

Green Infrastructure Analysis for the Pine Barrens Ecoregion of Southeastern Massachusetts



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Goals and Purpose

The green infrastructure analysis for the Pine Barrens Ecoregion of southeastern Massachusetts identifies a network of open space that if protected from development and managed properly address a set of related goals including:

- Biodiversity support, particularly rare, threatened and endangered species,
- Ecosystem service support, particularly clean air and water,
- Human community resiliency and quality of life,
- Minimization of tax burden associated with new urban development in hazard areas, and
- Support of groundwater recharge.

The green infrastructure analysis is intended to provide a shared focus for conservation efforts by multiple organizations working across the region.

Pine Barrens Ecoregion

The Pine Barrens Ecoregion of southeastern Massachusetts is unique within New England, supporting a range of species that don't thrive elsewhere. Development is encroaching on this resource and continued fragmentation both diminishes the habitat value and complicates management efforts.

The study area, as depicted in Figure 1, is based on the USEPA ecoregion boundary and is clipped to locality boundaries.



Figure 1

Process Description

The initial draft version of the green infrastructure analysis was carried out by Jennifer Shakun and Eric Walberg of Manomet, Inc. The analytic approach was based on a [similar analysis](#)¹ developed and completed by Mr. Walberg and Ms. Shakun for the Taunton River Watershed in 2017.

The project team, including Manomet, Southeastern Massachusetts Pine Barrens Alliance, Cape Cod Commission, and independent consultant Tim Simmons, held three stakeholder workshops in Barnstable, Carver, and Eastham in 2019 to both publicize the effort and solicit feedback on the analysis. Participants included a broad range of local government staff, elected officials, nonprofit organization staff, state and federal agency staff, and interested citizens.

¹ https://www.manomet.org/wp-content/uploads/old-files/Manomet_GreenInfrastructure_Analysis_for_TauntonWatershed_July2017.pdf.

Based on the feedback received in the workshops, the maps were updated to more precisely identify undeveloped areas and improve utility in conservation decision making. The map revisions were carried out by Gary Prahm of the Cape Cod Commission.

Inputs to the Analysis

Geospatial data used in the analysis includes the following:

- Habitat and biodiversity protection + groundwater recharge:
 - Biomap2² core habitat
 - Biomap2 critical natural landscape
 - Areas of above average resilience as identified in the Resilient Landscapes Analysis³
- Flood control + minimization of nonpoint source water pollution + habitat protection
 - Wetlands and 200 foot buffer surrounding aquatic features
- Minimizing new development in areas vulnerable to sea level rise + habitat protection
 - Areas below 4 meters elevation that are vulnerable to sea level rise
 - High risk coastal areas within 100 feet of and including FEMA A and V zones

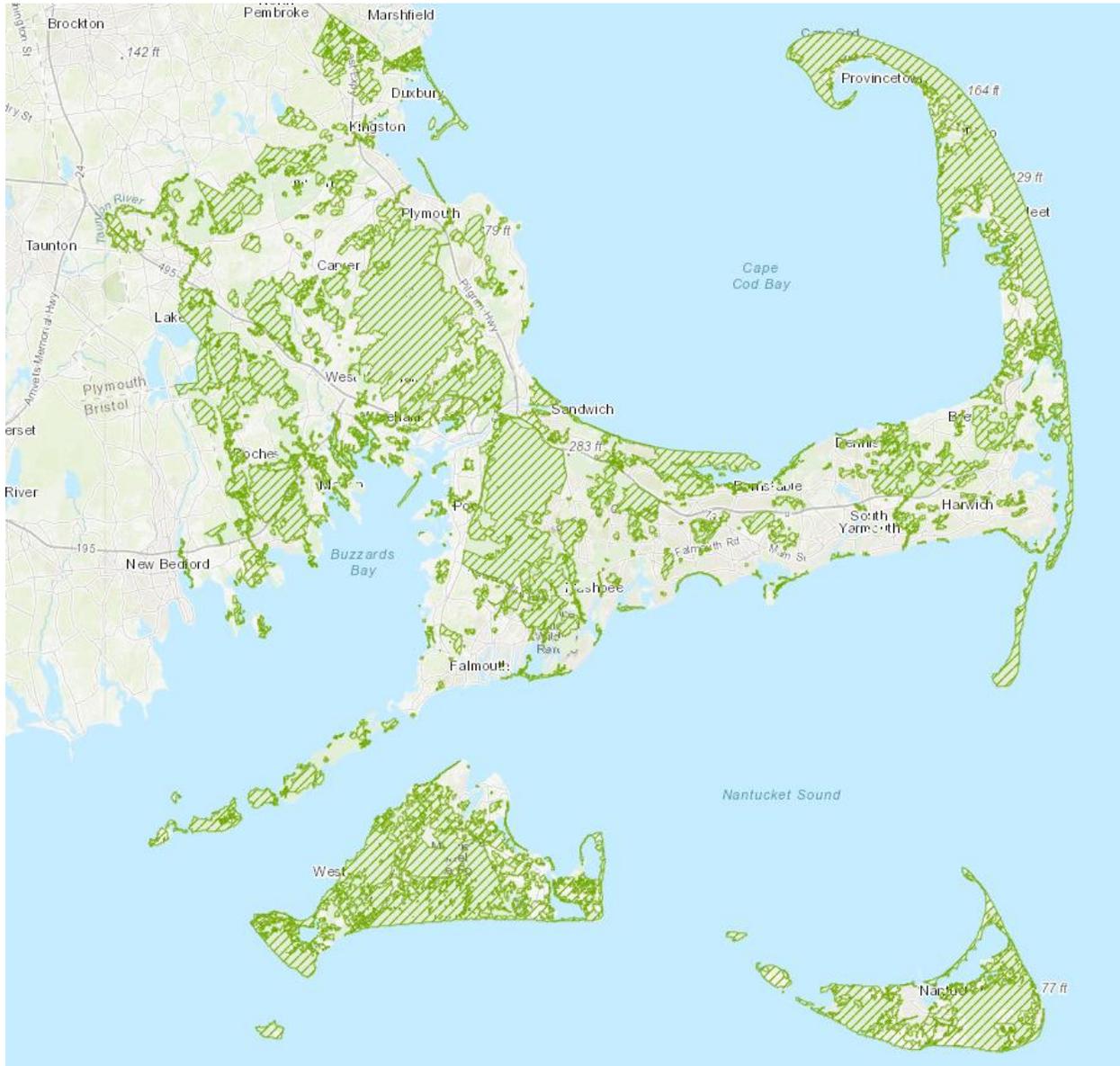
Example Maps

The following section contains examples of the geospatial inputs and the resulting aggregate green infrastructure maps. The aggregate green infrastructure map (Figure 7) includes both conserved lands within the network, shown in light green, and the undeveloped/unprotected areas of the network, shown in dark green. The undeveloped/unprotected lands are important from a conservation planning perspective in that they are areas of high ecologic and resilience value that are potentially subject to fragmentation and degradation associated with development.

² <https://www.mass.gov/service-details/biomap2-conserving-the-biodiversity-of-massachusetts-in-a-changing-world>.

³ http://easterndivision.s3.amazonaws.com/Resilient_Sites_for_Terrestrial_Conservation.pdf.

Figure 2: BioMap2 Core Habitat and Critical Natural Landscape



Legend

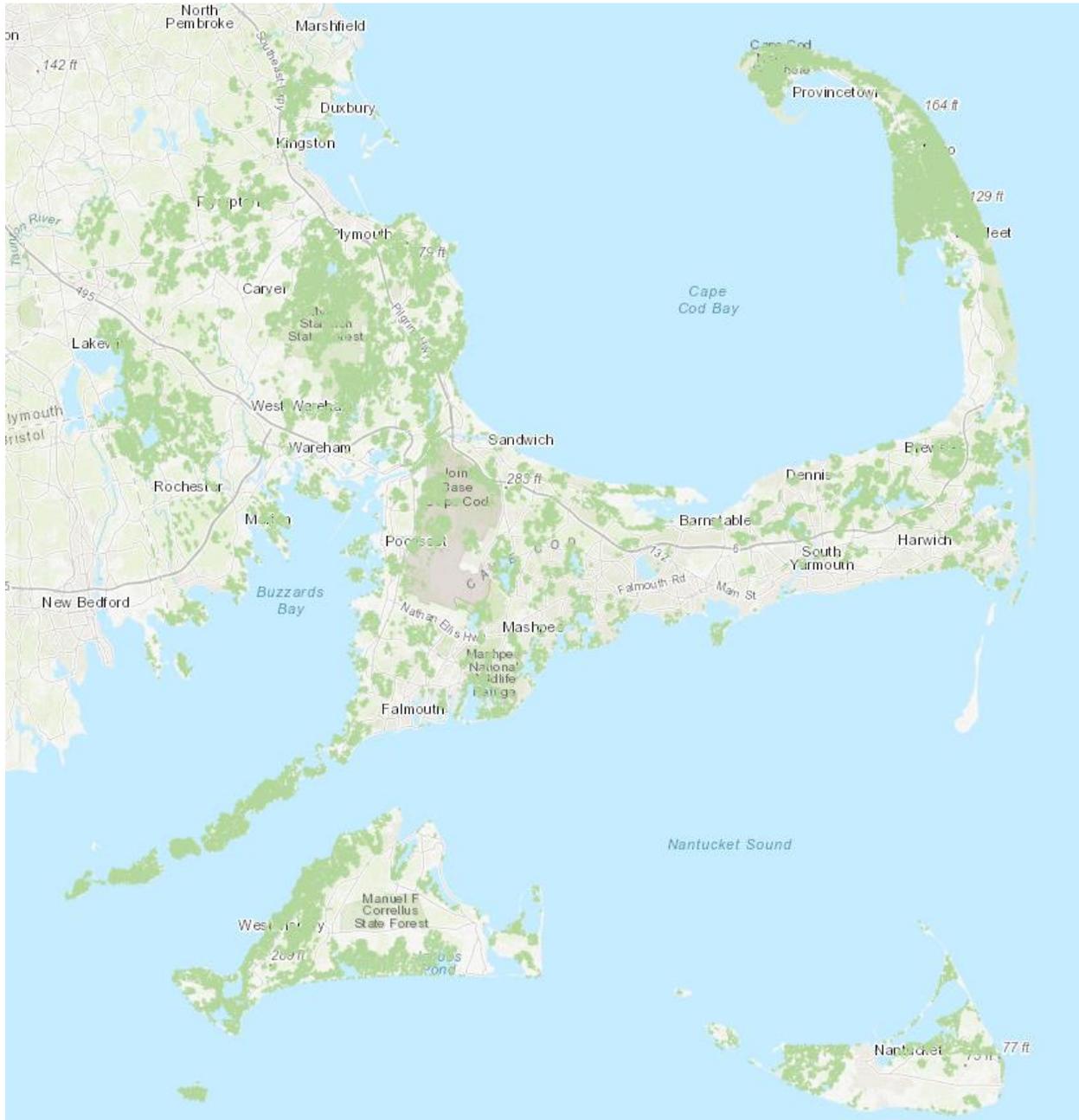
**Green Infrastructure: Bio Map 2
Core Habitat within study area**



**Green Infrastructure: Bio Map 2
Critical Natural Landscape
within study area**



Figure 3: Resilient Landscapes Analysis: Areas of Above Average Resiliency

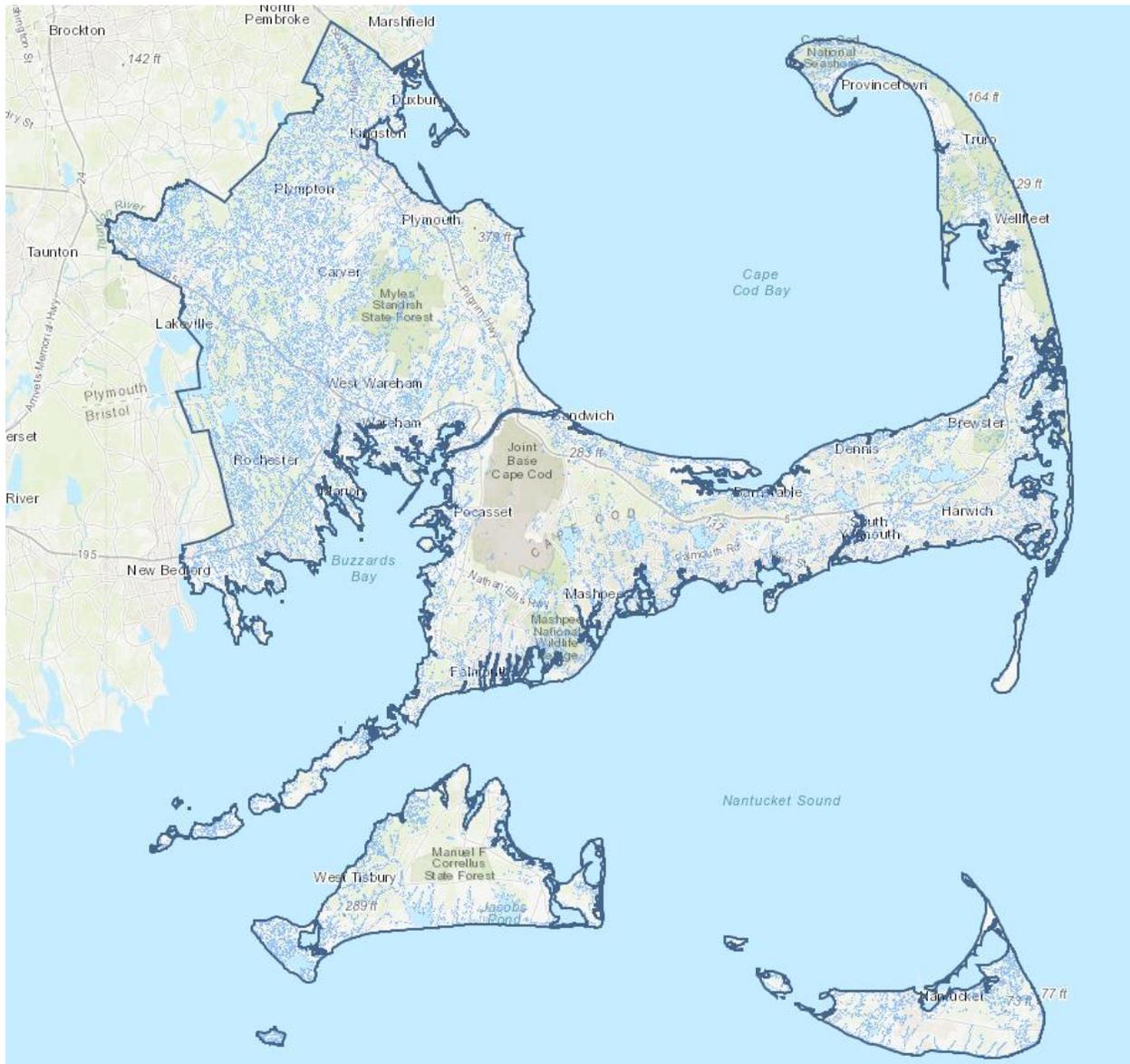


Legend

**The Nature Conservancy
Resilience analysis**



Figure 4: Buffered Aquatic Features



Legend

Buffered Water Features



Figure 5: Areas Vulnerable to Sea Level Rise

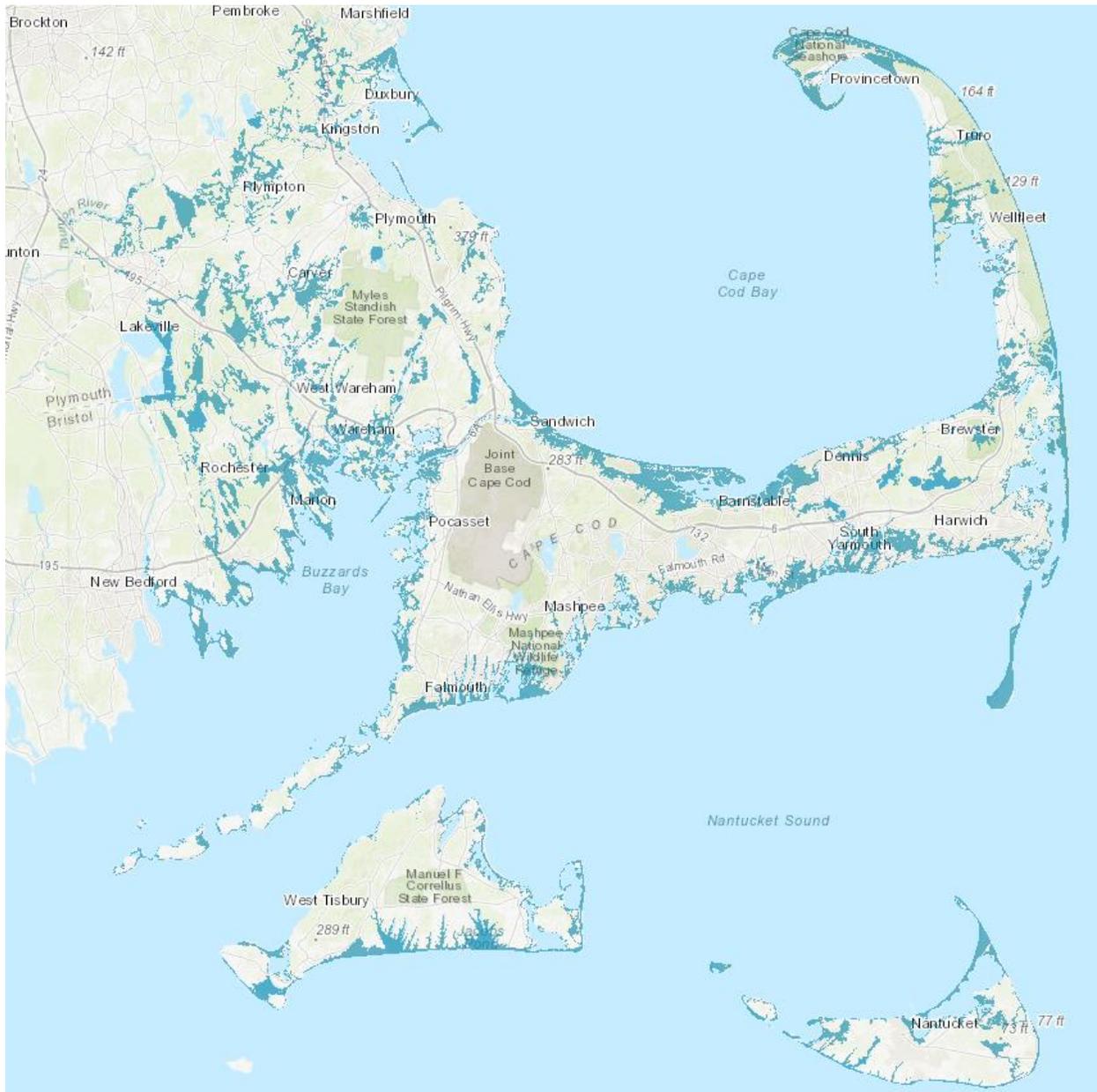


Legend

Elevation LTET 4m



Figure 6: FEMA Flood Hazard Areas

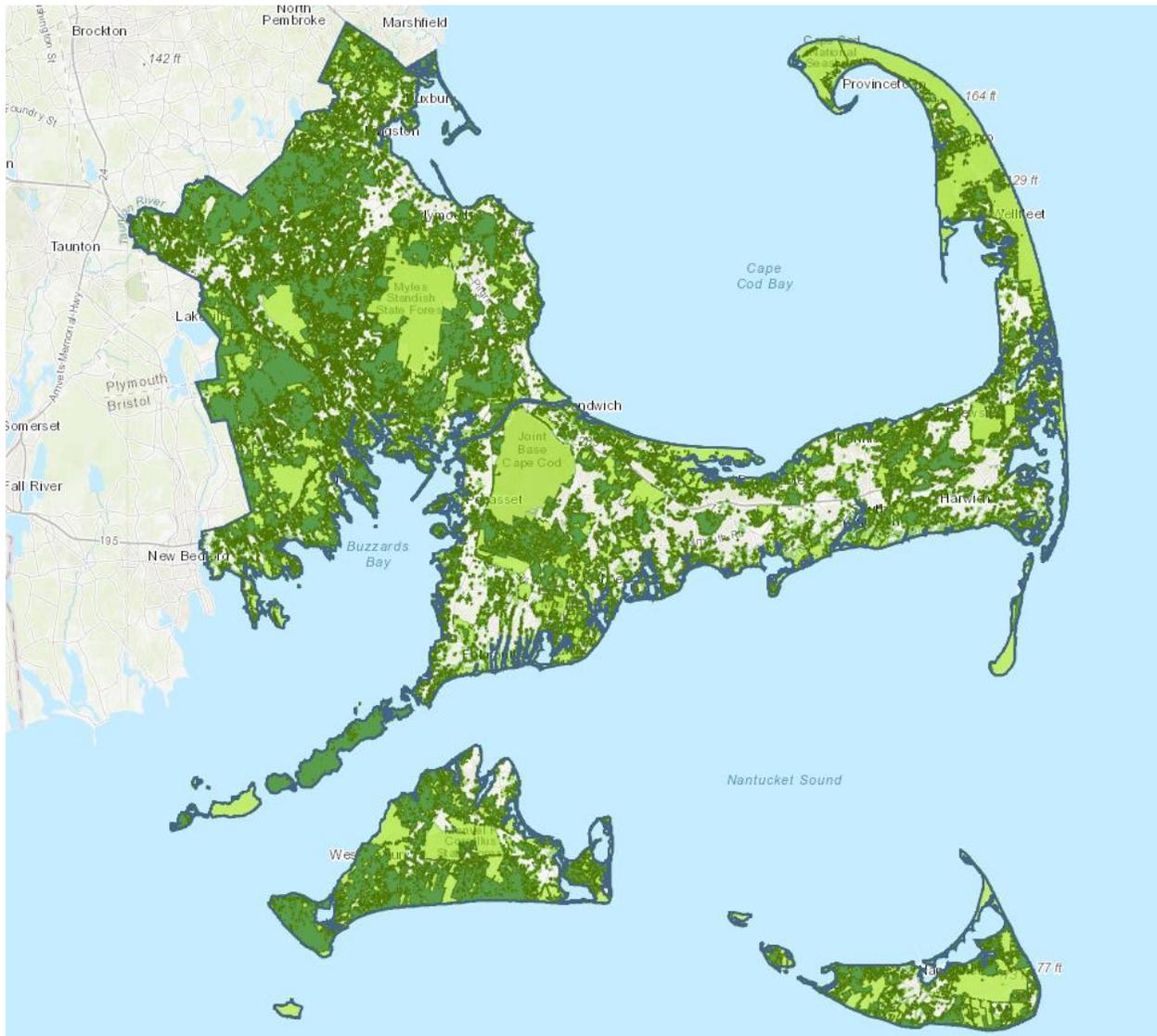


Legend

**Green Infrastructure: FEMA
High Risk Flooding within study
area**



Figure 7: Resulting Green Infrastructure Map with Undeveloped/Unprotected Component



Legend

**Green Infrastructure:
Undeveloped Unprotected**



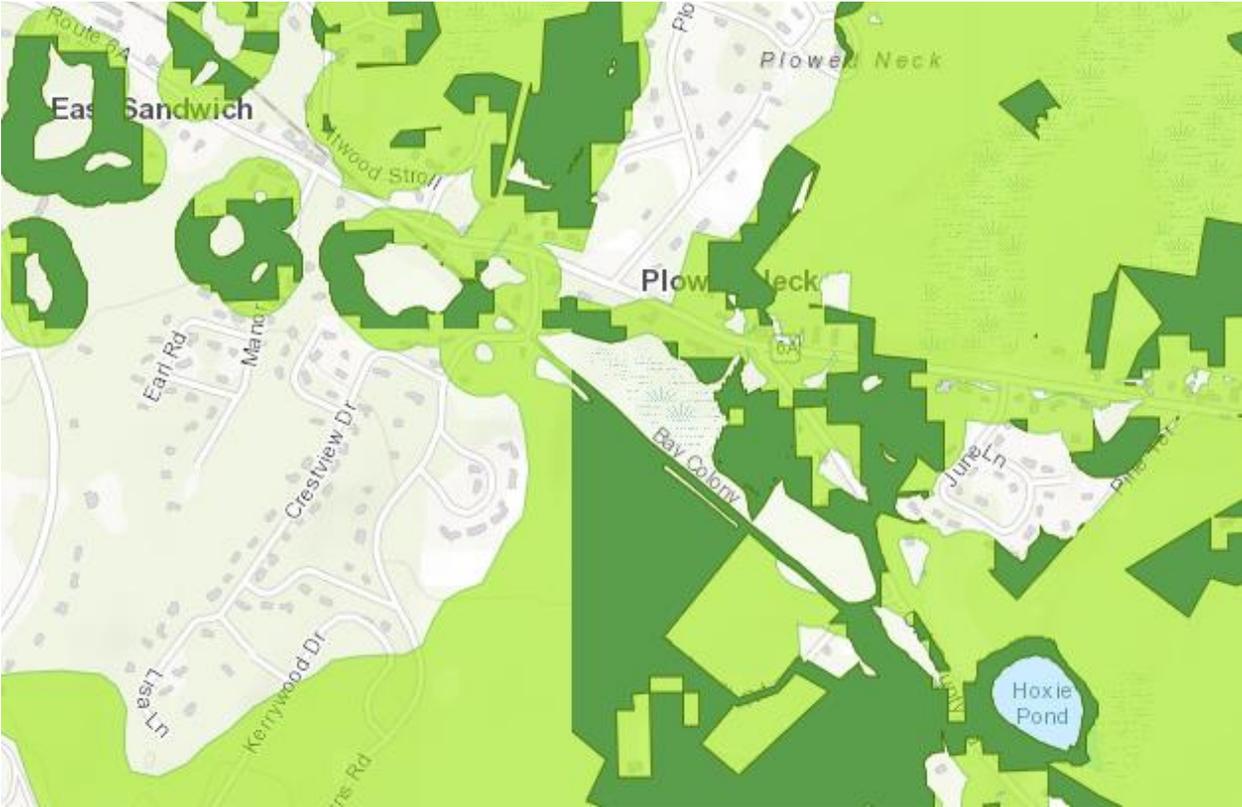
Green Infrastructure Network



Figure 8: Zoom to the Barnstable Harbor Region



Figure 9: Further Zoom in the Barnstable Harbor Region



Green Infrastructure Protection through Local Bylaw Integration

The green infrastructure analysis provides a regional perspective on conservation priorities in the Pine Barrens Ecoregion. Moving from conservation planning to implementation will require coordination among federal, state and local interests. Localities have an important role to play in guiding future land use decisions in southeastern Massachusetts. In particular, open space plans, comprehensive plans, subdivision bylaws, and zoning bylaws provide an opportunity to integrate the regional conservation vision with local planning. This approach has the potential to provide natural system and human community benefits while minimizing tax burden associated with open space protection.

The Benefits of Including Regional Priorities in Local Planning

The benefits provided by protected open space increase dramatically when local conservation efforts are linked to a regional prioritization scheme and coordinated on a regional scale. The functional units associated with natural systems, such as watersheds, groundwater recharge areas, and important habitat areas, rarely coincide with locality boundaries. The regional green infrastructure analysis for the Pine Barrens Ecoregion prioritizes open space for protection based on these functional units. Coordinated open space protection will benefit all of the localities in the Pine Barrens Ecoregion in ways that are simply not possible through uncoordinated local conservation initiatives. As an example, a regional approach to reducing water pollution by protecting vegetated buffers around streams and rivers provides water quality benefits that are simply not achievable by a single locality working alone.

Integration through Local Development Controls

Key steps in the regional/local integration process include 1) development of a local version of the regional green infrastructure map, 2) inclusion of the resulting map in the open space plan, 3) inclusion of explanatory text in the open space plan, 4) development or update to an open space subdivision ordinance, and 5) inclusion of reference to the open space plan and subdivision ordinance in local comprehensive plans and zoning. In addition, a local transfer of development rights program could be either established or updated to add the green infrastructure network as a sending area and focal areas for development as the receiving areas.

Local open space plans are a key element in establishing linkage between the regional green infrastructure analysis and local conservation initiatives. The open space plan template provided by the State of Massachusetts includes both structural elements and recommendations on connecting regional and local open space protection priorities. The Pine Barrens Ecoregion green infrastructure analysis meets this need by providing detailed mapping of high value unprotected/undeveloped open space at a resolution that supports integration with local land protection priorities.

Recommendations on Augmentation of Local Development Controls

The following elements are recommended to fully integrate the regional conservation vision into local development controls. Implementation of the full set of recommendations will set up a mechanism to leverage the development approval process by requiring protection of land within the green infrastructure network when land is subdivided. If it is not possible to do the complete integration, implementation of a subset will increase the priority for protection of the green infrastructure network but may fall short of the goal of having the development approval process support the open space protection goals established by the network.

Open Space Plan Integration

Development of Sub-regional and Local Green Infrastructure Maps

- Development of a sub-regional context map: The context map will be included in section 3.A of the open space plan, regional context.
 - **The Pine Barrens green infrastructure geographic information system data is available at:**

https://gisservices.capecodcommission.org/arcgis/rest/services/Project/PBSA_2020/FeatureServer.
 - The URL links to the aggregate green infrastructure network, the undeveloped/unprotected component of the network, habitat protection area, flood hazard areas, and the TNC Resilience Landscapes layer. The URL can be used to add data from the web to a GIS map and the data can be downloaded from there.
 - Layer with locality boundaries.
 - Clip to the desired sub-region of the watershed. The goal is to produce a map that includes the localities that abut the locality in question, providing guidance on possible linkage between open space protection within the locality and open space networks within the adjacent localities.
- Development of local green infrastructure map: The local green infrastructure map will be used in the open space plan and potentially in other documents such as the open space subdivision ordinance and comprehensive plan. Two options are available here, either creation of a standalone green infrastructure map based on a local clip of the regional map, or creation of an aggregate local map that includes both elements of the regional analysis and local priorities. Use of the second option allows more flexibility in terms of adapting the regional conservation vision to meet local needs. As an example, local conservation priorities could be added to the regional green infrastructure, creating an aggregate map that integrates regional and local conservation goals. Conversely, elements of the regional analysis could be removed for areas where local planning priorities such as economic development make conservation unfeasible.
 - Using the same GI components utilized in creation of the regional context map, clip the Pine Barrens Ecoregion green infrastructure map to your locality boundary

- If augmentation with local features is desired, add features such as:
 - Protected open space not currently included in MASSGIS: The Pine Barrens Ecoregion GI analysis included protected open space as documented in MassGIS. If your locality has protected open space that is not included in MassGIS you should include those polygons in the aggregate local map.
 - Local conservation priority areas: If local planning documents include conservation priority areas that are not reflected in the regional analysis they are added here.
 - Water supply protection areas: The regional analysis does not include wellhead or surface water supply protection areas. They may be added in this step.
 - Future land use map components: Successful implementation of local open space goals will be contingent on tight linkage with overarching land use plans. Integration of open space protection goals with local future land use maps, comprehensive plans, and zoning are all recommended.
 - Other local priorities

Augmentation of the Open Space Plan

Local open space plans provide the single most important opportunity for linkage between regional and local conservation priorities. The following outline for augmentation of local open space plans to implement the local green infrastructure map are based on the Massachusetts Open Space and Recreation Planner's Workbook.⁴ Specific recommendations for augmentation of local open space plans includes the following:

- Section 1: Plan Summary: Include a reference to the Pine Barrens Ecoregion green infrastructure analysis in the discussion of regional context to be considered in the open space plan.
- Section 3.A: Regional Context: Include a more detailed explanation of the Pine Barrens Ecoregion green infrastructure analysis and the sub-regional green infrastructure map developed in the previous step.
- Section 4: Environmental Inventory and Analysis: Much of the integration of green infrastructure will occur in this section. Include an introductory paragraph at the beginning of Section 4 that summarizes the components of the local green infrastructure map developed in the previous section.
 - 4.C. Water Resources
 - Include discussion of the water resources element of the GI map/analysis and the associated buffering.
 - 4.D. Vegetation
 - Include discussion of the BioMap2 and Resilient Landscapes elements of the green infrastructure analysis.

⁴ <https://www.mass.gov/doc/open-space-and-recreation-plan-workbook/download>.

- 4.E. Fisheries and Wildlife
 - Include discussion of the BioMap2 and Resilient Landscapes elements of the green infrastructure analysis.
- 4.F. Scenic Resources and Unique Environments
 - Include discussion of the BioMap2 and Resilient Landscapes elements of green infrastructure analysis.
- 4.G. Environmental Challenges
 - Discuss conservation and climate change resiliency needs in conjunction with the green infrastructure elements that address them.
- Section 5: Inventory of Lands of Conservation and Recreation Interest
 - Discuss undeveloped/unprotected element of the green infrastructure analysis.
- Section 8: Goals and Objectives
 - Prioritize land conservation to support protection of the undeveloped/unprotected component of the local green infrastructure map.
- Section 9: Five Year Action Plan
 - Include the local green infrastructure map in the action plan.

Inclusion of Green Infrastructure in Subdivision Ordinance

The previous steps will result in the creation of a local version of the regional green infrastructure map and a detailed discussion of how the components of the map link to local conservation and land use priorities. These components can then be used as a framework for required open space dedication when land is subdivided for development. The following recommendations build on the [open space subdivision ordinance template](#)⁵ included in the [Massachusetts Smart Growth Toolkit](#).⁶ In particular, this section provides guidance on modifying the Contiguity of Open Space subsection of the Open Space Requirements section of the template. The language in that section of the template is as follows:

Contiguity of Open Space: *Preserved open space shall be contiguous to the greatest extent practicable. Where noncontiguous pockets of open space are preferable to protect conservation areas, applicants shall attempt to connect these resources area to the greatest extent practicable through the use of trails and/or vegetated corridors. Open Space will still be considered contiguous if it is separated by a shared driveway, roadway, or an accessory amenity (such as a barn, paved pathway or trail, or shed for the storage of recreational equipment).*

In addition to implementing contiguity requirements to protect large blocks of open space, corridors between open space blocks should be preserved in order to allow for wildlife movement.

⁵ https://www.mass.gov/files/documents/2017/11/03/Open%20Space%20Design%20%28OSD%29-Natural%20Resource%20Protection%20Zoning%20%28NRPZ%29_0.pdf

⁶ <https://www.mass.gov/smart-growth-smart-energy-toolkit-information-and-resources>

Designating desired blocks and corridors in open space and recreation or other plans allows developers and regulators to incorporate them from the outset.

The recommended replacement for the draft language in the template is to require open space dedication to contribute to protection of the green infrastructure network as defined in the local green infrastructure map and the open space plan.

- When land being subdivided overlaps the green infrastructure network, require on-site protection.
- When land being subdivided does not overlap the green infrastructure network, utilize transfer of development rights to protect the network elsewhere in the locality.

Transfer of Development Rights

The Massachusetts Smart Growth Toolkit⁷ includes guidance on creation of local Transfer of Development Rights (TDR)⁸ programs. While not necessary to implement a local green infrastructure program, inclusion of a TDR program will increase flexibility in guiding conservation, development, and protection of community resources. TDR programs designate sending areas where conservation is a priority and receiving areas where new development is concentrated. In this scheme key components of the green infrastructure network are designated as sending areas and priority development areas are designated as receiving areas. This structure enables targeted open space dedication requirements associated with the open space subdivision bylaw/ordinance.

In combination, this toolkit provides an approach that leverages the development approval process to meet local land use and conservation priorities. These elements have the potential to greatly reduce the tax burden associated with governmental acquisition of open space.

⁷ <https://www.mass.gov/smart-growth-smart-energy-toolkit-information-and-resources>.

⁸ <https://www.mass.gov/files/documents/2017/11/03/Transfer%20of%20Development%20Rights%20%28TDR%29.pdf>.

Appendix A

Technical details of the map revisions carried out by Gary Prahm of the Cape Cod Commission

The methods we followed were based on the following screenshot of the report from Manomet, 2017, by Eric Walberg and Jennifer Shakun, page 4:

The green infrastructure network was developed by combining the following components in a Geographic Information System (ArcGIS 10.4):

- **Resilient Areas**
 - Areas of “above average” resilience (≥ 0.5 standard deviation) according to The Nature Conservancy’s Resilient Landscapes dataset (specifically, a higher-resolution 90m version generated by TNC for MassAudubon)
- **Important Habitat**
 - BioMap2 Core & Critical Natural Landscape areas
- **Riparian Buffers**
 - Areas within 100ft of surface waters and wetlands (based on features in National Wetlands Inventory V2)
 - Areas within 100ft of 100-year flood areas and high risk coastal flood areas (as defined by the National Flood Hazard Layer)
- **Areas Vulnerable to Sea Level Rise**
 - Areas ≤ 4 m elevation

There is also a companion version of the green infrastructure network that excludes lands that are already developed or permanently protected. The undeveloped and unprotected areas have important benefits for people and nature, and they are still “in play” in terms of the potential for restoration or conservation. In this case, the following criteria were used to define “developed” and “protected” lands:

- **Developed Land**
 - Areas categorized as “Commercial/Industrial/High Density Residential” or “Low Density Residential” in a 2013 MassAudubon land use/land cover layer
- **Protected Land**
 - Areas in the MassGIS Open Space layer where Protection Level = In Perpetuity

For the report, see https://www.manomet.org/wp-content/uploads/old-files/Manomet_GreenInfrastructure_Analysis_for_TauntonWatershed_July2017.pdf

The green infrastructure feature was created by a merging of these:

Areas below 4 meters elevation

Wetlands and 200 foot buffer

The Nature Conservancy areas of above average resilience

High risk coastal areas within 100 feet of and including FEMA A and V zones

Biomap2 core habitat

Biomap2 critical natural landscape

The subset of the green infrastructure includes this data:

Land use/land cover from MassGIS, 2016 photography.

Protected open space from MassGIS, Feb. 2020.

These layers were merged and used to create the undeveloped/unprotected area of towns through geo-processes.

To make a feature that was area below 4 meters above sea level, MassGIS elevation data was used. A feature of contour lines at three meter intervals created in 2005 was made into a TIN which was used to generate contours at four meter intervals.

Wetlands – MassGIS/DEP wetlands were used. A 200 foot buffer of both ponds and wetlands were included in the green infrastructure whereas only the buffer areas were included in original methodology. WETLANDSDEP_POLY_PBSA has fresh water wetlands and open water for the study area.

TNC_Resilience – The Nature Conservancy areas of above average resilience. CCC used what was provided by Manomet.

High risk coastal areas -The Manomet data provided to CCC appears to be FEMA FIRM A and V zones. The methodology implies that a 100 foot buffer be added to these areas, which is what CCC did.)

BioMap2_Core_Clip – Biomap2 core habitat (NHESP as the source; clipped to study area)

BioMap2_CriticalNaturalLandscape_Clip – Biomap2 critical natural landscape (NHESP as the source; clipped to study area)

Note: a series of steps where unions were dissolved before combining with other layers was used because the size of the features in some cases were overly large for our processors to handle.

Details of the undeveloped/unprotected data creation:

Developed land:

Land use/land cover from MassGIS - This statewide dataset contains a combination of land cover mapping from 2016 aerial imagery and land use derived from standardized assessor parcel information for Massachusetts. These categories from the 2016 Land cover/landuse from MassGIS have been selected for the "developed" category for Pine Barrens/Green Infrastructure project by the Cape Cod Commission, June 2020.

Generalized Use Name	Developed
Agriculture	
Commercial	Yes
Forest	
Industrial	Yes
Mixed use, other	*
Mixed use, primarily commercial	Yes
Mixed use, primarily residential	Yes
Open land	
Recreation	
Residential - multi-family	Yes
Residential - other	Yes
Residential - single family	Yes
Right-of-way	Yes
Tax exempt	
Unknown	
Water	

* note - these polygons are mostly vegetated undisturbed areas

Protected open space – MassGIS open space and recreation feature, February 2020, polygons selected where “level of protection = in perpetuity”.

These two layers were unioned and dissolved to make a protected or developed feature, then unioned again with the town polygons. In the result, the area of the town that is not protected or developed is marked as undeveloped or unprotected.