Relationship between Groundwater Nitrate Concentration and Density of Onsite Wastewater Treatment Systems:

Role of Soil Parent Material and Impact on Pollution Risk

Matthew Dowling & Jose Amador, PhD

CHARLESTOWN

THE UNIVERSITY OF RHODE ISLAND

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Summary of today’s talk

Study area / Setting – Coastal Southern RI, findings are transferable

Problem/Issue – Groundwater nitrate nitrogen plumes from densely clustered OWTS impact drinking and surface water quality

Study sites – Sampled over 350 private wells in a coastal aquifer serviced by OWTS for concentrations of nitrogen water samples

Methods and analyses – Conducted statistical analyses to identify trends and risks and developed predictive groundwater nitrogen modeling

Findings / recommendations –

Identified a significant positive relationship of #OWTS / area to groundwater nitrogen concentrations and risk to drinking water resources. Recommend upgrading conventional OWTS to modern N reducing technology

BACKGROUND – COASTAL OWTS AND GROUNDWATER

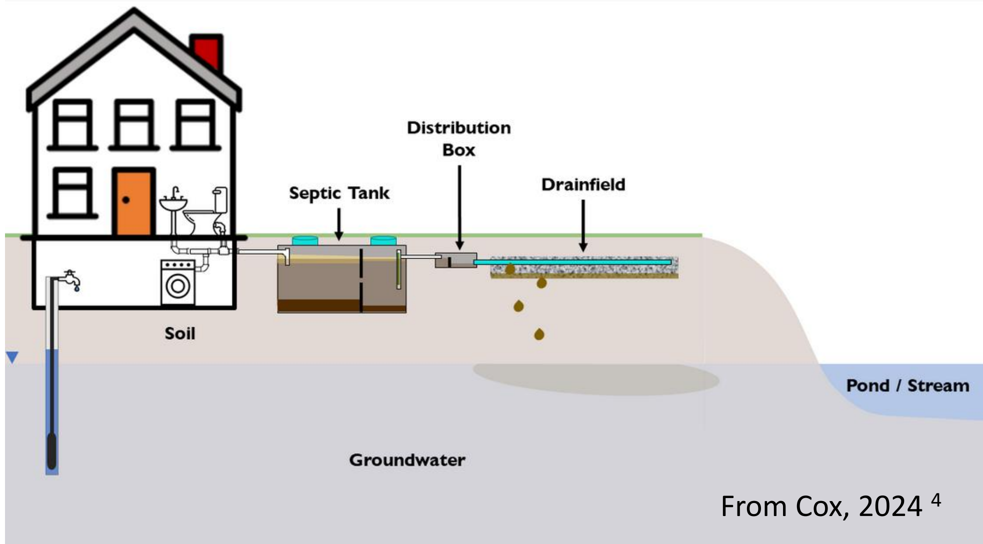
Even in the best circumstances, some pollution is discharged…

Modern nitrogen (N) reducing OWTS technologies are highly effective at minimizing pollution from OWTS [1,2,3]

Many coastal communities rely on OWTS also rely on groundwater for potable water

High densities of older conventional and substandard OWTS in coastal zones increase risk to potable water supplies and coastal surface water quality from nitrogen pollution

Preliminary research demonstrated positive correlation between OWTS density and groundwater nitrogen levels [5,6,7,8] – **Here we confirm this relationship, apply it to aquifer soil type and quantify risk to drinking water resources**

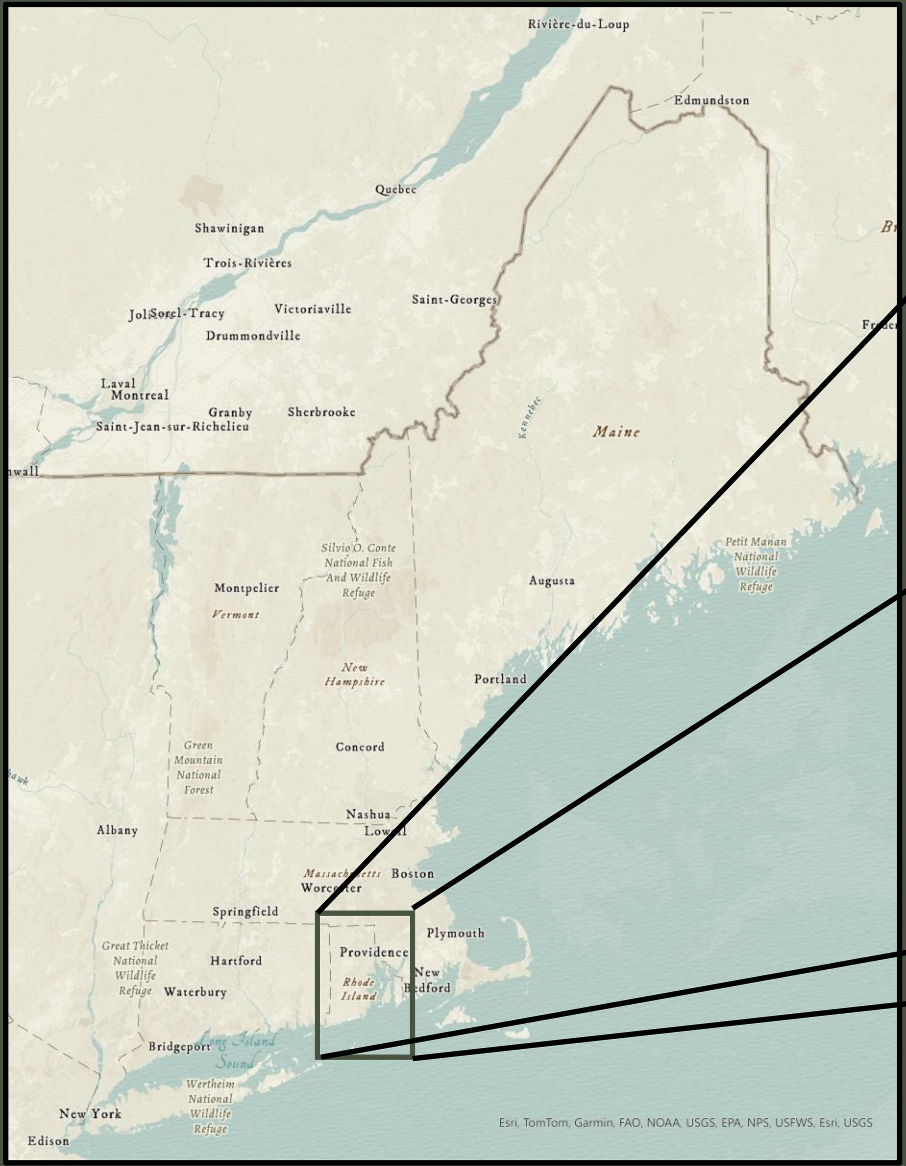


From Cox, 2024 [4]

CHARLESTOWN

STUDY AREA AND SETTING

RHODE ISLAND



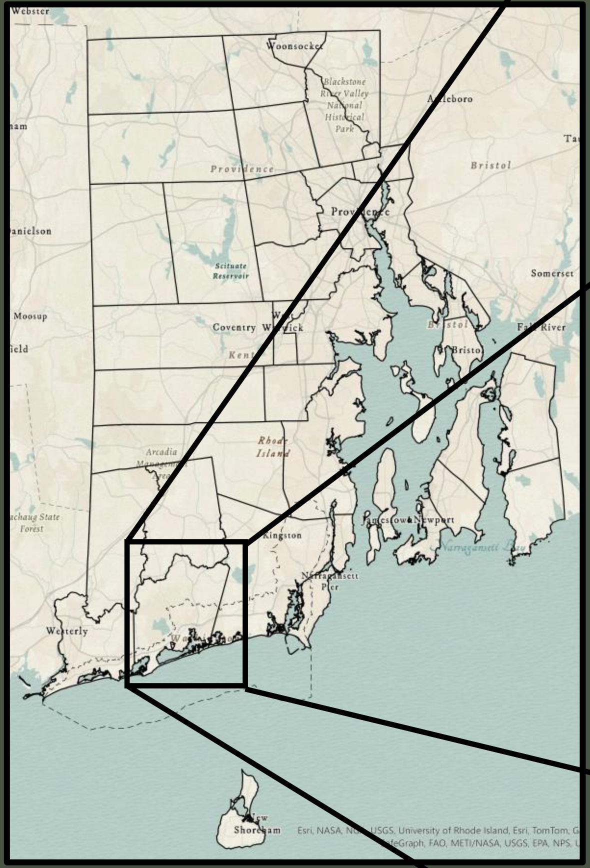
Rhode Island aka "Little Rhody"

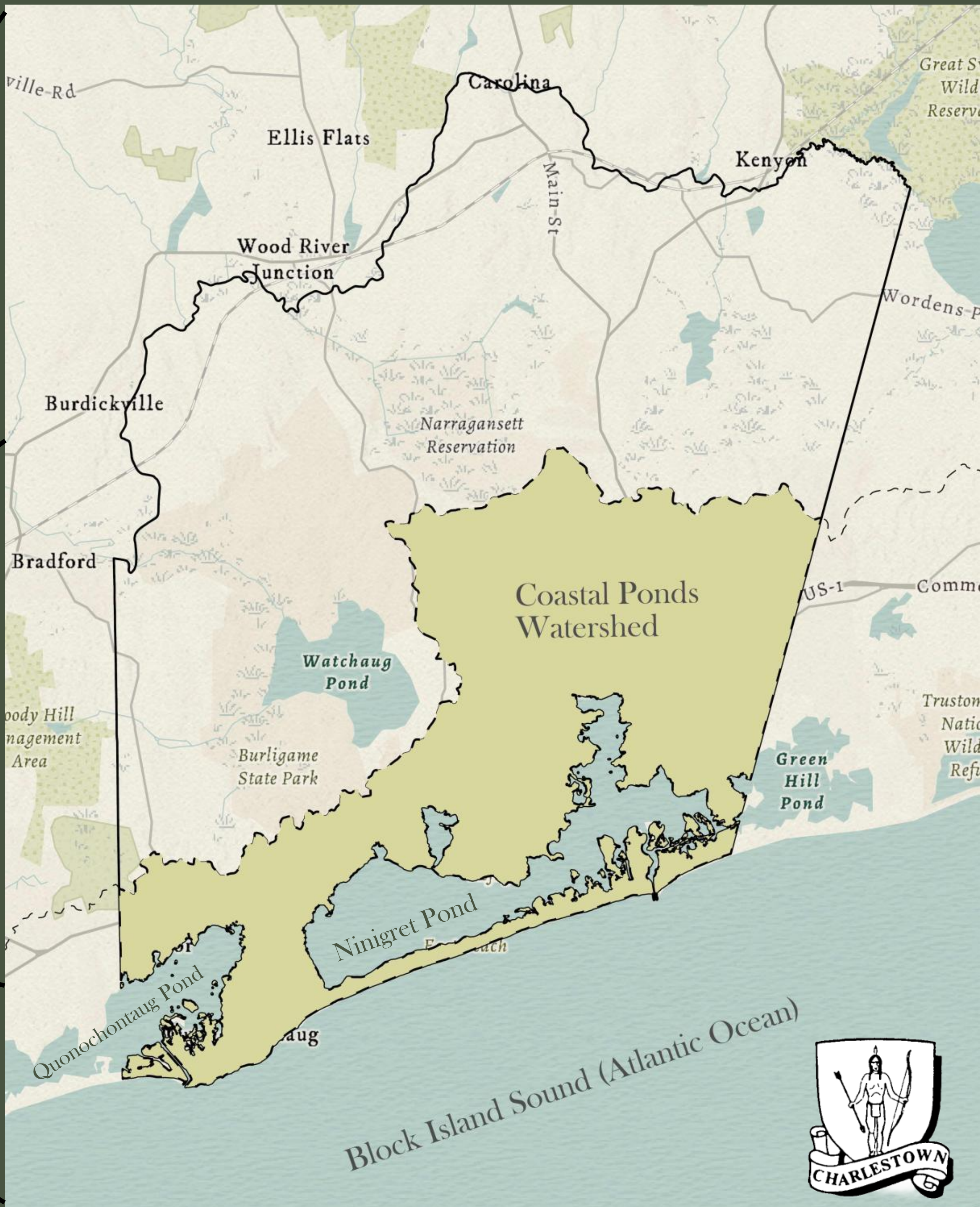
- Has over 125,000 OWTS
- Sensitive resources
- South shore salt ponds
- Narragansett Bay
- Groundwater Resources
- High development pressures

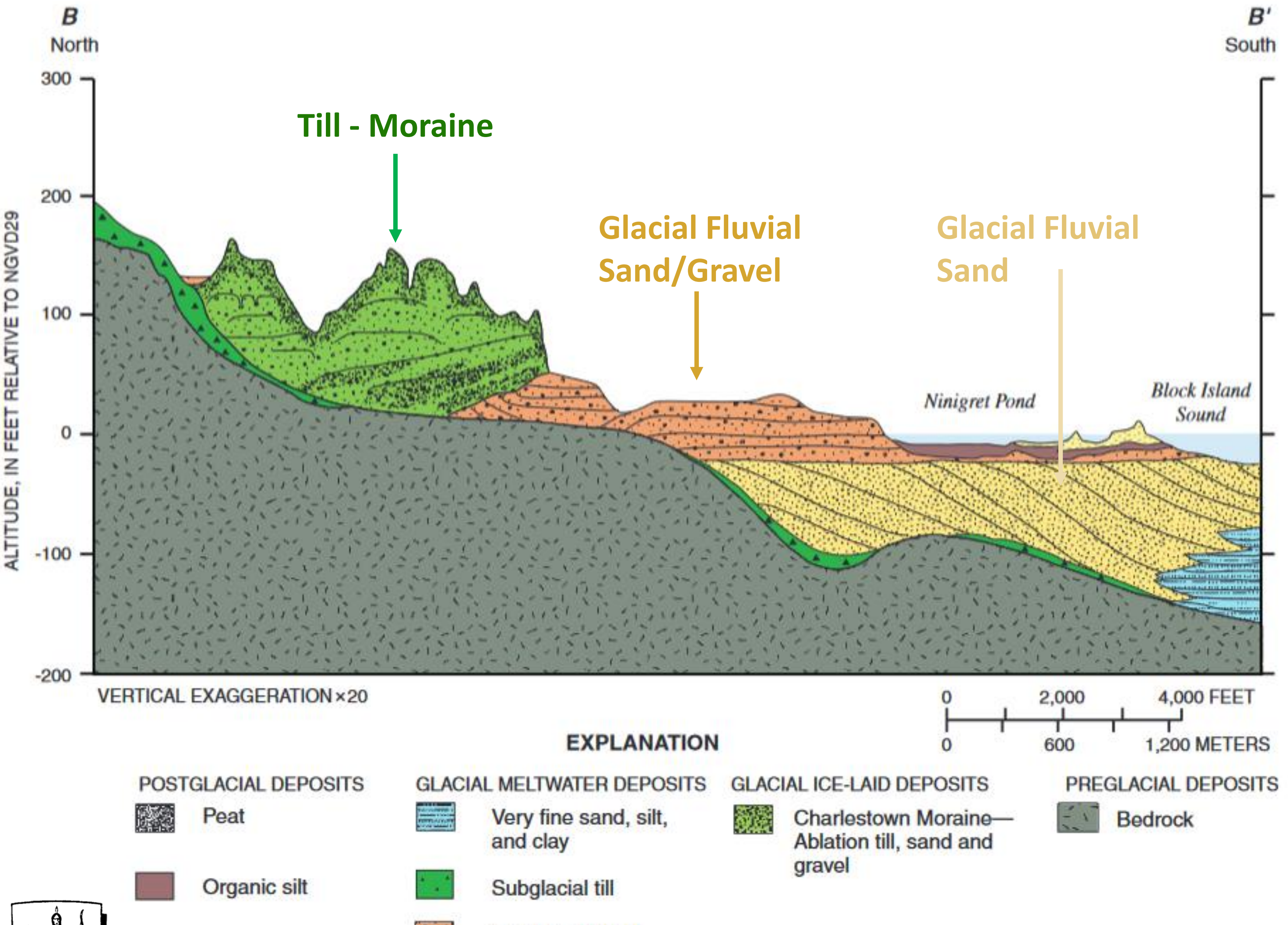
STUDY AREA AND SETTING

CHARLESTOWN – AN EXAMPLE OF A COMMUNITY RELIANT ON OWTS

- A coastal community located on the South Shore of RI, 100% OWTS and 100% local groundwater for potable supply
- Situated on three coastal lagoons and associated barriers and headlands
- Multiple beaches, coastal recreation, coastal industry, rentals and high value vacation properties
- About half of the Town lies within the Coastal Salt Ponds Watershed







From Masterson et al., 2007

COASTAL PONDS REGION
GEOLOGIC SETTING

- Dominated by glacial geology overlying Paleozoic bedrock
- South shore of RI characterized by sandy barrier beaches and coastal pond complexes separated by unconsolidated glacial till headlands
- Glacial till dominates the Charlestown recessional moraine feature which spans all of southern RI from west to east
- Charlestown moraine watershed boundary of the coastal ponds watershed

COASTAL PONDS REGION

GEOLOGIC SETTING

- Seaward of the Charlestown moraine geology is dominated by glacial fluvial sand and gravel
- Two primary soil parent materials
  - Glacial Fluvial – Stratified Sand and Gravel, high hydraulic conductivity (0 to 400 m/d),
  - Till – Unconsolidated sand, silt, clay and gravel, low hydraulic conductivity (10^{-8} to 4 m/d)

Photos by Town of Charlestown

PROBLEM / ISSUES

Charlestown is community reliant on OWTS!

- 2/3 of dwelling units located within the Salt Ponds Region Watersheds
- Some of the densest developed areas on the south shore of RI
- Some areas have >10 dwelling units per acre situated adjacent to coastal resources, all using OWTS and private wells
- ~80% of systems do not utilize modern Nitrogen Reducing Technology
- 80% of groundwater N originates from OWTS

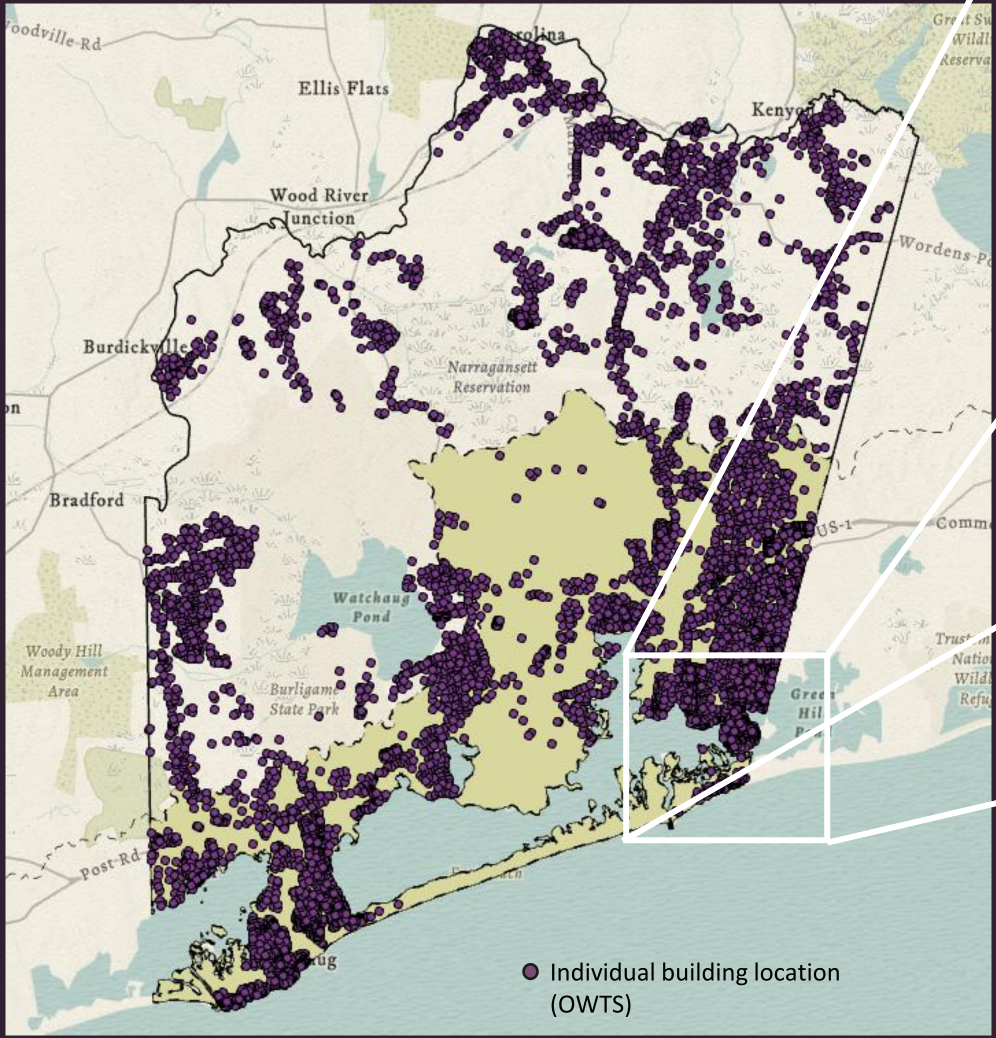
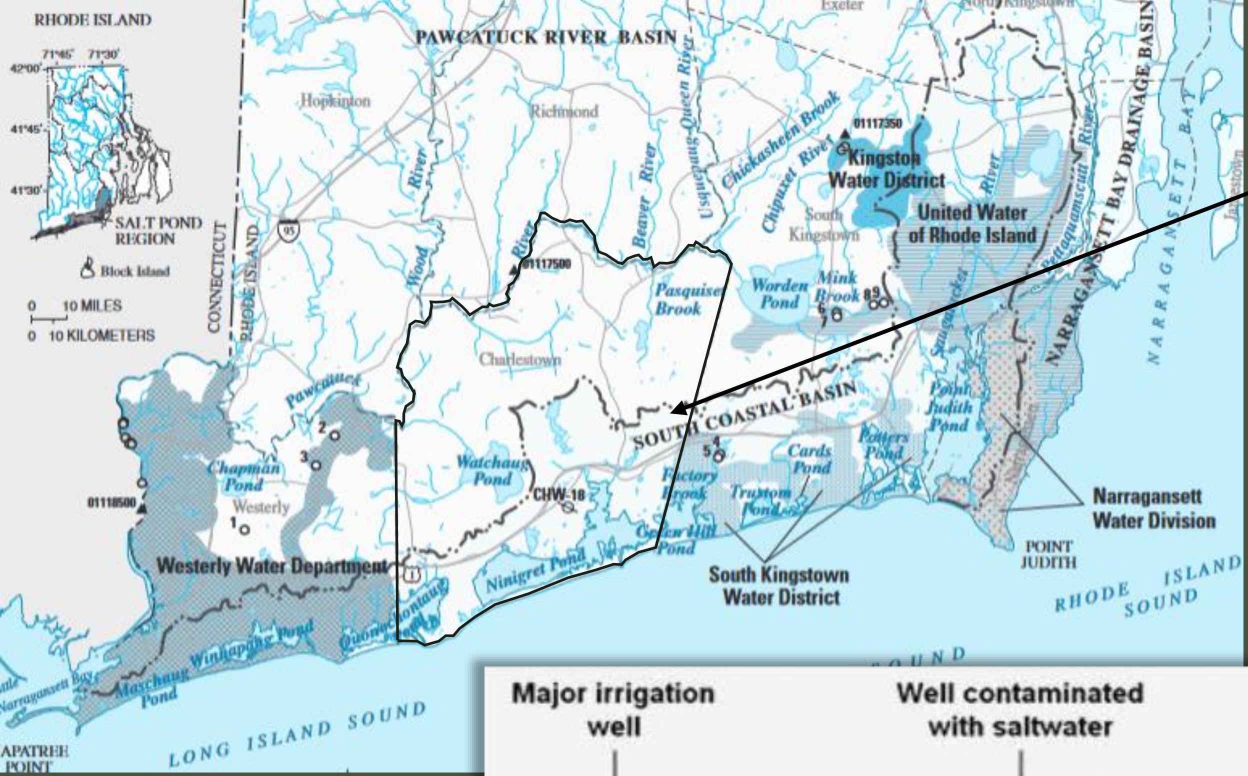
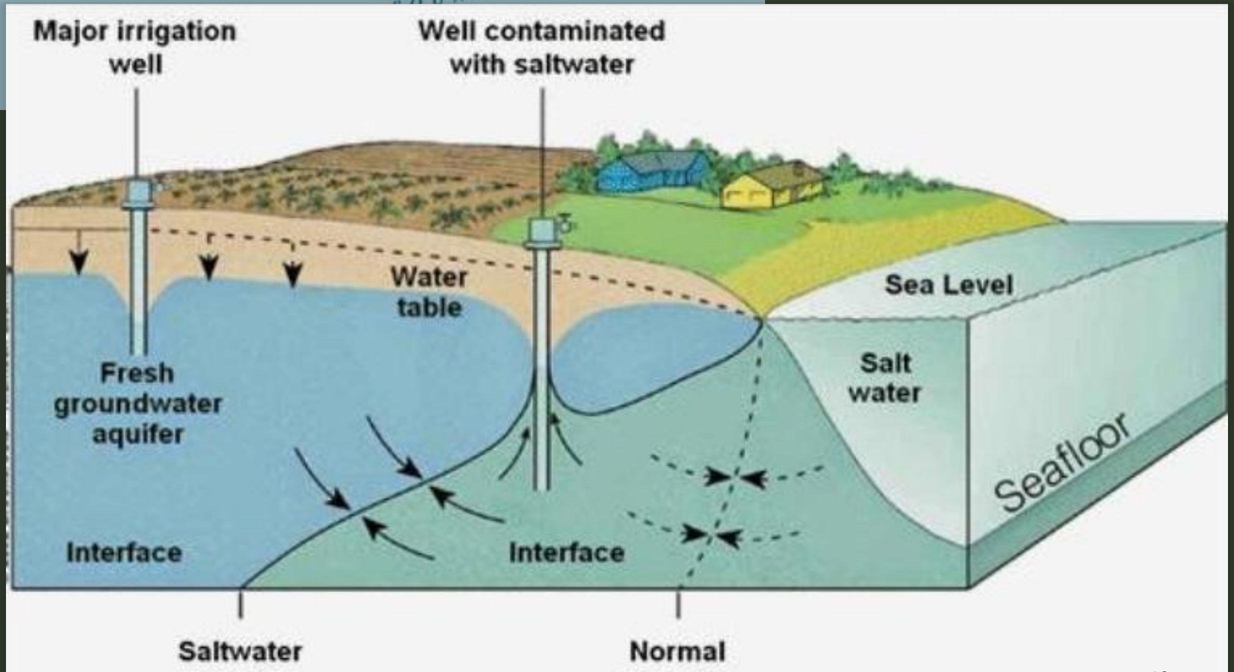


Photo by Town of Charlestown, 2022



(Masterson et al 2007)

No large public water systems



(Abd-Elaty et al 2018) [10]

PROBLEM / ISSUES

- Groundwater for drinking primarily through individual private onsite wells
- In the coastal zone, wells are typically shallow dug wells to minimize saltwater intrusion
- Shallow wells, small lots, high density of older septic systems = impaired groundwater
- Wells exceed the EPA action limit for NO3 in drinking water of 5 mg/L and some exceed the 10 mg/L MCL.

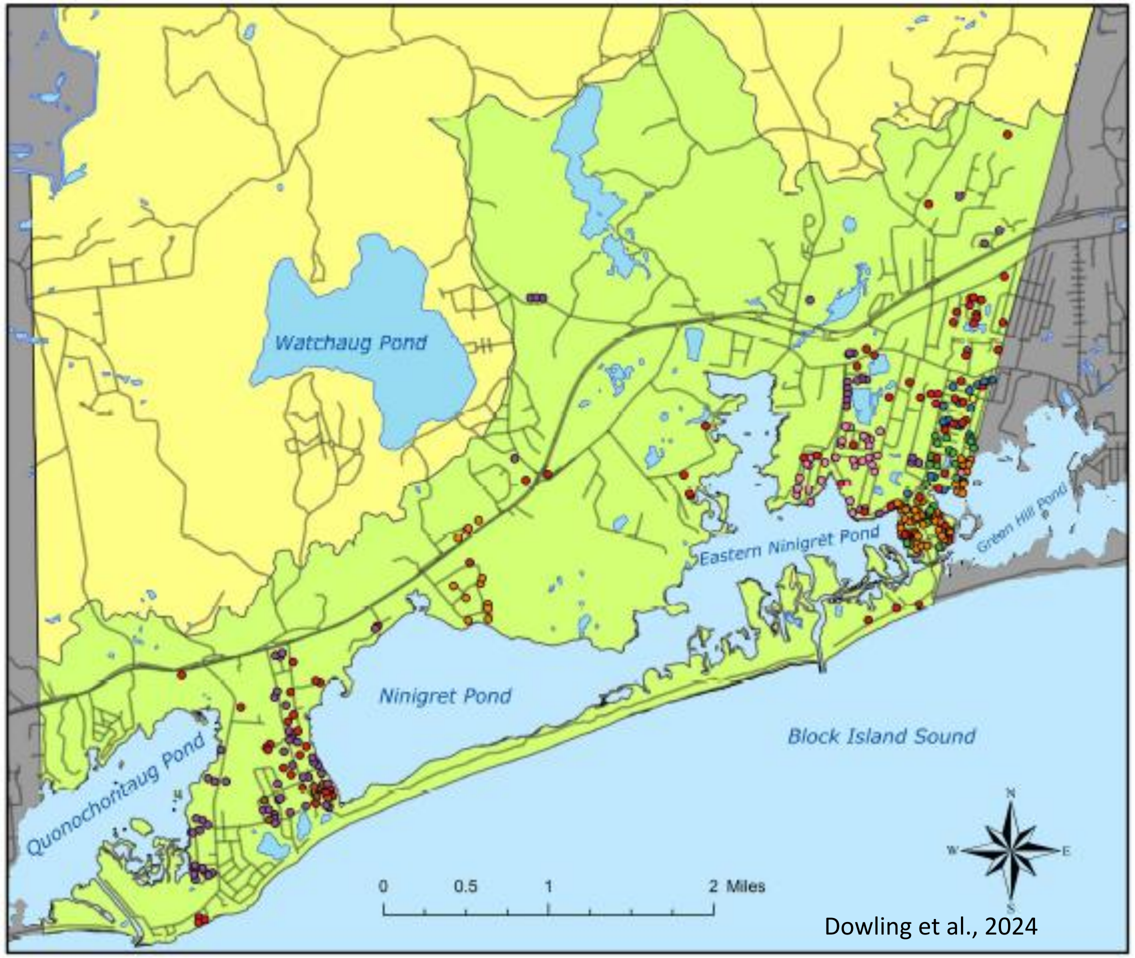
METHODS - STUDY DESIGN

- Examine the relationship between OWTS density and groundwater nitrate-nitrogen concentration
- Assess the impact of soil parent material
- Model nitrate distribution, and
- Evaluate pollution risk to GW

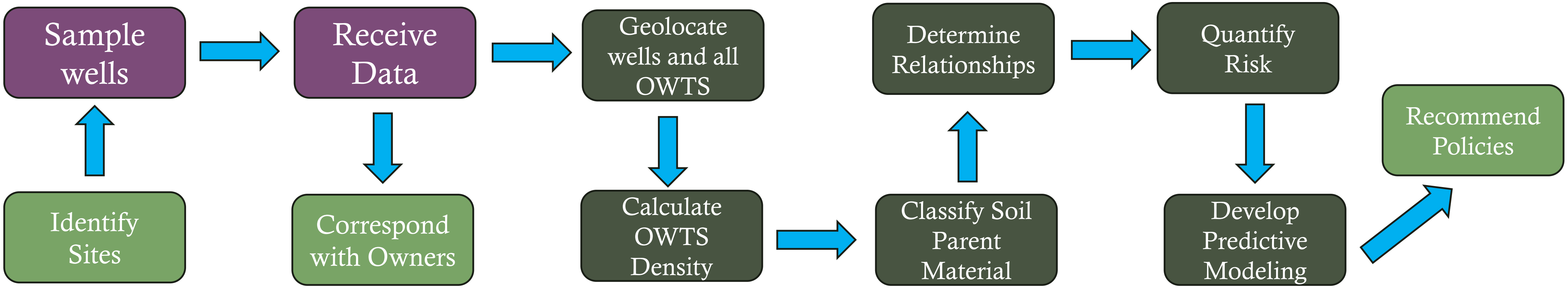
Photo by Town of Charlestown, 2022

METHODS - STUDY DESIGN

- Coordinated with town residents as part of public health community engagement to provide free private well sampling including nitrate nitrogen,
- 367 private well nitrate nitrogen samples collected from 2008 to 2022,
- OWTS density calculated in glacial till and fluvial aquifer areas,
- Regression analysis conducted to assess the relationship and quantify risk to potable water,
- Developed a model to predict groundwater nitrogen concentrations

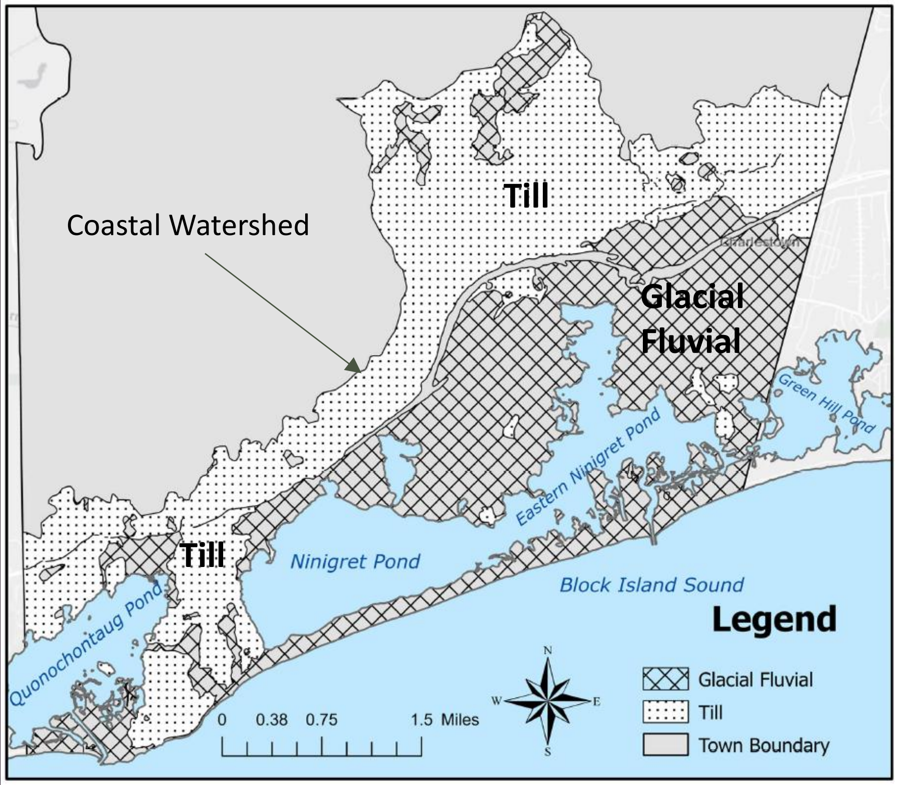


Dowling et al., 2024

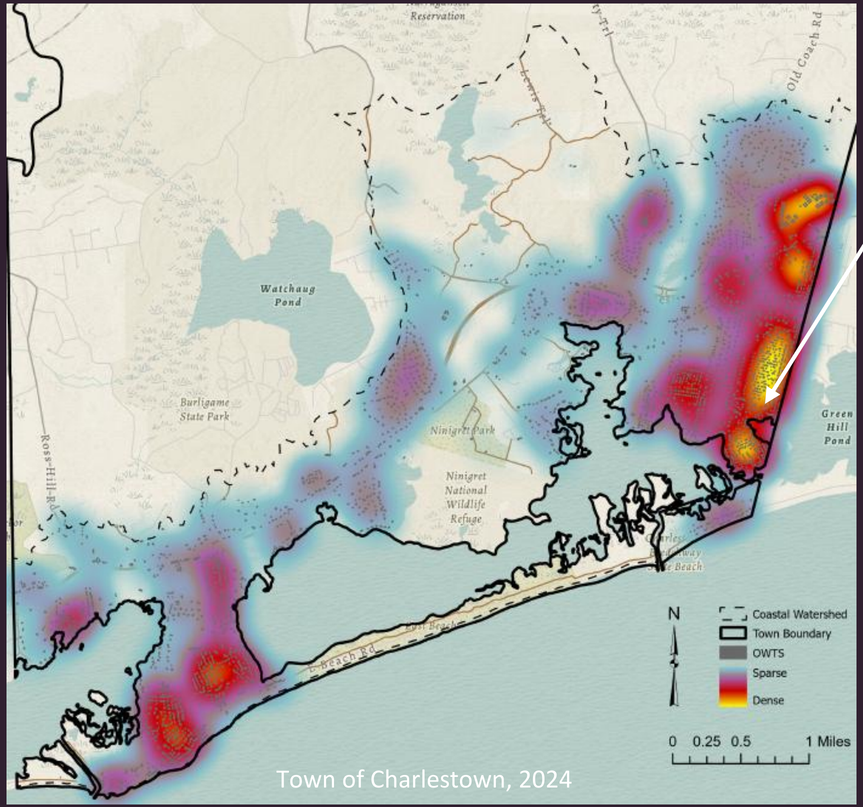


METHODS - STUDY DESIGN

- Spatial analysis to determine OWTS density relative to sampled potable well locations and nitrate concentration in well water
- OWTS density (units per acre) calculated in glacial till and fluvial areas



Dowling et al., 2024



OWTS Density
>10 per acre

- The number of OWTS within a 400 ft radius of each well was used to determine OWTS density
- Regression analysis using groundwater nitrate N concentration and OWTS density
- Cumulative probability distribution - proportion of samples with nitrate values in ten OWTS density categories ranging from (0.1 < to >9 OWTS/acre)

SOURCE WATER NO3-N POLLUTION RISK

Table 1. Pollution risk for maximum NO_3-N concentration in source water in the last five years

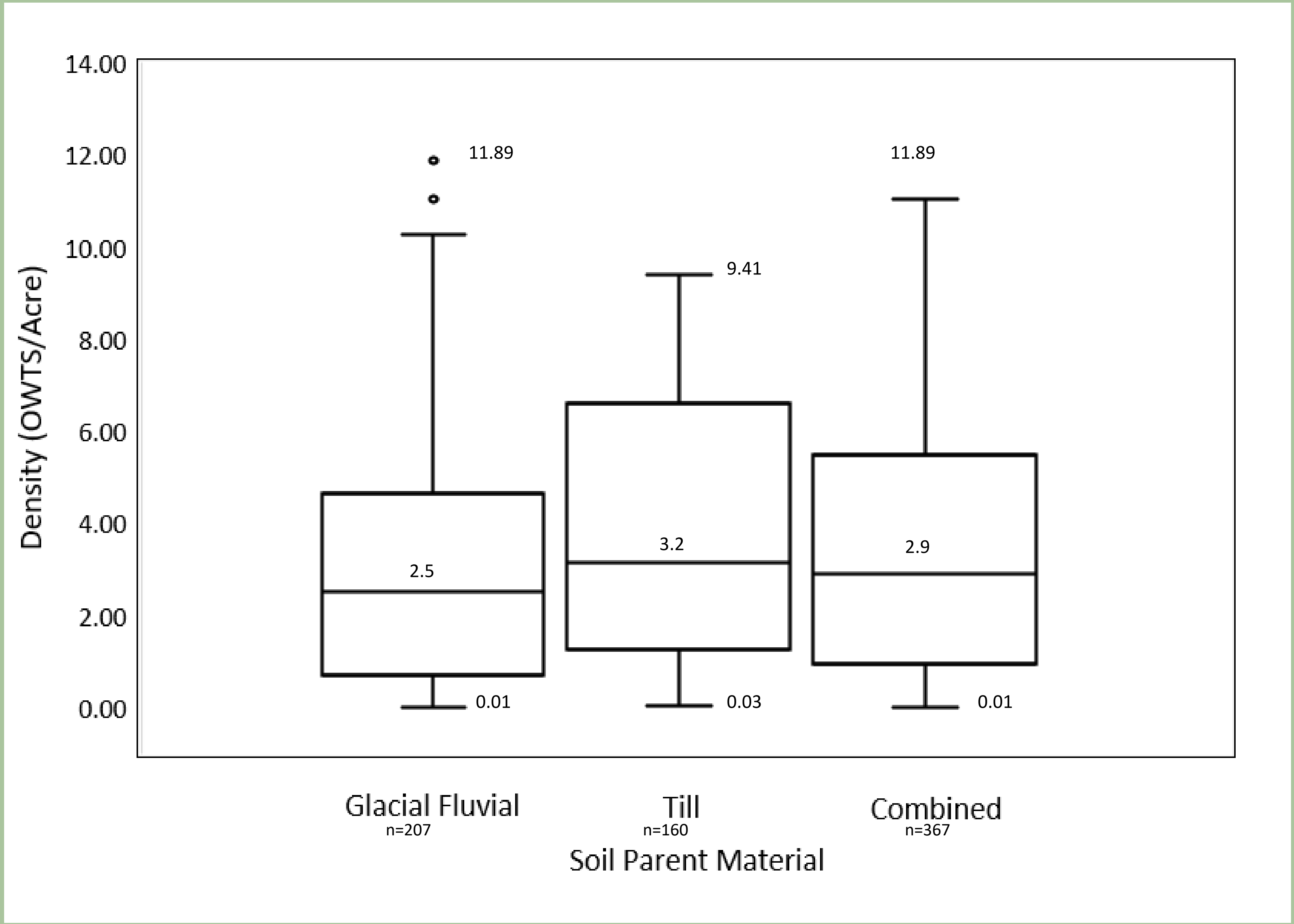
Risk rating	Concentration (mg/LNO_3 -N)	Description of risk
Low	<0.5	Nitrate levels in groundwater have been consistently low.
Medium	0.5–2	Nitrate levels in groundwater are somewhat higher than background levels, which may indicate contribution from human activity.
High	2–5	Nitrate levels in groundwater are higher than background levels, which may indicate contribution from human activity.
Extreme	>5	Nitrate levels in groundwater are higher than half the US EPA standard for nitrate. This indicates significant contribution from human activity. A program to reduce nitrate may be helpful.

Source: Reprinted from URI and RIDOH (2010).

- Low Risk <0.5 Background
- Medium Risk
- High Risk - Health risks observed in concentrations >2.5 mg/L
- Extreme Risk – EPA Action Level = ½ the MCL

RESULTS

OWTS Density at sample points
by Soil Type



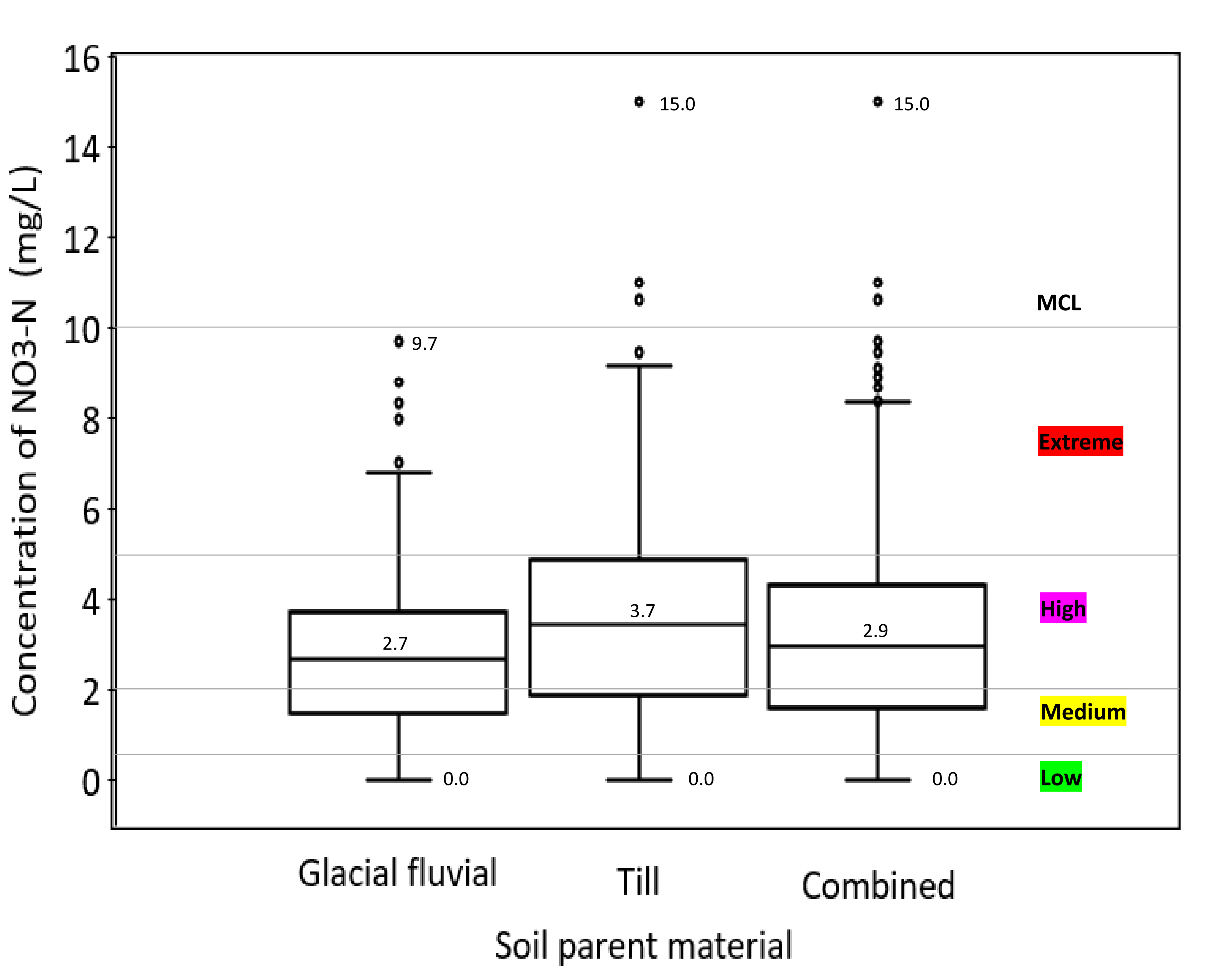
RESULTS

Groundwater Nitrate Concentration by Soil Type

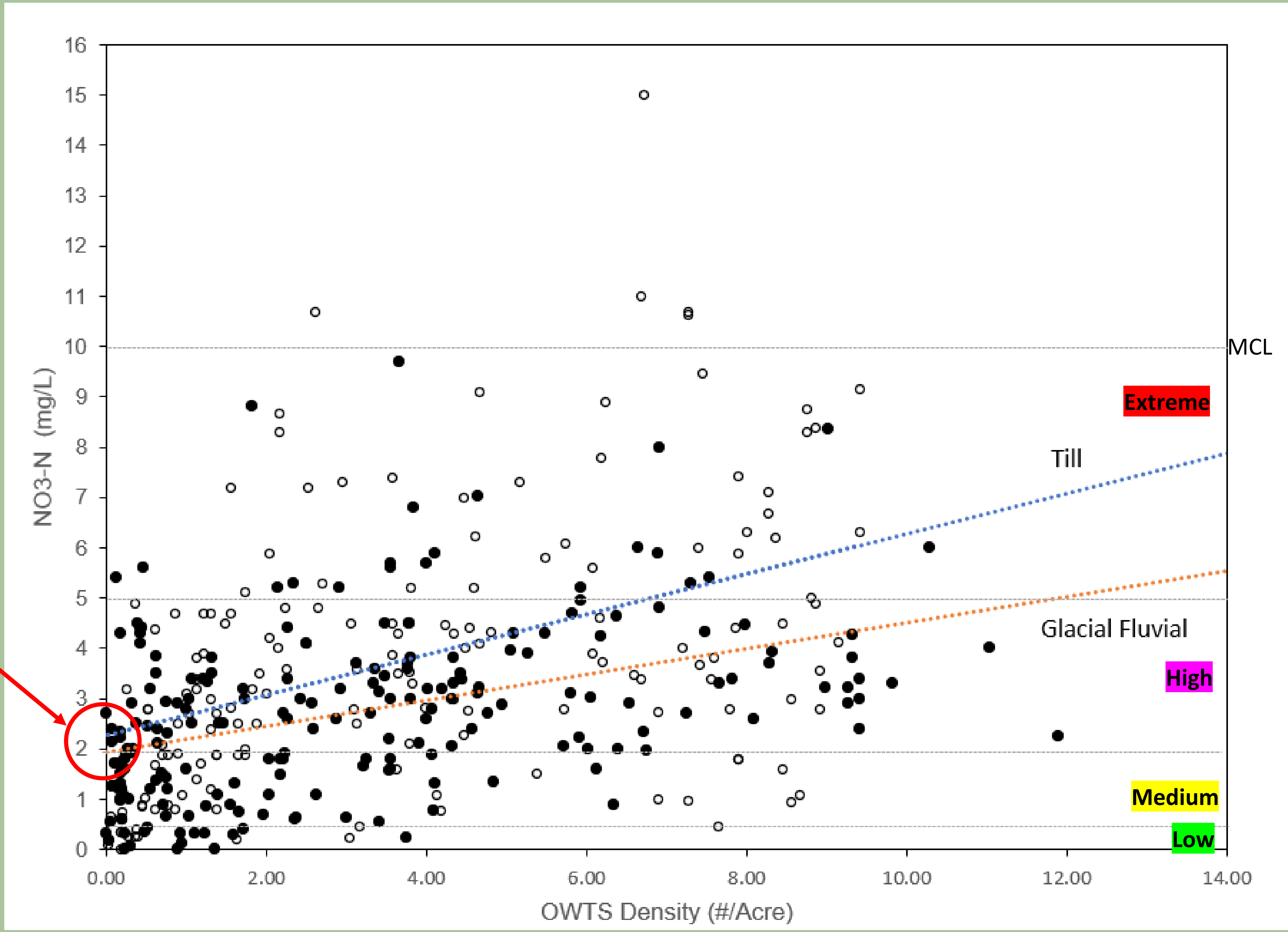
- Groundwater nitrate concentrations from all sites combined (n=367), ranged from 0-15 mg/L, with a median of 2.9 mg/L

- In glacial fluvial soil parent material (n=207), nitrate concentrations ranged from 0.0 to 9.7 mg/L, with a median value of 2.7 mg/L

- In till soil parent material (n=160), nitrate concentrations ranged from 0.0 to 15 mg/L, with a median value of 3.7 mg/L



RESULTS



Linear Regression

- Relationship between OWTS density and well water nitrate concentration
  - Till (open circles; n = 160)
  - Glacial fluvial (closed circles; n = 207)
- Y Intercept is 2.0 mg/L and 2.3 mg/L "Local Watershed Background"
- Undeveloped background typically <0.5 mg/L

POLLUTION RISK ASSESSMENT

Cumulative Distribution Frequency

$$P(X) = \left(\frac{1}{n}\right) + P(X-1)$$

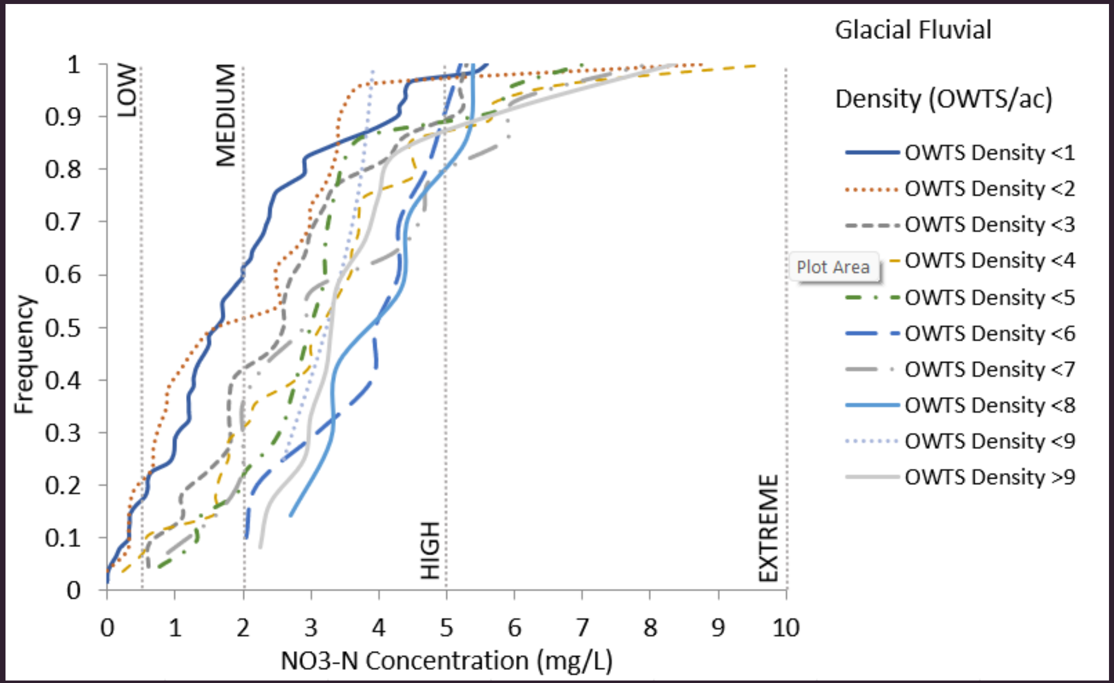
Where:

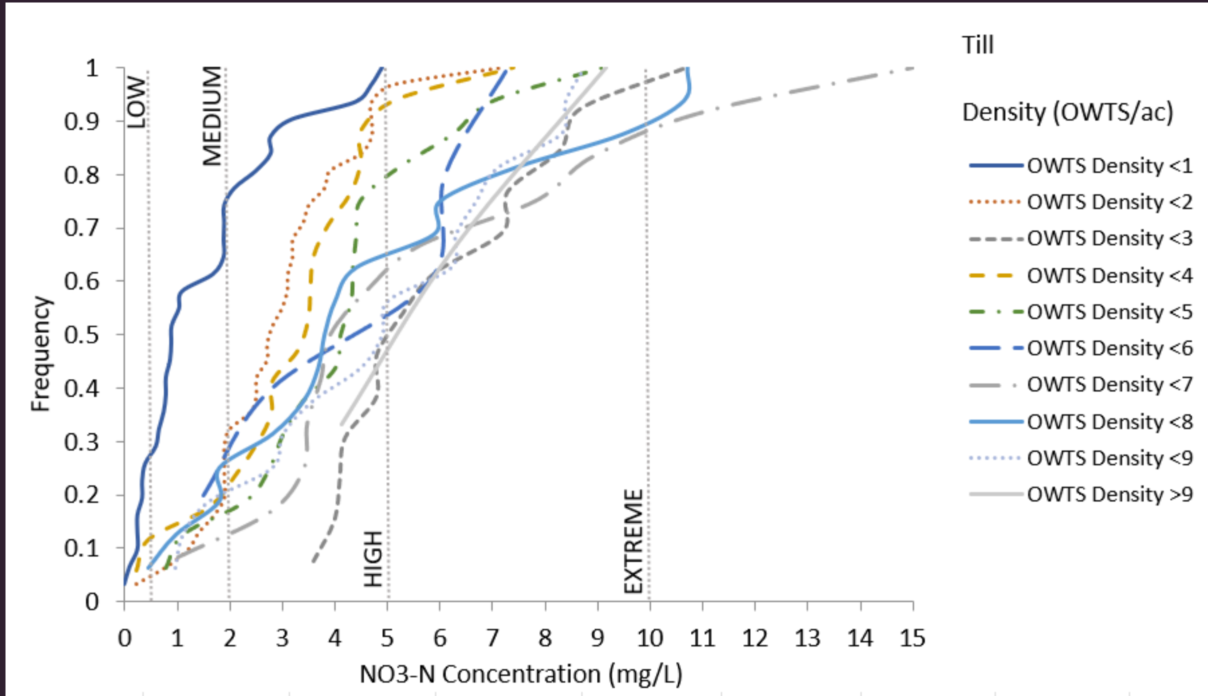
P = probability of groundwater NO−
3 concentration occurring in a sample density class;

n = number of samples in each density class; and

X = nitrate concentration detected at individual OWTS densities in each density class

Examined 10 separate density classes





POLLUTION RISK ASSESSMENT

More than 75% of all wells sampled had NO3 above the high-risk category of 2.0 mg/L

In glacial fluvial aquifers (n=207):

At OWTS densities of less than 5 per acre, fewer than 5% of the wells had probability of NO-3 greater than 5 mg/L or Extreme Risk

In areas where OWTS density exceeds 5 per acre, nearly 10% had a probability of NO3-N above 5 mg/L – Extreme Risk

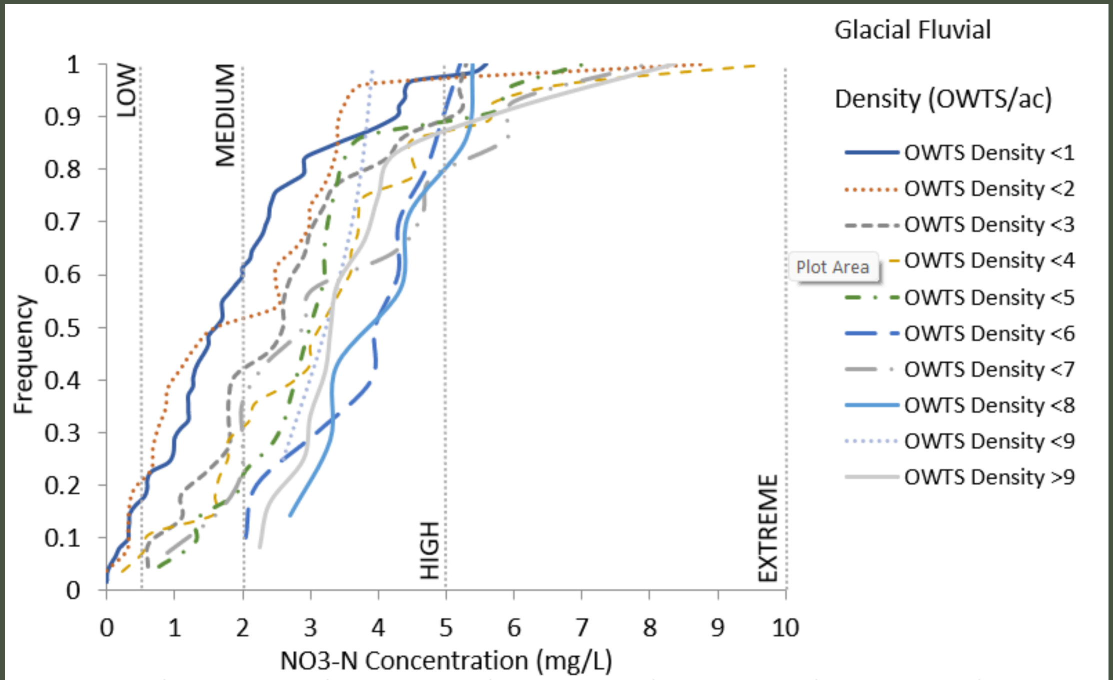
In till aquifers (n=160)

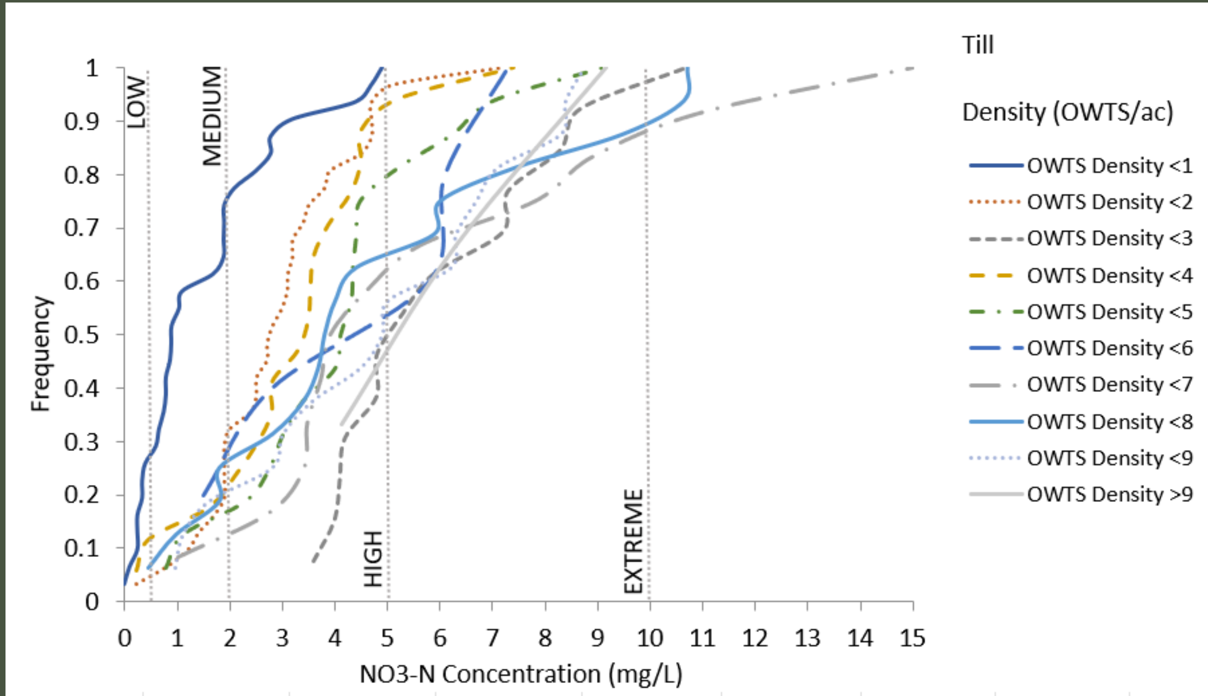
Higher proportion above the Extreme Risk threshold of 5 mg/L

At 0-2 OWTS per acre, 10% or fewer wells exceeded 5 mg/L

BUT – at 2-3 OWTS per acre, 50% of the wells exceeded 5 mg/L NO3-N and 8% exceeded the 10 mg/L MCL

Extreme Risk is expected in Till aquifers with OWTS densities of 2-3 per acre!

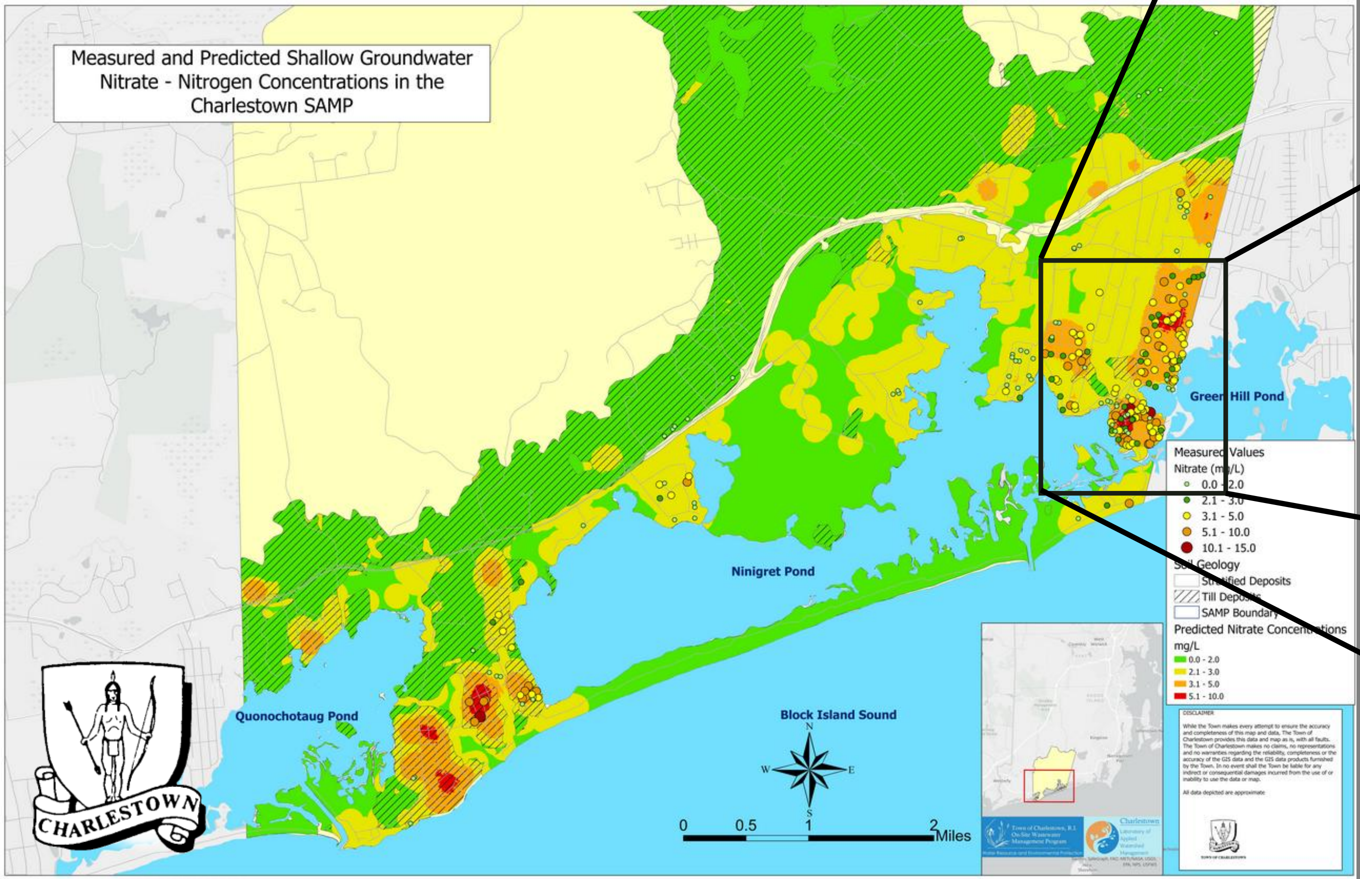


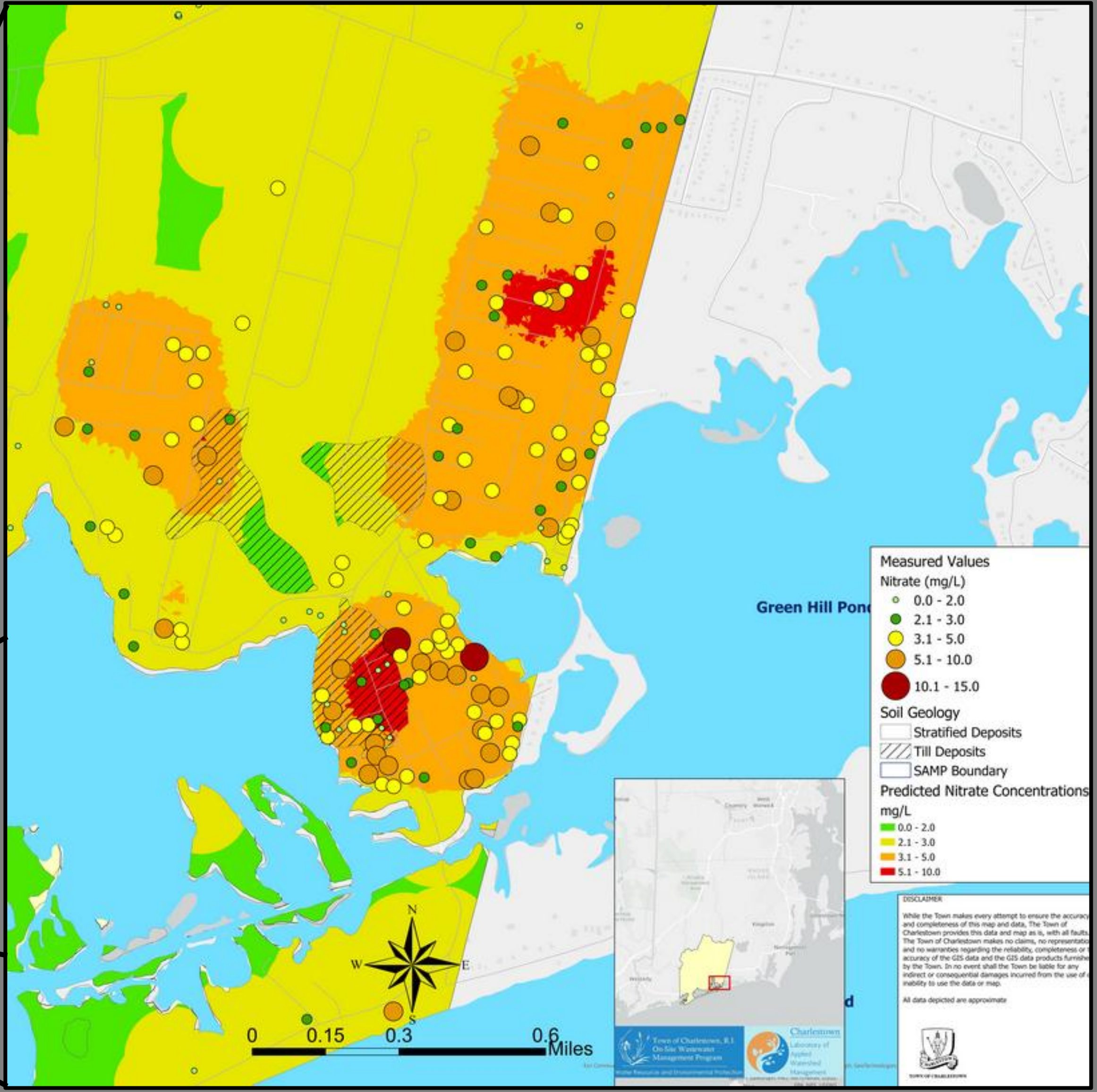


PREDICTIVE MODELING

<u>Using regression analysis predictive modeling conducted using ArcGIS Pro.</u>

Already used as a OWTS permitting and planning tool in RI





POLICY IMPLICATIONS

- Facilitate local OWTS management programing to develop OWTS tracking databases
- Promote the in-kind upgrade of conventional and substandard OWTS to N Reducing Technology
- Use risk-based analysis to identify at risk sites to fund upgrades through grants, appropriations etc…
- Existing OWTS density, predicted groundwater N concentrations and soil parent material should be considered when permitting new OWTS

CHARLESTOWN

CURRENT USE OF FINDINGS

- The coastal watershed in the Town of Charlestown requires a 61% total N load reduction for its receiving water bodies to meet state of RI surface water quality goals.
- If all 2,164 conventional OWTS in this jurisdiction were upgraded to modern N reducing technology, a total N load reduction by nearly 40%
- Using findings from this study, Charlestown has facilitated the upgrade of 30 most at risk OWTS in this watershed through EPA Southeastern New England Program funding

CONCLUSIONS

- OWTS density and aquifer soil type significantly impact groundwater nitrate levels
- Glacial till areas at higher risk for nitrate pollution
- Importance of informed land use and water management policies

PROJECT FUNDING AND SUPPORT

This research has been funded by the Town of Charlestown, RI through its Onsite Wastewater Management Program Office as part of public health community engagement stipulated under Town Code.

Many have supported this project

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PUBLIC MEETING ABOUT OWTS AT CHARLESTOWN TOWN HALL

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