River Run, Massachusetts

Climate Change Adaptation Plan

Manomet Center for Conservation Sciences

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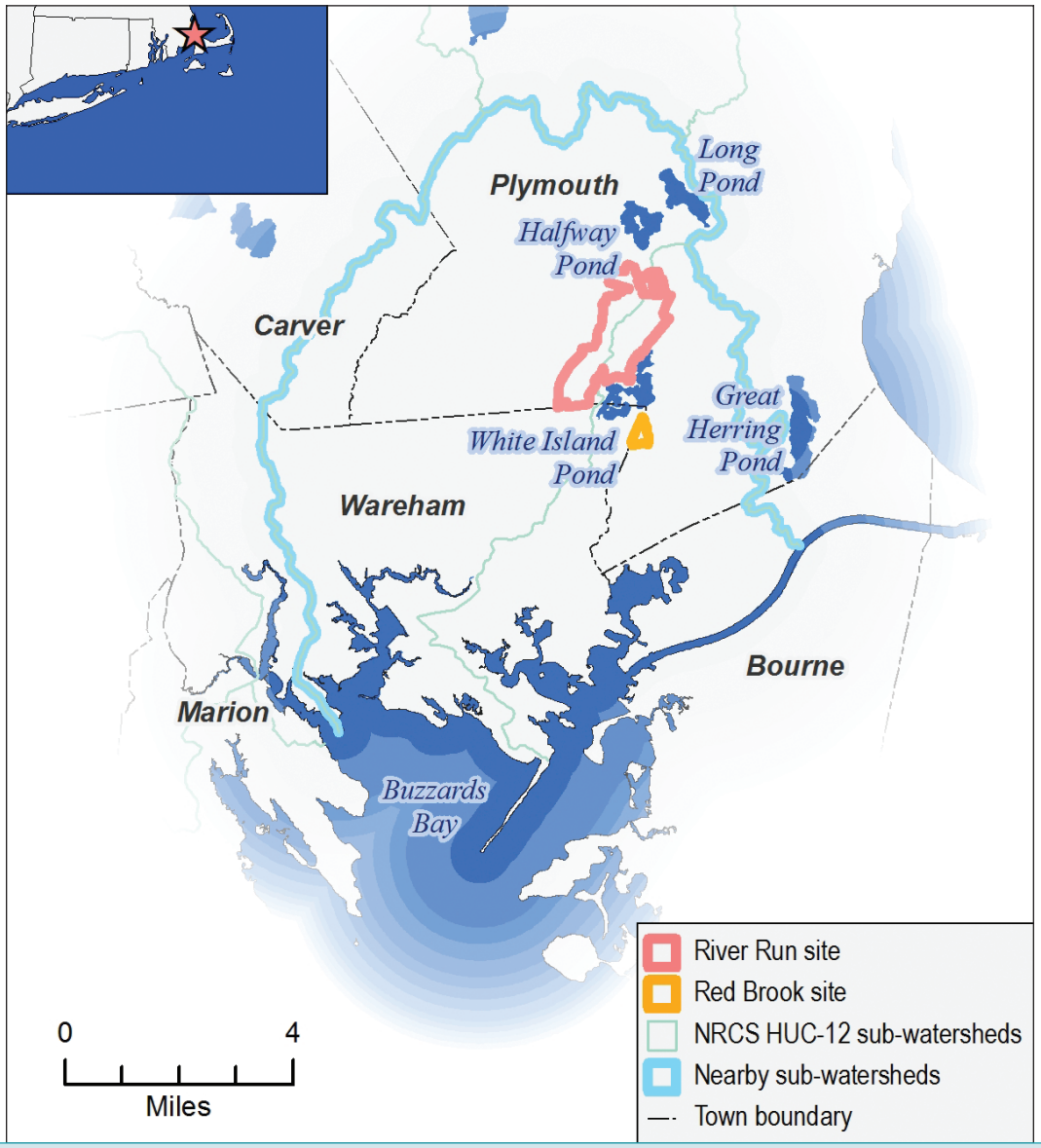
Introduction

River Run will be a major new mixed use development in Plymouth, Massachusetts (Map 1). The project has been through the majority of the permitting process and some of the infrastructure related to the development is in place. The downturn in the housing market has delayed construction of the project. Once construction begins, the development will be accomplished in phases with completion projected to take ten to thirteen years. At build-out the development will include approximately 1,175 homes, a community center, a small retail and office center and an assisted living facility (Figure 1).



Map 1. Location of the River Run and Century Bog/Red Brook sites and surrounding sub-watersheds in eastern Massachusetts.

MAP 1

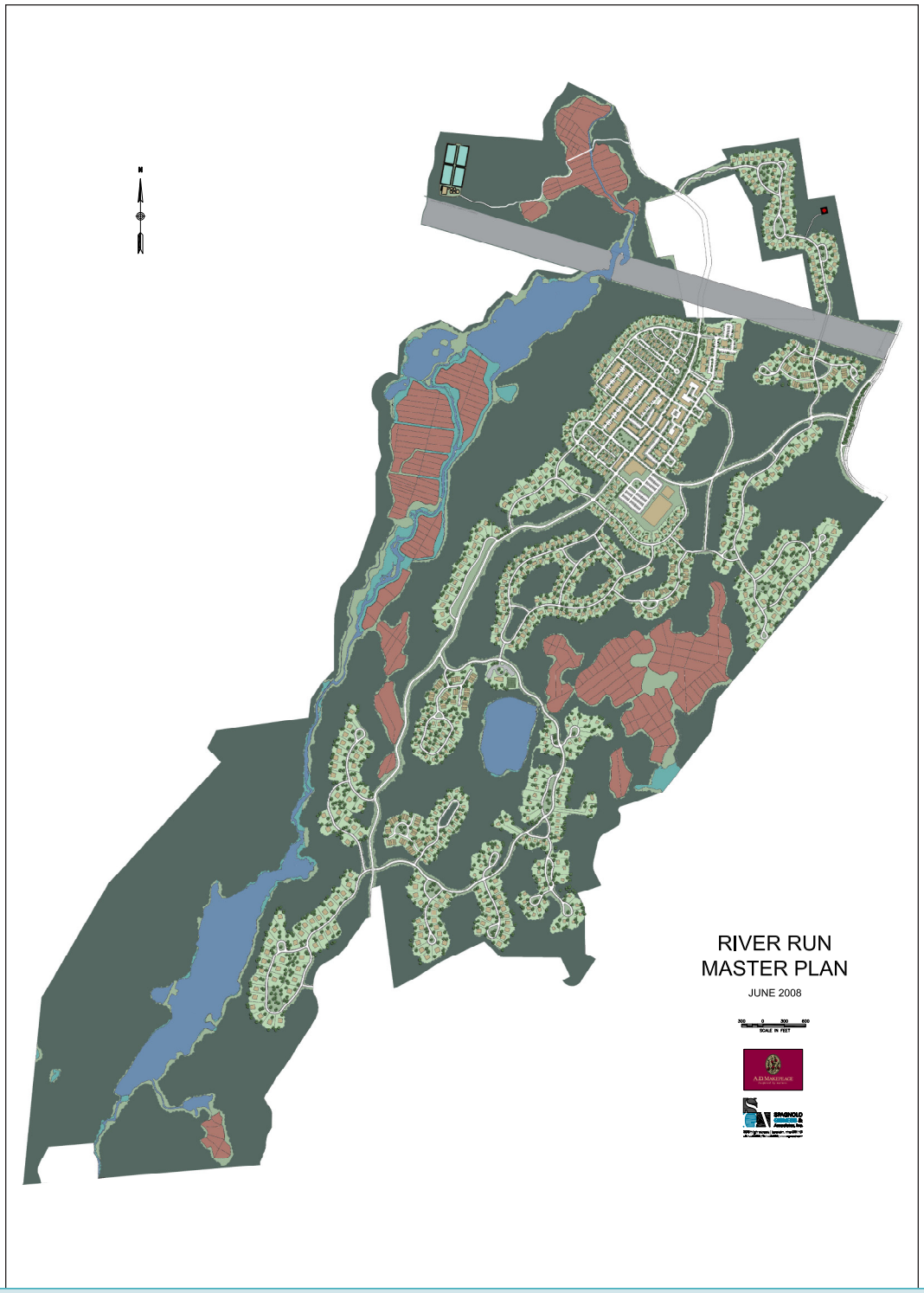


FIG. 1

Figure 1. Site plan for River Run

Site Description

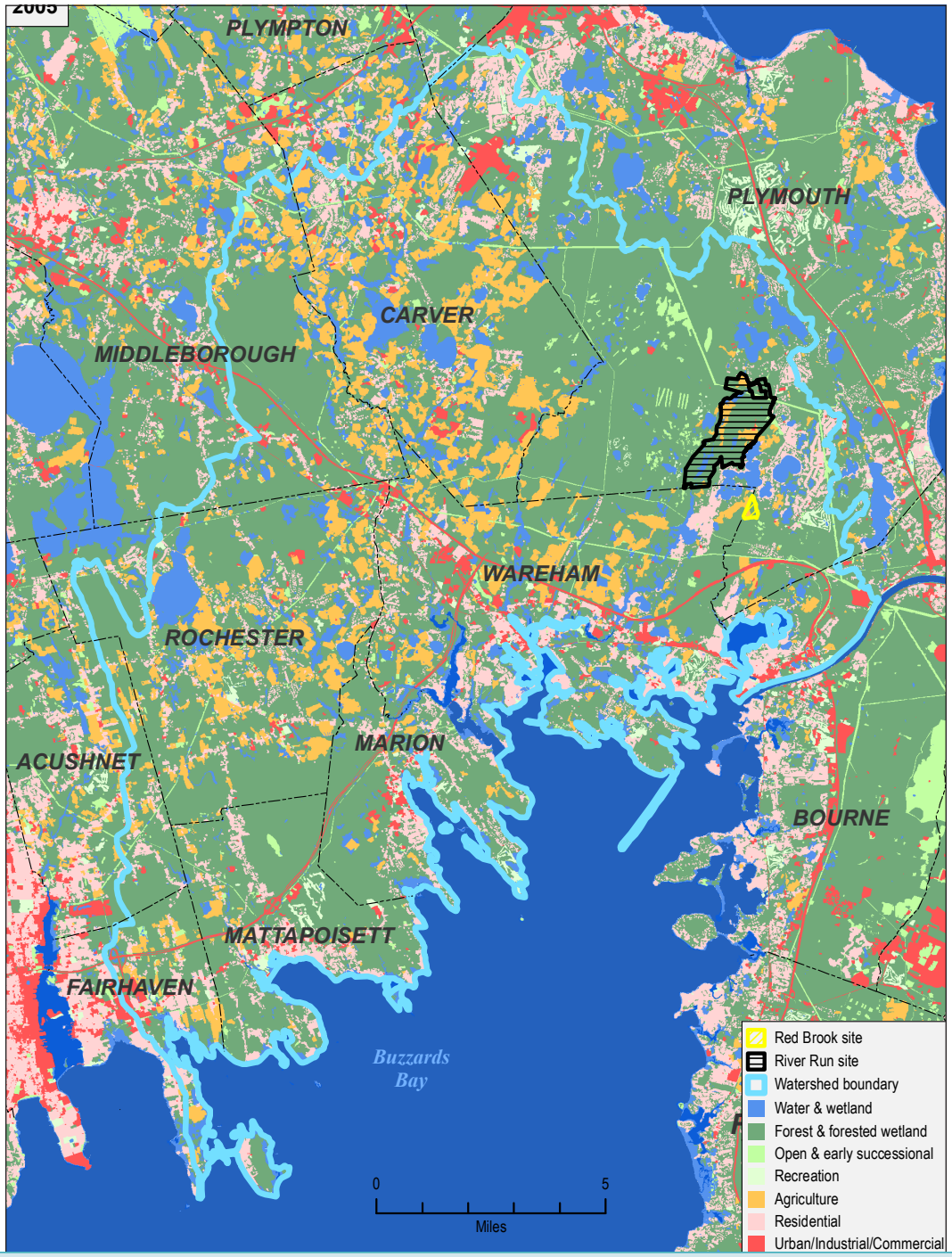
The River Run site is a predominantly undeveloped and vegetated 1,330 acre parcel owned by the A.D. Makepeace Company (Makepeace), the world's largest cranberry grower and the largest private landowner in eastern Massachusetts. The proposed development site, which is divided by Wareham Road, is bounded by the Town of Wareham to the south, Bourne Road and White Island Pond to the east, the Agawam River and undeveloped land to the west, and residential development near Halfway Pond Road to the north. The landscape consists primarily of forested uplands, wooded wetlands, actively farmed cranberry bogs, small ponds, man-made reservoirs, and the Agawam River.[1] The topography of the site is relatively flat with a maximum elevation of approximately 134 feet and a minimum of about 52 feet above sea level.[2]

Map 2 shows the 2005 land use in the watershed surrounding the River Run site. The Myles Standish State Forest, with extensive Pitch Pine/Scrub Oak habitat, is located to the northwest of the development site. Red Brook, the Lyman Reserve and the Century Bog restoration site are located to the south. Red Brook provides habitat for the rare Salter Brook Trout and has been the focus of extensive environmental restoration efforts. Cranberry production is the dominant agricultural activity in the watershed. Extensive residential development surrounds the ponds to the east and south of the development site.

Management Goals

The design guidelines for the project state that it will be "a mixed-use planned community with a focus on preserving the natural character of the landscape and creating a vibrant village community based on traditional neighborhood development and smart growth principles."[3] The development will contain approximately 1,175 homes, a full-service YMCA and community center, a village green, a small retail and office component, assisted living for the elderly population, and land allocated for use by the town for a school or other municipal purpose.

The project development footprint has been limited to 400 acres, concentrating development in higher densities than allowed under the baseline zoning. Plymouth's Transfer of Development Rights (TDR) Bylaw enables Makepeace to place permanent conservation restrictions on approximately 1,600 acres of adjacent land in exchange for the right to develop at higher density than the by-right zoning allows. The protected areas include land selected because of its valuable habitat and forest. The Design guidelines describe a planned open space network with conservation lands intended to protect rare, threatened and endangered species, a trail network, and areas for other/active recreation. Makepeace intends to keep much of the existing cranberry agriculture in place and will modify agricultural management practices to ensure compatibility with the mixed use development. The Final Environmental Impact Report was prepared by Vanasse Hangen Brustlin, Inc. and a Master Concept Plan Special Permit for the project has been granted by the Town of Plymouth.[4]



MAP 2

Map 2. Land Use Map

Land use in the watershed surrounding the River Run site.
Land use, town boundary, hydrologic, and parcel boundary data obtained from MassGIS; watershed boundary data obtained from USGS/NRCS.

Climate Change Vulnerabilities and Recommended Adaptation Actions

Overview

The River Run project has the potential to be an important example of climate smart development showcasing adaptation challenges and solutions for three land-use types in close proximity: agriculture, conservation and development. Most of the macro-scale land use decisions for the site have already been made through the design and permitting processes and the use of Plymouth's TDR program. However, many of the small-scale design decisions for the residential, commercial and open space areas are pending and will play an important role in adapting to climate change.

Climate change projections for southeastern Massachusetts include higher temperatures and changing precipitation patterns. Specifically, by the end of the century temperatures in New England are likely to increase by 5.3° C (9.5° F) under the A1FI emissions scenario. More total annual precipitation is also predicted, as is a higher prevalence and intensity of heavy precipitation events, and increased mild to moderate summer drought.[5] Combined, these changes will contribute to more uncertainty regarding water availability and flood threat. During summer months, the combination of projected higher temperatures, a lengthened growing season, and possible increased summer drought will reduce water availability. The timing will coincide with peak groundwater usage, further reducing summer water supply. The opposite situation is projected for winter months, when an increase in total precipitation amounts and intensity is likely. For instance, average winter precipitation in New England is projected to grow approximately 20 percent by the end of the century under higher greenhouse gas emission scenarios. More frequent and intense precipitation events will increase the rate and severity of freshwater flooding. Based on these predictions, it is anticipated that water resource management issues including drinking and agricultural water supply, as well as stormwater and wastewater management, will be affected by climate change and central to adaptation planning at River Run.

Ecosystem Services and Climate Change Vulnerability

Intact ecosystems generate a variety of goods and services (e.g., water supply, food), collectively called "ecosystem services", which sustain and enhance the quality of human life. Climate change in conjunction with other anthropogenic stressors, will impact ecosystem service delivery in southeastern Massachusetts. This plan focuses on the ecosystem services provided by the River Run site and examines each through the lens of climate and non-climate stressors and vulnerabilities.

Table 1 outlines key ecosystem service vulnerabilities for the River Run site, and Table 2 outlines recommended adaptation actions in response to these vulnerabilities.

Table 1. River Run: Vulnerabilities of Ecosystems and Ecosystem Services to Climate Change

ECOSYSTEMS AND ECOSYSTEM SERVICES	VULNERABLE TO CLIMATE CHANGE?	RATIONALE
PROVISIONING SERVICES		
Food: Cranberry Production	Yes	Multiple threats such as heat and frost damage, flooding and changing insect pressure.
Fresh Water: Municipal Drinking Water Supply and Individual Water Supply Wells	Perhaps	Changing precipitation patterns and increase in drought could cause fluctuation in water availability
REGULATING SERVICES		
Local Climate and Air Quality Regulation	Yes	Mixed-use development and increasing temperatures will result in increase in local heat island effect
Moderation of Extreme Events: Flood Control	Perhaps	Increase in heavy precipitation and impervious surface may result in a decrease in storm water infiltration.
Water Purification	Perhaps	Flooding rains may cause intermittent nutrient and bacterial overloads from aging septic systems
ECOSYSTEMS AND SUPPORTING SERVICES		
Ecosystems and Habitat Provision: General	Yes	Climate change will stress and may eventually disrupt existing habitats
Ecosystems and Habitat Provision: Cold Water Fish Habitat	Yes	Warming climate and increasing drought could degrade or eliminate this habitat

The River Run site.

Table 2. River Run: Adaptation of Ecosystems and Ecosystem Services to Climate Change

ECOSYSTEMS AND ECOSYSTEM SERVICES	ADAPTATION AND MANAGEMENT MEASURES	RATIONALE
PROVISIONING SERVICES		
Food: Cranberry Production	Enhanced management for frost damage, scald and rot.	Warmer winters, increasing frequency of extreme heat and increasing severity of heavy precipitation events will stress crops.
Fresh Water: Municipal Drinking Water Supply and Individual Drinking Water Supply Wells	Minimize increase in impervious surface in aquifer recharge areas. Monitor aquifer levels and implement water efficiency measures as needed.	Maximize aquifer recharge and minimize aquifer drawdown.
REGULATING SERVICES		
Local Climate and Air Quality Regulation	Utilize low impact development methods and site design elements to minimize heat island effect and cooling system demand.	Anticipate warming climate.
Carbon Sequestration and Storage	Maximize reforestation of site design elements.	Multiple benefits including carbon sequestration.
Moderation of Extreme Events: Flood Control	Utilize LID methods to minimize impervious surface and infiltrate storm water on site.	Anticipate continued increase in precipitation intensity.
Water Purification	Implement planned measures to connect septic systems adjacent to development site to new sewer system.	Compensate for projected changing precipitation patterns and associated infiltration/inflow problems with older septic systems.
Erosion Prevention and Maintenance of Soil Fertility	Utilize LID methods to minimize impervious surface and infiltrate storm water on site.	Anticipate continued increase in precipitation intensity.
ECOSYSTEMS AND SUPPORTING SERVICES		
Ecosystems and Habitat Provision: General	Maintain connectivity of habitat blocks as development takes place.	Support species migration and maximize resiliency.
Ecosystems and Habitat Provision: Cold Water Fish Habitat	Utilize LID methods to minimize impervious surface area and infiltrate storm water on site.	Minimize thermal pollution of receiving waters.

Food: Cranberry Production

Maintaining cranberry production in southeastern Massachusetts is a high priority for Makepeace. The intent of Makepeace staff managing the cranberry operations, both on the River Run site and elsewhere, is to adapt to climate change in an incremental fashion. Makepeace agricultural director, Tim Crawford, refers to this as a risk management based approach. From his perspective the cranberry operation is a balancing act between costs and profitability. Climate change adaptation measures will be evaluated from this perspective and incorporated in Makepeace operations based on the extent to which they address risk, control costs, or boost profitability.

› Climate Change Vulnerabilities: Cranberry production is viable in climates that are significantly warmer than Massachusetts, so a warming climate will not end cranberry production in the near future. However, growers in Massachusetts will be challenged by a combination of warmer temperatures, changing precipitation patterns, and increased risk of frost damage, pest and disease pressure, and increasingly problematic extreme weather events.[6]

- Recommended Adaptation Actions:
  - Chilling Requirements: Cranberry chilling requirements will likely be met in Massachusetts during the next 50 years even under higher emission scenarios. Beyond 50 years, under the A1FI emission scenario, the amount of chilling hours may be insufficient. Investigation of cranberry varieties that have been developed to thrive in warmer climates is recommended.
  - Frost damage: Currently, in Massachusetts the chilling requirements for cranberries are typically met by February. However, if a late winter/early spring warm period occurs, plants can come out of dormancy ahead of schedule, and frost damage can occur. In this situation, growers try to prevent crop damage by irrigating the bogs to form a layer of protective ice on the plants. This approach will still be viable under climate change, but costs associated with starting it earlier in the spring season will place an additional burden on growers. Automated irrigation systems have been used successfully to both lower labor costs and save water while providing effective frost protection. Continued development and implementation of automated and remotely operated systems that are capable of monitoring and responding to temperature fluctuations is recommended.
  - Scald: Cranberry Scald is a heat stress injury that occurs when plants can't transpire quickly enough to keep the fruit cool. Scald can damage the fruit on its own as well as make it more vulnerable to rot (fungus) damage. Preliminary studies by the University of Massachusetts Cranberry Research Station indicate that the hot, dry summer conditions projected to be more frequently under climate change are a factor in scald damage. The primary adaptive response is to insure that soil moisture is sufficient prior to the onset of heat stress conditions. An additional finding is that scald damage is more prevalent in bogs with relatively young plants (due to sparse vegetation that provides less shading) than more mature plants.[7]
  - Flooding: More frequent and intense precipitation events are predicted for New England. The region has already seen a 67 percent increase in very heavy precipitation events over the last 50 years. These factors will require new water management strategies to avoid crop damage. As bog infrastructure is updated, design features to accommodate increasingly heavy precipitation events should be incorporated.
  - Rot: Increasing stress associated with both scald and flooding will likely make cranberry crops more vulnerable to fungal damage. Increased monitoring and herbicide use may be required to compensate. Ensure that best management practices are followed for any herbicide application to eliminate or reduce environmental, wildlife, and human health impacts.
  - Changing insect pressure: Warming temperatures will allow some insects that are not currently a major threat in Massachusetts to move north into the state. For example, Gypsy Moths are currently a problem for cranberry producers in New Jersey. However, New England winters have historically been cold enough to kill their overwintering eggs.[8] As average winter temperatures increase, these moths may become more of a problem for Massachusetts producers. Increasing total precipitation could suppress insects such as cranberry fruitworm that are typically controlled through flooding of bogs.[9] Monitoring for changing insect pressure and incorporating new management techniques for pests as needed is recommended.
  - Productivity: Higher average summer temperatures are associated with a decrease in cranberry productivity in Massachusetts. Optimal productivity occurs when temperatures remain between 60 and 86 degrees F in July and August. As previously mentioned Massachusetts growers will eventually need to investigate varieties of cranberries developed for warmer climates such as New Jersey.

Water Related Services

Fresh Water: Municipal Drinking Water Supply:

- Climate Change Vulnerabilities: Climate change has the potential to impact both the quantity and quality of drinking water in southeastern Massachusetts. The contrasting effects of wetter winters and drier, hotter summers will likely lead to more seasonal fluctuations in surface and groundwater availability. In addition, the projected increase in heavy downpours and associated decrease in light to moderate rain events could lead to lower infiltration rates and reduced groundwater recharge. Sea level rise, in conjunction with other factors, may eventually cause saltwater intrusion into the coastal interface of the Plymouth Carver aquifer.[10] Water supply is a critically important ecosystem service for the River Run site. Ground water is the proposed drinking water source for the development and a mix of ground and surface water is utilized for cranberry production. These climate change related stressors on the Plymouth Carver aquifer will be exacerbated by anthropogenic stressors (e.g., population size, increased urbanization, and increased impervious surface cover).
- Recommended Adaptation Actions: Additional modeling work is needed to better characterize the impacts of climate change on the Plymouth Carver Aquifer. In 2009 the USGS studied the aquifer and modeled the impacts of future groundwater consumption scenarios.[11] Updating that study to include projected sea level rise, changing precipitation patterns and a warming climate would provide valuable insight into future water availability under climate change. In addition, management practices to protect groundwater quantity and quality such as LID methods to minimize impervious surface area and maximize storm water infiltration are recommended. Increased utilization of water efficiency measures on the part of Plymouth Carver aquifer users may also become necessary. The primary adaptation action to minimize salt water intrusion from sea level rise, should this prove necessary, is to avoid excessive drawdown of the aquifer.

Moderation of Extreme Events: Flood Control and Erosion Prevention

- Climate Change Vulnerabilities: The projected increase in both total annual precipitation and intense precipitation events will present storm water management challenges in southeastern Massachusetts. Stormwater management design standards and approaches that have historically been adequate in New England will likely be insufficient for future storm events.
- Recommended Adaptation Actions: The planned inclusion of LID features such as clustering of houses, minimizing impervious surface, maximizing storm water infiltration and avoiding development in flood prone areas will help moderate impacts of extreme precipitation events.
  - Include green infrastructure features: Map 3 depicts a combination of the TNC Active River Area and FEMA flood zones. Together these areas delineate riparian and pond buffers important for flood control, maintenance of water quality and ecological health. Maintaining and restoring riparian forest and vegetated buffers will play an important role in controlling flooding associated with heavy precipitation events. Minimizing development in or directly adjacent to these buffer areas will improve the site's resiliency to changing precipitation patterns associated with climate change.
  - Minimize increase in impervious surface area associated with the development: The River Run development site is split across two sub-watersheds. The eastern half of the development site is in the Cape Cod Canal/Stony Point sub-watershed, which in 2005 contained 13 percent impervious land cover. The western half of the development site is in the Stony Point/Cromeset sub-watershed, which in 2005 contained approximately 8 percent impervious land cover. While many factors impact watershed health, the percentage of impervious cover is a key indicator. As imperviousness approaches 10 percent watershed health typically starts to decline and impervious surface levels between 10 to 30 percent are associated with significant degradation. As development continues in these sub-watersheds, minimization of new impervious cover will be an important factor in managing storm water runoff quantity and quality.

» **Disconnect impervious surfaces from receiving waters and maximize on-site infiltration of storm water:** In addition to the percentage of impervious surface in a given watershed, the extent of connectivity between impervious surfaces and receiving waters has a significant bearing on the detrimental impacts to receiving waters associated with storm water runoff. Routing storm water through vegetated areas encourages sheet flow and infiltration, allowing pollutants to settle out and runoff to cool. The planned inclusion of low impact development and green infrastructure features at River Run will position the development to minimize both flooding and water quality degradation associated with changing precipitation patterns. Clustering of single residential and commercial structures, minimizing street width and including small-scale green infrastructure features will all be of benefit.

Wastewater Treatment

» **Climate Change Vulnerabilities:** Increasing total precipitation and heavy precipitation events may raise the threat of nitrogen and pathogen pollution from older septic systems adjacent to the project site, particularly if they are in a poor state of repair and are vulnerable to infiltration and inflow.

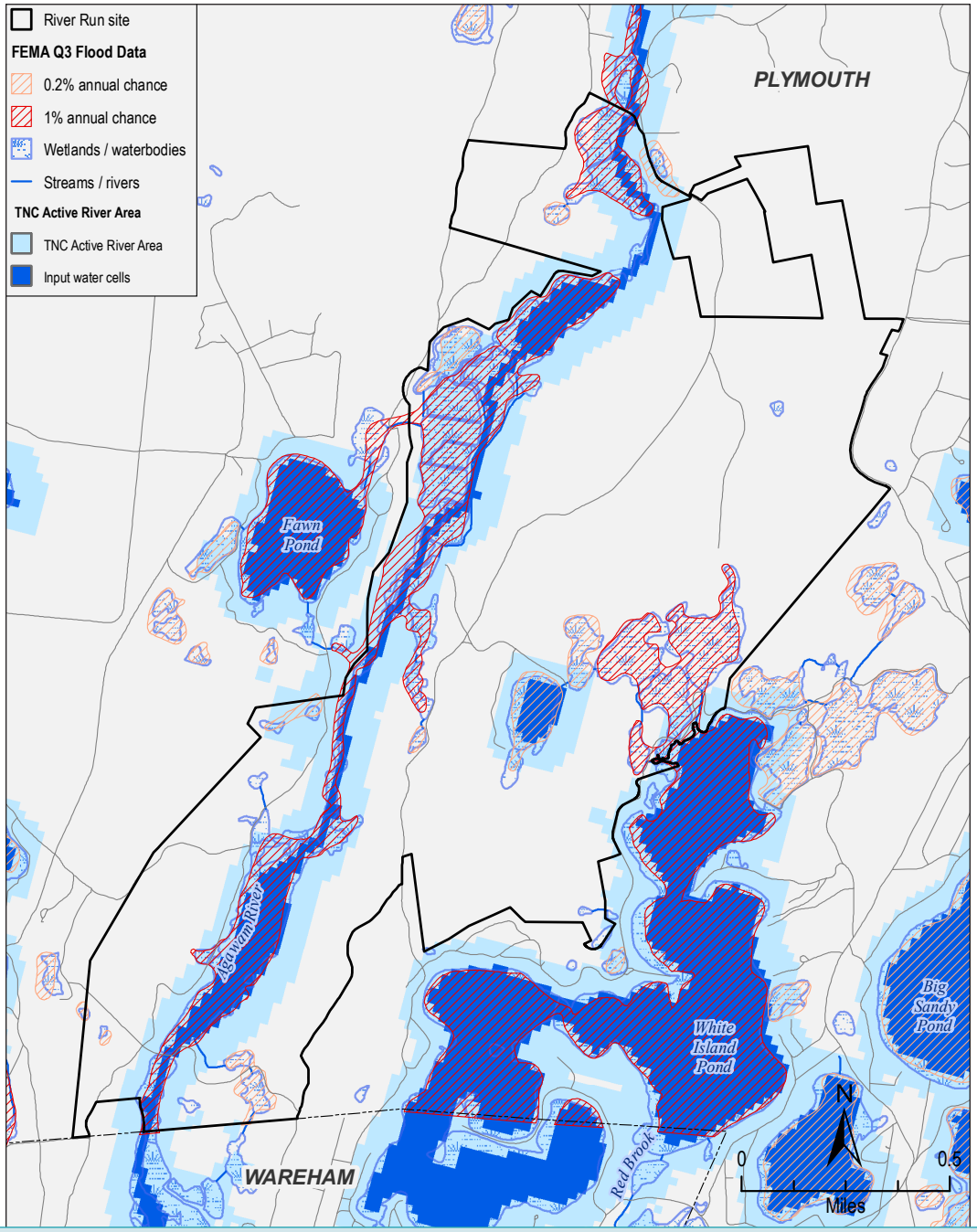
» **Recommended Adaptation Actions:** The proposed Wastewater treatment system at River Run will include excess capacity and the establishment of a fund to assist property owners outside of the project area with either upgrading existing septic systems to include a denitrification feature or offsetting the cost to connect to the new sewer system.

Ecosystems and Supporting Services

Ecosystem and Habitat Provision: General

› **Climate Change Vulnerabilities:** The warming climate and changing precipitation patterns will stress indigenous flora and fauna and increase competition from species currently found in warmer climates. These changes will disrupt existing ecosystems and shift their positions on the landscape. Climate change will also make invasive species that thrive in a carbon dioxide rich atmosphere more adept at competing for resources. Maintaining ecosystem resiliency and biodiversity in a changing climate will require managing for these transitions.

› **Recommended Adaptation Actions:** Land use decisions that support a linked network of open space, protection of critical habitat areas and protection of areas of high geophysical diversity will all contribute to maintaining ecological resiliency under climate change. Map 4 shows that the development site is currently part of a network of open space that provides numerous services associated with the intact habitat. A significant set of protected lands, including Myles Standish State Forest, abut the western edge of the River Run site. The Century Bog restoration site, Red Brook and the Lyman Reserve are to the south of the site. Utilizing a green infrastructure based approach and providing open space corridors through the River Run site to link with surrounding protected open space are recommended. Maintaining and restoring riparian forest and natural vegetation along the Agawam River and the shores of White Island Pond will also provide multiple benefits including habitat protection, corridors to link protected areas, flood control and water quality protection. Map 5 depicts important wetland and aquatic habitat areas that extend to the north and south of the River Run site.



Map 3. Riparian Resources and Flood Zone Map

Map showing areas vulnerable to flooding and important for riverine processes in and around the River Run site. FEMA Q3 Flood data acquired from MassGIS, not showing areas of undesignated flood hazard. The Nature Conservancy (TNC) Active River Area (ARA) data (Olivero, 2009) shows areas within which important physical and ecological processes of the river or stream occur. Road, town boundary, wetland, and watercourse data from MassGIS.

MAP 3

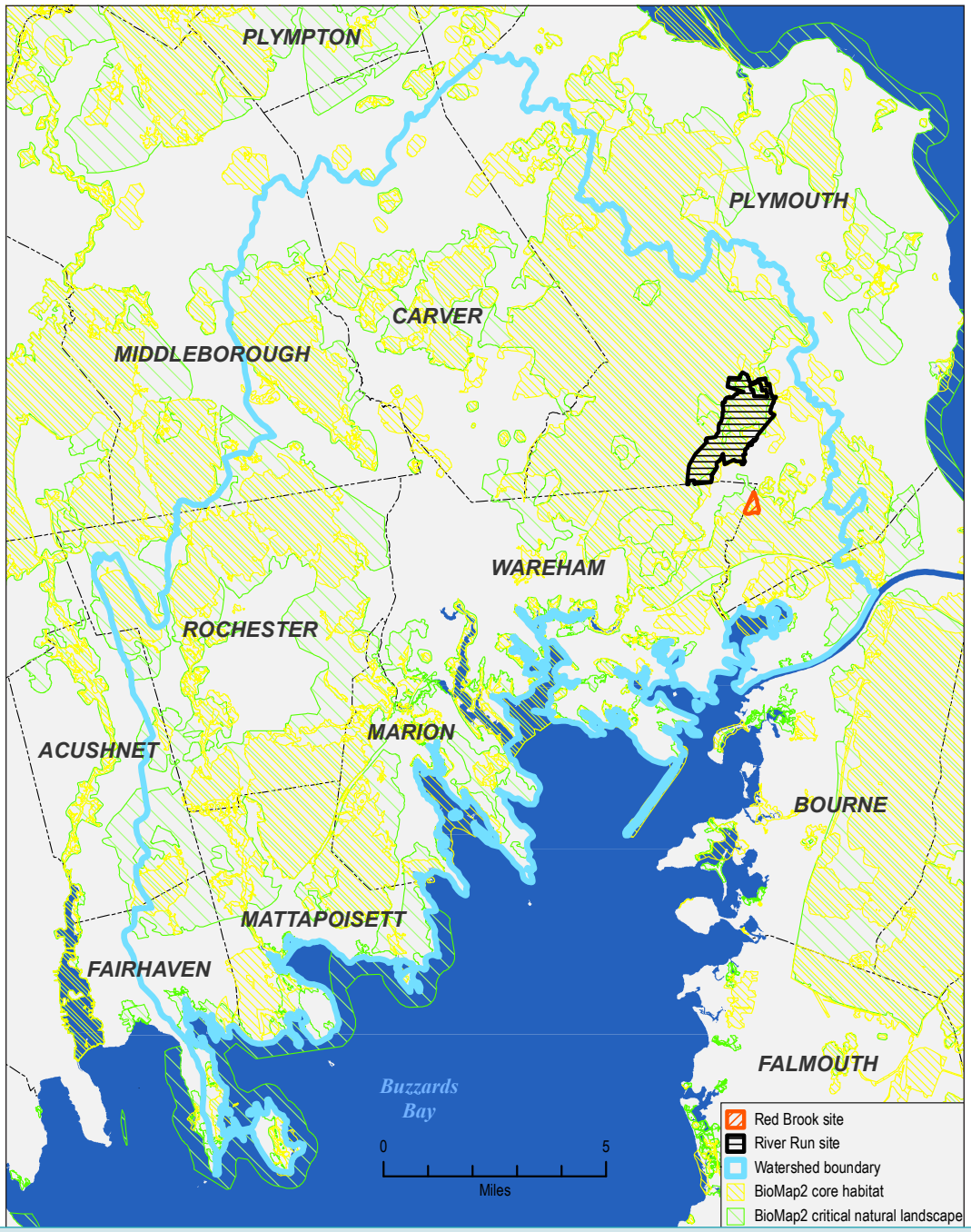
- **Rare, threatened and endangered species management:** Several species of State listed moths and the Eastern Box Turtle exist in and around the development site. Management of site areas being placed under conservation easement as part of the TDR program includes measures to maximize habitat value for these species. Primary management practices will include maintenance of the Pitch Pine/Scrub Oak forest type through removal of overstory trees and accumulated brush to increase open canopies and minimize severe fires. Pitch Pine/Scrub Oak was rated as having low vulnerability to climate change in the 2010 Massachusetts Habitat and Species Vulnerability Analysis.[12] This is a habitat type that extends far south of Massachusetts and is therefore likely to adapt to warmer conditions. However, increasing summer drought may adversely impact Pitch Pine/Scrub Oak forest. Prescribed fire may be used as a management tool pending resolution of health and safety issues with the Town of Plymouth. Wetlands and associated buffer zones will also be protected to preserve moth habitat. Management practices will need to be reviewed periodically to insure they keep pace with changing climate.

Ecosystem and Habitat Provision: Cold Water Fish Habitat

- **Climate Change Vulnerabilities:** Red Brook, to the southeast of the development site, provides highly valued cold water fish habitat for species such as Salter Brook Trout. Increasing atmospheric temperatures associated with climate change will threaten the viability of many cold water streams in Massachusetts, particularly those stream segments exposed to direct sunlight. The combination of a warming climate and increased impervious surface area from the development project will increase the temperature of storm water leaving the site and entering White Island Pond. The Pond is the primary surface water input to Red Brook. Water temperature is an important parameter in the Century Bog restoration project and the viability of measures such as maximizing stream shading and linkage of the reconfigured stream channel to groundwater inputs are under evaluation.
- **Recommended Adaptation Actions:** Low impact development features that minimize impervious surface and facilitate onsite infiltration of storm water are included in the design documents for River Run. Minimizing direct linkage between impervious surfaces and receiving waters will be important in minimizing temperature gain of storm water.

Maintenance of Genetic Diversity:

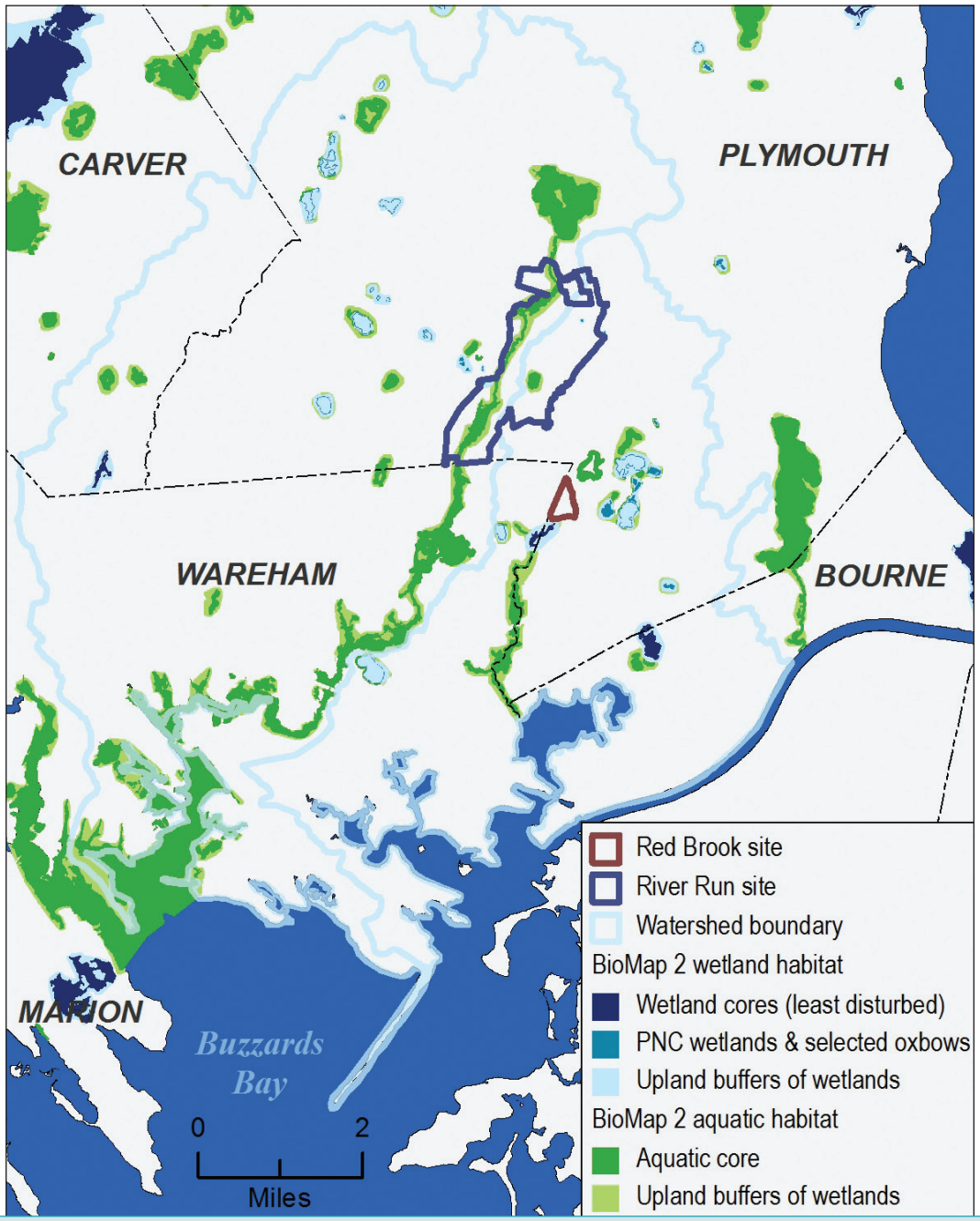
- **Climate Change Vulnerabilities:** Climate change will expand the range and enhance the competitiveness of several invasive species. Glossy buckthorn, Japanese barberry, and phragmites are already present in New England and invasive plants such as kudzu, Japanese stiltgrass and mile-a-minute vine are moving north.
- **Recommended Adaptation Actions:** An expanded program of monitoring and managing for invasive species on both the development site and the adjacent protected lands is recommended.



Map 4. Open Space Network

Map showing important habitat in and around the Buzzards Bay-Cape Cod Canal to Sconticut Neck watershed. BioMap 2 data produced by the Massachusetts Natural Heritage and Endangered Species Program (NHESP) and The Nature Conservancy (TNC). Core Habitat is critical to the long-term persistance of rare, threatened, and endangered species, diverse natural communities, and intact ecosystems. Critical Natural Landcape complements core habitat to ensure its long-term integrity. Town boundary, hydrologic, and parcel boundary data obtained from MassGIS; watershed boundary data obtained from USGS/NRCS.

MAP 4



MAP 5

Map 5. Wetland and Aquatic Habitat Map

NHESP/TNC BioMap 2 aquatic and wetland Core Habitat and Critical Natural Landscape in the Buzzards Bay-Stony Point to Cromeset Point (left) and Cape Cod Canal to Stony Point (right) watersheds. Core habitat includes Wetland Cores, the most intact and best-buffered wetlands in different ecological settings; Priority Natural Community (PNC) wetlands selected oxbows, exemplary natural communities, and Aquatic Cores, based on observations of state-listed species and exemplary natural communities. Critical Natural Landscape includes the upland buffers of these cores; the most intact and unfragmented areas around these core habitats.

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Regulating Services

Local Climate and Air Quality Regulation

- Climate Change Vulnerabilities: Climate change, in conjunction with continued urbanization in southeastern Massachusetts, has the potential to degrade ecosystem services associated with climate and air quality regulation. An increased incidence of extreme heat, drought, and stagnant weather patterns will likely combine to degrade air quality.[13] Higher summer temperatures will exacerbate ground-level ozone production in areas with an ample supply of volatile organic compounds (VOC). VOCs are emitted from a variety of man-made and natural sources. Anthropogenic sources include the burning of fossil fuels for transportation and for energy production. Primary natural sources in the Northeastern U.S. include oak, spruce, maple, hickory, pine, fir and cottonwood trees.[14] The most significant climate change related impacts to air quality and local climate will occur in urban areas with preexisting air quality problems, high local production of VOCs and a high percentage of impervious surface. The impacts in suburban areas such as River Run will be dependent on the prevalence of natural and anthropogenic sources of VOCs and the extent of local heat island effects.
- Recommended Adaptation Actions: Limiting local heat island effects and limiting local production of man-made VOCs are among the most effective approaches to minimizing the adverse impacts of climate change on local air quality and climate. For River Run and the surrounding towns, support of transit oriented development patterns and provision of multimodal transportation opportunities such as pedestrian amenities and bike paths will aid in minimizing local air quality degradation. The utilization of LID techniques and the inclusion of green infrastructure features to minimize new impervious surface are recommended to limit heat island effect.

Other Issues

- Climate Change Mitigation: Several opportunities exist to link climate change adaptation with mitigation at River Run. The inclusion of energy efficiency features in the residential and commercial buildings would minimize both carbon footprint and long-term operational expenses. The landowners have expressed an interest in alternative energy development on the site. Linking solar or wind energy infrastructure to the mixed-use development could provide an opportunity for a carbon neutral (net-zero) project. Finally, the establishment of urban forest on the site would provide carbon sequestration benefits.

Endnotes

1 River Run, Plymouth, MA: Final Environmental Impact Report (Vanasse Hangen Brustlin, Inc., August 15, 2008).

2 Ibid.

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