PROVIDING ECOLOGICAL BENEFITS IN ADDITION TO RECREATIONAL BENEFITS IN RAIL-TO-TRAILS DESIGN: THE FIREFLY TRAIL, ATHENS, GA

By

YiRan Zhao

(Under the direction of Katherine Melcher)

ABSTRACT

A rail-to-trail project is the conversion of an abandoned railway into a multiple use trail. A number of cases in the U.S. have shown that rail-to-trail transfers can serve to create recreational opportunities for jogging, cycling, and walking. However, providing ecological benefits along with recreational ones have not been widely considered in rail conversion projects. Furthermore, the conflicts between ecological use and recreational use along abandoned rail development sites are not fully understood. This thesis explores the concept of combining ecological conservation and recreational goals in developing rail-to-trail projects through the design of a practical application. A final framework followed the form of a greenway showing how its design can allow for harmonious use by both humans and wildlife. Design solutions were examined through the lens of a real project: Firefly Trail, Athens, GA.

INDEX WORDS: Rail-to-trail, Greenway, Ecological benefits, Corridor, Recreational benefits, Recreational ecology, Firefly Trail, Athens, Georgia.

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CHAPTER 1

INTRODUCTION

Nowadays, with the growth of urban areas, many natural landscapes have been dramatically cleared, making way for city construction. Forests have been cleared and replaced by new neighborhoods, rivers and channels have been lined and polluted, and wildlife habitats have been damaged or destroyed. However, there is a growing demand for linear open spaces for physical activities, such as walking, jogging and biking, and a growing awareness of the need to preserve natural resources (Swim, Zawadzki, Cundiff, and Lord 2014).

To resolve this critical conflict, Congress enacted the Rail-to-trail Act in 1968 to balance the growing number of abandoned railways and the need for recreational spaces. This Act seeks to make full use of existing abandoned rail lines and protect natural resources (Fowler 2009). In 1986, Rails-to-Trails Conservancy, a group whose major responsibility is to facilitate rail-to-trail programs all over the United States, was founded (http://www.railstotrails.org/about/history 2015). Since then, a large number of abandoned railways have been transformed into hiking, cycling or walking trails for public use. According to the Rails-to-Trails Conservancy's database, more than 160,000 members had joined Rails-to-Trails Conservancy and over 21,000 miles of rail-to-trail programs had been railbanked by August 2014 (http://www.railstotrails.org/about/history 2015). The railbanking

is a voluntary agreement between a railroad owner and a rail-to-trail agency who intends to transform an abandoned rail corridor into a trail until such time as the owner may need the corridor again for rail service (Fowler 2009). These large numbers show both the success of rail-to-trail projects and strong potential for further implementation.

1.1 Purpose

Throughout recorded history, natural resources have been sacrificed to benefit human life. Modern urbanism has accelerated the disappearance of natural habitats due to development and population growth. At the same time, though, humankind has formed a growing demand for natural space. This thesis explores various ways to bridge the gap between the two demands of human development and the preservation of natural areas. Specifically, since designing and transforming an abandoned railway for both recreational use and ecological benefit has not been widely applied, this thesis aims to explore theories that balance recreational uses and ecological benefits, analyze them, and demonstrate their practical application through a design. During the exploration, ecological objectives and recreational objectives are studied and synthesized for real-world use, following a proposed design framework of the Firefly Trail specifically intended to help resolve recreational and ecological conflicts. Finally, the results provide clear design principles for incorporating ecological benefits into the design of the Firefly Trail in Athens, GA.

The Firefly Trail, is a proposed 39-mile, multi-function regional greenway for walking, jogging, bicycling, and commuting (http://www.traillink.com/project/firefly-trail.aspx 2015).

It will be built along a historic railroad corridor between Athens and Union Point, Georgia while stretching through Clarke, Oglethorpe, and Greene counties. The purpose of this rail-to-trail program is to provide healthy, dynamic and safe open space for all users (http://www.traillink.com/project/firefly-trail.aspx 2015).

1.2 Significance

1800 rail-to-trail programs have been developed nationwide by 2013, compared to only 200 programs in 1986 when the Rails-to-Trails Conservancy was founded (America's Rails-with-Trail Report 2013). Many of the rail-to-trail projects constructed today offer recreational opportunities for people, but are not intentionally designed to provide ecological benefits for wildlife and native plants (Hellmundand Smith 2006). For project partners, planning teams or stakeholders, the design and accompanying design framework drawn from urban greenway design features may offer new approaches for achieving recreational and conservational goals at the same time.

Greenways are multi-function linear open spaces which can facilitate environmental conservation, recreation, and transportation (Lindsey, Wilson, Yang and Alexa 2008). Strategically, greenways can be developed from abandoned railway tracks, canal towpath trails, wildlife movement corridors, or other existing natural corridors (Schroeder 2002). Ecologically, greenways aim to connect adjacent ecological hubs and diminish the effects of fragmentation to disturbed ecological habitats (Yilin Shi 2011). To all these greenways offer the added social benefit of providing a place for recreation, thus enhancing the lives of users.

In the urban context, greenways can connect fragmented habitats and preserve ecological integrity (Yilin Shi 2011). They act as conduits for wildlife and people and contain distinctive margins affected by travel and human maintenance. Meanwhile, the adjacent habitats can offer habitat and resource functions for wildlife. These corridors are well suited for being transformed into trails or greenways for the following reasons (Rails-to-Trails Conservancy 1987):

1) Rail corridors have a remarkable number of edge species. Edge species are the least sensitive to the edge habitats' microenvironmental changes and act neturally to these changes (Ries and Sisk 2010).

2) Rail corridors can be long enough to link various types of land fragments to form an integrated ecosystem. Landscape connectivity is a fundamental element for greenways to maintain their ecological functions. Once landscape connectivity becomes low, the number of habitats may decrease, the quality and productivity of remaining habitats will decrease, and the distance between them may increase. As a result, gaps can form, which can disrupt interior animals' movements (Hellmund and Smith 2006). A rail-to-trail program's ecological function can improve if it becomes better connected. A connected greenway will not only function as a single entity, it will provide more comprehensive network benefits in the long run.

3) Successful cases show that rail-to-trail projects can improve the local economy by attracting large numbers of people to walk, run and ride bicycles along trails (Hellmund and

Smith 2006). Users of recreational sites who interact more with nature, and become more aware of the connections between human influence and vulnerable natural resources. Also, users who have a stronger bond to nature areas are tending to engage more into the outdoor physical activities (Wolsko and Lindberg 2013).

Athens's greenway network system also aims to achieve social benefits in three different ways: by offering new alternative transportation routes, encouraging good health and recreation, and providing educational opportunities (Department of Leisure Services, Natural Resources Division 2003). Transportation benefits can be achieved by providing alternative transportation corridors for bicycle riders and pedestrians. In this way, traditional on-road vehicle trails, bicycle corridors, and off-road trails combine to form a multimodal transportation network that can connect neighborhoods as well as promote social collaboration by connecting workplace, school, shops, and community services for local residents, all while attracting tourists to the area at the same time (Unified Government of Athens-Clarke County 2003). Greenways can provide an ideal place for health-related recreational activities, thereby encouraging a healthy lifestyle, which can lower healthcare costs (Unified Government of Athens-Clarke County 2003). Finally, greenways can benefit communities by promoting increased knowledge and awareness of ecological preservation. Citizens in turn learn that land property can be managed and may develop a greater appreciation of natural resources.

This thesis provides design methods that can be readily adopted by designers, project partners, and stakeholders in an urban setting to enhance biodiversity and preserve the natural habitats of rail-to-trail programs.

1.3 Limitations

There are two main limitations in this thesis. First, this thesis develops a general design framework for rail-to-trail programs. The design framework may not apply to problems caused by a specific plant or wildlife species. Similarly, the design framework may not be appropriate for every type of habitat found along trails, and is not meant to address every problem faced on site. Thus, varied and adaptive solutions will need to be developed to address these issues in the future. Secondly, given the Firefly Trail's unique soil, topography, and vegetation, this study can be applied only for its specific conditions. As well, it is limited to greenways designed for walking, jogging, and cycling. The unique properties of the study and its specific context make it hard to replicate exactly in another context.

1.4 Delimitations

There are four delimitations for this thesis. First, although transportation, recreational and ecological functions are each vitally important, the compatibility of the two is still poorly understood. Knight and Cole (1991) point out that the lack of data and poor understanding of the incompatible elements between recreational use and ecological use will, to some extent, undermine attempts to effectively conduct rail-to-trail programs for both human and wildlife. Certain outdoor recreation activities, such as walking, jogging, and cycling, have proved to

jeopardize many species (Boyle and Samson 1985), yet this largely depends on a specific environment's suitability for various recreation activities. It is still unclear whether a successful case study in a different location can help address this issue. Second, in this study, land ownership, funding sources, facilities management, and related laws and regulations are not discussed deeply due to the limited time, but they are still important for the rail-to-trail programs. Lastly, due to the limitation of the time, the proposed design frameworks of the Firefly Trail in this thesis will not engage the general public into the design and analysis, which may need to be emphasized in the real application.

1.5 Problem, issues or opportunities

The Rail-to-trail Conservancy aims to connect individual patches of natural habitats to provide recreational areas for humans (Feldman 2002). In 1803, due in part to the Louisiana Purchase, the U.S. needed more rail track to transport both human and goods westward (Drumm 1999). Since 1830, a scant one hundred miles of railway track had increased dramatically, and by 1860 some 27,000 miles of track had been functioning all over the U.S. (Drumm 1999). In 1920, when this period of railway growth finally peaked, over 272,000 miles of track had been constructed, and Congress agreed to use over 90 million acres of land for railways (Little 1995; Drumm 1999). However, a shrinking use of rail transportation today has resulted in a sharp decline of usable railway infrastructure. The distance of usable rail infrastructure declined by nearly half from 272,000 miles at its height to 141,000 miles in 1990 (Drumm 1999; Pearson 2008). Experts projected that the downturn will continue into

the foreseeable future (Drumm 1999). Congress tried to slow abandonment through the Railroad Revitalization and Regulatory Reform Act of 1976 (Drumm 1999). Under this Act, the Surface Transportation Board is working on transforming underutilized or abandoned rail track into trails by allocating management responsibilities to state and local agencies and private sectors who are willing to be responsible for managing rail-to-trail programs (Drumm 1999).

According to a 2013 outdoor participation report, running, jogging and rail running make up 19% of all outdoor activities (participation rate). Road cycling, mountain cycling, and bicycle motocross attract 15% of all outdoor participants (participation rate) (Outdoor Foundation 2013). Running and cycling rank first and third, respectively, among the most popular outdoor activities. By providing for multiple recreational purposes, rail-to-trail projects attract a diversity of users pursuing varied activities in different seasons. In addition to rail running and cycling; jogging and rail running, hiking and skiing are popular trail activities as well. By providing a natural, safe, and healthy environment for varying population groups, including the elderly, children, and physically challenged individuals, rail-to-trail projects can fulfill recreational needs in multiple ways.

The rail-to-trail programs have gained attention as a consequence of a remarkable number of public and private agencies attempting to transform abandoned rail lines into trails for recreational benefits. Even so, the idea of adopting the renovated trail as an ecological corridor for human, wildlife and vegetation, which is the original definition of the greenway,

is seldom considered (Hellmund and Smith 2006). Most of the existing programs neglect the importance of adjacent ecosystems along the abandoned rail lines. Only rarely are they designed to perform ecological functions, and seldom have they provided healthy ecological corridors for wildlife and plants.

Thus, the research question can be stated as: *How can a rail-to-trail project, such as Firefly Trail in Athens, GA, provide ecological benefits in addition to the development goal of recreational use?*

Meanwhile, the research questions can be divided into five sub-questions. First, *How does a greenway program provide ecological benefits and what is needed for such program to be ecologically beneficial?* Fabos (1995) concluded that greenways are ecological corridors that can be used to achieve goals, such as ecological preservation, community connectivity, cultural and historical conservation simultaneously. The goals mentioned above fit exactly with the proposed design goals for the Firefly Trail. To begin placing emphasis on natural or ecological considerations, Chapter 2 offers a brief history for rail-to-trail programs, and focuses on habitat preservation and conservation. Then, Chapter 2 uses archival research to provide reliable theoretical support, draw on the ecological notions common to greenway programs and begin integrating those into this new trail planning and design framework.

Secondly, *How can a real greenway program balance human recreational needs and ecological preservation?* To deepen understanding this question and show how the theoretical knowledge can be applied in real projects, case studies were introduced. Chapter 3

discusses and critiques three case studies of greenway design, uncovering practical ways to resolve conflicts between recreational and environmental uses. At the end, Chapter 3 draws together basic historical and ecological knowledge of rail-to-trail conservancy and greenway projects, analyzes the recreational and ecological benefits of the two kinds of projects, and points to the existing, unresolved problems.

Thirdly, *How can these concepts actually be applied to the design of a real rail-to-trail program?* The real project (the Firefly Trail, Athens, GA) and its data and information was generated from site surveys, analyzed and synthesized into the real design meant to achieve ecological goals as well as recreational ones. To encourage Athens's greenway network development and to enjoy fully its benefits, it is best to understand first what a greenway could bring to the city. According to the Greenway Network Plan and the Unified Government of Athens-Clarke County, Georgia, Greenways can attract tourists, generate recreational revenues, and even save on costs for public services. Additionally, greenways can attract new business and increase the value of adjacent property. Chapter 4 and Chapter 5 provide a general design framework, drawing upon existing greenway design principles. In these chapters, conflicts between human use and wildlife are explored and analyzed, and general solutions introduced. The proposed Firefly Trail site is carefully analyzed in this chapter, which also offers specific design frameworks for the Firefly Trail. The design frameworks apply to both design process and management of this site.

Lastly, *What is the strengths and limitations of such a design approach?* Chapter 6 provides a summary and conclusion to talk about the rail-to-trail programs and their potential ecological design approaches.

CHAPTER 2

ECOLOGICAL BENEFITS AND GREENWAY DESIGN

Ever since the U.S. Congress enacted the National Trails System Act in 1968, a large number of abandoned railways have been converted into hiking, biking, or walking trails for public use (Kielisch 2012). In this way, the old railways are not only reused, but also offer local residents opportunities to experience the natural environment. Furthermore, trails offer educational opportunities for users to develop a sense of the importance of natural preservation. This partnership encourages the practice of rail-to-trail renovation and the preservation of abandoned rail lines. However, many of these programs neglect the importance of wildlife and the native vegetation along the abandoned rails (Flink, Seansand and Schwarz 1993). Rarely do they consider the ecological potential of this type of project to provide healthy and ecologically beneficial corridors for wildlife (Flink, Seansand and Schwarz 1993). With the increase of recreational places, the equally-important ecological quality of a project is often overlooked or sacrificed in favor of recreation. Only seldom is a renovated trail thought of as an ecological corridor suitable for not only for humans, but also for wildlife and native plants. Among these successful programs, the majority are converted into multi-functional sustainable greenways. The literature review here offers a brief introduction to greenway programs and greenway ecology, followed by a succinct history of such programs. Then, ecological conflicts between natural conservation and recreation needs

are discussed to understand which design features can be integrated into a greenway design to be ecologically beneficial. Lastly, conclusions and recommendations drawn from greenway design theory are offered to help resolve these conflicts.

2.1 Greenway History

Although the term "greenway" emerged in the late 1950s, the idea of designing linear ecological areas can be traced back to 1860s, when Frederick Law Olmsted began designing what he called parkways (Smith 1993). Parkways are linear open spaces which offer ecological and social benefits to nearby neighborhoods (Zhao, Pan 2013). From 1866 to the mid-1870s, Olmsted and his partner, Calvert Vaux, started to apply linear connections in their designs. In their early works, they focused more on social and aesthetic issues (Smith 1993). However, from 1878 to 1890, Olmsted's remarkable design for Boston's Emerald Necklace (see Figure 2-1) started to address the additional ecological issues of drainage and water quality (Smith 1993). These ideas made Olmsted an early landscape design practitioner whose designs incorporated the multiple needs of what are now called greenways (Smith 1993). Following his lead, during the early 20th century, greenway networks and open space increased dramatically in America. These early projects accommodated not only the recreational needs of human beings, but also provided ecological benefits. However, with increasing car use, ecological considerations have succumbed to motor vehicle needs. Circuitous leisure parkways have been replaced with straight vehicle ways. Even as automobiles were taking hold, a brand-new idea was raised in Britain in response to

seemingly unlimited big city sprawl. In 1898, Ebenezer Howard proposed the design idea "Garden City". Howard's design idea, as well as the use of greenbelts (agricultural and recreational zones that surrounded urban development) (Kühn 2003), was successfully adopted in England. Following this trend, greenbelts were introduced to American cities. The Concept of greenbelt design was further deepened by American planner Benton MacKaye (Smith 1993). His idea is that the greenbelt serves not only as a tool for controlling city sprawl, but also to provide recreational open space for the local region. Later, he even combined the ideas of greenbelt and greenway.

Figure 2-1 1894 plan for the Emerald Necklace Park System (cited from National Park Service Olmsted Archives 1894)

In the 1960s, a new ecological approach to following ecological design and planning emerged, one highly influenced by the ideas of Olmsted, Howard, and MacKaye. Designers and planners had come to realize that natural information should be analyzed and overlapped

before any land conservation project began. Ian McHarg's *Design with Nature* turns the idea of ecological design into a systematic and theoretical framework which can be widely applied for real design, such as National Parks and Appalachian trail. More recently, the greenway has been regarded as a focus of open space protection (Hellmund and Smith 2006).

2.2 Greenway Ecology

For guidance in achieving ecological goals as well as recreational ones, rail-to-trail designers and practitioners can look closely at how greenways function. Greenway ecology joins landscape ecological principles with those of greenway design. Ecological needs are often pushed aside in landscapes dominated by people. Depending on their origins, landscape types and human usage, greenway ecology deals with the interior eco-system and its relationship with the surrounding landscape (Gökyer 2013). Greenway ecology studies habitats' structure, functions and their changing process (Forman 1995). Forman and Godron (1986) concluded that structures are ecological relationship between different habitats or different elements inside a habitat; functions indicate the spatial interaction, such as the flow of energy, nutrition and materials, and movement of species and habitat changes (Smith 1993). The habitat change is the dynamic ecological process of both the structure and function (Gökyer 2013).

There are three basic landscape elements of the ecological greenway: core area, hub, and corridor (Weber and Allen 2010). Core areas consist of ecologically-healthy habitats for a wide range of species (Weber and Allen 2010). Hubs are buffer zones for core areas that

provide resources for both human and wildlife (Weber and Allen 2010). Corridors link up the core areas and facilitate wildlife movement and dispersal (Gökyer 2013).

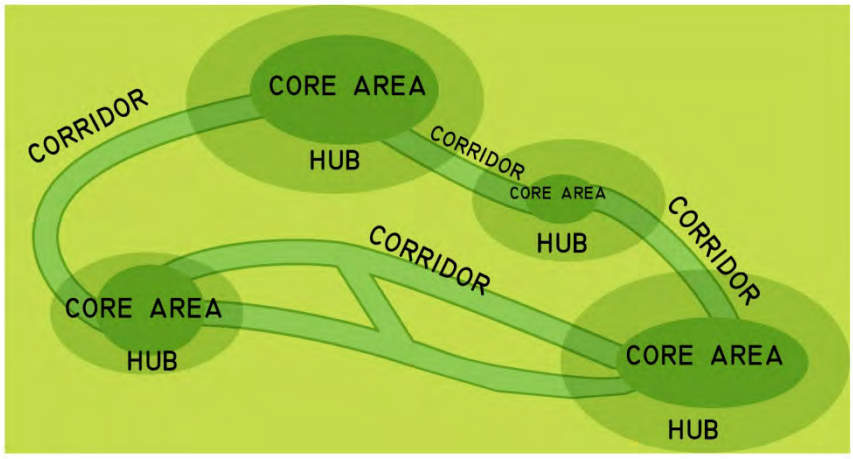


Figure 2-2 Greenway network structure (Created by the author based on Weber and Allen 2010)

Meanwhile, four greenway characteristics: corridor, matrix, mosaic, and patch (see Figure 2-3), are used to describe its spatial structure (Gökyer 2013). Matrix is the dominant habitat; patch is the dispersed habitat with relatively-low biodiversity, and the mosaic is the combination of several patches; corridor is the linkage for mosaics or patches (Forman 1995; Gökyer 2013).

Greenways are linear corridors that serve five functions (see Figure 2-4): habitat, conduit, barrier, source, and sink (Forman 1995). The continuous corridors provide habitats for diverse species (Bennett 1999); and the species will also use the corridors as conduits for movement or dispersal. Natural linear corridors or man-made disturbance, such as buildings

and highways, will have a negative impact on wildlife's diversity and abundance (serve as filters) through forming physical barriers (Askins 1994). Sometimes, the linkage corridor will provide shelter for the species that lived in the adjacent habitats (serve as sinks), or the species live inside the corridors will move to surrounding habitats (serve as sources) (Bennett 1999). Habitat, conduit, source, and sink are four beneficial functions that are identified in rails to trails projects such as the Firefly Trail, and therefore are described in more detail in the following sections.

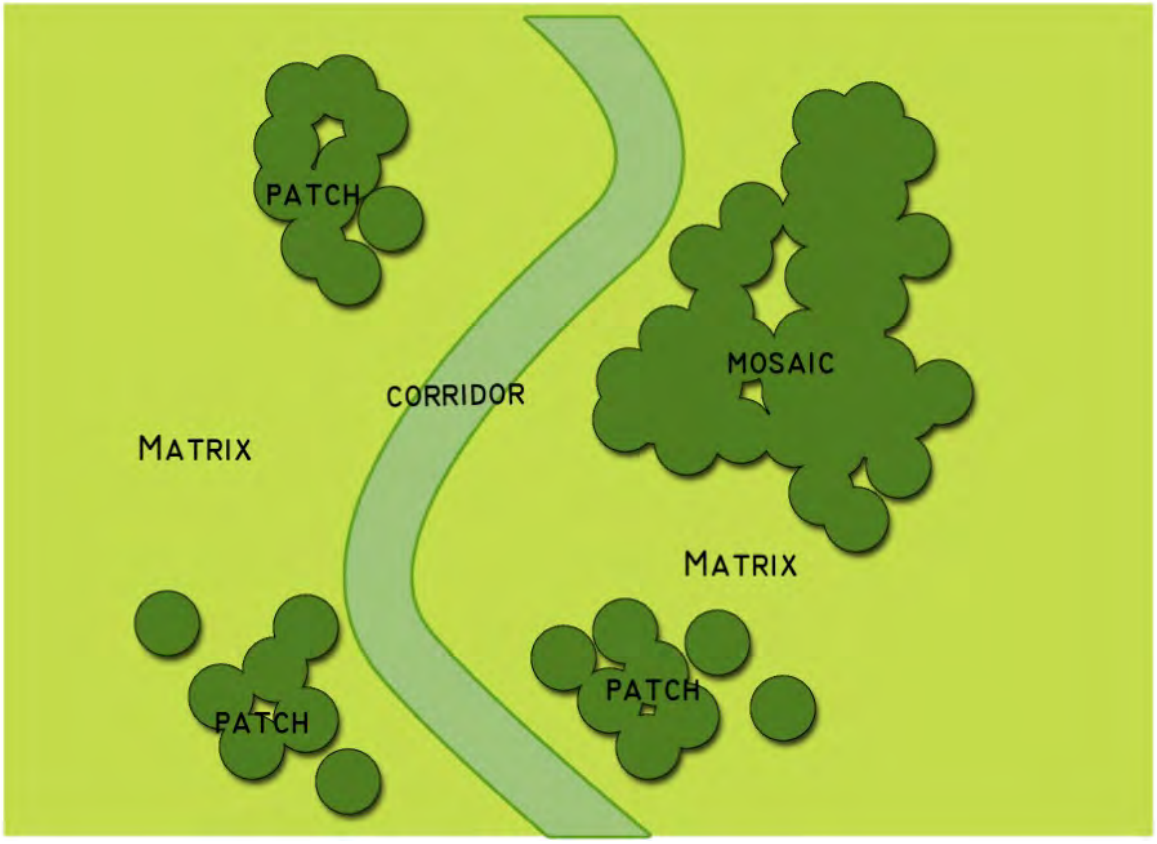


Figure 2-3 Corridor, matrix, mosaic, and patch (Created by the author based on Gökyer 2013)

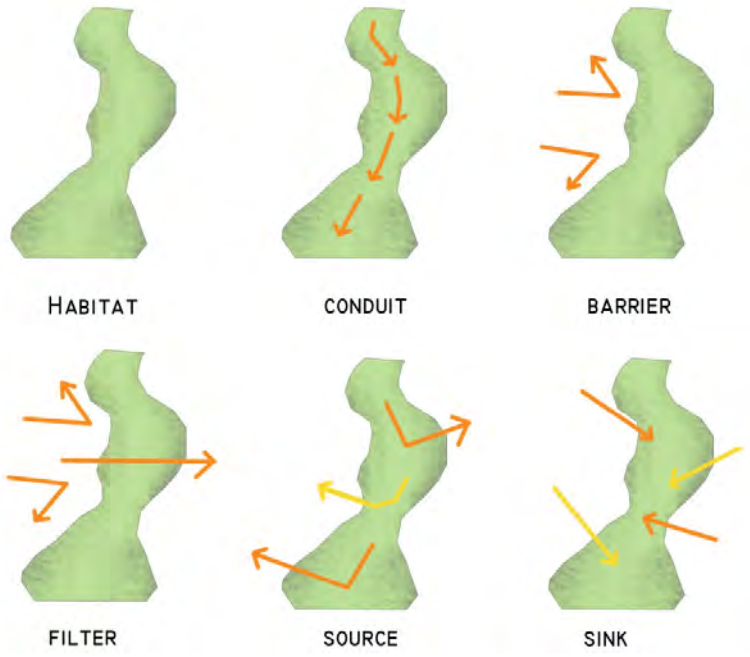


Figure 2-4 Corridors' ecological functions (Created by the author based on Forman 1995)

2.2.1 Habitat

Greenways can act as linear corridors that provide different types of habitats for a variety of species (Forman 1995). Greenway corridors are mostly occupied by edge animals that have limited mobility and small habitats (Forman 1995; Ries and Sisk 2010). The density and diversity of edge species are high since these species are intended to be gathered together (Forman 1995). On the other hand, greenways' interior spaces are wide enough to provide habitats for the interior species or corridor residents to predominate in the central areas (Forman 1995). However, sometimes greenway habitats might be too small to support interior species, thus restricting wildlife's natural behavior and reproductive success (Forman and Godron 1986). A too-small habitat is also vulnerable to disease and, in the event of disease, is less likely to be recolonized (With and King 1999). Thus, species diversity

decreases as habitats shrink, even leading to the possibility of species extinction. Similarly, vegetation and animals may become victim of human trampling when a habitat is over used. Trampling can affect the size of vegetation, reproductive capacity, and, in worst-case scenarios, kill vegetation altogether (Smith and Hellmund 1993). Over long term, natural areas that are separated from each other serve decreased ecological functions. Wildlife may change their behavior and movement, or reproduce less successfully as a result of human disturbance (Smith and Hellmund 1993). Thus, it is important and beneficial to understand factors that will influence vegetation and wildlife when we begin to occupy the places where they live.

2.2.2 Conduit

The conduit function facilitates the movement of wildlife along corridors. Specifically, large wildlife use greenway corridors to periodically migrate for living, surviving, and breeding, to move between patches to get food resources, or to switch their living environment (Forman 1995; NRCS 2015). Along these corridors, when human activities are confined within a center area, they will have less environmental impact than they otherwise would.

2.2.3 Source and sink

Sometimes, the greenway corridor functions as source that support resources or materials, such as food, nutrition, soil, and vegetation for wildlife that live in the matrix (Forman 1995); while sometimes, greenway corridors function as a sink when they receive

nutrition, food, energy, soil, vegetation, or even wildlife from the surrounding matrix (NRCS 2015). To sum up, the greenway corridor is a source when corridors provide resources or materials to the surrounding matrix; the corridor becomes a sink when corridors receive resources or materials from the matrix (Douglas, Goode, Houck, and Wang 2011). Corridor materials' competition between humans and wildlife can lead to species dispersal and habitat isolation or loss, resulting in wildlife vulnerability.

2.3 Conflict between recreational use and ecological use in greenway

Rail-to-trails programs keep miles and miles of rails from becoming ruined and abandoned sites. These programs can also preserve important historical rails; promote local economic development, even as they provide opportunities for recreation. Nevertheless, little of the existing data show natural or ecological consideration given to their initial design (Flink and Seans 1993).

2.4 Conflicts between natural conservation and recreation needs

Recreation and wildlife conservation are both commonly emphasized in greenway management plans (Adams and Dove 1989; Schiller and Horn 1997). Yet the relationship between conservation and recreation remains unclear to many. Recreational facilities, especially over-used ones, may prove to have an adverse effect on the ecology by increasing soil erosion, or by decreasing vegetation density (Groom, McKinney, Ball, and Winchell 2007).

Trails are designed for transportation and traveling. Although both recreation and wildlife conservation are commonly emphasized in greenway management plans (Adams and Dove 1989; Schiller and Horn 1997), human disturbance can still adversely affect soil, vegetation, wildlife, and water (Smith and Hellmund 1993). Travel and human maintenance will continually disturb the soil's content of air and nutrients, as well as the ability to support plants (Smith and Hellmund 1993). Even unknowingly, human disturbance may hinder the amount of vegetation supported by the soil, in turn threatening the microorganisms living within (Smith and Hellmund 1993). Recreational facilities may have adverse effects on the ecology of a site by increasing soil erosion, causing vegetation loss, and interrupting the natural habitat. Eventually, habitats which are detached are becoming ecologically vulnerable (Groom, McKinney, Ball, and Winchell 2007). Trampling will negatively affect vegetation height, density, photosynthesis, reproduction and nutrition cycle (Smith and Hellmund 1993). Trampling can also change animal behavior, movement along corridors, and reproduction (Smith and Hellmund 1993).

The Firefly Trail project will receive research direction from specialists in the field of recreation ecology, which is concerned with the environmental consequences of outdoor recreational activities and how to minimize them (Monz, Cole, Leung, and Marion 2009). Even when purposely combining ecological benefits for wildlife and recreational benefits for people, the compatibility between the two can be uncertain. Factoring in diverse recreational land uses creates even more uncertainty.

2.5 Conflict between different recreational uses

Landscape ecology recognizes five main factors influencing the environmental impact of human disturbance of the landscape for recreation. These are frequency of use, specific recreational activities done, users' behaviors, and use distribution over both long and short periods of time (Forman and Gordon 1986, Smith and Hellmund 1993). The adverse effects of these five factors in various combinations can appear simultaneously or separately. Thus, comprehensive design and management strategies are preferable to help reduce the impact of human use. Other factors such as safety, maintenance, public services, and emergency services should all be also taken into consideration in programming a trail like the Firefly Trail program.

2.6 Conclusions and recommendations

Greenways can preserve sensitive natural habitats, hold top soil on site, lessen stormwater impacts, and help improve air quality. By protecting important wetlands and forests, providing linkage or connection between habitat fragments, preventing habitat from future damaged, and restoring streams and rivers, greenways can help preserve and restore habitats, and breeding ground for native plants and wildlife, facilitate wildlife's movement and migration. Additionally, greenways can also help filter pollutants and keep them from entering clean water sources which are indispensable for humans and wildlife. (Unified Government of Athens-Clarke County 2003).

Since greenway corridors can act as habitat, conduit, and source and sink, in the Firefly Trail. It is crucial to maintain and enhance their ecological functions. As to plant and animal habitats, human interference should be confined to preserve such places. Meanwhile, the width of the corridor should be as wide as possible to provide habitats for the edge species and corridor residents. Conduits should be used to connect patches to form a regional greenway network for both human and wildlife. Human recreational activities should not interfere with wildlife movement and migration. When the corridors function as source and sink, buffer zones are needed to make sure the energy, nutrient flow through the greenway's ecosystem.

CHAPTER 3

CASE STUDIES

In this chapter, three greenway cases were chosen to be studied and analyzed according to their planning goals, strategies and processes. Each of them presents a particular way of preserving and enhancing natural habitats while providing recreational open space through systematic planning. Even though the case studies' site conditions, planning methods, and implementation strategies are widely diverse, the three share commonalities which can be readily applied to the proposed program, the Firefly Trail in Athens, GA. These three cases were found through online search and selected since they all incorporate ecological and recreational concerns simultaneously; and they provide examples for solving the conflicts between recreational needs and ecological preservation. In this chapter, most information was found online to inform the case studies.

3.1 Boulder Creek Greenway Plan, City of Boulder, Colorado

3.1.1 Introduction

In 1910, Frederick Law Olmsted Jr. suggested that Boulder Creek should be preserved and kept in its natural condition to maximize its ecological functions (City of Boulder 2001). He also suggested that the adjacent areas could be used to accommodate the recreational needs (City of Boulder 2001). However, this plan took 70 years to actually come into being (City of Boulder 2001). Facing issues such as critical flooding issues, damaged wildlife habitats, and

decreasing open space, installation of the Boulder Creek Greenway program finally began in 1984 (City of Boulder 2001). This innovative plan (see Figure 3-1) sought to preserve and enhance local riparian habitats, mitigate flooding impact as well as to provide a linear park along the Boulder Creek for recreational and transportation functions. Because of the successful implementation of the plan to Boulder Creek's main channel, it has since been widely applied to all 14 of its tributaries (City of Boulder 2001).

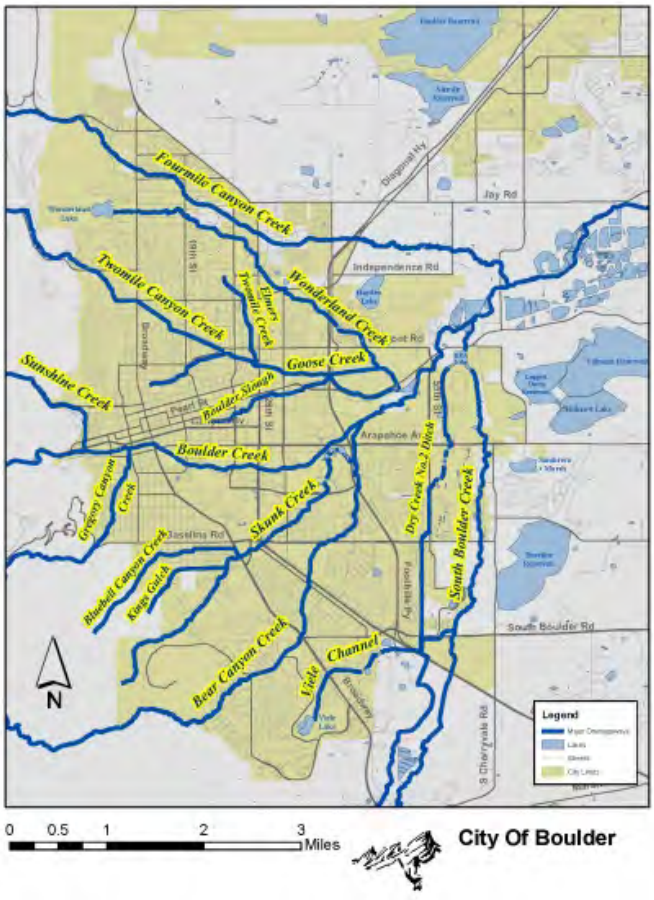


Figure3-1 Boulder Creek Greenway Plan (City of Boulder 2011)

3.1.2 Design goals

According to the Boulder Creek Greenway Plan (2001), its major planning goals were to protect and restore the existing habitats, to facilitate stormwater management, mitigate flooding, and to improve both the quantity and quality of the water in Boulder Creek. As proposed, the greenway plan provides recreational opportunities for pedestrians and bicyclists, protects cultural and historical heritage, offers alternative routes for non-motorized users and wildlife, and thus, creates a greenway network to connect the local neighborhoods. To achieve both the ecological and recreational goals mentioned above, developers and designers together with the general public generated four design objectives in workshops: habitat restoration and preservation, recreation improvement, transportation connection, and cultural conservation (Katie Knapp 2015; City of Boulder 2001).

3.1.3 Habitat Restoration and Preservation

The Greenway plan preserves and enhances the endangered terrestrial and aquatic habitats along the Greenway. Developers and designers conducted a field survey of existing habitats on the site and identified four vulnerable habitats with high preservation value: bird habitats, habitats for native plants and wildlife, habitats for vegetation structure, and wetland areas (City of Boulder 2001). The greenway plan not only prevented degradation of some endangered habitats, it also expanded the preservation zone to the surrounding buffer zone. To determine if they had achieved their goals and objectives, developers and designers also developed a series of criteria for further evaluation, which are outlined below (see Figure 3-2).

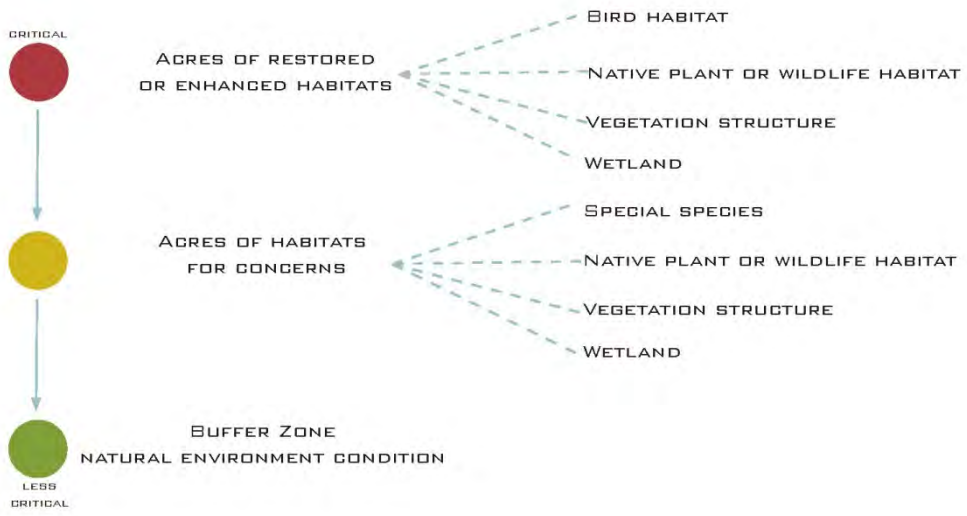


Figure 3-2 Criteria for evaluating program success (image developed by the author based on 2001 Boulder Creek Greenway Plan)

A greenway can offer any number of environmental education opportunities, especially for residents of nearby neighborhoods. Success of education programs, such as studying invasive species, vegetation structure, natural habitat study, and preservation were all also included in the evaluation criteria.

3.1.4 Recreation

The Boulder Creek Greenway plan aimed to improve the quality of life of its potential users (see Figure 3-3), to promote mutual interaction among them, and contribute to a strong sense of community. The plan promotes physical and mental health through individual and group sports, including organized and unorganized activities, such as bicycling, jogging and walking (City of Boulder 2001). Meanwhile, the greenway offers gathering places for

activities, promoting safe and constructive use. By contributing to school, work, social, and community life; the greenway has also helped residents form a sense of community and a mutual understanding. A series of criteria for further evaluation has been developed to ensure the plan continues to meet its goals (see Figure 3-4).

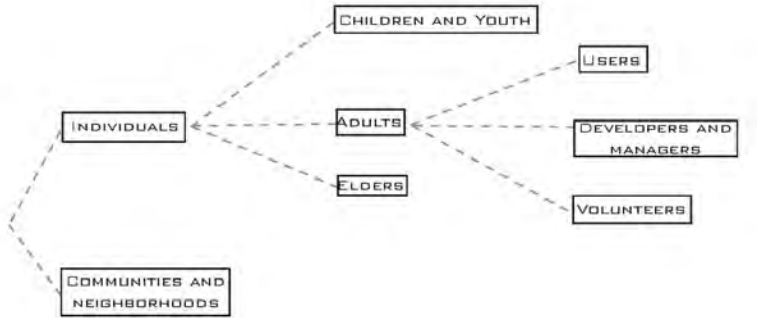


Figure 3-3 The potential users for Boulder Creek Greenway Plan (image developed by the author based on 2001 Boulder Creek Greenway Plan)

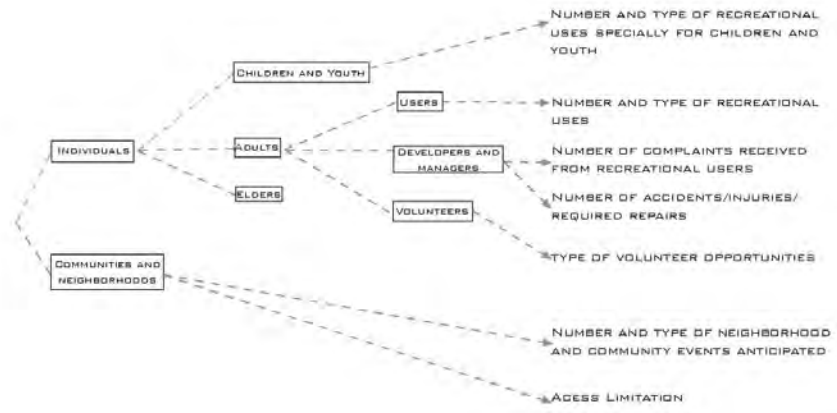


Figure 3-4 Criteria for evaluating program success at achieving recreational goals

The Boulder Creek Greenway Plan (2001) provided a new trail system connecting overall city transportation systems, and has helped promote an aesthetically pleasant, healthy, and natural environment for pedestrians and bicyclists. Users range from children and youth to the elderly. Through careful design, paths have been graded to minimize negative human impacts on natural areas. Since construction was completed, safety and maintenance issues have continually been managed and monitored (see Figure 3-5).

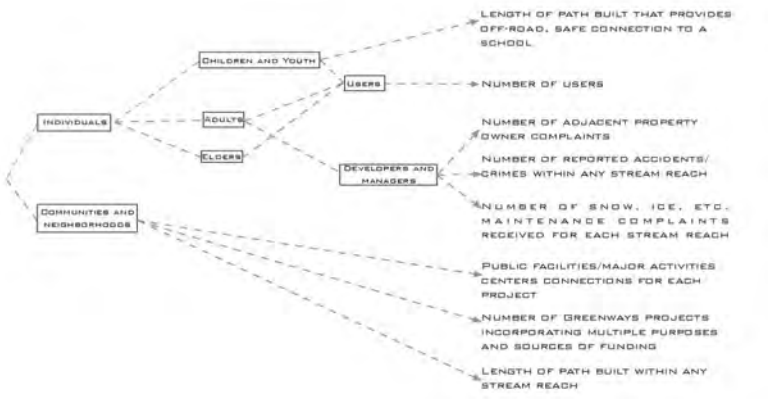


Figure 3-5 Criteria for evaluating program success at achieving transportation goals (image developed by the author based on 2001 Boulder Creek Greenway Plan)

3.1.5 Cultural conservation

This goal was not just to preserve important cultural and historic resources, but was also aimed to promote the awareness of preservation. The plan encouraged the community to fully understand these historical sites, to appreciate them, enjoy them and, finally, to preserve them. These review criteria have been established as indicated below:

1) The number of the National Register of Historic Places (NRHP) or State Register of Heritage Places (SRHP) nominated cultural resources were engaged in the greenway plan;

2) The number of educational opportunities was provided along the trails (City of Boulder 2001).

3.1.6 Conclusion

In 2011, greenway master plan has incorporated all 14 tributaries into the planning. The master plan started with the site inventory including site conditions, existing trail connections, and historic trail information. After inventory, a site plan was identified to connect the existing habitats and neighborhoods while providing places for transportation and recreation (LRAP 2011). This master plan included planning, construction, funding, and management (LRAP 2011). Now the improvement of the Boulder Creek Greenway focuses on disconnected trails and habitats where there are conflicts between natural conservation and recreation needs (LRAP 2011). This plan applies a wide range of educational criteria programs to ensure the ecological functions on the site. As a first step, the practitioners and planning teams divided existing habitats into three categories and applied different strategies to restore and enhance them. Recreational facilities are designed and built to facilitate recreational benefits while at the same time provide educational opportunities for the users.

3.2 Baird Creek Greenway in Fox-Wisconsin Heritage Parkway, the City of Green Bay, WI

Fox-Wisconsin Heritage Parkway (see Figure 3-6) runs through 45 communities along the Lower Fox, Upper Fox, and Lower Wisconsin Rivers. The 280 miles of parkway extend

from the Mississippi River to Green Bay, Wisconsin (http://www.heritageparkway.org/about/ 2015).

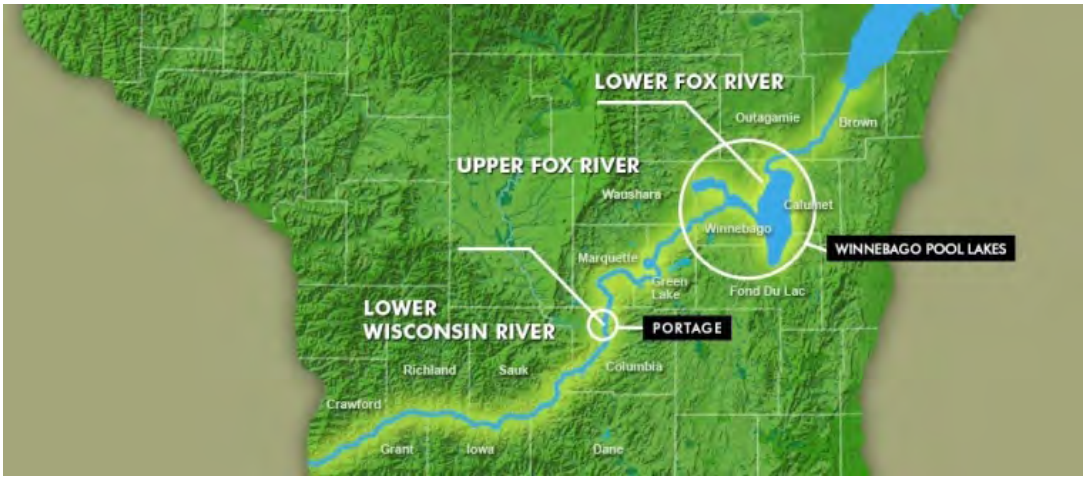


Figure 3-6 Fox-Wisconsin Heritage Parkway (http://www.heritageparkway.org/about/ 2015)

3.2.1 Introduction

Fox-Wisconsin Heritage Parkway intends to conserve varying natural habitats along the river, to preserve its rich and unique heritage assets, attract tourism, and improve community connectivity (http://www.heritageparkway.org/about/ 2015). According to the heritage parkway.org website (2015), priorities for the Fox-Wisconsin Heritage Parkway are as follows (Figure 3-7). The Baird Creek Greenway comprises over 500 acres of valuable green space around a portion of the Lower Fox River corridor, just east of the city of the Green Bay, WI (The City of Green Bay 2010).

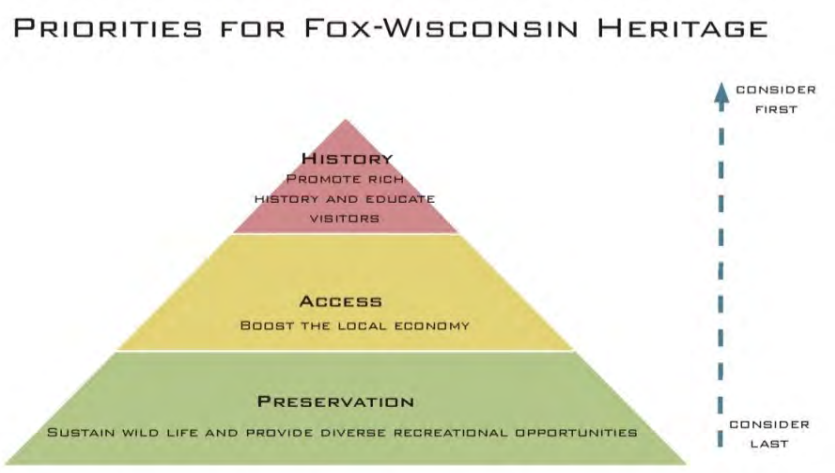


Figure 3-7 Priority for Fox-Winsconsin Heritage Parkway

3.2.2 Design goals

According to the Santy (2001), the river corridor has suffered from the following issues:

1) Habitat damage and loss

As a result of urban sprawl and industrialization, lakeshores and river fronts are replaced due to land cover change, wetlands are filled in for more buildable lots, natural habitats (see Figure 3-8) are separated into segments, and suffered from the loss of native species and wildlife population decrease.

2) Surface water contamination and groundwater degradation

An investigation from the 1980s shows the Fox-Wisconsin River Corridor contaminated by PCBs, mercury, chromium, and other industrial byproducts from decades of industrial use (The City of Green Bay 2010). The investigation also pointed to a lack of stormwater

management programs and erosion control methods, to a loss of natural vegetation filtration near the river, and to an increase of disconnected habitats.

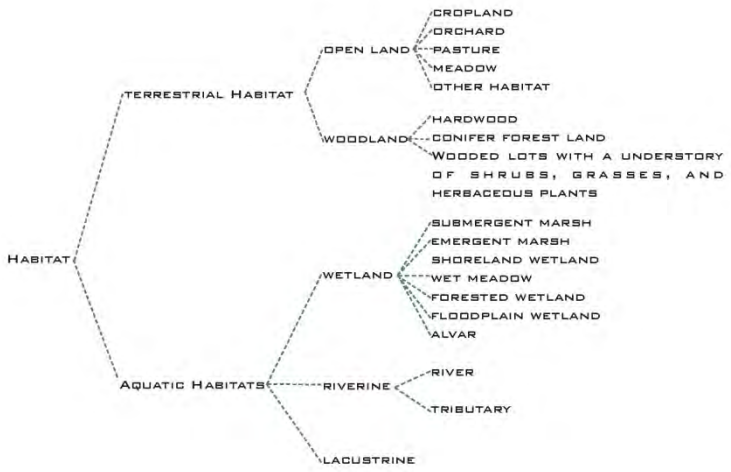


Figure 3-8 Habitats along the Bairdy River corridor

3) Natural resources deteriorated due to overly recreational use.

Rivers and lakeshores are gradually undermined due to the high impact of recreational use, such as boating (Fink, Fermanich, and Ehlinger 2005; The City of Green Bay 2010).

4) Lack of environmental education and other supportive programs.

Ineffective local ordinances, untrained staff, and a lack of practical education or training programs contributed to the ignorance of natural habitats, wildlife preservation and conservation, and general ecological awareness in the area.

3.2.3 Design Process

The City of Green Bay intended to address these issues through the Bairdy Creek Greenway Master Plan (2010) and its implementation. The master plan process began with an

analysis of site opportunities and constraints. Then, planning goals and strategies were set up by the planning teams accordingly. With the help of public engagement, a conceptual master plan was developed and adopted in the preliminary master plan and its report. Once the final master plan and report are approved by Bairdy Creek Preservation Foundation (BCPF) Board, the engineering and implementation will be performed (The City of Green Bay 2010).

Through the process (see Figure 3-9) of site inventory and analysis, the existing habitat types, environmentally sensitive areas, existing utilities within the greenway, railroad corridors, parking areas, and existing trails were all identified (The City of Green Bay 2010).

Figure 3-9 The Bairdy Creek Greenway Master Plan Process

To preserve the surrounding natural resource from further damage from human disturbance and city development, five major goals have been put in place: habitat restoration and preservation, water quality improvement, recreation, and education (The City of Green

Bay 2010). To implement these, feasible and compatible strategies and objectives were developed and integrated into the design, planning, implementation, management, and monitoring.

3.2.4 Habitat restoration and preservation

According to the Baird Creek Greenway Master Plan (2010), there are 17 vegetation communities along the Low Fox River Corridor system. Most of them are habitats or migration routes for wildlife and are extremely sensitive to human disturbance. Thus, recreational activities were stringently confined, while conservation and preservation practices were required. According to Natural Resources Objectives and Policies (2003), the master plan sought to restore the existing habitats, such as forests, wetlands, and riparian lands, to increase wildlife populations through preserving their habitats, and to restore ecological corridors, all while working to eliminate invasive species. To maintain conservation and preservation functions, the design and management teams investigated existing field conditions and generated maps for local habitats, corridors, and their links (The City of Green Bay 2010). The maps have been applied for preservation, restoration, and further management. Engaging stakeholders (see Figure 3-10) in both the design and management of the plan has helped to ensure the stewardship of the management plan and its implementation. In this case, stakeholders like schools, municipalities, county and regional planning commissions, regional and county land use commissions, Wisconsin Department of Natural Resources (WDNR) Fisheries and habitat Protection Program, Waster Management,

WDNR Watershed Protection Program, Landowners, local committees, counties, and partner teams were all engaged in planning, construction and management processes (The City of Green Bay 2010). Over that period, educational programs on habitat improvement and restoration provided specific knowledge of the ecological components for the wetland and shoreline habitats (The City of Green Bay 2010).

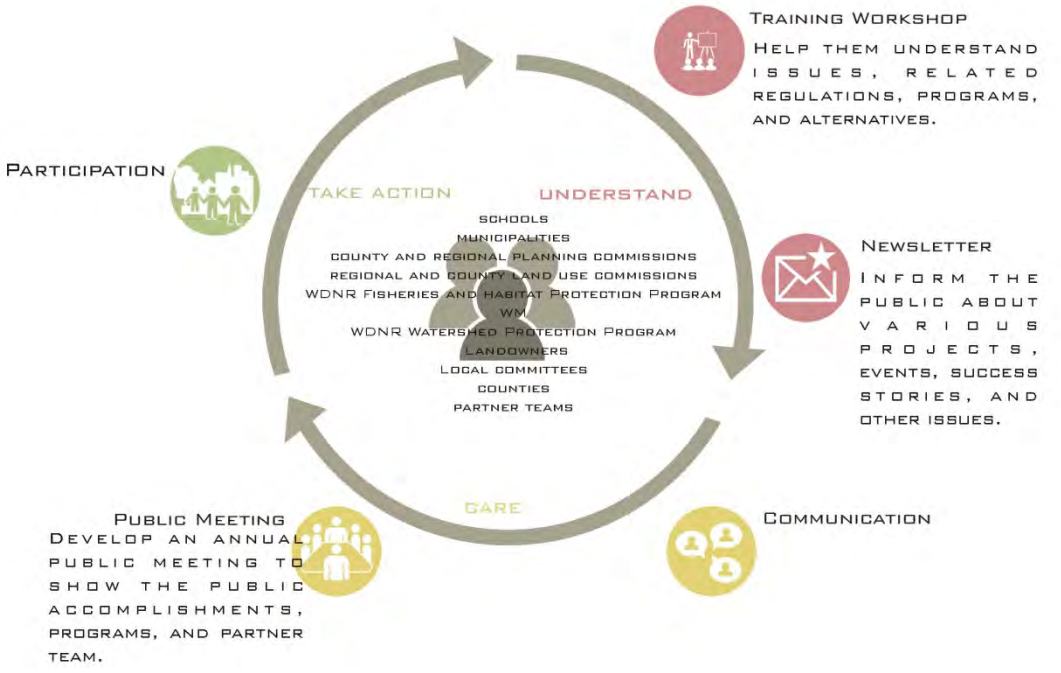


Figure 3-10 Public Engagement Process

The existing habitats were separated into three levels based on their importance. According to the Greenway Ecological Assessment and Management Plan (2001), three types of habitats were identified as high-priority habitats: cedar and hemlock forest, oak savanna, and sedge meadow. These habitats are ecologically sensitive areas that have since been

preserved from human interference and carefully managed by research teams. At habitats designated mid-priority, only two educational activities are allowed on site: using as an ecological demonstration site and the removal of garbage (Bairdy Creek Preservation Foundation 2001). The ecological demonstration site is mainly used for research and study of restoration strategies and related ecological principles. Also, as three of these mid-priority habitats were identified as dump sites, a large group of volunteers has worked to clean up construction debris, household garbage, and agricultural waste (Bairdy Creek Preservation Foundation 2001). At the same time, young distributed woods, degraded wetlands, and open shrub-invaded old fields were identified as low-priority habitats (The City of Green Bay, 2010). Now these habitats are being occupied by invasive species and subject to dangers that might be presented by increased farming and new construction. In face of these critical issues, stakeholders as well as volunteers applied design, engineering, and land acquisition to prepare for future planning and management. The degraded wetlands are prevented from increased spread of invasive species, while open, shrub-invaded old fields recover after the removal of agricultural and industrial waste, thus allowing native vegetation succession (The City of Green Bay, 2010).

3.2.5 Recreation

The plan provides access to the natural greenway while providing shoreline and habitat restoration within the greenway. Educational signage has been installed on the site, which creates opportunities for increased public awareness. Results from several multi-input design

workshops and on-site surveys suggested the following programs and enhancements:

1) Educational programs: bird watching, nature study, outdoor classroom, education programs on stormwater management and green infrastructure (The City of Green Bay 2010).

2) Recreational programs: biking, jogging, rollerblading, skating, biking, public access to the natural environment, and connect to the parks (The City of Green Bay 2010).

3) Service facilities: picnic areas, restrooms, education information boards, and bike racks.

4) Conservation program: restoration of native plants and stream system (The City of Green Bay 2010).

5) Based on the amount of use, vegetation, habitats, soil type, topographic survey, and analysis of site opportunities and constraints, the trails of Baird Creek Corridor were classified into four categories: bird watching and pedestrian trails, shared bicycle and pedestrian trails, multi-use trails, and cross-county ski trails (The City of Green Bay 2010). These bird watching and pedestrian trails support minimum intensity uses and non-motor activities, such as hiking, jogging, birding, and walking. These trails are designed to help visitors fully enjoy and experience nature, and at the same time to leave at least 20-foot setbacks from ecologically sensitive habitats and steep slopes to help prevent damage (The City of Green Bay 2010). The six-feet-wide shared bicycle and pedestrian trails are used for hiking, birding, and snowshoeing. These too leave a 20-foot setback from natural habitats (The City of Green Bay 2010). Multi-use trails, on the other hand, undergo a higher level of use. They are used for

hiking, bicycling, skiing, snowshoeing, and rollerblading, and also serve as alternative routes for commuters (The City of Green Bay 2010). These 10-foot-wide trails with a 12-foot clear zone were implemented to minimize recreational impact on vegetation, wildlife and their sensitive habitats (The City of Green Bay 2010). Cross-county ski trails are a special type of trails, and are up to 8 feet wide on hills (The City of Green Bay 2010). These trails are required to meet certain ski standards (The City of Green Bay, 2010). Aside from trail design, trail signage pointing to important facilities and adjacent communities must also be installed.

The first 5-year goals focused on greenway access, habitat restoration and preservation, education programs, and stormwater management. For greenway access, the plan offered easily accessible multi-trails for different users to enjoy. Also educational signage was installed along the greenway corridor. Educational opportunities were offered for schools, research teams, volunteer events, and birdwatching visitors on environmental awareness. The major goal of early-phase habitat restoration activities is to eliminate invasive species, such as Crown Vetch, Purple Loosestrife, Reed Canary Grass, and Black Locust, and to restore high-priority and medium-priority habitats (The City of Green Bay, 2010). Stormwater management would prioritize using native vegetation and carefully planned trails to prevent runoff as feasible objectives. A 10-year plan mainly focuses on improving facilities such as restrooms, bike racks, rest areas, and signage. The implementation of the 10-year plan will expand restoration to low-priority habitats, and expand research areas to surrounding regions (The City of Green Bay, 2010).

3.2.6 Conclusion

The Baird Creek Greenway are multi-function trails for recreational and ecological sense at the same time. In this plan, recreational ecology was used to balance recreational needs and ecological functions and a wide range of trails are developed according to their corresponsive habitats. These trails left 20 feet setback to minimize human impact on the natural habitats. On these trails, specific measurements can be applied in the Firefly Trail to maximize trails' ecological function.

3.3 Greenway Compact Program, Dutchess County, NY

3.3.1 Introduction and design goals

The Greenway compact program viewed 13 counties in the Hudson Valley region (see Figure 3-11) as one unit in an organized, multi-level cooperative effort to achieve these five main goals on behalf of a variety of the region's stakeholders:

1) Preserve natural habitats and cultural heritage sites
2) Improve economic benefits to the local region
3) Increase public access to the greenway
4) Increase educational programs related to habitat preservation and restoration
5) Implement and manage necessary facilities and infrastructure to fulfill Greenway's recreational goals (Greenway Connections 2000).

To achieve these five goals, Duchess County developed the first Greenway Compact Program in 1991. This joint program was adopted by the Greenway Communities Council and

the Greenway Conservancy for the Hudson River Valley (Greenway Connections 2000). The Greenway Communities Council cooperated with the local communities, while the Conservancy organized and implemented specific programs to improve ecological and economic functions simultaneously (Greenway Connections 2000).

Figure 3-11 Hudson River Valley Greenway, NY (Greenway Connections 2011)

3.3.2 Habitat preservation and conservation

This program uses sustainable design to enhance ecological conditions and functions and improve community connections The Dutchess County Department of Planning and Environmental Management Council conducted a preliminary inventory of natural resources,

which identified the important natural elements and possible design solutions for human interference (Greenway Connections 2000). The program intended to improve ecological function and reconstruct the integrity of the natural system to balance ecological preservation and regional development. Once greenway connections were established within walking distance of neighborhoods, the greenway system provided varied outdoor recreational programs to attract users. The system acted as an outdoor classroom, allowing nearby residents easy access to nature, and fostering strong awareness of the close relationship between nature and human (Greenway Connections 2000).

The natural pattern comprises two prominent characteristics; high land and low land. Highlands are those lands with steep slopes, such as mountainous areas, ridgelines, and hills (Greenway Connections 2000), which provide natural habitats for wildlife and plants, and often contain forests ideal for tourism. The Greenway Compact Program employed the following principles for designing and managing highlands. First, the management teams protect the steep slopes from human interference and use trails to minimize human impact on the natural habitats. Also, the new construction on the highlands are banned to maintain the natural views (Greenway Connections 2000).

Lowlands in the impacted areas, which include wetlands, bodies of water, and floodplain systems, were restored to filter pollution into the streams, and new construction occupying lowlands were forbidden. To achieve restoration goals, the amount of lowland habitats and their buffer zones should not decrease and new construction should be banned from these

areas. To make use of the existing natural habitat, any new trails in lowlands should be designed and constructed to minimize human impact.

3.3.3 Transportation function

Connecting discontinuous habitats for wildlife and plants, preserving existing stream corridors, reconstructing walkable communities for residents, building a connected bicycle network, adding landscape features on the roads were all listed as feasible strategies for the Greenway Compact Program (Greenway Connections 2000). Collaboration between government departments, private and non-profit groups, and individuals ensured multiple inputs, preserved local community character, and promoted a strong sense of community and awareness of the varied connections between people and spaces.

Based on its natural resources, functions, needs, and collective design preferences, the planning team for the Greenway Compact Program intended to preserve its distinct countryside landscape. A variety of possible programs, including bicycle lanes (see Figure 3-12), scenic roadways, stream corridors, trails, sidewalks, and greenway corridors, were proposed to connect the community network (Eoin Wrafter 2015).

types	site condition	design description
shared lane	average speed>30 mph(hamlets, villages, and cities)	street
paved shoulder	separate riders and motor vehicles	1.>4' 2.>6' when grade is over 5%, speed is over 50 mph, and more than 10000 vehicles /day
bicycle lane	average speed>45 mph	1.>4' 2. >5' when there is a curb on-street parking 3.>6' when grade is over 5%, vehicle speed is over 50 mph, and more than 10000 vehicles /day *2'- 3' painted buffer
bicycle boulevard	residential streets and vehicle speed <25 mph	residential street
shared-use path	no motor vehicles, just for pedestrians and bicyclists	>10' wide+>5' buffer form the roadways
bicycle parking	short-term parking at shops, restaurants, and parks	bicycle racks and sheltered facilities

Figure 3-12 Bicycle lanes Design Standard (image developed by the author based on 2000 the Greenway Compact Program)

3.3.4 Cultural conservation

Dutchess County is considered part of New York City's economic region. The county's interconnected regional and state highways, growing economic reputation, and the expansion of new business into Dutchess County combine to create significant economic potential (Warner, Hinrichs, Schneyer, and Joyce 1999). Specific strategies for economic improvement are:

1) Promote multiple economic models in the county through planning and implementation

2) Utilize regional advantages to increase business investment

3) Design a pedestrian-friendly county and greenway system to help curb sprawl

4) Preserve the local agriculture industry to encourage sustainable agriculture

5) Promote cultural and rural tourism (Greenway Connections 2000)

In this case, ecological benefits are realized by studying and analyzing their topographic and vegetation data to fit this plan into urban settings. One-third of the Firefly Trail is in the urban environment and can apply this case study to deal with the conflicts between the traffic road and greenway corridors.

3.4 Conclusion-Application of case studies to design problem

Even through the Firefly Trail project is a rail-to-trail project and not a river corridor like the case studies, it will also need to resolve recreational and ecological conflicts. Therefore, the case studies can provide clear design principles for integrating ecological benefits into the design of the Firefly Trail in Athens, GA. These three cases all create connections between existing fragmented habitats and discontinuous trails, restore and preserve existing sensitive habitats for wildlife and the native plants, create alternative accesses for the nearby neighborhoods. Each case study integrates a land use plan, future development plan, open space plan, and public infrastructure plan to generate a final greenway master plan. The following sections will show a general design process that is generated from these three cases to implement their objectives. This design process includes design and planning, construction, management and monitoring (see Figure 3-13).

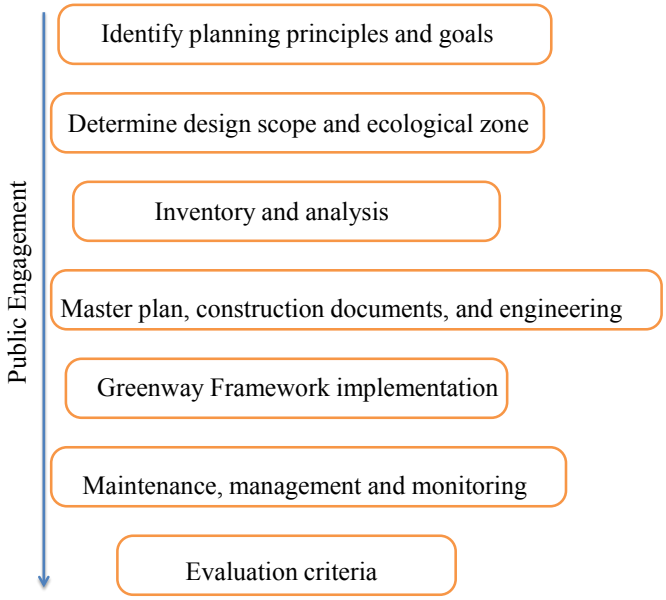


Figure 3-13 The general greenway planning framework

3.4.1 Identify planning principles and goals

In all three cases, project partners and planning teams held regular meetings to decide the planning goals and objectives. Meanwhile, they decided the potential stakeholders whom should be involved and incorporated into the planning process. All of these cases have maintained strong principles according to respective design goals. These three plans place a high priority on ecological preservation and conservation while at the same time are meant to accommodate recreational needs, conserving cultural and historical resources, improving local economy, and increase transportation connections.

3.4.2 Determine design scope and ecological zone

The project partners and planning teams used the design scope which defines the proposed design boundaries and ecological zones which are needed for preservation and

restoration to determine proposed sites, planning process which should be included into design framework. In the Baird Creek Corridor Masterplan, the habitats have been classified into three categories for preservation or conservation. The natural habitats with high preservation value are preservation zones which should be protected from human interference. The conservation zones are buffer zones which will provide open space for the potential users. The transportation zone is used to enhance community connection by reconnecting walkable communities, building bicycle network, and adding landscape features. Meanwhile, they also decided the potential stakeholders whom they should involve in each step of the planning process.

3.4.3 Inventory and analysis

In these three cases, they all try to analyze and incorporate the historical review report and specific information on this program to direct their future design after determining the design scope and ecological zones. In addition to the involvement of the public, private, and non-profit agencies, the general public can participate in the site survey and analysis through workshops, newsletters, communication, and public meetings since public engagement is a critical part in the collaborative planning process. All the planning teams will conduct site inventory to gather relevant data and information and present it to the general public in a variety ways: site inventory map, site survey report, photo and analysis map. In the Bairdy Creek Greenway Master Plan, the planning process identifies and establishes a general design direction for the greenway corridor and establishes a framework for short-term and long-term

goals. The whole process will be led by the general public, federal and municipal departments, research and design teams, and private non-profit organizations.

3.4.4 Master plan, construction documents, and engineering

Once design principles and goals are developed and established, existing conditions and design considerations are generated with input from a variety of stakeholders. A master plan then is organized into several segments and designed to meet the guiding design standards and be responsive to feedback generated during the planning process.

The design guidelines that can be applied to the Firefly Trail generated from these three cases are:

The existing patches, matrices, and mosaics can be connected with corridors to form a greenway network, so that to restore the fragmented habitats. The greenway network can function as the habitat, conduit, and source or sink for wildlife in the urban setting.

The corridors should be designed as wide as possible to eliminate the edge effect. For bicycle lanes, the lane width, slope, facilities and the surface materials can be considered as four main design elements. The shared trail can be 10-12 feet wide with at least 20 feet setback from the riparian habitat and at least 5 feet buffer zone from the roadways. The slope can be 5 percent slope maximum. As it is shown in the Dutchess County Greenway case, if the trail is suffered from heavy use, the trail can be paved with crushed stone and concrete and used by pedestrians only. If it is lightly used, the surface can be soft and the surface materials can be mineral stone and wood chips. Also, bicycle racks and sheltered facilities can be integrated into

the planning. For the trails for the pedestrians, joggers, and hikers, the lane width, facilities, and the surface materials are important design elements. The surface material can be crushed stone and concrete if the trails are frequently used, or otherwise can be mineral stone and wood chips. Also, facilities such as restrooms, benches, and rest areas should be provided.

Educational signage can be incorporated into the planning to avoid the confilicts between recreational activities and ecological preservation and restoration. Signage can be used to convey ecological, historic and cultural knowledge. The management and monitoring plan can ensure the implementation of the planning and construction.

3.4.5 Greenway Framework implementation

In this phase, activities, program costs, principals, and schedules are listed and used to guide and track both short-term and long-term implementation.

3.4.6 Maintenance, management and monitoring

After construction is finished, maintenance, management, and monitoring are applied to ensure planning framework implementation. Related educational programs can also be engaged into this process.

3.4.7 Evaluation criteria

In these three cases, there are four common goals: habitat preservation and conservation, increase recreational opportunities, increase education programs, and the improvement of the local economy. In habitat preservation and conservation, acres of preservation or conservation areas are used by planning teams and practioners in the Firefly Trail as criteria for achieving

the goal. As for recreational activities, the number of users, adjacent property owner complaints, and accidents on the site will be included into the evaluation. Besides, education programs will be applied to evaluate if the program has achieved this goal. As to improving local economic, investment, local property value; cultural or historical tourism programs become the important criteria.

CHAPTER 4

GEORGIA RAILROAD - RAIL TO TRAILS

4.1 Introduction

This chapter is about the existing planning and construction status of the Firefly Trail project. The Athens-Clarke County intended to include the Firefly Trail as a part of the Athens greenway network and intends to incorporate ecological benefits in its planning.

The 2005 special-purpose local option sales tax (SPLOST) Rail-to-Trails project focuses on the Athens-Clarke County (ACC) section of the Firefly Trail. As the Firefly Trail (see Figure 4-1) Facebook page explains, “the Firefly Trail program will initially try to develop this trail along the historic Athens Branch of the Georgia railroad corridor as the first segment of a multi-purpose regional trail system that complements local community initiatives" (https://www.facebook.com/fireflytrail/info 2015). Along these lines, the trail "creates connections to home, work, school and play while building tourism, healthy recreation, and economic opportunities for Northeast Georgia communities (https://www.facebook.com/fireflytrail/info 2015)”. Along this historic railroad, this Rail-to-Trails project seeks to create alternative connections that encompass neighborhood, work place, school and community asset while attracting tourism, boosting economy, and creating a healthy, dynamic, and fun outdoor environment for northeast Georgia (http://www.fireflytrail.com/proposed-trail.html 2015).

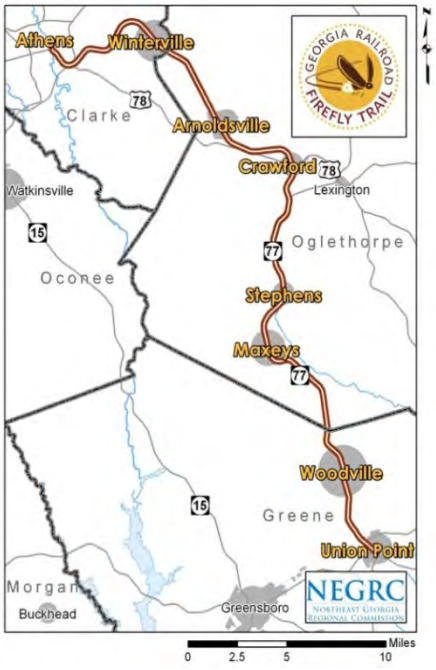


Figure 4-1 The Firefly Trail Masterplan

(https://www.facebook.com/fireflytrail/info 2015)

All rail-to-trail corridors are intended to provide multiple benefits to the communities where they are located. There are three fundamental uses identified for rail-to-trails; recreation, travel, and preservation and conservation for ecological benefits (Fowler 2009). The National Trails System Act also promotes rail corridor preservation and forms some state-level rail-to-trail programs (Fowler 2009) which are also the major goals of the Firefly Trail program.

4.1.1 Historical review

The Athens greenway development can be dated back to 1924 when Warren H. Manning, a landscape architect, designed the first greenway for Athens (Zaparnick 1998).

In the 1970's, Charles Aguar, a planner, designer and professor at the University of Georgia developed a greenway plan for the North and Middle Oconee River, which intends to preserve the natural habitats along the North and Middle Oconee River and help satisfy residents' recreational goals.

The Georgia Railway Athens branch is a 39-mile-long railway running from Athens to Union Point, GA (http://www.atlantarails.com/georgia-railroad-athens-branch.html 2015). There were railway stations situated in Athens, Winterville, Arnoldsville, Crawford, Stephens, Maxeys, Woodville, and a jointed station located at Union Point. The railroad began operation in 1847, and was abandoned in 1984 (Storey 2015).

4.1.2 Rail-to-Trails project

In 2012, ACC Department of Leisure Services applied the SPLOST program to sponsor this rail-to-trail project. The project plans to transform the existing historical railroad into a non-motorized trail suitable for diverse recreational activities. The budgeting indicated that $4,181,546 was needed to support design, construction and after-design implementation and management for the Athens-Clarke county part of the Firefly Trail planning (http://athensclarkecounty.com/2283/Project-29-Georgia-Railroad---Rail-to-Tr 2015). The mayor and commission applied the preliminary plan for the Firefly Trail on Aug 3th, 2010. The Firefly Trail plan had been divided into two segments for planning on August 31, 2012; the first segment starts from East Broad Road to Wilkerson Street. Its land acquisition, which was sponsored by 2005 SPLOST funding, was completed on June 30, 2009, and the trail

head plaza on the East Broad Street was finished on September, 2010 (http://athensclarkecounty.com/2283/Project-29-Georgia-Railroad---Rail-to-Tr 2015). The second segment is from Wilkerson Street to the old Winterville Road. The land acquisition will be funded by Federal Highway Administration High Priority Project Program Grant (FHWA) and its design and construction will be fulfilled by the Athens Clarke County Leisure Service, Planning Department and Georgia Department of Transportation (GDOT)(http://athensclarkecounty.com/2283/Project-29-Georgia-Railroad---Rail-to-Tr 2015). In this chapter, design principles and goals are set by the ACC Department of Leisure Services in 2012 and Greenway Network Plan created by ACC Leisure Services natural resource division in 2003.

4.2 Project location

The Firefly Trail is a program identifying a broad set of potential preservation, conservation, education, and recreational opportunities along the abandoned historic rail from Athens to Union Point, GA. The program is designed to provide guidance to ACC so that safe, healthy, and environmentally sound recreation and transportation for all residents, the linkage and other objectives of the program are realized over the long term.

4.3 Design goals

According to the Athens Clarke County Greenway Plan (2003), the major four goals of greenway program have been identified and ranked according to ecological priority; preservation and conservation, transportation, education, and recreation.

4.3.1 Preservation and conservation

The Firefly Trail intends to provide buffer zones between trails or paths and natural habitats, which will serve to filter water and air pollution, help preserve existing habitats, and enhance habitat quality. The interconnected greenway network for native plants and wildlife can be restored to promote rich biodiversity and continuing ecological corridors. Based on the proposed greenway network, the Firefly Trail can provide opportunities for wildlife to live in and move through the city and provide diverse native vegetation species thus increasing biodiversity. Existing natural habitats on site should be identified and incorporated in the master plan. To achieve this goal, the abandoned railway can be designed as a greenway which connected the nearby habitat fragmentations.

4.3.2 Transportation

This program will promote a transit system to connect major community facilities and assets, incorporating the existing public transit system and bicycle corridor network, encouraging non-motorized transportation for adjacent residents and commuters, while fostering healthy lifestyles (Athens Clarke County Greenway Plan 2003). To achieve this goal, the Firefly Trail can be used to link the existing public transit and bicycle network.

4.3.3 Education

Design programs and ordinances will be needed to guide self-oriented, easily accessible, and constructive educational programs concerning natural habitats, wildlife preservation, stormwater management, and conservation and restoration of cultural heritage (Athens Clarke

County Greenway Plan 2003). Meanwhile, facilities need to be designed to provide study and scientific research opportunities ranging from biology to zoology for nearby educational institutions, such as UGA.

4.3.4 Recreation

Design programs to provide an aesthetically welcoming outdoor environment for walking, jogging, cycling, and other recreational activities (Athens Clarke County Greenway Plan 2003).

4.4 Determine design zone

Zones are parcels along the abandoned rail which can be integrated into the design scope to contribute to ecological functions (Zonneveld 1989). According to the 2003 North Oconee River Greenway Network Plan, zones can be categorized into three types, based on their ecological functions: preservation, conservation, and transportation zones (see Figure 4-2). The Firefly Trail intends to connect with the North Oconee River Greenway, thus, the ecological zones for the Firefly Trail will keep using this system.

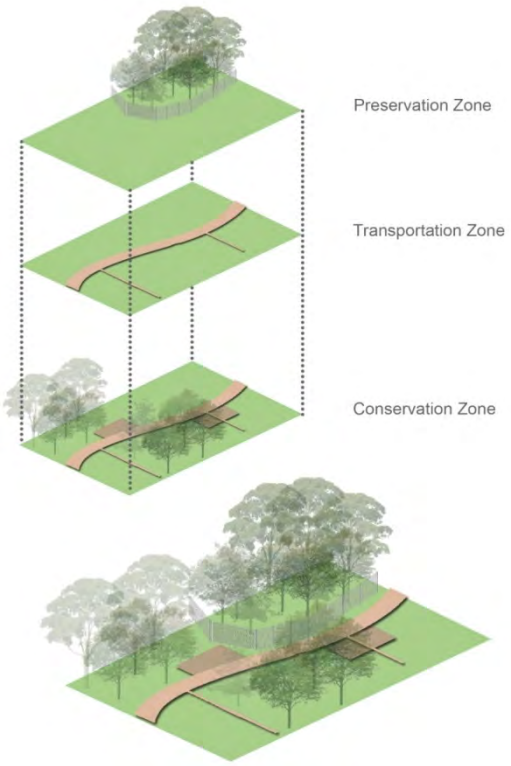


Figure 4-2 Three types of ecological zones

4.4.1 Preservation zone

Preservation zones consist of the endangered habitat. Preservation zones mainly protect existing habitats and prevent human interference through restricting activities on the site (Greenway Network Plan 2003). Only certain educational and research activities and restoration programs are permitted in this type of zone.

4.4.2 Conservation zone

This type of zone provides a transitional area between human recreational areas and natural habitats (Greenway Network Plan 2003). Conservation zones allow human interaction with natural resources and provide conservation functions such as stormwater management, wildlife conservation, and floodplain management (Greenway Network Plan 2003).

4.4.3 Transportation zone

The Transportation zone offers alternative transportation routes between neighborhoods, activity centers, and community assets along the trail, while also providing a connection for the entire length of the trail (Greenway Network Plan 2003).

4.5 Maintenance and management

According to the Athens Clarke County Leisure Services website, this Rail-to-Trails project needs $4,181,546 for research, analysis, design, and construction (http://www.athensclarkecounty.com/2283/Project-29-Georgia-Railroad---Rail-to-Tr 2015). However, there is no specific funding for ecological preservation and conservation, especially for wildlife habitat enhancement and wildlife migration. According to this design, more funding may need to integrate into this program.

According to the Firefly Trail Design, the implementation of the design program will be achieved through short term and long term. The short-term (0-3 years) goals will be:

1) Finish the Firefly Trail Framework and approved by the ACC mayor and commission.

2) Improve educational opportunities related to habitat restoration and preservation, water quality improvement, and negative impact of human pressure on ecosystem. Develop more public engagement programs for promoting a sense of community. Besides, alternative self-oriented routes will be provided for public and private, indoor and outdoor recreational activities.

3) Prevent endangered habitats from surfering human impact and conserve them for research and restoration use only. Protect and restore habitats and eliminate the invasive species on site (See Appendix A, Appendix B, Appendix C, and Appendix D).

4) Finish the trail construction and connect to the existing greenway system, public transit system, and bicycle path system in Athens.

The long-term (3-6 years) goals will be:

1) Improve facilities such as restrooms, bike racks, rest areas, and signage to facilitate the Firefly Trail's recreational benefits.

2) Expand restoration to low-priority habitats, and expand research areas to surrounding matrix; Replace the invasive species with the native vegetation.

3) Provide education and research opportunities for a wide range of users.

4.6 Conclusion

According to the 2014 Greenway Network Plan, the Firefly Trail has been identified as a high priority program which intends to connect Dudley Park, Athens Community Center, and the established North Oconee River Greenway, thus contributing to Athens Greenway Network connectivity. The network provides opportunities for multiple recreational activities, such as walking, jogging, hiking and bicycling. The Firefly Trail can provide a safe recreational space to a large portion of Athens' residential areas. Also, the newly enhanced habitat connectivity can provide homes and migration routes for wildlife. Since the Firefly Trail has been identified as a high priority trail corridor (the Athens Clarke County Greenway

Network Plan 2014), its construction, management, and funding will be supported by the ACC Leisure Services.

The Firefly Trail Program is sponsored by several agencies and groups, including the ACC Leisure Services Department, the ACC Planning Department, ACC Rails-to-Trails Committee, the Oconee Rivers Greenway Commission, the Northeast Georgia Regional Commission, the Georgia Department of Transportation and citizen-led volunteer groups (http://www.fireflytrail.com/proposed-trail.html 2015). These agencies work cooperatively with The Firefly Trail Inc. to identify the design scope and further necessary improvements. Once the design scope and the corresponding zones were identified and approved by the Athens Clarke County Planning Department, approved by the mayor and commission, individual parcels within the zones are analyzed, discussed, and identified to incorporate them into the design framework. At the same time, funding comes from the Federal Transit Administration (FTA) Grants for 2005 SPLOST project and the Federal Highway Administration (FHWA) grants for this Rail-to-Trails program. After design and plan framework have been established following the design standard set by the ACC Greenway Network, approved by the mayor and commission, detailed design of interactive facilities, habitats, and trails or paths will be developed (see Figure 4-3). In this thesis, only the design framework and detailed design are developed by the author in the next chapter. Athens-Clarke County Leisure Services Administrative Office, Athens-Clarke County Planning Department will implement the design. During implementation, community

engagement will be essential to ensure the long-term stewardship of the Firefly Trail Plan. The proposed stakeholders are Athens-Clarke County Mayor and commission, Athens-Clarke County Leisure Services Administrative Office, Athens-Clarke County Planning Department, Firefly Trail incorporation, Northeast Georgia Regional Commission (NEGRC), Athens-Clarke County Rails-to-Trails Committee, The Oconee Rivers Greenway Commission, Local neighborhoods and volunteers, and citizens and visitors.

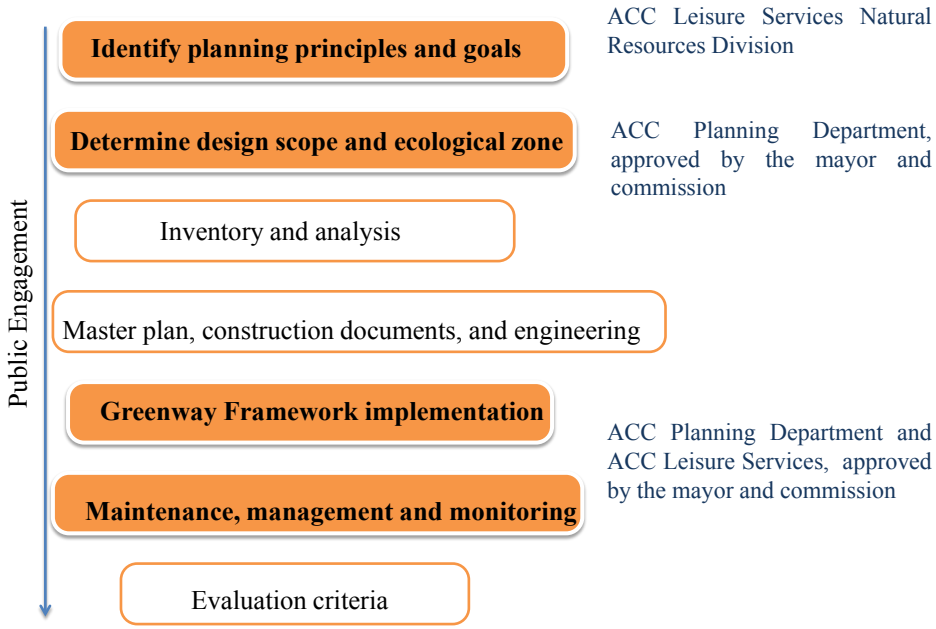


Figure 4-3 The Firefly Trail Planning Framework (based on Chapter 4)

The ACC Planning Department and Leisure Services Department have applied this greenway corridor to connect the existing matrixes and neighborhoods by providing trails for preservation and conservation, transportation, education, and recreation.

CHAPTER 5

THE FIREFLY TRAIL PLANNING FRAMEWORK (BY AUTHOR)

5.1 Existing conditions and design considerations

The Firefly Trail Planning Framework, which developed based on greenway principles and case studies, provides a specific planning process for this Rail-to-Trails program. To achieve the proposed ecological goals, the following objectives are identified:

1) Improve or preserve the existing migration corridors for the wildlife

2) Maximize natural habitat size

3) Remove the invasive species and replace them with the native species

4) Increase diversity of plants

5) Increase ecological education opportunities

For wildlife, this program intends to provide uninterrupted habitats and migration routes through the city. Because of this, the barriers like highways need to be removed to accommodate wildlife movement and migration. If removal is impossible, new transportation corridors should be established to facilitate wildlife conservation. To reduce the side effect, this greenway should be designed as wide as possible. Animal procreation, resting, and the gathering sites on the trails should be connected within a short distance to eliminate the side effect of habitat fragmentation. At the same time, since the habitats along the greenway will

support urban wildlife, the proposed vegetation must provide shelter and food for wildlife to thrive.

According to field surveys by the author, 75% of the proposed site is now occupied by invasive plant species, indicating that the very first step of implementation and management should be to remove the invasive plants and replace them with diverse native vegetation, similar to the Baird Creek Greenway in Chapter 3. Then, community-based restoration activities, such as native plants, stormwater management, and on-going native plants management, can be engaged to help preserve and restore the habitats. Human activities should be appropriate to site conditions, and compatible with habitat conservation goals. Thus, the whole Firefly Trail will act as a buffer zone between the recreational areas and the natural habitats to minimize human pressure on nature.

5.2 Guiding design principles

According to Athens Clarke County Greenway Design Standard, 2003, transportation trails can be separated into two types based on field conditions (see Figure 5-1).

Types	Trail	Path
Material	Mineral soil, wood chips, and soil stabilizer	Crushed stone, asphalt, and concrete
Usage Frequency	Low to medium	Medium to high
Standard	NTA, NRPA	ADA
Other	Additional facilities are required.	

Figure 5-1 Two types of trails based on field conditions

5.3 Determine design scope

The Firefly Trail planning framework, which is developed by the author, applied the ACC existing land use map (see Appendix E), future development map (see Appendix F), and 2014 Greenway Network Plan (see Appendix G) as guides to determine the proposed design scope. The former railbed is already marked by ACC and the design boundaries range from a 1/4-mile to 1/2-mile distance from the former railbed of the Georgia Railroad. This program not only provided natural spaces for recreational use and public access to the open space, it also connected existing forest resources (see Appendix H), wildlife habitat, and native vegetation. In this way, the local water resource map (see Appendix I), existing open space map (see Appendix J), forest resource map (see Appendix K), and topographic map (see Appendix L) are used to produce new connections between habitats, and the community map will be applied to increase community connection and regional connection.

5.4 Segments

The analysis and planning unit of this section is the segment. In each segment, specific problems are identified and need to be addressed by the design solutions. The intersection of North Main Road and Winterville Road in Winterville marks the route's starting point as it begins toward Athens. From there the route finishes at the intersection of Oak and Oconee Streets near downtown Athens (Oak/Oconee Street Corridor Study 2012). Segment 1 is connected with downtown area and the existing Dudley Park and North Oconee River Greenway. Segment 2 has traditional neighborhood centers which can be incorporated into

the planning. Segment 3 is a vehicle corridor which mainly has business and employment landuse. Segment 4 is mainly rural residential and agricultural land. These streets and roads face the pressure of development, on the one hand, and ecological and cultural preservation concerns on the other. To balance both the existing and future needs, the plan combining future economic, transportation, and residential development needs, as well as taking ecological preservation and conservation into account, is needed.

5.4.1 Segment1 the classic center-creek trail- S poplar St

Figure5-2 Trail Head Plaza of the Firefly Trail

The Trail Head Plaza is the starting point (see Figure 5-2) of the Firefly Trail. The restaurants, music pubs, and diverse shops in the classic center and Athens downtown bring potential users of the proposed trail. According to the ACC official land use map (2005), the starting point will contain downtown Athens, which includes high-density housing, retail, restaurant, and office uses. Within a 1/4 mile from its start, the trail goes south to the Oconee

River and merges into the existing trail in the Oconee River Park. The trail curves into a basin space before arriving the S Poplar St.. At the end of this segment stands the only remaining trail creek trestle (see Figure 5-3).

Figure 5-3 The only remaining trail creek trestle

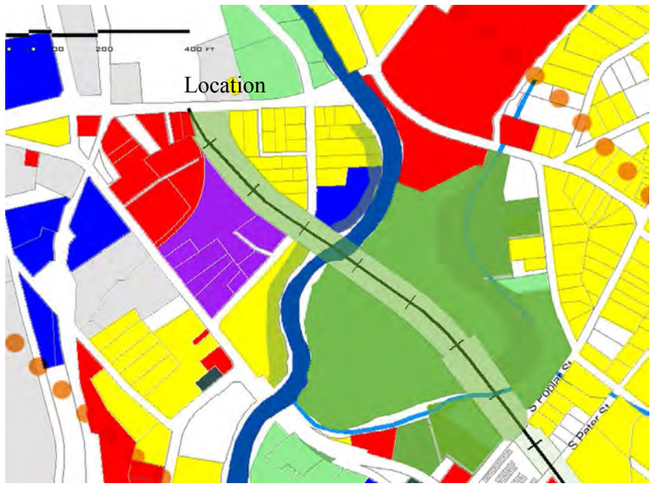
To preserve this historical railroad, the ACC decided to build a bridge which is 35' high above the river across the river to preserve the historical view of the site (The Firefly Trail website 2015). According to the author's site survey, the dominant species on the site are: Loblolly Pine, Black Locust, Pignut Hickory, Dogwood, Pecan, Water Oak, English Ivy, Redbud, Burning Bush, River Birch, Cedar, Mulberry, Red Maple, Athens-Clarke Squirrels, Eastern chipmunk, Blue Jay, Great Crested Flycatcher, Cardinal, Carolina Wren, American Robin (see Appendix M). However, the site was about 45% occupied by the invasive species.

This segment has a wide range of landuse and be connected with the street commercial areas of Oconee/Oak Street, the dwelling areas, the Dudley Park, and the existing North Oconee River Greenway. Thus, this segment is considered as the most important corridor in the urban area (The Jaeger Company 2006).

To achieve preservation and conservation goals, the proposed trail (see Figure 5-4) will leave at least 20 feet buffer zones from the business areas, and be facilitated with service facilities such as restrooms, benches, and rest areas. Also, buffer zones will be engaged into the trail design to minimize human pressure on the natural habitats (see Figure 5-5, Figure 5-6). To restore the existing habitats, the invasive species should be removed before replacing them with the native species. The selection of the native species is based on the author's site inventory (see Appendix M). These design ideas emerged from Chapter 3. To address the transportation issues and provide linage to the existing open space, the proposed trail will connect with the existing Oconee River Greenway, and the North Oconee River greenway to attract the residents from the west and east side of the trail. The end of this segment will be tied with main street business areas to connect the Oconee/ Oak Street. Meanwhile, education signage can be incorporated into this trail to convey historic and ecological knowledge. These installations will encourage an identity of the local place through informing local heritage and habitat preservation and restoration activities.

Figure 5-4 Proposed trail design for the segment 1

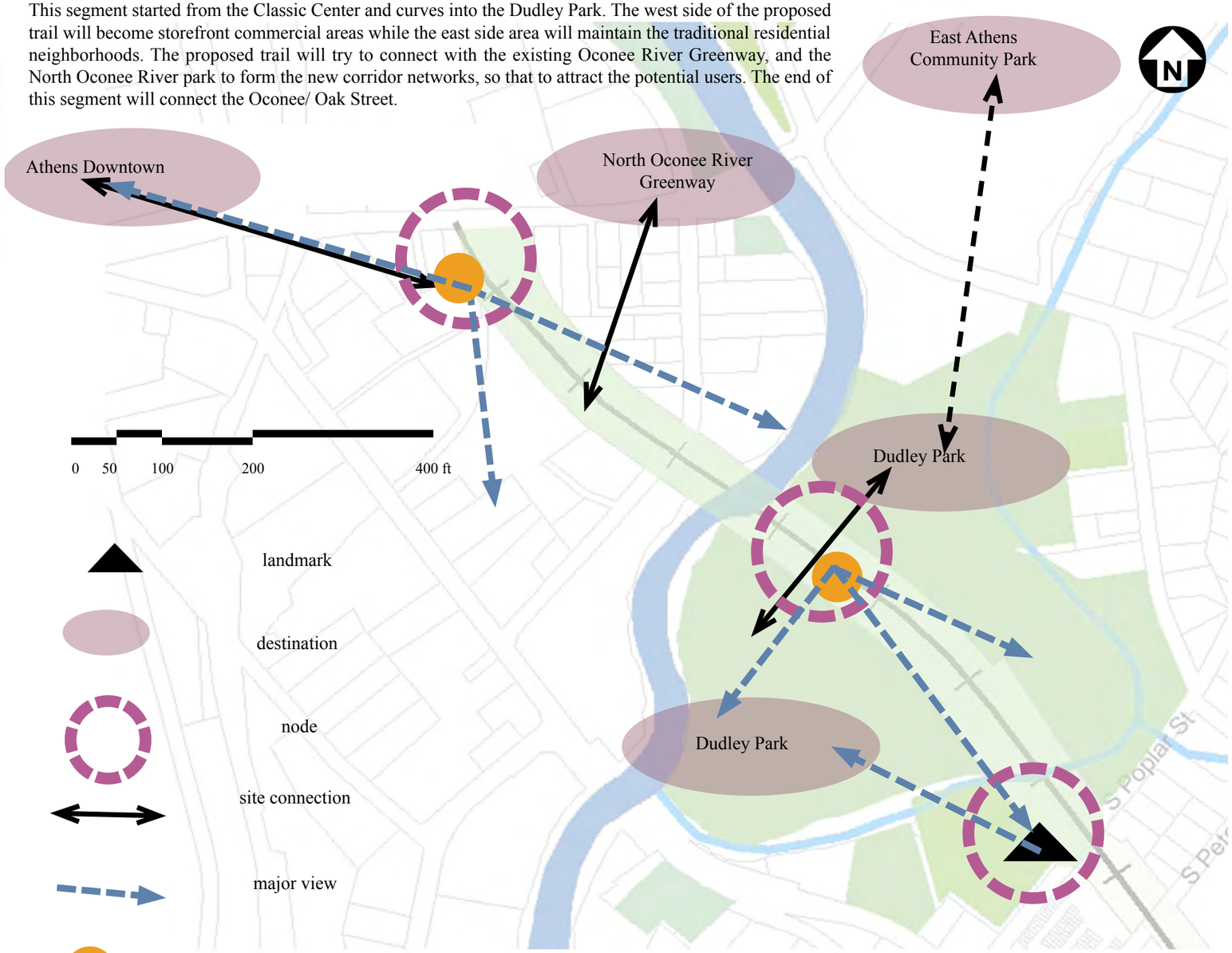
Segment 1 the classic center-creek trail- S poplar St



Existing Landuse for Segment 1

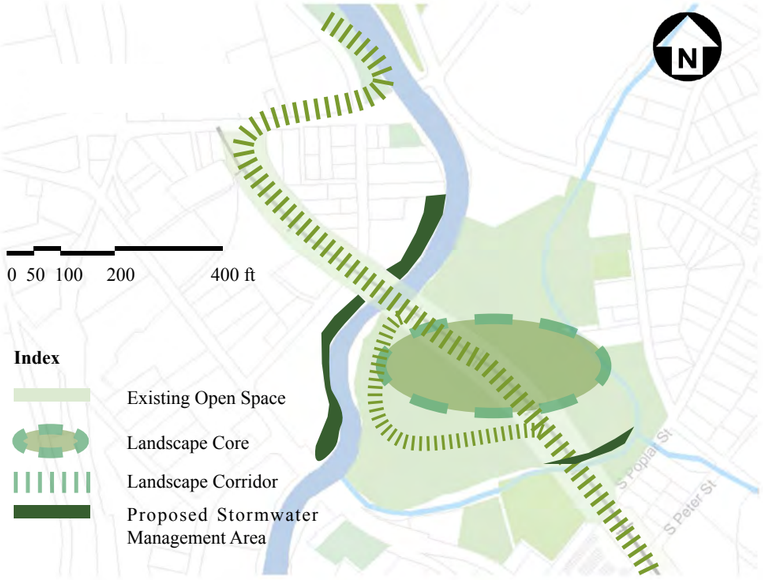
Length: 0.4 mile
Highest elevation: 641.8 ft at 0 mile
Lowest elevation: 620 ft at 0.1 mile

This segment started from the Classic Center and curves into the Dudley Park. The west side of the proposed trail will become storefront commercial areas while the east side area will maintain the traditional residential neighborhoods. The proposed trail will try to connect with the existing Oconee River Greenway, and the North Oconee River park to form the new corridor networks, so that to attract the potential users. The end of this segment will connect the Oconee/ Oak Street.



Program Concept for Segment 1

Figure 5-5 Masterplan for Segment 1 (part 1)



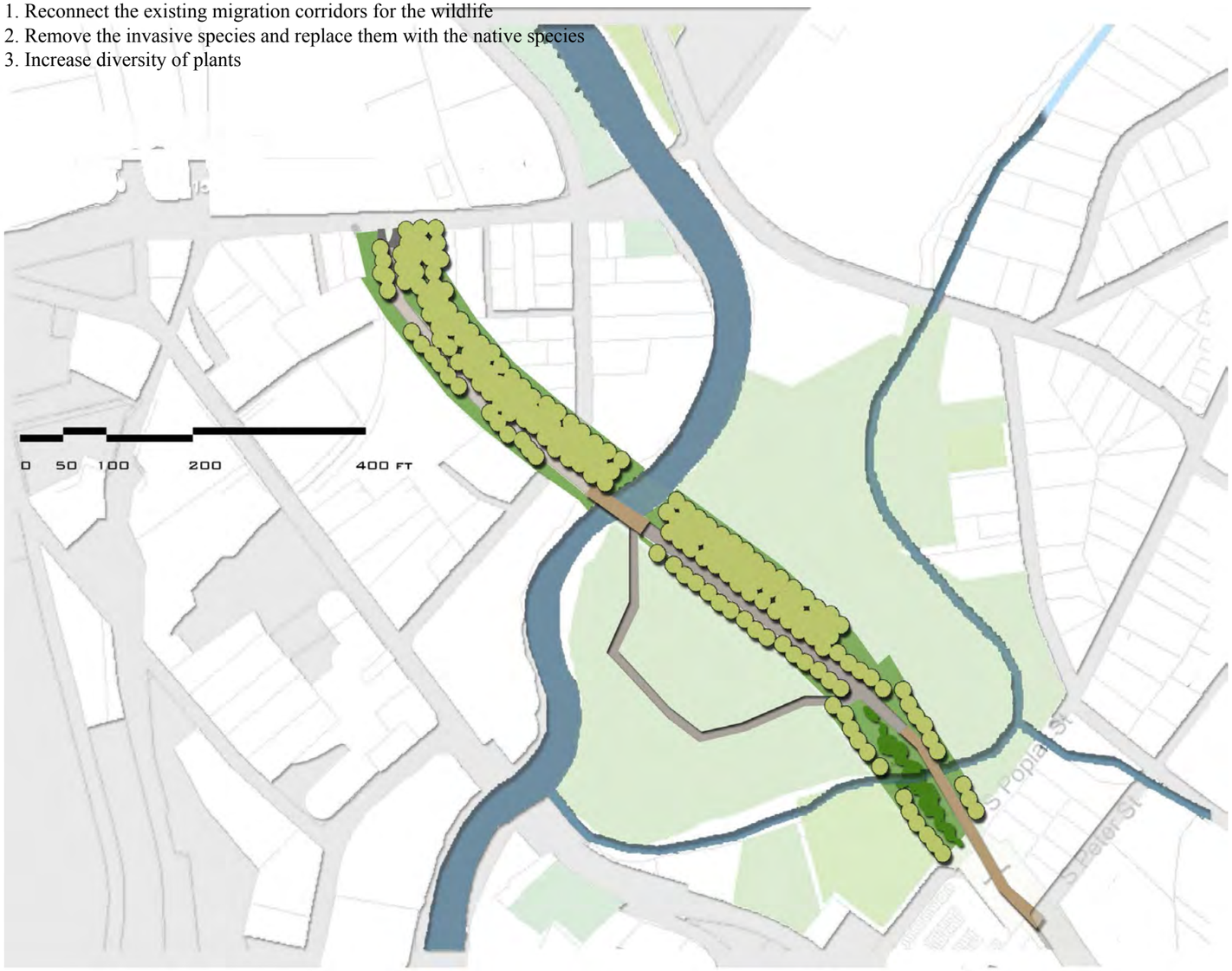
Open Space Use

Segment 1
According to site survey, the vegetation of segment 1 is suffering from the following issues:
1. Lack of sequence
According to site survey, most of vegetation species are canopy trees. There are no enough medium shrub layers, herb layers, and ground covers to display the planting composition change.

2. Only a few of the plants are for edible uses
Native edible plants provide an important link for butterflies, bees, birds, and mammals in the food chain. However, there are only a few native plants on the site which produce fruits for wildlife to support local food web.

3. Occupied by the invasive species
About 45% of the vegetated sites are occupied by the invasive species, such as Tree of Heaven, English Ivy, Paper Mulberry, Japanese Honeysuckle, and Mimosa. These plants will spread quickly to endanger other native species and wildlife.

Strategies:
1. Reconnect the existing migration corridors for the wildlife
2. Remove the invasive species and replace them with the native species
3. Increase diversity of plants



Proposed Plan for Segment 1

Figure 5-6 Masterplan for Segment 1 (part 2)

5.4.2 Segment 2 S Poplar St-end of little Oak St

Segment 2 starts from S Poplar St and goes up to a 15’ high mound behind the Tailgate center to S Peter St. Then, the trail follows Little Oak St before crossing the intersection of which is one of the main gateways into the Athens. This segment connects two neighborhood centers on the Vine Street and the Little Oak Street. Since the proposed trail will go across a heavily traveled road, the wildlife migration activities should be put to the priority through building a new trail to accommodate them. The proposed site has steep slopes (see Figure 5-7) on the both sides. Thus, steep slopes stabilization and soil erosion control are needed. To restore the proposed site to eliminate the invasive species, the slope and invasive vegetation issues will be addressed through designing and management. The dominant species are White Oak, Loblolly pine, Shortleaf pine, Water oak, Rhus, Box Elder, Cardinal, American Robin, Eastern chipmunk (see Appendix N).

Figure5-7 The existing site condition

The design of the proposed trail (see Figure 5-8, Figure 5-9) connects the nearby neighborhoods and street business areas and provides public access into the site while restoring the existing degraded habitats on this segment (see Figure 5-10, Figure 5-11).

The proposed segment enhances the connectivity between the existing neighborhoods and nature by providing a linear ecological corridor. The paved trail provides recreational open space for local residents to get close to the nature and conduits for human movement. Wooden board can be used to minimize human impact and preserve the sensitive natural habitats. The threat of the invasive species is extremely serious that triggered the native habitat destruction. To restore the existing habitats and use them for educational purpose, the nearby residents can be engaged in experiential learning in their own local neighborhoods (Hellmund and Smith, 2006).

Oak Street

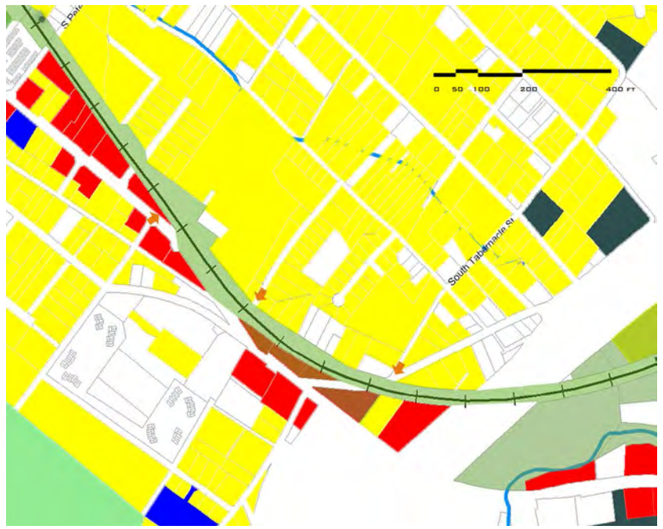
Figure 5-8 The proposed trail connects with the existing neighborhoods

Little Oak St

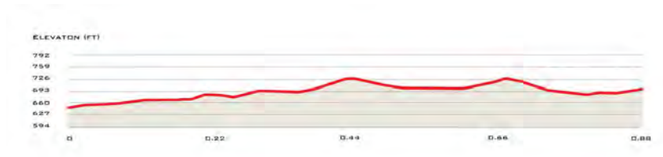
Figure 5-9 The proposed trail connects with the existing neighborhoods and business districts

Segment 2 S Poplar St-end of little Oak St

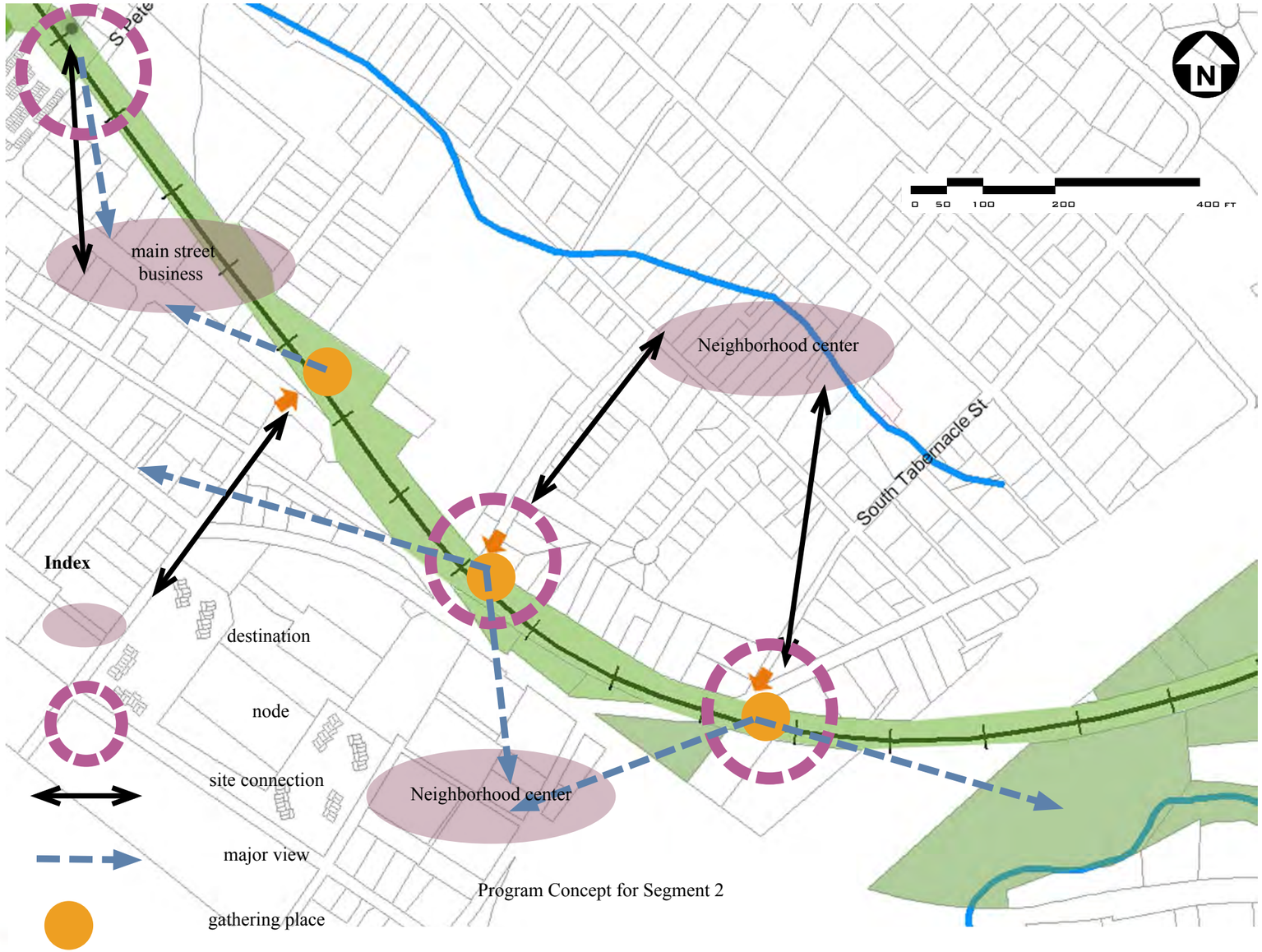
Location



Existing Land Use



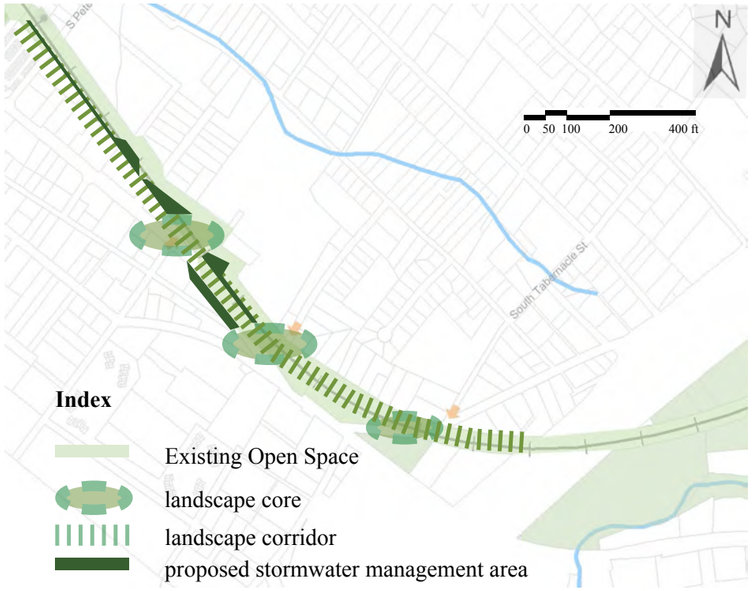
Length: 0.88 mile
Highest elevation: 730.8 ft at 0.69 mile
Lowest elevation: 643 ft at 0.00 mile



Program Concept for Segment 2

This segment connects two neighborhood centers on the Vine Street and the Little Oak Street. Since the proposed trail will go across a heavily traveled road, the wildlife migration activities should be put to the priority through building a new trail to accommodate them. The proposed site has steep slopes on the both sides. Thus, steep slopes stabilization and soil erosion control are needed. To restore the proposed site to eliminate the invasive species, the slope and invasive vegetation issues will be addressed through designing and management.

Figure 5-10 Masterplan for Segment 2 (part 1)



Open Space Use

Proposed Plan for Segment 2

Strategies:
1.Reconnect the existing migration corridors for the wildlife
2.Remove the invasive species and replace them with the native species
3.Restore the existing habitats

Figure 5-11 Masterplan for Segment 2 (part 2)

5.4.3 Segment 3 Winterville St-Springvalley St

This segment can be divided into two parts based on its main land use. The landuse from the end of Little Oak Street to the starting point of the Winterville Street is corridor business use. This part of the corridor is vehicle dependent corridor without pedestrian amenities and has inconsistent bike lanes. The second part, which is a suburban mixed use corridor, starts from the Winterville Street to the Springvalley Street. According to 2005 the Official Future Land Use Map of Athens-Clarke County, the employment use areas are large. The proposed trail follows the historical railroad after crossing the Oconee/Oak Street and then parallels the Winterville St. The Athens Ben App Airport is on the east side of the site. Also a tributary of the North Oconee River is on the east side. This segment is a transitional area from the city landscape to the rural landscape with limited pedestrian amenities, including sidewalks. The major species are Longleaf Pine, Red Oak, Shortleaf Pine, Loblolly Pine, Tree of Heaven, Paper Mulberry, Mimosa, Chinaberry, Pecan, Redbud, Northern Red Oak, Water Oak, and Kudzu, Rufous-sided Towhee, Cardinal, American Robin, Eastern chipmunk, Raccoon (see Appendix O).

The design of the proposed trails (see Figure 5-12) intends to minimize the trails' footprint on the natural resources (see Figure 5-13, Figure 5-14). However, there is a heavily traveled intersection in segment 3; the natural habitats may be disconnected there. However, another form of connections, such as overpass and underground route, can be proposed.

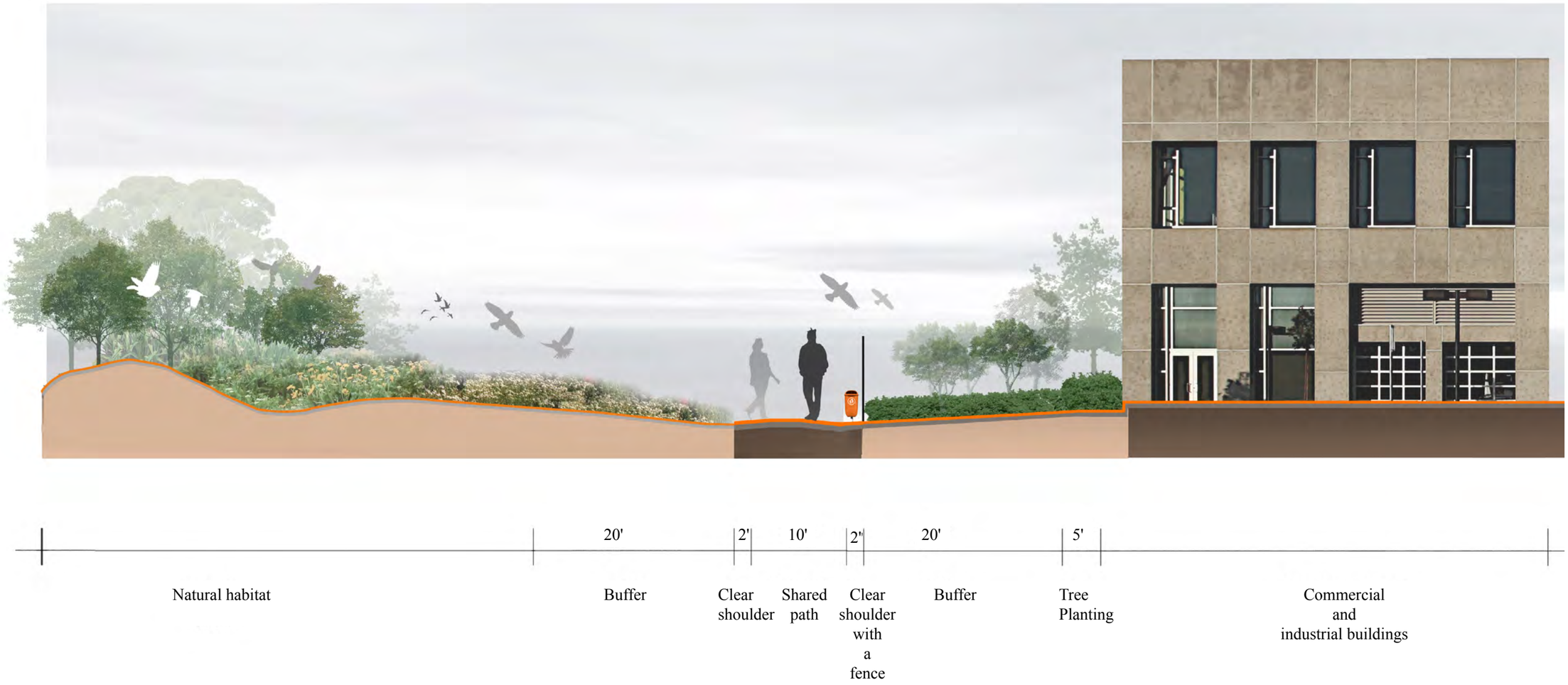
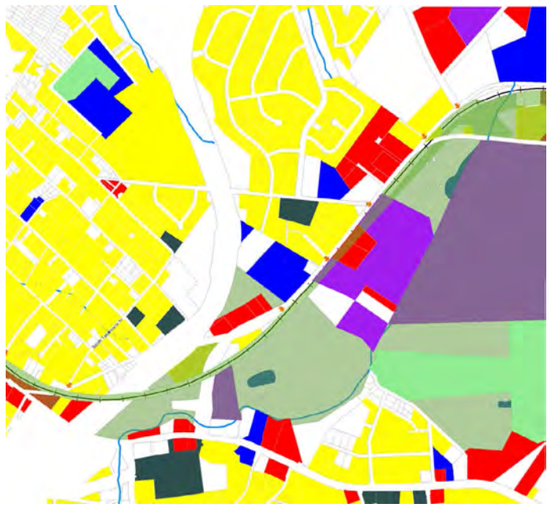


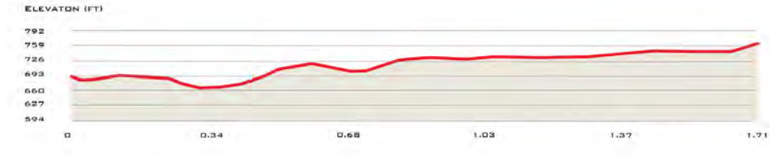
Figure 5-12 The proposed trail connects with industry, office, and research parks

Segment 3 Winterville St-Springvalley St

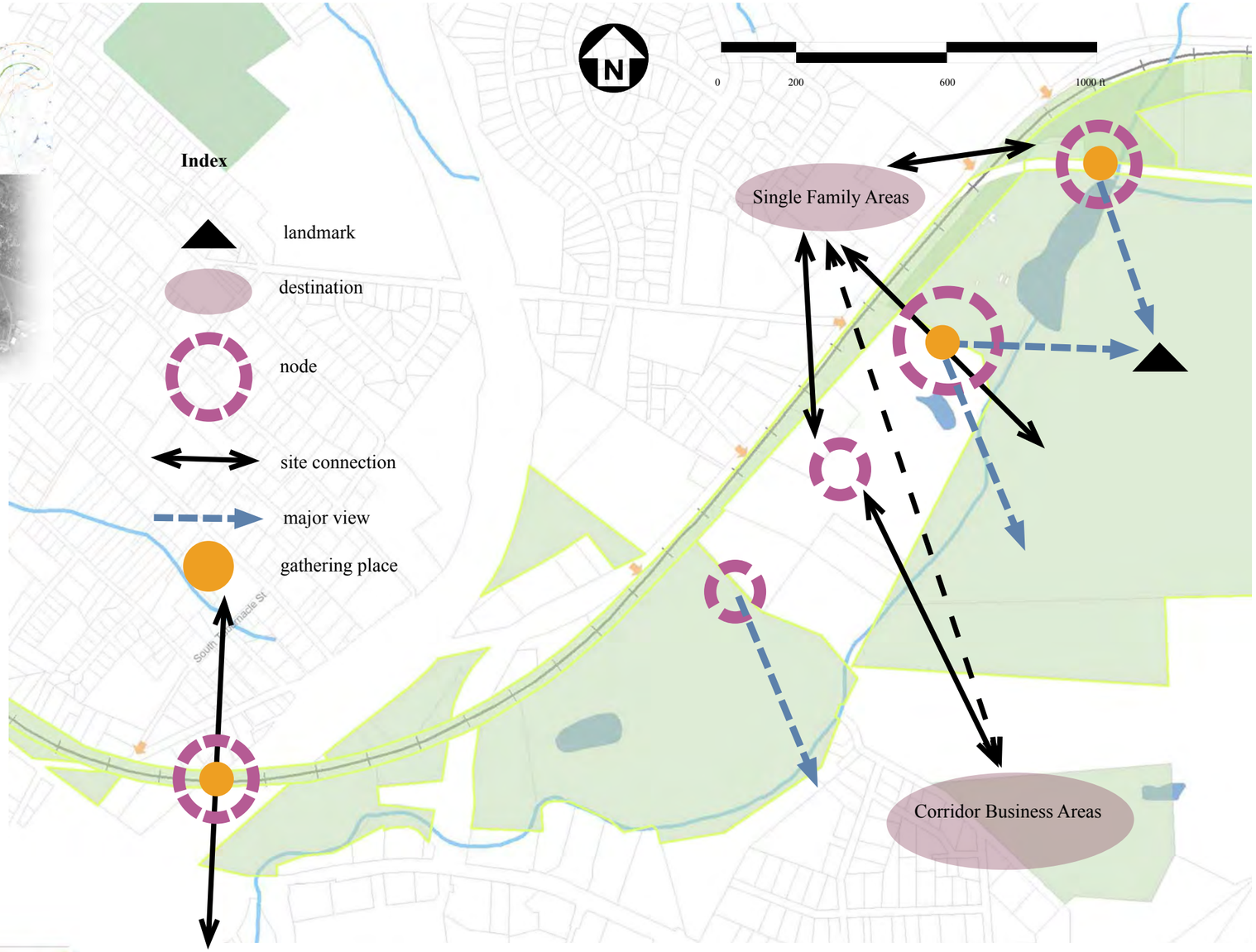
Location



Existing Land Use



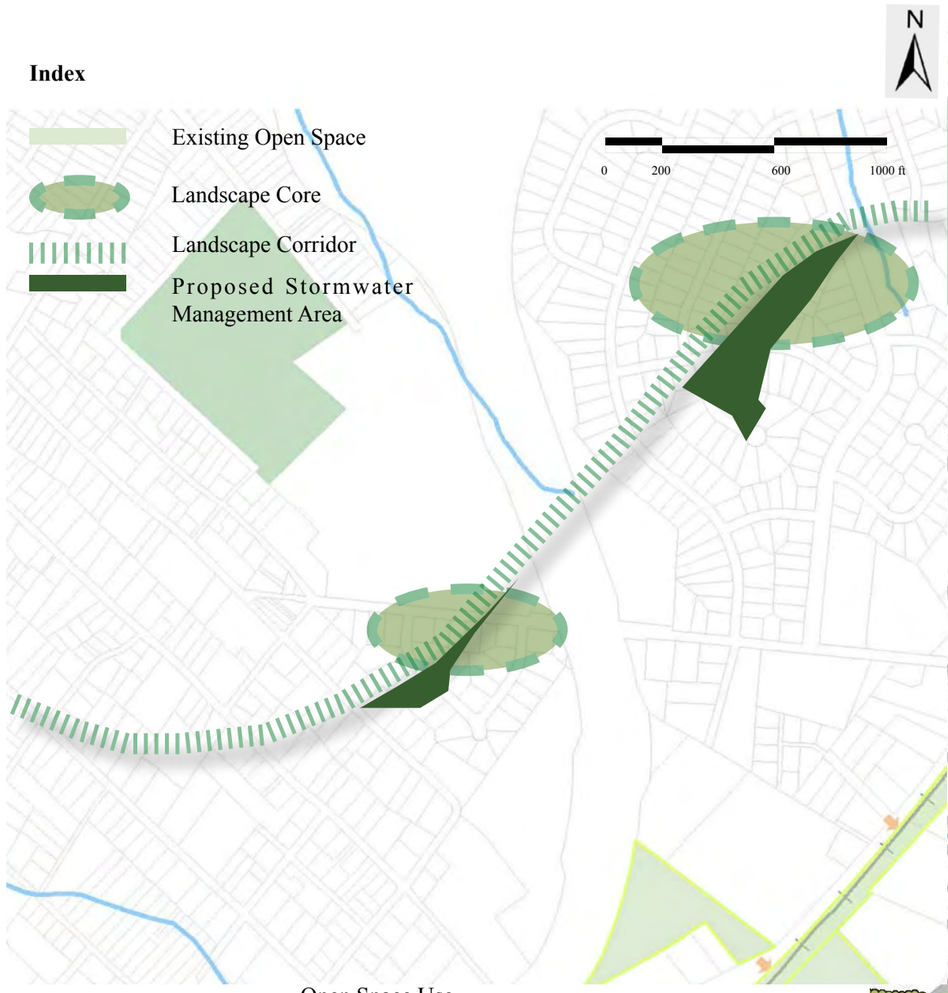
Length: 1.71 mile
Highest elevation: 769.5 ft at 1.71 mile
Lowest elevation: 660 ft at 0.30 mile



Program Concept for Segment 3

This segment can be divided into two parts based on its main land use. The landuse from the end of Little Oak Street to the starting point of the Winterville Street is corridor business use. This part of the corridor is vehicle dependent corridor without pedestrian amenities and has inconsistent bike lanes. The second part, which is a suburban mixed use corridor, starts from the Winterville Street to the Springvalley Street.

Figure 5-13 Masterplan for Segment 3 (part 1)



Open Space Use

Strategies:
1.Increase educational opportunities.
2. Add more recreational facilities.

Proposed Plan for Segment 3

Figure 5-14 Masterplan for Segment 3 (part 2)

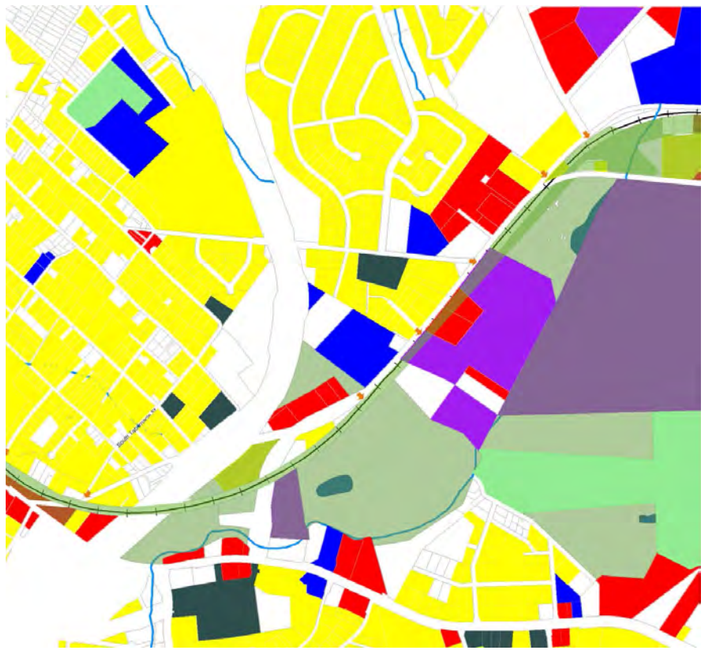
5.4.4 Segment 4 Springvalley St-Winterville, GA

This segment curves into Winterville, GA with landuse types shifting from suburban commercial landuse to the rural residential or agricultural landuse. The rural and employment lands are main landuse types in this segment. The rural areas have one unit for each five acres, which results in larger parcels with relatively lower density. Most of the open spaces, woods, or lawns will be kept for preservation or conservation use. Most of the open space will be kept for preservation and conservation use. Also, agricultural uses along with golf courses, hunting clubs, etc. are permitted (The Official Future Landuse Map of Athens-Clarke County, 2005). According to Athens Clarke County Recommended Character Areas Map, the Springvalley Street will experience road widening and intersection realignment to make it safer for the users. The major species are Water Oak, Red Maple, White Oak, Sugar Maple, Virginia Pine, Sweetgum, Loblolly Pine, Southern Magnolia, Mimosa, Redbud, Great crested flycatcher, American Woodcock, Rufous-sided Towhee, Cardinal, American Robin, Black Rat Snake, Athens-Clarke Squirrels, Eastern chipmunk, Cottontail Rabbit, Raccoon (see Appendix P). The proposed trail (see Figure 5-15) will provide a scenic corridor for non-motorized users (see Figure 5-16, Figure 5-17).

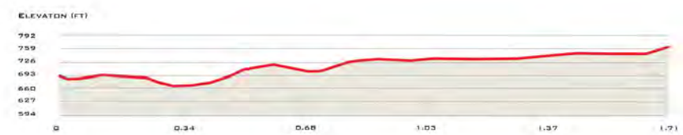
Figure 5-15 The proposed trail connects with the existing open space

Segment 4 Springvalley St-Winterville, GA

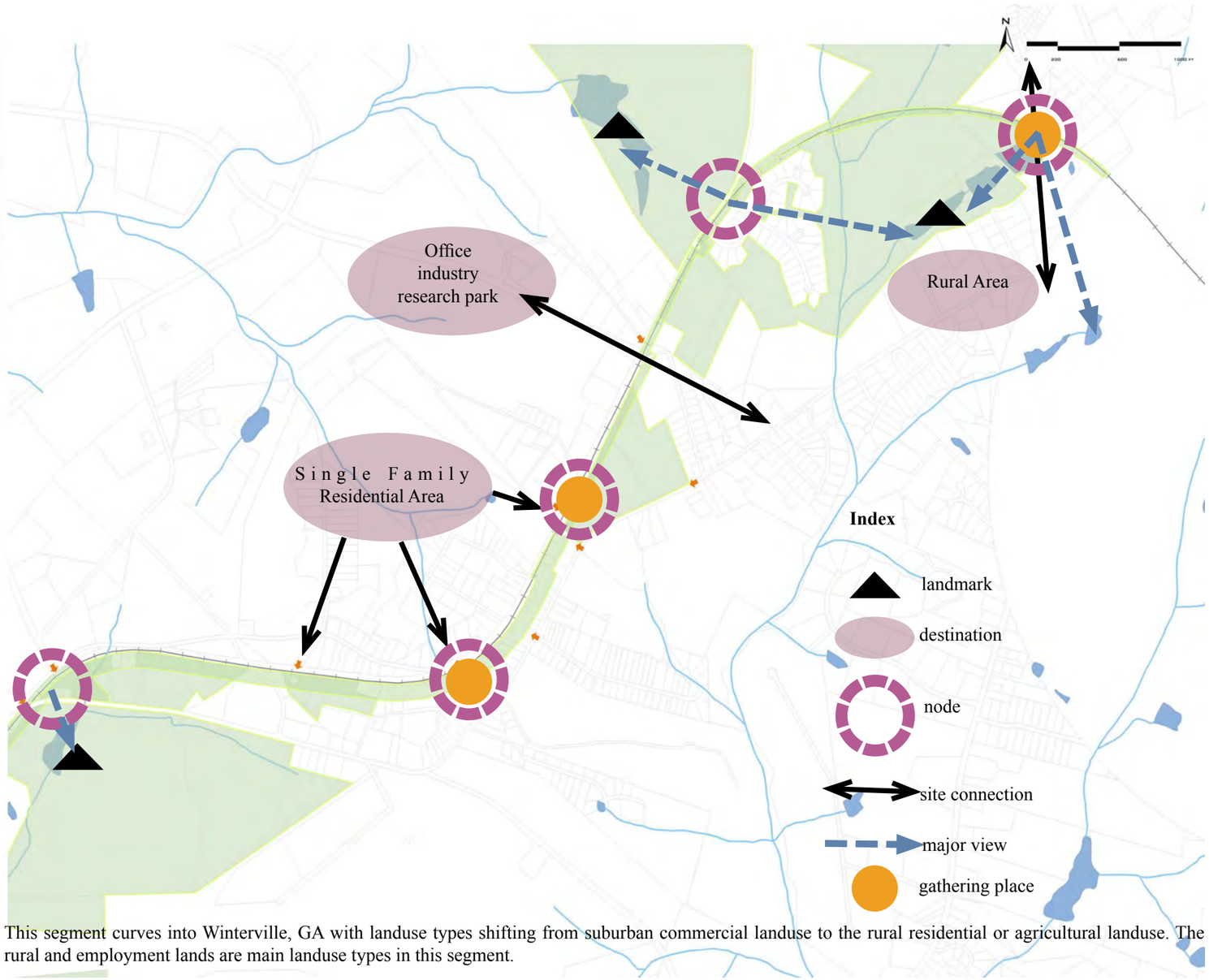
Location



Existing Land Use



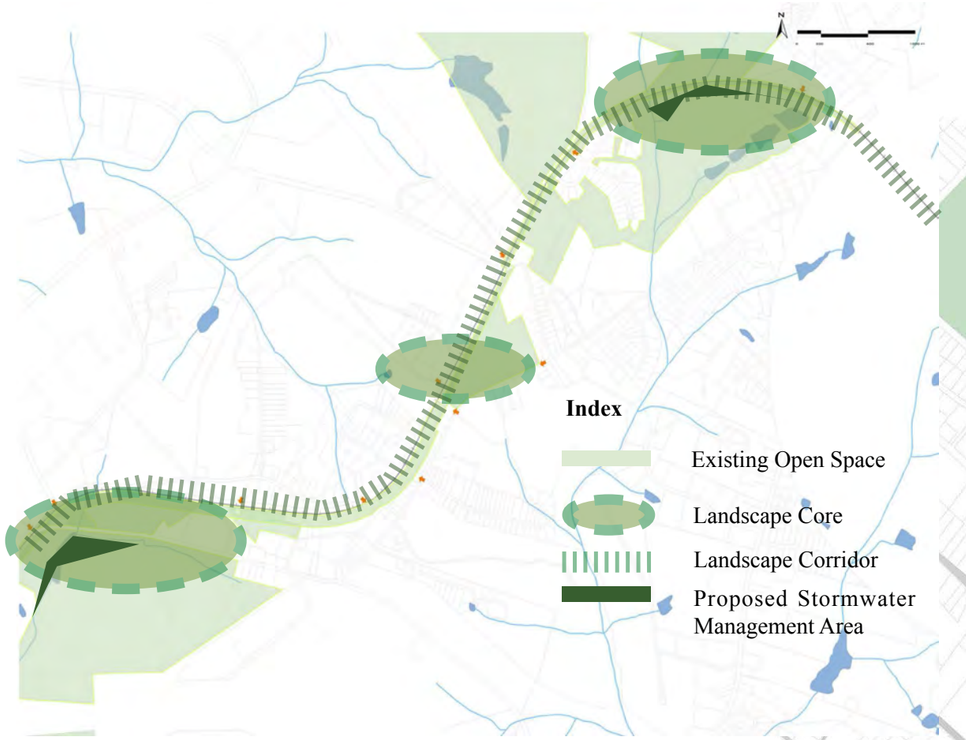
Length: 1.71 mile
Highest elevation: 769.5 ft at 1.71 mile
Lowest elevation: 660 ft at 0.30 mile



This segment curves into Winterville, GA with landuse types shifting from suburban commercial landuse to the rural residential or agricultural landuse. The rural and employment lands are main landuse types in this segment.

Program Concept for Segment 4

Figure 5-16 Masterplan for Segment 4 (part 1)



Open Space Use

Proposed Plan for Segment 4

Strategies:
1. Increase educational opportunities+ recreational facilities.
2. Improve or preserve the existing migration corridors for the wildlife.
3. Maximize natural habitat size.
4. Remove the invasive species and replace them with the native species.
5. Increase diversity of plants.

Figure 5-17 Masterplan for Segment 4 (part 2)

5.5 Master plan

See Figure 5-18, Figure 5-19, and Figure 5-20

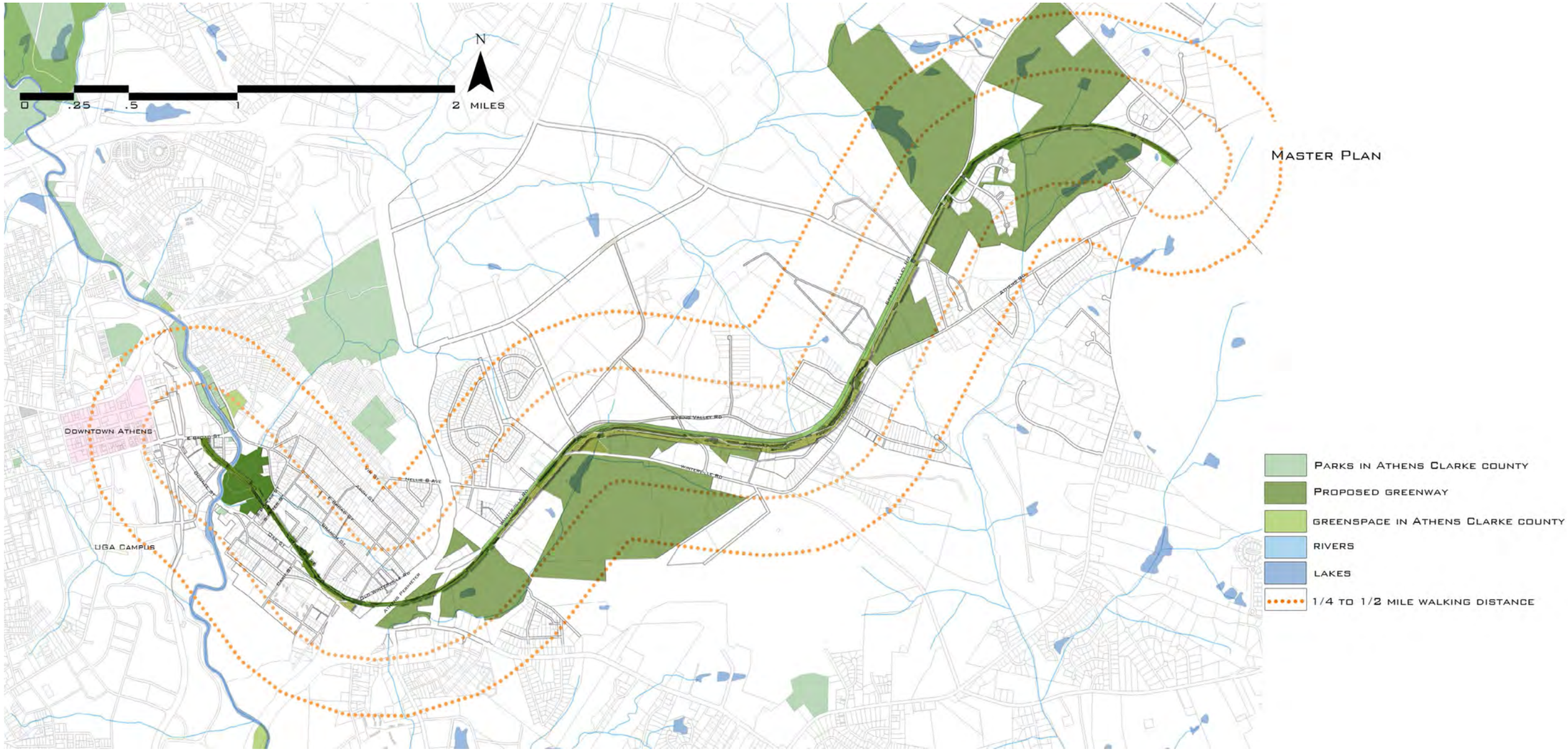


Figure 5-18 The Firefly Trail Masterplan

Figure 5-19 The Firefly Trail Ecological Zones Map

Figure 5-20 The Firefly Trail Facility Map

5.6 Evaluation criteria

The evaluation criteria are developed based on Chapter 2 and Chapter 3 and used to evaluate planning, construction and its management. The criteria can be classified into four categories based on their corresponsive goals: preservation and conservation, transportation, education and recreation. See Appendix Q, Appendix R, Appendix S, and Appendix T for the specific objectives.

5.7 Conclusion

Since the Firefly Trail can be used to achieve four major goals: preservation and conservation, transportation, education, and recreation, its design framework should be set up according to the existing landuse, future development goals, community facilities, the proposed greenway network plan as well as a transportation network plan which has been developed by ACC Planning Department. Then, according to soil type, topography, tree cover, and special areas, native plants, trails, gathering space, and facilities were designed to fulfill design goals.

However, several challenges need to be figured out. Firstly, there is a heavily traveled intersection in segment 3; the natural habitats may be disconnected there. However, another form of connections, such as overpass and underground route, can be proposed. Secondly, the post-design ecological performance is still unclear, so that the future supervision and management are never completed and needed to perform consistently. Thirdly, education

programs are required to involve more users in this program. In face of issues like traffic barriers towards wildlife migration, human disturbance, habitat degradation, and the increasing spread of the invasive species; the major design goals and their objectives intend to restore habitat integrity, minimize human impact, connect habitat fragments for wildlife and native plants, and finally contribute to the Athens Greenway Network. In the proposed design, a minimum 20 feet vegetation buffer zone was used to separate outdoor activity space and the natural habitats in this site. Meanwhile, natural habitats were separated into two categories based on preservation goals. For the preservation zones such as sensitive and endangered habitats, human activities will be confined and only be permitted for research and conservation use. As to the less sensitive habitats, human activities are encouraged and guided by signage and educational programs in relation to habitat preservation and conservation, wildlife preservation, and negative impact of human disturbance. The proposed corridor can connect adjacent open space to create green hubs for both human and wildlife. These green hubs can also act as homes and migration trails for wildlife through providing shelter, food, water, and space for them. Also, due to the time limitation of this thesis, public engagement into the next design step was unable to achieve. In the real design process and implementation, public engagement can be achieved through training workshop, newsletter, communication, public meeting and participation through the whole design and implementation process.

When combing recreation with ecological conservation and preservation, design solutions and its implementation are required, however, improving ecological awareness of

the users is also indispensable. The design framework in Chapter 4 offers two types of trails and related facilities to meet with different amounts of uses. Trails are designed for less to medium use and paths are designed for medium to high uses. Education programs, such as preservation and conservation program, outdoor classroom, native vegetation planting, and stormwater management as well as the educational signage could be actively engaged in application. The proposed trail increases public access through providing entrance points for the adjacent neighborhoods, connecting the community facilities and existing bicycle lanes, and providing gathering place for outdoor activities. Besides, management in respond to safety issues, repair, maintenance, and monitoring should be performed by the public and private agencies, such as Athens Clarke County Planning Department and the Firefly Trail Incorporation (See Figure 5-21).

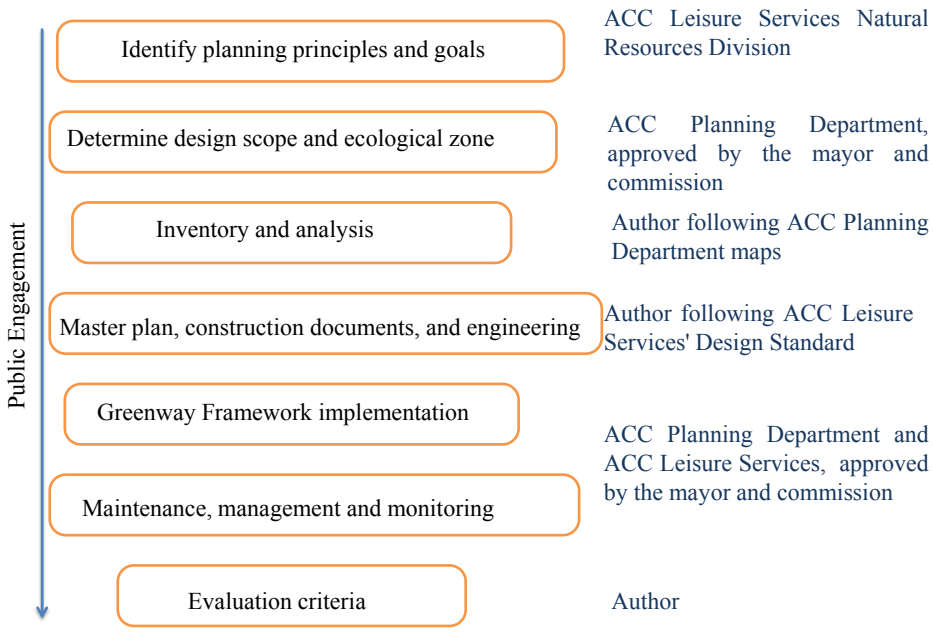


Figure 5-21 The Firefly Trail Planning Framework

CHAPTER 6

CONCLUSION AND SUMMARY

A number of cases in the U.S. have shown that rail-to-trail transfers can serve to create recreational opportunities for jogging, cycling, and walking. Design theory and strategies generated from Chapter 2 and Chapter 3 show the potential for combining conservation and recreational goals in developing rail-to-trail projects, to support the validity of such a concept, and finally to apply a design framework for putting these ideas into practice. The Firefly Trail Design Framework set up in Chapter 5 followed the form of a greenway showing how its design can allow for harmonious use by both humans and wildlife. The proposed greenway has habitat, conduit, sink and source functions which can provide shelter, movement routes, necessary food and resources for wildlife. Also the Greenway itself can act as an ecological corridor which connects the habitat fragmentation on this site and enhance regional habitat integrity.

The Firefly Trail Program can also provide recreational benefits as well as ecological benefits by integrating greenway design theory into its design framework. In Chapter 5, the proposed design draws on the ecological knowledge which stems from Chapter 2 and Chapter 3. Thus, conflicts between the recreational use and ecological preservation can be

addressed to maximize ecological functions, such as habitat, conduit, source and range and to minimize human interference.

Three real programs present a clear design framework on how to achieve ecological preservation while pursuing recreational benefits for greenways. This framework and specific design strategies have been involved in the design to maintain and enhance the Firefly Trail's ecological functions together with ecological theory of the greenways. In Chapter 4, the ACC Department of Leisure Services and Planning's existing design and construction status of the Firefly Trail is introduced and analyzed. Since it is still in the preliminary stage, only limited information can be accessed. In Chapter 5, a design framework was developed to help the ACC Leisure Services achieve the ecological goals as well as recreational goals. The design framework provides ecological benefits as well as recreational opportunities by removing invasive species, preserving the existing habitat, minimizing human impact, and providing education opportunities on ecological preservation and conservation. In this framework, the whole Firefly Trail is divided into four segments and applied diverse strategies to address the ecological issues on the site. Also, post-design management, design implementation and criteria are set by the author to ensure ecological benefits. This framework can be integrated into the Firefly Trail's future design and development.

To design rail-to-trail projects with ecological functions, design practitioners and teams should always start with setting the design goals and principles. Once they determine their design goals, they should conduct site inventory which includes information and data about

vegetation species, wildlife, invasive species, existing habitats, existing corridors, existing neighborhoods, and basic site condition. They should always put priority to natural habitats' preservation and conservation while generating design framework. After construction, the design and construction will never completely completed, the rail-to-trails projects are still require constantly management and evaluation with the help of public engagement.

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APPENDICES

A Proposed species for the Segment1

Tree	
Northern Red Oak	***Quercus rubra***
Sugar Marple	***Acer saccharum***
Black Locust	***Robinia pseudoacacia***
Pignut Hickory	***Carya glabra***
Red Marple	***Acer rubrum***
Loblolly Pine	***Pinus taeda***
Water Oak	***Quercus nigra***
Sweet Olive	***Osmanthus fragrans***
Pecan	***Carya illinoinensis***
American Holly	***Ilex opaca***
Redbud	***Cercis canadensis***
Shrub	
Gardenia	***Gardenia jasminoides***
Camellia	***Camellia japonica***
Leatherleaf Viburnum	***Viburnum rhytidophyllum***
Burning Bush	***Euonymus alatus***
Vine	
Virginia Creeper	***Parthenocissus quinquefolia***
Trumpet Creeper	***Campsis radicans***
Herbaceous Perennial	
Narrow Leaf Sunflower	***Helianthus salicifolius***
Joe Pye Weed	***Eupatorium hyemale***
Sedge	***Carex spp.***
Purple Coneflower	***Echinacea purpurea***
Yellow Flag Iris	***Iris pseudacorus***
Fern	
Cinnamon Fern	***Osmunda cinnamomea***
Royal Fern	***Osmunda regalis***
Southern Shield Fern	***Thelypteria kunthii***
Christmas Fern	***Polystichum acrostichoides***
Animal	

Mammal
Athens-Clarke Squirrel
Eastern Chipmunk
Bird
Cardinal
Blue Jay
Great Crested Flycatcher
Carolina Wren
American Robin
Butterfly and Bee

B Proposed species for the Segment2

Tree	
Shortleaf Pine	*Pinus echinata*
Box Elder	*Acer negundo*
Red Marple	*Acer rubrum*
Loblolly Pine	*Pinus taeda*
Water Oak	*Quercus nigra*
Pignut Hickory	*Carya glabra*
Sweetgum	*Liquidambar styraciflua*
Pecan	*Carya illinoinensis*
Persimmon	*Diospyros virginiana*
Smooth Sumac	*Rhus glabra*
White Oak	*Quercus alba*
Shrub	
Mountain Laurel	*Kalmia latifolia*
Gardenia	*Gardenia jasminoides*
Camellia	*Camellia japonica*
Leatherleaf Viburnum	*Viburnum rhytidophyllum*
Herbaceous Perennial	
Lizard's Tail	*Saururus cernuus*
Narrow Leaf Sunflower	*Helianthus salicifolius*
Joe Pye Weed	*Eupatorium hyemale*
Bushy Bluestem	*Andropogon glomeratus*
Sedge	*Carex spp.*
Inland Sea Oats	*Chasmanthium latifolium*
Little Bluestem	*Schizachyrium scoparium*
Muhly Grass	*Muhlenbergia capillaris*
Broomsedge	*Andropogon virginicus*
Purple Coneflower	*Echinacea purpurea*
Yellow Flag Iris	*Iris pseudacorus*
Animal	
Mammal	
Athens-Clarke Squirrel	
Eastern Chipmunk	
Bird	

Cardinal
American Robin
Blue Jay
Great Crested Flycatcher
Carolina Wren

C Proposed species for the Segment3

Tree	
Pignut Hickory	*Carya glabra*
Longleaf Pine	*Pinus palustris*
Northern Red Oak	*Quercus rubra*
Loblolly Pine	*Pinus taeda*
Shortleaf Pine	*Pinus echinata*
Persimmon	*Diospyros virginiana*
Water Oak	*Quercus nigra*
Pecan	*Carya illinoinensis*
Black Willow	*Salix nigra*
Eastern Redbud	*Cercis canadensis*
Shrub	
Mountain Laurel	*Kalmia latifolia*
Gardenia	*Gardenia jasminoides*
Camellia	*Camellia japonica*
Leatherleaf Viburnum	*Viburnum rhytidophyllum*
Glossy Abelia	*Abelia×grandiflora*
Catawba Rhododendron	*Rhododendron catawbiense*
Butterfly Bush	*Buddleia davidii*
Dwarf Fothergilla	*Fothergilla gardenii*
Summersweet Clethra	*Clethra alnofolia*
Wintersweet	*Chimonanthus praecox*
Herbaceous Perennial	
Lizard's Tail	*Saururus cernuus*
Narrow Leaf Sunflower	*Helianthus salicifolius*
Joe Pye Weed	*Eupatorium hyemale*
Bushy Bluestem	*Andropogon glomeratus*
Sedge	*Carex spp.*
Inland Sea Oats	*Chasmanthium latifolium*
Little Bluestem	*Schizachyrium scoparium*
Muhly Grass	*Muhlenbergia capillaris*
Broomsedge	*Andropogon virginicus*
Purple Coneflower	*Echinacea purpurea*
Yellow Flag Iris	*Iris pseudacorus*

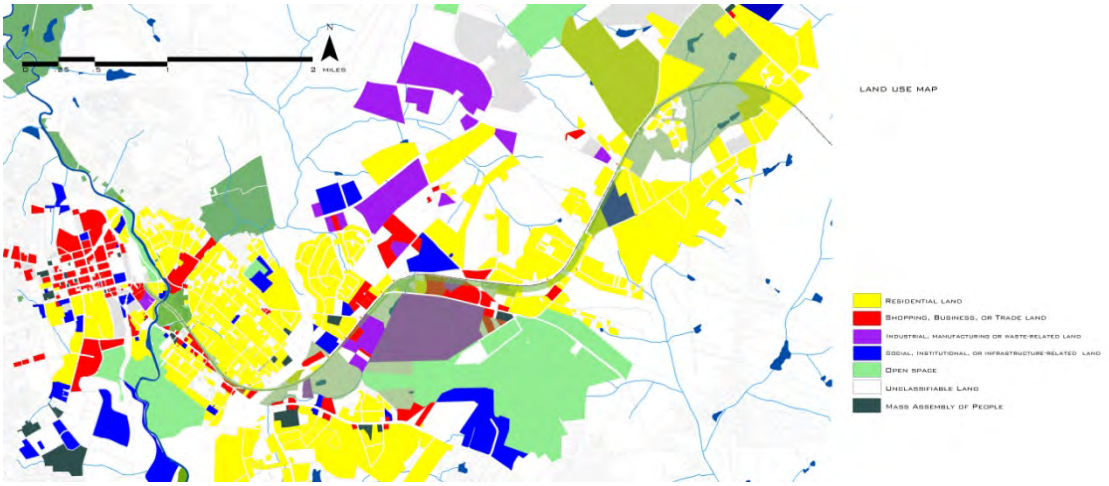
Animal
Mammal
Athens-Clarke Squirrel
Eastern Chipmunk
Raccoon
Bird
Rufous-sided Towhee
Cardinal
Blue Jay
Great Crested Flycatcher
Carolina Wren
American Robin
Butterfly and Bee

D Proposed species for the Segment4

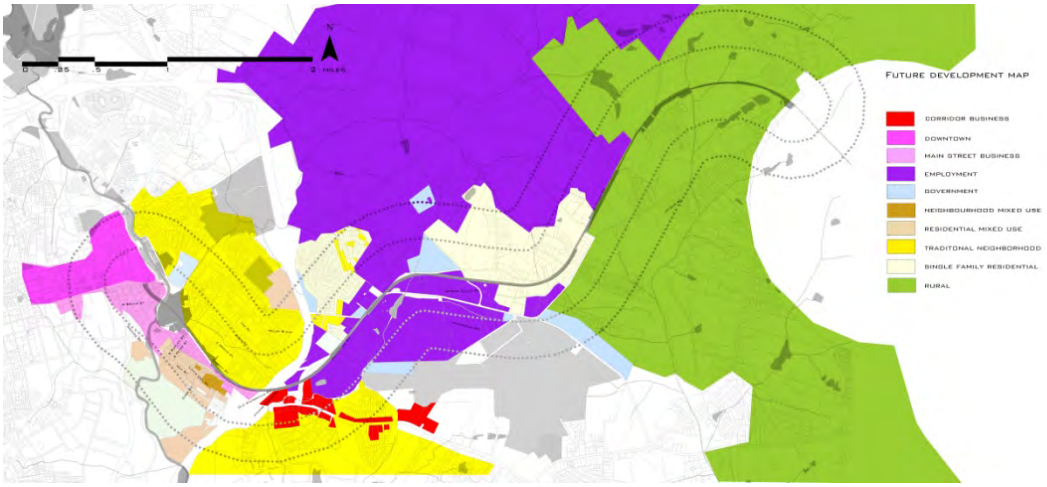
Tree	
Pignut Hickory	*Carya glabra*
Longleaf Pine	*Pinus palustris*
Northern Red Oak	*Quercus rubra*
Loblolly Pine	*Pinus taeda*
Persimmon	*Diospyros virginiana*
Pecan	*Carya illinoinensis*
Sugar Marple	*Acer saccharum*
Water Oak	*Quercus nigra*
Virginia Pine	*Pinus virginiana*
Sweetgum	*Liquidambar styraciflua*
Southern Magnolia	*Magnolia grandiflora*
Red Marple	*Acer rubrum*
Eastern Redbud	*Cercis canadensis*
Shrub	
Mountain Laurel	*Kalmia latifolia*
Southern Indica Azalea	*Rhododendron indicum*
Glossy Abelia	*Abelia×grandiflora*
Catawba Rhododendron	*Rhododendron catawbiense*
Butterfly Bush	*Buddleia davidii*
Dwarf Fothergilla	*Fothergilla gardenii*
Summersweet Clethra	*Clethra alnofolia*
Wintersweet	*Chimonanthus praecox*
Herbaceous Perennial	
Lizard's Tail	*Saururus cernuus*
Arkansas Bluestar	*Amsonia hubrichtii*
Bushy Bluestem	*Andropogon glomeratus*
Sedge	*Carex spp.*
Little Bluestem	*Schizachyrium scoparium*
Broomsedge	*Andropogon virginicus*
Purple Coneflower	*Echinacea purpurea*
Animal	
Mammal	
Athens-Clarke Squirrel	

Eastern Chipmunk
Cottontail Rabbit
Raccoon
Bird
Great Crested Flycatcher
Cardinal
American Robin
Rufous-sided Towhee
American Woodcock
Snake
Black Rat Snake
Butterfly and Bee

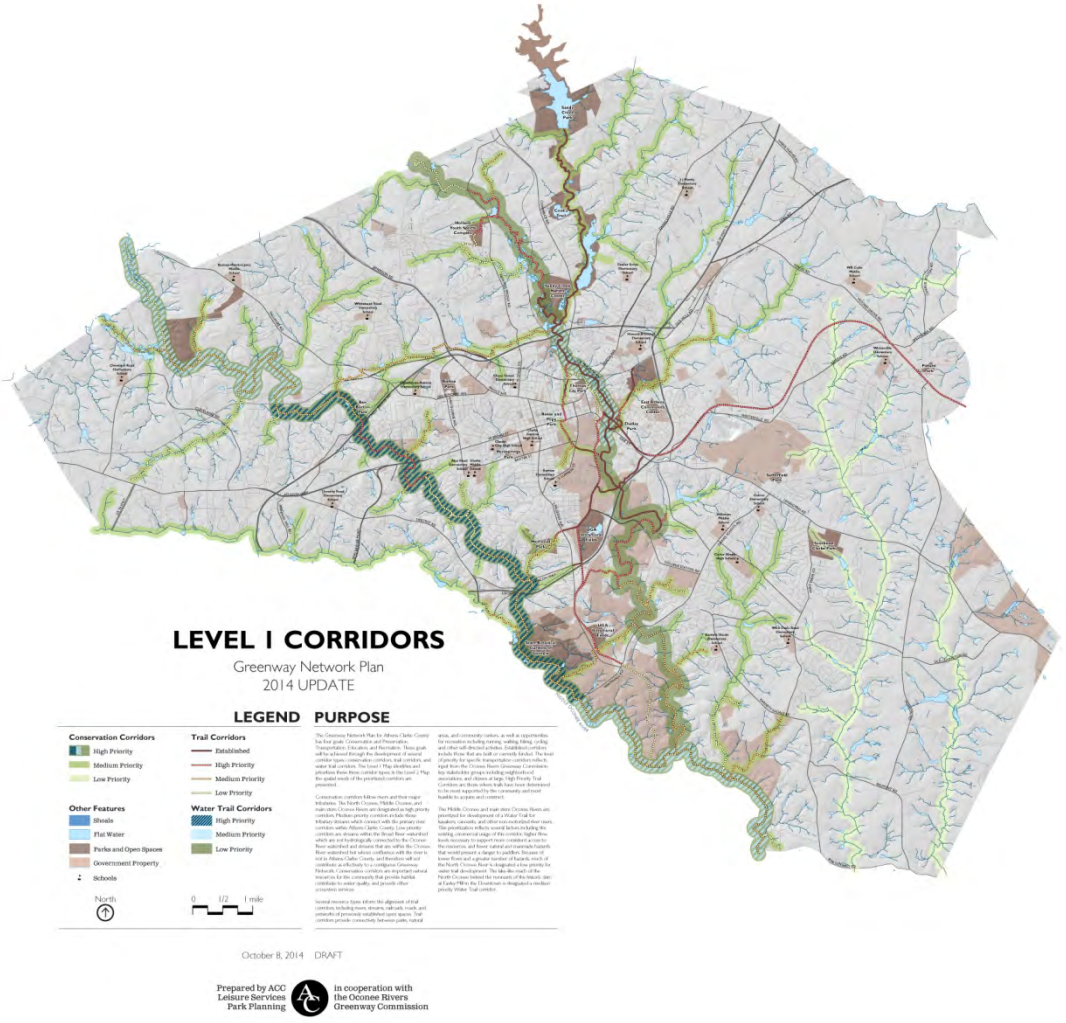
E ACC Exisitng Landuse Map (Created by the author based on ACC Land Use Map)



F ACC Future development Map (Created by the author based on ACC Future Development Map)

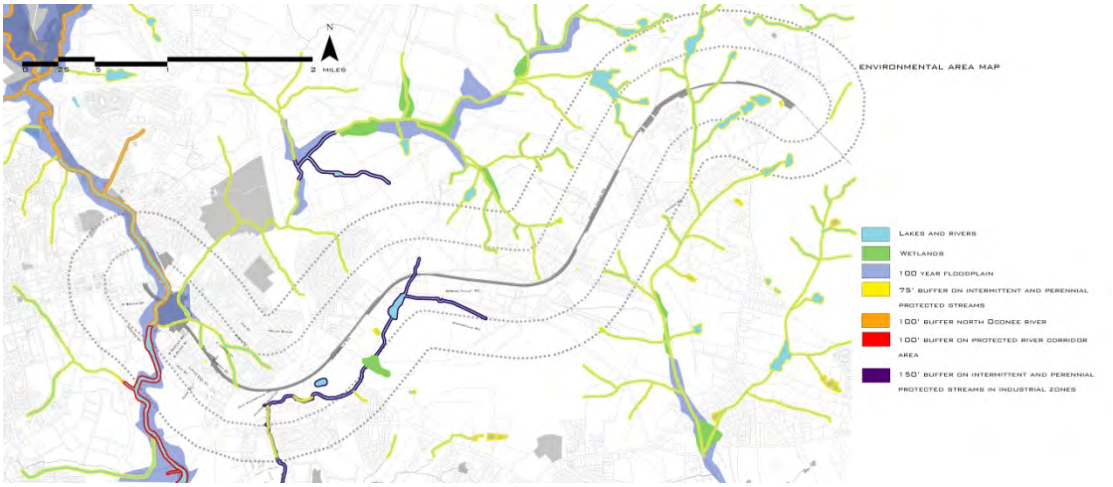


G 2014Greenway Network Plan
(https://athensclarkecounty.com/2873/Greenway-Network-Plan 2014)



H Existing Tree Cover Map (Created by the author based on ACC Tree Cover Map)

I Local Water Resource Map (Created by the author based on ACC Environmental Area Map)



J Existing Open Space Map

K Existing Transportation Network

L Topographic Map

M Existing species in Segment1

Tree	
Northern Red Oak	*Quercus rubra*
Sugar Marple	*Acer saccharum*
Black Locust	*Robinia pseudoacacia*
Pignut Hickory	*Carya glabra*
Red Marple	*Acer rubrum*
Loblolly Pine	*Pinus taeda*
Water Oak	*Quercus nigra*
Pecan	*Carya illinoinensis*
Redbud	*Cercis canadensis*
Shrub	
Burning Bush	*Euonymus alatus*
Vine	
Trumpet Creeper	*Campsis radicans*
Invasives	
Tree of Heaven	*Ailanthus altissima*
English Ivy	*Hedera helix*
Paper Mulberry	*Broussonetia papyrifera*
Japanese Honeysuckle	*Lonicera japonica*
Mimosa	*Albizia julibrissin*
Animal	
Athens-Clarke Squirrel	
Eastern Chipmunk	
Cardinal	
Blue Jay	
Great Crested Flycatcher	
Carolina Wren	
American Robin	

N Existing species in Segment2

Tree	
Shortleaf Pine	*Pinus echinata*
Box Elder	*Acer negundo*
Red Marple	*Acer rubrum*
Loblolly Pine	*Pinus taeda*
Water Oak	*Quercus nigra*
Sweetgum	*Liquidambar styraciflua*
Smooth Sumac	*Rhus glabra*
White Oak	*Quercus alba*
Vine	
Trumpet Creeper	*Campsis radicans*
Invasive	
Mimosa	*Albizia julibrissin*
Paper Mulberry	*Broussonetia papyrifera*
Kudzu	*Pueraria lobata*
Tree Ligustrum	*Ligustrum lucidum*
Animal	
Athens-Clarke Squirrel	
Eastern Chipmunk	
Cardinal	
American Robin	

O Existing species in Segment3

Tree	
Longleaf Pine	*Pinus palustris*
Northern Red Oak	*Quercus rubra*
Loblolly Pine	*Pinus taeda*
Shortleaf Pine	*Pinus echinata*
Water Oak	*Quercus nigra*
Pecan	*Carya illinoinensis*
Black Willow	*Salix nigra*
Eastern Redbud	*Cercis canadensis*
Invasive	
Tree of Heaven	*Ailanthus altissima*
Paper Mulberry	*Broussonetia papyrifera*
Mimosa	*Albizia julibrissin*
Chinaberry	*Melia azedarach*
Kudzu	*Pueraria lobata*
Animal	
Athens-Clarke Squirrel	
Eastern Chipmunk	
Raccoon	
Rufous-sided Towhee	
Cardinal	
American Robin	

P Existing species in Segment4

Tree	
Longleaf Pine	*Pinus palustris*
Northern Red Oak	*Quercus rubra*
Loblolly Pine	*Pinus taeda*
Sugar Marple	*Acer saccharum*
Water Oak	*Quercus nigra*
Virginia Pine	*Pinus virginiana*
Sweetgum	*Liquidambar styraciflua*
Southern Magnolia	*Magnolia grandiflora*
Red Marple	*Acer rubrum*
Eastern Redbud	*Cercis canadensis*
Invasive	
Paper Mulberry	*Broussonetia papyrifera*
Mimosa	*Albizia julibrissin*
Kudzu	*Pueraria lobata*
Animal	
Athens-Clarke Squirrel	
Eastern Chipmunk	
Cottontail Rabbit	
Raccoon	
Great Crested Flycatcher	
Cardinal	
American Robin	
Rufous-sided Towhee	
American Woodcock	
Black Rat Snake	

Q Evaluation criteria for Segment1

	Goals	objectives	good	ok	bad
segment1	Preservation and conservation	Perform invasive plant removal activities including cutting, mowing, pulling, and digging.			
		Apply proper way of disposal invasive plants.			
		Expand preservation zones to connect the existing Dudley Park and North Oconee Greenway.			
		Remove garbage.			
		Improve stormwater management and offer related public education program.			
	Transportation	Connect the downtown areas, the existing neighborhoods, and street business areas.			
		Trails or paths are identified clearly for multi-use.			
		Use signage to help self-guided travel.			
		Instill facilities for bicyclists and walkers, such as drinking fountains and bicycle racks.			
	Education	Provide educational programs, such as nature study, outdoor classroom, and green infrastructure program.			
		Apply practical education or training programs for the public or private agencies.			
	Recreation	Instill paths or trails for different recreational needs.			
		Instill facilities such as benches and rest areas.			
		Boardwalks are used to cross sensitive areas to minimize human impact.			
		Establish multiple outdoor activities to promote a health lifestyle.			

R Evaluation criteria for Segment2

	Goals	Objectives	good	ok	bad
segment2	Preservation and conservation	Perform invasive plant removal activities including cutting, mowing, pulling, and digging.			
		Apply proper way of disposal invasive plants.			
		Enhance and restore natural habitats.			
		Remove garbage.			
		Improve stormwater management and offer related public education program.			
	Transportation	Connect the existing neighborhood centers and street business areas.			
		Trails or paths are identified clearly for multi-use.			
		Use signage to help self-guided travel.			
		Instill facilities for bicyclists and walkers.			
	Education	Include educational programs, such as nature study, outdoor classroom, and green infrastructure program.			
		Apply practical education or training programs for the public or private agencies.			
	Recreation	Instill paths or trails for different recreational needs.			
		Instill facilities such as benches and rest areas.			
		Boardwalks are used to cross sensitive areas to minimize human impact.			
		Establish multiple outdoor activities to promote a health lifestyle.			

S Evaluation criteria for Segment3

	Goals	Objectives	good	ok	bad
segment3	Transportation	Connect the existing neighborhoods, street business areas and the existing open space.			
		Trails or paths are identified clearly for multi-use.			
		Use signage to help self-guided travel.			
		Instill facilities for bicyclists and walkers.			
	Education	Include research programs and educational programs, such as nature study, outdoor classroom, and green infrastructure program.			
		Apply practical education or training programs for the public or private agencies.			
	Recreation	Instill paths or trails for different recreational needs.			
		Instill facilities such as benches and rest areas.			
		Boardwalks are used to cross sensitive areas to minimize human impact.			
		Establish multiple outdoor activities to promote a health lifestyle.			

T Evaluation criteria for Segment4

	Goals	Objectives	good	ok	bad
segment4	Preservation and conservation	Perform invasive plant removal activities including cutting, mowing, pulling, and digging.			
		Expand conservation zones for research use.			
		Expand preservation zones.			
		Apply proper way of disposal invasive plants.			
		Enhance and restore natural habitats.			
		Remove garbage.			
		Improve stormwater management and offer related public education program.			
	Transportation	Connect the existing neighborhood centers and street business areas.			
		Trails or paths are identified clearly for multi-use.			
		Use signage to help self-guided travel.			
		Instill facilities for bicyclists and walkers.			
	Education	Include research programs and educational programs, such as nature study, outdoor classroom, and green infrastructure program.			
		Apply practical education or training programs for the public or private agencies.			
	Recreation	Instill paths or trails for different recreational needs.			
		Instill facilities such as benches and rest areas.			
		Boardwalks are used to cross sensitive areas to minimize human impact.			
		Establish multiple outdoor activities to promote a health lifestyle.			