As Sea Level Rises Groundwater Does Too – What is at Risk when Groundwater Rises?

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Department of Civil and Environmental Engineering

Hosted by NH Coastal Adaptation Workgroup (NH CAW)

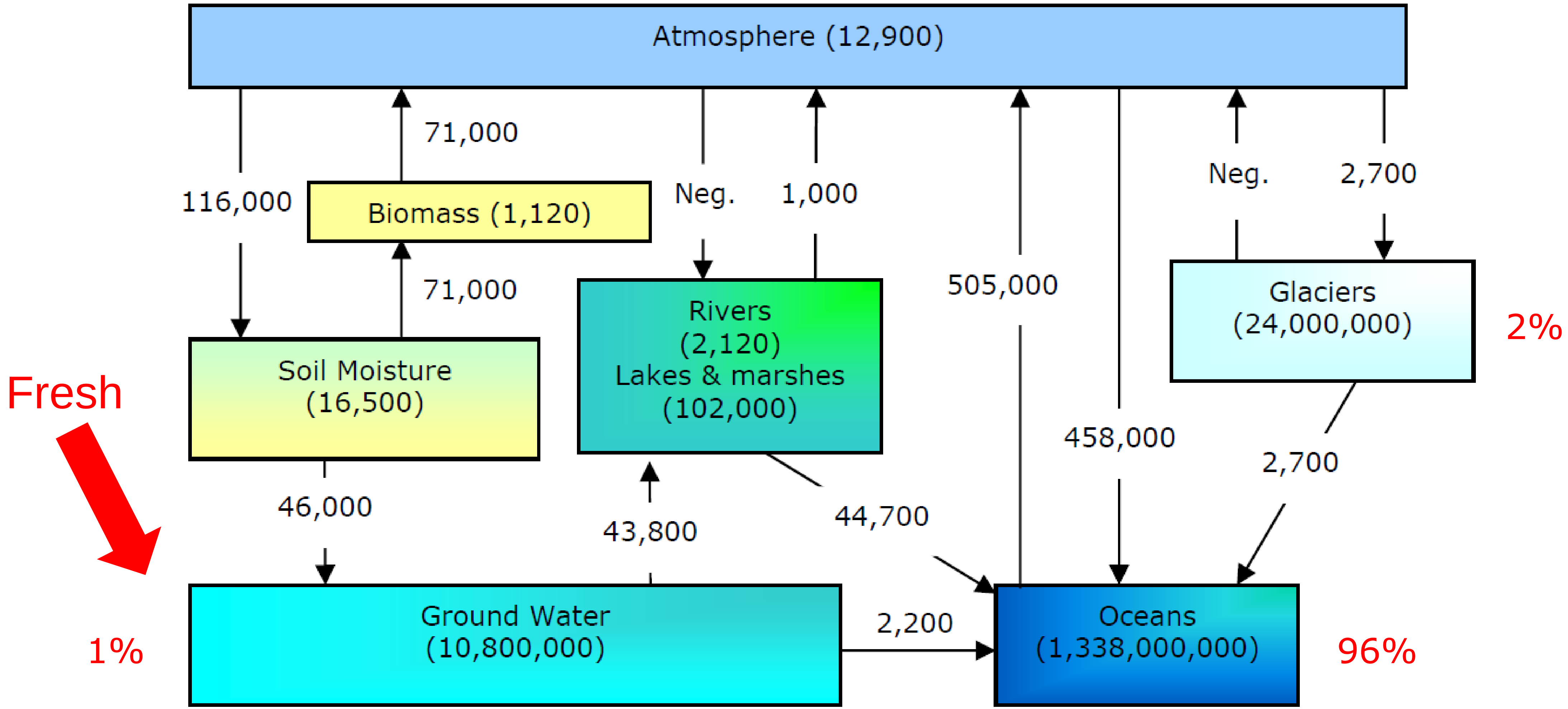
April 26, 2018

Outline

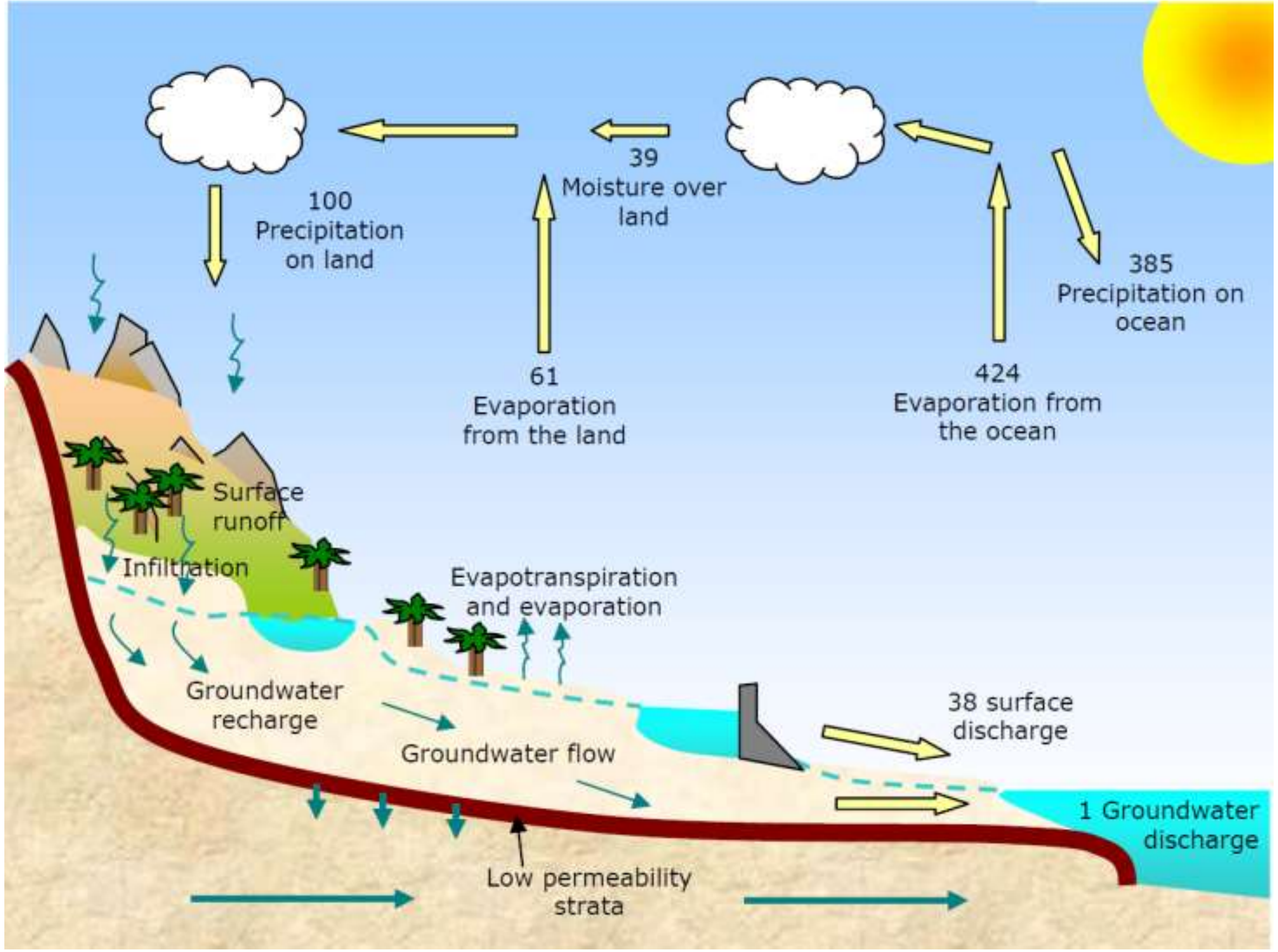
- Introduction - Groundwater
- Sea level rise (SLR) and coastal groundwater
- SLR in coastal New Hampshire (NH)
- Simulated SLR-induced groundwater rise
- Potential impacts of groundwater rise
- What can we do?

Introduction - Groundwater

Water Volumes (km^3)



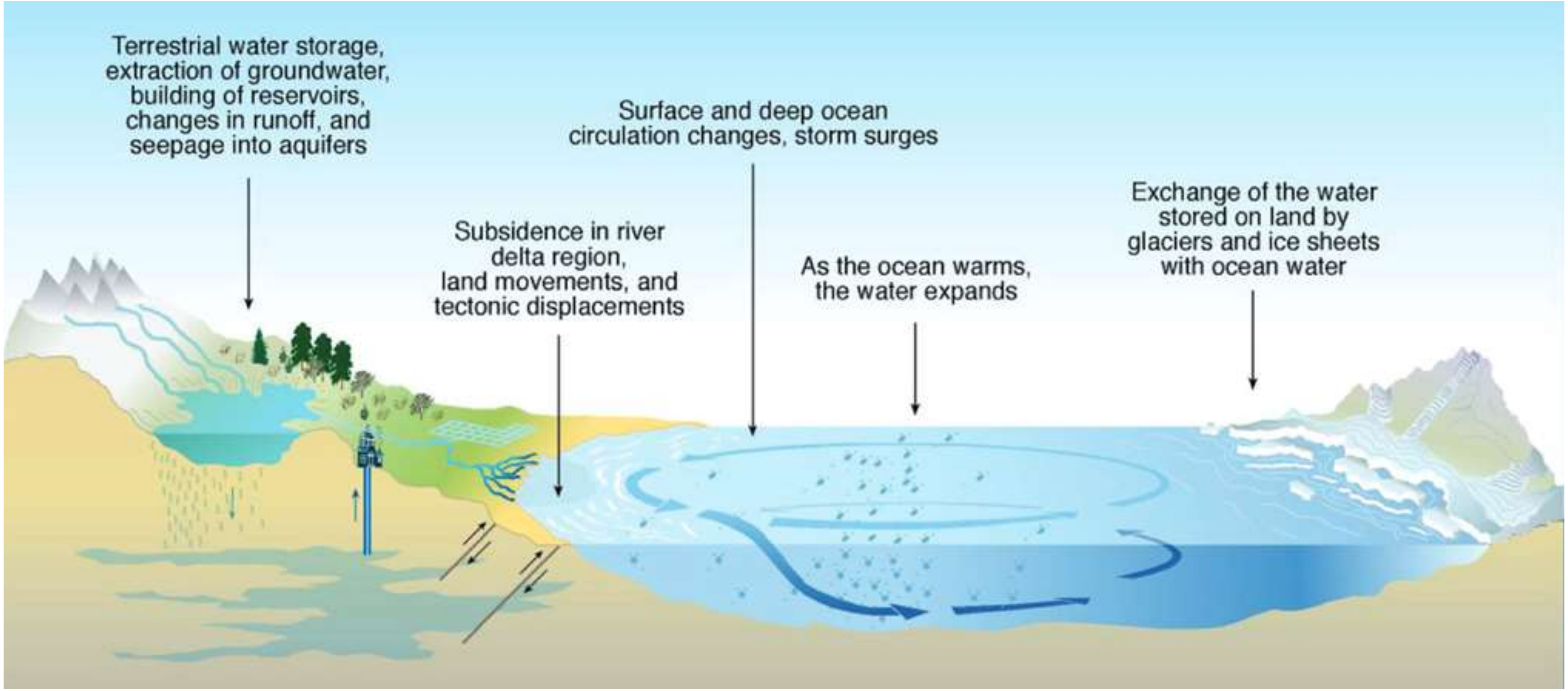
Hydrologic Cycle with Annual Volumes (thousand km³/year)



Charles Harvey, *CEE-1.72 Groundwater Hydrology, Fall 2005*. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed April 2, 2018). License: Creative Commons BY-NC-SA

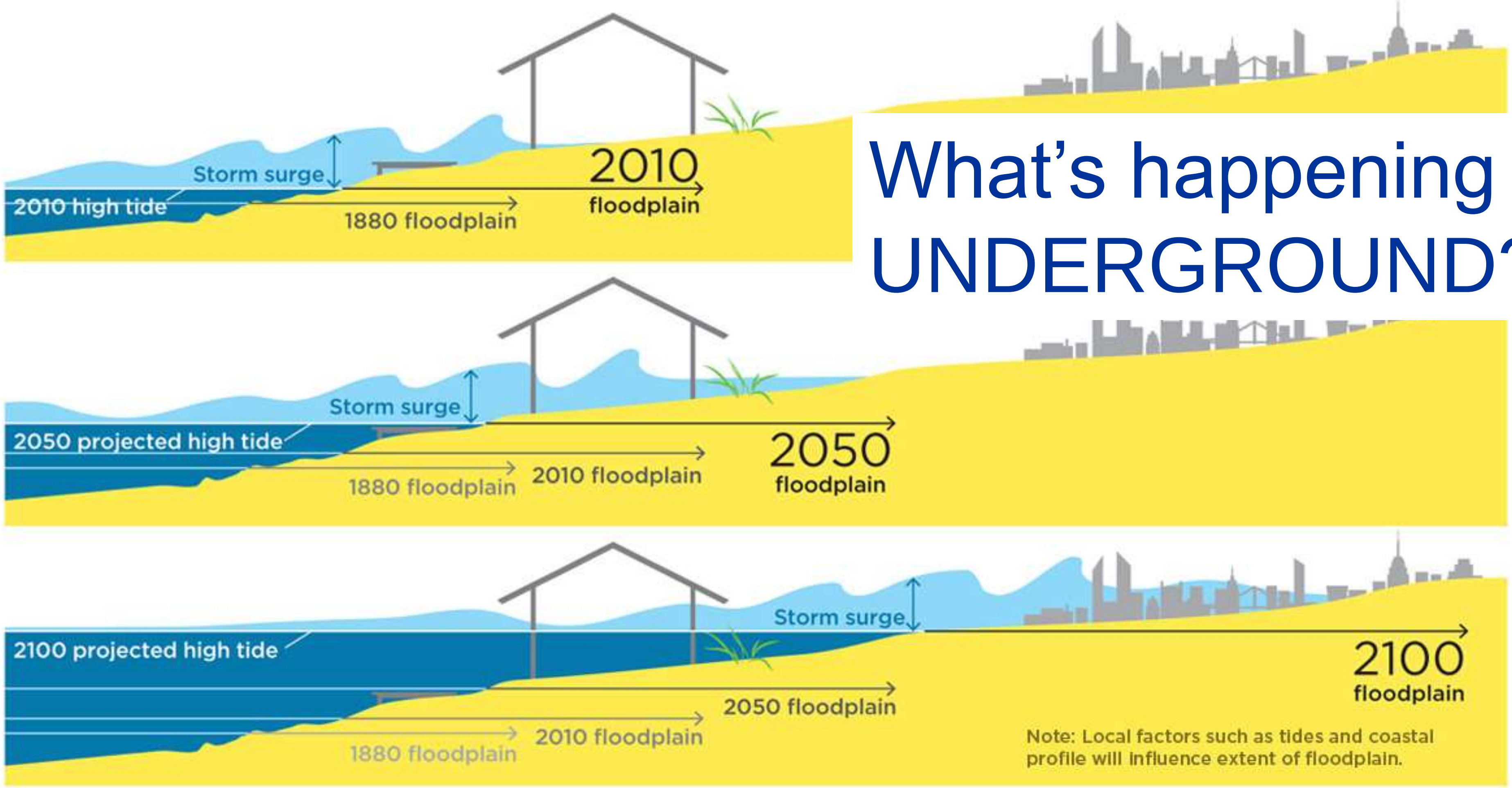
Sea level rise and coastal groundwater

Sea level is rising



Griggs, David. Climate Change 2001, Synthesis report, Contribution of working groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2001

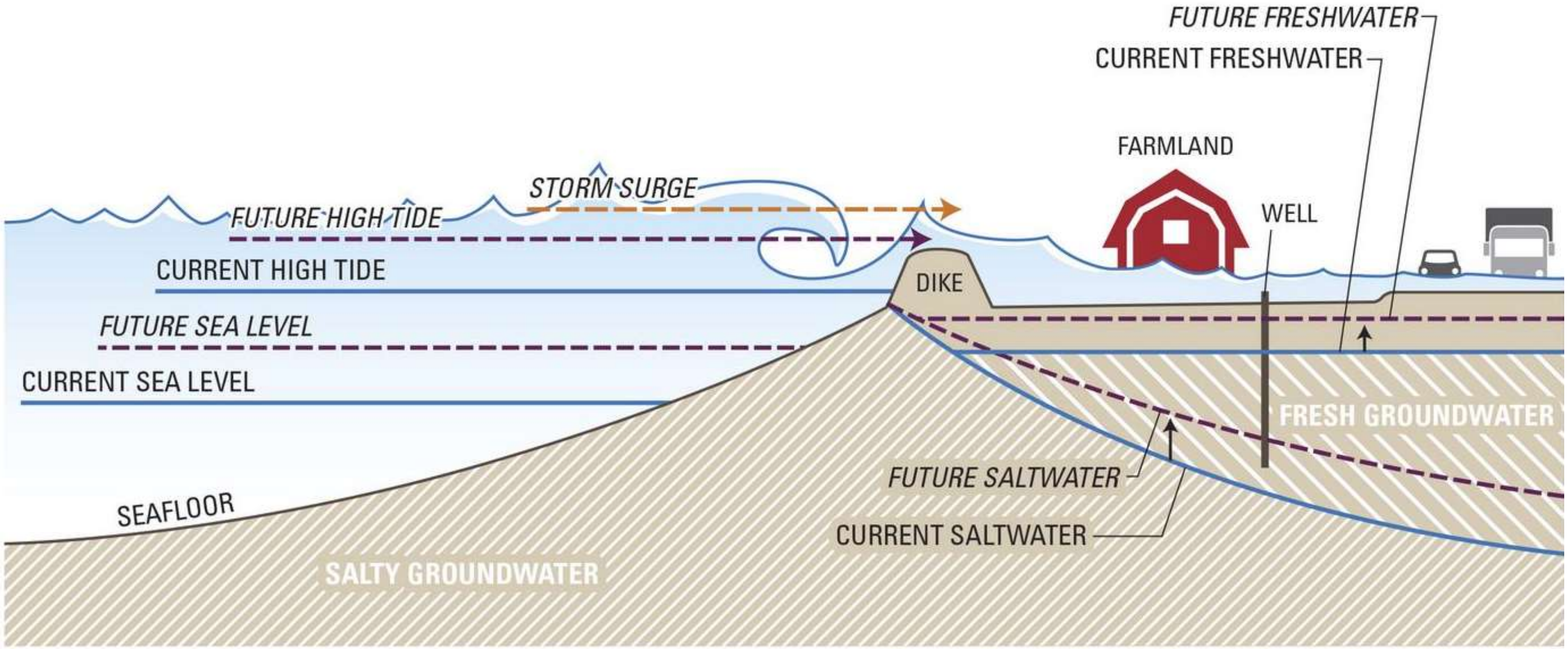
Surface water impacts of sea level rise



What's happening UNDERGROUND?

Union of Concerned Scientists, 2015; www.ucsusa.org/sealevelrisescience

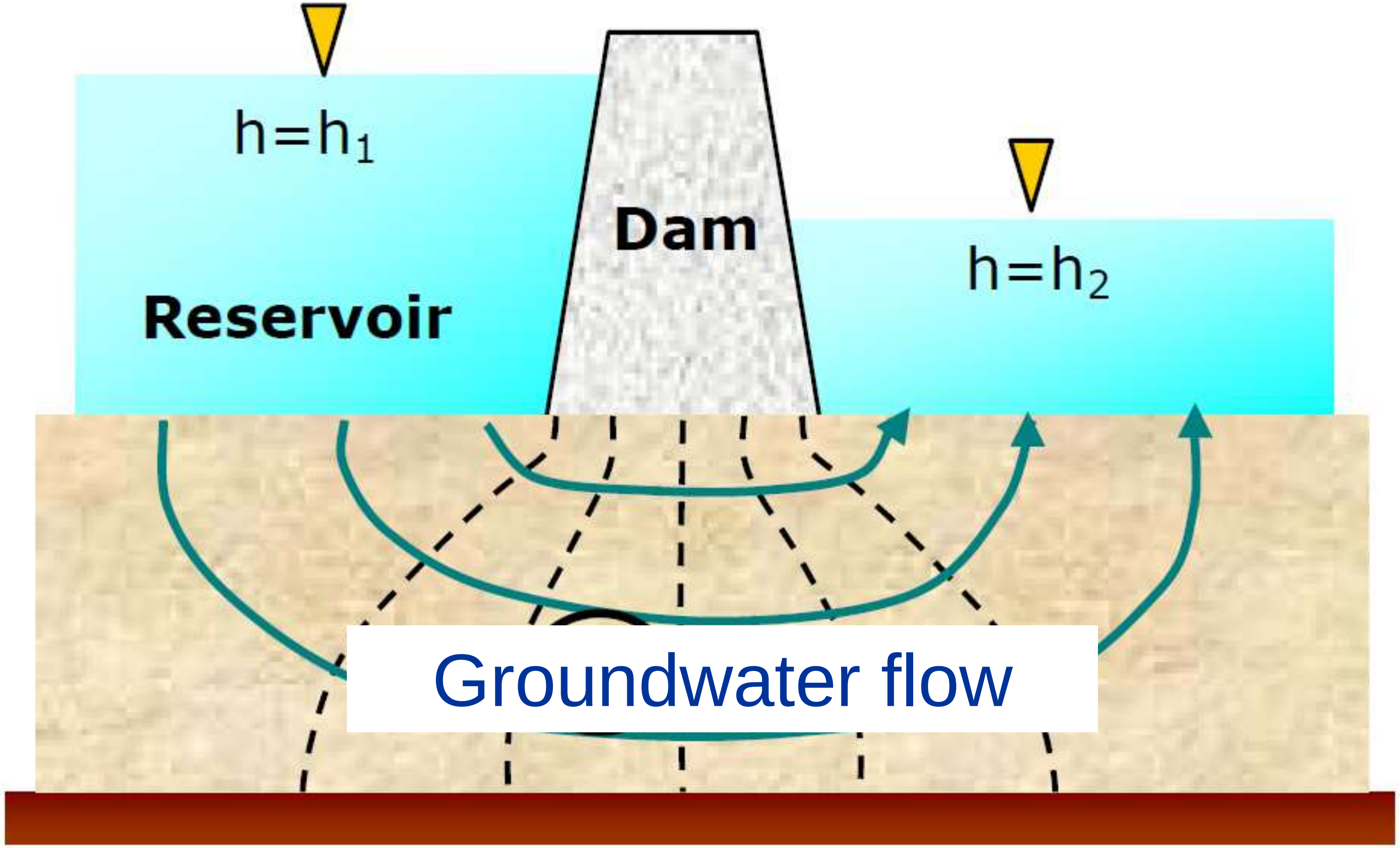
A more complete picture



NOTE: Sea, tide, and storm surge levels, depth of groundwater, and location of saltwater lens are for illustrative purposes only and do not depict actual or projected levels.

http://www.skagitclimatescience.org/skagit-impacts/sea-level-rise/
Seattle, Washington

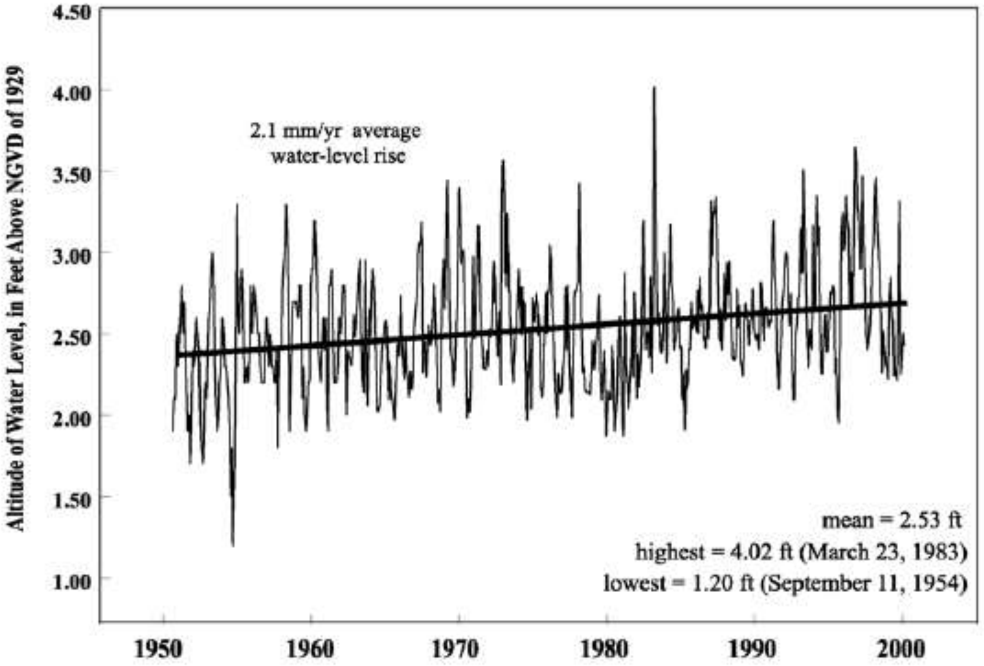
Can a sea wall really keep the water out?

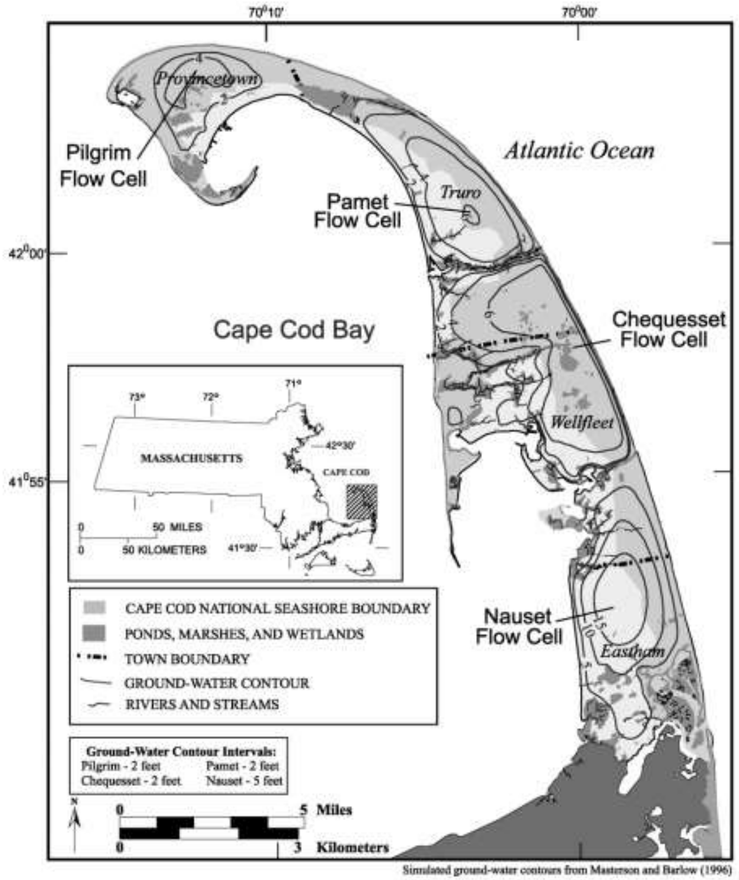


Charles Harvey, *CEE-1.72 Groundwater Hydrology, Fall 2005*. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed April 2, 2018). License: Creative Commons BY-NC-SA

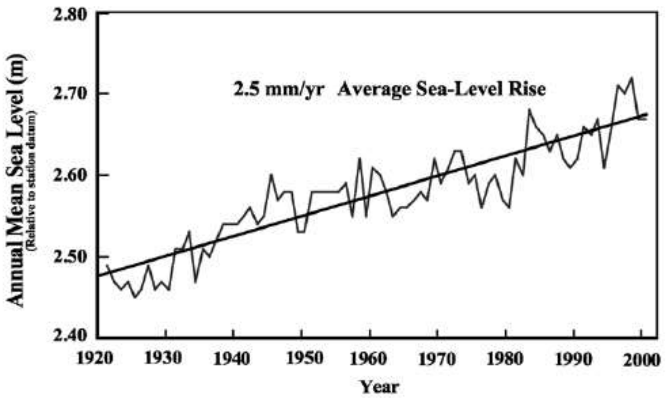
Has Groundwater Rise been Recorded? Yes - Cape Cod

2.1 mm/yr. average GW rise in a well 300 m from coast in Truro, Cape Cod



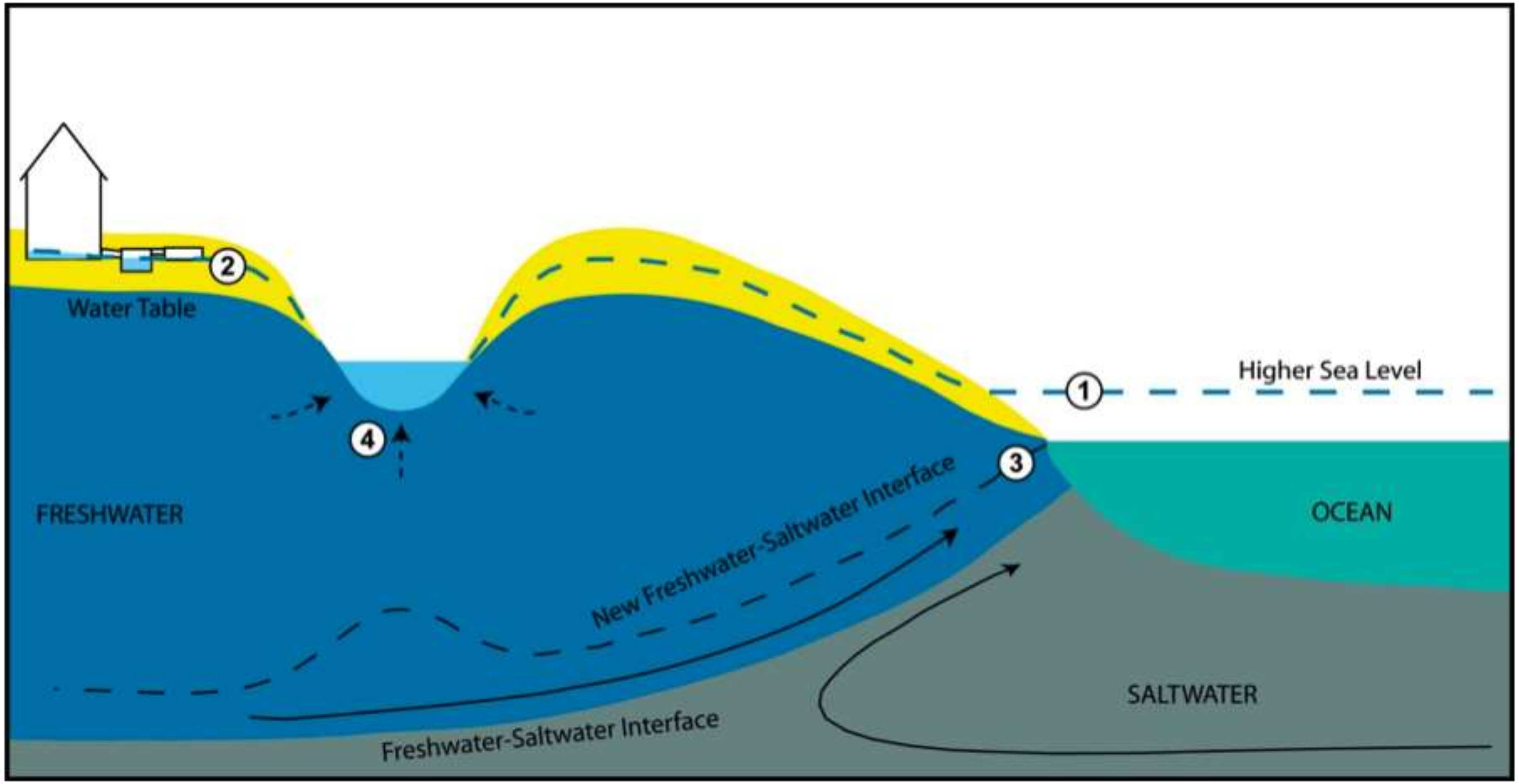


2.5 mm/yr. average sea-level rise at the Boston tide gage.



McCobb and Weiskel (2003)

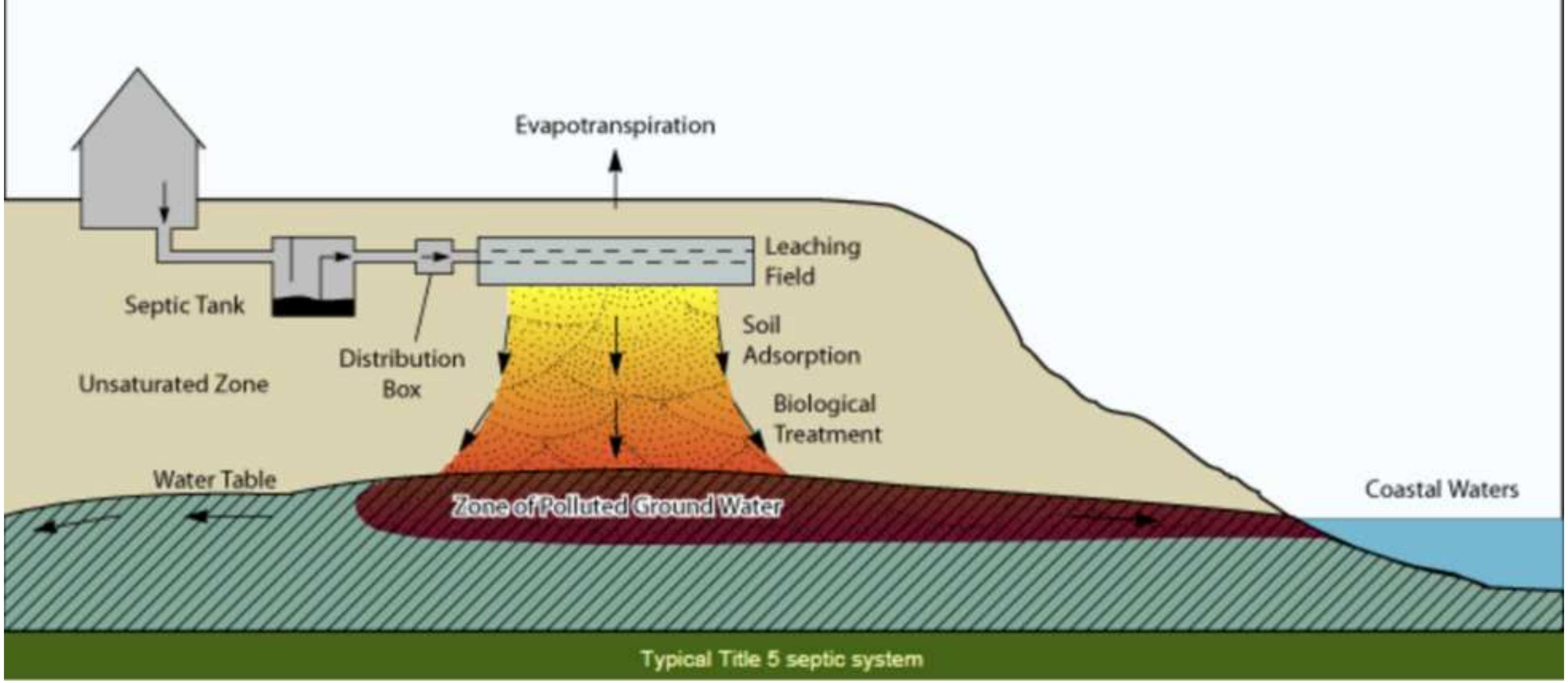
Groundwater will rise with sea level rise – Why do we care?



Source: U.S. Geological Survey

Groundwater contamination from septic tanks

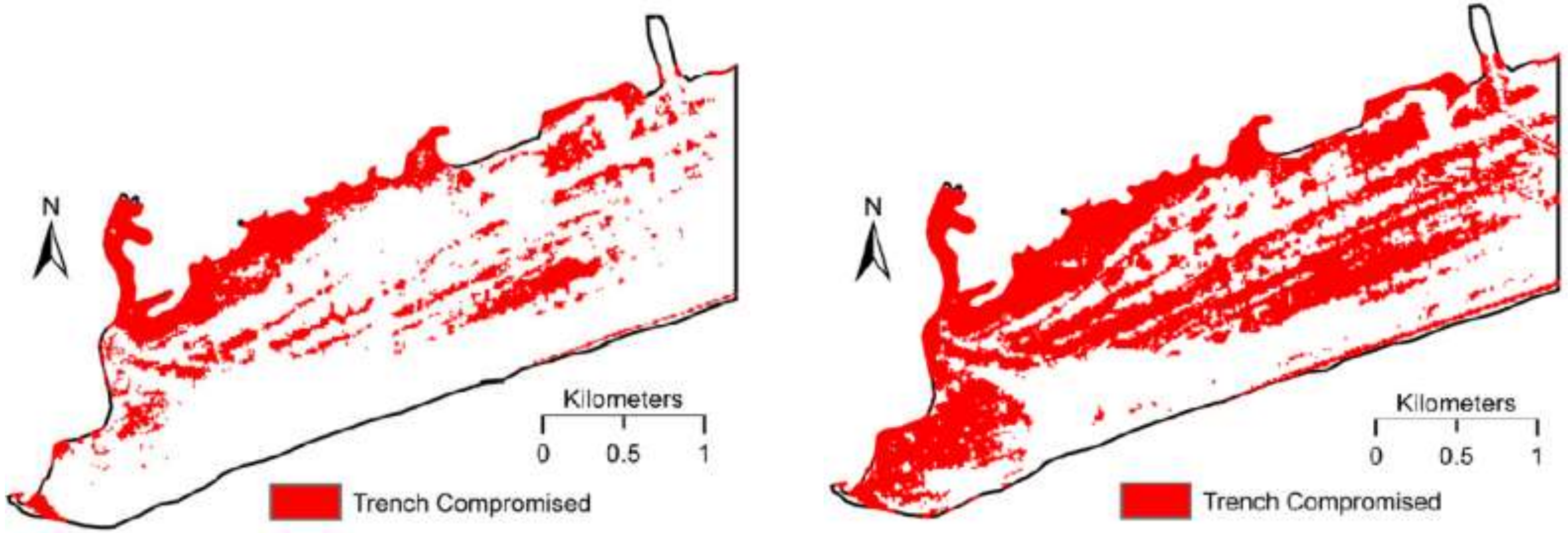
Vertical separation between the bottom of leaching field and groundwater decreases – total treatment decreases because there is less vertical passage.



Source: https://www.mass.gov/service-details/smart-growth-smart-energy-toolkit-modules-wastewater-alternatives

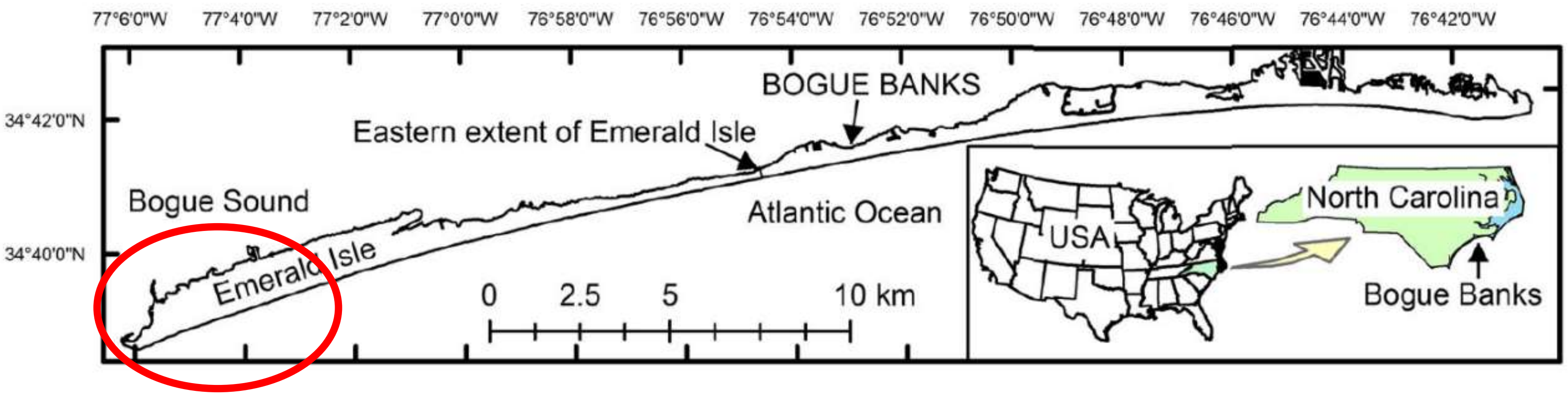
Groundwater rise and septic systems: North Carolina

Current seasonal high water table



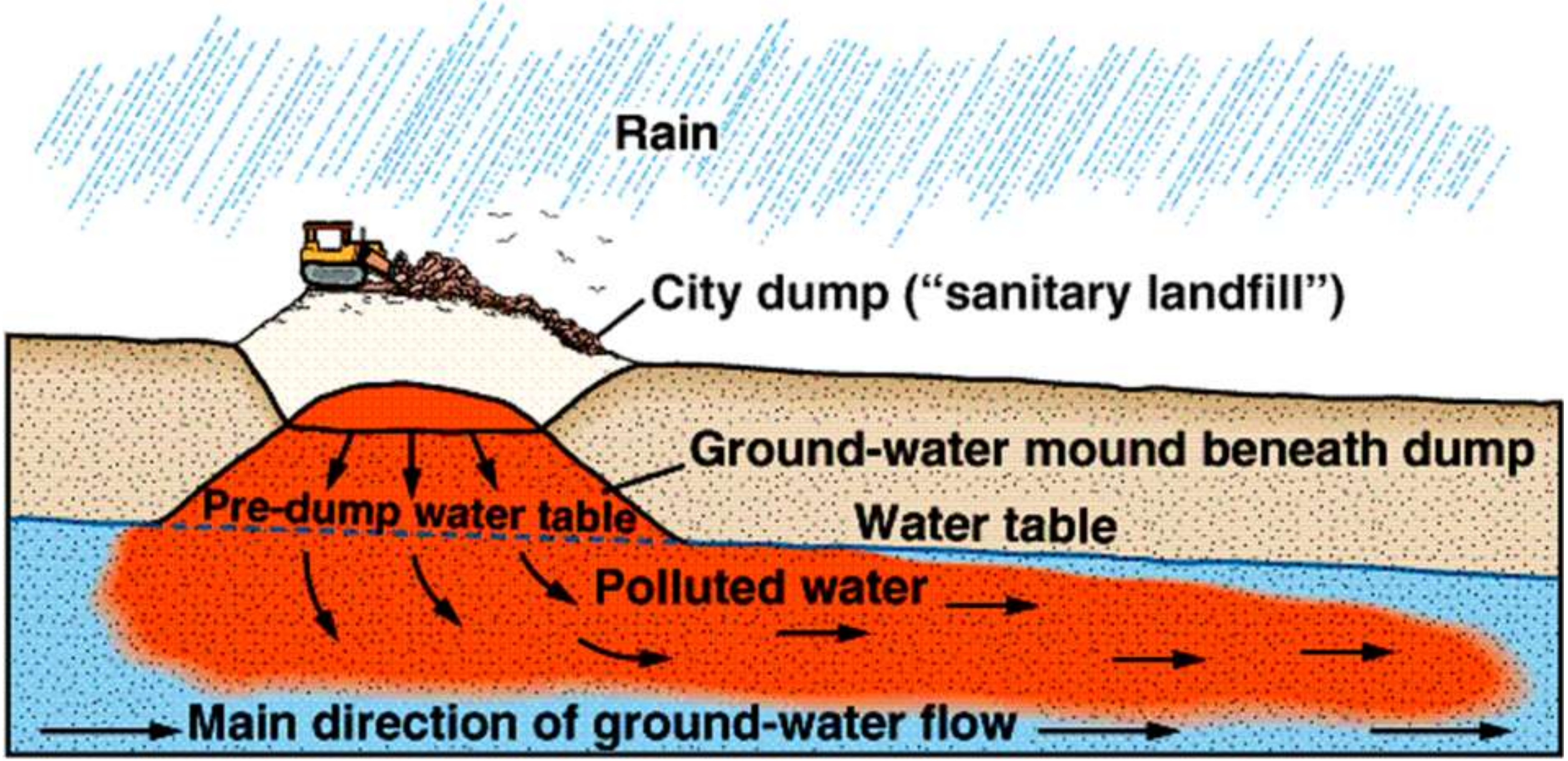
Seasonal high water table with 1.0 m SLR

RED - Simulated GW is above the leaching field trench



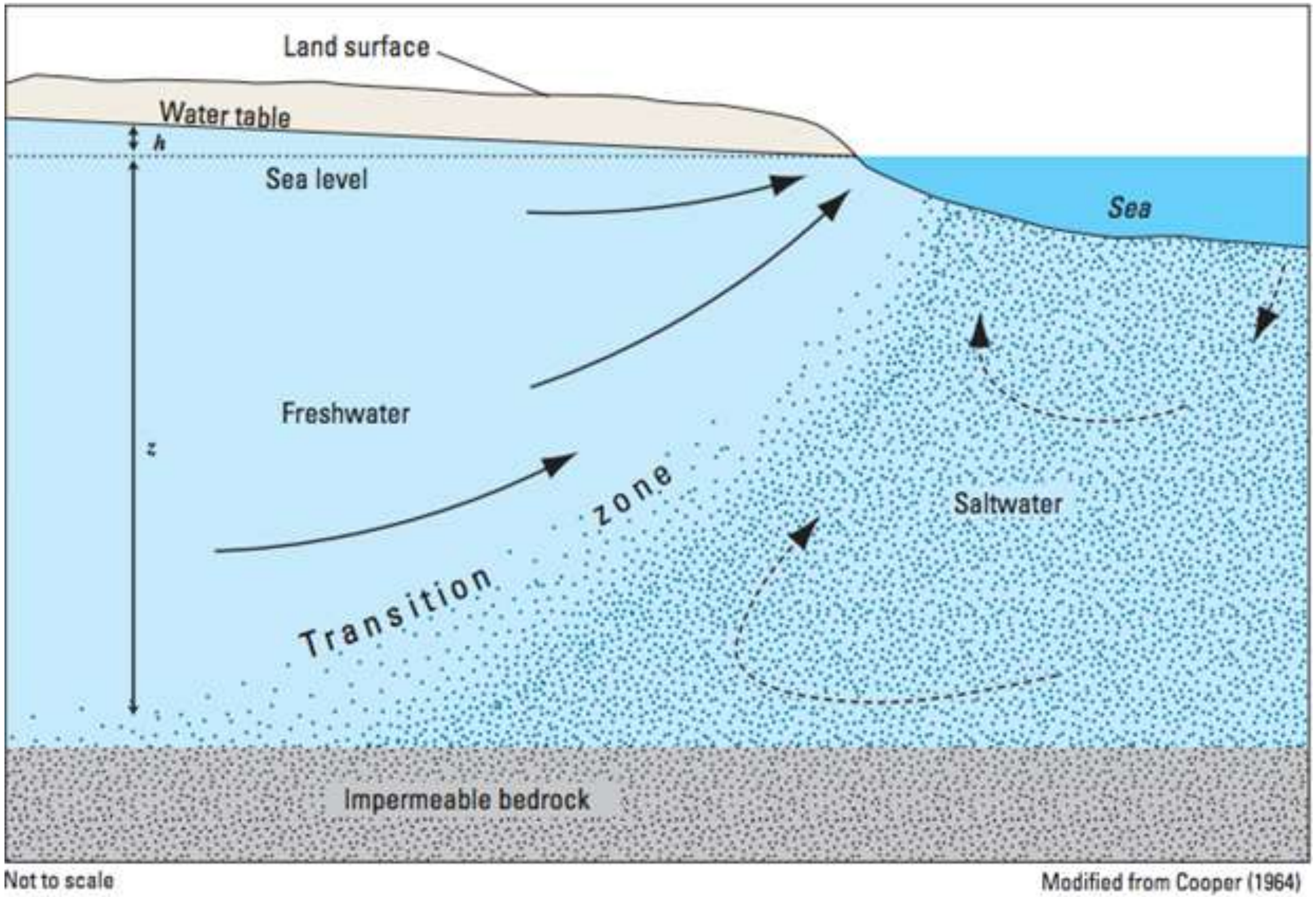
Source: Manda et al. (2015)

Rising groundwater can mobilize contamination from disposal sites



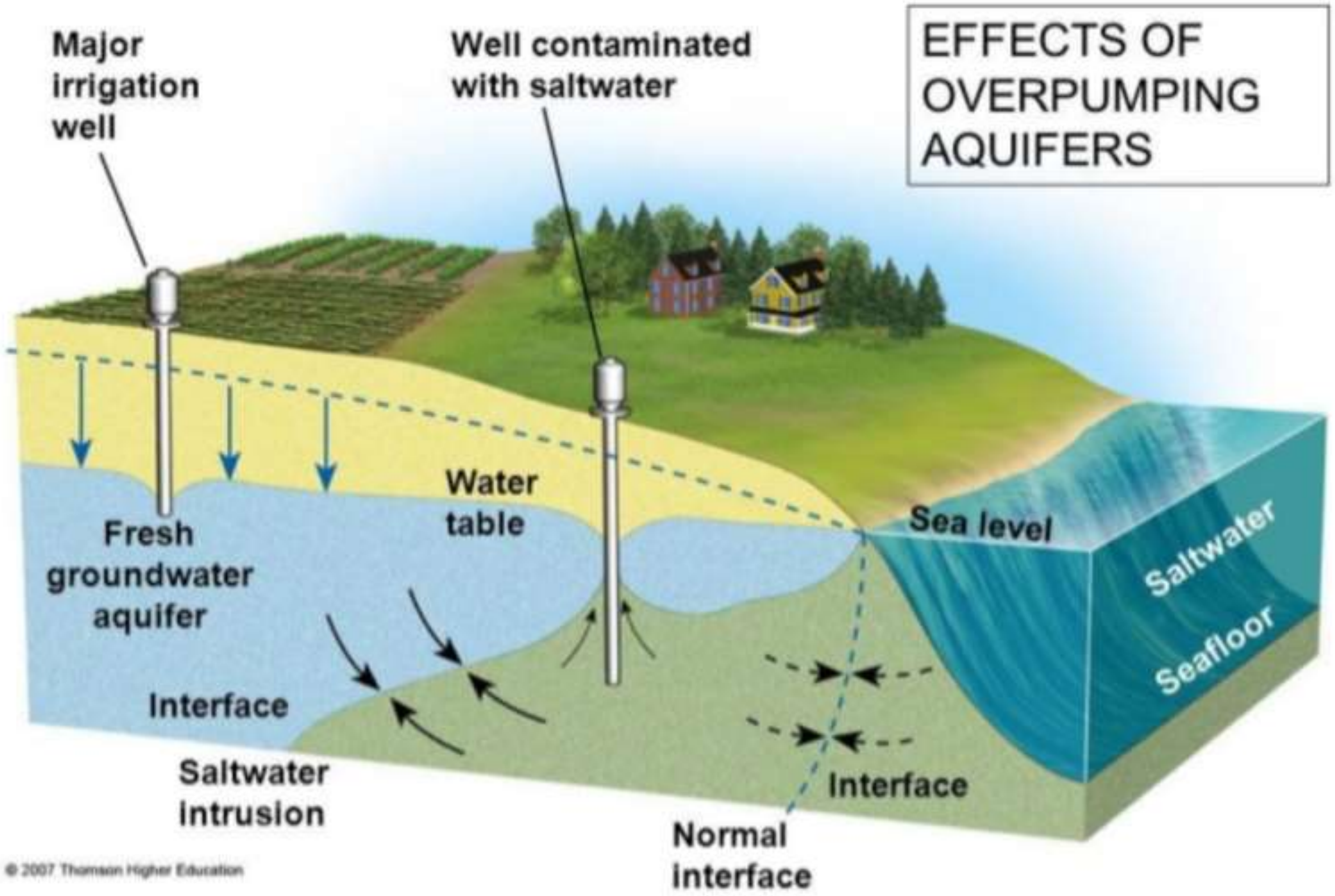
Plummer, McGeary, Carlson. Physical Geology, 8th ed., McGraw-Hill Companies, Inc., 1999

What will happen to the freshwater/saltwater interface? Will it move inland?



Source: U.S. Geological Survey

Saltwater Intrusion into Drinking Water Wells



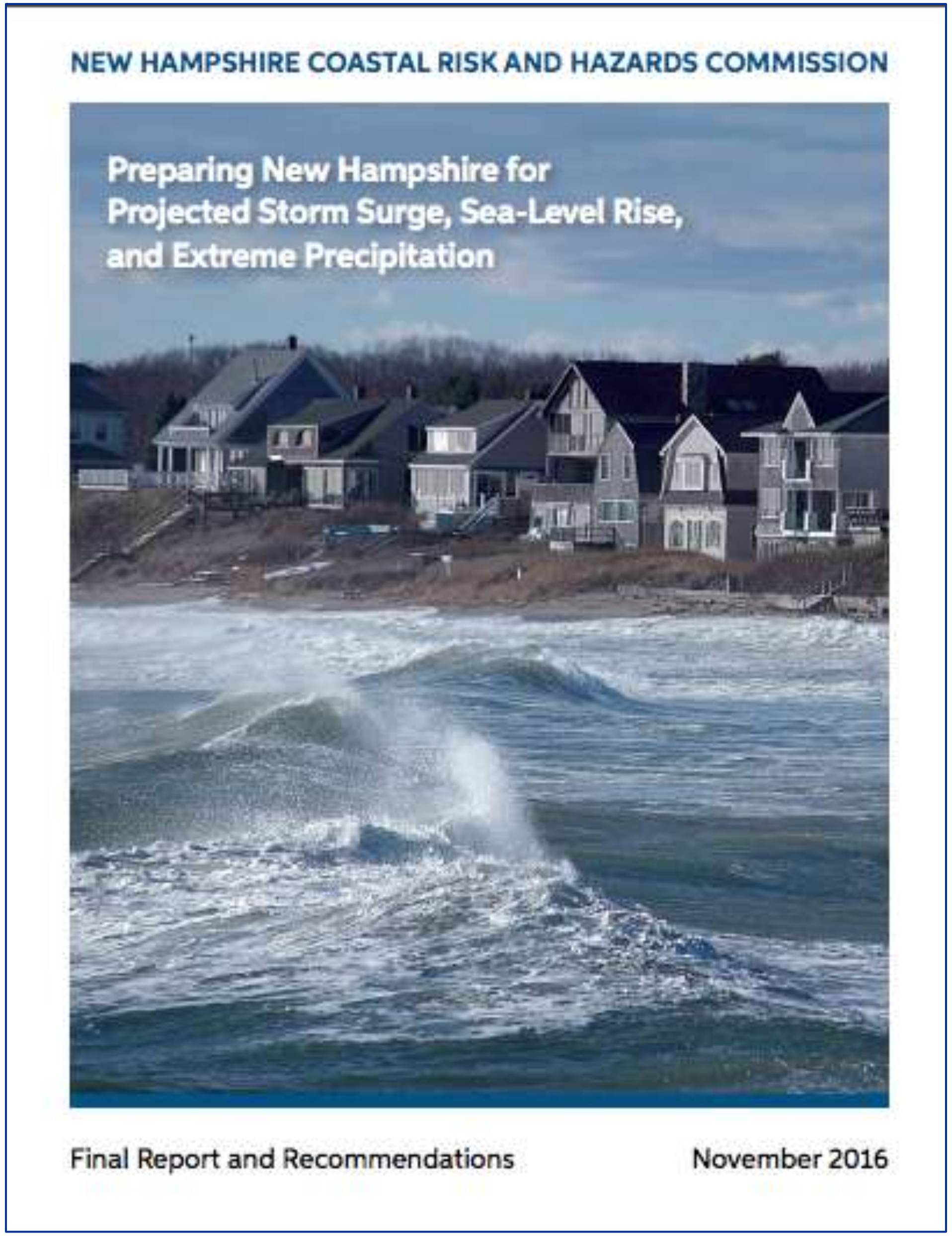
2007 Thompson Higher Education;
https://www.slideshare.net/prashantpkatti/sea-water-intrusion

Sea-Level Rise in Coastal New Hampshire

NH Sea-Level Rise Situational Awareness

NH Coastal Risk and Hazards Commission
NH Dept. of Environmental Services
NH Coastal Adaptation Workgroup

Photo Credit: Peter Digeronimo


NEW HAMPSHIRE COASTAL RISK AND HAZARDS COMMISSION

Preparing New Hampshire for Projected Storm Surge, Sea-Level Rise, and Extreme Precipitation

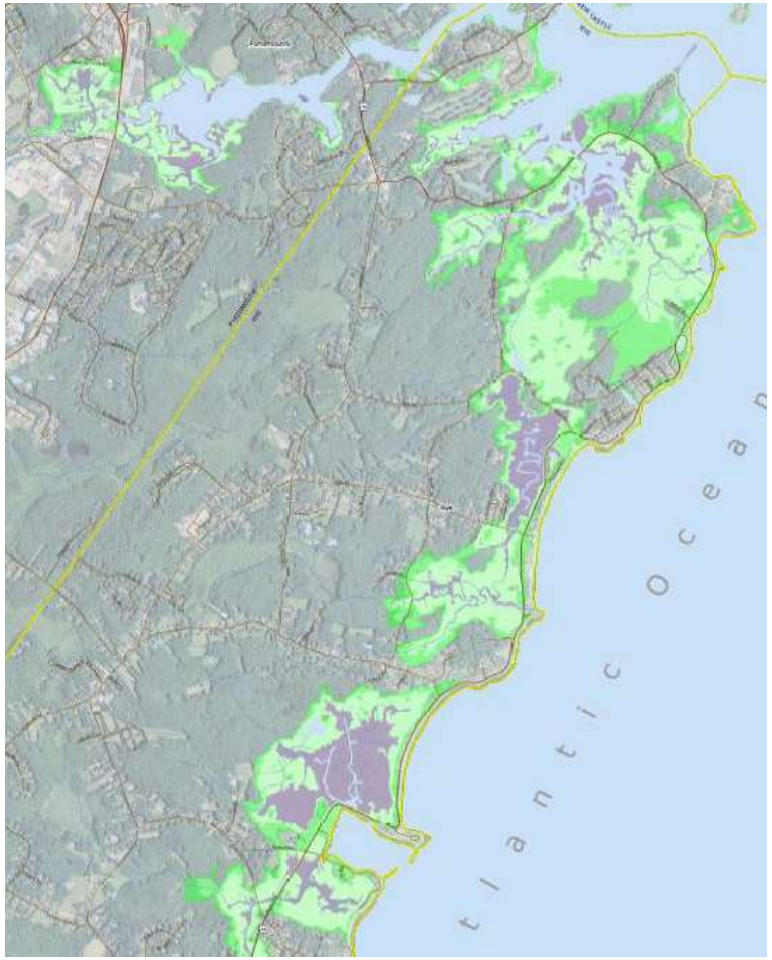
Final Report and Recommendations

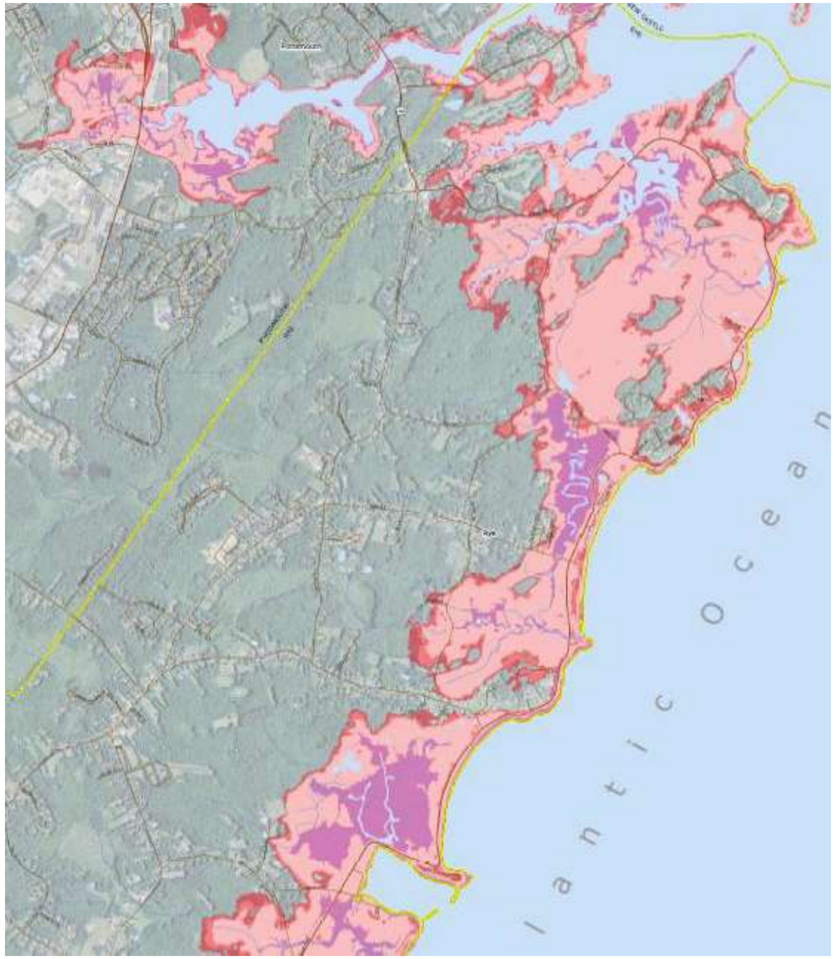
November 2016

NH Sea-Level Rise – Projected Tidal Flooding

Tidal water inundation with SLR

Green shading = 0.5 m, 1.2 m, and 1.9 m of SLR





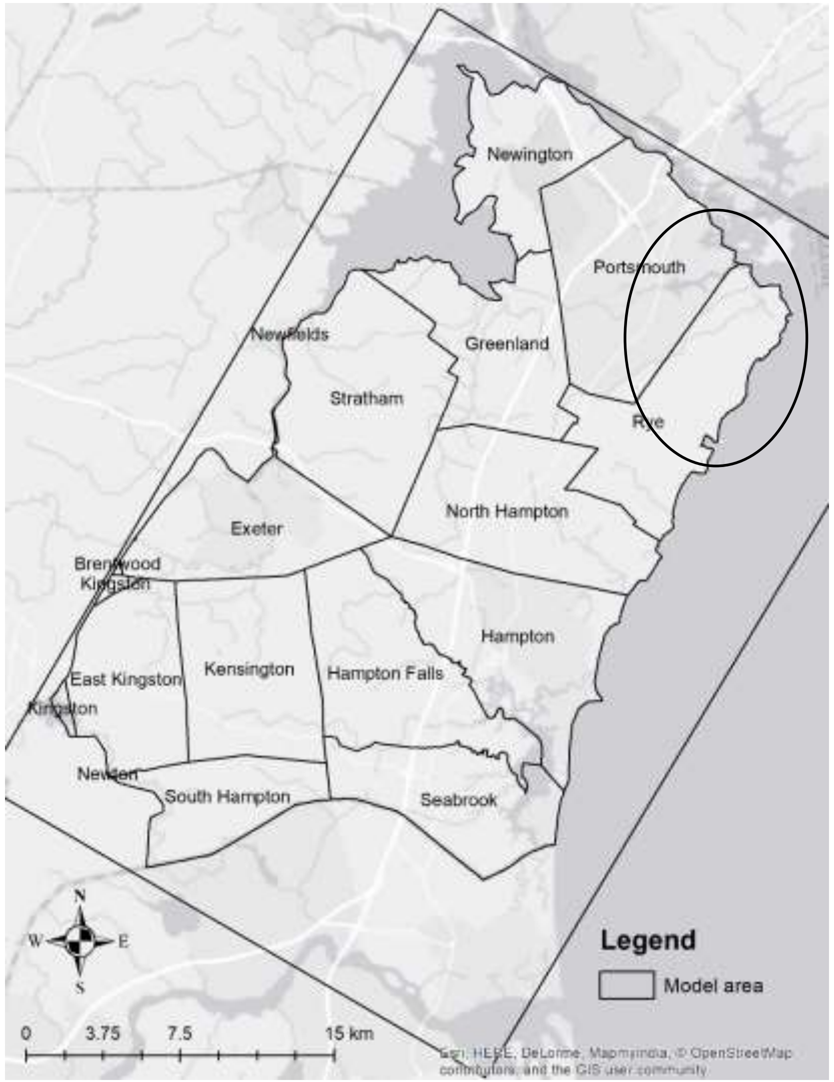
Tidal water inundation with SLR and storm surge

Pink shading = 0.5 m, 1.2 m, and 1.9 m of SLR

Note: Storm surge = flood extent from a 100-year/1% chance storm event

Map credit: Tides to Storms, Rockingham Planning Commission (2015)

New Hampshire Seacoast
What is coastal and what is inland?



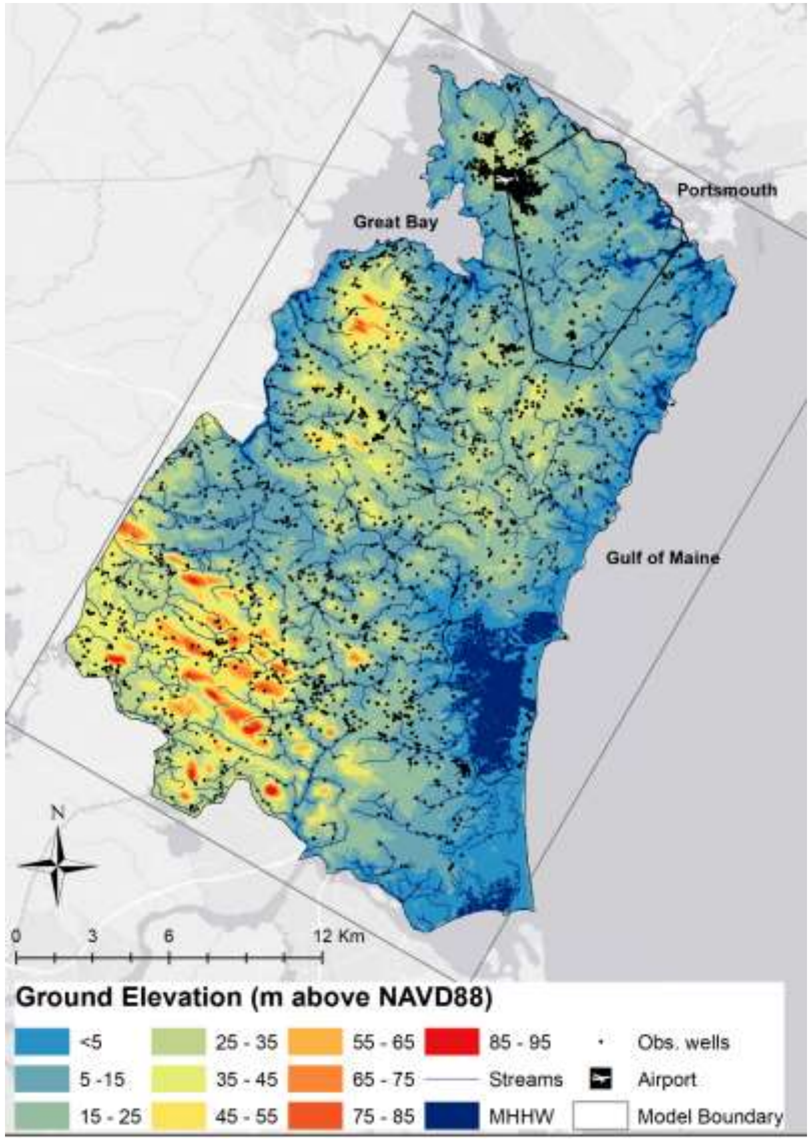
How far inland will the effects of SLR be felt?

Simulated SLR-Induced Groundwater Rise in Coastal New Hampshire

Modeling Groundwater Rise with SLR

Groundwater (GW) model:

- Existing 3D model (Mack, 2009) - modified for this study
- USGS MODFLOW

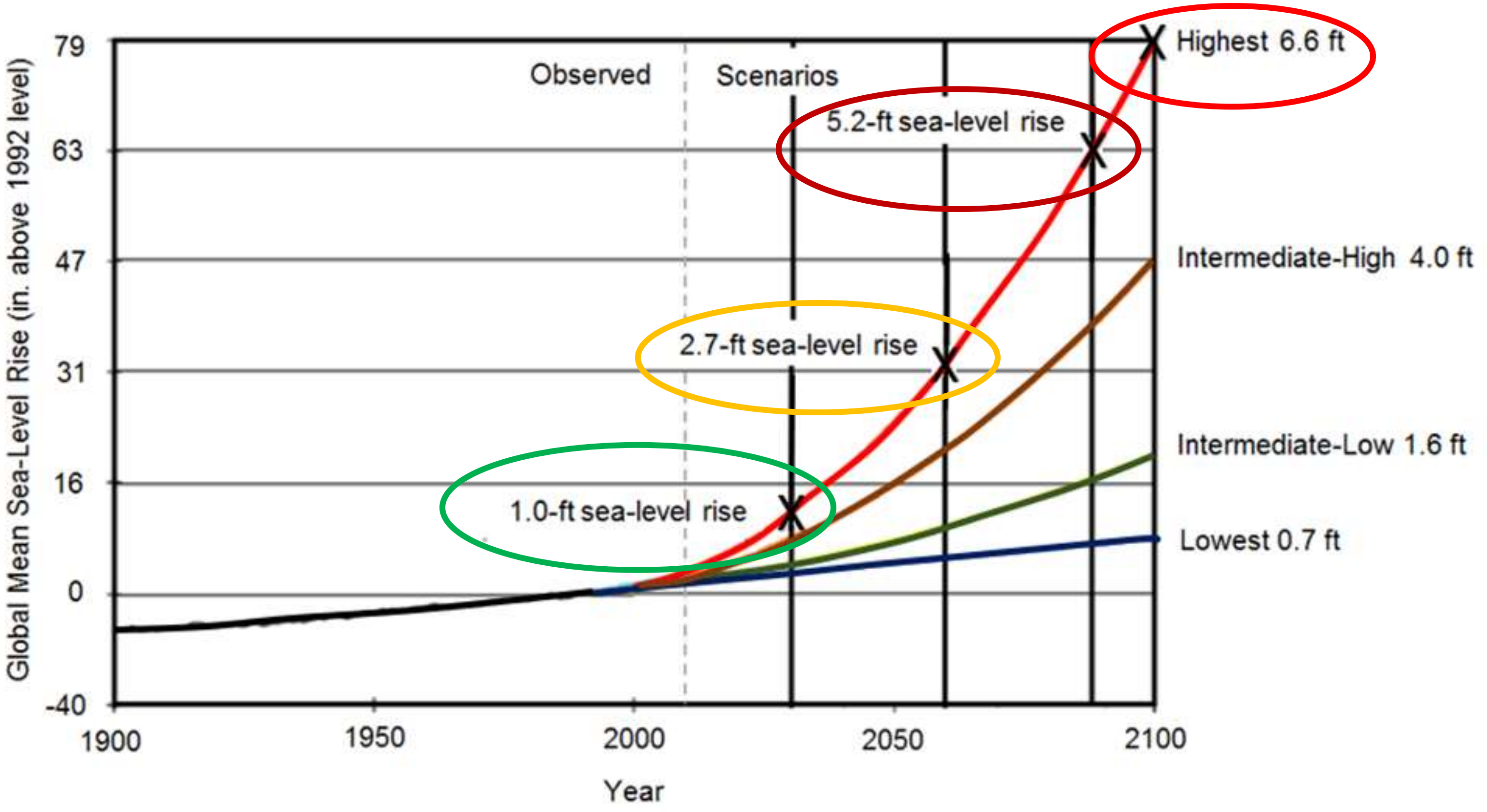


- Ran in steady state – no seasonal effects
- Grid – 200 ft. x 200 ft.

Sea Level Rise - Scenarios

Sea-Level Rise (SLR) High Emissions Scenario:

- 1.0 ft. SLR (Y: 2030)
- 2.7 ft. SLR (Y: 2060)
- 5.2 ft. SLR (Y: 2090)
- 6.6 ft. SLR (Y: 2100)

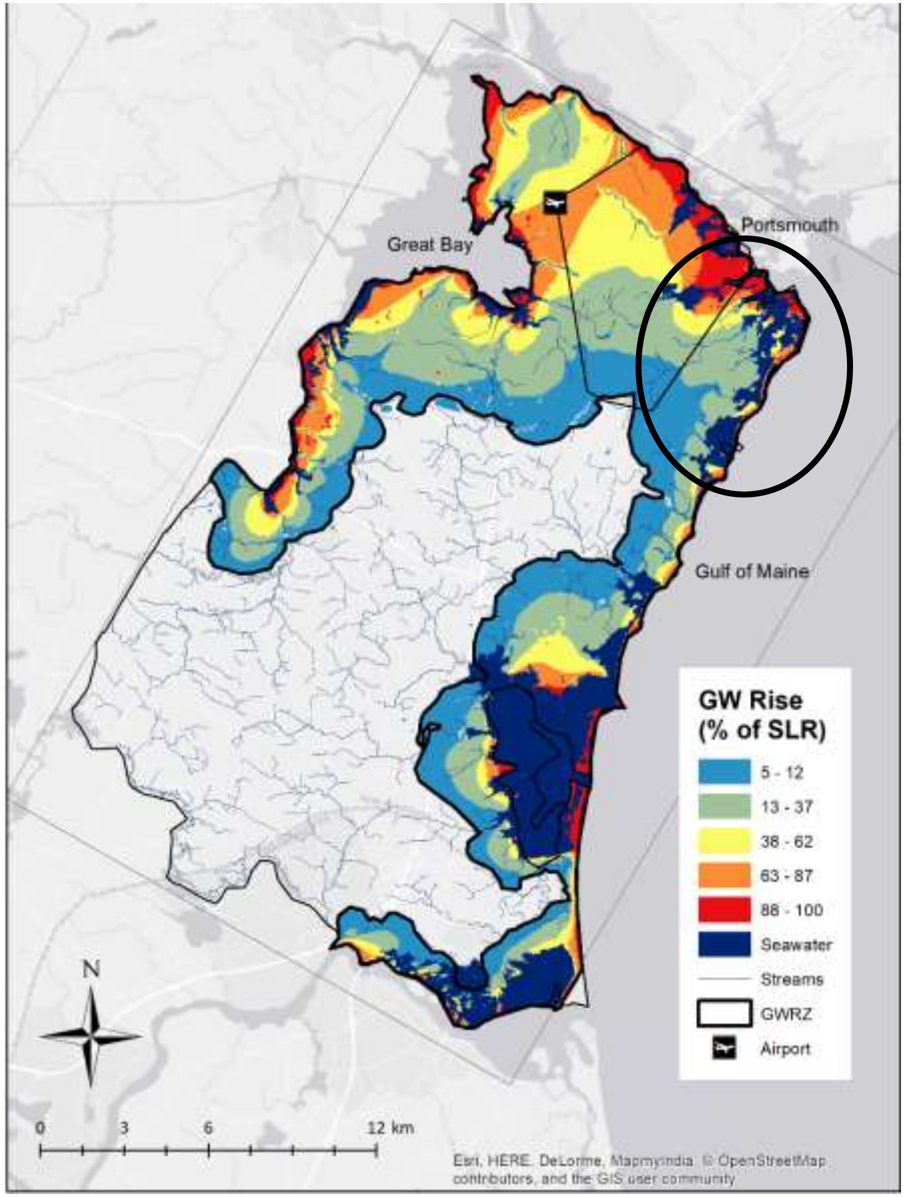


From: NOAA (Parris et al., 2012)

Model Results: Groundwater-Rise Zone (GWRZ)

Groundwater rise (% of sea-level rise):

- GW Rise: 4–5 km inland
- Tidal surface-water flooding: 1.5 km inland
- GW Rise is reduced near streams

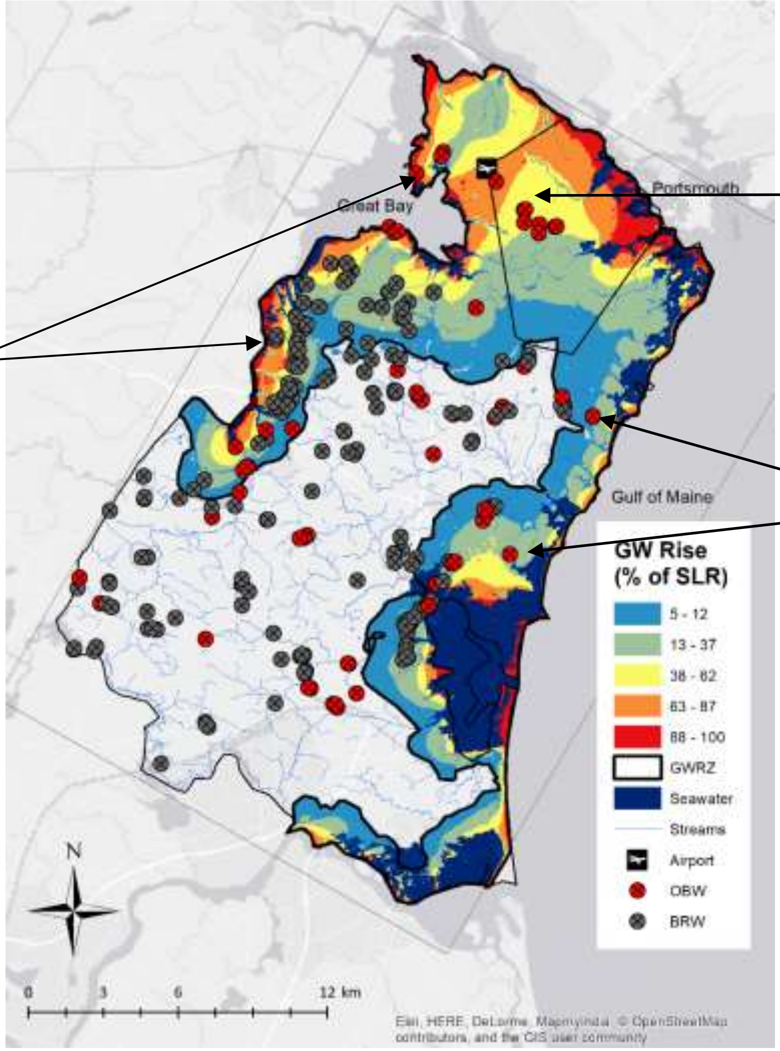


- Affected by:
  - geology
  - coastal geometry
  - GW pumping
- Can result in GWI of the land surface

Potential Impacts from SLR-Induced Groundwater Rise in Coastal New Hampshire

*Will **drinking water** supplies in the seacoast region be harmed by saltwater intrusion?*

Areas potentially at risk from saltwater intrusion



Area where GW is predicted to rise the most with SLR

Areas potentially at risk from saltwater intrusion

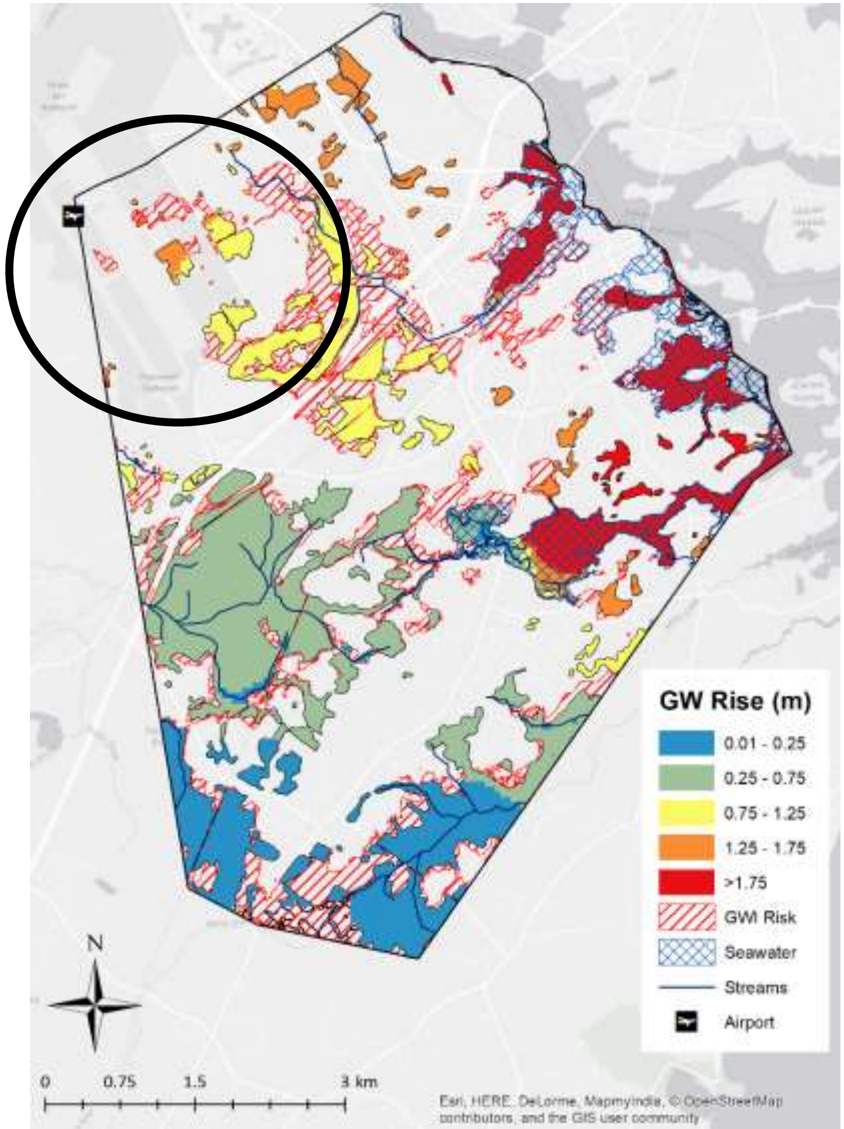
Red: Overburden wells
Grey: Bedrock wells

*Where might rising groundwater impact marine and freshwater **wetlands**?*

City of Portsmouth:

Approximately 9 km^2 (21%) is occupied by freshwater wetlands.

The depth of water in wetlands may increase – wetland type transition



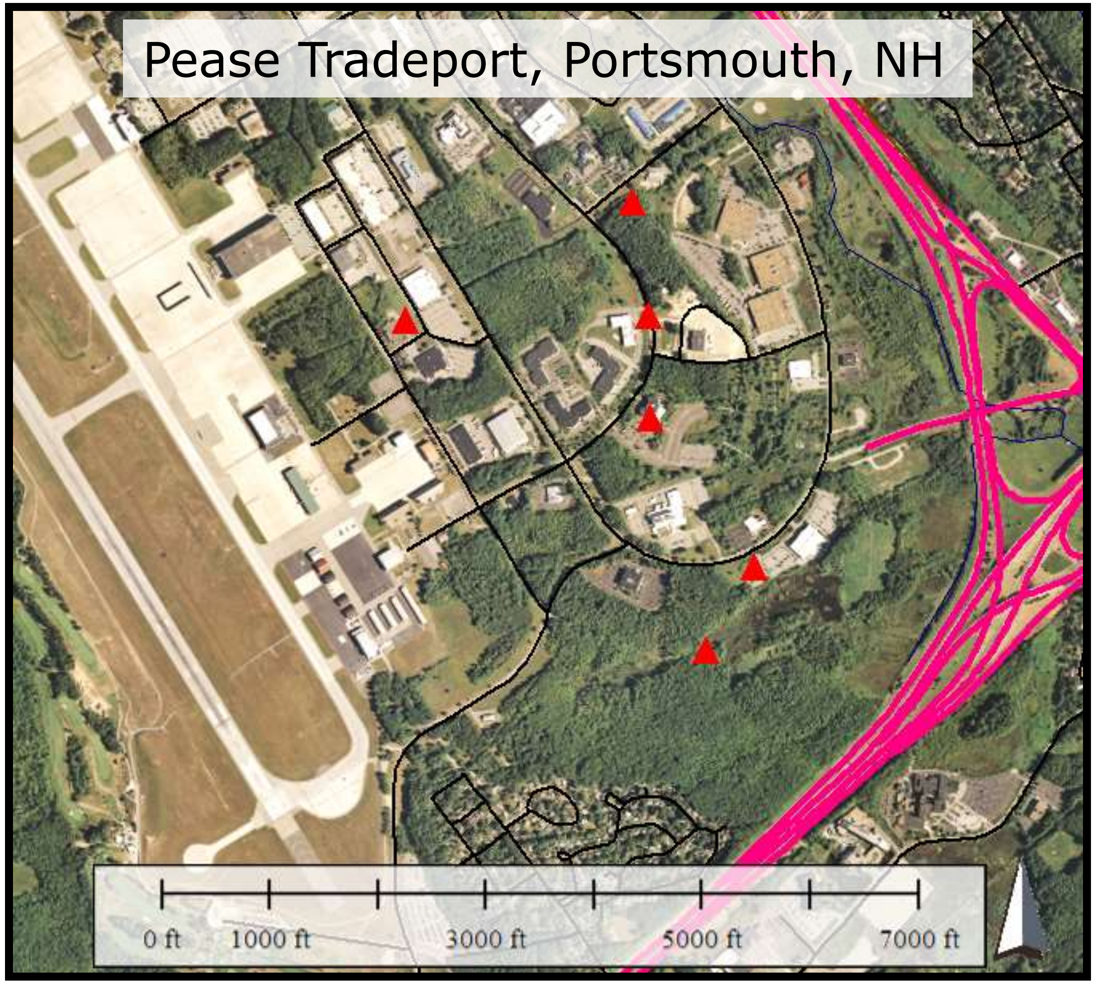
Freshwater wetland area will increase:

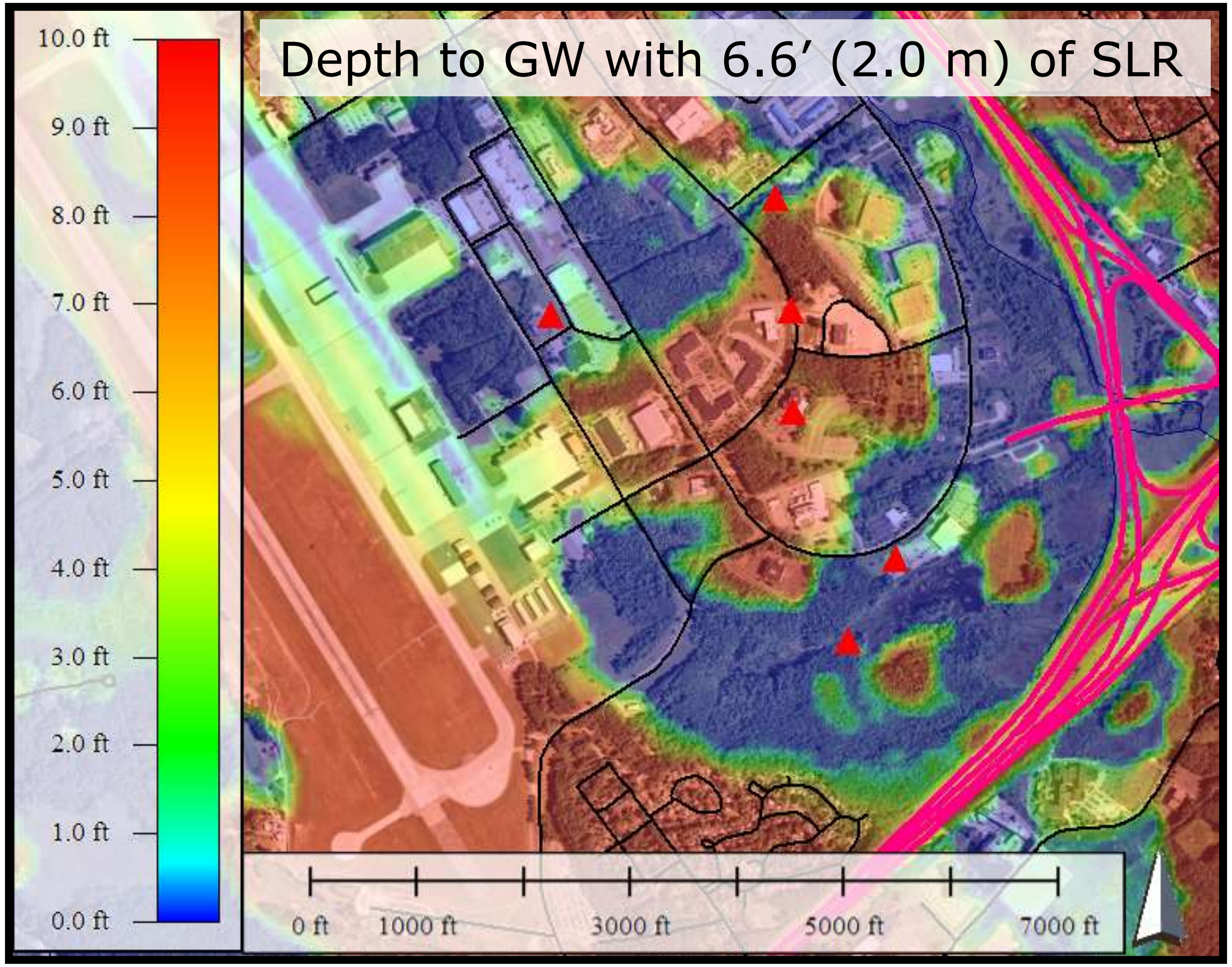
- 3% by 2030;
- 10% by mid-century;
- 19 to 25% by the end of century.

ICNet INFRASTRUCTURE & CLIMATE NETWORK

UNH CIRC

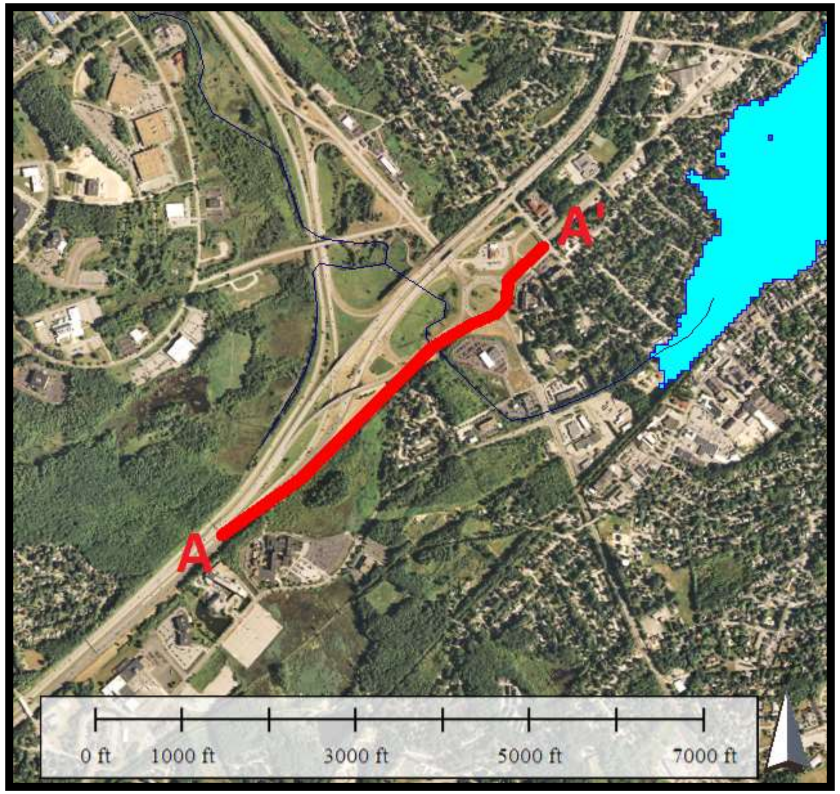
*Where might rising groundwater contact **contaminated soils**?*

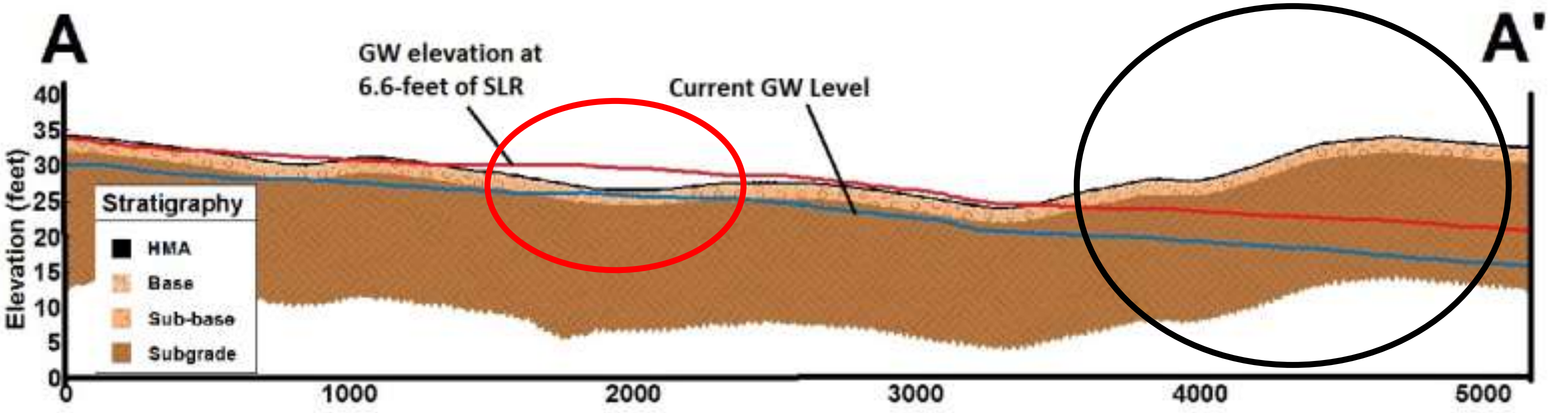




The red triangles are/were active remediation sites

*Which **pavements** may fail prematurely due to rising groundwater?*



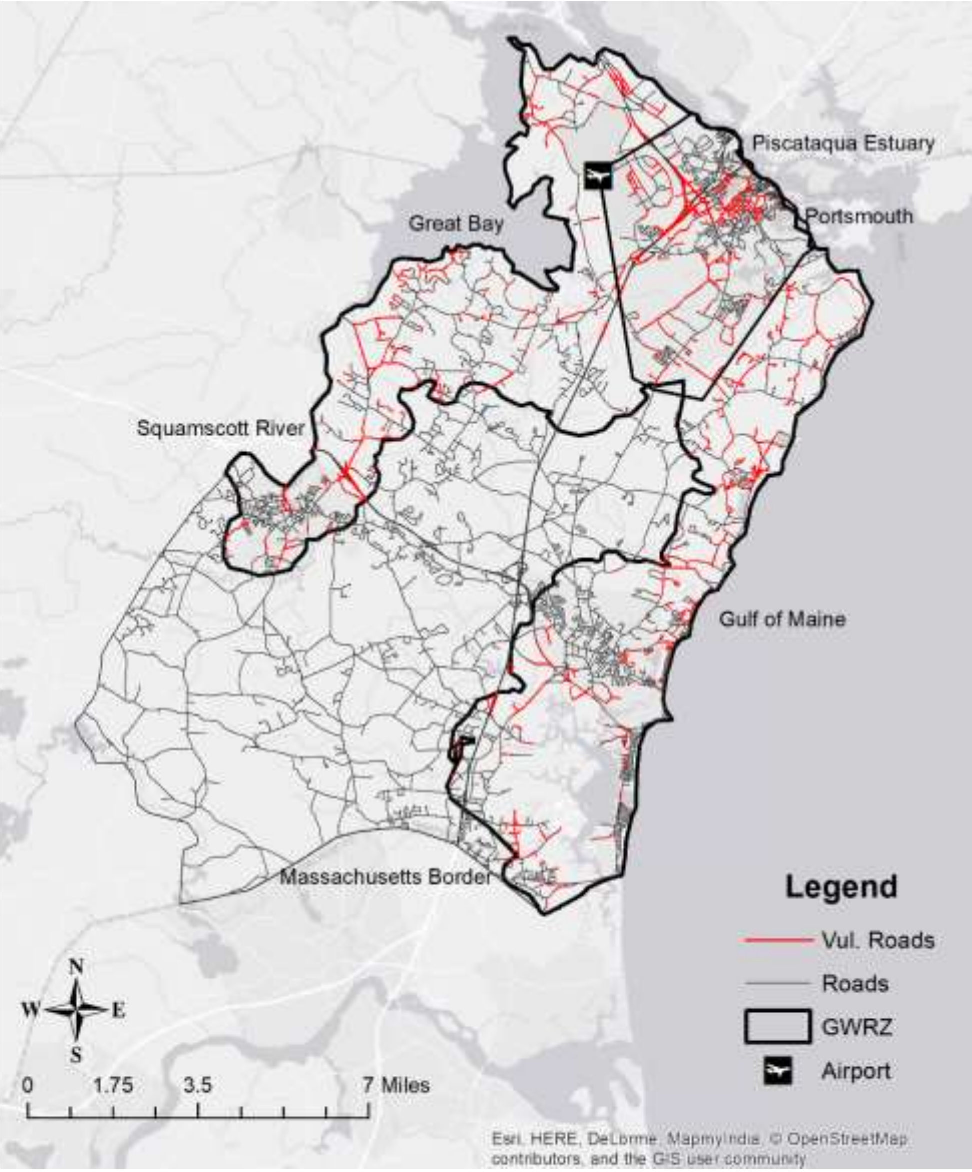


Roads in the zone of groundwater rise where groundwater is already close to the ground surface will be the most vulnerable.

Vulnerable sections of roadway

Vulnerable Roads –

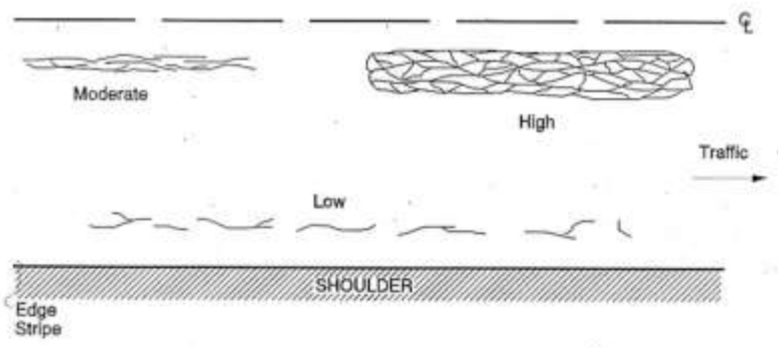
Roads within the GWRZ with GW less than 1.5 m below the road surface.



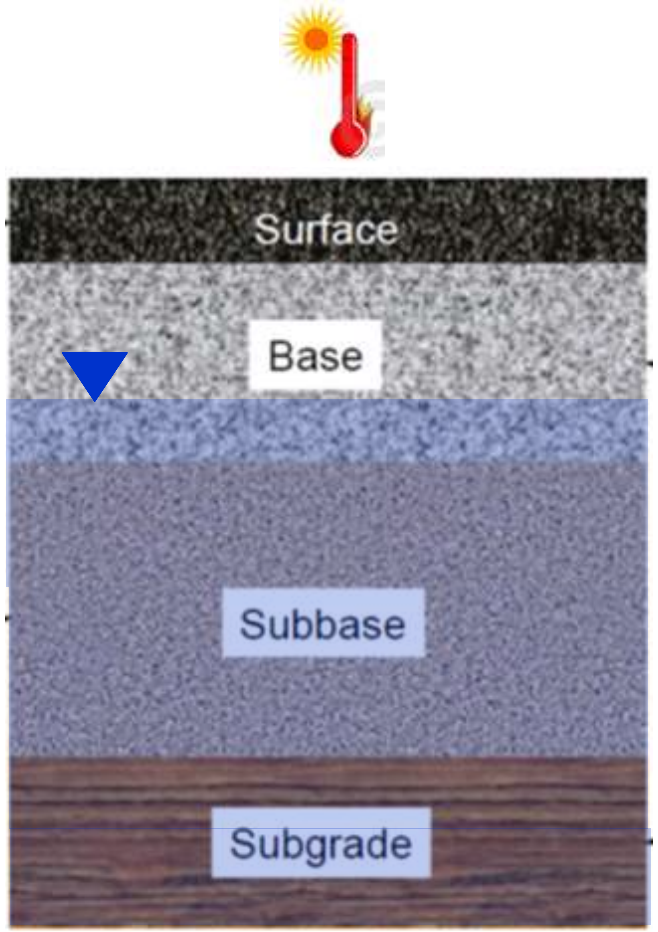
- 1022 km of roads are in the study area
- 783 km of roads (77% of the region's roads) are in the GWRZ.
- 235 km of the region's roads (23%) are vulnerable or 30% of the roads in the GWRZ.

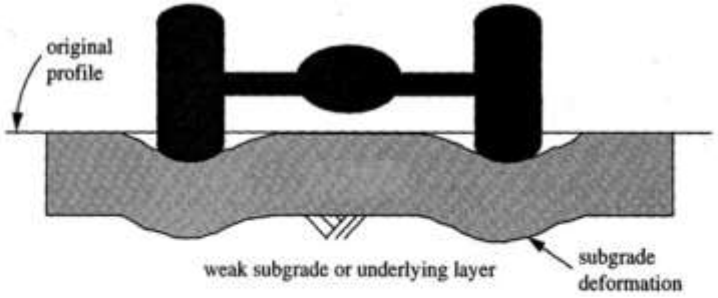
What happens when the underlying, supporting soils become saturated?

Pavement life decreases when GW moves into the underlying layers and increased temperature weakens the AC



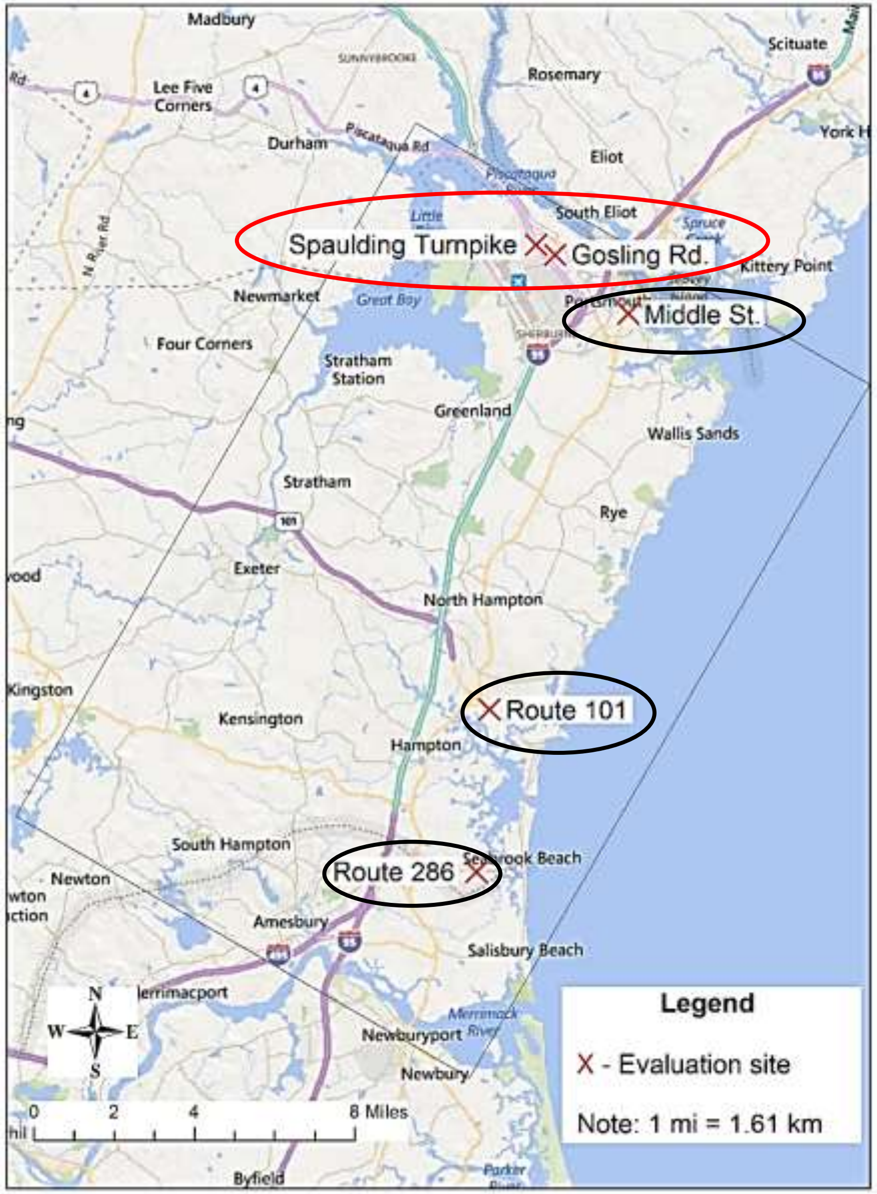
Fatigue cracking





Rutting

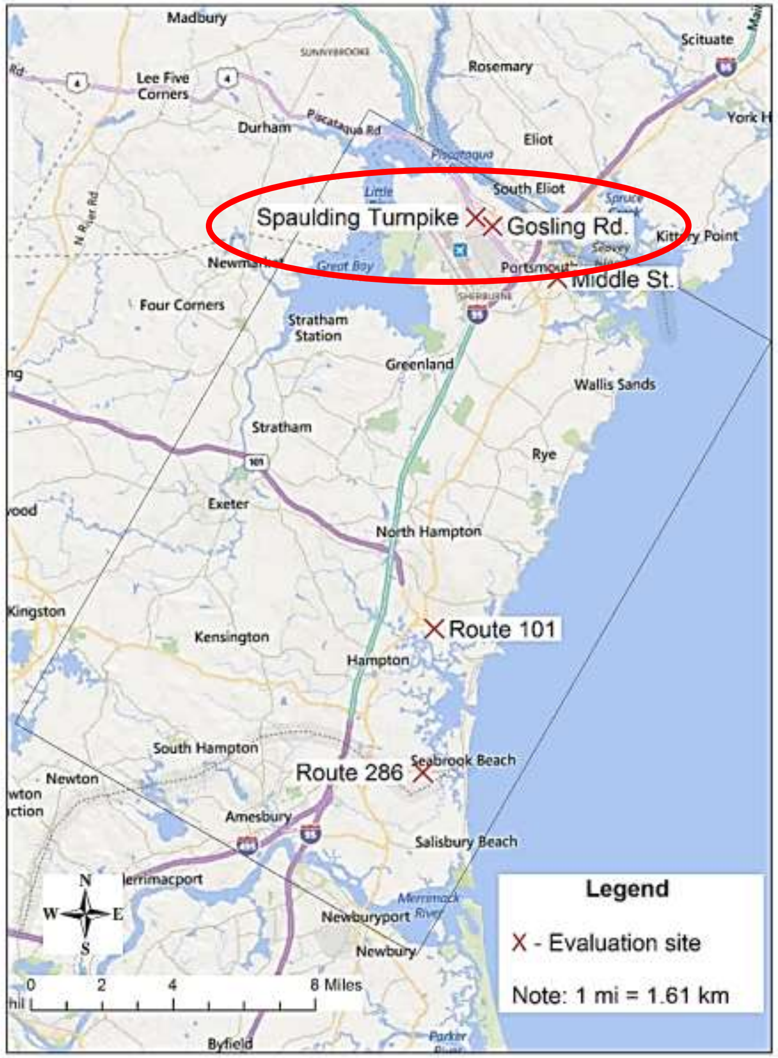
Pavement evaluation

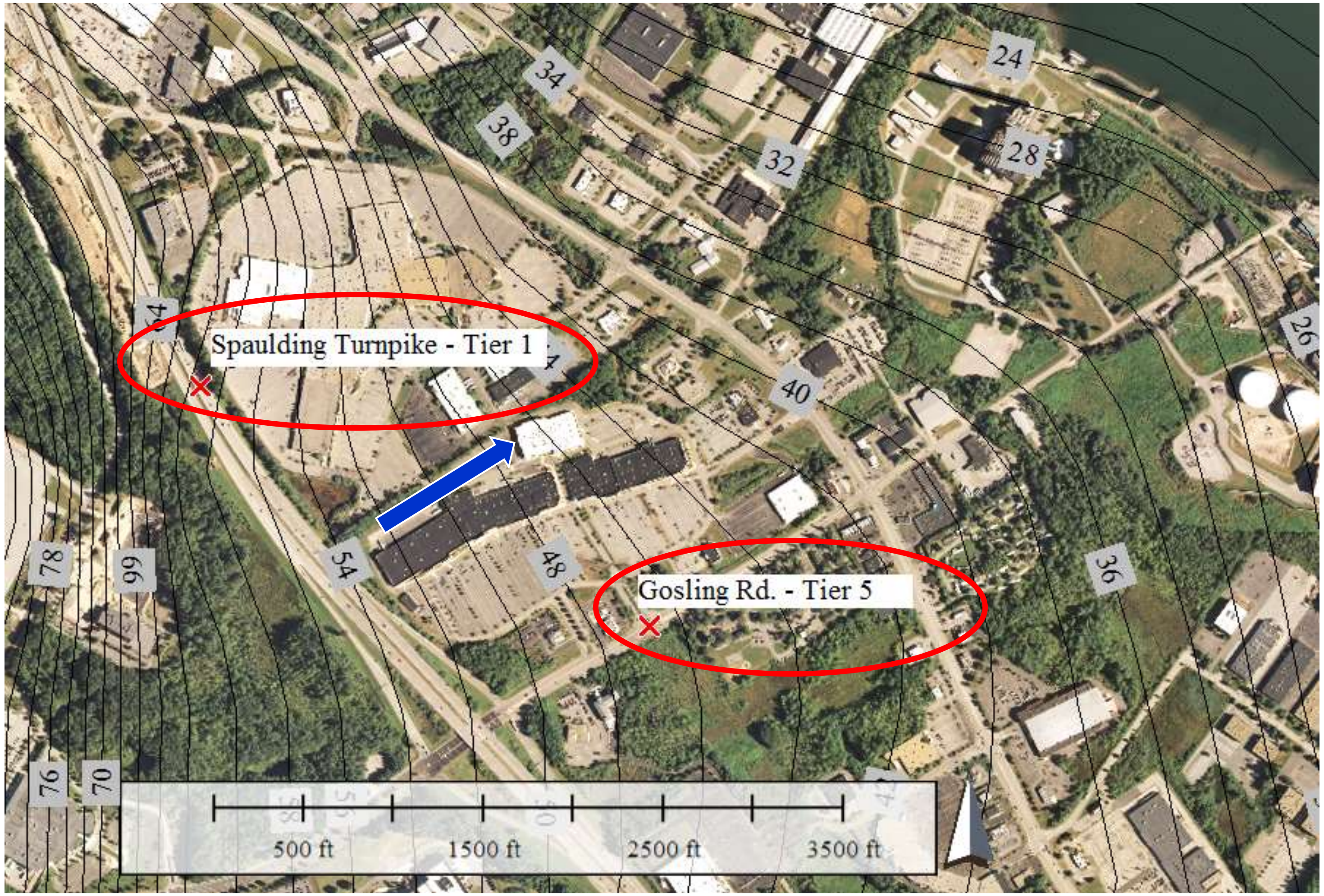


Pavement evaluation sites

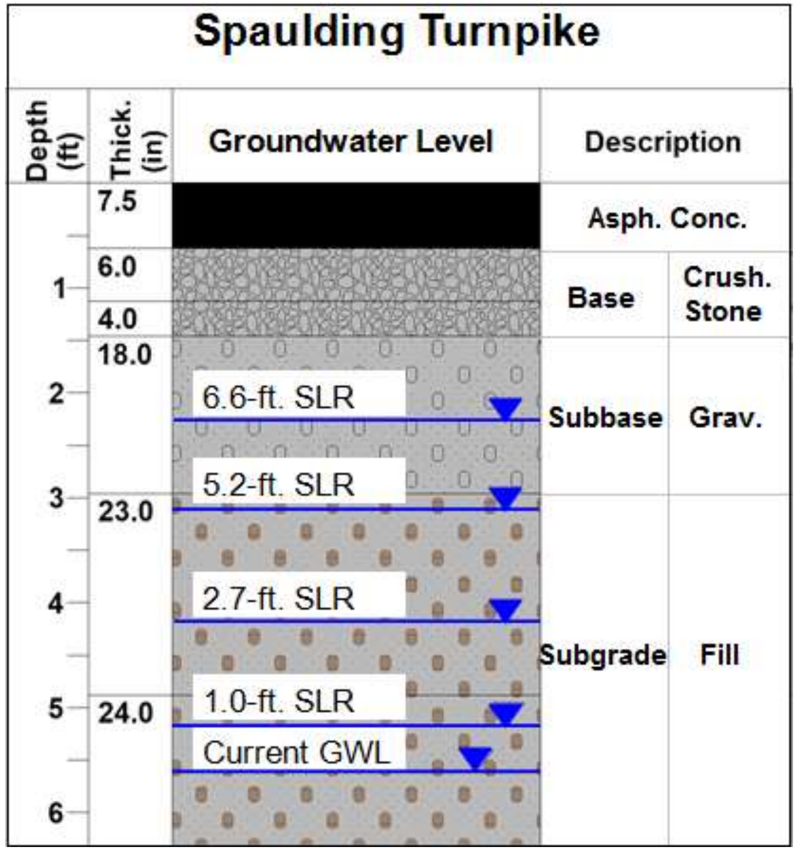
- Spaulding turnpike (Divided highway)
- Gosling Road (Local road)
- Route 101 (Statewide corridor)
- Route 286 (Regional corridor)
- Middle St. (Local road)

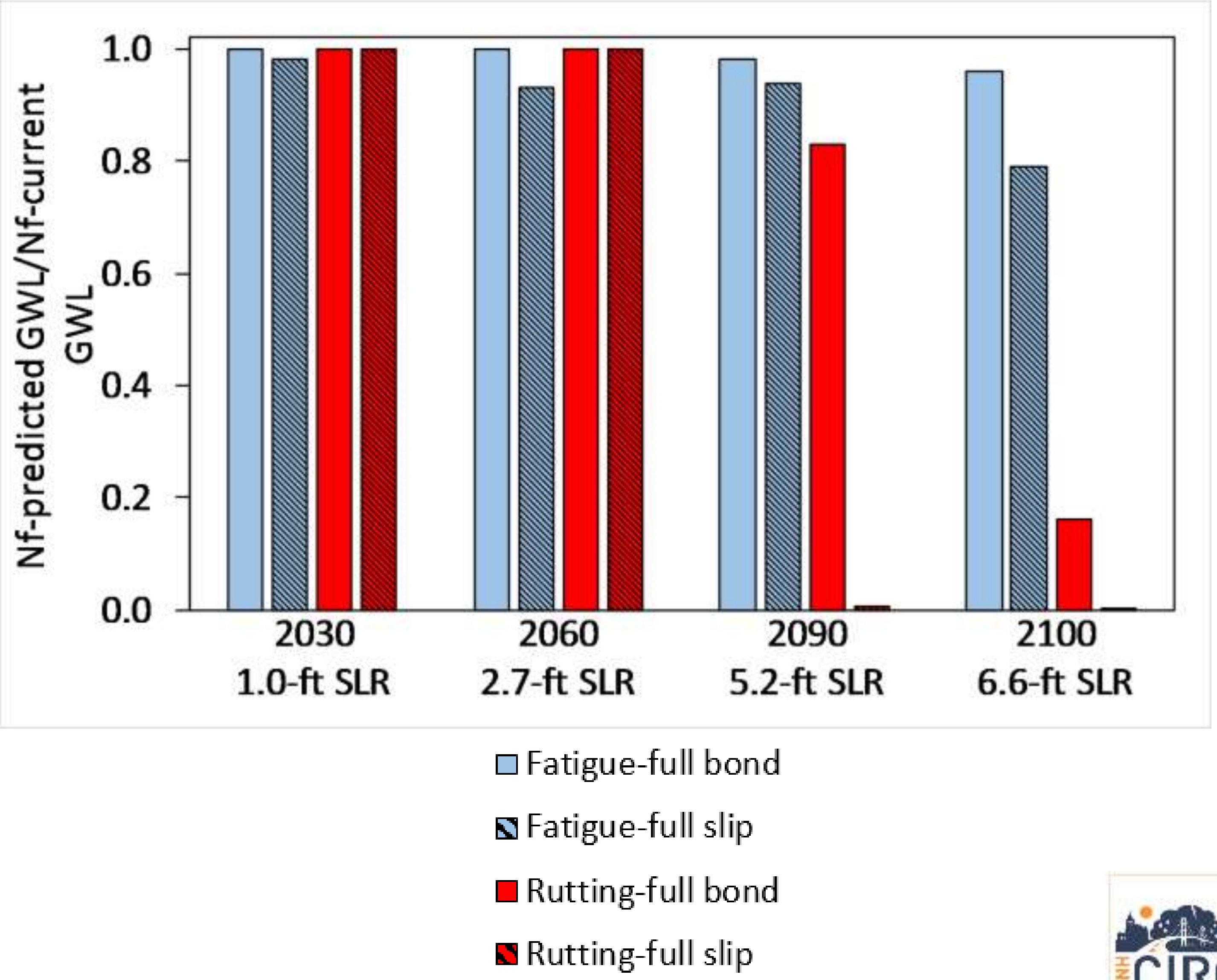
Spaulding Turnpike and Gosling Road





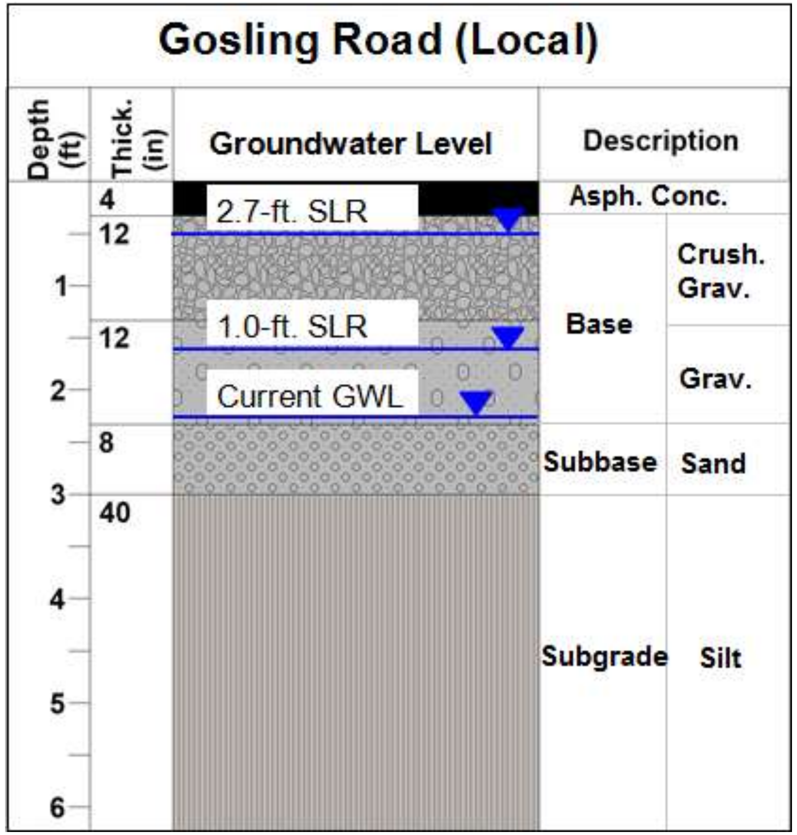
Spaulding Turnpike (divided highway)

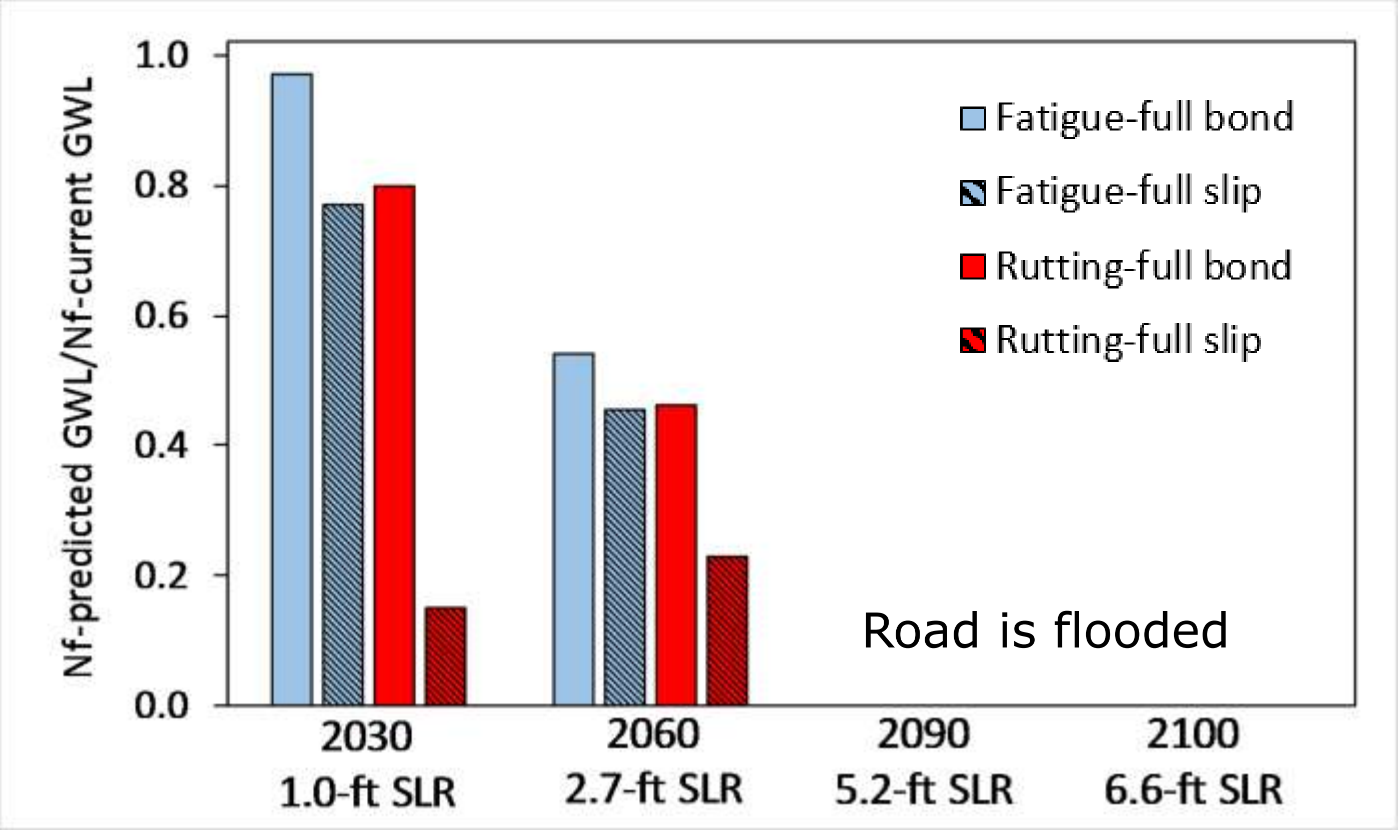




Road surface elevation = 64.9 feet (NAVD88)

Gosling Road – Pavement profile and analysis





Road surface elevation = 49 feet (NAVD88)

Fatigue cracking controls pavement failure

What can we do?

There are many options – we have some time . . .

1. Adopting **adaptation actions** now may save money in increased maintenance, emergency repairs, and environmental harm.

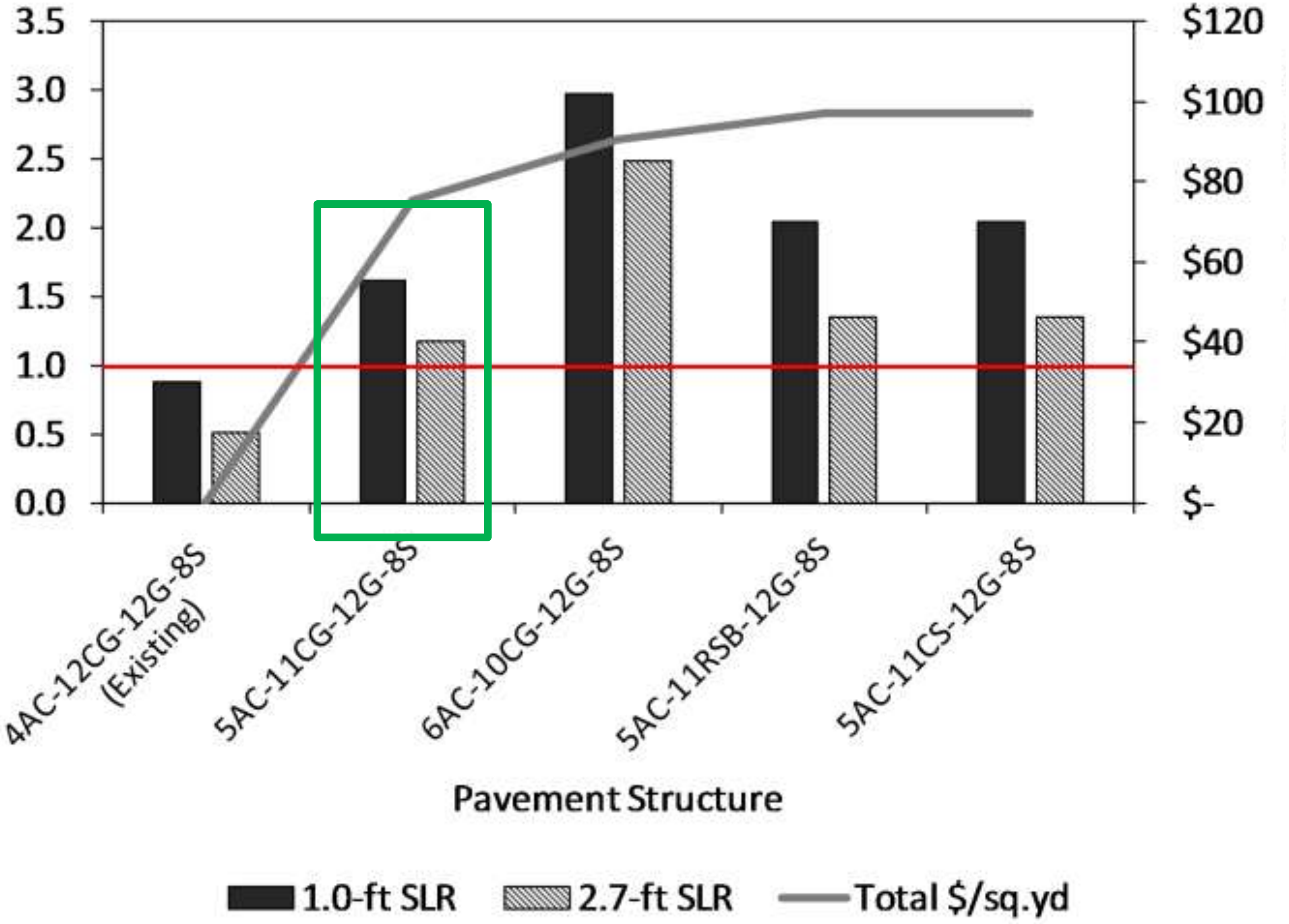
2. Ensuring that our **natural systems** remain healthy will enable them to continue performing essential protective functions.

3. Where infrastructure adaptation is extremely costly, a **wait and see approach** may be best.

4. **Staged adaptation planning**: what you do now can influence or constrain future options.

Example Adaptation Strategies – Local Road (Gosling Road)

Pavement Life (N_{fn}/N_{fe})



Adaptation Costs ($/yd²)

Pavement Options

Concluding Remarks

SLR, Rising GW, and Coastal NH Summary

1. The **Groundwater Rise Zone (GWRZ)** caused by sea-level rise was identified in coastal NH with a regional groundwater-flow model.

2. **Vulnerable assets**, within the GWRZ, are those where groundwater is already close to the base of the structure, i.e. within the range of projected groundwater rise.

3. Detailed **asset-specific vulnerability studies** are required to account for local conditions and to assess the asset's resiliency to groundwater and temperature rise from climate change.

4. Adoption of **adaptation strategies** now will avoid expensive emergency repairs, groundwater contamination, and harm to natural resources.

Acknowledgements

- Co-authors and advisors:
  - Jennifer Jacobs, Ph.D., University of New Hampshire
  - Jo Sias Daniel, Ph.D., University of New Hampshire
  - Paul Kirshen, Ph.D., University of Massachusetts Boston
- Advisors: David Burdick, Ph.D., University of New Hampshire; Eshan Dave, Ph.D., University of New Hampshire
- New Hampshire Sea Grant for funding this work
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- The Infrastructure and Climate Network (ICNet)
- NH Department of Transportation (NHDOT)
- NH Department of Environmental Services (NHDES)
- NH Seacoast Transportation Climate Working Group (NHS TCWG)
- NH Coastal Adaptation Workgroup (NHCAW)

Thank you for your interest.
Questions?

Source: www.huffingtonpost.com

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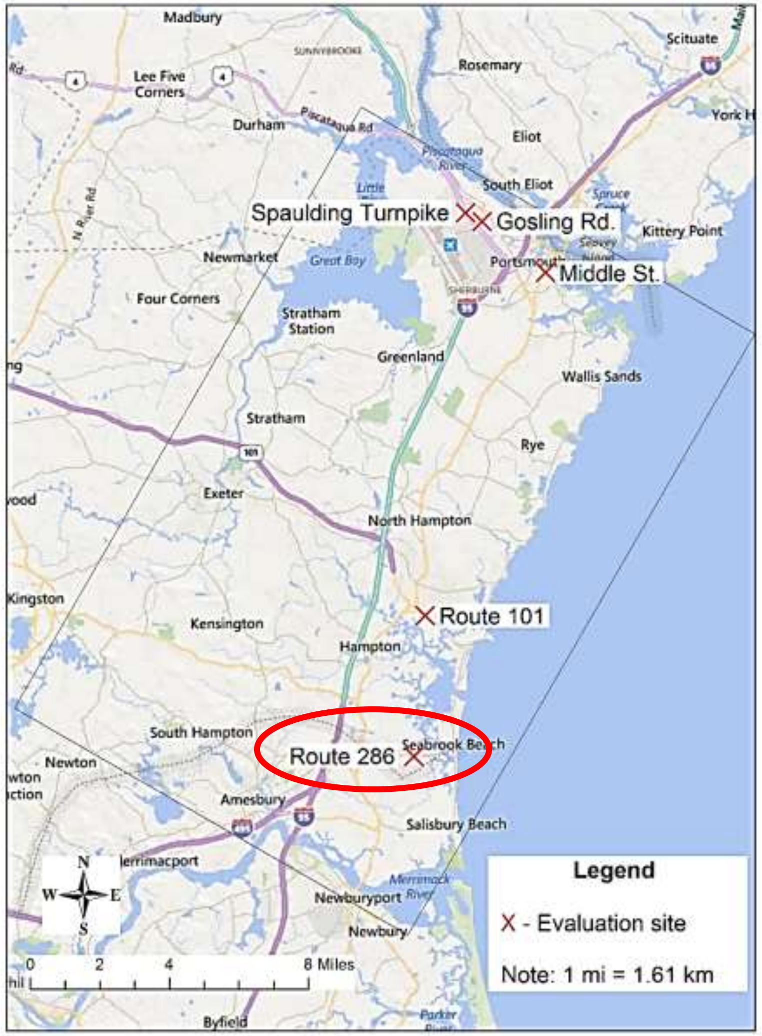
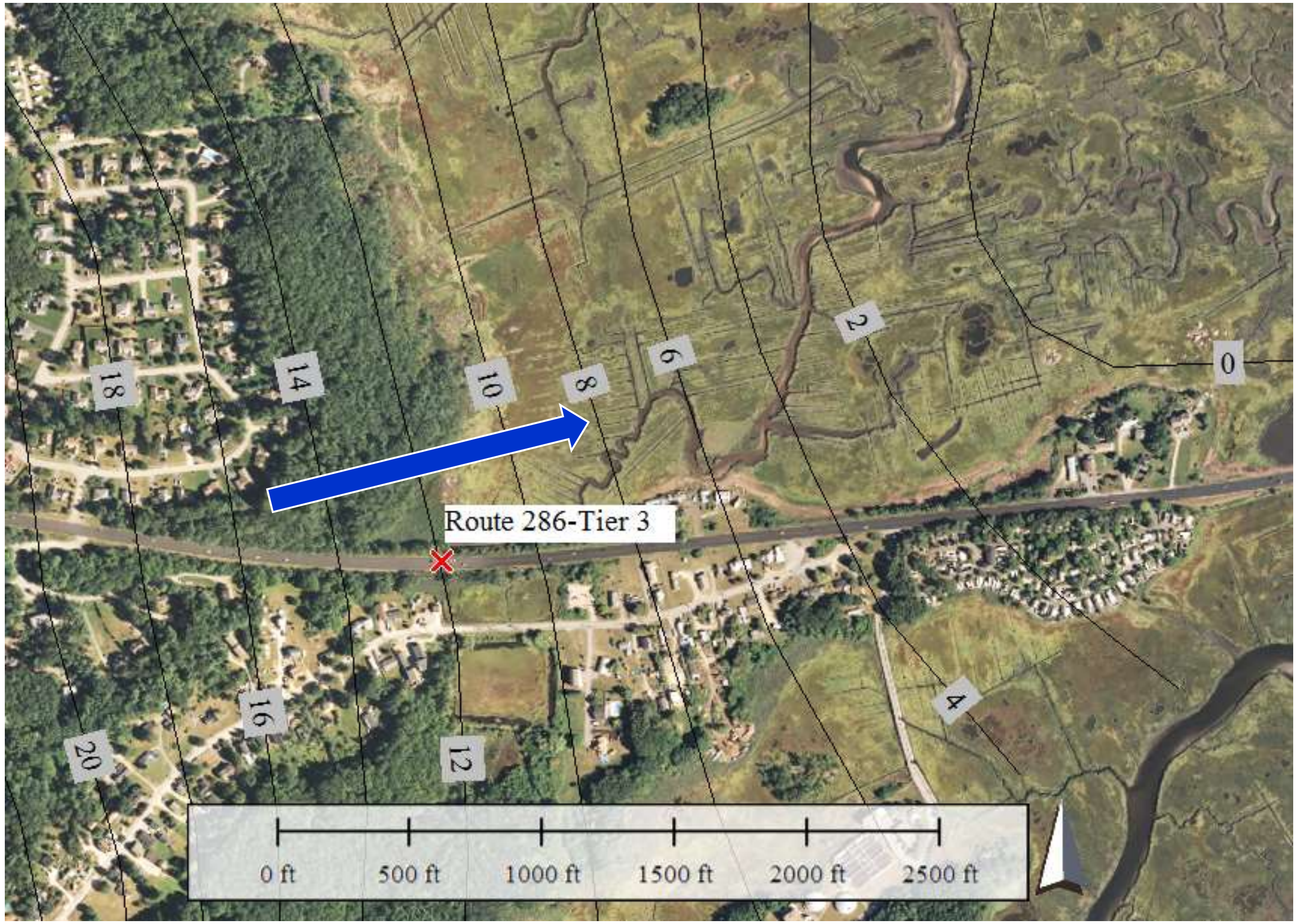
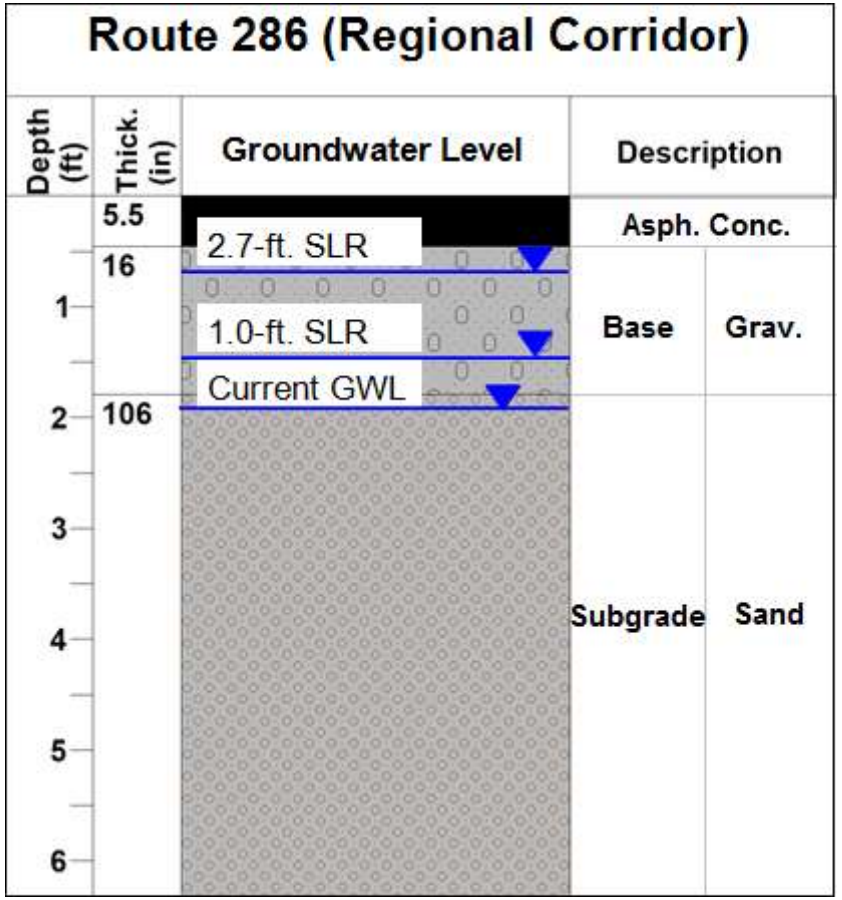
Jennifer.Jacobs@unh.edu

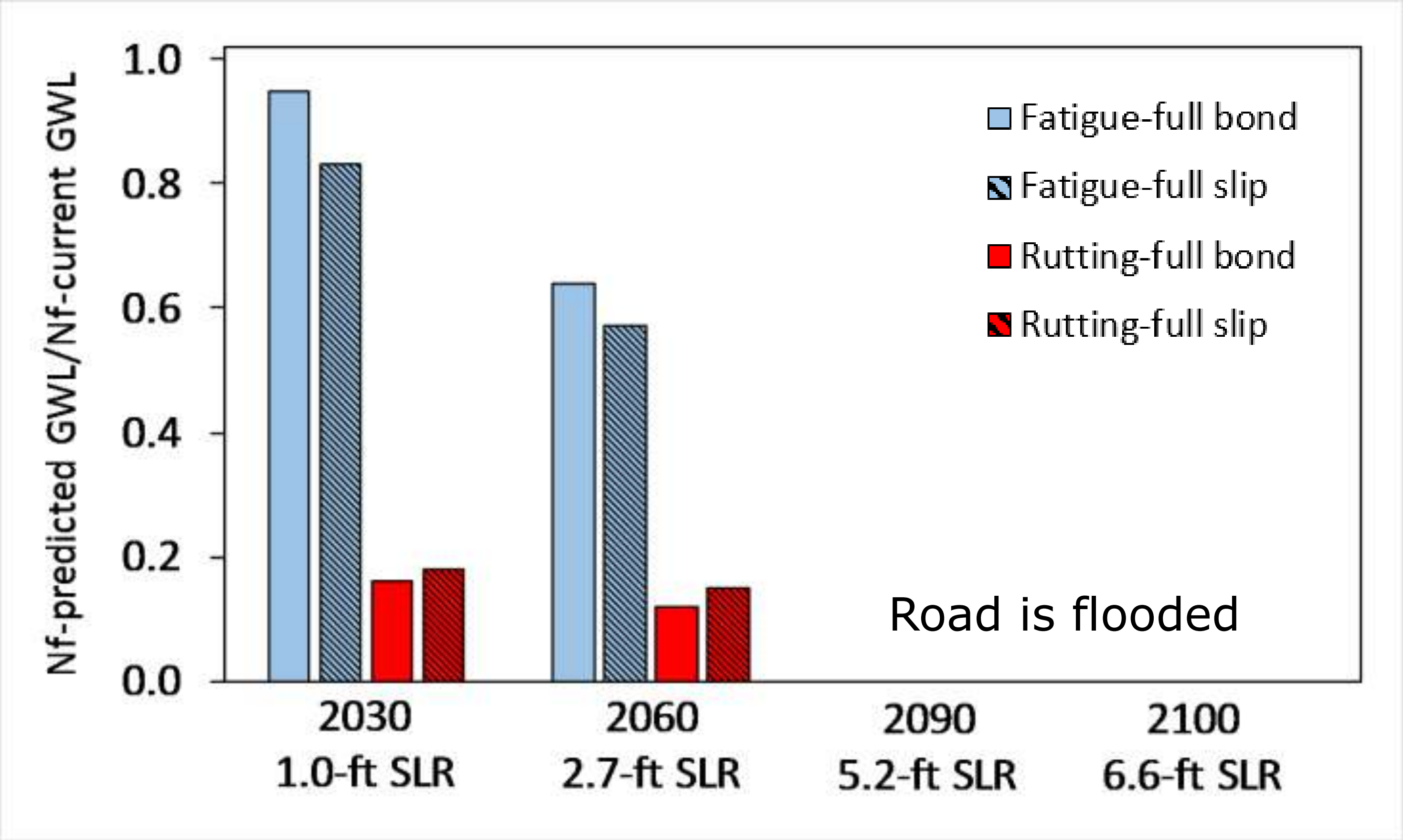
Route 286 (regional corridor)





Route 286 - Pavement profile and analysis



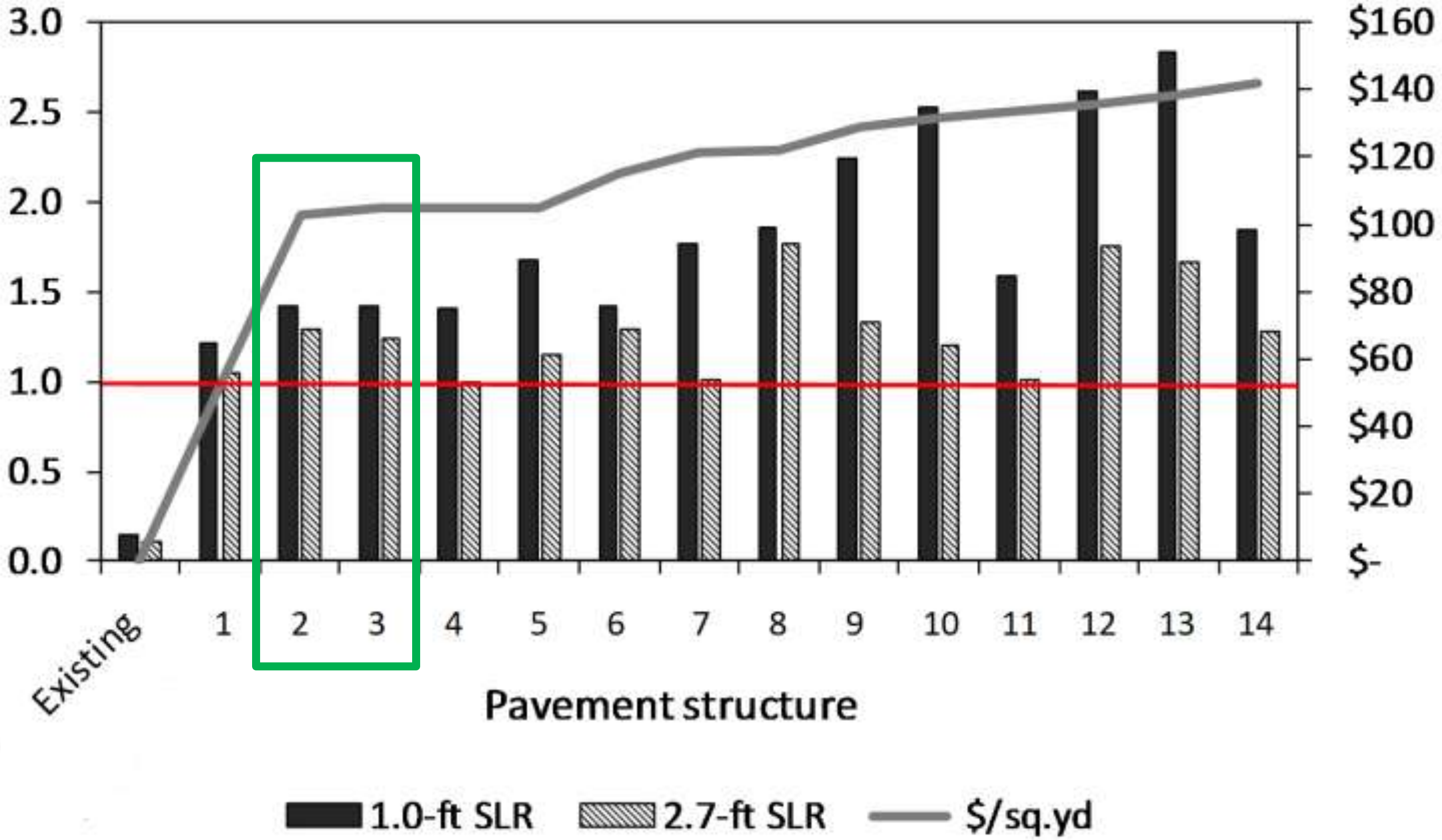


Road surface elevation = 13.9 feet (NAVD88)

Rutting controls pavement failure

Adaptation Strategies – Regional Corridor (Rte. 286)

Pavement Life (N_{fn}/N_{fe})



Adaptation Costs ($/yd^2)

Pavement Options