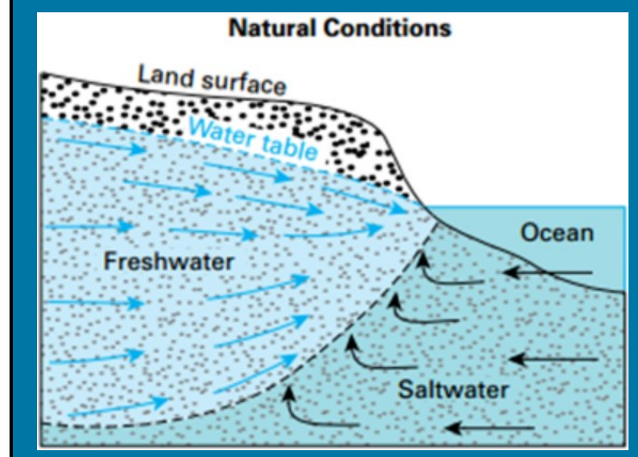
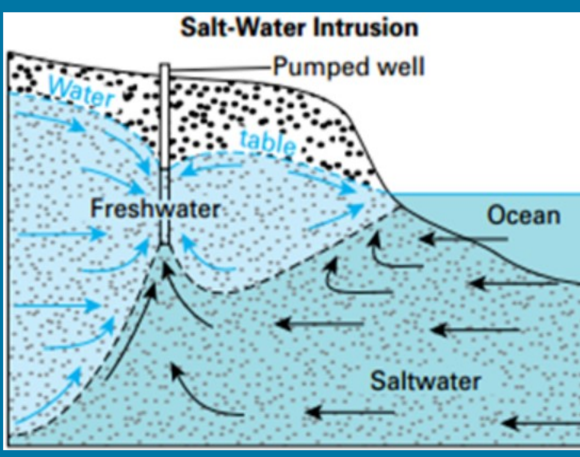



# Saltwater Intrusion

## A Risk Assessment for Groundwater Well Salinization in Southern Maine




Images from USGS

## Background

As sea level rise becomes a greater concern due to climate change, so does saltwater intrusion into groundwater wells. Using a projected sea level rise of about 3.3 meters above the highest astronomical tide, the risk of saltwater intrusion into domestic groundwater wells on the coast of Southern Maine was assessed (Figure 1). In Maine, around 40% of people rely on a private groundwater well for their household water supply. Understanding the risk of saltwater intrusion is crucial since it is costly to treat or abandon a well that has been contaminated by saltwater (Water Resources in Maine, 2013).

Throughout the world, groundwater quality is consistently monitored in order to maintain freshwater security. In previous studies, aquifer vulnerability has been determined by mapping concentrations of specific chemical components, such as chloride and sodium ions, and properties, such as electric conductivity (Kallioras et al., 2006). In order to look more closely at wells themselves, other studies have focused on physical parameters, such as distance to coast and surficial geology, which each affect the salinization risk differently (Eriksson, 2017).

Throughout the entire state of Maine, groundwater primarily exists in either sand and gravel or bedrock aquifers. Within the study area, there are 919 domestic groundwater wells, most of which are drilled into bedrock aquifers. This risk assessment answers which of these wells are most susceptible to saltwater intrusion based on distance to projected sea level rise, well depth, well density, well type, and surficial geology.

## Methods

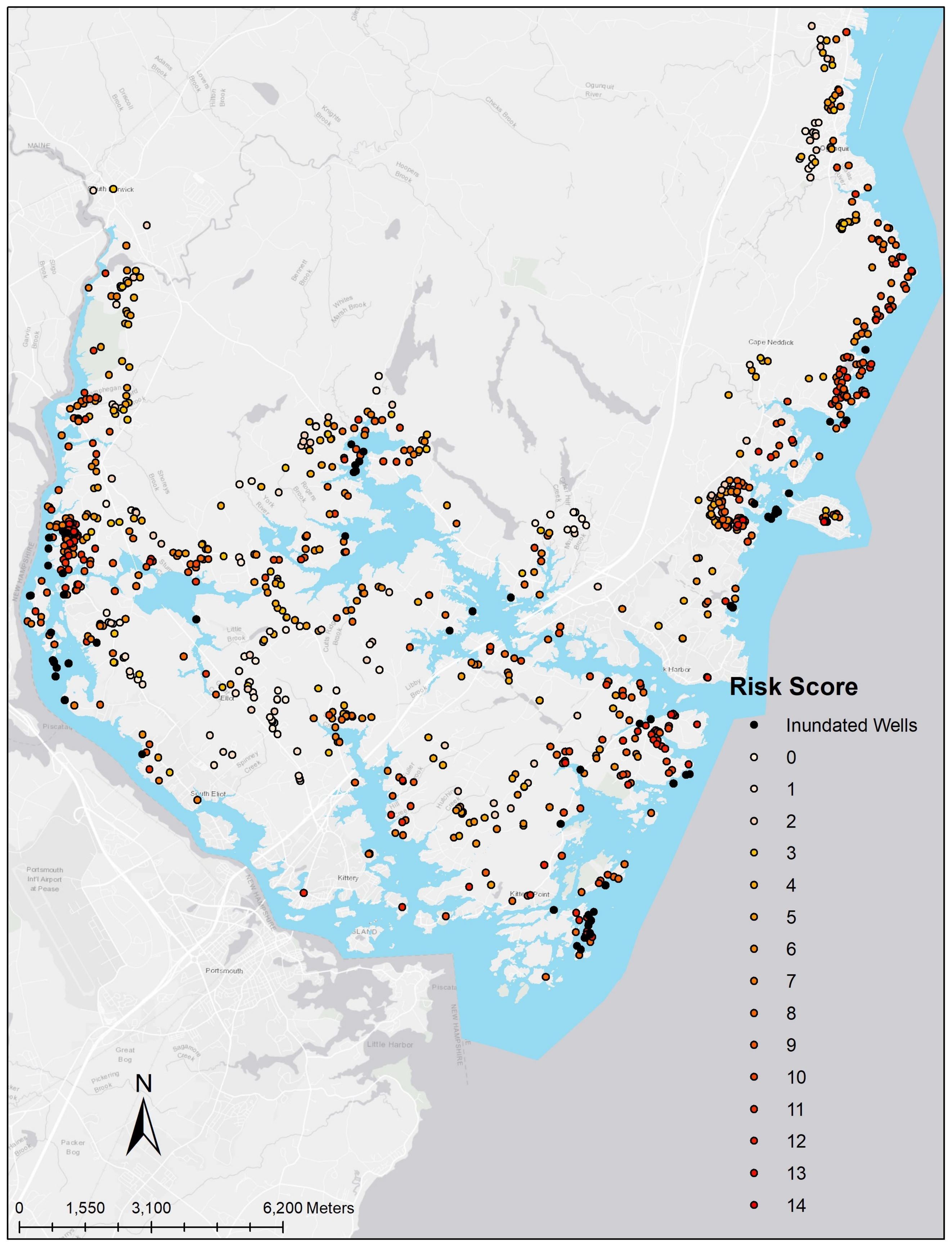
This risk assessment was carried out using ArcMap 10.7.1. First, using both select by attribute and select by location, a new layer displaying all domestic groundwater wells within 1,000 meters of the coast of Southern Maine was created from the original well locations data set. This layer was used for the remainder of the assessment. Select by location was then used in order to identify all of the wells inundated by the layer displaying 3.3 meters of projected sea level rise. In order to find the distance from each well to this layer, the near tool was used (Figure 2). Next, using natural breaks, well depth was broken up into three risk categories and mapped (Figure 3). As a first step in creating the well density map, a 100 meter undissolved buffer was created around each well in the study area. A spatial join was then used to join buffers to wells using the match option within (Figure 4). Well type was then mapped according to three the different categories (Figure 5). Finally, in order to create a map based on surficial geology, the field calculator was used in order to label each specific unit as course sediment, fine sediment, or wetland. A spatial join was then used to join surficial geology to wells using the match option within (Figure 6).

In order to map the final risk of saltwater intrusion for each well, each risk factor was assigned a risk value, based on predetermined subdivision values, using the field calculator (Table 1). Once this was complete, the field calculator was used to weigh and add each of the five risk factors.

Table 1: Risk Factors Contributing to Well Salinization

| Risk Factors | Subdivision Value | Risk Value | Weight Factor | Weighted Risk Value |
|---|---|---|---|---|
| Distance to Storm Surge (Meters) | < 300<br>300.1-500<br>>500.1 | 2<br>1<br>0 | 3 | 6<br>3<br>0 |
| Well Depth (Feet) | 0-210<br>210.1-370<br>370.1-820 | 0<br>1<br>2 | 2 | 0<br>2<br>4 |
| Well Density (Number of Wells) | 1-2<br>3-5<br>6-11 | 0<br>1<br>2 | 1 | 0<br>1<br>2 |
| Well Type | Bedrock<br>Overburden<br>Gravel | 0<br>1<br>2 | 1 | 0<br>1<br>2 |
| Surficial Geology | Coarse<br>Fine<br>Wetland | 0<br>1<br>2 | 1 | 0<br>1<br>2 |

### Groundwater Well Salinization Risk



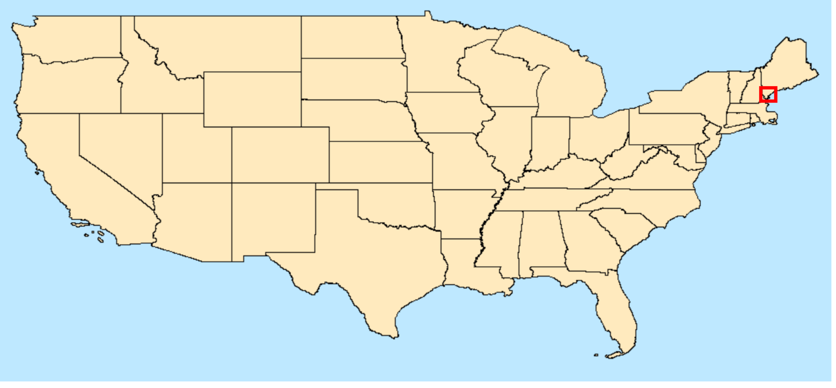



**Figure 1: Groundwater Well Salinization Risk**
Weighted risk of saltwater intrusion into domestic groundwater wells based on distance to the coast, well depth, well density, well type, and surficial geology. 14 is the highest risk and 0 is the lowest risk.

## Results

The final weighted risk assessment for groundwater well salinization in Southern Maine shows that deep gravel wells that are close to sea level rise and are drilled in an area where the surficial geology is a wetland, have the greatest risk of saltwater intrusion (Figure 1). While the highest possible weighted risk score in this analysis is 16, the highest score achieved was 14 by 7 different wells. Shallow bedrock wells far inland with coarse grained surficial geology have the lowest risk of saltwater intrusion (Figure 1). 53 wells achieved the lowest possible risk score of 0 (Figure 7). With 3.3 meters of projected sea level rise, not only would 11.86 percent of wells have a very high risk of saltwater intrusion, defined as having a risk score greater than or equal to 12, but 6.86 percent of wells would be directly inundated.

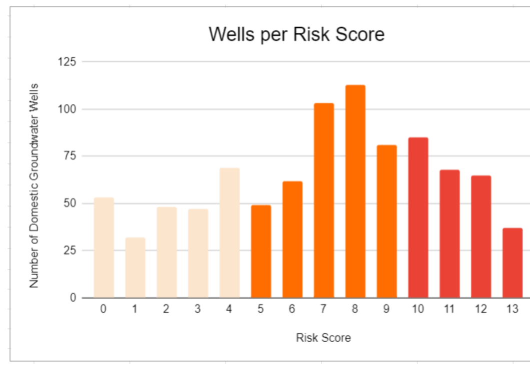



Figure 7: Histogram displaying number of wells per risk score.

## Discussion

Based on the high percentage of domestic groundwater wells that would be at risk of saltwater intrusion with a 3.3 meter sea level rise, freshwater security may be an issue for coastal communities in Southern Maine as the world combats climate change.

These results are consistent with previous understanding and do not contain any surprising or counterintuitive findings. This study, much like Eriksson's risk assessment of saltwater intrusion into freshwater wells on the Swedish island Öland, provides a simplified model of reality based on a few of the many risk factors that affect saltwater intrusion. This risk assessment, like many others, weighted distance from coast most heavily and therefore produced a final map that has a visibly greater risk along the coastline. This analysis is unique in its location and also because it utilizes both well type and surficial geology while many other studies use one or the other.

Wells that are identified as having a high risk of saltwater intrusion by this analysis can be targeted for prevention methods such as reduced pumping or increased freshwater infiltration. Lower risk areas may be suitable places for new wells to be drilled. Although all of the data sources are current, there may be inaccuracies in well locations since they have been compiled over many years by the drilling companies themselves. Since the surficial geology layer did not cover all parts of the study area, wells within those parts were left out of the surficial geology map. Because of this, only 895 out of the 919 wells in the study area had a final risk score taking surficial geology into account. The major limitation of this analysis is that it only takes five risk factors into consideration to describe the complex flow of groundwater. In a more extensive analysis, other factors relating to regional groundwater flow, aquifer properties, and infiltration would be included.

Jenna Mello

ENV 107 Introduction to GIS, Spring 2020

Projection: NAD 1983 UTM Zone 19N

References

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Kallioras, A., Pliakas, F., Diamantis, I., Kallergis, G. (2006) Application of Geographical Information Systems (GIS) for the Management of Coastal Aquifers Subjected to Seawater Intrusion, *Journal of Environmental Science and Health Part A, 41:9, 2027-2044. DOI: 10.1080/10934520600780669*

USGS. (n.d). The Process of Saltwater Intrusion [Image of Natural vs. Saltwater Intrusion Conditions].

Water Resources in Maine. (2013). *Maine Geological Survey: Water Resources in Maine, Maine.gov.*

Data Sources

Well Depths, March 2020, Maine Geological Survey (Open Data).

Maine Sea Level Rise Storm Surge Scenarios 2018, February 2019, Maine Geological Survey (Open Data).

Maine Surficial Geology Units, December 2018, Maine Geolibrary.

### Well Distance to Coast

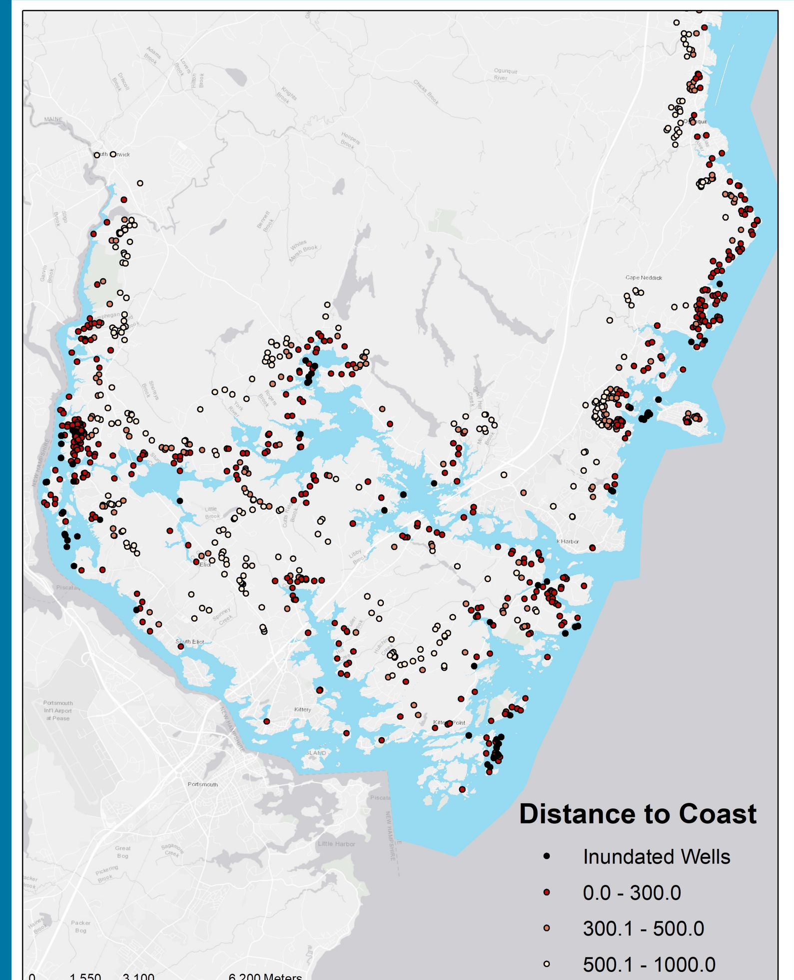


**Figure 2: Well Distance to Coast**
Wells that are closer to the coast, created by 3.3 meters of projected sea level rise, will have a greater risk of saltwater intrusion than those farther inland. The distance to storm surge is measured in meters.

### Well Depth

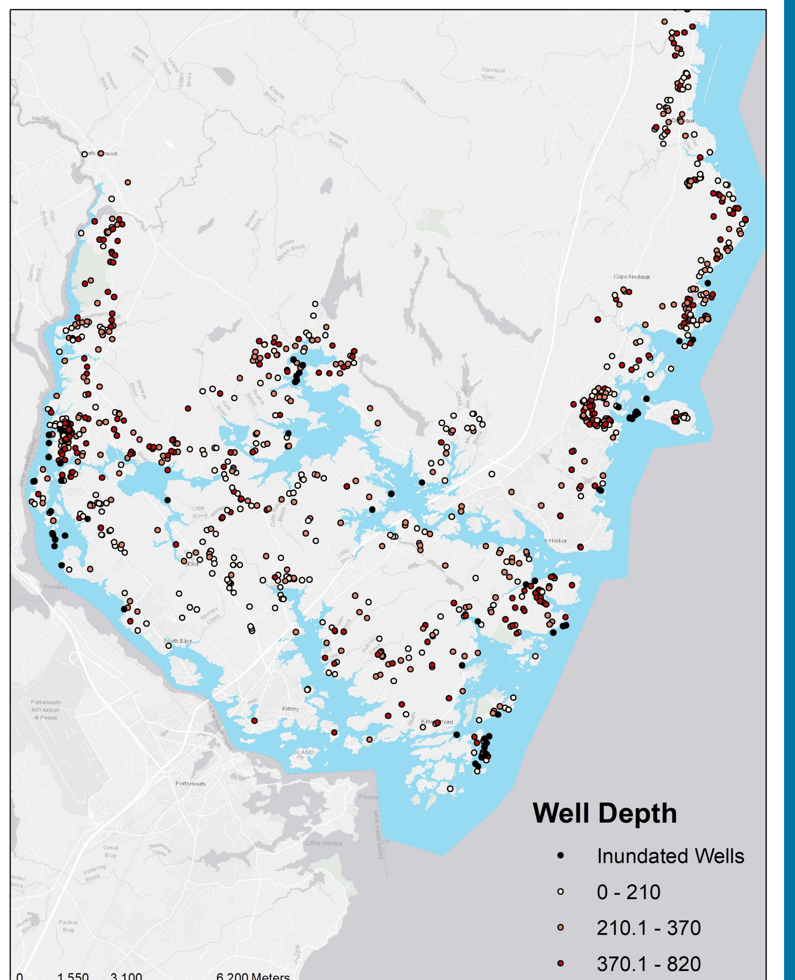


**Figure 3: Well Depth**
Wells that are close to the coast and very deep have a higher risk of saltwater intrusion since they may encounter the boundary between freshwater and seawater before shallower wells as sea level rises. Well depths are measured in feet.

### Well Density

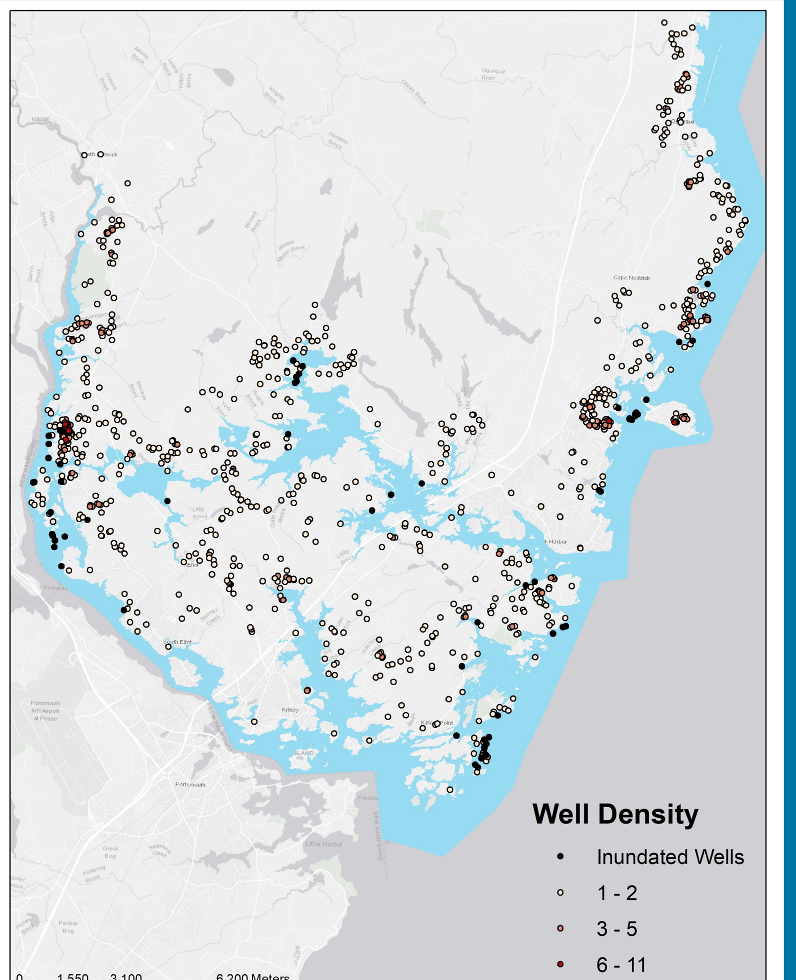


**Figure 4: Well Density**
Areas with a high well density will have a greater risk of saltwater intrusion. Well density is the number of wells within 100 meters of each well.

### Well Type

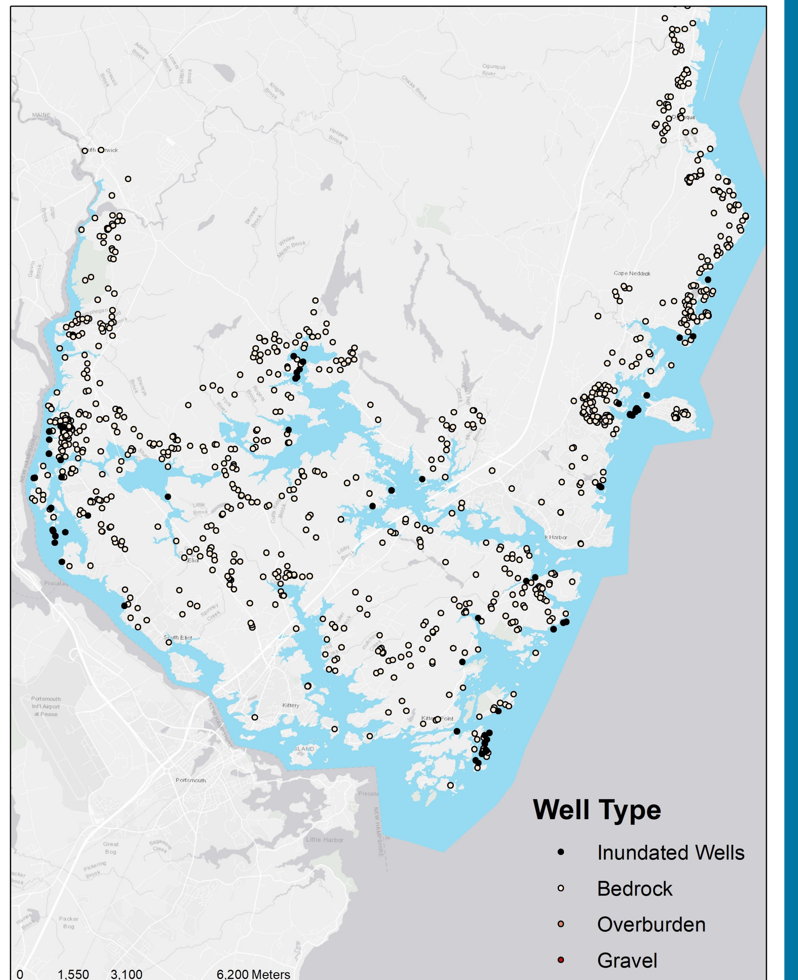


**Figure 5: Well Type**
Gravel wells allow for increased permeability in the immediate vicinity of the well and therefore have an greater risk of saltwater intrusion. The majority of study area wells are bedrock.

### Surficial Geology

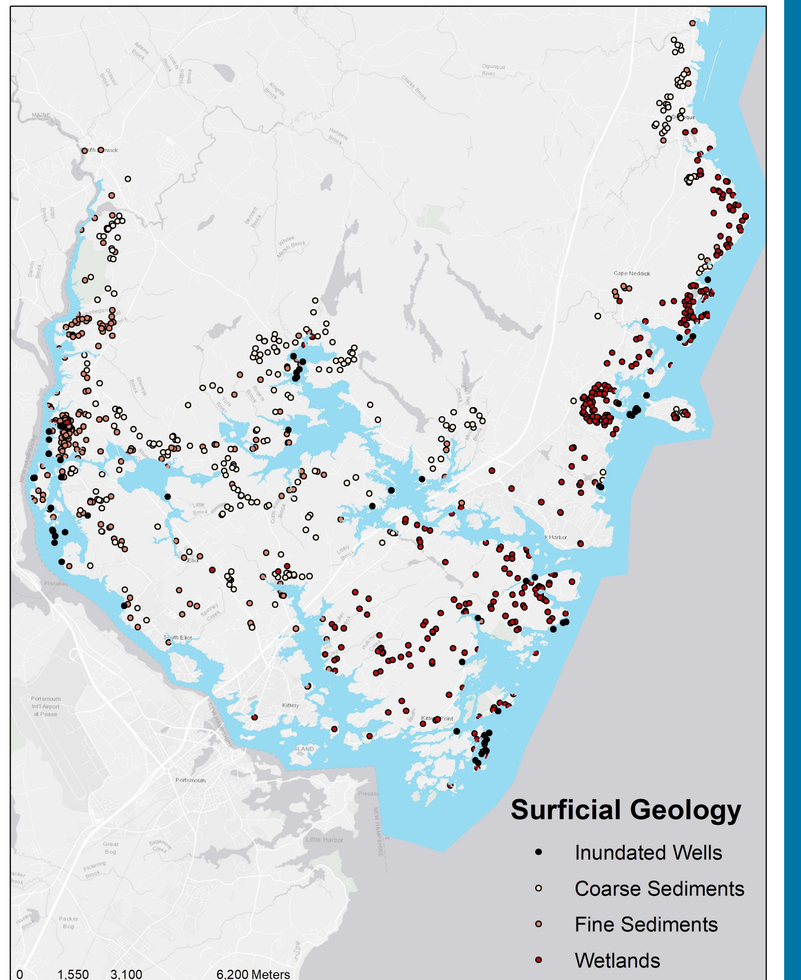


**Figure 6: Surficial Geology**
Surficial geology determines the amount and rate recharge from precipitation into the groundwater system. Wetlands have the greatest risk since there is no recharge in those areas.