6-2018

Parcel By Parcel in the Three Bays Watershed: Framing Ecological Residential Design for Water Quality

Doug Serrill
University of Massachusetts Amherst, wserrill@umass.edu

PARCEL BY PARCEL
IN THE THREE BAYS WATERSHED

Framing Ecological Residential Design for Water Quality

Masters of Landscape Architecture Final Project
By Doug Serrill
June 20, 2018

UMASS AMHERST LA&RP Landscape Architecture & Regional Planning
BARNSTABLE CLEAN WATER COALITION

PARCEL BY PARCEL IN THE THREE BAYS WATERSHED

FRAMING RESIDENTIAL ECOLOGICAL DESIGN FOR WATER QUALITY

A Master's Project Presented by

W. Douglas Serrill

Master of Landscape Architecture

June 20, 2018

Approved as to form and approach by:

____

Jack Ahern, Committee Chair

Department of Landscape Architecture and Regional Planning

____

Robert Ryan, Committee Member

Department of Landscape Architecture and Regional Planning

____

Robert Ryan, Department Head

Department of Landscape Architecture and Regional Planning

Conceptual sketch of residential driveway entrance.

Acknowledgments

I want to thank my committee chair, Jack Ahern for his support, insight, and encouragement throughout this entire process. I would also like to thank Robert Ryan for his support and encouragement as a member of my committee.

Thank you to Zee Crocker, Executive Director of the Barnstable Clean Water Coalition and Scott Horsley with Horsely Witten Group for their insight, time, and encouragement to pursue this conceptual investigation of residential landscapes within the Three Bays watershed.

Thank you to my classmates and colleagues for your inspiration and for many hours of dialogue around graphics and design.

Contents

Figure 1. Looking north across the Three Bays Watershed. Data Source: MassGIS, Google Maps.

Abstract

The Three Bays Watershed, located in the Towns of Barnstable, Sandwich, and Mashpee, is facing a crisis of water quality degradation. Excess nitrogen has been identified as the largest contributor to water quality degradation throughout Cape Cod including the Three Bays (Cape Cod Commission, 2015.) Residential waste water systems and non-point sources of pollution including stormwater run-off, and excess fertilization, are identified as the three primary sources contributing 77%, 13% an 10%, respectively, of the excess nitrogen flowing through groundwater and into the bays. Like other watersheds throughout the Cape, Three Bays is largely a residential watershed with 92% of its parcels zoned for residential use. In addition to nitrogen contamination, water quality degradation is recognized to have significant ecological, economic, and cultural impacts on the health and quality of life in the watershed.

Applications of ecological planning, design strategies, and best practices at multiple scales, from watershed to parcel, create opportunities to improve the ecological health and quality of life throughout the watershed. Research in ecological design and cultural perceptions of landscape help inform the development of conceptual residential ecological designs. Three residential parcel districts, Freshwater Waterfront, Saltwater Waterfront, and Upland Neighborhood are used to frame typical parcels. Within these parcels, conceptual ecological landscape designs are displayed that provide multiple ecosystem services to improve watershed health while honoring aesthetic and cultural norms, and possible expectations of the watershed.

Recommendations discuss potential impacts of a parcel by parcel approach to watershed planning and describe water quality improvement scenarios under varying levels of participation and consequent reductions of nitrogen in the watershed.

List of Figures & Tables

FIGURES

TABLES

1. Introduction

1.1 ESTUARIES AND THE COASTAL ZONE

Estuaries are ecosystems where fresh and salt water ecosystems converge, and are some of the most biologically productive ecosystems on the planet (McLusky, 2004). Primary functions of estuaries include flushing from rising and falling water levels from oceanic tidal flows. Estuaries provide many critical ecosystem services such as, erosion control, flood and storm surge mitigation, nutrient transfer, carbon sequestration, as well as, habitat for fisheries and other wildlife (Daily, 1997). Estuarine vegetation acts as a buffer from upland nutrient flows and from coastal storm surge. Freshwater sources including surface run-off, such as streams, and groundwater flows carry nutrients and various contaminants from upland sources that are mixed and flushed out of estuaries through diurnal tidal flushing processes. In healthy, functioning estuaries, this complex hydrology and nutrient mixing creates high levels of floral diversity which in turn acts as a nursery for many avian and aquatic fisheries. The fragility of these ecosystems has only recently been discovered in the past several decades as many have been damaged or destroyed due to fast-growing human settlements along coastal regions globally (Kennish, 2002).

Human coastal settlements have been shown to highly impact functions of estuarine ecosystems ranging from filling in wetlands, eutrophication from introduced excess levels of nutrients, bacteria, and pollutants above the assimilative capacity of the local ecosystem, and disrupting tidal flows that inhibit tidal flushing of excess pollutants. Upstream freshwater inflows that contain high levels of contaminants, increase the concentration of pollution in the upper reaches of the estuary. These upper reaches are fragile nursery grounds for many aquatic species, including oysters, clams, crabs, as well as, fish spawning grounds, that are an important part of coastal economies.

Ten percent of the world's population lives within 10 meters in elevation from the ocean in the Low Elevation Coastal Zone (McGranahan et al, 2007). In the U.S., 53% (153 million) of the population lives in a coastal county and 34% (52.6 million) of the U.S. coastal population resides in the Northeast with significant growth occurring in coastal counties around Boston and New York City (NOAA, 2004).

Increased urban and suburban development along the coastal zone in the Northeast over the past 60 years has significantly impacted fragile estuarine ecosystems and diminished ecosystem services increasingly considered critical infrastructure in the context of climate change and sea-level rise (Bergdoll, 2011).

1.2 A NITROGEN PROBLEM IN CAPE COD

The Cape Cod peninsula in Barnstable County, Massachusetts is a unique and stunning coastal peninsula that has seen significant population growth (400%) over the last 60 years, with a current population of 214,333 (U.S. Census, 2015). During this period of rapid development, the majority of homes, 85%, were built with on-site septic systems (Cape Cod Commission, 2015). 5 of the 15 municipalities on the Cape built forms of centralized wastewater treatment systems, though they are limited in their capacity and geographic areas of service.

Communities throughout the Cape are facing significant declines in water quality and impairment of surrounding estuaries from excess nitrogen in ground and surface water run-off (Cape Cod Commission, 2015).

PROJECT LOCATION

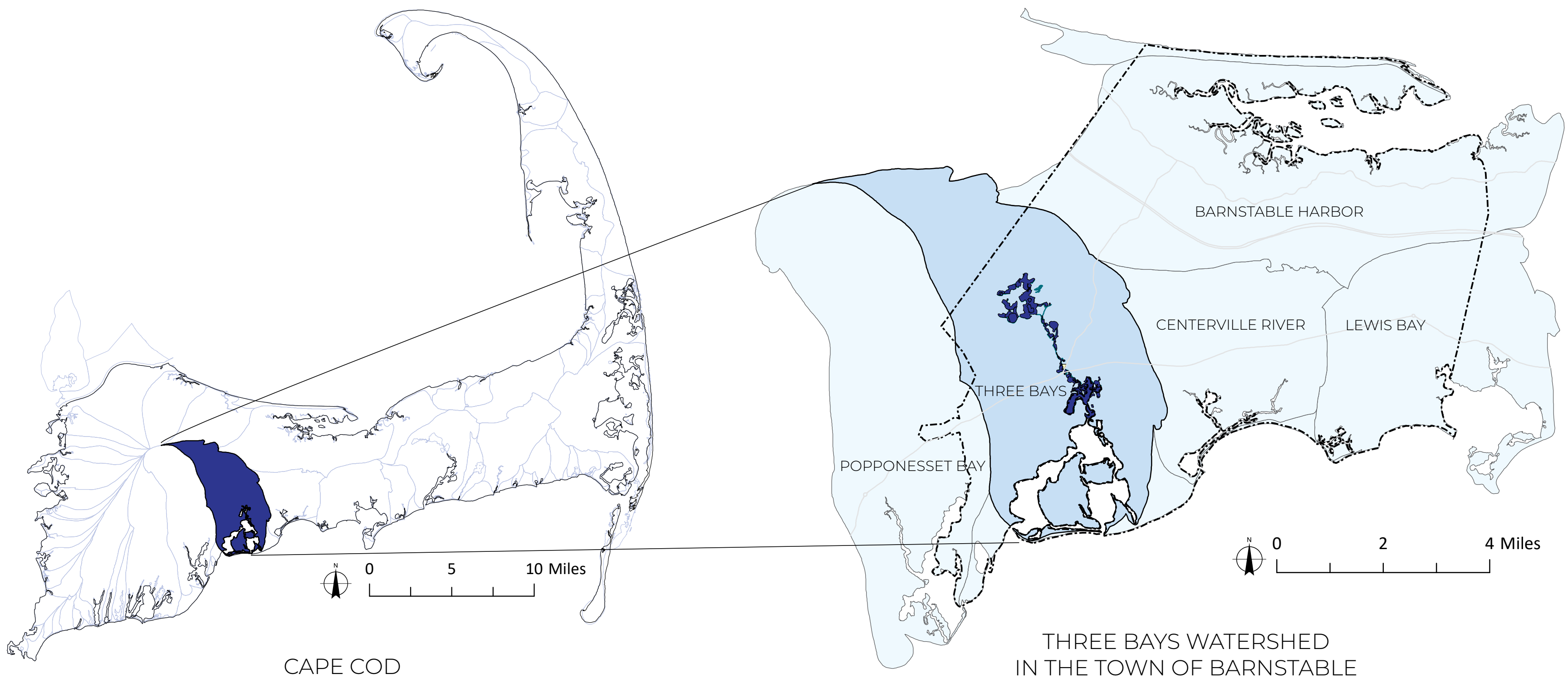


Figure 2. The geographic location of the Three Bays watershed in Cape Cod and in context of other watersheds in the Town of Barnsable. Data Source: MassGIS, Cape Cod Commission.

The three largest sources of controllable nitrogen are from septic systems, excess fertilizer, and stormwater run-off, and from traditional horticultural practices, 74%, 11%, and 9%, respectively (Cape Cod Commission, 2017). Over 85% of parcels in the 15 towns of Cape Cod are zoned single family residential indicating that solutions to these issues need to be addressed at multiple scales- from the watershed to parcel by parcel. Given the current lack of centralized sewer systems at a regional scale, a significant shift in landscape practices and septic system technology at the residential scale, implemented collectively, is of paramount importance to protect water quality and improve environmental health throughout the Cape.

1.3 IN THE CONTEXT OF CLIMATE CHANGE

Sea level rise is already occurring in many coastal communities and, although

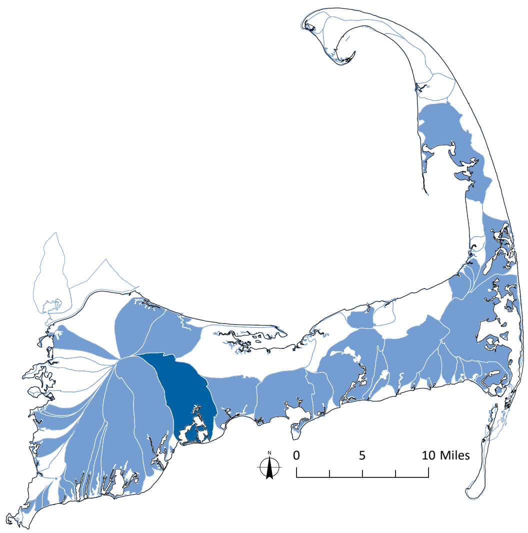


Figure 3. Embayments with identified TMDLs, including Three Bays Watershed. Data Source: MassGIS, Cape Cod Commission.

projections vary, it is increasingly understood that more severe storms and flooding from storm surge will occur and have adverse effects to coastal communities (Spalding 2010). It is broadly recognized that action needs to be taken to implement measures to protect coastal communities. Research by Spalding, et. al (2010) suggests the need to increase the restoration of natural systems for coastal protection to reduce vulnerability and support climate change adaptation.

Protection and restoration of estuarine systems is of paramount importance in the context of climate change and sea level rise. The Massachusetts Climate Change Adaptation Report predicts that sea level rise may be as high as 6 feet by 2100 (EOEEA, 2011). Along with rising tides, increased storm surge is another dynamic of climate change that already has greatly impacted urban coastal environments on the Cape. Protecting, restoring, and increasing wetland and upland ecosystems in the coastal zone is becoming increasingly recognized as critical “green” infrastructure to support the resilience capacity of coastal communities to adapt to and mitigate the impacts of climate change and sea level rise. Coastal green infrastructure includes protection and development of estuarine ecosystems, including living shorelines, living breakwaters, and increasing coastal zone wetland and upland habitat as buffers. It is critical in the broader frame of protecting natural resources to preserve biodiversity, provide clean water, maintain healthy fisheries, and provide healthy landscapes for people to experience and enjoy.

1.4 A WATERSHED PLANNING APPROACH: THE THREE BAYS WATERSHED

The Three Bays watershed is 12,458 acres and drains primarily through the Marstons Mills river corridor, through Prince Cove, the three Bays, North Bay, Cotuit Bay, and West Bay, and ultimately discharges into Nantucket Sound. The watershed is primarily located in the Town of Barnstable with smaller sections in Sandwich and Mashpee. It is largely a residential watershed, with 92% of the parcels zoned for residential use (MassGIS). There is a total of 7,840 parcels, of which 7,207 parcels used for residences. The current pattern of land use throughout the watershed is primarily low-density single family residential parcels ranging from 0.5 to over 20 acres, with an average parcel size of 1.6 acres. Zoning codes promote low density development to protect water quality of ground water and the aquifer. Much of the watershed is designated Aquifer Protection Overlay District and Groundwater Protection Overlay District (Town of Barnstable 1993). These overlay districts restrict parcel density to 2-acre minimum lot size and limit the number of buildings allowed for residential occupancy. It is important to understand the current conditions, however well-intentioned in their planning and design, have inevitably led to the current problem of excess nitrogen and broad water quality degradation in the Three Bays and throughout the Cape.

In 2015, the Cape Cod Commission, through the direction of the Massachusetts Department of Environmental Protection, and under broader mandate from the Environmental

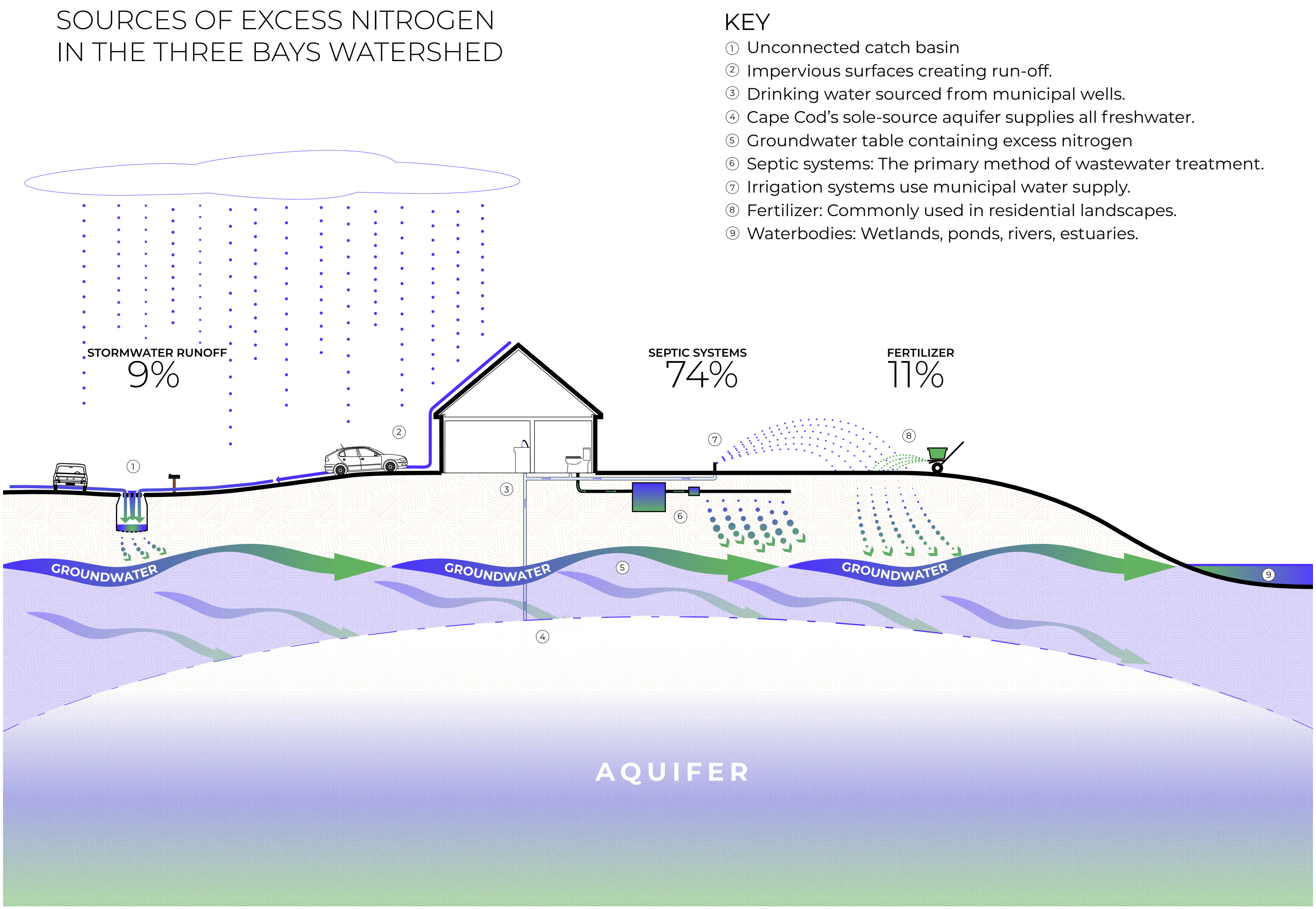


Figure 4. Sources of excess Nitrogen in the Three Bays Watershed. Data Source: Cape Cod Commission, 2017.

Protection Agency (EPA) through the federal Clean Water Act (CWA), completed an update of the Section 208 Plan, a Cape Cod Area Wide Water Quality Management Plan first completed in 1978 (Cape Cod Commission, 2015). Section 208 is part of the Clean Water Act to establish and regulate “Area Wide Waste Treatment Management” (CWA, Section 208). Known as the “208 Plan Update”, the plan set out to identity innovative and non-traditional technologies to solve the nitrogen problem throughout Cape Cod. In conjunction with the work of the Massachusetts Estuaries Project, each watershed embayment was ranked by level of impairment. 20 out of 53 embayments are considered highly impaired, including the Three Bays Watershed.

The Massachusetts Estuaries Project (MEP) was established in 2001 through a partnership with the Massachusetts Department of Environmental Protection and the University of Massachusetts, Dartmouth, Marine Science and Technology program. The goal of the MEP is to study and evaluate the health of coastal watersheds and to establish nitrogen Total Daily Maximum Loads (TMDL) within each watershed/ embayment. Completed in 2006, the Three Bays Linked Watershed-Embayment Management Model identified that significant reductions in nitrogen are needed to restore the health of the watershed and estuarine ecosystems (Howes, 2006). Total watershed load of Nitrogen, including natural and anthropogenic sources, was found to be 130.7 kg/ day. The reduction target, the Total Daily Maximum Load (TMDL), for the watershed is 70.2 kg/ day (Ibid). The findings indicate nitrogen levels need to be reduced by 46% to return to sustainable levels. Within the Three Bays watershed, excess nitrogen volumes are generated from three primary sources, septic systems, fertilizer, and stormwater, 74%, 11%, and 9%, respectively (Cape Cod Commission, 2017). The Town of Barnstable, the Association to Preserve Cape Cod, and the Barnstable Clean Water Coalition have initiated several strategies, studies and pilot projects to address this issue, including fertigation wells, floating wetlands, and dredging of the Mill pond along the Marstons Mills river corridor (Horsley, 2016). These projects are testing non-traditional technologies outlined in the 208 Plan Update that are promoted as techniques to mitigate excess nitrogen while being at a lower cost to implement than centralized sewer systems.

Excess nitrogen in groundwater is having negative ecological, economic and cultural effects. Excess nitrogen is causing algal blooms at the mouth of the Little river in Cotuit Bay and at the upper end of the estuary at the mouth of the Marstons Mills river in Prince Cove. Algal blooms are an effect of eutrophication and are having negative ecological effects on the health of fisheries, as well as, on aesthetics of the bays. Water quality degradation is also correlated with having a negative economic impact on property values. In one study that compared the relationship between property values in the Town of Barnstable and nitrogen levels, found there was a 1 percent decrease in property values for every 0.61 percent in nitrogen levels in the Three Bays watershed (Ramachandran, 2015).

Reducing nitrogen levels in the Three Bays watershed will have a myriad of positive ecological, economic and cultural benefits. It is important that many small actions are taken to have a collective impact. Small scale actions are more accessible and affordable to implement and maintain, and can enable many peope to get involved and have a positive impact on improving the health of the watershed.

1.5 LANDSCAPE-LEVEL SOLUTIONS

Developing long-term, sustainable solutions to reduce nitrogen and improve water quality will require wide-spread application of a range of non-traditional technologies on many parcels throughout the watershed. The 208 Plan Update outlines a series of "non-traditional" alternative technologies to capture and mitigate excess Nitrogen, such as floating wetlands, rain gardens and bioswales, fertigation systems, and permeable reactive barriers, among others. Landscape-level interventions are visible and are at the human-scale. They need to not only perform ecologically, they need to be culturally sustainable in that they are understood and valued by many residents and visitors throughout the region. One challenge in addressing environmental degradation is that there is not one single, identifiable source where the problem originates. There are many small actions over time, "death by a thousand cuts" (Horton, 2003), that facilitate the degradation. It's a classic example of a non-point source pollution problem. Furthermore, the damage is not always visible, so it is difficult to recognize it's happening, or that it's getting worse. Culturally sustainable solutions need to be recognizable so that people observe, understand, and value them. Long term solutions need to have social value and support to last. They need to perform functionally and aesthetically through their form and spatial qualities.

Landscape-level solutions to water quality implemented on residential properties can be designed and maintained to become ecologically and culturally sustainable. These solutions, framed as green infrastructure, low-impact development, or ecological design, are specific landscape elements throughout the landscape. These elements are designed to require lower levels of maintenance and inputs over time compared with conventional landscapes. Essential attributes of these elements integrate ecological functions and aesthetically pleasing, even inspiring, forms in ways that help increase awareness and engage others to also develop interventions on their own.

Rain gardens are one example of a garden intervention that has two primary performance functions, capture and pre-treat surface run-off, and be aesthetically pleasing through plant architecture, foliage color and texture, and seasonal floral displays. Native flora provide ancillary benefits as the garden may attract songbirds, butterflies, and dragonflies. Rain gardens are a prime example of small, cost effective, multi-scalar interventions that can engage many people through all phases of planning, design, installation, maintenance, monitoring, and education.

1.6 CONTENTS OF REPORT

The following chapters cover a review of design and perception as it relates to suburban landscapes, an analysis of natural resources and processes within the Three Bays watershed, development of three typical, residential parcel typologies, and conceptual residential ecological design strategies to address water quality.

Chapter 2 reviews concepts on ecological design and research on cultural perception of residential landscapes. The current decline in water quality is framed as a design crisis. The rise of suburban development is introduced and the role and influence of lawn as a dominant landscape element is framed through understanding the role that cultural perception of landscape plays in everyday landscape practices. The influence of ornamental horticulture is discussed and challenged by the position that landscapes need to perform multiple functions to address current environmental issues. The theories of cultural sustainability and cues to care are raised to suggest that society is more likely to shift its practices when there is increased awareness of ecological values and choose to incorporate novel practices into cultural norms.

Chapter 3 reviews the methods used to

conduct a watershed-level analysis and assessment of the Three Bays watershed, create three parcel-level district typologies and develop representative conceptual ecological designs that address water quality and other ancillary ecosystem services.

Chapter 4 provides a watershed-level analysis and assessment of the Three Bays watershed including, geology, soils, hydrology, including surface waters and groundwater, topography, rare and threatened species, protected open space, land cover, and native plant communities. A summary analysis suggests next possible steps in the design process.

Chapter 5 defines three residential district parcel typologies based a parcel's proximity to a 100-foot buffer surrounding all surface waters and wetlands. The three districts, Saltwater Waterfront, Freshwater Waterfront, and Upland Neighborhood are defined through representative, typical parcels that demonstrate current landscape conditions. Conceptual designs are proposed that demonstrate ecologically appropriate landscape elements that reduce the use of supplemental fertilizers and excess irrigation, while providing low-maintenance, aesthetically pleasing alternatives to lawn area, waterfront buffer, woodland edge and understory, and foundation plantings.

Chapter 6 provides broad projections to assess the impact of ecologically-oriented landscape practices on nitrogen reductions based on a range of participation and intervention levels. Further community outreach and participation studies are recommended.

1.7 PROJECT GOAL AND STRATEGIES

Project Goal:

Identify ecological landscape design strategies to reduce non-point source pollution from residential landscapes throughout the Three Bays watershed.

Project Strategies:

1. Identify strategies to enhance vegetation along waterfront buffers, and low-maintenance landscape elements that provide biofiltration services on non-waterfront properties;

2. Identify strategies that enhance biodiversity, increase ecological connectivity among residential landscapes, and perform aesthetically.

3. Identify the influence of key cultural norms in the design, maintenance, and vernacular of everyday landscapes and how to integrate these insights into ecological landscape enhancements.

2. Design and Perception

2.1 ADDRESSING A DESIGN CRISIS

"In many ways, the environmental crisis is a design crisis. It is a consequence of how things are made, buildings are constructed, and landscapes are used." (Van der Ryn & Cowan, 1996) In their book, *Ecological Design*, Sim Van der Ryn and Stuart Cowan advocate for the need to integrate ecological systems with human systems of the built environment. They define ecological design as, "any form of design that minimizes environmentally destructive impacts by integrating itself with living processes" (ibid). This kind of practice is integrative and systems-based (Franklin, 1999). Ecological and human needs are understood to be part of the same larger socio-ecological system. Through an emergent cultural valuation of natural systems, an ethic can form that ingrains this kind of thinking and prioritization into everyday culture. This kind of ethic was best defined by Aldo Leopold. "A land ethic, then, reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land" (Leopold, 1949).

Broad awareness manifests when it is taught in schools and built into the physical and spatial fabric of our communities. This level of awareness is what David Orr calls "ecological design intelligence", "the capacity to understand the ecological context in which humans live, to recognize limits, and to get the scale of things right. It is the ability to calibrate human purpose and natural constraints and to do so with grace and economy. At its heart, ecological design intelligence is motivated by an ethical view of the world and our obligation to it" (Orr, 1994).

This awareness, indeed, this ethical obligation, needs to also be motivated by a sense of urgency (Leigh, 2005). We are experiencing a myriad of shifting conditions around the world that is unprecedented- human population growth, climate change, sea level rise, environmental pollution, loss of biodiversity, scarcity in freshwater resources- are felt in one form or another, in every community around the world. "The urgent challenge before us is to redesign our communities in the context of their bioregional landscapes enabling them to adapt to climate change and mitigate its root causes." (Landscape Architecture Foundation, 2017). The practice of landscape architecture is uniquely positioned to provide planning and design solutions at multiple scales that integrate ecological systems into the functionality and form of human spaces to foster the health and well-being of people and minimize the impact of the built environment.

Although the problems we face are global, we need not feel overwhelmed and become apathetic. Small actions taken by many people can make a huge impact, in fact, it's exactly what has created the problems we're facing in the first place. The difference is, we need to take small actions that are intentional and reconnect ecological systems into our built environment. Van der Ryn and Cowan suggest five principles to frame ecological design that provide a framework to shape our future actions. The fourth principle, 'Everyone is a Designer' is fundamental to this collective effort. Small actions, such as planting a tree, a shrub, or perennial flowers in one's garden, or in public spaces like streets or parks with a community group, helps build connectivity in ecology, increases vegetation and root systems to filter surface run-off, and enhances the aesthetics of the space for other people, can have synergistic results that improve the health and well-being of our communities.

The current crisis of water quality degradation the Three Bays watershed poses a challenge and an opportunity to integrate greater ecological functionality within our buildings and residential landscapes. Water quality degradation is increasingly recognized as economic issue, community engagement is challenged to exercise a higher level of ecological design intelligence rooted in sense of urgency to resolve this issue now, before it continues to get much worse. The greatest challenge is not solely in developing an understanding of the problem, but in shifting cultural conventions of traditional landscape practices to enable homeowners to develop agency to become designers and seek creative solutions from their own homes and landscapes. The myriad of small scale innovative actions is critical to developing solutions that communities value and integrate into cultural landscape practices (Ahern, 2011).

2.2 THE RISE OF SUBURBIA AND THE AMERICAN LAWN

Suburban development has become the dominant form of residential development in the United States. "The owner occupied, single family home, surrounded by a yard, and set in a neighborhood outside the urban core came to define everyday experience for most American households, and in the world of popular culture and the imagination, suburbia was the setting for the American dream" (Nicolaides and Weise, 2017). As of 2010, more than half (51%) of the population of the continental U.S. resides in the suburbs (Ibid). Unchecked sprawling low-density development has resulted in land conversion from natural ecosystems to residential landscapes dominated by a singular vegetative form of turf grass and a network of impervious surfaces. "Habitat loss is considered the single greatest threat to biodiversity followed by the spread of alien species" (Wilcove, 1998).

Turfgrass is now the largest irrigated crop in the United States; three times larger than the largest irrigated agricultural crop and covers an estimate total area of 63,240 squares miles, over 40 million acres of land (Milesi, 2005). Homogeneous planting of turf grass is the unquestioned default ground cover and a quintessential part of the conventional residential landscape (Steinberg, 2006). Conventional landscape practices, particularly those necessary for a manicured, well-kept, green lawn, are under increasing scrutiny because of the environmental and social costs these practices incur. Ironically, conventional landscapes and sprawling suburban and exurban development are removing the very natural resources and "naturalness" people are moving to these regions to connect with in the first place (Kaplan, 2004).

In his book, Second Nature, Michael Pollan suggests that Frederick Law Olmsted invented the American lawn from his design of Riverside, the suburban neighborhood outside of Chicago. Homes were to be setback 30' from the road to have a front yard. Olmsted proposed that homeowners maintain a landscape of turf grass with several trees. Walls surrounding the perimeter were not allowed to open the view of each property and connect properties together for a unified aesthetic of houses set in a manicured, picturesque landscape. It enabled a connection between properties, a democratization of suburbia, that unifies a community.

Pollan and others point out that several other landscape designers, in particular, Frank J Scott, also played a pivotal role in the foundation and development of suburban landscape design. Scott wrote, *The Art of Beautifying Suburban Home grounds of Small Extent*, in 1870 which played a principal role in guiding the designs of suburban landscapes, still very evident today. Scott, as Pollan points out, argued that the lawn should be the most dominant element in the landscape, “Let your lawn be your home’s velvet robe, and your flowers its not too promiscuous decoration” (Pollan, 1991). The deeper power of Scott’s influence was that he suggested that homeowners who do not maintain their lawn landscape would be considered “unneighborly”, or “undemocratic, or even “unchristian” (ibid). Lawns became a symbol of the American dream and a powerful cultural norm that, like democracy, or the virtues of manifest destiny, should not be questioned.

Pollan further argues that lawns represent a form of an authoritarian regime of culture over nature. Civilization has carved places from the untamed forest for human settlement and the practice of regular maintenance of lawns symbolizes a domination over nature. With the use of machines, synthetic fertilizer, herbicides, and pesticides, humans can create and maintain a cultural aesthetic of control and order over nature. “A lawn was nature under culture’s boot” (Pollan, 1991).

Conversely, Pollan takes a very different argument in, The Botany of Desire, that humans are not in control, but that the plants are (Pollan, 2002). He posits that humans have been duped by specific plant species- through color, smell, taste, feel, and aesthetic- to enlist the help of humans to gain competitive advantage over other species for greater share of the landscape. From this perspective, turf grasses have ingeniously enlisted humans, through their green foliage, prostrate growth habit, and ability to tolerate frequent cutting and foot traffic, to compete against forested landscapes for sunlight and space to grow.

The intensive cultivation of a hand-full of non-native turf grass species, has reduced biodiversity, increased fragmentation of native plant communities, and introduced a range of synthetic contaminants into the environment- fertilizers, herbicides, pesticides, and air pollutants from the burning of fossil fuels. These additives such as fertilizer and irrigation have become necessary tools to help maintain an appearance of health in the process of growing plants like turfgrass, that in many cases geographically, would not otherwise survive. In the effort of everyone striving individually to be good citizens in their community, we are collectively poisoning our environment and destroying the very biodiversity that we need to support our survival as one species among the larger biotic community on this planet.

In an effort toward reconciliation, Pollan offers that gardening is a perspective and a practice that may help us lessen the divide and deepen our connection with nature. “Gardens teach the necessary, if un-American lesson that nature and culture can be compromised, that there might be some middle ground between the lawn and the forest – between those that would complete the conquest of the planet in the name of progress, and those who believe it’s time we abdicated our rule and left the earth in the care of it’s more innocent species. The garden suggests there might be a place where we can meet nature halfway” (Pollan, 1991)

Although most people are well intentioned and want to do the right thing, social pressures to follow conventional landscape practices have blurred the line between recognizing the collective harm conventional landscapes have on natural resources and water quality, and the desire to be a positive contributor to the neighborhood by maintaining the landscape to meet cultural norms.

Thomas Rainer and Claudia West, in their book, *Planting in a Post-Wild World,* propose seeking a balance between a cultivated lawn area and a more diverse, designed plant community. “In American gardens, where front lawns are such a dominant element of the vernacular, designed plant communities may be placed next to lawns- not replacing them entirely. In this way, lawn and planting beds can be somewhat symbiotic, each improving the visual quality of the other" (Rainer & West, 2015).

Aesthetics and visual qualities of the landscape influence people's understanding of alternative practices and techniques. Finding ways to blend lawn and designed plant communities, or as landscape designer Larry Weaner describes this as a balance between "wildness and formality" (Weaner, 2016). This balance, or transition in a garden can help bridge the gap between the vernacular of the traditional landscape, and the vernacular of local ecosystems.

The long-term application of pesticides and fertilizer are harmful to water quality and wildlife. Excess nutrients lead to eutrophication, and excessive pesticide applications lead to reduced species diversity and groundwater contamination, though the adverse effects of lawn chemicals regularly applied in the landscape may not be well understood and may be overshadowed by social pressures to apply lawn care practices. In one study that examined Ohio residents' perceptions and practices of landscape management found that social pressure to maintain their landscape greatly influenced their choices and actions. Residents were more apt to follow the actions of their neighbors regarding the application of lawn chemicals than reach out to County Extension services. When asked whether the application of lawn chemicals affected water quality, most residents surveyed did not think they would; 46% of respondents answered, "not at all", and 27% responded, "very little". To change landscape practices, community education at the neighborhood level is critical to increase awareness and gain broad support (Blaine, 2012).

The suburban lawn dominated landscape is deeply ingrained in American culture. It represents both the quest of American dream and a statement of one's character as a contributing member of society. This lawn-driven paradigm comes with a large cost to long-term water quality degradation and loss in biodiversity, as well as, mobilizing the agency of homeowners to seek out other options and implement other practices that may be more ecologically beneficial or entail less regular maintenance, because of strong social pressures to keep up current landscape practices. Improving strategies to increase homeowner awareness of the importance of environmental protection and the role suburban landscapes can play is important to shift the current paradigm to embrace more sustainable practices.

2.3 THE INFLUENCE OF ORNAMENTAL HORTICULTURE

Traditional horticultural practices promoted exotic ornamental plantings from faraway lands. Plants were bred to have showier flowers, augmented bloom periods, and to become "pest" resistant. Once desired features were selected, cultivars were cloned to be genetically identical so that all "off-spring" would have identical attributes of the mother stock. There are two fundamental differences between ornamental cultivars and regionally native flora. Many ornamental plants are non-native and the cultivars are genetically identical.

One of the primary functions of autotrophic organisms, i.e., plants, is to convert solar energy into energy for all other heterotrophic organisms. The vast majority of organisms that feed on plants are insects. Over many millions of years, insects have evolved alongside their plant counterparts developing very specialized relationships with specific plants to tolerate the complex biochemistry of plants' defenses. The majority of insects (90%) are specialized and rely on specific genera or species of plant to survive. Insects are the first layer in the food chain for many thousands of other species that do not feed on plants (Burghardt, 2008). Because of the desired exotic traits of ornamental species, our developed environments were largely converted from native habitat to non-native ornamental flora that did not contribute to the local food web for insects that previously fed on native flora. This floral conversion has had significant ripple effects through the food chain reducing available habitat for many species.

Bird populations are critically dependent on insect larvae to provide their young hatchlings essential nutrients and protein not available in seeds every spring (Burghardt, 2008). 96% of terrestrial song birds depend on insects to rear their young (Darke and Tallamy, 2014). In one study, author and entomology professor Doug Tallamy tracked the feeding patterns of a nest of chickadees. He tracked how many times a day the mama bird would return to the nest to feed her young and what specific larvae she returned with. His findings were astonishing. For this one nest, of this one species, mama bird brought back one larvae for each of the three young every five minutes for 21 days before they fledged the nest. In total, a range between 6,240 and 10,260 larvae were brought to the nest from nearby native flora habitat and were critical for these hatchlings to reach fledging stage. Insects are critically important to sustain songbird populations and native flora are critical to sustain insect populations. Increasing native flora throughout our built landscapes may be the most radical action we can take to help sustain biodiversity in our region.

Unfortunately, insects, generally, have developed a bad reputation amongst humans, particularly gardeners. The horticultural industry has gone to great lengths to develop cultivars that are resistant to damage from insects. These “pest-free” plants lead to insect-free gardens, which are gardens devoid of life. This has further contributed to cascading effects throughout the food web by reducing potential habitat for critical species in the food web. Even though less than 1% of all insects are considered pests (Sallam, 2000), we have developed a zero-tolerance attitude towards insects in our gardens. Yet, studies were done in suburban landscapes to identify the threshold of insect damage to plants in the landscape and found that homeowners do not notice insect damage to foliage below 10%. This indicates that we can co-exist with insects in our gardens, which is critical to maintain populations of desirable wildlife such as songbirds, dragonflies, and butterflies.

Rachel Carson published her seminal book Silent Spring to shed light on the devastating harm pesticides were causing throughout the environment to wildlife and to people, but the conversion of our landscapes from native to non-native flora, could be arguably more insidious. The only non-native flora to cause alarm are those that spread from the garden and became invasive. These species cause damage by occupying habitat and are considered to the be second greatest threat to biodiversity outside of development (Wilcove, 1998). Non-native, non-invasive flora grow and provide aesthetic pleasure to people, but provide limited, if any, habitat to local wildlife. There is limited awareness of this trade-off between aesthetic pleasure and loss of habitat availability for local wildlife.

Not only do we need to reduce our use of pesticides and allow insects to reside alongside us, Tallamy argues we need to increase our use of native species in our gardens as well (Tallamy, 2007). In research that compared the ability of native woody and herbaceous species with non-native species to host different species of Lepidoptera (moths and butterflies) in suburban landscapes in the mid-Atlantic region found that native species hosted 15 times more species of Lepidoptera than non-native species (Tallamy, 2009).

ECOSYSTEM SERVICES AND DISSERVICES OF CONVENTIONAL AND ECOLOGICAL LANDSCAPES

ECOSYSTEM SERVICES	**CONVENTIONAL LANDSCAPES**	**ECOLOGICAL LANDSCAPES**
SUPPORTING		
Nutrient cycling	Supplemental fertilizer applications; removal of lawn clippings and leaf debris	No supplemental fertilizer; foliage and stem debris retained on sight to cycle nutrients
PROVISIONING		
Fresh water	Application of pesticides, herbicides, and fertilizer in horticultural practices contributes to water pollution	Provides water filtration services
Habitat	Homogenous, non-native species provide nominal habitat functions	Heterogeneous diversity of native species provides wide range of habitat functions
REGULATING		
Air quality regulation	Lawn and ornamental species assist with air quality; regular lawn mowing increases air pollution and greenhouse gases	Vegetation layers provide air filtration services
Pollination	Lawn and non-native species offer minimal habitat for pollinators	Native species offer habitat for larval and adult insect pollinators; varies depending on species diversity
Water quality regulation	Some filtration	Increased water filtration, depending on health of ecosystem
CULTURAL		
Aesthetics	Attractiveness in neatness and order of conventional landscapes	Complexity and diversity of flowers, plant layer, native plant communities; provides a sense of place
Recreational	Passive and active; lawn area offers opportunities for active recreation activites	Passive and active; attracts birds and beneficial insects
ECOSYSTEM DISSERVICES		
PROVISIONING		
Habitat	Homogeneous, regularly maintained landscapes provide less opportunity for undesirable wildlife, though ticks and deer are found in conventional landscapes.	Provides greater opportunity for a diversity of undesirable wildlife species, such as ticks and deer.

Table 1. Ecosystem services and disservices of conventional and ecological residential landscapes.

The practice of integrated pest management (IPM) promotes a more nuanced approach to treating pests in our landscapes. IPM is based on the practice of monitoring and threshold levels. Pest insects are monitored on a regular basis and only when their populations rise above a critical threshold, is a management treatment prescribed; furthermore, the least toxic solution is attempted first before more potentially harmful approaches. A fundamental strategy of IPM is to select the right plant for the right place. If plants are healthy, they are far less likely to succumb to pest damage in the first place.

2.4 BEAUTIFUL AND ATTRACTIVE LANDSCAPES

Cultural preferences for suburban landscapes are rooted in the Picturesque; 18th Century idealized perceptions of nature typified by scenes of gently rolling hills, perhaps even distant mountains, forest edges with manicured understory, and curving landform along the water's edge (Hunt, 1992). Among our cultural perceptions of landscape, Joan Nassauer identifies two broad levels of desire toward landscape, the beautiful and the attractive. Beautiful landscapes are those that we as a culture hold in high regard. They are considered scenic, particularly awe-inspiring, but are not common. These are the landscapes of our state and national parks- the winding river valley of Shenandoah, the valley and cliffs of Yosemite, the rolling plains of Yellowstone, the majestic forests of Muir Woods, the geological wonder of Arches, Zion, and the Grand Canyon, and so forth. "The scenic landscape aesthetic is drawn from the eighteenth-century picturesque, in which the power of nature began to be seen as beautiful, as long as it was controlled" (Nassauer, 1997). The picturesque is a cultural construct of these wondrous landscapes, with the overarching influence of human management and control.

Attractive landscapes are those that we see on a regular basis in the places where we live and work. These are the everyday landscapes of farmlands, suburban yards, and urban streetscapes. The most integral reason they are considered attractive is because they display human intentions of care. They convey obvious signs of maintenance and attention. "Landscapes we describe as attractive tend to conform to aesthetic conventions for the display of care, which can be exhibited in virtually any landscape" (Nassauer, 1997).

2.5 CULTURAL PERCEPTION AND ECOSYSTEM SERVICES

There is a conflict between what we perceive as healthy landscapes and what is ecologically healthy. Healthy ecosystems often appear over grown, or messy, which through the cultural value lens of care, is often perceived as less healthy. Ecological patterns and processes are spatially, structurally, and temporally dynamic. Healthy ecosystems provide critical ecosystem services including, enhance biodiversity, maintain wildlife habitat, nutrient cycling, carbon sequestration, prevent soil erosion, protect water quality, among others. Simply defined, "Ecosystem services are the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment, 2005). These "free services" are the processes of healthy ecosystems that provide clean air, clean water, global temperature regulation, among many others, that human society needs for survival (Table 1). These services were initially assessed and valued to prioritize environmental protection from rampant human growth and expansion. The Millennium Ecosystem Assessment was initiated by the United Nations to evaluate the health of global ecosystems in terms of their ability to provide ecosystem services. 24 services are recognized in four categories, provisioning, regulating, cultural and supporting. Of these, 15 of the 24 services, or 60% of ecosystem services assessed are degrading and are being used unsustainably (UN, 2005). Ecosystem services can be understood regionally and assessed at the watershed level to understand the impacts to water quality, habitat protection, and the cultural implications of ecological health.

One study evaluated residents' valuation of ecosystem services in residential landscapes (Larson, etal, 2016). The study surveyed participants from six different cities throughout the U.S. and found that across regions, the green lawn is still a highly valued and prioritized element of a residential landscape. Values towards water conversation and naturalized landscapes varied throughout the country. Earlier studies, Nassauer, 1995, suggested that residents do not value naturalized landscapes because they are perceived to be messy. This study recognized that this was not the case entirely, and that the trend may be shifting towards elements promoting more drought-tolerant, or low-input landscapes. Similar to other studies, they found that while residents may value ecosystem services, to successfully incorporate services such as increasing biodiversity or promoting water conversation, they need to be designed in ways that incorporate values for low-maintenance and aesthetically appealing landscapes (Larson, 2016).

CUES TO CARE
1. MOWING
Mown expanses of lawn and mown edges of lawn next to other elements act as frames for other garden elements that may be less neat.
2. FLOWERING PLANTS AND TREES
Residents had higher levels of appreciation from densely planted flower beds, as compared to non-flowering herbaceous plants or groups of shrubs.
3. WILDLIFE FEEDERS AND HOUSES
Bird feeders and bird houses in residential landscapes or in unmanaged landscapes acted as signage to indicate that humans are managing these landscapes and their current condition, say from unmanaged fields, are intentional, and therefore indicated they are valued.
4. BOLD PATTERNS
Residents tended to find planted beds that were planted in large masses, that had an appearance of intentional planting pattern were appreciated more than random assemblages of plant species.
5. TRIMMED SHRUBS, PLANTED IN ROWS, LINEAR PLANTING DESIGNS
Alleés of trees along driveways, paths or other architectural elements, and trimmed shrubs provide a legibility through order and display that their planting and maintenance is intentional by others.
6. FENCES, ARCHITECTURAL DETAILS, LAWN ORNAMENTS, PAINTING
These elements provide orderly edges and frames to garden plantings and indicate that people are using these spaces intentionally. Painting elements, from buildings, to fences, to stone walls, are visible displays of care that people value.
7. FOUNDATION PLANTING
Nassauer found that there are nearly universal in suburban landscapes. When well maintained, they are designed to cover building foundations, but should not block doors, windows, or other openings into the building.

Table 2. Cues to Care (Nassauer, 1995).

2.6 THE AESTHETIC OF CARE

Nassauer defines care broadly as, "protecting or maintaining what we pay attention to" (Nassauer, 2011). Displays of care, or the "aesthetic of care" (Nassauer, 1988), refer to actions by people to maintain or protect something they value. These intentions of care symbolize that a place is owned by an individual or a community. In Nassauer's seminal article, *Messy Ecosystems, Orderly*

Frames, she finds that displays of care are recognized in the landscape as neatness and order (Nassauer, 1995). When places do not appear to be neat and organized, they are interpreted as messy, or neglected or otherwise not cared for and in need of human intervention or change. Places that may look overgrown, weedy, or messy, are perceived as unattractive and therefore less valued. Not only are the landscapes perceived as neglected, the homeowners may be judged as well. Because landscapes can be seen by the public, regardless of their ownership, they are part of the public sphere. If they aren't maintained, or appear messy, they can impact how others feel and the homeowners may be perceived as bad neighbors, or poor contributors to society. The maintenance of one's residential landscape is much deeper than simply their horticultural abilities; the degree to which the landscape displays visible signs of neatness and order is perceived as a statement of their character, who they are and how they contribute to society.

To accomplish this strategy of increasing ecological systems back into our built environment, designers and planners need to understand people's underlying perceptions of landscapes and their intentions with them. "In the everyday landscape, rather than simply designing to enhance ecological function as form, we must design to frame ecological function within a recognizable system of form" (Nassauer, 1995). Visible displays of the intention of landscape care, are referred to as "cues to care" (ibid). These cues vary based on regional cultural differences of landscape vernacular. From her studies conducted in the Midwest, the following vernacular landscape elements were highlighted (Table 2).

This research arguably provides the most detailed characterizations of the vernacular of everyday landscapes, the spatial elements that visually display signs of care. This vernacular is important to include when designing elements in the landscape that provide increased ecological functions and connectivity. They may be used individually, such as foundation plantings to frame something built, or in combination, such as mown edges, or fences, adjacent to masses of native wildflower communities. These two examples use manicured vegetation to frame other elements such as buildings or patches of nature. These 'cues to care' will be integrated into proposed strategies for ecological designs for water quality in Chapter 5.

2.7. CASE STUDY: INVESTIGATING HOMEOWNER WILLINGNESS TO ADOPT LOW IMPACT DEVELOPMENT IN THE IPSWICH RIVER WATERSHED.

A study was conducted in 2014 to identify the opportunities and barriers to adoption of Low Impact Development (LID) practices on residential properties the Ipswich River watershed (Stacey, 2015). The Ipswich river was considered one of the ten most endangered rivers in the country due to its ebb and flow of available water. The watershed has experienced significant pressure from urbanization. Nearly 300,000 people rely on the river as a municipal water supply. Groundwater depletion from use and increased impervious surfaces from development threaten the long term sustainability of the river. A survey was sent to nearly 1,000 homeowners to understanding their concerns and assess the opportunities and barriers to LID adoption.

There was moderate support from respondents for outdoor water conservation, but support was stronger by conservation-minded individuals and those who live in close proximity to the river. Regardless of expressed support, a number of barriers were identified. Landscape changes including design and maintenance, were perceived by respondents to be costly. Safety and health were concerns expressed by respondents, particularly with regard to taller grasses and rain gardens as they represented sources of ticks and mosquitoes. Lastly, there was a disconnect between broad support and a willingness to take action on their property in part because of the value of landscape aesthetics.

The results of this study provide insight into the concerns and reservations of a community to implement alternative landscape practices and highlights opportunities to improve strategies focused on addressing safety concerns, cost savings and aesthetics of rain barrels and rain gardens. This study provides an excellent model for a similar study in the Three Bays watershed would provide critical insight into the concerns and values of the local community.

2.8 THE INFLUENCE OF NEIGHBORS

In one study by Nassauer, Wang, and Dayrell, homeowners in Southeast Michigan were surveyed to assess the influence of what others in the neighborhood think has on individual choices in landscape variability from conventional turfgrass based landscape to native prairie and woodland based landscapes (Nassauer, 2009). Participants were shown four images of various landscape conditions of front yards that ranged from 100% turfgrass, and 50%, 75%, and 100% native plant cover of trees and herbaceous perennial groundcover and were asked to rate their acceptance of each condition. They were also shown images of the neighbors' landscapes which ranged from conventional to ecological landscapes. The results indicated that local neighborhood values were more pervasive that broader cultural norms. Participants were far more likely to choose the type of landscape their neighbors had, even it that went against broader cultural norms. For example, participants shown images of neighbors' yards planted with native prairie and partly lawn, they were far more likely to choose native prairie planted landscape, even though this is not the cultural norm. Results suggest that promoting ecological functions in residential landscapes may have more sustainable results when done at a neighborhood scale as compared to one individual parcel.

In another study conducted in Raleigh, North Carolina, participants were asked to rank their preference for native plant landscapes, as well as to rank their assumption of their neighbor's preferences (Peterson, 2012). Participants were shown the same four images used in the study conducted by Nassauer, Wang and Dayrell (Nassauer, 2009). Results of individual landscape preference were similar to findings in other studies (Ryan, 2010; Nassauer, 2009; Nassauer, 1995) in that the majority of participants rated the landscape with 50% native plant landscaping higher than the other scenarios. Surprisingly, participants' assumptions that their neighbors preferred the scenario of 100% turf grass were wrong, suggesting that while homeowners' landscape choices may be influenced by the choices of their neighbors, better understanding their neighbor's actual preferences may help to alleviate presumed social pressure towards homogeneous turf grass landscapes and enable homeowners to shift toward more ecologically balanced landscapes.

These studies highlight how important it is to work at the neighborhood scale to implement broad landscape changes. It is important that the community is involved from the very beginning of a project, such as a single rain garden to a neighborhood system of green infrastructure tools, from concept, all the way through to monitoring and evaluation. Community members need to feel a sense of obligation and ownership in the process and they need to communicate with their neighbors to share their concerns and perceptions and understand those of their neighbors. Efforts are far more likely to last and be sustainable and have a greater impact on long-term ecological health if homeowners work together.

2.9 CULTURAL SUSTAINABILITY

Cultural sustainability is a theory that says for any change in the appearance and management of landscapes to be long lasting, it needs to be valued by people, or "ecologically beneficial practices that elicit sustained human attention over time". (Nassauer, etal. 2001) If the landscape condition is not perceived as valuable, then it will not stand the test of time. For any landscape to be culturally sustainable, its value needs to be legible within a landscape vernacular already understood as valuable. "If people recognize an ecologically beneficial riparian landscape as something they value and enjoy, they are more likely to keep it that way" (Nassauer, etal. 2001). One challenge with improving riparian health is that people may find rivers aesthetically appealing, regardless of health. Stream degradation may not be visually apparent. Research highlights that people do find clean water, curving stream corridors, and riffles aesthetically pleasing, but people still have conceptions that rivers are appealing even if they don't have these qualities. It is challenging to promote changes to a riparian corridor people already value.

Education of the underlying issues is of paramount importance to understand why changes in the landscapes are necessary.

THREE BAYS HABITAT CLASSIFICATION*	ACRES	% TOTAL
Developed	5019	40.3%
Coastal Plain Pitch Pine Barrens	2,696	21.7%
Coastal Plain Hardwood Forest	1,336	10.7%
Coastal Plain Maritime Forest	801.3	6.5%
Water	1066	8.6%
Agriculture	305	2.4%
Wet Meadow- Shrub Swamp	214	1.7%
Appalachian Acidic Swamp	190.6	1.5%
Freshwater Marsh	25.5	0.2%
Coastal Plain Northern Bog	32	0.3%
Coastal Plain Heathland and Grassland	154	1.2%
Ruderal Shrubland/ Grassland	130	1%
Tidal Marsh	347	2.8%
Coastal Plain Beach and Dune	122	1%
TOTAL	**12,438**	**100%**

*Data from the Terrestrial Habitat Map for the Northeast US and Atlantic Canada. (Anderson, etal., 2013)

Table 3. Terrestrial Habitat types in the Three Bays watershed.

Community education at the neighborhood scale can have multiple positive impacts. Homeowners can share their concerns and perceptions with their peers and they can collaborate on alternative designs that will provide aesthetic value and provide ecological functions that there is common understanding of and value towards amongst those of the neighborhood.

2.10 LANDSCAPES NEED TO PERFORM

Suburban landscapes are highly modified, regularly and uniquely maintained, yet spatially and culturally interconnected with neighboring parcels. Because of these qualities, these landscapes provide opportunities to increase ecological functionality to improve water quality protection throughout a regional landscape. Arguably, it is imperative that suburban and urban landscapes begin to develop their ability to perform multiple roles beyond only aesthetic and cultural functions. A shift in cultural values driving the use and maintenance of residential landscapes can include gardens that are part of a broader network of ecological infrastructure. As infrastructure, landscapes can be designed and maintained to provide a range of ecosystem services such as , improve water quality, increase habitat connectivity, enhance biodiversity, improve air quality, sequester carbon, among others, while continuing to provide aesthetic and cultural functions inherent in residential landscapes (Tallamy, 2007; Weaner, 2016; Rainer and West, 2015; Darke and Tallamy, 2014).

There are concerns and fears, inevitably, that in creating wildlife habitat we will attract undesired species, not only the species we desire, such as ticks, deer, mosquitoes, among others. Design strategies can mitigate these concerns, and regular monitoring practices provide critical information to evaluate and improve garden elements, plant health, and overall functionality and value in the landscape.

2.11 DESIGNING WITH NATIVE PLANT COMMUNITIES

Fundamental to appropriate ecological design solutions is the incorporation of regionally appropriate native flora that represents the diversity of habitat types and plant communities present, or historically present, in the Three Bays watershed. Cape Cod is home to a wide range of unique flora and plant communities, many of which are found nowhere else in the state. (Carlozzi, 1975)

Within the Three Bays watershed, the following habitat types are classified though the Northeast Habitat Guide, a project of The Nature Conservancy.

There are 10 different habitat groups that make up the natural communities within the Three Bays Watershed. Each of these habitat groups, there are plant assemblages that are adapted to the specific conditions of the site, including, soil type, hydrology, sun and shade, salinity, temporality, among others.

Within each plant community, there is a range of layers based on tolerance of conditions and plant type. In a healthy woodland, for example, there are at least five vertically structural layers, groundcover, herbaceous vegetation, shrubs, understory trees, and canopy trees. These plants differ in size and tolerance of light, moisture needs, and competition for resources, but they have evolved to grow together as a community. In a salt marsh, the vegetation is stratified horizontally based on tolerance of salinity and moisture. Pond shorelines are a unique example, and a community listed by the Natural Heritage and Endangered Species Program as a Priority Natural Community. This plant community is dominated by herbaceous species that have adapted to the unique conditions of annual water table fluctuations, from complete inundation for much of the year, and dry for several months late in the growing season.

Each of these plant communities has evolved with a suite of wildlife- insects, birds, mammals, amphibians, fish- that depend on the habitat these flora provide, and in turn, are a critical part of survival for the flora as well, from seed dispersal to herbivory. These fragile ecosystems have been largely disrupted and fragmented from human population growth and development throughout the watershed.

One of the key aspects to restoring ecological function and enhancing habitat connectivity is through the establishment and restoration of native flora and native plant communities.

In many cases, our residential landscapes are designed in ways that are not compatible with ecological function or form. The challenge is finding common ground on a particular site between our horticultural desires and ornamental design principles and the ecological functions and habitat needs of the flora and wildlife used to or are still struggling to survive in that same landscape.

2.12 RIPARIAN BUFFERS

Riparian areas are lands directly adjacent to wetlands and rivers. These areas are typically vegetated by specific plant communities tolerant of regularly, or intermittent, saturated soils, or flooding. These areas are important components of healthy wetland and river ecosystems because of the ecological functions they provide, including nitrogen removal from surface and ground water, flood attenuation, sediment filtration, carbon sequestration, shading and cooling of waterways, and wildlife habitat.

Riparian buffers are designated, multi-functional zones of vegetation that are recognized as a best management practice (BMP) to provide a range of ecological functions including, nitrogen attenuation from surface and ground water, sediment retention, soil stabilization, carbon sequestration, and wildlife habitat (Wenger and Fowler, 2000; Mayer, etal., 2005; Hawes and Smith, 2005; .

Excess nitrogen is considered to be the largest threat to the health of aquatic ecosystems. Nitrogen enters surface and groundwater in a number of forms; nitrates from fertilizer applied to agricultural crops and ornamental vegetation, particularly turfgrass, ammonium from septic systems, combined sewer overflows and animal waste, as nitrous oxides from atmospheric deposition, and particulate nitrogen from fallen leaf material. Nitrates from fertilizer are the largest source of readily available nitrogen that in excess leads to eutrophication, causing algal blooms and dead zones. Estuaries are particularly susceptible to eutrophication from excess nitrogen.

Nitrogen attenuation from buffers varies widely. Soils, hydrology, and biogeochemistry appear to play a larger role in determining nitrogen removal than specific species of vegetation (Mayer, 2005). Wenger and Fowler found that although grasses within a riparian buffer do provide some ecological functions such as sediment trapping, forested vegetation provides a larger range of ecological functions for protecting aquatic habitat and forested vegetation should be planted in the riparian corridor whenever possible (Wenger, 2000). Studies on buffer width on nitrogen removal vary widely; wider buffers have been shown to be more effective at removing nitrogen than narrow buffers (Mayer, etal., 2005).

Soil type affects permeability and water holding capacity. Particle size, from clay, silt, to sand, affects its ability to retain nutrients though its cation exchange capacity. The majority of soils in the Three Bays watershed consist of a silt-loam to loam-sand mix, indicating that the soils have a high degree of porosity and a poor nutrient retention ability.

Effectiveness of buffer width for removal of nitrogen and other contaminants also had a wide range. Wenger and Fowler discerned that effective buffers ranged from at least 50 feet to 100 feet. They further point out that for effective wildlife habitat, buffers should at least 300 feet in width (Wenger and Fowler, 2000).

The Town of Barnstable established regulations to guide activities within a wetland buffer zone (Town of Barnstable, 2011). The by-law states that the buffer will be divided into two zones of activity. The first zone is the 50-foot undisturbed buffer zone, the second is the 50 foot – 100-foot buffer zone. These buffer regulations are similar to the Massachusetts Wetlands Protection Act which mandates a 100-foot buffer around all identified, permanent wetlands. The Massachusetts Rivers Protection Act, on the other hand, mandates a greater setback, a 200-foot buffer around all permanently flowing rivers and streams, except in areas of high urban density.

Riparian and wetland buffers are important zones of vegetation to protect water quality, capture sediment, stabilize soils to minimize erosion, and provide critical wildlife habitat. Research on buffer efficacy and vegetation types highlights that not one buffer prescription fits all locations because of site-specific conditions including, hydrology, soil type, slope, and goals of the buffer. Buffer width efficacy varies depending on goals, though wider buffers have been shown to be more multi-functional than narrower buffers. Both herbaceous and forested vegetation has been shown to provide nitrogen attenuation, forested buffers are more multi-functional to provide nitrogen attenuation, soil stabilization, and wildlife habitat, depending on width.

2.13 SUMMARY

The current issue of water quality degradation can arguably be considered a design crisis. Rapid development without long-term ecological planning and consideration for centralized infrastructure prior to development resulted in decentralized septic systems and low-density suburban development. Cultural norms influencing the design and maintenance of suburban landscapes perpetuate the dominance of manicured lawns, use of ornamental cultivars, and perennial additions of synthetic fertilizers, herbicides, and pesticides to residential landscapes. Cultural landscapes of residential development have modified former natural landscapes and their ecological patterns and processes. Forests are heavily fragmented, few intact large patches of healthy natural landscape remain and not all are currently protected as open space. Non-native turfgrasses and ornamental species far less habitat for insects, birds, and other species of wildlife compared to native plant communities development has displaced.

Research on cues to care and cultural sustainability suggest that signs of the intention of care are important catalysts to instill value in a landscape, but without broad awareness in and recognition of the value of an ecological landscape type or treatment, conservation efforts won't be sustainable in the long-term. Increasing ecosystem services and ecological functions in suburban landscapes will appear different and require broad community support to become long-term, sustainable solutions. Changes in practice need to be implemented concurrently with community input in planning and design, community education of the issues and proposed solutions. Ecological landscape solutions need to perform aesthetically and include regional cultural vernacular of valued landscape design and maintenance practices.

Efforts to understand community concerns in the Ipswich River watershed provide insight and a sound approach to develop further community engagement around homeowner willingness to shift practices and invest into novel and different landscape elements that provide greater ecological functionality in the garden.

The use of native plant communities can develop a more authentic, regional sense of place, and a deeper understanding of the fragility of the local ecosystem. The use of native plants can reduce the need for supplemental irrigation, fertilizers, and chemicals. Ecological landscape elements designed to improve water quality, such as rain gardens and vegetated buffer zones along the waterfront provide a critical opportunity to improve water quality and promote new levels of stewardship of the Three Bays watershed and the broader Cape Cod community.

3. Methods

The goal of this project is to identify landscape design strategies that homeowners can incorporate to reduce the impact of residential landscaping practices on water quality degradation in the Three Bays watershed and possibly other watersheds on Cape Cod.

Key findings from regional government studies and reports that address landscape-level strategies to protect water quality, and research on landscape cultural perceptions and people's willingness to adopt ecological landscape practices into their gardens were reviewed and summarized.

A literature review was conducted that focused on understanding cultural perceptions and aesthetics of everyday landscapes, the role of lawn in the evolution of suburban development, principles of ecological design, and the use of native plant communities in landscape design to provide ecosystem services. One case study conducted in the Ipswich River watershed that investigated homeowner willingness to adopt LID practices was reviewed because of the proximity of the watershed and similarity of issues to the Three Bays watershed.

A watershed analysis was conducted to understand the patterns and processes of the Three Bays watershed. Three residential districts have been mapped based on parcel overlap with a 100 foot waterfront buffer. Existing GIS data of land cover, soils, and nitrogen removal goals have been overlaid with the three districts to identify priority zones for application of ecological landscaping strategies.

Three diagrammatic residential landscape typologies were developed based on the typical vegetative cover of parcels in each district.

Conceptual designs of garden elements were developed to integrate native plant communities and ecological functions with traditional garden spaces to demonstrate where and how ecological landscaping can integrate into typical residential landscapes. Specific native plant communities are listed for the following conceptual elements:

1. woodland edge and understory
2. meadow
3. rain garden and bioswale
4. salt marsh and coastal bluff
5. riparian buffer

Recommendations highlight further research needed to understand the needs and perceptions of the Three Bays watershed.

METHOD FRAMEWORK

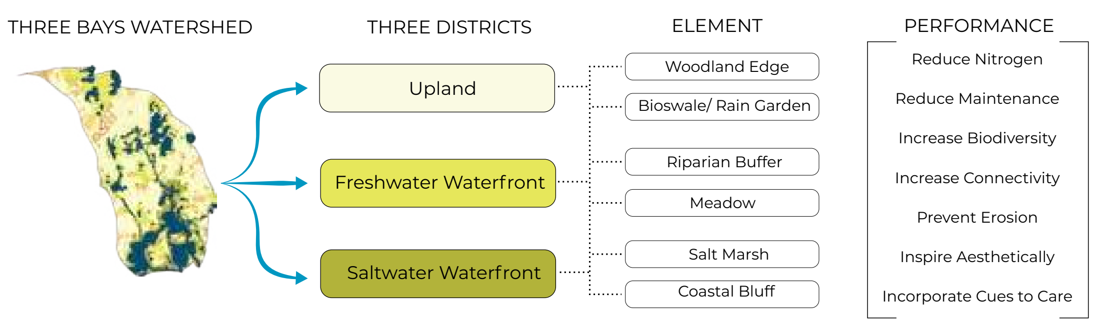


Figure 5. Project methods model.

4. Watershed Assessment

The Three Bays watershed was analyzed using Geographic Information Systems (GIS) data collected from Mass GIS, Cape Cod Commission, NRCS, and The Nature Conservancy. Analyses included asssessment of geology and surficial geological layers and soils to understand the porosity of the ground layer. Hydrological flows were assessed to determine time of groundwater flow in relationship to soils and areas of nitrogen concentration. Vegetation cover was assessed to determine the range of plant communities and habitat types. Slope analysis was conducted to assess locations prone to erosion. Land use and impervious surface patterns were assessed to understand the relationships between development patterns and open space. Land use patterns were correlated to nitrogen removal goals to assess priority locations to establish pilot programs and areas in need of greater protection.

Nitrogen removal goals established from the Massachusetts Estuaries Project assessement were reviewed and compared to land use data to prioritize regions to establish pilot projects for further study.

This data was reviewed to develop an understanding of the larger patterns and processes occuring throughout the watershed and how these are impacting and interacting with landscape conditions on a parcel-by-parcel basis.

SURFICIAL GEOLOGY

The Cape Cod landscape is a result of glacial deposition of a terminal moraine as the Wisconsin glacial formation retreated. Aggregate material from the moraine was deposited and layered with coarse stratified deposits, as well as, sands and silts from alluvial floodplain geomorphic activity.

The Three Bays watershed consists entirely of very porous till in the lowest layer above very deep bedrock. Post glacial materials include a mix of stratified deposits concentrated along areas of concentrated drainage in the Marstons Mills and Little river corridors. Pockets of finer sediments have developed in the undulating terrain forming bogs and wetlands. The bog areas have been further manipulated with sand to form cranberry bogs in the watershed.

These layers of till, sand, and silt have formed a very porous substrate containing a sole source aquifer below the landscape surface. Over time, a very fragile and diverse ecosystem formed, adapting to these unique conditions.

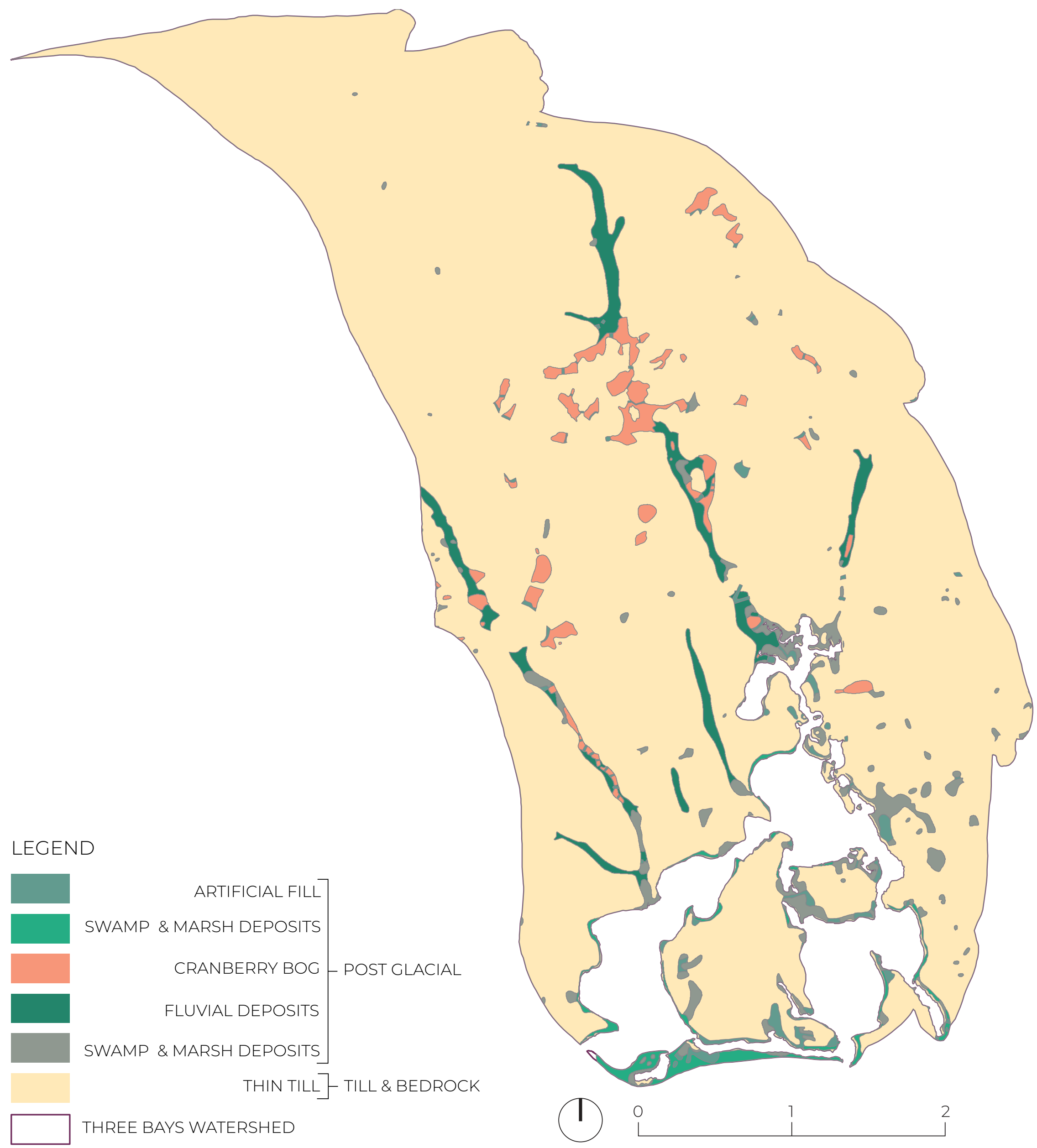


Figure 6. Surficial Geology Map of the Three Bays Watershed. Data source: MassGIS.

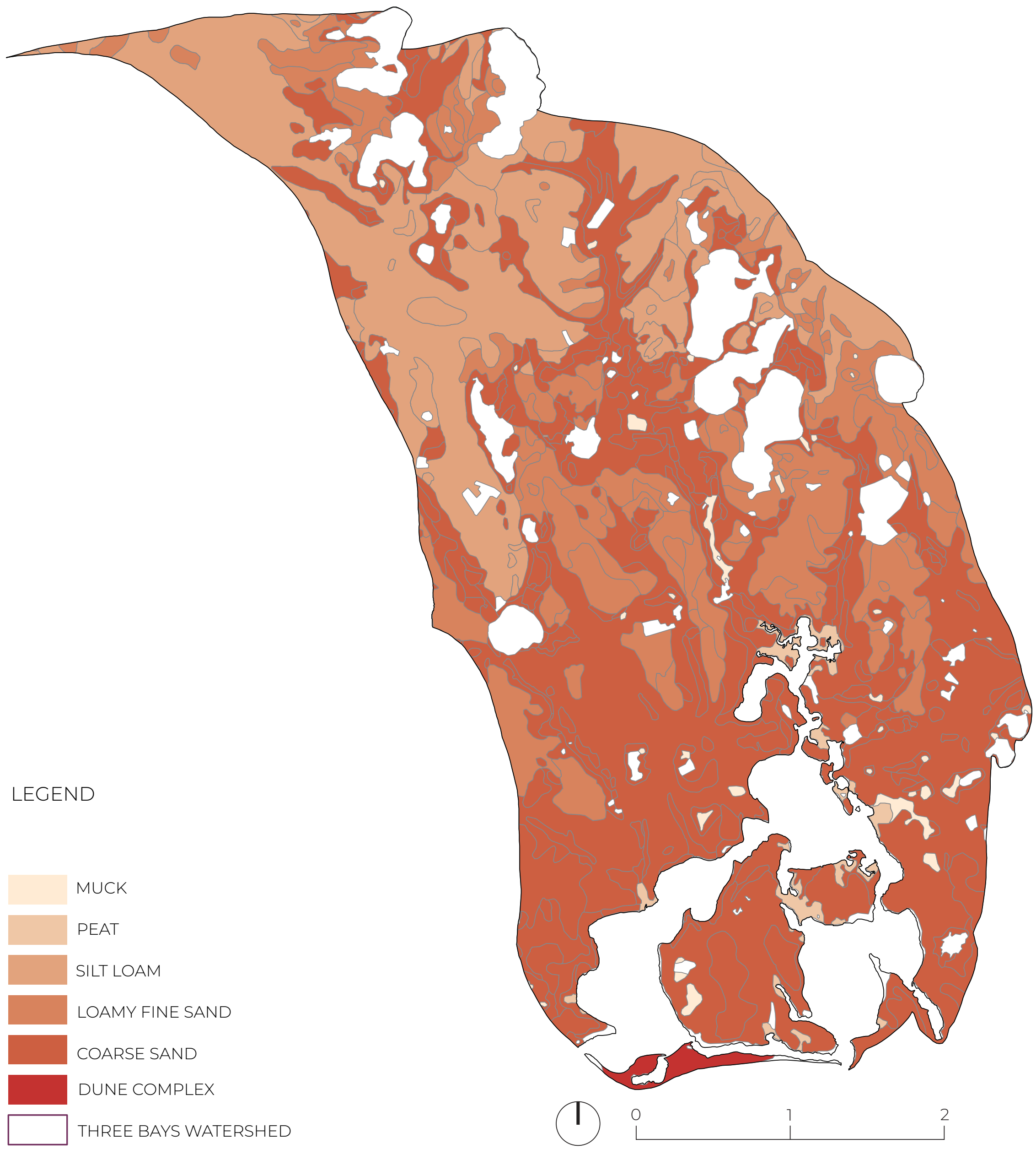


Figure 7. Soils Map of the Three Bays Watershed. Data source: MassGIS.

SOIL TYPES

Over many millenia since the glacial retreat, soils have formed from processes of erosion and deposition, concurrently with native plant communities that evolved and adapted in this region. Moving down-gradient, soils increase in porosity from silty loam compositions, to loamy fine sand, and to coarse sands connecting to Nantucket Sound with a dune complex of coarse sands. Finer muck and peat soils dot the landscape in pockets formed during the process of glacial recession.

Silt and sand based soils have limited ability to bind with nutrients such as Nitrogen and Phosphorus. Diverse native plant communities evolved and adapted to these porous, nutrient-poor soils. Land use changes from suburban development significantly altered native plant cover and increased Nitrogen levels through septic system leachate, supplemental fertilizers, and impervious run-off that these soils have very limited capacity to absorb and retain.

Limited buffering capacity indicates that landscape practices need to reduce supplemental fertilization and increase native plant communities that are adapted to thrive in low nutrient soils.

SURFACE WATERS & SUBWATERSHEDS

Surface waters are a significant portion (18%) of the watershed. There are two rivers, Little, and Marstons Mills, that flow into Cotuit and North Bay, respectively. There are 21 named ponds that cover 1,185 acres. Kettle ponds are a lens on the water table and contain unique habitat that has evolved on the annual rise and fall of water levels. There are 791 acres of identified wetlands that contain a wide range of freshwater and estuarine wetland types. Salt marsh is the largest area, 147 acres, of estuarine wetlands, and outside of cranberry bogs, 181 acres, forested swamps are the largest group of freshwater wetlands.

Landscapes adjacent to wetlands and waterways provide critical ecosystem services to project water quality, retain soils, and provide significant habitat to wildlife, though have been transformed and reduced from residential development. There are 1,614 parcels, 21% of all parcels, within the 100 foot buffer of surface waters and wetlands. Views and access to the water often outweigh wide swathes of undisturbed habitat along the water's edge. Enhancing riparian corridors on private lands is a priority for water quality protection.

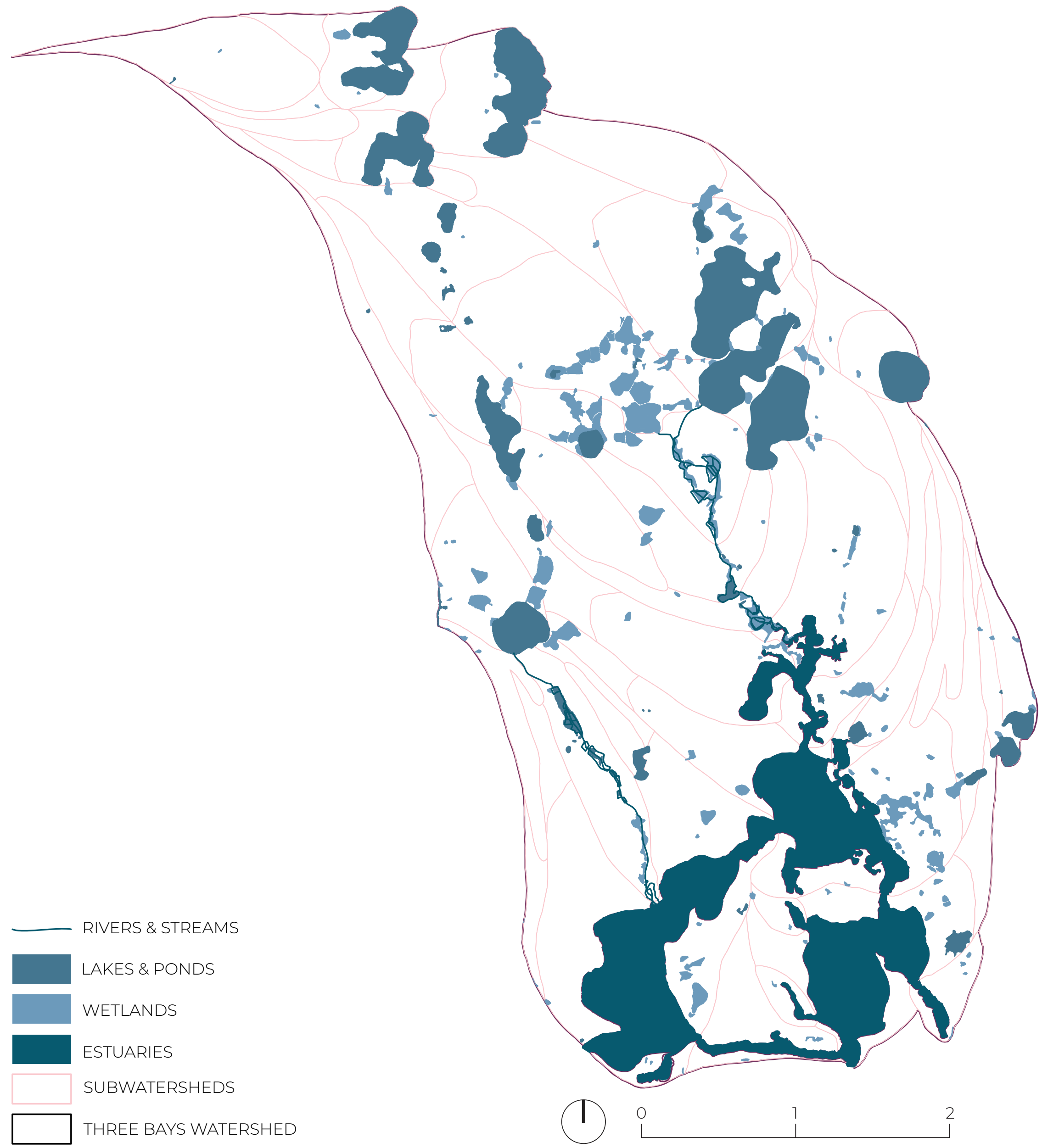


Figure 8. Surface Waters and Subwatersheds Map of the Three Bays Watershed. Data source: MassGIS.

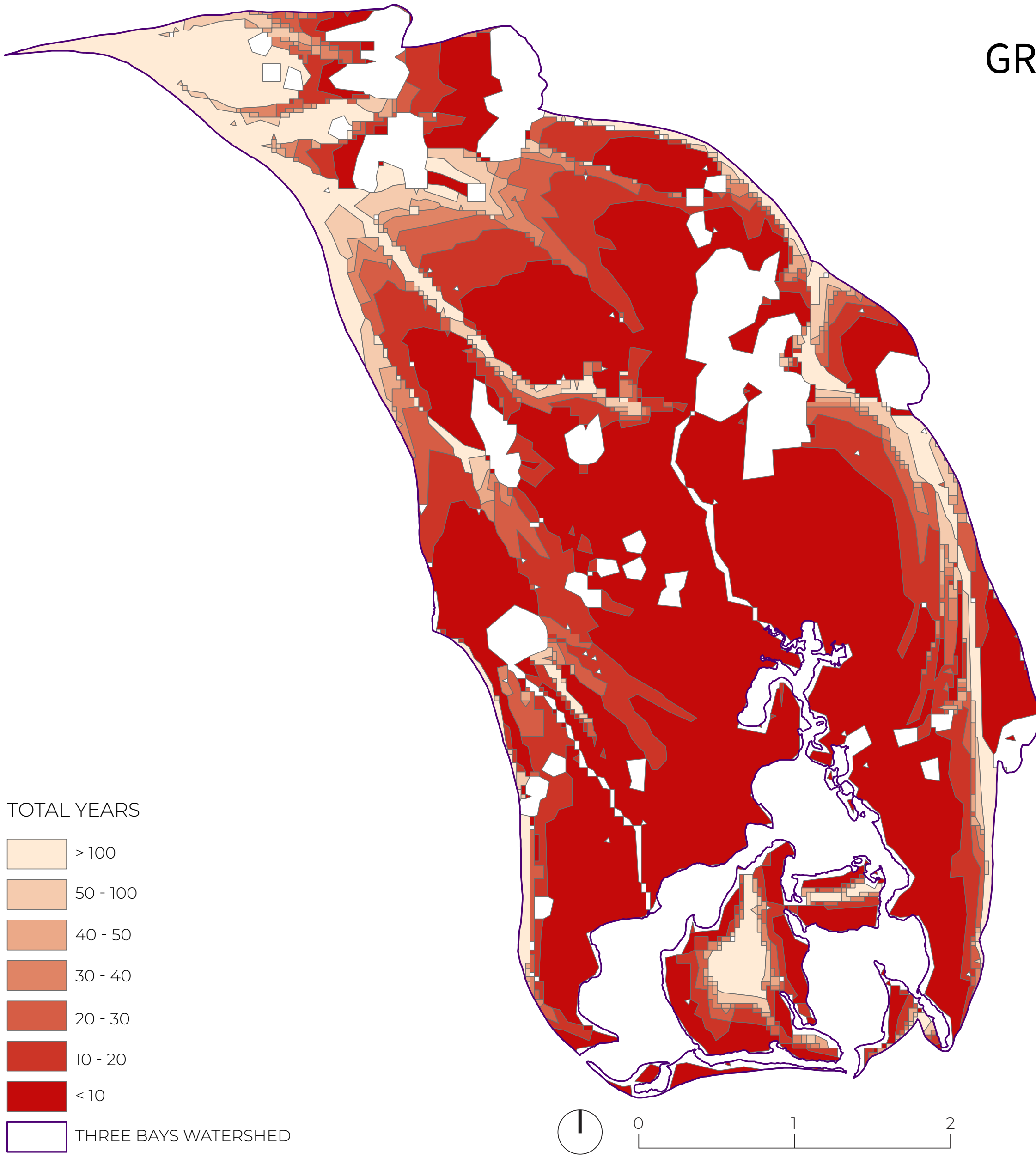


Figure 9. Groundwater Time of Travel Map of the Three Bays Watershed. Data source: MassGIS; Cape Cod Commission.

GROUNDWATER: TIME OF TRAVEL

As soils shift from finer silts in the upper watershed to coarser sands in the lower watershed, the time of travel of groundwater increases through the watershed. While there is a small area in the upper reaches of the watershed with a slow time of travel, greater than 100 years, from point of infiltration into groundwater flow to daylighting in surface waters of the embayments, groundwater moves relatively quickly throughout the vast majority of the watershed, at less than 10 years travel through the soil before reaching the bays.

This correlates with the low nutrient capacity of the soils. Soils offer limited capacity to retain excess nutrients such as Nitrogen and it doesn't take too long for that excess to be released into the bays. Porous soils indicate the fragility of the ecosystem. The current density of development with septic systems and lawn dominated landscapes has exceeded the threshold of the watershed and is causing a decline in water quality and aquatic habitat.

Short time of travel also suggests that positive results from restoration efforts can be experienced by the community. By reducing Nitrogen levels now, improvements, especially in the lower watershed, may be visible in as little as 10 years into the future.

SLOPE

The majority of the Three Bays landscape is gently sloping at under 16%, with more than half of this area under 8.3%. Steep slopes above 33% are concentrated along riparian corridors and pond shorelines. These areas are prone to erosion. Excessive erosion increases sediment into waterways and can diminish water quality and aquatic habitat.

Erosion is common along steeper slopes because broad social desires to obtain physical and visual access to open water. As riparian habitat is transformed by residential development, non-native, invasive species have taken hold in many riparian areas, further diminishing habitat quality and the ability of the former, native plant communities to re-establish in these critical buffer zones.

Reducing disturbance and maintaining healthy plant communities in riparian zones is critical to minimize soil erosion and protect water quality.

Figure 10. Slope Map of the Three Bays Watershed. Data source: MassGIS.

TMDL: NITROGEN PERCENT REMOVAL GOALS

Along with determining a Nitrogen threshold as a Total Daily Maximum Load for the watershed, The Massachusetts Estuary Project's assessment identified levels of concentration of excess Nitrogen within each subembayment within the watershed.

These areas mapped represent the target percentage goal of Nitrogen removal in each subembayment. The areas of highest concentration are located at the lower end of the watershed where the Marstons Mills river and surrounding groundwater daylights into the estuary at Prince Cove, Warren's Cove and North Bay. These waterbodies are already experiencing the negative effects of excess Nitrogen in the form of algal blooms, excessive sedimentation of the bays, and diminished oxygen levels for fish and aquatic life.

Waterfront buffers and residential properties in these subembayments play a critical role in helping to capture and filter excess nitrogen concentrated in groundwater flows. Best management practices include wide vegetative buffers along waterfront edges, and rain gardens and bioswales near storm strains.

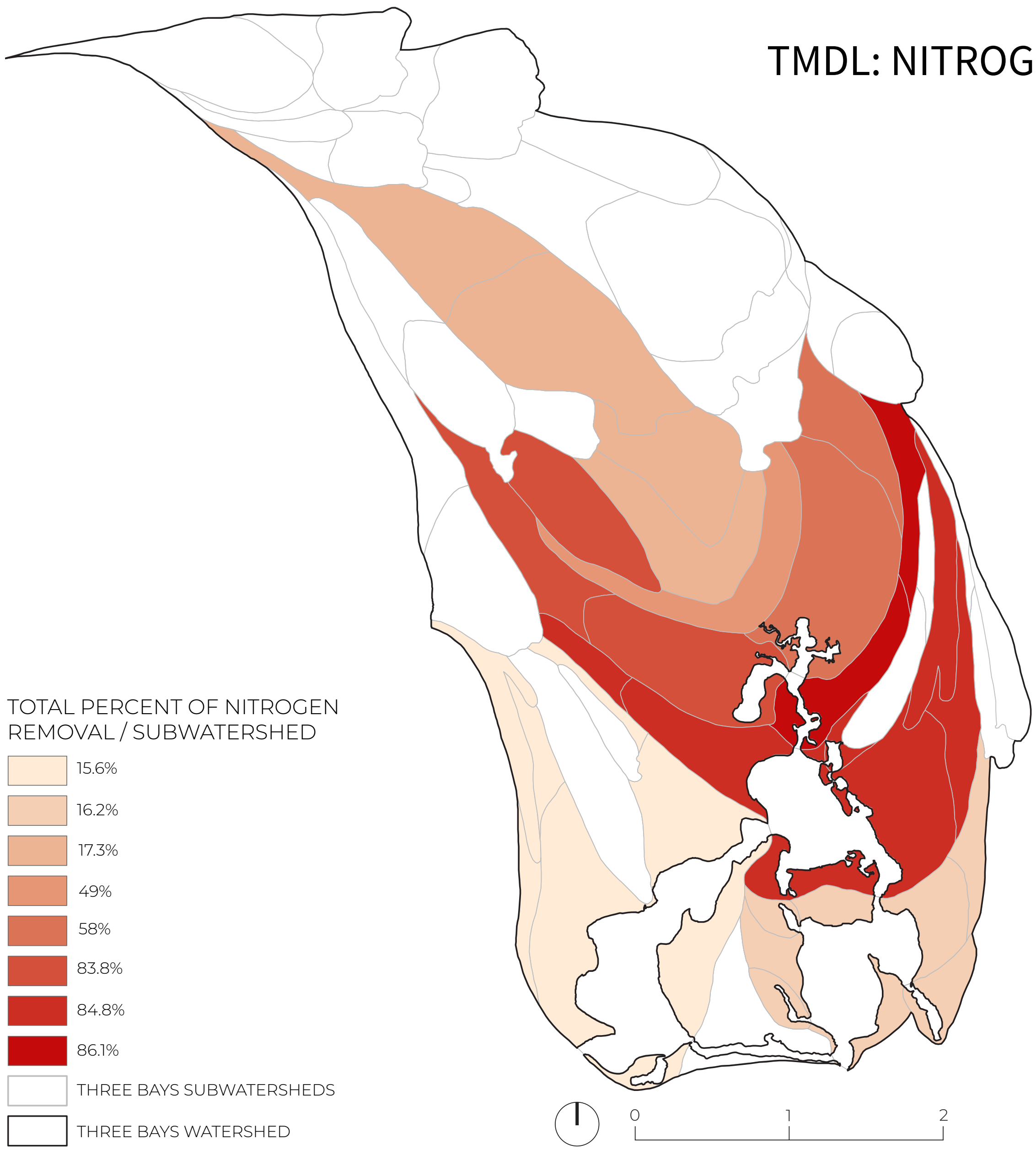


Figure 11. Total Daily Maximum Load: Nitrogen Percent Removal Goals Map of the Three Bays Watershed. Data source: MassGIS; Cape Cod Commission.

IMPERVIOUS SURFACE

Impervious surfaces cover approximately 13% of the land area within the watershed. These surfaces include buildings, driveways, streets, and parking lots. There are higher concentrations in subdivision neighborhoods and in commercial districts of Marstons Mills and Osterville.

The majority of storm drains throughout the watershed aren't connected to pipe systems because high soil porosity is able to absorb water flows. Surface run-off on neighborhood streets flows directly into the soil and groundwater and may contain a range of pollutants from lawn chemicals, to oil and heavy metals from street surfaces. "Research indicates that when impervious area in a watershed reaches 10 percent, stream ecosystems begin to show evidence of degradation..." (Luoni, 2011), and the Three Bays watershed is already past this initial threshold.

Best management practices of green stormwater infrastructure incorporate vegetation in drainage catchment systems to filter sediments and reduce nutrient pollutants flowing into ground and surface waters.

Figure 12. Impervious Surface Map of the Three Bays Watershed. Data source: MassGIS.

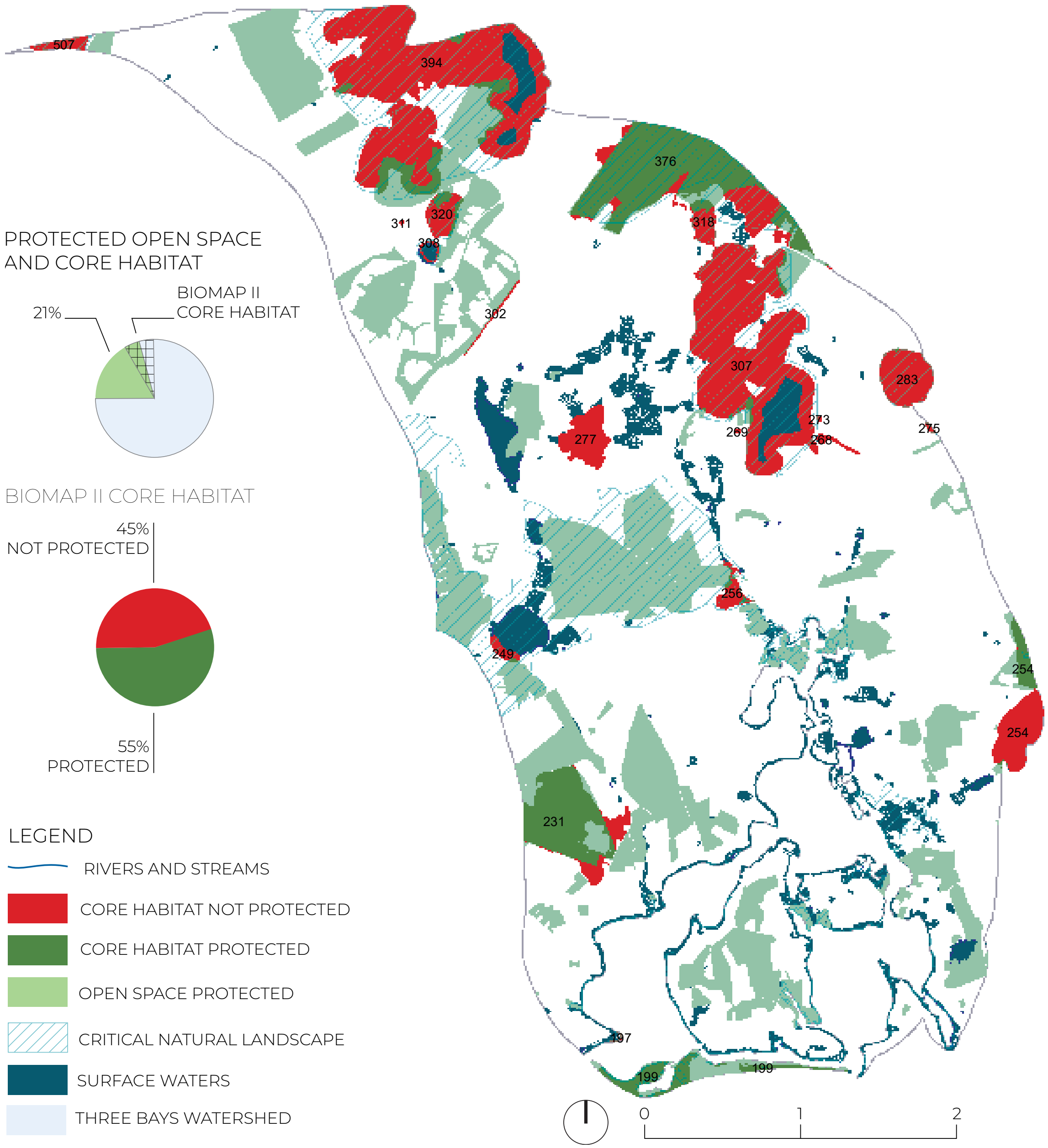


Figure 13. BioMap II and Open Space Map of the Three Bays Watershed. Data source: MassGIS.

BIOMAP II & OPEN SPACE

The Natural Heritage and Endangered Species Program, NHESP, identifies two spatial categories of significant landscapes, Core Habitat and Critical Natural Landscape.

Nearly 1,000 acres of land provides Core Habitat for 29 species of plants and animals listed as endangered, threatened, or of concern (NHESP, 2012). Almost half of this land is protected open space, but 445 acres, 45%, remains unprotected. A considerable amount of this unprotected land is along coastal plain pond shorelines, a significant natural community. Critical Natural Landscape, the supporting lands to Core Habitat, cover 3,032 acres, nearly 25% of the watershed and overlaps with a number of protected open spaces.

79% of the watershed is not protected and is developed for residential use. These landscapes provide opportunities to develop connectivity between larger tracts of Core Habitat and Critical Natural Landscape.

Prioritizing acquisition of Core Habitat and promoting connectivity at the parcel and neighborhood scale in strategic locations can increase wildlife habitat and watershed protection.

LAND COVER: PLANT COMMUNITIES

Data from The Nature Conservancy's Northeast Habitat Guide identifies 12 specific natural communities in the Three Bays watershed. These communities range from coastal plain hardwood forest to bogs and tidal marshes. Nearly 40% of the watershed is considered developed.

The largest plant communities are pitch pine barrens, followed by hardwood forest and maritime forest. Species include Pitch pine (*Pinus rigida*), Scrub Oak (*Quercus ilicifolia*), other Oaks including chestnut, black, scarlet, and white oaks. Ericaceous plants are common in the understory including low-bush blueberry (*Vaccinium angustifolium*), bear berry (*Arctostaphylos uva-ursi*) and huckleberry (*Gaylusaccia baccata*), among others.

This is a largely fragmented landscape with several larger patches around waterbodies providing opportunities to increase connectivity along riparian corridors, ponds and wetlands.

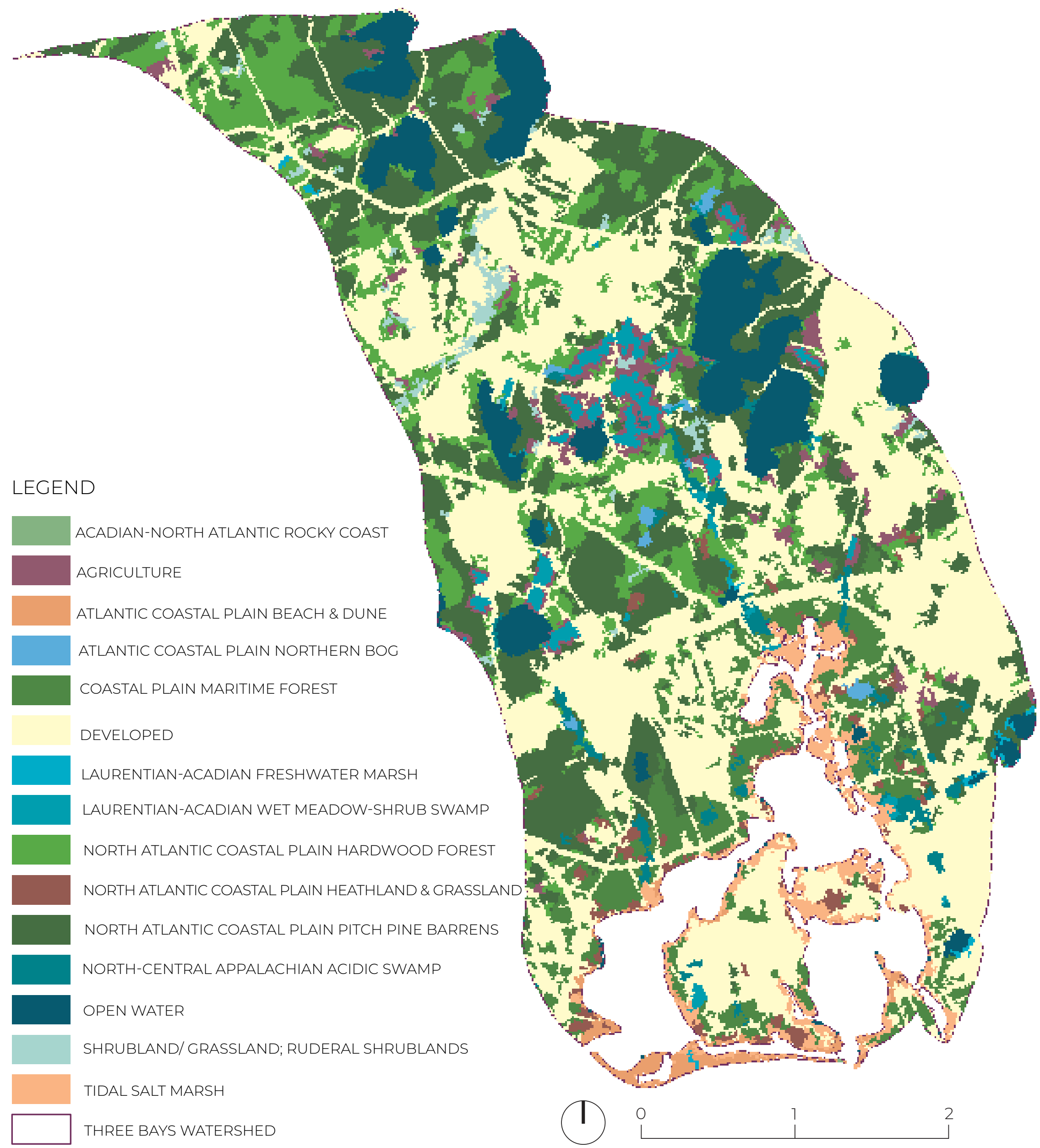


Figure 14. Land Cover: Plant Communities Map of the Three Bays Watershed. Data Source: MassGIS; The Nature Conservancy.

LAWN, SHRUB, AND TREE CANOPY

The Cape Cod Commission mapped vegetation at a finer scale calculating the area of lawn, shrub and tree canopy throughout Cape Cod. Over 65% of the watershed contains tree canopy with considerable overlap with lawn.

Lawn covers a total of 1,439 acres, 13% of all terrestrial vegetation cover in the watershed. Shrub cover occupies only 324 acres, or 3% of land cover. Lawn is concentrated in upland neighborhoods, though is a staple, to a greater or lesser degree, of nearly every residential property.

Nearly 11% of excess nitrogen comes from fertilizer and the vast majority of this is likely applied to residential lawns. Developing landscape alternatives to effectively reduce and replace lawn cover can be an effective strategy to reduce fertilizer use and irrigation water. Using native flora can provide further ancillary benefits of ecosystem services such as increasing biodiversity and habitat connectivity, enhance residential neighborhood aesthetics and deepen a sense of place and regional identity through unique and resilient flora.

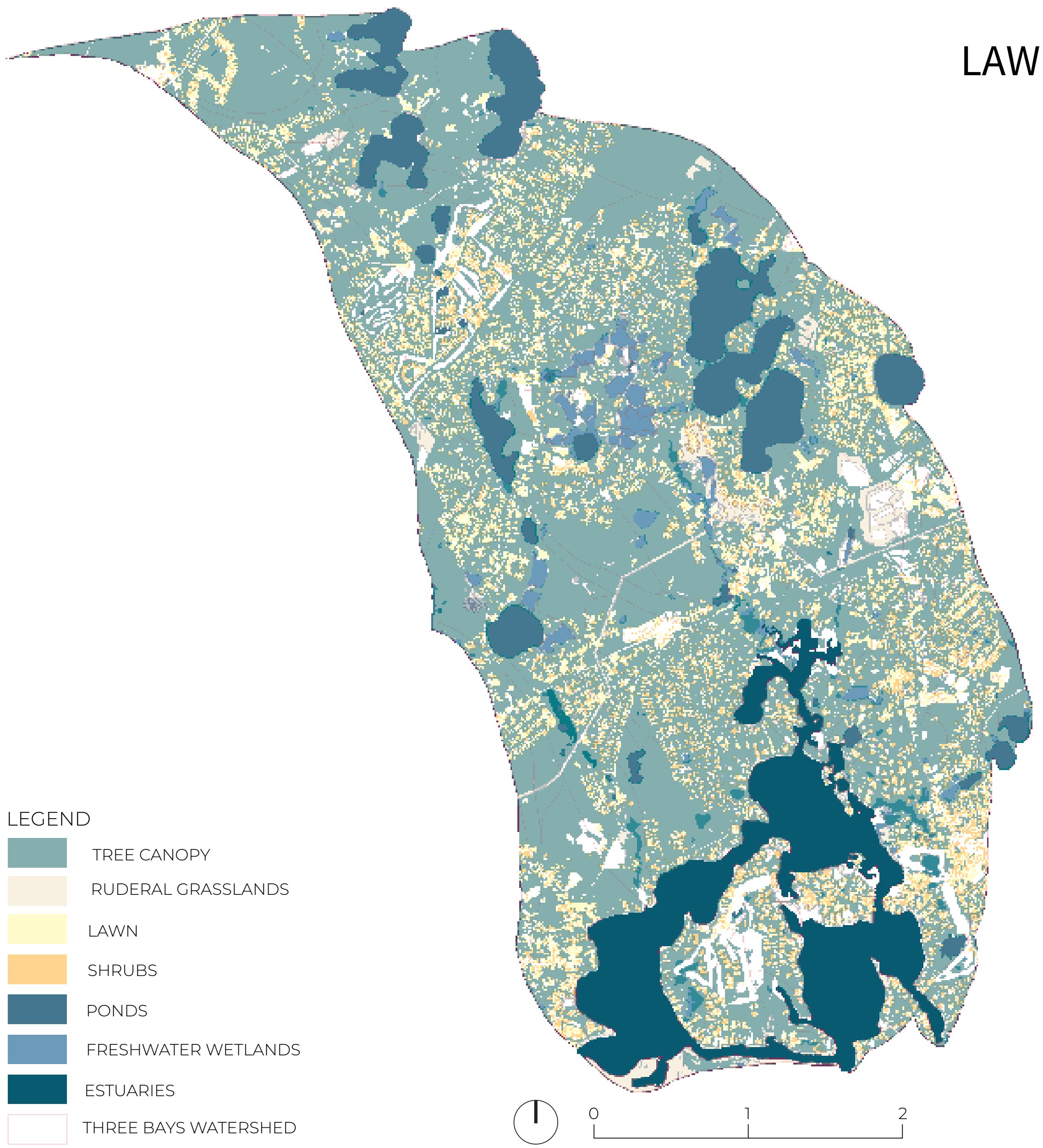


Figure 15. Lawn, Shrub, and Tree Canopy Map of the Three Bays Watershed. Data source: MassGIS; Cape Cod Commission.

SUMMARY ANALYSIS

The Three Bays watershed is a fragile ecosystem within the coastal plain that has been heavily impacted by population growth and residential development throughout the past century. Highly porous soils with low nutrient holding capacity have promoted the growth and evolution of plant communities adapted to drought-prone and low nutrient conditions, but provide little buffering capacity from excess Nitrogen from anthropogenic activities.

Groundwater moves quickly through porous soils and surficial alluvium carrying excess nutrients and other contaminants to surface waters, and ultimately to the estuaries and Nantucket sound. Prince Cove, North Bay, and Cotuit Bay subembayments are severely impacted from Nitrogen contamination. Aquatic habitats are threatened by eutrophication, and local shellfish and fisheries industries are already negatively impacted. Excess Nitrogen has even been shown to negatively affect real estate values, demonstrating how far reaching excess nitrogen can impact the watershed (Ramachandran, 2015).

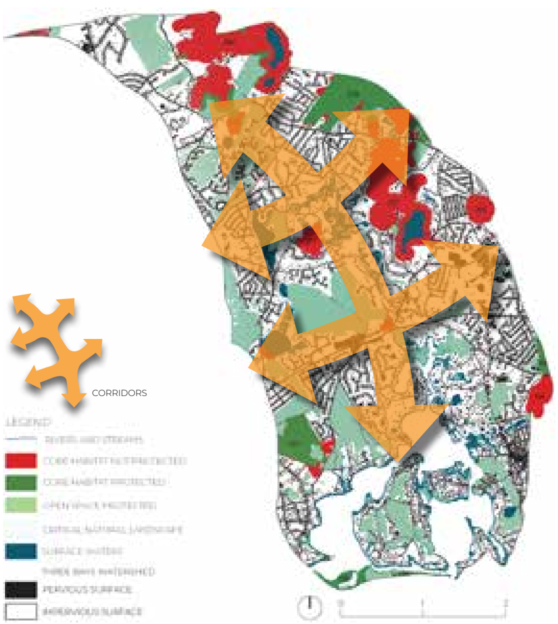
Unique vegetation communities have been significantly impacted from development. Habitat fragmentation reduced large intact patches of habitat that many animals and birds need for long term survival. 29 species of plants and animals are listed as endangered, threatened, and as species of concern.

Although nearly 21% of land in the watershed is already under permanent protection, very little lands within the 100 foot buffer along both fresh and salt waters are protected, leaving this critical nitrogen attenuation and soil stabilization zone vulnerable to further alteration and development.

The Town of Barnstable has developed regulations to protect critical riparian habitat within the 50-foot and 100-foot buffer zone, but cultural norms promote views and access over a wide, layered forest habitat along the waters edge. Unfortunately, these regulations often translate to the use of manicured and fertilized lawns close to the water's edge and infestations of invasive species along less managed areas such as steep slopes near the water's edge and in small patches of woodland grove separating residential parcels.

Habitat connectivity can be promoted along riparian corridors and in areas in between existing large patches of natural landscape and protected open space. All waterfront buffer zones should be enhanced to the greatest extent possible by developing and widening an undisturbed zone of native vegetation. Upland neighborhoods in the Prince Cove, Cotuit Bay, Marstons Mills River Corridor, and North Bay subembayments are priority locations for community engagement and pilot studies to develop parcel-based ecological landscape solutions implemented at a neighborhood scale.

PROMOTING CORRIDORS



PRIORITY EMBAYMENTS FOR NEIGHBORHOOD ENGAGEMENT

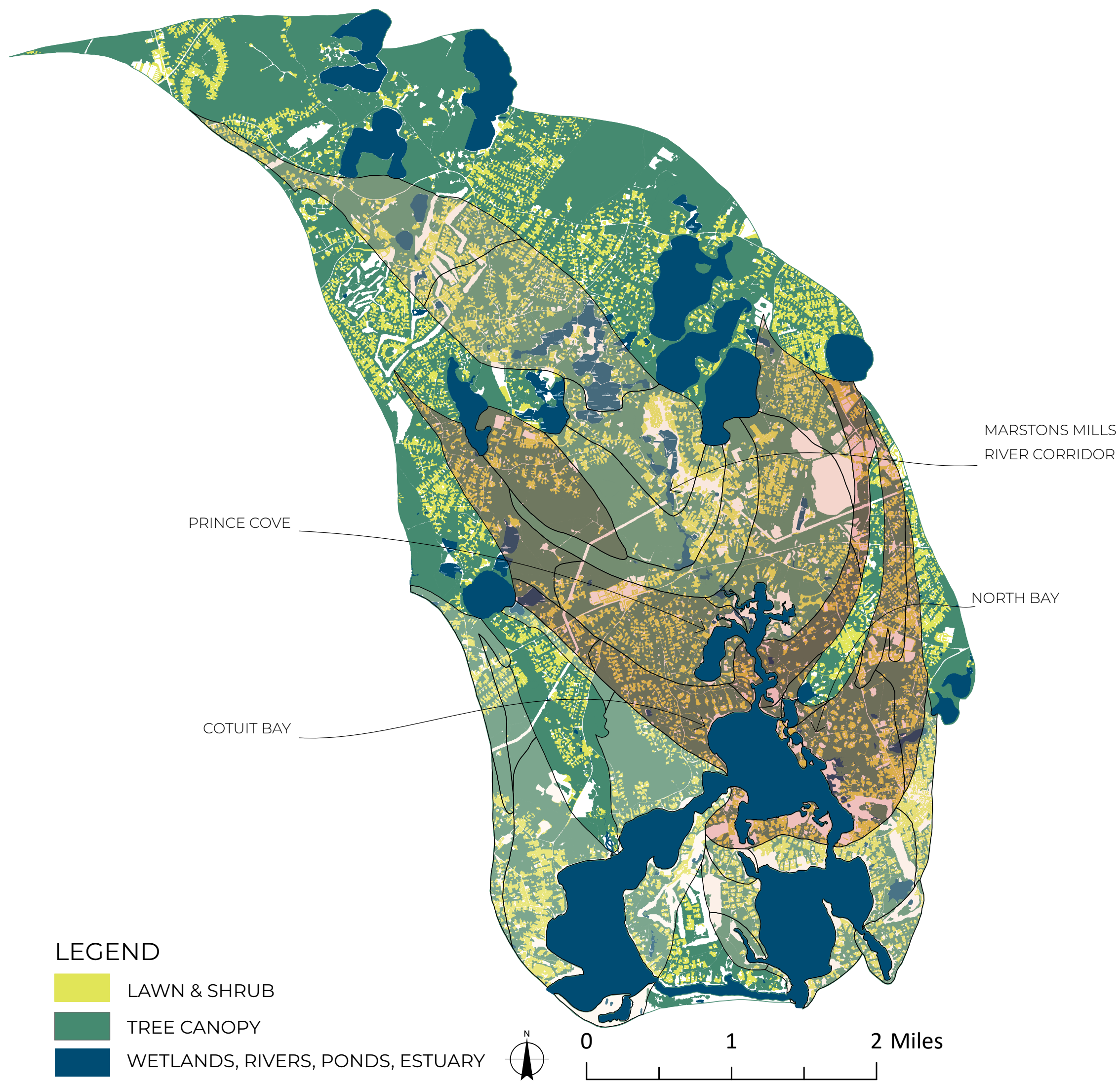


Figure 16. Summary Analysis Map of the Three Bays Watershed. Data source: MassGIS; Cape Cod Commission.

5. Three Districts Parcel Concepts

In this chapter, landscape design concepts are explored to enhance a range of ecological functions that reduce the need for fertilizer applications, increase nitrogen attenuation within the buffer zone, and increase biodiversity and wildlife habitat connectivity.

The Three Bays watershed is primarily residential and is heavily influenced by its relationship and proximity to water. Landscape design concepts are explored at a parcel by parcel basis through a lens of three districts that group residential parcels based on their relationship and proximity to wetlands and surface waters.

The three district typologies seek to address the following goals:

1. Use residential landscapes to improve water quality.
2. Increase biodiversity and habitat connectivity.
3. Reduce lawn.
4. Minimize use of lawn chemicals including fertilizers and pesticides.

These districts were analyzed using GIS vegetation data and on-site observations to develop three parcel typologies of 'typical' conditions that represent the range of conditions within each district. Ecological landscape design concepts are applied to these typical parcels to display how alternative landscape elements can be integrated into existing conditions. Thus, these parcel-based recommendations can be applied more broadly to similar landscapes in the watershed.

Ecological landscape concepts promote the use of native flora, invasive species removal, enhanced and expanded woodland edges, enhanced foundation plantings, and widened waterfront buffers. These garden elements build upon existing typical landscape conditions and expectations of neat, maintained gardens, while increasing ecosystem services that benefit water quality, habitat connectivity, and biodiversity.

These three districts can be used to guide community engagement and outreach efforts, incentive programs targeting buffer zone treatments along riparian corridors, fresh or saltwater shorelines, and upland neighborhood treatments including, rain gardens, bioswales, and woodland edges and understory. Community engagement and incentive programs can promote treatments at a neighborhood scale to encourage parcel by parcel actions to work collectively toward the larger objective of improving water quality throughout the watershed.

THREE DISTRICT TYPOLOGIES OF THE THREE BAYS

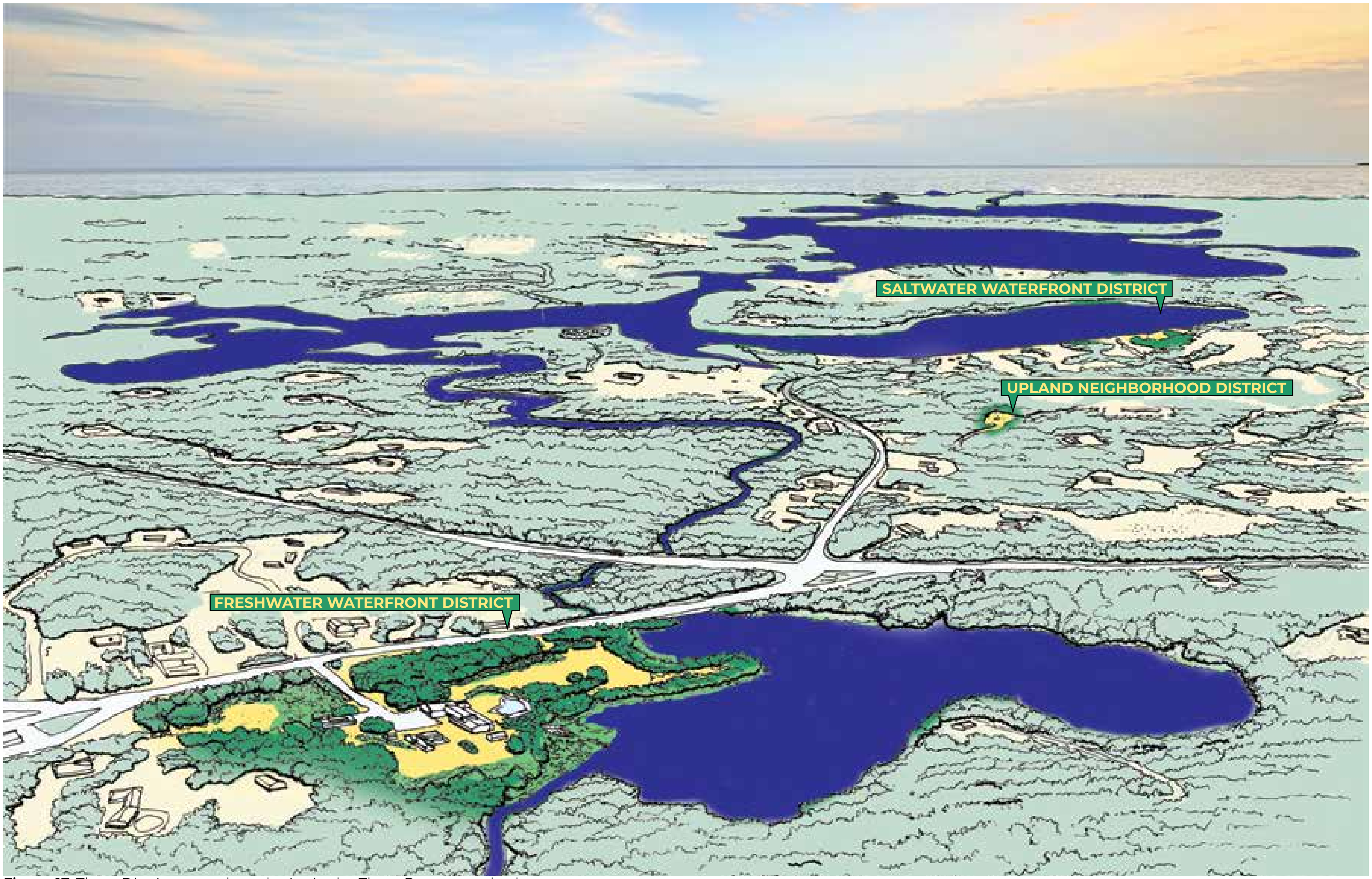


Figure 17. Three Districts parcel typologies in the Three Bays watershed.

THREE DISTRICTS

To further investigate residential landscape design strategies that contribute to improving water quality, parcels were divided into three districts based on their proximity to a 100-foot buffer around all wetlands and surface waters. Parcels intersecting the estuarine buffer are placed into the Saltwater Waterfront and parcels intersecting freshwater comprised the Freshwater Waterfront district. Parcels outside either waterfront buffer are part of the Upland Neighborhood District.

The waterfront buffer districts represent half of the acreage of the watershed, but only 20% of the parcels. Waterfront districts contribute to a reduction in vegetative buffer conditions in order to gain access and maximize waterfront views. 80% of the parcels in the watershed are part of the Upland Neighborhood district, though they only occupy 50% of the total area within watershed, indicating that they are more dense and contribute a higher volume of excess nitrogen from septic and landscape than properties in other districts.

Residential enhancements need to occur at a neighborhood level to maximize impact.

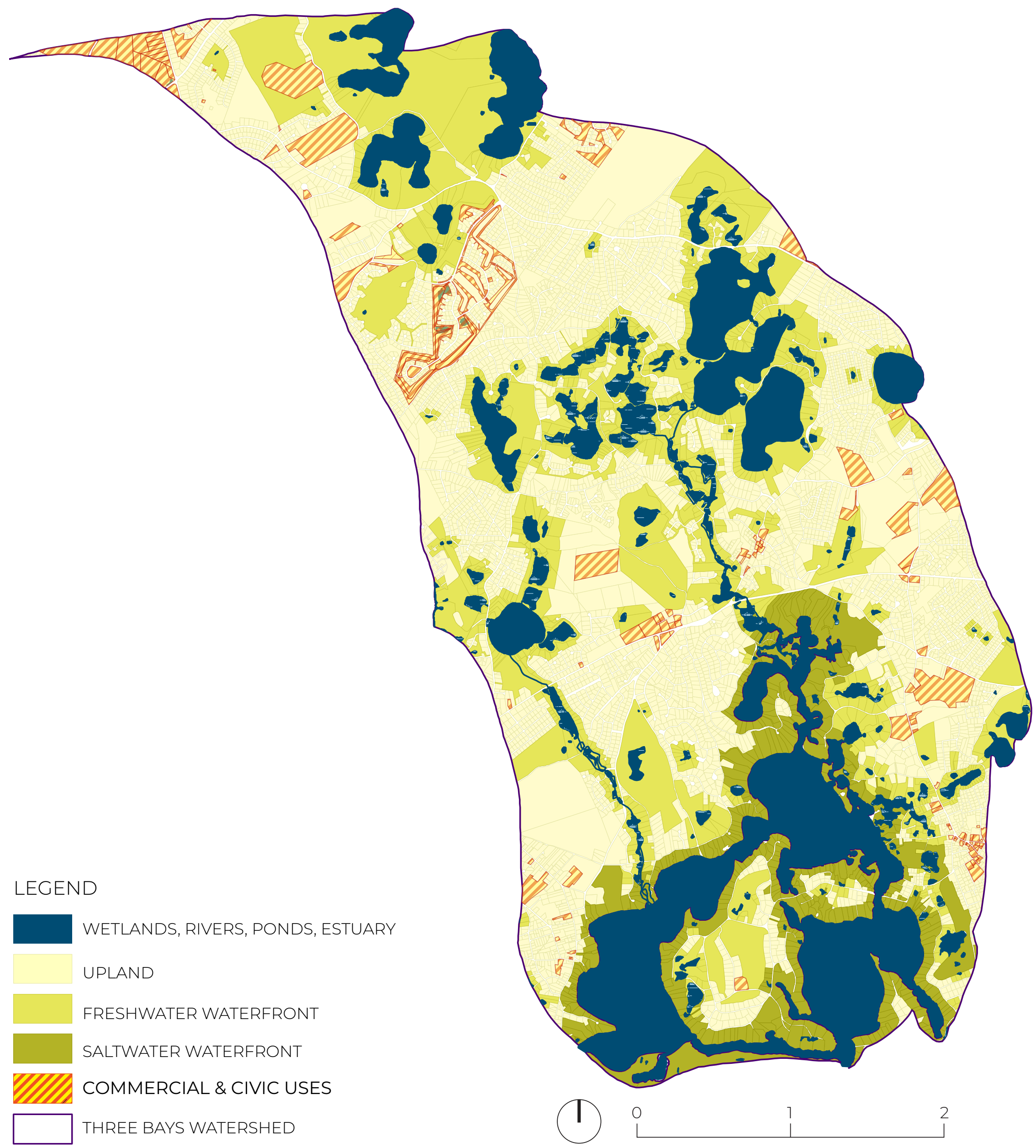


Figure 18. Three Districts Map of the Three Bays Watershed. Data source: MassGIS.

DISTRICT	# PARCELS	% OF WATERSHED	# ACRES	% OF WATERSHED	AVER. ACRES/ PARCEL	LAWN ACRES (% OF DISTRICT)	SHRUB ACRES (% OF DISTRICT)	CANOPY ACRES (% OF DISTRICT)	WETLANDS ACRES (% OF DISTRICT)	IMPERVIOUS ACRES (% OF DISTRICT)
SALTWATER	483	6%	1,457	14%	3	125 (9%)	41 (3%)	763 (52%)	345 (24%)	116 (8%)
FRESHWATER	1,131	14%	3,651	35%	3.2	276 (8%)	52 (1%)	2,467 (70%)	446 (13%)	243 (7%)
UPLAND	6,226	79%	5,742	50%	0.9	1,038 (17%)	231 (3%)	4,791 (65%)	N.A.	1,262 (17%)
	7,840*	100%	10,850	100%		1,439 (12%)	324 (3%)	8,021 (65%)	791	1,621 (13%)

Table 4. Three Districts Vegetative Land Cover Analysis.
*Subset of parcels zoned residential were removed from the total number of parcels (7,840); Open Space (224), non-residential uses (148), providing the current total of residential parcels; 92% of the total parcels in the watershed.

SALTWATER WATERFRONT

Figure 19. Saltwater Waterfront Parcel Map. Data source: MassGIS.

FRESHWATER WATERFRONT

Figure 20. Freshwater Waterfront Parcel Map. Data source: MassGIS.

UPLAND NEIGHBORHOOD

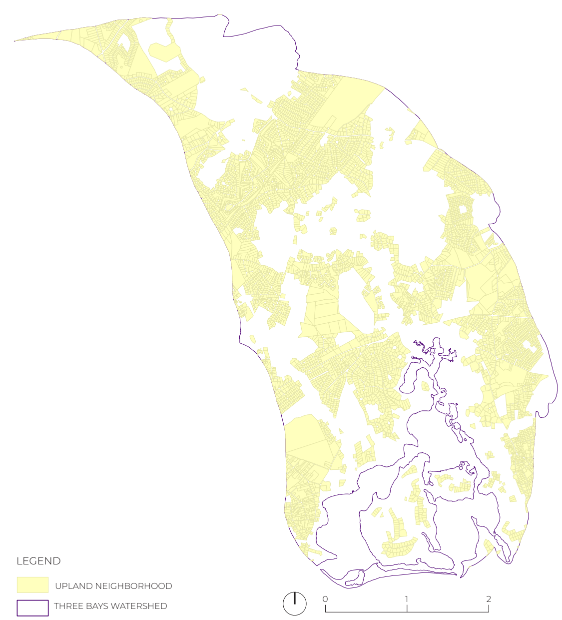
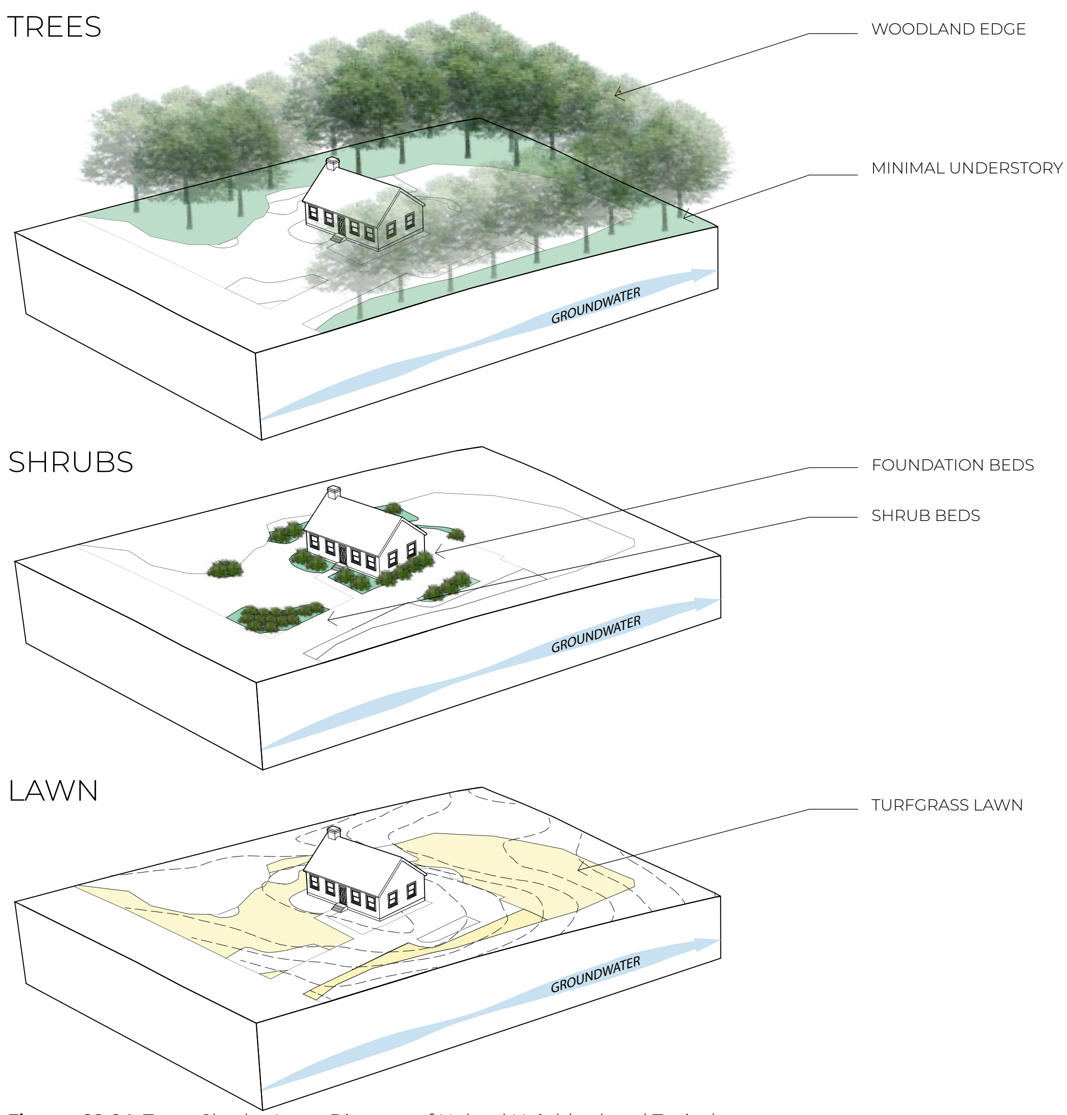


Figure 21. Upland Neighborhood Parcel Map. Data source: MassGIS.

UPLAND NEIGHBORHOOD: TYPICAL

The typical Upland Neighborhood property is framed by canopy trees and woodland along the back and sides. Well manicured turfgrass lawn often creates a buffer between the woodland edge and the foundation plantings of the house. Front yards are well maintained and often contain an island planting bed with trees, shrubs, or perennials, enhanced edges to frame the yard, or threshold plantings at the driveway entrance.

The proposed landscape design provides enhanced functions aimed to reduce Nitrogen and improve water quality. The woodland understory and edge contain a greater diversity of native species in a range of layers. The front yard threshold planting is expanded to connect to the woodland edge and is sunken to create a rain garden to capture and filter run-off through deeply rooted native species. Rain gardens should be located downhill of paved driveways, walks, and roofs to intercept and infiltrate stormwater. Lawn is reduced to provide corridors and a neatly mown edge around beds and the woodland edge. The backyard contains low-maintenance plantings that don't require supplemental fertilizer or regular mowing.



Figures 22-24. Trees, Shrubs, Lawn Diagram of Upland Neighborhood Typical..

UPLAND NEIGHBORHOOD: ECOLOGICAL

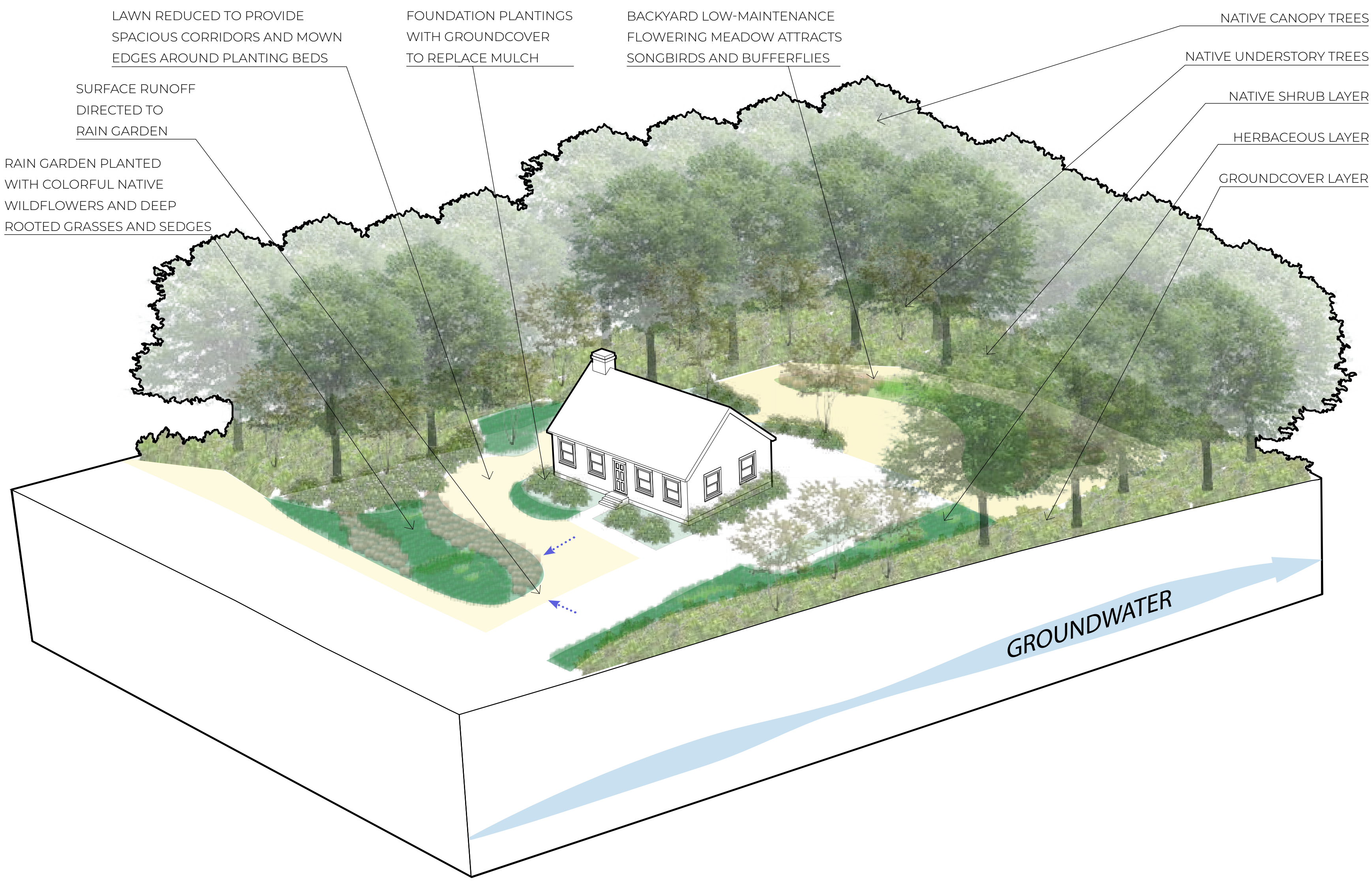


Figure 25. Proposed Conditions Diagram of Upland Neighborhood Parcel.

FRONT YARD: TYPICAL

1. Lawn.

The typical front yard displays a manicured lawn as the dominant form of vegetation.

2. Threshold planting.

Threshold plantings frame the arrival experience. They break up the monotony of a lawn by adding aesthetic complexity and plant diversity. They are often "dressed" in mulch to retain moisture and discourage weeds, and are mounded to promote drainage.

3. Foundation plantings.

Most homes have a range of shrubs or herbaceous perennials surrounding the foundation of the house.

4. Woodland groundcover.

These narrow strips of woodland grove are often managed to remove woody debris and dense vegetation. Minimal groundcover vegetation is present.

5. Understory trees.

Understory trees offer complexity and diversity in the woodland grove.

6. Woodland trees

Most homes were built in former forest. Nearly all homes have woodland bordering the back and side yards.

Figure 26. Front Yard: Typical Perspective of Upland Neighborhood Parcel.

FRONT YARD: ECOLOGICAL

1. Lawn

The lawn is reduced to key locations, as walking corridors and edges to frame more diverse planting beds.

Rain Garden:

The rain garden bed is concave to capture and filter water, rather than shed water. It is expanded from the woodland edge to frame the lawn and home, and to promote greater habitat connectivity. The rain garden includes three types of vegetation to provide a groundcover, structure, and seasonal display.

2. Sedges and rushes:

Rhizominous species that tolerate wet root zones

3. Herbaceous perennials

Seasonal wildflower displays from low-maintenance perennial species.

4. Bunchgrasses and shrubs:

Bunchgrasses provide deep roots that filter nutrients and improve soil stability, and, along with shrubs, provide the structural frame of the rain garden planting design.

Woodland Layers:

Woodland groves that frame the back and side yards are enhanced to provide structure and species diversity to promote woodland health, maximize water quality protection, and enhance wildlife habitat. Healthy woodlands contain five layers of vegetation.

5. Groundcover
6. Herbaceous perennial
7. Shrubs
8. Understory trees
9. Canopy trees

Figure 27. Front Yard: Ecological Perspective of Upland Neighborhood Parcel.

FRONT YARD: TYPICAL

Figure 28. Front Yard: Typical Section of Upland Neighborhood Parcel.

FRONT YARD: ECOLOGICAL

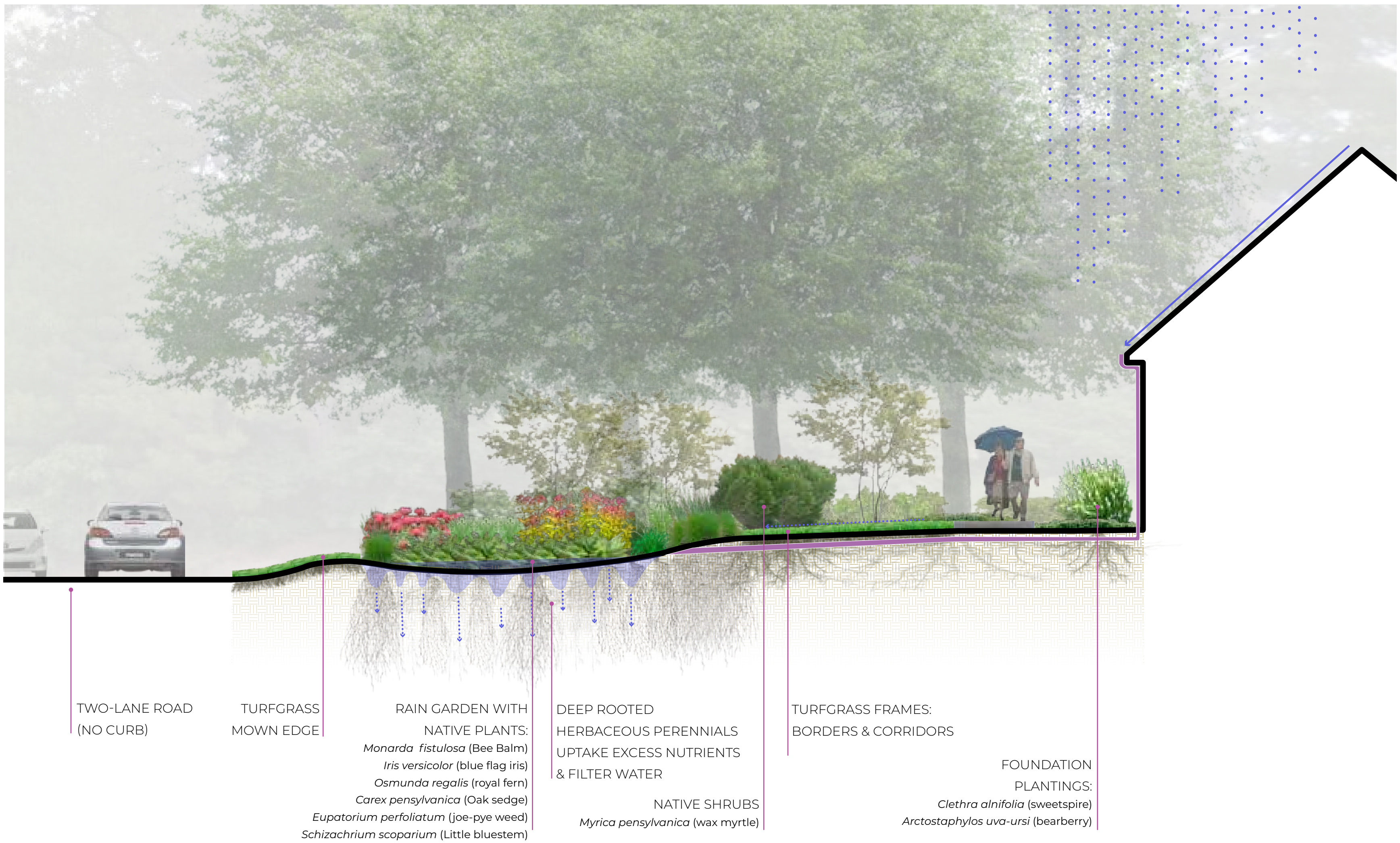


Figure 29. Front Yard: Ecological Section of Upland Neighborhood Parcel.

MEADOW: TYPICAL

Figure 30. Section of Typical Condition of Meadow Backyard.

MEADOW: ECOLOGICAL

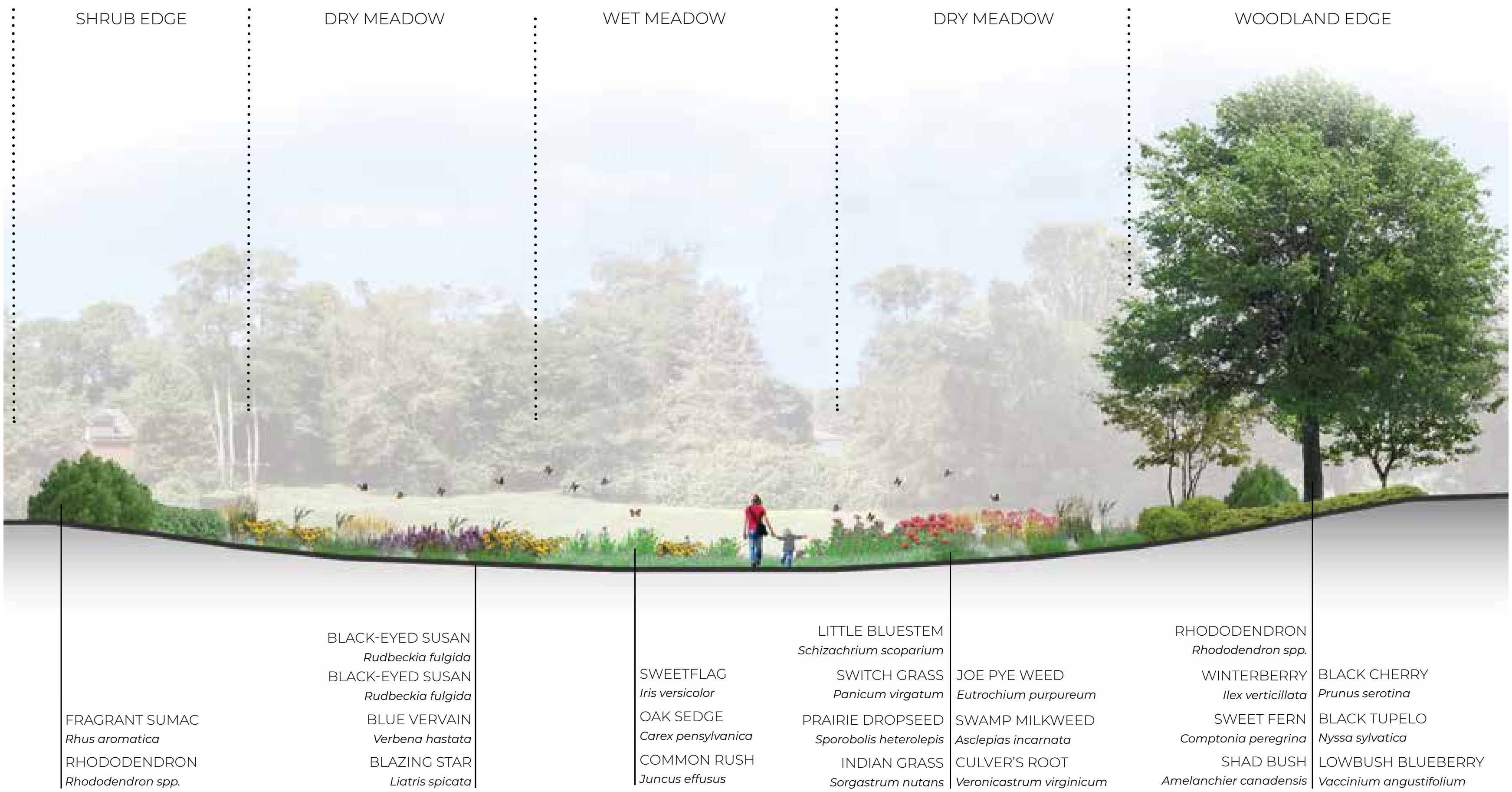


Figure 31. Section of Proposed Ecological Condition of Meadow Backyard.

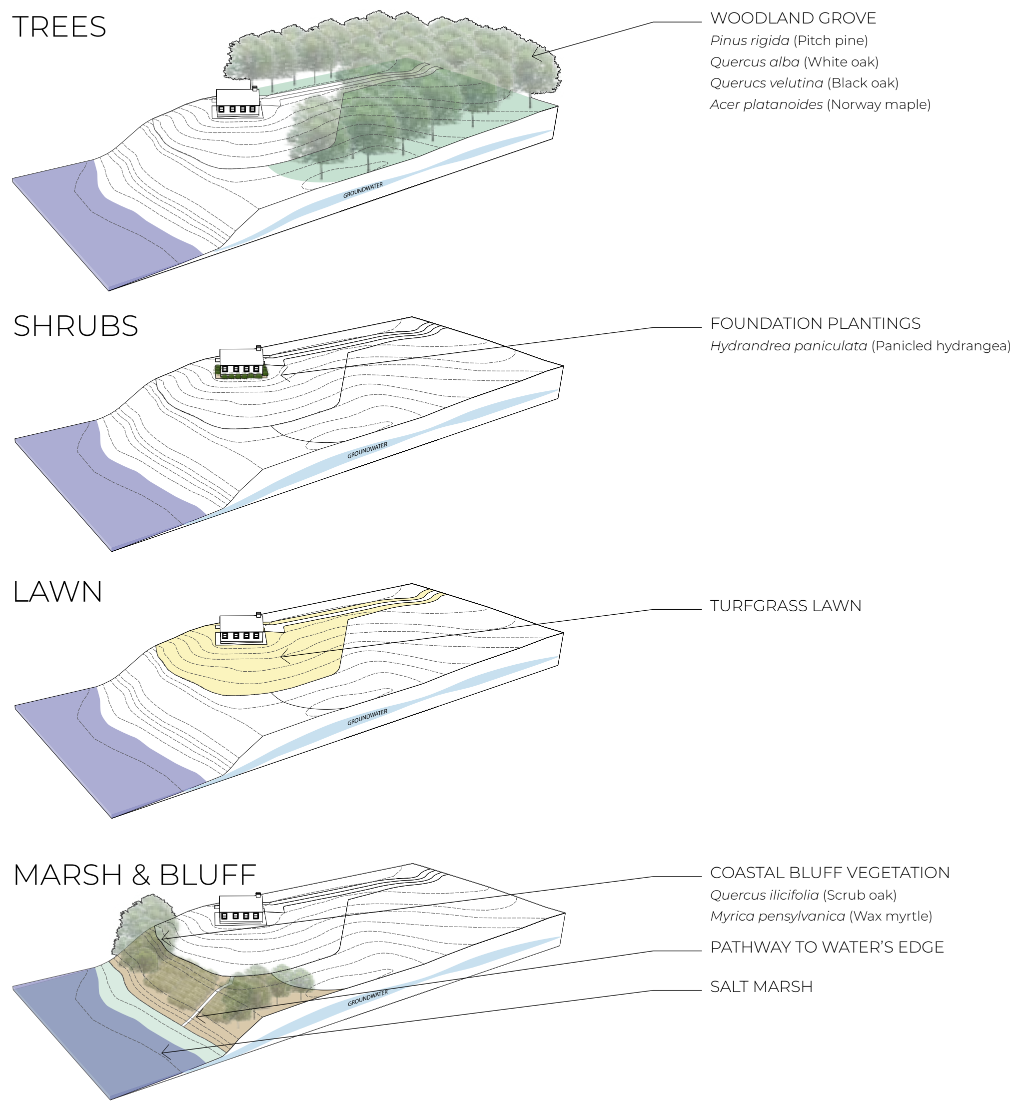
SALTWATER WATERFRONT: TYPICAL

Saltwater waterfront parcels are adjacent to the Three Bays, North, Cotuit, and West Bay, as well as, Prince and Higgin's Cove. Parcels in this district range in scale from approximately 1-20+ acres, with the average parcel at 3 acres.

The predominant shoreline conditions include salt marsh and coastal bluff, though salt marsh is the most common shoreline edge and vegetation. Landscapes within the 100 foot buffer typically include low vegetation to maximize the views and lawn up to the edge of the salt marsh.

On coastal bluffs, steep banks with "plants" that aren't maintained and let to be wild, often contain non-native invasive species hindering the ability of native vegetation to naturally re-establish.

These properties have the opportunity to enhance the salt marsh, improve the stability of steep slopes, and enhance the buffer width by developing aesthetically inspiring gardens that are part of the local flora to develop a sense of place and increase connectivity to other small patch habitats.



Figures 32-35. Trees, Shrubs, Lawn, Bluff Diagrams of Typical Saltwater Waterfront Parcel.

SALTWATER WATERFRONT: ECOLOGICAL

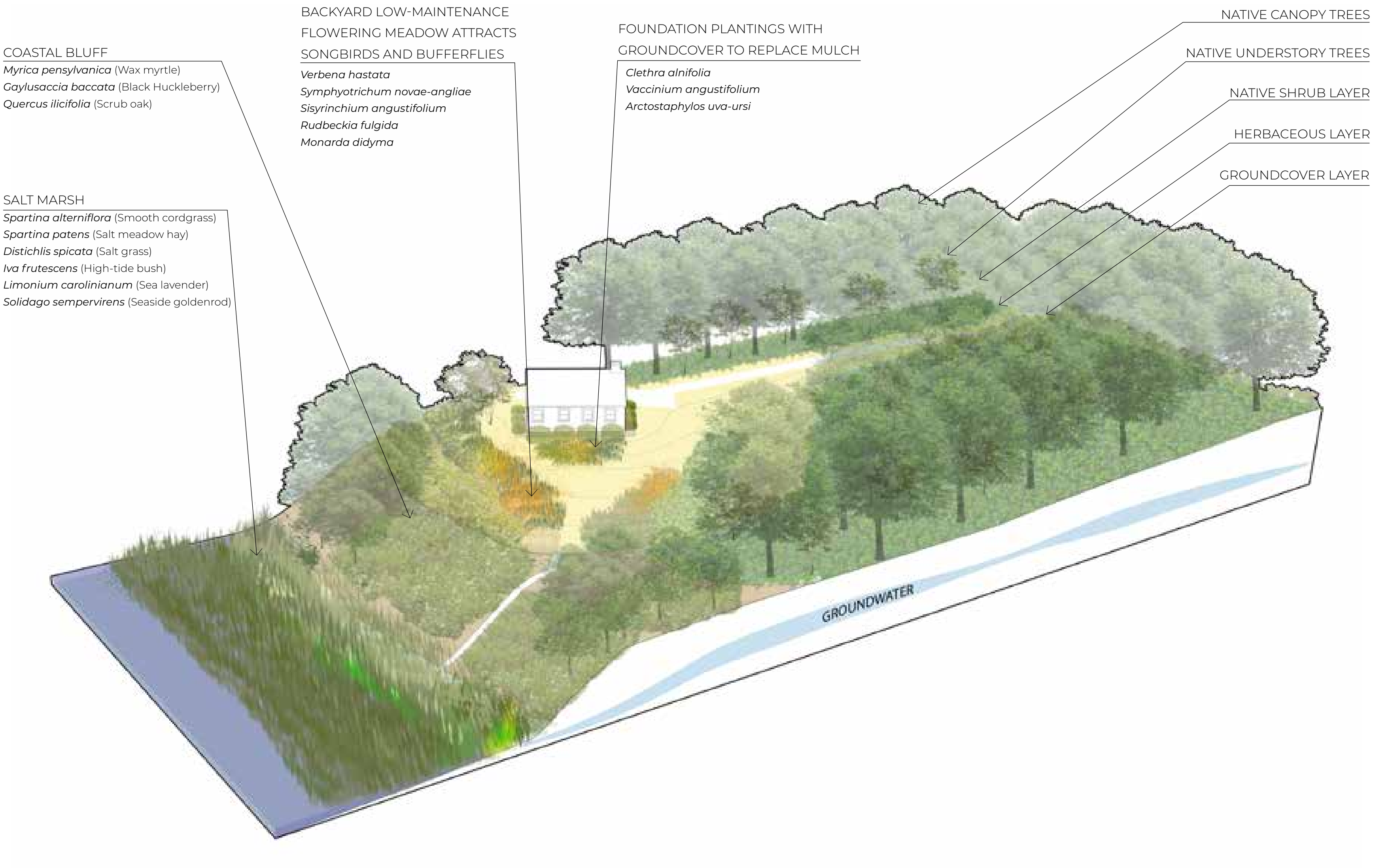
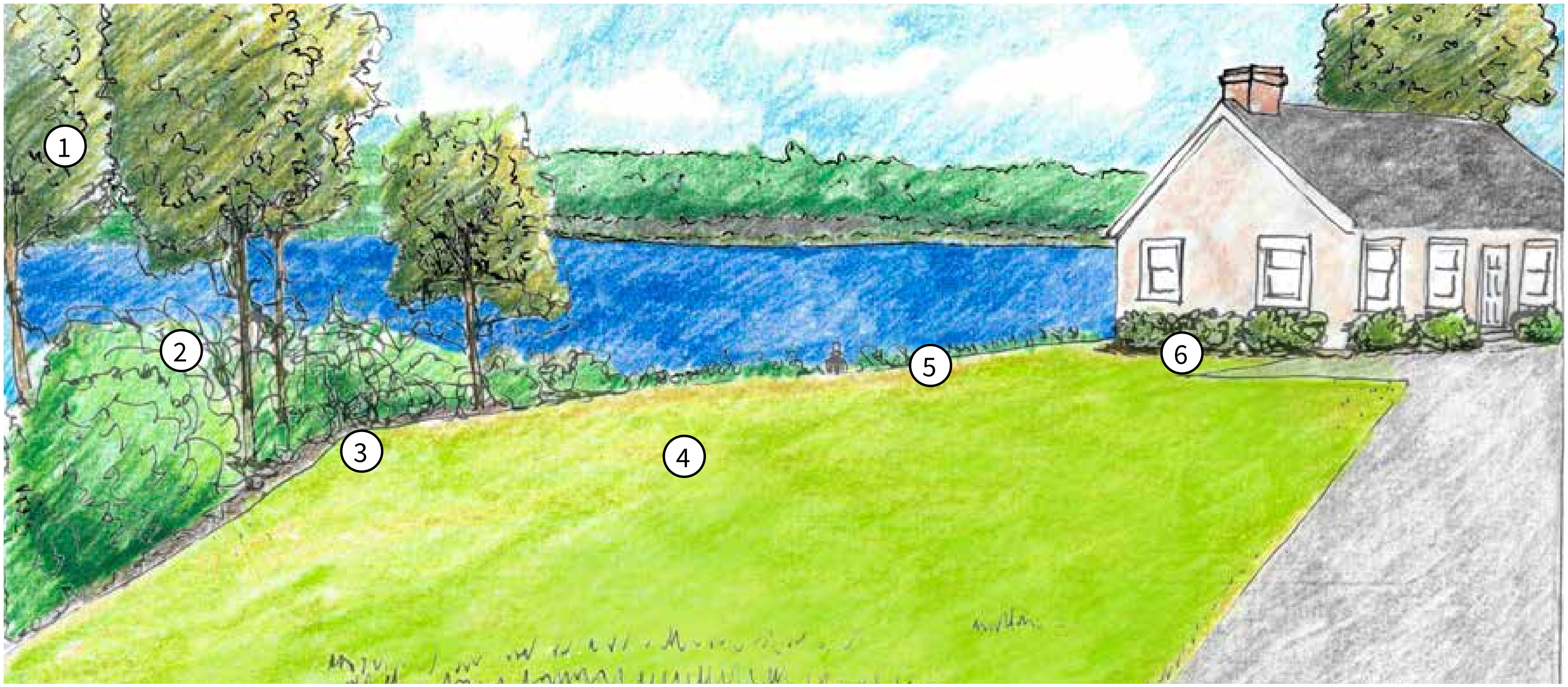


Figure 36. Proposed Ecological Diagram of Typical Saltwater Waterfront Parcel.

SALTWATER WATERFRONT: TYPICAL



1. Woodland trees

Most homes were built in former forest. Nearly all homes have woodland bordering the back and side yards. Maritime forest frames the property with trees removed along the bluff to enhance views of the bay.

2. Invasive species dominate understory

Highly fragmented forests create opportunities for invasive species to establish in newly created openings, crowding out other native understory species.

3. Lawn-woodland edge ecotone

Woodland edge ecotones are transition zones between habitat types and contain high levels of species diversity. The lawn-woodland edge, with limited diversity in understory vegetation, provides opportunities for invasive species like oriental bittersweet (*Celastrus orbiculatus*) to get established.

4. Lawn

The typical front yard displays a manicured lawn as the dominant form of vegetation.

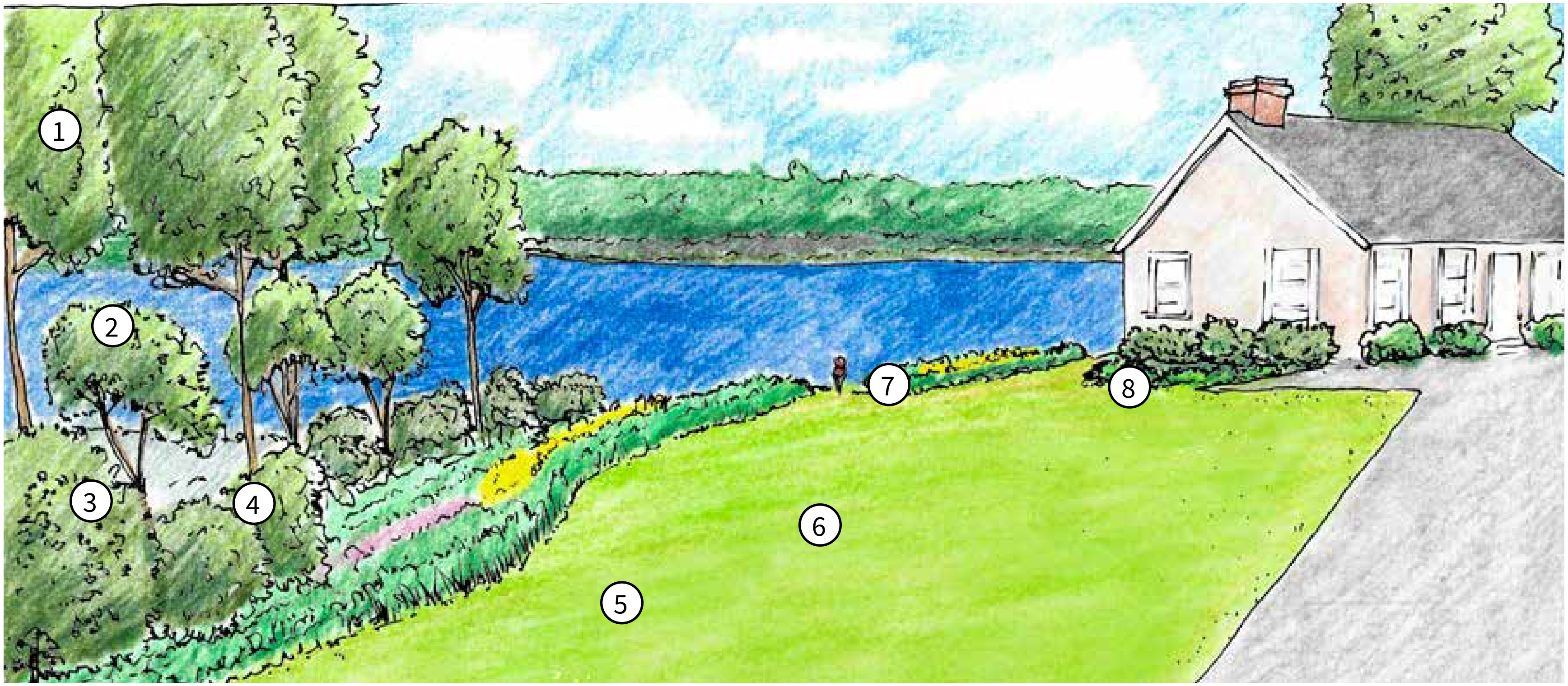
5. Bluff edge

Lawn is maintained directly to the bluff edge, but provides limited buffering ability to capture run-off and prevent erosion at the crest of the bluff's steep slopes.

6. Foundation plantings

Most homes have a range of shrubs or herbaceous perennials surrounding the foundation of the house.

Figure 37. Perspective of Typical Saltwater Waterfront Parcel.



Woodland layers

Invasive species are removed and replaced with a range of understory species. The maritime forest edge is softened and extended out from the canopy with a diversity of layered species to increase buffering capacity, enhance biodiversity, improve legibility of the woodland, and create an attractive edge of seasonal flowers.

1. Canopy trees
2. Understory trees
3. Shrubs
4. Herbaceous perennials
5. Groundcover
6. Lawn

Lawn area is reduced to create planting beds that improve the woodland edge, protect the bluff edge, enhance foundation plantings. Primary functions to provide corridors and neat edge frames to other beds are maintained. Best management practices in lawn care are applied to maintain lawn health while minimizing use of fertilizers and other lawn chemicals.

7. Bluff edge

Lawn is reduced at the bluff edge and replaced with shrubs, bunchgrasses and herbaceous perennials that provide deeper roots to increase bank stability and enhances species diversity.

8. Foundation plantings

Foundation planting beds are enhanced with a diversity of herbaceous perennials to provide colorful flowers throughout the season. Groundcovers are used to replace mulch.

Figure 38. Perspective of Proposed Ecological Saltwater Waterfront Parcel.

SALTWATER WATERFRONT: TYPICAL

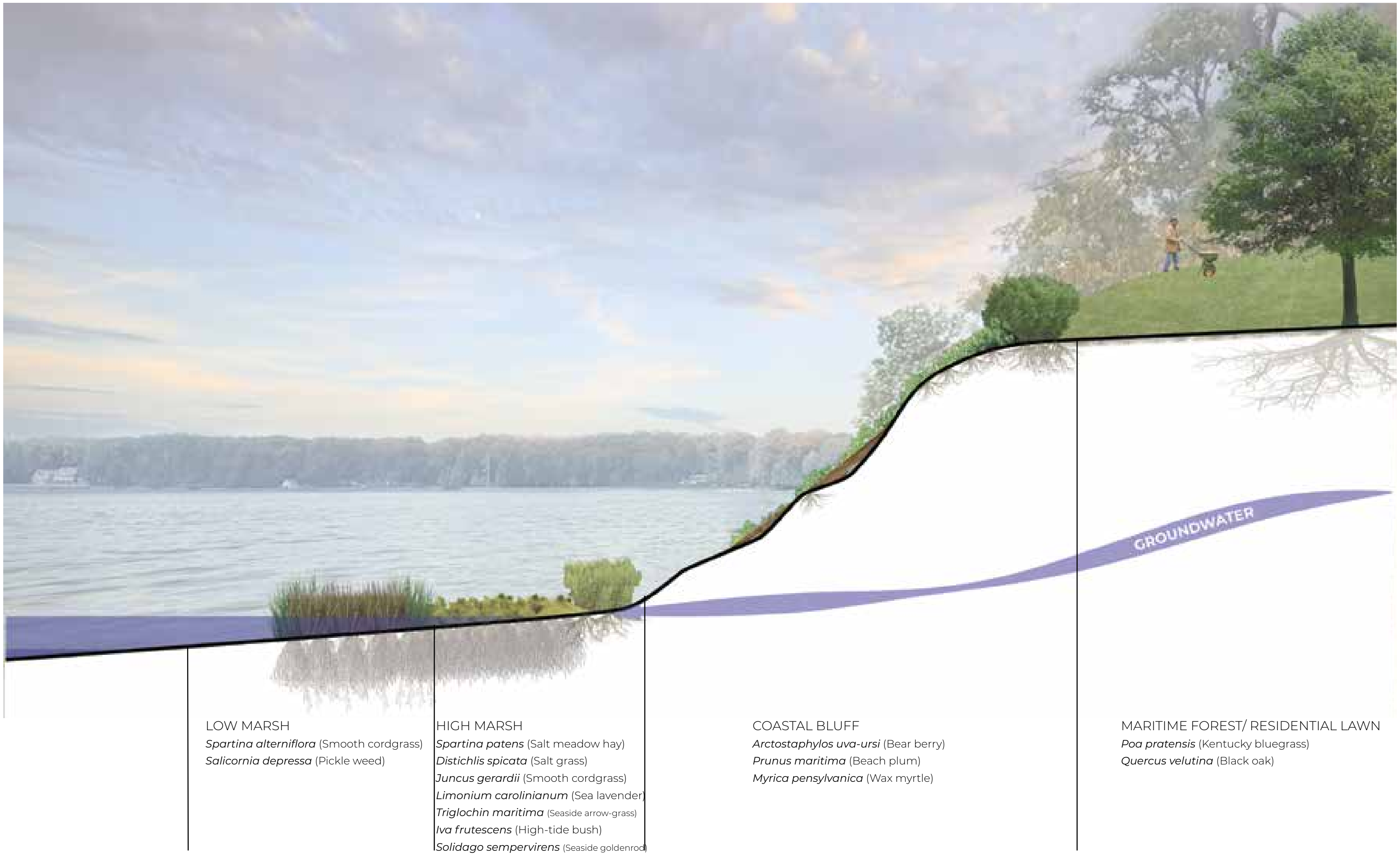


Figure 39. Section of Typical Saltwater Waterfront Parcel.

SALTWATER WATERFRONT: ECOLOGICAL

LOW MARSH
Spartina alterniflora (Smooth cordgrass)
Salicornia depressa (Glass wort)

HIGH MARSH
Spartina patens (Salt meadow hay)
Distichlis spicata (Salt grass)
Juncus gerardii (Black needle rush)
Limonium carolinianum (Sea lavender)
Triglochin maritima (Seaside arrow grass)
Solidago sempervirens (Seaside goldenrod)
Baccharis halimifolia (Groundseltree)

COASTAL BLUFF
Arctostaphylos uva-ursi (Bear berry)
Comptonia peregrina (Sweet fern)
Juniperus horizontalis (Creeping juniper)
Prunus maritima (Beach plum)
Myrica pensylvanica (Wax myrtle)

MARITIME FOREST/ RESIDENTIAL LAWN
Quercus velutina (Black oak)
Celtis occidentalis (Common hackberry)
Amelanchier canadensis (Service berry)
Schizachrium scoparium (Little bluestem)
Andropogon gerardii (Big bluestem)
Gaylusaccia baccata (Black huckleberry)
Poa pratensis (Kentucky bluegrass)

Figure 40. Section of Proposed Ecological Saltwater Waterfront Parcel.

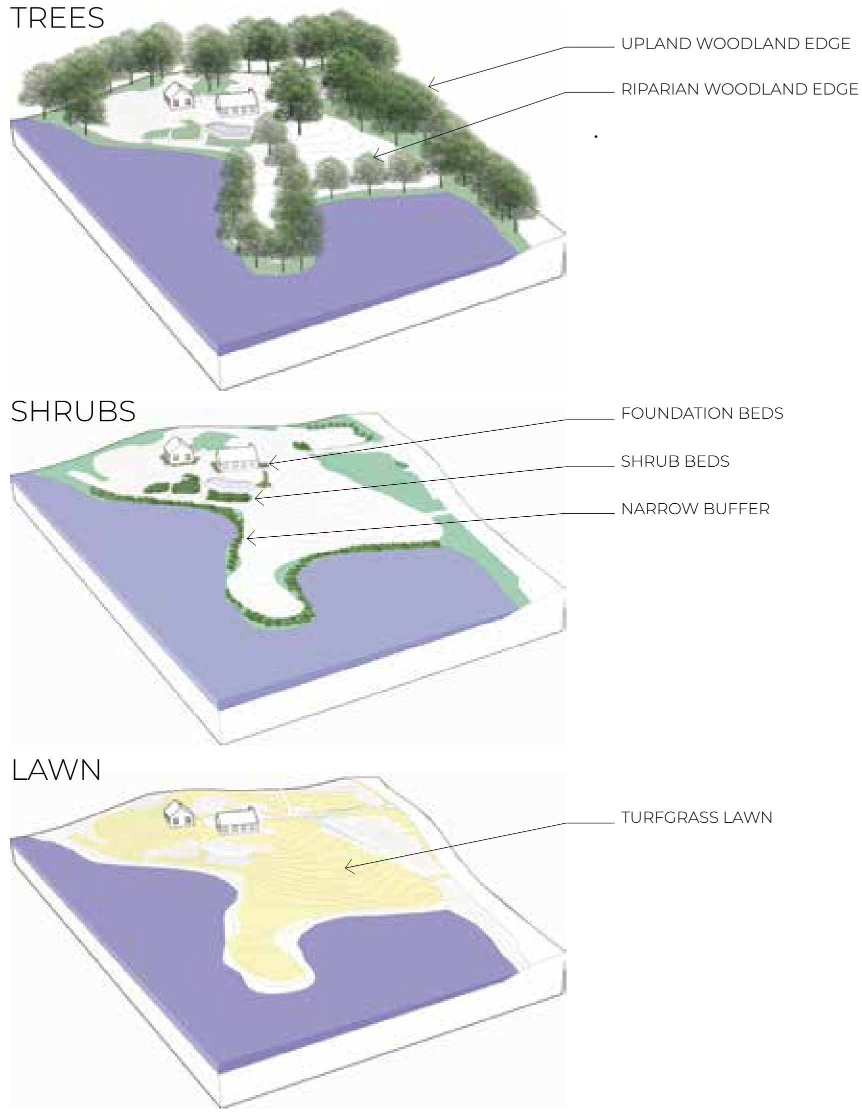
FRESHWATER WATERFRONT: TYPICAL

The Freshwater Waterfront District includes the largest area of waterfront edge connectivity of the three districts. The range of edge conditions includes wet meadow, pond shoreline, and the river's edge.

Riparian and pond edges are commonly compromised to enhance access to the water and maximize views. Invasive species are common in these landscapes that have been heavily impacted by development over time, yet neglected to remain "wild". These species inhibit other native species from re-establishing.

Replacing lawn within 10 feet in elevation provides an opportunity to plant deep-rooting native herbaceous perennials that can intercept and remove excess nitrogen in the groundwater as it is daylighting from the water table into the surface waters.

Lawn area can be reduced to provide neat, maintained edges to frame looser, more messy native garden beds. Lawn can also be directed to be more explicitly used as corridor to visit the new garden areas in the landscape.



Figures 41-43. Trees, Shrubs, Lawn Diagram of Typical Freshwater Waterfront Parcel.

FRESHWATER WATERFRONT: ECOLOGICAL

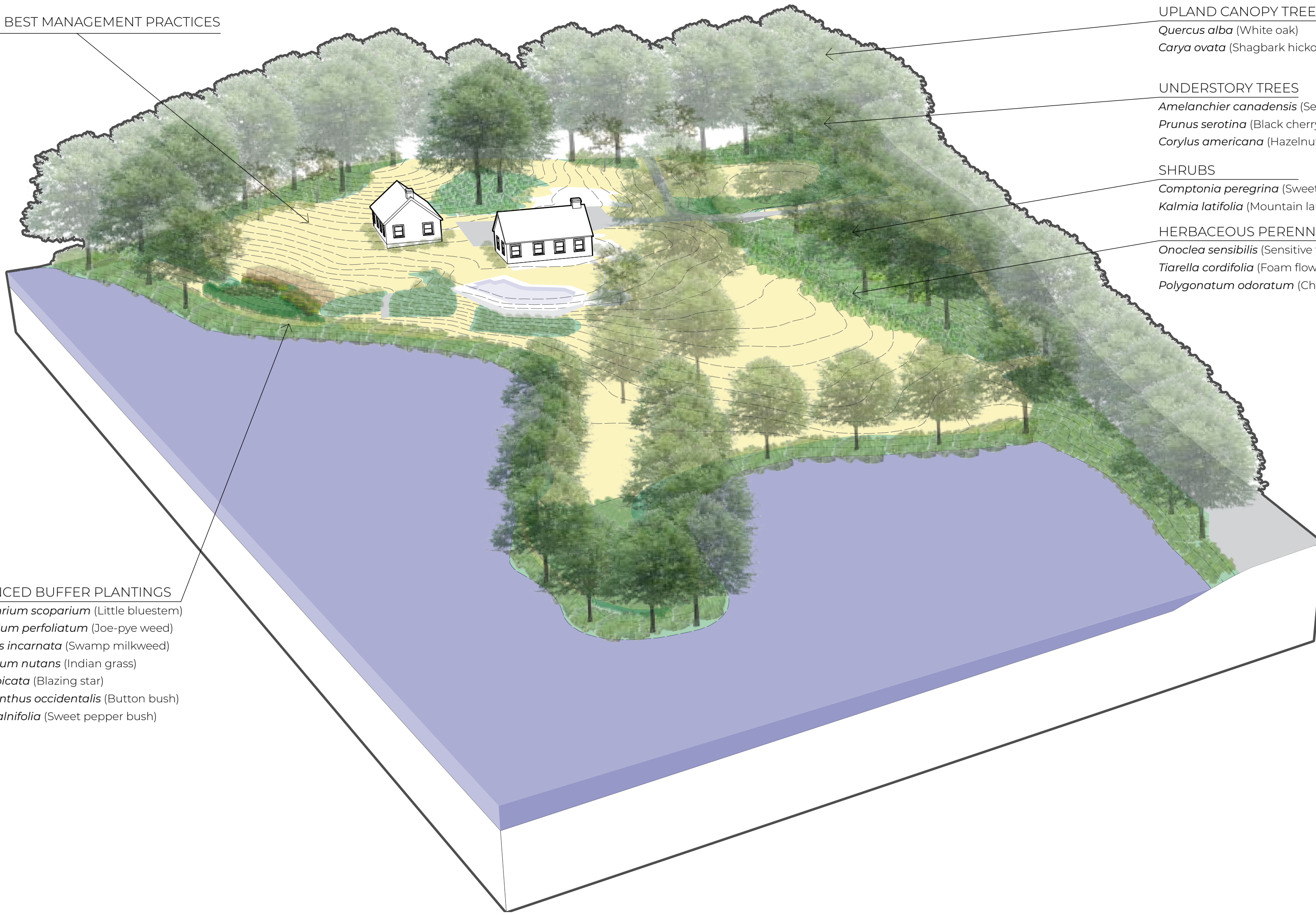
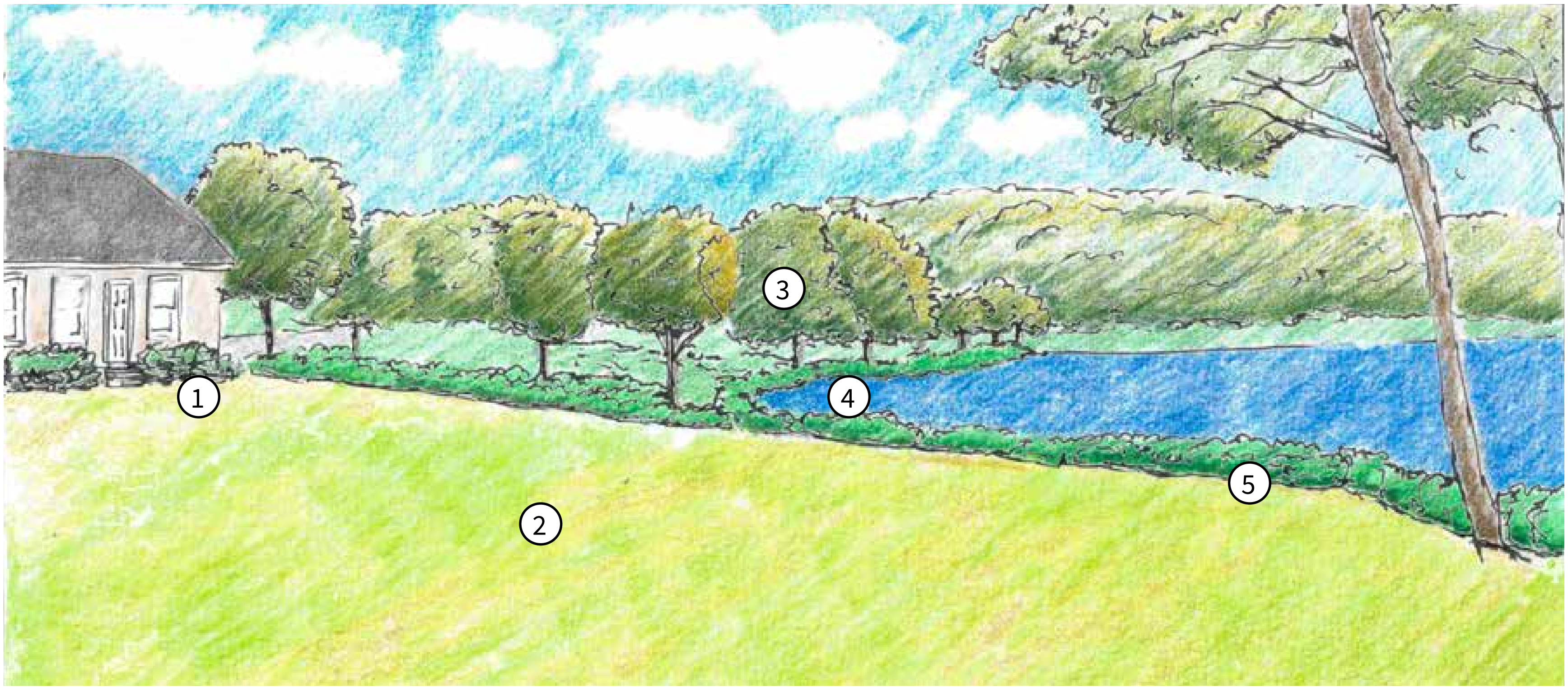


Figure 44. Proposed Ecological Diagram of Freshwater Waterfront Parcel.

FRESHWATER WATERFRONT: TYPICAL



1. Foundation plantings

Most homes have a range of shrubs or herbaceous perennials surrounding the foundation of the house.

2. Lawn

The typical yards of homes adjacent to ponds and rivers display a manicured lawn as the dominant form of vegetation.

3. Riparian trees

Most homes were built in former forest. Nearly all homes within the waterfront buffer have a range of widths of canopy coverage buffering the water's edge and variations of woodland bordering the back and side yards. In many cases, canopy trees are reduced or removed to enhance visual access to the water.

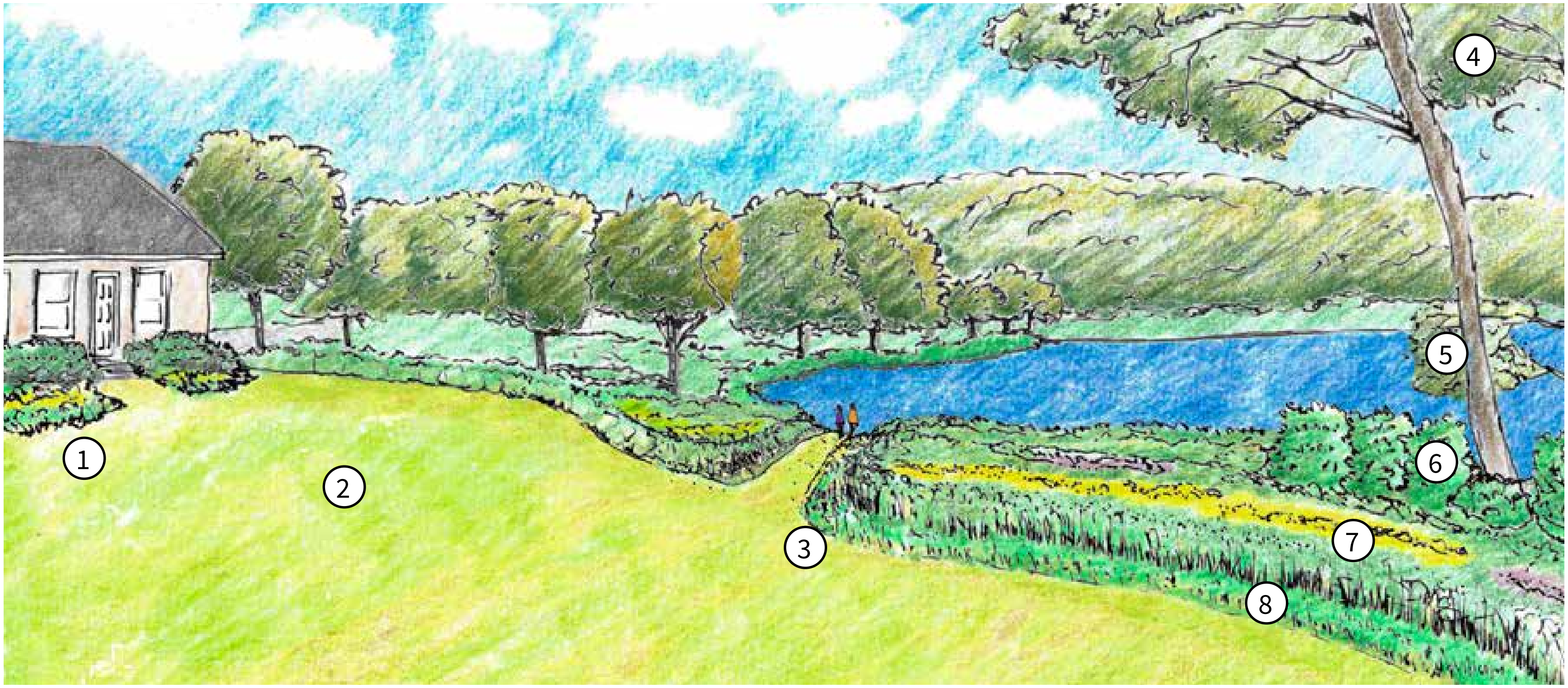
4. Invasive species dominate understory

As a area of transition, fragmented riparian buffers and pond edges are prone to invasive species establishment. These species crowd out a range of native species that are part of riparian habitats and provide higher levels of buffering capacity.

5. Narrow riparian buffer

Lawn is maintained close to the water's edge and there is a limited buffer width and limited species diversity. Shallow rooted lawn and a narrow buffer provide limited buffering capacity to uptake excess nitrogen at the groundwater - surface water interface.

Figure 45. Perspective of Typical Freshwater Waterfront Parcel.



1. Foundation plantings

Foundation planting beds are enhanced with a diversity of herbaceous perennials to provide colorful flowers throughout the season. Groundcovers are used to replace mulch.

2. Lawn

Lawn area is reduced to create planting beds that improve and widen the riparian edge and enhance foundation plantings. Primary functions to provide corridors and neat edge frames to other beds are maintained. Best management practices in lawn care are applied to maintain lawn health while minimizing use of fertilizers and other lawn chemicals.

3. Buffered edge with "Chelsea chop"

Lawn is reduced at the riparian edge and replaced with a vegetative buffer containing shrubs, bunchgrasses and herbaceous perennials that provide deeper roots to increase nitrogen absorption, maintain bank stability, as well as, enhance species diversity for floral displays and wildlife habitat. The herbaceous edge is mowed to create a widened, neater edge between lawn and buffer.

Riparian woodland layers

Invasive species are removed and replaced with a range of understory species. The riparian forest edge is softened and extended out from the canopy with a diversity of layered species to increase buffering capacity, enhance biodiversity, improve legibility of the woodland, and create an attractive edge of seasonal flowers and foliage.

4. Canopy trees
5. Understory trees
6. Shrubs
7. Herbaceous perennials
8. Groundcover

Figure 46. Perspective of Proposed Ecological Freshwater Waterfront Parcel.

RIPARIAN EDGE: TYPICAL

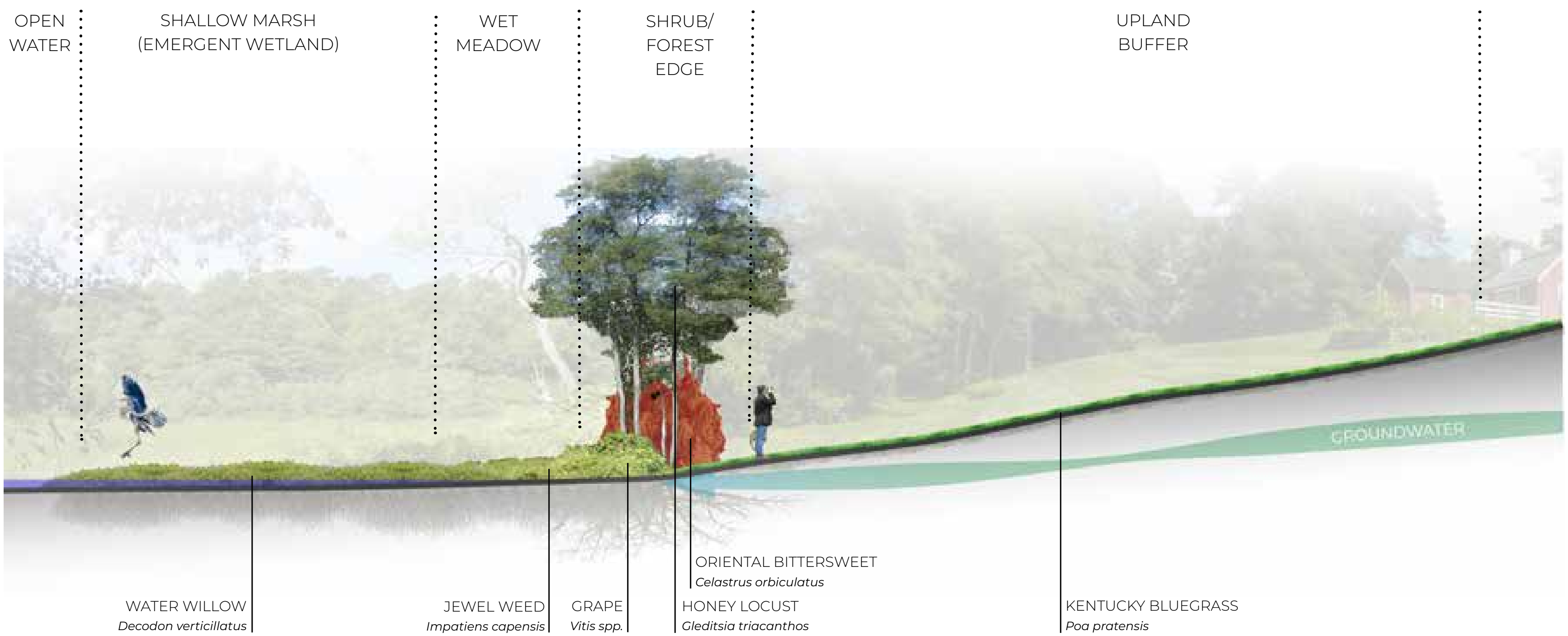


Figure 47. Section of Riparian Edge Typical Freshwater Waterfront Parcel.

RIPARIAN EDGE: ECOLOGICAL

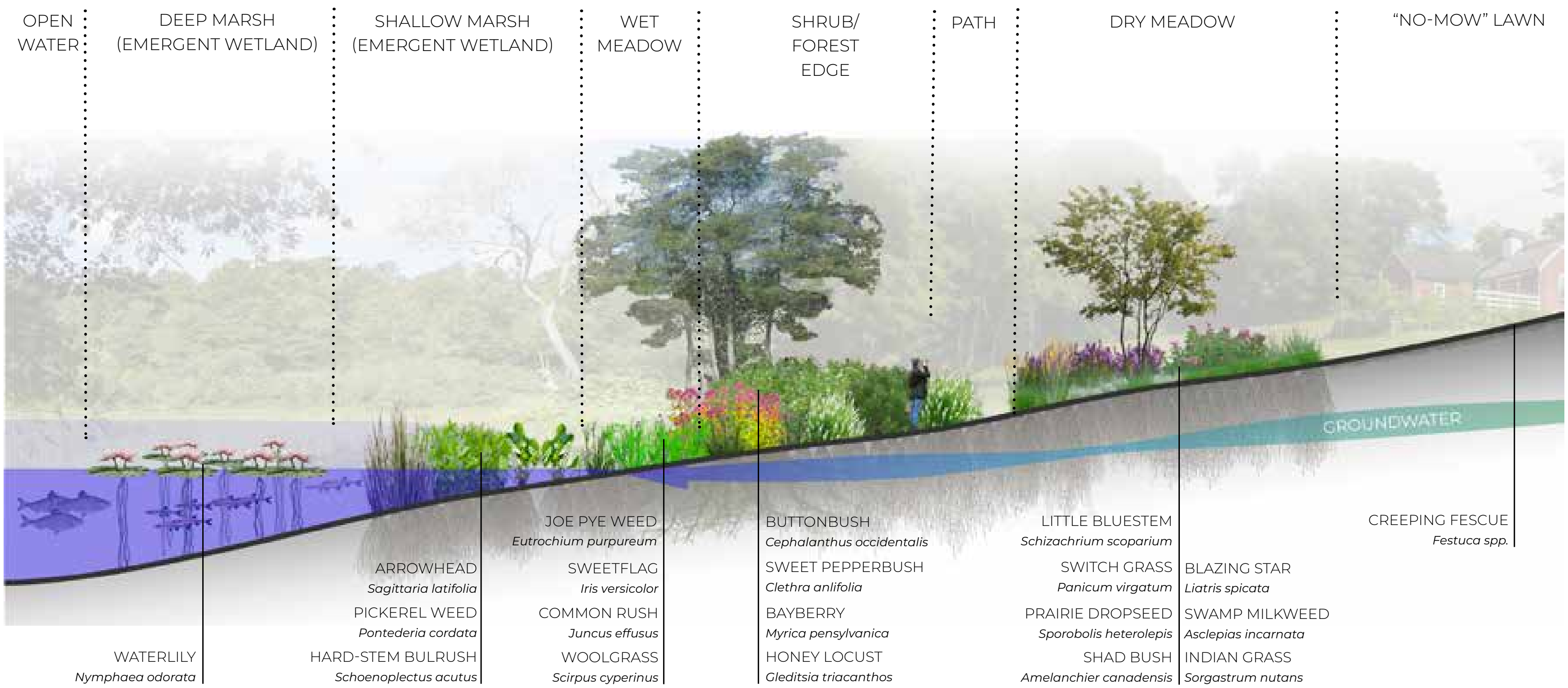


Figure 48. Section of Riparian Edge Proposed Ecological Freshwater Waterfront Parcel.

WOODLAND SWALE: TYPICAL

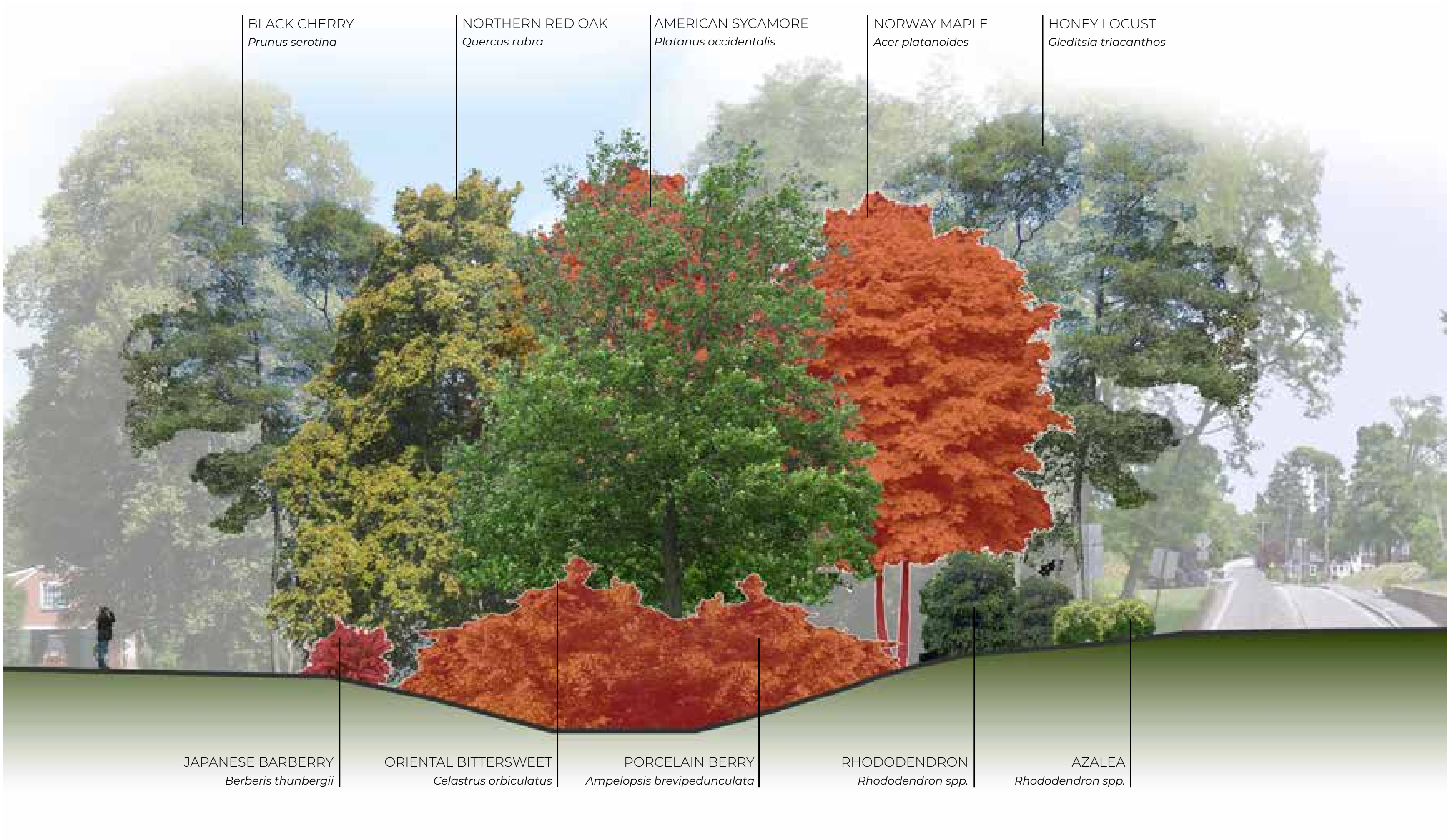


Figure 49. Section of Woodland Swale Typical Freshwater Waterfront Parcel.

WOODLAND SWALE: ECOLOGICAL

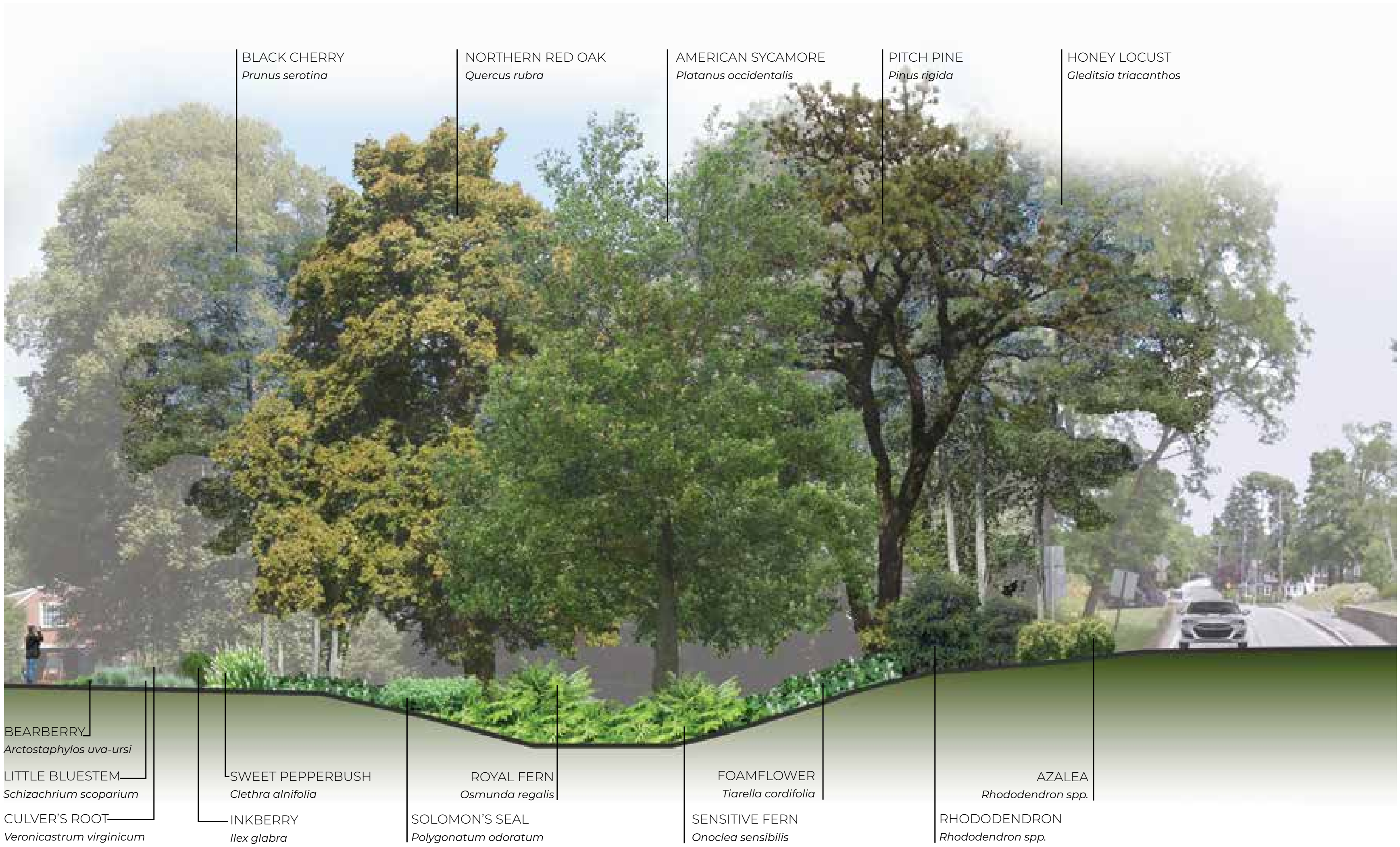


Figure 50. Section of Woodland Swale Proposed Ecological Freshwater Waterfront Parcel.

SUMMARY

The three districts parcel typologies provide a landscape-based approach to conceptualize the use of native plant communities and ecologically-oriented landscape elements to improve water quality. Three distinct districts were identified, Saltwater Waterfront, Freshwater Waterfront, and Upland Neighborhood based on a parcels' proximity to a 100-foot buffer created around all surface waters and wetlands.

A typical conditions parcel was developed for each district to describe typical vegetation coverage, land form, parcel size, setback, and shoreline conditions to the water for two districts. These conditions were identified from GIS data and on-the-ground observations of landscape conditions throughout the watershed.

Proposed parcels integrate ecologically-oriented landscape elements into existing conditions for each of the three typical parcels. These landscape elements are tactics within the strategy of using residential landscapes to improve water quality. Each of the elements presented incorporates native plant communities into garden elements within each parcel following garden design vernacular of the Cape Cod region in combination with elements of 'cues to care' from Joan Nassauer's research described in Table 2, Chapter 2 (Nassauer, 1995).

Typical existing conditions and proposed ecological landscapes are illustrated for representative properties in each district through section, perspective, and 3D model.

The proposed conditions demonstrate core landscape elements of rain gardens, bioswales, woodland edge and understory, riparian edge, coastal salt marsh, and coastal bluff conditions. These elements and landscape zones play a critical role in improving water quality within the Three Bays watershed.

6. Recommendations

The Three Bays watershed, along with other watersheds throughout Cape Cod, is facing a water quality problem from excess nitrogen. The three main sources of attenuated nitrogen are from septic systems, fertilizer applications, and stormwater run-off. This report focuses the use of residential landscapes as a strategy to improve water quality and enhance biodiversity mainly by reducing fertilizer and reducing stormwater.

Landscape-level strategies that address water quality improvement integrate four core tactics to achieve success. First, landscape-level interventions are multi-scalar, from residential sites to neighborhood and regional networks, and constitute cost-effective, small-scale changes in the landscape that reduce the need for supplemental fertilizer, water, and synthetic chemicals. Interventions are focused on creating and modifying landscape gardens, replacing maintenance-intensive lawn and areas disturbed by invasive non-native species with native plant community-oriented gardens that are not only lower in maintenance once established, they can capture and filter run-off, increase diversity and habitat connectivity, and deepen a sense of place of the authentic Cape Cod landscape. The critical landscape zones are riparian and estuarine waterfront buffers, woodland understory and edges, and expansive lawns.

Second, landscapes are visible interventions throughout the community. Landscape gardens have the power to evoke and inspire. As many authors have expressed (Kaplan, 2004; Larson, 2016; Nassauer, 1995; Peterson, 2012; Pollan, 1991; Ryan, 2010; Steinberg, 2006), residential landscape design and maintenance practices are largely driven by cultural norms that promote turfgrass as the dominant spatial feature to design around and other factors such as cues to care and neighbors' perceptions that drive values toward neatness and fitting in to cultural normatives over environmental and economic factors such as prioritizing the use of ecosystem services, protecting water quality, and enhancing biodiversity.

As visual elements, aesthetically pleasing landscapes that promote native flora and water quality demonstrate alternative options and increase awareness of garden designs that perform ecologically as well as aesthetically.

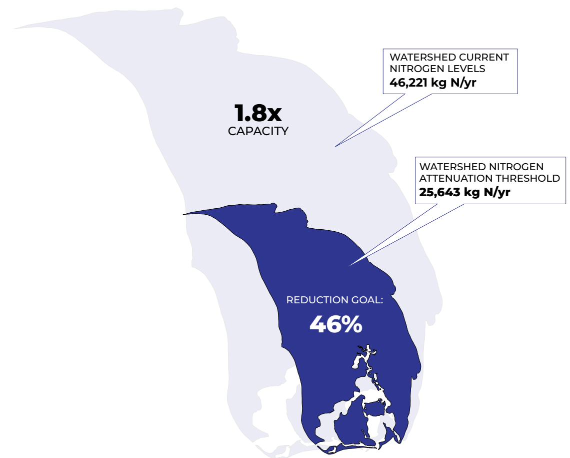


Figure 51. Total Attenuated Nitrogen Load Diagram.

TOTAL ATTENUATED WATERSHED NITROGEN LOAD VALUES (FROM WMVP)*

Three Bays Nitrogen Sources	Total Attenuated Watershed Nitrogen Load (kg-N/yr)
Wastewater[1]	34,376
Fertilizer[2]	5,070
Stormwater	4,361
Other[3]	2,414
Total Watershed Load	46,221
Total Watershed Threshold	25,643
TOTAL ATTENUATED LOAD TO BE REMOVED	**20,578**

1. Includes nitrogen loads from septic systems and wastewater tretment facilities

2. Includes nitrogen loads from septic systems and wastewater treatment facilities

3. Includes nitrogen loads from landfills and atmospheric deposition to vacant land.

Table 5. Total Attenuated Nitrogen Load Values. (Cape Cod Commission, 2017)

Broader awareness and receptivity to other practices can shift cultural landscape norms, values, and practices.

Third, landscape interventions have a short return on their investment. Once established, rain gardens and riparian buffer plantings make a measurable impact on nitrogen reductions and water quality improvement.

Lastly, it is increasingly recognized that today's landscapes are largely managed and need to perform aesthetically, culturally, and ecologically (Meyer, 2008; Nassauer, 1997; Rainer and West, 2015; Tallamy 2007; Weaner, 2016). Contemporary managed landscapes can integrate native plant communities that have evolved with the ecosystems of the Cape and do not require supplemental fertilizer and water to thrive. Thoughtful, ecological design practices can develop gardens that are aesthetically pleasing, conform to cultural values of maintenance and care, though require less maintenance and act as a network of garden infrastructure to improve water quality.

The following recommendations are developed from literature research, GIS mapping analyses, a case study in the Ipswich River watershed, and relevant areas of study this report was not able to address.

1. REDUCED LAWN = REDUCED FERTILIZER

The Three Bays watershed currently contains 1,439 acres of lawn; 13% of the terrestrial landscape is dominated by introduced turfgrasses.

In 2014, a Cape Cod-wide survey of fertilizer and pesticide use was conducted and found that approximately 70% of fertilizer applications occur on residential properties (Horsley Witten Group, 2014). Cape-wide, 57% of homeowners applied fertilizers to their lawns, either themselves, or by landscape professionals. Further, the average rate of fertilizer applied by homeowners was 49 lbs. per property per year assuming an average lawn of 5,000 square feet. Scott's was the most listed brand of fertilizer reported in the survey and the authors found that the average application rate reported by respondents correlates to Scott's brand fertilizer recommended application rates of 50 lbs/5,000 square feet of lawn. The study investigated a range of different fertilizers and found, on average, that fertilizers contain 25% nitrogen per lb of fertilizer. Lastly, Horsley-Witten's research on leach rates corresponds to the MEP model which assumed a 20% leach rate of applied nitrogen.

CAPE COD FERTILIZER APPLICATIONS

- Total fertilizer used on residential properties: 3.6 million lbs/ year.
- 70% of all fertilizer applications are used on residential properties.
- 57% of residents apply fertilizers annually on their lawns.
- 49 lbs of fertilizer per property per year; on average.
- ~50 lbs of fertilizer/ 5,000 ft^2 of lawn.
- 1 lb of fertilizer = 0.25 lb of nitrogen.
- 20% of applied nitrogen leaches into groundwater.

Table 6. Cape-wide Fertilizer Study Highlights. (Horsley-Witten Group, 2014)

Applying these average, annual rates of fertilizer application to properties in the Three Bays watershed, it is reasonable to estimate that if lawn area was replaced by other vegetation, such as native flora that doesn't require supplemental fertilizer, a reduction in lawn area would translate into a reduction in fertilizer applications, and thus, a reduction in excess nitrogen in the watershed.

The Three Bays watershed is 92% residential, with 7,207 parcels. Assuming the rates of Cape Cod-wide survey correlate to average application rates in the Three Bays watershed,

ESTIMATED NITROGEN REDUCTION FROM PROPOSED CONCEPT DESIGNS BASED ON HOMEOWNER PARTICIPATION AND PERCENT OF LAWN REDUCTION

Watershed District	**# Parcels**	**# Acres**	**Lawn (Acres)**	**Lawn/ Parcel (ft2)**	**Current N Fertilizer (kg-N/yr)**	**Homeowner participation**		**Nitrogen Reduction (kg-N/yr) & % of total N reduced from % Lawn Reduced throughout Three Bays watershed**							
								20% Lawn Reduction		**30% Lawn Reduction**		**40% Lawn Reduction**		**50% Law Reduction**	
						# parcels	**%**	**kg N**	**% N**	**kg N**	**% N**	**kg N**	**% N**	**kg N**	**% N**
Saltwater Waterfront	483	1,457	125	3,737	308	97	**20%**	12	**0.3%**	18	**0.5%**	25	**0.7%**	31	**0.9%**
						193	**40%**	25	**0.7%**	37	**1.0%**	49	**1.4%**	62	**1.7%**
						290	**60%**	37	**1.0%**	55	**1.6%**	74	**2.1%**	92	**2.6%**
Freshwater Waterfront	1,131	3,651	276	3,292	682	226	**20%**	27	**0.8%**	41	**1.2%**	55	**1.5%**	68	**1.9%**
						452	**40%**	55	**1.5%**	82	**2.3%**	109	**3.1%**	136	**3.8%**
						679	**60%**	82	**2.3%**	123	**3.5%**	164	**4.6%**	205	**5.8%**
Upland Neighborhood	6,226	5,742	1,038	7,874	2,560	1,245	**20%**	102	**2.9%**	154	**4.3%**	205	**5.8%**	256	**7.2%**
						2,490	**40%**	205	**5.8%**	307	**8.7%**	410	**11.5%**	512	**14.4%**
						3,736	**60%**	307	**8.7%**	461	**13.0%**	614	**17.3%**	768	**21.6%**
Totals	7,840	10,850	1,439	14,903	3,550	1568	**20%**	142	**4%**	213	**6%**	284	**8%**	355	**10%**
						3136	**40%**	284	**8%**	426	**12%**	568	**16%**	710	**20%**
						4704	**60%**	426	**12%**	639	**18%**	852	**24%**	1065	**30%**

***Total Nitrogen quantified is 70% of Total Attenuated Nitrogen Load (TANL). Percent quantified represents a reduction of TANL toward achieving the threshold.**

Table 7. Assumed reductions in annual nitrogen loads from range of homeowner participation and range in reduction of lawn area

57% of Three Bays residential parcels, or 4,108 parcels, apply fertilizer annually. If each parcel applies an average of 49 lbs of fertilizer per year, this equals 201,292 lbs of fertilizer, and at 25% nitrogen by volume, this equates to 50,323 lbs of nitrogen. A 20% leach rate equals 10,064 lbs of nitrogen annually. This roughly correlates with MEP findings of attenuated nitrogen loads, of 5,070 kg-N/year, which converts to 11,154 lbs-N/year at 2.2lbs /kg. For the purposes of this report, I will continue to use the findings from the Horsley-Witten study to calculate a proposed range of potential nitrogen reductions in the Three Bays watershed through landscape interventions.

The representative typical and proposed parcels from the three districts propose a potential, assumed range of reduction in lawn area. In these conceptual proposals, percentages of lawn area are strategically replanted with regionally appropriate native flora to create a variety of landscape elements that strive to be aesthetically desirable, while accomplishing a number of functions including nitrogen attenuation, run-off catchment and filtration, reducing erosion, increasing biodiversity, connectivity, and wildlife habitat.

Proposed percent estimates were calculated through a range of resident participation, 20%, 40%, and 60%, and a range of lawn area reduction, from 20% to 50%.

The highest range of lawn area reduction is based on findings from research on cultural perceptions of residential landscapes. Numerous studies found that homeowners were willing to replace their lawn area with other plant communities by up to 50% (Nassauer, 1995; Peterson, 2012; Ryan, 2010).

The following chart, Table 7, shows a wide range of reduction from 4% nitrogen reduction if 20% of residents replace 20% of lawn, to 30% nitrogen reduction if 60% of residents reduced lawn area by 50%.

There are a wide range of factors that can influence participation; only a small number of which were reviewed in the research of this report. The most significant factor that arose from research on cultural perceptions is the influence from the perceptions of one's neighbors. It is important to recognize that all pilot programs and watershed initiatives need to encompass a neighborhood-level focus for long-term success.

2. INVOLVE THE COMMUNITY IN DEVELOPING LANDSCAPE ALTERNATIVES.

The importance of community involvement in decision making and implementation cannot be overstated. Gathering input from members of the community to allow their voices to be hear and engaging people in the actions of implementing projects are both critical forms of engagement.

Community surveys to identify residents' concerns, fears, desires, and current level of understanding of the issues and of alternatives would provide invaluable information to develop community education and incentive programs that are best able to target the specific desires and concerns of the community. Numerous studies reviewed for this report (Larson etal., 2016; Nassauer, 1995, 1997, 2009; Peterson, 2012; Ryan, 2010; Stacy, 2015) provide a range of frameworks to survey residential homeowners and establish a baseline of community interest and awareness.

Community-based programs that engage people in the process of building ecological landscapes, from rain gardens, to living shorelines and riparian corridors provide hands-on, place-based, experiential education. This is a powerful tool to increase awareness and deepen connection to both the community and their local natural resources.

3. DEVELOP WATERSHED-WIDE INCENTIVIZATION PROGRAMS TO ENCOURAGE MORE HOMEOWNERS TO PARTICIPATE IN ECOLOGICAL LANDSCAPE PROGRAMS ON THEIR PROPERTIES.

There are a number of incentive-based programs that promote best management practices on private property for green stormwater infrastructure, use of drought-tolerant vegetation, reductions in impervious surface, and others. A full review of these programs was outside the scope of this report. It is recommended that incentive programs be reviewed and developed in conjunction with community input to best target the drivers and key motivating factors that will encourage homeowners to take action and change landscape practices. Incentives can include: awards, certification, garden tours, tax rebates, discounted plant material, and rebates on installation.

4. DEVELOP MONITORING PROTOCOLS AT MULTIPLE SCALES TO EVALUATE ECOLOGICAL LANDSCAPE PRACTICES AND CHANGES IN NITROGEN LEVELS.

Monitoring is an critical process of this initiative to improve water quality. This initiative is built on the idea of a network of many small-scale actions. Monitoring conditions before and after installations of ecologically-oriented gardens is important to quantify how well, if at all, these installations are functioning. Data collection can be built into community-based initiatives as volunteer programs, citizen science programs, school educational programs, or marketed as enhanced services of landscape service businesses. Monitoring over time and at a range of scales will provide the community with evidence-based research to understand the impact of landscape-level changes. This data is a powerful tool for advocacy and decision making, and strategic thinking.

5. DEVELOP REGIONAL CAMPAIGNS TO PROMOTE LANDSCAPE-LEVEL INITIATIVES.
In the San Francisco Bay Area, "Bay Friendly Landscaping Guidelines" were developed by the Alameda County Waste Management Authority, now directed by ReScape California, to promote ecological design based landscaping practices to property owners . A certification-driven training program was developed for landscape practitioners to enhance the marketability of ecologically-oriented landscape practices. Refer to ReScape California's website for more information: https://rescapeca.org/.

In the Chesapeake Bay region, the Chesapeake Conservation Landscaping Council was created to promote best management practices of ecologically-oriented landscapes. A certification program was developed to train practitioners and increase marketability of conservation landscapes to protect the health of the Chesapeake Bay watershed. For more information: http://www.chesapeakelandscape.org/.

In the midwest, Kansas City, Missouri developed the 10,000 rain gardens initiative to promote water quality improvement through better landscape practices. A number of other "10,000 rain garden campaigns have since been developed, in Marin County, California and in the City of Seattle to promote ecological landscape practices to improve water quality and ecosystem health.

Developing a campaign to promote a watershed initiative provides opportunities for community members and visitors alike to give back and deepen connections to the community. People are more likely to take care of what they believe is valuable. Awareness of the importance of native plant communities and the role of landscapes in protecting water quality is the foremost priority to develop value in the landscape and the watershed.

6. PROMOTE A PARCEL BY PARCEL APPROACH TO WATERSHED PROTECTION.
The Three Bays watershed is one of the most populated watersheds on Cape Cod. Residential parcels constitute 92% of the lands of the watershed. The residential population is a vital asset and link to the improvement of water quality throughout the watershed.

Engaging the entire community in a parcel by parcel approach, is a core strategy for all supporting initiatives: gathering community input and engagement in decision-making processes, creating volunteer stewardship and experiential education opportunities , and economic marketing opportunities. The residents have an opportunity to work together to influence each other to improve the water quality and long-term health of the Three Bays watershed.

Appendices

APPENDIX 1. WETLAND TYPES* TABLE.

		FRESH			
CODE	WETLAND TYPE	FOREST (acres)	NON-FOREST (acres)	SALT (acres)	WATER (acres)
1	COASTAL BANK BLUFF OR SEA CLIFF			9.6	
2	BARRIER BEACH SYSTEM			24.9	
3	COASTAL BEACH			34.6	
4	BOG		2.0		
5	CRANBERRY BOG		181.6		
6	COASTAL DUNE			25.4	
7	DEEP MARSH		14.8		
8	SHALLOW MARSH MEADOW OR FEN		27.6		
9	OPEN WATER				2428.2
11	SALT MARSH			147.2	
12	SHRUB SWAMP		95.0		
13	TIDAL FLAT			1.5	
14	WOODED SWAMP DECIDUOUS	74.1			
15	WOODED SWAMP CONIFEROUS	26.1			
16	WOODED SWAMP MIXED TREES	24.5			
17	BARRIER BEACH-COASTAL BEACH			33.9	
19	BARRIER BEACH- COASTAL BEACH-COASTAL DUNE			67.7	
21	BARRIER BEACH- MARSH			0.8	
21	BARRIER BEACH- MARSH			0.8	
27	BARRIER BEACH- SALT MARSH			0.4	
	TOTALS	124.8	320.9	346.8	
			445.7		

*Data from MASS GIS Wetlands Data. Accessed 3/1/2018.

References

Ahern, Jack. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. Landscape and Urban Planning. 100. 341-343.

Anderson, M.G. M. Clark, C.E. Ferree, A. Jospe, A. Olivero Sheldon and K.J. Weaver. 2013. Northeast Habitat Guides: A companion to the terrestrial and aquatic habitat maps. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA. http://nature.ly/HabitatGuide.

Bergdoll, Barry. (2011). Rising Currents: Projects for New York's Waterfront. Museum of Modert Art, New York.

Blaine, T., Clayton, S., Robbins, P., & Grewal, P. (2012). Homeowner Attitudes and Practices Towards Residential Landscape Management in Ohio, USA. Environmental Management, 50(2), 257-271.

Burghardt, K.T., Tallamy, D.W., & W., Shriver, G. (2009). Impact of Native Plants on Bird and Butterfly Biodiversity in Suburban Landscapes. Conservation Biology, (1), 219.

Cameron, R. W. F., & Blanuša, T. (2016). Green infrastructure and ecosystem services - is the devil in the detail? Annals of Botany, 118(3), 377-391.

Cape Cod Commission. (2015). Cape Cod Area Wide Water Quality Management Plan Update. Barnstable, MA.

Cape Cod Commission. (2017) Watershed Report: Mid Cape. Three Bays. Barnstable and Sandwich. Website:http://www.capecodcommission.org/resources/208/watershedreports/ 2017_Watershed_Report_MC_Three_Bays.pdf Accessed: 4/6/2018.

Carlozzi, Carl. (1975). Ecosystems and Resources of the Massachusetts Coast. Massachusetts Coastal Zone Management. Boston, MA.

Carson, R., Darling, L., & Darling, L. (1962). Silent spring. Boston: Houghton Mifflin.

Commission, Conservation. (2011) Chapter 740. Wetlands Buffer Zone Activity. Town of Barnstable Regulations. Approved 6/5/1990. Amended 10/11/2011. Web: https://ecode360.com/6565397. Accessed: 4/6/2018.

Daily, Gretchen, C., Alexander, S., Ehrlich, P. R., Goulder, L., Lubchenco, J., Matson, P. A., Harold A. Mooney, Sandra Postel, Stephen H. Schneider, David Tilman, George M. Woodwell. (1997) Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems. Issues in Ecology, ESA. Vol. 2.

Darke, R. and Tallamy, D.W. (2014). The Living Landscape: Designing for beauty and biodiversity in the home garden. Portland, OR.: Timber Press, 2014.

Dramstad, W. E., Olson, J. D., & Forman, R. T. (1996). Landscape ecology principles in landscape architecture and land-use planning. [Cambridge, Mass.] : Harvard University Graduate School of Design ; Washington, DC : Island Press ; [Washington, D.C.?] : American Society of Landscape Architects, [1996].

Franklin, Carol. (1999). Designing as if the Earth Really Mattered. ASLA/LAF Summit White Papers. Washington, D.C. American Society of Landscape Architects.

Harlan, Sharon L., Ruddell, Darrell M. (2011) Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. Current Opinion in Environmental Sustainability, 3:126–134.

Hawes, Ellen, and Smith, Markelle. (2005). Riparian Buffer Zones: Functions and Recommended Widths. Report Prepared for the Eightmile River Wild and Scenic Study Committee. Web: http://www.eightmileriver.org/resources/digital_library/appendicies/09c3_Riparian%20Buffer%20Science_YALE.pdf. Accessed: 4/6/2018.

Horsley, S., Perry, E., Counsell, L. (2016). Three Bays Estuary (Barnstable, Cape Cod) Watershed Restoration Plan: A Green Infrastructure Approach. Journal of Green Building, 11(2), 22-38.

Horsley Witten Group. (2014). Cape Cod Fertilizer and Pesticide Use Inventory: Final Report. Published by the Cape Cod Commission. Barnstable, MA. Website: http://www.capecodcommission.org/resources/waterresources/Cape_Cod_Pesticide_and_Fertilizer_Use_Inventory_Final_Report_April_2014.pdf Accessed: 5/6/2018/

Horton, Tom. (2003). Turning the Tide: Saving the Chesapeake Bay. Chesapeake Bay Foundation.

Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner (2006). Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, MA

Hunt, J. D. (1992). Gardens and the picturesque: studies in the history of landscape architecture. Cambridge, Mass.: MIT Press, [1992].

Kaplan, Rachel, Austin, Maureen, B. (2004). Out in the Country: sprawl and the quest for nature nearby. Landscape and Urban Planning. Vol. 69. pp 235-243.

Kennish, M. (2002). Environmental threats and environmental future of estuaries. Environmental Conservation, 29(1), 78-107.

Landscape Architecture Foundation, ed. (2017) The New Landscape Declaration: A Call to Action for the Twenty First Century. Los Angeles, California. Rare Bird Books.

Larson, K. L., Nelson, K. C., Samples, S. R., Hall, S. J., Bettez, N., Cavender-Bares, J., & ... Trammell, T. E. (2016). Ecosystem services in managing residential landscapes: priorities, value dimensions, and cross-regional patterns. Urban Ecosystems, (1), 95. doi:10.1007/s11252-015-0477-1

Leigh, Peter. (2005). The ecological crisis, the human condition, and community-based restoration as an instrument for its cure. Ethics in Science and Environmental Politics. Published April 4, 2005. p. 3-15.

Leopold, Aldo. (1949). A Sand County Almanac. New York. Oxford University Press.

Luoni, Stephen. (2010). Low Impact Development: A Design Manual for Urban Areas. University of Arkansas Press. Fayetteville, AR.

Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

Mayer, P.M., Reynolds Jr., S.K., Canfield, T.J. (2005) Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. U.S. Environmental Protection Agency. Office of Research and Development. EPA/600/R-05/118. Cincinnati, OH.

McLusky, D. S., & Elliott, M. (2004). The estuarine ecosystem: ecology, threats, and management / Donald S. McLusky, Michael Elliott. In Oxford; New York: Oxford University Press, 2004.

McGranahan, G., Balk, D., & Anderson, B. (January 01, 2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and Urbanization, 19(1), 17-37.

Meyer, Elizabeth. (2008). Sustaining Beauty: The Performance of Appearance. Landscape Architecture Magazine. 98(10), 92-131.

Milesi, C., Running, S. W., Elvidge, C. D., Dietz, J. B., Tuttle, B. T., & Nemani, R. R. (2005). Mapping and modeling the biogeochemical cycling of turf grasses in the united states. Environmental Management, 36(3), 426-438.

Millennium Ecosystem Assessment, (2005). Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Nassauer, J. I. (1993). Ecological Function and the Perception of Suburban Residential Landscapes. In Gobster, P.H., ed., Managing Urban and High Use Recreation Settings, General Technical Report, USDA Forest Service North Central Forest Exp. Sta., St. Paul, MN.

Nassauer, J.I. (1995). Messy ecosystems, orderly frames. Landscape Journal, (2), 161

Nassauer, J. I., (1997). Cultural sustainability: Aligning aesthetics and ecology. In Placing Nature: Culture and Landscape Ecology. J. I. Nassauer, ed. Island Press. Washington, D. C.

Nassauer, J. I., Kosek, S. E., and Corry, R. C. (2001). Meeting public expectations with ecological innovation in riparian landscapes. Journal of the American Water Resources Association 37(6): pp 1-5.

Nassauer, J.I., Wang, Z., Dayrell, E. (2009). What will the neighbors think? Cultural norms and ecological design. Landscape and Urban Planning, Vol. 92, pp 282-292

Nassauer, J.I. (2011). Care and stewardship: From home to planet. Landscape and Urban Planning, Vol. 100, pp 321-333.

National Oceanic Service (NOS). (2010) What percentage of the American population lives near the coast? http://oceanservice.noaa.gov/facts/population.html Visited: March 1, 2017.

Natural Heritage and Endangered Species Program [NHESP]. (2012). BioMap2: Conserving the Biodiversity of Massachusetts in a Changing World: Barnstable. Massachusetts Division of Fisheries and Wildlife.

Nicolaides, Becky, and Weise, Andrew. (2017). Suburbanization in the United States after 1945 Website: http://americanhistory.oxfordre.com/view/10.1093/acrefore/9780199329175.001.0001/acrefore-9780199329175-e-64 Accessed: March 24, 2018.

Orr, David. (1994). Earth in Mind: On Education, Environment, and the Human Prospect. Washington, D.C. Island Press.

Palone, R.S., Todd, A.H. Editors. (1997). Chesapeake Bay Riparian Handbook: A guide for Establishing and Maintaining Riparian Forest Buffers. USDA Forest Service. NA-TP-02-97. Radnor, PA

Peterson, M. N., Thurmond, B., Mchale, M., Rodriguez, S., Bondell, H. D., & Cook, M. (2012). Predicting native plant landscaping preferences in urban areas. Sustainable Cities And Society, 5(Special Issue on Third Global Conference on Renewable Energy and Energy Efficiency for Desert Region - GCREEDER 2011), 70-76. doi:10.1016/j.scs.2012.05.007

Pollan, M. (1991). Second Nature: a gardener’s education. New York, N.Y.: Dell Publishing, [1991].

Pollan, M. (2002). The botany of desire: a plant’s-eye view of the world. New York: Random House, 2002.

Rainer, T. a., & West, C. (2015). Planting in a post-wild world: designing plant communities for resilient landscapes. Portland, Oregon: Timber Press, 2015.

Ryan, R. L. (2010). Local Residents' Preferences and Attitudes toward Creating Defensible Space against Wildfire in the Northeast Pine Barrens. Landscape Journal, 29(2), 199-214.

Ramachandran, Mahesh. (2015). Water Quality and Cape Cod's Economic Future: Nitrogen Pollution's Economic Impact on Homes and Communities. Cape Cod Commission. Website: http://www.capecodcommission.org/3bays/assets/three_bays_study_full_report.pdf Accessed: 4/14/2018

Sallam, Mohamed. (2000). Insect Damage: Post-Harvest Operations. Food and Agriculture Organization of the United Nations. Website: http://www.fao.org/publications/card/en/c/8d4df8eb-6d58-4594-87a0-ebf8bc55cb54. Accessed: 4/11/2018.

Spalding, Mark D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L. Z., Shepard, C. C., Beck, M. W. (2010) The role of ecosystems in coastal protection: Adapting to climate change and coastal hazards. Ocean and Coastal Management. 90:50-57.

Stacy, Johanna R. (2015). Homeowner Willingness to Adapt Low-Impact Development Practices in the Ipswich River Watershed: Opportunities and Barriers. Masters Thesis. University of Massachusetts, Amherst.

Steinberg, T. (2006). American Green: the obsessive quest for the perfect lawn. New York: W.W. Norton, c2006.

Tallamy, D. W. (2007). Bringing Nature Home: how native plants sustain wildlife in our gardens. Portland, Or.: Timber Press, 2007.

Tallamy, D.W., & Shropshire, K.J. (2009). Ranking Lepidopteran Use of Native versus Introduced Plants. Conservation Biology, (4), 941.

Town of Barnstable, (1993). §240.35. Groundwater Overlay Protection Districts.

Town of Barnstable. (2011). §740 Wetlands Buffer Zone Activity.

Van der Ryn, S., & Cowan, S. (1996). Ecological Design. Washington: Island Press.

Walter, D.A., McCobb, T.D., Masterson, J.P., and Fienen, M.N., 2016, Potential effects of sea-level rise on the depth to saturated sediments of the Sagamore and Monomoy flow lenses on Cape Cod, Massachusetts (ver. 1.1, October 12, 2016): U.S. Geological Survey Scientific Investigations Report 2016–5058, 55 p., http://dx.doi.org/10.3133/sir20165058.

Weaner, L., & Christopher, T. (2016). Garden Revolution: how our landscapes can be a source of environmental change. Portland, Oregon: Timber Press, 2016.

Wenger, S.J., Fowler, L. (2000). Protecting Stream and River Corridors: Creating Effective Local Riparian Buffer Ordinances. Carl Vinson Institute of Government, University of Georgia, Athens, GA.

Wilcove, D., Rothstein, D., Dubow, J., Phillips, A., & Losos, E. (1998). Quantifying Threats to Imperiled Species in the United States. BioScience, 48(8), 607-615.