Transportation

CLIMATE ACTION FACT SHEET

Adapt infrastructure for resilience

PREPARE LOW-LYING INFRASTRUCTURE FOR FLOODING AND SEA LEVEL RISE

Description and purpose of strategy: Without preventative measures, sea level rise and flooding from climate change are expected to inundate roads and infrastructure throughout Cape Cod. Municipalities should consider elevating, relocating, or even abandoning some resources. While these proposals are costly, the most costly option would be doing nothing to prepare for sea level rise. Investing in infrastructure can increase resilience and property values, as well as lower the risks of physical or economic losses.

Content of fact sheet: Overview of the costs and benefits of infrastructure adaptation, with qualitative descriptions of the costs and benefits for several prominent strategies. Includes a description of the process of relocating a parking facility in Orleans, tools to evaluate the anticipated degree and location of flooding, and resources for more detailed planning.

Implementation support: This fact sheet expands upon strategies and actions from the Climate Actions Database, which can be found at: capecodcommission.org/climate.

BENEFITS

- ☐ Greenhouse gas (GHG) emissions reductions or sequestration
- ☐ Health improvement from reduced pollutants
- ☐ Increased recreation
- ☐ Lower maintenance/operational costs
- ☑ Environmental enhancement/protection
- ☑ Less damage to infrastructure
- ☑ Higher property values
- ☑ Increased resilience
- ☑ Job and economic growth

COSTS

- ☑ Higher capital costs
- ☐ Higher maintenance costs
- ☐ Higher operational costs
- ☑ Additional time for municipal staff to implement

KEY FINDINGS

Equity: Focusing infrastructure adaptation in areas with vulnerable populations and avoiding potential impacts of rising property values can help maximize potential benefits and ensure equitable distribution of outcomes.

Financial benefits: While infrastructure adaptation can require substantial investment, these projects are typically justified by preventing damage from sea level rise. Costs vary by the strategy implemented.

Non-market benefits: Resilience to disasters and the ability to evacuate during storm surges and flooding are major benefits of infrastructure adaptation. Protecting shorelines can have important ecosystem benefits.

GHG reductions: Construction is a large source of GHG emissions, particularly from the production of concrete and asphalt.

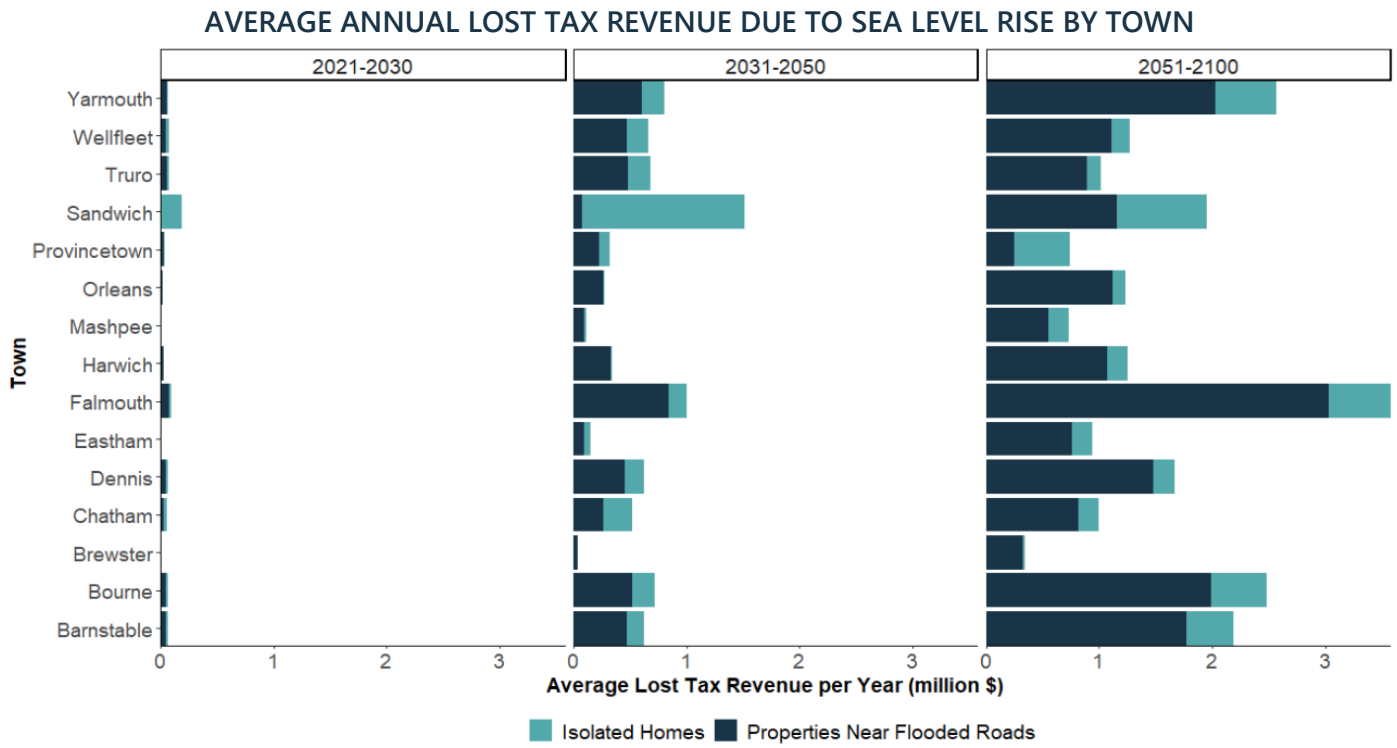
Ease of implementation: Site-level study is necessary to find the best implementation strategy for each infrastructure project. While resources are available to prepare these assessments, significant planning and permitting work is required.

BENEFIT COST ANALYSIS

Infrastructure adaptation projects can have large benefits by preventing damage from flooding or sea level rise.

Roads

The magnitude of benefits depends on the cost of doing nothing, or the expected damage absent any improvements to existing infrastructure. Doing nothing will be an expensive option for municipalities—as sea level rises and roads become unusable, municipalities will lose tax revenue from isolated homes and properties near flooded roads. The figure below shows the estimated lost annual tax revenue due to flooded roads through the end of the century (Cape Cod Commission, 2021). In total, Cape Cod is projected to lose approximately $290 million in tax revenue due to flooded roads by 2100. Sea level rise can also cause direct damage to roadways, which can result in traffic congestion (Fant et al., 2021). Non-monetary damage would also be significant. For example, flooded roads, particularly during storms or significant coastal flooding events, could hinder emergency response and evacuation and potentially lead to loss of life.



Source: Cape Cod Commission, 2021

Over 212 miles of roads on Cape Cod are projected to be flooded by 2100. Municipalities can use the low-lying roads tool to learn when and where flooding is projected. When flooding is projected during the typical useful life of a road (around 30 years), municipalities should conduct detailed analyses to find the appropriate adaptation plan. There are four general strategies to prepare roads for flooding and sea level rise: elevate, relocate, abandon, or protect. The costs and benefits of each strategy depend on many local factors, such as the degree of sea level rise, the population that depends on a given road, and the condition of land and property surrounding a road. Producing the asphalt and concrete required for new road construction is a considerable source of GHG emissions, although new production methods may lower the emissions intensity (Woodall, 2021). When implementing road improvements, municipalities should also promote alternative transit, including Complete Streets.

The following table may help assess which methods are best for roads in a given location by summarizing where methods are most suitable and providing some details about each strategy.

ADAPTATION OPTIONS FOR LOW-LYING ROADS

STRATEGY	RECOMMENDED USE	DETAILS
ELEVATE	Locations where environmental impacts to sensitive resource areas are minimal and other options are not cost-effective	Costs can vary dramatically but are substantially higher than typical road construction. The least expensive option is modifying the thickness of existing roads, although this is not feasible if a large degree of sea level rise is anticipated, if roads are used to drain water from neighboring properties, or if there are clearance restrictions. Overall, estimated costs per mile for an average road range from $1–$14 million.
RELOCATE	Roads at low elevations relative to surrounding features	Municipalities can find a suitable location for the existing road on higher-lying land and reconstruct that road at a higher elevation. The site of the current resource can be used as a living barrier or open space following demolition. The cost of relocation depends on the value of the land municipalities need to purchase. While there are not examples of relocating Cape Cod roads for sea level rise, costs and challenges may be similar to those from relocating parking lots in Brewster, Provincetown, and Orleans.
ABANDON	Repetitive loss areas with few year-round residents	The municipality must purchase and demolish all houses serviced by the targeted road, abandon road segments, and ensure proper disposal of any potential hazardous materials. This option incurs high monetary costs (purchasing private property, lost property tax revenue) and non-monetary costs (personal, cultural, and historic value of land). The monetary cost depends on the value of neighboring land. Pending legislation could provide funding and support for voluntary property buyouts.
PROTECT	Areas without existing natural buffers, and where storm surges are a greater concern than sea level rise	While some human-made strategies are also available, the most cost-effective protective approaches appear to be nature-based solutions such as building living shorelines and preserving coastal wetlands (Costanza, 2021). Buffers do not prevent inundation of roads below sea level, but they can be effective at reducing flood risk and coastal erosion during storms. Research estimates that the average acre of wetland worldwide prevents over $27,000 per year in storm-related damage (Costanza et al., 2021).

Other Infrastructure

Sea level rise will also impact a variety of other key infrastructure components, including bridges and culverts; electric, gas, sewer, and water utilities; and ports. Municipalities can use the Cape Cod Commission's sea level rise viewer to identify critical facilities that would be impacted by sea level rise. The same general strategies above can be applied to other infrastructure components, with some exceptions. For bridges and culverts, efforts to upgrade or relocate facilities must be done in conjunction with road planning. A 2015 study found that upgrading culverts for increased water flow was on average 38% less expensive than replacing and maintaining culverts without upgrading them. For some sites (such as wastewater disposal sites), abandoning a facility may require additional expenses to properly dispose of or store hazardous materials. To protect water infrastructure from sea level rise, research suggests constructing intrusion barriers to prevent saltwater from entering freshwater reserves; rerouting pipes inland, using non-corrosive materials, and/or scheduling more frequent maintenance for pipes where saltwater leads to accelerated corrosion; and elevating key electrical equipment in treatment facilities to prevent service interruption during floods (Chalek 2020).

EQUITY

With careful implementation, infrastructure adaptation can be a tool for equitable climate adaptation. Infrastructure projects may have a variety of economic and non-monetary benefits for communities. A few potential benefits include:

- **Decreased exposure to hazards:** Infrastructure adaptation will decrease exposure of communities to risks from coastal hazards and flooding on low-lying roads.
- **Improved transportation quality:** Infrastructure adaptation can improve quality of transportation, including safer transportation options and fewer transportation delays for communities due to improved roads and infrastructure. These improvements can enhance access to critical services such as healthcare or emergency services.
- **Potential economic opportunities:** Infrastructure projects will lead to opportunities and jobs in construction related to road retrofitting and relocation, as well as replacement of culverts and bridges.

Optimizing Equity During Implementation

To maximize benefits to environmental justice and vulnerable populations, the planning process for infrastructure adaptation should incorporate community feedback, focus on non-monetary benefits of proposed projects, and aim to minimize gentrification impacts from improved infrastructure. While soliciting community feedback, municipalities should provide materials in multiple languages or provide translation services to include the many Cape Cod residents whose primary language is not English (MassGIS 2022).

Non-monetary benefits of proposed projects are important for towns to consider. Decisions based solely on lost property tax revenue might systematically disadvantage low-income residents. Other non-monetary factors to consider include access to emergency services or evacuation routes, roads used for bus routes, number of full-year residents impacted, and number of vulnerable residents impacted. Infrastructure investments can increase property value and rents, adding financial pressure to low-income residents. Municipalities should design adaptation strategies so local residents benefit from opportunities related to construction projects and are protected from displacement (Dorazio 2022).

Costs of infrastructure projects are largely borne by the tax base (through state or federal grants) and local municipalities. If tax increases are required to fund infrastructure projects, municipalities should consider modified fee structures for local infrastructure costs borne by residents. Examples could include a room occupancy excise tax (a tax targeting hotel rooms and other visitor accommodations) or a property tax on second homes.

STATE OF PRACTICE

General State of Practice

While many coastal regions in the U.S. recognize the importance of infrastructure adaptation for sea level rise, few have begun the costly process of preparing critical infrastructure. Many coastal regions have implemented vulnerability assessments to find regions that require infrastructure adaptation investments (e.g., San Francisco, New Hampshire, Puget Sound), and some regions have already begun implementing plans to prepare for sea level rise. For example, Florida has begun elevating roads in Miami Beach and is planning to elevate roads on the Florida Keys (Harris and Ariza, 2021). In addition, a New Jersey program is buying out properties in high-risk flood zones and investing in coastal resilience projects. Infrastructure planning on Cape Cod should learn from these examples, particularly if designing a buyout program, but the practice of infrastructure adaptation is still emerging and implementation may require strategies not tested elsewhere.

Cape Cod Context

Municipalities on Cape Cod recognize the immediate threat of sea level rise for their communities, and several towns have begun extensive planning or implementation of projects to prepare for this threat. Relocation projects for parking lots are either completed or in progress in Brewster (completed 2016), Provincetown (completed 2019), and Orleans (in progress). Lessons learned from these projects include the importance of community engagement. For instance, the project in Brewster encountered several difficulties in building community support for the intended project, leading to substantial project delays.

Municipalities have already begun planning the extensive road investments required to keep pace with the rising sea level. The Town of Eastham conducted a study in 2020 to identify infrastructure adaptation strategies to prepare for sea level rise. The report included a vulnerability assessment for four key roads, found a range of potential adaptation strategies to address sea level rise, and included community feedback. The report presented timelines for implementation and general permitting requirements, and it identified preliminary costs of alternatives. The Cape Cod Commission is developing similar assessments throughout Cape Cod. As of March 2023, these efforts to produce assessments throughout Cape Cod and to implement adaptation strategies in Eastham are ongoing. The low-lying roads project includes vulnerability assessment, community engagement, project selection, and conceptual roadway design for each municipality.

CASE STUDY: NAUSET BEACH, ORLEANS, MA

Sea level rise and coastal erosion have long threatened the current parking lot and sewer lines at Nauset Beach, Orleans. Nauset Beach moved westward at a rate of 12 feet per year between 1990 and 2015 (Zuckoff, 2022). In 2010, the Town of Orleans acquired a parcel of land uphill of the existing site to prepare for a managed retreat of facilities near the coast. In 2021, the town was awarded a Massachusetts Office of Coastal Zone Management (CZM) Coastal Resilience Grant for design and permitting of the parking lot removal. In a 2021 election, voters approved the project to relocate the parking facility, and in 2022, the town was awarded a CZM Coastal Resilience Grant to help fund the project. The new lot is expected to open by Memorial Day 2023, and to last for decades longer than the current site.

IMPLEMENTATION

The steps below are required to implement infrastructure adaptation of roads and other vulnerable infrastructure resources. With relatively little historical precedent for the necessary projects, infrastructure adaptation may require more intensive design and planning than other strategies. Grant funding is available for all stages of implementation from state and federal agencies.

1. **Assess site vulnerability.** Assess the vulnerability of existing sites to projected sea level rise. Environmental scientists should help assess the risks to existing sites.
2. **Identify priority roads or infrastructure projects.** This planning should consider non-monetary impacts from infrastructure adaptation projects such as access to emergency services, evacuation routes, and public transit. Planning should engage diverse community stakeholders.
3. **Design potential solutions.** Design potential solutions for each project, considering elevation, relocation, abandonment, and protection. Solutions should attempt to minimize financial burdens and the displacement of socially vulnerable populations.

REQUIRED EXPERTISE

Internal: Town planner, grant writer, GIS analysis, department of public works staff, emergency services staff

External: Transportation engineer, environmental scientist

4. **Select a project solution.** The selection process should incorporate feedback from the impacted community.
5. **Implement the proposed construction project.** This stage should engage local companies and individuals. When possible, it should also engage contracting companies that are women or minority owned.

The following resources may assist with planning and funding infrastructure adaptation projects.

FINANCIAL AND TECHNICAL SUPPORT	
Cape Cod Commission Sea Level Rise Viewer	Planning tool to visualize the extent of sea level rise and identify critical infrastructure that would be affected.
Cape Cod Commission Low Lying Roads Project	Planning tool to identify roads at risk from sea level rise, and sample project solutions for a range of adaptation strategies. Includes town-level visualizations and reports. To view resources for each town, use the town buttons at the bottom of the webpage to access individual low-lying road viewers.
Cape Cod Commission Managed Retreat Tool	An education and communication tool to present options related to coastal resiliency. Summarizes multiple adaptation plans and includes examples of outreach best practices to develop communications and outreach plans.
Massachusetts Coastal Resilience Grant Program	Provides funding for a range of coastal resilience projects, including vulnerability assessments, public outreach, proactive planning, redesigns or retrofits, and shoreline restoration.
Massachusetts Dam and Seawall Repair or Removal Program	Provides support for repairing or removing dams, levees, seawalls, and other forms of flood control, particularly when the project would benefit public safety, a key economic center, or ecological services.
FEMA Hazard Mitigation Grant Program and Flood Mitigation Assistance Grants	Two federal grant programs that municipalities can use to provide funding for projects that reduce or eliminate the risk of repetitive flood damage. The Flood Mitigation Assistance Grants are limited to buildings insured by the National Flood Insurance Program, but both programs can help fund managed retreat.
Natural Resources Conservation Service's Watershed and Flood Prevention Operations Program	A federal program that provides resources to projects that protect and restore watersheds. Elevation projects may be eligible under flood prevention or watershed protection. Projects must demonstrate agricultural benefits, including benefits to rural communities. Sandwich, Massachusetts, earned support from this program to improve water quality at Town Neck Beach.
ADDITIONAL INFORMATION	
CZM Port and Harbor Planning Publications	Collected publications and resources from CZM on how to plan resilient ports and harbors, including technical assistance to receive CZM support for harbor resilience projects.
Act Establishing a Massachusetts Flood Risk Protection Program	Legislation in Massachusetts state legislature that, if approved, could provide additional funding and support for flood risk protection programs including, voluntary property buyouts.
Environmental Protection Agency (EPA) Resilient Strategies Guide for Water Utilities	Helps water utilities identify potential adaptation strategies based on expected climate vulnerabilities, including potential sea level rise and storm surge scenarios.

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Additional climate change information and resources can be found at capecodcommission.org/climate.