GEOG 181A
WINTER 2022

Impact of Sea Level Rise on Private Wells

SUSSEX COUNTY, DELAWARE

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Photo courtesy of Grant Brown Photography

BACKGROUND

What is Salt Water Intrusion?

The water table represents a layer beneath the surface where the pore spaces between soil particles are saturated with water – rightfully called groundwater (1). This water table often reflects the land surface above it: rising and falling with higher and lower elevations (1). The groundwater can be pumped to the surface for use by municipalities or individuals.

In coastal communities, there is a balancing act between fresh groundwater and salt groundwater from the ocean. The zone where the fresh and saltwater meet is called an interface (2). Naturally, water flowing from beneath the land surface towards the oceans keeps the saltwater interface far enough away such that the groundwater is kept fresh and can be used by the public to meet their water needs (2). However, if too much of the freshwater is pumped before it reaches the saltwater interface, it can cause the saltwater to move inland (2). This process is called saltwater intrusion. Saltwater intrusion occurs due to unsustainable water demand and can contaminate freshwater supplies, threatening drinking water (1). Therefore, it is important for communities to take steps against saltwater intrusion.

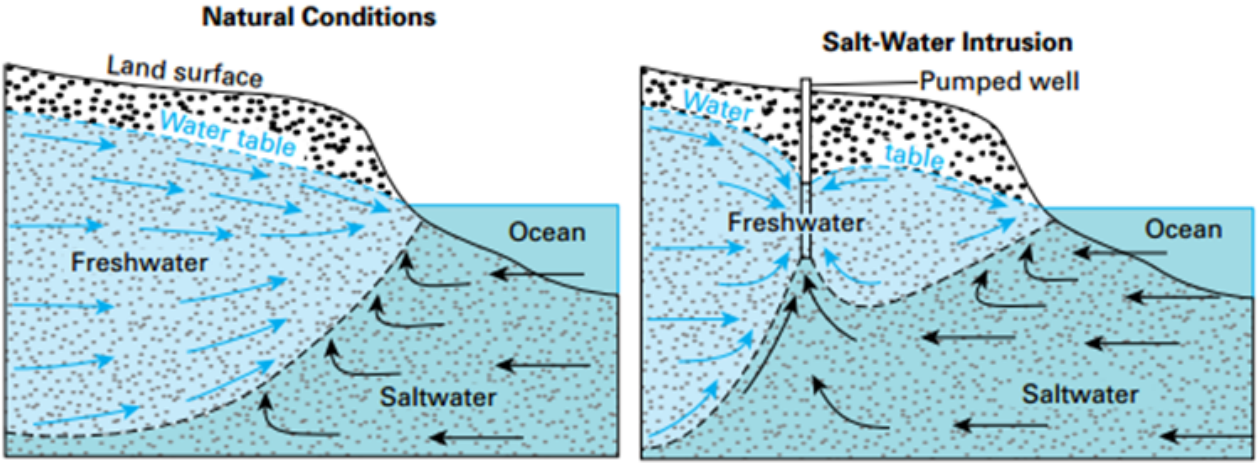


Figure 1: Saltwater intrusion occurs when saltwater moves where freshwater is normally located. This can occur due to over pumping or sea-level rise. (Source: USGS)

BACKGROUND

How can Climate Change Impact Salt Water Intrusion?

Climate change can increase the risk of saltwater intrusion in two ways: increasing the demand for fresh water and sea-level rise.

As climate change is expected to bring about more extreme weather events, dry seasons will become drier and hotter. During these times, groundwater demand increases because there is no natural precipitation to offset the demand. Thus, the amount of groundwater getting pumped increases which can lead to saltwater intrusion.

Sea level rise can also lead to saltwater intrusion through the rise in elevation of the saltwater table. As the saltwater table pushes closer to a well's sphere of influence, the more likely it is for drinking water to become contaminated.

Sussex County, Delaware

Delaware is a small Mid-Atlantic state, home to three counties and a slew of nationally rated "best beaches" (3). Located in its southern-most part, Sussex County is 35 miles across and 35 miles north to south (4).

With all of Delaware's oceanside beaches, no sales tax, and major cities like New York, Baltimore, Philadelphia, and Washington DC within a few hours drive, people can have a "low-cost" beach house in Sussex while still holding higher-income jobs in the city. This opportunity has only increased with the COVID-19 pandemic bringing the option of remote work. According to a 2019 report, "Sussex County is expected to need to add 1,549 net new housing units each year over the next 10 years" (5). Previous research found that inland coastal communities situated along canals and bayfront are experiencing the highest rates of development (6).

As a low-lying peninsula state, Delaware is at risk for sea-level rise. Thus, it is crucial to take into account the potential risks of sea-level rise when planning any new development in the area.

MAIN OBJECTIVE AND GOALS

This study is part of a series to ultimately answer the questions :

HOW DOES TOURISM DRIVE DEVELOPMENT IN SMALL COASTAL COMMUNITIES?

HOW DOES THIS DEVELOPMENT IMPACT HYDROLOGY IN SMALL COASTAL COMMUNITIES IN LIGHT OF CLIMATE CHANGE?

My focus on Sussex County, Delaware comes from my family ties to the area. As a long-term resident of the area, I fear the county is not adequately planning for the effects of rapid development of second homes or for the effects climate change may bring to the area. I aim to quantify the impact tourism has on the area in order to ultimately provide the county a plan for sustainable development and tourism in light of changes climate change may bring – one that allows the tourism industry to thrive without threatening the "Slower Lower" pace of life or the county's infrastructure.

This part of the study aims to use GIS analysis to explore the questions:

WHAT AREAS OF SUSSEX COUNTY RELY ON PRIVATE WELLS FOR THEIR WATER NEEDS?

HOW WOULD SEA LEVEL RISE IMPACT THE WATER TABLE?

Through answering these questions, I hope to establish if there is a connection between areas that are experiencing the most development to those that rely on private wells. If there is a connection and those areas are threatened by sea level rise, then new homes in those areas should begin transitioning to a public water supply rather than relying on private wells that may succum to saltwater intrusion.

If you would like to see previous studies in this series, please see Appendix A and B.

DATA SOURCES

This project consisted of 5 different data layers from different data sources. A description of each layer can be found in Table 1.

Table 1: Summary of Data Layers Used

Layer	Source	Description
County Boundaries	Office of State Planning and Coordination	Polygon layer
Census Block Group Boundaries	US Census Bureau	Polygon layer from 2020 Census
Census Block Group Occupancy	US Census Bureau	CSV File
Wells	The Department of Natural Resources and Envronmental Control (DNREC)	Point layer
Water Table	The Delaware Geological Survey	Raster file for dry season water table elevation
Water Bodies	United States Geological Survey	Polygon layer

Delaware First Map is the state of Delaware's hub for GIS data sharing. The county boundaries, census block group boundaries, and water bodies data files were downloaded off the website. Block groups were chosen as the unit of analysis because they are smaller than zip code areas. Additionally, previous studies in this series used block groups so the consistent geographical unit allows for easier comparison of data.

The water table data was taken from a Delaware Geological Survey. The dry season water table was chosen because Sussex County experiences an influx of tourists to the area during the Summer season. As there are more people, the demand for water increases. Combined with climate predictions showing hotter and drier summers, the summer season seems to be Sussex County's most vulnerable time to saltwater intrusion (2).

METHODOLOGY

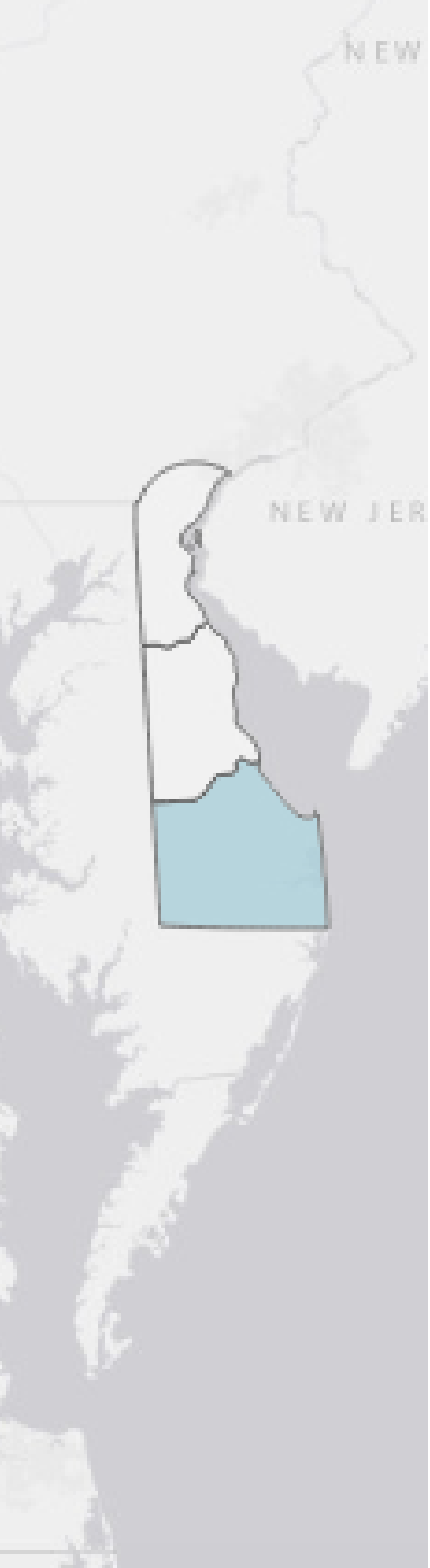
To begin the GIS analysis, a Sussex County boundary layer was created by filtering the Delaware boundary layer. Similarly, the Sussex County Census block groups layer was created by filtering the Delaware Census Block Groups layer.

What areas rely on private wells?

The data from DNREC consisted of wells for the entire state. Initially, these were filtered using the "Select by Attributes" tool to show wells only in Sussex County. However, it was found that some wells' locations were misclassified. Therefore, the well data was instead clipped to the Sussex boundary layer in order to ensure the wells included were within Sussex County's boundary. However, the data set was substantial in size, consisting of over 86,000 features. To minimize the size of the data set, the wells were filtered to only consist of "Domestic–Standard" wells; those used for private residences. This minimized the data set to 46,764 features. To further reduce the size of the data file, unnecessary attributes were removed. A summary of attributes that were kept can be found in Table 2.

Table 2: Summary of Attributes Within Wells Data Layer

Attribute	Description
Well Type	Type of well
Well Status	Status of well
URL	Web page for more specific information
Owner	Owner of the well
Owner Address	Full address of the well owner
Date_Permi	Date of approved permit
Date_Aband	Date of well abandonment
Total Depth	Total depth of well in feet
Lon	Longitude location
Lat	Latitude location
County	County location
Watershed	Watershed well is located in
Basin	Water basin well is located in



METHODOLOGY

After the wells were filtered to the extent of the Sussex County boundary layer, the "Count Points in Polygon" Vector data tool was used for the well point file and the block groups polygon. This created a new attribute in the block group file with the count of how many wells intersected each block group.

A table join was then performed using the "Geoid" between the block group layer and the occupancy file. The field calculator was used to find the percentages of households within a block group using private wells.

With the well counts, the map was then designed to have a graduated color scheme, with lighter colors showing block groups where fewer households rely on private wells and darker colors representing block groups that heavily rely on private wells.

Modeling Sea Level Rise

Sea level rise scenarios were chosen as 1ft, 3ft, and 5ft to be consistent with current projections for the year 2100 (7). A rise in sea level should correspond to an equal rise in the ocean water table. Therefore, locations where the freshwater table sat at or below 1ft, 3ft and 5ft elevations would be threatened by the corresponding sea-level rise scenarios.

METHODOLOGY

The water table elevation data was presented as a raster image. Using the "Polygonize" tool, the elevation data was converted into a vector format.

The temporary vector data file was then filtered such that the only polygons in each file were for elevations equal to or less than 1ft, 3ft, and 5ft to correspond to respective sea level rise scenarios. The filtered data files were then exported to their own geodatabase files.

The elevation vector files were run through the "fix geometry" tools after discovering that some of the geometries were invalid. Using the "Select by Location" tool, I was then able to get a count of how many private wells are threatened by current sea-level rise predictions.

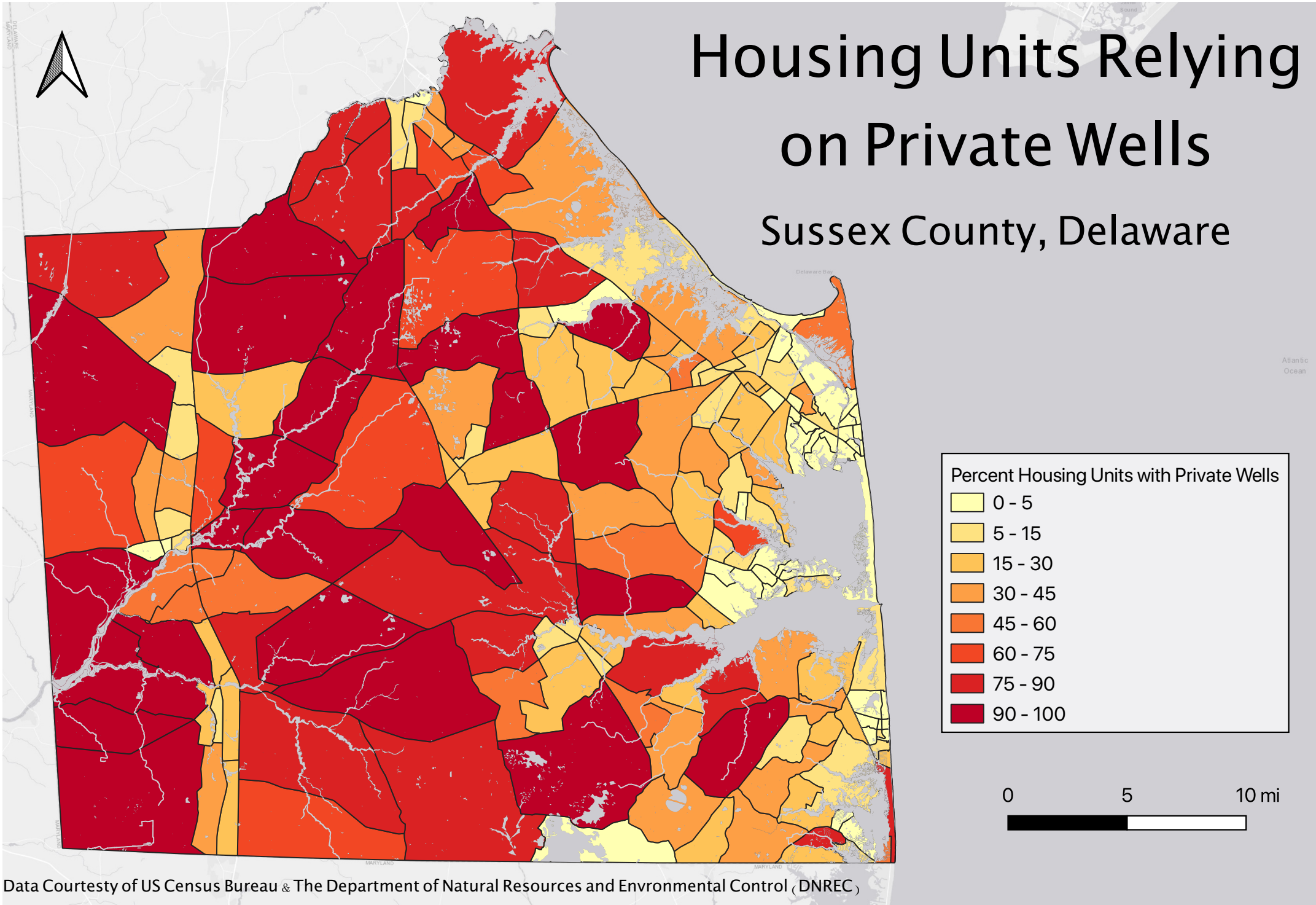
Private Wells, Sea Level Rise & Development

The Block Groups where more than 30% of total households rely on private wells were filtered and exported to their own data file. The same was done for block groups that intersected with 1ft, 3ft, and 5ft sea level rise. Block groups that were in both data sets were labeled as "High Risk" for saltwater intrusion.

High-Risk block groups were then compared to block groups experiencing the most development according to a previous study. The map from the study can be found in appendix C.

Housing Units Relying on Private Wells

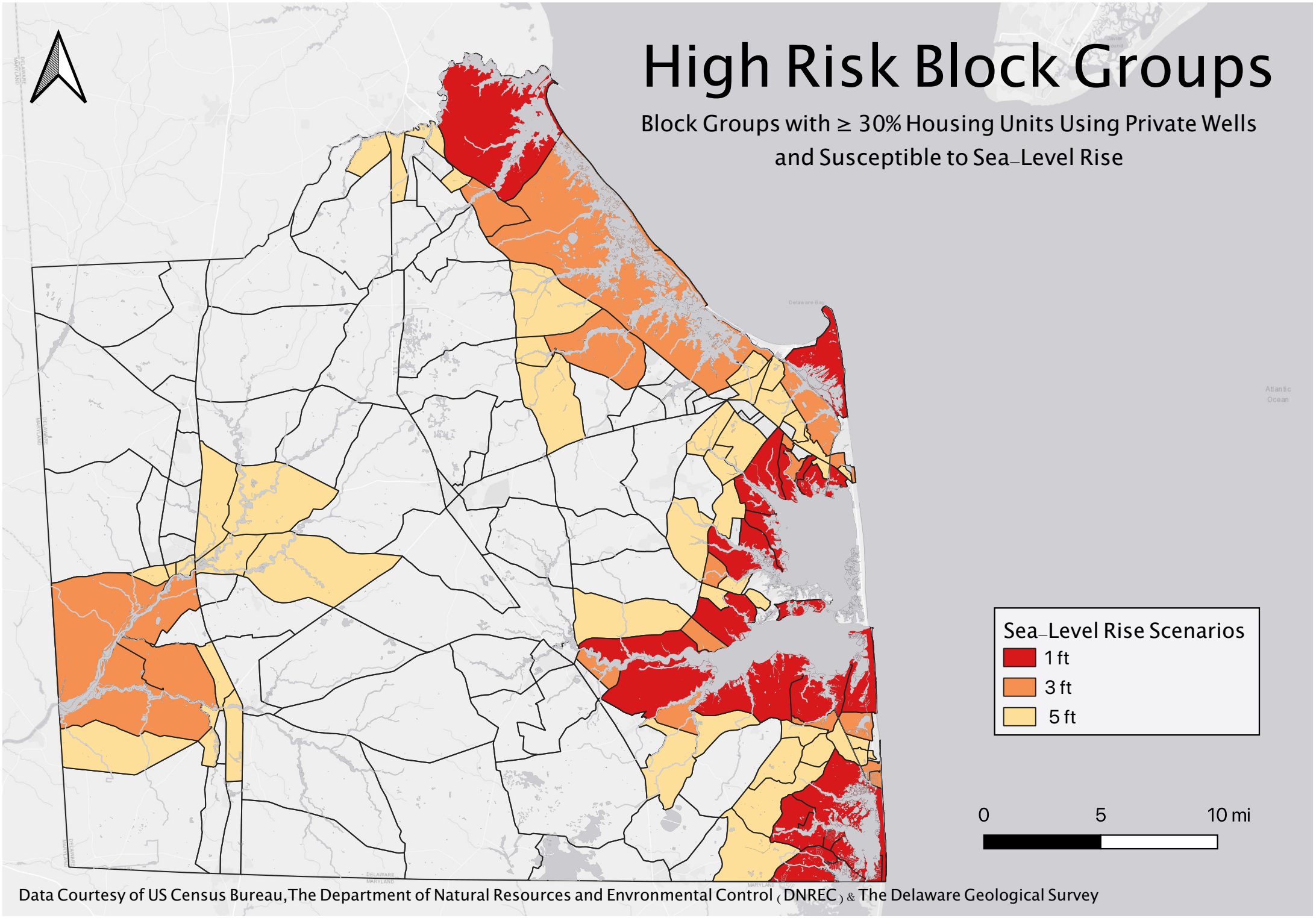
Sussex County, Delaware



Data Courtesty of US Census Bureau & The Department of Natural Resources and Envronmental Control (DNREC)

High Risk Block Groups

Block Groups with ≥ 30% Housing Units Using Private Wells and Susceptible to Sea_Level Rise



Data Courtesy of US Census Bureau, The Department of Natural Resources and Envronmental Control (DNREC) & The Delaware Geological Survey

RESULTS

KEY FINDINGS

- A large portion (31.7%) of housing in Sussex County relies on private wells
- Coastal communities are at the highest risk for saltwater intrusion from sea-level rise.
- Bay and canal front communities are experiencing the highest rates of development and are at high risk for saltwater intrusion.

From the maps, a trend can be seen that more housing units in inland communities rely on private wells compared to coastal areas. This makes sense because the coastal areas are more susceptible to saltwater intrusion under normal conditions.

However, several areas within the "transition zone" heavily rely on private wells, namely those bordering the Indian River Bay in the Millsboro/Frankford area as well as along the oceanfront in the Broadkill Beach and Fenwick Island areas.

Several "High Risk" block groups were identified as having more than 30% of the housing units using private wells as well as being vulnerable to sea-level rise.

In fact, many coastal block groups fell into the "High Risk" category, with those bordering the Indian River and Assawoman Bays being the most vulnerable.

Comparing "High-Risk" block groups to the map previously created for development trends reveals that new communities bordering the Bays should be especially conscious of their water source. These areas historically rely on private wells and are vulnerable to salt water intrusion, even under the lowest sea-level rise scenarios of 1ft. Therefore, these new communities should consider alternative options for their water source.

Table 3: Number of Wells Threatened with Salt Water Intrusion According to Sea-level Rise Scenarios for 2100.

Sea-level Rise Scenario	# of Wells Threatened
1 ft	28
3 ft	1043
5 ft	4628

Photo Courtesy of Elliot Macguire

CONCLUSION

Sussex County is expected to continue seeing rapid development for the coming decade(5). It is important to consider the environmental, cultural, and economic costs of this development, especially when over a third of this development is for "second homes" – aka beach homes (5).

The "Slower Lower" pace of life that draws people to the area in the first place is threatened by development. The tourism industry is an important sector to Sussex County's economy (8), but the county should consider the impacts tourism has in order to ensure the industry thrives for generations to come. Too often do areas not plan for sustainable development and residents pay for the repercussions.

Previous studies have shown development is occurring along wetlands and flood plains that are important for flood control measures, and even more so in light of sea-level rise projections (6). This study has shown that sea-level rise projections also threaten the water supplies of thousands of current and future Sussex County residents. In order to develop sustainably, new developers should look at alternatives to private wells to satisfy water needs.

Future studies should look at how land-use change due to development is impacting hydrologic flows in the area: water table recharge, stormwater flow, and flooding. A step further would be studying how the changes in hydrology impact the local ecosystems. A study should also be done to solidify the link between tourism and development. It will also be important to quantify the impact development will have on current infrastructures such as roads, landfills and waste water treatment.

CITATIONS: MAP

Delaware Census Bureau Block Groups
https://opendata.firstmap.delaware.gov/datasets/0a435290c7d7461d934f3466194ad5ed/explore?layer=2&location=38.898177%2C-75.577457%2C9.00

Delaware Census Bureau Block Groups Occupancy
https://firstmap-delaware.opendata.arcgis.com/datasets/block-group-occupancy/explore

Delaware State and County Boundaries
https://opendata.firstmap.delaware.gov/datasets/delaware::state-and-county-boundaries/about

Delaware Wells
https://data.delaware.gov/Energy-and-Environment/Well-Permits/2655-qn8j

Delaware Water Table
https://firstmap.delaware.gov/arcgis/rest/services/Geology

Delaware Water Bodies
https://firstmap-delaware.opendata.arcgis.com/maps/delaware-water-2-0/about

Sea-level Rise Data
https://coast.noaa.gov/slrdata/

CITATIONS: REPORT

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8. Visit Delaware.com. (n.d.). The Value of Tourism 2019. https://www.visitdelaware.com/sites/default/files/2021-06/The_Value_of_Tourism_2019_77ac3097-b2ea-444f-9b1d-090b01d5b9b8.pdf

APPENDIX

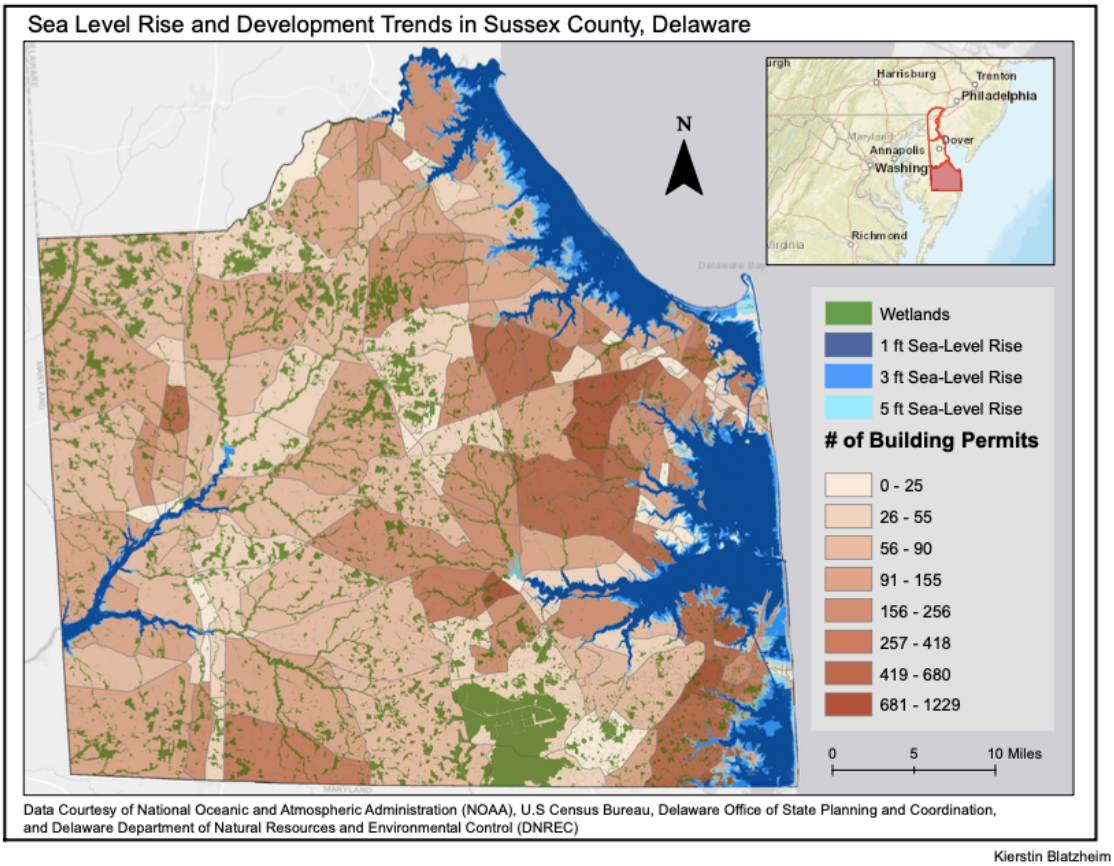
A: SUSSEX COUNTY, DELAWARE DEVELOPMENT AND SEA-LEVEL RISE

To view please visit:
https://drive.google.com/file/d/1xhwj-M75A_x9UyHl_PJEH8Bw67ed8L71/view?usp=sharing

B: HOW TOURISM IS LEADING TO GENTRIFICATION IN SOUTHERN DELAWARE

To view please visit:
https://drive.google.com/file/d/17yZgZDZLQYmqpSnyY2QOEi5hIO5UYMPb/view?usp=sharing

C: SUSSEX COUNTY, DELAWARE DEVELOPMENT AND SEA-LEVEL RISE: MAP



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