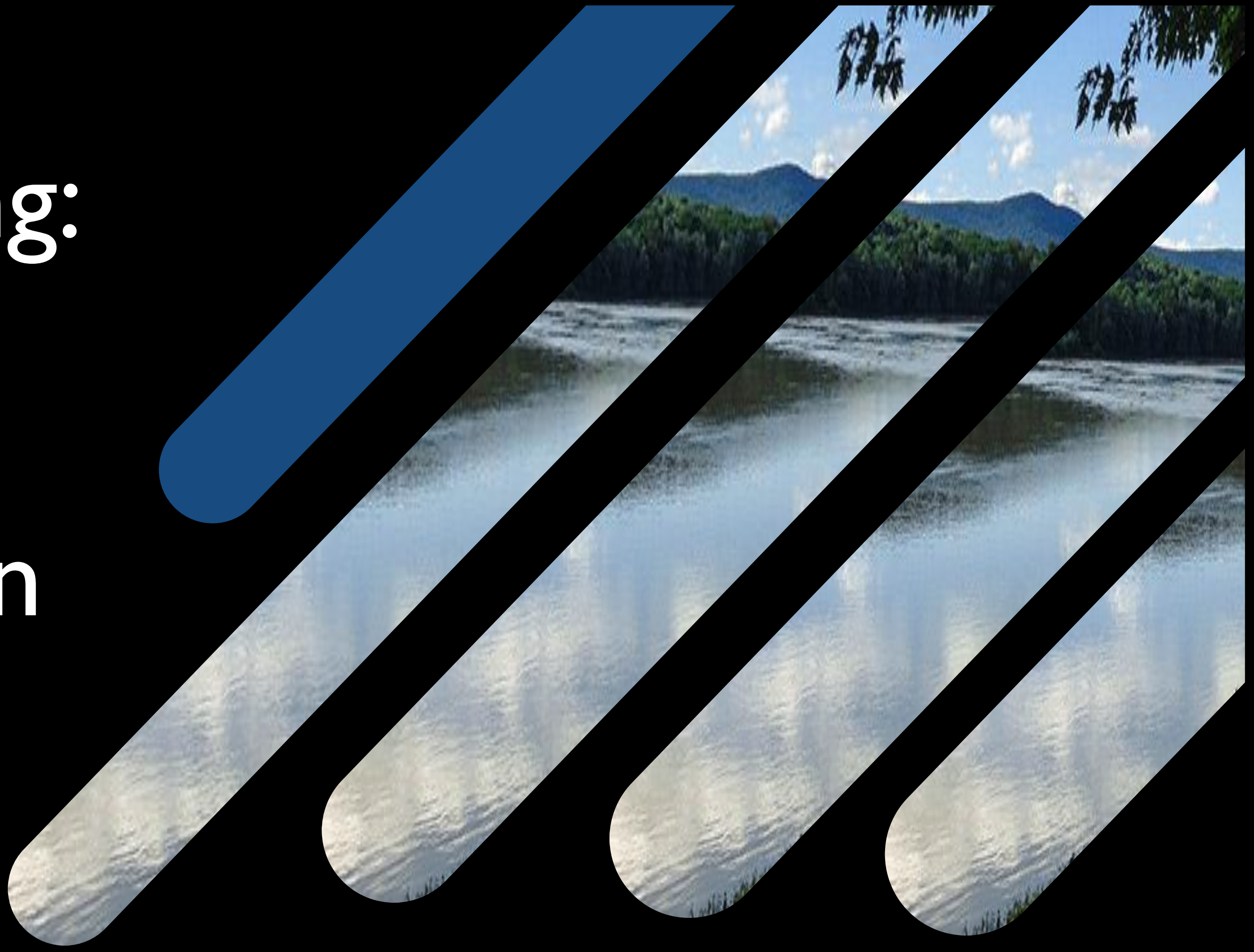
Hydrologic Modeling: The Impact of Urbanization and Impervious Land on Stream Floods



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Statement of Purpose

In response to the recent hurricanes that have hit our southern border, many believe that the rapid growth of the population, urban land has created superfluous amounts of impervious land (land that water can not penetrate), thus causing the flood levels to increase. To establish the effect if any of urban land of stream discharge, this researcher will predict and model the effects by data provided by online databases such as USGS (United States Geological Survey). In the process, new technologies will be considered to decrease the risks of floods in urban areas.

Research: Imperviousness

Statistics:

- With normal land cover conditions (soil), 50% of rain infiltrates the ground, 40% evaporates, and 10% becomes runoff. However, with urbanization the land cover is mostly roads, which are impervious, in this situation 45% of rainfall penetrates the ground, 35% evaporates, and 30% becomes runoff.

Effects:

- The runoff from the impervious land can pick up sediments, which can over time rise the discharge levels. The small deposits would sink to the bottom of the creek, thus, displacing the water.
- Impervious land can also change natural water routes which can change vegetation growth, because the plant wont get enough water.
- Also, impervious land can inflict loss of wetland because the water can't seep into the ground.

Research Question

How do increased levels of urbanization and imperviousness of land affect stream floods? What is the most efficient technology to limit the floods discharge?

Hypothesis

If urbanization, and imperviousness of land increases, then a nearby stream's discharge will also have a increase when compared to a past floods with similar weather conditions.

This was hypothesized because the rainfall will cause runoff to increase since the imperviousness land will limit the amount of water that can percolate through the ground. Hence, the runoff will flow into the stream.

Study Area:

Urban Creeks:

- Paxton Creek
- Brandywine Creek

Rural Creeks:

- Muncy Creek

Variables

Controlled variables	Independent variable	Dependent variable
• Precipitation • Rainfall • Elevation • Water Gauge Type	• Land Use	• Discharge

Methods

1. Historical Evaluation
2. Land Use and Discharge Correlations
3. Design Storm (Predictive Modeling)
4. Impact Analysis

Methods

1. Historical Evaluation

- Gather data from historical databases, USGS (United States Geological Survey), NLCD (National Land Cover Database), GFCD (Global Forest Change Database), NOAA (National Oceanic and Atmospheric Administration), and FWS (Fish and Wildlife Service).
- Find correlations between wetland area and developed land.
- Probe different floods with similar precipitation and have correlation.
- Explore the flood relationships with wetlands data and developed lands.

2. Land Use and Discharge Correlations

- Graph the land cover in the watershed over a period of time on a line graph. Graph the discharge of a stream on the same graph, but on a secondary y axis.
- Find different correlations between discharge and developed land.
- Analyze different floods with similar/same discharge to find correlation.
- Investigate the flood relationships found with discharge and land cover data.

Methods (cont.)

3. Predicting Urbanization

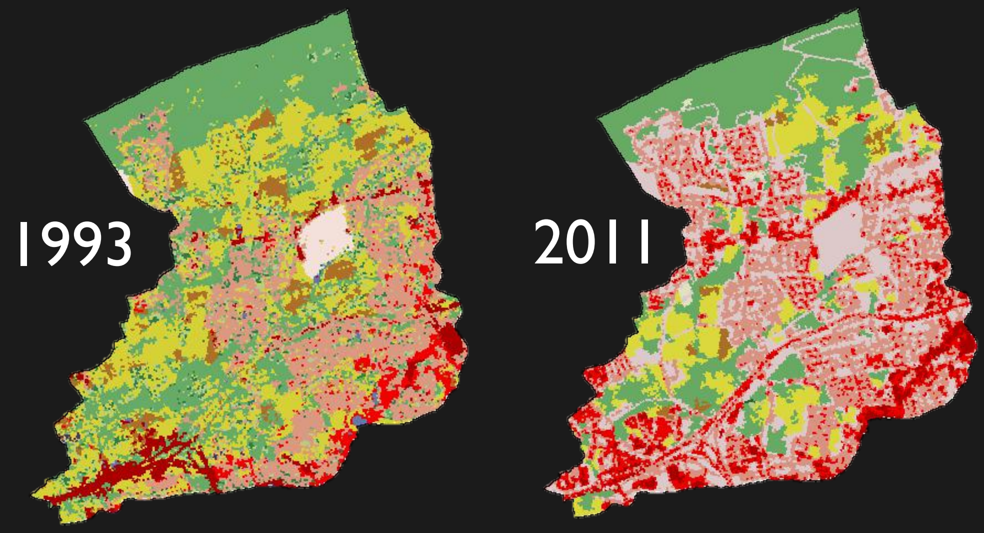
- Plot each land use category, and their percentage in the creek's watershed from 1993-2011 (1993, 2001, 2006, 2011) on a coordinate plain.
- Use logarithmic regression to model the points in each graph
- Use the logarithmic function to predict and estimate each land use categories percentage in the creek's watershed.

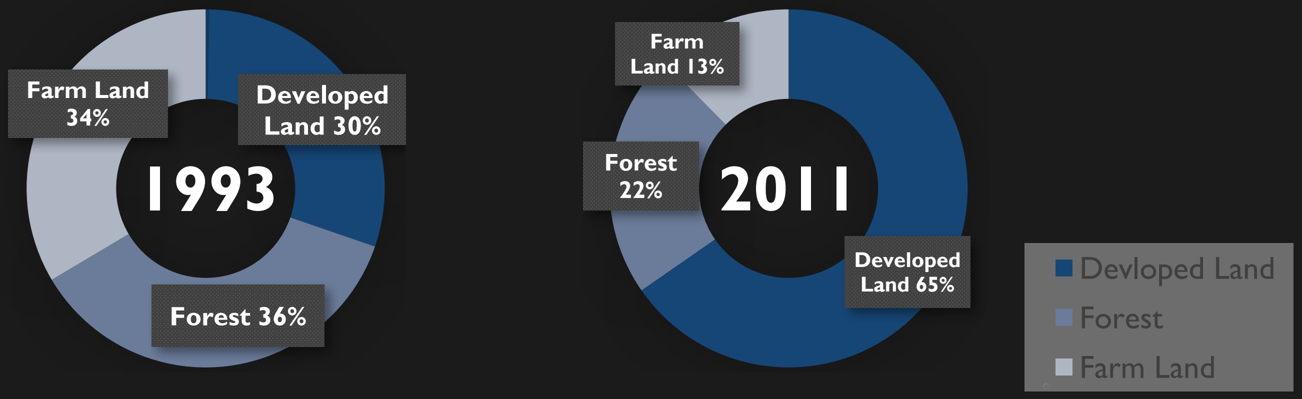
4. Design Storm (Predictive Modeling)

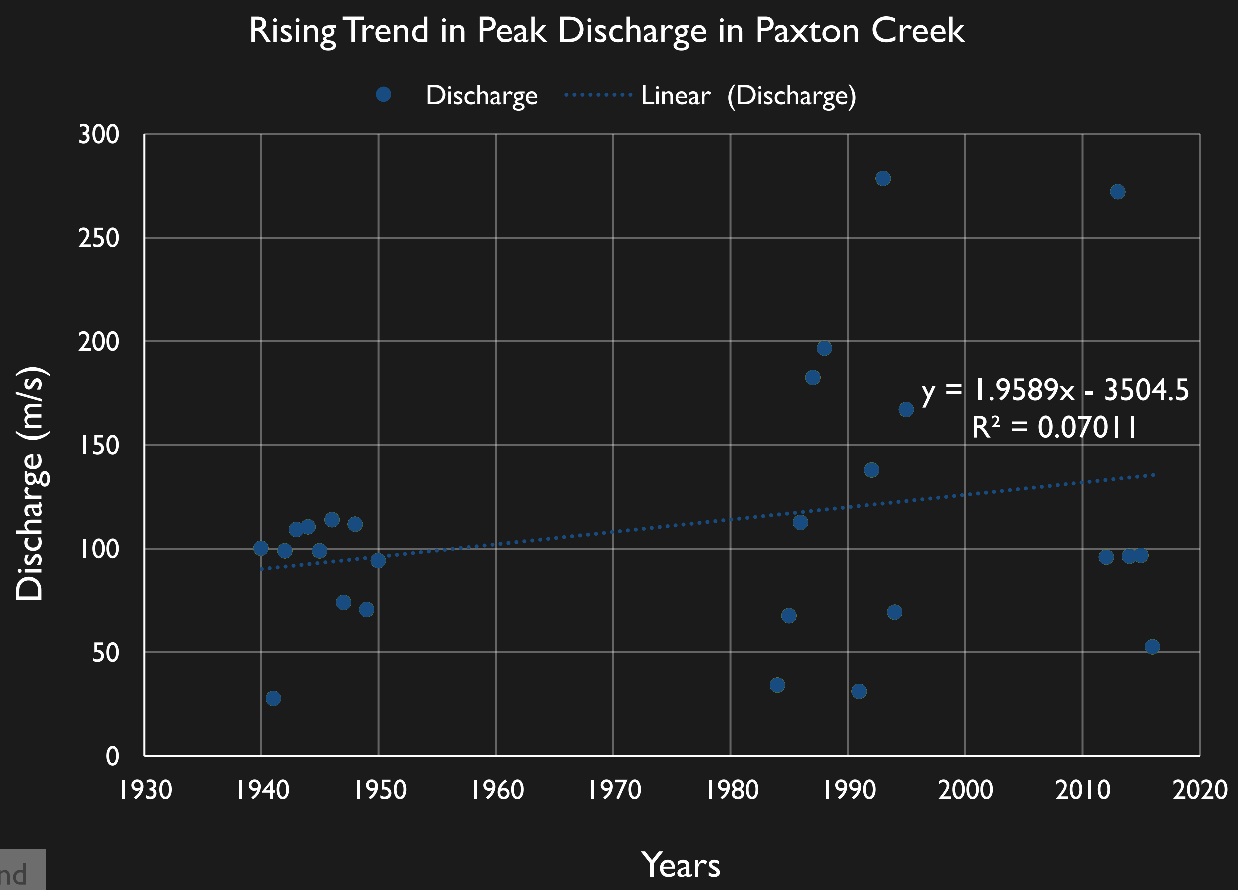
- Using the current land use data and soil data, compile each soil types Curve Number.
- Take the average of all the Curve Numbers to find the mean (, weighted Curve Number).
- From the weighted Curve Number figure out the average runoff of the soil using the TR-55 hydrologic model.

Data Analysis: Land Use Change

Land Cover Comparison of the Paxton Creek Watershed (1993, 2011)



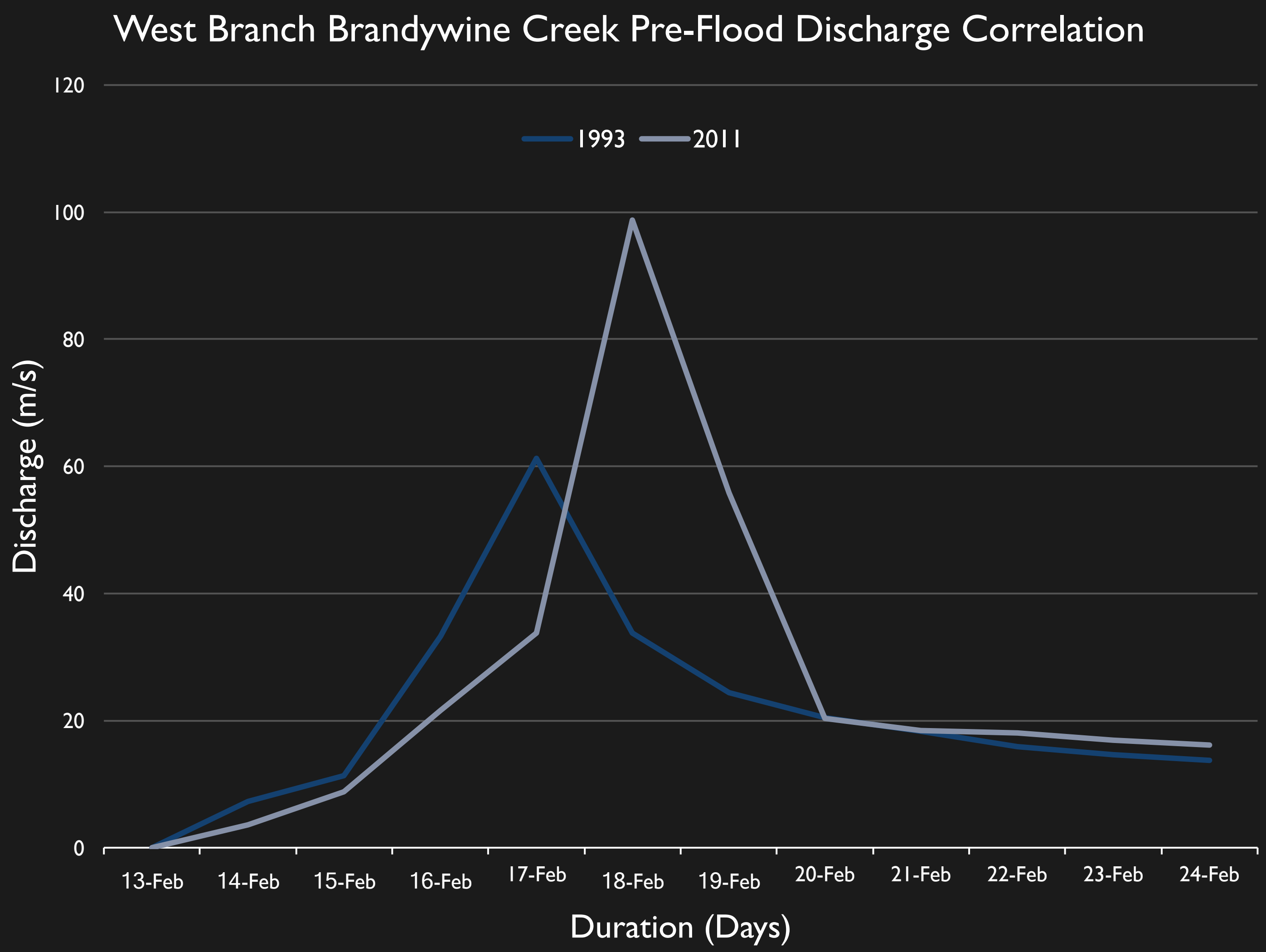




Data Analysis: Land Use and Floods (cont.)

As the rain falls down onto the land, some of the rain evaporates, some of the rain infiltrates the soil, and the rest is runoff which eventually makes it way towards the creek. As urbanization increases impervious land Increases, thus creating more runoff. Not only that, the water moves so quickly on the land that a direct correlation can be made between rainfall and discharge of a near by creek. So, as rainfall fluctuate, so does the the creek's discharge. Hence giving the discharge graph a quick increase followed by a quick decrease (the Decrease happens because of the dissipation of water).

	W. Brandywine Creek: 1993	W. Brandywine Creek: 2011
Urban Land	**6%**	**25%**
Forest	42%	37%
Farm Land	51%	35%
Wetland	1%	3%

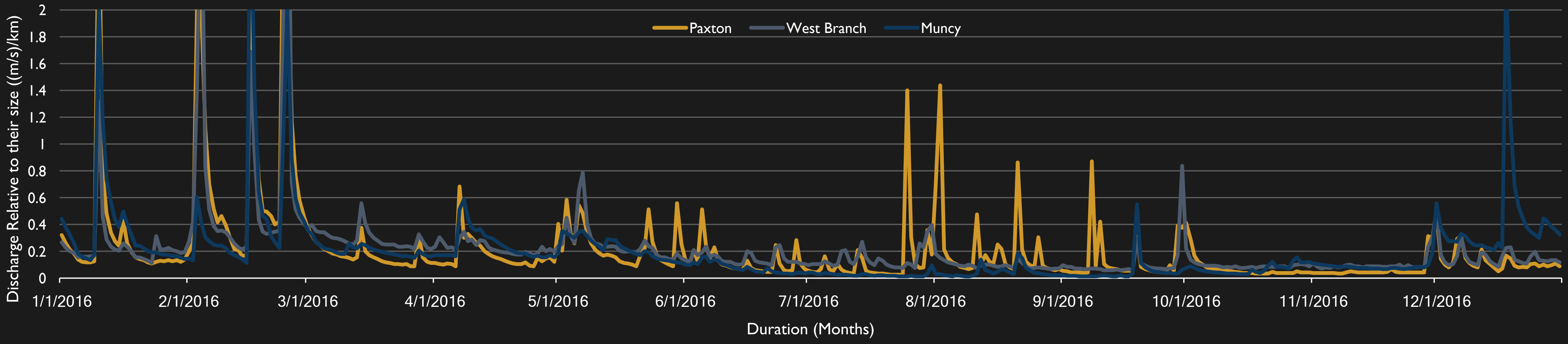


Data Analysis: Land Use and Floods

The peaks in Paxton Creek quickly rise as the rain fall increases, and dramatically drop when rain fall diminutions. This is because around 60% of the rainfall is going directly into the stream, thus increasing the discharge of the creek at a rapid pace (this is what creates the peaks). Where as in a less rural area like Muncy Creek for example, steadily increases and steadily dwindles due to the fact that around 40% of the rainfall becomes runoff and flows into the stream.

	Paxton Creek	W. Brandywine Creek	Muncy Creek
Condition	**Urban**	**Suburban**	**Rural**
Urban Land	**65%**	**25%**	**2%**
Forest	22%	37%	88%
Farm Land	13%	35%	9%
Wetland	0%	3%	1%

Discharge Comparison Between West Brandywine Creek, Paxton Creek, and Muncy Creek Relative to their Size

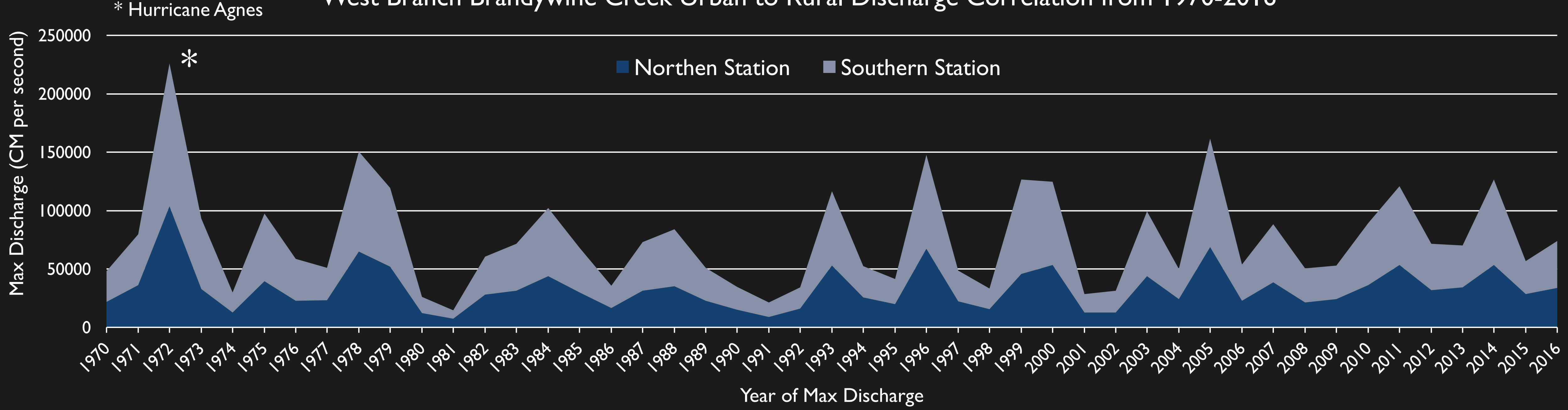


Data Analysis: Land Use and Floods (cont.)

Both the discharge stations are located on the same river and are collection data simultaneously, but at different locations. This difference solely emphasizes the effect the creek's watershed has on it's discharge. In the graph, the southern station, which is more urban has major increases when compared to the northern station which is more rural. This difference creates more runoff thus creating a higher discharge value.

	W. Brandywine Creek	W. Brandywine Creek
Condition	**Urban**	**Suburban**
Urban Land	**25%**	**20%**
Forest	37%	37%
Farm Land	35%	39%
Wetland	3%	4%

West Branch Brandywine Creek Urban to Rural Discharge Correlation from 1970-2016



Data Analysis: Land Use and Floods

The discharge rates in 1993 compared to the discharge rates in 2011 are marginally lower. This is cause by the development of urban land. As urban land increases, so does Impervious land. Thus, the impervious land increase the runoff during rainfall and the runoff then flows towards a near by creek.

	W. Brandywine Creek: 1993	W. Brandywine Creek: 2011
Urban Land	**6%**	**25%**
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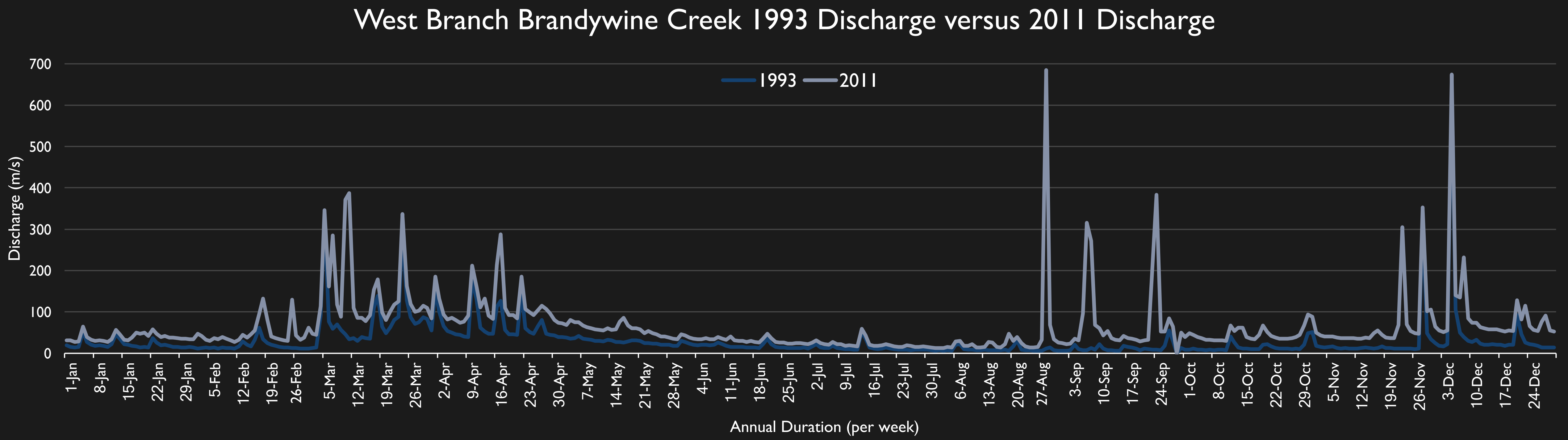
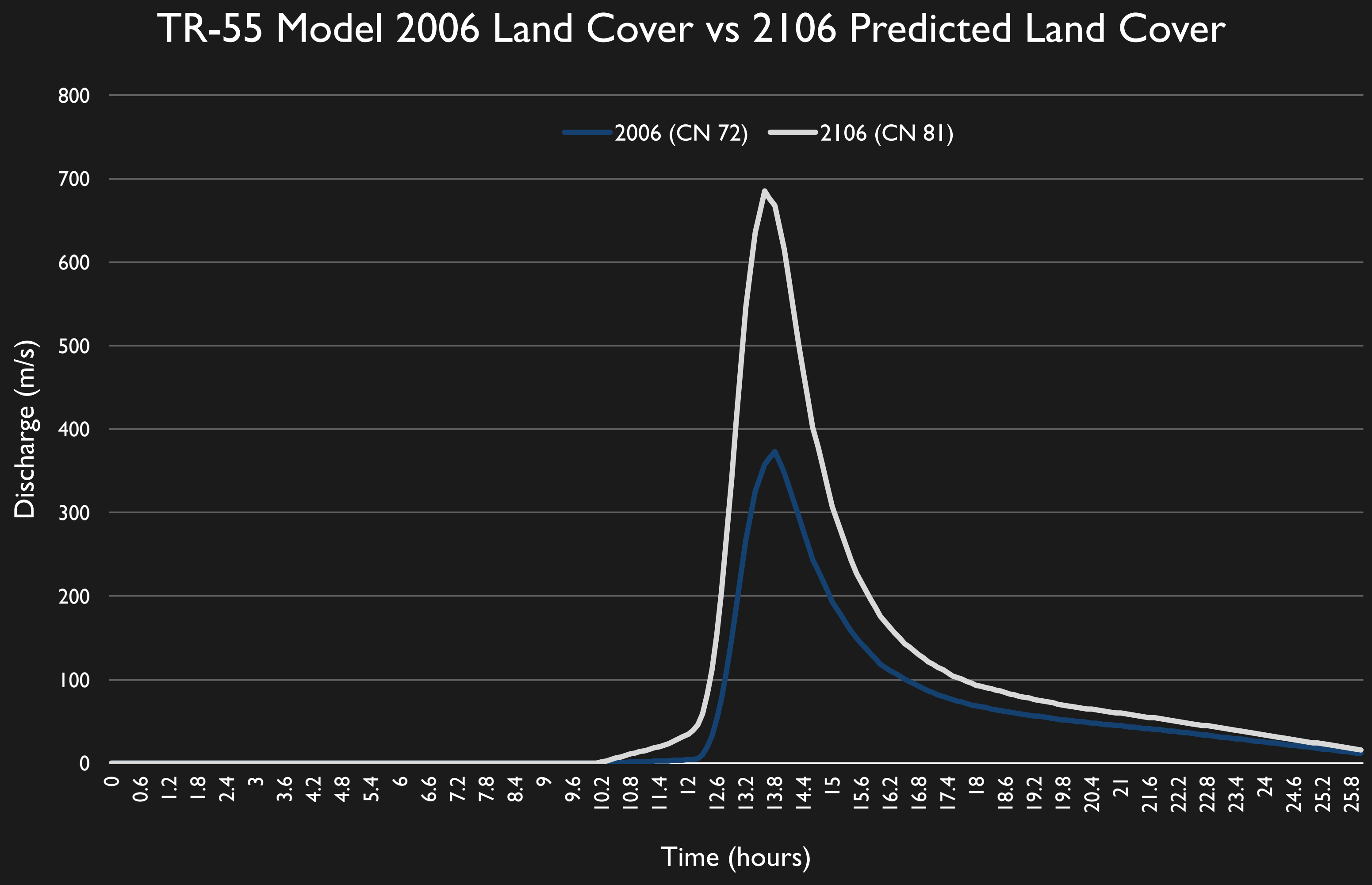


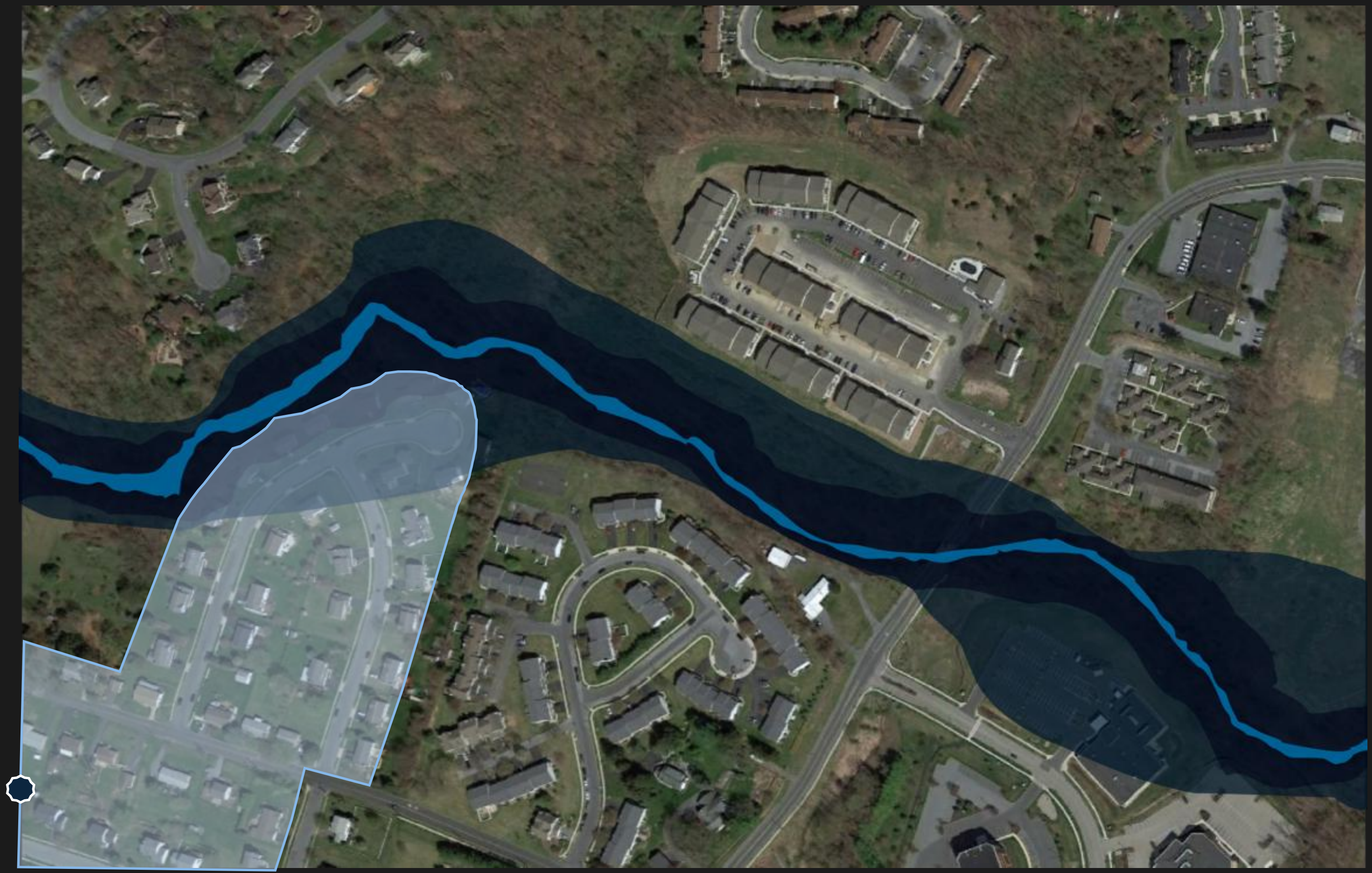
Figure . This graph compares the discharge rate between Brandywine Creek in 1993 and 2011.

Data Analysis: Design Storm

This prediction shows a dramatic increase from previous 100-year flood (Hurricane Agnes). This peak of the discharge rises to close to double the discharge of the previous 100-year flood. Not only that, the discharge rises at the same time ends at the same time. This implies, that the consequences of this storm would almost be twice as mush as Hurricane Agnes.



Data Analysis: Impact Analysis



Future Flood Prediction 2106

Hurricane Agnes 1972

Normal Flow 2006

Storm Drainage Area

Storm Location (Storm Drain)

Map Location:

Conclusion / Discussion

In the end this researcher decided to accept his hypothesis and formulate the following conclusions. As seen on Figure 8 the comparison between West Branch Brandywine Creek in 1993 and 2011 have a dramatic change in discharge. The average rate of discharge for 2011 was 26, while the rate of discharge in 1993 was 22 meters/second. This increase of 4 m/s in the last 18 years has caused many new flood zones that endanger nearby residence. Additionally, a characteristic of an urban flood includes quickly rising measures along with rapidly dropping discharge, this creates a narrower peak when compared to a rural scenario where the water levels gradually rise and drop. Moreover, the positive trend line assures the increase of peak discharge over time as seen on the scatter plot. This alongside the increasing amount of urbanization in the Paxton Creek watershed is sure to have a correlation between discharge and urbanization.

Acknowledgments

First, this scientist would like to thank a researcher from Shippensburg University's Geography department for helping this scientist collect the information needed to gather the data and the proper model for this project. Next, this researcher would like to thank his helpful, and always supportive science teachers at both Cumberland Valley High School and at Eagle View Middle School. This project would not have been possible with them.

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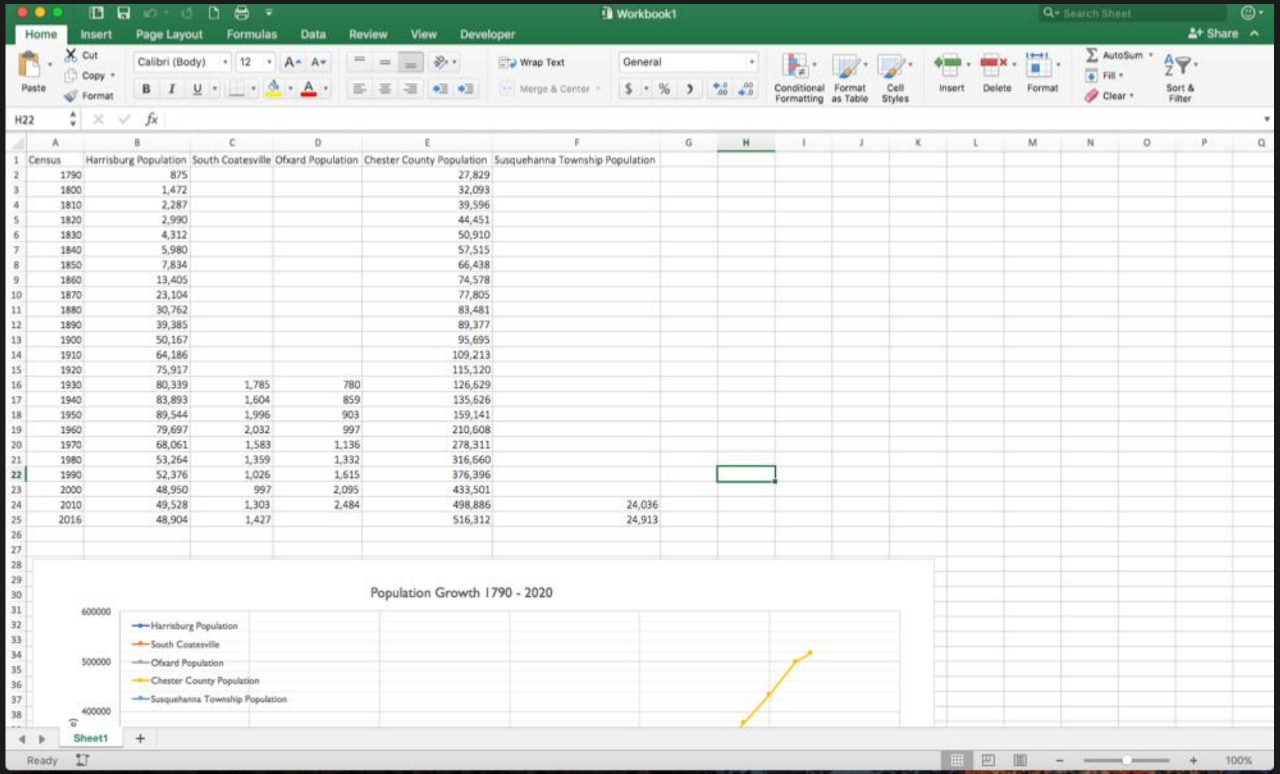
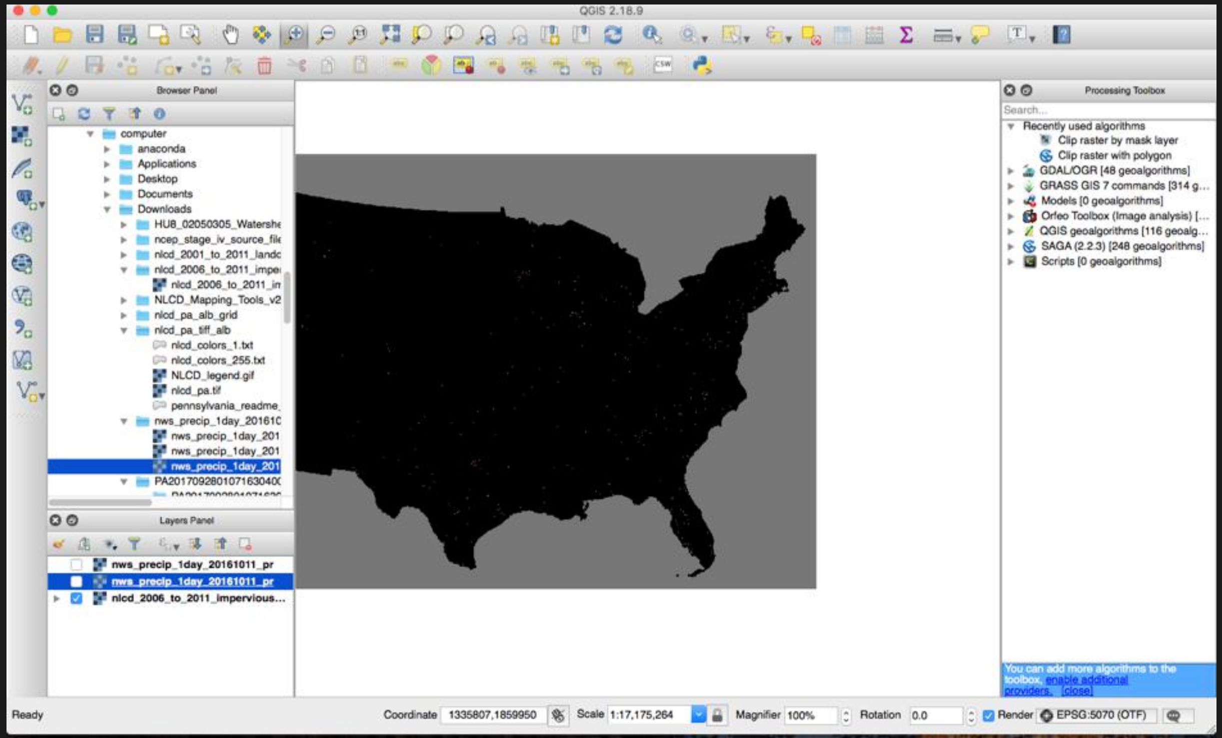
Photos Experiment





Thank You!

Do you have any questions?