



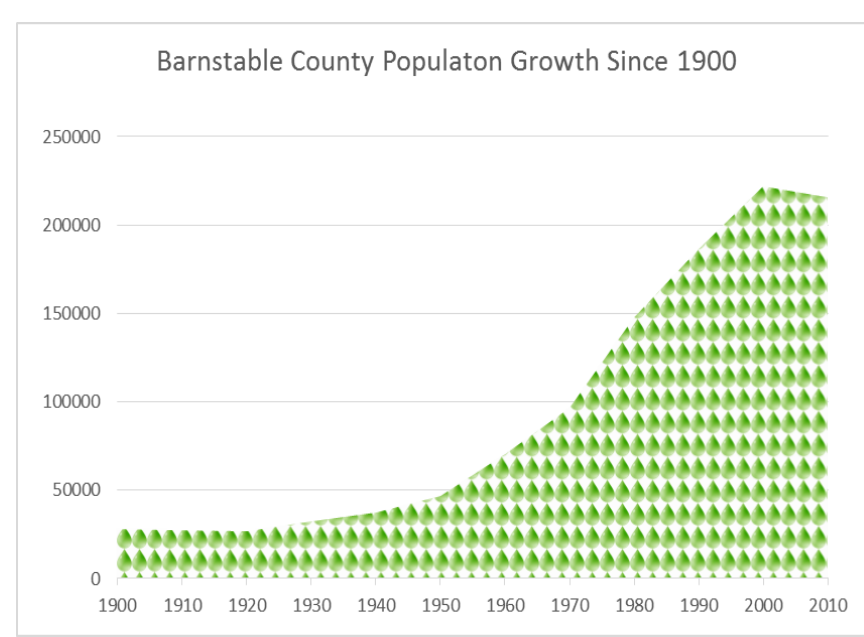
Saving Vital Waters

Estimating the Nitrogen Load Reduction from Urine Diverting Toilets In the Bass River Watershed on Cape Cod

The Problem

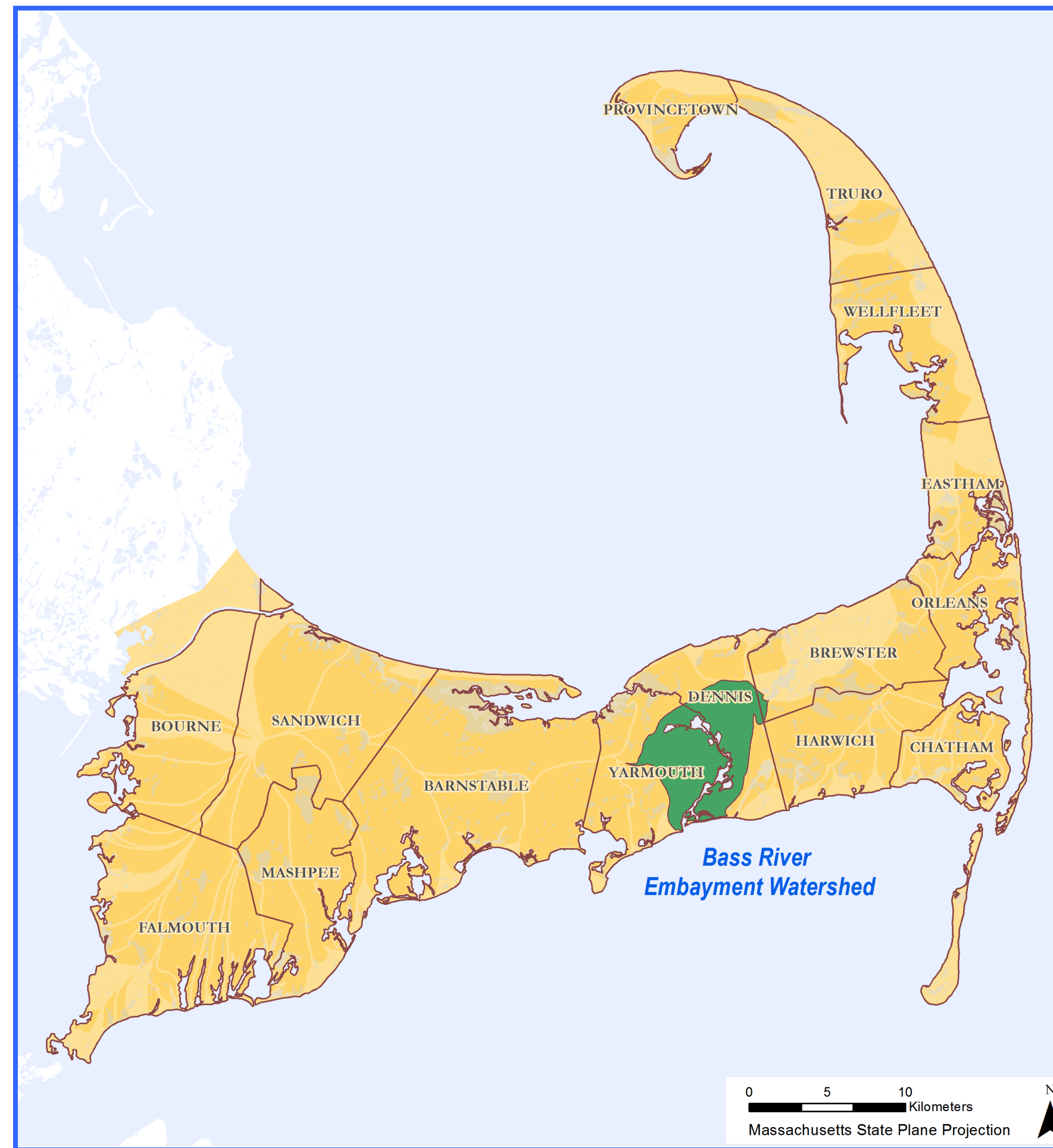
On Cape Cod, impaired water quality caused by the accumulation of nutrients in coastal embayments poses a serious threat to the economy and the natural environment. In salt water ecosystems, the main culprit is nitrogen, a potent fertilizer that can trigger a cascade of water quality degradations. This process, known as eutrophication, starts with enhanced fertility and leads to harmful, self-perpetuating phenomenon such as algae blooms, fish kills, and dead zones.

Nitrogen enter a watershed in a variety of forms, including atmospheric deposition, fertilizer runoff, and animal manure. However, the largest controllable source of the nitrogen entering embayments on Cape Cod is human waste from septic systems, which process 97% of the urine and solid excrement produced on Cape Cod.



Septic systems were once adequate for meeting the peninsula's sanitation needs, however, due to population growth in the last 50 years, the natural filtration processes they rely on just aren't able to keep pace with the vast quantity of waste we pipe into them. Today 19 of 53 embayment watersheds on Cape Cod are highly threatened by nitrogen.

The natural splendor that defines Cape Cod's sensitive marine ecosystems is being slowly ravaged by the cumulative effects of poop and pee



Straddling the towns of Dennis and Yarmouth, the critically impaired embayment system in the Bass River Watershed typifies the regulatory challenge of addressing a problem that is spatially defined by subsurface hydrology rather than physical boundaries.

The Solution

Residents and planning authorities on Cape Cod are currently considering how a variety of tactics, traditional and innovative, can be employed to address the nutrient problem. Traditional waste management systems require the construction of sewers and waste water treatment plants. While this centralized approach may be cost effective in densely populated urban areas, the dispersed footprint of residential and commercial parcels makes it unfeasible in much of Cape Cod.

The Cape Cod Commission, Barnstable County's planning authority, is currently encouraging residents to consider a suite of nontraditional approaches, including green technologies such as phytoremediation and bioretention. These are designed primarily to mitigate the impact of nitrogen that has already entered the groundwater. A more direct opportunity is offered by eco-toilets, which separate human waste at the source and capture it in a specially designed hygienic container until it can be physically removed.

A 2015 study conducted in the town of Falmouth by Wood, et al.¹ found that urine diversion flush toilets presented the most cost effective means of reducing nutrients from household wastewater. The efficacy of urine diversion toilets is conservatively estimated as around 60% reduction, at a cost of \$333 per kg of nitrogen removed.



Urine diverting toilets have a divider built into the bowl so that urine can be captured separately in a special storage container and later removed from the watershed. Around 80% of the nitrogen from human waste is excreted in urine.

Spatial Analysis Methodology

This analysis begins with an understanding that urine diverting toilets will only make an impact on nutrient flows if they are widely adopted by many individual homeowners. However, capital costs and behavior changes may present a barrier to successful deployment. In seeking to maximize the incremental benefits of the technology, the following analysis seeks to identify evidence that retrofitting toilets in publically accessible restrooms of Cape Cod's eating and drinking establishments would be a worthwhile place to start. It asks: *If all the urine produced in restaurants, bars, coffee shops, and similar commercial spaces were collected and removed, how much nitrogen could be intercepted before it ever enters a watershed?*

Eating and drinking establishments were first identified using SIC codes in the national business database Reference USA, and later reclassified based on descriptive details.

These businesses were plotted in ArcMap, clipped to the boundaries of the water

shed, and spatially joined to the parcels on which they fall. In doing so, data on annual water usage, expressed in average gallons/day, could be attributed to 310 commercial establishments in the watershed.

Where there was no actual water usage data available, averages values were developed by calculating means for other eating and drinking establishments on Cape Cod that share a similar business description and square foot range.[†]

Water usage rates from parcel data and estimations sets were added and used to derive a total annual nitrogen flow estimate for all eating and drinking establishments in the watershed. (2452.42 kg)

Following a model employed by the Cape Cod Commission, wastewater is calculated as 90% of water usage/day; kilograms of nitrogen removed per year is calculated as a function of wastewater, using a coefficient of 0.03626.

Building Footprint (Square Foot Range)	Mean Estimated Water Usage for All Description Categories in Range
0-2,499	478.62501
2,500-9,999	733.524
10,000-39,999	1,325.64

Findings

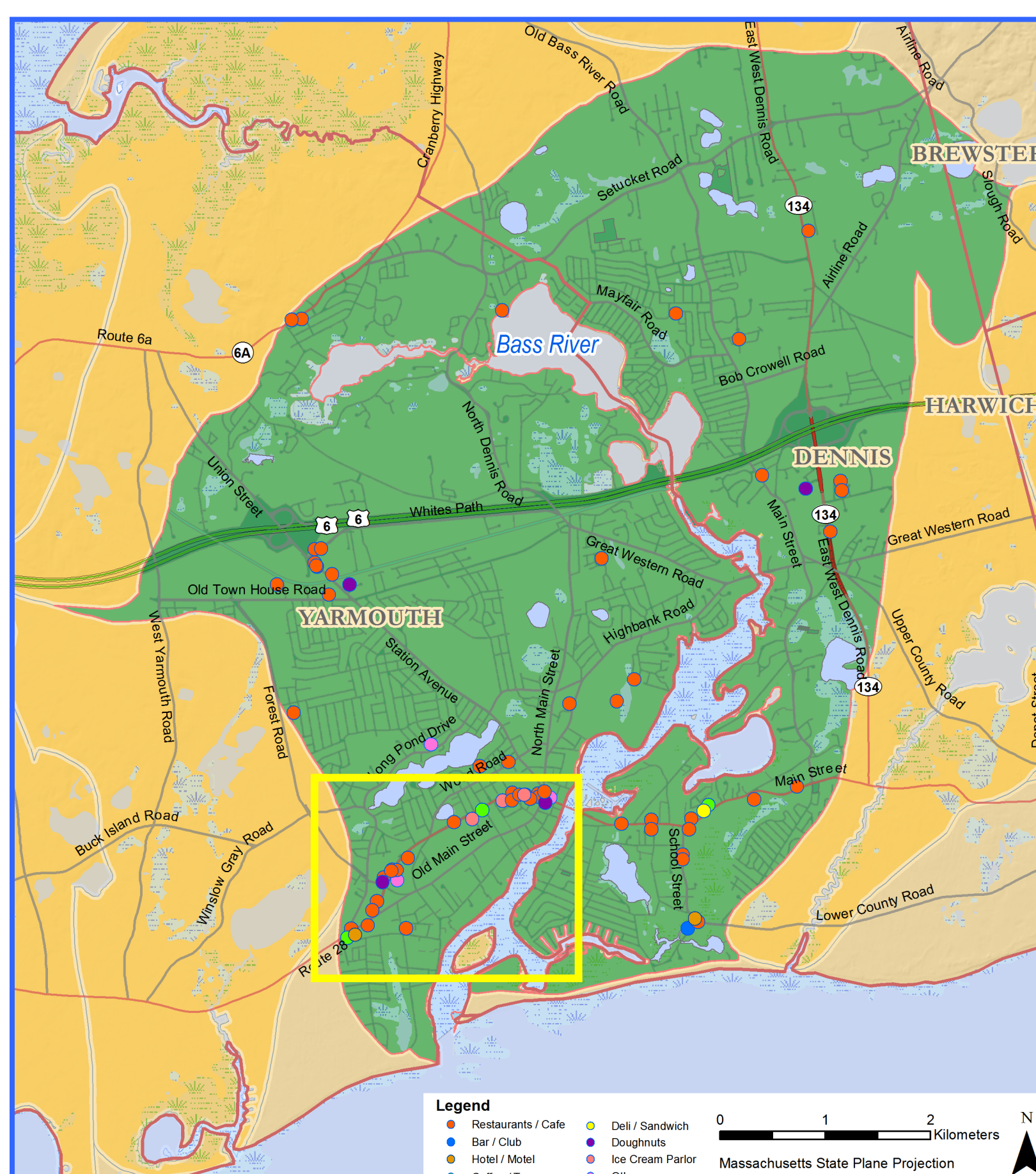
If all eating and drinking establishments in the Bass River watershed were to install urine diverting toilets, the analysis predicts that 1961.936 kg of nitrogen would be kept out of the embayment annually.

Sources of Error

Potential weaknesses in the model include:

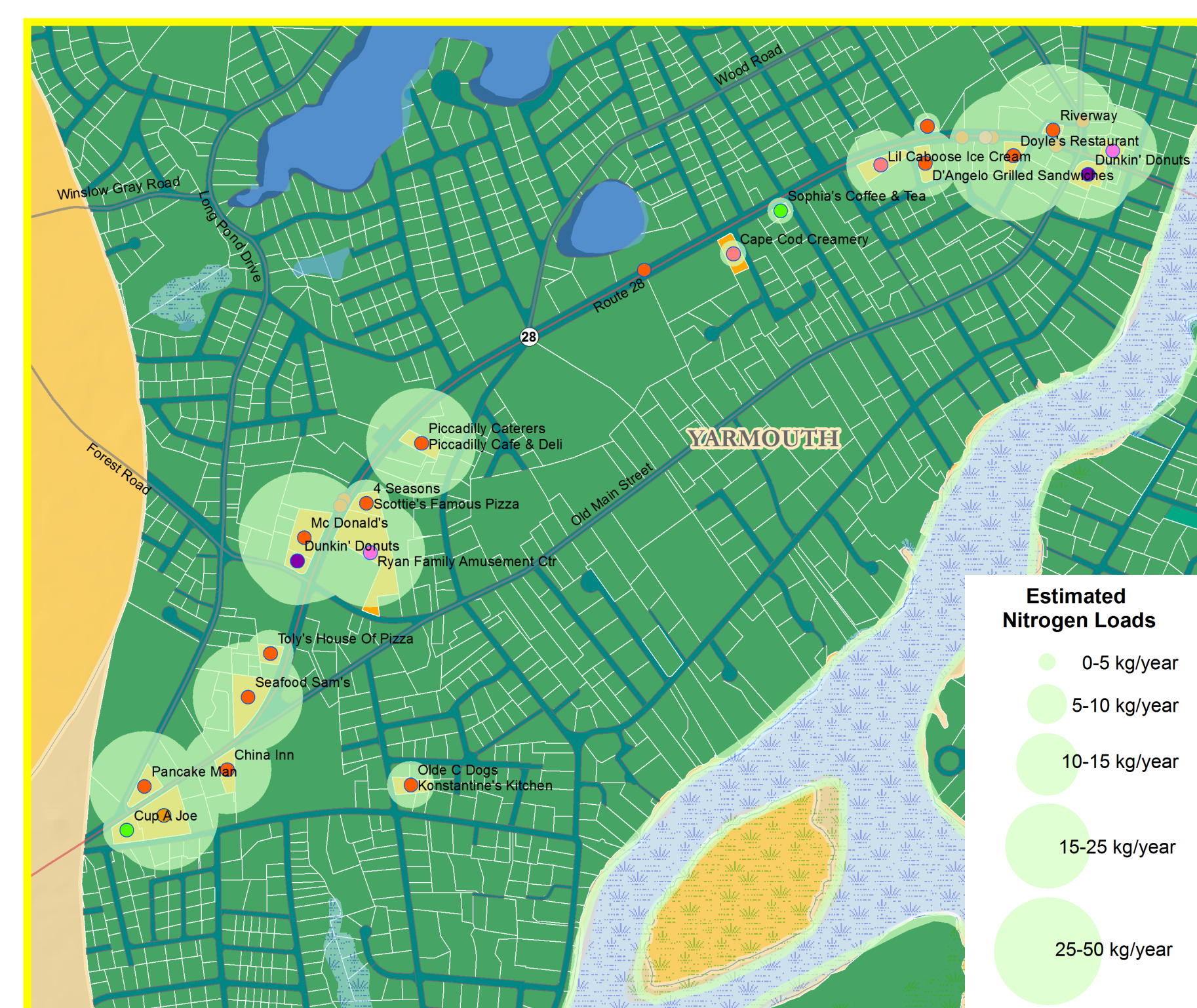
- Seasonality** - Cape Cod experiences large fluctuations in residents and visitors during summer months, complicating the calculation of annual water usage rates. (Some establishments are only open during the summer. Others, such as ice cream parlors, may only be frequently visited then.)
- Variance within parcels** - Commercial establishments are often collocated in parcels that serve mixed uses, as in strip malls or restaurants that also serve as homes. In most cases, this resulted in an higher attribution of water usage to the establishment when in reality it was shared.
- Variance between businesses** - Even if establishments have bathrooms for patrons, the rate at which they are used may vary according to the availability of nearby facilities or other convenience factors.
- Reliability of data** - The Reference USA database used to identify eating and drinking establishments may contain businesses that no longer exist, or are not visited by the public, such as caterers. Some businesses included in the analysis were unverified.

[†] Using regression analysis, none of the variables used to estimate water usage were found to be significantly significant.



Areas for Future Research

The model should be applied in other watersheds on Cape Cod to compare estimated nitrogen flows across spaces and improve the model. This model presents a method for estimating wastewater output and nitrogen flows that is based solely on water usage. If the ultimate goal is to decrease the nitrogen balance in coastal embayments, a more comprehensive model would evaluate impacts in actual water quality monitoring data, taking geological time of travel into account. Finally, other properties with publically accessible restrooms should be added to create a more robust analysis, including but not limited to airports, schools, libraries, nursing homes, police and fire stations, town halls, parks, etc.



Data Sources

- Base features from MassGIS: Major Roads by Road Type, Towns, 25K Hydrography Water Bodies, Level 3 Assessor's Parcels. (2015)
- Population Data: Minnesota Population Center. National Historical Geographic Information System, University of Minnesota. (2011)
- Hillshade Relief from USGS National Map Viewer 1/3 arc second DEM Rasters(2015)
- Business information from Reference USA from Infogroup, Inc. (2015)
- Parcel water usage data compiled from queries on the Waste Water Flow feature layer on ArcGIS online, hosted by Cape Cod Commission. (2014)
- Embayment Watershed boundaries provided by the Cape Cod Commission
- ¹ Wood, Alison, et al. "Cost-effectiveness of nitrogen mitigation by alternative household wastewater management technologies." Journal of Environmental Management 150 (2015).

- According to real and estimated water usage, 310 commercial parcels in the Bass River watershed contribute an estimated 7,357.26 kg of nitrogen to the embayment annually.
- Generally, the data show a direct positive relationship between sq. foot range size and water usage. However, when reclassified into 6 categories, businesses with square footage under 1500 show water usage that is on average 233 gal/day higher than businesses between 1500-2500 sq ft.
- Several parcels could be externally verified as the exclusive site of a current full service restaurant even when the parcel is registered as residential.

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