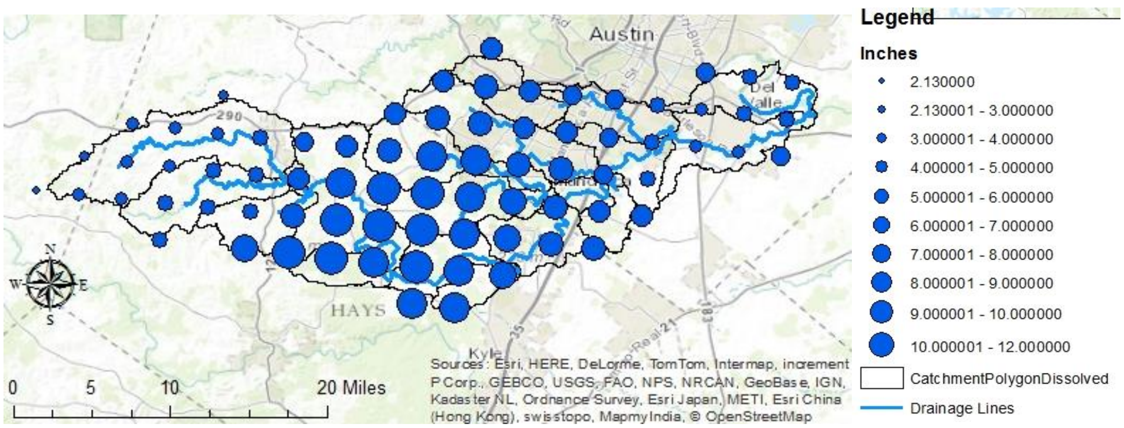

Figure 16: Precipitation over October 31, 2013

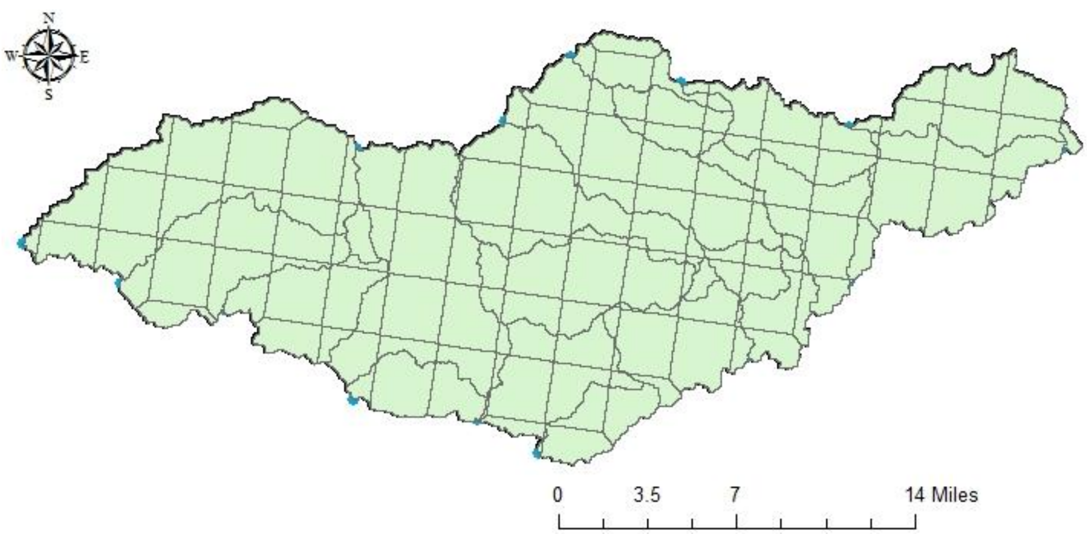

Figure 17: Thiessen Polygon Generated

7) **Gage Weights Meteorology File:** The gage weight method is employed to determine the contributing area of each precipitation data point into a sub-catchment. A meteorology (MET) file is generated to incorporate precipitation data into the watershed. Depth weights

(percent of precipitation gage depth that contributes to a sub-catchment) are determined using this process. Time weights are assumed to equal the depth weights for this project. A gage file is also generated with the MET file. Figure 18 displays the time and depth weights for a randomly selected subbasin in the HMS model.

Element Name: W240

Gage Name	Depth Weight	Time Weight
175032	0.0642	0.0642
175033	0.1379	0.1379
175034	0.163	0.163
175035	0.0003	0.0003
176082	0.0286	0.0286
176083	0.2066	0.2066
176084	0.2399	0.2399
176085	0.1567	0.1567
176086	0.0028	0.0028

Figure 18: Depth and Time Weights for a Selected Subbasin in HMS

The Basin, Meteorology (MET), and the gage files are then imported into HMS to generate a model for the Onion Creek Watershed.

Generating HMS Project and Simulating Runs

The Basin, MET, and the gage files are imported into the HMS model displayed in Figure 19 below under SI units.

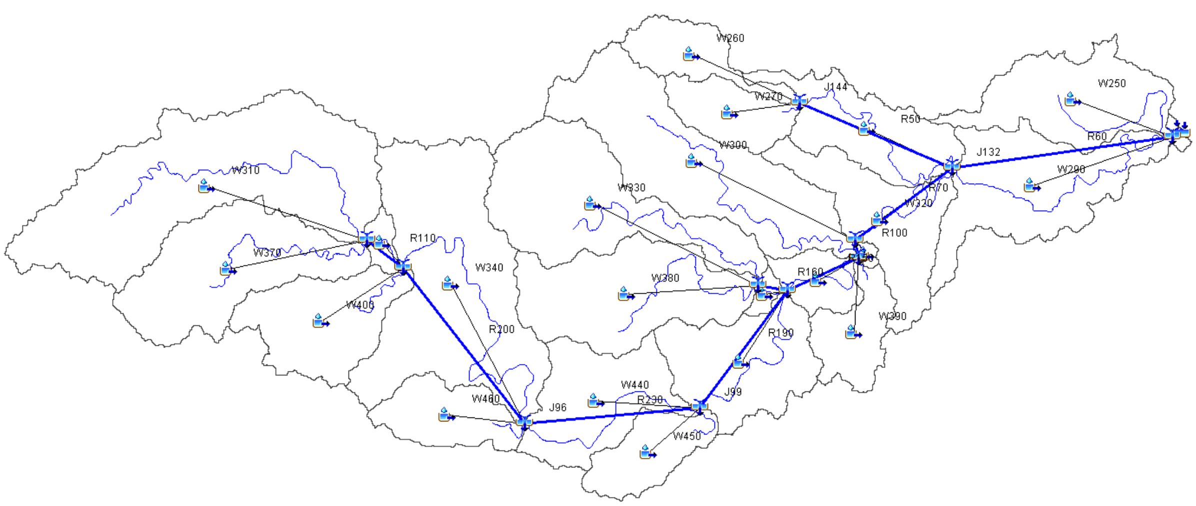

Figure 19: HMS Model for the Onion Creek Watershed

To calculate the streamflow for the subbasins and reaches shown in Figure 4, the following procedures are done in the HMS model:

1) **Precipitation Gage Data:** The HMS model imports the depth weights and the time weights (assumed to equal the depth weights for this project) but not the precipitation values. For this project, the precipitation values were manually entered for all the gages developed by HMS. The precipitation data provided by NOAA correspond to the 24-hour values for

October 31, 2013. However, since water begins to intensify by 5:00 AM on this day (Jervis, 2013), a 6-hour cumulative precipitation hyetograph is implemented for each gage, starting at 12:00 AM on October 31, 2013. The 24-hour values are assumed to be dominated by the precipitation from 12:00 AM to 6:00 AM for this project. Therefore, the data for the precipitation gages at 6:00 AM on October 31, 2013, are populated by the 24-hour precipitation values for this analysis. Figure 20 displays the input for the precipitation gage hyetograph while Figure 21 shows the cumulative precipitation depth in inches inputted into the HMS model for a precipitation gage.

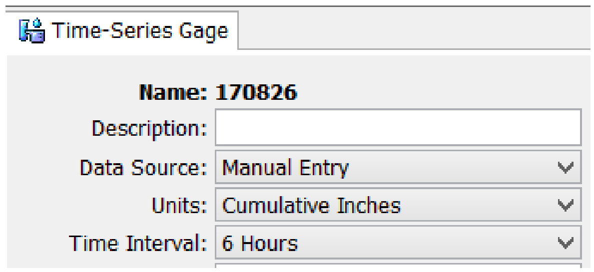

Figure 20: Precipitation Gage Properties for Time-Series Data

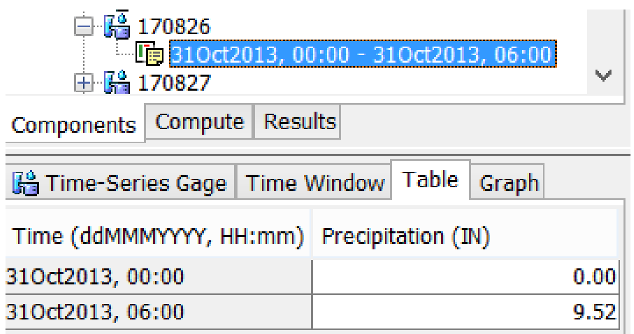

Figure 21: Precipitation Time-Series Data Inputted Manually

2) **Simulation Run Creation:** A simulation run for calculating the streamflow is created for the HMS model for this watershed. Data showing the peak flow rate, the time to peak, and the volume have been generated from the runs.

Table 2 below displays the simulation results for peak flow, time to peak, and the number of hours from 6:00 AM (the time when the cumulative precipitation is inputted).

Table 2: Simulation Results from HMS Run

Hydrologic Element	Drainage Area (km^2)	Peak Flow (cfs)	Time to Peak on October 31, 2013	Hours from 6 AM, 10/31/2013 (HH:mm)	Volume (*1000 m^3)
J104	599.1996	2479.2	9:00	3:00	77681.1
J109	633.5406	2527.8	10:00	4:00	81723.6
J112	229.1482	536.9	8:00	2:00	14741.1
J117	128.265	726.3	9:00	3:00	21698.1
J120	183.386	348.7	9:00	3:00	9628.6
J123	714.4947	2822.8	10:00	4:00	92192.9
J132	835.1667	3162.2	10:00	4:00	104133.8
J139	939.3337	3263.3	11:00	5:00	108144.1

J144	40.386	233.8	7:00	**1:00**	5226.2
J96	358.2902	1242.2	9:00	3:00	37125.7
J99	423.2902	1601.5	9:00	3:00	48801.6
Outlet1	939.3337	3242.5	11:00	5:00	107878.6
R100	633.5406	2521.7	10:00	4:00	81679
R110	183.386	347.2	9:00	3:00	9627.1
R150	599.1996	2469.7	10:00	4:00	77460.2
R160	128.265	723.4	9:00	3:00	21701.8
R190	423.2902	1582.4	10:00	4:00	48518
R200	229.1482	523.1	10:00	4:00	14587.3
R230	358.2902	1220.8	10:00	4:00	36941.3
R40	939.3337	3242.5	11:00	5:00	107878.6
R50	40.386	229.8	8:00	2:00	5232.9
R60	835.1667	3108.9	11:00	5:00	102404.2
R70	714.4947	2768.4	10:00	4:00	91568.1
W240	38.033	121.1	9:00	3:00	3658.4
W250	45.891	66.4	12:00	6:00	2584.2
W260	19.352	110.2	7:00	**1:00**	2432.8
W270	21.034	123.6	7:00	**1:00**	2793.5
W290	58.276	88.5	11:00	5:00	3155.6
W300	79.472	301.1	10:00	4:00	10374.4
W310	121.54	205.6	9:00	3:00	5833.2
W320	42.253	133	8:00	2:00	3674.4
W330	68.366	372.1	9:00	3:00	10771.9
W340	104.52	584.2	9:00	3:00	17718.6
W350	4.8832	30.3	6:00	0:00	535.6
W360	1.4821	8.5	6:00	0:00	139.4
W370	61.846	150.4	8:00	2:00	3795.4
W380	59.899	354.2	9:00	3:00	10926.2
W390	20.701	128.7	7:00	**1:00**	2694.7
W400	40.879	208.2	7:00	**1:00**	4578.4
W410	13.64	75.3	7:00	**1:00**	1568.7
W420	3.0014	22.2	6:00	**0:00**	385.8
W430	44.643	261.8	8:00	2:00	7075.5
W440	42.928	318.4	8:00	2:00	8047.8
W450	22.072	145.7	8:00	2:00	3812.4
W460	24.622	208.4	7:00	**1:00**	4819.8

Appendix A gives the corresponding maps for the subbasins and reaches for the HMS model. For Table 2, the hydrologic element starting with “W” represent a subbasin, which “J” indicates junction and “R” indicates reach, for the HMS model. Figure 22, shown on the following page, displays the flow profile for a randomly selected reach (Reach 50 for this case), with the flow rate in units of cubic meters per second.

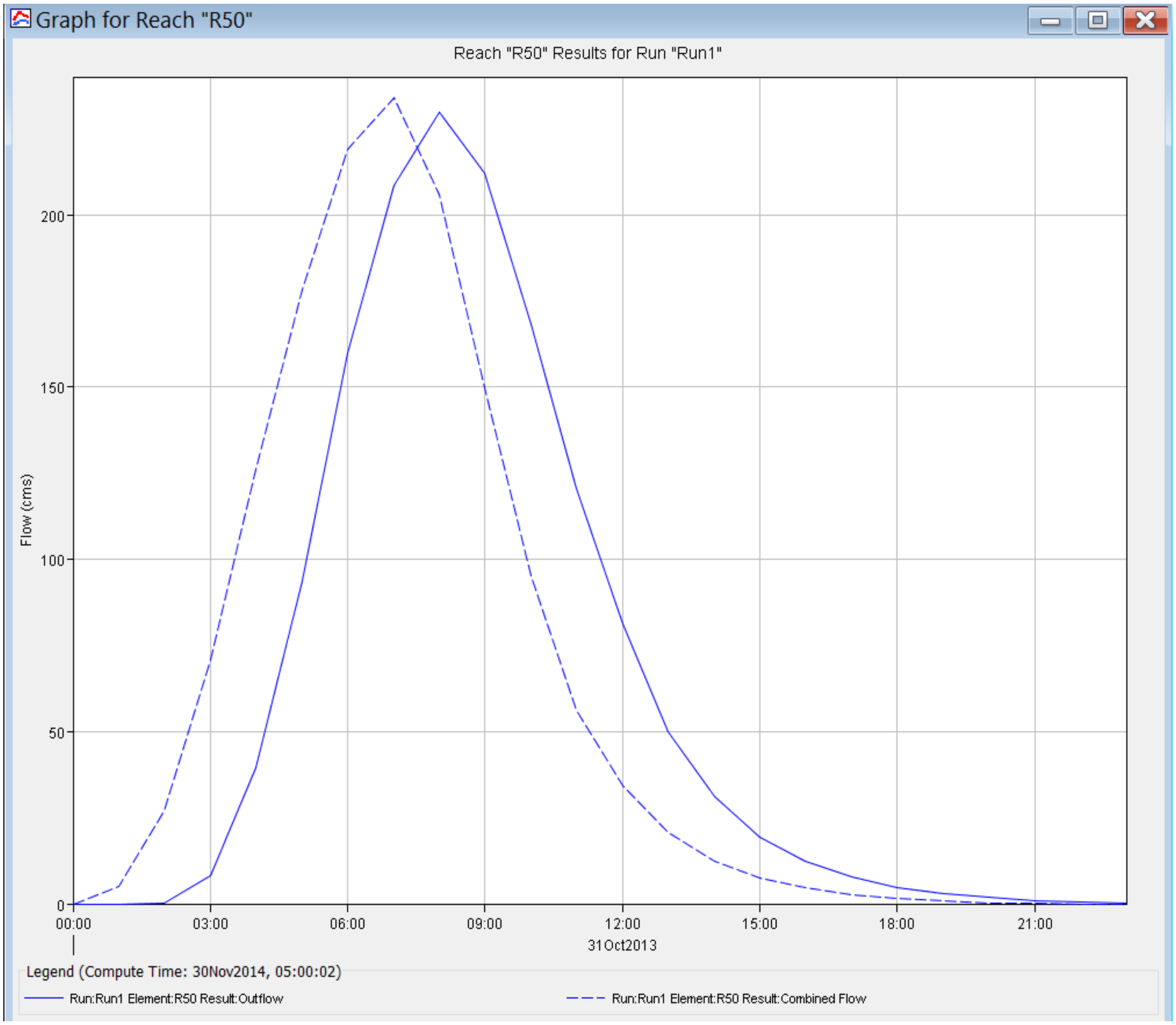

Figure 22: Flow Profile for Reach R50 in HMS

As shown in Table 2, some of the hydrologic elements exhibit peak flows at approximately 0 to 1 hour (indicated in **bold**) from 6:00 AM during the Halloween Flood simulation. Meanwhile, the upstream elements seem to exhibit higher peak flows, indicating that many of the downstream processes experience great water flows from upstream mechanisms. Therefore, if the precipitation shown in Figure 16 (for the precipitation data for October 31, 2013) had all occurred within the 6-hour period, then an emergency response may be necessary and done quickly to lower the risk of this event from reoccurring.

Conclusion

This project investigates the Halloween Flood that occurred along the Onion Creek Watershed in 2013. ArcHydro was employed to generate the drainage lines and sub-catchments for the watershed while HEC-GeoHMS creates the feature classes and HMS files needed for the HMS model. These files are imported into a HMS model, and precipitation data was manually entered applying assumptions for this project that was at a small scale relative to a major project that involves complex hydrologic modeling of a watershed. The project may be significantly improved if more complex methods are employed for the HMS model simulation. For instance, instead of using the SCS curve number method for analyzing losses for a subbasin, a more complex method, such as not averaging the curve number over the subbasin or implementing groundwater characteristics, may be employed. A similar change can also be applied for the Routing Method for rivers, which a more complex model other than the Muskingum Cunge may be used to further complicate the analysis. Finally, based on a simulation run, an emergency response seems needed to react to the great peak flows to lower the risk of a similar event as the Halloween Flood from reoccurring.

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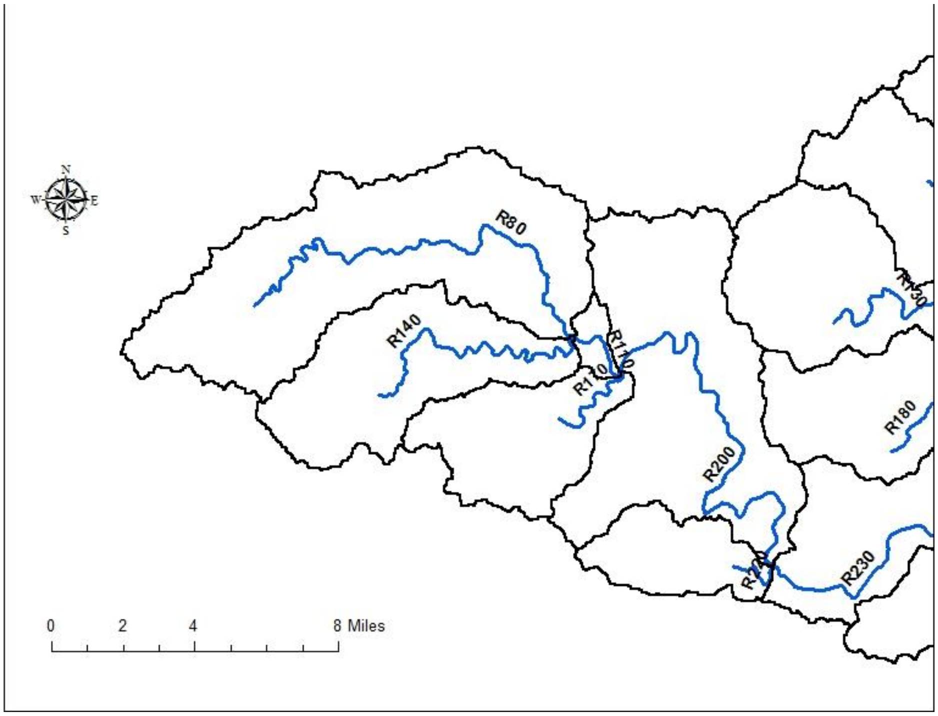
Appendix A: HMS Maps

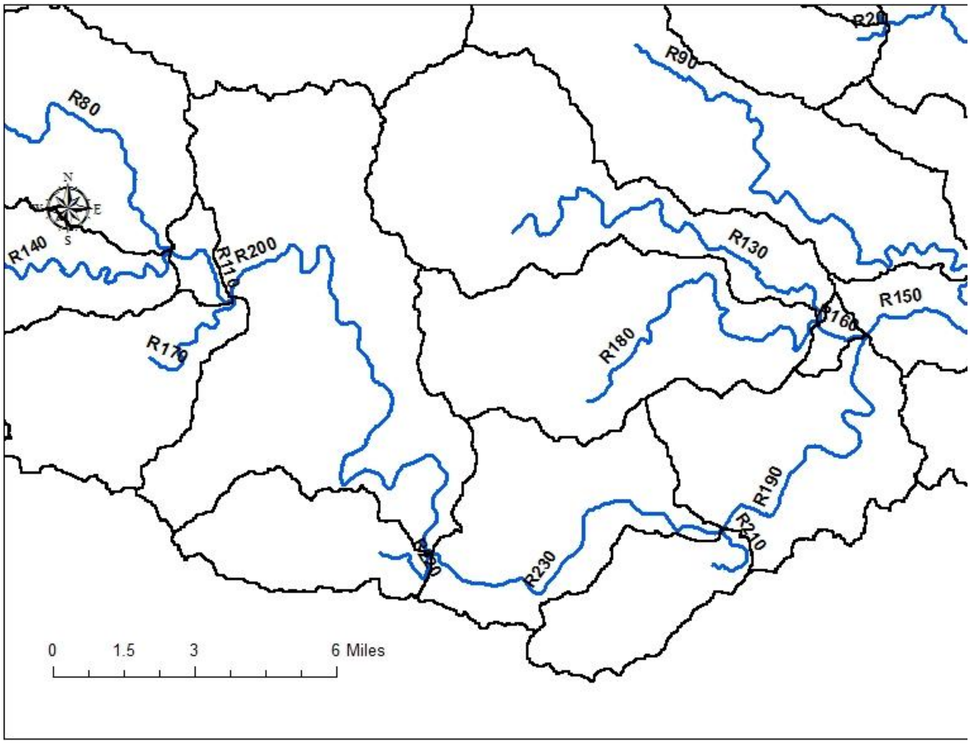
This section displays the maps of the subbasins and reaches for the HMS model.

Map of Reaches

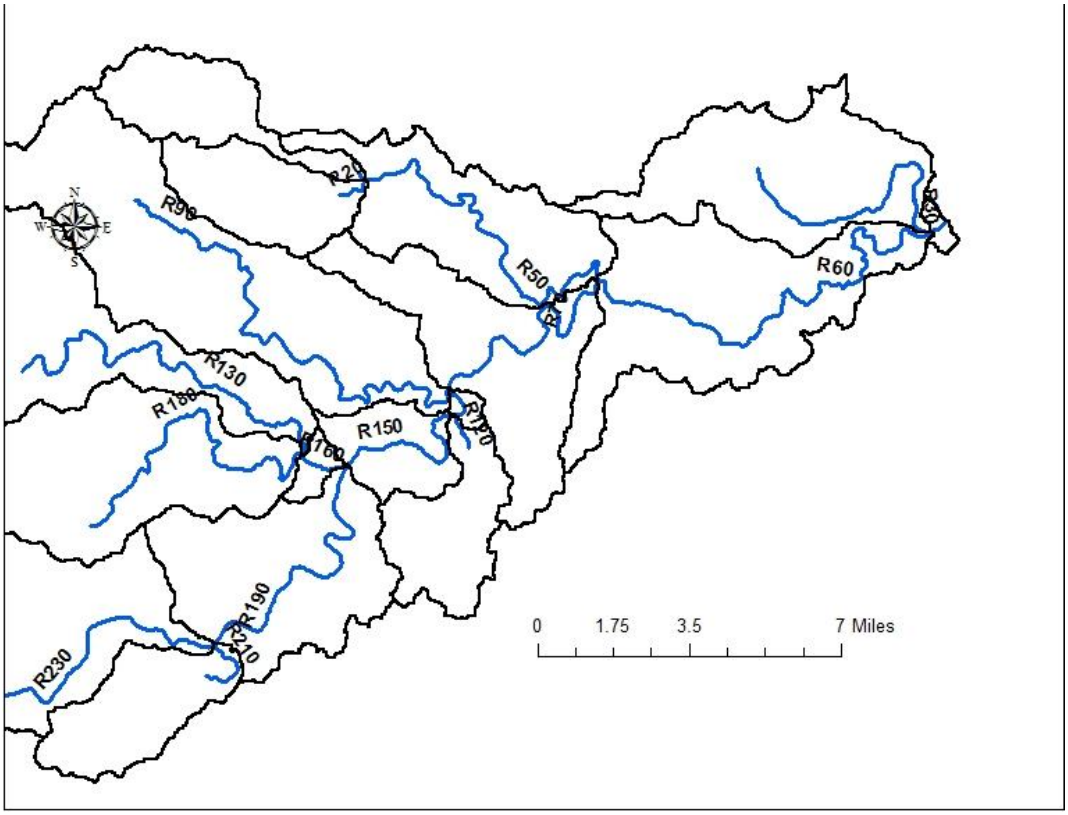
Upstream Portion:



Middle Potion:



Downstream Portion:



Subbasin Map

HMS Subbasin Labels