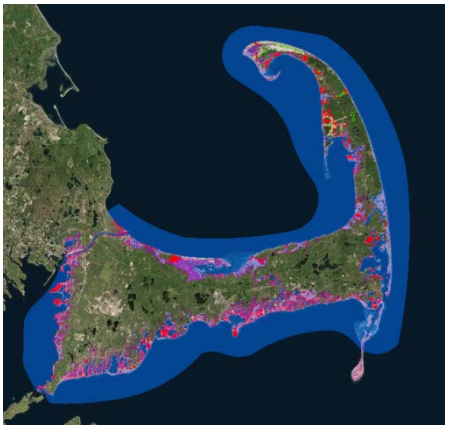
CAPE COD COMMISSION

Critical Transportation Assets and Their Vulnerability to Sea Level Rise
FINAL REPORT

February 2015



COUNTY OF BARNSTABLE MASSACHUSETTS

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Table of Contents

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Introduction

BACKGROUND

Cape Cod supports a growing year round and seasonal population. In the summer months, Cape Cod more than doubles its year-round population and on any given day in July or August, there are nearly 500,000 visitors to the Cape. As more people visit and settle on this small peninsula, the demand for and usage of the transportation system increases in Barnstable County. The Mid-Cape Highway and Route 28 are in high demand on a year-round basis. For example in 2013, Route 6 was used by 18,578,060 cars and Route 28 by over 9,529,055 cars. There is also high demand for sea travel. Over 2 million people used the Steamship Authority ferry service in 2013. Cape residents also rely on transit service. The Cape Cod Regional Transit Authority's (CCRTA) fixed and demand route services transported over 1,128,728 passengers in 2013. The demand for train service on Cape Cod is also growing. In only its second year of operation, the Cape Flyer which provides rail service between Boston and Hyannis increased the number of passengers by nearly 25%. This growing demand for all modes of transportation on Cape Cod suggests that considerable effort should be undertaken to maintain and preserve critical transportation infrastructure that already exists on Cape Cod.

Barnstable County is a unique coastal community compared to other parts of Massachusetts because it is almost completely surrounded by water (Figure 1).

Figure 1. Map of marine waters surrounding Cape Cod.

With this geography, all 15 towns in Barnstable County have access to the coast, making the Cape a popular place to live, but it also makes Cape Cod vulnerable to sea level rise.

There are three main causes of rising water - tidal fluctuations, storm surge, and sea level rise[1] (Figure 2).

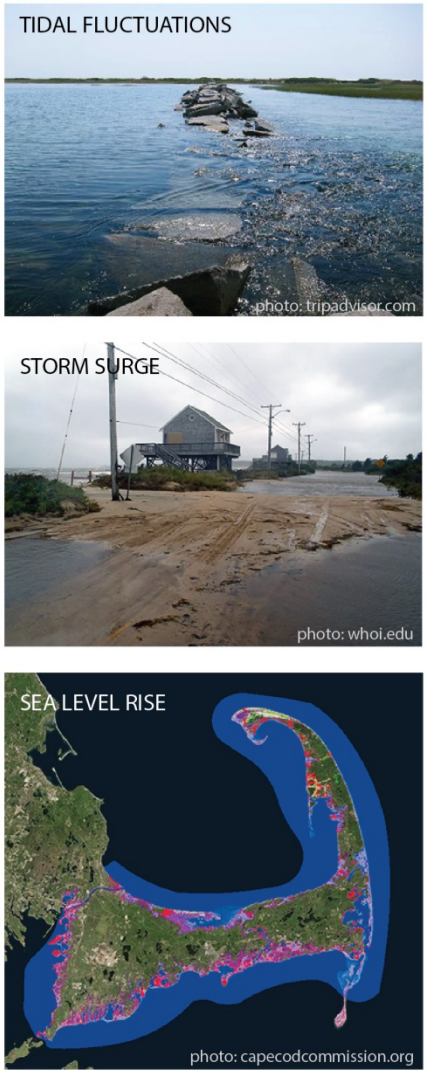

Figure 2. Causes of water rise

The most familiar cause of water rise is tidal fluctuation, which is defined as periodic variations of surface water level caused by the gravitational attraction of the sun and the moon on the Earth. Storm surge is another mechanism for water rise, defined as an abnormal rise of water generated by a storm. Massachusetts Emergency Management Agency defines “abnormal” as a level of water over and above astronomical high tide. Storm surge is caused by storms events such as heavy rain, high winds, tropical storms,

[1] Commonwealth of Massachusetts State Hazard Mitigation Plan, 2013

and hurricanes. Sea level rise is a slower, more gradual process than storm surge. It is defined as a mean increase in sea level over time and the amount of water rise varies locally and regionally. The cause of sea level rise is the thermal expansion of the ocean as they warm and the melting of glaciers. Although there is a wide range of estimates for future sea level rise in peer-reviewed scientific literature, there is a high confidence (greater than 90%) that future sea level rise will be within the ranges of 0.7 to 6.6 feet by 2100.[2]

On Cape Cod, sea level rise is a concern because the Cape is mostly surrounded by water and there are many valuable transportation assets close to the water's edge.

STUDY OBJECTIVES

The objective of this study is to understand the impact of sea level rise on the transportation network in Barnstable County. Public transportation assets in each mode (air, highway, sea, transit and rail) were examined to determine whether the asset was critical to the network and/or the community and to assess the asset's vulnerability to sea level rise.

METHOD

This study involved several activities: 1) developing online maps; 2) measuring criticality with stakeholders (defined below); 3) measuring vulnerability to sea level rise and 4) generating a list of transportation assets that are both critical to the modal system and vulnerable to sea level rise (Figure 3).

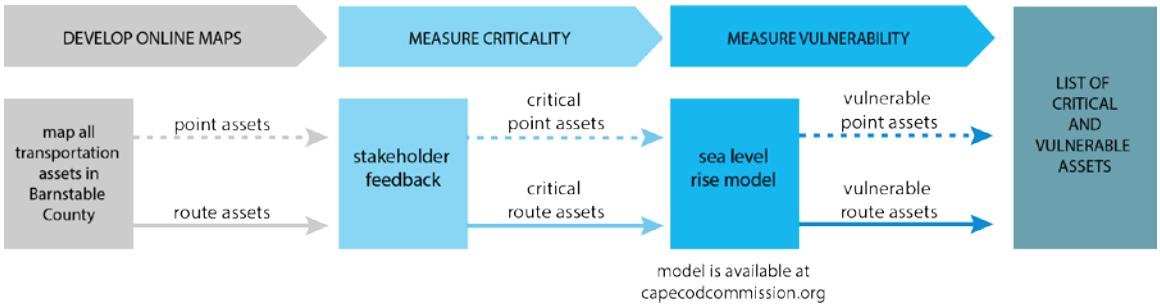

Figure 3. Outline of project activities and deliverables

[2] Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning, December 2013, Massachusetts Office of Coastal Zone Management

There are five transportation modes in Barnstable County - air, highway, rail, sea, and transit. Research was performed to determine which assets are important to the functioning on each transportation mode (Table 1). This list includes point assets, such as bridges, runways, and passenger terminals that are fixed to a single point on the land (Table 2) as well as route assets, such as roadways, bus routes, and train lines.

AIR	runway, air traffic control tower, passenger terminal
HIGHWAY	regional roadways, rotaries, roundabouts, bridges, large culverts
RAIL	track, transfer stations, passenger stations, bridges, large culverts
SEA	ferry slips, dispatch facilities, passenger terminals, parking lots, docks/piers (only if a ferry operates at the end)
TRANSIT	bus routes including roadways and bridges, hubs, maintenance facilities

Table 1. List of transportation modes and associated assets examined in this study

AIRPORT

RUNWAYS	AIR TRAFFIC CONTROL TOWERS	PASSENGER TERMINALS
Barnstable Municipal Airport	Barnstable Airport Tower	Barnstable Terminal
Cape Cod Airfield	Otis Tower	Chatham Terminal
Chatham Municipal Airport		Falmouth Airpark
Falmouth Airpark		Provincetown Terminal
Otis National Guard Airport		
Provincetown Municipal Airport		

HIGHWAY

ROTARIES/ROUNDABOUTS	BRIDGES	CULVERTS
Hyannis Rotary	Main Street Bridge (Barnstable)	Shore Rd Culvert (Bourne)
Belmont Rotary	Bourne Bridge	Town Cove Culvert (Eastham)
Bourne Rotary	Sagamore Bridge	Route 28 Culvert (Harwich)
Otis Rotary	Buttermilk Bay Bridge	Pamet River Culvert (Truro)
Orleans Rotary	Shore Rd Bridge (Bourne)	Fresh Brook Culvert (Wellfleet)
Mashpee Rotary	Frost Fish Creek Bridge (Chatham)	Black Fish Creek Culvert (Wellfleet)
Rotary at Woodend	Swan River Bridges (Dennis)	
Chatham Roundabout	Bass River Bridges (Dennis)	
Harwich Roundabout	Eel Pond Bridge (Falmouth)	
Race Lane Roundabout	Menauhant Bridge (Falmouth)	
	Herring River Bridges (Harwich)	
	Lower County Rd Bridge (Harwich)	
	Mill Creek Bridge (Sandwich)	
	Lietenant Island Bridge	
	Parkers River Bridge (Yarmouth)	
	Bass River Bridge (Yarmouth)	

RAIL

BRIDGES AND CULVERTS	STATIONS
Cape Cod Canal Bridge	Otis Transfer Station
Railroad Bridge (Barnstable)	Yarmouth Transfer Station
Barlows Landing (Bourne)	Hyannic Transportation Center
Back River Bridge (Bourne)	
Village Marsh Bridge (Sandwich)	
Culvert (Bourne)	

SEAPORT

FERRY SLIPS AND NAVIGATION	PASSENGER ASSETS	DOCKS AND PIERS
Canal Monitoring Station	Steamship Authoriy Parking Lots	Dock at NMFS
Boston Harbor Cruise Slip	Steamship Authority Terminal	Mirant Energy Dock
Hyline Ferry Slip	Hyline Ferry Terminal	WHOI pier
Steamship Authority Ferry Slips	Island Queen Terminal	MacMillan Pier
Island Queen Ferry Slip	Patriot Party Boat Terminal	
Pied Piper Slip	Freedom Cruise Line Terminal	
Baystate Ferry Slip	Steamship Authority Reservation Office	

TRANSIT

HUBS	MAINTENANCE/FUELING STATION
Hyannis Transportation Center	Maintenance Facility (Dennis)
Patriots Square Hub (Dennis)	
Mashpee Commons Hub	
Stop & Shop Hub (Orleans)	

Table 2. List of all transportation point assets identified in this study

All transportation assets listed in Table 2 were plotted on digital maps using ArcGIS online.

Representatives from the Barnstable Municipal Airport, the Highway Division of Massachusetts Department of Transportation (MassDOT), Mass Coastal Railroad, the Steamship Authority, and the Cape Cod Regional Transit Authority (CCRTA) were identified as stakeholders for this project. During stakeholder meetings, Commission Staff presented mode specific online maps. Stakeholders were asked to review the maps for errors and make additions or corrections where appropriate. They also commented on the criticality of each asset in their mode. Next, stakeholders were asked to provide volume and ridership data from the year 2013 to understand the functioning of an asset in the community. In addition to the stakeholder meetings, online maps were also presented at two Metropolitan Planning Organization meetings where the general public, members of Federal Highway Administration, and MassDOT had the opportunity to comment on the list of assets.

Commission Staff input all transportation assets into a Sea Level Rise Viewer developed by the Cape Cod Commission (http://www.capecodcommission.org/SeaLevelRise/). The model output is a list of point assets vulnerable at 1 - 6 feet of sea level rise. The model also identified portions of route assets that were vulnerable to rising sea levels. Specifically, sections of roads, train tracks, and bus routes, were identified as impassable at 3 and 6 feet of water rise. The list of vulnerable assets was then quality checked by Commission Staff to ensure the accuracy of the data.

CRITICAL INFRASTRUCTURE

This study defined a "critical" transportation asset as either:

- vital to the functioning of the modal transportation network (i.e. maintains the mobility and accessibility function of the network)
- important to the social and economic functioning of the community (i.e. provides access to employment centers or increases connectivity between community components)

This definition of criticality is similar to the one described in a recent study conducted in the Gulf Coast.[3]

[3] Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: The Gulf Coast Study, Phase 2, Task 1: Assessing Infrastructure for Criticality in Mobile, AL, U.S. Department of Transportation, September 2011, FHWA-HEP-11-029

AIR TRANSPORTATION

Stakeholders identified the runway as the most important asset to the functioning of the airport because planes cannot land safely without a runway or cleared strip of land. The air traffic control tower was ranked second and the passenger terminal was identified as the third most important asset.

Stakeholders identified the Barnstable Municipal Airport as a critical airport on Cape Cod. It is the third busiest commercial airport in Massachusetts, behind Logan Airport and Nantucket Airport. Barnstable Municipal Airport plays an important role in the community; it provides access to, from and within the region, all-season emergency transportation, and full-time jobs to area residents. The present study used emplanement and employment data to quantitatively assess criticality of the airport. In 2013, the airport had over 85,000 emplanements (the number of people departing on a commercial aircraft) and provided over 2,000 jobs. For comparative purposes, Provincetown Municipal Airport had 11,288 emplanements and generated 343 jobs. It is important to note that the Provincetown Municipal Airport is also critical, but stakeholders ranked it under the Barnstable Municipal Airport because there is no control tower and it has less emplanements.

HIGHWAY TRANSPORTATION

Highway stakeholders classified Routes 6, 6A, 28, 132 and Woods Hole Road as critical to the functioning of the highway network and to the community of Barnstable County. Urban Principal Arterial Roads, Willow Street and Route 134 were also considered critical. This study used AADT (Annual Average Daily Traffic) from 2013 to quantify network criticality. Routes 6, 28 and 132 have higher AADT than other roads on the Cape (Figure 4). Routes 6, 28, and 132 were considered important to the connectivity of Cape Cod because they provide access to town economic centers, villages, town facilities and emergency shelters. While Route 6A has a lower AADT than other roadways, stakeholders identified it as critical because it provides access to village centers across several towns in Barnstable County. Woods Hole Road has a lower AADT than other roadways on the Cape (Figure 4), but it is considered critical because it provides access to village centers and technology hubs located in Woods Hole, such as the Woods Hole Oceanographic Institution, ferry service to Martha's Vineyard the Steamship Authority, the National Marine Fisheries Service and U.S. Coast Guard.

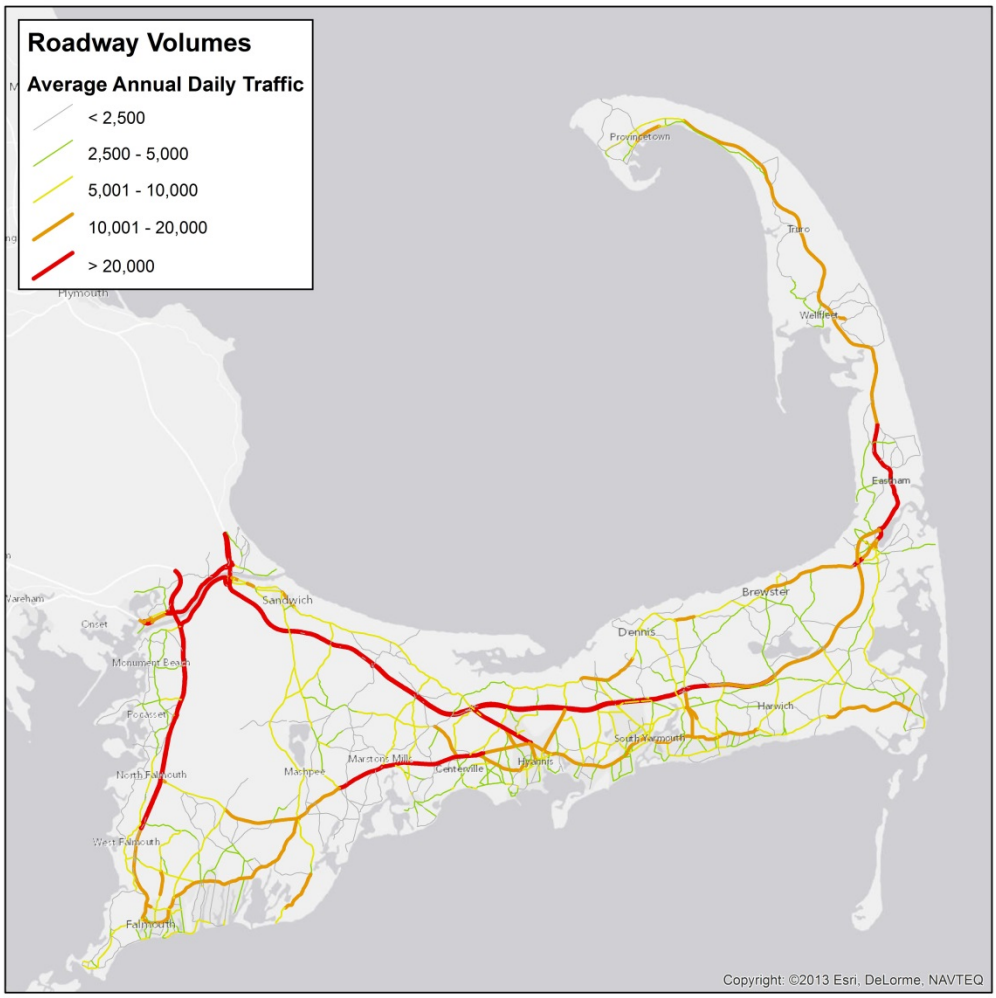

Figure 4. Road volumes on regional roadways

RAIL TRANSPORTATION

Stakeholders identified the railroad bridge as the most critical asset to the functioning of the rail transportation system. The railroad bridge provides the only entry/exit point for trains in Barnstable County. The Yarmouth Line was identified by stakeholders as the second most critical asset because it carries more freight and passengers than the Otis line. The Otis line was also identified as critical because it carries over 35,000 tons of solid waste off of Cape Cod each year.

SEA TRANSPORTATION

Stakeholders identified navigational aids (bells and buoys) as the primary critical asset to the functioning of the ferry system. These instruments are located in coastal waters and provide directional assistance to ferries coming into port. Ferry slips were ranked as the second most critical asset, the passenger terminal as third, and passenger parking lots as fourth.

Stakeholders considered the Steamship Authority, which operates out of Woods Hole and Hyannis, as highly critical to the network and community of Cape Cod. In 2013, the Steamship Authority ferry service carried over 2 million people, over 450,000 automobiles, and over 162,000 other vehicles (including trailers, pickups, vans, buses, campers, trucks of all sizes) between Cape Cod and the Islands. The Island Queen, which provides ferry service between Falmouth and Oak Bluffs, was also identified by stakeholders as a critical asset because it is one of the larger ferry services out of Falmouth with a 100+ occupancy. Stakeholders also ranked Patriot Party Boats as critical. This ferry service is small with a <40 person occupancy, but it is vital to the island communities since it runs early in the morning bringing over commuters and freight.

TRANSIT TRANSPORTATION

The Cape Cod Regional Transit Authority (CCRTA) is unique compared to other modes of transportation in Barnstable County because it offers two types of services: fixed route services and on-demand services. The demand response line, called the DART bus, provides 1100 rides per day and operates on every roadway on Cape Cod, including dirt roads. The DART bus is highly critical to the functioning of the community because it provides transportation to those with limited mobility options.

Stakeholders identified the fixed route H_2O Line and the Sealine as highly critical route assets in Barnstable County. Within the CCRTA network, the H_2O Line and Sealine are the most robust services, carrying 155,717 and 132,406 people, respectively. Transit stakeholders also identified Routes 6, 28, 132, 134, and Woods Hole Road as highly critical to the operation of the CCRTA buses. There are several transportation hubs located throughout the Cape; the largest is located in Hyannis. Stakeholders identified the Hyannis hub as highly critical to the transit system because it is used by CCRTA, Plymouth & Brockton, Peter Pan, and the Steamship Authority Shuttle.

VULNERABILITY TO SEA LEVEL RISE

POINT ASSETS

All point assets identified in this study were run through the Cape Cod Commission's Sea Level Rise Viewer to determine whether the assets were submerged at 1 - 6 feet of water rise. Figure 5 shows the transportation assets that are vulnerable to sea level rise in Barnstable County and Figure 6 shows how many vulnerable assets are located in each town.

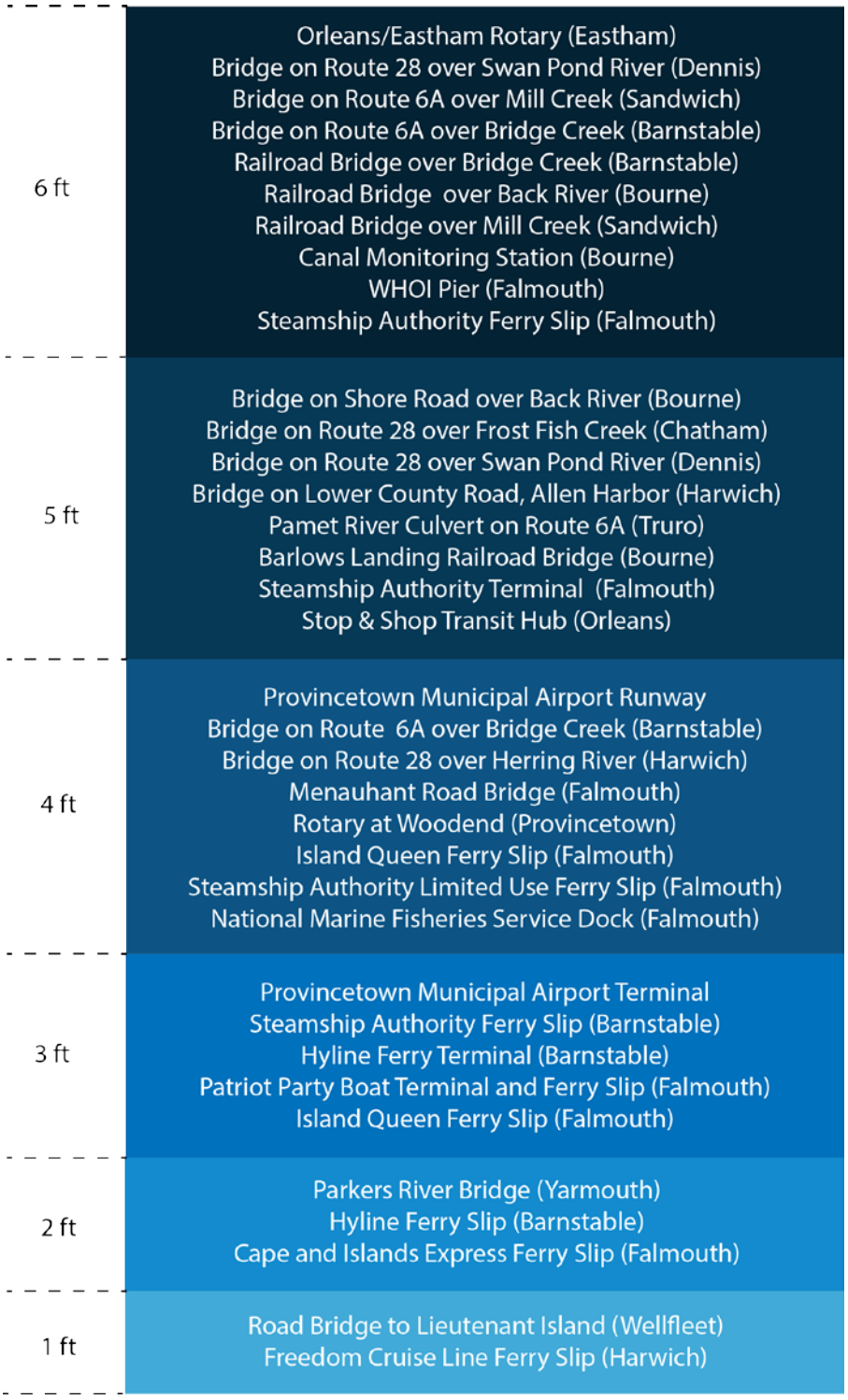

Figure 5. Transportation point assets that are vulnerable to 1-6 feet of sea level rise

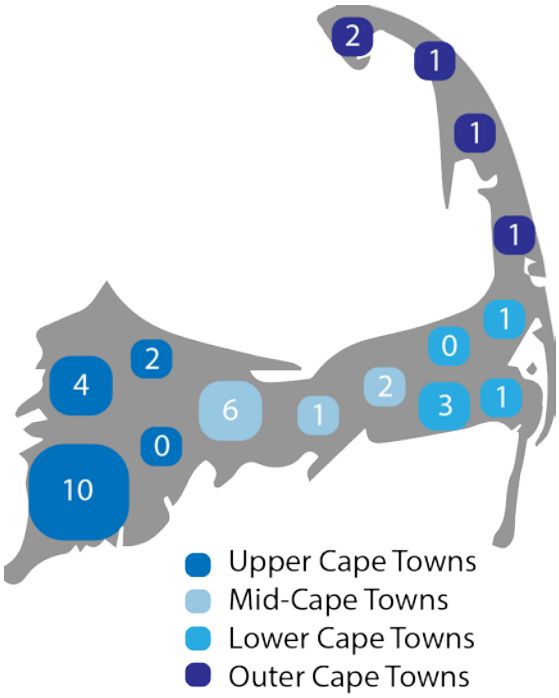

Figure 6. Vulnerable transportation point assets by Town

ROUTE ASSETS

The Sea Level Rise Viewer also identified areas of roads and track that are vulnerable to 3 and 6 feet of water rise. Figures 7 and 8 show areas of impassable roadways at 3 feet and 6 feet of rise. Figures 9 and 10 highlight portions of transit routes that are impacted at 3 feet and 6 feet of water rise. Figure 11 shows the portions of track that will be submerged at 6 feet of water rise. According to the Cape Cod Commission's Sea Level Rise Viewer, track lines are not vulnerable at 3 feet of sea level rise; although stakeholders reported seeing water in the rail ballast during full moon high tides.

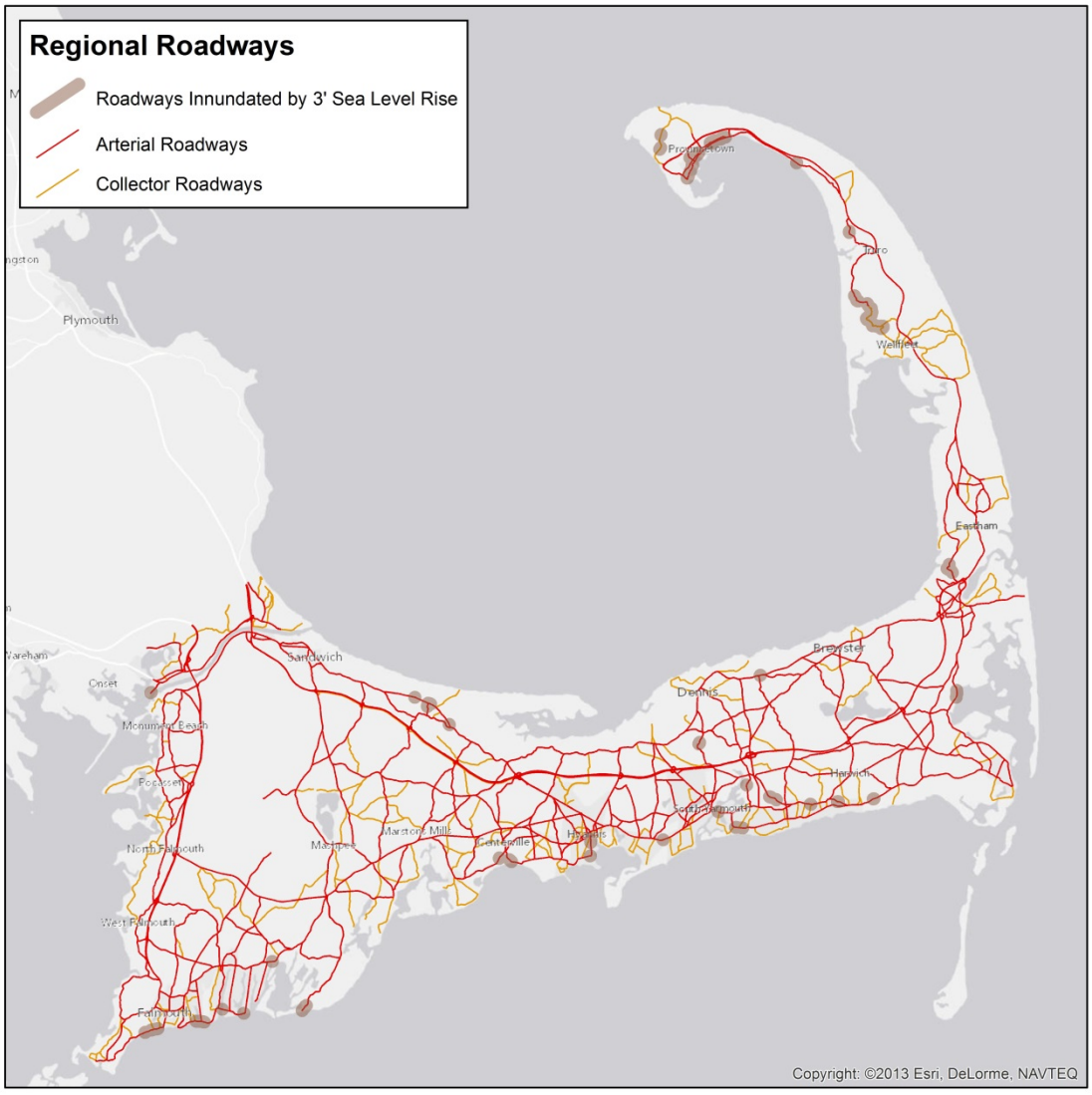

Figure 7. Submerged regional roadways at 3 feet of sea level rise

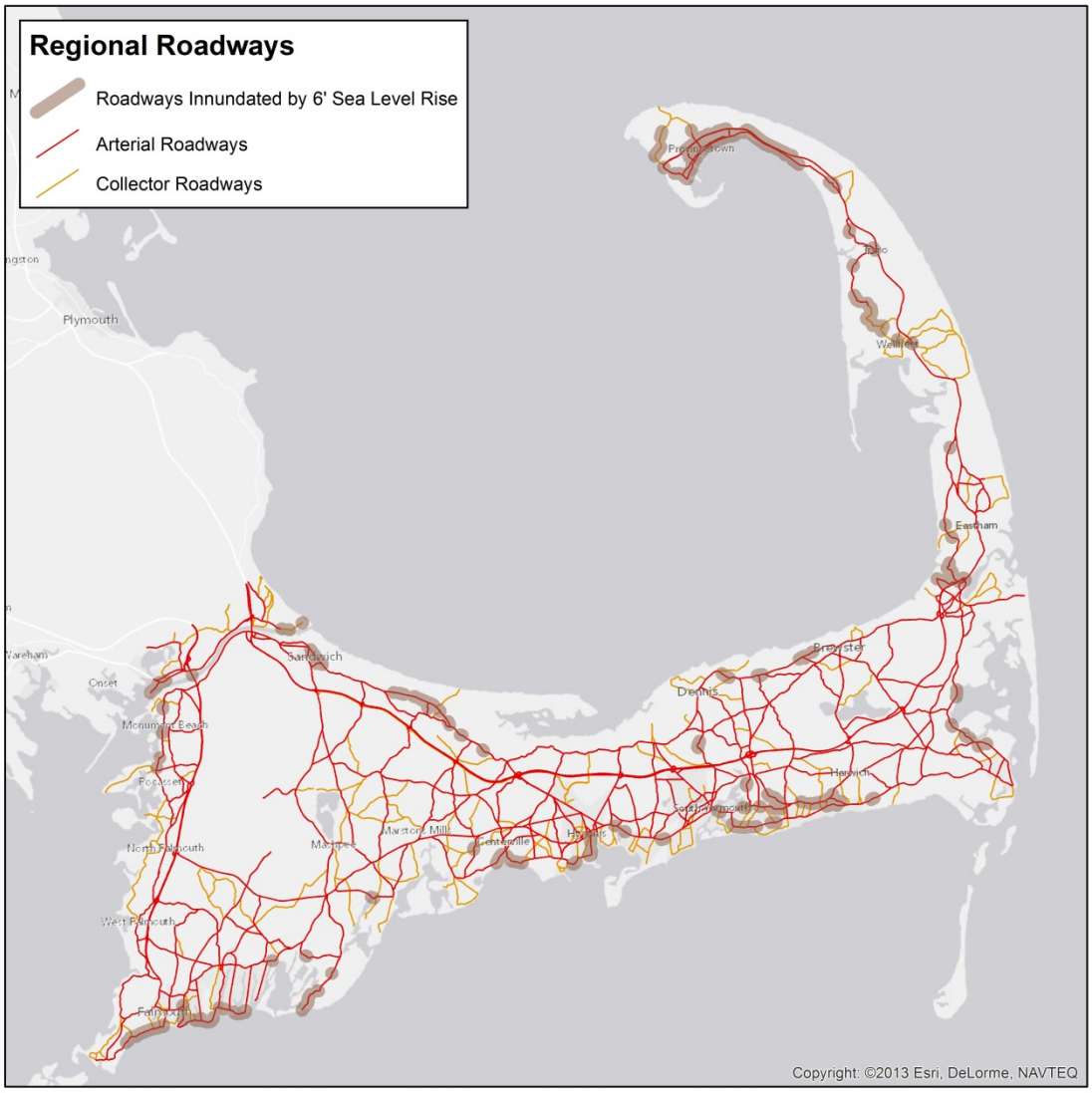

Figure 8. Submerged regional roadways at 6 feet of sea level rise

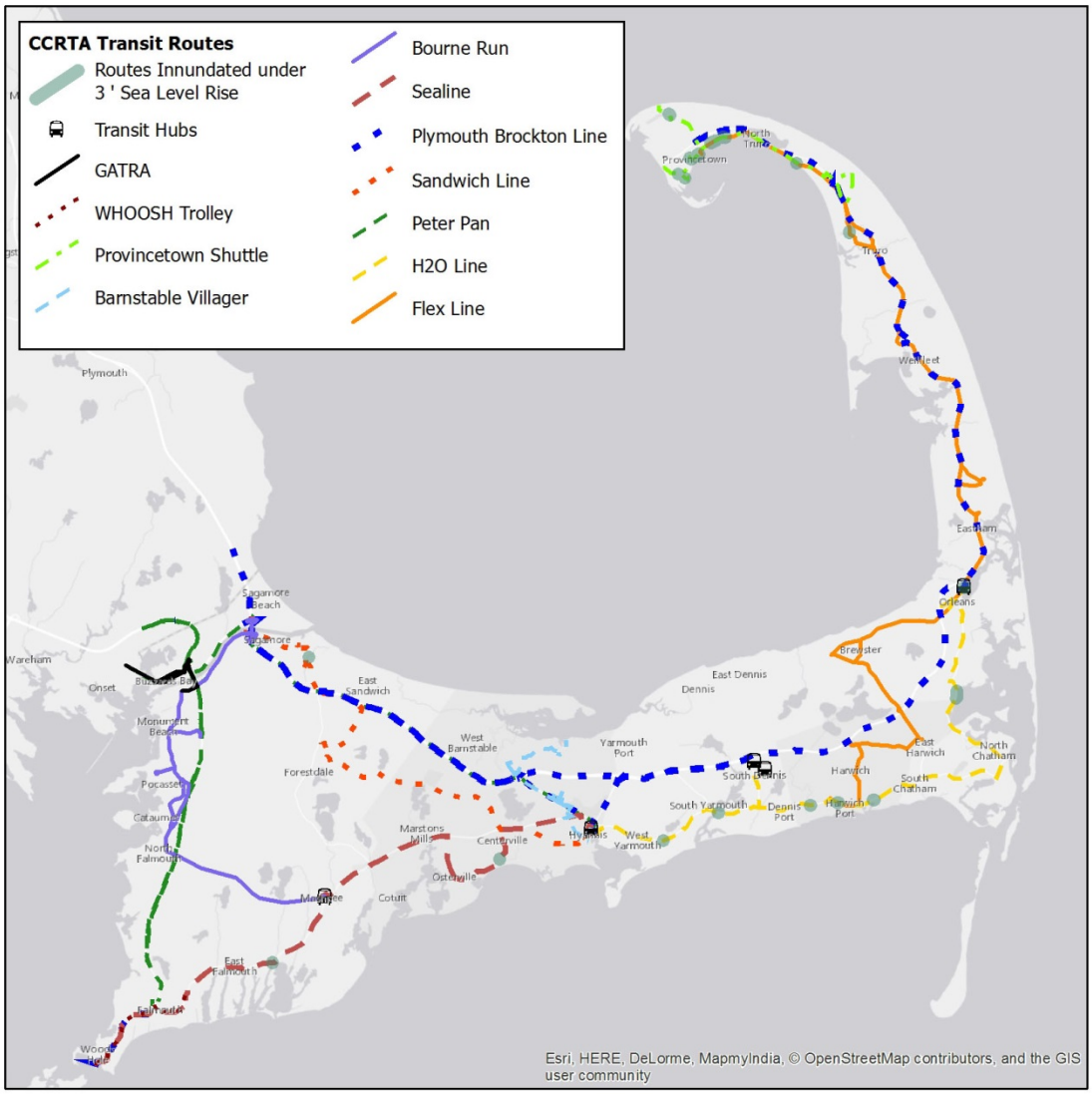

Figure 9. Submerged transit routes at 3 feet of sea level rise

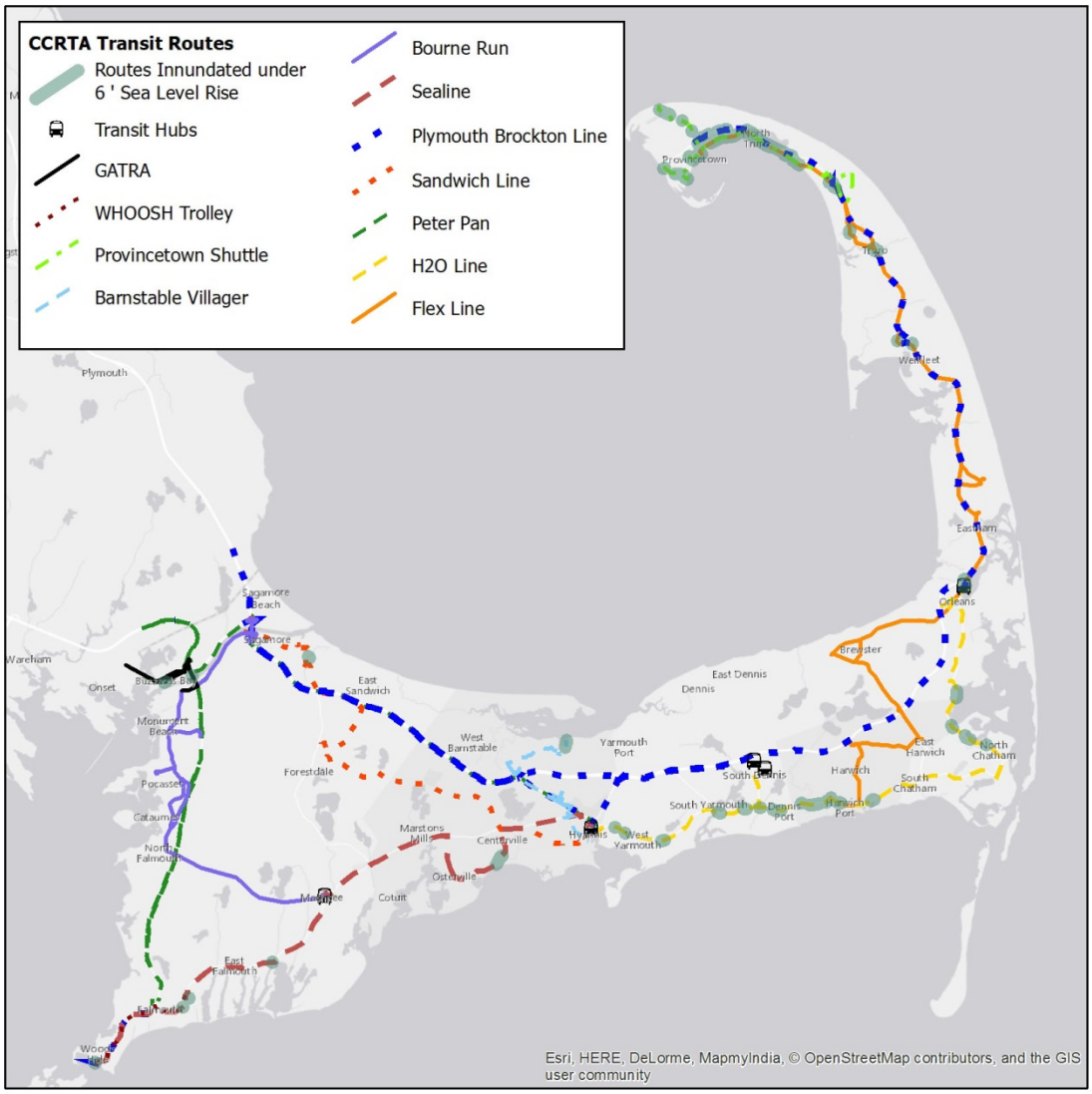

Figure 10. Submerged transit routes at 6 feet of sea level rise

Figure 11. Submerged track at 6 feet of sea level rise

CONCLUSIONS

The data collected in this report shows that Cape Cod has many transportation assets that are vulnerable to sea level rise (Figures 5-11). During the drafting of this report, MassDOT announced they are constructing a dynamic sea level rise model for the coastline of Massachusetts. While the Cape Cod Commission's Sea Level Rise Viewer is an excellent first-step, the dynamic model generated by MassDOT will be more accurate in predicting asset vulnerability. Given the number of assets vulnerable to sea level rise on Cape Cod, it is critical that this dynamic model become available to Planning and GIS Staff in Barnstable County as soon as possible. Commission staff and several Barnstable County Commissioners advocate that MassDOT construct the model starting with the southern coastline of Massachusetts.

This study identified several transportation assets that are both vulnerable to sea level rise and critical to the community and the transportation network, including:

- AIR: The runway and passenger terminal at the Provincetown Municipal Airport will likely be submerged at 3 - 4 feet of sea level rise. This asset was also identified as vulnerable in the UPWP 2.5 Report from 2013.

- HIGHWAY and TRANSIT: The Orleans/Eastham Rotary on Route 6 will likely be submerged at 6 feet of sea level rise. Once this asset is submerged, the Outer Cape will essentially become an island, completely isolating Route 6 in Eastham, Wellfleet, Truro and Provincetown from other regions. When the Rotary becomes submerged, both Highway and Transit infrastructure will be affected.

- RAIL: Portions of the Yarmouth rail line in Sandwich will likely be submerged at 6 feet of water rise. In this area, the track traverses marsh areas in the Town of Sandwich. This site was also identified as vulnerable in a report generated by the Provincetown Center for Coastal Studies[4].

- SEA: The Steamship Authority ferry slip in Barnstable will likely be submerged at 3 feet of sea level rise.

[4] A Proposal to Assess Inundation Vulnerability of CCRTA Rail Infrastructure to Coastal Flooding Associated with Tides, Storms and Sea Level Rise, prepared by the Provincetown Center for Coastal Studies

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