GIS-Based Site Assessment and Recommendations for Best Management Practices at Mount Hope Farm, Bristol, Rhode Island

By

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Lauren Phipps Photography, 2014

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ABSTRACT

As development pressures dissect and eliminate the remaining blocks of natural areas, it has become increasingly important to make informed, ecologically-based decisions about the use of protected open space. Most open space areas serve a variety of functions, and so must be designed to accommodate multiple, often conflicting uses. Mount Hope Farm provides a wealth of historic, cultural and ecological resources that need to be stewarded for the future. The most effective way to manage these resources, address current problems and plan for the future is to utilize the framework for designing sustainable multifunctional landscapes. The steps in the framework include defining the project site and landscape context, analyzing the landscape structure and function, creating a Master Plan using and ecosystem approach, designing sites to highlight their ecological functions and monitoring ecological functions once the designs have been implemented. This paper addresses the first two steps in the framework in order to provide a foundation for the preparation of the Master Plan. Site visits, use of ArcGIS data layers and a survey of the primary literature where used to describe the property, the landscape context and the site characteristics. Key site issues have been identified as access/ circulation within the site, invasive plant species in the hay fields and wetlands, and water quality in the farm ponds. Recommendations for best management practices include a breakdown of the approximate area currently in use and available for future infrastructure development or expansion of agriculture, as well as discussions on designing sustainable multifunctional landscapes, site development, invasive species and agriculture, water quality, natural communities and biodiversity, and sea level rise. GIS-based maps have been created to outline key site characteristics and landscape features.

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INTRODUCTION

As development pressures dissect and eliminate the remaining blocks of natural areas, it has become increasingly important to make informed, ecologically-based decisions about the use of protected open space. Most open space areas serve a variety of functions, and so must be designed to accommodate multiple, often conflicting uses. The spatial allocation of land has traditionally been based on soil and landscape features that define the suitability for particular activities, while neglecting the environmental impacts and conflicts with other potential land uses (Nin, 2016). The challenge today is to design sustainable multi-functional landscapes that simultaneously provide food security, livelihood opportunities, maintain critical ecosystem function, service flows, and biodiversity retention, and fulfill cultural, economic, aesthetic and recreational needs (Lovell, 2009). This is the key to halting and reversing the declining trends in the majority of our ecosystem services. We need to maintain and create landscapes that assist species in responding to increasing climate pressures, facilitating movement and establishing in new emerging ecosystems (O'Farrell, 2010).

Together, Mount Hope Farm and Brown University own more than 500 contiguous acres that include a range of natural communities and habitats: working farmland, abandoned farmland in a variety of successional stages, mature hardwood forest, wetlands, and bedrock outcrops and upland (RINHS, 2016). The site is one of the largest undeveloped tracts in Bristol County, Rhode Island's most densely populated county. Mt. Hope Farm is also an important historic resource; it is one of approximately sixty historic sites that are open to the public in the State of Rhode Island. The Mount Hope Farm property and the Brown tract also encompass one of the approximately 2,000 known archeological sites in the state (HPHC, 2016). The farm serves as a wedding and event facility, produces local food at its Community Garden, teaches environmental education and history through camps that integrate Native American culture and rituals, and serves as a quiet retreat to countless visitors who come to enjoy its woodlands, wetlands and shoreline.

It important for the farm to continue to maintain both the historic and ecological resources at the site, while improving its infrastructure to better accommodate existing and future activities. Utilizing the framework for the ecological design of landscapes is valuable because it will benefit the site through a multi-scale approach for connecting sites to their surroundings, provide a multifunctional design for sustainability, and it encourages the involvement of ecologists throughout the entire design process (Lovell S. T., 2008). In order to design this property as a sustainable multifunctional landscape, the Board of Directors should implement the framework using the following steps:

1. Define the project site and landscape context.
2. Analyze landscape structure and function.
3. Create a Master Plan using an ecosystem approach.
4. Design sites to highlight ecological functions.
5. Monitor ecological functions.

HISTORICAL CONTEXT

Mount Hope (originally *Montaup* in the Pokanoket language) is the ancestral headquarters of the Wampanoag Indians, and figured prominently in King Philip's War. Also known as Metacom's Rebellion, the conflict lasted fourteen months, destroyed seventeen English settlements and resulted in the death and enslavement of thousands of Native Americans. The leader of the rebellion, King Philip (the Wampanoag sachem) was surprised and killed on August 12, 1676, at Cold Spring on the south slope of Mount Hope (Williamson, 1976). Immediately the Wampanoag lands were claimed by four colonies, Massachusetts Bay, Plymouth, Rhode Island, and Connecticut. Plymouth won the dispute and in 1680 sold the land to four Boston merchants, including Nathaniel Byfield, who acquired Mount Hope as part of his share. Bristol, incorporated in 1680, remained part of Massachusetts until annexation by Rhode Island in 1746 (Munro, 1880).

In 1702, Byfield sold Mount Hope Farm to his son-in-law Col. Henry MacKintosh. In 1742, the estate of the late Col. MacKintosh was split between Thomas and Mary Palmer and Isaac and Elizabeth McIntosh Royall (RIHPC, 1990). Isaac Royall and his wife Elizabeth received the southerly portion of 376 acres and began construction of the house known today as the Governor William Bradford House. Because they were Loyalists, Elizabeth and Isaac fled Bristol during the Revolutionary War and their home and farm were confiscated by the State of Rhode Island. The house was used by Generals Stark and Sullivan and the fields by the 2nd Rhode Island Continental regiment during the Revolution. In 1783, it was sold to Brigadier General Nathan Miller of Warren; the proceeds were used to discharge the balance of pay due officers and soldiers of the Continental Battalions of Colonel Christopher Greene and Colonel Henry Sherburne (Williamson, 1976).

Nathan Miller sold the farm to William Bradford, Deputy Governor and later United States Senator from Rhode Island. Bradford willed Mount Hope Farm to his son John. John's sister Ann, the wife of Captain James DeWolf, who owned abutting land, received 1/5 of the remainder of the estate (Mount Hope Farm, 2013). In 1836, John Bradford's heirs sold Mount Hope Farm to Samuel W. Church, a wealthy Massachusetts grain and flour merchant. In 1854, Church moved to the family farm on Poppasquash; Mount Hope Farm remained in Church ownership until sold by his heirs to Rudolph L. Haffenreffer II, a Massachusetts brewer, in 1917 (Mount Hope Farm, 2013). Haffenreffer restored the neglected property and operated it as a dairy farm. The Haffenreffer family held several successful industrial interests in Rhode Island, including ownership of the Herreshoff Manufacturing Company from 1924-1942, the Mount Hope Bridge Corporation from 1932 to 1953, and the Narragansett Brewing Company from 1933 to 1965 (Williamson, 1976). The Haffenreffer family deeded approximately 500 acres of the original farm including Mount Hope, the creamery, and other additions which contained their father's Indian relics and early American memorabilia to Brown University in the 1950's. After the death of Rudolph Haffenreffer and his wife Virginia, the Mount Hope Trust in Bristol acquired Mount Hope Farm in 1999.

ENVIRONMENTAL CONTEXT

Site characteristics can have an impact on activities and installations planned for a given location. Soil properties affect suitability for roads, buildings and agriculture, topography and vegetation will have an impact on soil erosion, and wetlands impact that amount of land that can be disturbed. Land use and cover changes greatly affect many environmental aspects and ecological processes (Chen, 2016). An examination of current and historic land uses at the Property, as well as surrounding land use will help to determine potential impacts to soils, wetlands and water quality and natural communities and biodiversity, which can then be applied to inform Best Management Practices for future improvements.

Soils and Site Use

Existing soils will to a large extent determine the property's potential as a building site, a lawn, a garden, and the ability to support an onsite wastewater treatment system. The USDA - Natural Resources Conservation Service (NRCS) and the Rhode Island Department of Administration's Division of Planning have identified those lands in Rhode Island that have a combination of physical and chemical features that make them best suited for farming. These "Important Farmlands" are subdivided into: 1) "Prime Farmlands" which are the best soils for agricultural use, and 2) "Additional Farmlands of Statewide Importance" which are other soils that are lass well suited for intensive farming but are still valuable for many farm enterprises (USDA NRCS, 2013). In general, prime farmland soils have an adequate and dependable water supply from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, acceptable salt and sodium content, and few or no rocks. They are permeable to water and air. Prime farmlands are not excessively erodible or saturated with water for a long period of time, and they either do not flood frequently or are protected from flooding.

The texture of the subsoil indicates the building site potential. If the subsoil is coarse (sand, loamy sand), water drains through it rapidly (assuming there is no highwater table). Coarse-textured soils are easily excavated and quite stable during both dry and wet conditions. Fine-textured soils tend to expand as the amount of moisture increases and to contract as moisture decreases, this can be especially problematic during the winter and spring as the moisture in the soil freezes and thaws. This lack of stability can crack foundations, sidewalks, and driveways. Organic soils (peat and muck) are easily compacted, resulting in settling if foundations are installed, this makes them unsuited for building.

Soil texture significantly influences the ability of a soil to accept and treat septic tank effluent. Fine-textured soils have slower percolation rates, requiring a larger treatment area. However, the small size of the particles provides a greater surface area, resulting in a more effective treatment of the effluent. Sandy soils tend to have faster percolation rates, requiring a smaller area, but their larger particle and pore sizes provide less effective treatment. Moderately coarse-to-medium-textured soils (sandy loams, silt loams) have a larger variety of soil particle and void sizes. These soils are ideal for treatment, combining a moderate rate of water movement with a large amount of soil particle surface for treating the effluent (Anderson, 2016).

Soil Erosion, Vegetation and Topography

Soil erosion results in increased mobilization of suspended solids to receiving waters. This causes increased turbidity in receiving waters and contributes to additions of non-point source pollutants by exporting sediment-associated components, such as particulate phosphorus, organic contaminants, and trace metals (Dunn, 2015). Turbidity in water reduces light penetration into waterbodies, decreasing photosynthesis, and limiting the energy available to fish and other aquatic animals (Giri, 2013). The processes that lead to soil erosion and losses of sediment from the land to water are strongly related to high intensity precipitation landing on bare soil, which provides the energy to dislodge particulate material and to transport it across the land surface; the amount of energy required to dislodge the particles decreases as slope increases (Lu, 2016). Vegetative coverage is an important factor with regard to soil erosion control. Vegetation can reduce the direct effect of raindrops on the soil, reduce surface runoff, alleviate runoff denudation of the soil, enhance the organic matter content in the soil, and increase the infiltration rate of water (Qiang, 2016). The physical barrier provided by vegetation influences the transportation of sediments on the soil surface. The vegetation coverage and mosaic pattern influence the connectivity of runoff and form areas of soil erosion and sediment deposition on the surface (Mayor, 2008). Therefore, the continuity of vegetation coverage is important for protecting the soil from erosion; the presence of small uncovered areas can determine a strong reduction of soil conservation effect (Porto, 2009).

Wetlands and Water Quality

Freshwater wetlands are ecological systems that provide services that directly benefit the health, welfare and general well-being of people and the environment (RI DEM, 2007). Ecosystem services provided by freshwater wetlands include, but are not limited to, the protection and maintenance of water quality, protection against floods, maintenance of surface and groundwater supplies, the provision of habitats for plants and animals, and recreational and aesthetic opportunities. Wetlands protect water quality by filtering and removing nutrients, pollutants and sediments, reducing turbidity, producing oxygen, and maintaining temperature and oxygen regimes in standing and flowing surface waters (Nilsson, 2008).

Water quality is defined as a measure that can evaluate the usage of water for different purposes (drinking, agricultural, industrial, recreational, and habitat) using physical, chemical, and biological parameters (Giri S. Z., 2016). Water quality is affected by a broad range of different factors in the environment, including basic physical attributes such as soil type, geology and topography. However, anthropogenic influences, including land use and management, are superimposed on this, and in some cases have a much greater influence on water quality than the natural characteristics of the system (Sun, 2013). Together land use changes and climate can be considered as the key drivers of variation in water quality.

Water quality varies based on location, time, weather, and presence of pollution sources. Maintaining proper water quality is a challenging task, primarily due to the presence of point and non-point sources of pollution (Giri S. Z., 2016). Site development increases the amount of impervious surface through the installation of man-made features such as parking lots, rooftops, roads, and sidewalks. This can result in an increase in runoff, creating an additional avenue for the transportation of pollutants from the landscape into waterbodies (Wilson, 2010). Whereas agricultural activities can increase the amount of fertilizers, pesticides, herbicides, and manures moving from the agricultural areas into adjacent wetlands.

Ecological Communities and Biodiversity

Open space areas not only provide recreational and aesthetic value to visitors, but also a place where ecological communities and biodiversity can be preserved and enhanced. Losses to ecological communities and biodiversity result in subsequent losses in ecosystem services (i.e., pollination, carbon sequestration, filtration of pollutants). Efforts to protect natural areas are frequently hampered by the inability to appraise the value of services provided by the ecological communities in those areas (Woodruff, 2016). Ecosystem services help to reframe natural areas on a continuum of their use to humans, which spans from expendable, extremely low quality areas to an indispensable source of clean air, flood protection, recreation, clean water, and other services (Brauman, 2007). By relating the health of natural systems with human well-being, ecosystem services provide a powerful lens to advance sustainable and resilient development (Woodruff, 2016).

GOALS AND METHODS

This report will seek to answer the first two needs of the framework design, defining the project site and landscape context and analyzing the landscape structure and function. The analysis can then serve as the foundation of a Master Plan for the site. Maps of the various site conditions will be created using ArcGIS layers, topographic maps and aerial photographs. Maps will also be created showing the optimal locations for different activities based on soils, topography and wetlands. Background information will be compiled through interviews of Mount Hope Farm staff, internet research and site visits. Recommendations for Best Management practices will be based on a review of the primary literature and internet research.

SITE ASSESSMENT

Note: This Site Assessment reflects the condition

of the Property as ascertained from ArcGIS layers and several site visits conducted in 2016.

CURRENT LANDOWNER

Mount Hope Trust

LOCATION OF PROPERTY

Street Address: 250 Metacom Avenue

Municipality: Bristol

County: Bristol

State: Rhode Island

Plat/Lot: Bristol Tax Assessor's Plat 137, Lots 1, 3, 4, 6, 7, 9, 13 and Plat 41, Lot 40 (Figure 2).

PROPERTY DESCRIPTION

Acreage: The conservation area totals 130 acres (Figures 1, 3).

Location: Mount Hope Farm is located in the southeastern section of the Town of Bristol; this area consists of large tracts of undeveloped, forested land bordered by predominantly medium to medium-high density development. Additional land uses in close proximity to the Property include small areas of low/ medium-low and high density development, commercial developments, industrial usage, and the town transfer station (formerly the town landfill) (Figure 4) (RIGIS, 2015). The Property is comprised of deciduous woodlands and forest, plantation and ruderal forest, grasslands, shrublands, estuarine areas, open water and forested wetlands (Figure 4). Anthropogenic installations consist of the Governor Bradford House, North Pasture House, South Pasture House, Cove Cabin, Manager's House, the Playhouse, the barn and its associated buildings, a greenhouse, livestock buildings/ pens, gardens, agricultural fields, driveways, access roads, walking trails, and historic stone walls (Figure 5).

Landscape Context: Mount Hope Farm is one of 35 Designated Historic Properties located outside of the Bristol Downtown Historic District (BETA Group, Inc., 2010). There are approximately 530 acres of conservation land within one mile of Mount Hope Farm (Figure 6) (RIGIS, Municipal & Non-

Governmental Organization Conservation Lands , 2014). The Property is part of the largest block of contiguous preserved open space in the Town of Bristol, consisting of approximately 558 acres. To the north and west is Brown University's approximately 375-acre holding, adjacent to the northern boundary of the Brown parcel are the 30 acres of the Hopeworth Conservation Area and Glenview (Town of Bristol). Adjacent to the SE boundary of Mount Hope Farm lies the 24 acres of the Bristol Landing Preserve (privately held protected open space), this is bordered to the south by an 11-acre parcel protected by the Audubon Society of Rhode Island (privately held protected open space).

Prior Land Uses: During the Settlement Era, Mount Hope Farm and the adjacent Brown University lands were part of a Pokanoket village. After King Phillip's War ended, the lands were confiscated by the English colonists. The original owner of the farm, Nathaniel Byfield, established a farm on the property. Over the years, the farm consisted of at least agricultural fields, orchards, livestock and a dairy. During the Revolutionary War, the house and lands served as temporary lodging for Generals Stark and Sullivan and a camp for the 2nd Rhode Island Continental Regiment.

Current Land Use: Mount Hope Farm currently serves multiple historic, social, cultural and ecological functions. The Mount Hope Trust, a 501(c)(3) non-profit corporation, operates the farm. Its mission is to preserve and protect the integrity of its natural assets and its historical structures (Mount Hope Farm, 2013). The Property functions as a wedding and event venue and educational camp for children, offers lodging in 3 historic buildings, hosts a community garden and farmer's market, as well as providing visitors a place to walk and enjoy nature. In addition to the community garden, agricultural endeavors on the farm include livestock, hay production fields, and flower production.

Proposed Future Use: The Board of Directors plans to maintain and potentially expand the current uses on the Property. Upgrades to existing infrastructure may include improvements to circulation, the construction of additional buildings to support weddings and events, and trail and shore access improvements.

SITE CHARACTERISTICS

Topography

Elevations on the Property range from greater than 0 to less than 110 feet above sea level; topographically high areas include the southern end of Juniper Hill, which encompasses the farm proper along Metacom Avenue, the adjacent area to the NE of the farm and to the SW of Doris Avenue, and a small hill that straddles the northern boundary of the Property and the southern boundary of the panhandle of the Brown property (RIGIS, Rhode Island Topographic Maps, 2015). Topographically low areas are generally located along Mount Hope Bay. The topography is such that storm water from the medium-high density development to the N of the Property discharges to the N and E (away from the Property). However, storm water from the medium density development, industrial development, and landfill to the NW discharges into the river that flows through the Property, feeding into the two ponds (Figure 9). Limitations based on slope are discussed in the soils section.

Surficial/ Bedrock Geology

Soil parent materials consist of ablation till, ablation till over bedrock, and lodgement till (mixed lithology, Narragansett Basin Lithology and Narragansett Basin Lithology, sandy mantle) (RIGIS, Rhode Island Glacial Deposits, 1989). The entire site is underlain with Avalon bedrock, an intrusive granite from the late Proterozoic period; part of the Granites of Southeastern Rhode Island suite (RIGIS, Bedrock Geology of Rhode Island, 1994).

Soils

The Rhode Island Soil Survey describes 15 different soil types on the Mount Hope Farm property (**Table 1, Figure 8**) (RIGIS, Soils, 2016).

Table 1. Mapped soils at Mount Hope Farm, in Bristol, Rhode Island (NRCS, 2013).

Soil Type	Label	Farmland Rating	Erosion Rating	Approx. Acres
Beaches, bouldery surface	Bax			0.8
Birchwood sandy loam	Bc	Prime		39.7
Canton and Charlton fine sandy loams, very rocky, 3-15% percent slopes	CeC			8.6
Newport silt loam, 0-3% slopes	NeA	Prime		4.1
Newport silt loam, 3-8% slopes	NeB	Prime	Potentially High	5.4
Newport silt loam, 8-15% slopes	NeC	Important	High	10.1
Pittstown silt loam, 3-8% slopes	PmB	Prime	Potentially High	<0.1
Poquonock loamy fine sand, 3-8% slopes	PsB	Prime	Potentially High	10.5
Ridgebury fine sandy loam	Re	Important		8.1
Ridgebury, Whitman, and Leicester extremely stony fine sandy loams	Rf			27
Rock outcrop	Rk			0.7
Sandyhook mucky peat, 0-3% slopes	Sa			1.2
Sutton extremely stony fine sandy loam, 0-8% slopes	SvB		Potentially High	0.2
Water	W			2.6
Water, saline	Ws			1.1

Bc: Birchwood fine sandy loams consist of nearly level, moderately well drained soils found on the crests of upland hills and drumlins and in transitional positions between uplands and outwash terraces. Slopes range from 0 to 3 percent. Included with this soil in mapping are small areas of well drained Poquonock, Newport, and Paxton soils; moderately well drained Woodbridge and Pittstown soils; and poorly drained Stissing soils. Also included are small areas of soils that have slopes of more than 3 percent. Included areas make up about 10 percent of this map unit. The permeability of this soil is moderately rapid in the surface layer, rapid in the subsoil, and slow or very slow in the substratum. Available water capacity is low, and runoff is slow. This soil has a seasonal high water table at a depth of about 20 inches from late fall through mid-spring. The soil is very strongly acid through medium acid. This soil is suited to trees, woodland wildlife habitat, and openland wildlife habitat; it is too dry to provide wetland wildlife habitat.

CeC: Canton and Charlton very rocky fine sandy loams with 3-15% slope consist of gently sloping to sloping, well drained soils on side slopes and crests of bedrock-controlled glacial upland hills and ridges. Stones and boulders cover 2 to 10 percent of the surface, and rock outcrops cover up to 10 percent. The permeability of the Canton soils is moderately rapid in the surface layer and subsoil and rapid in the substratum. Available water capacity is moderate, and runoff is medium. This soil is extremely acid through strongly acid. The permeability of the Charlton soils is moderate to moderately rapid. Available water capacity is moderate, and runoff is medium. This soil is very strongly acid through medium acid. These soils are suitable for community development but are limited by stoniness, bedrock outcrops, and slope. Stones and rock outcrops make these soils unsuitable for cultivated crops and severely hinder the use of farming equipment. These soils are suitable for woodland wildlife habitat.

NeA: Newport silt loams with 0-3% slopes are nearly level, well drained soils on the crests of drumlins and glacial till plains. Included with this soil in mapping are small areas of well drained Poquonock soils and moderately well drained Pittstown and Birchwood soils. Also included are small areas of soils that have slopes of more than 3 percent. Included areas make up about 10 percent of this map unit. The permeability of this soil is moderate or moderately rapid in the surface layer and subsoil and slow or very slow in the substratum. Available water capacity is moderate, and runoff is medium. The soil is very strongly acid through medium acid. This soil is suited to trees, woodland wildlife habitat, and openland wildlife habitat. It is too dry to provide wetland wildlife habitat.

NeB: Newport silt loams with 3-8% slopes are gently sloping, well-drained soil found on the side slopes of drumlins and glacial till plains. Included with the soil in mapping are small areas of well drained Poquonock soils and moderately well drained Pittstown and Birchwood soils. Also included are small areas of soils that have slopes of more than 8 percent. Included areas make up about 10 percent of the map unit. The permeability of this soil is moderate or moderately rapid in the surface layer and subsoil and slow or very slow in the substratum. Available water capacity is moderate, and runoff is medium. This soil is very strongly acid through medium acid. This soil is suited to trees, woodland wildlife habitat, and openland wildlife habitat. It is too dry to provide wetland wildlife habitat.

NeC: Newport silt loams with 8-15% slopes are sloping, well-drained soil found on the side slopes of drumlins and glacial till uplands. Included with this soil in mapping are small areas of well drained Poquonock soils and moderately well drained Pittstown and Birchwood soils. Also included are small areas of soils that have slopes of less than 8 percent. Included areas make up about 15 percent of this map unit. The permeability of this soil is moderate or moderately rapid in the surface layer and subsoil and stow or very slow in the substratum. Available water capacity is moderate, and runoff is rapid. The soil is very strongly acid through medium acid. This soil is suited to trees, woodland wildlife habitat, and openland wildlife habitat. It is too dry to provide wetland wildlife habitat.

PmB: Pittstown silt loams with 3-8% slopes are gently sloping, moderately well drained soil found on side slopes of glacial upland hills and drumlins. Included with this soil in mapping are small areas of well drained Newport soils and poorly drained Stissing soils. Also included are small areas of nearly level soils, that have slopes of more than 8 percent, and stony soils. Included areas make up about 10 percent of this map unit. The permeability of this soil is moderate in the surface layer and subsoil and slow in the substratum. Available water capacity is moderate, and runoff is medium. This soil has a seasonal high water table at a depth of about 20 inches from late fall through mid-spring. The soil is very strongly acid through medium acid. This soil is suited to woodland wildlife habitat and openland wildlife habitat. It is poorly suited for wetland wildlife habitat because it is too dry during the summer.

PsB: Poquonock loamy fine sand with 3-8% slopes are gently sloping, well drained to somewhat excessively drained soil on side slopes of drumlins and glacial till uplands. Included with this soil in mapping are small areas of excessively drained Windsor soils; well drained Broadbrook, Newport, and Paxton soils; and moderately well drained Birchwood soils. Also included are small areas of nearly level soils. Included areas make up about 10 percent of this map unit. The permeability of this soil is rapid in the surface layer and subsoil and slow to very slow in the substratum. Available water capacity is slow, and runoff is medium. The soil is very strongly acid through medium acid. This soil is suited to woodland wildlife habitat and openland wildlife habitat. Droughtiness is the main limitation for woodland. Seedling mortality is high during dry summers.

Re: Ridgebury fine sandy loams are nearly level, poorly drained soil occurring in depressions and drainageways of glacial upland hills and drumlins. Slopes range from 0 to 3 percent but are dominantly less than 2 percent. Also included are small areas of soils that have stones on the surface. Included areas make up about 10 percent of this map unit. The permeability of this soil is moderate or moderately rapid in the surface layer and subsoil and slow or very slow in the substratum. Available water capacity is moderate, and runoff is slow to medium. This soil has a seasonal high water table at or near the surface from late fall through spring. The soil is very strongly acid through medium acid.

The slow or very slow permeability in the substratum and the seasonal high water table make this soil *poorly suited* to community development. Onsite septic systems require special design and installation, and areas need extensive filling. Subsurface drains are needed to help prevent wet basements. The soil is suited to most types of wildlife habitat. This soil is suited to trees. The main limitation for woodland is wetness; tree windthrow is common, and the use of equipment is limited during wet seasons.

Ridgebury soils are HYDRIC soils associated with wetlands which are protected from disturbance under state and Federal law. Any work done in or near this soil should be conducted following the proper permit procedures.

Rf: Ridgebury, Whitman and Leicester extremely stony fine sandy loams are nearly level, poorly drained and very poorly drained soils are along drainage ways and in depressions in glacial till uplands.
Stones and boulders cover 10 to 35 percent of the surface of the unit. Slopes range from 0 to 3 percent but are dominantly less than 2 percent. The areas of this unit consist of Ridgebury soils, Whitman soils, or Leicester soils or of all three soils. The soils were mapped together because they have no major differences in use and management. The permeability of the Ridgebury and Whitman soils is moderate or moderately rapid in the surface layer and subsoil and slow or very slow in the substratum. The permeability of the Leicester soils is moderate or moderately rapid in the surface layer and subsoil and moderate to rapid in the substratum. Available water capacity in all three soils is moderate, and runoff is slow to medium. These soils are very strongly acid through medium acid.

The high water table and the slow or very slow permeability in the Ridgebury and Whitman soils make this unit *poorly suited* to community development. The use of onsite septic systems is not feasible without extensive filling. The stones and boulders on the surface make these soils unsuitable for cultivated crops and the use of farming equipment impractical. These soils are poorly suited to trees. The main limitations for woodland are wetness and the stones and boulders on the surface, which hinder the use of equipment. Tree windthrow is common. These soils are suited to woodland wildlife habitat and wetland wildlife habitat. They are not suited to openland wildlife habitat.

This map unit consists of HYDRIC soils associated with wetlands which are protected from disturbance under state and Federal law. Any work done in or near this soil should be conducted following the proper permit procedures.

Rk: Rock outcrops consist of level to very steep areas of exposed bedrock. The areas are unprotected from the ocean. During storms, they are subject to strong wave action. Included with this unit in mapping are small areas of well drained Newport soils, poorly drained Matunuck soils, and Beaches. In places in the intertidal zone the rock is sparsely covered with aquatic plants. Small tidal pools are common.

Included areas make up about 20 percent of this map unit. Rock outcrop is suitable for summer recreation activities, including surf fishing, sunbathing, and hiking.

Sa: Sandyhook mucky peat with 0-3% slopes are nearly level, very poorly drained soils found in tidal marshes and are subject to tidal flooding. Most areas are in salt marshes, some areas are in brackish phragmites marshes. Slopes are dominantly less than 3 percent. Included with this soil in mapping are a few small areas of very poorly drained Ipswich, Pawcatuck, and Matunuck soils on similar positions. Succotash and Fortress soils are on higher elevations, and Nagunt, Marshneck, and Massapog soils are in permanently submersed areas. Some areas have human transported dredge material in the surface layers. Included areas make up about 5 percent of this map unit. The permeability of this soil is rapid in the surface layer, rapid to very rapid between depths of about 12 and 18 inches, and very rapid at a depth of more than 18 inches. Available water capacity is low. Runoff is very slow, and water is ponded on some areas. The soil is strongly acid through neutral. The daily tidal flooding and a high salt content make this soil unsuitable for most uses except as habitat for saltwater-tolerant wildlife.

Sandyhook soils are HYDRIC soils associated with wetlands which are protected from disturbance under state and Federal law. Any work done in or near this soil should be conducted following the proper permit procedures.

Se: Stissing silt loams with 0-3% slopes are nearly level, poorly drained soils found on glacial upland hills and drumlins. Included with this soil in mapping are small areas of moderately well drained Pittstown soils and very poorly drained Mansfield soils. Also included are small areas of soils that have stones on the surface and a few small areas of soils with a surface layer and subsoil of sandy loam. Included areas make up about 10 percent of this map unit. The permeability of this soil is moderate in the surface layer and subsoil and slow in the substratum. Available water capacity is moderate, and runoff is slow. This soil has a seasonal high water table near the surface from late fall through spring. The soil is extremely acid through medium acid.

The seasonal high water table and the slow permeability in the substratum make this soil *poorly suited* to community development. Onsite septic systems need special design and installation, and areas require extensive filling. This soil is suited to trees, but most areas are cleared and used for pasture. Wetness is the main limitation for woodland. Tree windthrow is common. This soil is suited to cultivated crops, but artificial drainage is needed. This soil is suited to most types of wildlife habitat.

Stissing soils are HYDRIC soils associated with wetlands which are protected from disturbance under state and Federal law. Any work done in or near this soil should be conducted following the proper permit procedures.

SvB: Sutton extremely stony fine sandy loam with 0-8% slopes are nearly level to gently sloping, moderately well drained soil on the lower side slopes of glacial upland hills and in low areas that border uplands. Stones and boulders cover 10 to 35 percent of the surface. Included with this soil in mapping are small areas of well drained Canton and Charlton soils on convex slopes, moderately well drained Woodbridge soils and Wapping soils on similar landforms, and poorly drained Leicester and Ridgebury soils on concave slopes and drainageways. Also included are small areas of soils with slopes of more than 8 percent and soils with a surface layer of silt loam. Included areas make up about 15 percent of this map unit. The permeability of this soil is moderate or moderately rapid. Available water capacity is moderate. This soil has a seasonal high water table at a depth of about 20 inches from late fall through midspring. The soil is very strongly acid through medium acid in the surface layer and subsoil and very strongly acid through slightly acid in the substratum. The soil is not suited to cultivated crops, because the stones and boulders make the use of farming equipment impractical. This soil is suited to woodland wildlife habitat. It is not suited to openland wildlife habitat and is poorly suited to wetland wildlife habitat.

Wa: This map unit consists of large streams, rivers, ponds, lakes, reservoirs, ocean, bay's, lagoons, and human made water bodies. Areas range from less than 1 acre to the 3,500 acre Scituate Reservoir. The map unit is unsuited for most non-aquatic uses.

Ws: Water, saline consists of salt water bodies (ocean, bays, estuaries, coastal lagoons, and brackish areas) subject to tidal fluctuations. The map unit is unsuited for most non-aquatic uses.
UPDATE: Shallow water bodies are now considered soil areas, particularly areas with rooted vegetation (fresh and salt water).

Hydrography/ Wetlands

Disclaimer: Information on wetlands was taken from layers available on RIGIS, these were delineated through interpretation of topography and aerial photography, and do not represent official field delineations.

The majority of the Mt. Hope Farm property falls within the Mount Hope Bay watershed, thus the majority of the water from the site drains into Mount Hope Bay (**Figure 9**) (RIGIS, Rhode Island Watershed Boundary Dataset, 2007). An approximately 7-acre parcel along the eastern side of Metacom Avenue maintained as open field/lawn, and an approximately 9.25-acre forested and forested wetland parcel fall within the Upper East Passage Watershed.

Mount Hope Farm contains a variety of salt and freshwater wetland resources; land uses on the property, as well as surrounding land uses will have an impact on the quality of these resources. Freshwater wetlands onsite include a river, ponds, forested wetlands, shrub wetlands, and emergent wetlands (**Figure 10**) (RIGIS, National Wetland Inventory (NWI) for Rhode Island, 2014). Freshwater wetlands may also include intermittent streams that have not been identified on the ArcGIS layers. Salt-influenced wetlands include estuarine and marine wetlands. Below are listed several terms from the *Act*, with their respective definitions, followed by comments about the occurrences of each type on the property.

River: Defined in Section 2-1-20(8) of the *Act* as a body of water that is designated as a perennial stream by the United States Department of Interior Geologic Survey on 7.5-minute series topographic maps, and that is not a pond (RI DEM, 2007).

One river flows through the property, the headwaters are approximately adjacent to the southwestern corner of the Bristol Landfill. The river is dammed in two locations, creating the two farm ponds on the property, and terminates in Mount Hope Bay.

Stream/ Intermittent Stream: Any flowing body of water or watercourse other than a river that flows long enough each year to develop and maintain a defined channel. Such watercourses may carry groundwater discharge or surface runoff, may not have flowing water during extended dry periods, but may contain isolated pools or standing water.

No intermittent streams were identified within the ArcGIS layers utilized. However, this does not preclude them from the site. Small intermittent streams often have little to no signature on aerial photos and may require a field visit to identify.

Pond: In Accordance with Section 2-1-20(7) of the *Act*, a place not less than 0.25 acre in extent, natural or manmade, wholly or partly within the State of Rhode Island, where open, standing water or slowly moving water shall be present for at least six months a year.

Two man-made ponds can be found on the property, the upper (northern) pond is approximately 1.2 acres in size. Water control structures include a gate valve, 2 stand (overflow) pipes and a spillway. This pond has a large population of cattails (*Typha*), a native wetland plant, along its northern, northwestern and eastern margins. This species provides good habitats for marshbirds and songbirds. The lower (southern) pond is approximately 3.5 feet deep and 1.8 acres in size. Water control structures include 2 stand pipes and a spillway. There is also a pumphouse for a fountain that previously existed in the pond.

Shrub Wetland: A freshwater wetland dominated by woody plants less than 20 feet tall that occurs along the margin of a pond or river, isolated in a wet depression or valley, or as a transition community between a marsh and upland communities. The substrate is usually mineral soil or muck. Common species at Mount Hope Farm include red maple (*Acer rubrum*), swamp white oak (*Quercus bicolor*), black gum (*Nyssa sylvatica*), buttonbush (*Cephalanthus occidentalis*), swamp rose (*Rosa palustris*), alder (*Alnus spp*.), willow (*Salix spp*.), sweet pepperbush (*Clethra alnifolia*), winterberry (*Ilex verticiallata*), highbush blueberry (*Vaccinium corymbosum*), bayberry (*Myrica pensylvanica*), briar (*Smilax spp*.), multiflora rose (*Rosa multiflora*), sensitive fern (*Onoclea sensibilis*), steeplebush (*Spiraea tomentosa*), Sphagnum and soft rush (*Juncus effusus*).

Forested Wetland: A freshwater wetland dominated by woody plants greater than 20 feet tall. See Shrub Wetland for species common to Mount Hope Farm.

Natural Communities/ Natural Heritage Areas

The Property is comprised of oak dominated deciduous woodlands and forest, plantation and ruderal forest, grasslands, coastal shrublands, estuarine areas, open water and forested wetlands and agricultural areas (**Figure 11**) (RIGIS, Ecological Communities Classification, 2014). The RI Natural History Survey 2005 BioBlitz identified over 972 species of plants and animals on the Mount Hope Farm and Brown University parcels.

Deciduous Woodlands and Forests are communities comprised of 25-60% tree cover (woodlands) or >60% tree cover (forests), with >75% deciduous species. Oak Forest communities are dominated by oaks (Quercus); species composition is generally dependent on site conditions, especially soil type and hydrology. Variants include Black Oak/Scarlet Oak – Heath Forest, White Oak – Mountain Laurel Forest, Chestnut Oak Forest and Mixed Oak – American Holly Forest. Mount Hope Farm appears to host mainly the Mixed Oak – American Holly Forest variant. Additional tree species include red cedar (*Juniperus virginiana*), red maple (*Acer rubrum*) and white pine (*Pinus strobus*). The understory is generally dominated by briar (*Smilax spp.*), mixed with American holly (*Ilex opaca*), winterberry (*Ilex verticillata*), highbush blueberry (*Vaccinium corymbosum*), grape (*Vitis spp*.), and American bittersweet (*Celastrus orbiculatus*).

Tree plantations generally consist of land cover that is apparently modified and appears to have been managed, usually as coniferous, even-aged trees planted in rows. Species may be native or non-native and include various spruces (*Picea*), pines (*Pinus*), firs (*Abies*), and larch (*Larix*). At Mount Hope Farm this type of community is dominated by red cedar (*Juniperus virginiana*) interspersed with red maple (*Acer rubrum*) and white pine (*Pinus strobus*).

Ruderal forests are undifferentiated upland forests, typically even-aged, resulting from succession following removal of native woody cover for agriculture or logging. Soil alteration from agriculture tends to lead to low diversity forests, often with exotic species in the understory that do not resemble natural forest systems. Generally, a ruderal forest is characterized by a combination of early-successional trees that cannot be identified as natural ecological systems even in an incipient state. These forests often contain substantial amounts of red maple (*Acer rubrum*), white pine (*Pinus strobus*), red cedar (*Juniperus virginiana*), and gray birch (*Betula populifolia*). Where soil disturbance has not been severe, many sites will follow a trajectory towards one of the later successional and more natural forest communities.

Ruderal grasslands/ shrublands are anthropogenic communities of herbaceous or mixed herb/shrub vegetation resulting from succession following complete removal of native woody cover. The grasslands on the Property are maintained as hay fields. Due to a last season visit, the only native grass identified in the fields was Broomsedge (*Andropogon virginicus*), other plants included Pennsylvania sedge (*Carex pensylvanica*), goldenrod (*Solidago spp*.), Euro grasses and Spotted Knapweed (*Centaurea stoebe*). Broomsedge thrives in nutrient-poor soils and is often an indicator of low organic content, or "worn out" soils.

Coastal shrublands/ Salt shrub are shrubland communities that develop at the ecotone of salt marsh and upland where the elevation is somewhat higher than the adjacent salt marsh community and salinity levels are lower. This community usually occurs as a linear feature along the upper edge of salt marshes, or as shrub islands on higher elevations within large marshes. At Mount Hope Farm this community is dominated by salt marsh elder (Iva frutescens), with scattered groundsel-tree (Baccharis halimifolia); salt meadow cordgrass (Spartina patens) and switchgrass (Panicum virgatum) occur in the herbaceous understory.

Estuarine areas include deepwater tidal habitats and adjacent tidal wetlands that are semi-enclosed by land but have open, partly obstructed, or ephemeral access to the open ocean, and in which ocean water is partially diluted by freshwater influx. This system extends from the upstream limit of tidal influence seaward to an imaginary line closing the mouth of a bay or river.

As with many sites in Rhode Island modified by agricultural practices, most of the communities at Mount Hope Farm are fairly young, do not contain a full complement of native species, and are heavily impacted by exotic invaders. Invasive species observed on the Property during a November 2016, site visit include Oriental Bittersweet (*Celastrus orbiculatus*), Multiflora rose (*Rosa multiflora*), Autumn Olive (*Elaeagnus umbellata*), Asian Raspberry (*Rubus phoenicolasius*), Bush Honeysuckle (*Lonicera maackii*), Japanese Honeysuckle (*Lonicera japonica*), Garlic Mustard (*Alliaria petiolata*), Spotted Knapweed (*Centaurea stoebe*) and Tall Reed (*Phragmites australis)*. The main concentrations of these species can be found along the trails, roads and the borders of fields on the Property (**Figure 12**).

Natural Heritage Areas refer to the estimated habitat and range of State or Federally listed rare or threatened species, species deemed noteworthy by the State, and noteworthy Natural Communities in Rhode Island, and are delineated as polygons within the ArcGIS layer. This dataset was developed to aid in the identification and protection of plant and animal species listed in the RI Natural Heritage Data. One of the five Natural Heritage Areas within the Town of Bristol co-occurs on Mount Hope Farm and the Brown University parcel (**Figure 13**) (RIGIS, Rhode Island Natural Heritage Areas, 2016).

KEY SITE ISSUES

Mount Hope Farm is a complicated site, as it encompasses not only a variety of uses, but also important historic sites and natural areas. Although there are a number of issues that will need to be addressed in the construction of the Master Plan, this section focuses on three that have been identified as especially relevant.

Access

Access at this site encompasses not only ingress/egress and parking for motor vehicles, but also trails throughout the property. The existing circulation pattern for the activities at the farm proper has resulted in congestion at times of heavy use. Delivery vehicles at times block the flow of traffic, and it can be difficult to navigate through the site if you are not familiar with it. Improvements are also needed for the trails. Upgrades could include improved accessibility, additional shoreline access points and signage to direct users and provide information on the site.

Invasive species

During a site visit in November of 2016, it was noted that there were four areas (fields) maintained as some type of open grassland. All four fields had some level of Spotted Knapweed (*Centaurea stoebe)* infestation. The northwestern field was dominated by knapweed (>70% cover). The northeastern field had much lower levels, but it did appear to be distributed throughout the field. The only populations in the southern field and the field bordering Metacom Avenue were found at the periphery of the fields.

Spotted knapweed (*Centaurea stoebe*)

Spotted Knapweed is a perennial, invasive forb; the roots exude catechin, this acts as an herbicide to inhibit competition by a wide range of other plant species (Bais, 2002). This phytotoxic compound inhibits seed germination and growth. Some native species ability to produce oxalate confers a resistance to catechin-induced toxicity (Weir, 2005). Native grasses grown in conjunction with oxalate-producing plants benefit from the presence of oxalate. Large concentrations of spotted knapweed, as observed in at least one of the fields, can eventually exclude nearly all other species, and greatly reduce the natural and agricultural productivity of the site.

Although *Phragmites* was not observed in the ponds, a population was found at the edges of the forested wetland downstream, where it borders the southern trail a second population was observed to the NW of the northern pond. These populations do pose a colonization risk to the ponds; they should be monitored regularly and treated quickly if colonization does occur. A treatment plan should be developed as soon as possible, so that treatment can be applied immediately in the event that the species does colonize one or both of the ponds.

Phragmites on both sides of southern trail.
Photo: K. Justham 11/23/2016

Water Quality

Two main issues have been identified relative to the ponds: maintenance of the water control structures and the quality of the water. One of the two standpipes in the lower (southern) pond is blocked, causing the water levels in the pond to remain high, with the spillway functioning as the main overflow mechanism. This constant use is eroding the spillway. The water control structures in both of the ponds require repair and maintenance to provide for maximum safety, ease of control and functioning of the structures.

Aerial photo showing algae in pond.
Google Earth imagery: 8/22/2016

The ponds wetland provide habitat, recreational, and aesthetic value to the Property. Algae blooms have become a persistent problem; they were observed during a site visit in May, and again, in late August. Aerial photographs of the site from 22 August, 2016, show that the northern pond is completely covered in algae. Approximately two thirds of the southern pond is covered, with the worst areas located at the inlet from the northern pond. Severe algae blooms can lead to eutrophication of the affected water body, extended periods of oxygen depletion can in turn result in die-offs of organisms within the water body.

RECOMMENDATIONS FOR BEST MANAGEMENT PRACTICES

Current use of the site (agricultural fields, lawn, roads, parking, structures) encompasses approximately 54 acres (**Table 2**). Areas that have been left in a mostly natural, vegetated state include approximately 76 acres, and wetlands/ hydric soils equal approximately 37 acres. Based on soil, slope and wetland limitations, approximately 82 acres, or 63% of the site, is available for some type of development or infrastructure improvement and approximately 87 acres is considered prime agricultural land. Of course, most of these designations overlap. For example, although 87 acres are considered to be prime agricultural land, approximately 6 acres of those acres are also designated as hydric soils.

Table 2. Approximate acres of current and potential land use types.

Use Category	Acres	% of site
Currently in use (developed or agriculture)	54	42
Currently in a natural state	76	58
Wetland/ hydric soil	37	28
Available for development	82	63
Available for agriculture	87	67

Designing Sustainable Multifunctional Landscapes

The process of designing sustainable multifunctional landscapes should have a foundation in the basic principles of Ecosystem Planning (Williams, 2000). Planning units should be based on natural boundaries and reflect ecological functions. Planners should design with nature, blending naturally occurring processes and features into the design. The design should reflect a respect for human activity and its effect on the environment. Planning should account for the limits of resource availability and ecosystem resilience, taking cumulative effects into consideration. This requires noting off-site and cross-boundary effects. Development should aim to avoid further damage, reduce stresses and enhance the integrity of ecosystems and communities.

Site Development

Soils suitable for installation of buildings, roads, and other infrastructure include CeC, NeA, NeB, NeC, PmB, PsB, and SvB (NRCS, 2013). CeC soils are limited by stoniness, bedrock outcrops, and slope. Soil units NeA, NeB, NeC, and PsB are limited by the slow or very slow permeability of the substratum; NeC units are also limited by slope. Bc and PmB soil units are limited by the high water table and the slow permeability of the substratum. If suitable outlets are available, subsurface drains can be used to help prevent wet basements. SvB soil units are limited by the seasonal high water table and the stones and boulders on the surface. If suitable outlets are available, subsurface drains can be used to help prevent wet basements. The stones and boulders need to be removed for landscaping. The use of mulch, sediment barriers, temporary diversions, and siltation basins and quickly establishing plant cover help to control erosion during construction within all units. With the exception of the CeC soil units, all of the above-mentioned soils require specially designed and installed onsite sewage disposal systems; roads and streets need careful design to prevent frost heaving. In the Bc and PsB units, lawn grasses, shallow-rooted trees, and shrubs require watering in summer.

Any improvements to the infrastructure of the site should consider and attempt to reduce the amount of impermeable surface (green roofs, permeable pavers and parking areas). When it is impossible to do so, and where lawn and impermeable surfaces may impact wetland areas, stormwater management structures should be installed. These may include rain gardens, bioswales, detention ponds, retention ponds and constructed wetlands. Rain barrels can be a good way to collect water for small-scale agriculture (i.e., the community garden) and are an effective means of reducing the impacts of stormwater from rooftops. There is also a wide array of low impact design measures that have been designed to be artistic and aesthetically pleasing; if utilized, these could add to the character of the Property. A thoughtfully designed landscape will not only help to mitigate stormwater issues, but can and should support environmental functions as well, such as conserving water and providing wildlife habitats.

Impacts during the construction process also need to be considered and mitigated, thus any work done on a slope or in proximity to a wetland area should include erosion control measures (compost socks, hay bales, jute mesh, silt fence).

Agriculture

In order to maximize the productivity of the pasture/ hay fields, it will first be necessary to reduce the influence of spotted knapweed and increase the soil organic content. Recommended control measures include grazing, mechanical control, and chemical control. Management of large-scale spotted knapweed infestations is more effective when herbicides are combined with other treatments, including proper grazing with domestic livestock, mechanical methods, and/or rehabilitation of disturbed sites with desirable species.

The literature indicates that sheep can prescriptively graze light or moderate spotted knapweed infestations in either June or July; the nutritive quality of sheep diets was similar to sheep grazing uninfested rangeland (Thrift, 2008). Sheep consumption and relative consumption of graminoids will be less if light infestations are grazed in June rather than July. In moderate infestations, sheep will eat fewer graminoids and utilize spotted knapweed more heavily when grazed in July rather than June. Prescribed sheep grazing can also be applied immediately following cattle grazing in either June or July to suppress spotted knapweed without overusing desirable graminoids. Cattle and sheep will eat fewer graminoids and more spotted knapweed if cattle and sheep graze sequentially when spotted knapweed is in its late-bud/early flowering stage (mid-July) rather than its bolting stage (mid-June) (Henderson, 2012).

Mechanical control consists of mowing and/or hand-pulling the plants prior to seed set. Hand-pulling is most effective in smaller populations and requires the use of long sleeves and gloves, as the plant can be a skin irritant to some people. Establishing a volunteer work force and/or initiating volunteer control days is a good way to get the public involved and to amass enough of a work force to be effective. As there is already a Master Gardener project at the site, the organization may be a good resource for additional volunteers. The main concern with using volunteers is their ability to correctly identify the species to be controlled. Spotted knapweed is relatively easy to ID in the field, so this should not be problem.

The duration of knapweed control on any site is dependent on herbicide properties, and environmental conditions such as soil type, rainfall, and presence of competitive desirable vegetation. In general, control with herbicides tends to be shorter in duration on coarse textured soils, disturbed areas, and on sites with annual rather than perennial grasses. The Minnesota Department of Natural Resources recommends applying the selective herbicide clopyralid during bud growth in early June (48 oz. per 100 gal. water) as an effective means of chemical control (MDNR, 2016). Be sure to use caution in quality natural areas as this herbicide affects native plants of the sunflower and pea family as well. Another herbicide option, Milestone (aminopyralid), applied at the rate of 5-7 fluid oz. product per acre (1.25 to 1.75 oz ae/A), provides greater than 90% control the year following treatment (Duncan, 2012). The herbicide can be applied any time during the growing season, including fall when plants are actively growing. While herbicide application can be an effective means of control when applied properly, it can have negative impacts on both the environment and the applicator. It is important that any chemical control of invasive species be conducted by a licensed professional.

In addition to suppressing problematic invasive species, the soils of any potential agricultural/ garden sites should be tested to identify soil pH, nutrient shortages and possible pollutants. This will help determine the best siting (in addition to prime agricultural soils map) and necessary amendments. Prime and important agricultural soils on the Property include the Bc, NeA, NeB, NeC, PmB, PsB and Re units

(Table 1, Figure X); the use of cover crops and the return of crop residue to the soil help to maintain tilth and organic matter content in all units (NRCS, 2013). Bc and PmB soils dry out and warm up slowly in the spring and artificial drainage is needed; irrigation is necessary in dry seasons. Artificial drainage is also required in Re soil units. The hazard of erosion is moderate in NeB and PsB soil units. The use of cover crops and diversions, strip cropping, and the return of crop residue to the soil help to control erosion; irrigation is needed in the PsB units. NeC soils are suited to cultivated crops, and some areas are used for pasture. The hazard of erosion is severe; strip cropping and using long crop rotations help to control erosion.

Water Quality

The pollutants that affect water bodies are generally broken into two categories based on their point of origin. Point sources of pollution have an easily identifiable source, like an outfall pipe emptying into a river. Non-point sources are more diffuse and harder to treat, as the type of pollutant often has to be identified before it can be linked to a potential source. This is the case with the water quality issues at the Mount Hope Farm ponds.

One of the first, and most critical steps in controlling non-point source pollution is to correctly identify and document the existence of a water quality problem. The water quality problem may be defined either as a threat or impairment to the intended use of a water resource; uses typically include human consumption, agriculture, recreation, habitat, and aesthetics. Existing data from past or ongoing water quality studies is necessary for the proper identification and documentation of a water quality problem. This information should include a physical description of the water resource and the watershed, the designated use of the water resource, and data that indicate a water quality impairment or threat to the resource (Gale, 1993). If adequate water quality data are not available, a monitoring program should be initiated. Monitoring should include both storm and base flow sampling of surface water over a 6-18 month period and may require measurements of chemical, physical, and biological factors (Osmond, 1995). Ground water monitoring may also be needed.

Clear problem identification and documentation will help to develop a water quality problem statement that:

1. Defines the water resource of concern.
2. Delineates the water use impairment/ threat, its location and history.
3. Describes the pollutants, the pollutant sources and the magnitude of the sources.

4. States assumptions about the association between pollutants and impairments.
5. Identifies habitat attributes that have been found to limit ecological health (Gale, 1993).

The water quality problem statement provides the basis for a strategy to effectively remediate a water quality impairment and enhance the designated water resource usage. The strategy can then be used to inform the selection and placement of best management practices (BMPs) that will effectively reduce, remediate or retard the pollutants in question. Unfortunately, the underlying cause of the enrichment of the ponds may be generated and enter the system off-site. It is generally more effective to treat for a pollutant by intercepting it with BMPs before it reaches the system. If the source of the Mount Hope Farm enrichment is found to occur off-site, it may require coordination with other entities to remedy.

The State of Rhode Island recognizes that wetlands perform a variety of ecosystem functions that are vital to the health, safety and well-being of the citizens of the State. In order to prevent random, unnecessary and undesirable alterations that would diminish these ecosystem services, the State has enacted legislation (the Fresh Water Wetlands Act) that is intended to preserve and regulate the use of swamps, marshlands, and other fresh water wetlands.

Fresh Water Wetlands: Section 2-1-21

"No individual, group or organization may excavate; drain; fill; place trash, garbage, sewage, highway run-off, drainage ditch effluents, earth, rock, borrow, gravel, sand, clay, peat or other materials or effluents upon; divert water flows into or out of; dike; dam; divert; change; add to or take from or otherwise alter the character of any fresh water wetland as defined in Section 2-1-20 without first obtaining the approval of the director of the Department of Environmental Management." (RI DEM, 2007)

Thus, any work that occurs in a wetland, or has the potential to impact a wetland needs to be approved by the State through the permitting process. The general recommendation is to hire a wetland professional to assist with this process.

Natural Communities/ Biodiversity

The most effective means of maintaining and enhancing the current biodiversity at the Property would be to maintain or restore structural complexity, heterogeneity and environmental gradients, retain and create habitat corridors and buffer areas and to preserve as many of the intact native community assemblages as possible (O'Farrell, 2010). The primary means of achieving these goals would be through the preservation of existing native ecological communities and the removal of exotic invaders. This would mean limiting disturbance (i.e., roads, trails, clearing, structures) in intact communities to the greatest extent possible. Any new disturbance is an opening for exotic species to invade and, with time, alter the chemical and biological make-up of that community. Additions to infrastructure should be limited to currently disturbed and/or maintained areas, or sited as close to the edge of intact communities as possible. Removal of concentrations of invasive species can open up additional habitat for native species, but may need to be planted or seeded to prevent re-colonization by exotic invaders; complete removal of an invader is often impossible to achieve. Additional benefits to birds, pollinators and other insects can be achieved at relatively low cost by reducing the size of turf lawns through the expansion of existing gardens that incorporate native plants, and/or converting some areas to natural grasslands.

Sea Level Rise

Although the majority of this site is at elevations beyond the reach of storm surge and sea level rise associated with climate change, there are a few vulnerabilities that should be kept in mind when considering long-term planning. Under a 5-foot inundation scenario, all of the existing shoreline and part of the lawn in the vicinity of Cove Cabin would be underwater, as well as the existing shore access to the west of the cabin and a small section of the access road (RIGIS, Sea Level Rise: Rhode Island Division of Planning, 2014). The cabin itself and additional sections of the access road would be under threat from storm surge during a hurricane or other weather event. Approximately half of the area between the Church Cove shoreline and the southern border of the southern-most field will be also be under water according to this model. Any improvements to the Cove Cabin site, its access road, and/or the shoreline access points should be designed to accommodate this inundation scenario.

CONCLUSION

This report has addressed the first two steps in using ecological processes to design sustainable multifunctional landscapes; the project site and landscape context have been defined and an analysis has been prepared regarding the landscape structure and function. This includes a discussion of the major site constraints and recommendations for best management practices. Soils, wetlands and invasive plants have been identified as major constraints to site use. Access, invasive species and water quality have been identified as the key site issues and recommendations have been made for best management practices. The next step will be to create a Master Plan using an ecosystem approach. An effective plan will seamlessly blend the multiple uses on the farm in a way that preserves the historic and cultural resources at the site, while maintaining the integrity of its ecological communities and planning for future stressors. Sites should be designed to highlight ecological functions. Once the plan has been implemented, ecological functions should be monitored.

A way to extend the concept of sustainable multifunctional landscapes beyond the bounds of the farm is to promote it as part of the environmental education program provided through the camps and family activities. Environmental education is one of the solutions to sustainable development, directing human behavior towards nature and promoting environmental ethics (Rangel, 2015). This creates awareness among the students and promotes positive attitude towards the environment; when individuals have to make decisions about land use in their town or on their own property, they will be more likely to do so with a mind to conservation and sustainability.

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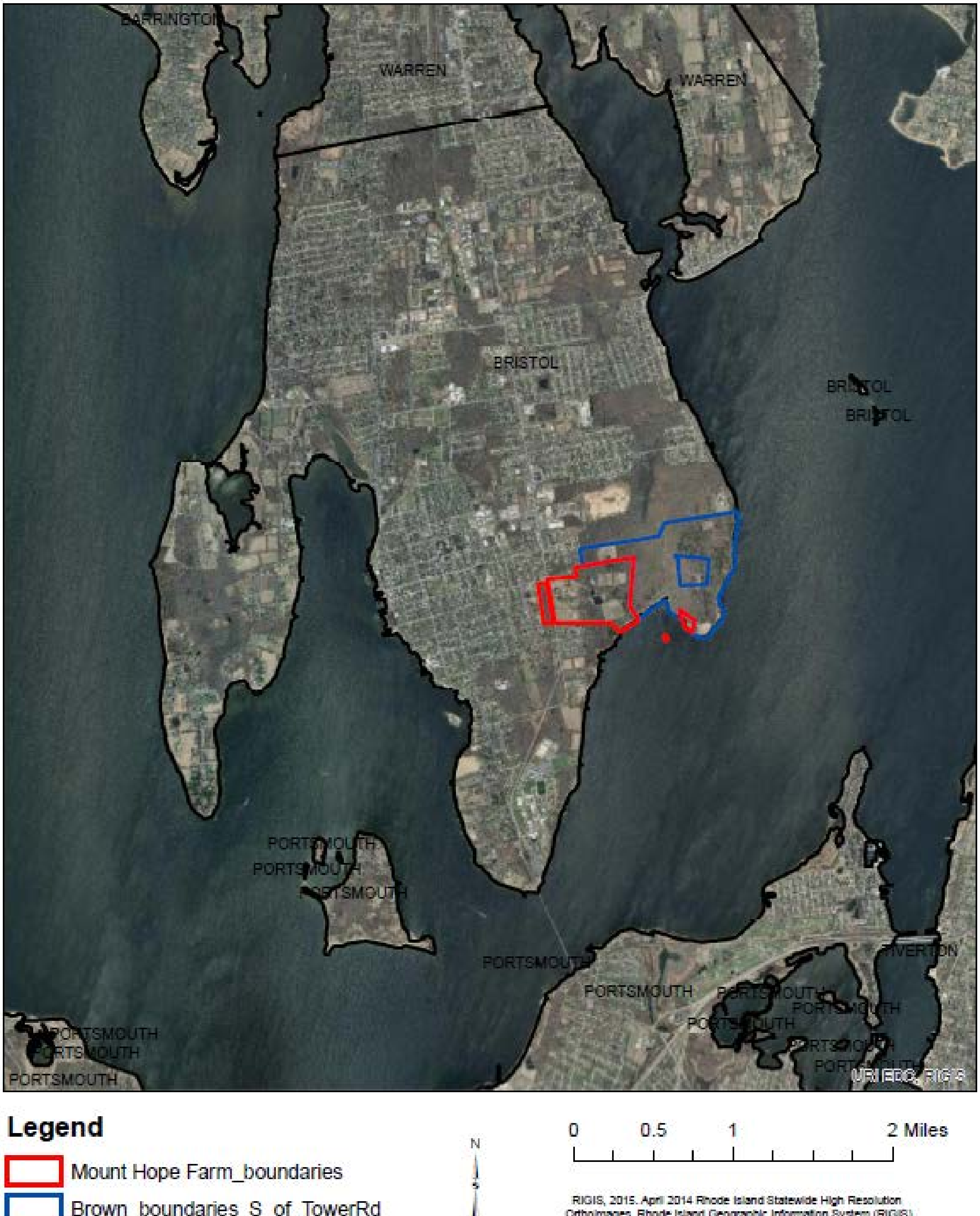
Appendix A

Site Assessment Maps

Mount Hope Farm Location Map

Figure 1



RIGIS, 2015. April 2014 Rhode Island Statewide High Resolution Orthoimages. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: <http://www.rigis.org>, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island (last date accessed: 9 October 2016).

Mount Hope Farm Parcel Map

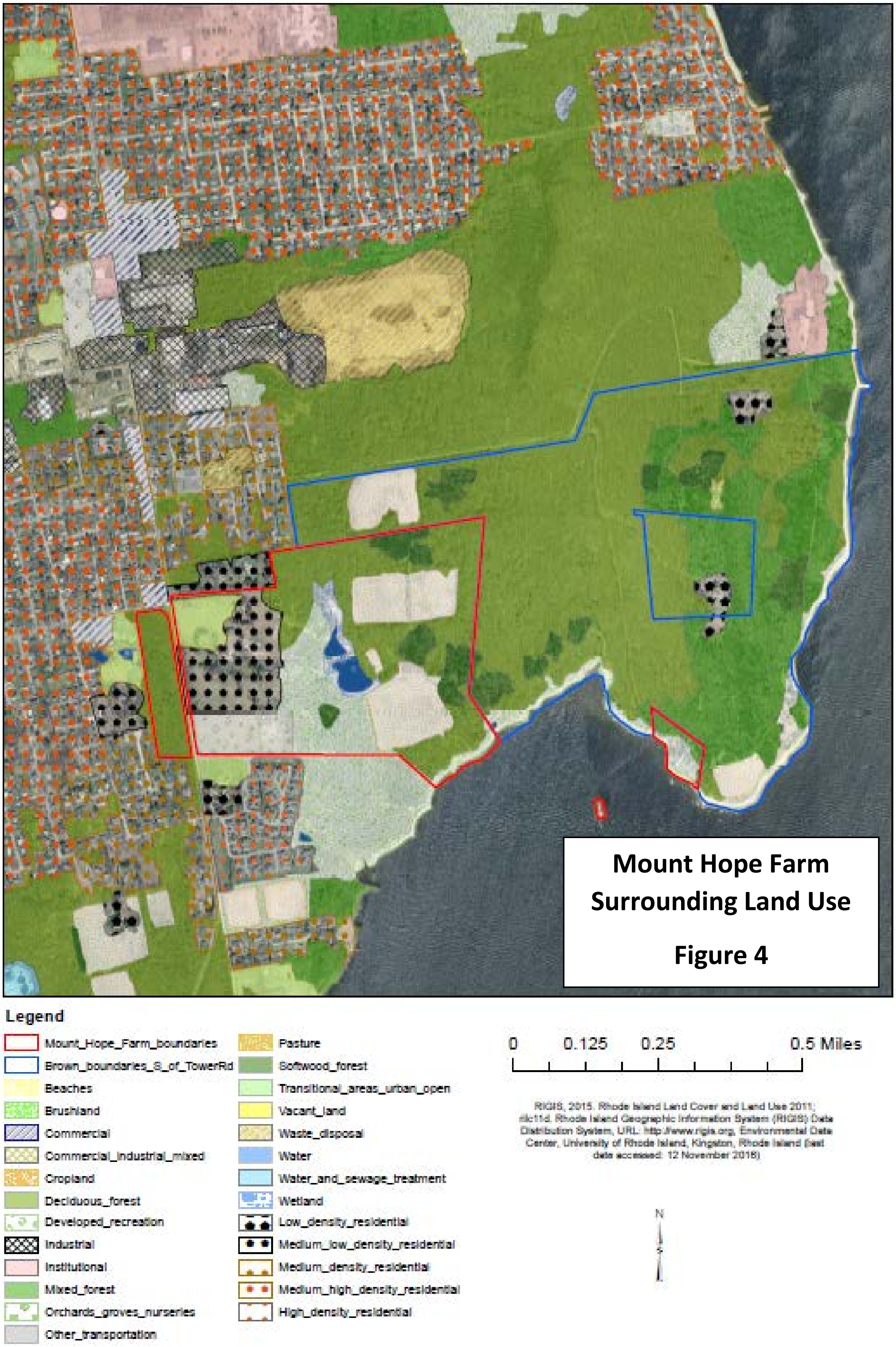
Figure 2

RIGIS, 2016. Historic Candidate Sites of Rhode Island; s44chc92.
Rhode Island Geographic Information System (RIGIS) Data
Distribution System, URL: http://www.rigis.org, Environmental Data
Center, University of Rhode Island, Kingston, Rhode Island (last date accessed: 9 June 2016).

Mount Hope Farm Topographic Map

Figure 3

RIGIS, 2015. Rhode Island Topographic Maps. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: <http://www.edc.uri.edu/rigis>, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island (last date accessed: 13 November 2016).


Mount Hope Farm
Surrounding Land Use
Figure 4
Legend
Mount_Hope_Farm_boundaries
Brown_boundaries_S_of_TowerRd
Beaches
Brushland
Commercial
Commercial_Industrial_mixed
Cropland
Deciduous_forest
Developed_recreation
Industrial
Institutional
Mixed_forest
Orchards_groves_nurseries
Other_transportation
Pasture
Softwood_forest
Transitional_areas_urban_open
Vacant_land
Waste_disposal
Water
Water_and_sewage_treatment
Wetland
Low_density_residential
Medium_low_density_residential
Medium_density_residential
Medium_high_density_residential
High_density_residential
0 0.125 0.25 0.5 Miles
RIGIS, 2015. Rhode Island Land Cover and Land Use 2011; rlc11d. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: http://www.rigis.org, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island (last date accessed: 12 November 2016)
N

Mount Hope Farm Constructed Features

Figure 5

Mount Hope Farm Constructed Features – Farm Proper

Figure 6

Conservation Land/ Open Space within 1 Mile of Mount Hope Farm

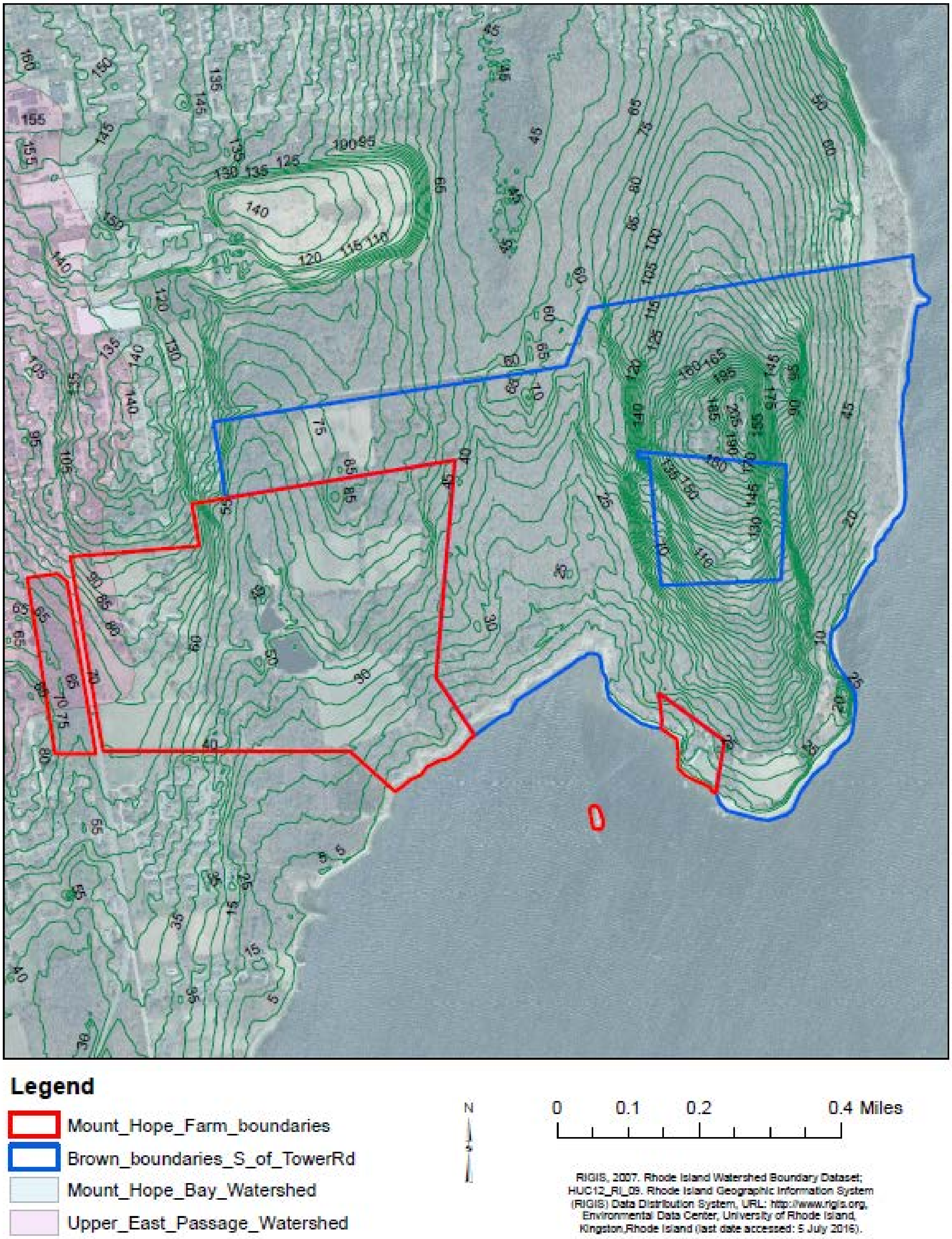
Figure 7

Mount Hope Farm Soils

Figure 8

Mount Hope Farm Topography and Watersheds

Figure 9



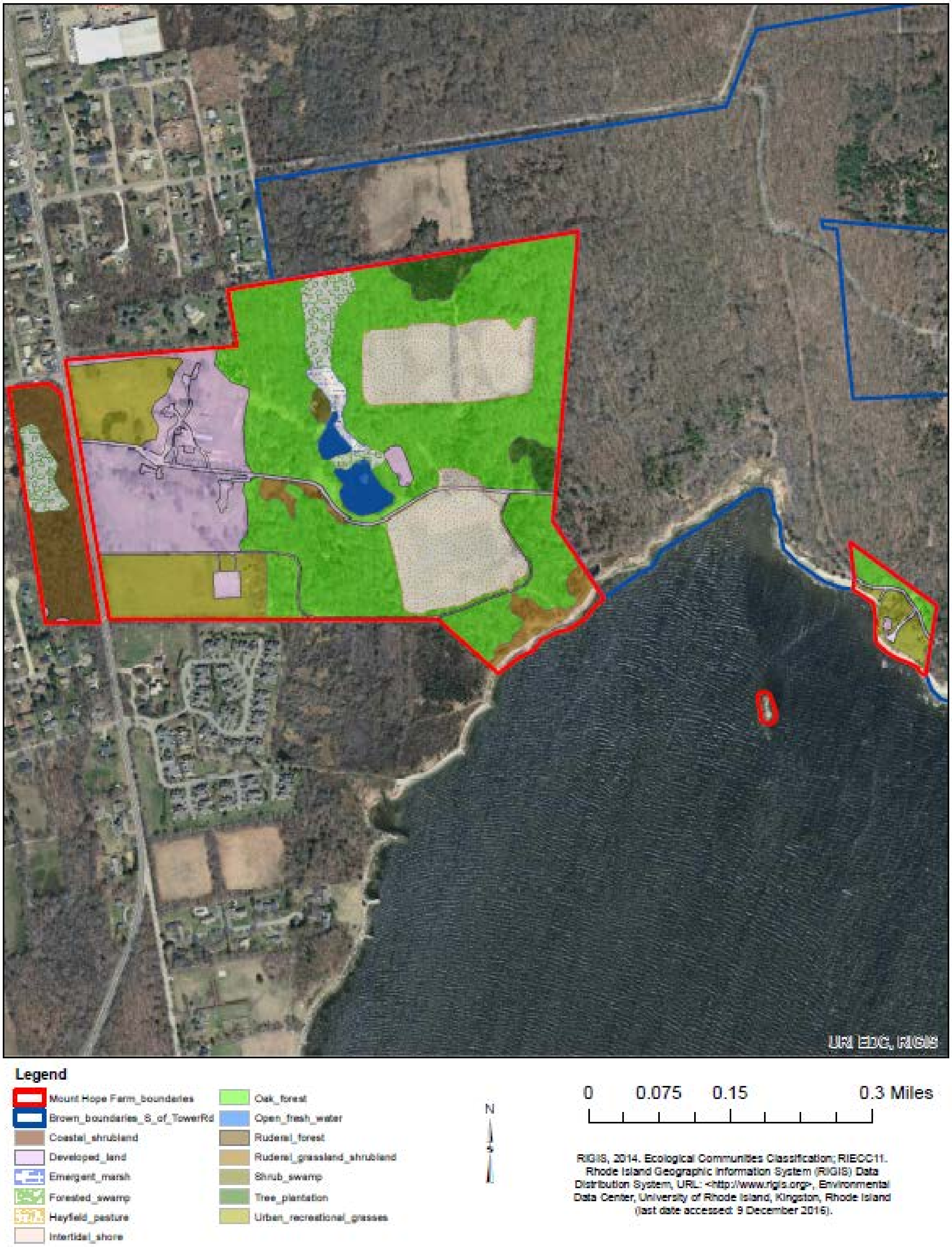
Mount Hope Farm Wetlands and Streams

Figure 10

RIGIS, 2016. Freshwater Rivers and Streams; streams5k. RIGIS, 2001. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: http://www.rigis.org, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island. RIGIS, 2014. National Wetland Inventory (NWI) for Rhode Island; NWI14. Rhode Island Geographic Information System (RIGIS) Data Distribution System (last date accessed: 10 June 2016).

Mount Hope Farm Natural Communities

Figure 11



RIGIS, 2014. Ecological Communities Classification; RIECC11. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: <http://www.rigis.org>, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island (last date accessed: 9 December 2016).

Mount Hope Farm Invasive Species Concentrations

Figure 12

Mount Hope Farm Natural Heritage Areas

Figure 13

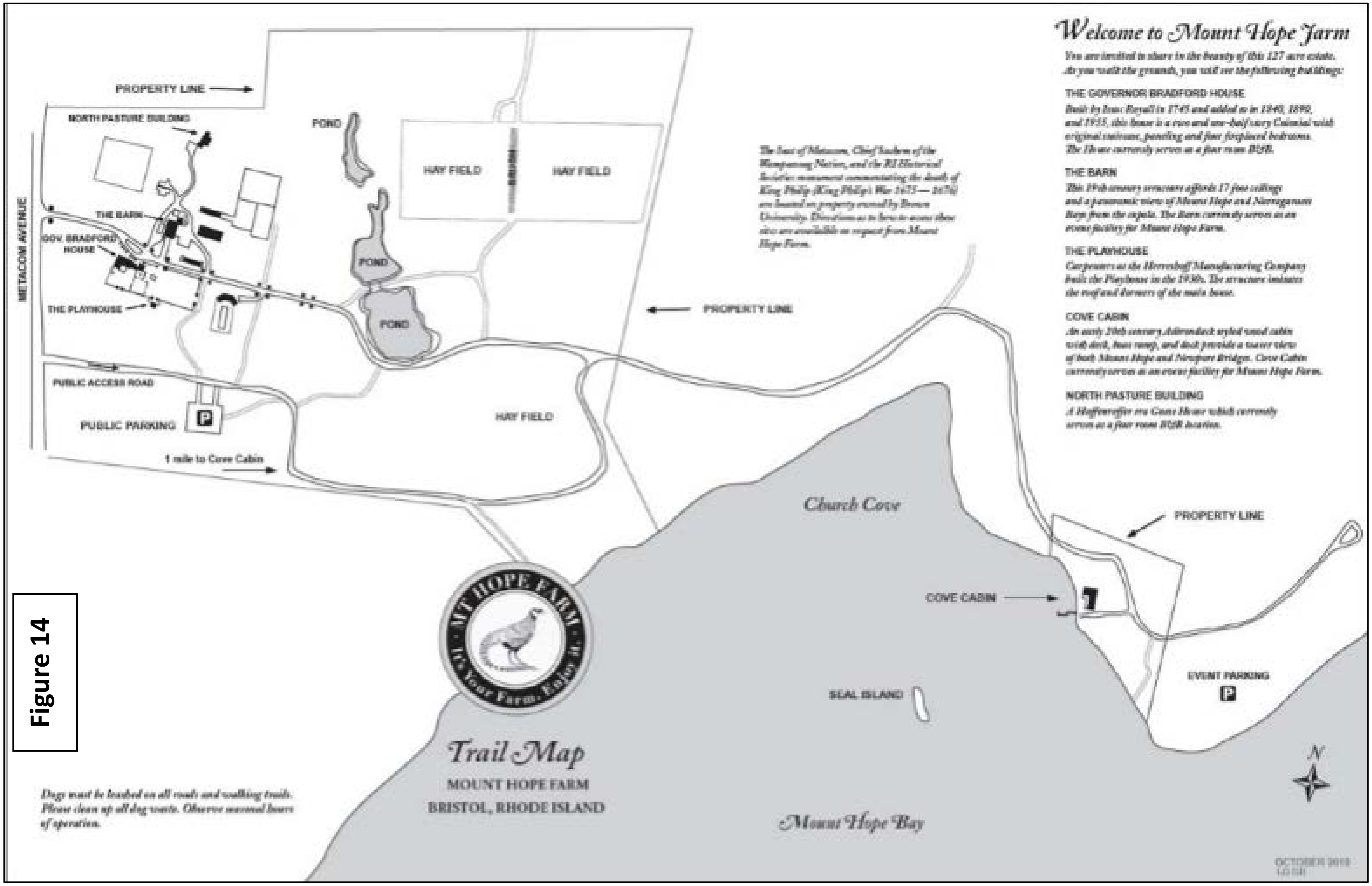

Welcome to Mount Hope Farm
You are invited to share in the beauty of this 127 acre estate.
As you walk the grounds, you will see the following buildings:
THE GOVERNOR BRADFORD HOUSE
Built by Isaac Royall in 1745 and added to in 1840, 1890, and 1955, this house is a two and one-half story Colonial with original staircase, paneling and four fireplaced bedrooms. The House currently serves as a four room B&B.
THE BARN
This 19th century structure affords 17 foot ceilings and a panoramic view of Mount Hope and Narragansett Bays from the cupola. The Barn currently serves as an event facility for Mount Hope Farm.
THE PLAYHOUSE
Carpenters at the Herreshoff Manufacturing Company built the Playhouse in the 1930s. The structure imitates the roof and dormers of the main house.
COVE CABIN
An early 20th century Adirondack styled wood cabin with deck, boat ramp, and dock provide a water view of both Mount Hope and Newport Bridges. Cove Cabin currently serves as an event facility for Mount Hope Farm.
NORTH PASTURE BUILDING
A Haffenreffer era Guest House which currently serves as a four room B&B location.
The Seat of Metacom, Chief Sachem of the Wampanoag Nation, and the RI Historical Society monument commemorating the death of King Philip (King Philip's War 1675 — 1676) are located on property owned by Brown University. Directions as to how to access these sites are available on request from Mount Hope Farm.
METACOM AVENUE
PROPERTY LINE
NORTH PASTURE BUILDING
THE BARN
GOV. BRADFORD HOUSE
THE PLAYHOUSE
PUBLIC ACCESS ROAD
PUBLIC PARKING
P
1 mile to Cove Cabin
POND
POND
POND
HAY FIELD
BRUSH
HAY FIELD
HAY FIELD
PROPERTY LINE
Church Cove
PROPERTY LINE
COVE CABIN
SEAL ISLAND
EVENT PARKING
P
MT HOPE FARM
It's Your Farm. Enjoy it.
Trail Map
MOUNT HOPE FARM
BRISTOL, RHODE ISLAND
Mount Hope Bay
N
Dogs must be leashed on all roads and walking trails. Please clean up all dog waste. Observe seasonal hours of operation.

Figure 14