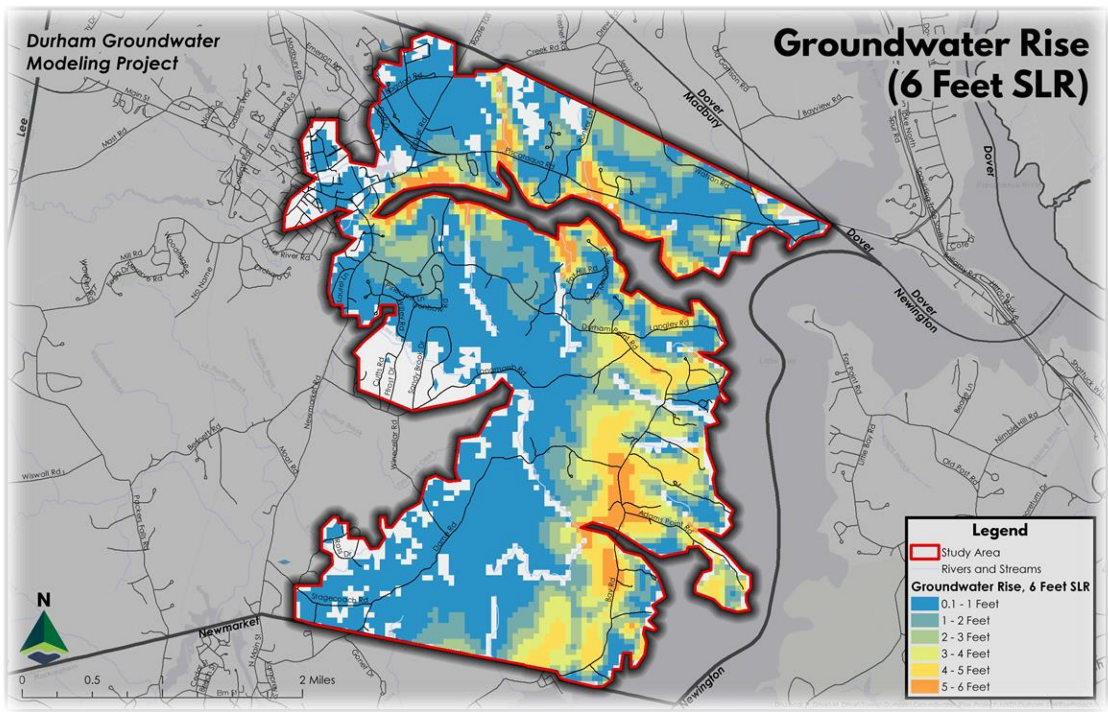
Sea Level Rise Impacts on Groundwater Levels and Water Quality:

A Vulnerability and Planning Study in Durham, New Hampshire

FINAL NON-TECHNICAL REPORT



Developed for the:

Town of Durham

in coordination with

Strafford Regional Planning Commission, JFK Environmental Services LLC, University of New Hampshire
and the
New Hampshire Department of Environmental Services

February 2022

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GIS Disclaimer

Base data layers are generally from Environmental Systems Research Institute, NH Geographically Referenced Analysis and Information Transfer System, NH Department of Transportation, NH Department of Environmental Services, Maine Office of Geographic Information Systems, U.S. Census, U.S. Fish and Wildlife Service, U.S. Geological Survey, and/or the 18 municipalities[1] represented by SRPC. These agencies and organizations have derived this data using a variety of cited source materials, at different time frames, through different methodologies, with varying levels of accuracy. As such, errors are often inherent in GIS data and should be used for planning purposes only. The presented data is sometimes only a subset of the original data. Please visit the original location of the data, contact the original host source, or contact SRPC for information on the full data set.

Model Limitations

The groundwater model created for this project is a conceptual model to investigate the effects of sea level rise on groundwater levels and saltwater intrusion. It is not designed to predict groundwater head and/or concentration at individual wells, but to simulate groundwater-flow patterns and trends with sea level rise. Uncertainties are associated with the groundwater measurements, bedrock geology, properties of the geologic materials, salinity distribution at the coast, and sea level rise scenarios. The location of fracture zones in bedrock, which could have significant effect on saltwater intrusion, are not well known. Pumping is assumed to be at a constant rate throughout the simulation and there is uncertainty in the vertical distribution of withdrawal volumes. Despite these limitations, the groundwater model is useful in identifying the areas that are most at risk from saltwater intrusion (both shallow and deep in the geologic materials) and zones of groundwater rise caused by sea level rise. This information can be used to direct monitoring programs, target areas for additional studies and data collection, assist in managing assets that may be vulnerable to premature failure, and protect both surface and groundwater quality.

[1] Barrington, Brookfield, Dover, Durham, Farmington, Lee, Madbury, Middleton, Milton, New Durham, Newmarket, Northwood, Nottingham, Rochester, Rollinsford, Somersworth, Strafford, Wakefield

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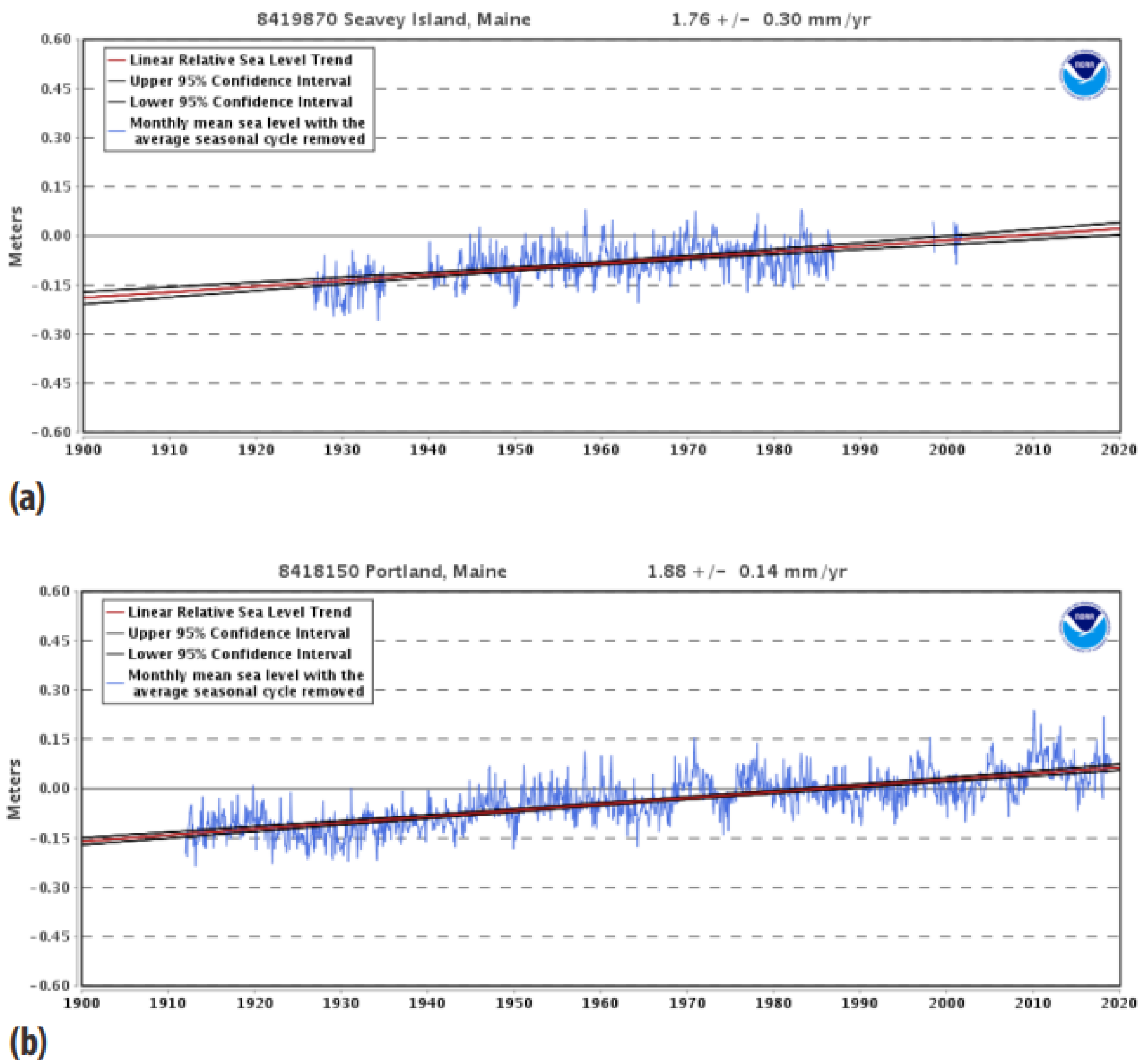
1.0 Introduction

As sea levels rise and storms become more intense, existing coastal flooding along New Hampshire's shoreline is expected to increase in frequency and severity. According to tide-gauge data from Seavey Island and Portland, Maine, referenced in the Coastal Flood Risk Summary Part 1: Science (CFRS), sea level has risen approximately 7.5 – 8.0 inches from 1912 – 2018 (Figure 1) and is expected to rise at least for centuries.

Figure 1. Seavey Island and Portland, Maine tide gauge data



While surface-water flooding is dramatic and impactful, a more insidious process is also happening under the ground. Sea level rise induced groundwater rise, which can be described as an increase in groundwater tables in areas where the groundwater is not confined, is projected to extend up to 2.5 to 3 miles inland from coastal New Hampshire. This is approximately three to four times farther inland than tidal-water inundation.

The Coastal Flood Risk Summary projects that rising groundwater can lead to inland flooding hazards (groundwater inundation in low-lying areas), the weakening of roads, early deterioration or the failure of underground infrastructure, foundation weakening, changes in the hydrology of natural resources, and harm to both groundwater and surface-water quality.

This modeling and vulnerability study identifies future risks from rising groundwater and saltwater intrusion. To assess vulnerabilities JFK Environmental LLC and the University of New Hampshire (UNH) constructed a groundwater flow and transport model to investigate the effect of sea-level rise on groundwater in Durham.

1.1 Background and Purpose

The Town of Durham, in partnership with the Strafford Regional Planning Commission (SRPC), the University of New Hampshire (UNH), and JFK Environmental Services LLC, applied for and received funding from the CWSRF Loan Program to conduct a study to determine the susceptibility of public and private drinking water supplies, private septic systems, contaminated sites, stormwater infrastructure, utilities, roads, and municipal critical facilities in low-lying areas to groundwater rise and saltwater intrusion.

1.2 Goal Statement

The goal of this project is to improve Durham's understanding of future groundwater rise vulnerabilities, build off and expand UNH's ongoing research on the impacts of sea-level rise on groundwater, and ultimately enable Durham decision-makers to better plan for future conditions so that the Town can continue to improve water quality in the Great Bay Estuary.

1.3 Plan Development Process

This plan was developed through the collaborative efforts of numerous project management team meetings and conference calls between the Strafford Regional Planning Commission (SRPC), JFK Environmental LLC, University of New Hampshire, and New Hampshire Department of Environmental Services (Watershed Assistance Section, Wastewater Engineering Bureau, and the Coastal Program), hereunto referred to as the project management team. Staff from partnering organizations, such as the Climate Adaptation Workgroup (CAW), Piscataqua Region Estuaries Partnership (PREP), and NH Sea Grant were often consulted during the project for their expertise and feedback. In addition, a local steering committee made up of select members of Durham's Leadership Committee, including the Town Administrator, Public Works Director, Town Planner, Town Engineer, and Code Administrator were responsible for providing technical input, localized data, and overall guidance throughout the length of the project.

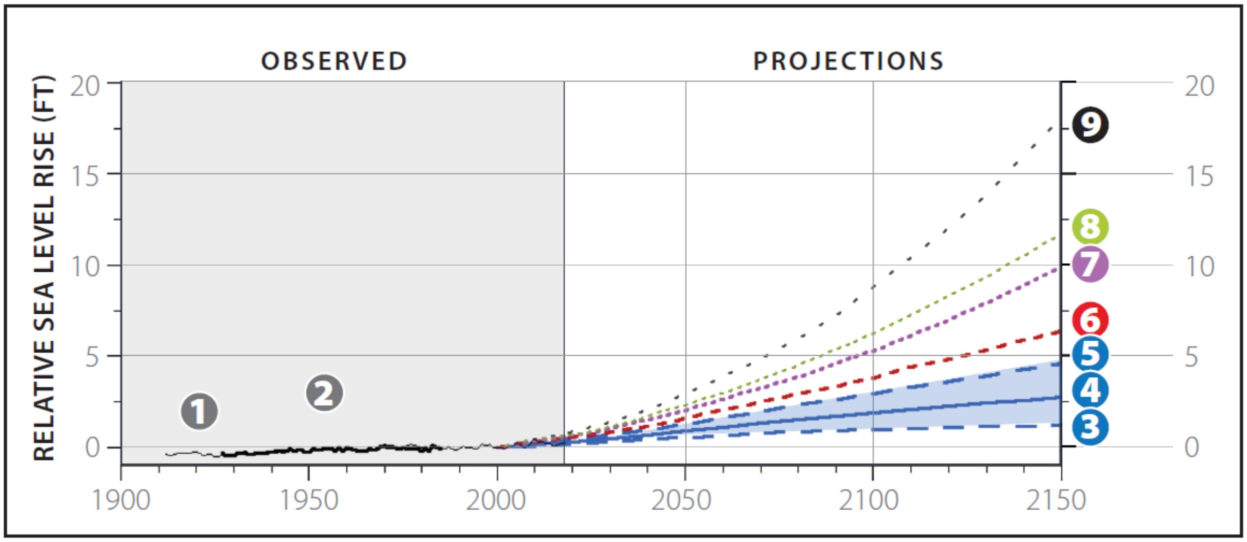
2.0 Modeling, Mapping, and Assessment Methods

This vulnerability assessment used the results from a groundwater model to produce maps and statistical data about the potential impacts to public and private drinking water supplies, private septic systems, contaminated sites, stormwater infrastructure, utilities, roads, and critical municipal facilities in low-lying areas to groundwater rise and saltwater intrusion.

2.1 Sea Level Rise Scenarios

This study uses the projections developed in the NH Coastal Flood Risk Summary Part I: Science as the coastal boundary conditions for modeling groundwater rise and saltwater intrusion in the Town of Durham, NH over the next century. The sea level rise scenarios used in this study correspond with Curve #5 and Curve #7 (Figure 2).

Figure 2. Global mean sea-level rise scenarios



Curve #5 represents the preferred greenhouse gas concentration scenario because it is an intermediate emission pathway and represents a somewhat optimistic perspective whereby global concentrations of greenhouse gases stabilize at current levels by the middle of the century and then begin to decline. Curve #7 uses the same scenario; however, projects higher sea level rise estimates with a lower probability. Both scenarios and their associated sea level rise ranges are detailed in Table 1.

Table 1: Projected local sea level rise (in feet) estimates above 2000 levels

Year	Curve #5	Curve #7
	Likely Range	1-100 Chance
	67% probability SLR is between:	1% probability SLR meets or exceeds:
2050	0.5 – 1.3	2.0
2100	1.0 – 2.9	5.3
2150	1.2 – 4.6	9.9

These curves were selected by the Steering Committee, with input from the project team, to provide a realistic range of what sea level rise estimates Durham is likely to experience.

2.2 Modeling Process

USGS MODFLOW2000 and the variable-density flow package SEAWAT2000 were used to model the effects of sea-level rise on groundwater levels and saltwater intrusion in the Town of Durham. The model area includes all of Durham and parts of the adjacent communities Dover, Madbury, Barrington, Nottingham, Lee, Epping, and Newmarket (Figure 3).

Figure 3. Study area of the groundwater modeling study

The model grid consists of uniformly spaced cells that are 200 feet x 200 feet. The grid consists of 260 rows and 330 columns with 22 layers that extend from the water table to a uniform depth of 1100 feet below current mean sea level. The layer thicknesses vary from 15 to 100 feet thick. Many layers are needed to simulate the location of the freshwater/saltwater interface. Typically, the bottom of the model is defined by the bedrock surface, but in this area of NH the bedrock surface is shallow, less than 100 feet below ground surface within the study area, and many of the residential and public water-supply wells remove water from the fractured bedrock. Unconsolidated deposits were simulated to a depth of 110 feet below mean sea level and bedrock was simulated down to a depth of 1100 feet below mean sea level. This depth was chosen to include water supply wells in the area, the maximum depth of which is approximately 1100 feet below mean sea level in Lee, NH.

More detailed information on the model can be found in the "Sea Level Rise Impacts on Groundwater Levels and Water Quality: A Vulnerability and Planning Study in Durham, NH, Final Technical Report." (Knott, Jayne. February 2022)

2.3 Mapping Methodology

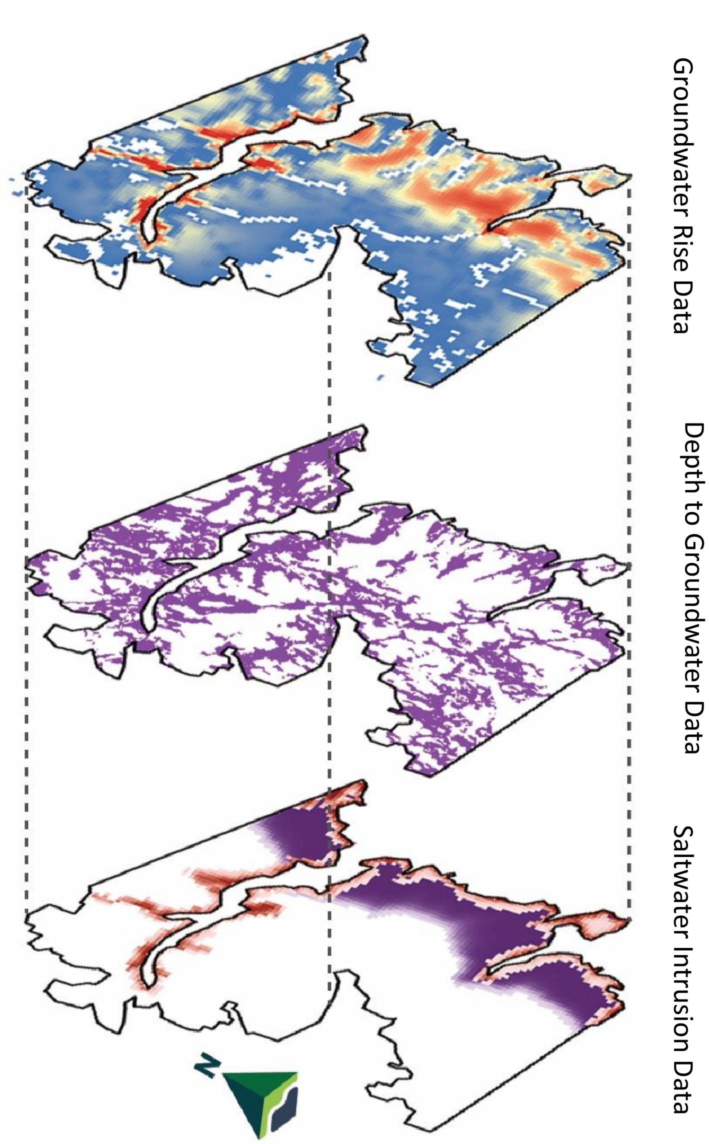
A series of maps were created to display detailed groundwater data that was modeled by JFK Environmental Services, LLC. These maps include groundwater rise under a variety of sea level rise scenarios, current depth to groundwater, projected depth to groundwater, and simulated saltwater intrusion. In addition, a groundwater assets map was created which displayed key assets and resources identified by the Town to be analyzed in this study (Table 2).

The current depth to groundwater map was used to identify the most vulnerable locations in the study area, and then the projected groundwater rise scenario given 6 feet of sea level rise was overlayed on top. The project team chose 6 feet of sea level rise by 2100 to evaluate for groundwater rise predictions to try and capture a realistic worst-case scenario for long-term planning purposes. Only the saltwater intrusion maps were created using the 8 feet of sea level rise scenario.

An overlay analysis was performed using these two data layers to identify locations within the study area that have the shallowest groundwater depths and highest levels of projected groundwater rise. The saltwater intrusion layers were overlayed on top of that to look at impacts to drinking water supplies. (Figure 4).

These areas of shallow groundwater and high groundwater rise were used to perform an intersect analysis with the Town's municipal assets and resources to determine which are the most vulnerable and predicted to be the most negatively impacted by future groundwater rise. A map series was created to display the most vulnerable assets by category (Figures 12-20).

Figure 4. Overlay analysis graphic



2.4 Assets and Resources Evaluated

When deciding on which key assets and resources were going to be analyzed as part of the vulnerability assessment, the project team, in coordination with the steering committee, identified six categories of data points, including stormwater infrastructure, critical facilities, private infrastructure, contaminated sites, utility infrastructure, and public water supplies (Table 2).

Table 2: Assets and resources evaluated for the vulnerability assessment

Category	Assets and Resources	Data Source
Stormwater Infrastructure	Best Management Practices (BMPs) Catch Basins Culverts Drainage Manholes Outfalls Stormwater Pipes Swales	NH Statewide Asset Data Exchange System (SADES) Durham Public Works Dept.
Municipal Critical Facilities	Emergency Response Facilities Non-Emergency Response Facilities Facilities and Populations to Protect Potential Resources Water Resources Transportation Assets	Durham Hazard Mitigation Plan
Private Infrastructure	Private Wells Septic Systems	Durham Planning Department NH Department of Environmental Services
Contaminated Sites	Leaking Underground Storage Tanks Underground Injection Control Non-Hazardous, Non-Sanitary Holding Tank	NH Department of Environmental Services
Utility Infrastructure	Sewer Pipes Water Pipes	Durham Public Works Dept.
Public Water Supplies	Public Drinking Water Wells	NH Department of Environmental Services

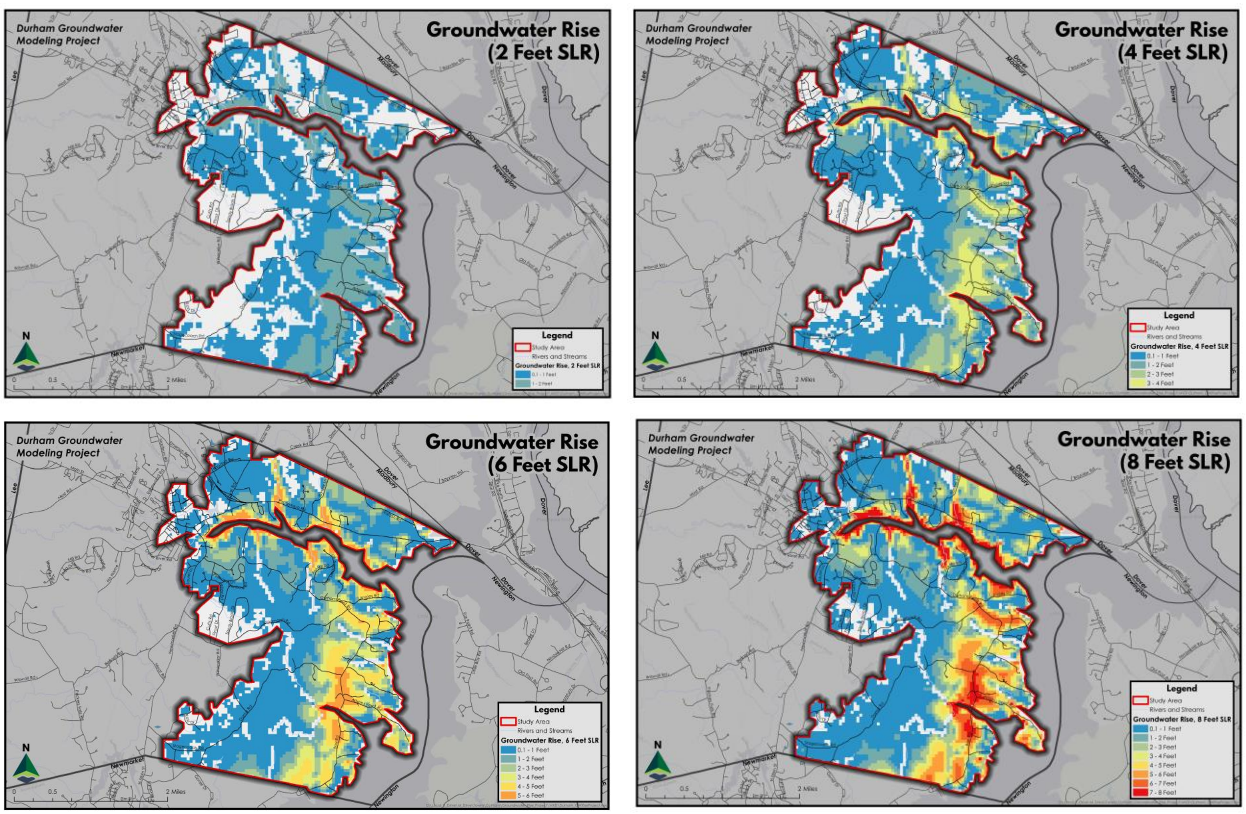
These assets and resources are listed in subsequent tables with more details about their specific vulnerability to groundwater rise in Section 4.0.

3.0 Modeling Results and Mapping Analysis

3.1 Groundwater Rise

Groundwater rise ranging in magnitude from less than one foot to 8 feet is predicted to occur up to 1.5 miles inland from the Durham coastline with 8 feet of sea level rise. The maximum extent of the groundwater-rise zone (GWRZ) for the sea level rise scenarios considered is shown in Figure 5. The tidally influenced Oyster River contributes to the inward extent of the groundwater-rise signal resulting in a farther inland extent of groundwater rise than in areas not influenced by the estuary. The projected magnitude of groundwater rise is indicated by the colors ranging from blue to red for 2, 4, 6, and 8 feet of sea level rise. The magnitude of groundwater rise is highest along the coast of Little Bay, Great Bay, and the Oyster River and decreases farther inland from the shoreline.

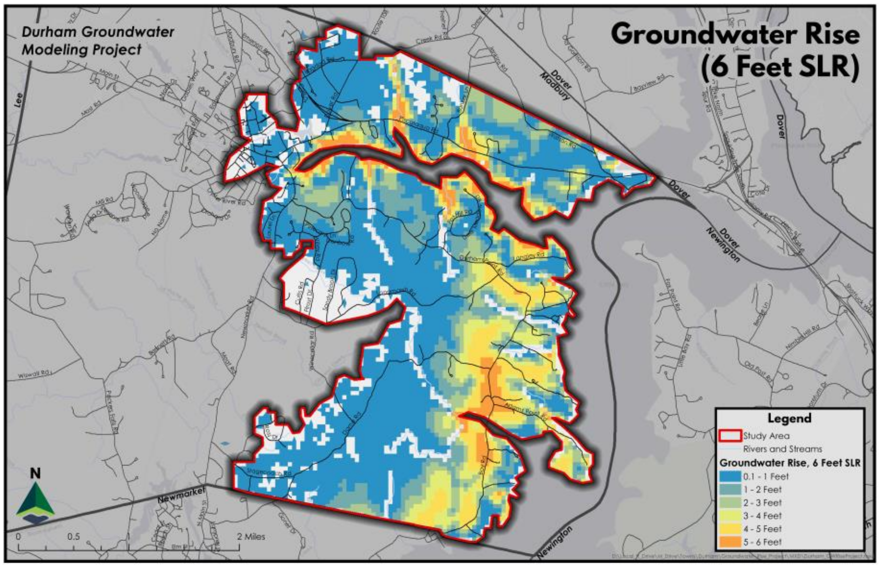
Figure 5. Projected groundwater rise for 2, 4, 6, and 8 feet of sea level rise



Groundwater rise near freshwater streams is reduced relative to other areas because groundwater discharge (flow) to these stream increases, keeping heads lower. Conversely, groundwater discharge to tidal surface waters is reduced because the surface-water head at the coast increases more quickly with sea-level rise than the groundwater head just inland of the coast. The reduced coastal discharge drives increased groundwater elevations at the coast. This is described in greater detail in the "Sea Level Rise Impacts on Groundwater Levels and Water Quality: A Vulnerability and Planning Study in Durham, NH, Final Technical Report." (Knott, Jayne. February 2022)

As referenced in Section 2.3, the project team chose 6 feet of sea level rise by 2100 (Figure 6) to evaluate for groundwater rise predictions to try and capture a realistic worst-case scenario for long-term planning purposes. Only the saltwater intrusion maps were created using the 8 feet of sea level rise scenario.

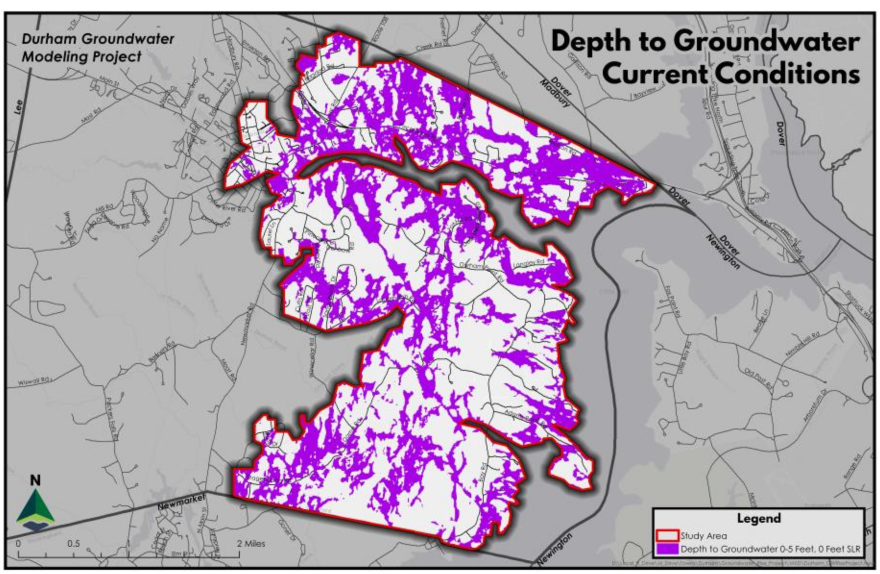
Figure 6. Projected groundwater rise with 6 feet of sea level rise



3.2 Potential Impacts from Groundwater Rise

Rising water tables can damage underground infrastructure in areas where the water table is shallow. To investigate this in Durham, the project team combined the groundwater rise dataset with LiDAR land surface elevation to identify areas where the groundwater is currently shallow. The project team decided to analyze areas where groundwater was less than 5 feet from the land surface (Figure 7).

Figure 7. Shallow groundwater depth of less than 5 feet



An intersect analysis was performed by overlaying the groundwater rise data with the depth to groundwater data (Figure 8). Using this information, the project team was able to identify areas within the groundwater rise zone where rising groundwater has the highest potential to damage underground infrastructure and pavement structure (Figure 9).

Figure 8. Intersect analysis

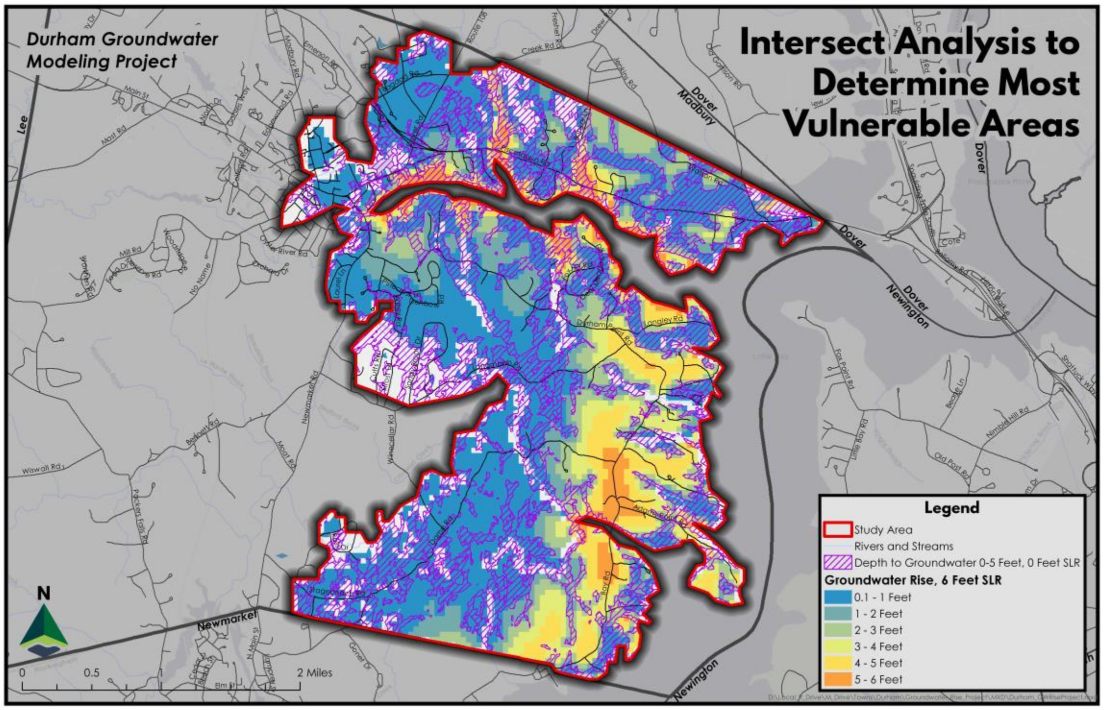
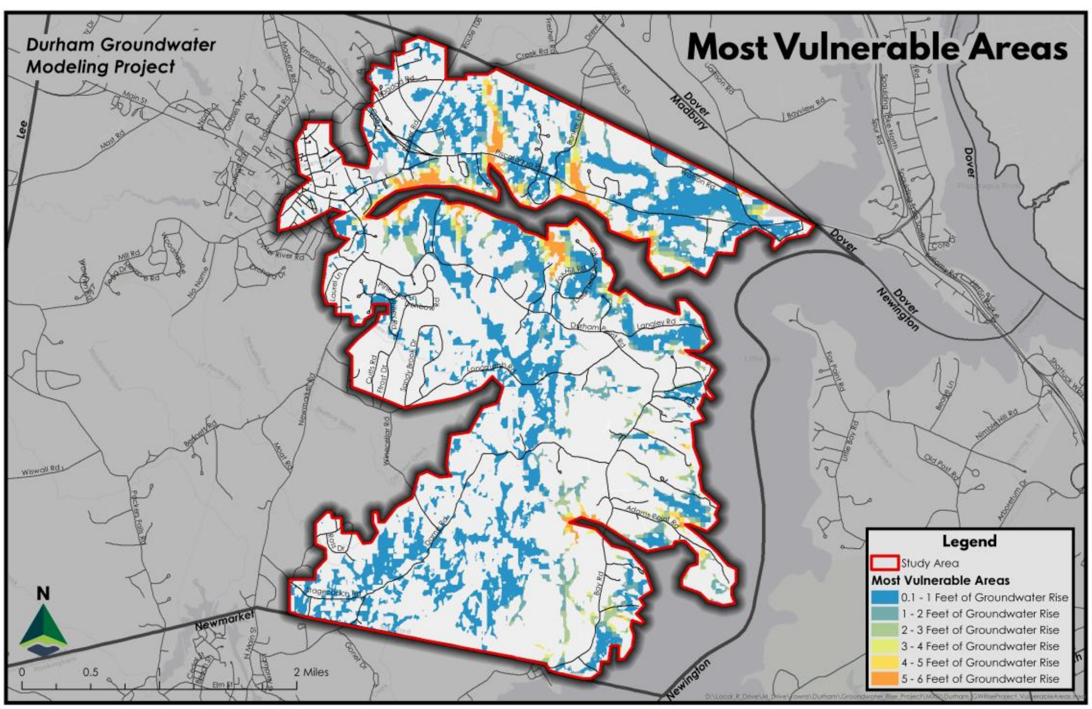


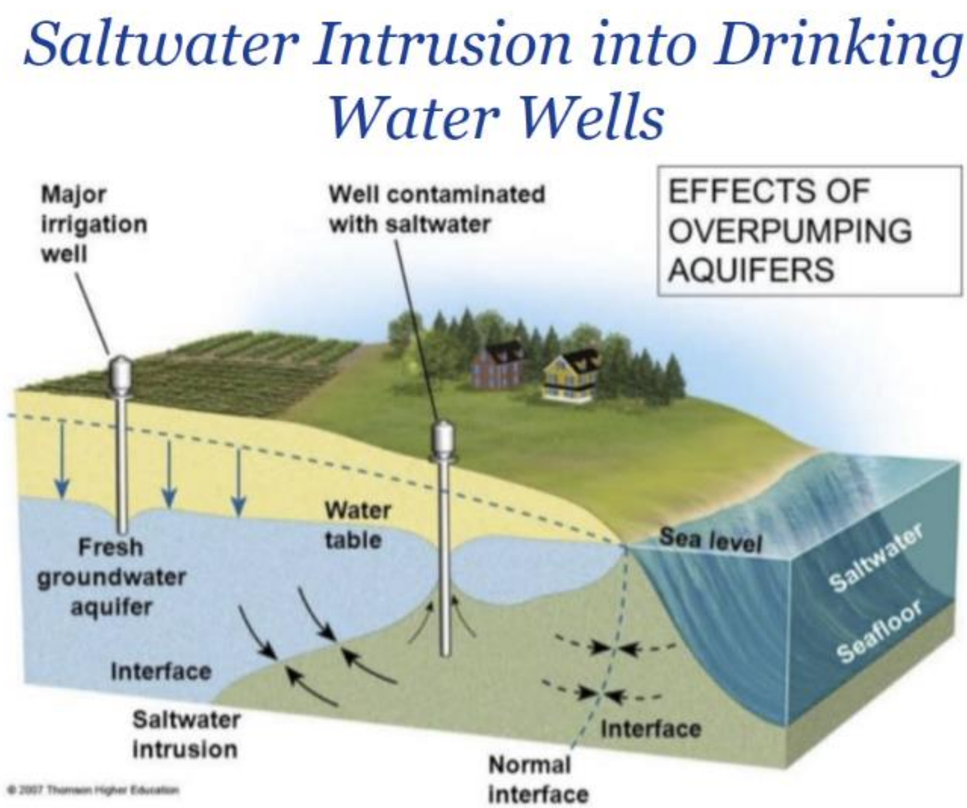
Figure 9. Most vulnerable areas within groundwater rise zone



3.3 Saltwater Intrusion

Saltwater intrusion can be defined as the movement of saline water into freshwater aquifers. Nearly all coastal aquifers experience some naturally occurring saltwater intrusion. As the elevation of saltwater bodies increases and as coastal flooding continues to occur, saltwater intrusion may increase. For example, rising sea-levels can change the normal interface between salt water and fresh water – moving further inland (Figure 10).

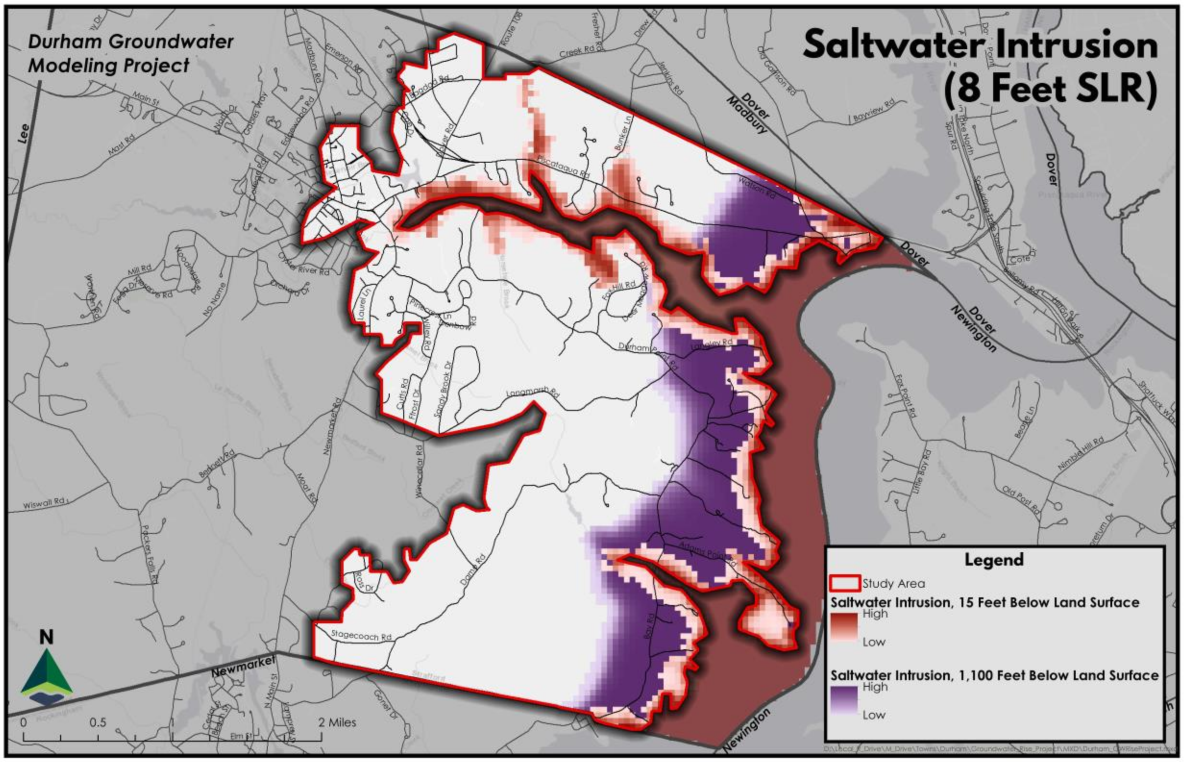
Figure 10. Saltwater intrusion into drinking water wells



2007 Thompson Higher Education; https://www.slideshare.net/prashantpkatti/sea-water-intrusion

In addition, groundwater withdrawal and pumping of aquifers can increase saltwater intrusion, resulting in elevated levels of sodium and chloride. This may increase the potential for a salty taste to the water and corrosive water damage to plumbing fixtures.

Figure 11. Simulated salt concentrations



3.3 Potential Impacts from Saltwater Intrusion

Saltwater intrusion modeling demonstrates negligible impact of sea level rise on salt concentrations in public supply wells (Figure 11). Neither the stratified drift aquifers nor the bedrock aquifers currently being used or contemplated for public water supply are predicted to be impacted by saltwater intrusion because of sea level rise. The coastal stratified drift aquifer in the northeastern portion of Durham may experience saltwater intrusion if it has not already. The farthest inland extent of non-zero relative salt concentrations is deep in the bedrock. This suggests that drinking water wells both public and domestic drilled deep into bedrock near the coast are more vulnerable to saltwater intrusion than shallow wells. Shallow wells, however, are more vulnerable to surface contaminants including the infiltration of saltwater from tidal water inundation.

4.0 Vulnerability Assessment Results

Groundwater is projected to rise in Durham, NH with sea level rise projected to occur in the Oyster River, Little Bay, and Great Bay estuaries. The groundwater rise signal is predicted to extend up to 1.5 miles inland from the coastline with 8 feet of sea level rise and has the potential to weaken or damage coastal roads, underground infrastructure, critical facilities, private septic systems and wells, and other key assets and resources in areas where groundwater is already shallow. In some cases, this may result in increased maintenance and repair costs and water-quality concerns.

The modeling analysis produced groundwater rise scenarios based on 1, 2, 4, 6, and 8 feet of sea level rise. In addition, groundwater depth data ranging between 0-5 feet, 0-10 feet and 0-15 feet were used. The project team used the groundwater rise data assuming 6 feet of sea level rise (by 2100) in association with groundwater depths of 5 feet or less for the vulnerability assessment. Key assets were broken down by point data (Table 3) and line data (Table 4). The following are the results of that analysis.

Table 3: Total vulnerable assets impacted by groundwater rise (Point Data)

Category	Assets and Resources (*Point Data*)	# of Assets Impacted by Groundwater Rise*
Stormwater Infrastructure	Best Management Practices (BMPs)	1
	Catch Basins	71
	Culverts	92
	Drainage Manholes	2
	Outfalls	14
Municipal Critical Facilities	Emergency Response Facilities	1
	Non-Emergency Response Facilities	1
	Potential Resources	4
	Water Resources	7
Private Infrastructure	Private Wells	110
	Septic Systems	110
Contaminated Sites	Leaking Underground Storage Tanks	2
	Underground Injection Control	1
	Non-Hazardous, Non-Sanitary Holding Tank	1
Public Water Supplies	Public Drinking Water Wells	4
*Assuming 6 feet of sea level rise w/ depth to groundwater less than 5 feet		

Table 4: Total vulnerable assets impacted by groundwater rise (Line Data)

Category	Assets and Resources (*Line Data*)	Length of Assets Impacted by Groundwater Rise*
Stormwater Infrastructure	Stormwater Pipes	1,030 feet
	Swales	4,637 feet
Municipal Critical Facilities	Roadways	9.8 miles
Utility Infrastructure	Sewer Pipes	2.2 miles
	Water Pipes	3.3 miles
*Assuming 6 feet of sea level rise w/ depth to groundwater less than 5 feet		

4.1 Stormwater Infrastructure

The Impacted Stormwater Asset maps (Figures 12 and 13) show where the Town's existing stormwater infrastructure may be vulnerable to future groundwater rise.

Figure 12. Impacted stormwater assets - points

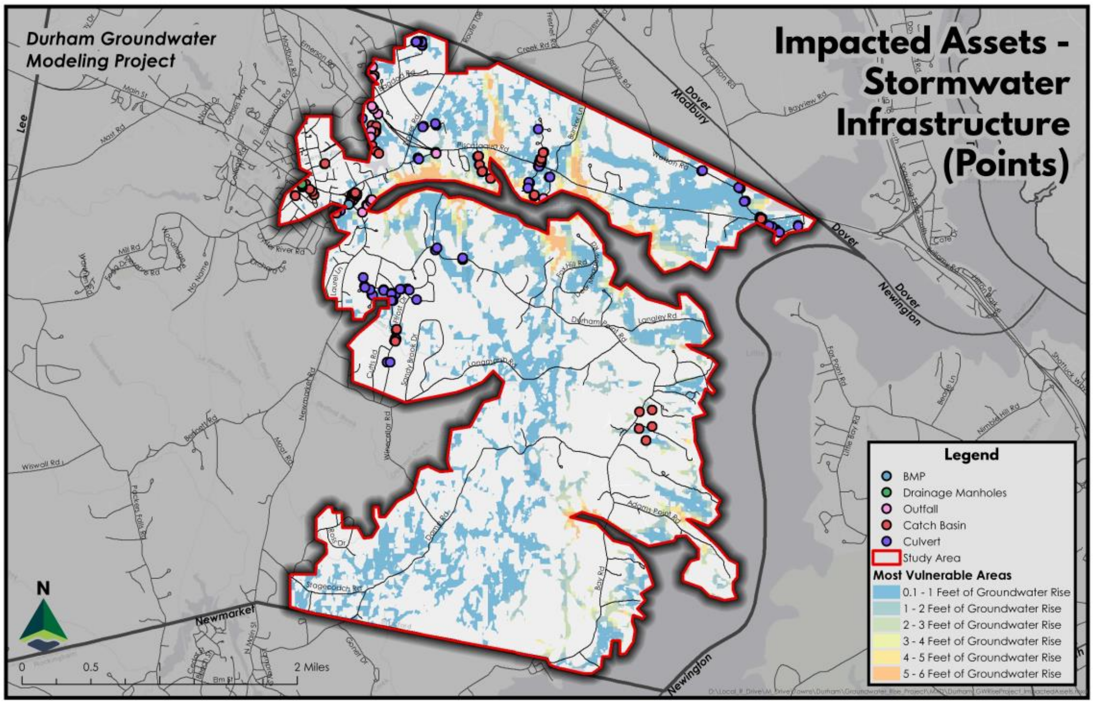
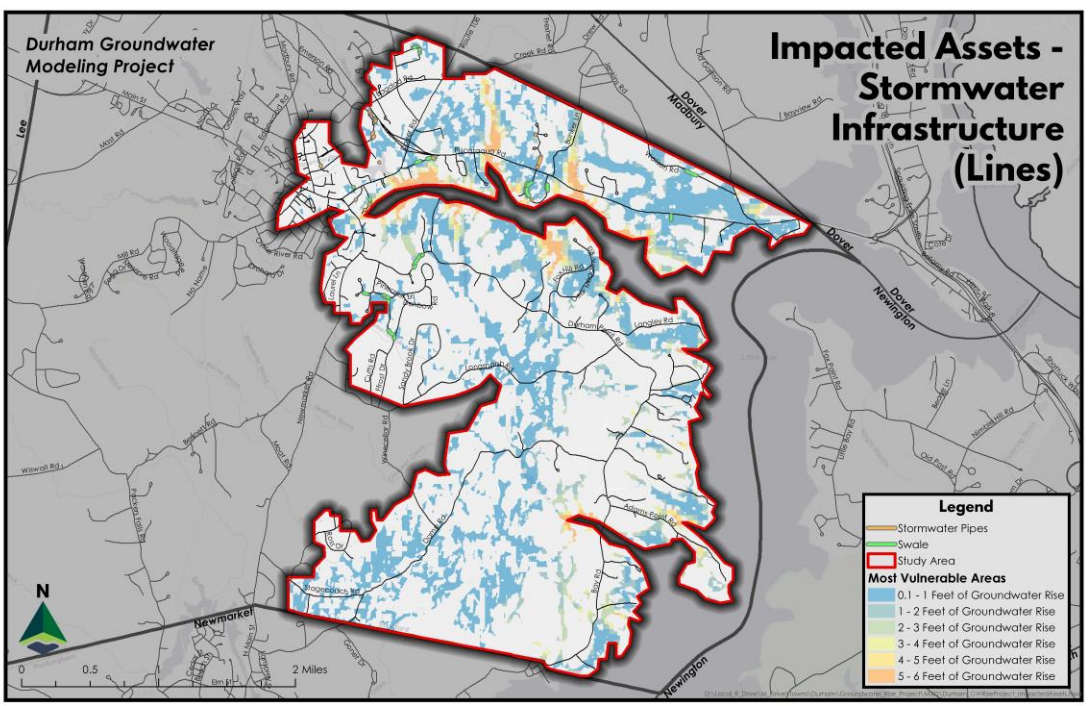


Figure 13. Impacted stormwater assets - lines



According to the mapping analysis, there are an estimated 180 stormwater assets vulnerable to groundwater rise (Table 5). This includes:

- One bioretention system on Mill Pond Road
- Seventy-one catch basins, located in the following areas: Ffrost Drive, Main Street and Route 108 intersection, near Mill Pond Plaza, Coe Drive near the Oyster River High School, Briggs Way, Shearwater Street, and Route 4 at the intersection of Back River Road
- Ninety-two culverts, located on Cedar Point Road, Back River Road, Riverview Road, Gerrish Drive, and the Sunnyside Drive neighborhood
- Two drainage manholes located near Mill Pond Plaza
- Fourteen outfalls in the Main Street and Route 108 intersection and Route 4.

In addition, there is approximately 4,637 feet of drainage swales scattered along Watson Road, Riverview Road, Durham Point Road, Old Piscataqua Road, and the Sunnyside Drive neighborhood. Impacts to stormwater pipes is limited to roughly 1,030 feet along Shearwater Street and Coe Drive near the Oyster River High School.

A report entitled, "Inundation of Stormwater Infrastructure is Common and Increases Risk of Flooding in Coastal Urban Areas" was published by the Institute for the Environment, University of North Carolina at Chapel Hill, found that not only will a stormwater network have difficulty functioning properly during a storm event, but recurrent inundation by saltwater also corrodes stormwater infrastructure, promotes saltwater intrusion to groundwater, and can mobilize fecal bacteria from co-located sanitary sewer lines. The report goes on to suggest that the most direct engineering solution to address stormwater inundation in the short-term is to install tide gates that prevent flow up-network when receiving water levels are elevated. Though this retrofit may be effective in the short- to medium-term, predicted increases in sea level and groundwater levels will inevitably lead to continuously inundated outfalls in vulnerable locations and decreased surface storage of stormwater further inland.

Most of this data was obtained through the NH Statewide Data Exchange System (SADES), which establishes a primary transportation inventory of assets for many state and local agencies. Statewide datasets, such as this, often have margins for error and it is likely that additional field verification will be needed to confirm current condition and locations. In addition, depth data for these assets were not available, as such, it is difficult to predict which assets may be the most vulnerable to increases in groundwater rise.

Table 5: Impacted stormwater assets

Category	Assets and Resources (*Point Data*)	# of Assets Impacted by Groundwater Rise*
Stormwater Infrastructure	Best Management Practices (BMPs)	1
	Catch Basins	71
	Culverts	92
	Drainage Manholes	2
	Outfalls	14
	Assets and Resources (*Line Data*)	Length of Assets Impacted by Groundwater Rise*
	Swales	4,637 feet
	Stormwater Pipes	1,030 feet
*Assuming 6 feet of sea level rise w/ depth to groundwater less than 5 feet		

4.1.1 Actions to Consider

The following are strategies intended to provide guidance to the Town on how to address impacts of groundwater rise on stormwater infrastructure.

1. Goal: Gain a better understanding of the vulnerability of existing identified stormwater assets
   a. Obtain additional data for existing stormwater infrastructure by applying for a Clean Water State Revolving Fund (CWSRF) stormwater loan to complete an Asset Management Program (AMP) to obtain specific information on vulnerable stormwater assets, including depth data and infrastructure condition, which will assist with managing several requirements of the NH MS4 permit. The CWSRF Asset Management Loan Forgiveness Guidance Document is a useful resource to reference prior to applying.
      i. The Town could apply for additional funds through an application of a CWSRF planning loan to fill in data gaps; however, utilizing the AMP may be a more suitable option and should be completed as a first step for infrastructure inventory, condition, and location.

2. Goal: Create a more resilient stormwater system
   a. In vulnerable areas, ensure that any stormwater BMPs and/or retrofit provides adequate infiltration from mobilizing contaminants and used to maximize groundwater recharge.
   b. Consider including the impacts from groundwater rise when updating the Town's infiltration and inflow (I&I) maintenance and survey practices.
   c. Review drainage manuals from places that are currently planning for groundwater rise (e.g., Florida-Dade County) for suggestions on more resilient stormwater construction materials and innovative retrofit techniques. This may include things like installing concrete coated asphalt storm drains, slip-lining, and anti-seep collars.
   d. Require that any stormwater project (including new construction, reconstruction, and projects rebuilding stormwater drainage systems) within the groundwater rise zone refer to the Coastal Flood Risk Guidance to assess impacts to design.
   e. Investigate if there is a need to retrofit or transition to a closed pipe system in existing low-lying areas within the groundwater rise zone.

4.2 Critical Facilities

The Impacted Municipal Critical Facilities maps (Figures 14 and 15) show where the Town's existing key resources and assets may be vulnerable to future groundwater rise.

Figure 14. Impacted municipal critical facilities - points

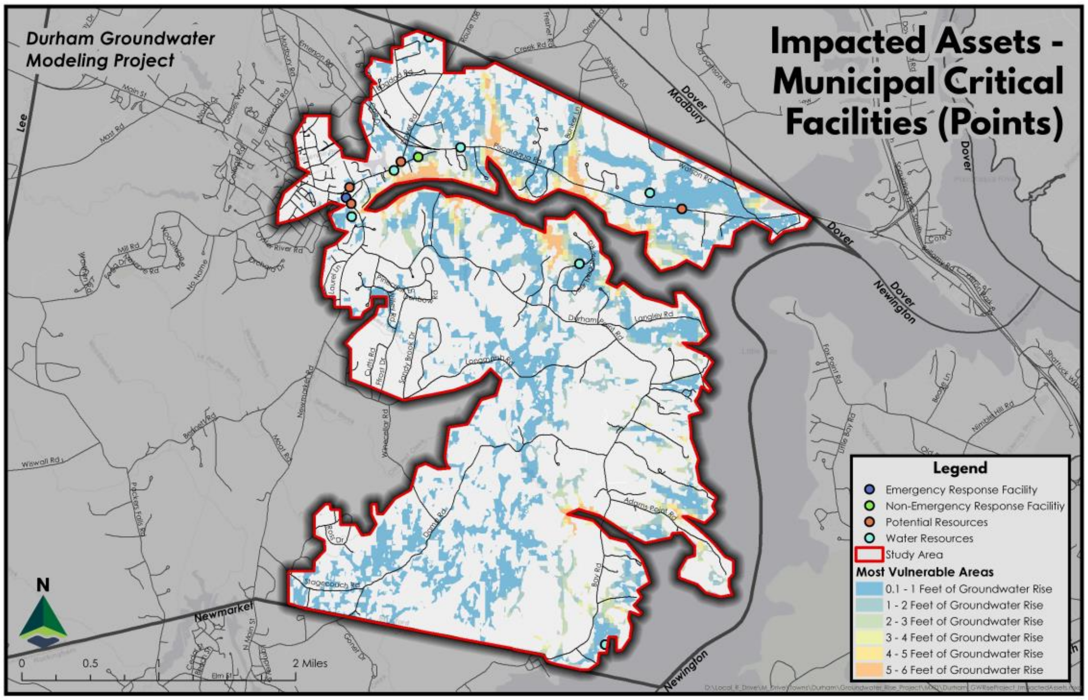
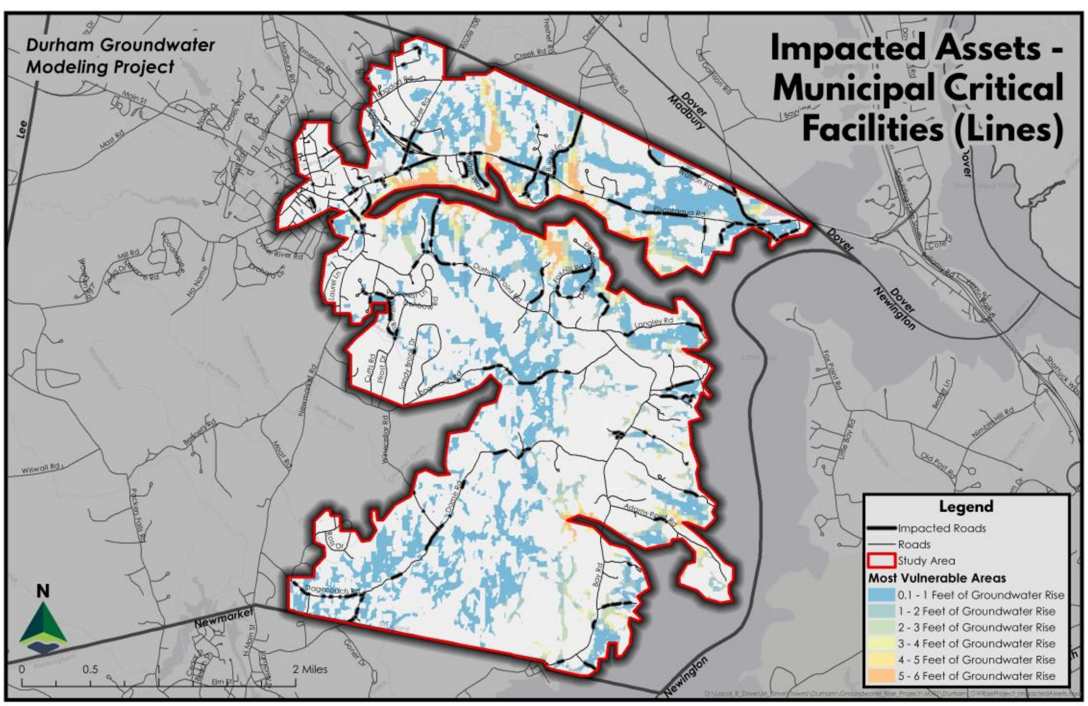


Figure 15. Impacted municipal critical facilities - lines



According to the mapping analysis, there are 13 municipal facility assets vulnerable to groundwater rise (Table 6). This includes the:

- Town Hall (Emergency Response Facility)
- Jacksons Landing Ice Rink (Non-Emergency Response Facility – Hazardous Materials)
- Three Chimneys Inn, Pines Guesthouse, Phillips 66 Gas Station, and Wagon Hill (Potential Resources)
- Durham Wastewater Treatment Plant, primary sewer pump station on Route 108, dry hydrant on Fox Hill Road, Mill Pond Dam, two fire ponds, and the Canney Farm Upper Dam (Water Resources)

In addition, there is approximately 9.8 miles of existing roadways scattered throughout the groundwater rise study area. Some of the longer sections of roadway include large portions of Route 4, Back River Road, Watson Road, Riverview Road, Briggs Way, Old Piscataqua Road, Durham Point Road, the Sunnyside Drive neighborhood, Fox Hill Road, Longmarsh Road, and Dame Road.

These data were obtained through the Town's 2017 Multi-Hazard Mitigation Plan Update. That chapter includes Critical Facilities and Key Resources (CF/KR) within Durham that were identified by the Committee during the update of this plan. It is likely that additional field verification will be needed to confirm locations and current condition. In addition, depth data for these assets were not available at the time this report was developed, as such, it is difficult to predict which assets may be the most vulnerable to increases in groundwater rise; however, when discussing roads, a reasonable assumption can be made that the base layers of roads are typically 3 feet. With a groundwater depth of 5 feet, it would take only 2 feet of rise to bring groundwater into the base layers of the pavement; a condition that will cause premature failure. In areas where groundwater is less than 5 feet deep, any amount of groundwater rise could be damaging given the uncertainties of the analysis and water table depth.

Table 6: Impacted municipal critical facilities

Category	Assets and Resources (*Point Data*)	# of Assets Impacted by Groundwater Rise*
Municipal Critical Facilities	Emergency Response Facilities	1
	Non-Emergency Response Facilities	1
	Potential Resources	4
	Water Resources	7
	Assets and Resources (*Line Data*)	Length of Assets Impacted by Groundwater Rise*
	Roadways	9.8 miles
*Assuming 6 feet of sea level rise w/ depth to groundwater less than 5 feet		

4.2.1 Actions to Consider

The following are strategies intended to provide guidance to the Town on how to address impacts of groundwater rise on municipal critical facilities.

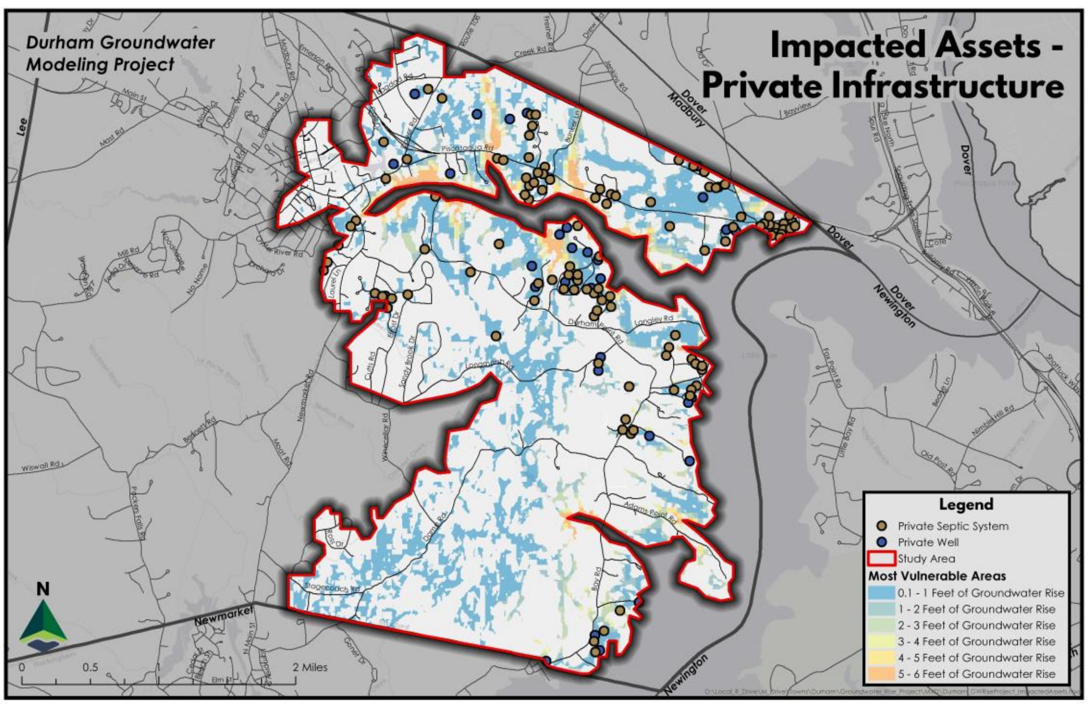
1. Goal: Gain a better understanding of the vulnerability of existing identified critical facilities
    a. Seek assistance from the regional planning commission to obtain additional information on the 13 critical facilities identified, including depth data and infrastructure condition.

2. Goal: Protect existing and future roadways from groundwater rise impacts
    a. Consult existing resources and studies, such as "[A Framework for Introducing Climate-Change Adaptation in Pavement Management]" when planning for the construction of new roads or upgrades to existing roads in the most vulnerable areas within the groundwater rise zone to determine the most appropriate approach for implementing a climate-ready flexible pavement design. This may include using the NHDOT design methodology, but with an additional amount of asphalt pavement to provide the same structural capacity as currently exist and minimizing additional operations and maintenance costs due to accelerated damage from groundwater rise.

4.3 Private Well and Septic Systems

The Private Infrastructure maps (Figures 16 and 17) shows the location of existing on-site septic systems and private wells within 1 kilometer of the coast that may be vulnerable to failure as the water table rises due to future groundwater rise.

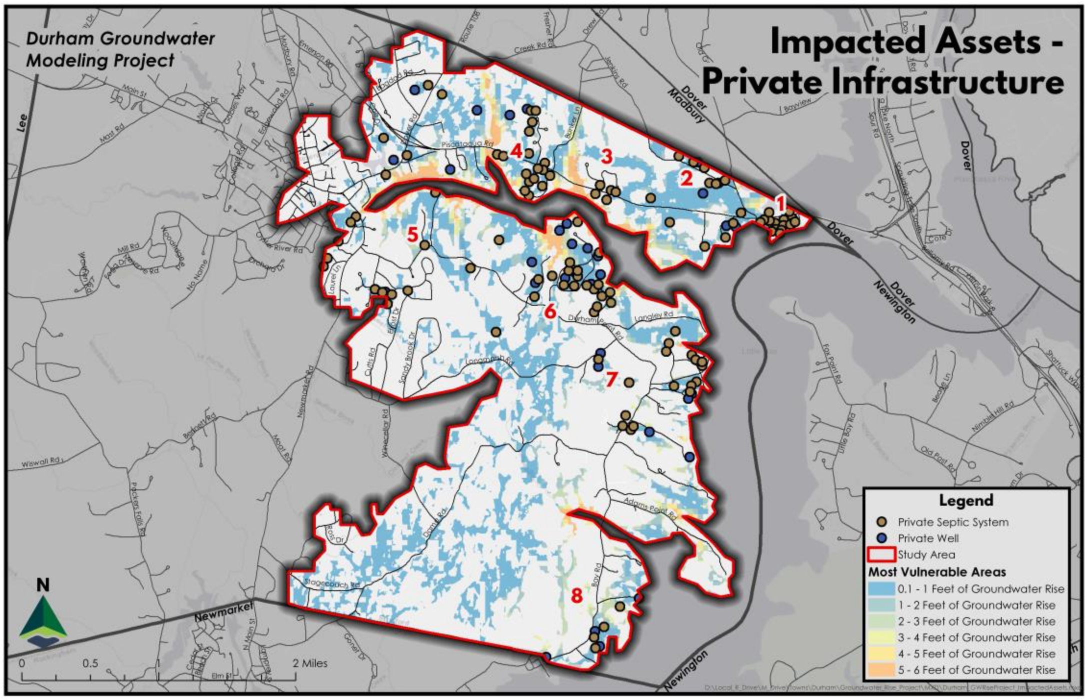
Figure 16. Impacted private septic systems and wells



Many of the homes located within the groundwater rise zone are not connected to the Town's municipal water or sewer facilities and are instead serviced by private septic and wells. As part of the vulnerability assessment, eight residential clusters were identified (Figure 17). These clusters included 1) Cedar Point

Road; 2) Watson Road; 3) Morgan Way; 4) Riverview Road and Shearwater Street; 5) the Sunnyside Drive neighborhood; 6) Deer Meadow Road, Fox Hill Road, and Mathes Cove Road; 7) Colony Cove Road; and 8) Bay Road. Within those areas, there was a total of 110 septic systems and private wells (Table 7).

Figure 17. Impacted private septic systems and wells



As groundwater rises, septic systems in coastal areas may no longer function optimally – reducing the ability of systems to treat bacteria and pathogens in wastewater and resulting in impacts to local water supplies and nearby surface waters through nutrient and pathogen loading. Generally, most septic tanks can be buried anywhere from four inches to four feet underground and provide filtration by removing solids from wastewater before it enters a drain field; however, for a septic system to function properly it requires a layer of soil at least two feet deep, and that layer will shrink as water tables rise and may lead to an increase in septic failures. A failed septic system can lead to groundwater contamination and impact local aquifers that residents depend on for drinking water.

Similarly, private wells in these areas may be susceptible to saltwater intrusion. According to the U.S. Geological Survey, if too much freshwater is pumped from an aquifer system, then saltwater can migrate landward. If a pumping well is close to the landward migrating freshwater/saltwater interface, saltwater could enter the well and contaminate the water supply; however, this is less likely to happen with residential wells and is a larger concern for municipal or community-size wells where pumping rates are much higher. It is unknown as to whether any private wells identified as part of this vulnerability analysis are experiencing high salinity levels. It will likely depend on the depth of the well.

Table 7: Impacted private infrastructure

Category	Assets and Resources (*Point Data*)	# of Assets Impacted by Groundwater Rise*
Private Infrastructure	Private Wells	110
	Septic Systems	110
*Assuming 6 feet of sea level rise w/ depth to groundwater less than 5 feet		

Septic system data was obtained by reviewing individual property files at the Town Hall, which provided depth data for roughly half the septic systems in the entire groundwater rise zone. During the vulnerability analysis, the percentage increased as the total number of at-risk septic systems decreased. Private well data for roughly half the wells in the groundwater rise zone was supplied by NHDES through the state's water well inventory. Aligning the septic and well data, certain assumptions were used to fill gaps by looking at the minimum, maximum, and average depths of the available data for each cluster (Table 8). Depths for septic systems in these areas averaged around 7 feet, with wells approximately 300 feet. Based on this data, septic systems along Cedar Point may be the most vulnerable from groundwater rise due to their location and relatively shallow average depth. Likewise, private wells along Morgan Way may be the most vulnerable from saltwater intrusion because of groundwater rise due to their location and how deep their wells are.

Table 8: Average depths for private septic systems and wells in groundwater rise zone

Cluster	Name	Average Septic Depth	Average Well Depth
1	Cedar Point Road	5 feet	233 feet
2	Watson Road	8 feet	241 feet
3	Morgan Way	6 feet	423 feet
4	Riverview Road & Shearwater Road	7 feet	320 feet
5	Sunnyside Drive neighborhood	7 feet	342 feet
6	Deer Meadow Road, Fox Hill Road, & Mathes Cove Road	7 feet	315 feet
7	Colony Cove Road	9 feet	251 feet
8	Bay Road	7 feet	296 feet
AVG.		**7 feet**	**303 feet**

4.3.1 Actions to Consider

The following are strategies intended to provide guidance to the Town on how to address impacts of groundwater rise on private wells and septic systems.

1. Goal: Educate homeowners within groundwater rise zone on ways to lower risk.
    a. Distribute outreach materials on water conservation measures, water testing, and general septic system maintenance.

2. Goal: Gain a better understanding of the vulnerability of existing private septic systems and wells
    a. Seek assistance from the regional planning commission to obtain location, age, and maintenance records for those private septic systems located within the groundwater rise zone that do not have data.

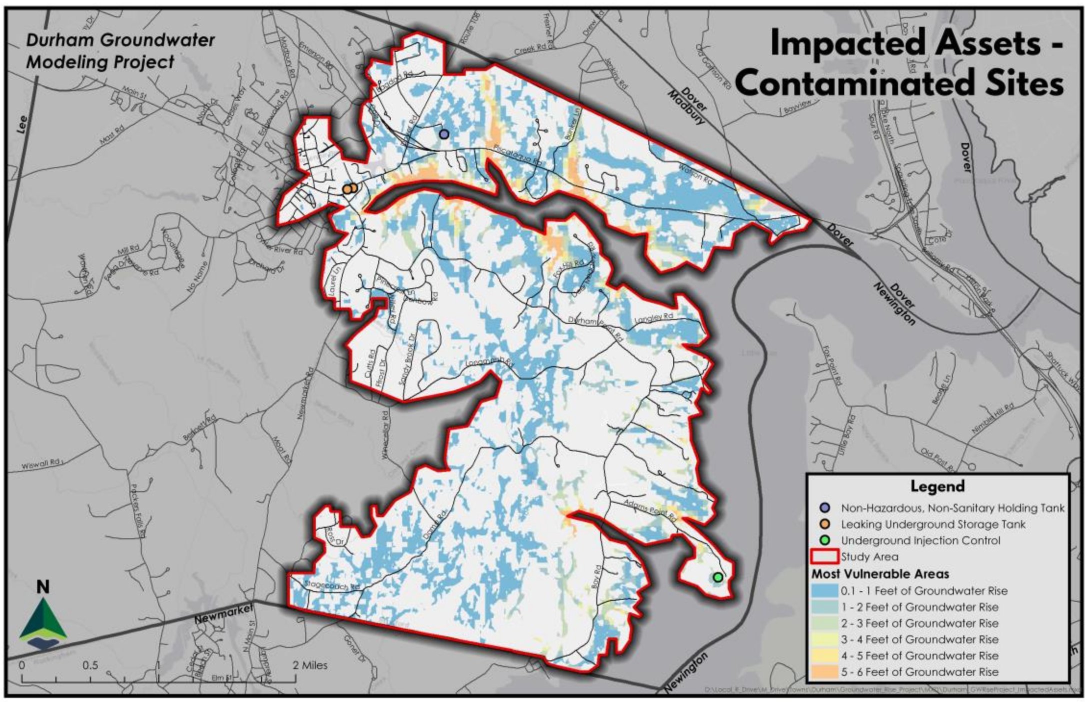
b. Seek assistance from the regional planning commission to obtain depth data for those private wells located within the groundwater rise zone that do not have data.

3. Goal: Improve resilience to groundwater rise for private infrastructure
    a. Investigate opportunities to connect these locations to the municipal wastewater or water system
    b. Explore regulatory options for higher septic system standards in affected areas

4.4 Contaminated Sites

The Contaminated Sites map (Figures 18) shows existing contamination sites that may be vulnerable to future groundwater rise.

Figure 18. Impacted contaminated site



According to the mapping analysis, there are 4 active contaminated sites vulnerable to groundwater rise (Table 9). This includes:

- Two leaking underground storage tanks – one located at the Durham Village Garage and the other at the former Cumberland Farms
- One underground injection control at the Jackson Estuarine Laboratory
- One holding tank at the Durham Public Works Department

Table 9: Impacted contaminated sites

Category	Assets and Resources (*Point Data*)	# of Assets Impacted by Groundwater Rise*
Contaminated Sites	Leaking Underground Storage Tanks	2
	Underground Injection Control	1
	Non-Hazardous, Non-Sanitary Holding Tank	1
*Assuming 6 feet of sea level rise w/ depth to groundwater less than 5 feet		

The Durham Village Garage, located at 8 Dover Road, is the site of a past discharge of petroleum compounds and chlorinated hydrocarbons and thus subject to periodic groundwater monitoring since 2007. According to the most recent monitoring report, released in October 2021, depth to groundwater has ranged between 2.6 feet and 3.9 feet for well MW-2R, 4.4 feet and 11.1 feet for well MW-4DR, and 3.3 feet and 4.6 feet for well MW-8R. The report goes on to state that in October 2017 the site continued to show the presence of volatile organic compounds (VOCs) in the groundwater. No exceedances of Ambient Groundwater Quality Standards (AGQS) were observed during this monitoring round, and chlorinated VOCs, which have historically been site contaminants of concern, were not detected at concentrations above the laboratory reporting limits. Though methyl tert-butyl ether (MtBE) concentrations did not exceed AGQS, the laboratory noted that recoveries for MtBE in quality control samples were low, indicating a potential low bias in sample MtBE concentrations.

The former Cumberland Farms property, located at 3 Dover Road, was considered as abandoned by the Durham Code Administrator and had their underground storage tanks removed in 2005, is the site of a release of petroleum hydrocarbons and thus subject to periodic groundwater monitoring. According to the most recent monitoring report, released in April 2021, depth to groundwater has ranged from 3.4 feet to 8.7 feet over the past several years. The report goes on to state that in October 2017 concentrations of MtBE and tertbutyl alcohol (TBA) were detected above the NHDES AGQS in the groundwater sample collected from monitoring well MW-6.

Jacksons Estuarine Laboratory, located on 85 Adams Point Road, is the site of a Class V well (septic system leach field approved in 1982), which are generally low-tech and depend on gravity to infiltrate water and wastewater. According to NHDES data, the Laboratory has separated its waste streams and no longer disposes of hazardous waste to the septic system but sends the separated hazardous waste to the University of New Hampshire for forwarding to an approved hazardous waste disposal site; however, there was a request for VOC (chloroform, methylene chloride, and toluene) screening, which were previously found in discharges from subject laboratory wastes, of the mixed septic tank effluent.

The Durham Public Works Department received approval from NHDES for their 2,000-gallon holding tank in 1996 when their headquarters moved to their current location on Stone Quarry Drive. The tank is used to collect water from snow melt and washing of vehicles from a trench type floor drain system installed in the vehicle bays of the facility. The concrete tank is roughly 4 feet underground and has two separate compartments. The first contains oil and grit and the second contains water. This tank must continue to meet all current requirements of the state's groundwater protection rules.

As groundwater rises, it saturates the soil, unlocking existing contaminants. Some of these chemicals are highly volatile, and as gases they can easily find their ways through sewer lines and into homes. Responsible parties for these contaminated sites may wish to seek grants through the NHDES Petroleum Remediation Fund Program to conduct future cleanup work.

4.4.1 Actions to Consider

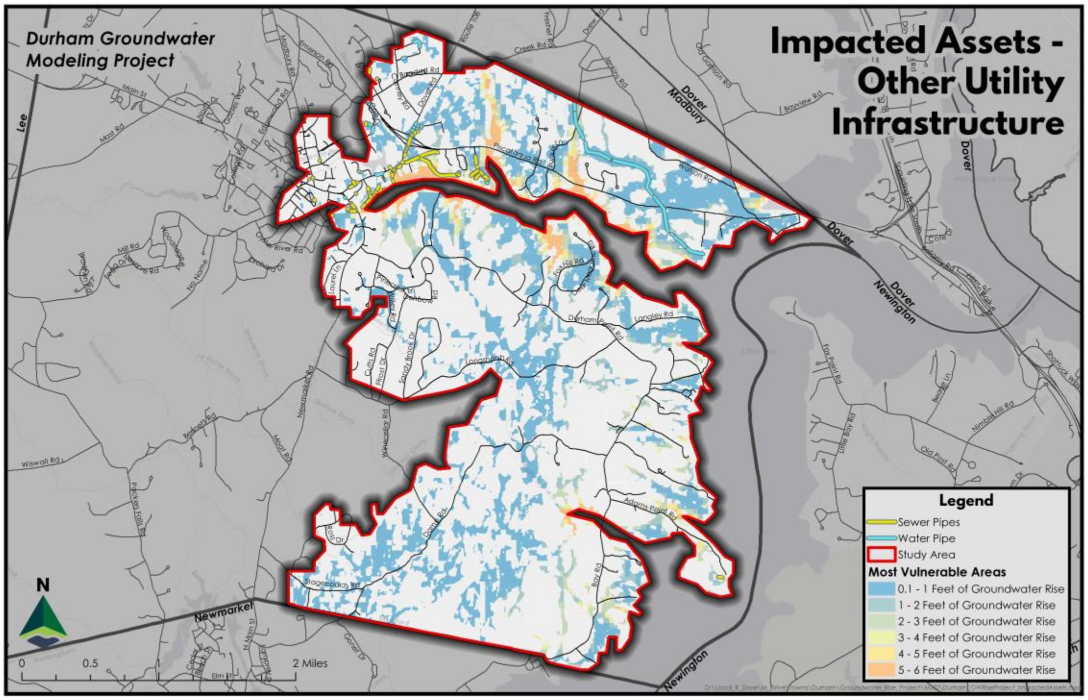
The following are strategies intended to provide guidance to the Town on how to address impacts of groundwater rise on potentially contaminated sites.

1. Goal: Improve resilience to groundwater rise
    a. In addition to the sampling of monitoring wells MW-2R, MW-4DR, MW-8R at the Durham Village Garage site, the Town should consider altering the existing scope of work to determine the potential impacts of transporting hazardous materials from changes to groundwater flow because of groundwater rise.
    b. In addition to the biannual sampling of monitoring wells MW-1, MW-2, MW-3 and MW-6 at the former Cumberland Farms site, the Town should consider altering the existing scope of work to determine the potential impacts of transporting hazardous materials from changes to groundwater flow because of groundwater rise.
    c. Investigate if either of the leaking underground storage tank sites are exceeding soil remediation standards to determine if state funding could be obtained for excavation.
    d. Partner with property owners or responsible parties to apply for funding through the Petroleum Remediation Fund Program to reimburse remediation work.
    e. The Town should partner with UNH to advocate whether the septic system at Jacksons Laboratory be evaluated for potential risk to groundwater rise.
    f. The Public Works Department should investigate that their existing tank is watertight and that all sealers used are adequate to handle potential impacts from groundwater rise to ensure any waste, including but not limited to oil, grease, silt, antifreeze, detergents, and any other automotive fluids do not seep out of the tank.

4.5 Utility Infrastructure

The Utility Infrastructure map (Figures 19) shows where there is existing utility information that may be vulnerable to future groundwater rise.

Figure 19. Impacted utility infrastructure



According to the mapping analysis, there are roughly 2.2 miles of sewer pipes and 3.3 miles of water pipes vulnerable to groundwater rise (Table 10). These areas are predominately found in locations where sewer lines are leading to/from the wastewater treatment plant, along Old Piscataqua Road, portions of Route 108, and the Old Landing Road neighborhood. There is also a lengthy section of water line north of the Oyster River that belongs to the City of Portsmouth that conveys water from the Bellamy Reservoir in Madbury to a booster pump station across the bay in Newington.

While it is somewhat unclear as to the impact of groundwater rise, groundwater inundation, if located at a low elevation, could seep into pipes and increase treatment volume, and corrosion of treatment plant equipment. Groundwater intrusion could also possibly harm the treatment bacteria. This is an area that may need additional exploration.

Unitil does provide for natural gas service in Durham; however, that infrastructure was not obtained for this assessment. Studies in Massachusetts have shown that cast iron pipes that make up roughly a third of the National Grid's infrastructure in Massachusetts are prone to rust and corrosion. In coastal areas, there have been some cases where pipes, which once were located above the water table, are now finding themselves sporadically under water during seasonal high tide events. During these events, groundwater may seep into gas mains and cause damage and interruptions in service. This is also an area that may need additional exploration.

Table 10: Impacted utility infrastructure

Category	Assets and Resources (*Line Data*)	Length of Assets Impacted by Groundwater Rise*
Utility Infrastructure	Sewer Pipes	2.2 miles
	Water Pipes	3.3 miles
*Assuming 6 feet of sea level rise w/ depth to groundwater less than 5 feet		

4.5.1 Actions to Consider

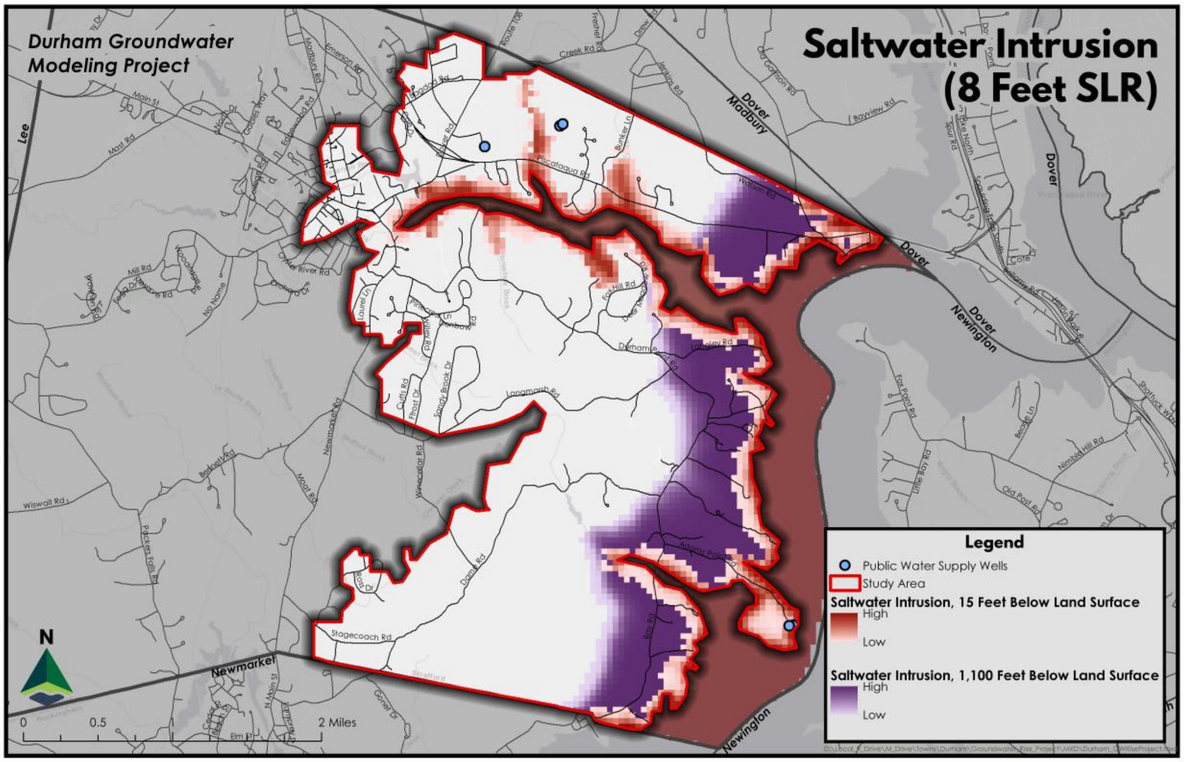
The following are strategies intended to provide guidance to the Town on how to address impacts of groundwater rise on water and sewer infrastructure.

1. Goal: Gain a better understanding of the vulnerability of existing identified utility infrastructure
    a. Obtain additional data for existing utility infrastructure by applying for a Clean Water State Revolving Fund (CWSRF) wastewater loan to complete an Asset Management Program (AMP). The Town may wish to apply for both a stormwater and wastewater AMP loan at the same time.
        i. In addition, there are funds through the CWSRF Drinking Water Grant Program that could be used to further investigate the Town's drinking water infrastructure (for both groundwater rise and saltwater intrusion). An Asset Management Guidance Document with more information on the CWSRF Drinking Water Grant can be used prior to applying.
    b. Ensure that the City of Portsmouth is aware of this report and its findings on the potential vulnerability of their water line from Madbury to the booster pump station.
    c. Partner with Unitil to determine what, if any, vulnerabilities exist with the Town's gas lines.

4.6 Public Water Supplies

An increase in saltwater intrusion caused by sea level rise does not appear to be a concern under current pumping conditions; however, it may become problematic at the Durham Public Works or Johnson Creek water supplies if pumping rates are increased. While not used as a Town water supply, the wells located at the Jackson Laboratory have had some salinity issues in the past and may be susceptible to saltwater intrusion due to their proximity to the estuary. Saltwater intrusion could be a concern in the stratified drift aquifer beneath Cedar Point in northeastern Durham if it is developed as a public water source.

Figure 20. Impacted public water supply wells



4.6.1 Actions to Consider

The following are strategies intended to provide guidance to the Town on how to reduce saltwater intrusion in any existing and future public water supplies.

1. Goal: Protect existing public water supplies.
    a. To the extent practicable, avoid increasing water withdrawals and monitor pumping rates at the Durham Public Works and Johnson Creek public water supply wells.
    b. Determine if the existing wellhead protection areas around both the Durham Public Works and Johnson Creek public water supply wells are providing adequate recharge.
    c. Purchase salinity monitoring devices for Durham Public Works and Johnson Creek public water supply wells to ensure that secondary levels of chloride concentrations (250 mg/L) meet Federal Safe Drinking Water program standards.
    d. Ensure that UNH is aware of this report and its findings on the potential vulnerability of the Jackson Estuarine Laboratory public water supply well.

5.0 Goals and Recommendations

In summary, groundwater is projected to rise in Durham, with sea level rise projected to occur in the Oyster River, Little Bay, and Great Bay estuaries. The groundwater rise signal is predicted to extend up to 1.5 miles inland from the coastline under the 8 feet of sea level rise scenario and has the potential to weaken or damage roads, underground infrastructure (i.e., utilities such as gas lines and water/sewer pipes; pump stations; and other stormwater infrastructure), municipal critical facilities, and on-site septic systems in areas where groundwater is already shallow. This may result in increased maintenance and repair costs and water-quality concerns. Several properties with known contaminated sites may also be impacted by groundwater rise, resulting in water quality impairments to other areas if shifts in the groundwater table alter existing groundwater flow patterns. An increase in saltwater intrusion to public water supplies does not appear to be a concern under current pumping conditions; however, it may become problematic at the Durham Public Works or Johnson Creek water supplies if pumping rates are increased at these locations. Regardless, drinking water wells both public and domestic drilled deep into bedrock near the coast are more vulnerable to saltwater contamination than shallower wells, especially those located in the stratified drift aquifer beneath Cedar Point in northeastern Durham and those along Durham Point Road.

Table 11: Implementation matrix

Action	Category	Responsibility	Timeframe
Goal: Gain a better understanding of the vulnerability of existing identified stormwater assets			
Obtain additional data for existing stormwater infrastructure by applying for a Clean Water State Revolving Fund (CWSRF) stormwater loan to complete an Asset Management Program (AMP) to obtain specific information on vulnerable stormwater assets, including depth data and infrastructure condition, which will assist with managing several requirements of the NH MS4 permit. The CWSRF Asset Management Loan Forgiveness Guidance Document is a useful resource to reference prior to applying. The Town could apply for additional funds through an application of a CWSRF planning loan to fill in data gaps; however, utilizing the AMP may be a more suitable option and should be completed as a first step for infrastructure inventory, condition, and location.	Stormwater Infrastructure	Town Council, Town Administrator, and Public Works Department	Short (1-2 years)
Goal: Create a more resilient stormwater system			
In vulnerable areas, ensure that any stormwater BMPs and/or retrofit provides adequate infiltration from mobilizing contaminants and used to maximize groundwater recharge.	Stormwater Infrastructure	Public Works Department	Medium (2-5 years)
Consider including the impacts from groundwater rise when updating the Town's infiltration and inflow (I&I) maintenance and survey practices.	Stormwater Infrastructure	Public Works Department	Short (1-2 years)

Table 11: Implementation matrix

Action	Category	Responsibility	Timeframe
Review drainage manuals from places that are currently planning for groundwater rise (e.g., Florida-Dade County) for suggestions on more resilient stormwater construction materials and innovative retrofit techniques. This may include things like installing concrete coated asphalt storm drains, slip-lining, and anti-seep collars.	Stormwater Infrastructure	Public Works Department	Medium (2-5 years)
Require that any stormwater project (including new construction, reconstruction, and projects rebuilding stormwater drainage systems) within the groundwater rise zone refer to the Coastal Flood Risk Guidance to assess impacts to design.	Stormwater Infrastructure	Planning Department	Medium (2-5 years)
Investigate if there is a need to retrofit or transition to a closed pipe system in existing low-lying areas within the groundwater rise zone.	Stormwater Infrastructure	Public Works Department	Medium (2-5 years)
Goal: Gain a better understanding of the vulnerability of existing identified critical facilities			
Seek assistance from the regional planning commission to obtain additional information on the 13 critical facilities identified, including depth data and infrastructure condition.	Critical Facilities	Town Council and Town Administrator	Short (1-2 years)
Goal: Protect existing and future roadways from groundwater rise impacts			
Consult existing resources and studies, such as "A Framework for Introducing Climate-Change Adaptation in Pavement Management" when planning for the construction of new roads or upgrades to existing roads in the most vulnerable areas within the groundwater rise zone to determine the most appropriate approach for implementing a climate-ready flexible pavement design. This may include using the NHDOT design methodology, but with an additional amount of asphalt pavement to provide the same structural capacity as currently exist and minimizing additional operations and maintenance costs due to accelerated damage from groundwater rise.	Critical Facilities	Public Works Department	Medium (2-5 years)
Goal: Educate homeowners within groundwater rise zone on ways to lower risk			
Distribute outreach materials on water conservation measures, water testing, and general septic system maintenance	Private Infrastructure	Conservation Commission	Short (1-2 years)
Goal: Gain a better understanding of the vulnerability of existing private septic systems and wells			
Seek assistance from the regional planning commission to obtain location, age, and maintenance records for those private septic systems located within the groundwater rise zone that do not have data.	Private Infrastructure	Planning Department	Short (1-2 years)
Seek assistance from the regional planning commission to obtain depth data for those private wells located within the groundwater rise zone that do not have data.	Private Infrastructure	Planning Department	Short (1-2 years)
Goal: Improve resilience to groundwater rise for private infrastructure			
Investigate opportunities to connect these locations to the municipal wastewater or water system	Private Infrastructure	Public Works Department	Long (5-10 years)
Explore regulatory options for higher septic system standards in affected areas	Private Infrastructure	Planning Department	Medium (2-5 years)

Table 11: Implementation matrix

Action	Category	Responsibility	Timeframe
Goal: Improve resilience to groundwater rise			
In addition to the sampling of monitoring wells MW-2R, MW-4DR, MW-8R at the Durham Village Garage site, the Town should consider altering the existing scope of work to determine the potential impacts of transporting hazardous materials from changes to groundwater flow because of groundwater rise.	Contaminated Sites	Town Council and Town Administrator	Medium (2-5 years)
In addition to the biannual sampling of monitoring wells MW-1, MW-2, MW-3 and MW-6 at the former Cumberland Farms site, the Town should consider altering the existing scope of work to determine the potential impacts of transporting hazardous materials from changes to groundwater flow because of groundwater rise.	Contaminated Sites	Town Council and Town Administrator	Medium (2-5 years)
Investigate if either of the leaking underground storage tank sites are exceeding soil remediation standards to determine if state funding could be obtained for excavation.	Contaminated Sites	Town Council and Town Administrator	Medium (2-5 years)
Partner with property owners or responsible parties to apply for funding through the Petroleum Remediation Fund Program to reimburse remediation work.	Contaminated Sites	Planning Department	Long (5-10 years)
The Town should partner with UNH to advocate whether the septic system at Jacksons Laboratory be evaluated for potential risk to groundwater rise.	Contaminated Sites	Planning Department	Medium (2-5 years)
The Public Works Department should investigate that their existing tank is watertight and that all sealers used are adequate to handle potential impacts from groundwater rise to ensure any waste, including but not limited to oil, grease, silt, antifreeze, detergents, and any other automotive fluids do not seep out of the tank.	Contaminated Sites	Public Works Department	Medium (2-5 years)
Goal: Gain a better understanding of the vulnerability of existing identified utility infrastructure			
Obtain additional data for existing utility infrastructure by applying for a Clean Water State Revolving Fund (CWSRF) wastewater loan to complete an Asset Management Program (AMP). The Town may wish to apply for both a stormwater and wastewater AMP loan at the same time. In addition, there are funds through the CWSRF Drinking Water Grant Program that could be used to further investigate the Town's drinking water infrastructure. An Asset Management Guidance Document with more information on the CWSRF Drinking Water Grant can be used prior to applying.	Utility Infrastructure	Town Council and Town Administrator	Short (1-2 years)
Ensure that the City of Portsmouth is aware of this report and its findings on the potential vulnerability of their water line from Madbury to the booster pump station	Utility Infrastructure	Public Works Department	Short (1-2 years)
Partner with Unitil to determine what, if any, vulnerabilities exist with the Town's gas lines.	Utility Infrastructure	Public Works Department	Medium (2-5 years)
Goal: Protect existing public water supplies			
To the extent practicable, avoid increasing water withdrawals and monitor pumping rates at the Durham Public Works and Johnson Creek public water supply wells.	Public Water Supplies	Public Works Department	Long (5-10 years)
Determine if the existing wellhead protection areas around both the Durham Public Works and Johnson Creek public water supply wells are providing adequate recharge.	Public Water Supplies	Public Works Department	Long (5-10 years)

Table 11: Implementation matrix

Action	Category	Responsibility	Timeframe
Purchase salinity monitoring devices for Durham Public Works and Johnson Creek public water supply wells to ensure that secondary levels of chloride concentrations (250 mg/L) meet Federal Safe Drinking Water program standards.	Public Water Supplies	Town Council and Town Administrator	Medium (2-5 years)
Ensure that UNH is aware of this report and its findings on the potential vulnerability of the Jackson Estuarine Laboratory public water supply well.	Public Water Supplies	Planning Department	Short (1-2 years)

6.0 Potential Funding Sources

The Town may wish to consider the following funding sources to build upon this study.

Critical Flood Risk Infrastructure Grant Program

The Critical Flood Risk Infrastructure Grant Program, administered through the NHDES Watershed Management Bureau, intends to support flood resilience and stormwater management planning and assessment work, as well as implementation projects in New Hampshire's coastal watershed. This grant program will utilize ARPA funds to award approximately $4.5 million in grants (no match required) in 2022.

Eligible applicants include New Hampshire municipalities, quasi-governmental organizations (e.g., regional planning commissions, county conservations districts, etc.), non-governmental organizations, and academic institutions. Projects must take place within one or more of the 42 New Hampshire communities located within New Hampshire's coastal watershed.

Clean Water State Revolving Fund

The Clean Water State Revolving Fund (CWSRF) provides low-cost financial assistance for planning, design, and construction projects to communities, nonprofits, and other local government entities for both wastewater infrastructure projects (collection systems, pumping stations, and wastewater treatment) and other water pollution control projects (nonpoint source, watershed protection or restoration, and estuary management).

This funding could be used to conduct asset management plans for stormwater, drinking water, and wastewater. In addition, there are also planning loans available.