EVALUATING COMMUNITY DESIGN FOR THE CONSERVATION OF FIRE DEPENDENT ECOSYSTEMS AND REGIONAL PROCESSES

By

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A Quote to Shara Himmel

“If I fail, if I am fired, or if I pass on, I will do just that. But first I will live.”

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LIST OF ABBREVIATIONS

DRI	Development of Regional Impact
FDEM	Florida Division of Emergency Management
FEGN	Florida Ecological Greenways Network
FEMA	Federal Emergency Management Agency
FGDL	Florida Geographic Data Library
FLMA	Florida Managed Lands
FM	Fuel Model
IBPF	Interagency Basic Prescribed Fire Training Program
MFSL	Missoula Fire Science Laboratory
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Agency
PI	Principal Investigator
SLP	Suwannee Lake Plantation
SWOT	Strengths Weakness Opportunity and Threat (Analysis)
WRCC	Western Regional Climate Center
WUI	Wildland Urban Interface

Abstract of Thesis Presented to the Graduate School
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The current approach to development design in the Southeast does not fully envision the ramifications of development at the regional level. In Florida considerable progress has been made in how we plan for development around water and wetlands; however, less attention has been given to planning at the regional level for the movement of wildfires and the movement of wide-ranging species that depend on fire-dependent ecosystems. Planners use geospatial modeling tools to assess what aspects of development have negative impacts on regional processes. This research is an approach to understanding how spatial modeling of landscape level processes can influence investment-backed decisions in development. By employing these methods ‘before the concrete is poured’ developers can understand how to reduce the impact of development on wide-ranging wildlife movement and reduce the risk of property to wildfire. One conclusion of this research suggests how development design of land use components at the site scale influences functional movement of wildlife at the regional scale. The second outcome of this research concludes that development components are least vulnerable to wildfire when located in fire-dependent ecoystems which are

already managed with prescribed fire. The outcomes of this work offer planners an expanded toolset to understand how to work with developers to maintain large scale processes in fire dependent, ecologically significant areas.

CHAPTER 1
INTRODUCTION

Intent

When people think of Florida their first thoughts are often of beaches, hurricanes, oranges, swamps, and mosquitos. Planning for wetlands and watershed planning has been adopted into practice by developers to minimize vulnerability to flooding from major weather events. As a result, green construction improvements and best management practices for development in wetland areas have been adopted to support the ecologically sensitive wetlands in Florida. During the development design phase this accepted practice has shifted the focus to develop on lands that are within ecologically sensitive, fire-dependent, upland ecosystems. The resiliency of development designs in the interior part of Florida will be measured in the ability to plan for watersheds, and more importantly in the ability to plan for firesheds.

It is undeniable that development interacts with the connectivity of landscape and regional level processes. Before development began in Florida water and open land had a continuous connection throughout evolutionary time. The balance of wetland and upland areas creates the diversity of fire-dependent ecosystems that compose the landscape (Figure 1-1). Ecosystem type in Florida can be determined by the depth to the water table and the fire return interval (Interagency Basic Prescribed Fire Training Program (IBPF) 2012). The structure and composition of pyrophillic ecosystems are determined by ecological functionality; something that is itself dependent on landscape level disturbance processes. Pyrophillic ecosystems do not harbor fire, they adapted to coexist and make the disturbance possessable. Developments can also be designed to accommodate disturbance from fire in ecologically significant corridors of open space in the Southeast. But Florida’s remaining connected open space and wide ranging wildlife cannot afford to repeat the past and learn lessons from the results of poor planning.

Though many ecosystems in Florida depend on fire, Florida has seen an increase in destructive wildfires in recent decades. The loss of property would not occur if fires happened at greater distances to uninhabited areas (NFPA 2014). The wildland urban interface (WUI) is the general term for areas where people, structures, and natural areas intermix. As populations continue to grow in Florida so will the size of the WUI. Development has fragmented the landscape and the ability of these landscape level processes to continue.

The Florida Ecological Greenways Network is a system of open space that can be applied by planners to focus conservation priorities. Ecologically significant corridors are defined by the variety and availability of functional open space that support landscape level processes. The network of open space historically supported the distribution of wide-ranging species throughout the state of Florida. Development has constricted the landscape level movement of Florida’s wide-ranging wildlife.

Planners can play a major role in addressing safety concerns in WUI near fire-dependent ecotypes. Historically, the creation of hazard mitigation plans has been a responsive action by planners after a disaster occurs. A retrospective, or in-fill, approach to wildfire planning could be avoided if planners assessed landscape-level ecological processes before development occurs on lands previously in agricultural, silvicultural, or conservation uses. This research uses scenario planning for resiliency to assess and reduce the risk of developments to catastrophic wildfire in ecologically significant corridors. The research approach is to determine the scenario planning outcomes of a development project in Florida by first modeling ecologically significant ecosystem corridors, then designing developments, and then modeling wildland fire before physical construction occurs. The purpose of this research is to simulate land use conflicts with landscape level processes before they occur. My research is about Florida’s wildlife, people, and the economy.

Justification

The following justification will look at small segments of general background details. First, relevant terminology will be defined to establish transparency and convey background information important to this thesis. Then, a summary of objectives will be provided.

Terminology

Human Population Growth in Florida. It is common knowledge that when people populate a given space they interact with the environment. Across the United States human population growth has had a two-fold consequence. Human population growth has accelerated the exposure of developed property to natural hazards and has disrupted the natural landscape. The economic disruption that has occurred from poor anticipatory planning has created a need for proactive land development and land management practices.

The amount of visible information about the landscape available in the 21st Century is far more accurate and detailed than when the first European settlers arrived in the United States. At the time the Spanish settled in Florida the landscape level comprehension of the land was far different than it is today (Figure 1-2). Juan Ponce De León documented that in the 16th century the Timucuan race settled in regional tribes across Florida. Native American populations reached approximately 100,000-900,000 before Europeans arrived (Dobyns 1966). The Pre-DeLeon Floridian population was not reached again until the 1920s (Dobyns 1983). In present time, The University of Florida GeoPlan Center uses data from the Bureau of Economic and Business Research (BEBR) to project population growth in Florida to the year 2060. In 2005 17.9 million people inhabited Florida. Using moderate population growth models BEBR predicts that the population of Florida will increase to 35.8 million people by 2060, as shown in Figures 1-3 and 1-4 (Zwick 2006).

Projections made before the 2008 financial crisis have since changed. A stronger focus on conserved, less speculative real estate development spending and informed investment into equities has affected the geographic distribution of population growth forecasts. Additionally, climate change scenarios have led policy makers to reevaluate the resiliency of land at low elevations susceptible to flooding along the coast (Figure 1-5). Pending updates to the 2060 population growth model are expected to hold current population growth forecasts constant, and factor in the loss of coastal development to moderate climate change scenarios (Zwick, pending). This means that Florida will still expect 35.8 million people by 2060, except it will be concentrated away from coastal counties. The result is hypothesized to show a greater dependence on developable land inland, and will disproportionately impact pyrophillic, upland ecosystems.

Development Design. For this research development designs are classified as the geospatial creation of housing and built infrastructure that integrates environmental policies and development strategies (Roufechaei et al. 2013). Development designs inherently satisfy human needs and aim to provide a quality of life (Manoliadis et al. 2007). The history of development ranges extensively. After World War II the American dream of a traditional rural home on a large estate rapidly evolved amidst social, political, and environmental conditions. Adam Rome's *The Bulldozer in the Countryside* reflects that at this point in United States history, troops were returning to the mainland to encounter a postwar revolution in construction. "The adoption of mass production techniques greatly intensified the environmental impact of homebuilding" (Rome 1994). This type of cookie cutter, perfectly manicured, development pattern lead to sprawling networks of roads, unstable demands on water, and unsustainable wastewater treatment. Today, development design seeks balance between environmental, social, and economic factors through planning, implementation and decision-making to create development designs that are able to serve current and future generations (Szekely and Knirsch 2005; Goebel 2007; Roufechaei et al. 2013).

Site Synthesis. One of the key initial steps in a development design is the site synthesis phase. In practice, the site synthesis process begins with a site inventory and a data synthesis (Conservation Design and Planning Studio 2012). Site specific development suitability analyses inform the development design process before planning and construction occur. A site synthesis creates information on potential development conflicts and constraints, as well as potential opportunities for the appropriate distribution of development elements.

Florida Ecological Greenway Network. Threats and Actions for Florida's Comprehensive Wildlife Conservation Strategy, is a report for the Florida Fish and Wildlife Conservation Commission that was drafted by The Nature Conservancy. The report uses a problem and conservation action identification process to review threats and create attainable goals for terrestrial, freshwater, and marine ecosystems. In this document, and in the Five Year review completed in 2010, it was explicitly claimed that conversion to housing and other forms of urban development is the most pervasive threat to Florida's wildlife habitats. In this report dry prairie, natural pineland, sandhill, and scrub are all listed as threatened by the development process.

A significant statement from section 2.7, Conversion to Housing and Urban Development, is that stress to the conversion of natural wildlife habitat in many cases includes converting habitat in adjacent areas where such a conversion "results in substantial loss of function of adjoining natural habitat. Conversion to housing/urban development is implicated as the source of many ecological stresses, including habitat destruction, habitat fragmentation, altered hydrologic regime, altered fire regime, altered habitat mosaic, and others" (Gordon et al. 2005). This document created the foundation from which cooperative research and grant funding was commissioned by the State Wildlife Grant from the Florida Fish and Wildlife Conservation Commission to the University of Florida's GeoPlan Center to create the Cooperative Conservation Blueprint and the Critical Land and Waters Identification Project (CLIP). The CLIP 2.0 project is an expansion of the Department of Environmental Protection's Statewide Greenways System.

The first installation to the Statewide Greenways System was the Florida Ecological Greenways Network (FEGN), planned by Dr. Tom Hoctor and Dr. Peggy Carr at the University of Florida GeoPlan Center (Figure 1-6). The participatory process used to design the FEGN "[accomplished] the goal of identifying a functionally connected statewide ecological network of public and private conservation lands. [The FEGN is intended to] maximize the protection of high priority natural communities and species identified in the Florida State Wildlife Action Plan, and maximize the potential of Florida’s native biodiversity to functionally respond to climate and other changes.” Regional landscape connectivity is the cornerstone of the statewide ecological network. Seen in Figure 1-7, the updated FEGN is divided into two classes of critical linkages and six classes of priority linkages to achieve resilient statewide ecological connectivity (Florida Greenways and Trails System Plan 2013).

Connectivity and Scales. Connectivity is the strength of interactions across and between ecotones (Tewksbury et al. 2002). Urban planners have previously used the term, ‘ecotones,’ to define efforts to integrate the life of a city with its local landscape (May 2006). This type of place-based thinking has been repurposed from the original definition of connectivity. The original definition and the new connotation overlap in their environmental context. Connectivity is an ecological term that describes the natural habitat continuum within the landscape (Harrison 199). Large ranging wildlife have first, second, and third orders of selection that lead them in space through the continuum of their habitat (Johnson 1980). The first, second, and third orders directly correspond to local, landscape, and regional scales. At the local scale specific resources such as water, protein sources, and cover influence the character of habitat. At the landscape scale vegetation classes and available space become factors that begin to outline connectivity for a given specie. At the regional scale landscape processes and available landscape connectivity inhibit or assist the connectivity of multiple populations of species or ecosystems.

Landscape Level Processes. Upland and wetland ecosystems are pattern based ecosystems. Figure 1-8 reflects the concept of disturbance. Natural stochastic disturbances disrupt upland and wetland systems and support a greater diversity of flora and fauna across the landscape. Mandates and ecological requisites exist that recognize the importance of maintaining uplands and wetlands to provide ecosystem services to people, such as recreational space, water recharge, and carbon sequestration. That policy also recognizes wetlands for construction and planning purposes because of the vulnerability of human infrastructure to hurricanes in flood prone areas. Yet, there is little recognition of the upland side of the synergistic system when risk assessments for resiliency are performed in the pre-construction, development design phase.

Wildlife Continuity. When ecosystems become fragmented the proximity of the remaining patches has measureable influences on genetic connectivity for species of both plants and animals (Levins 1969). The strength and weakness of these connected linkages (or corridors) can assist or inhibit the ability of flora and fauna adapted to fire-dependent ecosystems to persist. Florida’s population growth has disrupted natural landscape scale connectivity. The “disruption of extensive habitats into isolated and small patches” has an external decimating effect on landscape processes (Meffe et al. 1997). Figure 1-9 clarifies the types of fragmentation that can occur. Furthermore, Figure 1-10 serves to illustrate faunal relaxation; how after fragmentation occurs, the change in conditions on the edge adversely changes the interior composition of the fragment (Laurance et al. 2008). When patch fragments are initially formed there is an increase in population size of species within an isolated patch. Sometimes referred to as “crowding of the ark,” the reality is that the future loss of species as a consequence of past actions has already occurred. The remaining linkages (corridors) affect plants, animals, and their landscape and regional scale interactions.

Fire-Dependent Ecosystems. Longleaf pine (*Pinus ellioti*) and the associated bunch-grass, scrub, and prairie ecosystems are among the most distinct upland ecotypes in the Southeastern Coastal Plain (Figure 1-11). Upland ecotypes are characterized by the frequency of fire return, flat topography, a pine-dominated overstory, little to no midstory, and an understory dominated by grasses and forbs. Historically, tropical cyclones and periodic lightning strikes provided stochastic fire as a natural disturbance process that promotes species biodiversity and maintains the understory in these systems. During the summer growing season, the natural range of variation in these fires stimulates connectivity, growth and reproduction in native, pyrophillic species (fire-liking) (Hilmon 1965: Willcox 2010).

Fuels Continuity. The biomass of connected, pyrophillic vegetation communities are also called fuels. Natural hazards like wildfire flip the focus from concern for the environment and the disruption of ecological processes to concern for the community and for the social disruption caused by natural processes (Prior and Eriksen 2013). After a series of wildfires hit Florida in 1998 the population size of the Rugel’s pawpaw, a federally endangered species, increased from an estimate of 200 individuals to over 2000 individuals (Grace 2000). The largest barrier to successful comprehensive wildland fire mitigation is that wildfires are viewed as a threat to development, and development is not viewed as a threat to naturally occurring wildfires in the landscape. Because landscape and regional scale wildfires are combatted to prevent the loss of households and human structures, the abundant diversity of Florida’s rangelands and prairies now does not exist naturally without human fire management. Prescribed burning is a necessary tool utilized by land managers to reduce fuel loads and to perpetuate the pyrophillic species who inhabit fire-dependent, upland areas. Prescribed fire management decreases the relative risk of development to wildfires by removing large buildup of fuels. In Firewise development design fuels are measured to determine the appropriate action needed for reducing wildfire hazard and to create separated space for infrustructure. A method is needed to determine if development designs are disrupting fuel continuity and if developments are fragmenting the landscape level processes of firesheds in the interior counties of Florida.

Summary

There has been no direct Firewise design investigation that attempts to merge the two concepts of wildlife continuity and fuels continuity in regional analysis. Both corridor movement of wide-ranging species and wildfire defense planning for developments have dependencies on the existence of an open space network. Yet upon review of comprehensive federal hazard plans, state comprehensive natural resource regulation, and local community development strategies, it appears that the two planning methods remain separate.

The two approaches that this research will be concerned with, conservation planning and development planning, both rely on the geospatial pattern of development but have separate policy objectives and standards. This research will apply two embedded units of scenario analysis –wildlife corridor modeling and wildfire modeling- to determine if these two influences on development can be mutually beneficial rather than mutually exclusive (Figure 1-12).

The main objectives of this scenario planning research are as follow:

1. To compare proposed development designs by their impact on the facilitation of wildlife movement.
2. To rank proposed development designs from most to least resilient to wildfire.

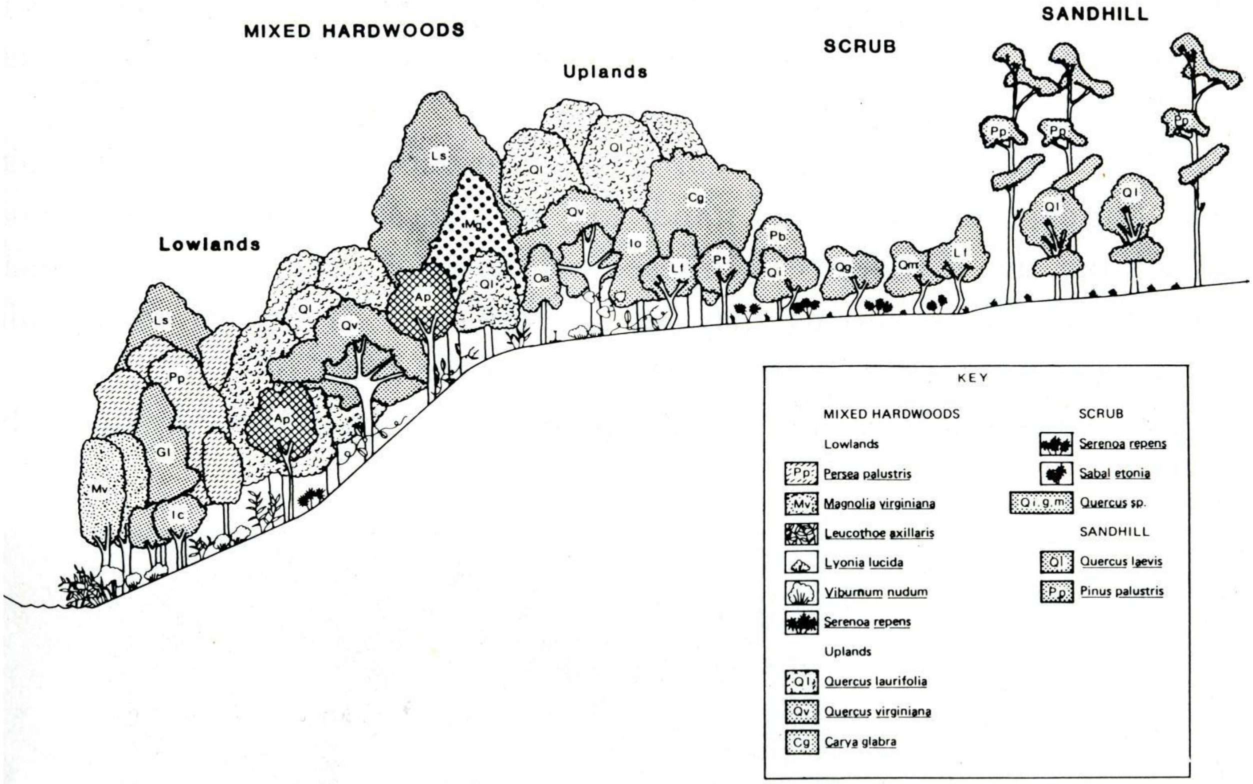


Figure 1-1. An illustration of community development and depth to water table. Community profile from Mike Roess Gold Head Branch State Park, Keystone Heights, Florida. (Myers and Ewel 1990; Adapted from IBPF 2012).

Figure 1-2. Map of La Floride (Florida) circa 1657 (Sanson 1657).

Figure 1-3. Florida Population Growth Rate. The Study Extent for this research contains projected increases ranging from 4 to greater than 10 %. (Zwick 2006).

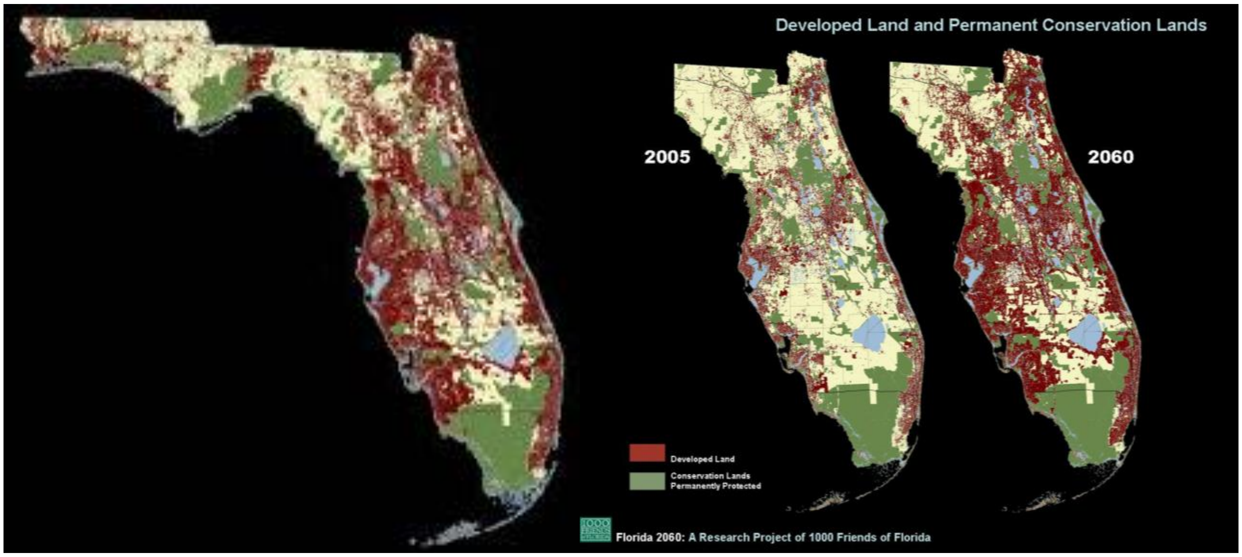


Figure 1-4. Florida 2060. An urbanized area expansion model created in partnership with 1000 Friends of Florida. (Zwick 2006).

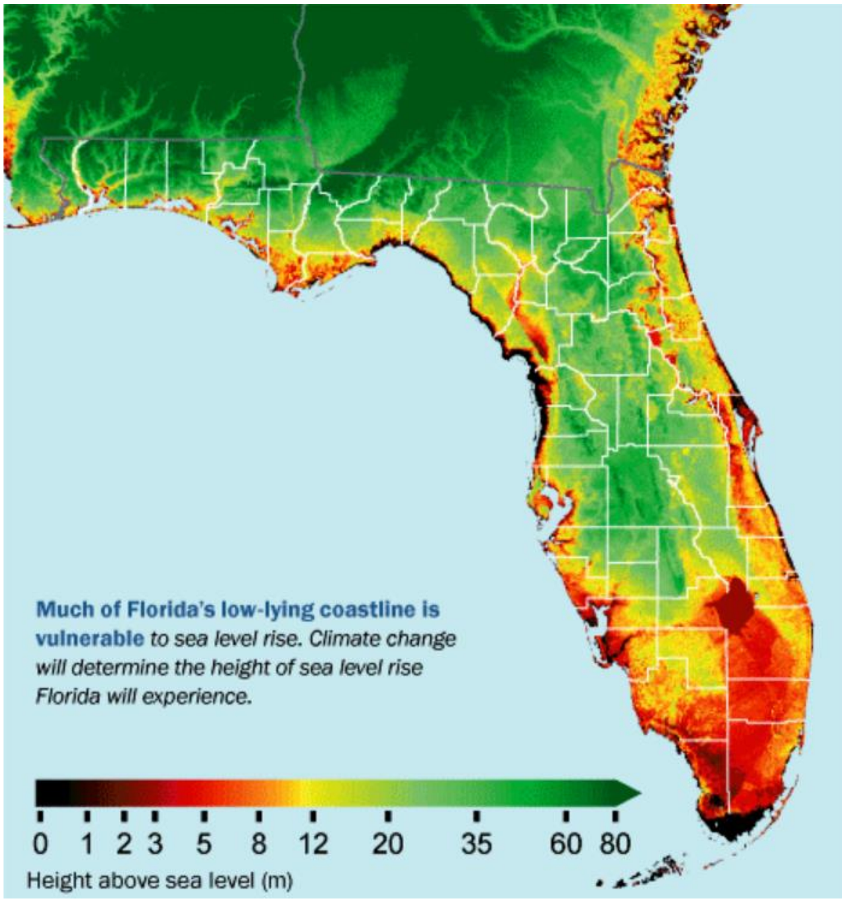
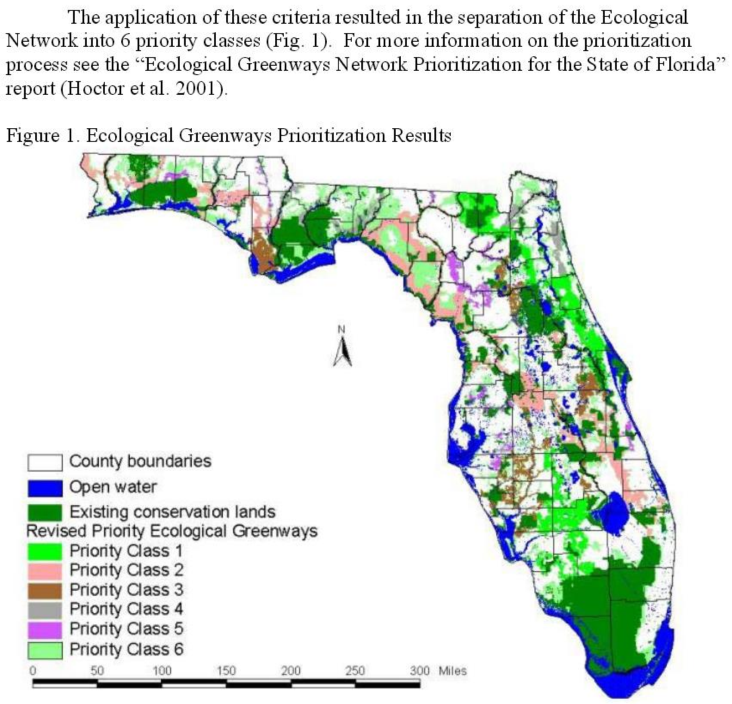


Figure 1-5. Vulnerability of Coastal Florida to changes in mean sea level, By Robert A. Rohdes (FWC 2008).



The application of these criteria resulted in the separation of the Ecological Network into 6 priority classes (Fig. 1). For more information on the prioritization process see the "Ecological Greenways Network Prioritization for the State of Florida" report (Hoctor et al. 2001).

Figure 1. Ecological Greenways Prioritization Results

Figure 1-6. The Florida Ecological Greenway Network.

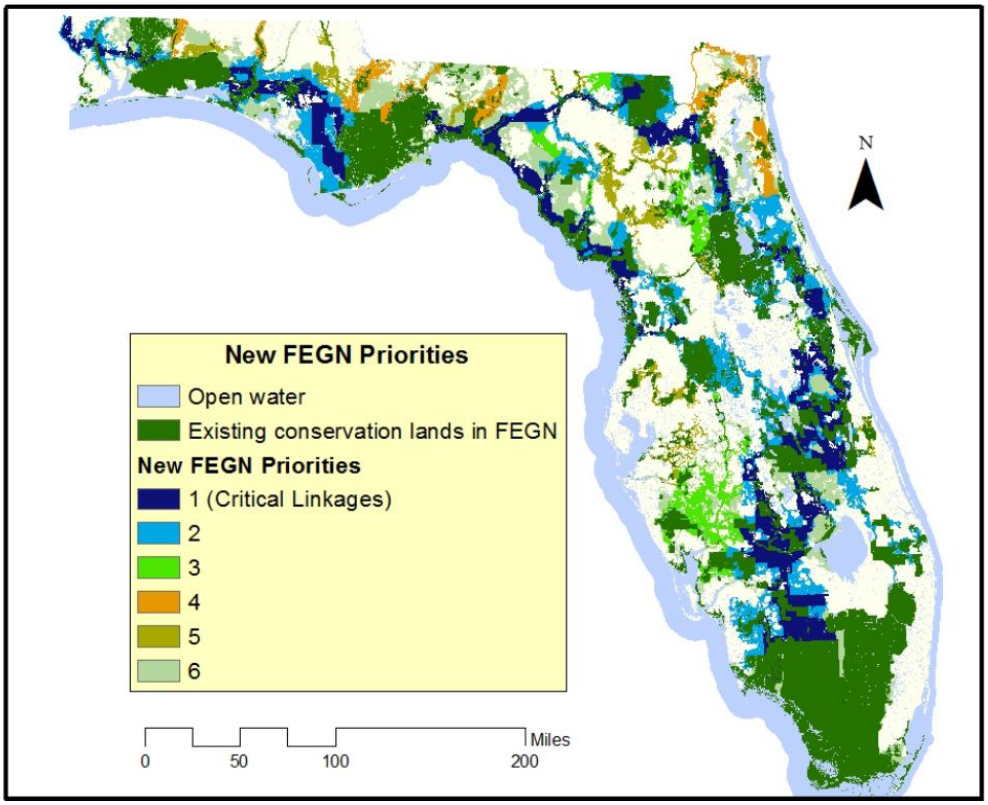


Figure 1-7. The Florida Ecological Greenway Network: December 2013 Update.

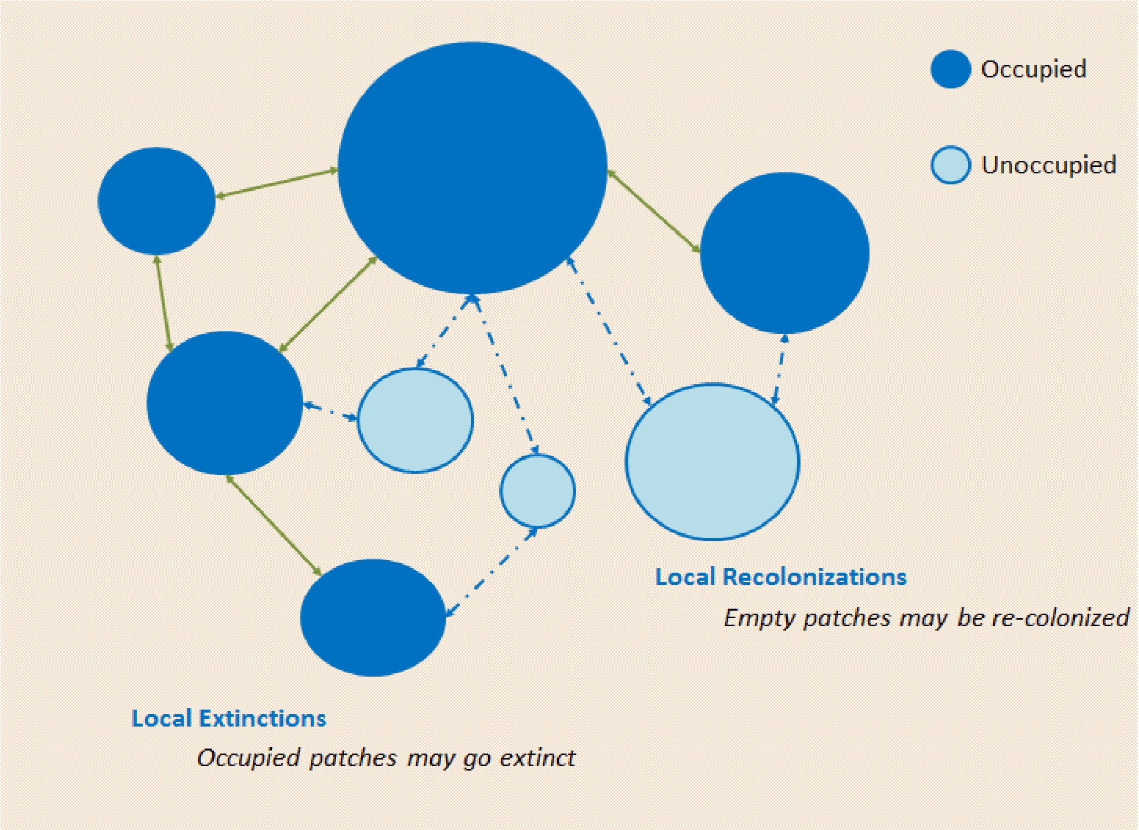


Figure 1-8. Metapopulations are connected populations of varying size and spatial configuration. Stochastic disturbances create a pattern of local populations that are connected through the migration of abiotic and biotic materials, i.e. water, pollen, air, nutrients, plants, and wildlife (Levins 1969).

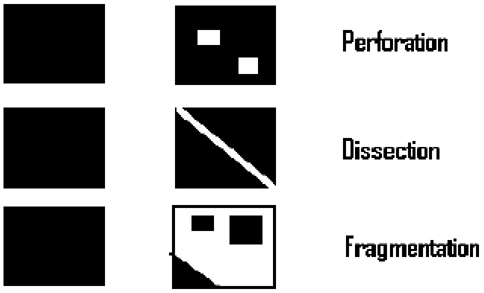


Figure 1-9: Varieties of fragmentation of a landscape.

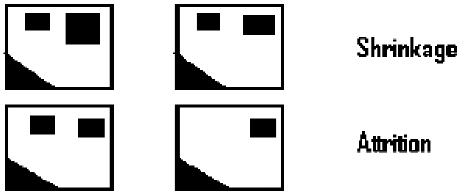
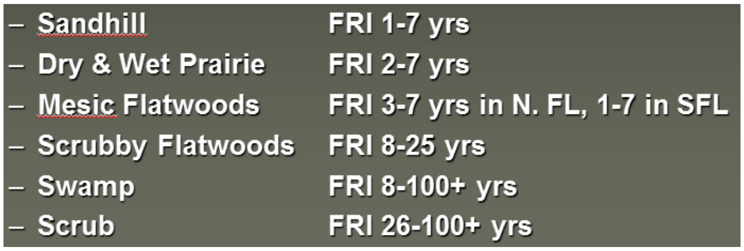


Figure 1-10: Edge effects, as the outcome of fragmentation (Laurance et al. 2008).



– Sandhill	FRI 1-7 yrs
– Dry & Wet Prairie	FRI 2-7 yrs
– Mesic Flatwoods	FRI 3-7 yrs in N. FL, 1-7 in SFL
– Scrubby Flatwoods	FRI 8-25 yrs
– Swamp	FRI 8-100+ yrs
– Scrub	FRI 26-100+ yrs

Figure 1-11. Six Florida ecotypes and their associated fire return intervals (FRI). It is important to note that though the frequency of the FRI may operate on significantly different time frames, the effect of the FRI is to perpetuate the species that depend on fire as a stochastic disturbance process.

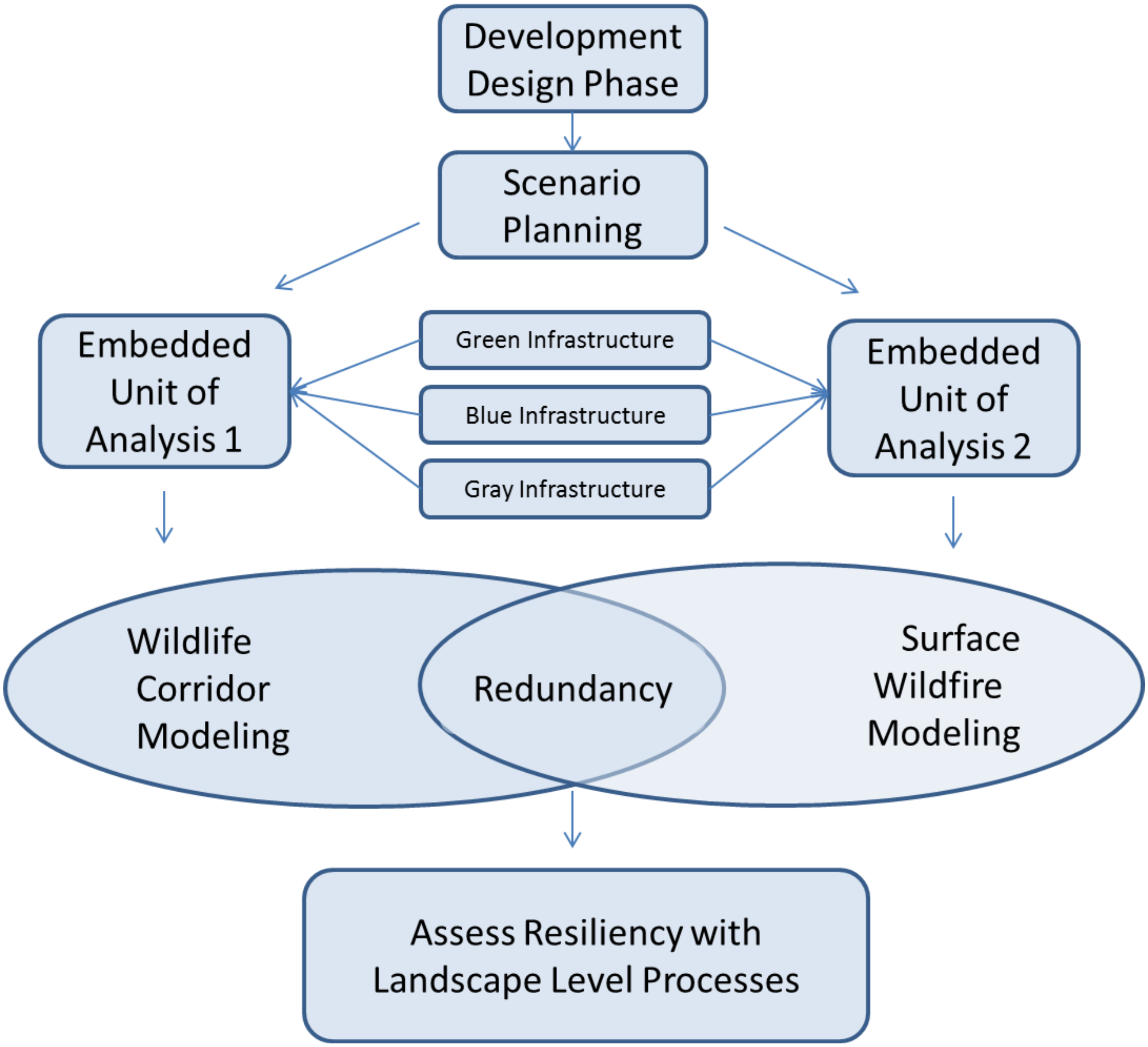


Figure 1-12. Research Design Conceptual Framework.

CHAPTER 2
LITERATURE REVIEW

Introduction

The Justification section in Chapter 1 provided a brief summary of the subject area of this research. There are three purposes for this literature review. First, the review will establish a conceptual foundation for research in scenario planning and resiliency planning. Second, the review will look at Federal and State policy in order to concentrate the socio-ecological focus to Florida. This section of the review will present and follow a policy improvement model that summarizes the history of Florida’s Community Resiliency policy pattern as cataloged by the Florida Department of Economic Opportunity (DEO) (Figure 2-1). Following this discussion will be an outline of the methods of previous community and development planning attempts to correct the policy pattern and examples of the development designs that were created from those attempts.

Scenario Planning

Scenario planning is a comparative method of analysis that investigates alternative futures to inform decisions in the present. Rather than focusing on the accurate prediction of a single outcome, scenario planning evaluates multiple possible futures (Peterson et al. 2003). The evolution of scenario planning has its roots in forecasting and in adaptive management. Adaptive management seeks to improve future management action by learning from outcomes. Originally this ‘learning while doing’ approach was separated into *passive* or *active* adaptive management depending on financial or resource limitations (Randolph 2012). *Passive* management concentrated on constructing one hypothesis based on historical or comparative analysis to create one action. The real outcomes of that action were used to alter management if the desired results were not produced (U.S. DOI 2009). In its infancy *active* management was implemented to overcome the shortcomings of a *passive*, single loop approach to planning and management. The *passive* approach can be useful when there is a high level of scientific confidence in ecological responses to management decisions or where regulatory constraints create limitations (Randolph 2012). However even today it is difficult to predict the ecological outcome of action in the rapidly changing global environment. The operating policy of federal, state, and municipal agencies have shown heightened recognition of the current biodiversity crisis (U.S DOI 2009; Dearing et al. 2012). Valuable time and resources are wasted through the *passive* single loop trial and error approach. In *active* management multiple competing, adaptive management strategies are hypothesized and operationalized. In practice the strategy that most effectively meets the targeted objective transpires over time through a process of monitoring and analysis. Then, the optimal strategy is reevaluated and applied over a greater area (U.S. DOI 2009; Randolph 2012).

The concept of a ‘scenario’ was originally produced from work by Herbert Kahn “in response to the difficulty of creating accurate forecasts (Kahn and Weiner 1967; May 1996; Peterson et al. 2003). Kahn’s forecasts were based on constructed scenarios with minor variations to future potential demographic trends, socio-technical developments, and strategy assumptions (Kahn and Weiner 1967). The difficulty in creating accurate forecasts occurs because small variations in trends introduce large levels of uncertainty into projections.

Figure 2-2 is a chart synthesized by John Randolph based on Peterson's *Scenario Planning: A tool for Conservation Planning in an Uncertain World* and the Department of the Interior's *Technical Guide to Adaptive Management*. The chart is intended to be a deterministic tool for decision making between the management options that have previously been discussed. The appropriate choice of approach to management is dependent on both the level of controllability and the level of uncertainty (Randolph 2012). In the field of spatial planning perhaps the most evident key shift from forecasting, to adaptive management, to scenario planning is that the purpose of urban and regional planning is to go beyond preparation for a range of potential futures and use modeling to identify what features of strategies create more desirable futures (Myers and Kitsuse 2000; Larsen et al. 2011). From Figure 2-2 it can be inferred that scenario planning is most applicable in situations of low controllability and high uncertainty. For this research the scenario planning process model outlined by Garry Peterson and colleagues is the most appropriate because it is a linear process with the opportunity for iterative review. There are six interactive stages:

1. Identification of a Focal Issue
2. Assessment
3. Identification of Alternatives
4. Building Scenarios
5. Testing Scenarios
6. Policy Screening (*Exempt from this research*)

Scenario alternatives are created in stage 3 as a result of the central issue becoming a focusing device for assessment in stage 2 (Peterson et al. 2003). In the assessment stage the framework for identifying alternatives can be thought of as a framed circle inscribed within a square of reality. Peterson et al. views uncertainty recognition as a valuable result of the process model because early into the process the focal issue is confronted with the complexity of the world. When the uncertainty figuratively takes the form of the remaining space in the square, a set of dynamic alternative scenarios can be built and tested within the framework. In stages 4 Peterson et al. caution that the appropriate number of scenarios ranges between three and four (For further discussion see Wack 1985; Schwartz 1991; van der Heijden 1996). The multiplicity of scenarios are used in stage 5 to spot the benefits and shortcomings between future scenarios (Gunnarsson-Östling and Höjer 2011; Tapinos 2012). One of the primary goals of this research is to inform development design decisions, and consequently this will exclude the testing and analysis portion of policy screening in stage 6. Instead, scenario planning in this research is a technique for analyzing resiliency in future alternative development designs.

Resiliency Planning

The theory of resiliency binds the dynamic relationship of conservation planning and development planning at the regional scale. The resilience concept is generally understood as “the capacity of a system to absorb disturbances and still retain its basic function and structure” (Walker and Salt 2006; Chappells and Medd 2012). The applicability of resiliency to planning emerged with the evolution of sustainability in the beginning of the 21st century. Early facets of sustainability conceptualized sustainability as taking equal account of the social-political, economic, and ecological components (Theile 2011). Campbell’s interlocking circles, Elkingston’s triple bottom line, and the three legged stool all are first generation sustainability diagrams that envision these components as additives; it was assumed that a balance of the components, informed by the public interest, would lead to system integrity (Campbell 1996; Elkington 1997; Holden 2012). Second-generation sustainability “[recognized] that human and natural systems are dynamic and constantly evolving [processes, and that] uncertainty is endemic" (Holden 2012).

The growth of resiliency in practice paralleled the interpretation of sustainability in landscape and urban planning. Jack Ahern describes smart growth and new urbanism approaches to design in the context of the rudimentary, first generation, "fail-safe" approach to sustainability. The argument is that if each of the three sustainability components is accounted for, a static development design will endure from generation to generation. In light of the evolution of the second, non-equilibrium generation of sustainability Ahern poses, "How can a static landscape condition be sustainable in a context of unpredictable disturbance and change?" (Ahern 2011). Ahern suggests "safe-to-fail" resiliency planning as a possible solution, wherein unforeseen failure (uncertainty) is anticipated, contained, and minimized beforehand (Steiner 2006; Ahern 2011).

Presently, sustainability is emerging into a third generation at which point integration of environmental concern is dependent on interdisciplinary collaboration. The incorporation of environmental objectives into non-environmental arenas is often recognized as a need yet it is seldom successfully characterized in policy. To fully integrate the capacity for resilience into a plan the built evidence needs to be counterbalanced by visible, dynamic information about the landscape. "Building resilience capacity through landscape and urban planning requires that planners and designers identify the stochastic processes and disturbances that a particular landscape or city is likely to face, the frequency and intensity of these events, and how cities can build the adaptive capacity to respond to these disturbances while remaining in a functional state of resilience (Vale et al. 2005; Ahern 2011). This research will be limited to the physical resilience capacity of development designs and to the functional resilience of landscape processes, and will not test social infrastructure or stakeholder participation in planning and policy decision making. Multiple landscape processes are integrated into this study to establish a level of redundancy when comparing the resiliency of a design to its regional landscape. Redundancy spreads anticipatory site-scale risk and can be useful in identifying cross-scale interactors. Rather than placing "all of your eggs in one basket," this strategy informs pre-planning for when a system, such as development design, fails (Ahern 2011).

The Pattern of Florida Policy

"The state of Florida promotes innovative planning and development strategies to support a diverse economy, vibrant communities, and provide economic incentives to businesses that create new jobs" (DEO 2013). Achieving this mission is the intent of the Community Planning and Development (CPD) Programs of the Florida DEO. The CPD Programs include Comprehensive Planning, Areas of Critical State Concern, Technical Assistance (Community Resiliency), and Developments of Regional Impact and Florida Quality Development. The CPD policy programs evolved out of the 1990s to maintain Florida's economic growth potential and to help mitigate the impact of development on Florida's open space (and to mitigate the impact of Florida's open space on development). A simplification of the evolution of CPD is provided in Figure 2-1. Frst this review will step back to the beginning of Florida's history cycle, before CPD becomes involved in the late 20th century.

Wetlands. The history of development in wetlands and the recognition of coastal vulnerability to water hazards outline the beginning of the cycle before policy intervention occurred in Florida. Figure 2-1 depicts two linked cycles in which shifts in development and conservation policy lead to consequences. In the first revolution of the cycle -from Point 1 to Point 5- Florida policy clearly prioritizes water and watershed planning. Wetlands have played a unique role in Florida’s history. Florida is characterized by flat topography, a high water table, and high rainfall. After statehood was granted to Florida in 1845, 15 million acres of wetlands, or 40% of the state, was transferred from the federal level to the state level for the purpose of making “them productive through farming and drainage” (1850 Swamp Lands Act). The Water Resources Atlas of Florida catalogs satellite imagery of the state. Depictions from the early 1970s show that “wetlands and their associated open-water areas accounted for almost a third of the total land area for the state” (Hampson 1984, Fernard and Purdum 1998, Rubino and Starnes 2008). Still today, interspersed ephemeral wetlands are fueled by cyclic rain and drought cycles, predominantly from tropical cyclones.

Instrumental observations of hurricane activity only go back approximately 100 years (Liu et al. 2003). In 1926 rapid urbanization in previously drained swampland faced a category 4 hurricane. Massive flooding caused by the hurricane led to 392 deaths and injured 6,000 people (NOAA 2009). Only two years later a category 5 hurricane caused the dike wall surrounding Belle Glade and South Bay to collapse, drowning 2,000 people (Kleinberg 2004). In contemporary times, “[nine] of the U.S. top 12 costliest hurricanes of all time occurred between 2001 and 2005, including four that hit Florida in 2004” (Randolph 2012).

The Federal Emergency Management Agency (FEMA) administers the Natural Hazard Mitigation Program and the National Flood Insurance Program. FEMA prepares for communities Flood Insurance Rate Maps that illustrate special flood hazard areas and insurance risk premium zones that would be applicable for assistance through the National Flood Insurance Program. Before FEMA can provide any federal funding or assistance to a locality the National Environmental Policy Act (NEPA), 42 U.S.C. 4321-4347, ensures that localities comply with environmental considerations (Florida Division of Emergency Management (FDEM) 2012). Delineated in any flood insurance rate map are base flood elevations, a 100-year, and a 500-year floodplain (FDEM 2012). Due to the frequency of variation in Florida's hydroperiod, and the successful recognition of FEMA flood zones by developers, the 100-year floodplain is heavily avoided during the development-design phase of planning as a method of minimizing insurance costs.

Adaptation planning emerged under the Community Resiliency Initiatives to prioritize government funding for infrastructure needs and for planning in adaptation action areas. Adaptation areas specifically include "areas below, at, or near mean high water, areas which have a hydrological connection to coastal waters, and areas designated as evacuation zones for storm surge" (Florida Statutes 163.177; DEO 2013). Florida planning policy adopted the three most referenced strategies from the literature to help coastal communities become more resilient to the impacts of rising sea levels: Protection, Accommodation, and Retreat (Southeast Florida Regional Climate Change Compact Counties 2012; DEO 2013). *Adaptation Planning In Florida,* a handout, outlines Florida's policy interpretation of the relationship between adaptation planning and hazard mitigation (DEO 2013):

> The main difference is that sea level rise adaptation assumes a longer timeframe for impact and therefore a longer timeframe for need and implementation. Sea level rise also assumes an increase in the vulnerability of areas already subject to coastal flooding and

therefore adaptation projects take into account the increased vulnerability.

Coastal High Hazard Areas (CHHA) receive individual attention as an initiative under the Community Resiliency Initiatives. This initiative references that the intent of the Florida legislature is for local governments to restrict development activities in CHHA (FS 163.3178(1)). Furthermore, Florida Statutes require local governments to limit public expenditures that subsidize development in CHHA, and limit or restrict residential density or the type of development permitted in those areas (FS 163.3177(6)6). In many ways, the underlying justification for a reevaluation of human population growth forecasts in Florida are an outcome of these initiatives. Illustrated in Point 5 in Figure 2-1, the specificity of the Community Resiliency Initiatives has discontinued the perpetuation of the first cycle, and has guided the focus of construction and development to uplands.

Uplands. The second cycle of Figure 2-1 is a conceptual cycle of the construction and development pattern occurring in Florida and a forecast of the consequences. To restate from the previous section, federal FEMA regulations directly incentivize development to occur above the 100-yr floodplain to limit rate increases to insurance premiums. At the state level indirect incentives to develop in areas with less hydrological connection to coastal waters and with less coastal hazard vulnerability leads development to occur in uplands in the interior of Florida.

Wildfires have historically posed a threat to the economic resources of forestlands, ecosystems, and watersheds and only recently have become a threat to urban development. In 1985, as a result of wildfire 600 homes burned down in Florida and 1,400 burned nationally (NFPA 2014). In 1998 a Florida wildfire burned from May

25 to July 22 requiring the assistance of 7,000 firefighters from 44 states (McMillan 1998). When the wildfire was extinguished approximately 500,000 acres had burned, resulting in the loss of 270 businesses and homes and a cumulative built and natural resource loss of $620,000,000 USD (Mercer et al. 2000). In 2000 the same amendment to the Stafford Act that mandated local governments to prepare coastal hazard plans mandated governments to create local mitigation strategies to reduce the risk and vulnerability of developments to wildfires. The outward sprawl of urban development into wildland areas led the U.S. Congress to create the Healthy Forests and Restoration Act (HFRA) in 2003. Under this federal act the USDA Forest Service (USFS) and the Bureau of Land Management (BLM) are required to "consider local communities when developing and implementing forest [management], hazardous fuels [management], and fire management" plans (Randolph 2012). To assist communities vulnerable to fire the HFRA designated the creation of a natural hazard mitigation planning assessment tool, *Community Wildfire Protection Plans*. In 2002, the National Fire Protection Agency (NFPA) also began the *Firewise Communities/USA Recognition Program*. These programs stress three factors: *Collaboration* of communities with local and state government representatives, *Prioritized Fuel Reduction* in hazardous areas, and *Treatment of Structural Ignitability* at the homeowner and community level (CWPP Committee et al. 2004).

Community Resiliency Initiatives in Florida are skewed toward watershed planning. At the State level, there is a 3:1 ratio of Community Resiliency Initiatives between watershed planning and fireshed planning, and fire is only regarded in one of four sections in the Hazard Mitigation Planning Initiative. The guidebook for Hazard

Mitigation contains a best practices section for wildfire risk reduction. *Wildfire Risk Reduction in Florida: Home, Neighborhood and Community Best Practices* describes the planning approaches for resilient development design in Florida. In its first pages the Best Practices guide documents projected land uses to 2060 and documents the future conflict between population growth and Florida's natural areas in interior counties (DACS 2010). For communities at risk to wildfire in the WUI perhaps the most important principle is defensible space. Defensible space, illustrated in Figure 2-3, uses firewise construction, firewise landscaping, and fuels reduction to reduce hazard immediately around developed structures. In defensible space, Zone 1 is 0-30 ft. from the structure. This area is designed with well irrigated, low growing vascular plants and built surfaces that are intended to protect the home from fire. In Zone 2 fuels reduction is extended from 30 ft. to 60 ft. in order to limit the availability of hazardous fuels to the home. Zone 3, also known as the Transition Zone, is designed to progressively remove the continuity of fuels from a potential encroaching wildfire. The intention of the Best Practices Guidebook is to educate agencies and communities about the hazards of wildfire. Indicated by the "?" in Figure 2-1, this review exposes an uncertain future for development in Florida, and an opportunity to explore development designs for whether they capacitate or inhibit regional processes.

Contemporary Methods and Development Designs in Florida

Attributes of Firewise Development Designs

Design for wildfire preparedness in practice has progressively moved away from 'command and control' and shifted "to a social focus that emphasizes the role of human behavior, values, attitudes, and decisions in managing wildfires" (Prior and Eriksen 2013). Under the Firewise index on the Florida Forest Service website it could not be stated more explicitly; “The simple truth is that few fire departments have adequate resources to protect every home in the wildland/urban interface.” Firewise Communities/USA is a recognition program that standardizes and certifies communities based on an assessment of risk to catastrophic wildfire. Many Florida communities have gained recognition under the Firewise Communities program (NFPA 2014).

The premier review of community design in Florida for risk to wildfire is *Planning Strategies for Community Wildfire Defense Design*. Brzuszek et al. provide a descriptive analysis of the 1998 catastrophic wildfire season and then provide a comparative analysis between three Firewise subdivisions in Florida. The findings of the study suggest that communities which balanced green infrastructure, blue infrastructure, and gray infrastructure create the greatest defenses for communities at risk to wildland fires.

Green infrastructure is naturally vegetated, undeveloped, open lands. Green infrastructure is a collective name describing riparian areas, open fields, upland pine, and other non-wetland features in the landscape. Blue infrastructure includes the streams, lakes, swamps and other wetland feature types. Lastly, gray infrastructure includes urbanized land uses including buildings, infrastructure, roadways and their associated rights of way. Brzuszek concludes and claims that for Firewise development it is important to conserve “natural and constructed fire barriers, including wetlands, roads, and maintained utility corridors. The report supports the Florida Hazard Best Practices guide by stating that structures should be concentrated and located proximally to fire barriers, separating them from wildland fuels and primary fire travel directions. Land-use planning should identify areas at risk to wildfire and use this information to inform regulations that mitigate the relative risk (Brzuszek et al. 2010). The Brzuszek article describes that green belts are useful for supporting wildlife conservation and plant species conservation, but conservation design principles have received separate individual attention in the literature.

Attributes of Conservation Development Designs

Today, building new infrastructure in the WUI means dealing with spatial process-pattern relationships within landscapes (Forman 1995). Many of the design principles from *Planning Strategies for Community Wildfire Defense Design* and from *Wildfire Risk Reduction in Florida: Home, Neighborhood and Community Best Practices* have a strong resemblance to Randall Arendt's principles in *Conservation Design for Subdivisions*, in which Arendt describes densification of structures as a method to promote efficient resource use (Arendt 1996).

Conservation subdivisions are one of many site-scale design approaches that were created to correct the issues of traditional development. In the design phase, conservation subdivisions employ a technique of clustering built land uses into a consolidated space to effectively conserve natural areas, productive agriculture, and forested lands from development (Arendt 1997). To conserve biodiversity in developments the common focus of planning is to establish green infrastructure, referred in this case as protected natural open space and corridors (Hostetler et al. 2011). Target objectives for conservation subdivisions are reached when the pattern of development and the densities of that pattern can operate in the least resource-intensive manner achievable.

Conservation subdivisions have grown in popularity in the 21st century. Yet, many studies have shown that homeowners often are unaware or do not understand the importance of individual actions toward the functionality of conserved natural areas and waterways (Hostetler et al. 2011). As an alternative, developments of regional impact or sector plans have gained favor for their thorough participation processes, government agency involvement, and growth management focus at the regional scale.

Developments of Regional Impact (DRIs) are “any development which, because of its character, magnitude, or location, would have a substantial effect upon the health, safety or welfare of citizens of more than one [Florida] county” (FS 380.06(1)). To illustrate the participation component, the DRI process is diagramed in Figure 2-4. Sector plans are DRIs that have a minimum size area of 15,000 acres. Sector plans require a two stage approval process involving two separate, but linked, components. The first is a long-term master plan, and the second is a detailed specific area plan. The long-term master plan is required to identify regionally significant natural resources as part of the framework map for the development (FS 163.3245(3)(a)). The detailed specific area plan must also identify the areas that will be placed under permanent preservation, including documentation for all conservation easements (FS 163.3245(3)(b)). There are many examples of sector plans and there are many examples of modeling tools that have been used to demonstrate the ability of sector plans to promote or inhibit the functionality of areas under conservation easements.

Wildlife Corridor Design Methods

As technology has improved modeling approaches have been developed to conceptualize the functional need for linkages across the landscape. Many of these modeling techniques have been used to assess the health of currently conserved lands and have been used to demonstrate the impact of DRIs at the regional scale. Tewksbury and his colleagues investigated the indirect effects of corridors to facilitate movement using a suite of focal species. The suite of species included fauna, seed, and pollen so that the experimental design would cover taxa with a diverse range of life history characteristics. This type of experimental landscape design allowed the authors to distinguish “effects due to corridor-facilitated movement from effects to changes in patch size and shape” (Tewksbury et al. 2002). The immediate evidence from the study was that movement for the entire suite of species from connected patches was greater than movement from unconnected patches. Their research claims “that corridors can have substantial effects on [colonization, pollination, and dispersal], and thereby help overcome the depressed reproduction frequently reported for [isolated populations]” (Tewksbury et al. 2002). A sub claim made by Tewksbury et al. is that effects of corridors can have notable consequences for population dynamics at larger, regional scales. The authors caution and advocate that future large-scale research should include studies of unmanipulated landscapes. Identifying Florida lands before physical development occurs will enable landscape connectivity analysis to be included in this research into the site synthesis portion of the development design phase.

Due to the rapid pace of urbanization a focal species approach can be used to assess landscape connectivity. This approach is advantageous because “species-based management is accepted and supported by managers, decision-makers, and public opinion (Lambeck 1997; Miller et al. 1999; Carroll et al. 2001; Bani et al. 2002; Noss and Daly Chapter 23; Beier 2006). Least-cost corridor analysis is a geospatial method for determining the optimal location of a landscape linkage (Singleton et al. 2002; Beier 2006). Geographic Information Systems (GIS) are digitized visualizations that can be spatially analyzed to display geographically referenced information (ESRI 2011). This research will use geostatistical analysis, rather than investing in research of inter– and intra– corridor movement, to measure the degree to which facilitation and impediments of movement of a wide-ranging specie, the Florida black bear (*Ursus americanus floridanus*), is provided by land use changes. Habitat factors customarily used in corridor analysis in the study of black bear are:

- Vegetation/Land Use
- Elevation metric
- Topographic features
- Road Density

These habitat factors are weighted based on surveys of biologist that work closely with the focal specie. The first two habitat factors, Vegetation/Land Uses and Elevation, are ranked on their relative importance and relative deterrence to the specie. Topographic features that influence movement typically include ridges, canyon bottoms, flats, or slope. Last, road densities are usually paved road densities per km^2. Road densities can also be substituted for distance to roadways when contiguous parcel size is more indicative of movement for the focal specie. (Beier 2006: Beier 2008).

Wildfire Planning Methods

Many of the same inputs required for least-cost corridor analyses are also required as inputs for wildfire spread prediction. ArcGIS can be used to transform spatial data into inputs for wildfire simulators. Program FARSITE 4 is a fire behavior and movement simulator that is used by fire behavior analysts, including the United States Forest Service and the Florida Forest Service (Fire.org 2008). FARSITE 4 incorporates spatial and temporal information on topography, fuels, and weather to display fire growth (MFSL 2010). In ArcGIS, topographic information is transformed into elevation, slope, and aspect data in the form of text-based ASCII inputs. When combined with fuel models and weather and wind files FARSITE can process hourly rates of spread for a wildfire while recording output feedback on flame length (MFSL 2010).

Program FamilyFirePlus can be used to retrieve and transform weather and wind data into processable information for Program FARSITE 4. The Western Regional Climate Center (WRCC) is one such climate information service that monitors and records high quality historical climate data. The WRCC feeds from weather stations across the United States and is partnered with the National Climate Data Center, DOI Climate Science Centers, and DOI Landscape Conservation Cooperatives among others (WRCC 2013). Weather and wind information is collected in hourly intervals in most stations, but erroneous records often blight datasets. Therefore quality control is necessary when working with historical weather information. After correcting for erroneous records, FireFamilyPlus has the ability to categorize and divide historical weather patterns into three categories of fire weather; low, medium, and high fire intensity (Weise et al. 2010). The 90th, 95th, and 97th percentiles are normally attributed to low, medium, and high fire intensities, although in Florida the 80th, 90th, and 95th percentiles are sufficient (Helfmen et al. 1980; Weise et al. 2010). An hourly data analysis is performed to generate an hourly list which is a requirement to incorporate weather data into program FARSITE for wildfire simulations.

In wildfire simulation modeling, a fuel model is a numeric attribute for a cell in a raster surface. Together, a raster coverage of fuel models provides the fuel inputs for Rothermel's mathematical model that predicts surface fire spread (FARSITE 2009). Fuel models are derived from the following sources:

- The 53 standard behavior models (National Fire Danger Rating System 1972)
- The 13 original models (Anderson 1982)

- The 40 defined models (Scott and Burgan 2005)
- Custom Fuel Models

Each of these models uses average fuel load estimates for the different fuel types and size classes. When simulating a wildfire, one option is to use a fuel model that resembles the ecosystem to be modeled. To reduce generalization and increase the fuel model’s ability to predict fire behavior, the Custom Fuel Model is an option that can be used in the place of the standard fire behavior fuel models (FARSITE 2009). This option uses precise field measurements of fuel loading. Field measurements include Shrub and Herbaceous Loads, Downed Woody Debris loads, and Duff and Litter Depths. The most commonly used method for fuel load measurement is the Brown’s Planar Intercept method (Brown 1974). This method uses three random azimuth transects at specific stratified points to collect sample fuel volume and surface area characteristics to quantify fuel load in tons/acre (Brown 1971). The surface area characteristics are referred to as Timelag Size Classes and are based on diameter classes taken in inches (Figure 2-5). Because the Brown’s Planar Intercept method is a single plane transect, the intercept methodology is highly susceptible to changes in surface slope.

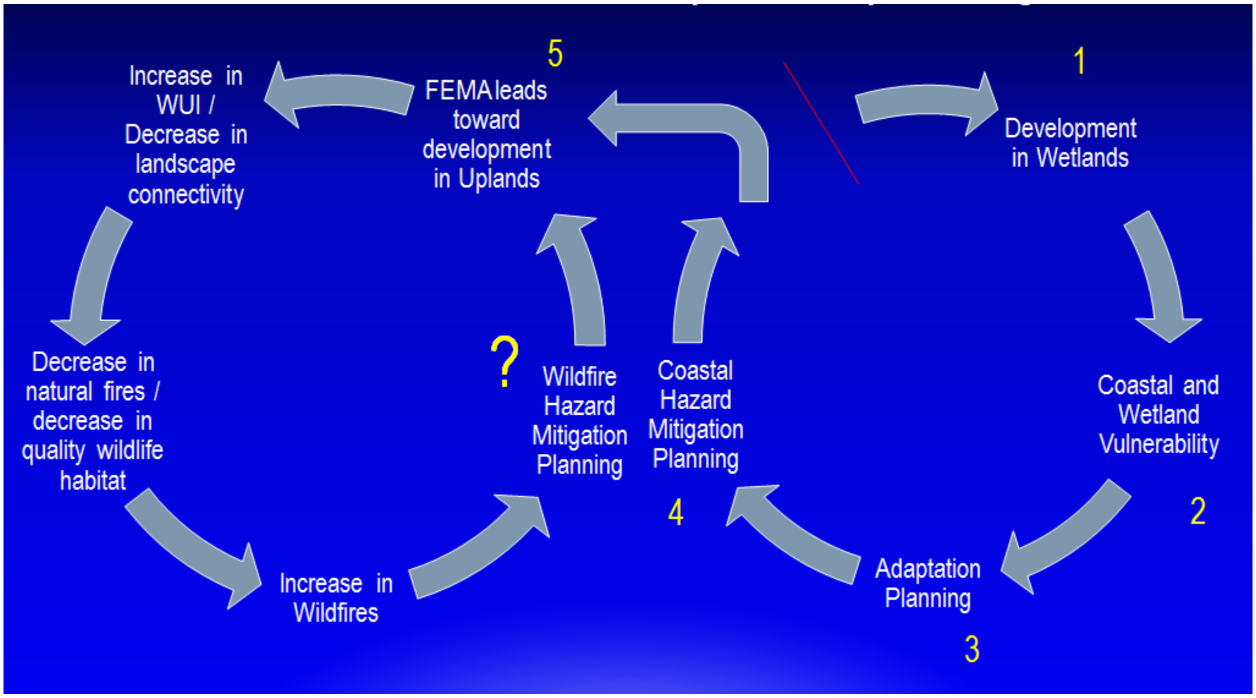


Figure 2-1. Identified Problems with Florida's Community Resilliency Planning.

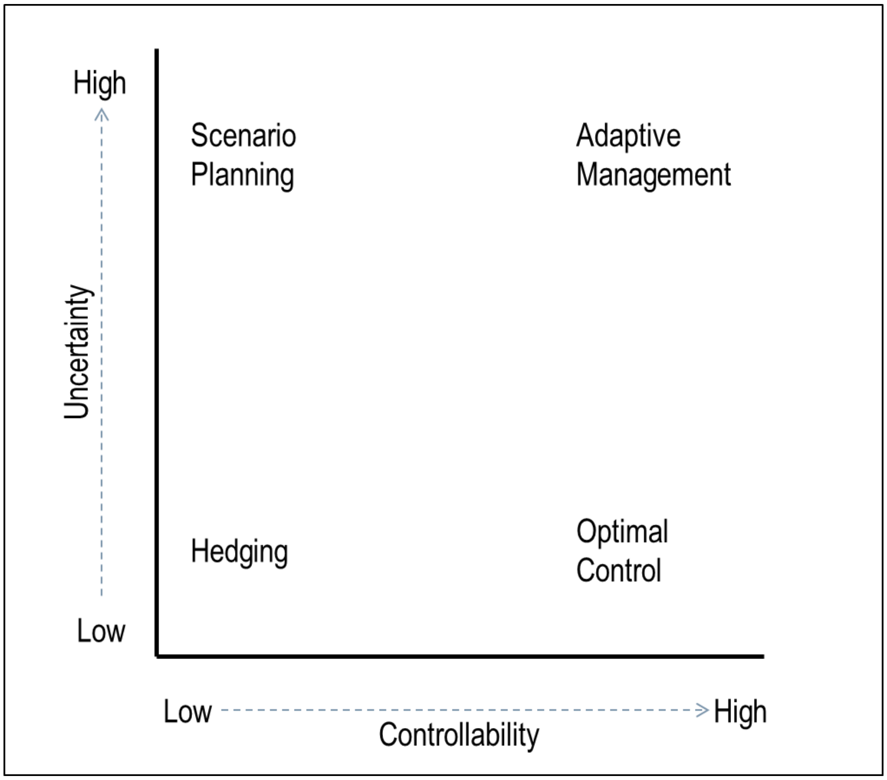


Figure 2-2. A decision making tool for selection between multiple management options. The chart is categorized according to the level of control and the level of uncertainty (Randolph 2012).

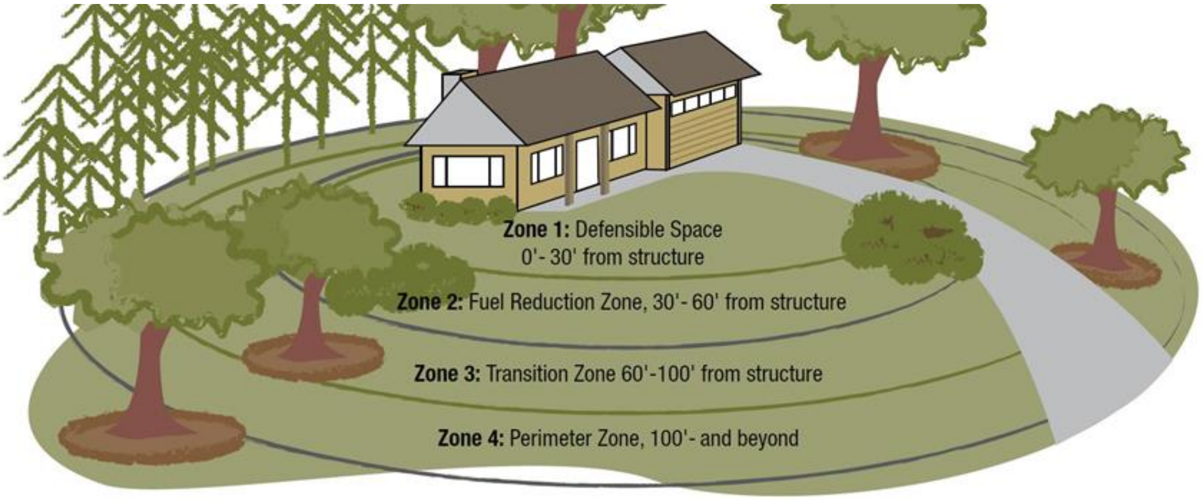


Figure 2-3. Diagram of defensible space. Each of the four Zones has progressively stricter landscaping principles that reduce the availability of hazardous fuels near the structure.

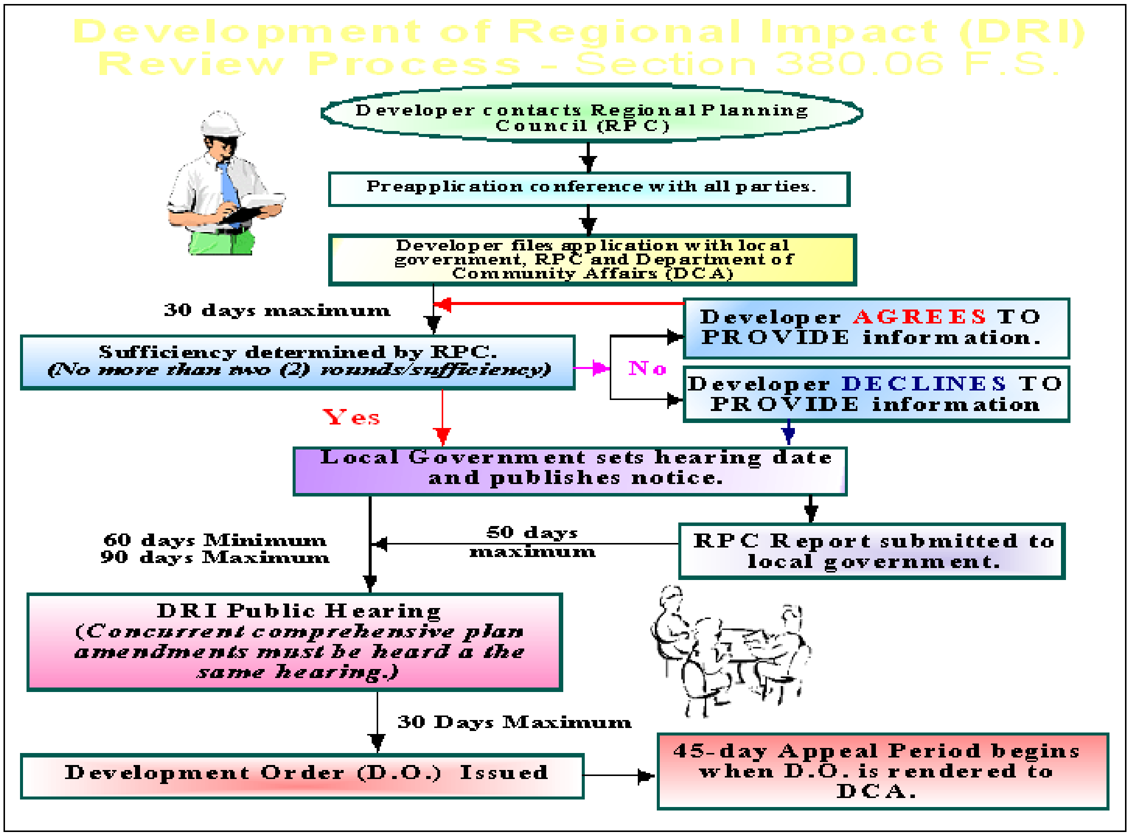


Figure 2-4. The Development of Regional Impact Review Process (FS 380.06).

Diameter Class *(inches)* :	**0-0.25”**	**0.25-1”**	**1-3”**	**3+”**
Timelag Size Class:	**1 hour**	**10 hour**	**100 hour**	**1000 hour**

Figure 2-5. Classes for Downed Woody Debris measurement in the Brown’s Planar Intercept Method.

CHAPTER 3
METHODOLOGY

Overview of Methodology

Two embedded units of regional analysis were used to assess alternative development designs for one property in Florida. The first is a before-development and after-development analysis of a least-cost wildlife corridor (LCC). The second analysis is a comparative analysis of a surface wildfire across the development site (Figure 3-1). First, the methodology will overview the Site Description. Second, a site synthesis is briefly described in the Site Description to outline the participation process that led to the preparation of alternative development designs. Next, the methodology is divided into two parts to discuss the technical procedure for each embedded unit of analysis of the research design. Part I will be *The Production of Before and After Wildlife Corridor Scenarios*. Part II will be *The Production of Surface Wildfire Scenarios*. The main objectives and sub-objectives of this research follow:

1. To compare proposed development designs by their impact on the facilitation of regional wildlife movement.
    i. What is the effect of the application of wildlife corridors modeling on development design during the pre-development, site synthesis phase?
    ii. What is the impact of development design on the facilitation of wildlife movement in regionally significant ecological corridors?
2. To rank proposed development designs from most to least susceptible to surface wildfire.
    i. What is the effect of development design on fire behavior (flame length, area burned, burn duration, and spread rate) during a wildfire?
    ii. What characteristics of development design increase vulnerability to wildland fire in an ecologically significant corridor?
    iii. What lessons can be learned from fuel load estimates in ecologically significant areas adjacent to future development in the Wildland Urban Interface?

Site Description

Study Area

To study the effects of conservation planning before development physically occurs, a study location was chosen within the context of a regional area in Florida. The regional area north of Crystal River National Wildlife Refuge, West of Interstate 75, and South of Ecofina River State Park was chosen for this study because it contains all six priority linkages and both classes of critical linkages as described in the FEGN (Figure 3-3). Within the regional study area the Principal Investigator (PI), Scott Rothberg, contacted private landowners interested in development.

For this study the PI entered into a land use contract with Suwannee Lake Plantation Inc. (SLP) in Gilchrist County in the Spring of 2012. SLP is a ~28,000 acre site located entirely within a Priority 5 Link of the FEGN (Figure 3-4). The property is located in an area called the Waccasassa Flats. The Waccasassa Flats is a general term for a landscape originally described as 65,070 acres, or 102 square miles, composed of remnant swamp and sandhill barrier islands to the Brooksville Ridge that formed during the Pleistocene (Vernon 1951, Nolan 1997, Yon and Puri 2004). The geomorphology of the area contains Miocene and Pleistocene sediments that create a relatively high water table and characteristically a high level of water retention. The soils in the Waccasassa Flats are mainly Group C and Group D, as seen in Figure 3-5. (USDA 1992, Nolan 1997). Soils in Group C and D generally lie shallow to impervious layers in the soil horizon and tend to be clayey, impeding the downward movement of water (Nolan 1997). Relative to the context of Gilchrist County, the Waccasassa Flats have higher elevations and steeper gradients (Col et al. 1997). Sandhill ridges in this area reach an average of 90 to 100 feet above sea level, and the ridges lie within a mosaic of gum sloughs, cypress ponds, and wetlands averaging approximately 60 feet in elevation (Nolan 1997). Inferences by R. Vernon attribute the Wacassasa Flats as ancient sand dunes during a time when the Gulf Coastal Lowlands were previously submerged below sea level, and later on as a stream course (Vernon 1951).

The vegetation and land use history of the Waccasassa Flats are a reflection of the divergent conditions in the Flats compared to Gilchrist County. The land surrounding the Waccasassa Flats historically has been used for productive agriculture and human settlement. In recent decades the Waccasassa Flats have been zoned for silvicultural use with some intermittent settlement. FNAI classification of this area identifies primary ecosystem types as pine-mesic oak forests, pine plantation, oak sandhill scrub, wetland mixed forest, wet flatwoods, and cypress swamp (FGDL 2013).

Development Design

The development design scenarios were generated by a graduate level Design, Construction, and Planning Landscape Studio in the Fall of 2012 at the University of Florida. The studio was divided into three different groups of both graduate level planners and landscape architects. Each group created a development design for the SLP property. Preliminary site synthesis was a collective effort involving all three groups. The site synthesis started with information gathering. Geographic information was collected from the Florida Geographic Database Library (FGDL) and was shared between groups. Additional information was gathered from the Gilchrist County Property Appraisers, the North Central Florida Economic Development Plan, and both Florida and local municipality Comprehensive Plans. The process of a site synthesis is outlined in Figure 3-6.

To create the designs each group applied value-based decision making. First, a maximum build out design was created by each group. The maximum build out design is intended to determine the maximum amount of developable land space available above the 100 year floodplain and to design and examine the road network that would be needed to connect that space. For an example of a maximum build out design, see Figure 3-6. Strengths, Weaknesses, Opportunities, and Threats (SWOT) of the site were analyzed to inform the groups' individual decisions on the proportion of developed land uses to include in the final development designs (GTZ 2002). Applying this value-based decision approach created three unique development designs with independent proportions and geospatial distributions of high, medium, and low density residential development, commercial areas, civic buildings, utility infrastructure, educational areas, recreation and open space areas, and roadway networks (Figure 3-7).

Research Design

An expansion of Figure 3-1, Figure 3-2 illustrates the conceptual framework of the methodology.

Part 1: The Production of Before and After Wildlife Corridor Scenarios

For this modeling approach ArcGIS 10.1 was used to analyze habitat factors for the focal specie, the Florida black bear (*U. floridanus*). Due to funding limitations, habitat factors were adopted from previous literature (Garshelis and Pelton 1981; Powell et al. 1997; Beier 2006; Rose 2013). Habitat factors customarily used in corridor analysis in the study of black bears are:

- Vegetation/Land Use
- Topographic features
- Elevation metric
- Road Density

The habitat factors that were used in this corridor analysis of the Florida black bear differ from typical factors because the Florida landscape is less influenced by topographic relief. Additionally, rather than using road densities Euclidean distance to roads was used in the analysis. Euclidean distance is a more accurate account of road proximity as well as road density for wildlife because it considers the compounded effects of multiple roads. Because development patterns are dependent on road network and development design, this research used the opportunity to compare an initial ecological corridor to a future scenario with encroached development.

Determining the effect of the application of wildlife corridor modeling on development design during the pre-development, site synthesis phase.

During the site synthesis phase a base model of regional wildlife movement was provided to all groups (Figure 3-8). The base model was a simple Least-cost Path Corridor (LCP) model produced in ArcGIS that illustrated the concept of a ‘before development’ scenario to the three design groups. The LCP and LCC model uses existing land cover information, topographic position, elevation, and distance to paved roads as inputs to create a surface raster of resistance. The cost surface is on a virtual value scale of 1 to 10, with 1 being the lowest cost to traversal and 10 being the highest resistance cost. This base model was provided to the Fall 2012 Planning Studio as an initial representation of regional wildlife movement through the SLP property.

Determining the impact of development design on the facilitation of wildlife movement in regionally significant ecological corridors.

For the before and after analysis, the LCP model was replaced with a more technical LCC model (Figure 3-9). A comprehensive technical discussion of the LCC model methodology is available in Appendix A. A summary of the required inputs is outlined here for clarity.

The LCC map algebra expression uses mean factor weights (%) to synthesize and attribute an output value for each cell in the new cost raster (ESRI 2011). The expression uses the following python sintax -

("%flma_raster%" * 0.02) + ("%euc_dis_rds_raster %" * 0.15) + ("%dist_water_raster_%" * 0.02) + ("%reclassify_slope%" * 0.13) + ("%Internal_parcel_raster%" * 0.68)

- where Distance to FLMA is weighted 2%, Distance to Water Bodies is 2%, Euclidean Distance to roads is weighted 15%, Topography is weighted 13%, and Land Cover per parcel is weighted 68%.

To create the before scenario this research used the current Land Cover per parcel information available through the FGDL. The lowest accumulative cost resistance was analyzed from the top of the FEGN network entering the Northern end of the Waccasassa Flats and from the Southern end of the FEGN network entering the Waccasassa Flats. This final before corridor was analyzed and saved for comparison between the before development scenario and the after development scenarios.

When the three development designs were finalized, adjustments were made to the Land Cover per parcel and Euclidean Distance to roads inputs to reflect changes in land use. After this process was completed for each group the new datasets were recalculated with the other weighted habitat factors that were created in the before scenario. The same python script was used to create the after development wildlife corridor scenario for each of the three groups. A qualitative and quantitative comparison of the after scenarios provides insight into the effect of development design on the facilitation of regional wildlife movement.

Summary

The before and after analysis of a LCC through the Waccasassa Flats created quantitative metrics of regional scale movement of wildlife. The created metrics are one before-development scenario and three unique after-development scenarios. The scenarios are used to qualitatively compare the following objective and two sub-objectives:

1. To compare proposed development designs by their impact on the facilitation of regional wildlife movement.
    i. What is the effect of the application of wildlife corridors modeling on development design during the pre-development, site synthesis phase?
    ii. What is the impact of development design on the facilitation of wildlife movement in regionally significant ecological corridors?

Part II: The Production of Surface Wildfire Scenarios

The project inputs necessary to create an operational project file for this analysis in FARSITE 4 are a Landscape File, a Weather File, a Wind File and any attached vector files that will influence surface wildfire front propagation. To create the landscape file there are four input requirements; Elevation, Slope, Aspect, and Fuel Model. For FARSITE to be able to model a surface wildfire and generate measurements of flame length, this analysis also included an input for Duff Loading and for Course Woody Debris. First, the processing method of Elevation, Slope, and Aspect inputs are presented, followed by the processing method for the Fuel Model. Then, the method for creating the Weather and Wind Files is described. Last, the output information from FARSITE 4 that will be used to analyze the sub-objectives is described. A comprehensive technical discussion of the Surface Wildfire modeling methodology is available for review in Appendix B.

Elevation, Slope, and Aspect. The Spatial Analyst tool in ArcGIS 10.1 was used to create these three inputs. USGS 5 ft. contour information from the FGDL was converted in ArcGIS 10.1 into a topography raster dataset. The Spatial Analyst tool created Elevation, Slope, and Aspect raster outputs that were each converted into ASCII files for input into the Landscape File in FARSITE 4.

Cluster Analysis. The final required input (Fuel Model) and the optional inputs (Duff Loading and Course Woody Debris) for Program FARSITE are based on field data collected on the SLP property in 2013. The ~28,000 acre SLP property was classified into uplands and wetlands. From the FGDL, the FEMA 100 year flood-zone was used to delineate Suwanee River Water Management District land use data for Gilchrist County as an uplands class or a wetlands class. 100 random GPS points were generated between the two classes at 50 GPS points per class. Using ArcGIS 10.1, an Average Nearest Neighbor cluster analysis was performed on each class individually, as well as on all 100 GPS points aggregated together (Figure 3-10). The purpose of the cluster analysis was to determine if any portion of the property was underrepresented and likewise to avoid oversampling.

Average Nearest Neighbor summaries are reported in Figures 3-11 – 3-13. Both the upland random points and the wetland random points returned a pattern revealing no significantly different distribution deviating from random. Investigating the returned data shows that for uplands, the observed mean distance is 723.9 m., and the expected mean distance is 764.7 m. A negative z-score of -0.072 further confirms that the spatial configuration of upland points is slightly clustered even though it is reported graphically as random.

For wetland points the same slight deviation from random is observed. In this case the nearest neighbor ratio of 0.977 is also just less than 1. A z-score of -0.311 confirms that the random spatial configuration is closer to clustered than to dispersed and is slightly more clustered than the distribution of upland points. When the points were aggregated into a 100 point surface the level of clustering increased. Figure 3-13 illustrates the more clustered than random distribution. The ratio of observed to expected mean distance is 0.91 and the z-score has decreased to -1.72. Across the site there is significant clustering; yet it is not severely clustered. There remains a 90% likelihood that this clustered pattern could not be the result of random chance. Furthermore, the three distributions reported in Figures 3-11 – 3-13 were the 6th of 10 iterations of the random points tool. This cycle of random points was selected because it out performed other observed to expected ratios in both categories.

Field Data Collection. The Brown’s Planar Intercept method was used at each GPS point for data collection. This method uses three random azimuth transects at specific stratified points to collect sample fuel volume and surface area characteristics to quantify fuel load in tons/acre (Brown 1971). At each GPS point three transects were taken at azimuth (compass-based) directions separated by a minimum of 60 cardinal degrees. All data was collected on the Data Collection Tool, as shown in Figure 3-14. For each GPS point, a GPS tagged photo was taken such as in Figure 3-15. Lastly, if any GPS point was inundated with water it was marked as indeterminate and no measurements were taken. Field data was then transferred into ArcGIS.

Fuel Model, Duff Loading, and Coarse Woody Debris. Variables recorded in the field were used to create a spatial surface as an input for FARSITE 4. The first input to process for the surface was a Custom Fuel Model for the SLP property. The Custom Fuel Model is a raster coverage of numeric values used to predict surface fire spread. The Custom Fuel Model uses the herbaceous and shrub percentages and height estimates at each point as spatial references. The Geostatistical Analyst tool in ArcGIS was used to separately create an Inverse Distance Weighted (IDW) spatial surface for uplands and wetlands. After the statistically appropriate surface model was created, the Merge tool was used to create the final Custom Fuel Model surface raster of the entire site. The raster file contains one integer number of a fuel model for each 30 x 30m cell. The raster was then transformed using the Raster to ASCII tool in Conversion tools.

The two remaining inputs required for constructing the spatial surface are Duff Loading and Coarse Woody Debris. For the Duff Loading input, the litter depth (in.) and the duff depth (in.) measurements for each point were used in Geostatistical Analyst to process this input for the ASCII spatial surface. The same method for creating the Custom Fuel Model surface was used. For Coarse Woody Debris the same process for creating the Custom Fuel Model surface was used to create this input for the ASCII spatial surface. This time, the measurements of 1, 10, and 100 hour fuels for each point were used in Geostatistical Analyst.

Weather and Wind Files. The program, FireFamilyPlus, was used to export the Weather and Wind files into program FARSITE 4. Historical fire weather data corresponding to the study extent were downloaded from the WRCC. The most appropriate weather station, ID 083001, is located within the study extent at the Lower

Suwanee National Wildlife Refuge. From Station 083001 records are available from October 2003 to September 2013. Low, Medium, and High fire intensity percentiles were located using the Fire Danger projections tab. Ignition components of 15, 21, and 27 corresponded to the 79.70th, 90.70th, and 95.40th fire intensity percentiles respectively. For the low fire intensity percentile the most appropriate match was 1-10 June 2007. For the medium fire intensity percentile the most appropriate match was 1-9 April 2010. For the high fire intensity percentile the most appropriate match was 1-9 April 2006 (Table 3-1). The Weather and Wind Files for these ranges were exported using an Hourly Data Analysis.

Ranking proposed development designs from most to least susceptible to surface wildfires. With all of the data layers produced and in the appropriate format, all data files were imported into FARSITE 4. The shapefiles that were added are those that can influence the pattern of spread during a surface fire. The shapefiles included major water bodies and the major roadway network. The road network shapefile for each development design are replaced corresponding with each wildfire simulation.

Three simulations of a surface wildfire were performed for each of the three development designs for a total of nine simulations. For each development design three simulations were performed using low, medium, and high fire intensity weather information respectively. To correlate with field data collection in 2013 the Point of Ignition was selected as the GPS location of a lightning strike fire, The Horseshoe Fire, that occurred on the SLP property in the Summer of 2013. A simulated surface wildfire was then started. The simulation finishes when a ‘fire-ending event’ occurs in the hourly weather data or when the <15 day time period expires. Lastly, the Output results are imported into ArcGIS 10.1 for a comparative analysis of how the application of wildfire modeling can identify the resiliency of the development designs to a surface wildfire.

Summary. The three development designs and the three fire intensity scenarios led to the simulation of nine total wildfires. The wildfires produced Output information on areas consumed by fire, rates of spread, and flame lengths. The quantitative analysis of scenario wildfires investigated the following objective and three subobjectives:

1. To rank proposed development designs from most to least susceptible to surface wildfire.
    i. What is the effect of development design on fire behavior (flame length, area burned, burn duration, and spread rate) during a wildfire?
    ii. What characteristics of development design increase vulnerability to wildland fire in an ecologically significant corridor?
    iii. What lessons can be learned from fuel load estimates in ecologically significant areas adjacent to future development in the Wildland Urban Interface?

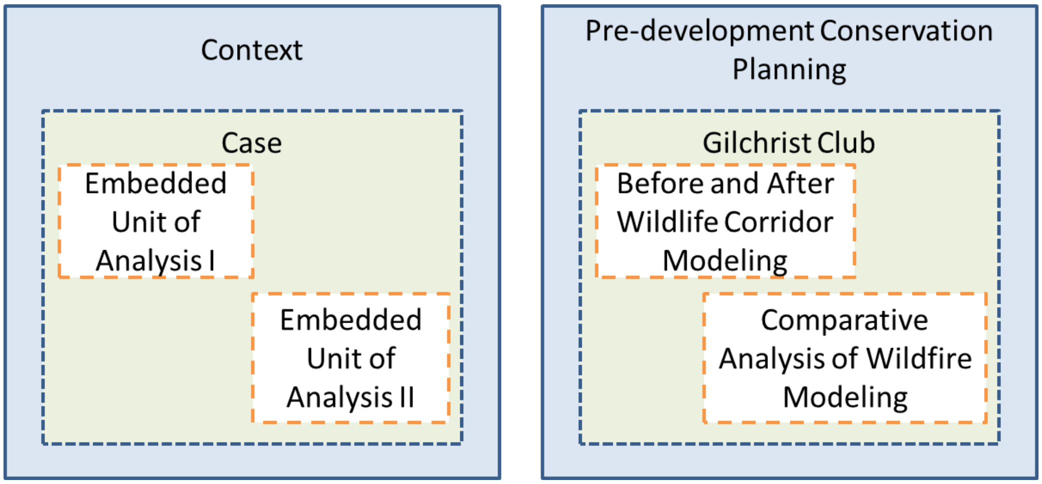


Figure 3-1. Research Design. Two embedded units of Analysis will be used to assess development designs in the SLP property.

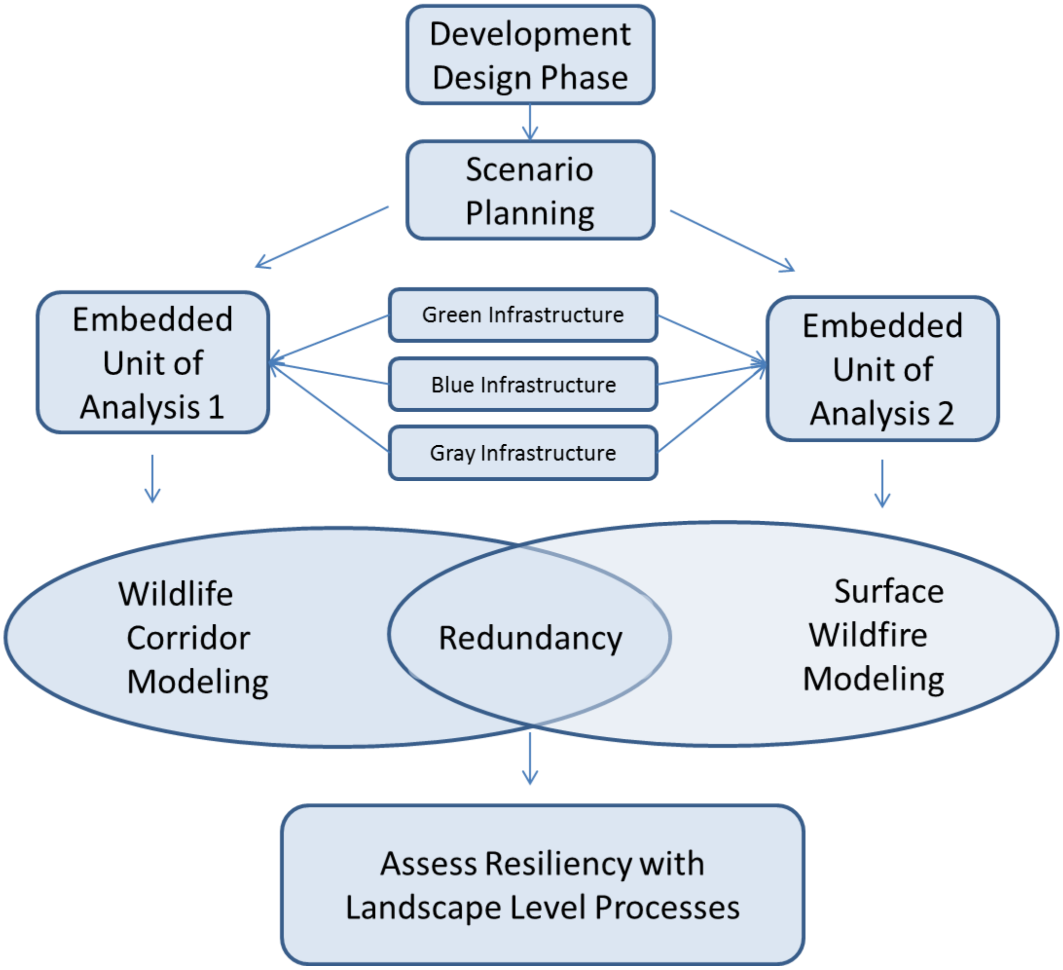


Figure 3-2. Research Design Conceptual Framework.

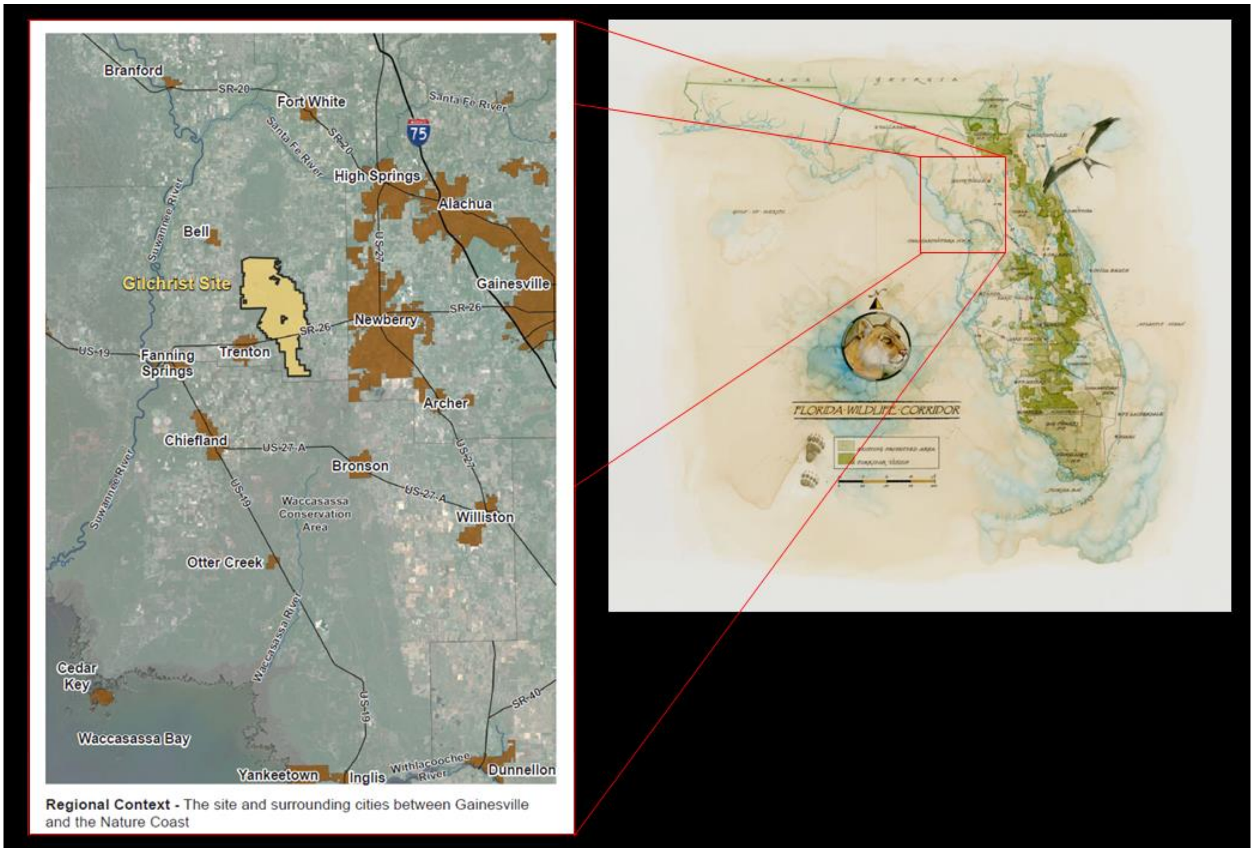
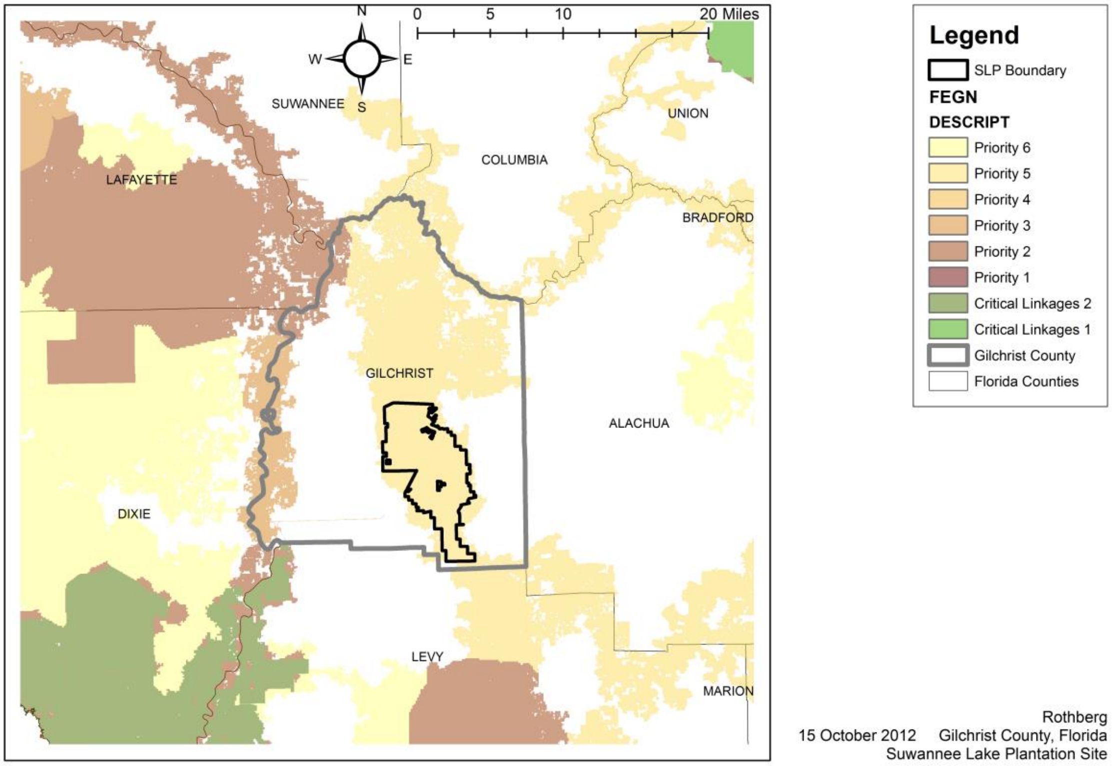


Figure 3-3. Study area (Right) and site location (Left). The study area is outlined in Red and the site location is highlighted in yellow.



Rothberg
15 October 2012 Gilchrist County, Florida
Suwannee Lake Plantation Site

Figure 3-4. Outline of the Suwannee Lake Plantation. The Florida Ecological Greenways Network is visible around the exterior and interior of Gilchrist County.

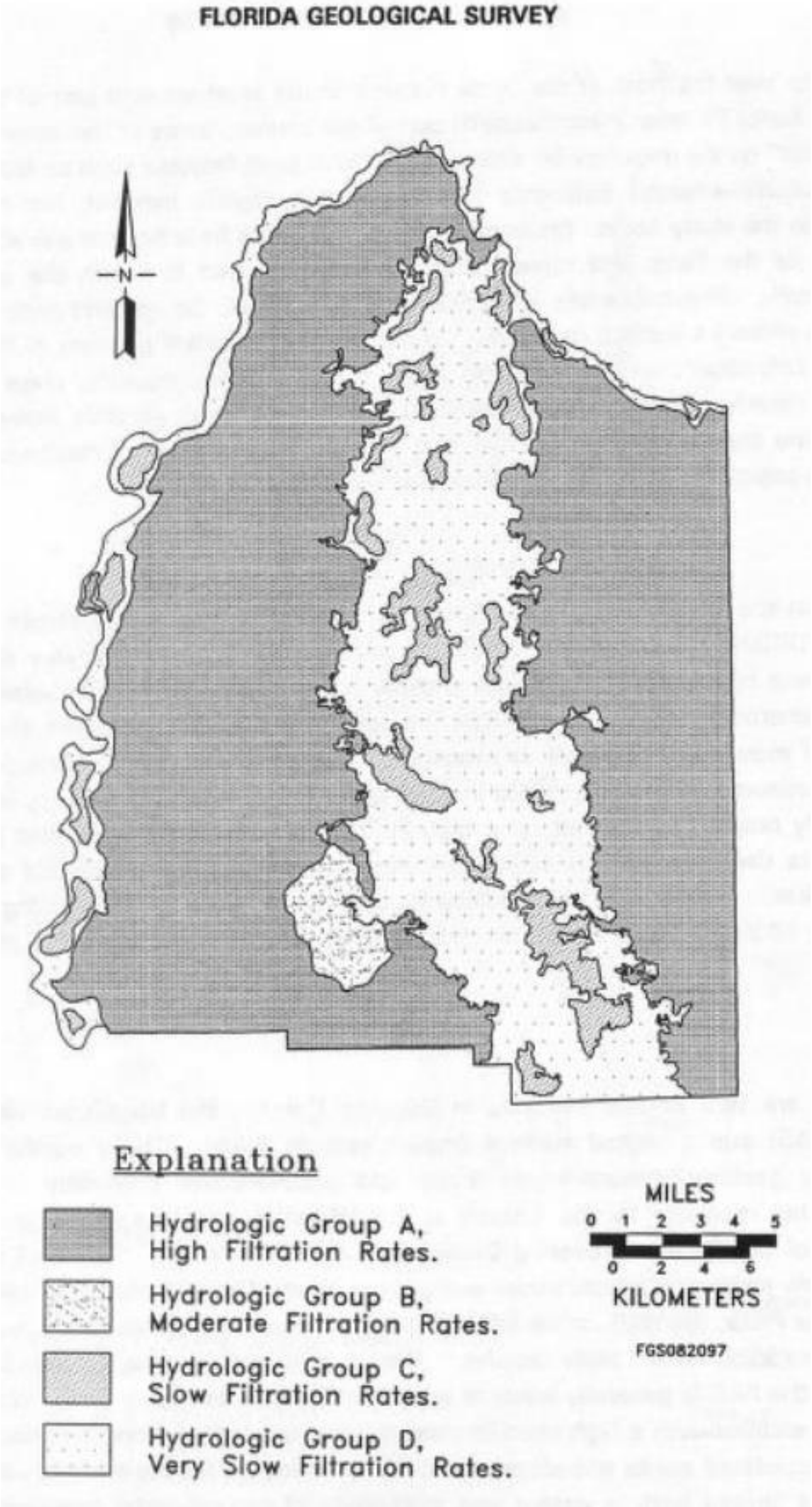
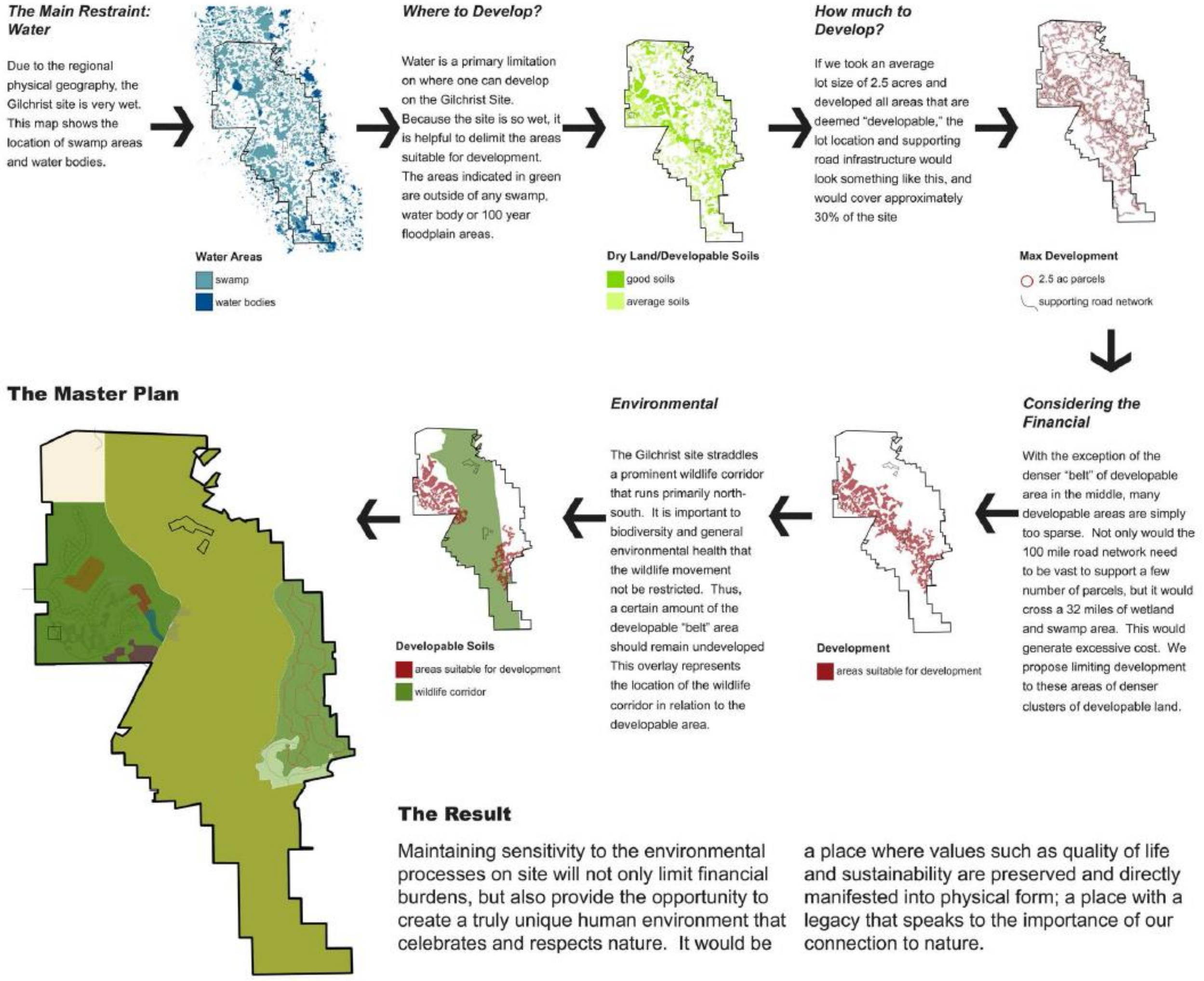


Figure 3-5. Soil Groups in Gilchrist County represented by the Florida Geological Survey (Nolan 1997).



The Main Restraint: Water

Due to the regional physical geography, the Gilchrist site is very wet. This map shows the location of swamp areas and water bodies.

Where to Develop?

Water is a primary limitation on where one can develop on the Gilchrist Site. Because the site is so wet, it is helpful to delimit the areas suitable for development. The areas indicated in green are outside of any swamp, water body or 100 year floodplain areas.

How much to Develop?

If we took an average lot size of 2.5 acres and developed all areas that are deemed "developable," the lot location and supporting road infrastructure would look something like this, and would cover approximately 30% of the site

Considering the Financial

With the exception of the denser "belt" of developable area in the middle, many developable areas are simply too sparse. Not only would the 100 mile road network need to be vast to support a few number of parcels, but it would cross a 32 miles of wetland and swamp area. This would generate excessive cost. We propose limiting development to these areas of denser clusters of developable land.

Environmental

The Gilchrist site straddles a prominent wildlife corridor that runs primarily north-south. It is important to biodiversity and general environmental health that the wildlife movement not be restricted. Thus, a certain amount of the developable "belt" area should remain undeveloped This overlay represents the location of the wildlife corridor in relation to the developable area.

The Master Plan

The Result

Maintaining sensitivity to the environmental processes on site will not only limit financial burdens, but also provide the opportunity to create a truly unique human environment that celebrates and respects nature. It would be a place where values such as quality of life and sustainability are preserved and directly manifested into physical form; a place with a legacy that speaks to the importance of our connection to nature.

Figure 3-6. Example of the Site Synthesis Process. This example is the Group 3 Plan Synthesis Diagram. The iterations progressively lead to the final area of the site that is considered developable and outline the future potential land uses within the property.

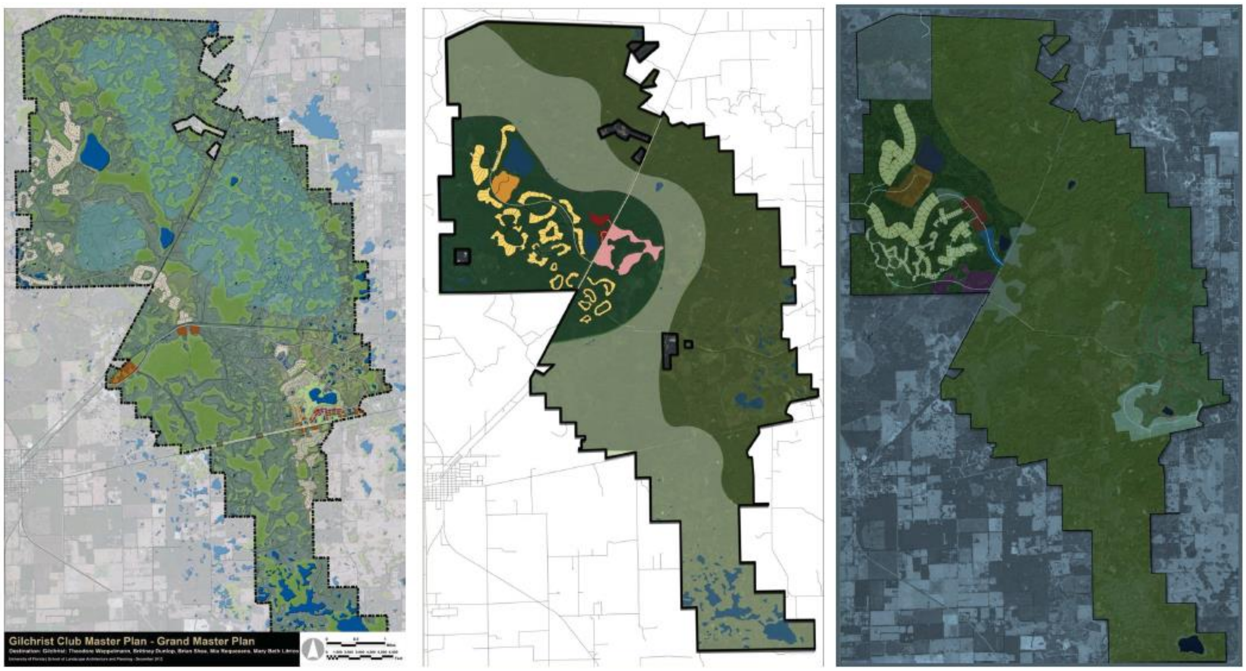
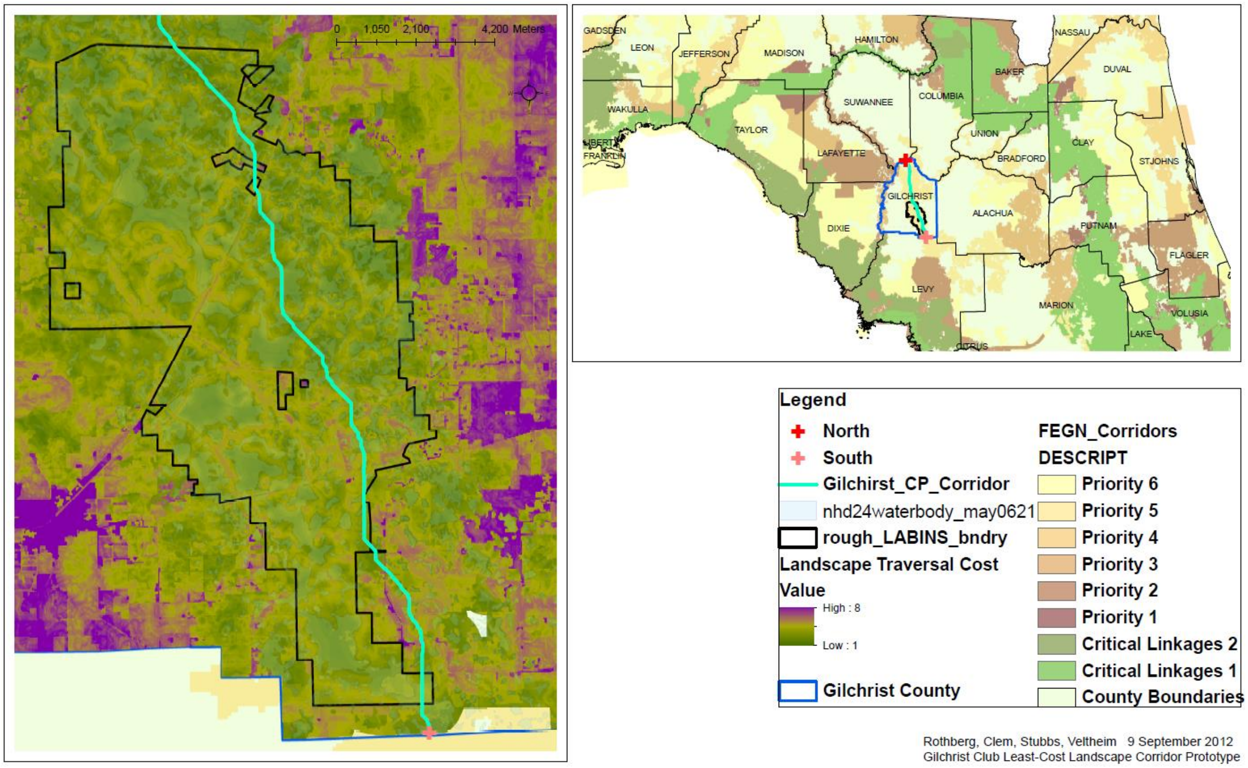


Figure 3-7. Development designs created in Fall 2012 Studio. These will be the basis for comparison for both embedded units of analysis.



Rothberg, Clem, Stubbs, Veltheim 9 September 2012
Gilchrist Club Least-Cost Landscape Corridor Prototype

Figure 3-8. Site location is illustrated in black outline. The entire property is located within a Priority 5 link of the FEGN (Right). The Base model of a Least-Cost Path (Left). The surface of the roster is a representation of the weighted average. A greater or more difficult cost is represented in purple, and less resistant costs to traversal are indicated in green. This base model was provided to the Fall 2012 Planning Studio as an initial representation of regional wildlife movement through the SLP property.

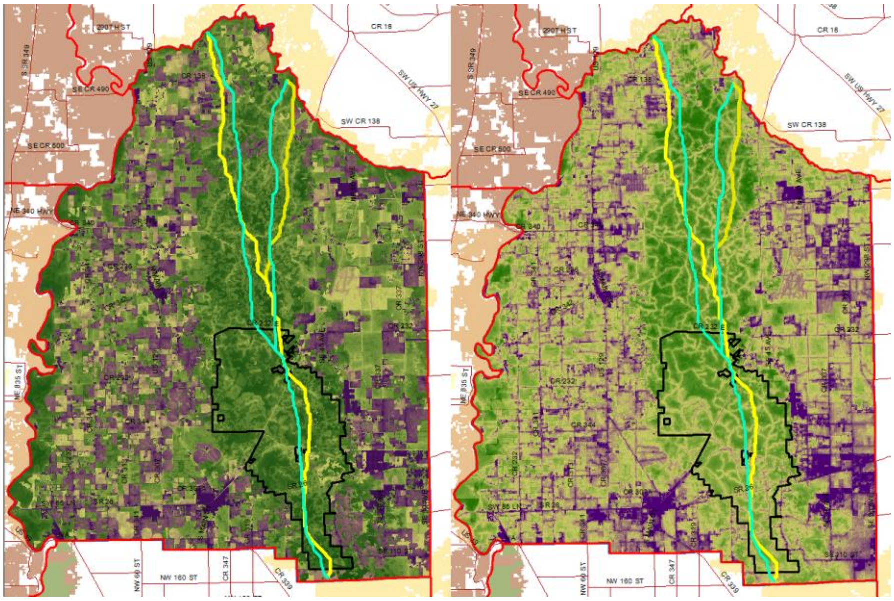


Figure 3-9. A side by side of the cost rasters. The rudimentary base model used in LCP analysis (right) and the technical model used in the before and after LCC analysis (left).

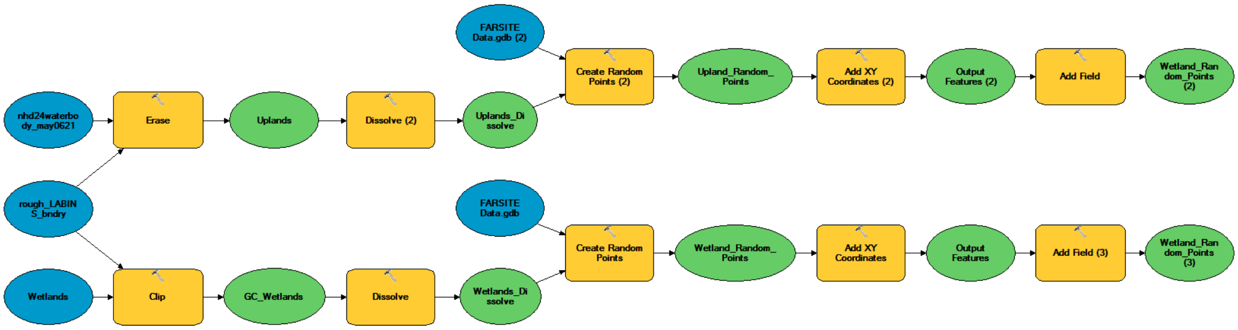
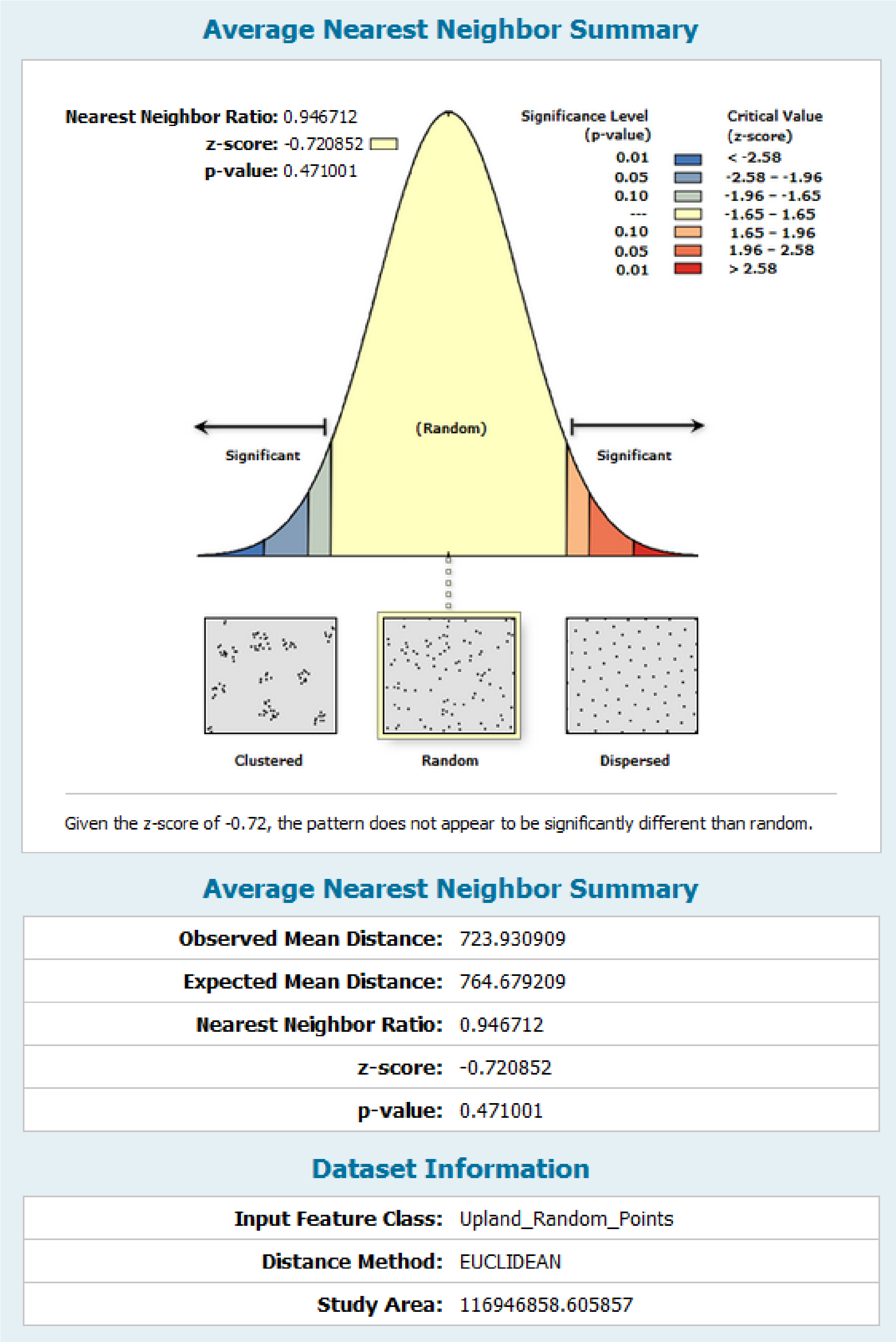


Figure 3-10. Portion of Modelbuilder designed to create the random points as part of the WildfireVulnerability Toolbox.



Average Nearest Neighbor Summary

Nearest Neighbor Ratio: 0.946712
z-score: -0.720852 🟨
p-value: 0.471001

Given the z-score of -0.72, the pattern does not appear to be significantly different than random.

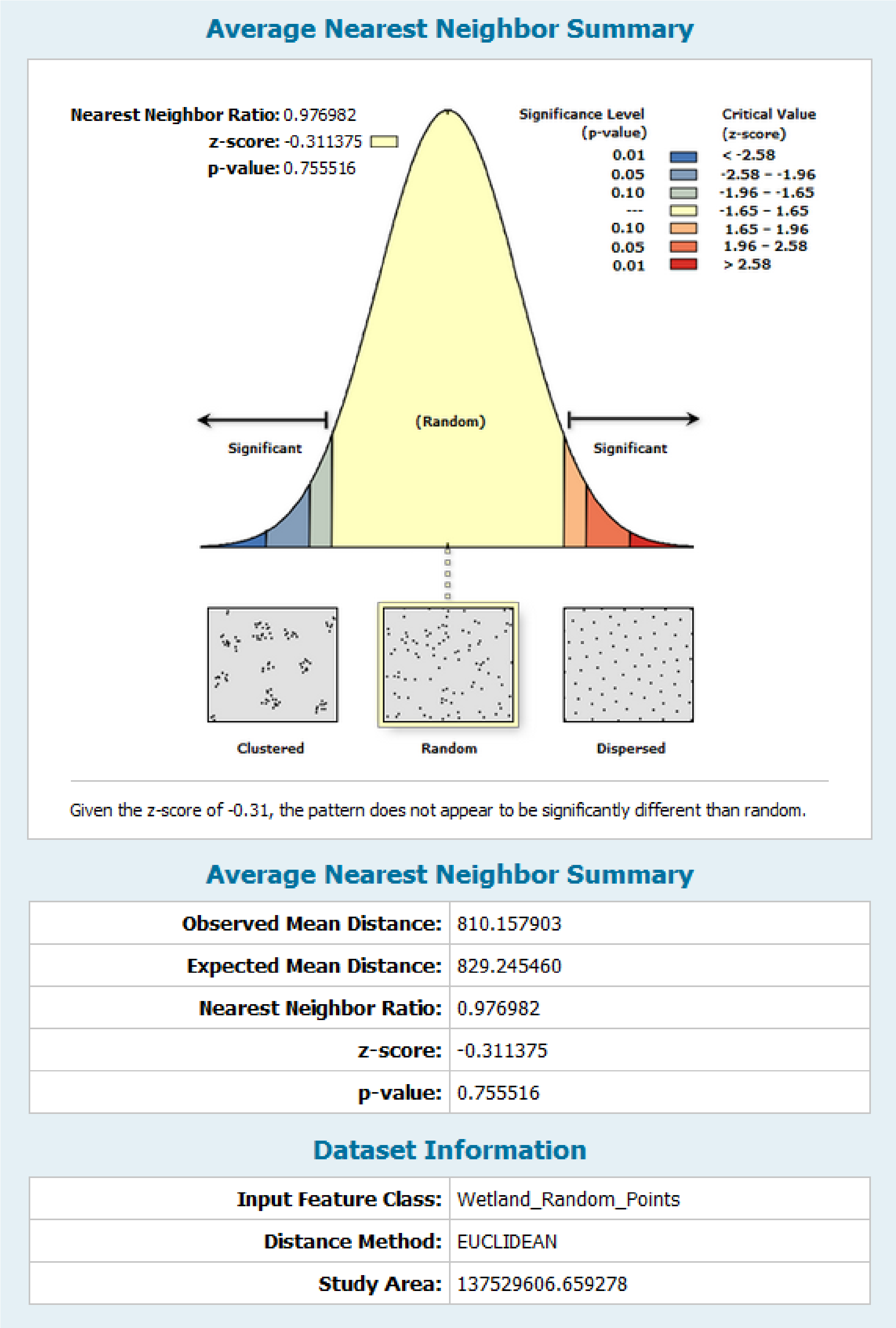
Average Nearest Neighbor Summary

Observed Mean Distance:	723.930909
Expected Mean Distance:	764.679209
Nearest Neighbor Ratio:	0.946712
z-score:	-0.720852
p-value:	0.471001

Dataset Information

Input Feature Class:	Upland_Random_Points
Distance Method:	EUCLIDEAN
Study Area:	116946858.605857

Figure 3-11. Average Nearest Neighbor for Upland Points Dataset



Average Nearest Neighbor Summary

Nearest Neighbor Ratio: 0.976982
z-score: -0.311375
p-value: 0.755516

Given the z-score of -0.31, the pattern does not appear to be significantly different than random.

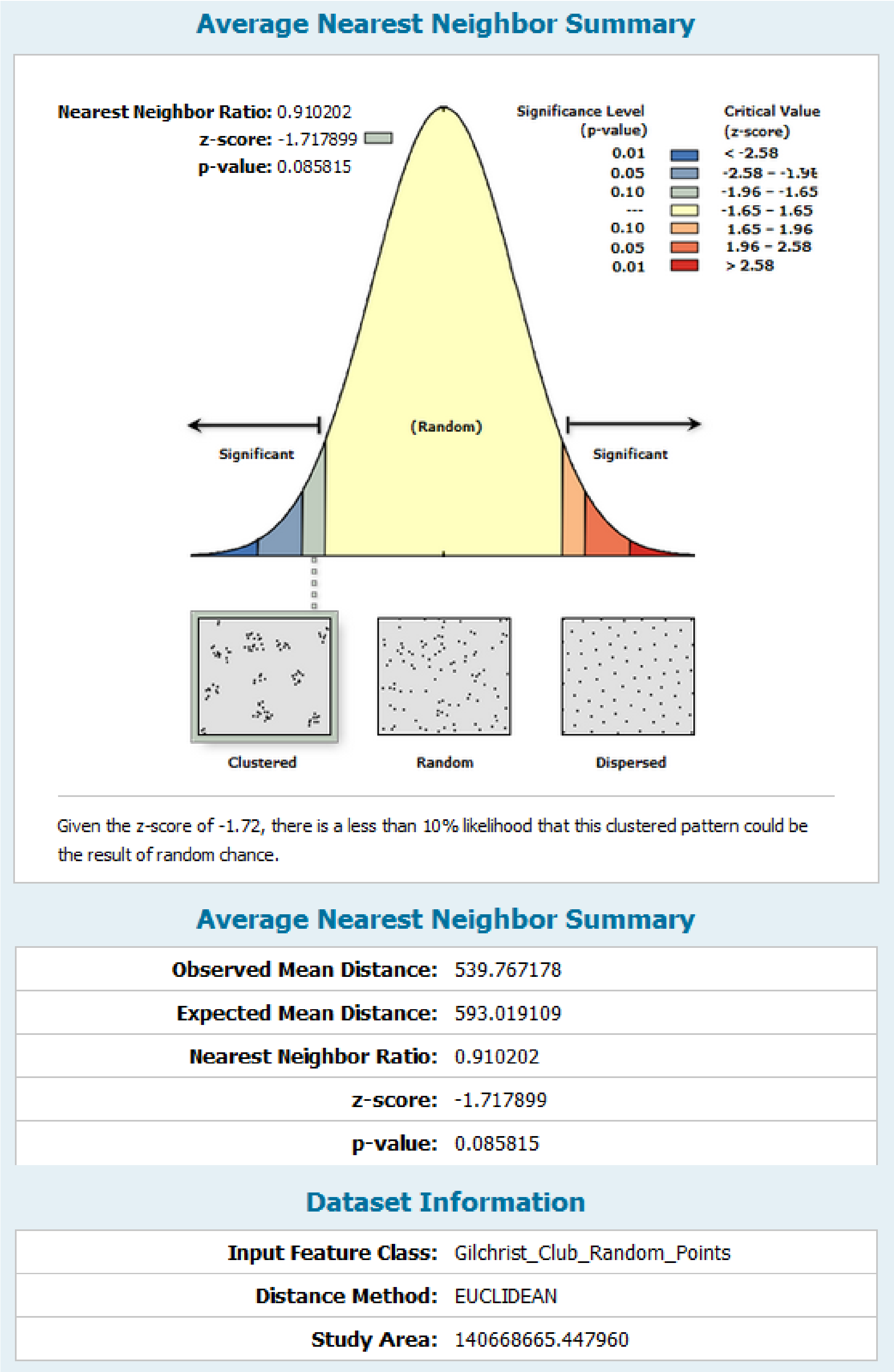
Average Nearest Neighbor Summary

Observed Mean Distance:	810.157903
Expected Mean Distance:	829.245460
Nearest Neighbor Ratio:	0.976982
z-score:	-0.311375
p-value:	0.755516

Dataset Information

Input Feature Class:	Wetland_Random_Points
Distance Method:	EUCLIDEAN
Study Area:	137529606.659278

Figure 3-12. Average Nearest Neighbor for Wetland Points Dataset



Average Nearest Neighbor Summary

Nearest Neighbor Ratio: 0.910202

z-score: -1.717899 ▨

p-value: 0.085815

Given the z-score of -1.72, there is a less than 10% likelihood that this clustered pattern could be the result of random chance.

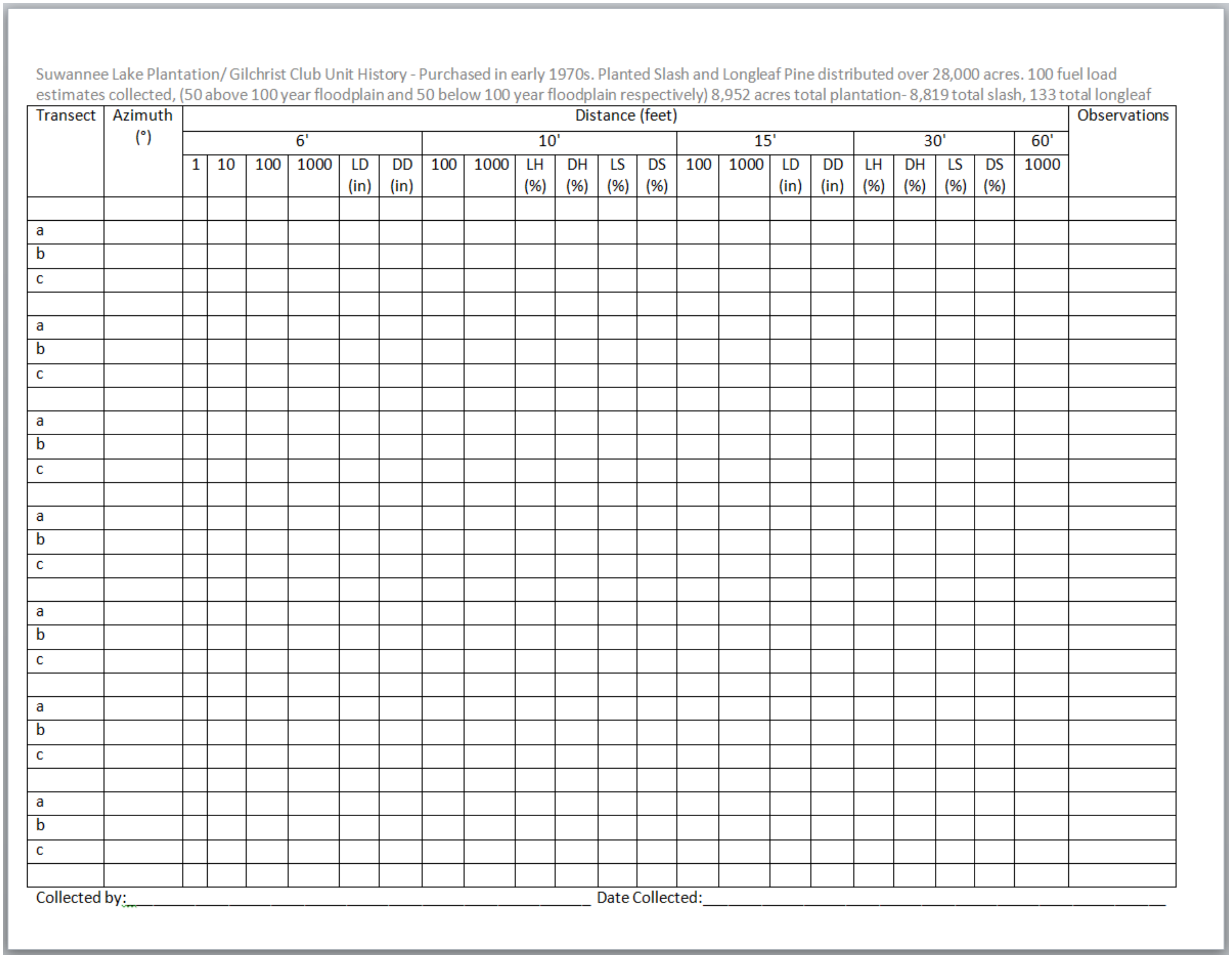
Average Nearest Neighbor Summary

Observed Mean Distance:	539.767178
Expected Mean Distance:	593.019109
Nearest Neighbor Ratio:	0.910202
z-score:	-1.717899
p-value:	0.085815

Dataset Information

Input Feature Class:	Gilchrist_Club_Random_Points
Distance Method:	EUCLIDEAN
Study Area:	140668665.447960

Figure 3-13. Average Nearest Neighbor results for combined SLP Points.



Suwannee Lake Plantation/ Gilchrist Club Unit History - Purchased in early 1970s. Planted Slash and Longleaf Pine distributed over 28,000 acres. 100 fuel load estimates collected, (50 above 100 year floodplain and 50 below 100 year floodplain respectively) 8,952 acres total plantation- 8,819 total slash, 133 total longleaf

Transect	Azimuth (°)	Distance (feet)																					Observations
		6'						10'						15'				30'				60'	
		1	10	100	1000	LD (in)	DD (in)	100	1000	LH (%)	DH (%)	LS (%)	DS (%)	100	1000	LD (in)	DD (in)	LH (%)	DH (%)	LS (%)	DS (%)	1000	
a																							
b																							
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Collected by:______________________________ Date Collected:______________________________

Figure 3-14. Data Collection Tool used to collect fuel load estimates at SLP.

Figure 3-15. Example of Browns Planar Intercept transect collection. The 60 foot transect is identified with yellow flagging extending across the pine flatwoods. Courtesy of Scott Rothberg. *Fuel Data Collection Documentation 03755*. 06/26/2013. Gilchrist County, Fl, Personal Collection.

Table 3-1. Weather Import from FireFamilyPlus for Low, Medium, and High Fire Intensity Scenarios.

Fire Intensity Scenario	Month	Date	RN	AM	PM	Tlo	Thi	Hhi	Hlo	ELV
	5	31	0	300	1600	65	90	98	38	15
	6	1	8	400	1100	63	81	99	57	15
	6	2	518	100	1700	64	76	99	79	15
	6	3	0	500	1300	68	82	92	57	15
	6	4	0	100	1200	74	83	95	69	15
	6	5	0	2300	1300	74	85	95	67	15
	6	6	0	0	1600	73	88	99	64	15
	6	7	0	600	1300	69	87	99	58	15
	6	8	0	500	1500	67	90	99	55	15
	6	9	0	400	1300	70	92	99	49	15
	6	10	0	500	1200	73	92	99	54	15
Low	6	11	0	400	1300	72	93	99	56	15
	3	31	0	700	1300	48	74	99	49	15
	4	1	0	500	1300	49	79	99	38	15
	4	2	0	500	1400	49	85	99	39	15
	4	3	0	300	1300	55	80	99	39	15
	4	4	0	600	1300	53	83	99	46	15
	4	5	0	500	1300	56	82	99	48	15
	4	6	0	600	1500	56	81	99	53	15
	4	7	0	600	1500	56	81	99	42	15
	4	8	4	0	1300	59	82	99	60	15
	4	9	1	2300	1500	57	79	97	26	15
	4	10	0	500	1400	47	81	97	22	15
Medium	4	11	0	400	1500	60	83	95	36	15
	3	31	0	300	1100	56	71	99	35	15
	4	1	0	600	1600	44	63	97	34	15
	4	2	0	600	1300	42	69	99	34	15
	4	3	0	600	1200	47	70	73	29	15
	4	4	0	600	1500	50	71	99	27	15
	4	5	0	600	1200	45	71	86	17	15
	4	6	0	400	1300	44	77	99	25	15
	4	7	0	600	1400	47	78	99	36	15
	4	8	0	100	1000	65	76	99	70	15
	4	9	0	2300	1300	60	81	99	48	15
	4	10	0	100	1300	58	82	99	48	15
High	4	11	21	600	1100	53	80	99	38	15

CHAPTER 4
RESULTS

Before and After Least-Cost Corridor Modeling

Regional Scale Analysis

Before. The development designs are reproduced in Figure 4-1 A-C to allow for convenient qualitative comparison between the before and after LCC analysis. Figure 4-3 displays the regional scale LCC surface before development occurs on the SLP property. Outlined in red inside the inset map is the general study extent of this research. The Priority 5 portion of the FEGN that passes through the Waccasassa Flats is seen entering Gilchrist County at the Southeastern corner between Levy County and Alachua County, and exiting the Northern extent of the Waccasassa Flats in the North between Suwannee County and Columbia County. The before-development cost surface is represented as a gradient of green to purple, signifying low cost to traversal and high cost respectively. Several qualitative inferences can be made from the cost surface. The Waccasassa Flats are distinctly outlined in the center of the county by a matrix of low cost and very high to moderately high costs to traversal. Urban centers are indicated as dense sections of purple, with a value of 9.84 (Figure 4-2). Even though the maximum potential value of a LCC surface is 10, the raster calculator factors all weighted variables before assigning a value to each cell. For example, located 10 miles east of the Gilchrist County border and approximately 10 miles South of the label “Gilchrist,” the city of Trenton has a larger city limit in reality than is represented by the 9.84 value for cost to traversal in the LCC surface. Radially as one moves away from the urban center, the outer limits of the city diminishes in value as lower rankings for other variables take over.

The extent of the before development scenario LCC is observed as a band of light yellow. The total acreage of the corridor at the regional scale is 50,857.02 acres and is predominantly concentrated within the Waccasassa Flats. The maximum width of the before development scenario is 4.89 miles and the minimum width, also referred to as the bottleneck, is 2.08 mi (Table 4-1). A mask was used during data processing to control for sections of high cost to traversal, yet some small, isolated areas of high cost can still be seen within the corridor. Comparison to LandSat imagery reveals these areas as small ranchettes, or one housing unit/10 acres. In the real world it is assumed that Florida black bears would not be as discouraged to use the areas around these dwellings compared to urban centers. At the regional scale small perforations in the modeled corridor would not influence the landscape process of movement, but it is clearly evident in the areas outside of the Flats that the synergistic effect of multiple perforations creates large swaths of unsuitable habitat for bear movement.

After. This concept is distinctly recognizable in the after development scenarios. Figures 4-4 – 4-6 display the regional scale perspectives of the three after development scenarios. The after development LCCs are observed as a band of light orange in each of the maps. In all scenarios the geospatial distribution of development within the SLP has an effect on the total extent of the regional scale corridor. Seen in Table 4-1, the total acreage of the corridor at the regional scale decreases to 29723.13 ac., 34,553.14 ac., and 39,307.43 ac. for Group 1, 2, and 3 respectively. In the Group 1 scenario, the maximum width of the regional corridor decreased to 2.99 mi. or 61% of the before scenario maximum width. The bottleneck in Group 1 decreases to 1.34 mi. or 64% of the before scenario. The Group 2 scenario maximum width decreased to 3.28 mi. and the bottleneck decreased to 1.38 mi. The Group 3 scenario maximum width decreased to 3.6 mi. or 73.6% of the before scenario maximum width. The bottleneck in Group 3 only decreased to 1.81 or 87% of the extent of the before development scenario bottleneck.

The scenario examples illustrate the regional impact of development within the Waccasassa Flats. When development occurs in the SLP property the small perforations in the before scenario model are amplified. Directing attention to the northern extent of Gilchrist County, a comparison between Figure 4-3 and Figures 4-4 – 4-6 reveals that development in the South forces the after model to consider the isolated perforations in the before model as barriers to landscape level bear movement. The initial qualitative comparison at the regional scale pinpoints indicators of reduced facilitation of wildlife movement in a regionally significant ecological corridor.

Site Scale Analysis

A site scale analysis appropriately reinforces the issue of functional landscape process connectivity. Figure 4-7 is a site scale depiction of the three after scenario LCCs. At this scale, the individual units of additional development are distinguished from the surrounding, low cost, natural space as high cost to traversal in the LCC surface. A comparison of the site scale perspective to each of the Group designs in Figure 4-1 A-C shows how the raster calculator variably interprets the different geospatial arrangements of land uses. After seeing the simple LCP model during the Fall 2012 Design Studio, each of the groups located the majority of commercial, residential and educational areas along the edges of the SLP property. Group 1 consolidated a significant portion of their development in one urban center on the Eastern edge of the property and along the Western Edge. This group also permitted development at the sharp central corner of the property and conserved the remaining open space. The result of this scenario development pattern was an overall reduction in within-site corridor acreage from 20,844.46 ac. down to 11,50936 ac., or 55.2% of the original corridor size. Group 2 designed larger areas of recreational space nestled within the development pattern in the Western portion of the property, effectively conserving the Eastern portion of the property from development. The scenario development pattern of Group 2 accounted for only a reduction to 34,553.14 ac., or 71.8% of the original corridor size. Group 3 was similar to Group 2 in development in the Western portion of the property. Rather than accommodating recreational space within each portion of development Group 3 outlined the recreational space as a buffer from the remaining open space in the SLP property. To reallocate space Group 3 densified the development pattern further West of County Road 47. The Group 3 scenario development reduced the before corridor to 39,307.43 ac., or 83.4% of the original corridor size. At the regional scale scenario planning identified development in the SLP property as a contributory factor to corridor constriction. At the site scale the development scenarios provide clarity to the regional wildlife movement-development relationship, indicating that encroachment toward the interior of the Waccasassa Flats from County Road 47 reduces the total area of the modeled Florida black bear corridor.

Comparative Analysis of a Surface Wildfire

Data Processing

General Statistics. In the Geostatistical Analyst feature in ArcGIS the fuel load estimates can be observed using a histogram. Figure 4-8 is the upland fuel load estimate and figure 4-9 is the wetland fuel load estimate. The mean fuel load value of 16.1 tons/acre in uplands is less than the 18.3 tons/acre mean value for wetlands. This is as expected. The data processing of the Brown's Planar Intercept method for fuel load estimates lends significant weight to accumulated leaf and duff layers found in damp wetlands, and conversely penalizes more xeric uplands which typically have less dense, drier accumulation of duff.

For the upland fuel loads the median is reported as 17 tons/acre in Figure 4-8. This is slightly greater than our mean and is represented in the histogram by marginal negative skewness at -0.116. The histogram appears to have a large proportion of values centered about the mean, which is reflected in a leptokurtic distribution. The histogram for wetland fuel loads varies greatly from uplands. The median value of 19 tons/acre and a skewness of -0.633 describe a more clustered quantity of fuel loads that are greater than the mean. The spread of the data in Figure 4-9 depicts an underrepresented proportion of lower fuel load estimates for wetland points.

Upland Inverse Distance Weighted (IDW) Analysis. A considerable amount of time was spent confirming that all age classes and ecosystems were reflected in the data collection process. A visual, exploratory analysis of both LCP timber surveys and water management district spatial data was performed. Furthermore, a visual comparison of this information to photographs taken during data collection was performed to validate that upland and wetland data collection points varied across the site. IDW was chosen because of its ability to predict surfaces based on local variation and for its sensitivity to clustering (ESRI 2011). Though the wetland IDW was analyzed first, for the purposes of this paper the upland analysis is described first. The Geostatistical analyst tool provides sufficient information to examine statistical errors between predicted IDW models. The predicted models can be ocularly examined and iteratively refined until the most predictive surface is created. The Geostatistical Analyst tool first offered a base model with an adjusted power of 2. Changes to maximum and minimum neighborhoods made no significant difference to wetland nor upland surface evaluation. When the number of sectors was adjusted to 4 the range of maximum error in the y-axis decreased from 1.65 to 1.593, as seen in Figure 4-10. When adjusted to 8 sectors or to any variation in angular offset no significant improvements in predictability of the model occurred. Changes to the major axis also provided little variation in error. When the minor axis was adjusted from ~4500 to 10,000 the model improved. Residuals were noticeably minimized and all points shifted closer to the expected line. A range of minor axis shifts were explored and 15000 provided the most effective surface based on the upland points (Figure 4-11). Figure 4-14 A depicts the improved model and Figure 4-15 A is the same model with the inapplicable wetland areas removed.

Wetland IDW Analysis. Figure 4-12 is the cross validation of the wetland base model. The initial base model with a power of 1 is adjusted to a power of 2, decreasing the range of error from 1.612 to 1.494. No significant change occurred by expanding the maximum or minimum number of neighborhoods. By changing the number of sectors the model improved. 8 sectors performed far better than any 4 sector model with angular change. Figure 4-13 shows the most significant model attained, with a y-axis range of error of 1.377.

In Figure 4-13 there is noticeable conditional bias. This was first highlighted in the histogram of wetland points. IDW is extremely sensitive to outliers which may have adversely effected the representation in the model of actual fuel load variation across the site. To illustrate the effect of outliers, Point 45 provides an example. Figure 4-14 is a cross validation of the same 8 sector model but with Point 45 removed. Clearly the bias has changed, and the error range reports a maximum y-axis of 1.03. What does this mean in reality? The final 8 sector model with Point 45 included is depicted in Figure 4-15 B. Point 45 has an approximate measured fuel load estimate of 6 tons/acre. The expected value predicted by the model for this point is 19.77 tons/acre. The effect of this considerable variation in the model is the central light blue circle in Figure 4-15 B. The low fuel load value here is adjacent to a heavily managed restoration site. Here the canopy has been thinned, the vegetation has received frequent fire return, and vegetation has been restored to promote forage and habitat for species such as Bobwhite quail, gopher tortoise, and fox squirrels. This point was not excluded from the final surface because significant variation in fuel load in locations such as this will have dramatic influences on fire behavior when these estimates are exported into program FARSITE. A low fuel load may be all that is necessary to slow the rate of fire spread and bring the flame length below a hazardous flame length.

The final wetland model is depicted in Figure 4-15 B, and Figure 4-16 B depicts the same model with the inapplicable upland areas removed. Figure 4-17 represents the final combination of both models into one Custom Fuel Model for the entire SLP site. As a result of the modeling process the PI hypothesizes that, by expanding the minor axis in both the wetland and upland IDW analysis, the custom model more appropriately captures the natural topographical bands that divide the landscape diagonally Northwest to Southeast into different vegetation classes (Figure 4-18).

Comparison of Standard Fuel Models to Custom Fuel Model.

Referring back to the literature review, the authors stated that Scott and Burgan’s standard fuel models as well as stereo photo series can be used as inputs for wildfire modeling in program FARSITE. This method is useful when financial, accessibility, or time restrictions limit modelers from more precise field sampling. The conditions of this research permitted access to the site to collect fuel load information and reduce generalization about the current fuels at the SLP site. The custom fuel model depicted in Figure 4-17 is more precisely described as a spatial surface of the entire property with 1 integer number assigned to each 30 x 30m cell. The 1 integer number relates to the 1 custom fuel model that most accurately describes the fuels of that cell. The color variation in Figure 4-17 corresponds to 18 different classes of geostatistically estimated custom fuel models at the SLP site. A qualitative comparison of the custom fuel model information to the Scott and Burgan standard fuel models will help demonstrate how a custom fuel model, even at the regional scale, increases the fuel model's ability to predict fire behavior.

Table 4-2 displays the 18 custom fuel models that best describe the fuel conditions at the SLP site. The custom fuel models are named FM15-32 because FARSITE recognizes FM1-13 as the fuel models originally described by Anderson in 1982. Table 4-3 shows the relationship of the 18 custom models to the standard fuel models. The parameters in Table 4-3 are adapted from the description of standard fuel models from Scott and Burgan's *Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model*.

Six standard fuel models correlate to the 18 custom fuel models at the study site. The geostatistical estimates of fuel loading minutely varied in Fuel Models 15-19 (FM15-19) and correlated strongest to Scott and Burgan's TU3 model. This class is described as grasses or shrubs mixed with litter from the forest canopy (Timber-Understory) in a humid climate. TU3 specifically has a fuelbed with moderate litter load with grass and shrub components, a high spread rate, and moderate flame length (Scott and Burgan 2005). The custom FM15-19 varied strongest from the standard model in a significantly lower measurement of 1hr and 100hr fuel loading. All other categories of fuel loading begin in FM15 at lower quantities in tons/ac and then increase to or marginally surpass the TU3 in FM19. The subtle variation is expected in FM15-19 because these fuel models are aggregated in a small section of the total property size located in the Southwest corner and partially in the Northeast corner.

FM20 significantly changes in terms of mass of downed woody debris and total fuel bed depth. FM20 most closely resembles Scott and Burgan's GR2 model. This class is described as nearly pure grass and/or forbs, with moderately course continuous grass coverage that averages about 1 foot in depth. The spread rate in GR2 is typically high with moderate flame lengths (Scott and Burgan 2005). GR2 regularly has no large downed woody debris and has 0.10 tons/ac of 1 hr fuels. FM20 was significantly influenced by the quail fields in the central portion of the SLP property that are managed with prescribed fire every year. FM20 also appears in the Northeastern corner and Southwestern corner that were recently prepared for pine seeding before data collection. The annual burn rotation explains why only 0.01 tons/ac of 1hr fuels are present in FM20 and why the fuel depth was recorded at 0.30 ft instead of the standard 1.0 ft in the GR2 model.

FM21 accounts for 42% of the entire custom fuel model surface. FM21 is most closely related to Scott and Burgan's SH4. SH4 is described as shrub coverage of at least 50%, with sparse to nonexistent grasses in a subhumid to humid climate. The loading is characterized by low to moderate shrub and litter load, with possible pine overstory, a fuel bed depth approximately 3 ft., and a high spread rate with moderate flame length (Scott and Burgan 2005). FM21 differs most from SH4 by a significantly lower 1 hr fuel load, 0.03 tons/ac. in FM21 compared to 0.85 tons/ac. in SH4. This difference is compensated by a larger 10 hr fuel loading in FM21, at 1.50 tons/ac. compared to 1.15 tons/ac. The Lower values were expected in FM21 than those typical to SH4 because IDW in geostatistical analyst factors all data collection points across the regional space. FM22, which most closely relates to Scott and Burgan's SH3, also was characterized by slightly lower loading in all categories. FM22 had significantly lower live shrub loading at 1.30 tons/ac. compared to 6.20 tons/ac. SH3 has many of the same characteristics of SH4, but instead of a typically 3 ft fuel bed SH3 usually ranges from 2-3 ft. and has a larger fraction of herbaceous cover (Scott and Burgan 2005). The live herbaceous content of SH3 can classify most southern rough that has lower spread rates and lower flame lengths. SH3 covers 14% of the total fuel model surface and corresponds to the more xeric upland portions of the property.

FM23, the last upland custom fuel model for the SLP property, relates most to SH9. SH9 is described as dense, finely branched shrubs with significant fine dead fuel about 4 to 6 feet tall, creating the potential for very high spread rate and very high flame lengths (Scott and Burgan 2005). The very high loading in FM23 and the very tall high fuel bed depth (3.42 ft.) again are slightly lower than SH9. The concluding hypothesis reached from the evaluation of the upland custom fuel models is that use of the standard models during wildfire simulation would have led to arbitrarily larger flame lengths and spread rates at the SLP property.

FM24-32 variably relate to TL5. TL5 is dead and down woody fuel litter beneath a forest canopy. Specifically TL5 is characterized by high load conifer litter, with light slash, a low spread rate and a low flame length (Scott and Burgan 2005). FM24-30 appear to steadily increase in 10 hr fuel loading up to the standard TL5 loading value, and are severely under value in all other categories. FM31 and FM32 both have significantly larger 10 hr fuel loads at 2.01 and 6.00 tons/ac, and signicantly larger live shrub loading at 1.20 and 5.10 tons/ac. The variation in FM24-32 is a result of highly variable fuel measurements across the wetland portions of the SLP property, including multiple very high fuel load measurements in the center of the property.

Simulations of Surface Wildfire

The purpose of the wildfire simulations was to create a scenario where flame lengths can be measured and the resiliency or otherwise the vulnerability of the development design components can be interpreted. A single wildfire simulation at any of the fire intensity percentiles could not cover the entire SLP site. To account for this, at each percentile of fire intensity two wildfires were simulated using two different ignition points. The result was six simulations of low, medium, and high fire intensity for Group 1, 2, and 3 for a total of 18 wildfire simulations.

A few qualitative inferences highlight the success of the wildfire simulations. Screen captures of the final extents of the wildfires are displayed in Figures 4-19 – 4-36 beginning with low fire intensity and progressing through high fire intensity. A graph of the total fire area (acres) over time (days) is paired with each simulation (Figures 4-46 – 4-48). Demonstrating first with Figures 4-19, the spread of the surface wildfire is depicted as concentric white bands expanding outward from the ignition point. Each individual band corresponds to a two hour time step. The darker clusters that appear as bolder white lines therefore are depictions of a decrease in the rate of spread of the flaming front.

Directing attention secondly to Figures 4-23, 4-29, and 4-35, the progression from Low to Medium to High fire intensity is portrayed as an example for one of the studio group designs (Group 3). Starting in Figures 4-23, the proximity of one band to the next illustrates the relatively low rate of spread throughout the entire simulation time frame. Compact banding is typical in a Low fire intensity scenario where variables such as high humidity or low wind speed negatively influence fire behavior. In Figure 4-29, it is noticeable that in the Medium fire intensity scenario there are 8 or more distinct time periods where the rate of spread decreases the advancement of the propagating front. The Low fire intensity scenario had only 4 or more of these abeyances which accounts for the larger total fire area in Figure 4-23. Qualitative comparison of the graphs indicates the difference between Medium and Low fire intensity. Ocular estimation from the Medium fire intensity graph in Figures 4-47 shows a noticeably more exponential rate of spread toward the end of the simulation than the Low fire intensity graph in Figures 4-46. During the simulation the distance between bands began to increase in the North and Northwestern portion of the SLP property as the graph of fire area became more exponential. Observation notes marked stronger winds during that time frame as the reason for the difference between Low and Medium fire intensity. Lastly, Figures 4-48 displays the High fire intensity scenario for Group 3. In the High fire intensity scenario the total surface fire area is approximately 7,320 ac., compared to 6,300 ac. in the Low fire intensity scenario. At first glance this appears to be a discrepancy in the simulator. However there is clear justification that distinguishes the

High fire intensity scenario. Evident in the banding pattern the High fire intensity scenario has the greatest distance between hourly time steps of all of the scenarios. Moreover, the duration of the Low fire intensity scenario is 10 days, whereas the High fire intensity scenario occurs within an 8 day interval. Fire behavior in the High fire intensity scenario is intensified due to extremely high winds from the West throughout the simulation. Banding structure and qualitative analysis confirms that sufficient variability exists between the fire intensity percentiles. The next section will examine the resulting surface wildfire flame lengths and interactions between fuel loads, flame lengths, and geospatial locations of development design components.

Wildfire Flame Lengths and Development Scenarios

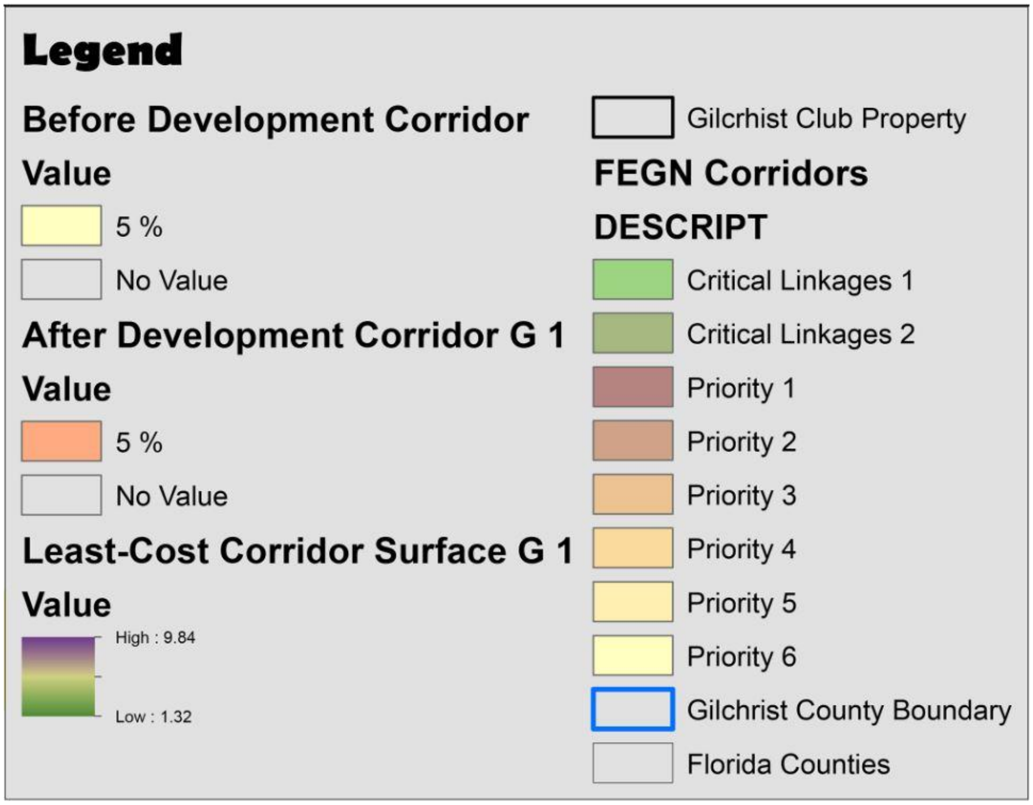
The surface wildfire flame lengths are visually displayed in Figures 4-37 through 4-45. In each map the flame lengths vary from 0.01 ft, represented in dark blue, up to 4.40 ft, represented in red. In the previous section the white hourly time bands were qualitative indicators of spread rate. There is evident consistency between the time bands and the flame lengths. The flame lengths vary clearly demonstrate the pulses in fire spread rate during the wildfire simulation regardless of low, medium or high fire intensity. The range of fuel load classes also had a distinct effect on fire behavior. The flame lengths are uniform to the final fuel model surface in Figure 4-17.

Each of the three development design scenarios had unique proportions and geospatial locations of built land uses. The only land uses that occurred in all three of the development design scenarios were commercial areas, low density residential, medium density residential, and high density residential areas. Figures 4-49 A-C show the average flame lengths in each of these four land use classes, and each of the bar graphs represents a different fire intensity scenario. The maximum and minimum flamelengths recorded in each of the categories are displayed on the graphs. In general the graphs show that the greater the fire intensity scenario the greater the flame length. For example, in Group 1 the flame length grew from 1.84 ft., to 1.76 ft., to 2.38 ft. in low density residential for low, medium, and high fire intensity scenarios respectively. This outcome was expected because intensification of weather and wind generally increases fire behavior. In all Groups and all fire intensity scenarios the commercial areas displayed the lowest flame lengths, ranging from approximately 0.40 ft – 2.15 ft. The between group variation in commercial areas was also minor.

Group 1 had the largest flame lengths in residential medium density areas in all fire intensity scenarios. From low to high fire intensity scenario the flame lengths in residential low density lots ranged from 1.21 ft. to 1.56 ft. The flame lengths in medium density lots varied similarly, ranging from 3.05 ft. to 3.39 ft. Group 1 also had the largest flame lengths in the commercial areas. From low to high fire intensity scenario the average flame lengths grew from 2.0 ft – 2.17 ft. Figure 4-50 A displays the justification behind why the flame heights are larger in Group 1 and 3. In Figure 4-50 A the high fire intensity scenario wildfire is represented on a variable surface of flame height with the Group 1 design and roadway network visible beneath the surface. The simulated surface wildfire shows rapid intensification in flame height as the flaming front of the wildfire reaches these developed land uses. High fuel loading in upland areas surrounding these land uses contributes to the overall vulnerability of the Group 1 and 3 development design to wildfires.

In all scenarios Group 2 had the lowest average flame lengths per land use class. The maximum average flame lengths for Group 2 were in the high fire intensity scenario in the residential medium density land use class, at 0.66 ft, and in the low fire intensity scenario in the residential low density land use classes, also at 0.95 ft. The principle reason for low average flame lengths in all Group 2 scenarios is the placement of developed land uses in areas of the property with currently low fuel loading. By random chance Group 2 placed a significant portion of their developed land use components in a section of the SLP property containing exceedingly low fuel loading. The low loading in this portion is the reason why the wildfire simulations did not carry fire through the East Central part of the property. This concept is more accurately portrayed in Figure 4-50 B. In this map of variable flame height, growth in flame height occurs away from the majority of Group 2’s developed areas. Alternatively, the East Central part of the property shows no active fire during the wildfire simulation.

Figure 4-1 A-C. Development designs created in Fall 2012 Studio. These have been reproduced from Figure 3-7 in this section for ease of access.



Legend

Before Development Corridor

Value

🟨 5 %

⬜ No Value

After Development Corridor G 1

Value

🟧 5 %

⬜ No Value

Least-Cost Corridor Surface G 1

Value

High : 9.84

Low : 1.32

⬜ Gilcrhist Club Property

FEGN Corridors

DESCRIPT

🟩 Critical Linkages 1

🟩 Critical Linkages 2

🟥 Priority 1

🟫 Priority 2

🟧 Priority 3

🟧 Priority 4

🟨 Priority 5

🟨 Priority 6

🟦 Gilchrist County Boundary

⬜ Florida Counties

Figure 4-2. Legend for All Least-Cost Corridor Maps (both Regional and Site Scale).

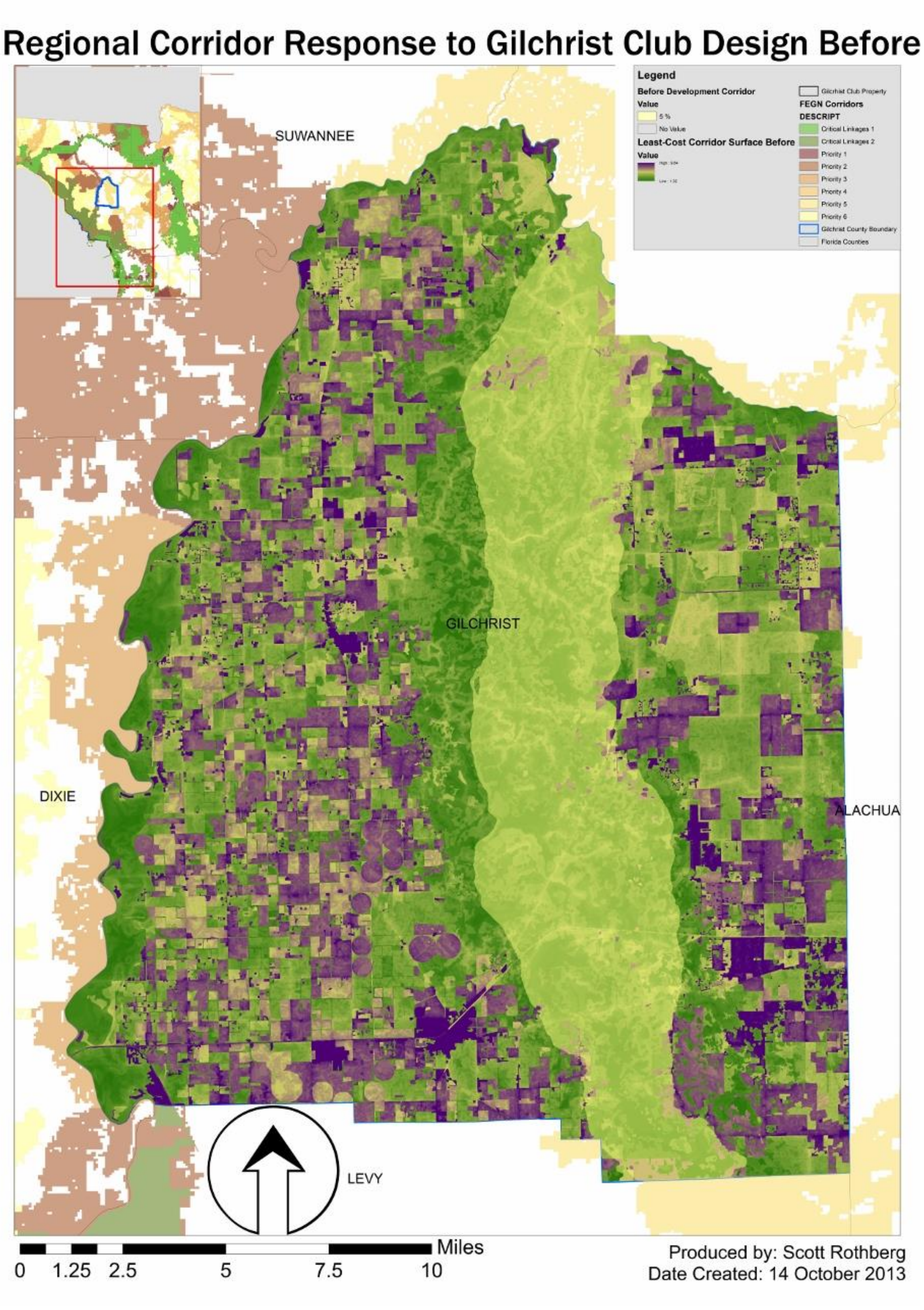


Figure 4-3. The Least Cost Corridor for the before development scenario.

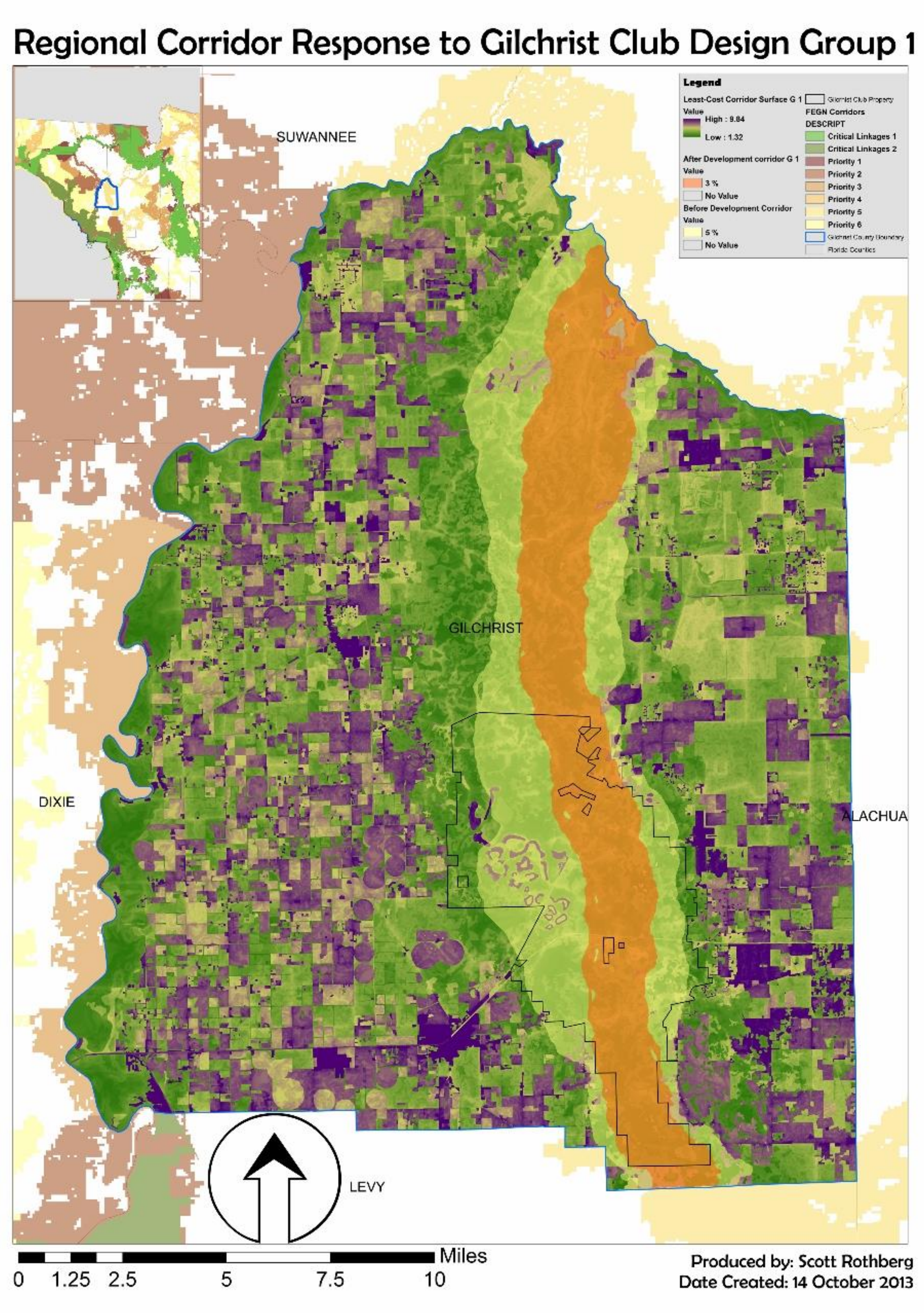


Figure 4-4. The Least Cost Corridor for the Group 1 after development scenario.

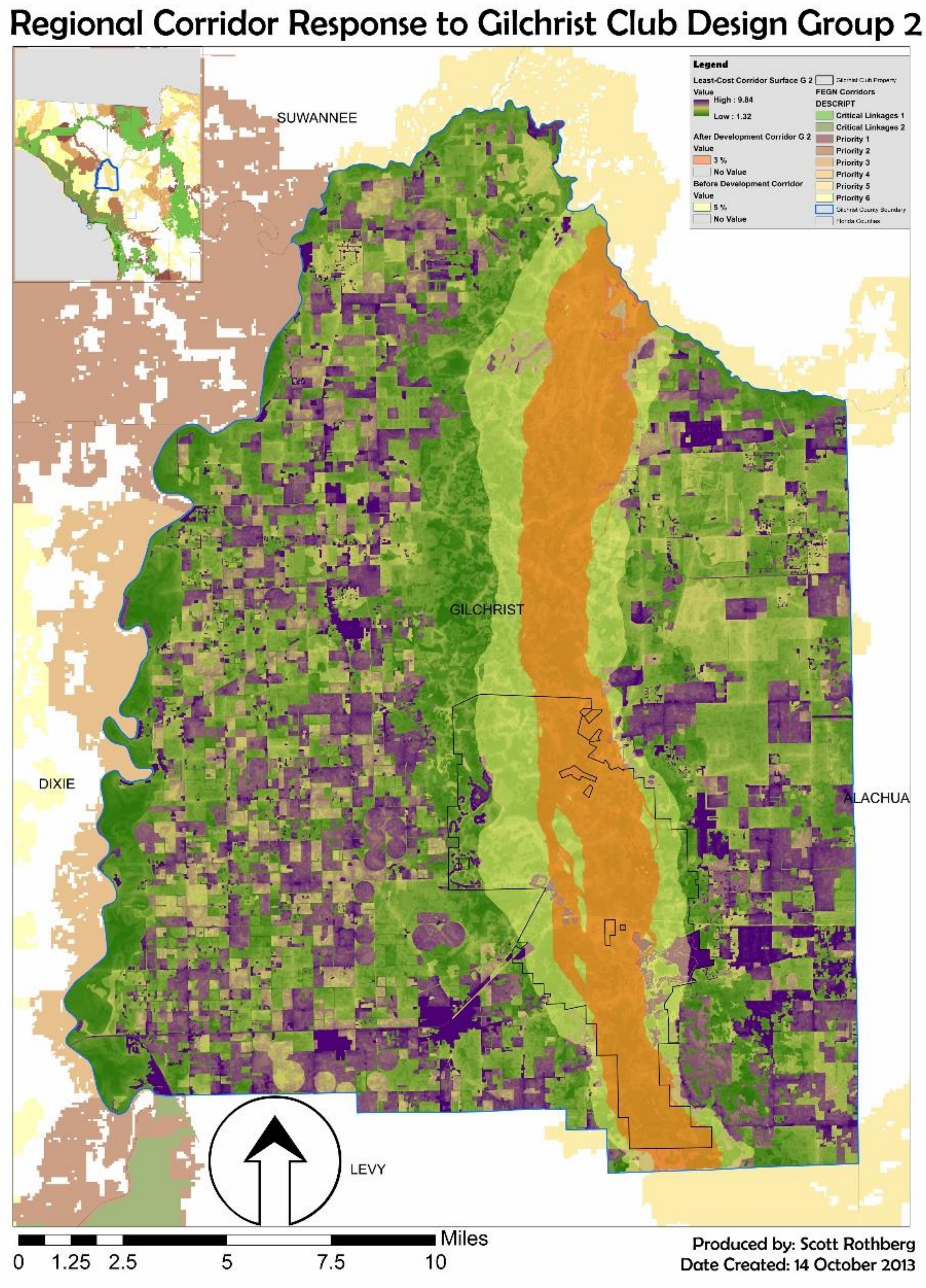


Figure 4-5. The Least Cost Corridor for the Group 2 after development scenario.

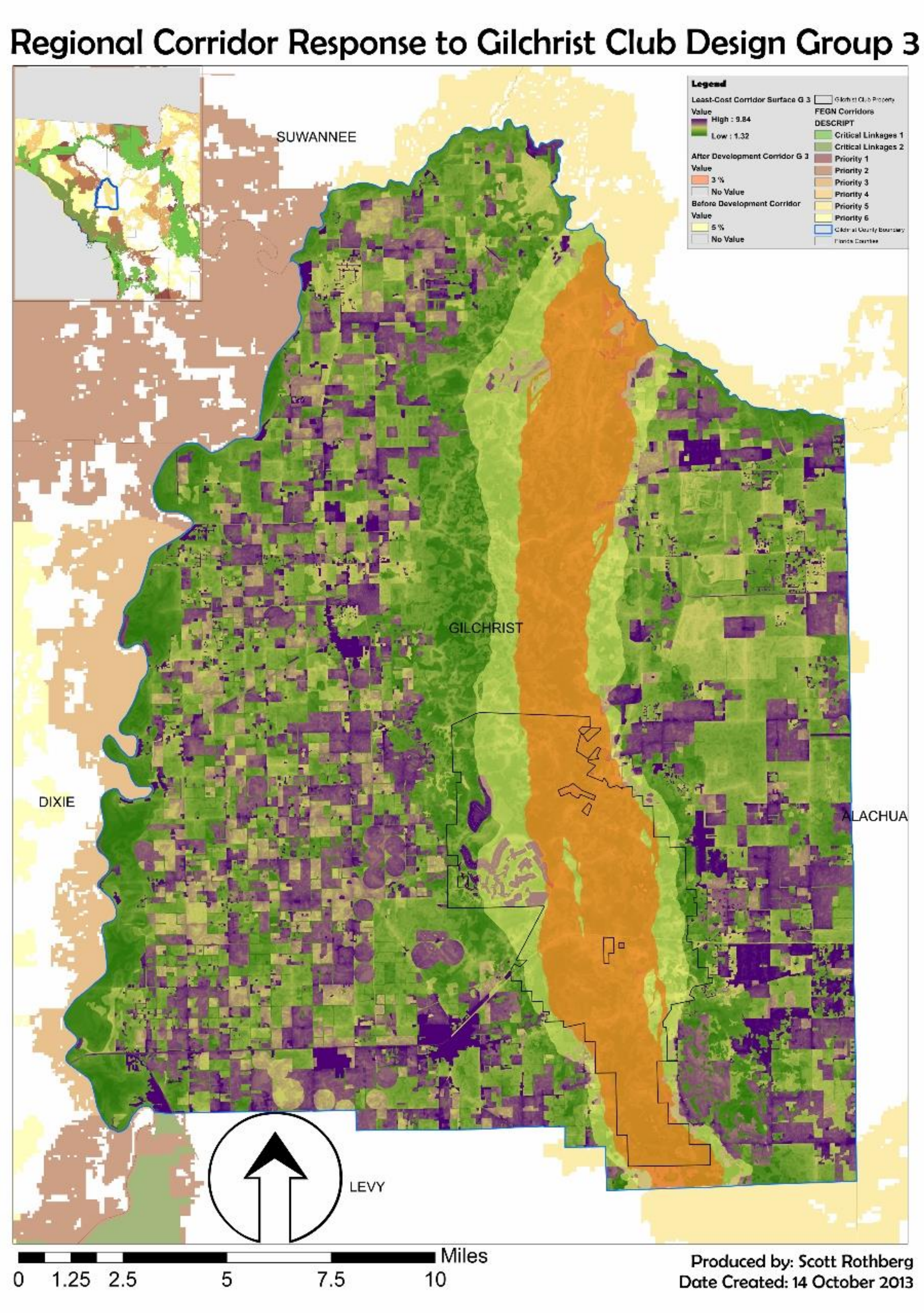


Figure 4-6. The Least Cost Corridor for the Group 3 after development scenario.

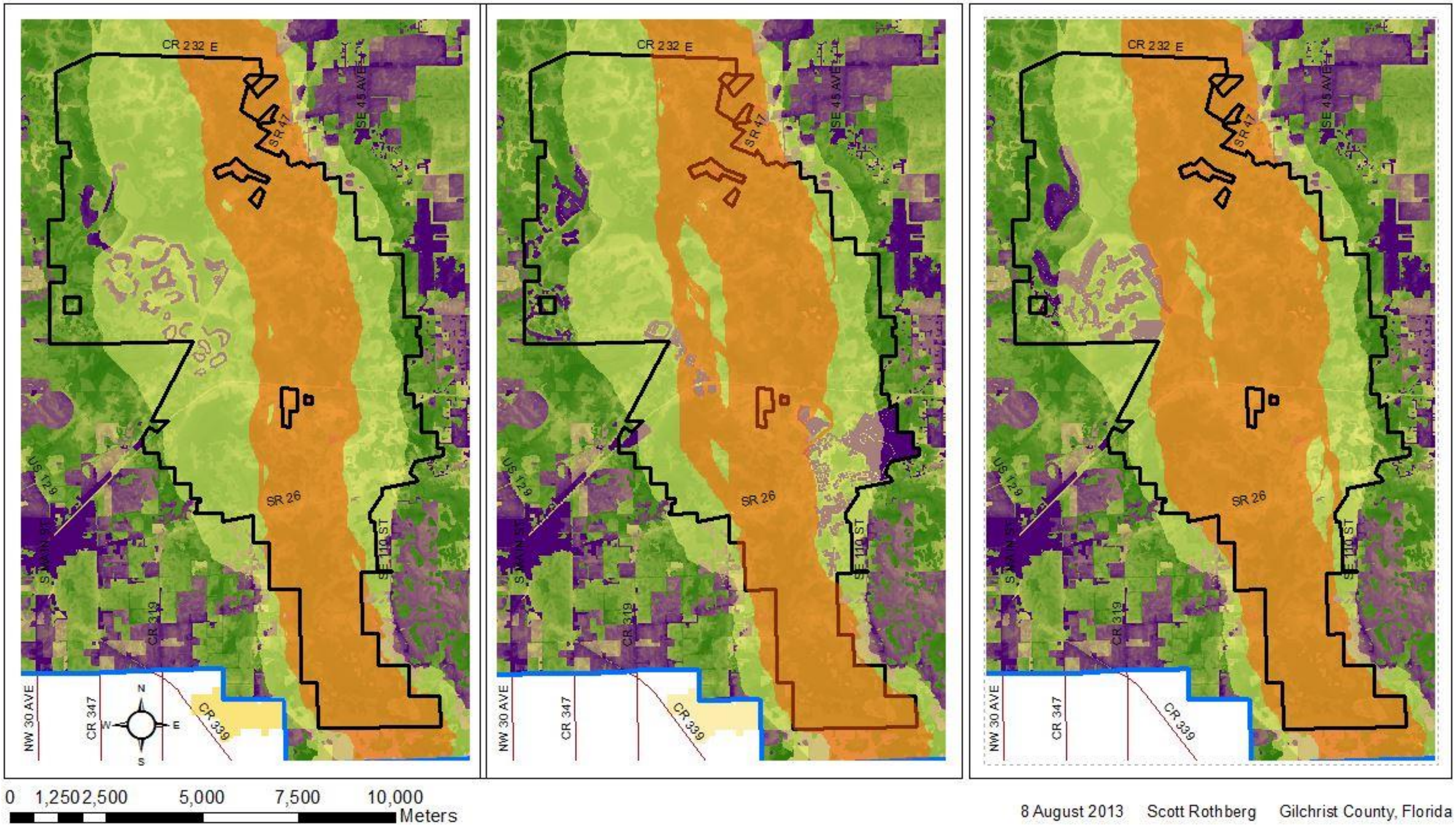


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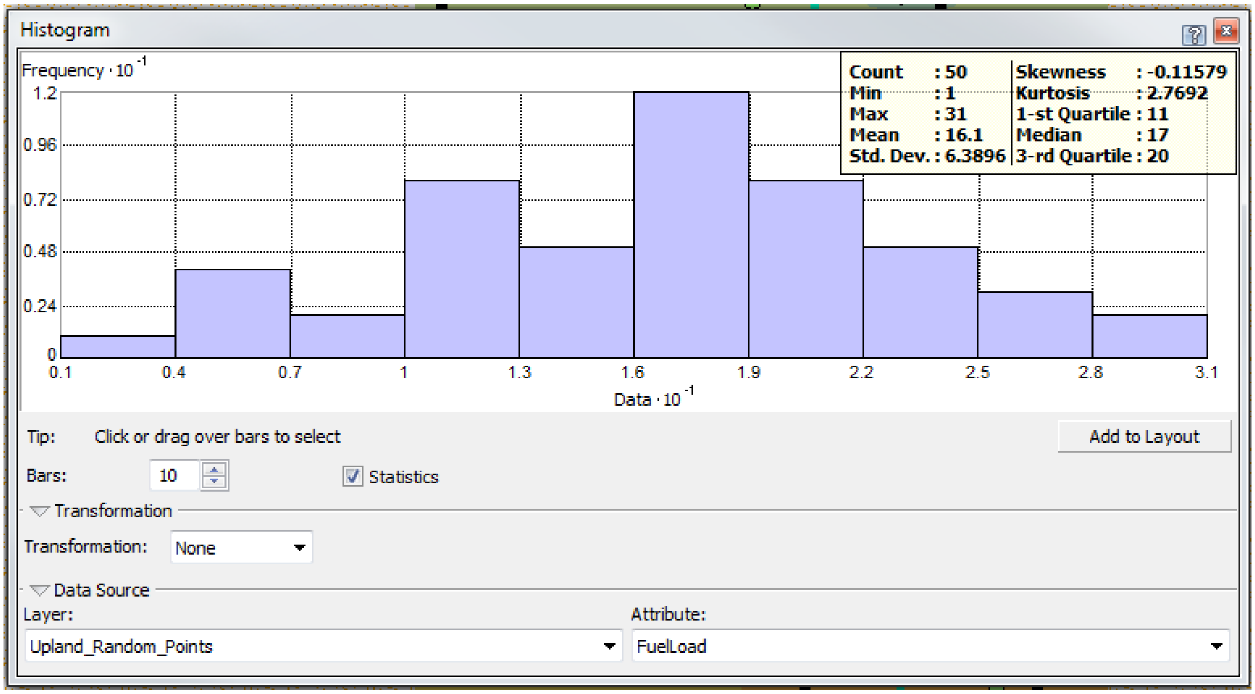
Figure 4-7. Site level comparison of the change in size of a least-cost wildlife corridor as a result of land use changes from each development design. In this representation the Before Corridor is indicated in light yellow, and the After corridor is indicated in orange.

Table 4-1. A Corridor Analysis quantifies the change in corridor size between groups.

Metric Change Measurement	Before Corridor	After Corridor Group 1	 Group 2	 Group 3
Maximum Width (miles)	4.89	2.99	3.28	3.6
Average Width (miles)				
Bottlenecks (miles)	2.08	1.34	1.38	1.81
Total Acreage (County)	50857.02	29723.13	34553.14	39307.43
Total Acreage (Site)	20844.46	11509.36	14959.84	17374.62

Percent Change Measurement	Before Corridor	After Corridor Group 1	 Group 2	 Group 3
Maximum Width (%)	100	61.1	67.1	73.6
Average Width (%)				
Bottlenecks (%)	100	64.4	66.3	87.0
Total Acreage (County)	100	58.4	67.9	77.3
Total Acreage (Site)	100	55.2	71.8	83.4



Count	**: 50**	**Skewness**	**: -0.11579**
Min	**: 1**	**Kurtosis**	**: 2.7692**
Max	**: 31**	**1-st Quartile**	**: 11**
Mean	**: 16.1**	**Median**	**: 17**
Std. Dev.	**: 6.3896**	**3-rd Quartile**	**: 20**

Tip: Click or drag over bars to select

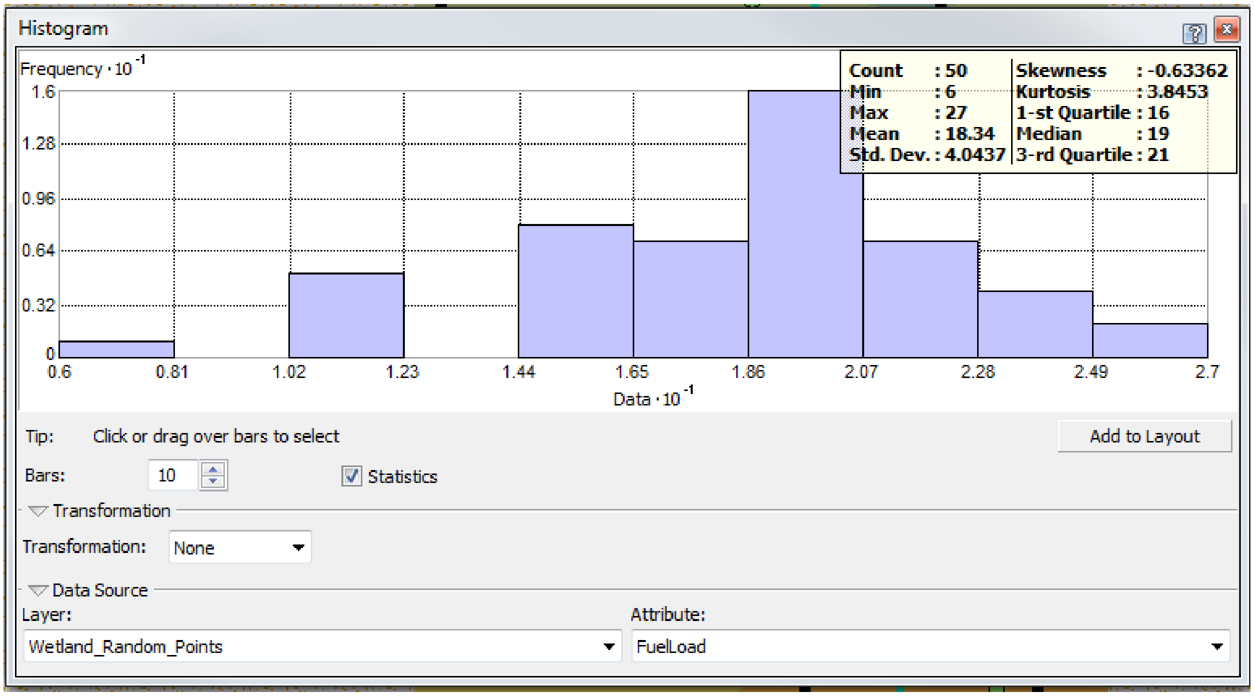
Bars: 10 ☑ Statistics

Transformation: None

Layer: Upland_Random_Points

Attribute: FuelLoad

Figure 4-8. Histogram with general statistics for upland fuel load estimates.



Count	**: 50**	**Skewness**	**: -0.63362**
Min	**: 6**	**Kurtosis**	**: 3.8453**
Max	**: 27**	**1-st Quartile**	**: 16**
Mean	**: 18.34**	**Median**	**: 19**
Std. Dev.	**: 4.0437**	**3-rd Quartile**	**: 21**

Tip: Click or drag over bars to select

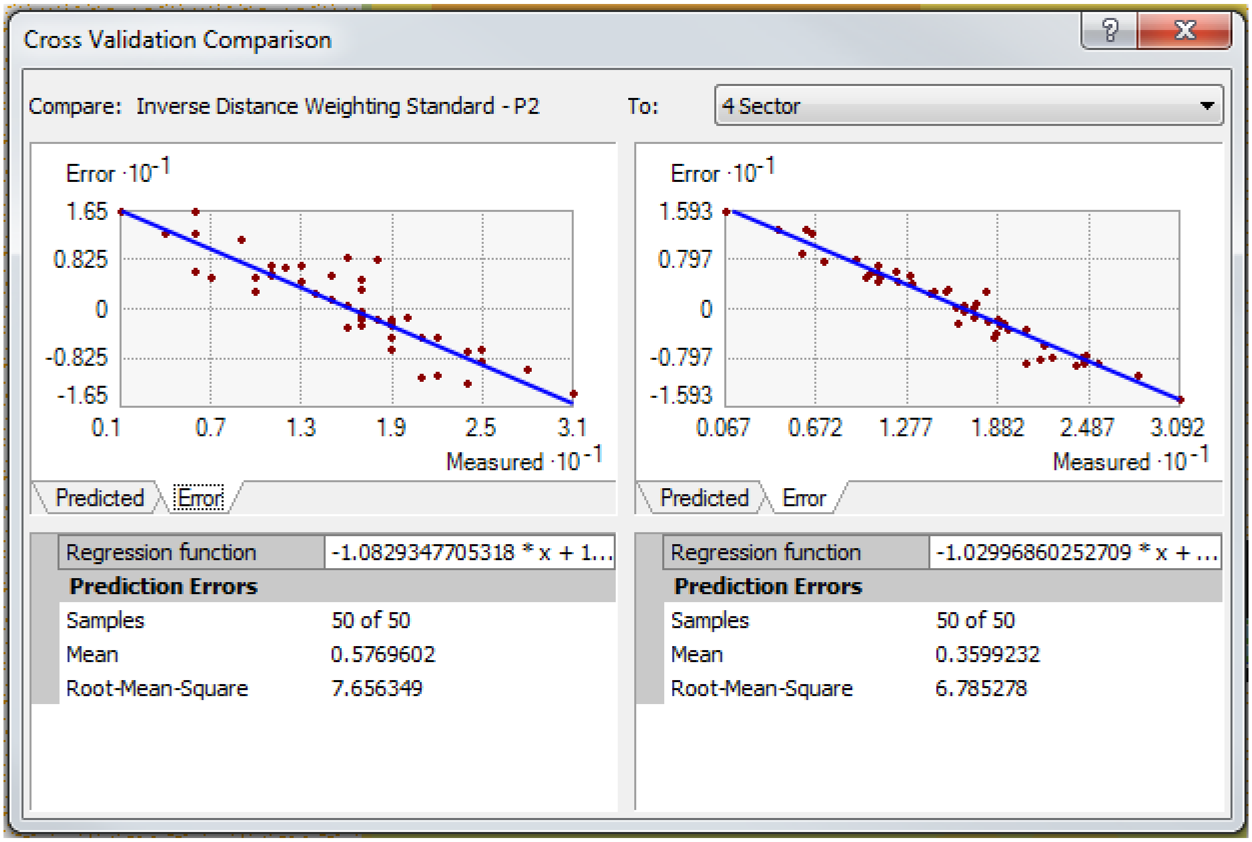
Bars: 10 ☑ Statistics

Transformation: None

Layer: Wetland_Random_Points

Attribute: FuelLoad

Figure 4-9. Histogram with general statistics for wetland fuel load estimates.



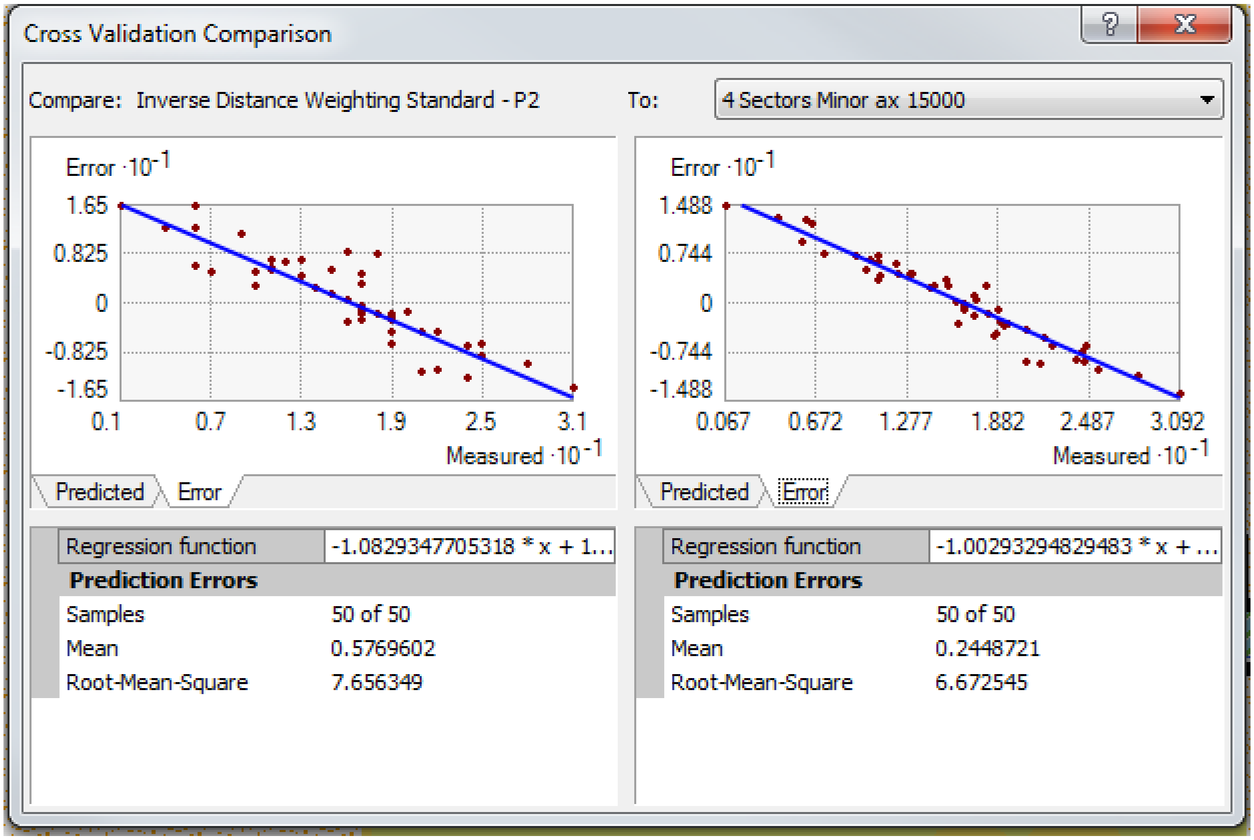
Compare: Inverse Distance Weighting Standard - P2

To: 4 Sector

Regression function	-1.0829347705318 * x + 1...
Prediction Errors	
Samples	50 of 50
Mean	0.5769602
Root-Mean-Square	7.656349

Regression function	-1.02996860252709 * x + ...
Prediction Errors	
Samples	50 of 50
Mean	0.3599232
Root-Mean-Square	6.785278

Figure 4-10. Upland fuel load IDW cross validation of base model with power of 2 compared to power of 2 with sectors adjusted from 1 to 4 sectors.



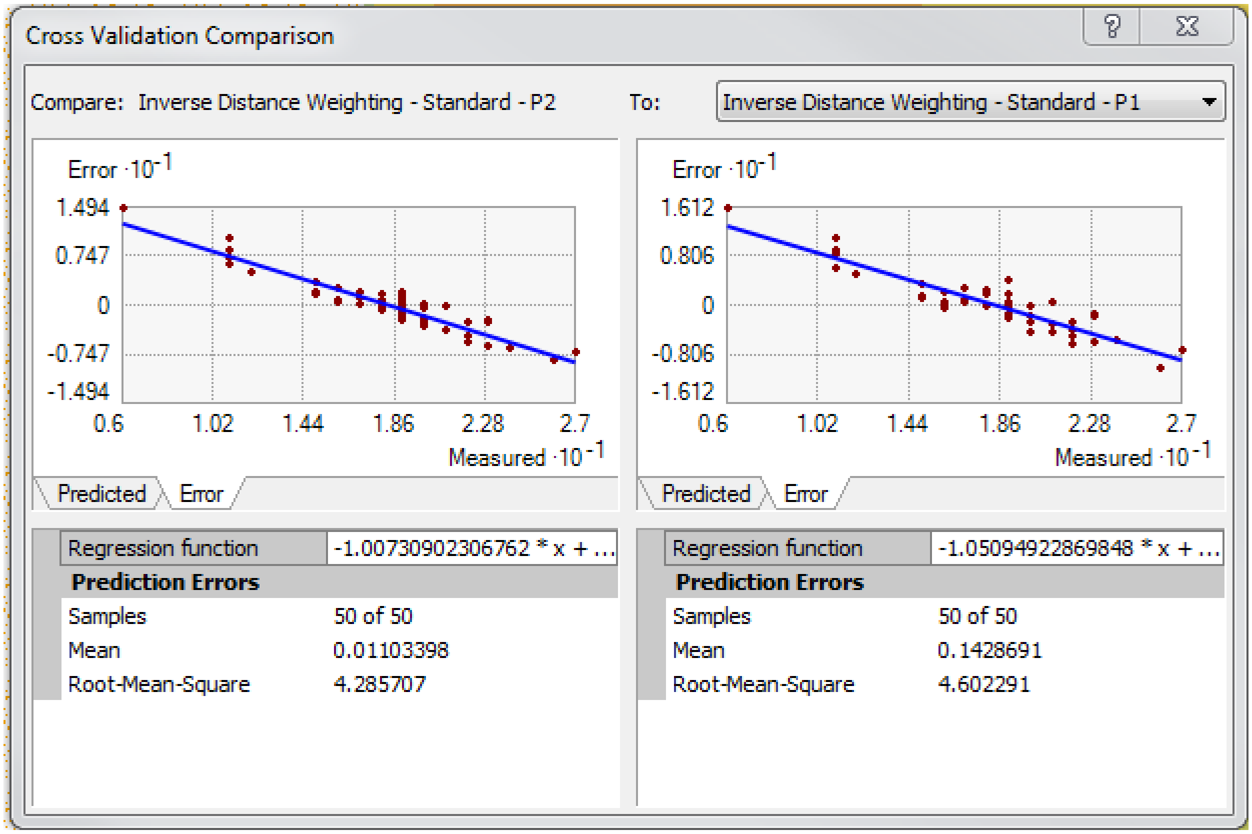
Compare: Inverse Distance Weighting Standard - P2

To: 4 Sectors Minor ax 15000

Regression function	-1.0829347705318 * x + 1...
Prediction Errors	
Samples	50 of 50
Mean	0.5769602
Root-Mean-Square	7.656349

Regression function	-1.00293294829483 * x + ...
Prediction Errors	
Samples	50 of 50
Mean	0.2448721
Root-Mean-Square	6.672545

Figure 4-11. Upland fuel load IDW cross validation of 4 sectors to 4 sectors with a minor axis change to 15000.



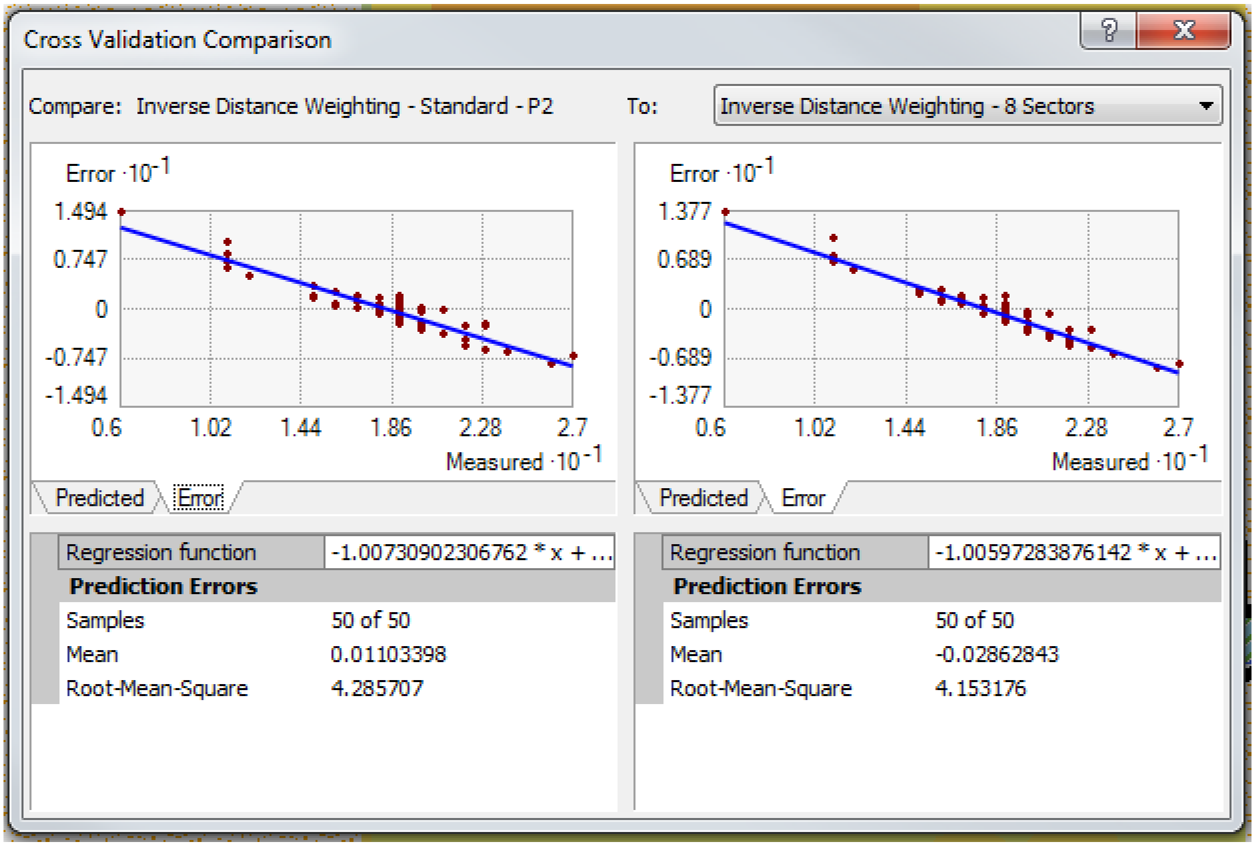
Compare: Inverse Distance Weighting - Standard - P2

To: Inverse Distance Weighting - Standard - P1

Regression function	-1.00730902306762 * x + ...
Prediction Errors	
Samples	50 of 50
Mean	0.01103398
Root-Mean-Square	4.285707

Regression function	-1.05094922869848 * x + ...
Prediction Errors	
Samples	50 of 50
Mean	0.1428691
Root-Mean-Square	4.602291

Figure 4-12. Wetlands IDW of Fuel load. A power level of 1 cross validated with a power level of 2.



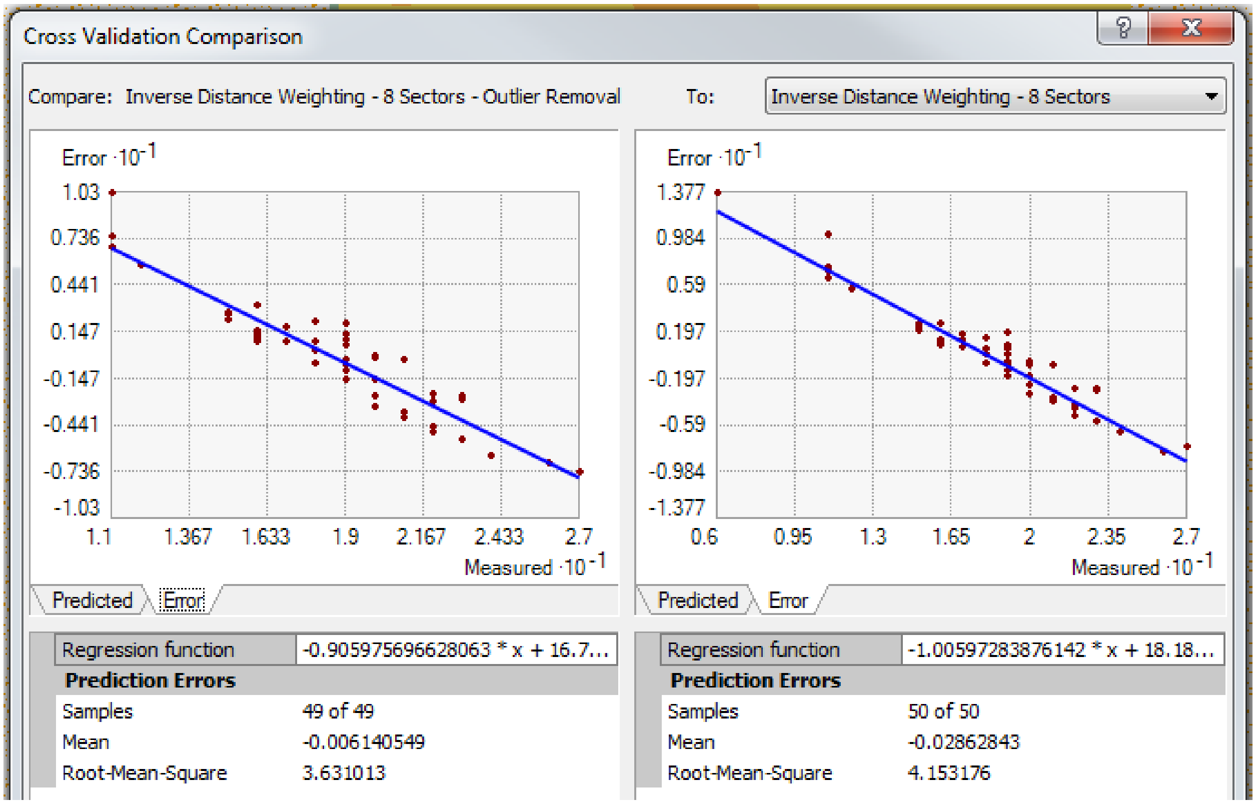
Compare: Inverse Distance Weighting - Standard - P2

To: Inverse Distance Weighting - 8 Sectors

Regression function	-1.00730902306762 * x + ...
Prediction Errors	
Samples	50 of 50
Mean	0.01103398
Root-Mean-Square	4.285707

Regression function	-1.00597283876142 * x + ...
Prediction Errors	
Samples	50 of 50
Mean	-0.02862843
Root-Mean-Square	4.153176

Figure 4-13. Wetland IDW of power level of 2 compared to 4 sectors, than to 8 sectors



Cross Validation Comparison

Compare: Inverse Distance Weighting - 8 Sectors - Outlier Removal

To: Inverse Distance Weighting - 8 Sectors

Regression function	-0.905975696628063 * x + 16.7...
Prediction Errors	
Samples	49 of 49
Mean	-0.006140549
Root-Mean-Square	3.631013

Regression function	-1.00597283876142 * x + 18.18...
Prediction Errors	
Samples	50 of 50
Mean	-0.02862843
Root-Mean-Square	4.153176

Figure 4-14. Wetland IDW cross validation with Point 45 removed.

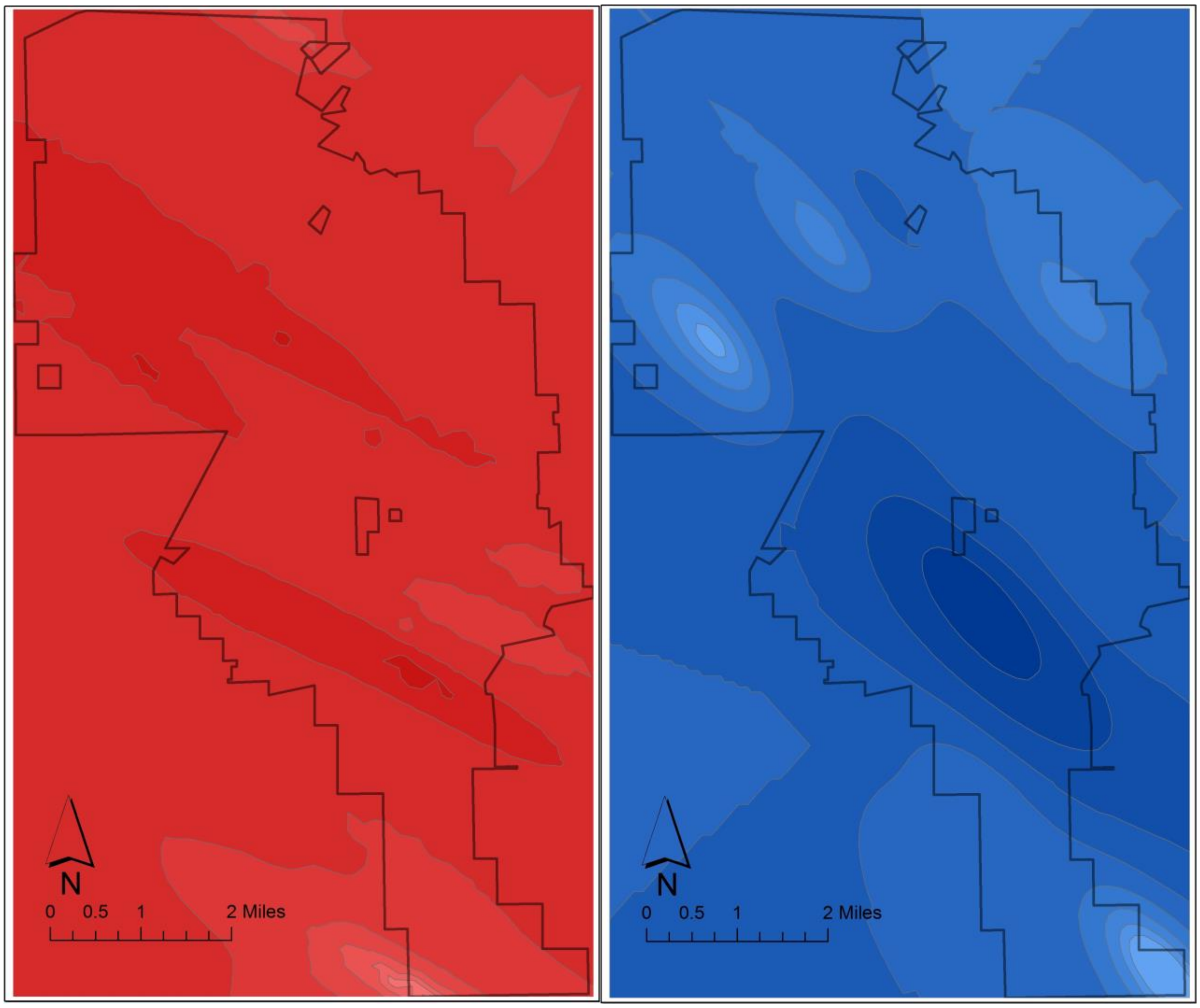


Figure 4-15. A. Upland IDW Final Model (Left). B. Wetland IDW Final Model (Right).

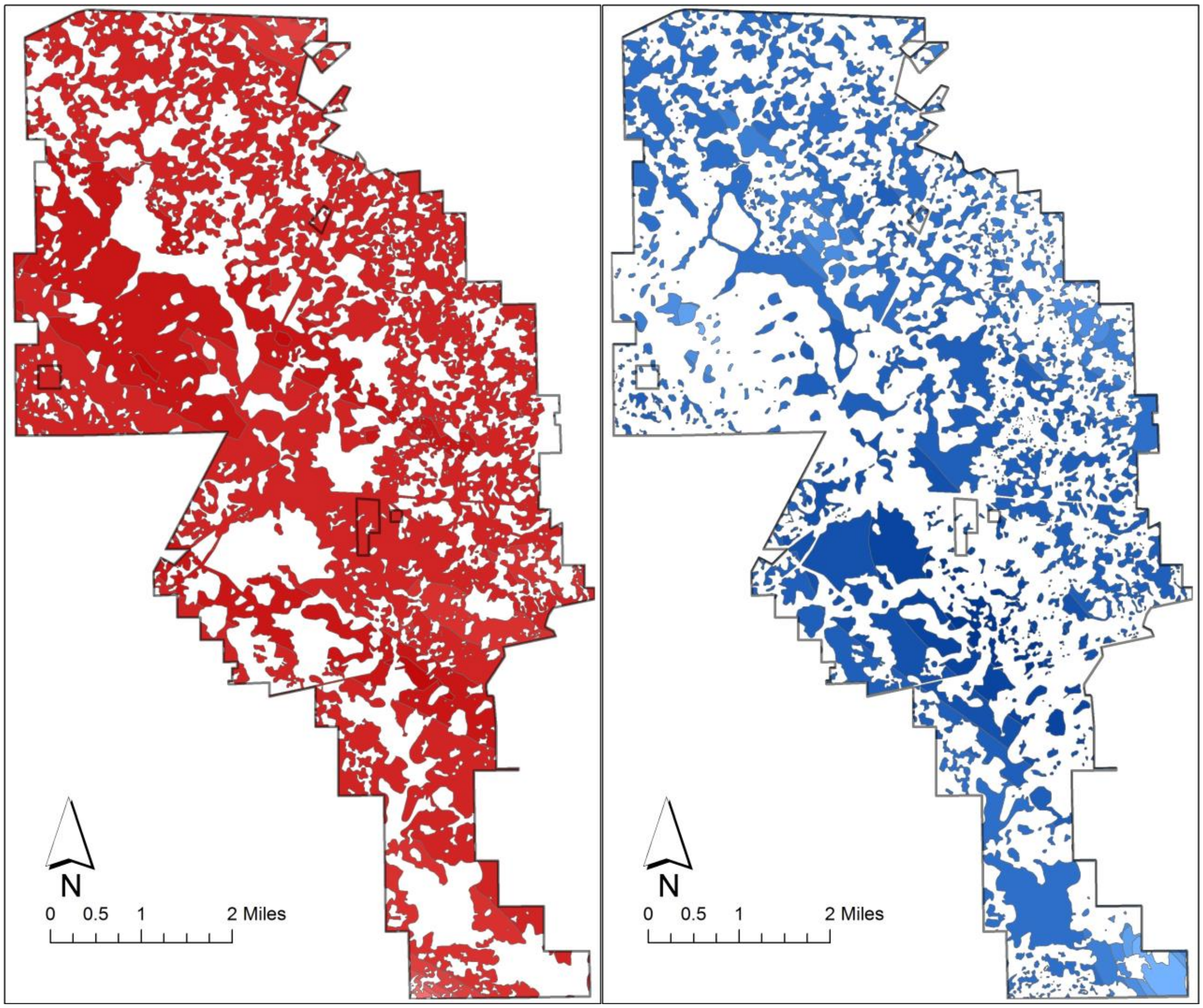


Figure 4-16. A. Upland IDW Final Model Clipped (Left). B. Wetland IDW Final Model Clipped (Right)

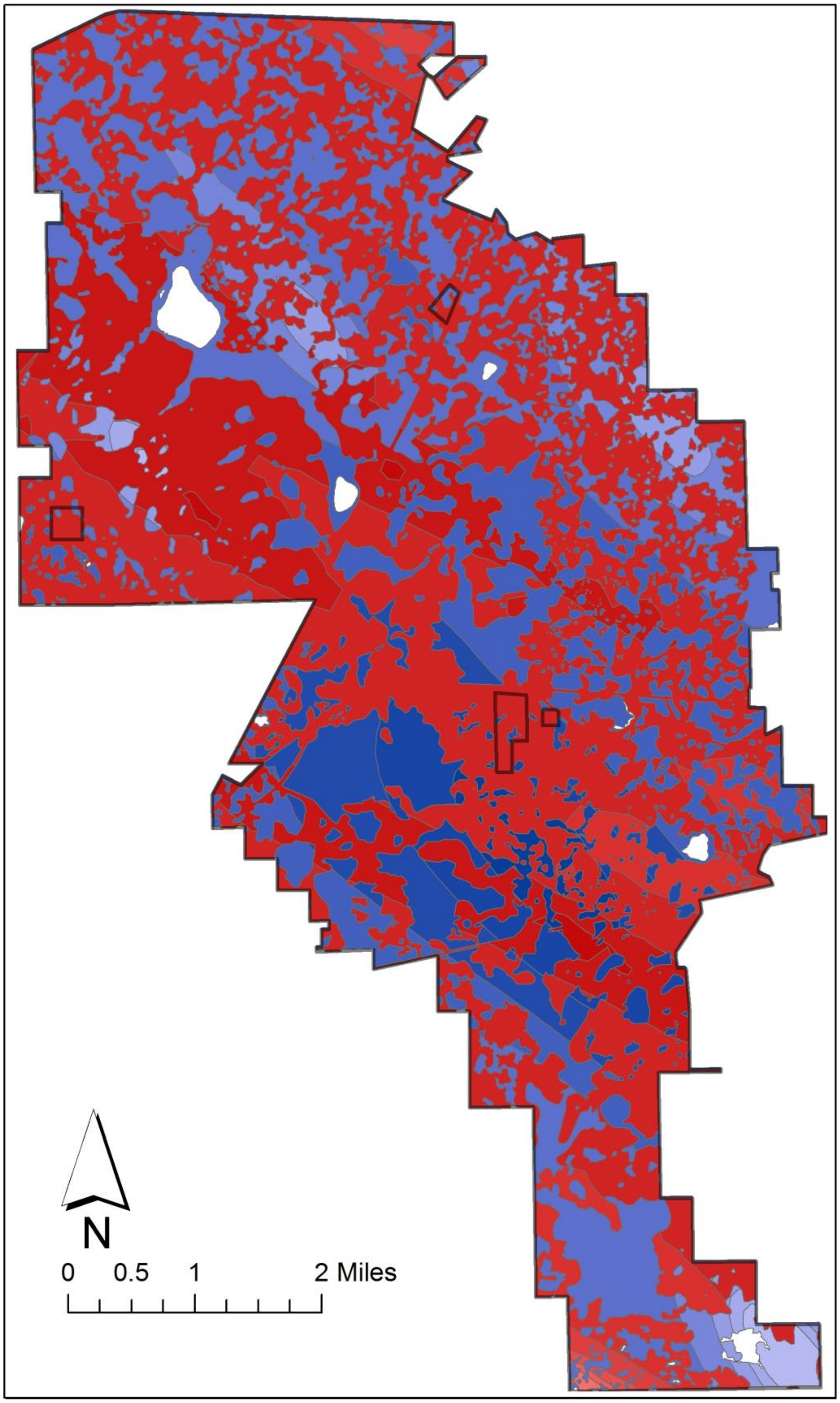
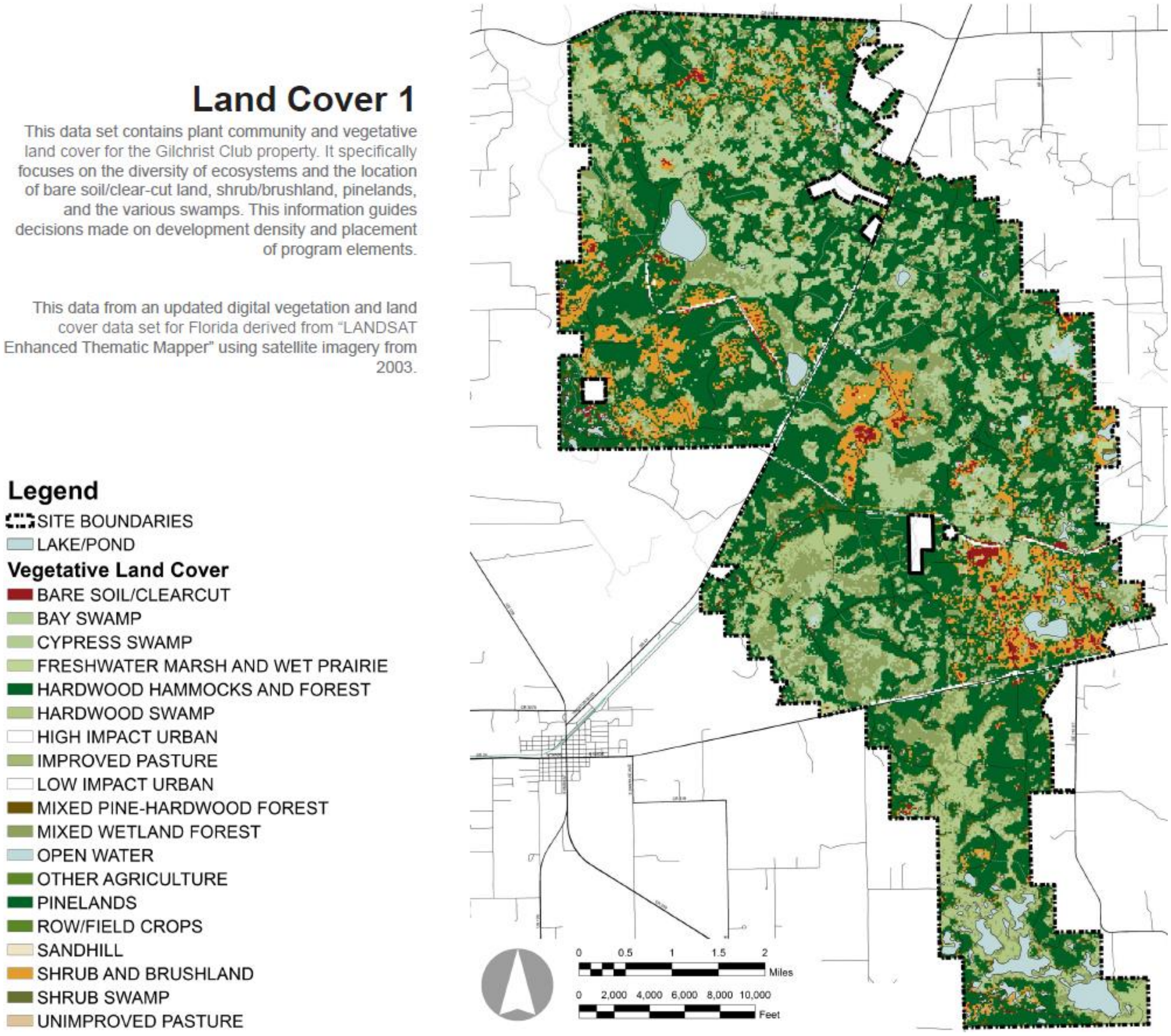


Figure 4-17. Suwannee Lake Plantation Combined Final Custom Fuel Model.



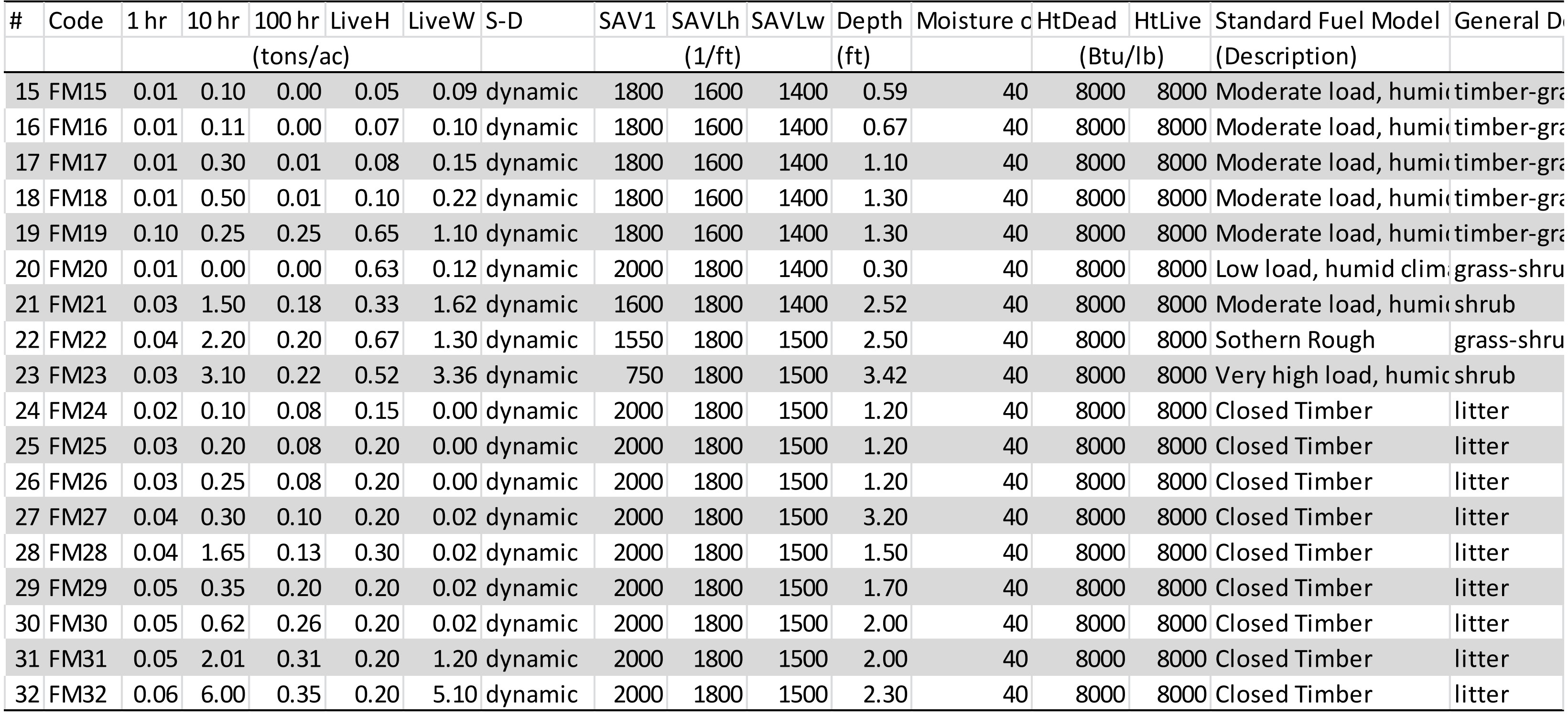
Land Cover 1

This data set contains plant community and vegetative land cover for the Gilchrist Club property. It specifically focuses on the diversity of ecosystems and the location of bare soil/clear-cut land, shrub/brushland, pinelands, and the various swamps. This information guides decisions made on development density and placement of program elements.

This data from an updated digital vegetation and land cover data set for Florida derived from "LANDSAT Enhanced Thematic Mapper" using satellite imagery from 2003.

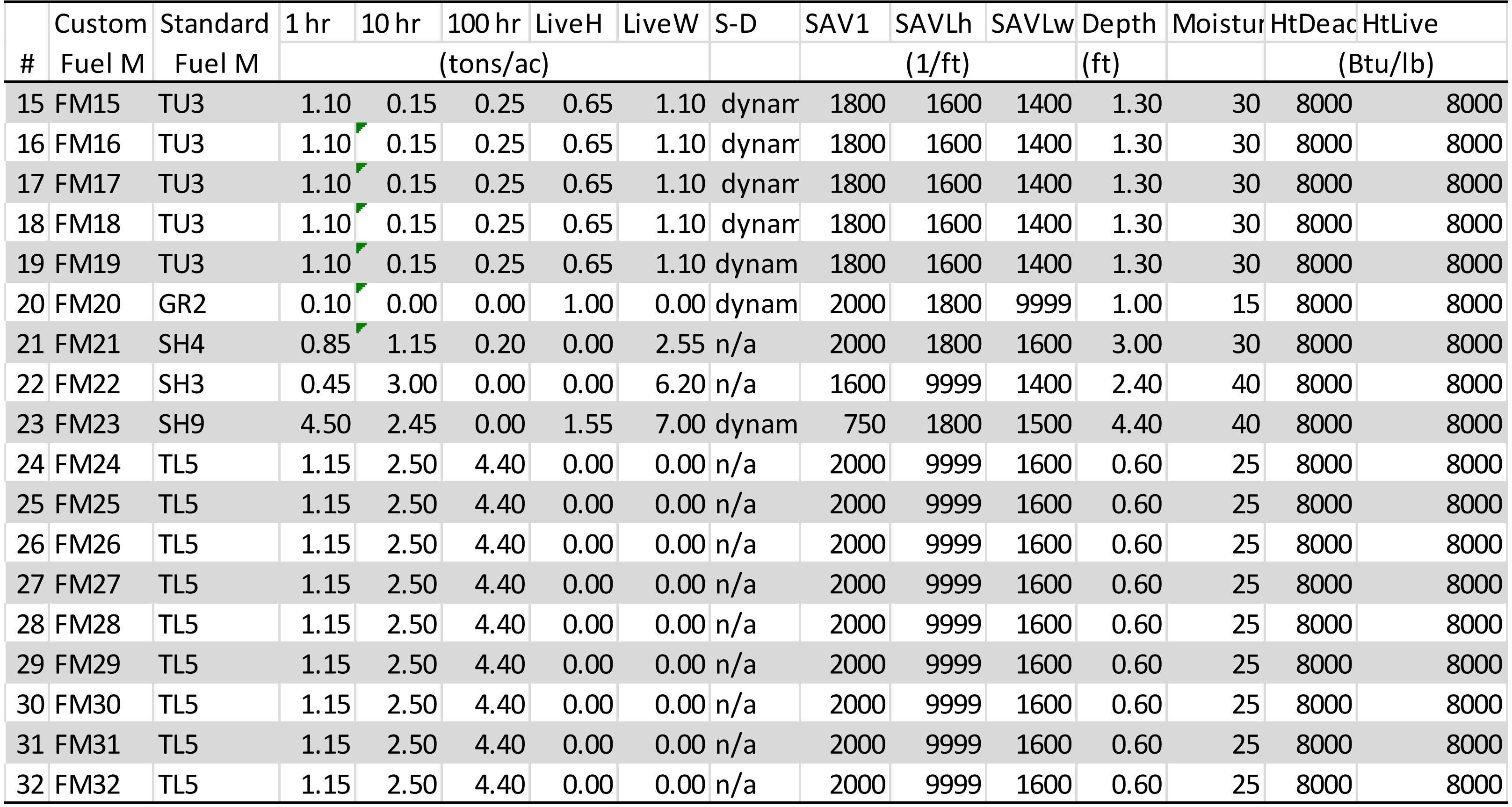
Figure 4-18. Land use classes for the Suwanee Lake Plantation.

Table 4-2. Program Screen Shots of Custom Fuel Models as entered into Program FARSITE.



#	Code	1 hr	10 hr	100 hr	LiveH	LiveW	S-D	SAV1	SAVLh	SAVLw	Depth	Moisture c	HtDead	HtLive	Standard Fuel Model	General D
				(tons/ac)					(1/ft)		(ft)		(Btu/lb)		(Description)	
15	FM15	0.01	0.10	0.00	0.05	0.09	dynamic	1800	1600	1400	0.59	40	8000	8000	Moderate load, humi	timber-gra
16	FM16	0.01	0.11	0.00	0.07	0.10	dynamic	1800	1600	1400	0.67	40	8000	8000	Moderate load, humi	timber-gra
17	FM17	0.01	0.30	0.01	0.08	0.15	dynamic	1800	1600	1400	1.10	40	8000	8000	Moderate load, humi	timber-gra
18	FM18	0.01	0.50	0.01	0.10	0.22	dynamic	1800	1600	1400	1.30	40	8000	8000	Moderate load, humi	timber-gra
19	FM19	0.10	0.25	0.25	0.65	1.10	dynamic	1800	1600	1400	1.30	40	8000	8000	Moderate load, humi	timber-gra
20	FM20	0.01	0.00	0.00	0.63	0.12	dynamic	2000	1800	1400	0.30	40	8000	8000	Low load, humid clim	grass-shru
21	FM21	0.03	1.50	0.18	0.33	1.62	dynamic	1600	1800	1400	2.52	40	8000	8000	Moderate load, humi	shrub
22	FM22	0.04	2.20	0.20	0.67	1.30	dynamic	1550	1800	1500	2.50	40	8000	8000	Sothern Rough	grass-shru
23	FM23	0.03	3.10	0.22	0.52	3.36	dynamic	750	1800	1500	3.42	40	8000	8000	Very high load, humi	shrub
24	FM24	0.02	0.10	0.08	0.15	0.00	dynamic	2000	1800	1500	1.20	40	8000	8000	Closed Timber	litter
25	FM25	0.03	0.20	0.08	0.20	0.00	dynamic	2000	1800	1500	1.20	40	8000	8000	Closed Timber	litter
26	FM26	0.03	0.25	0.08	0.20	0.00	dynamic	2000	1800	1500	1.20	40	8000	8000	Closed Timber	litter
27	FM27	0.04	0.30	0.10	0.20	0.02	dynamic	2000	1800	1500	3.20	40	8000	8000	Closed Timber	litter
28	FM28	0.04	1.65	0.13	0.30	0.02	dynamic	2000	1800	1500	1.50	40	8000	8000	Closed Timber	litter
29	FM29	0.05	0.35	0.20	0.20	0.02	dynamic	2000	1800	1500	1.70	40	8000	8000	Closed Timber	litter
30	FM30	0.05	0.62	0.26	0.20	0.02	dynamic	2000	1800	1500	2.00	40	8000	8000	Closed Timber	litter
31	FM31	0.05	2.01	0.31	0.20	1.20	dynamic	2000	1800	1500	2.00	40	8000	8000	Closed Timber	litter
32	FM32	0.06	6.00	0.35	0.20	5.10	dynamic	2000	1800	1500	2.30	40	8000	8000	Closed Timber	litter

Table 4-3. Program Screen Shots of Custom Fuel Models and their associated Standard Fuel Models that were used as a Base for processing and input into Program FARSITE.



	Custom	Standard	1 hr	10 hr	100 hr	LiveH	LiveW	S-D	SAV1	SAVLh	SAVLw	Depth	Moistur	HtDeac	HtLive
#	Fuel M	Fuel M	(tons/ac)						(1/ft)			(ft)		(Btu/lb)	
15	FM15	TU3	1.10	0.15	0.25	0.65	1.10	dynam	1800	1600	1400	1.30	30	8000	8000
16	FM16	TU3	1.10	0.15	0.25	0.65	1.10	dynam	1800	1600	1400	1.30	30	8000	8000
17	FM17	TU3	1.10	0.15	0.25	0.65	1.10	dynam	1800	1600	1400	1.30	30	8000	8000
18	FM18	TU3	1.10	0.15	0.25	0.65	1.10	dynam	1800	1600	1400	1.30	30	8000	8000
19	FM19	TU3	1.10	0.15	0.25	0.65	1.10	dynam	1800	1600	1400	1.30	30	8000	8000
20	FM20	GR2	0.10	0.00	0.00	1.00	0.00	dynam	2000	1800	9999	1.00	15	8000	8000
21	FM21	SH4	0.85	1.15	0.20	0.00	2.55	n/a	2000	1800	1600	3.00	30	8000	8000
22	FM22	SH3	0.45	3.00	0.00	0.00	6.20	n/a	1600	9999	1400	2.40	40	8000	8000
23	FM23	SH9	4.50	2.45	0.00	1.55	7.00	dynam	750	1800	1500	4.40	40	8000	8000
24	FM24	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
25	FM25	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
26	FM26	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
27	FM27	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
28	FM28	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
29	FM29	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
30	FM30	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
31	FM31	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000
32	FM32	TL5	1.15	2.50	4.40	0.00	0.00	n/a	2000	9999	1600	0.60	25	8000	8000

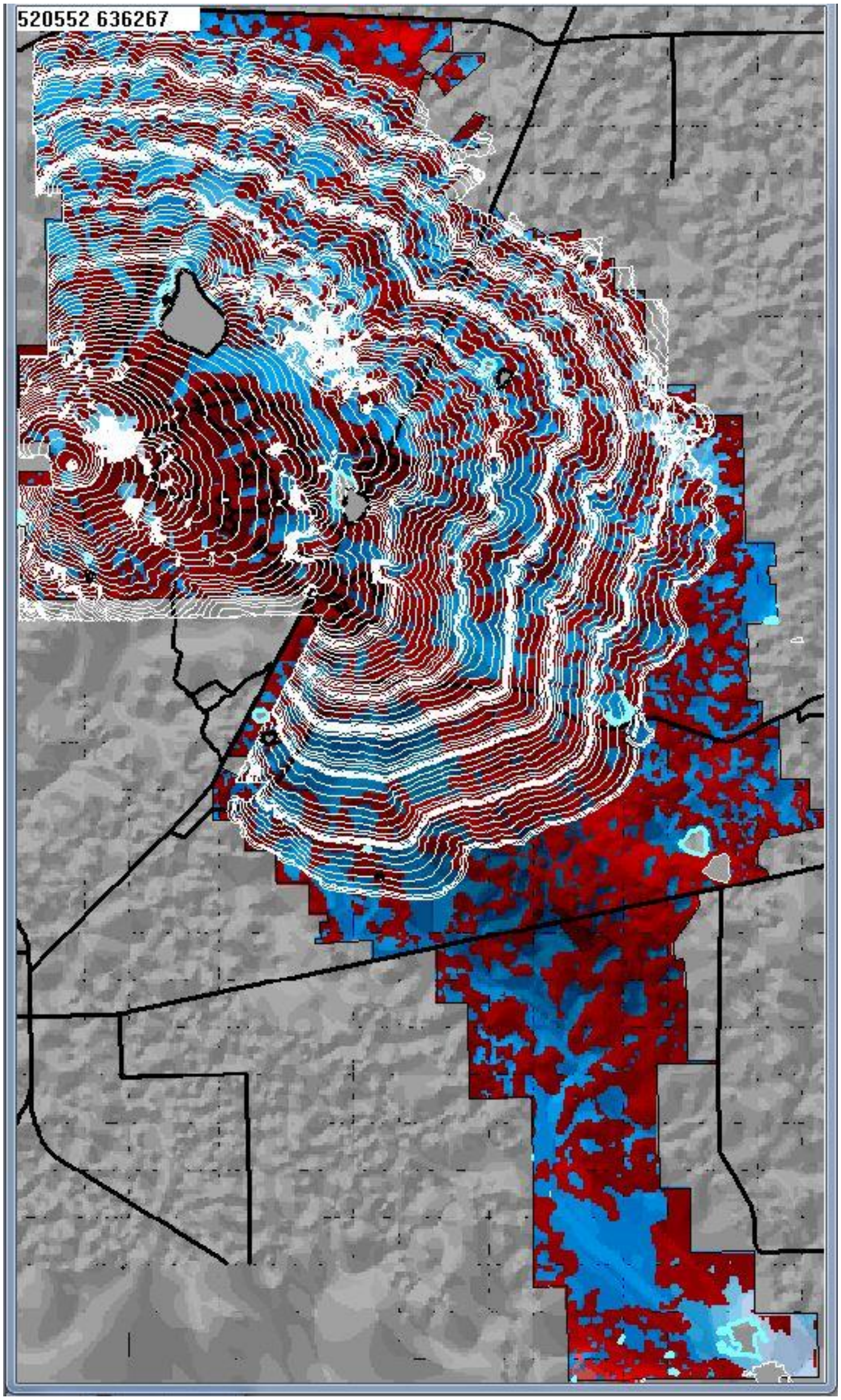


Figure 4-19. Group 1, Low Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

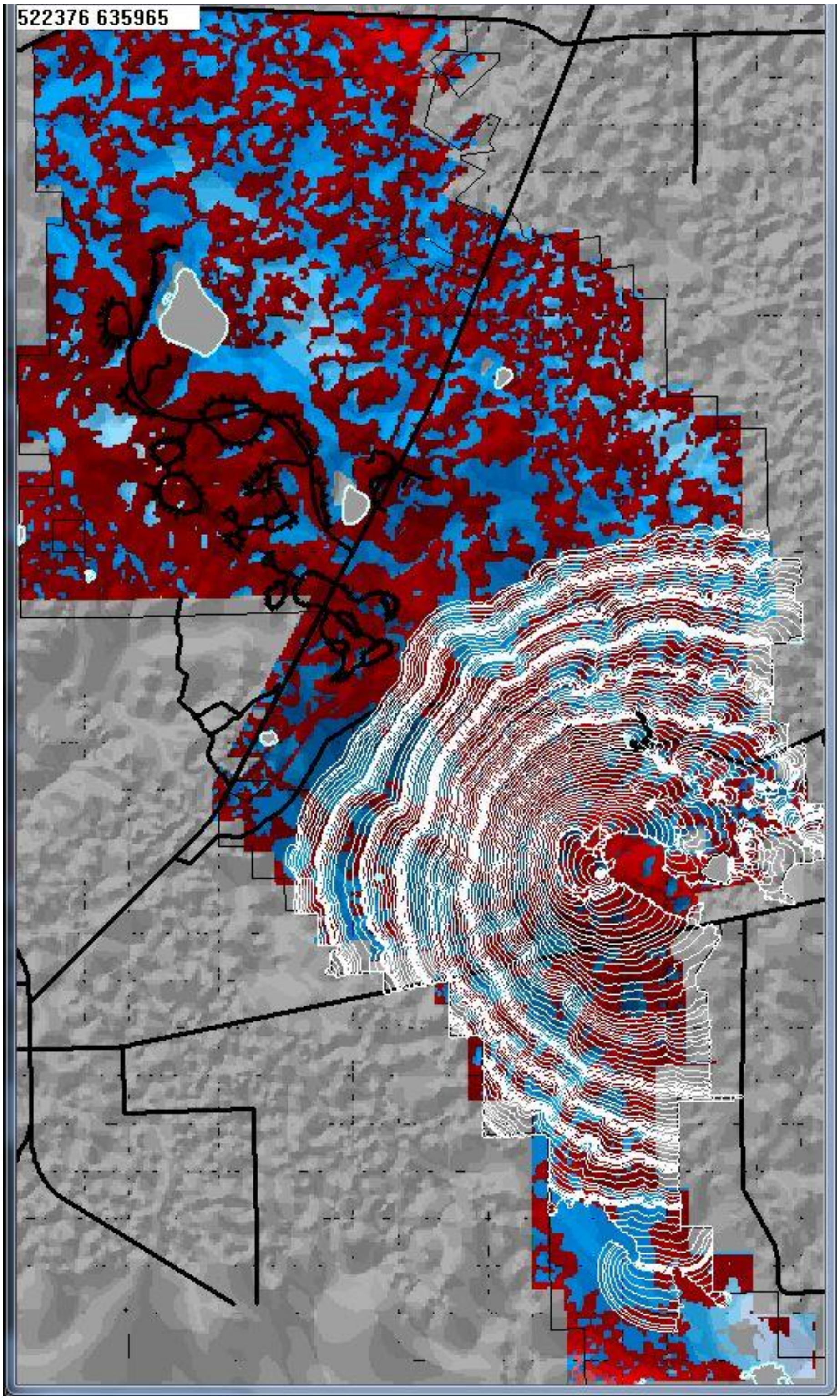


Figure 4-20. Group 1, Low Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

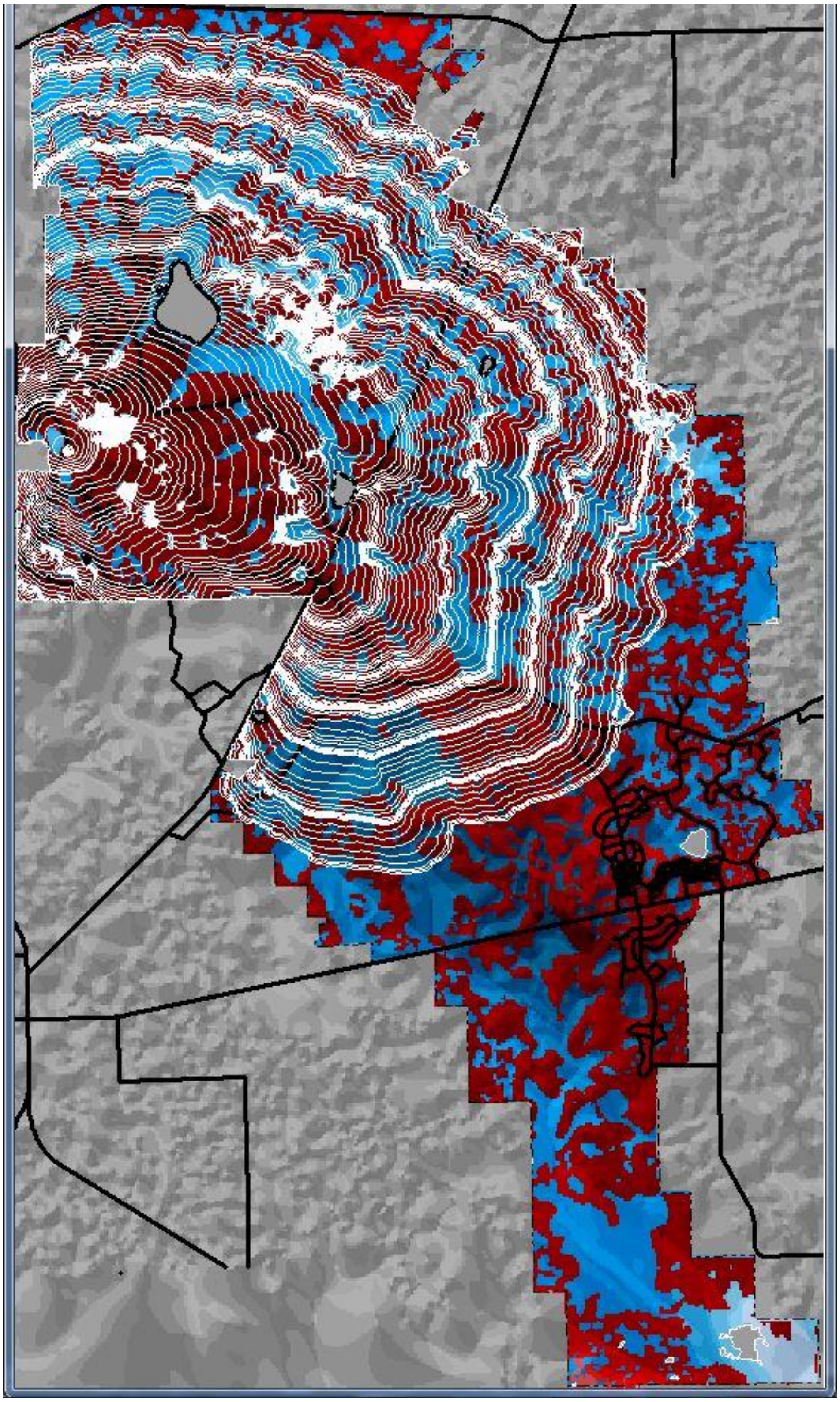


Figure 4-21. Group 2, Low Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

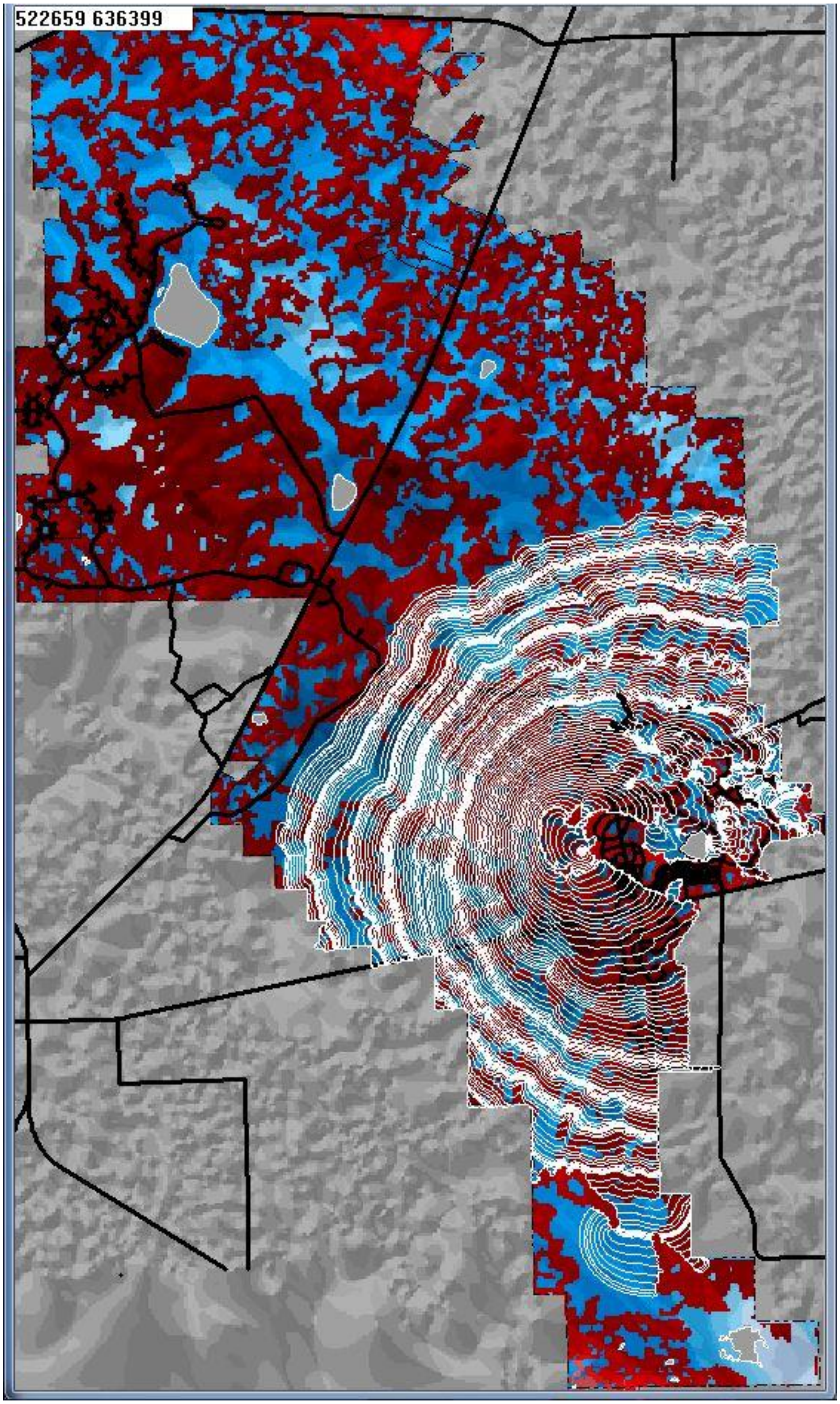


Figure 4-22. Group 2, Low Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

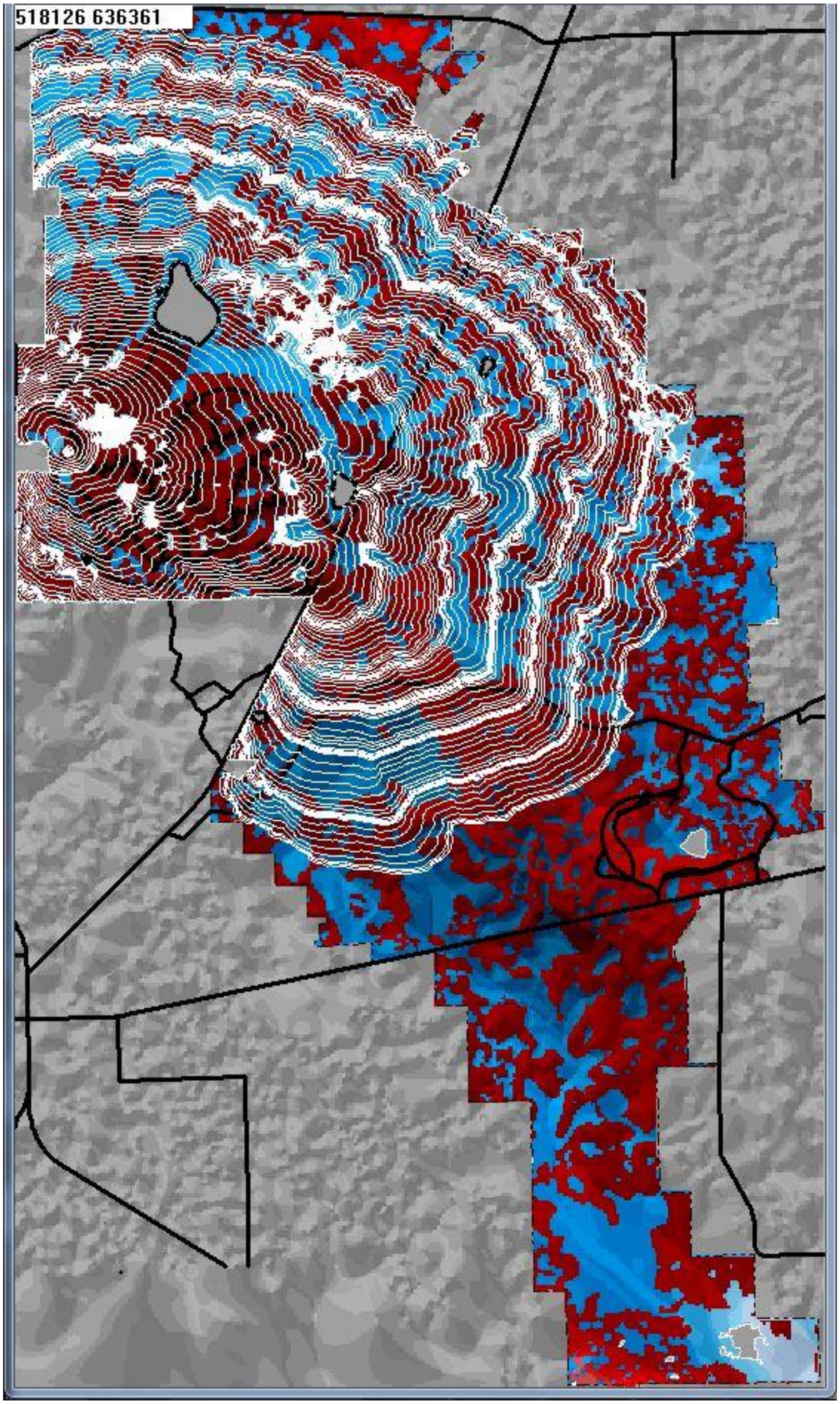


Figure 4-23. Group 3, Low Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

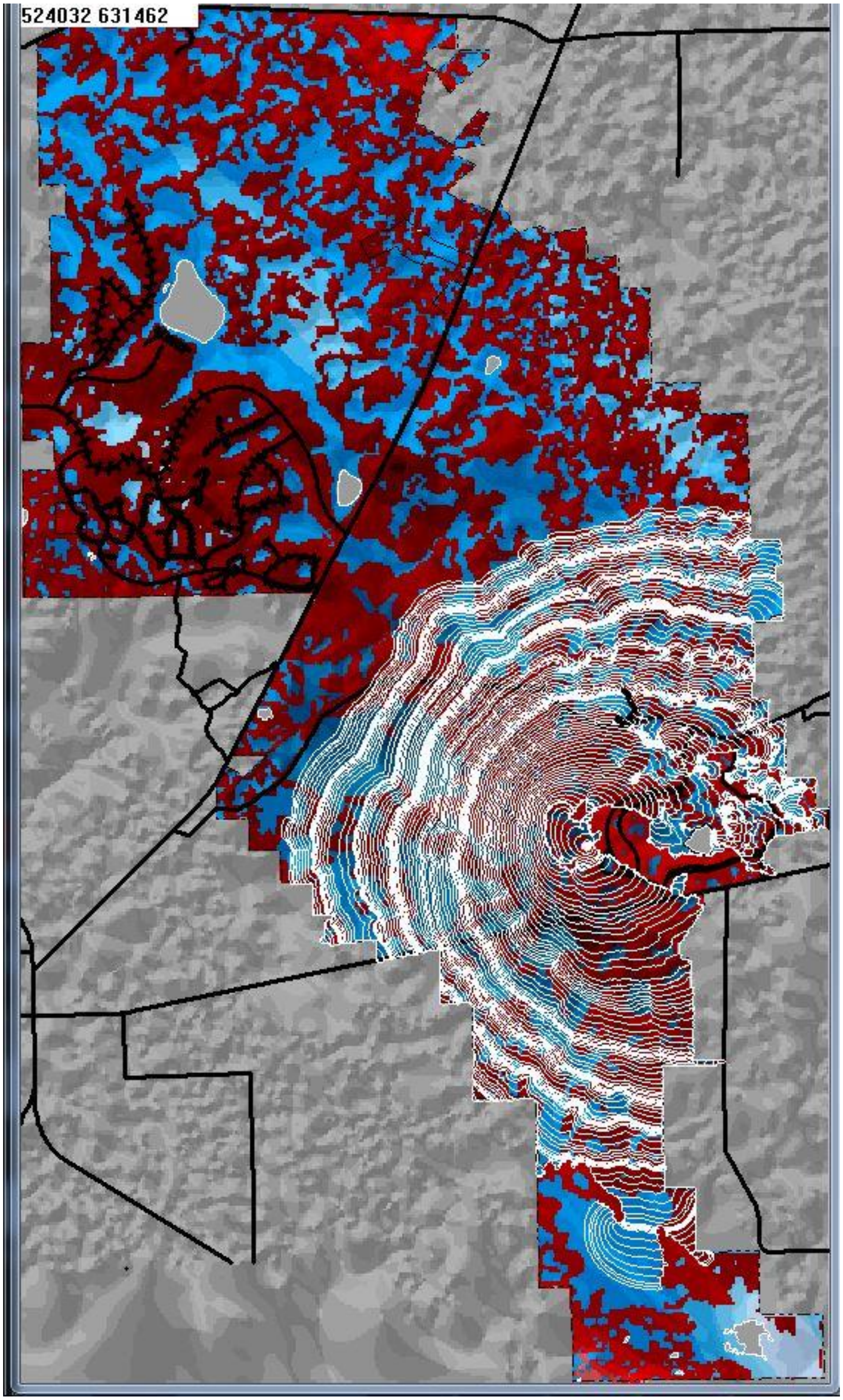


Figure 4-24. Group 3, Low Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

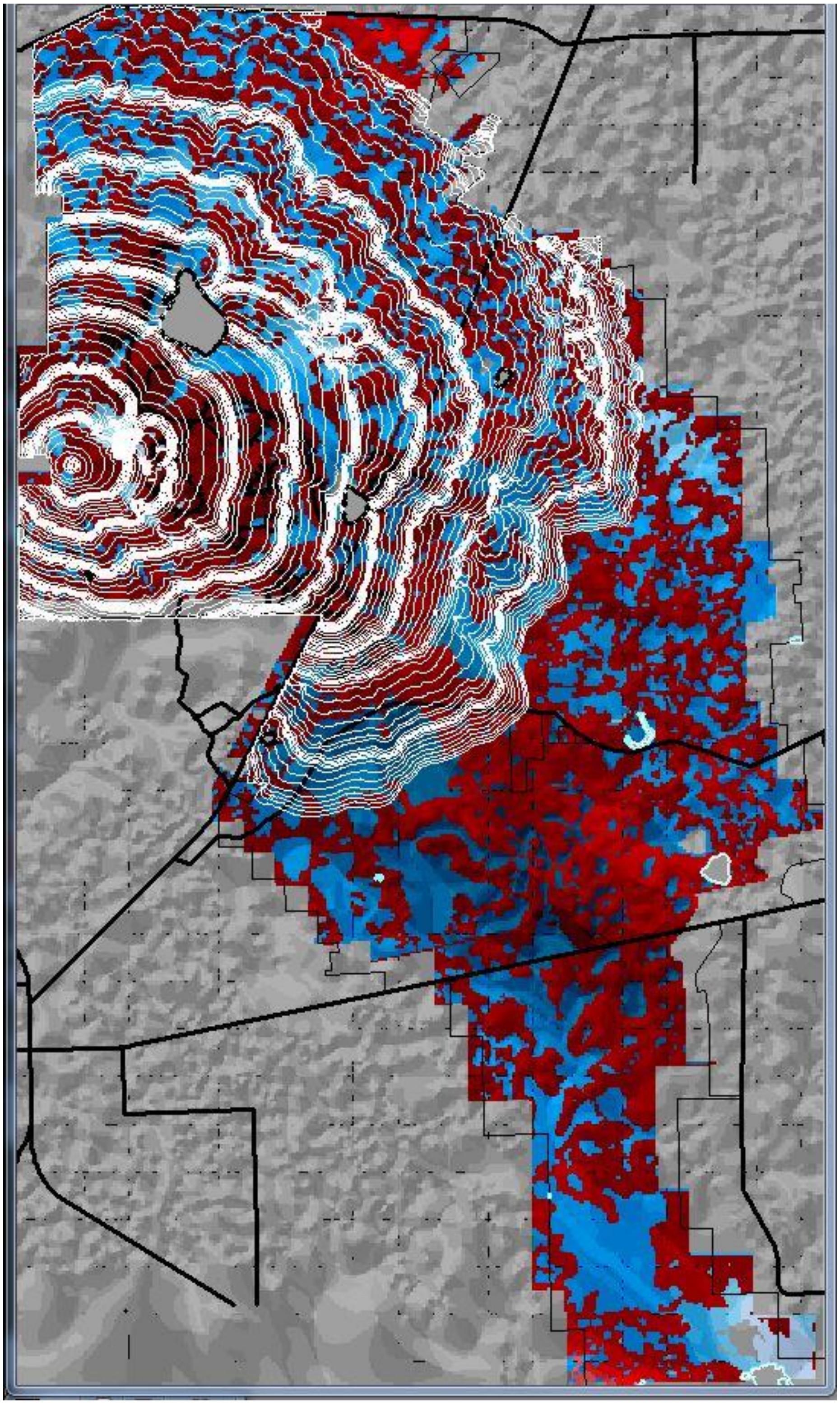


Figure 4-25. Group 1, Medium Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

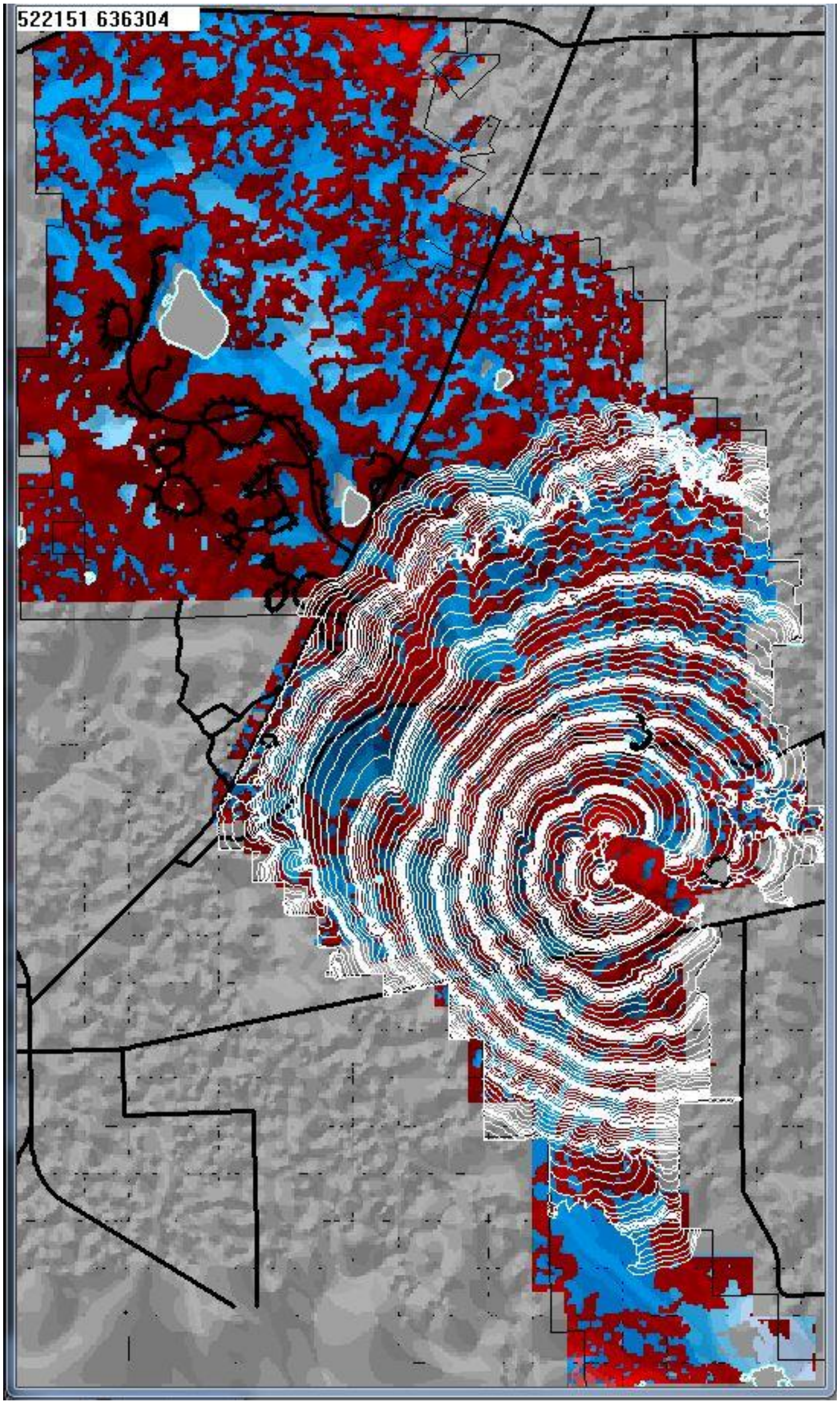


Figure 4-26. Group 1, Medium Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

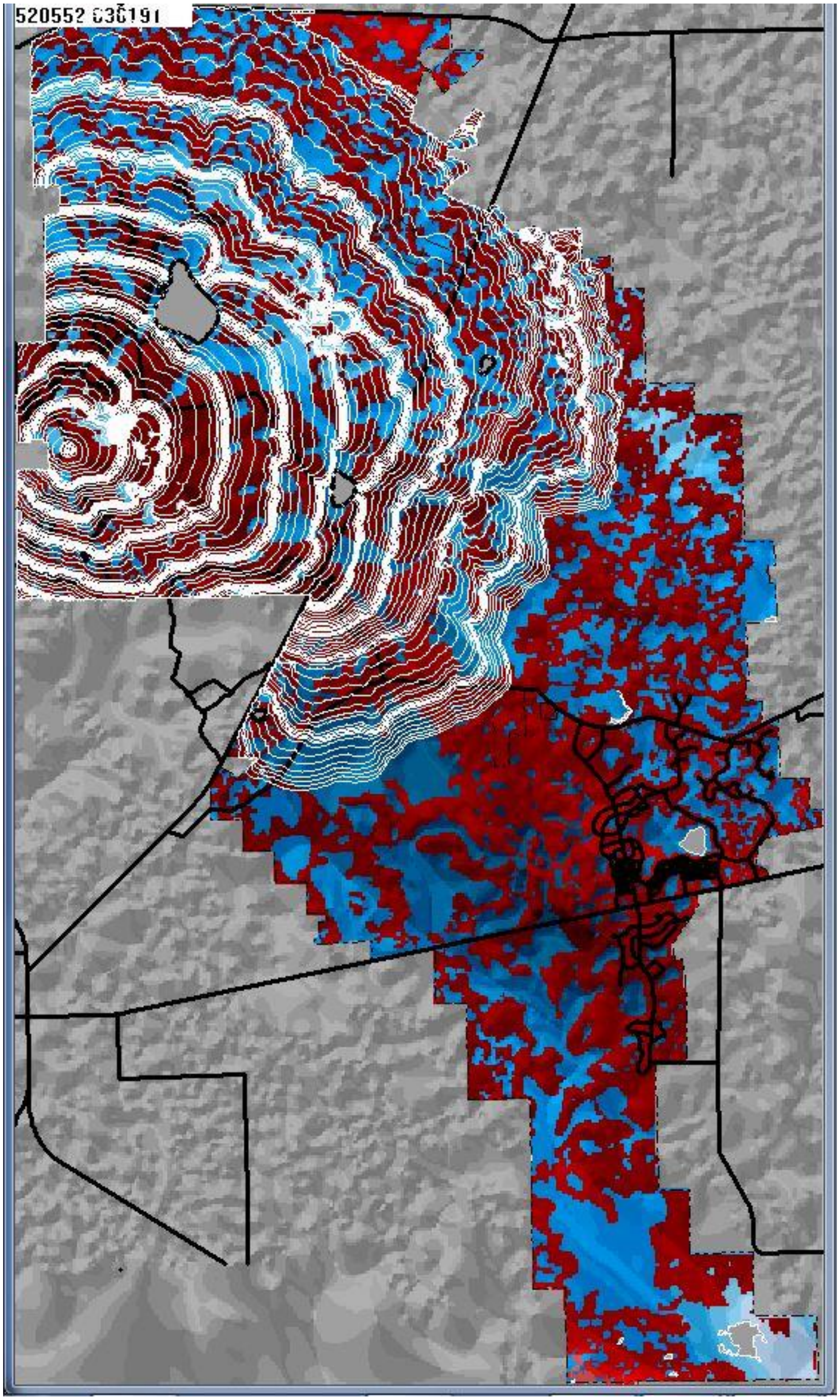


Figure 4-27. Group 2, Medium Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

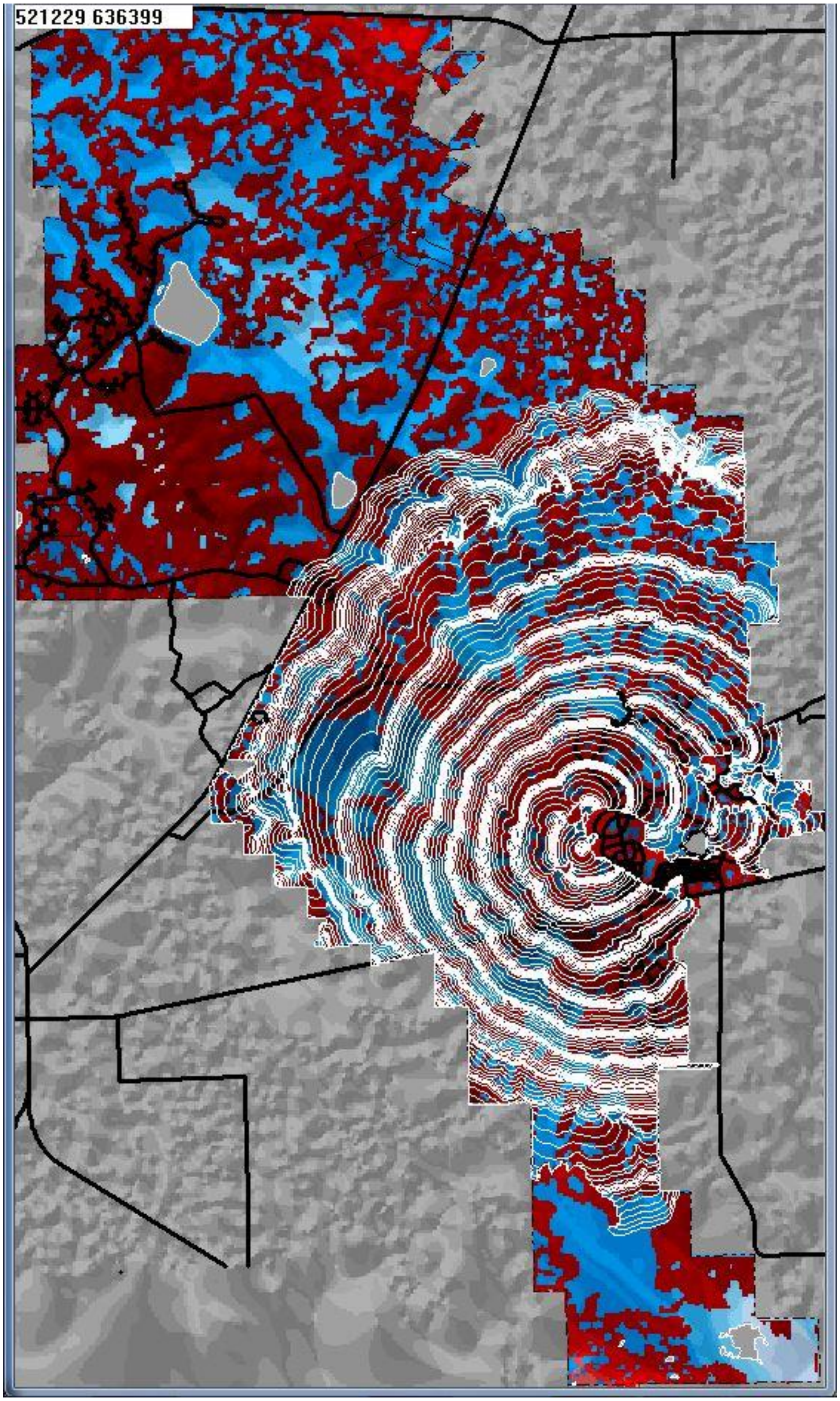


Figure 4-28. Group 2, Medium Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

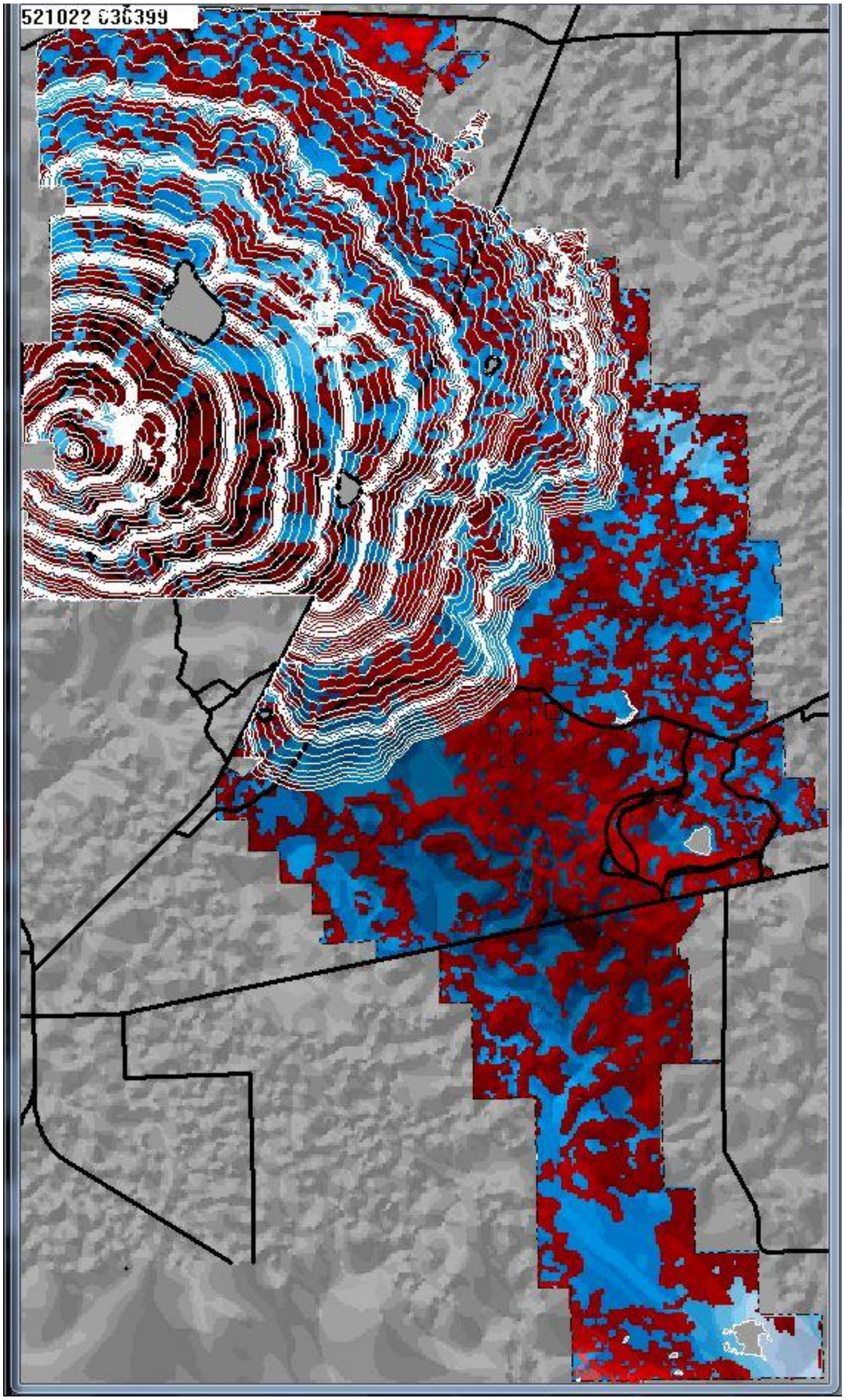


Figure 4-29. Group 3, Medium Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

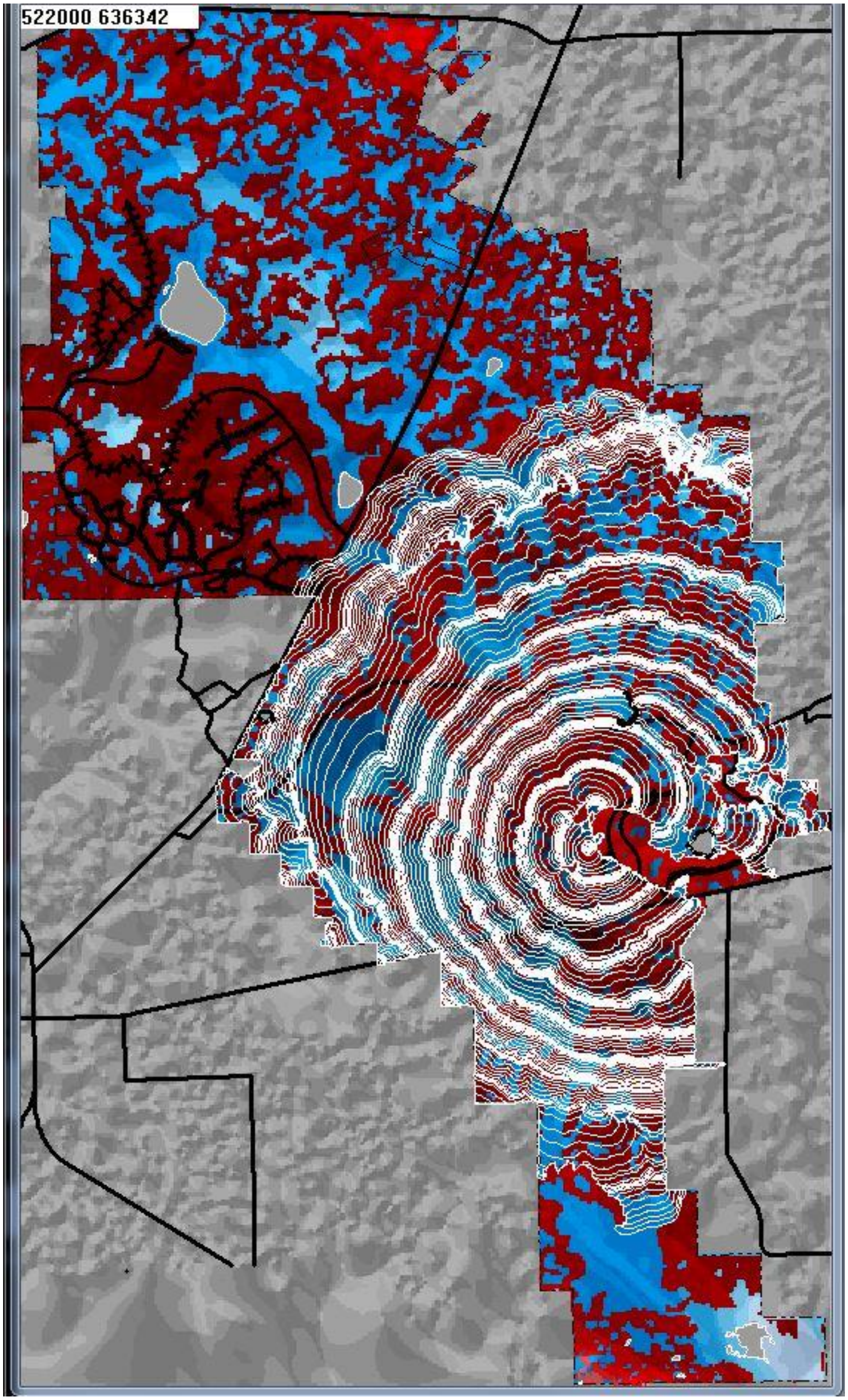


Figure 4-30. Group 3, Medium Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

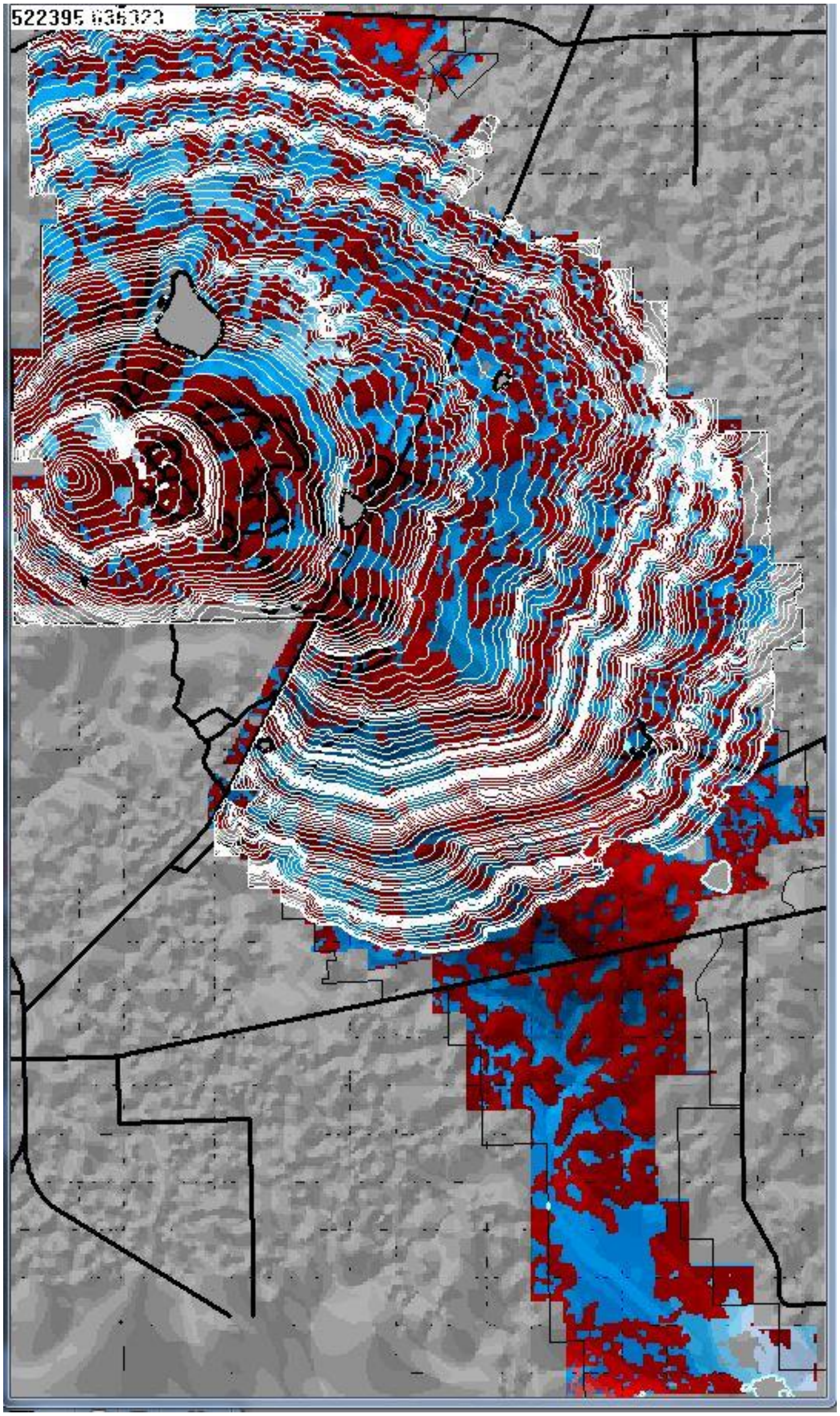


Figure 4-31. Group 1, High Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

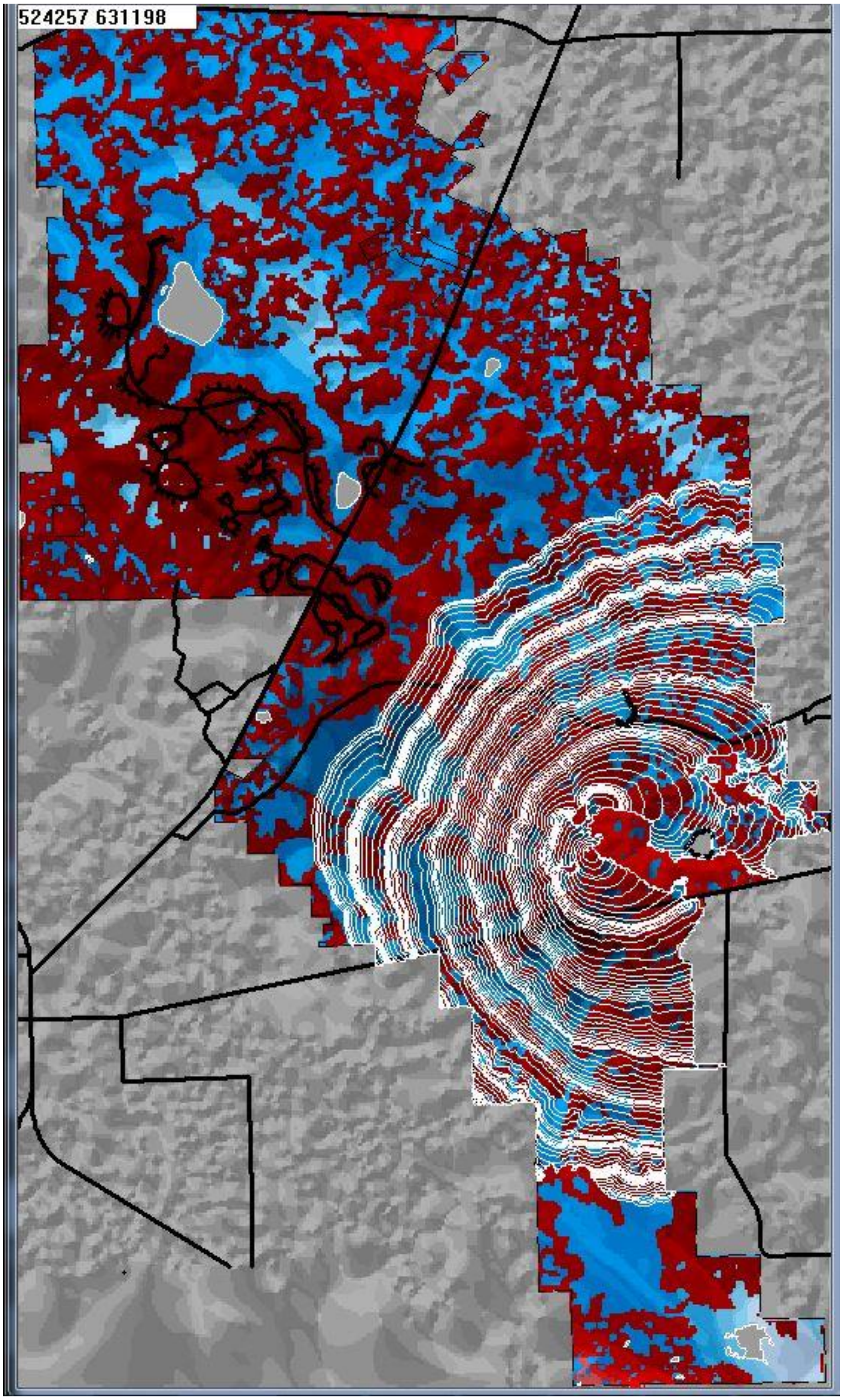


Figure 4-32. Group 1, High Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

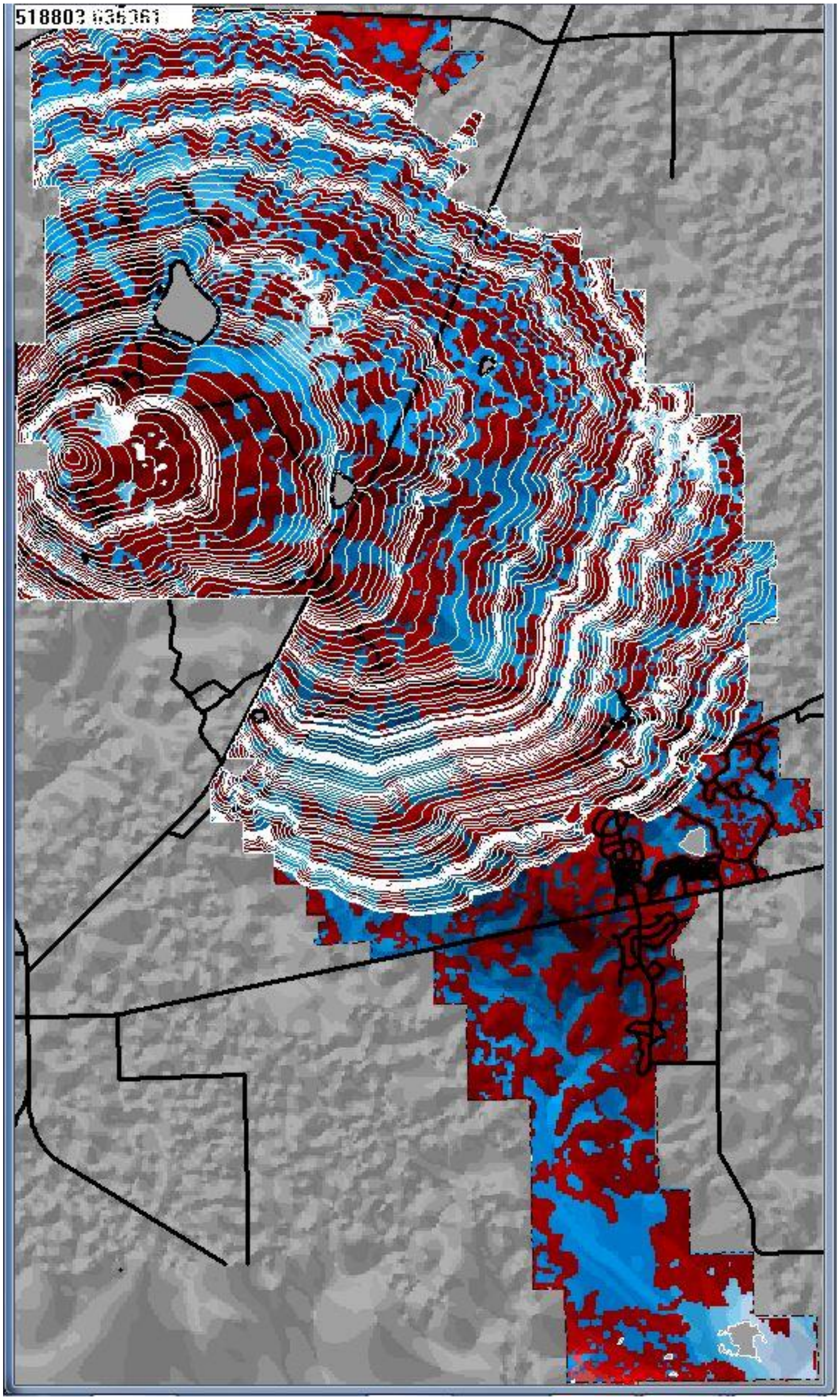


Figure 4-33. Group 2, High Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

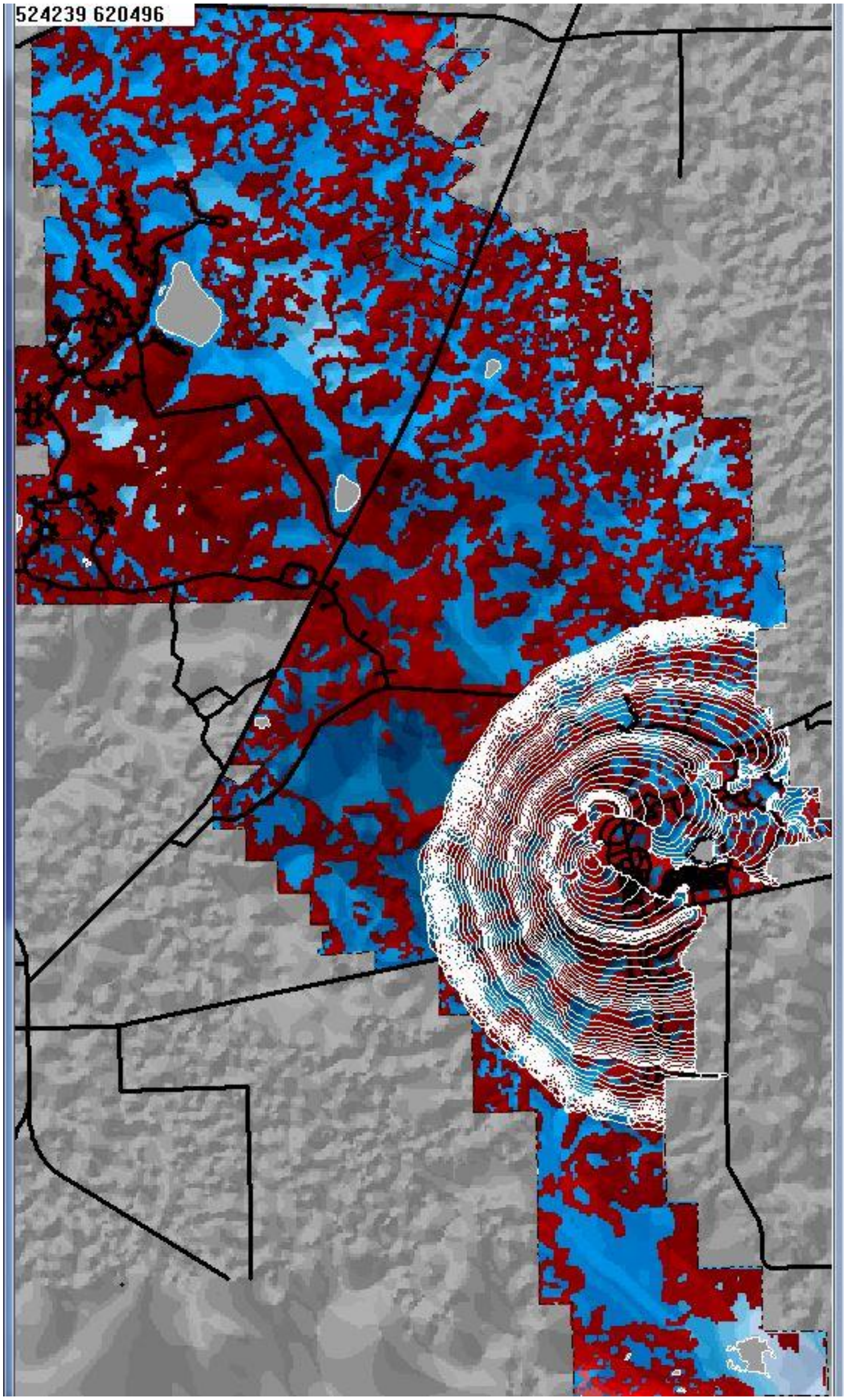


Figure 4-34. Group 2, High Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

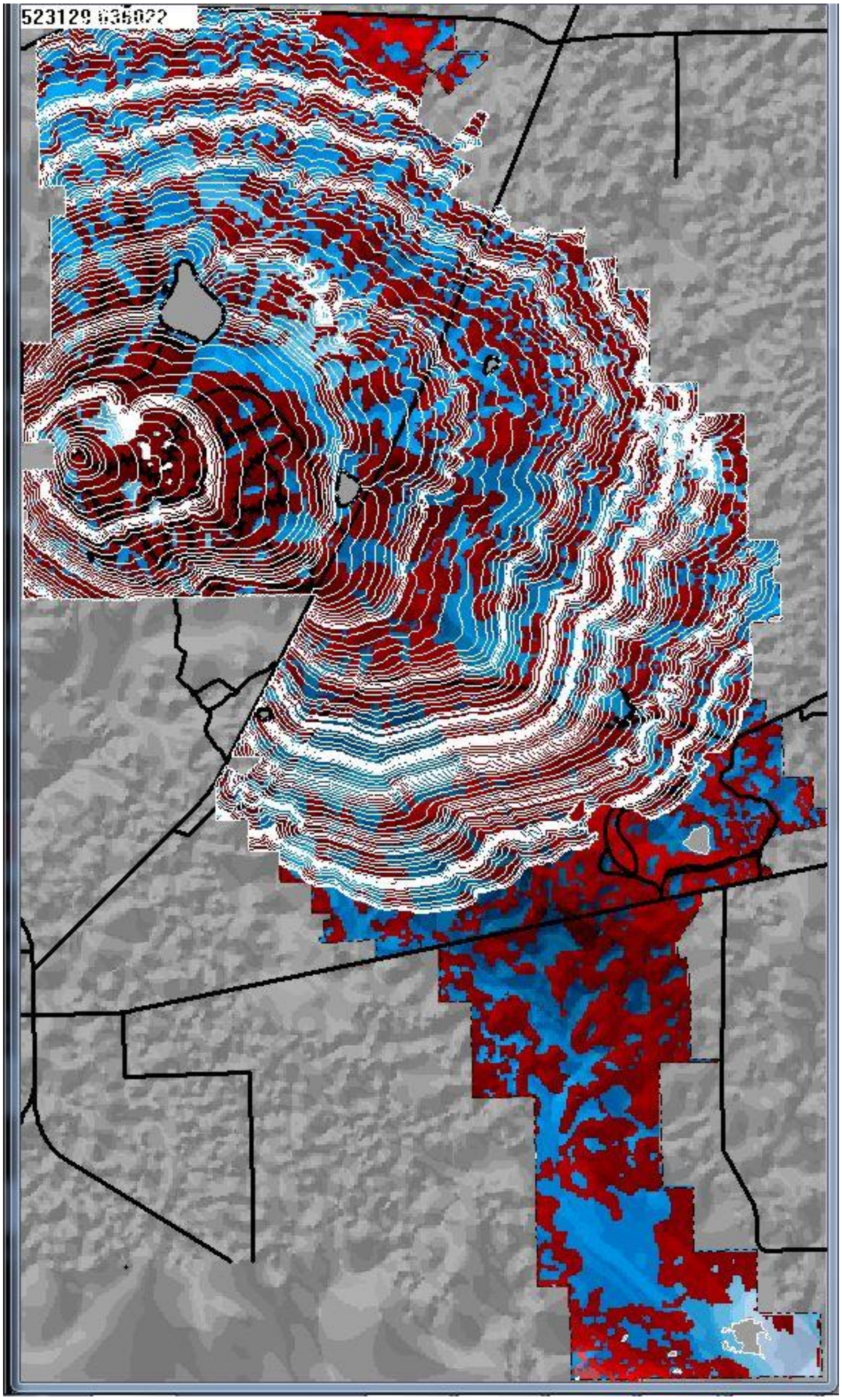


Figure 4-35. Group 3, High Fire Intensity 1. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

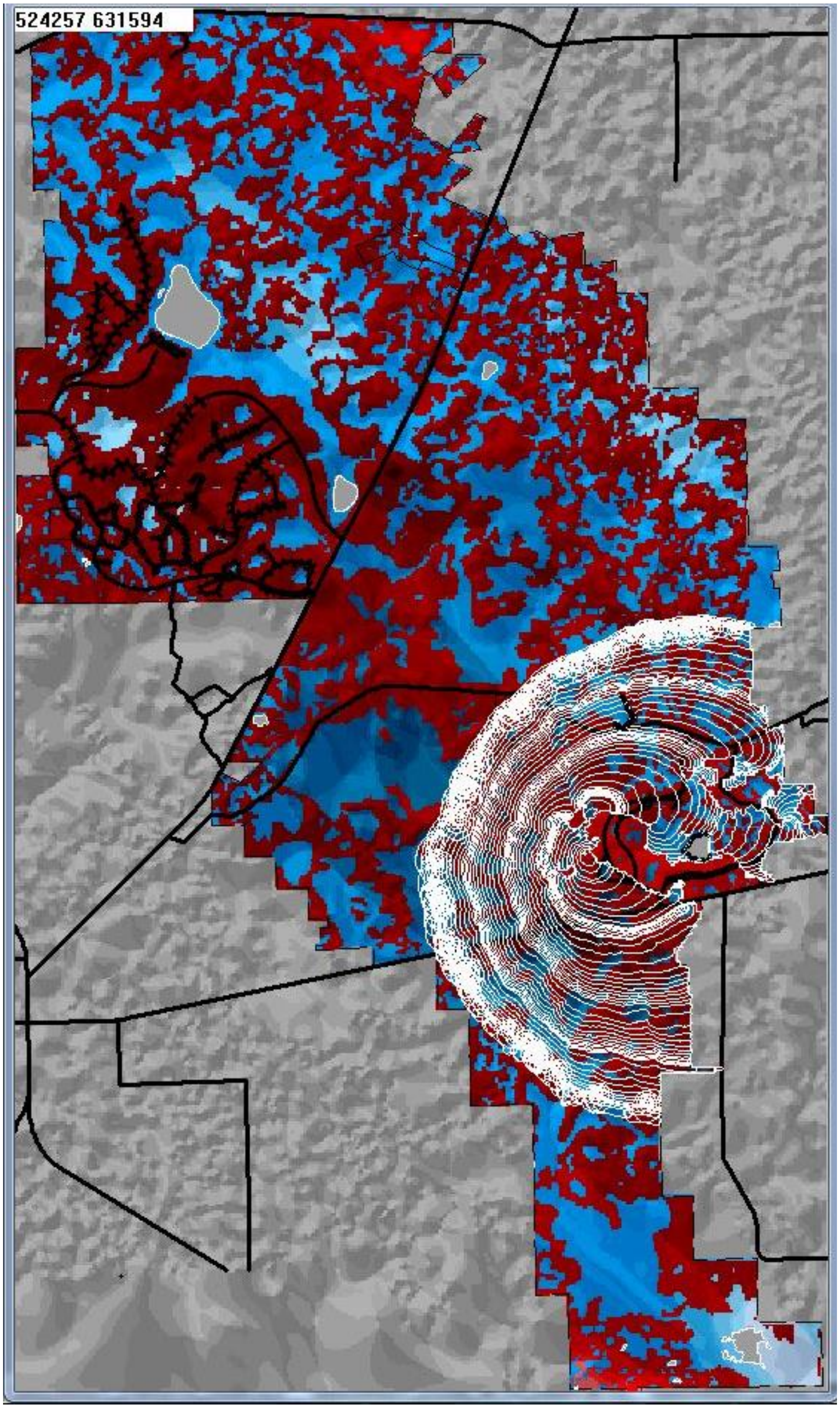


Figure 4-36. Group 3, High Fire Intensity 2. Program FARSITE displays each hour as a white band. The alternating color patterns are only color symbols reflecting a change in the fuel model.

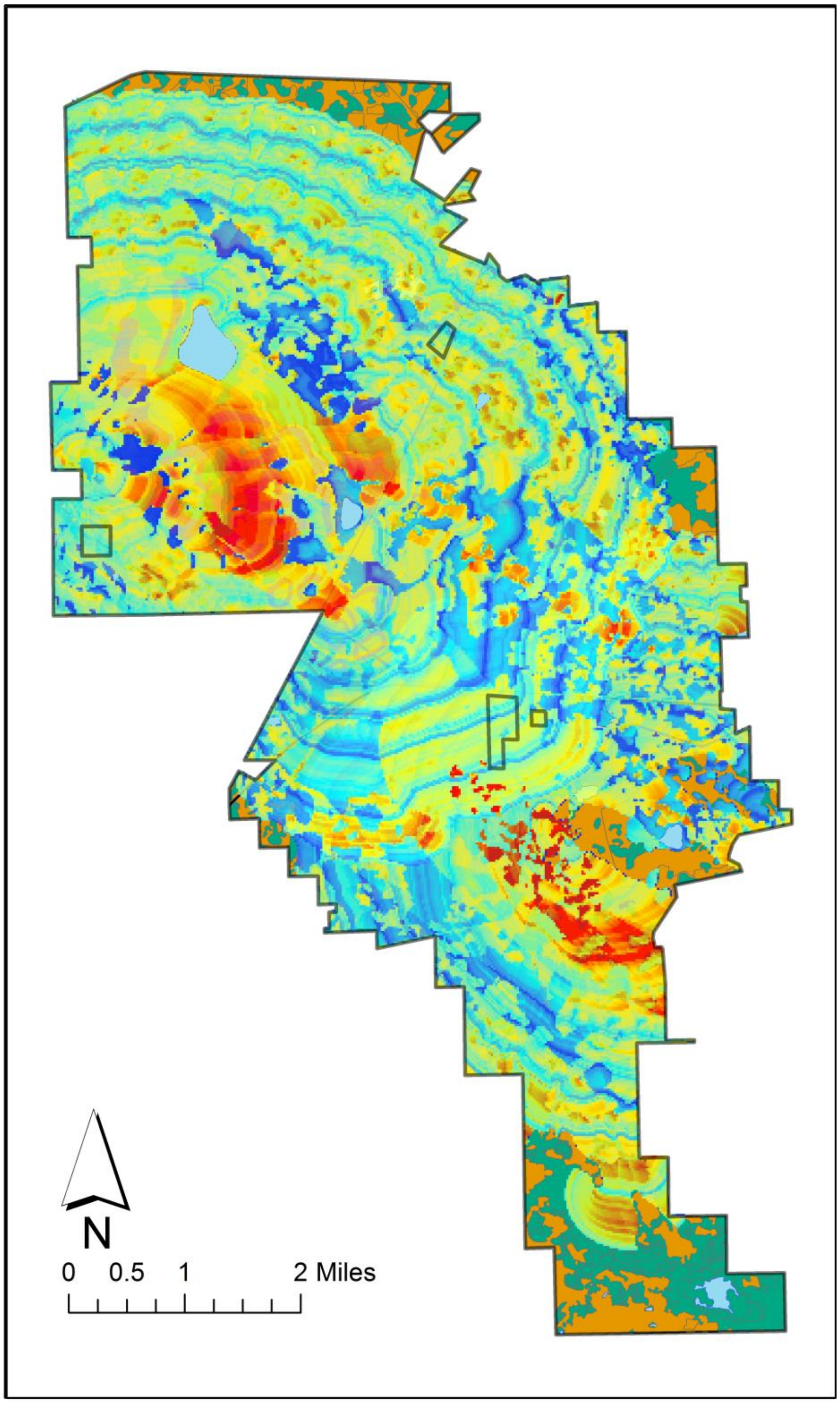


Figure 4-37. Group 1, Low Fire Intensity. Flame lengths are represented from low to high as blue to red.

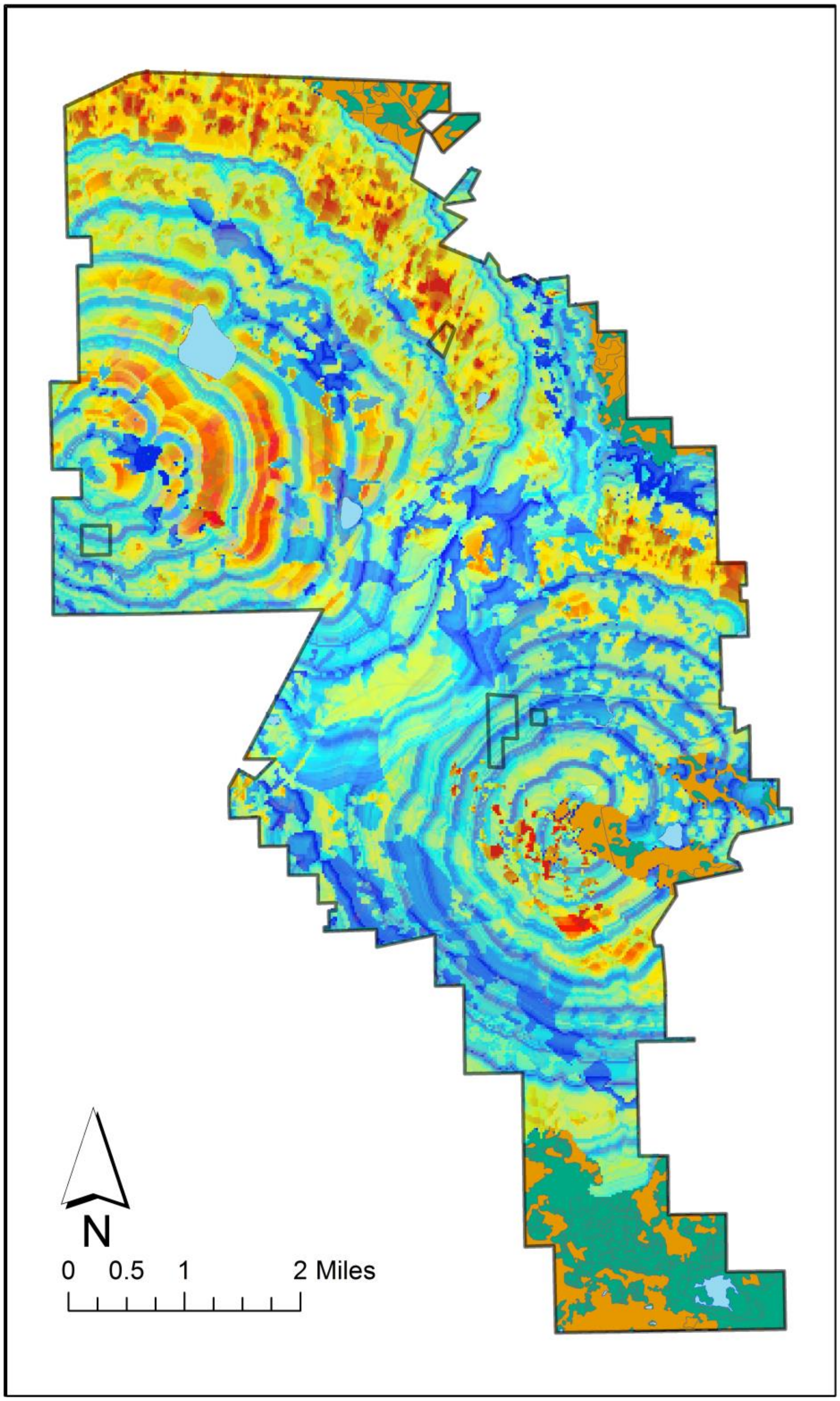


Figure 4-38. Group 1, Medium Fire Intensity. Flame lengths are represented from low to high as blue to red.

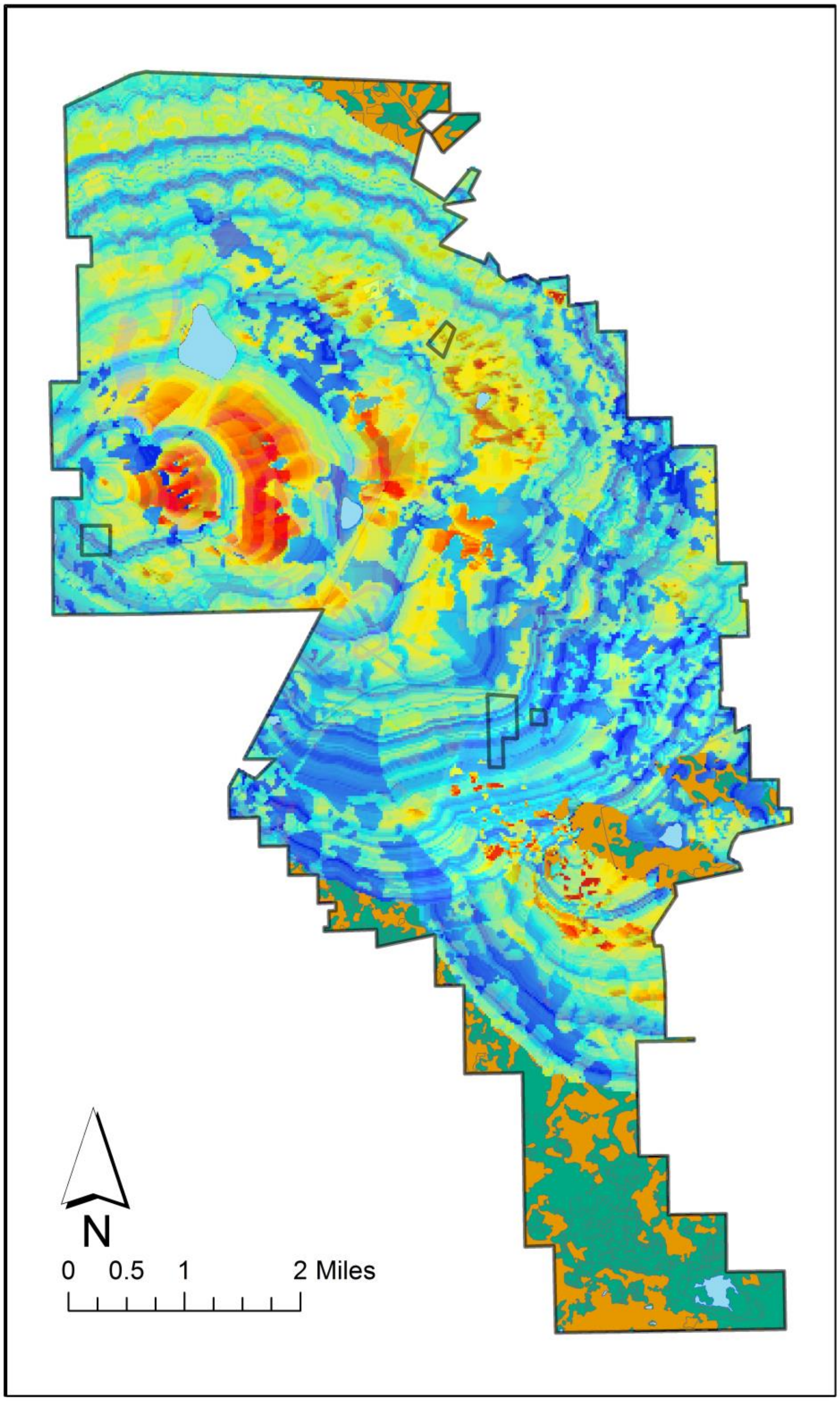


Figure 4-39. Group 1, High Fire Intensity. Flame lengths are represented from low to high as blue to red.

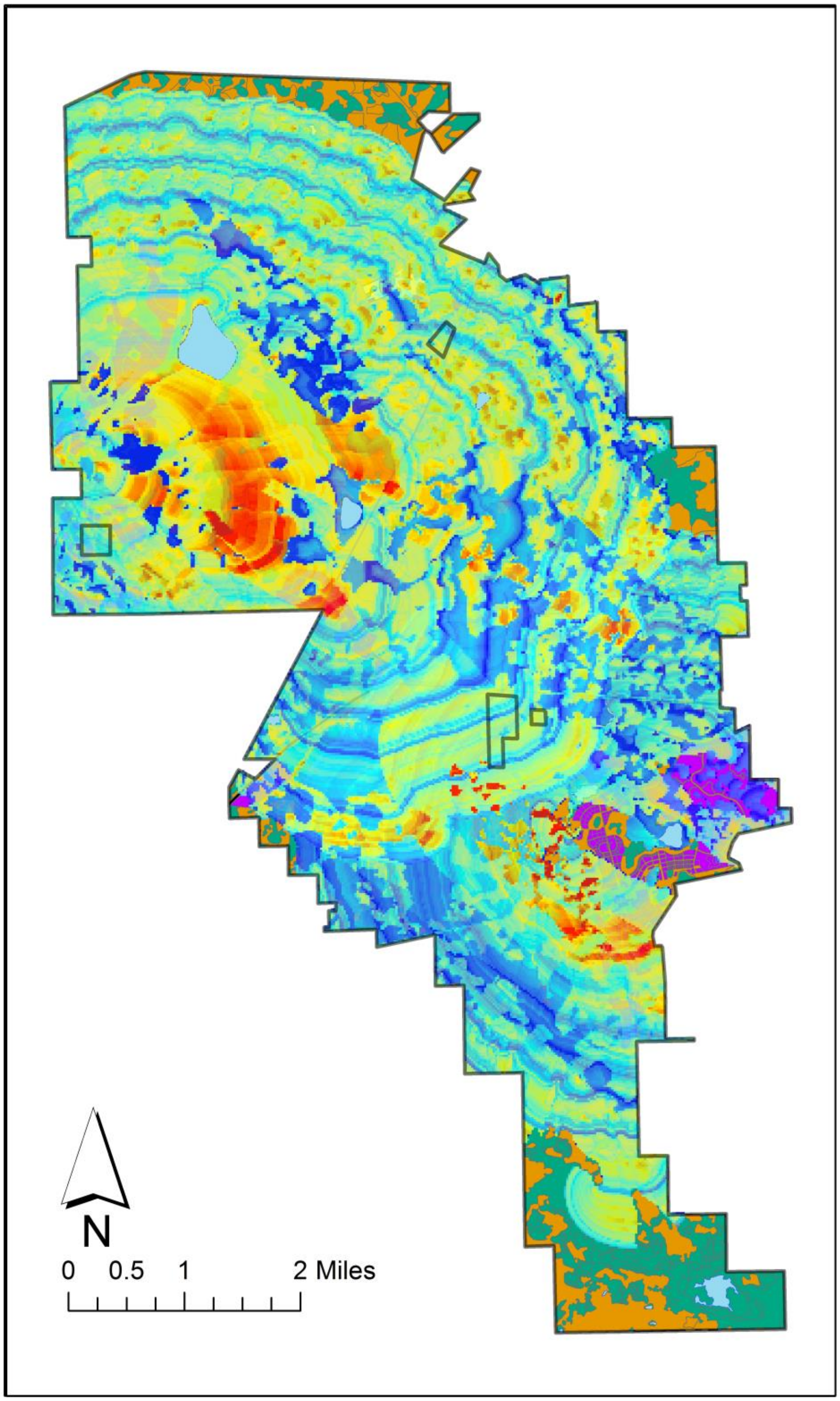


Figure 4-40. Group 2, Low Fire Intensity. Flame lengths are represented from low to high as blue to red.

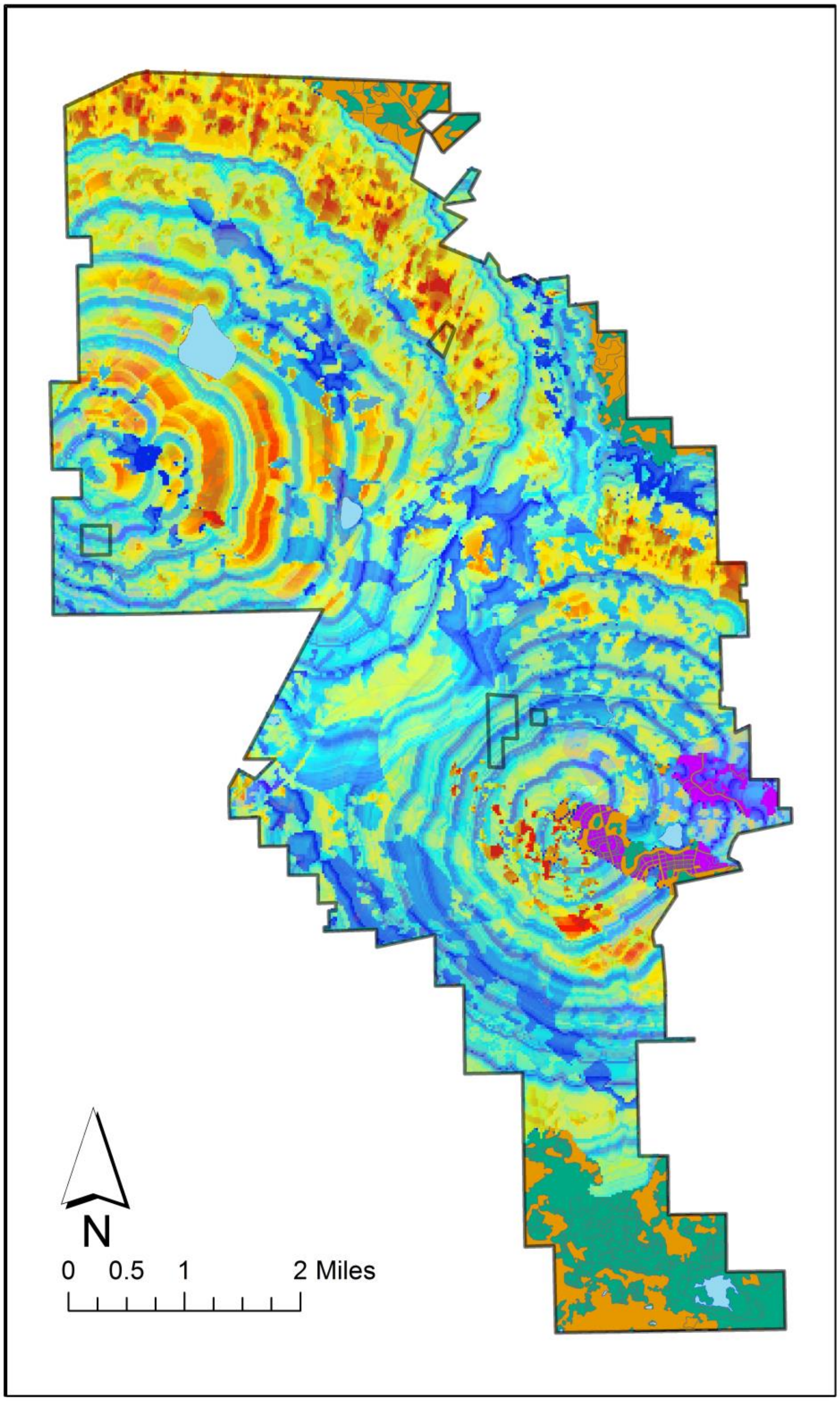


Figure 4-41. Group 2, Medium Fire Intensity. Flame lengths are represented from low to high as blue to red.

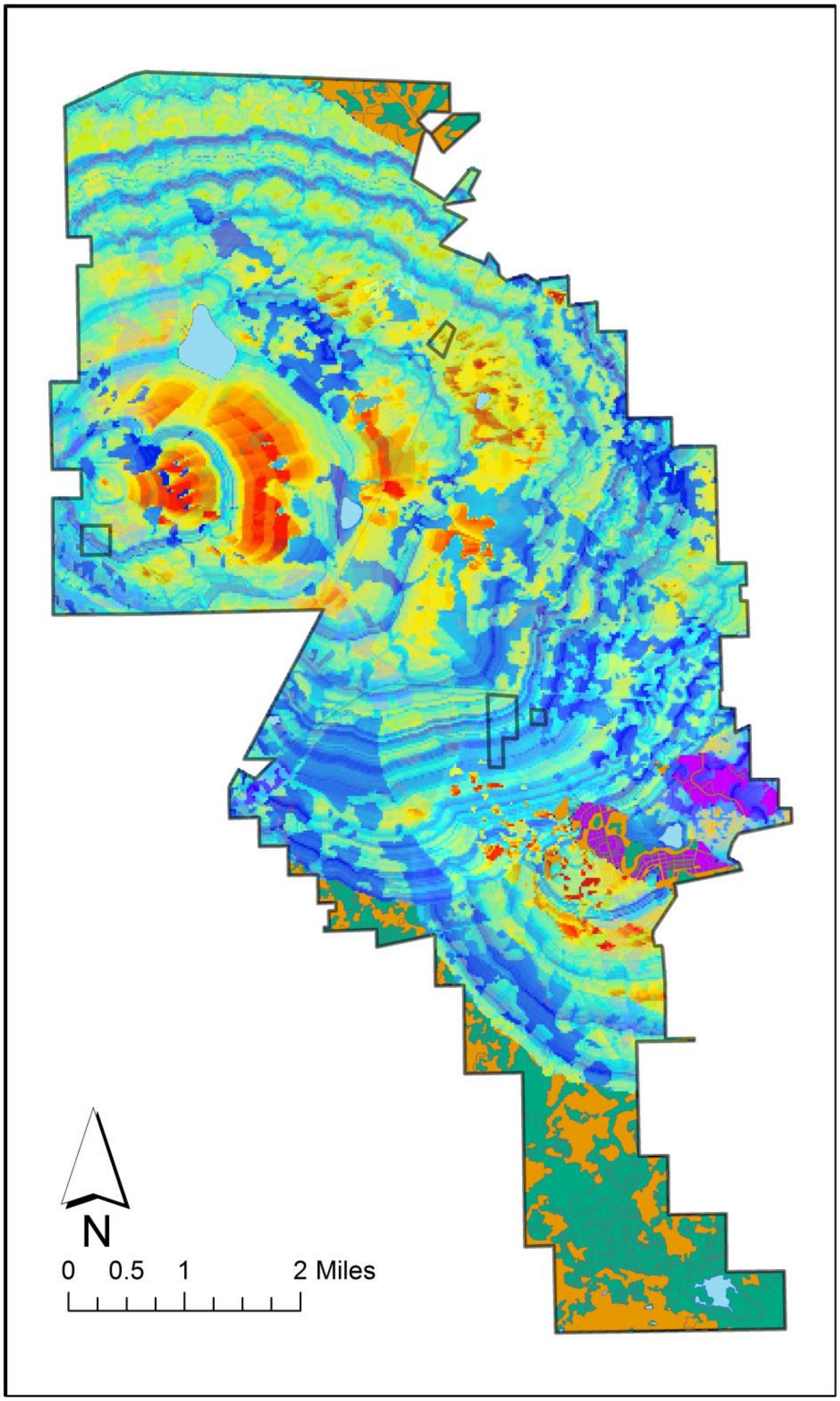


Figure 4-42. Group 2, High Fire Intensity. Flame lengths are represented from low to high as blue to red.

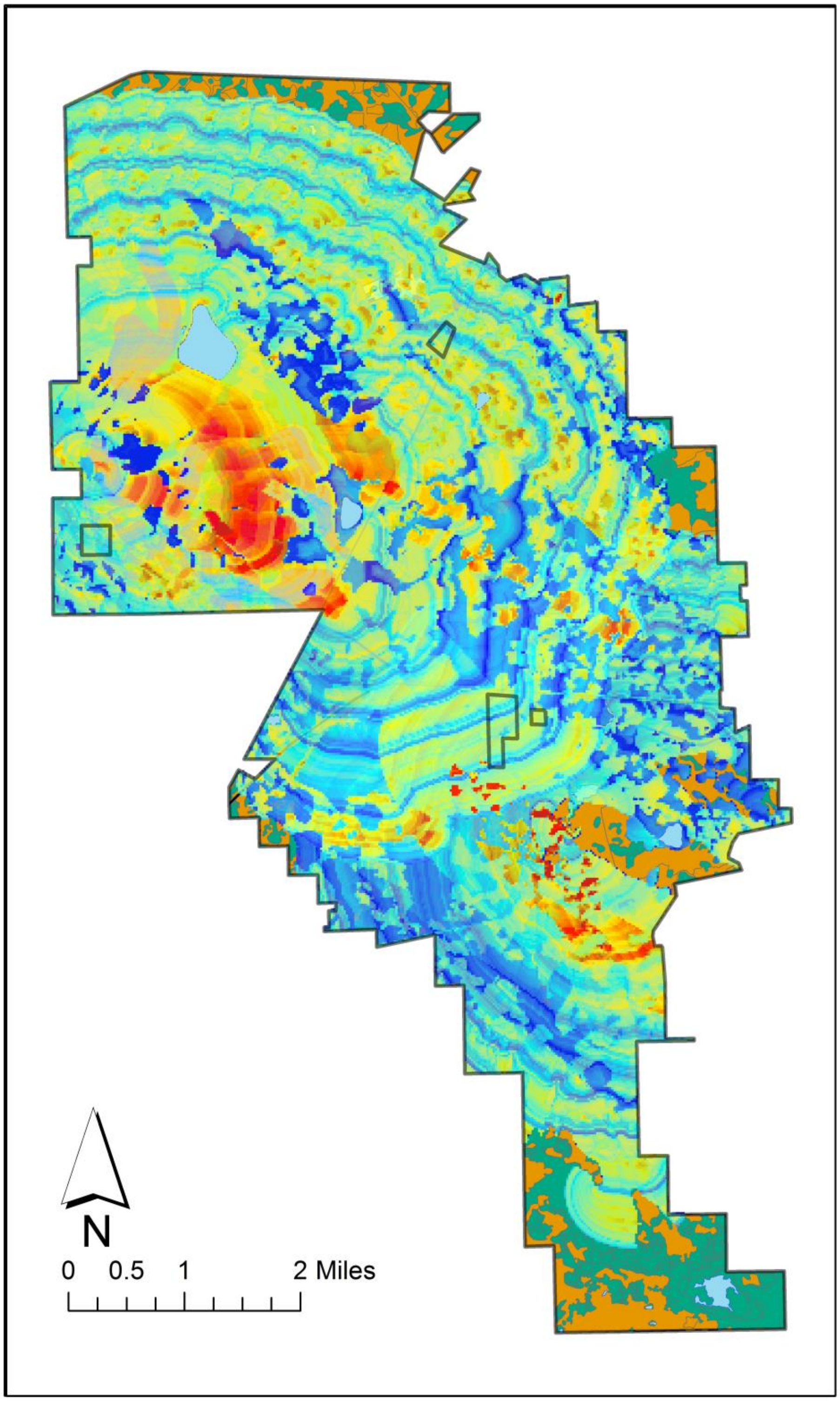


Figure 4-43. Group 3, Low Fire Intensity. Flame lengths are represented from low to high as blue to red.

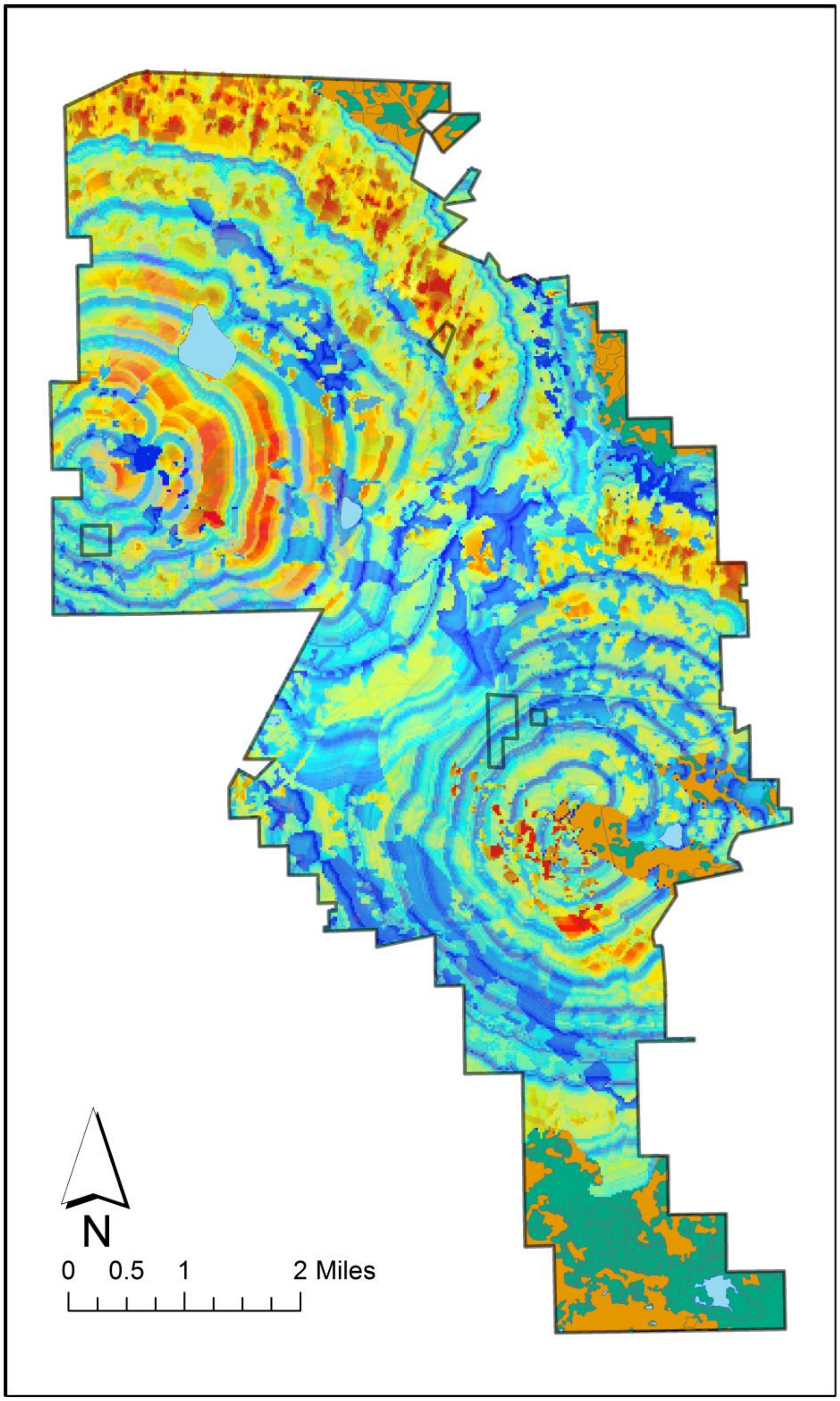


Figure 4-44. Group 3, Medium Fire Intensity. Flame lengths are represented from low to high as blue to red.

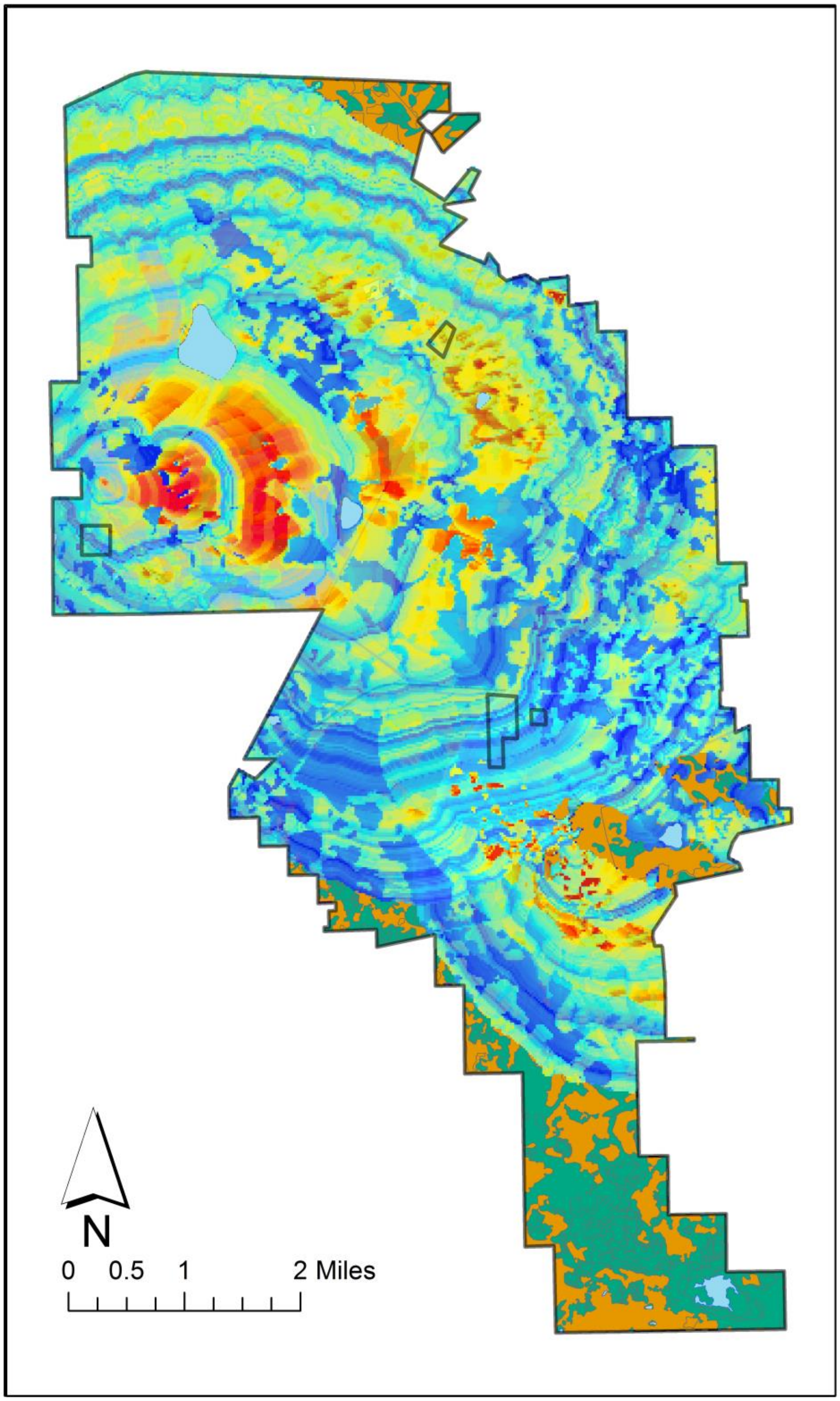


Figure 4-45. Group 3, High Fire Intensity. Flame lengths are represented from low to high as blue to red.

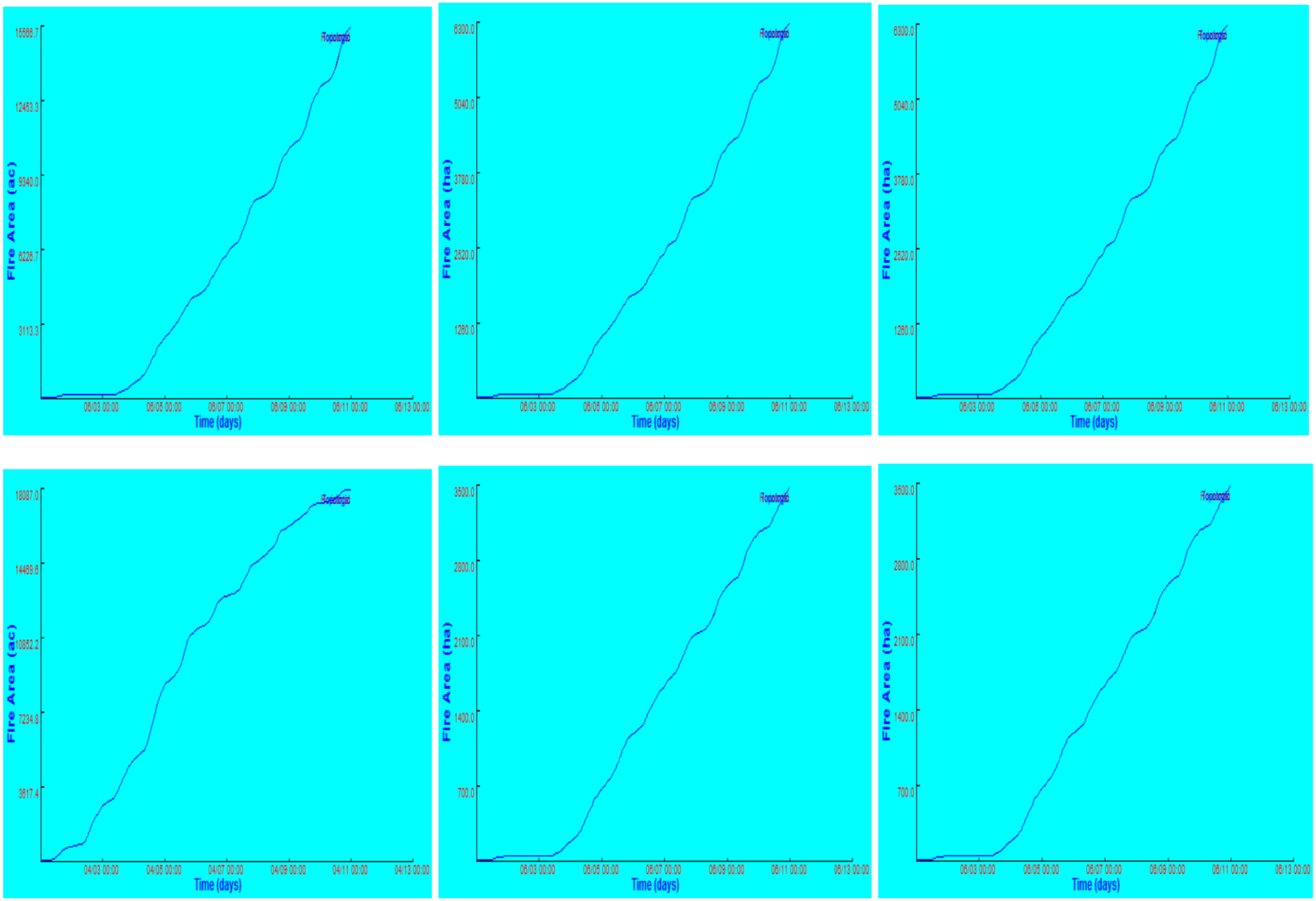


Figure 4-46. Spread Rate Comparison, Low Fire Intensity. Group 1, Group 2, Group 3 (Left to Right).

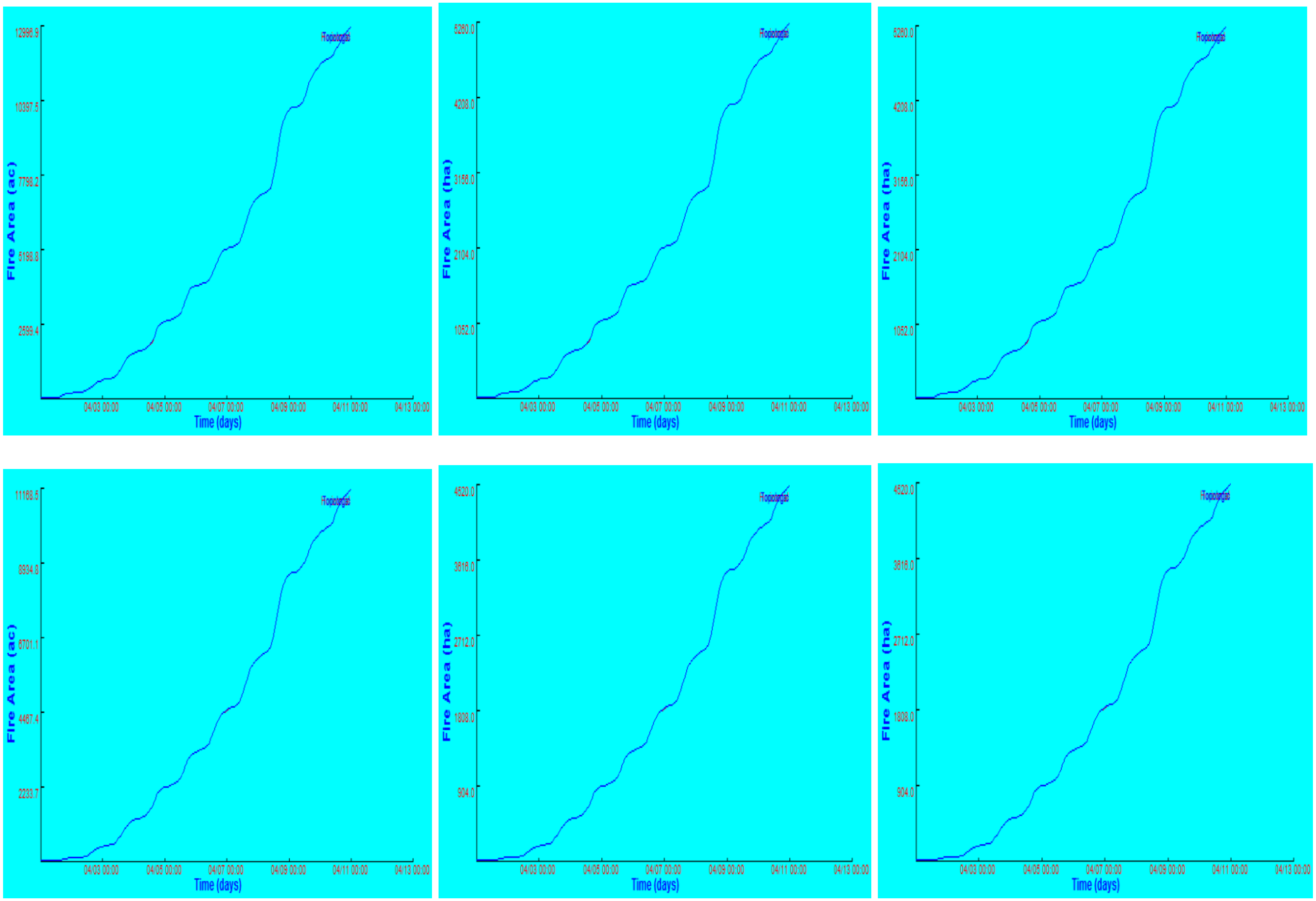


Figure 4-47. Spread Rate Comparison, Medium Fire Intensity. Group 1, Group 2, Group 3 (Left to Right).

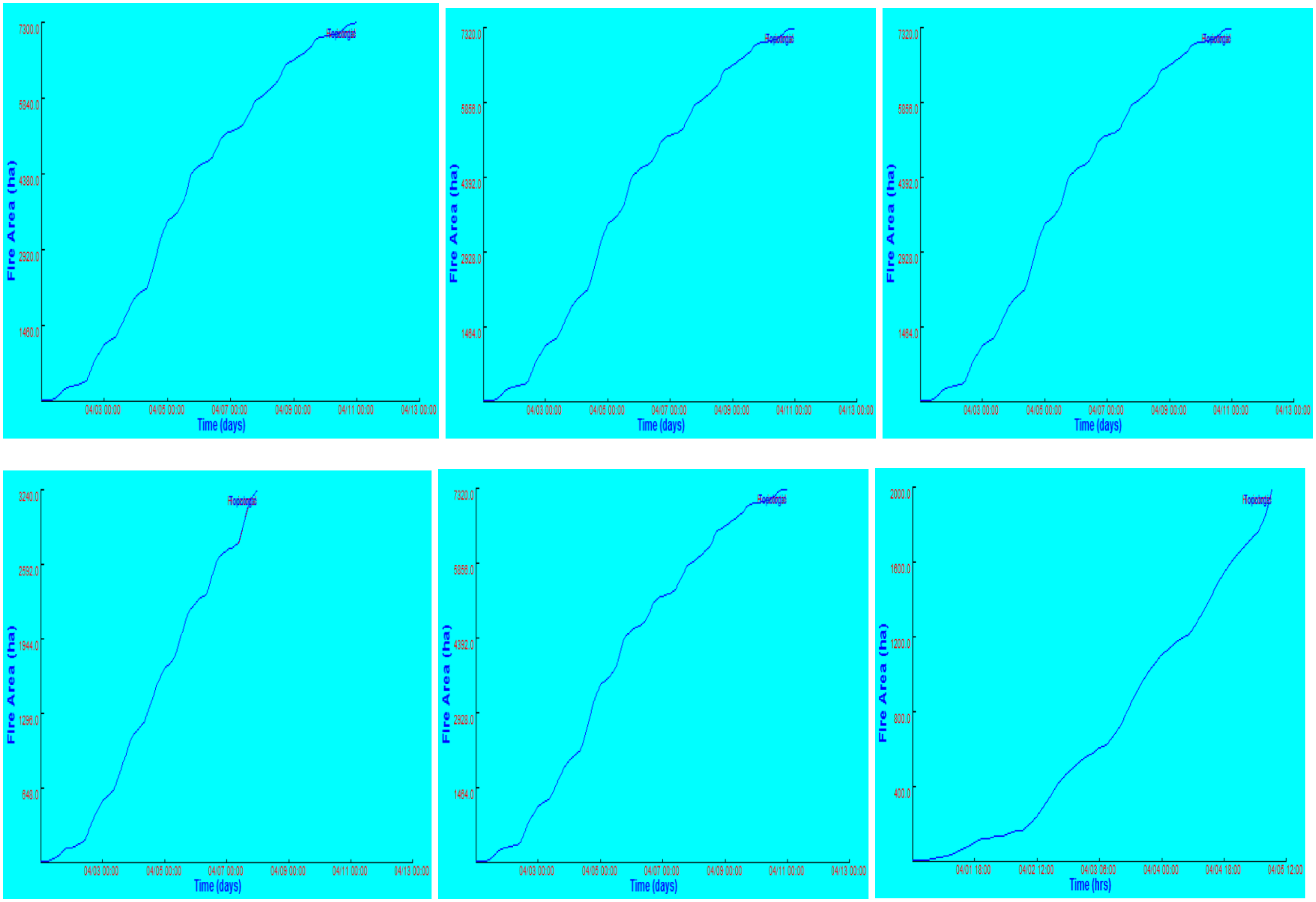


Figure 4-48. Spread Rate Comparison, High Fire Intensity. Group 1, Group 2, Group 3 (Left to Right).

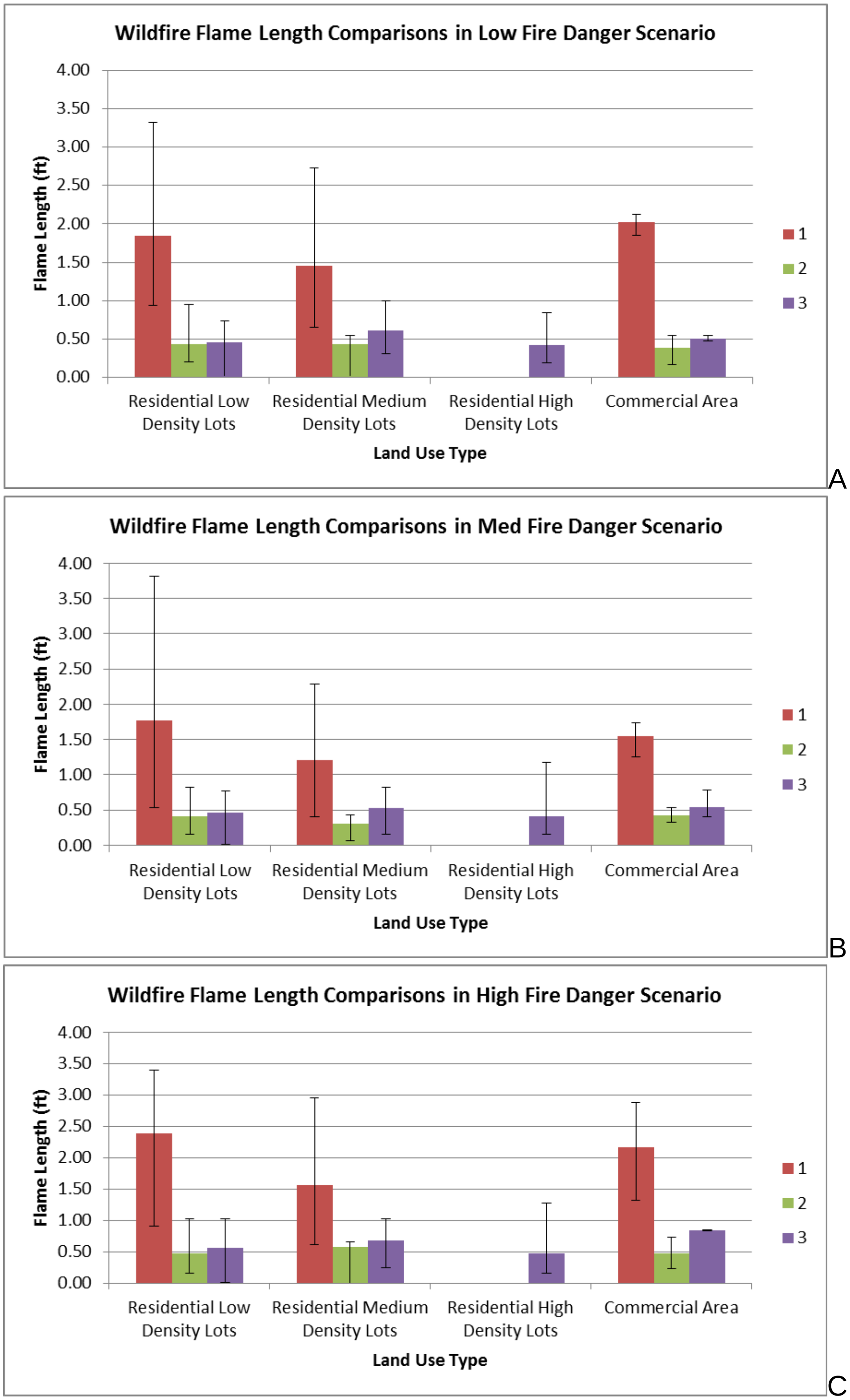


Figure 4-49. Bar graphs representing the average flame lengths of a surface wildfire. The flame lengths are presented per the land use classifications of the scenario development designs. A. The Low Fire Intensity scenario. B. The Medium Fire Intensity scenario. C. The High Fire Intensity scenario.

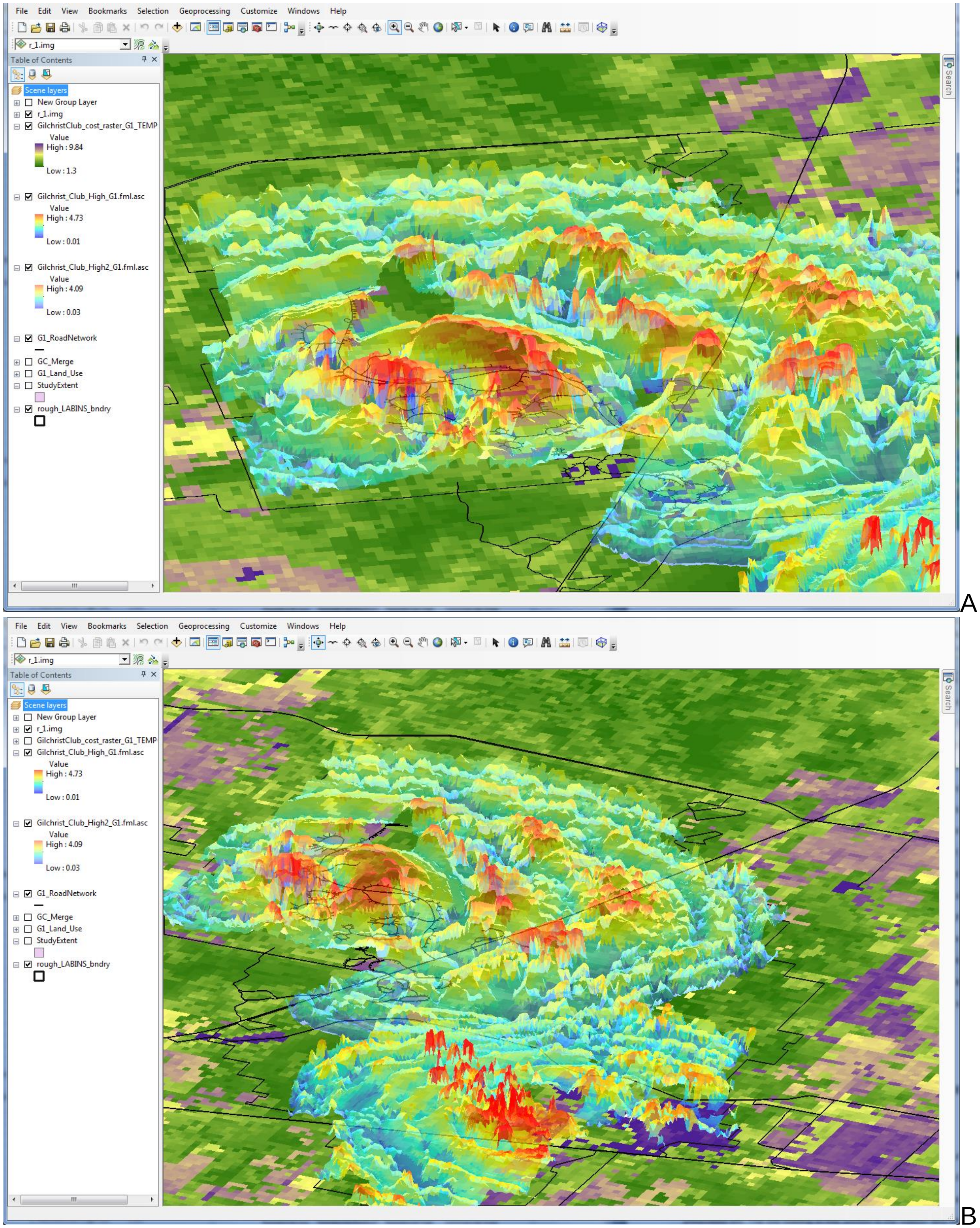


Figure 4-50. ArcScene screenshot of flame length displayed using a variable base height for the flame length surface. A. The Group 1 design and roadway network is visible in areas with the greatest flame lengths. B. The group 2 design and roadway network.

CHAPTER 5
DISCUSSION

Resiliency of Development, of Wildlife Movement, and of Fire-dependent Systems

Reiteration of Target Objectives

The initial claim of this research was that planners have little recognition of the upland side of the synergistic watershed and fireshed system when risk assessments for resiliency are performed in the development design phase. The research approach was to determine the scenario planning outcomes of a development project in Florida by first modeling ecologically significant ecosystem corridors, then designing developments, and then modeling wildland fire before physical construction occurs. The resulting outputs of the data analysis can now be evaluated for any new significance or practical application in the planning field. The two embedded units of analysis were intended to answer the following questions:

1. To compare proposed development designs by their impact on the facilitation of wildlife movement.
   i. What is the effect of the application of wildlife corridors modeling on development design during the pre-development, site synthesis phase?
   ii. What is the impact of development design on the facilitation of wildlife movement in regionally significant ecological corridors?
1. To rank proposed development designs from most to least resilient to wildfire.
   i. What is the effect of development design on fire behavior (flame length, area burned, burn duration, and spread rate) during a wildfire?
   ii. What characteristics of development design increase vulnerability to wildland fire in an ecologically significant corridor?
   iii. What lessons can be learned from fuel load estimates in ecologically significant areas adjacent to future development in the Wildland Urban Interface?

Development Design and Regional Wildlife Movement

The development design studio was clearly influenced by the LCP base model. *All three of the development designs integrated the concept of regional wildlife movement in the pre-development, site synthesis phase*. The original conditions of the studio set a target goal at 30% development and 70% conservation of the ~28,000 ac. property. The final three development designs maximized at less than 20% development and had more than 80% of land in conservation uses. The scenario of resilient regional wildlife movement is evident in the placement of developed land uses along the periphery of the property boundary in all designs.

Yet for pre-development site synthesis a simple LCP model did not wholly convey the concept of regional scale processes. The areas of blue-grey in Figure 4-1 A and B are areas that were identified by Groups 1 and 2 to be conserved space for wildlife. Groups 1 and 2 took the concept of a least cost path and determined that wildlife movement is flexible, and will adapt to land development in an ecological corridor. The value of this statement is expressed in the more technical LCC models. *The before and after least cost corridor models conveyed how design at the property scale effectively bottlenecks functional movement of large-ranging wildlife at the regional scale*. At the site scale roughly the same proportion of open space was provided by the Group 1 and 2 designs as was provided in Group 3. The authors believe that the practical reality of a bottleneck does not result in complete severing of regional wildlife movement. Instead the flexibility and adaptation of wildlife movement manifests in greater human-wildlife conflict. The small percentage of commercial and housing development toward the interior section of the property in Groups 1 and 2 increases the likelihood that Florida black bears will encounter built land uses and become earmarked as nuisances. Often, the outcome for nuisance bears in Florida is relocation or alternatively euthanization when the initial conflict in a greenfield development could have been resolved in development design. Similarly, the developed areas and roadway infrastructure create more susceptibility for vehicular collision with terrestrial wildlife. The outcome of modeling before and after LCC scenarios is that, yes, some open space intermixed into development designs is necessary to preserve environmental and ecological assets as well as produce economic incentives that make a development human habitat; a place and space that people want to live not just reside. However landscape process modeling of large ranging wildlife indicates that a balance of abundant space must be provided to preserve the value of land in ecological corridors as functional wildlife habitat.

Development Design and Landscape Level Wildfire Movement

To preface, this research provided little evidence that development design had any influence on flame length during a scenario wildfire. The lack of evidence can be explained by the fuel model inputs for wildfire simulation. The lake inputs distinctly carried no fire during the simulation. It was anticipated that the major road network inputs would result in alteration in fire behavior and reduction in spread rate. The width of existing county roads and additional roadway networks that would provide access to the development design components in each group were less than or equal to 30 ft. The wildfire simulations showed no inhibited behavior when reaching these additional fire break inputs. It is important to note that fuel model “99” can be used in wildfire simulation to classify developed land uses. However the purpose of this work was also to determine the flame lengths of the flaming front of a wildfire intersecting different development components, and so use of FM99 would have been counterintuitive.

Resiliency analysis of a development design to wildfire has multiple opportunistic outputs. *Outstanding, Group 2 is the most resilient development design to all wildfire scenarios.* The results section identified that resiliency was achieved in the Group 2 design because a substantial quantity of development was placed in a section of the SLP property with low fuel loading. Under a jurisprudence discipline this occurrence would be classified as a case of the "tipsy coachman" doctrine. The authors find it necessary to insert an excerpt the same way that the Supreme Court of Georgia quoted Oliver Goldsmith's poem, Retaliation, in its 1879 case (Lee v. Porter, 63 Ga. 345 (1879)):

> The pupil of impulse, it forc'd him along,
> His conduct still right, with his argument wrong;
> Still aiming at honour, yet fearing to roam,
> The coachman was tipsy, the chariot drove home…

In the case of resiliency planning, Group 2 reached the correct result based on the wrong reasoning (Herb and Kauffman 2007). Group 2's planning and design summaries note that the 2003 LANDSAT Enhanced Thematic Mapper satellite imagery was used to identify areas of bare or clear-cut soil, as well as open brushland (Conservation Design and Planning Studio 2012). The notes further state that the purpose of this method was to target areas with low cover and low ecosystem service value, and use these already cleared sites as an opportunity to improve the state of land through intense development (Conservation Design and Planning Studio 2012). This reasoning is flawed. The area of the property with low loading in fact coincides with 3,000 acres of quail fields, heavily managed by the Suwannee Lake Plantation to provide quality habitat for quail. The quail fields are managed to resemble an open pine savanna and prairie ecotype by means of an active fire management program. The fire management program includes an annual burn of all 3,000 acres. The Spring burn rotation promotes a greater diversity of animal and herbaceous species and habitat in this location than compared to the remainder of the property. A conservative estimate for the ecosystem service value of this type of private forest land is $1,615.00/ac./year –for pollination, habitat conservation, and aesthetic services alone– or a benefit transfer value of $4,845,000 USD/yr. for this 3,000 acre area (Moore 2011). Generalization of the LANDSAT imagery classified the area of low loading as open brushland. The concept of the ‘tipsy coachman’ is applicable here because the general classification further led Group 2 to assume these lands had a low ecosystem service value and were therefore most suitable for development. *A lesson learned from fuel load estimates in ecologically significant areas adjacent to future development in the WUI is that expansion of existing fire management programs before development occurs can lead to increased development resiliency and increased local biodiversity*.

Redundancy and Synergies

Redundancy. Taken together, a synthesis of wildlife corridor modeling and wildfire modeling conveys information that is perhaps not visibly understandable. Redundancy was included in this analysis for two reasons. The first is this research was intended to explore how effective scenario planning of fire-dependent ecosystems and landscape level processes can be during the development design phase. Redundancy using two embedded units of analysis gave the research its own resiliency, in case either unit of analysis failed to contribute to discernible differences between development design scenarios. The second is redundancy allowed the researchers to identify cross scale interactors or even cross method interactors, in case the units of analysis collectively construct a new implication for practical application in the field of environmental planning.

Synergies of Wildlife Continuity and Wildfire Continuity. The success of merging the modeling techniques is dependent on the basic model inputs. Similarities between the least cost corridor cost raster and the custom fuel model raster allow for both modeling techniques to be overlapped to examine cross model interactors and reinforce the issue of landscape level processes and development. Preliminary results for Group 1 suggest *low fuel loading is a characteristic analogous to fuel continuity and wildlife continuity, and decreases vulnerability of development to wildfire in Florida's ecologically significant greenway corridors.* However, this analysis cannot be completed with the information gathered in this research. The entire corridor of the Waccassassa Flats cannot be merged with the partial coverage of the wildfires. To perform this analysis expanded estimates on fuel loading and canopy cover are required.

Limitations

The first limitation of this research originated as a result of the Fall 2012 design studio. The studio allowed each group to foster innovative approaches to planning and design that could balance development values with a strong stewardship ethic (Conservation Design and Planning Studio 2012). An unintended consequence of the flexibility of the studio was each group did not necessarily need to create mixed use areas, artist village lots, conservation subdivision lots, urban parks, eco resort areas, or institutional areas. The flexibility caused an issue with the second unit of analysis, development resiliency to a surface wildfire hazard. During data processing resiliency of a development design to wildfire was only comparable in 4 of 14 final development components. Auspiciously, compared to other infrastructure investments the development components that were able to be analyzed are those that are most frequently at the focal point of wildfire mitigation planning; i.e. commercial areas, low density, medium density, and high density residential areas.

A second limitation to the research process was the timeframe of the thesis research design. The fuel load data collection did not occur until Summer of 2013. For this reason there was no opportunity to directly demonstrate wildfire movement in the Waccasassa Flats to the Fall 2012 planning studio before the development design phase began. In a two year graduate program small timeline limitations are bound to befall the research design. The negative side to this limitation is the studio groups had limited to no exposure to how fuel loads in the landscape can create hazards for greenfield development in the WUI. The beneficial outcome is this limitation also acted as a control for each development design group. If the researchers disclosed the locations of low, medium, and high fuel loading the development designs could have been biased. Instead this research was able to conclude with validation that a knowledge gap exists for development in fire-dependent ecosystems. Circumstantially, a recommendation for future research with development in fire-dependent ecosystems is to have each design group perform scenario exercises where the groups are instructed to adjust fuel load models and in real-time see the effects that different fuel loads have on the severity of wildfires.

A third limitation is a compounded result of the previous timeframe issue. Data collection in Summer of 2012 would have created extremely different fuel load estimates than those collected in Summer of 2013. In addition to seasonal wet and dry seasons, Florida experiences decadal drought and sequences of abundant water. Half way through data collection in the Summer of 2013 Florida had an above normal deposit of rain. Many of the wetland and upland data collection points that could have been measured successfully were instead inundated with water. A sufficient amount of data collection points were collected to meet the needs of statistical significance (>30), but more points would have led to more accurate fuel load models and potentially a larger quantity of custom fuel load models. Additionally, the restricted time frame limited modeling to only surface wildfire movement. If qualitative and quantitative canopy data were collected, simulations of canopy fires could have also been modeled. Once more, this limitation is often inevitable in field data collection in a two year graduate program.

The final limitation is a result of redundancy analysis. This research focused on the regional movement of *U. americanus floridanus* and landscape level interaction with a large scale development. The Florida black bear is known to forage in recently burned patches, but areas frequently burned may not always be good or ideal bear habitat. Particularly, insufficient forest cover information creates an issue with hypothesizing that low fuel loading has a relationship to low cost to traversal for a large ranging species like the Florida black bear. A suggestion for future research is to use a suite of species in addition to *U. americanus floridanus* to concentrate corridor analysis down to smaller scales within the landscape that are maintained by fire for habitat. Supplementary scenario planning investigation into connectivity of wildlife movement in low intensity fuel types would complement the previous conclusion of this work; which suggested that expansion of a fire management program before development begins could dually serve to increase wildfire resiliency and promote habitat that harbors fire adapted species. To offer an example, potentially fox squirrels (*Sciurus niger*) could be used to model site or local scale connectivity against assumptions of fuels based on various scenarios of fuel loading.

Conclusion

Outcome 1

This research project shows the response of regional scale wildlife movement within an ecologically significant corridor to the pattern of development design. The research also shows that as the geospatial location of land use type changes, the relative importance value of land as wildlife habitat shifts. What does this mean? In the Waccasassa Flats the shift from the before corridor scenario to the after corridor scenario concentrates the importance of lands in the interior portion of the property. This provides evidence that planners and architects can work with developers at regional and local levels to minimize the impact of development on landscape level processes. In Florida, growth pressure will continue to encroach new development into ecologically significant lands. Since planners have the resources to identify development before the construction phase, planners can use capacity building and community education to inform the operation managers of adjacent public and private open space. In this case, information transfer can shift the expenditure of resources and funds to protect potentially newly important land in the interior of the County.

Outcome 2

The methodology used to address this research topic is multifaceted and has a high level of complexity. To integrate the two units of analysis required the work of regional and local geospatial data sources, as well as four different analytical software programs. ArcGIS played an important role as a platform to operate between the four programs. Modelbuilder in ArcGIS allowed the researchers to create individual Tools for each step. Albeit a considerable amount of time was expended operationalizing the Tools and creating each input, once the Tools were created and collected into a single Toolbox the researchers were able to replicate the method at a much faster rate. Now that a Toolbox exists for analyzing landscape processes in fire-dependent systems the next step in the research is to explore the transferability of the method to other developments of regional impact in the wildland urban interface.

Recommendations for Planning Improvement in Interior Counties

The first recommendation for planners in interior counties is to rely on <u>both</u> regional wildlife movement modeling and wildfire modeling before developing designs. If planners and designers cannot rationalize the impact of development on long-term functional connectivity than their ability to see greenfield development in the context of regional processes will be inhibited. Both modeling techniques require a particular level of scientific knowledge to successfully illustrate the accurate details of landscape process data. But as mapping technologies improve this simple type of mapping interface will become a reliable method to transfer knowledge. Development has become a joint venture requiring public and private partnership. This research justifies that interior counties and developers literally cannot afford to subject development to the damages of catastrophic wildfire.

Equally, community risk assessment and mitigation plans in interior counties cannot afford to be responsive after greenfield development occurs. Budgetary constraints and insufficient partnership between regional, state, and local planners and private developers continue to be cited as reasons for why wildfire assessments are not implemented. Indisputably community Wildfire Protection Plans and Firewise Communities Recognition Programs are invaluable options for communities. The impact of pro-active scenario planning for wildfires fits the informative gap in wildfire protection and identifies the regional impact that development in the WUI has on fire-dependent ecological systems, not just the impact the fire has on development.

The last recommendation to improve planning in interior counties is to correct the maldistribution of development design above and below the 100-year floodplain. To reiterate from Chapter 2, at the State level in Florida there is a 3:1 ratio of Community Resiliency Initiatives between watershed planning and fireshed planning, and fire is only regarded in one of four section in the Hazard Mitigation Planning Initiative. Interior counties which host environmentally sensitive, fire-adapted ecosystems face the challenge of balancing watersheds and firesheds with human population growth in the wildland urban interface. Given the cost efficiencies of computer modeling, it is becoming more and more opportunistic to scenario plan the resiliency of development designs to wildfire at a fraction of the cost that the impact of wildfires would have on developments and human security.

APPENDIX A
LEAST-COST CORRIDOR METHODOLOGY

In ArcGIS 10.1, the Geoprocessing environment is first set. A Study Extent shapefile will be created using the Select feature to select the counties surrounding Gilchrist County from the county boundary shapefile from FGDL. A split function will be used to constrain the area within counties that are west of I-75, and the final Study Extent is be exported as a shapefile. The Environment Geoprocessing Dialog will be accessed from the Geoprocessing tab to input the following settings:

- The extent is set to Study Extent.
- The Raster Analysis is set to a 10 x 10 m cell size.
- The Mask is set to Study Extent.

The LCC is created using the ModelBuilder window. In ArcGIS 10.1, The LCC is created using the ModelBuilder window. To prepare all inputs for use in the Raster Calculator all features are added, transformed to match projection and resolution, and reclassified as habitat factor raster data on a 1-10 scale.

The first required input feature is land cover data. The Gilchrist County Land Use shapefile is transformed into a raster dataset using the Polygon to Raster tool. Cover types are reclassified. Proximity to lands already managed by the State of Florida (FLMA) is included in this input. Euclidean Distance to the shapefile, FLMA, will be used to create a raster classification.

The next input is Topography. A Topography dataset for Gilchrist County is imported from the FGDL. The Topography dataset is the latest USGS digitization of quadrangle maps using five foot contour elevations (FGDL 2011). Topography for Gilchrist County is transformed using the Slope tool found in the Spatial Analyst toolbox under Surface. Due to the low topographic change in the Study Extent, an exponential classification is used to reclassify this input.

The next input is Elevation. Here, low variation in elevation change will create problems distinguishing permanent water bodies from seasonally inundated wetlands. Elevation within the Study extent will be substituted for water bodies. Euclidean distance to water bodies is used to convert the shapefile information into raster. An exponential classification is used again to reclassify this input.

The last input is Road Density. Using the USGS digital line graph for the State of Florida, major roadways are clipped to the extent of Gilchrist County. Next, the major roadways shapefile is processed to remove trails and other low impact road classes. The density of remaining roadways is determined using the Line Density tool from the Density section of the Spatial Analyst toolbox. The area units will be specified to square meters.

After all of the habitat factor input rasters are reclassified, the Raster Calculator tool is added to ModelBuilder to build a single Map Algebra expression. The expression uses mean factor weights (%) to synthesize and attribute a value for each cell in the new cost raster (ESRI 2011). The expression uses the following python sintax -
("%flma_raster%" * 0.02) + ("%euc_dis_rds_raster %" * 0.15) +
("%dist_water_raster_%" * 0.02) + ("%reclassify_slope%" * 0.13) +
("%Internal_parcel_raster%" * 0.68)
- where Distance to FLMA is weighted 2%, Distance to Water Bodies is 2%, Euclidean Distance to roads is weighted 15%, Topography is weighted 13%, and Land Cover per parcel is weighted 68%.

Next, the Cost Distance tool calculates the lowest accumulative cost resistance from the top of the FEGN network entering the Northern end of the Waccasassa Flats and from the Southern end of the FEGN network entering the Waccasassa Flats. Finally, a cost corridor is determined between the Northern and Sothern blocks of the FEGN. The final corridor is converted using the Slice tool to keep only the top 3% of the least-resistance corridor for comparison between the before development scenario and the after development scenarios.

After. When the three development designs are finalized, adjustments are made to the Land Cover and Euclidean Distance to roads inputs to reflect changes in land use. For Land Cover, the dataset for each development design contains a GX_LandUse shapefile, where the groups are numbered G1, G2, and G3. The table for GX_LandUse contains the fields FID, Shape, and LU_Type. The LU_Type field contains a simplified land cover classification name that requires conversion in order for it to be reclassified. A table is created in Microsoft Excel with one column labeled, 'LU_Type,' and one column identifying the appropriate land use description from the Land Use Gilchrist County shapefile, 'DESCRIPT.' A relate is added to the GX_LandUse layer identifying the new description, DESCRIPT. Next, the Update tool from the Data Management Toolbox combines the Land Use Gilchrist County shapefile with the GX_LandUse shapefile. After this process is completed for each group the new land cover datasets are reclassified using the same scalar template as the before model.

For the after development Euclidean Distance to roads input, the dataset for each development design contains a GX_RoadNetwork shapefile that must be reconfigured. The Clip tool is used to constrain the road network to the Study Extent.

Then, the Merge tool is used to combine the new road network with the already processed roadway shapefile (the road shapefile that already has trails and other low impact road classes removed). The density of the remaining new roadways is determined for each group design using the Euclidean Distance tool from the Distance section of the Spatial Analyst toolbox. The area units are specified to square meters.

For the after development Euclidean Distance to roads input, the dataset for each development design contains a GX_RoadNetwork shapefile that must be reconfigured. The Clip tool is used to constrain the road network to the Study Extent. Then, the Merge tool is used to combine the new road network with the already processed roadway shapefile (the road shapefile that already has trails and other low impact road classes removed). The density of the remaining new roadways is determined for each group design using the Euclidean Distance tool from the Distance section of the Spatial Analyst toolbox. The area units are specified to square meters.

APPENDIX B
SURFACE WILDFIRE MODELING METHODOLOGY

Elevation, Slope, Aspect. To begin the analysis, a Wildfire Vulnerability toolbox is created in ArcGIS 10.1. The first tool to be created in the toolbox uses an input Topography dataset to streamline the production of each of the Elevation, Slope, and Aspect input requirements into one step. In ModelBuilder, the input file is the Topography dataset for Gilchrist County. First, the contour data (in feet) is transformed using the Polyline to Raster tool from the Conversion Toolbox. Then, the Elevation raster is transformed using the Raster to ACII tool from the Conversion Toolbox. The output is the ASCII input of Elevation (in meters) for the .FPJ file in Program FARSITE 4. Next, the Topography for Gilchrist County dataset is transformed using the Slope tool found in the Spatial Analyst toolbox under Surface tools. Next, the Slope raster is transformed using the Raster to ASCII tool from the Conversion toolbox. The output is the ASCII input of Slope (in degrees) for the .FPJ file in Program FARSITE 4. Last, the Topography for Gilchrist County dataset is transformed again using the Slope tool found in Spatial Analyst toolbox under Surface. The slope raster is then transformed using the Aspect tool, another tool found in the Surface tab. The output is the ASCII input of Aspect (in degrees and cardinal direction) for the .FPJ file in Program FARSITE 4. This tool is then saved into the Wildfire Vulnerability toolbox for future use.

Field Data Collection. The final required input (Fuel Model) and the optional inputs (Duff Loading and Course Woody Debris) for Program FARSITE is based on field data collected on the SLP property in 2013. First, a new tool in ModelBuilder was created for random point generation. The ~28,000 acre SLP property was classified into uplands and wetlands. The FEMA 100 year flood-zone is used to delineate Suwanee

River Water Management District land uses for Gilchrist County as uplands or wetlands. 100 random points were stratified between the two classes at 50 points per class. Using ArcGIS 10.1, an Average Nearest Neighbor cluster analysis was performed on each class individually, as well as aggregated together. The purpose of the cluster analysis was to determine if any portion of the property was underrepresented and likewise to avoid oversampling. XY Coordinates were attributed to each of the random points. Data frame properties were adjusted so that the X and Y fields could be entered into the Calculate Geometry tool to be converted into UTM points.

At the SLP property, the PI and undergraduate volunteers from the University of Florida drove and hiked to each point. The Brown's Planar Intercept method is used for data collection. Three transects are taken at azimuth (compass-based) directions separated by a minimum of 60 cardinal degrees. At each point, a center stake is driven into the ground. For each of the three transects, high visibility open reel fiberglass tape is used to measure 60 feet in the given cardinal direction from the center point. All data is collected on the Data Collection Tool. Up to the first 6 ft. counts of 1, 10, 100, and 1000 hour fuels are tallied. At 6 ft. the litter depth and the duff depth are recorded in inches. Up to 10 ft. only counts of 100 and 1000 hour fuels are tallied. At 10 ft. a meter stick are used to plot a square meter on the ground. Percentages of cover are recorded for Live Herbaceous, Dead Herbaceous, Live Shrub, and Dead Shrub within the square meter. The heights of Herbaceous and Shrub cover are recorded at 10 ft as well. Up to 15 ft. counts of 100 and 1000 hour fuels are tallied. At 15 ft a second recording of litter depth and duff depth are recorded. At 30 ft. Herbaceous and Shrub measurements are recorded again. From 15-60 ft only 1000 hour fuels are recorded. For each point, a GPS tagged photo was taken. Lastly, if any GPS point was inundated with water it was marked as indeterminate and no measurements were taken. Field data was lastly transferred into ArcGIS. The Relate feature in ArcGIS was used to add to each point a table of the average measurements from the three transects.

Fuel Model, Duff Loading, and Coarse Woody Debris. Variables recorded in the field are used to create three different spatial surfaces as inputs for program FARSITE 4. The first input to process was a Custom Fuel Model for the SLP property. The Custom Fuel Model is a raster coverage of numeric values used to predict surface fire spread. The Custom Fuel Model surface uses the herbaceous and shrub percentages and height estimates at each point as spatial references. The Geostatistical Analyst tool in ArcGIS was used to separately create an Inverse Distance Weighted (IDW) spatial surface for uplands and wetlands. Inferences were made from the general statistics window, and commentary in the Results section will provide logical flow to describe the decision process for determining each surface model. After the statistically appropriate surface model is created, the Merge tool is used to create the final Custom Fuel Model surface raster of the entire site. The raster file contains one integer number of a fuel model for each 30 x 30m cell. The raster was then transformed using the Raster to ASCII tool in Conversion tools.

The two remaining inputs are Duff Loading and Coarse Woody Debris. For the Duff Loading input, the litter depth (in.) and the duff depth (in.) measurements for each point are used in Geostatistical Analyst to process an ASCII spatial surface. The same method for creating the Custom Fuel Model surface is used. The final ASCII file is a unit (tons/acre) for each 30 x 30m cell. For Coarse Woody Debris the same process for creating the Custom Fuel Model surface is used to create an ASCII spatial surface. This time, the measurements of 1, 10, and 100 hour fuels for each point are used in Geostatistical Analyst. The final ASCII file is a unit (tons/acre) for each 30 x 30m cell.

Weather and Wind Files. The program, FireFamilyPlus, is used to export the .WTR and .WND files into program FARSITE 4. Historical fire weather data corresponding to the Study Extent were downloaded from the Western Regional Climate Center (WRCC). The most appropriate weather station, ID 083001, is located within the study extent at the Lower Suwanee National Wildlife Refuge. From Station 083001 records are available from October 2003 to September 2013. After correcting for erroneous records, FireFamilyPlus categorizes and divides historical weather patterns into three categories of fire weather; low, medium, and high fire intensity. An hourly data analysis is performed to generate an hourly list from which to incorporate into program FARSITE for a wildfire simulation. The FARSITE Exports Dialog box is used to generate the two FARSITE data files, .WTR (WTR for FARSITE Version 4) and .WND.

Program FARSITE 4. With all of the data layers synthesized and in the appropriate format, the PI imported the data into Program FARSITE 4. First, the LCP file was generated. The Elevation ASCII, Slope ASCII, Aspect ASCII, Fuel Model ASCII, Duff Loading ASCII, and Course Woody Debris ASCII were uploaded. All other variables in the LCP Generation window are left unchecked. In the FARSITE Project window, the LCP file that was just created is uploaded. In this window the .WTR and .WND files from FireFamilyPlus are also uploaded. Next, the ‘Attached Vector Files’ button is selected to add additional surface shapefiles. For this analysis the shapefiles that will be added are those that can influence the pattern of spread during a surface fire. The shapefiles include major water bodies and the major roadway network. The road network shapefile for each development design are replaced with each corresponding wildfire simulation.

Three simulations of a surface wildfire were performed for each of the three development designs for a total of nine simulations. On the task bar, the Simulate tab was set to Initiated. To correlate with field data collection in 2013 the Point of Ignition was selected as the GPS location of a lightning strike fire, The Horseshoe Fire, that occurred on the SLP property in the Summer of 2013. A simulated surface wildfire is than started. The simulation finishes when a 'fire-ending event' occurs in the hourly weather data or when the <10 day time period expires. For each development design three simulations are performed using the low, medium, and high fire intensity weather information respectively. The Output results of each simulation are than exported. In the Export and Outputs Options window, Display Units and File Output units are selected as metric. The checkbox for Raster File, 'Flame Length (m),' is selected and the Resolution is set to 30 x 30m. Lastly, the Output results are imported into ArcGIS 10.1 for a comparative analysis of the resiliency of the development designs to a surface wildfire.

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BIOGRAPHICAL SKETCH

Scott Rothberg entered into coursework for a Master of Arts in Urban and Regional Planning after receiving a Bachelor of Science in Wildlife Ecology and Conservation at the University of Florida. Taking the step from the College of Agriculture and Life Sciences to continue into a graduate master’s program housed in the College of Design Construction and Planning personally benefitted his workmanship as a planner. Scott earned a Specialization in Environmental Planning while completing his master’s coursework. The transition enabled Scott to practice the language of city and regional planning and enhance his understanding of geospatial statistical analysis. His fields of study and grant writing have focused on cities, species, and ecosystems that are area dependent and fragmentation sensitive. Specifically, Scott has drafted research proposals for upland conifer pine forests, isolated wetlands, and scrub ecotypes that support fire dependent species of scrub jays, fox squirrels, black bears, and panthers.