Oregon State University

Baltimore Base Dataset

CE 413 GIS in Water Resources

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Introduction

The purpose of this project is to create a base dataset of the sub-basin surrounding the city of Baltimore, Maryland. This sub-basin is called the Gunpowder-Patapsco Watershed, named after the two largest rivers that flow through it. The base dataset displays hydrologic and soil properties within the region. Soil properties are used to determine the maximum water storage within the top meter of the ground, while hydrologic properties are examined to find the mean annual flow (average flowrate) of streams. Mean annual flow can be estimated using either stream gages or methods utilized by the National Hydrography Dataset (NHD), which are compared in this paper. Creating a base dataset provides a glimpse at how the Gunpowder-Patapsco Watershed operates hydrologically. A detailed review of just the city of Baltimore is also included.

Site Description

Maryland is situated in the Mid-Atlantic region of the Eastern Seaboard. The state borders the Atlantic Ocean, but has its largest water border with the Chesapeake Bay. Its biggest city is Baltimore, which lies within the Gunpowder-Patapsco Watershed, as shown by Figure 1.

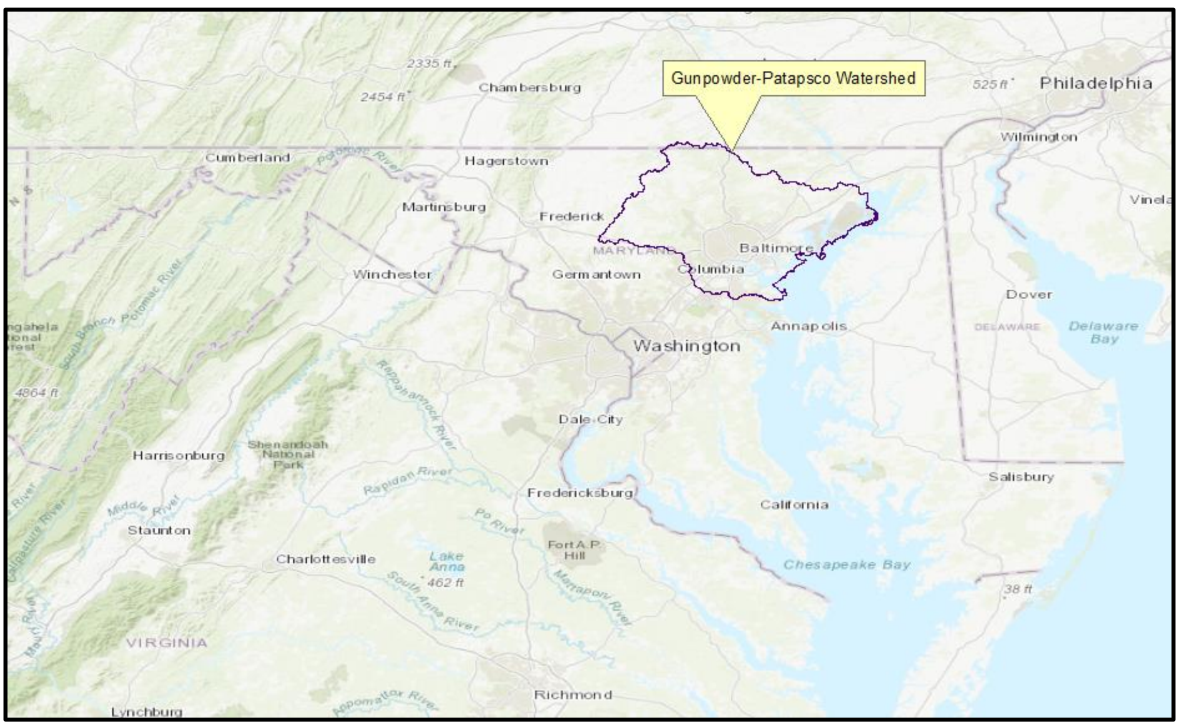


Figure 1: Location of the Gunpowder-Patapsco Watershed in Maryland

The Gunpowder-Patapsco Watershed has an area of 1,375 square miles, and is part of a larger water resource region. There are 21 of these regions across the nation, as defined by the United States Geological Survey (USGS). The state of Maryland is part of the Mid-Atlantic region, which can be defined by its hydrologic unit code (HUC) of 02. These codes are used to define specific watershed areas, and contain more digits as the areas get smaller. The Gunpowder-Patapsco Watershed examined in this project has an eight-digit HUC of 02060003, and can be further broken up into 12 ten-digit HUCs and 43 twelve-digit HUCs. Figure 2 displays these hydrologic units, with ten-digit HUCs grouped by color and twelve-digit HUCs outlined in black.

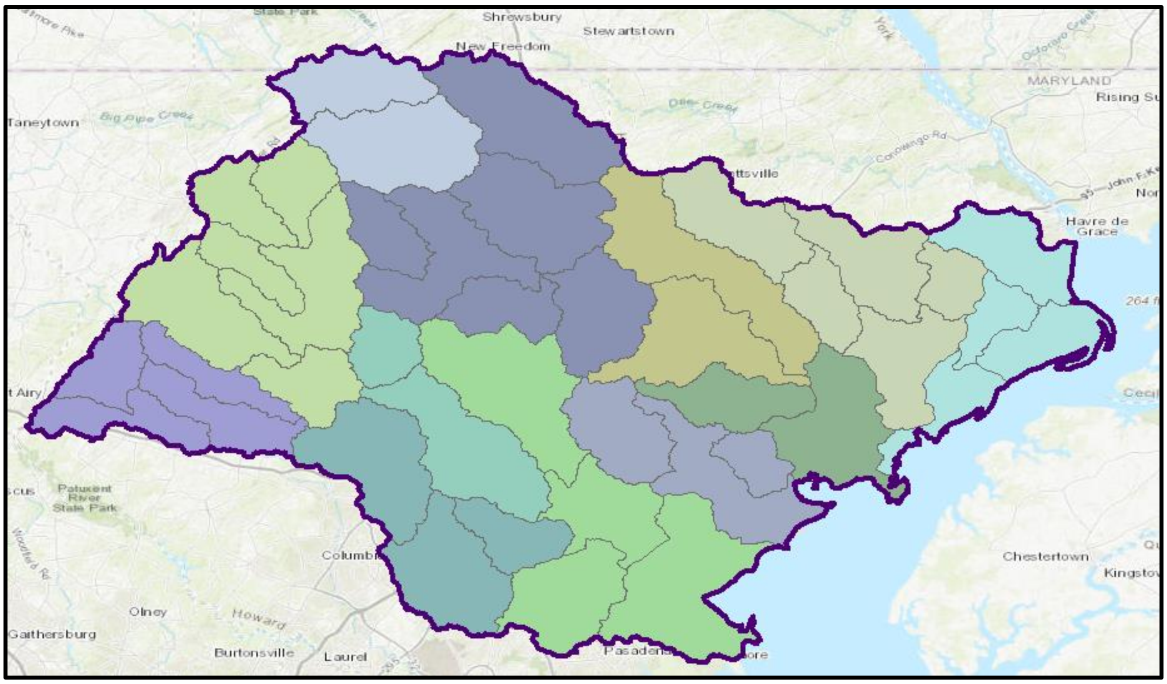


Figure 2: Hydrologic Units within the Gunpowder-Patapsco Watershed

The Gunpowder-Patapsco Watershed is made up of multiple land uses. Highly urbanized areas dominate in the southeast, while the Piedmont Plateau runs through the east, containing grassy plains, mixed forests, and farmland. A closer look at 73 square mile area that is the city of Baltimore shows a densely populated urban area with impermeable surfaces. This can be seen in Figure 3, with the city area drawn in red. The city experiences 41 inches of rainfall annually with an average temperature of 58°F (4). To put this into perspective, Portland, Oregon receives 36 inches of rainfall per year and has an average temperature of 55°F (4). Because of the large volume of rainfall in the region, it is important to understand its soil and drainage properties to find out where that water may end up.

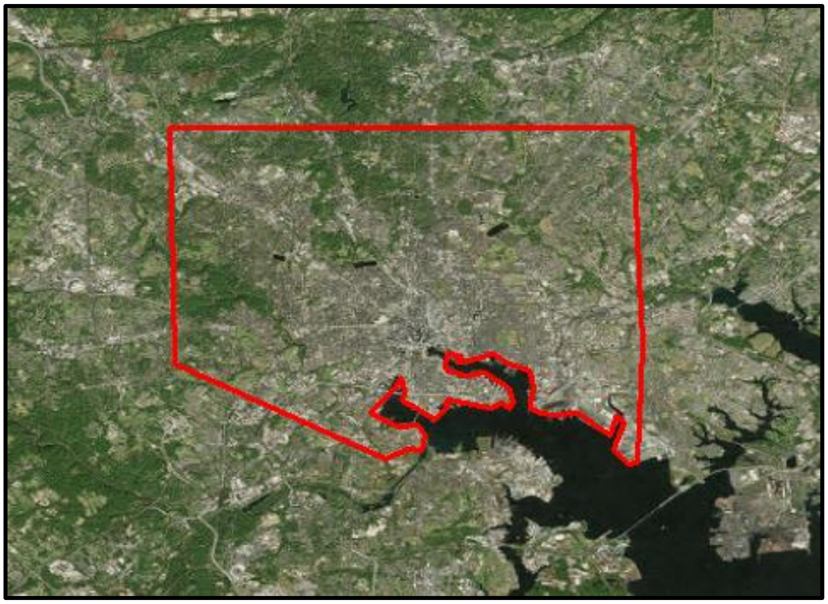


Figure 3: Urban Features of Baltimore City Study Area

Data

A majority of the data used for this project can be downloaded from the USGS website, NHDPlus Version 2. This includes the watershed boundary and flow line shape files as well as the Enhanced Unit Runoff Method (EROM) table used to determine stream mean annual flowrates. Stream gage shape files are also available for download from USGS. Soil vector data for the watershed was retrieved from the SSURGO downloader provided by ESRI. All of this data is portrayed using the NAD83 coordinate system.

Methodology

Stream Information

The goal of presenting stream information is to manipulate the watershed and flow line shape files in a way to display relevant flowrate characteristics. This process begins with creating a new file geodatabase and feature dataset with the NAD83 coordinate system. Figure 4 is a flowchart outlining major steps of this part of the project.

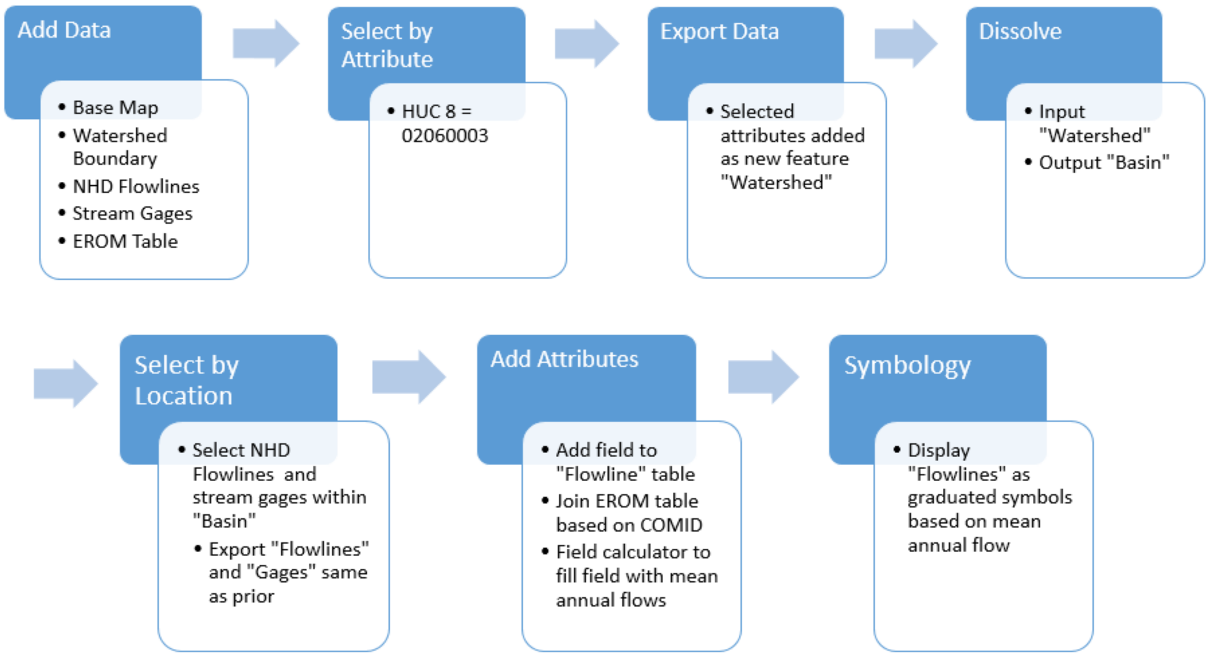
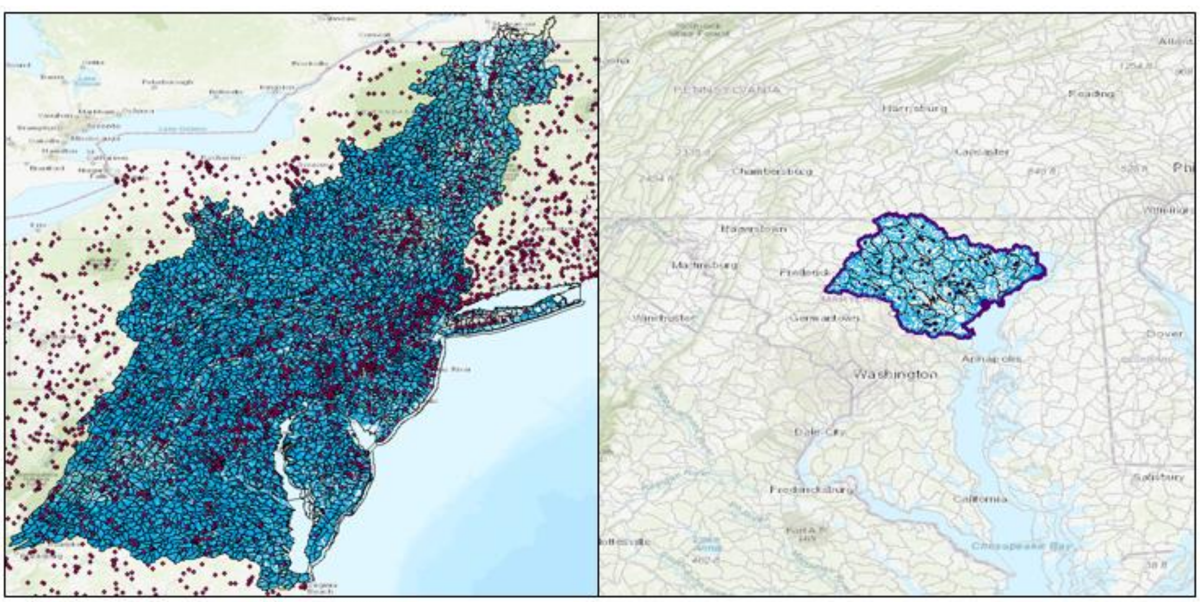


Figure 4: Stream Information Process Flowchart

The unaltered data must be simplified to just the area of interest, which is the Gunpowder-Patapsco Watershed (HUC 8 = 02060003). Once this data is identified, it is exported to create the new feature. This transformation can be seen in Figure 5.



(a) Unaltered watershed, stream gage, and flow line data

(b) Isolated watershed, stream gage, and flow line data

Figure 5: Exported Features from Raw Data

Once the flow lines and watersheds have been isolated, characteristics such as basin area and total stream length can be found using the statistics option within the layers' attribute table. To express more information, the EROM table is joined with the flow line attribute table, providing the ability to display streams based on their flowrate. Three unique stream gages have also been selected to compare flowrate values. These three are South Branch Patapsco River at Henryton, Jones Falls at Maryland Avenue at Baltimore, and Gunpowder Falls near Carney. The fully updated map is shown in Figure 6.

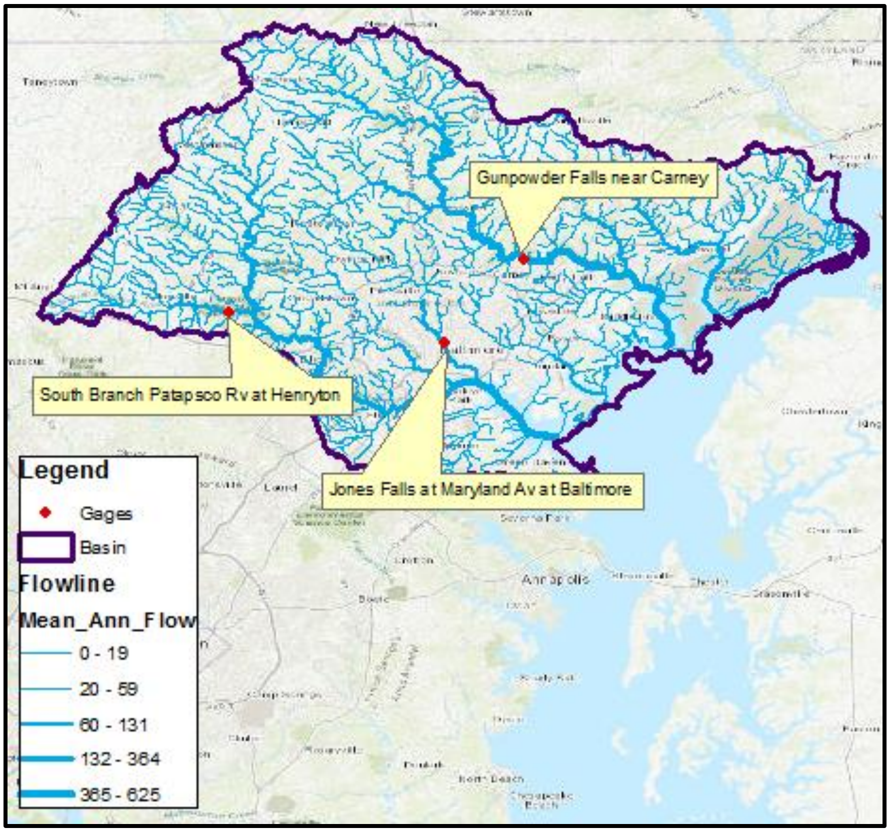


Figure 6: Map of Gunpowder-Patapsco Watershed Streams and Gages

As seen in Figure 6, the streams appear larger as the mean annual flow (measured in cubic feet per second) increases. With the information provided from this map, the average mean annual flow of the watershed can be determined, along with its drainage density. This information can also be determined for just the city of Baltimore. This involves creating a new feature class, editing its shape, and clipping the flow line data. This can be visualized by the flowchart in Figure 7.

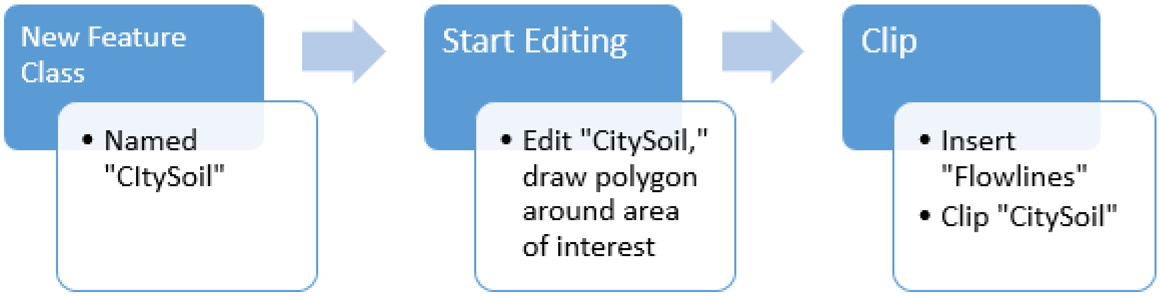


Figure 7: Flowchart for Isolating Baltimore City Flow Lines

The resulting area and streams of the city of Baltimore are shown in Figure 8.

Figure 8: Baltimore City Area and Accompanying Flow Lines

Soil Information

Soil characteristics are helpful in determining the ground's ability to infiltrate and store storm water. As previously mentioned, soils data is retrieved from ESRI's SSURGO downloader, which provides raw sub-basin soils data as shown in Figure 9.

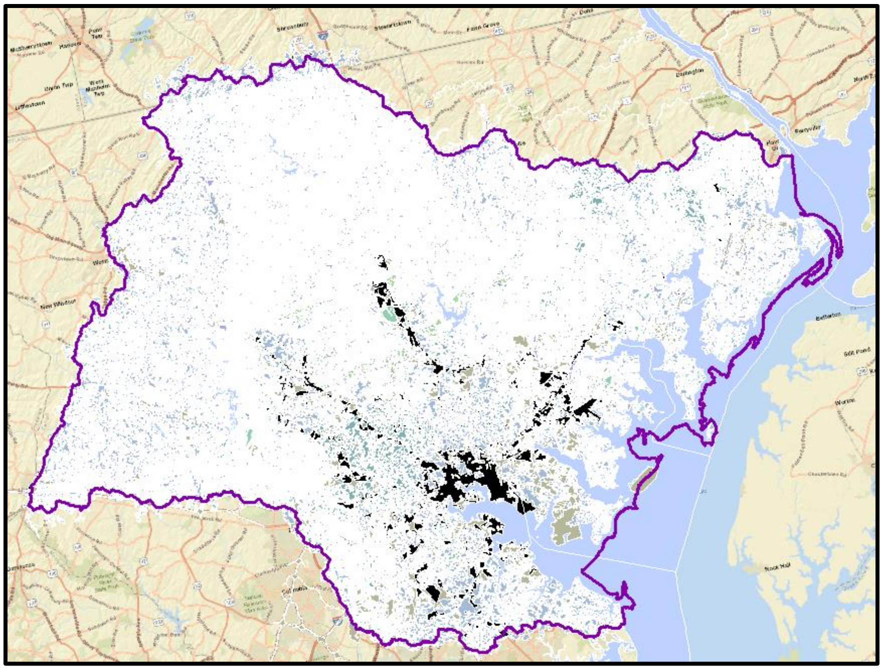


Figure 10: Raw Soils Data

The information portrayed in Figure 9 shows the different types of soil in the region. The data that is of interest is the available water capacity in the top meter of soil as well as the hydrologic soil group. This information can be gathered by summarizing the category of interest according to its area within the soil's attribute table. To portray the water storage capacity on the map, the raw data is clipped and symbolized according to its capacity. This process is visualized in the flowchart in Figure 10.

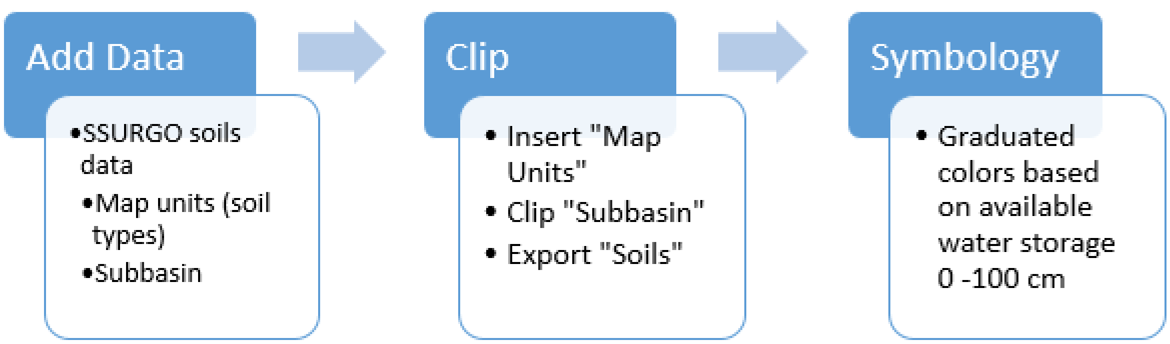
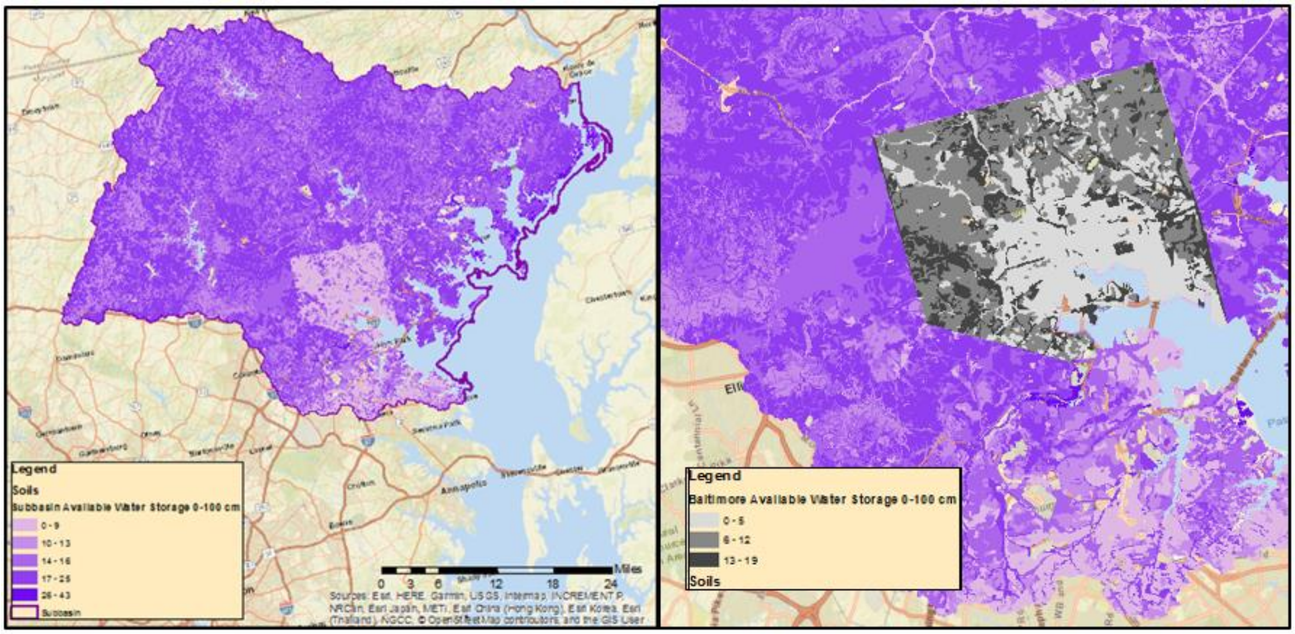


Figure 9: Soil Information Flowchart

The resulting map in Figure 11(a) displays the available water storage averages throughout the watershed. Similar to the process described for finding stream information, the water storage property for just the city of Baltimore is also found and seen in Figure 11(b).



(a) Gunpowder-Patapsco Available Water Storage Map

(b) Baltimore City Available Water Storage Map

Figure 11: Available Water Storage Maps

Results and Discussion

Soil and stream data that is obtained by the methods described can help describe basic hydrologic characteristics of the areas of interest. Stream flowrates is a simple initial observation that can be made. However, this data may differ between the enhanced runoff method provided by NHDPlus, and the stream gage flowrate values from USGS. Table 1 shows mean annual flow values for the three stream gages located in Figure 6.

Table 1: Mean Annual Flowrate Values (cfs) by Calculation Method

Method	Gunpowder Falls	Jones Falls	Patapsco South Branch
Gage	146	75	75
EROM	415	73	87

As seen in Table 1, the flowrate for Gunpowder Falls has a large discrepancy between the two calculation methods, while the other two locations have comparably similar flowrates. Such a large difference in flowrates can be concerning, but can be attributed to the varying stream gage recording intervals. The EROM flowrate values reflect a time period from 1971 to 2000, while the USGS gages do not have a constant time period (3). The Gunpowder Falls stream gage is currently displaying flowrate information from 1949 to 1964 (5). Considerable changes are expected to occur between the two recording intervals, such as urbanization. In this case, a reservoir is also in place upstream of the gage, likely changing the flowrate of Gunpowder Falls. It is important to check the recording dates for flowrate information before deciding on the value to use.

Another stream characteristic to determine for the watershed is drainage density. This is a ratio between the area of the watershed and the total length of streams flowing through it. Drainage density can provide an understanding of the amount of rainwater that becomes streamflow in a given area. Table 2 displays the drainage densities of both the Gunpowder-Patapsco sub-basin and Baltimore City.

Table 2: Drainage Densities

Region of Interest	Area (km^2)	Total Stream Length (km)	Drainage Density (km^-1)
Baltimore	188.2	103.8	0.55
Subbasin	3560.1	2805.5	0.79

The drainage density results shown in Table 2 also go hand in hand with the type of soil present and its water storage properties. Soil type can be classified into hydrologic groups, based on its ability to infiltrate. This is given in a range from A to D, with type A soil having the best infiltration properties, and type D having the worst. Table 3 displays the percentage of hydrologic soil groups by total area for the sub-basin and Baltimore City, and Table 4 shows each region's available water storage in the top meter of soil.

Table 3: Hydrologic Soil Groups by Percent of Total Area

Group	Baltimore	Subbasin
A	9.6%	5.2%
B	18.1%	46.9%
C	15.4%	31.5%
D	56.9%	16.4%

Table 4: Available Water Storage in Top Meter of Soil

Region of Interest	Area (km^2)	Water Storage (cm)	Total Storage (km^3)
Baltimore	188.2	10.2	0.019
Subbasin	3560.1	15.0	0.534

As seen in Table 3, the city of Baltimore is dominated by type D soils. The Gunpowder-Patapsco Watershed, however, has a much more even mix of soil types and is occupied primarily by type B soils. Tables 2, 3, and 4 can be compared to show a relationship between drainage density and hydrologic soil types within an area. However, the two areas of interest are providing different relationships. It is likely that drainage densities will decrease as infiltration increases. This is because a more porous soil with greater depth of water storage will retain more rainwater than a soil with the opposite properties. In this case, the city of Baltimore has a lower depth of water storage and a much lower percentage of porous soils than the Gunpowder-Patapsco sub-basin, but has a smaller drainage density. This is counterintuitive, but is likely because the city of Baltimore has other means of routing its storm water other than streams denoted by the NHD.

The results provided from creating a base dataset of the Gunpowder-Patapsco Watershed show that useful information can be found, but must be scrutinized to validate its accuracy and reasoning. Building a base dataset such as this is a simple project but is useful for storing primary data layers. Because of its simplicity, it is also very limited in its capabilities. More in depth hydrologic projects will implement the use of digital elevation models to determine stream and watershed delineation as well as flooding characteristics. The Baltimore Base Dataset project is only used to compare stream flowrates and basic soil properties for the areas of interest.

References

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