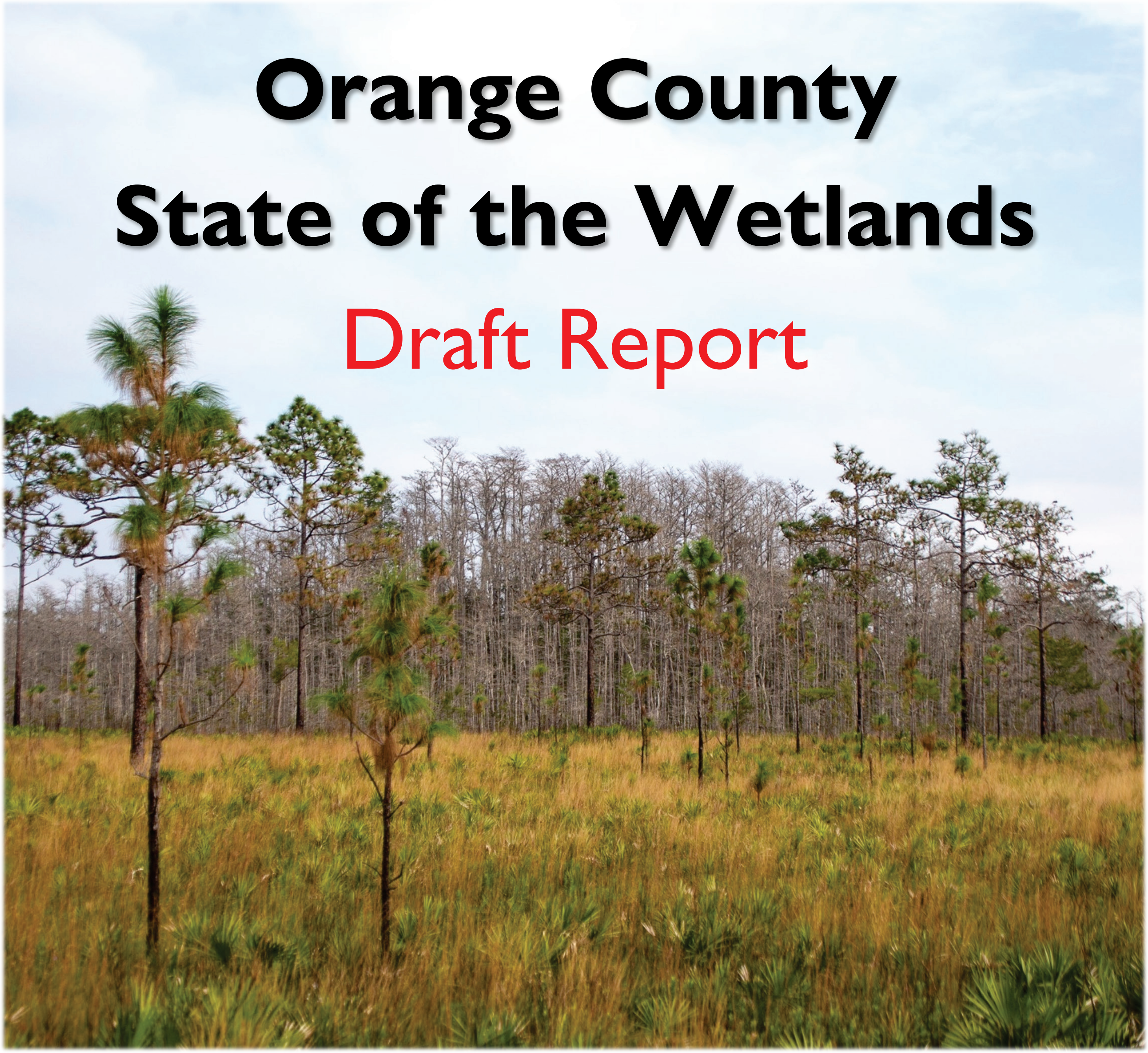
Orange County
State of the Wetlands
Draft Report



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EXECUTIVE SUMMARY

Drummond Carpenter, PLLC (Drummond Carpenter), together with sub-contractor Applied Ecology, Inc. (AEI), were contracted by the Orange County Environmental Protection Division (OCEPD) under the Orange County (County) Y21-950E contract to complete the Orange County State of the Wetlands Assessment and report. The State of the Wetlands Assessment provides the scientific foundation to guide updates to the Orange County wetland ordinance (Chapter 15 Article X of the Orange County Code of Ordinances).

The primary goal of the State of the Wetlands Assessment was to assess the effectiveness of the County's wetland ordinance, which was originally adopted in 1987, at preserving both the quantity (i.e., spatial coverage) and quality (i.e., functional score) of the County's wetlands. To accomplish this, a comprehensive scientific evaluation within the County was completed that compares the historic inventory of the County's wetlands with present day conditions and provides an analysis of the ecosystem services and hydrologic responses associated with changes to wetland area and function.

This study consists of four major components:

1. The initial component consisted of an extensive literature review effort that would guide the development of methodology used in the State of the Wetlands Assessment. Information gathered during the literature review assisted the project team in comparing methods of analysis to peer reviewed approaches and provided ecological context to apply the data collected during this project to large-scale applications and management recommendations.
2. The second component focused on the development of a wetland inventory of Orange County using a simplified classification system that discretized all wetlands into one of seven distinct wetland habitats. These wetlands were digitally mapped in a GIS environment using an Aerial Photograph Interpretation (API) process for the years 1990, 2000, 2010 and 2022. The inventory maps were then used to conduct wetland spatial analyses for habitat fragmentation, wetland change, environmentally sensitive areas, and other potential environmental impacts that have occurred or are anticipated to occur in the future.
3. The third component consisted of completing a functional ecosystem analysis using the Universal Mitigation Assessment Methodology (UMAM) of 51 previously permitted mitigation sites in the County to assess whether function was preserved or lost through the mitigation process. This component included an experimental investigation to assess the validity of using aerial hyperspectral imaging analysis to assess wetland health (a surrogate for wetland function), which was conducted on a subset of 15 of the 51 field assessed mitigation sites.
4. The final component was to develop hypothetical wetland impact scenarios associated with hypothetical development activities that routinely occur with the County. These hypothetical scenarios are analyzed in terms of the impacts of hydrologic change on wetland systems and water quality impact from typical developments versus those that incorporate low impact development (LID) approaches.

Between 1990 and 2022, the area of wetland habitats in the County increased by 2.3% (3,723 acres), largely due to the wetland restoration efforts that were initiated on the north shores of Lake Apopka that increased wetland area in the County by over 10,000 acres. However, these added wetland areas resulted from restoration efforts and were not attributed to mitigation practices related to wetland impacts. If the Lake Apopka restoration project area is removed from the wetland change analyses, a total of 6,507 acres of wetlands would have been lost in the County between 1990 and 2022. Over this same period, and despite the added restoration area, wetland habitat fragmentation has increased within the County. An example of this fragmentation can be seen in the number of distinct (by wetland habitat type) wetland areas, or 'patches', which increased from around 15,258 patches in 1990 to almost 21,000 in 2022, while the mean patch area decreased by just under an acre. Fragmentation impacts have important ecological implications, including loss of habitat for selected species, increases in edge effects, greater exposure to exotic species, potential hydrological impacts, and greater susceptibility to direct human impacts.

An analysis of the habitat succession or reversion that occurred within wetland patches, as they change from one wetland habitat type to another (i.e., freshwater marsh to scrub shrub), found that just over 81,000 acres of wetland habitat persisted as the same wetland habitat from 1990 through 2022. Considering that in 2022 over 162,000 acres of wetland habitats existed, half of all wetlands in the County changed from one wetland habitat type to another, either through natural successional processes or through anthropogenic disturbances that caused reversion to a less mature habitat state.

Data from the wetland change analyses was used to identify spatial patterns related to environmentally sensitive areas or environmentally concerning practices, including aquifer recharge areas, flood prone areas, Outstanding Florida Waterbodies (OFWs), impaired waterbodies, and proximity to major groundwater withdrawals. Results from these analyses indicated that most wetland gains and losses occurred in the western half of Orange County and were associated with areas of major development projects. Additionally, results from modeled simulations of groundwater withdrawal coupled with the wetland change analyses revealed areas of wetland vulnerability in western Orange County where the effects of major pumping centers and groundwater withdrawals are clearly visible.

The wetland mitigation site assessment found that ecosystem function in the 51 mitigation sites significantly changed since the sites were permitted, with UMAM scores decreasing from the initial mean value of 0.78 to the current mean value of 0.74, indicating a net loss of function over time. However, the loss of function was not universal for every location. Further analysis that considered buffered versus non-buffered wetlands found that the wetland mitigation sites that had some form of buffer showed increased functionality over mitigated wetlands that lacked buffers, and that the sites with buffers maintained their ecosystem function over time better than the non-buffered sites.

Testing of the hyperspectral imaging (HSI) platform and its ability to accurately assess wetland ecosystem function (i.e., wetland health) indicated that remote sensing is a plausible alternative to on-the-ground assessments or, at minimum, a tool that can be leveraged to cover larger areas in addition to field validation efforts. Unique spectral signatures were successfully established for numerous wetland species assemblages and species; additionally, stressed versus healthy vegetative communities could be distinguished using reflectance values across the visible and near-infrared spectrum. As technology advances and more remote sensing data becomes publicly available, the likelihood of having automated computer systems accurately assess wetland function is a distinct possibility. This technology would save time and effort and allow for large areas of wetland habitats to be assessed on an ongoing and regular basis to ensure that wetland mitigation practices are effective. While no current hyperspectral sensors are available freely on a satellite platform, UAV mounted HSI sensors are becoming more cost-effective and could allow for a sentinel wetland monitoring program to be implemented across Orange County.

Finally, the hypothetical development and wetland impact scenarios found that significant hydrologic and water quality impacts can occur for development projects that meet current environmental regulatory standards. Detailed surface water, groundwater, and water quality modeling of a typical Orange County development indicated that the design approach taken during the development process can drastically change offsite hydroperiods of surrounding systems and increase pollutant discharges above their pre-development levels, whereas lower impervious area designs that adopt LID approaches reduced the pollutant footprint and better managed groundwater resources. Additionally, impacts to wetland systems from development activity were not found to cause adverse flood impacts for inland, open systemsbecause these projects are already required to mitigate flood impacts by current stormwater permitting standards. This assumes, however, that the development activity appropriately considers the existing wetland storage and hydrologic function, and that existing regulations associated with water quantity and design storms adequately address flood risk.

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ACRONYMS AND ABBREVIATIONS

%	Percent
ACS	American Community Survey
AEI	Applied Ecology, Inc
AEPI	Aerial Empower Intensity
API	Aerial Photo Interpretation
APLUS	Aerial Photo Look Up System
BEBR	Bureau of Economic and Business Research
CAI	Conservation Area Impacts
CIR	Color InfraRed
CLC	Cooperative Land Cover
CLEAR	Centre for Land Use Education and Research
County	Orange County
DC	Drummond Carpenter, Inc.
EVI	Enhanced Vegetation Index
FDEP	Florida Department of Environmental Protection
FGDC	Federal Geographic Data Committee
FGDL	Florida Geographic Data Library
FLUCCS	Florida Land Use, Land Cover Classification System
ft	Feet
FWC	Florida Fish and Wildlife Conservation Commission
FWS	U.S. Fish and Wildlife Service
GeoTIFF	Georeferenced Tag Image File Format
GIS	Geographic Information Systems
HSI	Hyperspectral Imaging
km	kilometers
L8	Landsat 8
LABINS	Land Boundary Information System
LAN	Lake Apopka North restoration area
LDI	Land Use Development Intensity
LST	Land Surface Temperature
LULC	Land Use Land Cover
LULCC	Land Use and Cover Change
MCA	Multivariate Cluster Analysis
N	Nitrogen
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index

NHD	National Hydrologic Dataset
NIR	Near Infrared
NLCD	National Land Cover Dataset
nm	nanometer
NWI	National Wetlands Inventory
OCEPD	Orange County Environmental Protection Division
P	Phosphorus
REIP	Red-Edge Inflection Point
S-2	Sentinel-2
SAR	Synthetic Aperture Radar
SFWMD	South Florida Water Management District
SILVIS	Spatial Analysis for Conservation and Sustainability
SJRWMD	St Johns River Water Management District
SOTW	State of the Wetlands
SWIR	Short Wave Infrared
U.S.	United States
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UMAM	Uniform Mitigation Assessment Method
USDA	U.S. Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WMD	Water Management District
WRAP	Wetland Rapid Assessment Procedure

1 INTRODUCTION

Applied Ecology, Inc. (AEI) was contracted by Drummond Carpenter, PLLC (DC) on behalf of Orange County (County) to perform a State of the Wetlands (SOTW) study to evaluate, characterize, and quantify the ecological conditions of wetlands present within Orange County, Florida, and to assess the effectiveness of the past and current wetland regulations which are aimed at preventing a net loss in wetland acreage and functionality within the County. This study is part of an overarching effort, led by the Orange County Environmental Protection Division (OCEPD), to update the wetland ordinance (Chapter 15, Article X) that has not been substantially modified since its implementation in 1987.

The results of this study provide the scientific baseline to provide specific guidance during the ordinance update effort, ensuring recommendations are scientifically sound and based on regionally available data. This study was undertaken specifically to provide the County with valuable information to help identify areas within the county that might require planning policies that provide additional wetland protection and/or implementation of Special Protection Areas.

1.1 Scope of Project Tasks

This report summarizes the methods and results of the SOTW study performed by AEI and DC. The methods/tools used by AEI to evaluate the ecological health of wetlands within the County and the effectiveness of wetland regulations included literature and database review, geospatial analysis, field validation, and remote sensing techniques. The results of the geospatial analysis were shared with DC, who performed additional spatial analysis and numerical modeling simulations to assess environmental impacts from wetland loss, as well as the vulnerability of different wetland regions from future County growth and the application of the County's groundwater resources. The project tasks are briefly summarized below.

1.1.1 Literature Review

An extensive literature review effort was completed to guide the development of methodology used in the State of the Wetlands Assessment. Information gathered during the literature review assisted the project team in comparing methods of analysis to peer reviewed approaches and provided ecological context to apply the data collected during this project to large-scale applications and management recommendations.

1.1.2 Wetland and Land Use Mapping

The geospatial analysis conducted by AEI utilized existing aerial photography, satellite imagery, Land Use Land Cover (LULC) datasets, and other spatial data beginning with the implementation of the County wetland ordinance in 1987 through the present day to achieve two main objectives: 1) establish baseline wetland extents and, 2) to create an estimate of change in both total wetland area and distribution of wetlands across Orange County. Additionally, changes in urban land use and population growth were assessed to explore conceptual scenarios of potential wetland impacts based on projected future population growth. The conceptual scenario presented in this study utilized previously available modeled future household units from the University of Maddison-Wisconsin Spatial Analysis for Conservation and Sustainability Lab to develop a wetland loss risk matrix across Orange County.

1.1.3 Wetland Functional Analysis

A field validation effort focusing on 51 wetland sites in the County was undertaken to confirm wetland presence, wetland type, and provide a functional assessment using accepted protocols established under the Florida Uniform Mitigation Assessment Method (UMAM) that included a qualitative assessment of invasive species cover. The field assessment selected wetlands that had been previously permitted for mitigation approximately ten or more years ago and evaluated the long-term success of these sites in maintaining or improving the original wetland function. Wetlands were selected to represent different wetland habitat types, patch sizes, and locations within the county.

Hyperspectral imaging of fifteen of the 51 field visited wetland sites was also conducted to assess the wetland health indices and map community types using a separate, experimental methodology. Available published literature and white papers regarding the impacts of wetland degradation and loss of related ecosystem services, wetland Best Management Practices, and optimal methodologies for determining wetland conditions via remote sensing were also queried as part of this study. Data from the literature review was used to inform the methods and approaches of the techniques employed and the recommendations provided in this report.

1.1.4 Wetland Fragmentation Analysis

Wetland fragmentation, or the breakdown in wetland connectivity across a landscape, is attributed to a loss in biodiversity and important wetland functions. To determine if the wetlands in Orange County have become more fragmented over time, often considered a surrogate for wetland function at a landscape scale, a well-known open-source application for assessing the heterogeneity of a landscape called FRAGSTATS (version 4.2) was used. The analysis was conducted on the four wetland land cover datasets (1990, 2000, 2010, and 2022) and run through FRAGSTATS with metrics computed for two different scales – Landscape and Wetland Class (Habitat Type), including Cypress, Freshwater Marsh, Hydric Pine Flatwoods, Mixed Wetland Forests/Hardwoods, Wet Prairies, and Mixed Scrub Shrub Wetlands.

1.1.5 Wetland Spatiotemporal Analysis

To assess changes that took place to wetland habitats in Orange County between 1990 and 2022, the project team conducted a series of spatial analyses designed to identify where and what changes occurred during this 32-year period. These analyses included:

- Wetland change and persistence analysis that examined the persistence, gains, and losses of wetlands in the county,
- Ecological Succession and Reversion Spatial Analysis that analyzed the ecological changes or shifts that occurred between wetland habitat types,
- Spatial analysis of patterns in wetland change and environmentally sensitive areas such as flood prone areas, impaired waterbodies, groundwater recharge areas, and Outstanding Florida Waterbodies (OFWs).

1.1.6 Water Resources and Wetland Vulnerability

Regional groundwater consumptive use data was explored to better understand the relationship between groundwater withdrawals and areas of wetland change mapped as part of this study. Groundwater modeling simulations were conducted to evaluate the impacts of groundwater withdrawals in the Surficial Aquifer and Floridian Aquifer on water levels and groundwater-dependent wetlands within Orange County.

1.1.7 Conceptual Wetland Impact Scenarios

A hypothetical 50-acre mixed used development that included wetland impacts was conceptualized to assess the water quantity and water quality implications of developments that routinely occur within the County. This effort assesses environmental risks, such as flooding and water quality degradation, caused by everyday developments (e.g., subdivisions, commercial, etc.) which meet current state and County minimum environmental regulatory, and how current regulations may be modified to mitigate these risks in the future.

Detailed numerical modeling of surface water, groundwater, and water quality was performed for four scenarios, including a base "predevelopment" condition and three alternative development or "proposed" condition scenarios. The alternative development scenarios explored how conventional design approaches compared with LID-based design approaches at managing hydrologic change and pollution from impacting offsite wetland and surface waters.

1.2 Recommendations

Based on the lessons learned from this comprehensive wetland study, several recommendations were developed to be specifically evaluated during the drafting of the revised ordinance, Chapter 15, Article X. These are further discussed throughout this report and in Section 9, and include the following:

- The recommended elimination of the current wetland classification system (Class I, II, and III) that focuses on wetland size in favor of a tiered permitting system that protects wetland function.

- Refinement of critical variables (modifiers) to be considered during the wetland permitting process, such as defining vulnerable wetland habitats and fragmentation variables (surrogates for landscape wetland function).

- Development of proposed upland buffer recommendations (larger buffers, appropriate planting, etc.) to better preserve long-term wetland function.
- Establishment of mitigation approaches that incentivize in-County mitigation, as well as ensuring long-term preservation of wetland functions via the development of more robust maintenance and assessment requirements, including trash removal, appropriate fire management, maintaining less than 5% invasive/exotic species coverage, and providing recommended planting lists. Enact an internal monitoring program to assess wetland function in mitigation areas every 5 years.
- Require permittees to restore permitted wetland habitats to their natural, historic state, prior to anthropogenic impacts.
- Develop the Orange County Water Use Caution Area (OCWUCA) and require on-site activities such as hydrologic and groundwater monitoring.
- Promote the use of low-impact development (LID), other infiltrating BMPs (e.g., rapid infiltration basins), and the reduction of impervious surface areas throughout the County to facilitate increased groundwater recharge to the Surficial Aquifer System and Upper Floridian Aquifer.
- Require applicants seeking a wetland impact permit to provide detailed flow maps of the project site and any off-site wetlands within a specified boundary to indicate differences between pre- and post-construction conditions.
- Codify the County's development review process for hydroperiod review, which would require applicants to demonstrate that off-site wetland hydroperiods will not be significantly impacted by development activities.
- Evaluate the flood risk of wetland loss associated with more intense design storms than is currently performed. This analysis could assume back-to-back storms or storm events with a greater depth of rain, to assess the potential impact to floodplains under increasingly more intense rain events that the County is experiencing.
- Protect small wetlands, particularly those most vulnerable due to significant losses in the past 30 years (i.e. wet prairies), which is critical to maintaining biodiversity, and develop permitting policies that promote the retention of wetland connectivity.
- Incorporate protection for uplands, as wetlands are inter-connected ecologically to upland habitats and fragmentation and isolation of these habitats will impact both wetland and upland ecological function.
- Maintain high functioning wetland systems, increase their footprints, and limit further fragmentation to benefit all wetlands and help maintain biodiversity.

2 LITERATURE REVIEW

Extensive literature review was conducted to guide the development of the methodology to be implemented during the wetland assessment effort, compare the wetland change analyses to peer reviewed approaches, and to provide the ecological context to leverage the selected field data collected during this study to inform large scale ecological applications and practical management recommendations. The literature review effort focused on the following topics:

- Impacts to aquifer recharge, including research and gaps related to the findings by the Central Florida Water Initiative.
- Impacts to flood attenuation and storage for inland waterbodies, including potential increases in insurance rates/FEMA's Community Rating System (CRS).
- Impacts to water quality, nutrient and carbon uptake, pollutant filtration, and impacts to lakes and other surface waterbodies.
- Regional and watershed scale versus local, minimum dynamic area for preserving high functioning wetlands and wetland ecosystem services. This includes reviewing best practices for wetland viability, mitigation, and impacts.
- Best practices on establishing adequate wetland buffers to protect wetland functionality.
- Methods for assessment of wetland viability in post-development/impact conditions.
- Impacts on species diversity associated with wetland loss.
- Impacts to ecosystems and listed species using remote sensing and wetland change analysis.
- The value of wetland size, location, pattern, and connectivity for ecosystem function, stability, and habitat quality.

2.1 Impacts to aquifer recharge, including research and gaps related to the findings by the Central Florida Water Initiative

Wetlands provide various hydrologic benefits to the watersheds in which they reside, including aquifer or groundwater recharge and discharge, runoff velocity reduction, water storage, and evapotranspiration (Nilsson et al 2011, Bullock and Acreman 2003). Reductions in wetland groundwater recharge services can be caused by heavy pumping activity, increases in impervious surface area, and other anthropogenic alterations. Maintaining adequate groundwater levels is especially important for preserving local water supplies and wetland functions during periods of drought (Harbor, 1994).

Groundwater recharge typically occurs during moderately wet periods or during dry periods at the first increase in water levels from precipitation (Harvey, J.W., et al 2004). Groundwater recharge rates can vary depending on changes in wetland stage (from natural or anthropogenic causes), precipitation, groundwater level, and hydraulic conductivity of wetland soils. (Lee et al, 2009). Nilsson (2011) studied the groundwater recharge potential of 56 unimpacted wetlands in west-Central Florida and found that wetlands provided recharge services at least 50% of the time over a seven-year period. Wetlands included in the study were geographically isolated and held standing water 61% of the time over the seven-year period. The study wetlands were of various types, including cypress, cypress-marsh, hardwood, marsh, and wet prairie, and of various sizes, ranging from 0.27-acres to 97 acres.

However, in a separate study conducted in west-central Florida, enhanced wetlands were found to provide greater groundwater recharge services than natural or impaired wetlands due to the increases in vertical head when groundwater levels are lowered from pumping activities, or when wetland stage was increased from wetland restoration or enhancement (Lee et al, 2009). All wetlands included in the study were isolated wetlands that occurred in natural topographic depressions. Augmented or impaired wetlands were located on the three largest Tampa Bay Water well fields and defined as those affected by groundwater withdrawals and augmented for at least 5 years with supplied groundwater (Lee et al, 2009). Results from this study can be useful in implementing mitigation or preservation practices, especially regarding impacts to groundwater-dependent wetlands.

A recent modeling study in the Prairie Pothole Region of North America analyzed changes in wetland hydrology following varying degrees of wetland impacts over a 50-year period. The study revealed that impacts to wetland hydrology led to a shift and redistribution of groundwater contributing areas which resulted in less runoff reaching local surface waterbodies, and more runoff reaching regional surface water bodies. Wetland loss not only impacted the source of groundwater contributing areas, but also lengthened the subsurface pathway and increased groundwater transit time. The redistribution of groundwater discharge and recharge areas can impact wetland ecosystem services and wetland and groundwater dependent species. Although the Prairie Pothole Region has different topography and geology than central Florida, similarities can be drawn from the permeability of the karst Floridian aquifer. This permeability renders watersheds less resilient to wetland impacts and associated changes in groundwater availability (Ameli et al., 2019), especially in central Florida where limestone of the Upper Floridian Aquifer resides closer to the land surface than other parts of the state (Haag and Lee, 2010).

Hydrologic stressors and impacts to local wetlands have been heavily studied through the Central Florida Water Initiative (CFWI), whose study area consists of Orange, Lake, Osceola, Seminole, and Polk Counties. A recent study conducted through the CFWI in 2020 investigated the impact of environmental stressors from groundwater withdrawal on 189,000 acres of groundwater-dominated wetlands. Groundwater-dominated wetlands were defined by the CFWI as "those wetlands whose water budget is largely driven by the exchange (both inflow and outflow) of groundwater due to their connectivity to an aquifer; they are mostly isolated, but also include headwater wetlands and seasonally inundated wetland strands that would be defined under regulatory rules as "connected wetlands"." Hydrologic stress to wetlands was determined by comparing current wetland water levels and stressed wetland acreages to projected changes in 2025, 2030, and 2040. Results showed an increase in hydrologic stress of 1-5% in the 2025 condition, 1.5-7% for the 2030 condition, and 2-9% in the 2040 condition due to increased groundwater withdrawals. The current condition was developed from a prior CFWI study that assessed 357 wetlands in the CFWI boundary and found that 25% of the assessed wetlands showed groundwater drawdown between -1.0 to 0.2 feet. Approximately 1% of sites showed groundwater drawdown greater than or equal to 1 foot. The study also demonstrated a pattern of hydrologic stress to wetlands occurring along the U.S. 27 corridor in western Orange County and southeastern Lake County. (CFWI, 2013). This study is solely focused on impacts to groundwater recharge from pumping activities. More research is needed that quantifies the total effect of natural and anthropogenic impacts on local wetland groundwater recharge services.

2.2 Impacts to flood attenuation and storage for inland waterbodies, including potential increases in insurance rates/FEMA's Community Rating System (CRS)

Wetlands provide hydrologic benefits to watersheds, downstream waterbodies, and developed areas through flood attenuation. The composition of wetlands allows them to act as a sponge, soaking up water through plant uptake, storage in the soil, or through aquifer recharge. Novitski (1985) showed that just 5% wetland coverage can reduce flood peaks by 40-60%. Altering the composition in wetlands can cause flooding to downstream waterbodies, flood local communities, and weaken the resiliency of watersheds to heavy precipitation events. Hydrologic benefits provided by wetlands can be impaired through increases in impervious surface area, filling or fragmentation of isolated wetlands, and transferring impacted wetland services to mitigation areas that do not provide equitable benefits (Brody et al., 2007).

In 2020, Goldberg and Watkins studied the spatial patterns of wetland loss and wetland mitigation in FEMA-designated floodplains in the lower St. Johns River basin. Results indicated that the greatest acreages of wetland loss occurred in the 100- and 500-year floodplains, areas that have the least resilience against projected sea level rise and king tides. Mitigation for these impacts occurred within banks located in zones with a low flooding risk. Consequently, impacts within these floodplains could also result in the greatest monetary losses following storm events, as older and more expensive homes most often occurred in these areas (Goldberg and Watkins, 2020).

Participation in FEMA's Community Rating System (CRS) encourages governing bodies to limit development in wetlands and flood-prone areas and maintain adequate open space through a reduction in flood insurance premiums. Highfield and Brody (2013) demonstrated that, from 1999-2009, nationwide CRS participation reduced property damage costs from flooding by $290,036 annually. Additionally, property owners in CRS participation areas saved approximately $98.5 million per year on their insurance premiums (Highfield and Brody, 2013).

Brody et al. (2007) analyzed 383 flood events in coastal Florida counties over a 5-year period coupled with spatial trends in wetland loss. Results indicated that the greatest predictor of property damage was the amount of precipitation, followed by adjacent damages, and the third most powerful predictor was wetland alteration. However, Highfield and Brody (2006) showed that individual wetland alteration permits located inside a special flood hazard zone had a greater impact on flood damages than precipitation. Brody et al. (2007) also demonstrated that one wetland alteration permit increased the costs associated with each flood in Florida by approximately $1,596 USD/2020, on average (Brody et al., 2007; Goldberg and Watkins, 2020). When these values were extrapolated per county, one wetland alteration permit increased the costs of flood damages by $908,581 USD/2020 annually (Goldberg and Watkins, 2020).

Additionally, one unit increase in CRS rating corresponded with a 5% reduction in insurance costs, a reduction in flood damages of $303,525, and protected the locality against two additional inches of rainfall (Brody et al., 2007). Similarly, Costanza et al. (2008) estimated that as little as 2.47 acres of wetland losses resulted in an increase of $45,213 USD/2020 in storm damages (Goldberg and Watkins, 2020).

Orange County currently has a Class 5 CRS rank, which provides any resident with a 25% discount on their flood insurance premium. The County has 3,035 credits, which would qualify them as a Class 4; however, certain prerequisites to meet the Class 4 requirements are lacking. These prerequisites include retaining enough points under Activity 430, which requires that the community demonstrates that it enforces higher regulatory standards to manage new developments in the floodplain, as well as Activity 450, which requires that the community receive enough credits toward its watershed management plan. If the County were to retain a Class 4 rank, its residents would benefit from an additional 5% reduction in their flood insurance premiums.

2.3 Impacts to water quality, nutrient and carbon uptake, pollutant filtration, and impacts to lakes and other surface waterbodies

One important ecosystem service of wetlands is water quality improvement through biological processes including denitrification, plant uptake, and accumulation of organic matter, as well as geochemical processes such as adsorption, precipitation, and sedimentation, which results in long-term nutrient storage (Widney et al., 2018). Through organic matter accumulation and geochemical processes, wetlands also store significant amounts of carbon that prevents excess CO_2 from entering the atmosphere. In fact, the treatment capacity of wetlands is so significant that wetlands are often constructed within watersheds to provide water quality treatment (Dunne et al., 2012). Dunne et al. (2012) reviewed the effectiveness of a constructed wetland that was designed to treat total phosphorus and total suspended solids from inflows to Lake Apopka. Phosphorus removal in the treatment wetland increased as loading increased, and seasonal releases of SRP decreased to negligible concentrations after 2.5 years of treatment.

The nutrient removal capacity of wetlands to downstream waterbodies depends on multiple factors, including size, connectivity, pollutant loading concentrations, and position in the landscape. Widney et al. (2018) investigated the nutrient removal value of wetlands in the St. Johns River watershed. The study found that wetlands stored nitrogen and phosphorus via burial in the soil at a rate of 6.56 to 27 g/m^2/year and 0.11-1.31 g/m^2/year, respectively. In total, wetlands in the St. Johns River watershed removed 79,873 MT of nitrogen and over 2,400 MT of phosphorus annually via burial alone. The value of this pollutant storage was estimated to be $240 million to $150 billion per year for nitrogen and $17-497 million per year for phosphorus. These estimates were derived from nitrogen and phosphorus removal costs within wastewater treatment plants. This study also suggested that wetlands in greater proximity to high-intensity agricultural operations have greater value in terms of nutrient removal, as results indicated that wetlands buried twice as much N and P when they were located the same distance from high-intensity agriculture compared to medium-intensity agriculture. Whigham (2003) conducted a literature review of the connection between impacts to isolated wetlands and downstream water quality. Although isolated wetlands may be visually isolated, the literature has shown that these systems are hydrologically connected to other wetlands and uplands within a watershed via groundwater interactions. Isolated cypress dome depressions in Florida that received wastewater stored 90% of the influx of nutrients and organic matter, preventing that pollutant load from reaching downstream waterbodies (Whigham, 2003).

While wetlands provide pollutant filtration services, they also store more carbon than any other terrestrial ecosystem. Despite covering only 2-6% of Earth's land surface, wetlands store approximately 15×10^{14} kg of carbon. Carbon sequestration capacity of wetlands is dependent upon water table depth, regional climate conditions, soil temperature, and the amount and quality of organic matter within the wetland. Tropical climates, high water tables, and increased organic matter availability are favorable conditions for carbon storage (Kayranli et al., 2009). Therefore, altered or drained wetlands with bounded hydrology will be limited in carbon sequestration capacity, as well as pollutant filtration capability. Additionally, wetland impacts can lead to a release of greenhouse gases if wetland sediments are dredged and stored carbon comes in contact with the atmosphere. In these cases, wetlands can transform into a source of carbon rather than a sink.

2.4 Regional and watershed scale vs local, minimum dynamic area for preserving high functioning wetlands and wetland ecosystem services, including best practices for wetland viability, mitigation, and impacts

Wetlands provide countless ecosystem services and functions (e.g., floodwater attenuation, water purification, sediment trapping, energy flow, habitat to support biological diversity, nutrient cycling), and wetland loss has a direct impact on local populations and environments through the corresponding loss of these services. The United States has a No-Net-Loss policy, which seeks to lessen the loss of ecosystem services by using wetland mitigation projects to replace lost wetlands based on area and function. Within the state of Florida in the Atlantic coastal region, the United States Army Corps of Engineers, the Florida Department of Environmental Protection, and regional water management districts have an operating agreement to use a joint application for modification of wetlands via an Environmental Resource Permit (ERP). Permit applicants can propose to mitigate impacted wetlands with wetland or upland preservation, creation, enhancement, or restoration on the project site or off-site. Off-site mitigation may occur on another property, at a mitigation bank, or at a regional off-site mitigation area.

Replacement of lost wetland function is the cornerstone of wetland mitigation. Unfortunately, because wetlands provide a variety of benefits, there is no single metric to evaluate wetland function (Reiss, 2008). Additionally, it is unlikely that any mitigation activity could perfectly replace every wetland function lost through impact. As such, regulators must weigh the location and function of mitigation activities based on specific direct or indirect benefits to human society and ecosystem services (e.g., production of food and fiber, storm protection, flood abatement, recreation). Preserving wetlands within developed urban areas may improve the distribution of important wetland functions throughout the landscape (e.g., flood attenuation), but it will not necessarily replace all the lost functions from wetland impact (Reiss, 2008).

Several studies have examined ERP permits to determine which wetlands in Central and Northern Florida are most likely to be negatively impacted by human development and require mitigation. Forested palustrine wetlands are the most likely environment to be impacted through development (Brody et al., 2008; Goldberg & Reiss, 2016). Most impacted wetlands were located within mid to high development urban areas (Brody et al., 2008; Goldberg & Reiss, 2016). Roughly half of the lost wetlands were located within the 100-year floodplain (Brody et al., 2008; Goldberg & Watkins, 2021). A study of 3000 cypress domes, located in Orlando, FL, found that between 1984-2012, over 26% of the cypress domes were destroyed or degraded to the point that they were no longer cypress-dominated (McCauley et al., 2013). Small and large end-member sized cypress domes tended to be most affected by development (McCauley et al., 2013).

These lost urban wetlands have been mitigated in a variety of ways; with on-site mitigation accounting for 29% of permits, 27% through mitigation banks, and 20% through off-site only mitigation (Goldberg & Reiss, 2016). Wetland preservation (880 ha/yr.) was a far more common mitigation strategy than wetland creation (9 ha/yr.) (Goldberg & Reiss, 2016). This discrepancy may be concerning as preservation results in net loss of wetlands and is unlikely to compensate for the loss in wetland ecological function (Owley, 2014). The distance between impacted sites and off-site mitigation locations has also increased through time (Levrel et al., 2017). Notably, the uplands and wetlands preserved by purchasing credits from banks are in areas with lower risk of flooding than those lost to development (Goldberg & Watkins, 2021). Collectively, these data help explain how each wetland permit was estimated to increase the average cost of each flood in Florida by $1,596 USD/2020, with an average $908,581 USD/2020 of flood damage per county per year, and an average of $49,063,397 USD/2020 per year for all of Florida (Brody et al., 2008).

These data help emphasize that, given the significant social and economic costs from flood damage, community planners should prioritize protection of wetlands and open spaces in areas most vulnerable to flood hazards (Goldberg & Watkins, 2021). Larger and less fragmented wetlands provide the most value in terms of reducing peak annual runoff (Kim & Park, 2016). However, smaller, geographically isolated wetlands do provide important hydrological and biogeochemical functions, particularly ecological benefits for endangered and threatened species (Cohen et al., 2016).

The replacement of wetland function will never be perfect, but regulators should prioritize wetlands that provide direct or indirect benefits to the surrounding landscape and community. Isolated urban wetlands provide critical water storage function even if their ecological function is limited (Reiss, 2008; Goldberg & Watkins, 2021; Cohen et al., 2016). Regional mitigation banks or off-site mitigation areas often represent wetlands with significant wildlife habitat function but are typically less valuable for flood attenuation (Reiss, 2008; Levrel et al., 2017). Overall, wetland mitigation, be it local or regional, should seek to replace lost wetland functionality most comparable to the existing wetland system.

2.5 Best practices on establishing adequate wetland buffers to protect wetland functionality

The benefits of buffers to wetland and surface water protection and preservation have been well established in the literature. Effective buffers can protect adjacent wetlands and receiving water bodies from sedimentation, pollutant loads from surface water runoff, groundwater contamination, and preserve habitat suitability for wetland-dependent and aquatic wildlife populations. In fact, buffer zones commonly include a greater diversity of plant species than the adjacent upland or wetland (Clewell et al., 1982; Gross, 1987; Hart, 1984; JEA, 2000). Additionally, herpetofauna species richness and abundance was found to be greater along wetland edges than the adjacent wetland or upland habitat in six wetlands studied in north Central Florida (Vickers et al., 1985; JEA, 2000). While the concept of buffers for wetland protection is simple, establishing effective buffer widths and regulations is much more complex and can require a balancing act between resource conservation and realistic needs of a growing human population.

Defining a purpose for buffer regulations is a critical first step in identifying and prioritizing protections for wetland ecosystem services. Brown (1990), a study prepared for the East Central Florida Regional Planning Council (ECFRPC), identified three critical wetland protections that buffers should provide: protection of groundwater resources, reduced impacts from sedimentation and turbidity, and habitat protections for wetland-dependent wildlife. This study developed buffer criteria on a site-specific basis, including variables for landscape type, construction impacts to groundwater drawdown, slope of the groundwater table, soil class and type, and percent of vegetative cover. Formulas developed for these variables resulted in a buffer width for each of the three identified priorities, of which the most conservative width was recommended. For example, an isolated flatwood wetland required a minimum buffer of 100 feet to minimize groundwater drawdown, 75 feet to control sedimentation, and 322 feet to maintain protections for wildlife habitat.

In 2003, the Environmental Law Institute (ELI) released a metanalysis study of recommended buffer widths in the literature, reviewing over 150 studies, titled *Conservation Thresholds for Land Use Planners*. The studies had varying objectives for buffer purposes, including appropriate buffer widths for temperature regulation, detrital input, bank stabilization, flood attenuation, sediment removal, nutrient removal, wildlife and plant species protection, protection of aquatic systems, and miscellaneous items like noise pollution and wind damage. The metanalysis found recommended buffer widths ranging from 3 feet to 5,250 feet, with 75% of the values extending up to 100 meters, or 328 feet. Based on the metanalysis results, the ELI recommended that resource managers require the following buffers by category:

- Nutrient Removal: 25 meters (82 feet)
- Temperature Regulation and Sediment Removal: 30 meters (98 feet)
- Detrital Input and Bank Stabilization: 50 meters (164 feet)
- Water Quality and Wildlife Protection: Minimum 100 meters (328 feet)

Other studies also suggested extensive buffers for wildlife protection compared to other wetland ecosystem services. Semlitsch and Jensen (2001) recommended a habitat protection zone of 642 feet from the wetland edge. This protection zone was divided into sections, including an aquatic buffer, core habitat zone, and a terrestrial buffer of 150 feet as the final layer of protection from adjacent development. The Ochlockonee River and Bay Surface Water Improvement and Management Plan reviewed generalized buffers for wildlife protections and found that maintaining protections for diverse stream invertebrates, bird corridors, and reptile and amphibian habitat required minimum buffers of 100, 300, and 1,000 feet, respectively. The Hillsborough County Environmental Protection Commission (EPC, 2006) conducted a comprehensive review of buffers adopted throughout the U.S. for environmentally specific purposes, including protections for water quality, water quantity, riparian habitat, and lakes. Based on their findings, the EPC recommended a 100-foot minimum undisturbed buffer landward of all Outstanding Florida Waterbodies (OFW) or their adjacent wetlands. For non-OFW sites, scientifically defensible buffers were identified by priority, including a 50 to275-foot buffer for wildlife habitat, 50 to 225-foot buffer for flood mitigation, 50 to175-foot buffer for sediment removal, 25 to125-foot buffer for nitrogen removal, 25 to 50-foot buffer for water temperature moderation, and 15 to 40-foot buffer for bank stabilization and aquatic food web protections. Although these buffers were recognized by the EPC as being scientifically defensible, the EPC recommended establishing a minimum buffer width of 50 feet for all non-OFW sites.

Castelle et al. (1992) points out that ensuring the longevity of buffers is just as important as establishing scientifically defensible buffer widths. In this study, 21 sites in two Washington counties with wetland buffers of varying widths were surveyed over an 8-year period. Results indicated that 95% of buffers less than 50-feet suffered impacts from human interference, including noise and trash pollution and physical disturbance, compared with 35% of buffers greater than 50 feet. Within one to eight years, 86% of all sites had reduced buffer zones. In 2008, the ELI drafted a *Planner's Guide to Wetland Buffers for Local Governments* that states that monitoring, reporting, and enforcement of buffer widths and non-disturbance areas are key to maintaining wetland ecosystem services that buffers are designed to protect. Ensuring buffer protection starts with strong, defensible regulations enacted in a local government ordinance. The ELI described a strong wetland buffer ordinance as one that explicitly defines the purpose of the ordinance, what activities are allowed within buffer zones, and identifies what entity has the authority to review and determine buffer sizes and enact any necessary enforcement. The ELI also recommended that, since buffer quality will likely be reduced over time, conservatively large buffers allow for long term integrity and protection of adjacent wetlands.

Literature reviewed for this assessment echoed many commonalities, including that wetland buffers can be designed to support a variety of purposes, and that those purposes should be clearly defined in any established regulations. The determined purpose should drive scientifically defensible metrics to calculate appropriate buffer widths. Whether site-specific or blanket buffer widths are required, the most conservative width across buffer protection priorities (ex. habitat protection vs. turbidity control) should take precedent. Lastly, buffer regulations are increasingly protective of wetland longevity when robust monitoring and enforcement programs are established.

2.6 Methods for Assessing Wetland Viability in Post-Development/Impact Conditions

Understanding the status and impacts to wetlands is valuable to ensure continued mitigation and protection of wetland resources. Utilizing various sources of aircraft and satellite imagery combined with in-situ observations and assessments can be used to determine wetland viability, stressors, and impacts. The Environmental Protection Agency (EPA) initiated a National Wetland Condition Assessment in 2011 as a part of the National Aquatic Resource Survey program and recognized three levels of standard wetland assessment methods (USEPA - Wetlands Monitoring and Assessment | US EPA; Miller et al., 2016; Chen and Lin, 2011; Olsen et al., 2019). These methods are shown in **Figure 2-1** and include:

Level 1 - Landscape Assessment

Level 2 - Rapid Assessment

Level 3 - Intensive Site Assessment

These methods go from course, large-scale data and analysis techniques (Level 1) to intensive, very detailed on-the-ground site assessments (Level 3).

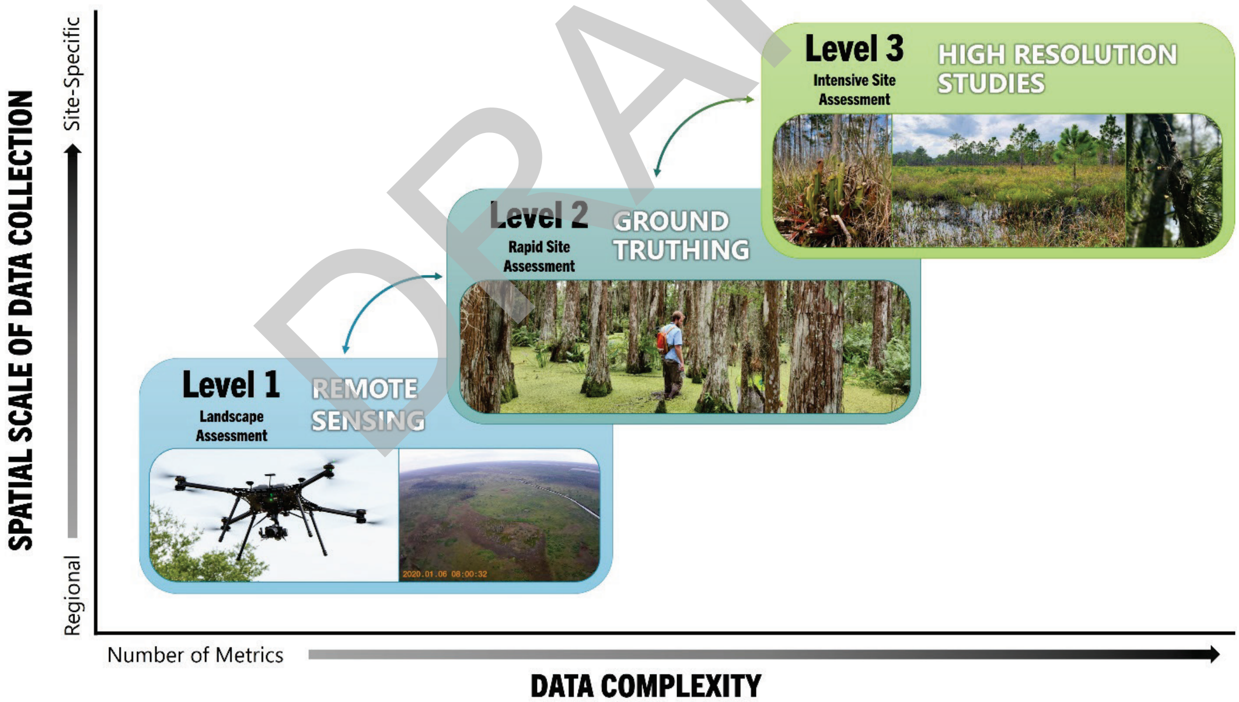

Figure 2-1. Wetland Condition Assessment methods by scale and complexity.

Level 1 landscape assessments are typically coarse, landscape scale assessments that use remote sensing and imagery technology to provide an inventory of wetland habitats. These include wetland classification using aerial photo interpretation (API) methods, the process that was used in this assessment to classify wetland habitats throughout Orange County. In addition, wetland classification Level 1 assessments can also be used with supplemental information to develop more sophisticated models to assess, for example, the persistence of wetlands through time (see Section 6) or the impacts of groundwater removal on wetland habitats (see Section 7). Another example of a Level 1 assessment is the Landscape Development Intensity (LDI) index (Reiss and Brown, 2007). The LDI is an index that can serve as a human disturbance gradient reflecting local human activity, combining the effects from air and water pollutants, physical damage, and changes in environmental conditions on the structure, process, and function of ecosystems (Reiss et al., 2014; Rain et al., 2013; Dooley and Brown, 2020).

Level 2 rapid site assessments use basic on-the-ground data collection methodologies conducted at the specific wetland site scale. With Level 2 assessments, visual observations are made of wetland form, structure, and the presence of human stressors that may degrade wetland form and function (Nestlerode et al., 2014). Metrics to score the state of the wetland may include measures of landscape connectivity, buffering habitat width and condition, hydrologic connectivity, topographic complexity, organic matter accumulation, plant species composition, and vertical biological structure (Nestlerode et al., 2014).

In Florida, the US Army Corps of Engineers, Jacksonville District adopted the Wetland Rapid Assessment Procedure (WRAP) for evaluating wetland impacts and mitigation protocols that can be used as a Level 2 wetland assessment method, a protocol that was originally adopted by Miller and Gunsalus (1999). WRAP assesses six different components at an impact site - Wildlife Utilization, Overstory, Ground Cover, Buffer, Hydrology and Water Quality Input. The Uniform Mitigation Assessment Method (UMAM), which was used as part of this assessment, is another wetland assessment method utilized to determine the amount of mitigation needed to offset adverse impacts to wetlands. UMAM provides a standardized procedure for assessing the ecological functions provided by wetlands and how anticipated impacts (i.e., development) might affect those functions (FDEP, 2022).

There are two parts to the UMAM: Part I provides a reference for the type of community being assessed and what functions will be evaluated while Part II includes numeric scores and narratives to support the scores. During a UMAM assessment three components - Location and Landscape Support, Water Environment, and Community Structure - are assigned a score of 0 (no function) to 10 (optimal). The assessment scores are based on the professional judgment of the experts and are then averaged to provide one score for the site. UMAM scores can then be used in combination with acreage, time lag between impacts and mitigation, and/or environmental risk factors to estimate the amount of loss or gain in wetland ecosystem function. Both the UMAM and WRAP can also be used to determine if a wetland is functioning at a "minimum" level to determine eligibility for a Minimal Effect exemption. Analysis of these assessments can determine specific wetland features that have been impacted to provide restoration guidance (Jacobs et al., 2010). Site evaluations typically involve making visual observations of wetland form, structure, and the presence of anthropogenic stressors that may degrade the wetland form, structure, and ecological functions (Nestlerode et al., 2014).

For Level 3, a more rigorous, field-based approach is used that often uses wetland bio-assessment procedures to collect high-resolution information on the conditions of the wetlands being assessed (USEPA, 2006; Miller et al., 2016). An example of a Level 3 intensive wetland assessment procedure is the Florida Wetland Condition Index which incorporates metrics based on changes in abundance, structure, and diversity of diatoms, macrophytes and macroinvertebrates (Reiss et al., 2007). Different variations of the Florida Wetland Condition Index have been created for palustrine emergent, palustrine forested, and forested strand and floodplain wetlands. Ground-based Level 3 site assessments provide detailed information about flora and fauna, water quality and chemistry, and soil data (Frohn et al., 2011).

Although useful, there are limitations to field-based monitoring including the high cost of equipment and personnel, time constraints, and access to the wetland. Therefore, remote sensing has been utilized to help establish baselines of the extent and condition of habitats and associated species diversity as well as to quantify losses, degradation, or recovery of the wetlands associated with specific events or processes (Frohn et al., 2011). Unmanned aerial vehicles (UAV), or drones, can be used to identify specific species and structural characteristics of wetlands if the images are accurately located using ground control points (Chasmer et al., 2020). Connectivity can be estimated by using high point density lidar data and UAV structure from motion data (Chasmer et al., 2020). Comparing in-situ measurements with changes in the absorption, reflection, emission, and transmission of energy detected by remote sensing technology temporally can be used to assess changes in wetland class and extent (Chasmer et al., 2020). Historical and existing wetlands can be mapped consistently with the LULC mapping protocols provided in the FLUCCS manual (Florida Department of Transportation, 1999). Coupled with in-situ assessments, land observation satellite images have proven to be effective techniques to quantify changes in wetlands and can be used to monitor land use and land cover change over time (Wu et al., 2017; Hu et al., 2019).

Even though Level 1 assessment methods using remote sensing data are currently unable to provide detailed analysis of wetland function they do provide an important tool for quantifying the spatial and temporal changes caused by human activity and the associated impacts these changes have on wetlands, particularly connectivity, hydrology, and habitat fragmentation (Klemas, 2013). Rapid advances in remote sensor technology and analytical techniques have made remote sensing a very cost-effective and practical method for assessing wetlands and monitoring both natural and anthropogenic driven changes to wetland habitats. New methods are being developed using a combination of remote sensing technologies including satellite and aerial photography, lidar, multispectral and hyperspectral imaging, and radar to not only classify wetlands and quantify spatial and temporal changes, but to assesses wetland function, hydrologic conditions, and identify species assemblages at a much finer scale (Ozesmi and Bauer, 2002; Klemas, 2011; Klemas, 2013; Mahdavi et al., 2018). Given the cost-effectiveness of remote sensing over ground-based, labor-intensive methods, especially over large geographic areas, the use of remote sensing technology will continue to be the primary method of wetland assessment; although, use of on the ground assessment methods (Level 2 and Level 3) will still be necessary to validate remote sensing results.

2.7 Impacts to Species Diversity Associated with Wetland Loss

Florida is a biologically diverse state, with the most proportional wetland cover and some of the highest values of species richness for amphibians, reptiles, birds, and mammals within the continental United States (Dertien et al., 2020). Wetlands are recognized as important habitats for wildlife as they serve as migratory stops, nesting grounds, forage sources, and general habitats. The continual conversion and development of wetlands, degradation of their hydraulic regimes, and fragmenting of connections are some of the greatest threats to conserving species diversity. Within Florida, it has been estimated that 44% of the total wetland area has been lost due to human activities, with alterations in drainage patterns being the main component of wetland loss in agricultural areas (FWC, 2022). Urbanization can lead to a decrease in species diversity by increasing the area of impervious surfaces that reduces and fragments suitable habitats, including wetlands, available for plants and animals (McKinney, 2008).

Amphibians and Reptiles

Amphibians and reptiles are particularly sensitive to changes in wetland hydrology and have therefore been regarded as important bioindicators of habitat suitability and the success of wetland restoration projects. They are also experiencing the most severe population losses of all the vertebrate groups, likely due to the loss and/or alteration of suitable habitat (Collins, 2010; Waddle et al., 2013). Houlahan and Findlay (2003) found that species richness for wetland amphibians was negatively correlated with road density and nitrogen concentrations and positively correlated with wetland area, forest cover, and the number of wetlands on adjacent land.

Cassani et al. (2015) established a baseline inventory for southwest Florida from 1995 to 1997 at a managed preserve and repeated their sampling methods fifteen years later from 2010 to 2011 to assess the change in amphibian and reptile community composition. Their results showed a significant decline of several native species including the southern toad (*Anaxyrus terrestris*), pig frog (*Lithobates grylio*), green anole (*Anolis carolinensis*), and southern water snake (*Nerodia fasciata*). Species that were abundant in 1995-97 including the southern leopard frog (*Lithobates sphenocephalus*), greater siren (*Siren lacertina*), and eastern newt (*Notophthalmus viridescens piaropicola*) declined by over 50% (Cassani et al., 2015). The only two species that increased significantly were the non-native brown anole (*Anolis sagrei*) and the native ringneck snake (*Diadophis punctatus*) (Cassani et al., 2015).

Birds

Goddard (2010) found the presence and functionality of cypress dome habitats decreased with increasing urban development and invasive species presence. Goodard (2010) also observed that there was a shift to mixed wetland hardwoods in developed areas older than 20 years, suggesting long-term changes to wetland hydrology can be associated with a decrease in annual hydroperiod. Cypress domes and associated bird communities can be negatively impacted because of urban development which can change the water chemistry, vegetative structure, hydroperiod and surrounding land use, leading to a decrease in the overall function of the wetland (Goddard, 2010). Migratory birds are particularly sensitive to changes in forested wetland and riparian structures and their populations can decline rapidly with urban development (Rodewald and Matthews 2005). McCauley et al. (2013) estimated a total of 3,393 cypress domes (6,363.4 ha) in Orlando, Florida from aerial photos in 1984, and by 2004 the total dropped to 2,298 (4,677.2 ha), which is equivalent to a 26% decrease in the number and area.

Bird community structures may serve as bioindicators of habitat suitability, productivity, and identification of changes within habitats (Zakaria and Rajpar, 2014). Converting large portions of land to urban and agricultural land negatively impacts wetland breeding birds because isolated wetlands are more susceptible to anthropogenic stressors like pollution, pesticide runoff and invasive species (Tozer et al., 2010). Many waterbirds move around at landscape levels when deciding where to settle, and the connectivity between/within wetlands enables the exchange and movement of aquatic animals and plants among wetlands and different patches, increasing potential food sources for birds (Ma et al., 2010). With reduced connectivity, between-wetland movements of birds get impeded while the abundance of generalist nest predators that frequent wetlands increases (Tozer et al., 2010). As the urban regions around wetlands increase, the abundance and diversity of invertebrates, amphibians and fishes decrease and fewer birds move through the landscape, impacting the overall metapopulation dynamics (Tozer et al., 2010). Wetland-scale variables including wetland size, water depth, the perimeter-to-area ratio, interspersion, and different vegetation metrics impact the abundance and reproductive success of wetland-breeding birds, particularly wetland size (Tozer et al., 2010). Wetland size influences waterbird species richness and abundance, with larger wetlands capable of supporting a greater diversity of waterbirds compared to smaller wetlands (Ma et al., 2010).

Wading birds rely on wetlands and regular hydroperiods for feeding, nesting and foraging, and Florida has 4 state-threatened wading birds: the little blue Heron (*Egretta caerulea*), reddish egret (*Egretta rufescens*), roseate spoonbill (*Platalea ajaja*), and tricolored heron (*Egretta tricolor*) (FWC, 2022). The reddish egret is a non-migratory resident of Florida and is listed as threatened due to the species' small population size, limited habitat, and restricted range (Ogden et al., 2014). The juvenile birds are typically associated with freshwater habitats following the breeding season, but much of their historic habitat has been lost to dredge-and-fill urban development projects. Roseate spoonbills also have small populations with restricted ranges and occur mostly in mangrove-dominated wetlands fringing the southern and central Florida mainland, however their population has been declining because of water management practices that lowered the overall productivity of the habitats (Ogden et al., 2014). Little blue herons and tricolored herons nest in different woody habitats like cypress (Taxodium distichum), willow (Salix spp.), red maple (*Acer rubrum*), buttonwood (*Conocarpus erectus*), mangroves (most commonly Rhizophora mangle), and Brazilian pepper (*Schinus terebinthifolius*) (FWC, 2022). Major threats that impact these species include the loss of wetland habitat, habitat degradation due to changes in hydrology and water/soil quality that impact foraging success, disruption at breeding sites, and increased populations of native and non-native nest predators (FWC, 2022).

Although some species populations have increased because of proactive wetland conservation, other species like the northern pintails (*Anas acuta*), which are widespread in North America but can spend the winters in Florida wetlands, have declined due to shifting agricultural practices that do not align with the behavioral traits of nesting hens (Donnelly et al., 2022).

Mammals

Mammals that inhabit wetlands play an important role in shaping wetland communities by preying on aquatic organisms, serving as prey for other vertebrates, improving soil turnover, and altering the habitat used by other wetland fauna (Kurz et al., 2013). Biodiversity in wetlands is threatened by habitat fragmentation that reduces the genetic variability and persistence of populations (Larkin et al., 2003). One mammal that could benefit from connecting forested wetland habitats is the threatened Florida black bear (Ursus americanus floridanus). In the present day, these organisms reside in several scattered subpopulations within a larger area of habitat and human settlement. Fragmentation also impacts their ability to acquire food as well as compromising their reproductive performance (Larkin et al., 2003).

Other studies have assessed the impacts of wetland restoration on the populations of smaller mammals, like rodents. Specifically, Romañach et al. (2021) evaluated the restoration progress of a project in the southwestern Everglades to determine if the presence and density of the marsh rice rat (*Oryzomys palustris*), hispid cotton rat (*Sigmodon hispidus*), and cotton mouse (*Peromyscus gossypinus*) differed between areas with hydrologic restoration and areas without. The study concluded that the cotton mouse had greater densities in restored habitat and lower densities of the hispid cotton rat were found in regions with higher water levels (Romañach et al., 2021). Overall, the cotton rat was the one species that exhibited a positive effect because of restoration, and they found a significant impact of water level on the density of the cotton rat (Romañach et al., 2021). The results support the idea that restoring ecosystem hydrology can improve habitat and habitat use by small mammals that reside in wetlands.

Protecting Biodiversity Through Mitigation

Programs to mitigate wetland impacts aim to maintain wetland function by avoiding and minimizing wetland impacts and through compensating for unavoidable impacts. These programs take the form of on-site mitigation/remediation and mitigation banking. Originally, the preferred method for wetland mitigation was on-site remediation because many wetland functions are specific to their location (Bonds and Pompe, 2003). When on-site remediation was being used, a study in Florida found that one-third of the required mitigation projects were not implemented (Bonds and Pompe, 2003). Of the projects that were completed, only 27 percent were considered an ecological success (Bonds and Pompe, 2003). However, Reiss et al. (2006) suggested that although the biological integrity of urban wetlands is compromised because of lower diversity, fewer native flora, increased invasive species and impacted water and soil quality, a wetland with 30-70% biological integrity of reference wetlands can still provide vital wetland services like runoff retention and nutrient removal/sequestration.

During the 1990s, wetland mitigation banking, modeled after emission trading, was created by state and federal agencies to help improve the efficiency of wetland offsets (Levrel et al., 2017; Bonds and Pompe, 2003). Essentially, a third-party anticipates the wetland offset requirements of developers through preemptive large-scale restoration efforts or through the enhancement of natural areas, known as mitigation banks. The mitigation banking system requires compensation for impacts on wetlands to maintain a balance between ecological function losses and gains, and mitigation credits are determined by using assessment methods (e.g., UMAM).

The extent of biodiversity gain created by a mitigation banker and the extent of biodiversity loss by developers corresponds to the credits received (Vaissière and Levrel, 2015). If developers need to compensate for an impact, they can purchase mitigation credits from the mitigation bank. Anyone, including concerned individuals or groups, can purchase mitigation credits and generate more wetland restoration (Bonds and Pompe, 2003).

Although mitigation banking was created to offset the loss of wetlands, more recent research has suggested there continues to be a real risk of temporal loss of wetlands because some credits are released before ecological outputs are gained, yet this is not compensated by the fact that credits are usually sold in three stages (Levrel et al., 2017). According to Levrel et al. (2017) a mitigation banker does not receive all potential mitigation credits at once but the release of credits occurs over three main stages: 1) Administrative credits are released after site acquisition and approval of a restoration plan, 2) Works and planning credits are released after hydrological work and plantings have been completed, and 3) Ecological success credits are gradually released based on the successful fulfilment of ecological criteria set under the restoration plan.

An additional risk, particularly within Florida, is the spatial disconnection between impact sites and compensation sites. Many compensation sites are located 'off-site', in areas distant to the impact sites which redistributes ecosystem services for local populations (Levrel et al., 2017). This is especially true within Orange County, as most of the wetland mitigation required for impacts within the County takes place outside the boundaries of the County, resulting in a net loss of wetlands and ecosystem services when viewed at the county level.

Notwithstanding the risks of mitigation, Reiss et al. (2009) found that banking in Florida was generally considered successful in meeting permit requirements and compliance considerations. However, if permits have unclear goals and directives, the functional performance of banking is uncertain. Out of the 29 banks examined in the study, 11 of them addressed wildlife in the final success criteria, 9 of them addressed wildlife through monitoring not directly tied to the final success criteria, and 9 banks did not mention wildlife in state permits (Reiss et al., 2009).

One benefit of mitigation banking is that mitigation is put in place before the wetlands have been impacted, while on-site mitigation allows for the wetland to be impacted prior to the enhancement or creation of another (Reiss et al., 2007). Additionally, there are ecological benefits because banks can select sites that have a better chance of successful restoration to enhance wetland services (Bonds and Pompe, 2003). On the other hand, it is unclear how much wetland function is really provided when the credits are released, and it may result in a temporary loss of wetland function (Reiss, 2007). To improve the ecological performance of banks, Reiss et al. (2009) suggested implementing detailed monitoring plans, that describe in the ecological success criteria, that award credits only after the detailed success criteria are met and the wetland demonstrates desirable ecosystem response or functional equivalency.

2.8 Identifying Impacts to Ecosystems and Listed Species Using Remote Sensing Tools and Wetland Change Analysis

Synergetic approaches involving the use of in-situ assessments and remote sensing from multispectral satellites and hyperspectral Unmanned Aircraft Systems (UAS) are cost-effective means of accurately mapping and monitoring complex environments like wetlands. Optical imagery obtained from the United States Geological Survey (USGS) Landsat and European Space Agency Sentinel satellites are a common tool used to characterize wetland type, class and form attribution, while the high spatial resolution available with UAS platforms allows for the identification of species and structural characteristics of wetlands (Chasmer et al., 2020; Guo et al., 2017; Mahdianpari et al., 2020; Jamali et al., 2021; Diaz-Delgado et al., 2018; Sànchez-Espinosa and Schröder, 2019; Amani et al., 2018).

Spectral indices are an effective means to interpret optical satellite data and are useful in the delineation of water bodies and vegetation. A list of peer-reviewed indices used for both Landsat-8 and Sentinel-2 imagery is provided in **Table 2-1** and **Table 2-2**, while **Figure 2-2** highlights the differences between Landsat-8 and Sentinel-2 spectral bands. For the delineation of wetlands, it is likely that the Red Edge and Near Infrared (NIR) spectral bands will be utilized to monitor vegetation and the quality of inland water bodies with high phytoplankton presence (Amani et al., 2017).

For wetlands in particular, the Normalized Difference Water Index (NDWI) was developed by Gao (1996) based on the relationship between Short Wave Infrared (SWIR) being absorbed by water and NIR being reflected by vegetation. Additionally, the Normalized Difference Vegetation Index (NDVI) is commonly used to quantify vegetation greenness and used to understand vegetation density and assess changes in plant health (Ashok et al., 2021). Analyzing temporal and spatial patterns of specific vegetation indices like the NDWI and NDVI can be used to identify habitat and landscape change, and combine metrics of landscape structure (Nagendra et al., 2013).

Landsat imagery is available for free download in several formats, and the launch of Sentinel-2 satellites opened new opportunities for remote sensing attributed to the Multi-Spectral Instrument aboard these (Sànchez-Espinosa and Schröder, 2019). Sentinel-2 is widely used because the data are freely available, have global coverage and are multi-temporal with a relatively high revisit time of five days making it feasible to assess wetlands (Kaplan and Avdan, 2018; Chasmer et al., 2020; Fekri et al., 2021). These land observation satellites can be used to monitor land use and cover change (LUCC) over time, indicative of spatial and temporal changes in anthropogenic activity and the associated impacts on wetlands (Wu et al., 2017). Several studies had indicated that the NIR and Red Edge bands are the most useful when classifying wetland types as well as the Shortwave Infrared (SWIR) bands that are sensitive to soil and vegetation moisture (Amani et al., 2018; Mahdavi et al., 2018). For accurate interpretation of imagery, is it vital to have in-situ data on species distribution and wetland characteristics to maximize the use of the remote sensing data (Nagendra et al., 2013).

In addition to optical analysis, remotely sensed Synthetic Aperature Radar (SAR) observations are widely used for monitoring wetlands, especially in subtropical regions, as they can collect images through clouds, rain or fog and the images are sensitive to biomass and flooded vegetation structures (Hong et al., 2015; Kaplan and Avdan, 2018). SAR can also be used to estimate surface soil moisture (Chasmer et al., 2020). Supplementing single-polarization SAR with optical imagery and/or dual or quad polarization data can improve the detection of water (Chasmer et al., 2020). As with optical sensors, SAR sensors have their own constraints, but combining optical and SAR images can help to compensate for individual limitations (Fekri et al., 2021).

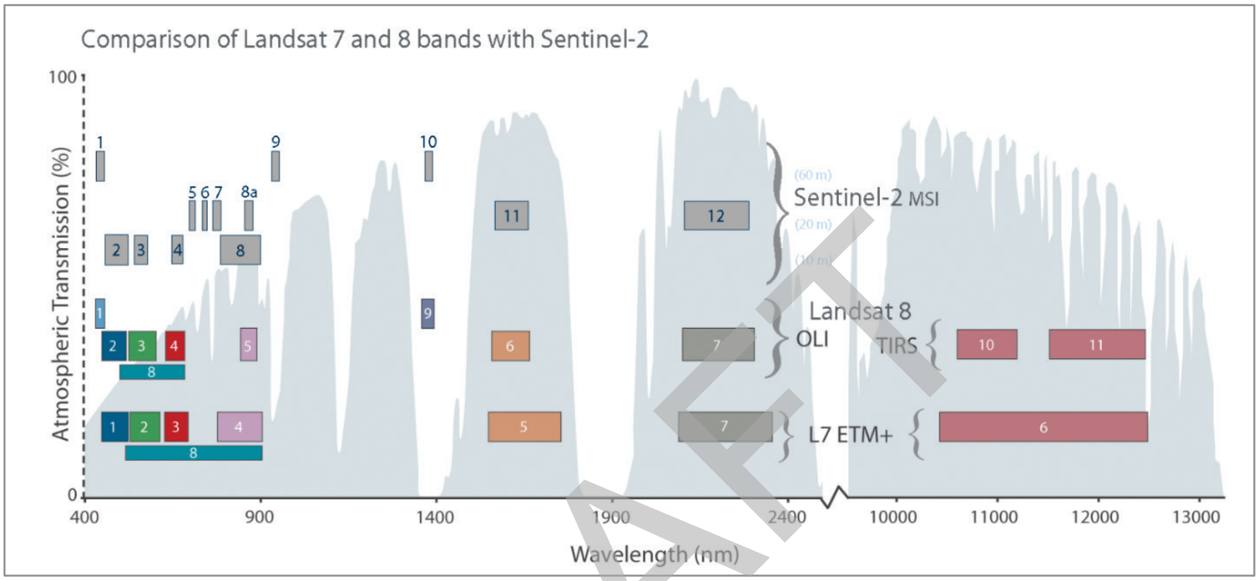

Figure 2-2. Comparing Landsat-7 and 8 bands and Sentinel-2. Figure from NASA.gov (https://landsat.gsfc.nasa.gov/wp-content/uploads/2015/06/Landsat.v.Sentinel-2.png).

One specific parameter important to understanding existing processes in a wetland is Land Surface Temperature (LST), which is closely related to the surface energy balance and the water status of land cover, which is dependent on the radiative energy that the land absorbs (Kaplan and Avdan, 2017). LST data has the potential to serve as a global indicator of the status of wetlands and changes in their hydrological and evapotranspiration regimes, which are often linked to land use and cover changes (Muro et al., 2018). However, there are multiple challenges associated with LST data as it has high temporal variability and largely depends on the right climatic and light conditions for accuracy (Muro et al., 2018).

In terms of analyzing the size of wetlands and wetland fragmentation, the Centre for Land Use Education and Research (CLEAR) created a GIS tool that can be used to identify six types of wetland fragments: patch, edge, perforated, small core, medium core, and large core (Kundu et al., 2021). Connectivity is crucial to understanding the movement of material to downstream environments and can potentially be used as an indicator of resilience versus sensitivity to watershed impacts. Connectivity can be estimated by using high point density lidar data and UAV structure from motion (Chasmer et al., 2020). Comparing in-situ measurements with changes in the absorption, reflection, emission, and transmission of energy detected by remote sensing technology through time can be used to assess changes in wetland class and extent (Chasmer et al., 2020).

Table 2-1. Conventional vegetation indicates and equations for Landsat 8 (L8) cited in a review by Chaves et. al., 2020. Asterisk's ** indicate indices commonly utilized by USGS.

Spectral Vegetation Indices	Index Equation	Landsat 8 Equation	Application
Normalized Difference Vegetation Index (NDVI) (Rouse Jr. et al., 1974)**	$\frac{NIR - Red}{NIR + Red}$	$\frac{B5 - B4}{B5 + B4}$	Produces a linear index more sensitive in areas of sparse vegetation compared to Ratio Vegetation Index.
SAVI (Huete, 1988) **	$\left(\frac{NIR - Red}{NIR + Red + L}\right) * (1 + L)$	$\frac{(B5 - B4)}{(B5 + B4 + 0.5)} \times 1.5$	Attempts to minimize soil brightness influences using a soil-brightness correction factor. Typically used in arid regions where vegetative cover is low.
NDWI (McFeeters 1996) **	$\frac{Green - NIR}{Green + NIR}$	$\frac{B3 - B5}{B3 + B5}$	Estimates the leaf water content at canopy level.
EVI (Huete et al., 2002) **	$G * \left(\frac{NIR - Red}{NIR + C1 * Red - C2 * B + L}\right)$	$2.5 * \frac{(B5 - B4)}{(B5 + 6 \times B4 - 7.5 \times B2 + 1)}$	Used in regions of high biomass, where it is possible for NDVI values to become saturated. Attempts to reduce atmospheric influences.
MNDWI (Xu 2006)	$\frac{Green - MIR}{Green + MIR}$	$\frac{B5 - B6}{B5 + B6}$	Estimates the leaf water content at canopy level.
EVI-2 (Jiang et al., 2008)	$G * \left(\frac{NIR - Red}{NIR + 2.4 * Red + 1}\right)$	$\frac{2.5 \times (B5 - B4)}{(B5 + 6 \times B4 + 2.4 + 1)}$	Designed to enhance the vegetation signal with improved sensitivity in high-biomass regions. De-couples canopy background signal and reduces atmospheric influences.
MSAVI (Qi et al., 1994)	$\left(\frac{NIR - Red}{(NIR + Red + L) \times (1 + L)}\right)$	$\frac{2 \times B5 + 1 - \sqrt{2 \times B5 + 1})^2 - 8 \times (B5 - B4)}{2}$	Designed to substitute NDVI and NDRE when there is low vegetation or lack of chlorophyll in the plants.
OSAVI (Rondeaux et al., 1996)	$\left(\frac{NIR - Red}{(NIR + Red + 0.16)}\right)$	$\frac{1.16 \times B5 - B4}{B5 + B4 + 0.16}$	A soil-adjusted index that can accommodate greater variability due to high soil background values.

Table 2-2. Conventional vegetation indices and equations for Sentinel-2 (S2) cited in a review by Chaves et al., 2020. Asterisk's ** indicate indices commonly utilized by USGS.

Spectral Vegetation Indices	Index Equation	Sentinel-2 Equation	Application
Normalized Difference Vegetation Index (NDVI) (Rouse Jr. et al., 1974)**	$\frac{NIR - Red}{NIR + Red}$	$\frac{B8 - B4}{B8 + B4}$	Produces a linear index more sensitive in areas of sparse vegetation compared to Ratio Vegetation Index.
SAVI (Huete, 1988) **	$\left(\frac{NIR - Red}{NIR + Red + L}\right) * (1 + L)$	$\frac{(B8 - B4)}{(B8 + B4 + 0.5)} \times 1.5$	Attempts to minimize soil brightness influences using a soil-brightness correction factor. Typically used in arid regions where vegetative cover is low.
NDWI (McFeeters 1996) **	$\frac{Green - NIR}{Green + NIR}$	$\frac{B3 - B8}{B3 + B8}$	Estimates the leaf water content at canopy level.
EVI (Huete et al., 2002) **	$G * \left(\frac{NIR - Red}{NIR + C1 * Red - C2 * B + L}\right)$	$\frac{2.5 \times (B8 - B4)}{(B8 + 6 \times B4 - 7.5 \times B2 + 1)}$	Used in regions of high biomass, where it is possible for NDVI values to become saturated. Attempts to reduce atmospheric influences.
MNDWI (Xu 2006)	$\frac{Green - MIR}{Green + MIR}$	$\frac{B8 - B11}{B8 + B11}$	Estimates the leaf water content at canopy level.
EVI-2 (Jiang et al., 2008)	$G * \left(\frac{NIR - Red}{NIR + 2.4 * Red + 1}\right)$	$\frac{2.5 \times (B8 - B4)}{(B8 + 6 \times B4 + 2.4 \times B2 + 1)}$	Designed to enhance the vegetation signal with improved sensitivity in high-biomass regions. De-couples canopy background signal and reduces atmospheric influences.
MSAVI (Qi et al., 1994)	$\left(\frac{NIR - Red}{(NIR + Red + L) \times (1 + L)}\right)$	$\frac{2 \times B8 + 1 - \sqrt{2 \times B8 + 1)^2 - 8 \times (B8 - B5)}}{2}$	Designed to substitute NDVI and NDRE when there is low vegetation or lack of chlorophyll in the plants.
OSAVI (Rondeaux et al., 1996)	$\left(\frac{NIR - Red}{(NIR + Red + 0.16)}\right)$	$\frac{1.16 \times B8 - B4}{B8 + B4 + 0.16}$	A soil-adjusted index that can accommodate greater variability due to high soil background values.

2.9 Review Conclusions

Wetlands are some of the most productive and economically valuable ecosystems that provide important ecological functions to surrounding habitats and numerous ecosystem services beneficial to humans. Wetland processes and the ecological role that they fill in the natural system provide vital services that help to sustain and enhance our existence. The ecosystem services that wetlands provide include numerous benefits like recreation, coastal protection, habitat provision, nutrient cycling, pollutant removal, floodwater storage, carbon sequestration, and they also provide habitat for many ecologically and commercially important species (Davila and Bohlen 2021; McClellan et al., 2017; McLaughlin et al., 2013; Widney et al., 2018; Lane and D'Amico 2010; An and Verhoeven, 2019).

Despite the numerous ecosystem services provided by wetlands, anthropogenic impacts have significantly reduced historic wetland cover and have disturbed natural water flow and connectivity throughout the landscape (Davila and Bohlen, 2021). Increased pressures exerted on wetlands from urbanization and development can disrupt wetland and upland connectivity, altering the natural movements of organisms and flow of materials that positively influence overall ecosystem biodiversity and function (Mitchell et al., 2013). Connectivity is altered through human activities that lead to habitat fragmentation and loss, which can significantly disrupt important biotic factors like pollinator movement and seed dispersal, both of which are important for the replenishment and survival of plant species throughout the landscape. Additionally, changes in land cover and land use can impact the hydrologic regime causing changes in depth, duration, and/or spatial extent of flooding leading to a decrease in habitat quality and species composition at multiple trophic levels (McLaughlin et al., 2013). Disruption of the natural flow of water and loss of wetland habitats can also impact the regulation of air quality, water quality, erosion, natural hazards, and even the climate (McLaughlin et al., 2013).

This holds true for both large and small, isolated wetlands. Studies have indicated that larger wetlands are more ecologically important in terms of ecosystem services compared to fragmented and smaller wetlands, largely due to their sensitivity to urbanization (Mitchell et al., 2015; Talukdar et al., 2021). Land use alterations and urbanization can impact both small and large wetlands differently, depending on the various biotic and abiotic variables affected, but regardless of the magnitude of the change a loss of wetlands will ultimately result in a loss of vital ecosystems services. The important thing to remember is that every wetland provides significant ecosystem services to the surrounding communities despite their size (Lane and Autry, 2016).

It has become plainly obvious that the conversion and destruction of wetlands are posing serious issues in Florida. The good news is that there are major federal, state, county, and local efforts to restore wetlands and their hydrologic functions - efforts that are having an impact. In addition, rapid advances in remote sensing technology can help resource managers evaluate the state of their wetlands efficiently and cost-effectively to provide accurate and up to date assessments for planning that will help preserve wetlands and the services they provide.

The following analyses will provide an overview of the impacts that urbanization, land use change, and water usage are had on the wetlands of Orange County over the past 32 years and set forth recommendations that can be adopted to help preserve and restore the wetlands that remain.

3 MAPPING WETLAND COVER AND LAND USE CHANGES OVER TIME

The State of the Wetlands Assessment used a multifaceted approach to assess the extent of wetlands within the County, changes in acreage and distribution of specific wetland habitat types, and the effectiveness of Orange County's wetland ordinance over the last 35 years. Effort consisted of data compilation and review, aerial photointerpretation (API) of wetlands countywide, and identifying changes in urbanization and population growth. Changes in urban land use and population growth were assessed to explore conceptual scenarios of potential wetland impacts based on projected future population growth. The sections below describe the data collection process and analysis, results, and insight gained on how these factors have influenced wetlands within Orange County since the adoption of Article X in 1987.

3.1 Wetland and Land Use Data Compilation

The wetland mapping and inventory effort focused on capturing wetland changes in overall areal extent by general wetland habitat type from 1990, several years after Orange County's Wetland Ordinance implementation (1987), through 2022. To highlight decadal shifts in wetland coverage and type, a total of four years were mapped - 1990, 2000, 2010, and 2022. The selection of the exact mapping years was based on the availability of best data sources, including imagery and ancillary land use/land cover (LULC) datasets. A comprehensive data compilation and review task was completed which included data collection, processing, and organizing of aerial imagery, LULC, U.S. Census, and other spatially relevant datasets within Orange County. A summary of the available spatial data is provided in **Table 3-1**. Data sources used for identifying wetland mapping years and the full list of available spatial data is provided in **Appendix A**.

The selection of the four temporal periods was based on the availability of coincident datasets. Priority was given to the years where U.S. Decennial census data, LULC datasets, and high-resolution aerial photography were concurrent and available. For mapping purposes, a data inventory evenly distributed across the timeline of interest is typically ideal for change analyses applications. The objective was to capture the wetland inventory, at minimum, corresponding to a representative year in each of the 1990, 2000, 2010, and then 2020 decades.

Table 3-1. Data sources used for identifying wetland mapping years.

Source	Data Type	Link to Data Source
Florida Geographic Data Library (FGDL)	U.S. Census Decennial Block Groups, U.S. Census American Community Survey (ACS), Florida Department of Environmental Protection LULC	www.fgdl.org/
U.S. Census Bureau	U.S. Census Decennial Block Group	www.data.census.gov/cedsci/
St Johns River Water Management District (SJRWMD)	LULC	www.sjrwmd.com/data/gis/
South Florida Water Management District (SFWMD)	LULC	www.sfwmd.gov/science-data/gis
FDOT Aerial Photo Look Up System (APLUS)	Orthophotos	www.fdotewp1.dot.state.fl.us/AerialPhotoLookUpSystem/
Land Boundary Information System (LABINS)	Orthophotos	www.labins.org/
USGS EarthExplorer	Orthophotos	www.earthexplorer.usgs.gov/
USGS National Land Cover Database (NLCD)	LULC	www.usgs.gov/centers/eros/science/national-land-cover-database
FWC Cooperative Land Cover (CLC) Map	LULC	www.myfwc.com/research/gis/regional-projects/cooperative-land-cover/
FWS National Wetlands Inventory (NWI)	LULC	www.fws.gov/program/national-wetlands-inventory
County Green PLACE Locations	LULC	Provided by OCEPD
County Natural Communities	LULC	Provided by OCEPD

Based on the criteria described above the pertinent data was compiled, with consensus of the County, for 1990, 2000, 2010 and 2022. The inclusion of 2022, instead of 2020, was predicated by the fact that new high-resolution imagery of Orange County was taken in 2022 and available throughout the county. In addition, utilizing the 2022 imagery would provide the most up to date wetland assessment, which was vital to provide the best recommendations for the current wetland ordinance review process for OCEPD. The data that was available for mapping and compiled to represent each of the four years is outlined below.

1

1990

- 1990 Decennial Census
- 1990 SJRWMD and SFWMD LULC
- 1984 and 1990 black and white imagery, 1995 CIR imagery

2

2000

- 2000 Decennial Census
- 1999 SJRWMD and SFWMD LULC
- 1999 CIR Imagery

3

2010

- 2010 Decennial Census
- 2009 SJRWMD and SFWMD LULC
- 2010 CIR and true color imagery

4

2022

- 2020 Decennial Census
- 2014-2016 SJRWMD and 2017-2019 SFWMD LULC
- 2022 true color imagery

To determine the change over time in urban or developed land use in Orange County from 1990 to 2022, LULC datasets from the SJRWMD and SFWMD were used. These merged, state-wide LULC datasets were obtained from the Florida Geographic Data Library for 1990 and 2016. The 1990 dataset contains land use/land cover features for 1990 that were classified using FLUCCS and were photo interpreted from 1:24,000 color-infrared digital orthophoto quarter quadrangles. It was compiled by the University of Florida GeoPlan Center. The LULC layers used to represent the most recent conditions were compiled by FDEP in the Cooperative Land Cover dataset using data from SJRWMD (2013-2016) and from SFWMD (2017-2019), which were the most recent datasets available for this analysis.

The total acreage for each of these categories was summed to represent developed urban land cover in Orange County for 1990 and 2016, and the changes that took place between 1990 and

2016 were calculated. This analysis was included in this report to address the change in the urban landscape that can be referenced in relation to the wetland change.

3.2 Wetland and Land Use Data Analysis

3.2.1 Aerial Photo Interpretation

A comprehensive effort was conducted to develop a consistent aerial photo interpretation method for mapping all wetlands in the Orange County. API is the process of using aerial imagery, either black and white, true color, or color infrared, depending on availability, to visually interpret and digitally map wetland features using GIS technology. This method has been well established since the 1970s (or earlier in specific settings) and is currently still used by academia and public agencies, including the Florida water management districts, to develop land use land cover classifications across the landscape.

Based on the best available data described in Section 3.1., wetland coverage development for Orange County focused on four years: 1990, 2000, 2010, and current (2022). To reduce the magnitude of the mapping effort, it was determined that AEI would leverage, as much as possible, previously developed land use and land cover features from SJRWMD and SFWMD datasets to synthesize wetland mapping. Wetland land cover classifications were extracted from the WMD FLUCCS layers for each of the four mapping years and put through a verification process using the corresponding imagery and additional LULC datasets to determine accuracy.

The other sources of wetland GIS data that were used to help determine wetland type included the National Wetland Inventory (NWI) and the Florida Cooperative Land Cover (CLC) datasets; however, the WMD FLUCCS datasets were found to be the most detailed and accurate based on initial assessments using the aerial imagery. The NWI is a national dataset that is compiled using a 1:24,000 or larger scale, so smaller wetlands are not mapped, and although it is updated every two years only some areas of the country are included in each update. For instance, parts of the NWI data for Orange County was based on 1984 imagery while other areas of the county were updated using 2010 imagery, which is why the NWI was only used to help verify the accuracy of the WMD data when the data was temporally aligned. The CLC dataset was also used to check the accuracy of the WMD FLUCCS data prior to the API process in the areas where the SJRWMD and SFWMD data overlapped, since it is an amalgamation of FLUCCS data from all the WMDs in Florida.

During the API process any wetlands that were difficult to classify due to resolution or clarity issues in the imagery were cross checked with the NWI and CLC datasets to ensure the highest level of accuracy was achieved. The aerial imagery and WMD FLUCCS data sources that were used during the API process for the selected wetland years are presented in **Table 3-2**.

Table 3-2. Aerial imagery, source, LULC years and sources for Orange County wetland mapping.

Wetland Year	Aerial Imagery Year	Aerial Imagery Source	Land Use Year and Source
1990	1984, 1990, and 1995	USGS Earth Explorer	1995 SJRWMD and SFWMD LULC
2000	1999	USGS Earth Explorer	1990 AEI's API Wetlands
2010	2009	USGS Earth Explorer	2000 AEI's API Wetlands
2022	2022	Orange County	2015/2016 SJRWMD and 2017/2019 SFWMD LULC

A grid system extending slightly beyond the borders of Orange County, composed of 0.7-mile square grids, was used to ensure that all wetlands in the county were mapped and to keep track of the mapping progress for each API year (**Figure 3-1**).

The best available georeferenced aerial imagery was chosen for the selected wetland years. As shown in Table 3-2 three sources of aerial imagery were utilized for the 1990 wetland mapping base layer. This was due to the lack of complete aerial imagery covering Orange County for that year. During the API process, the 1990 imagery was used as the primary source for digitizing wetland features, supplemented with 1984 and then 1995 aerial imagery in areas where the 1990 imagery was deficient (**Figure 3-2**). Aerial imagery for the 2000, 2010 and 2022 APIs came from single data sources and had georeferenced imagery tiles covering the entire County.

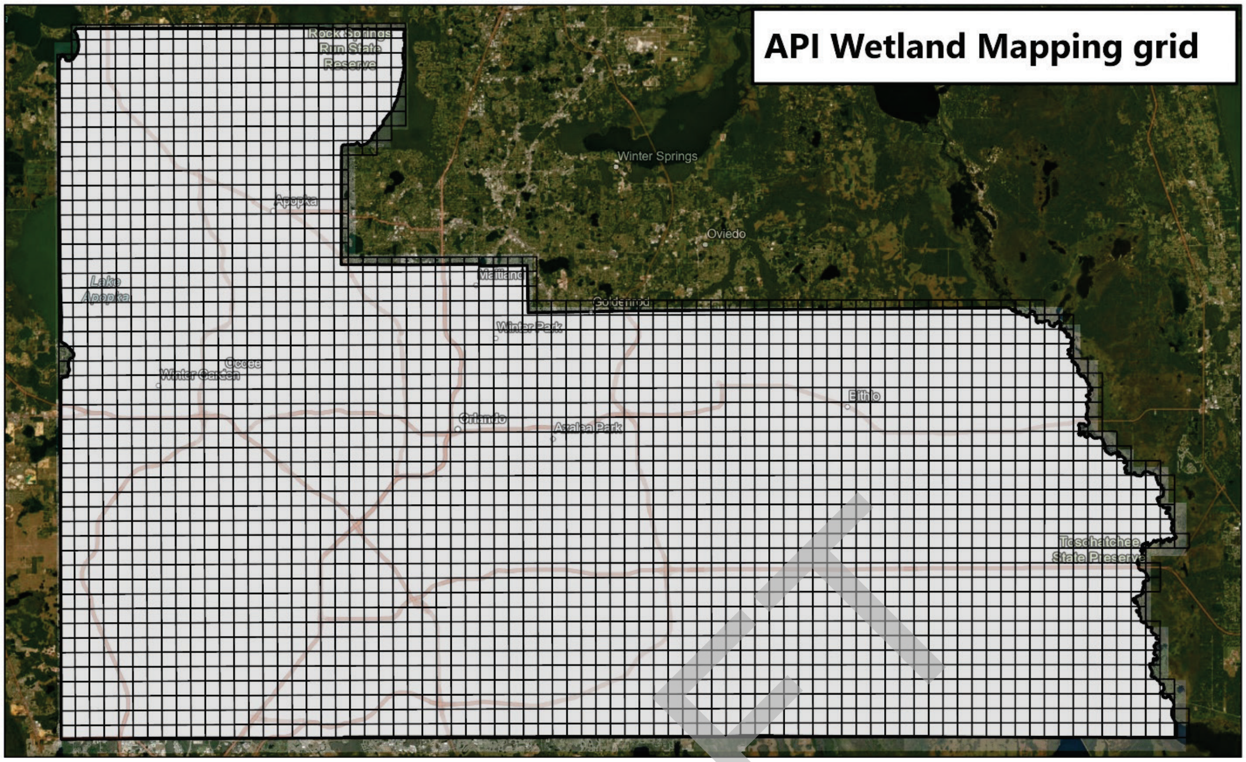

Figure 3-1. Developed API wetland mapping grid (0.7 x 0.7 miles) covering Orange County for quality assurance and tracking.

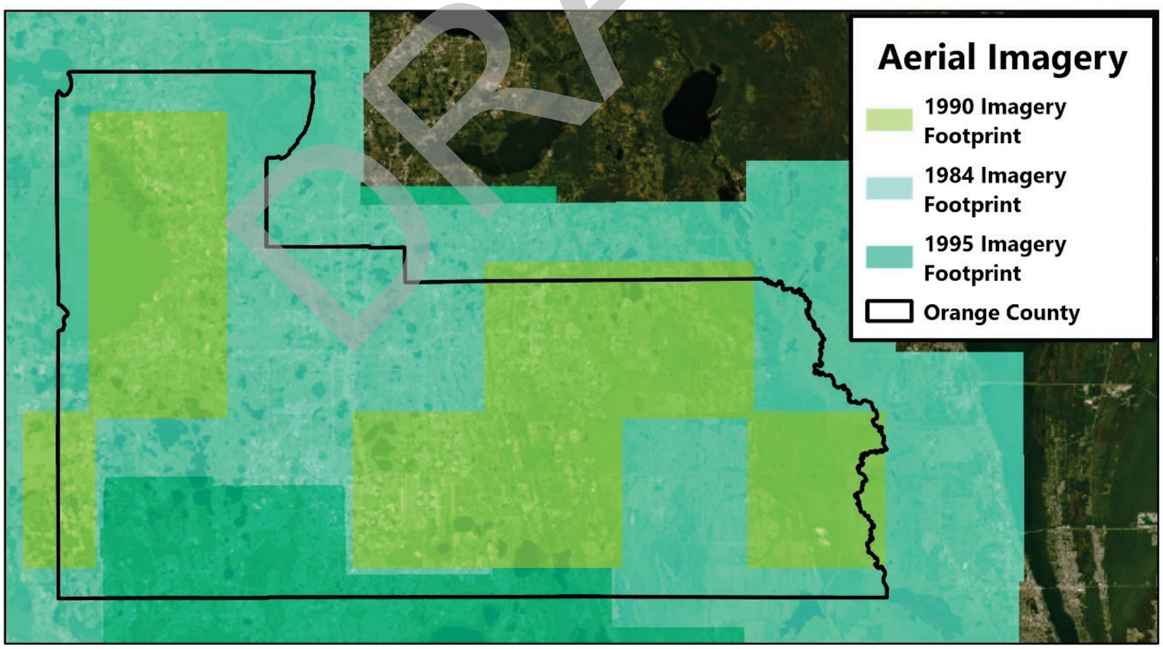

Figure 3-2. Aerial imagery footprints used during the 1990 wetland API process for Orange County by year of aerial photography dataset.

The imagery for each year of the API process differed both in format and resolution with the highest quality color imagery available for the 2010 and 2022 wetland mapping years, which makes the classification of the wetland types during the API process more precise. The three different sources of imagery available for the 1990 API are shown in **Figure 3-3** at a resolution of 1:2,500. These three imagery datasets, when compared to those available for 2000, 2010, and 2022, had the lowest spatial resolution which made the classification of the different wetland types more challenging, especially when trying to differentiate between the various types of forest classifications. In addition, the 1990 imagery was taken using black and white photography, while the 1984 and 2005 imagery was color-infrared with limited color-resolution.

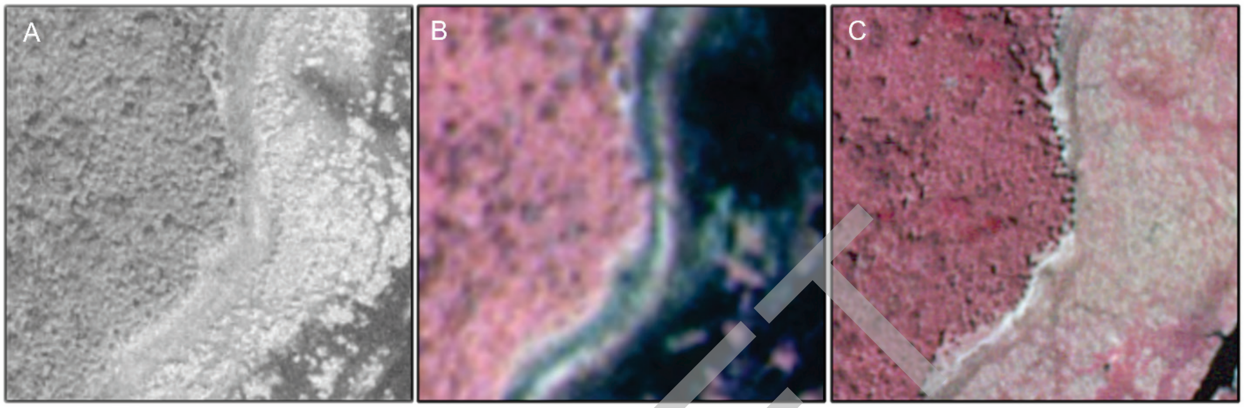

Figure 3-3. Imagery used for the 1990 API showing differences in resolution and color attributes for (A) 1990, (B), 1984 and (C) 2005 at a scale of 1:2,500.

A comparison of the 1990 imagery and the color-infrared imagery available for the APIs conducted in 2000, 2010 and 2022 is shown below at a scale of 1:2,500 (**Figure 3-4**) and 1:5,000 (**Figure 3-5**). Some obvious interpretations emerge when reviewing the imagery, such as the land cover on the left side of the images is forested land while the right side consists of marshes, inundated marshland, and waterways. However, discerning the type of forest cover was more difficult in 1990 and 2000 imagery compared to the images available for the 2010 and 2022 APIs, which have much higher resolution and color clarity and clearly show cabbage palm (classified as "other wetlands" in the API process) as the dominant forested wetland type in this area of Orange County.

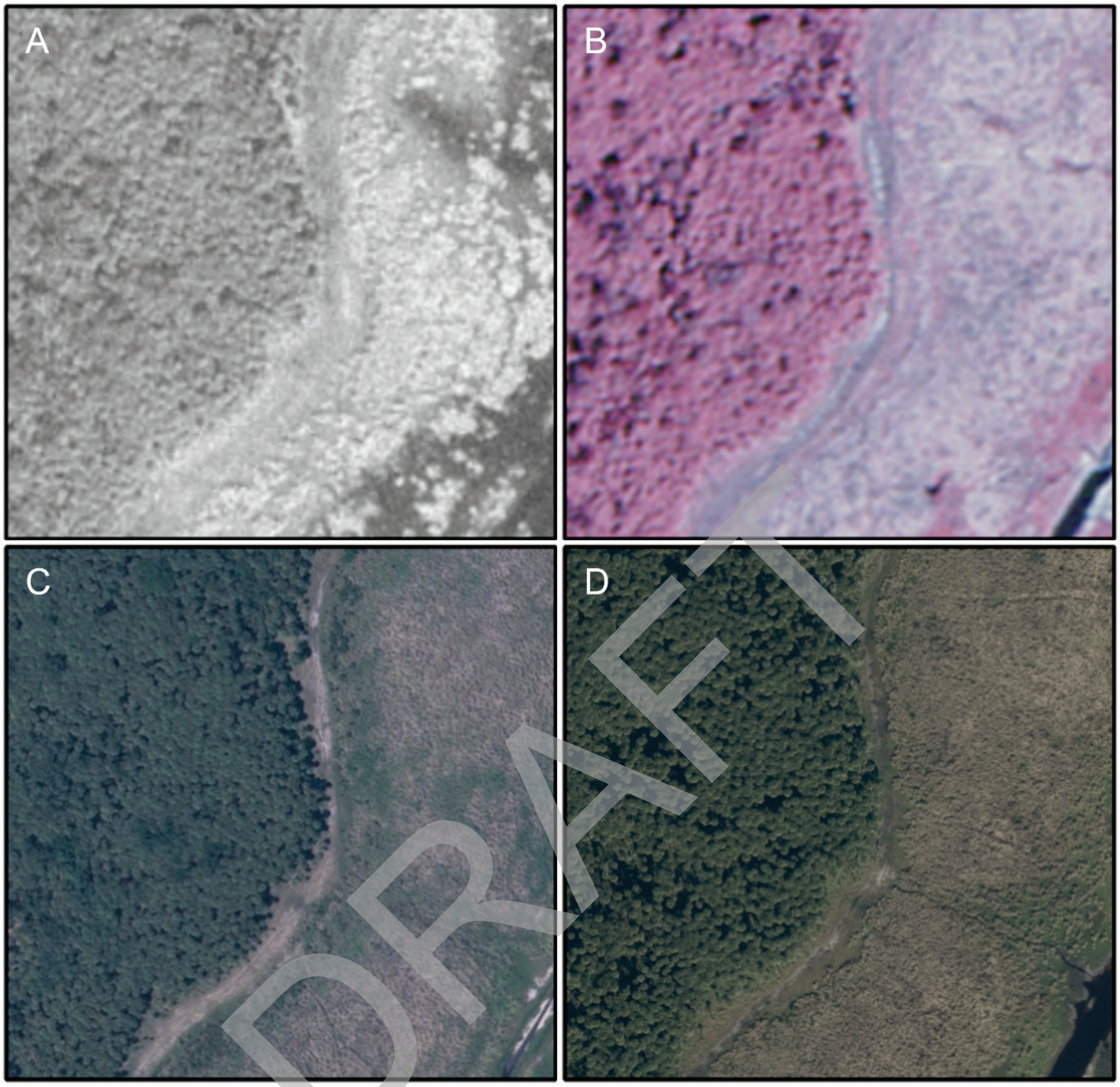

Figure 3-4. A comparison of the imagery used for the (A) 1990, (B) 2000, (C) 2010, and (D) 2022 API wetland mapping shown at a scale of 1:2,500.

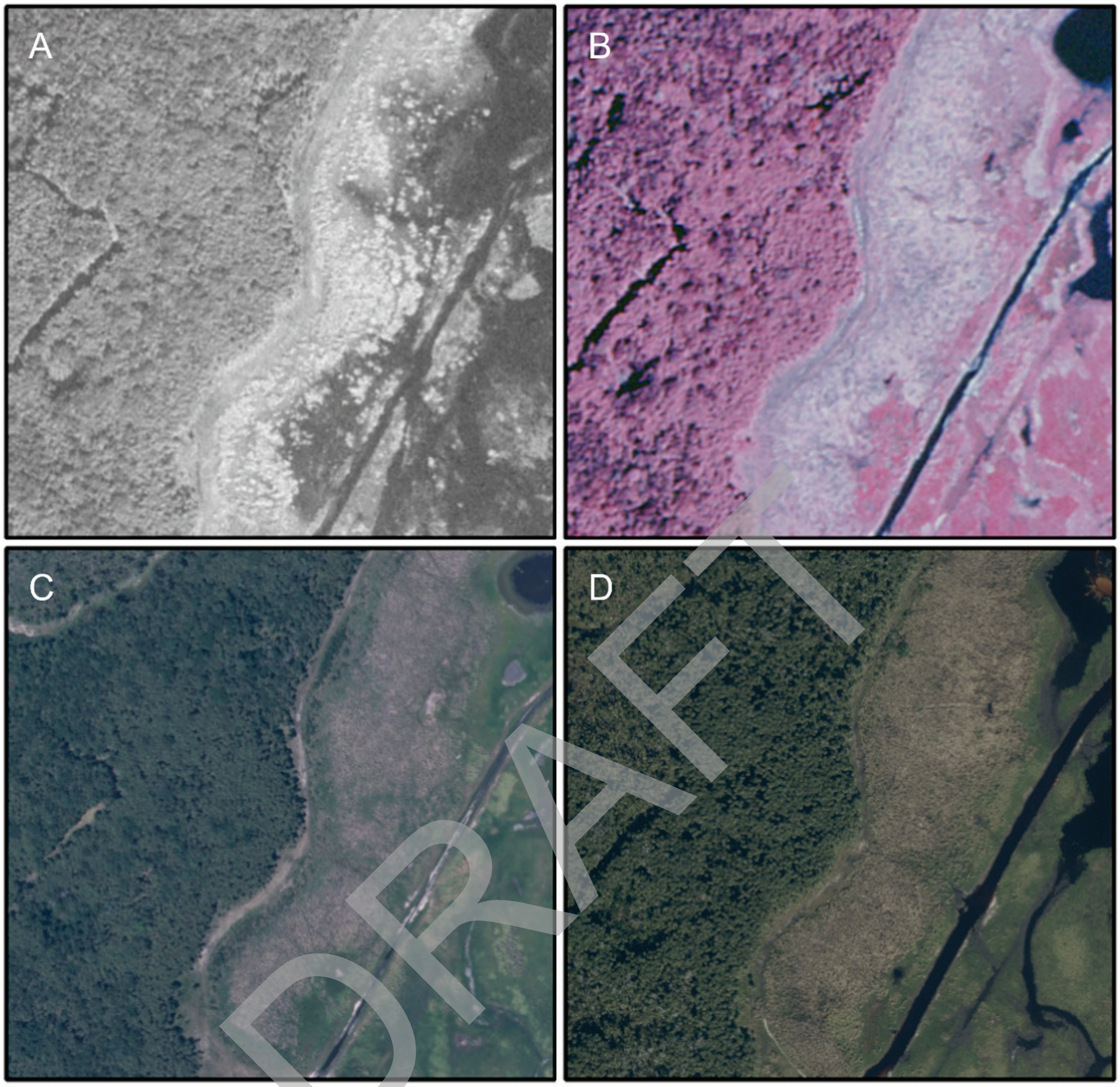

Figure 3-5. A comparison of the imagery used for the (A) 1990, (B) 2000, (C) 2010 and (D) 2022 API wetland mapping shown at a scale of 1:5,000.

Because the WMD FLUCCS datasets are generally compiled over a four-to-five-year period some of the classified wetlands were found not to be consistent with the aerial imagery, which only correspond to the wetlands present during the year they were captured. Due to these discrepancies, it was determined that the best way to accurately map the wetlands in the county was to use the 1995 WMD FLUCCS as the starting point for the 1990 wetland API and the 2015-2019 WMD FLUCCS for the base of the 2022 wetland API.

The API process started with the 2022 wetland mapping using the 2022 aerial imagery received from Orange County and the merged LULC dataset consisting of the 2015-2016 St. Johns River Water Management District data and the 2017-2019 South Florida Water Management District data. These initial LULC datasets were overlayed onto the 2022 aerial imagery and then modified to represent the land cover present in the 2022 aerial imagery. Both the polygon boundaries and land cover classifications were modified when justified by photo interpretation. In addition, wetlands that were identified during the API and not present in the initial LULC datasets were digitized and added, while wetlands no longer in existence in 2022 were deleted from the new 2022 wetland dataset.

After completing the API process for 2022, the 1990 API was conducted under the same methodology using the best available aerial imagery from that period and the 1995 LULC data obtained from the water management districts (see **Table 3-2**). After completion of the 1990 API, the resulting feature class was then used as the LULC base layer for the 2000 API process. Subsequently the completed 2000 API was used as the initial layer for the 2010 wetland mapping efforts. Using the API results from the previous period assured that the same methods were followed to provide consistency and reduce bias between the datasets. This method also alleviated any inconsistencies that resulted from the multi-year mapping efforts undertaken by the WMD's. Any mapping discrepancies that were encountered were cross-checked with the FLUCCS, CLC, and NWI datasets coincident with the aerial imagery to ensure accuracy.

Each layer was mapped individually based on the imagery and the wetland boundaries present during that year. This results in wetland areas (polygons) that may exist from one API year to the next which have different shapes and areas, even in wetlands that persisted from 1990 to 2022. This can be seen in **Figure 3-6**. This figure shows a persistent wetland area that changes in size and shape over time from 1990 (A) to 2000 (B) then to 2010 (C) and finally into 2022 (D).

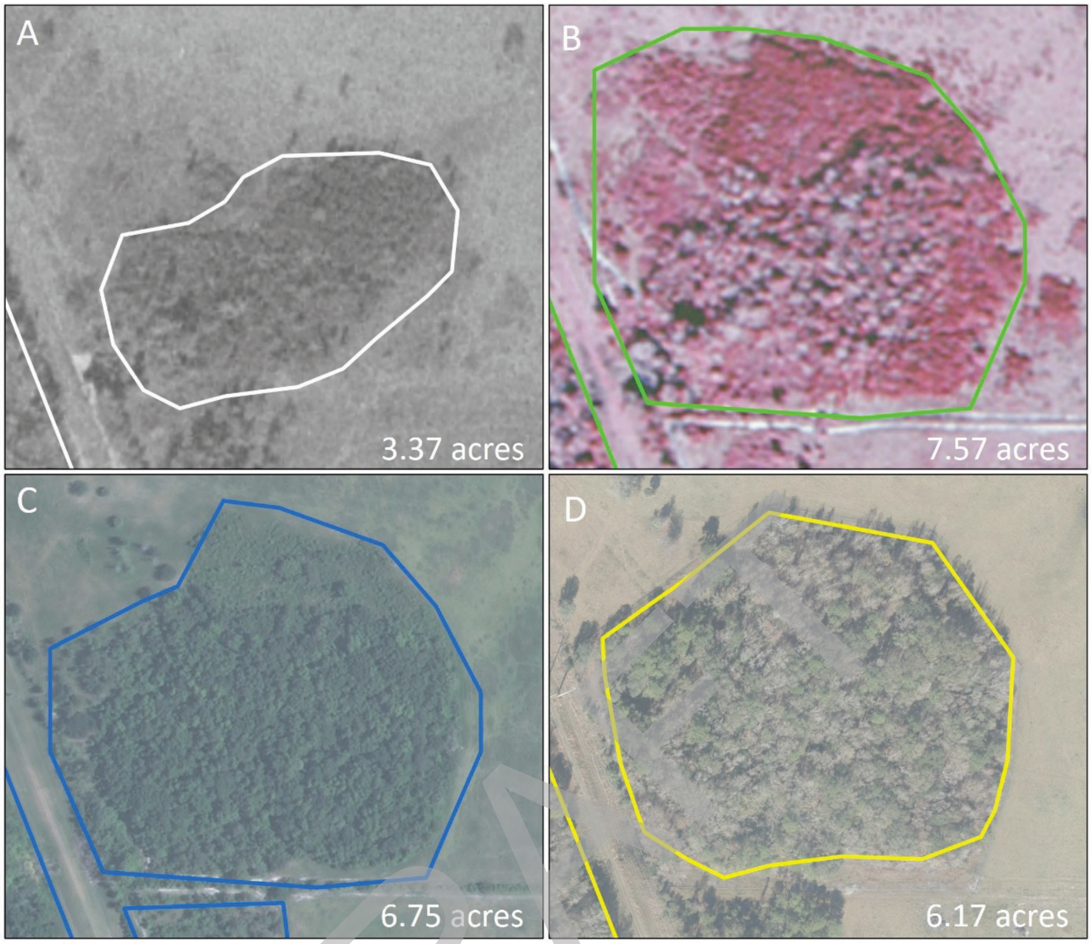

Figure 3-6. This figure shows a persistent wetland area that changes size and shape over time from 1990 (A) to 2000 (B) then to 2010 (C) and finally into 2022 (D) at a scale of 1:1,900.

After completing all four wetland datasets, each one was assessed against the other three using a multidimensional analysis to identify wetland areas that were mapped in one or more of the other years but were missing in the year being compared. All wetlands greater than ten acres identified in the multidimensional analysis were then verified against the corresponding imagery to ensure accuracy in each of the four wetland APIs. This quality assurance process ensured that wetlands lost or gained throughout time were accurately depicted. All GIS digitizing, processing, and spatial analysis completed during the API process was conducted using ESRI's ArcGIS Pro 3.0 software program for both feature class and raster datasets.

As previously described, the focus of the wetland inventory (and field assessment) was based on seven aggregated wetland classifications and a single aggregated water classification. The conversion table below (**Table 3-3**) shows the initial FLUCCS wetland codes provided in the LULC datasets and the eight aggregated API codes specified in the four final wetland layers. While **Figure 3-7** provides examples and a more detailed description of the types of wetland habitats used in this analysis, and commonly referred to throughout this report.

Table 3-3. Conversion table showing the initial FLUCCS wetland codes and the eight API codes used for analysis.

FLUCCS Codes	FLUCCS Description	API Code	API Classification
6210	Cypress	1	Cypress
6410	Freshwater marshes	2	Freshwater Marshes
6250	Hydric pine flatwoods	3	Hydric Pine Flatwoods
6172	Mixed Shrubs	4	Mixed Scrub-Shrub Wetlands
6460	Mixed scrub-shrub wetland	4	Mixed Scrub-Shrub Wetlands
6150	Lowland Hardwood Forest/Swamp	5	Mixed Wetland Forests/Hardwoods
6170	Mixed wetland hardwoods	5	Mixed Wetland Forests/Hardwoods
6300	Wetland Forested Mixed	5	Mixed Wetland Forests/Hardwoods
6110	Bay swamps	6	Other Wetlands
6181	Cabbage palm hammock	6	Other Wetlands
6182	Cabbage palm savannah	6	Other Wetlands
6200	Wetland Coniferous Forest	6	Other Wetlands
6411	Sawgrass marsh	6	Other Wetlands
6440	Emergent aquatic vegetation	6	Other Wetlands
6500	Non-vegetated Wetland	6	Other Wetlands
6430	Wet prairies	7	Wet Prairies
5100	Streams and waterways	8	Water
5120	Channelized waterways	8	Water
5200	Lakes	8	Water
5250	Marshy Lakes	8	Water
5300	Reservoirs	8	Water
5330	Reservoirs larger > 10 < 100 acres	8	Water
5500	Major Springs	8	Water

Figure 3-7. Analyzed Wetland Habitat Types

3.2.2 Population Change and Environmental Impact Analysis

Population changes and subsequent land use changes can put wetlands at risk due to increased development pressure and other disturbances such as dumping, pollution, encroachment of invasive species, and more. The relationship between changes in human population and wetland coverage was explored for the decennial censuses 1990, 2000, 2010, and 2020 to assess the impact of population growth on wetland distribution across Orange County. The Oak Ridge National Laboratory's LandScan Global (https://landscan.ornl.gov/about) estimates of the spatial distribution of individuals within Orange County was utilized to provide increased spatial resolution over the US Census Bureau's blocks. LandScan Global utilizes a range of data inputs to provide population estimates at an approximately 1 km pixel resolution from 2000 to 2020.

As there were no comparable distributed population datasets for 1990, an EPA dasymetric disaggregation method (https://github.com/USEPA/Dasymetric-Toolbox-ArcGISPro) was utilized within ESRI ArcGIS Pro to generate a 1990 population raster of Orange County. The dasymetric process identifies population density relationships between various land use types, then creates a spatial model to distribute the population counts of a census block into population estimates at a 1 km pixel resolution.

To account for the variable size and density of wetlands, a half mile grid was created across Orange County to aggregate wetlands into cells for analysis. Within ESRI ArcGIS Pro, the Union tool was used to assign wetlands to the overlapping grid cell. Then, a half mile buffer was generated for each of the grid cell grouped wetlands to be used in the estimate of proximate population density. If there were no wetlands present in the grid cell for a given year, no population counts were assigned to the grid cell. The 2022 wetlands were compared against the 2020 decennial census, which was the closest census available.

To identify potential patterns in the change in population and wetland coverage, the ESRI ArcGIS Pro Optimized Hot Spot and Multivariate Clustering tools were run on the countywide grid cells. The Hot Spot analysis was used to determine the statistically significant clusters of increasing or decreasing human populations and wetland coverage. The Multivariate Clustering tool utilizes an unsupervised K-Means clustering method to identify which groupings of the grid cells will result in the least variability between the clusters. Eight clusters were selected after utilizing the Multivariate Clustering tool's cluster recommendation feature.

The tool was run using the following as inputs:

- Population counts within a half mile of wetlands in 1990, 2000, 2010, 2020.
- Change in population counts within a half mile of wetlands from 1990 to 2000, 2000 to 2010, and 2010 to 2020.
- Percent areal coverage of wetland by grid cells in 1990, 2000, 2010, 2022.
- Change in percent areal coverage of wetlands by grid cell from 1990 to 2000, 2000 to 2010, and 2010 to 2020.

Future human population growth impacts on the wetlands of Orange County were assessed using the University of Wisconsin-Madison Spatial Analysis for Conservation and Sustainability

(SILVIS) lab forecasted housing unit change from 2020 to 2050 (http://silvis.forest.wisc.edu/). The SILVIS housing unit change forecast is based on a combination of historical trends in population and housing from the US Census between 1940 and 2000 as well as generalized national and regional trends that were observed between 2000 and 2010 when the model was created. It is assumed the change in housing units is a proxy for population change. The SILVIS data was forecasted at the census block scale and was compared against the 2022 wetlands by determining the number of housing units within a half mile buffer of a wetland and then further aggregated to the half mile grid.

3.3 Wetland and Land Use Mapping Results

This analysis focuses on the wetland API mapping that was completed by AEI for the years 1990, 2000, 2010, and 2022. The results presented here provide a series of snapshots of the change that occurred in spatial extent within each of the seven wetland habitat types from 1990 to 2000, 2000 to 2010, and 2010 to 2022. In addition, the total change in area for each of the wetland types from 1990 through 2022 is also presented along with the total combined wetland and water area for each API dataset.

The polygon feature classes resulting from the wetland aerial photo interpretation for the years 1990, 2000, 2010 and 2022 in Orange County, Florida are shown in **Figure 3-8**, **Figure 3-9**,**Figure 3-10** and **Figure 3-11**, respectively. They consist of seven wetland classifications and water, which includes lakes, reservoirs, and waterways (see Table 3-5). As stated under the methods section, each year was mapped independently because wetland features changed between each of the API years mapped, both in type and extent. The acre values shown in the tables have also been rounded to the nearest whole number which can result in slight area discrepancies not accounted for in some of the calculations.

The total acreage of each wetland type, and water, by feature class for each of the API years is shown in **Table 3-4**. The combined wetland and water land cover in Orange County increased from 1990 to 2022 by 14,405 acres. Most of this increase stemmed from a 16% increase in areas classified as water, which corresponds to an additional 10,682 acres of surface water area added in the county between 1990 to 2022.

Total wetland area, not including water, within Orange County increased from 158,959 acres in 1990 to 162,683 acres in 2022, a 2.3% increase or 3,723 acres. It is important to note, however, that the total wetland area in 2022 includes over 10,000 acres of restored freshwater marshland from the Lake Apopka restoration area that took place between 1990-2000. Without this restoration effort, which is unrelated to a wetland mitigation effort or permitting, the county would have experienced a loss of just over 4% in total wetland area from 1990 through 2022. After an increase of almost 5,000 acres from 1990 to 2000 in wetland land cover (due in large part to the restoration projects), the total area of wetlands in Orange County stayed relatively stable, decreasing just over 1,200 acres from the high in 2000 through 2022 - less than a -1% change in total wetland land cover.

Table 3-4. Wetland API mapping results for the eight wetland and waterbody classes (in acres) and combined totals for the years 1990, 2000, 2010 and 2022.

Wetland Classification	1990 Acres	2000 Acres	2010 Acres	2022 Acres
Cypress	22,522	23,907	22,108	26,213
Freshwater Marshes	24,529	31,129	33,564	32,871
Hydric Pine Flatwoods	5,998	6,821	9,627	12,842
Mixed Scrub-Shrub Wetlands	19,492	18,622	21,588	16,135
Mixed Wetland Forests/Hardwoods	72,680	71,459	63,742	56,272
Other Wetlands	5,842	6,212	7,699	13,536
Wet Prairies	7,897	5,770	4,221	4,813
Water	64,268	68,370	70,849	74,949
Total Wetland Acreage without Water	158,959	163,921	162,549	162,683
Lake Apopka Restoration Area Acreage	0	7,925	9,085	10,231
Acreage Without Lake Apopka Restoration	158,959	155,996	153,464	152,452
Total Wetland Acreage with Water	223,227	232,292	233,398	237,632

The largest increase in total wetland area occurred between 1990 and 2000 when wetland land cover in the county increased by 4,962 acres. This increase was primarily due to the conversion of farmland to freshwater marshes in the north Lake Apopka restoration area, that was undertaken after the state purchased over 13,000 acres of farmland in 1999 and 2000 to cleanup and restore the lake. By 2000, over 7,900 acres were beginning the transition to marshland with an additional 2,306 acres converted between 2001 and 2022, for a total of 10,231 new acres of marshland created. When this restored marshland is removed from the equation, which was not mitigation based, the county lost just under 3,000 acres of wetland land cover in other areas of the county between 1990 and 2000, almost 5,000 acres between 1990 and 2010, and an overall wetland loss from 1990 to 2022 of 6,507 acres.

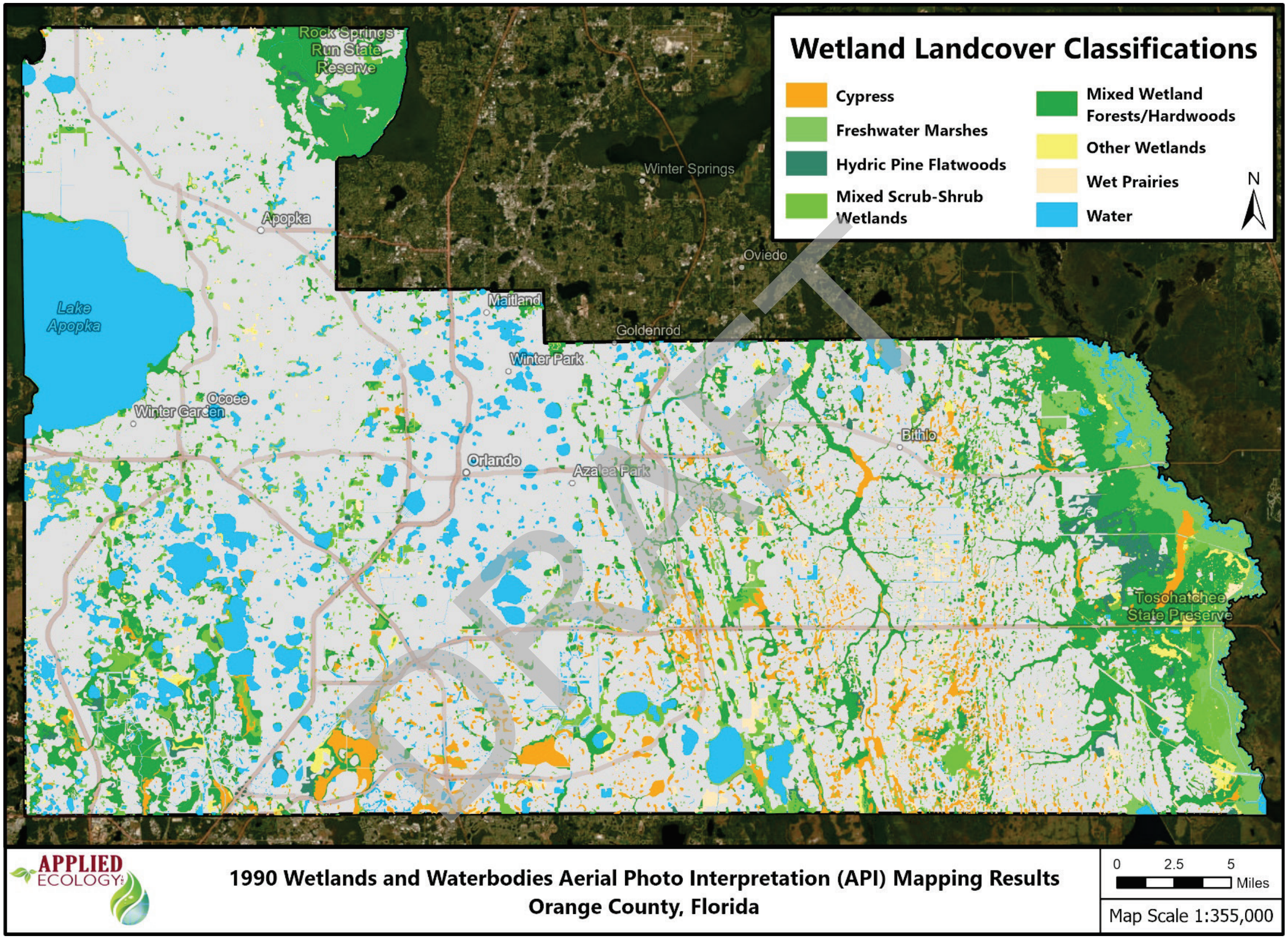

Figure 3-8. 1990 Wetland and Water Aerial Photo Interpretation mapping results for Orange County, Florida.

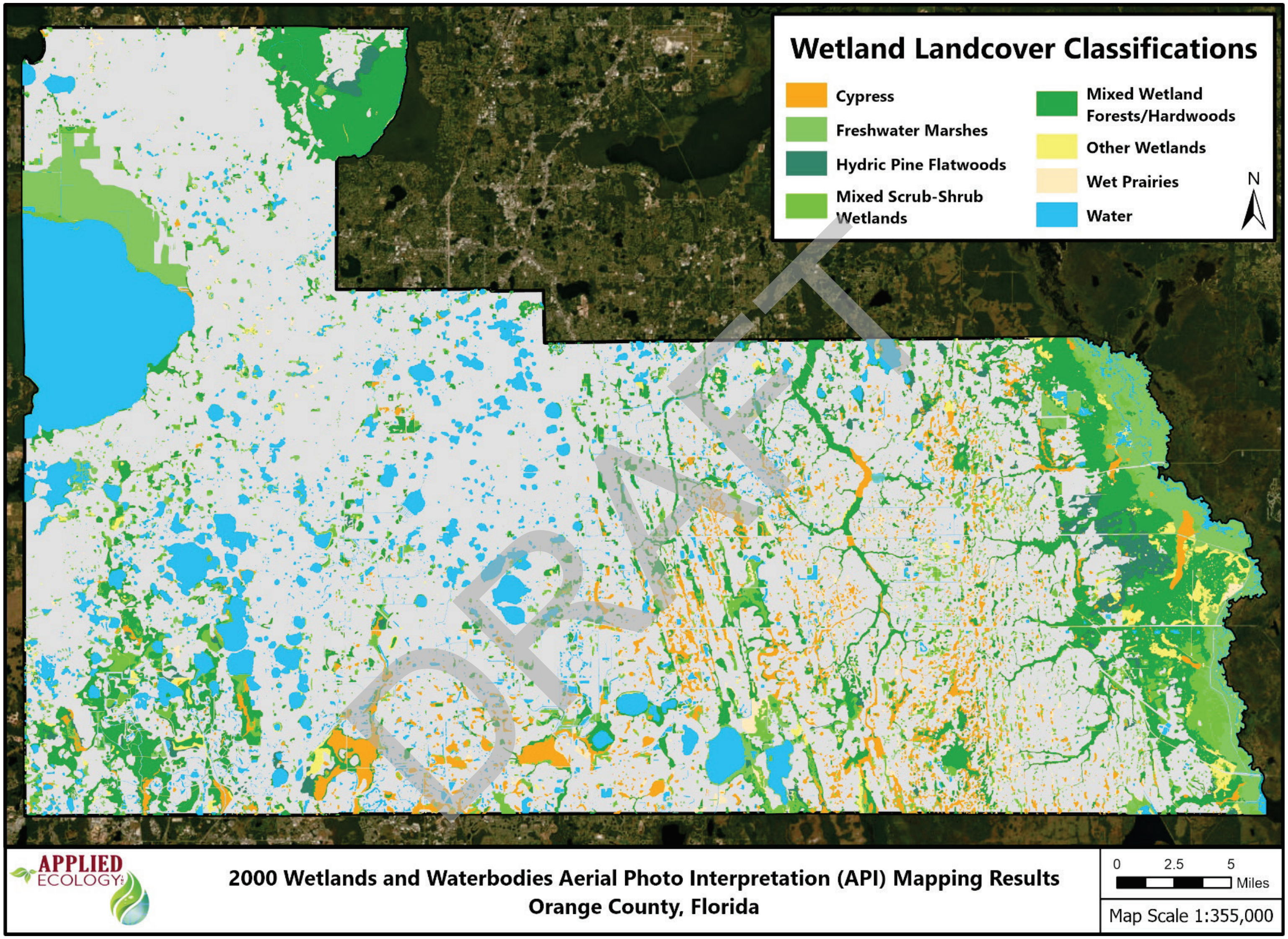

Figure 3-9. 2000 Wetland and Water Aerial Photo Interpretation mapping results for Orange County, Florida.

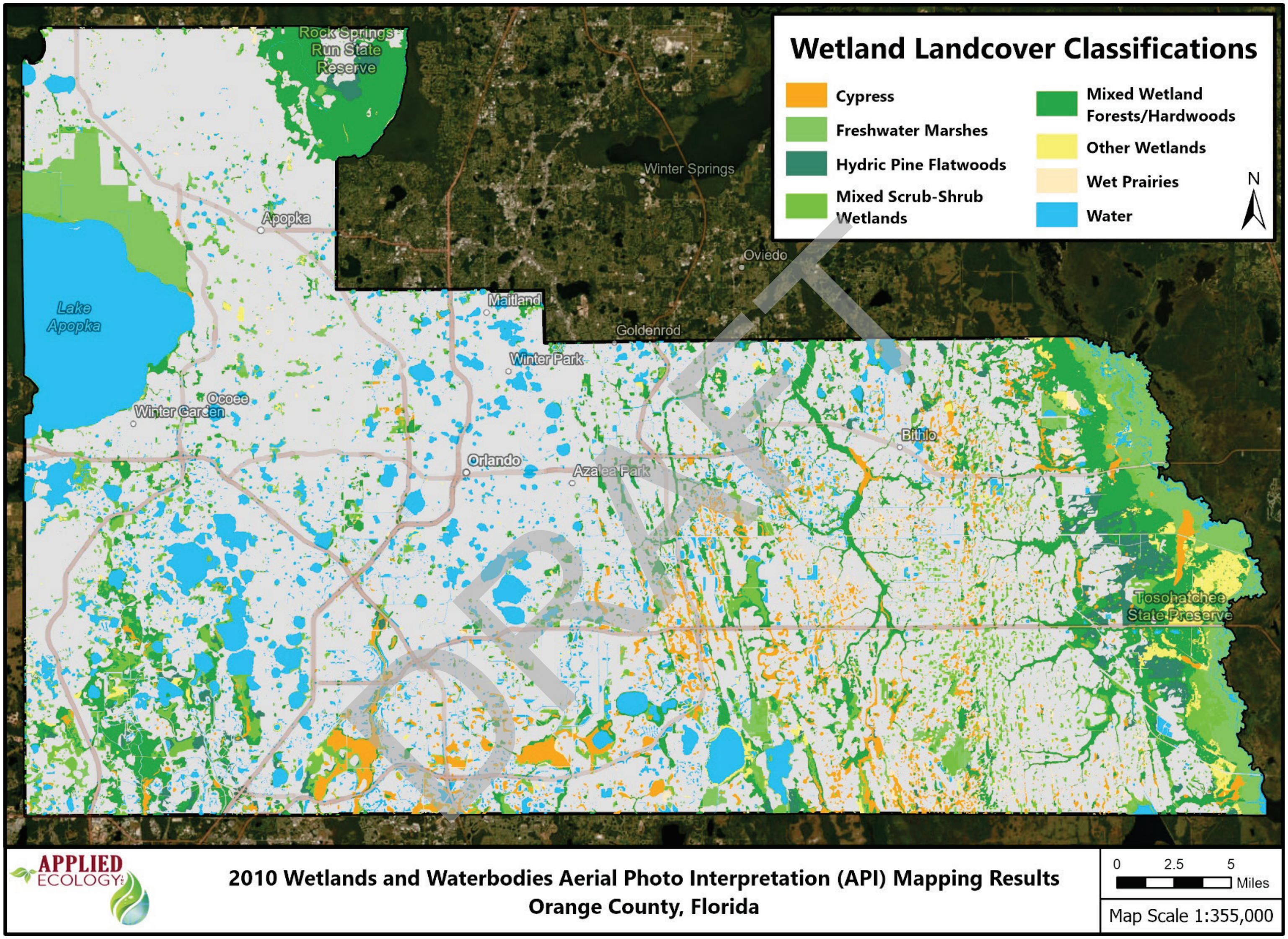

Figure 3-10. 2010 Wetland and Water Aerial Photo Interpretation mapping results for Orange County, Florida.

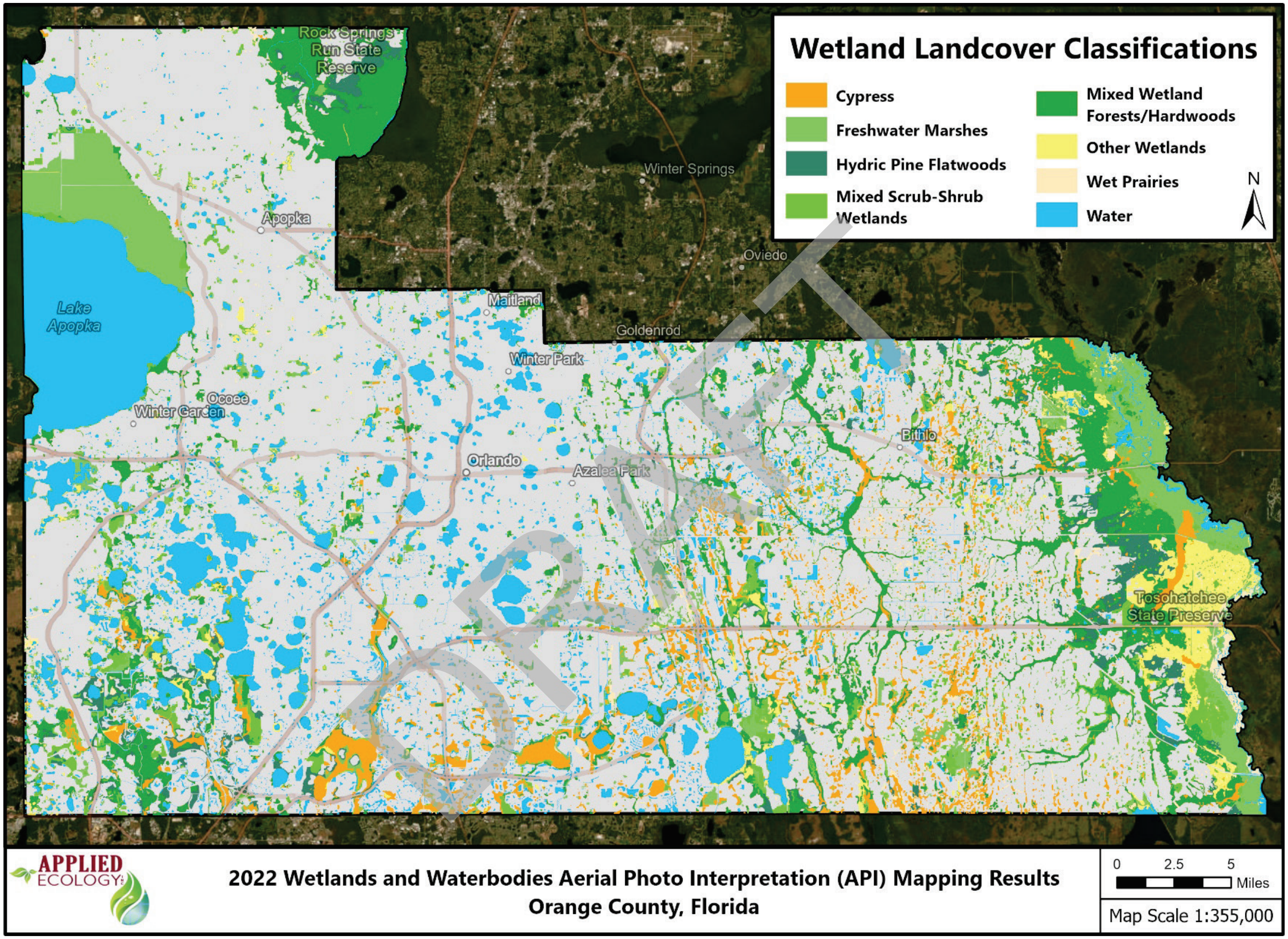

Figure 3-11. 2022 Wetland and Water Aerial Photo Interpretation mapping results for Orange County, Florida.

3.3.1 Cypress Land Cover

Cypress habitats increased by 3,691 acres between 1990 and 2022, from 22,522 acres to 26,213 acres. After increasing to over 1,300 acres from 1990 to 2000, there was a decrease of 1,799 acres by 2010. From the aerial imagery it was apparent that timber harvesting had occurred in some parts of the county during this time, however most of the cypress area lost remained as some form of wetland, either freshwater marsh or scrub-shrub wetland. This was followed by a rebound of over 4,000 acres from 2010 to 2022. Gains in cypress habitat typically occurred as freshwater marshes and scrub-shrub habitat went through successional stages, so generally a gain in cypress translates to a loss in another wetland type. This is true for most of the forested wetlands.

3.3.2 Freshwater Marsh Land Cover

Freshwater marshes covered 24,529 acres of land in Orange County in 1990 increasing to 32,871 acres by 2022. The largest area covered by freshwater marshes was in 2010 with 33,564 acres. As mentioned earlier, this increase was due to the restoration efforts taking place north of Lake Apopka. While gains were being made by Lake Apopka, some other areas of the county were losing freshwater marshes. From 1990 to 2022 a total of 1,888 acres disappeared elsewhere in the county. It is important to note, however, that some of the losses occurring may be due to marshes converting over time to another type of wetland. On the other hand, some losses were offset by gains in freshwater marsh habitat when forested wetlands were altered, reverting to marshlands.

3.3.3 Hydric Pine Flatwood Land Cover

Hydric pine flatwood habitats showed the second greatest percentage increase from 1990 to 2022 of the seven wetland types increasing from 5,998 to 12,842 acres, a gain of over 114% in total area within the county. Hydric pine flatwoods showed a steady increase since 1990, gaining over 800 acres by 2000, 3,606 acres by 2010 and over 6,800 acres through 2022. This is due in part to regrowth and focused restoration in previously harvested areas. Some of the differences, however, may be attributed to the challenges of accurately classifying and distinguishing between some of the forested habitats in 1990 and 2000 due to the quality of the aerial imagery, which was further described in Section 3.2.

3.3.4 Mixed Scrub-Shrub Wetland Land Cover

Mixed scrub-shrub wetlands covered over 19,000 acres in 1990, but by 2022, had lost a total of 3,356 acres of area in the county. After losing around 4.4% of their area from 1990 to 2000, they rebounded in 2010 adding over 2,900 acres, or 15.9% of total area. Like freshwater marsh habitat, some of this increase was due to the harvesting of cypress and other wetland forests that left mixed-scrub-shrub habitat in its place. These gains were followed by losses between 2010 and 2022 of over 5,400 acres which left the coverage of mixed scrub-shrub habitat in Orange County over 17% below the level it maintained in 1990.

3.3.5 Mixed Wetland Forest/Hardwood Land Cover

Mixed wetland forests, which also include mixed hardwoods forests, showed the largest decrease by total area of any of the wetland classes between 1990 and 2022. Declining since 1990, mixed wetland forests lost over 16,000 acres with the largest declines happening in between 2000-2010 and 2010-2022, when over 7,717 acres and 7,470 acres were lost, respectively. Overall, mixed wetland forests lost a total of 22.58% of their total coverage within the county over the last 32 years. Of course not all of this is wetland area lost, as wetlands still persist in many of the areas that were classified as mixed forests. For instance, the increase in "other wetlands" (i.e., cabbage palm habitat) within the Tosohatchee Wildlife Management Area accounts for a portion of this change.

3.3.6 Wet Prairie Land Cover

The largest areal coverage of wet prairies occurred in 1990 where 7,897 acres were mapped. By 2000, the total area of wet prairies in the county fell to 5,770 acres which corresponds to a loss of over 26%. They continued to decrease in areal coverage through 2010 dropping another 1,549 acres before expanding to cover 4,813 acres by 2022, a 14% increase from 2010. Overall, wet prairie habitats lost over 39% of their land cover in the county since 1990.

Wet prairies are some of the most difficult habitats to map using aerial photo interpretation because they can appear to be dry in periods of low rainfall. Some of the differences that occurred in wet prairie land cover may be attributed to the time that the aerial photos were taken (typically winter/dry season).

3.3.7 Other Wetlands Land Cover

The classification "other wetlands" used during the API wetland mapping process contains a mix of habitat types (see **Table 3-3**) including forested and marsh-like habitats. Out of the seven wetland classifications incorporated into the wetland mapping, the group making up other wetlands had the largest percentage increase (131%) in area, gaining 7,694 acres between 1990 and 2022. By far the greatest gains were between 2010 and 2022 when over 5,800 acres were added. As mentioned previously, much of this change occured in the Tosohatchee Wildlife Management Area along the St. Johns River as cabbage palm habitats expanded.

3.3.8 Water Land Cover

The final category mapped was the water classification, which includes all the different water types listed in **Table 3-3**. From 1990 to 2022, Orange County gained 16.6%, or 10,682 acres, of water coverage. This increase was due to several factors which include new stormwater pond construction, new golf course construction, resort development, and removal/elimination of emergent aquatic vegetation and marsh habitat in and along lake shores. Some of the differences are also attributable to fluctuating lake levels due to dry/wet periods at the times when the aerial photos were taken. In 1990 there were 2,655 water features mapped, and by

2022, there were 6,897 which is an increase of over 4,200 new water features. This corresponds to an average increase of over 3,500 new acres of water coverage every ten years.

3.3.9 1990 to 2022 Wetland and Water Land Cover Summary

From 1990 to 2022, the area of wetlands in Orange County expanded from 158,984 to 162,683 acres, an increase of 2.34%, which translates into 3,723 acres. A summary of the land cover classification changes that occurred and their magnitude is provided below in **Table 3-5**. With the addition of new water land cover, the total increase in wetlands and water amounts to 6.45%, or 14,405 acres. However, as mentioned earlier, over 10,000 acres of new freshwater marshes were restored on the north shores of Lake Apopka between 1990 and 2022. Without these restoration efforts, which were not associated with wetland mitigation practices or permitting, the County would have lost just over 6,500 acres of freshwater marsh wetlands over the same period.

Table 3-5. Total acreage of the wetland and water land cover for 1990 and 2022 with the difference in acres and percent change that occurred over the 32-year time frame.

Wetland Classification	1990 Acres	2022 Acres	Acre Difference 1990 to 2022	% Difference 1990 to 2022
Cypress	**22,522**	**26,213**	**3,691**	**16.39**
Freshwater Marshes	**24,529**	**32,871**	**8,343**	**34.01**
Hydric Pine Flatwoods	**5,998**	**12,842**	**6,844**	**114.12**
Mixed Scrub-Shrub Wetlands	**19,492**	**16,135**	**-3,356**	**-17.22**
Mixed Wetland Forests/Hardwoods	**72,680**	**56,272**	**-16,408**	**-22.58**
Other Wetlands	**5,842**	**13,536**	**7,694**	**131.68**
Wet Prairies	**7,897**	**4,813**	**-3,084**	**-39.05**
Water	**64,268**	**74,949**	**10,682**	**16.62**
Total Wetland Acreage	**158,959**	**162,683**	**3,723**	**2.34**
Total Wetland and Water Acreage	**223,227**	**237,632**	**14,405**	**6.45**
Total Wetland Acreage without Lake Apopka Restoration Area	**158,959**	**152,452**	**-6,507**	**-4.09**

In additon to the overall change between 1990 and 2022, the change in wetland acres that occurred between each of the API years was also calculated. In **Figure 3-12**, shown below, the total acreage of each wetland clasification and water are presented graphically to show the change in acreage over time between each of the four time periods - 1990 to 2000, 2000 to 2010 and 2010 to 2022. The data is also summarized in **Table 3-6**, including values for both the change in acres and the areal percentage change that occurred between each of the three time periods.

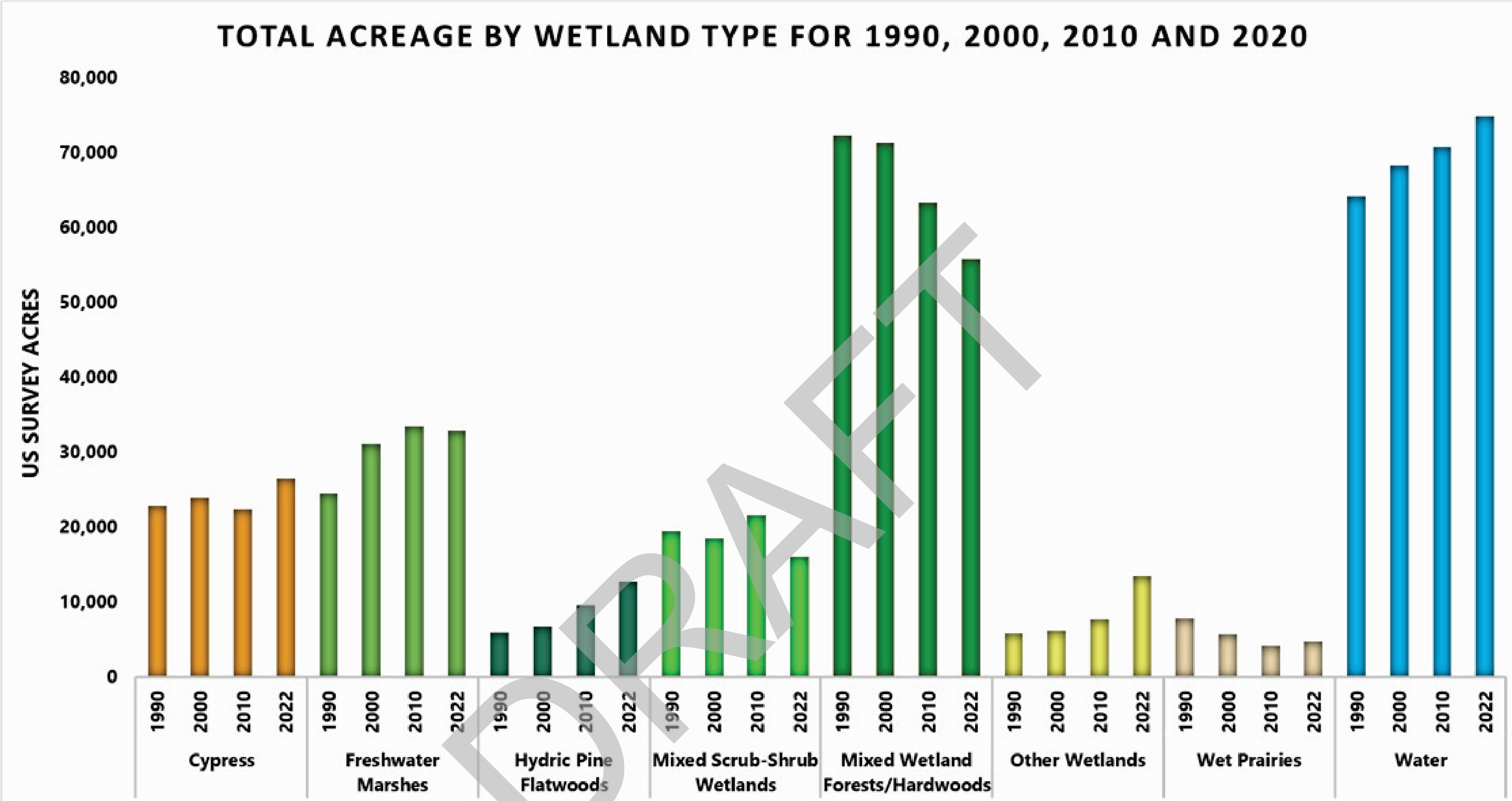

Figure 3-12. Total acreage in Orange County for the seven wetland classifications and water for each of the four years mapped in the API process – 1990, 2000, 2010, and 2022.

Table 3-6. Total acreage in Orange County of the seven wetland/water classes for the years 1990, 2000, 2010, and 2022 with change in acres and areal percent change corresponding to the 10 or 12 year period between each API year.

Wetland Classification	1990 Acres	2000 Acres	Acre Change 1990 to 2000	% Change 1990 to 2000	2010 Acres	Acre Change 2000 to 2010	% Change 2000 to 2010	2022 Acres	Acre Change 2010 to 2022	% Change 2010 to 2022
Cypress	22,522	23,907	1,385	6.15	22,108	-1,799	-7.52	26,213	4,104	18.57
Freshwater Marshes	24,529	31,129	6,601	26.91	33,564	2,435	7.82	32,871	-693	-2.06
Hydric Pine Flatwoods	5,998	6,821	824	13.74	9,627	2,806	41.13	12,842	3,215	33.39
Mixed Scrub-Shrub Wetlands	19,492	18,622	-869	-4.46	21,588	2,965	15.92	16,135	-5,452	-25.26
Mixed Wetland Forests/Hardwoods	72,680	71,459	-1,221	-1.68	63,742	-7,717	-10.80	56,272	-7,470	-11.72
Other Wetlands	5,842	6,212	369	6.32	7,699	1,488	23.95	13,536	5,837	75.80
Wet Prairies	7,897	5,770	-2,127	-26.93	4,221	-1,549	-26.85	4,813	592	14.03
Water	64,268	68,370	4,103	6.38	70,849	2,478	3.62	74,949	4,101	5.79
Total Acreage without Water	158,959	163,921			162,549			162,683		
Net Change without Water			4,962	3.12		-1,372	-0.84		133	0.08
Total Acreage with Water	223,227	232,292			233,398			237,632		
Net Change with Water			9,064	4.06		1,106	0.48		4,234	1.81

3.3.10 Field Validation of API Wetland Mapping

To verify the accuracy of API wetland mapping, field validation of the Orange County wetland API mapping was conducted on 33 publicly accessible sites that were digitized as wetlands in the final wetland feature class layers. Of the 33 sites that underwent supervised field classification, 88% (29 out of 33) were found to be the same wetland type that was assigned in the API classification, based on the predominant vegetation type. These sites were made up of wetlands that ranged from under 1 acre to over 88 acres. Two other sites were found to be a partial match which had interspersed wetlands of two different classifications. These sites were both small wetlands of less than 5 acres. One site was a 0.7-acre site and was classified in the API as mixed wetland hardwoods that was found to be a combination of mixed wetland hardwoods and cypress, with cypress making up about 50% of the land cover in the wetland. The other site, which was 4.8 acres, was classified as mixed scrub-shrub wetland in the API and was found to be interspersed with half mixed scrub-shrub wetland and half wetland forested mixed.

Of the sites that were found to be inconsistent with the API results, both were under ¾ of an acre in size. One site that was adjoining a creek was classified as freshwater marsh in the API that was field verified as upland grassland. The other site was classified as freshwater marsh in the API, however field verification found that it was about 70% mixed scrub-shrub with small areas of freshwater marsh interspersed throughout the patch.

The field validation results were in alignment with the standards set by the Federal Geographic Data Committee (FGDC) for aerial photo interpretation mapping. These standards set a 98% producer accuracy rate and an 85% wetland attribute accuracy rate. The producer accuracy rate is based on the ability of the interpreters to identify wetlands versus non-wetlands, while the wetland attribute rate is the accuracy at which the wetlands were classified by the correct wetland type.

3.3.11 Change Detection of Mapped Wetlands

Orange County covers an area of approximately 642,000 acres. Based on the API wetland mapping results, wetlands make up about 25% of the land cover within the county (**Figure 3-13**). Although there was 0.75% increase shown between 1990 and 2000, the amount of wetland coverage in Orange County has remained relatively stable from 1990 through to 2022. Over the same time frame, water land cover types have shown a steady rise, covering 10% of the county in 1990 and increasing to 11.67% in 2022. Overall, the total land cover of both wetlands and water within the County increased 2.24% between 1990 and 2022, from 34.77% to 37.01%.

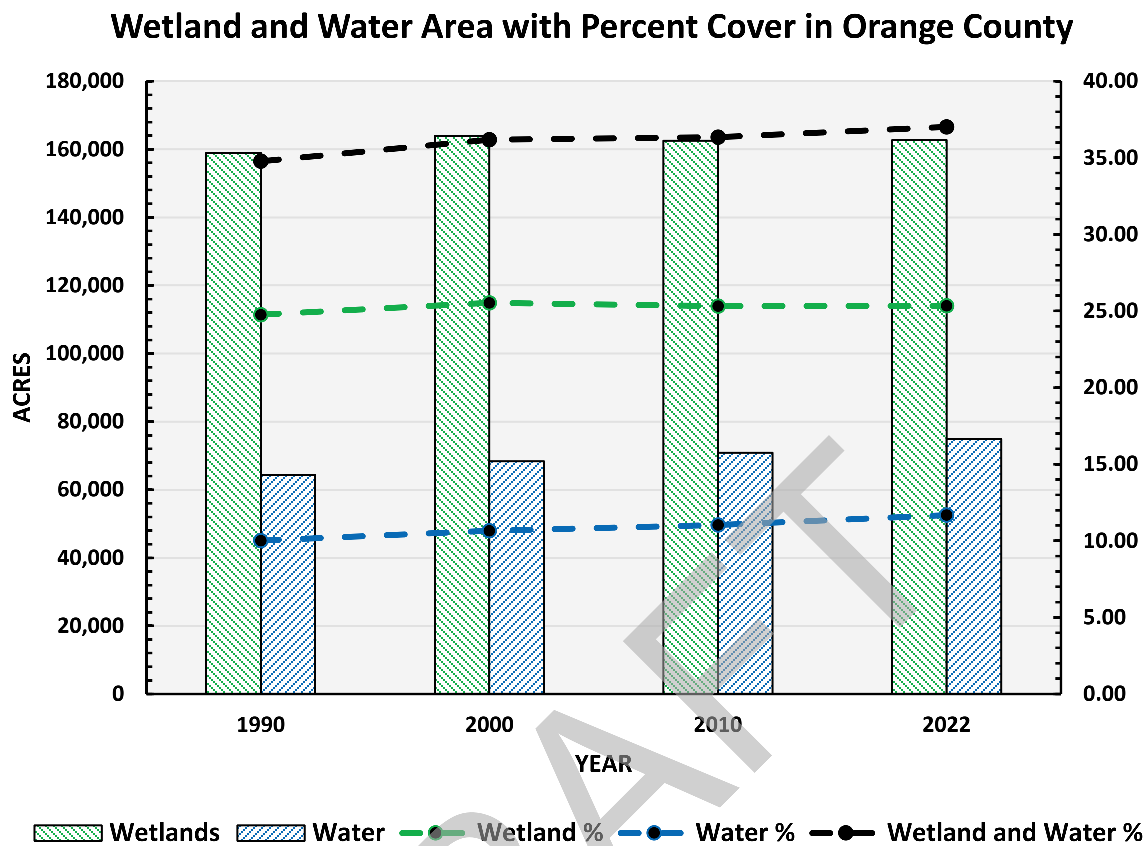

Figure 3-13. Wetland and water area (in acres) and the percentage of land they cover in Orange County.

While the total percentage of land cover for all wetlands in the County remained relatively consistent from 1990 to 2022, the percentage of coverage within the seven different wetland types did fluctuate between the four time periods. These changes are shown below in **Figure 3-14**.

In 1990, cypress wetlands made up 14.4% of the total wetland area. By 2022, they increased in area by just under 2%, making up 16.3% of total wetland area within the county. Overall, cypress wetlands were the third most prevalent wetland type in the county.

Freshwater marshes, which cover the second largest area by wetland type, also showed an increase over time. In 1990 they made up 15.4% of all wetlands in the county, and by 2010, that increased to over 20.6%. Although the area of freshwater marshes decreased slightly between 2010 and 2022, they still make up over 20% of all wetlands in Orange County. The increase of freshwater marsh area since 1990 was due to the restoration of farmland to marshland north of Lake Apopka, which in total added over 10,000 acres of new freshwater marshes in the county from 1990 to 2022.

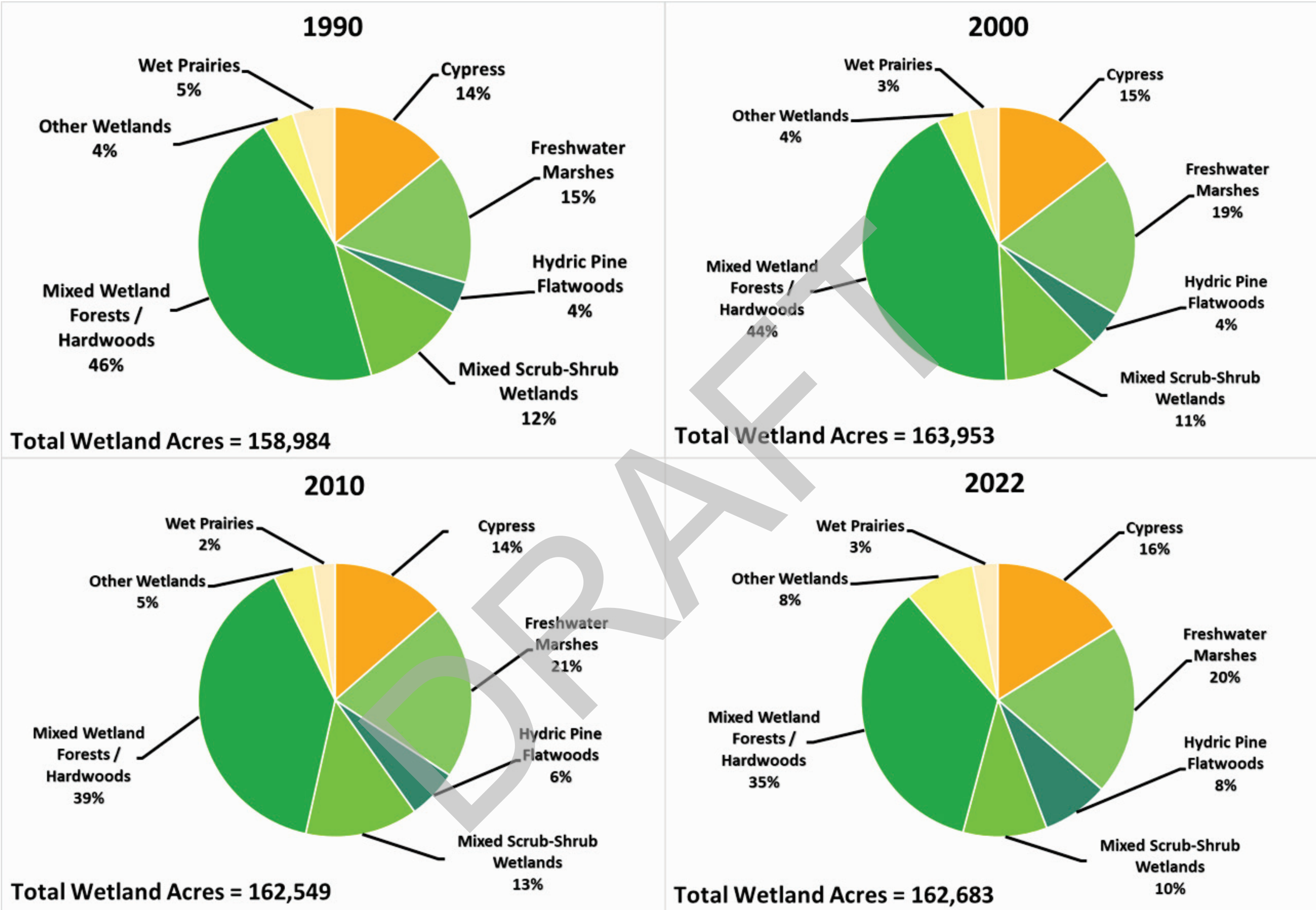

Figure 3-14. The percentage distribution of the seven wetland types that make up of the total wetland area in Orange County for the years 1990, 2000, 2010 and 2022.

Hydric pine flatwoods also showed a steady increase in areal coverage from 1990 to 2022. In 1990, they made up less than 4% of all wetlands in the county. By 2022, they more than doubled in area and currently make up 7.9% of all wetlands. The classification “other wetlands” also grew in area over the last 30 years. From 1990 to 2022, the area they covered grew from 3.7% to over 8.3%. Much of this change occurred as one wetland type, primarily mixed wetland forest, was reclassified as other wetlands in 2010 and 2022. The reason for these changes can be explained by the increase seen in cabbage palm habitat.

Of the seven wetland classifications, three of them decreased as a percentage of the total wetland coverage in Orange County between 1990 and 2022. The largest decrease occurred in the mixed wetland forests/hardwoods category, which is also the most predominant wetland type in the county. In 1990 mixed wetland forests made up about 45.5% of the total wetland area. The downward trend started in 2000 where they lost close to 2% of their area and continued through 2022, losing around 5% in each ten-year period. Currently they make up 34.4% of the current wetland land cover in Orange County.

The other two wetland types that showed a decline in area coverage since 1990 were mixed scrub-shrub wetlands and wet prairie habitats. Mixed scrub-shrub wetlands went from being 12.3% of the total wetlands in 1990 to just under 10% in 2022. However, this decline did not follow a trend. After losing just under 1% of coverage in 2000 they rebounded in 2010, increasing 2%, to 13.3% of total wetland area, before losing over 3% of their total area between 2010 and 2022.

Wet prairie habitats decreased 2% in area from 1990 to 2022. Making up almost 5% of wetland area in 1990, they lost area in 2000 and 2010 reducing the acreage of wet prairies in the county to 2.6% of total wetlands. Between 2010 and 2022 they rebounded slightly and now make up 3% of wetland area.

As mentioned previously, a large factor in preserving and increasing the total amount of wetland area in the County between 1990 and 2022 was the addition of over 10,000 acres of restored freshwater marsh habitat on the north shores of Lake Apopka. Without the addition of these restoration efforts the County would have lost over 6,500 acres of wetlands during this same period. The following **Figure 3-15** provides a comparison of the wetland area with and without the restoration of this marshland and how much of their total area each wetland class gained or lost between 1990 and 2022.

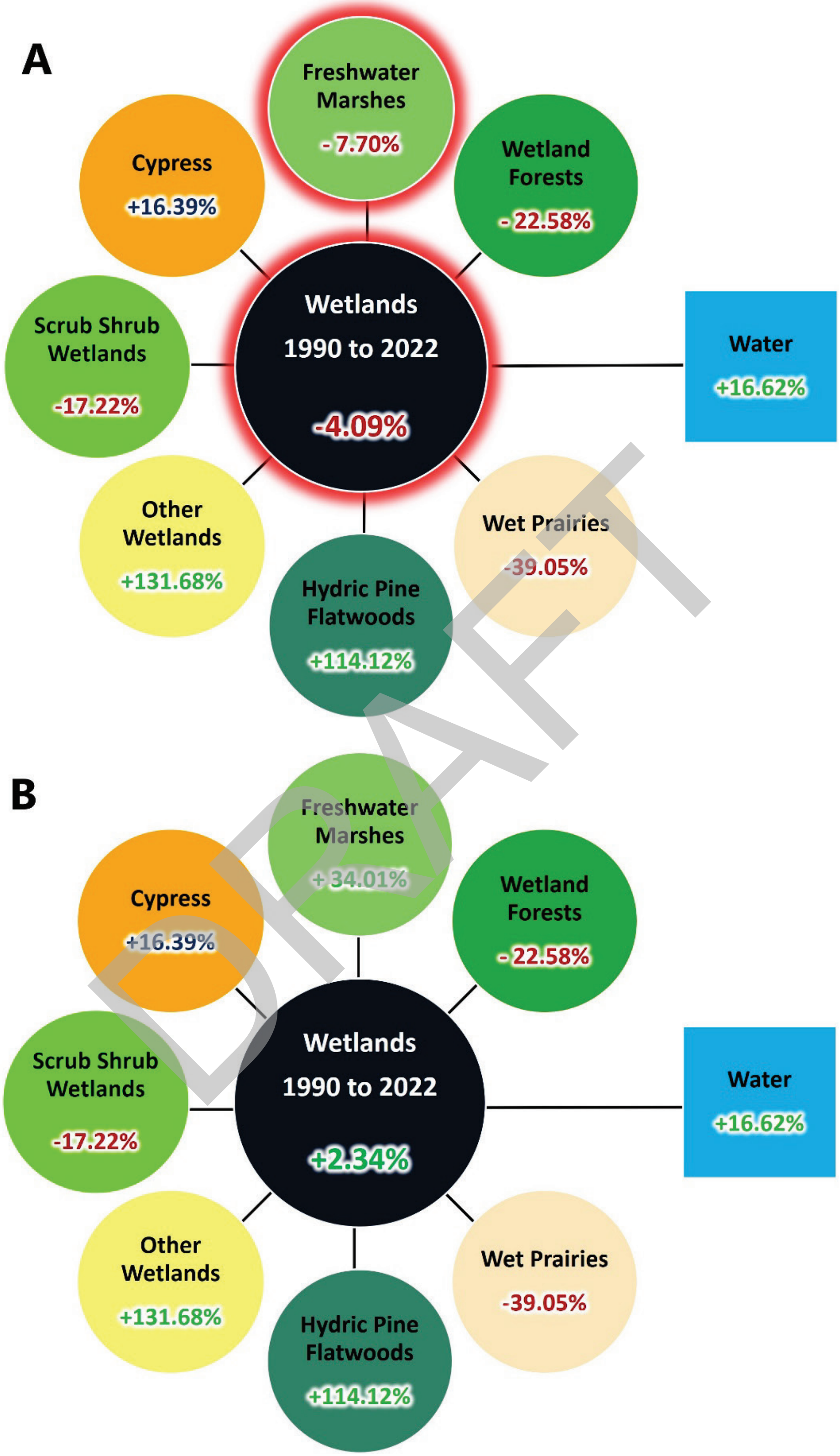

Figure 3-15. Percent gain or loss of wetland area by class from 1990 to 2022 (A) without Lake Apopka restoration area and (B) with the restoration area included.

3.3.12 Urban Land Use Changes

According to the most recent LULC data compiled by the two water management districts with jurisdiction in Orange County (SFWMD and SJRWMD), urban and built-up land use classifications (FLUCCS Level 1) have grown significantly from 1990 to 2016 as shown in **Table 3-7**. Since 1990, urban land cover within the county has increased by over 56%, from 130,331 acres in 1990 to over 204,000 in 2022 (**Figure 3-16**). Urban land cover, which now makes up 32% of the county's landscape, has grown in every category except two, extractive and industrial uses. These two land cover classifications, which made up just under 7% of urban development in 1990, lost a total of 3,701 acres combined and occupied only 2.5% of the urban landscape in 2016.

The largest increases in urban land cover were seen in the Commercial and Services, Residential High Density, and Residential Medium Density classifications which accounted for over 88% of the gains between 1990 and 2016. During this time, residential high-density developments increased by 191%, from 10,758 acres in 1990 to over 31,000 acres in 2016. The next greatest percentage increase (114%) was in the Commercial and Services sector which more than doubled in land area from 17,554 to 37,627 acres.

Table 3-7. Urban and Built Up FLUCCS level 2 classifications with total acres for 1990 and 2016, including the change in acres and percentage change from 1990 to 2016.

LULC Type	1990 Acres	2016 Acres	Change in Acres 1990 to 2016	% Increase 1990 to 2016
Commercial and Services	17,554	37,627	20,073	114.35
Extractive	1,585	1,398	-188	-11.84
Industrial	7,363	3,850	-3,513	-47.71
Institutional	5,938	10,972	5,034	84.77
Recreational	8,042	11,279	3,238	40.26
Residential High Density	10,758	31,379	20,620	191.67
Residential Low Density	19,641	23,678	4,038	20.56
Residential Medium Density	59,450	84,156	24,705	41.56
Totals	130,331	204,339	74,008	56.78
% Cover in Orange County	20	32		

Residential Medium Density land cover grew by 41%; however, it had the largest increase in total area covering 24,705 acres more in 2016 than it did in 1990. Despite these gains, it decreased as a percentage of the total urban and built-up land cover in Orange County. In 2016, Residential Medium Density made up 41% of the urban land cover, down from 45% in 1990.

Institutional, Recreational and Residential Low Density land cover classifications all increased gaining 84.77%, 40.26% and 20.56%, respectively. However, the total amount of new acres covered, 12,310 combined, was significantly lower than the 65,398 acres gained by the three other land cover classes that showed growth.

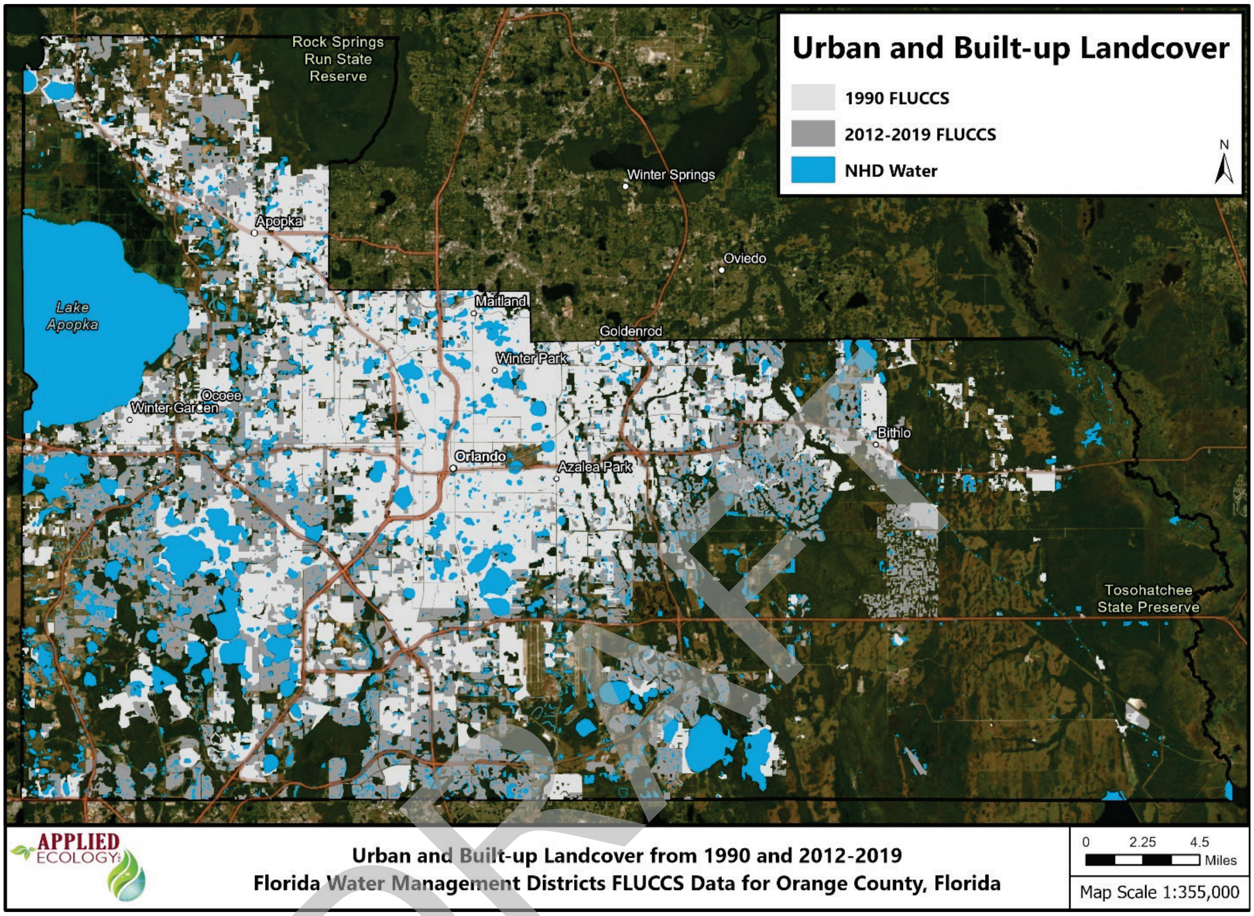

Figure 3-16. Urban and Built-up land cover in 1990 and growth though 2016 in Orange County, Florida using FLUCCS data.

3.3.13 Population Change and Environmental Impact Analysis Results

1990 Population and Wetland Conditions

The approximate distribution of wetland coverage across Orange County in 1990 is depicted in **Figure 3-17**. The largest contiguous areas of high wetland coverage were in the northwest corner of the county around the Rock Springs Run State Reserve area and east along the Tosohatchee State Preserve. The largest contiguous areas with no wetland coverage largely coincided with the urbanized areas of the cities of Orlando, Winter Park, Winter Garden, and Apopka in the western half of the county. From the southwest to the center of the county are areas of scattered high wetland coverage

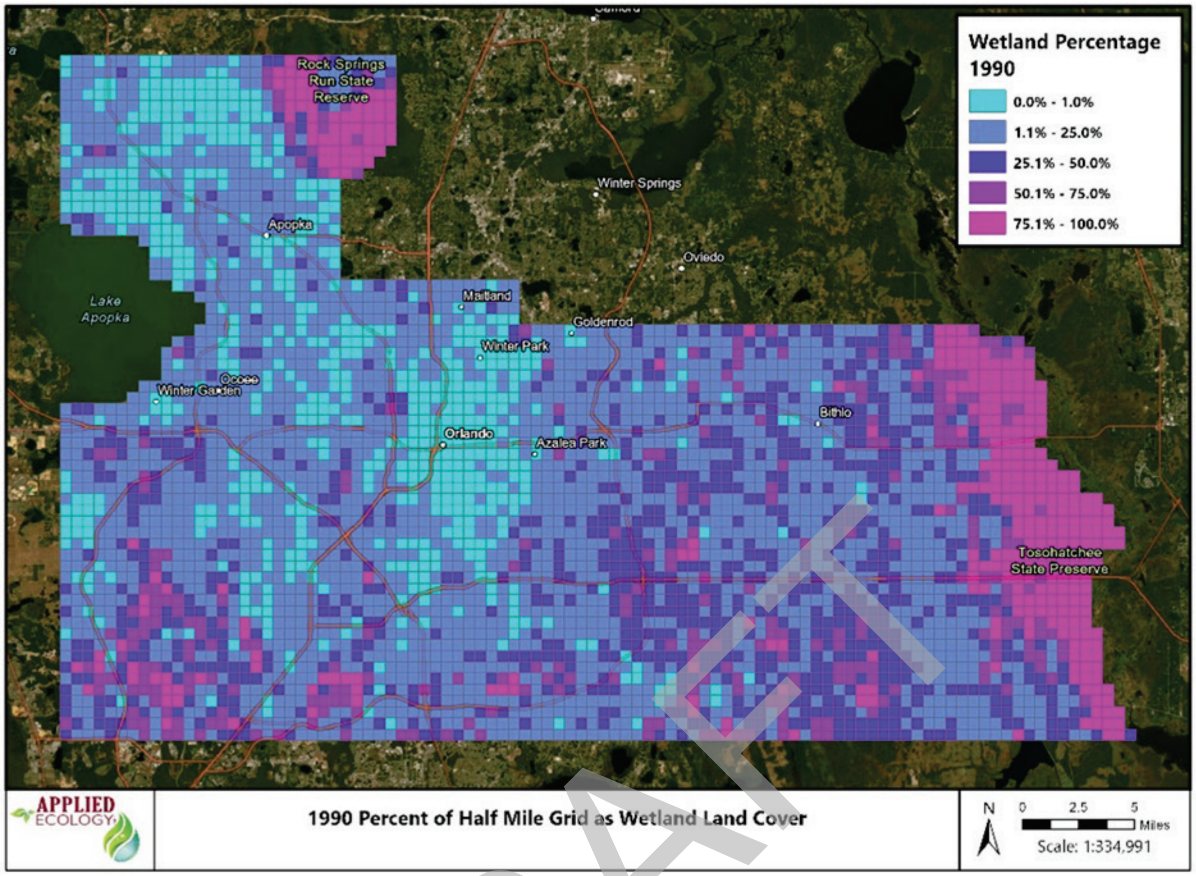

Figure 3-17. Distribution of wetland cover across Orange County, FL in 1990 as summarized by half mile grids.

The approximate distribution of population counts within a half mile of wetlands across Orange County in 1990 is depicted below in **Figure 3-18**. Locations with less than 1 person per mile within a half mile of a wetland represent situations where there are no wetlands present in the grid cell, such as the highly developed areas around the City of Orlando. It can also represent situations where there was no population within a half mile of any wetlands in the grid cell, such as within the Tosohatchee State Preserve. Overall, there is a range of population densities within a half mile of wetlands which range from high to low density.

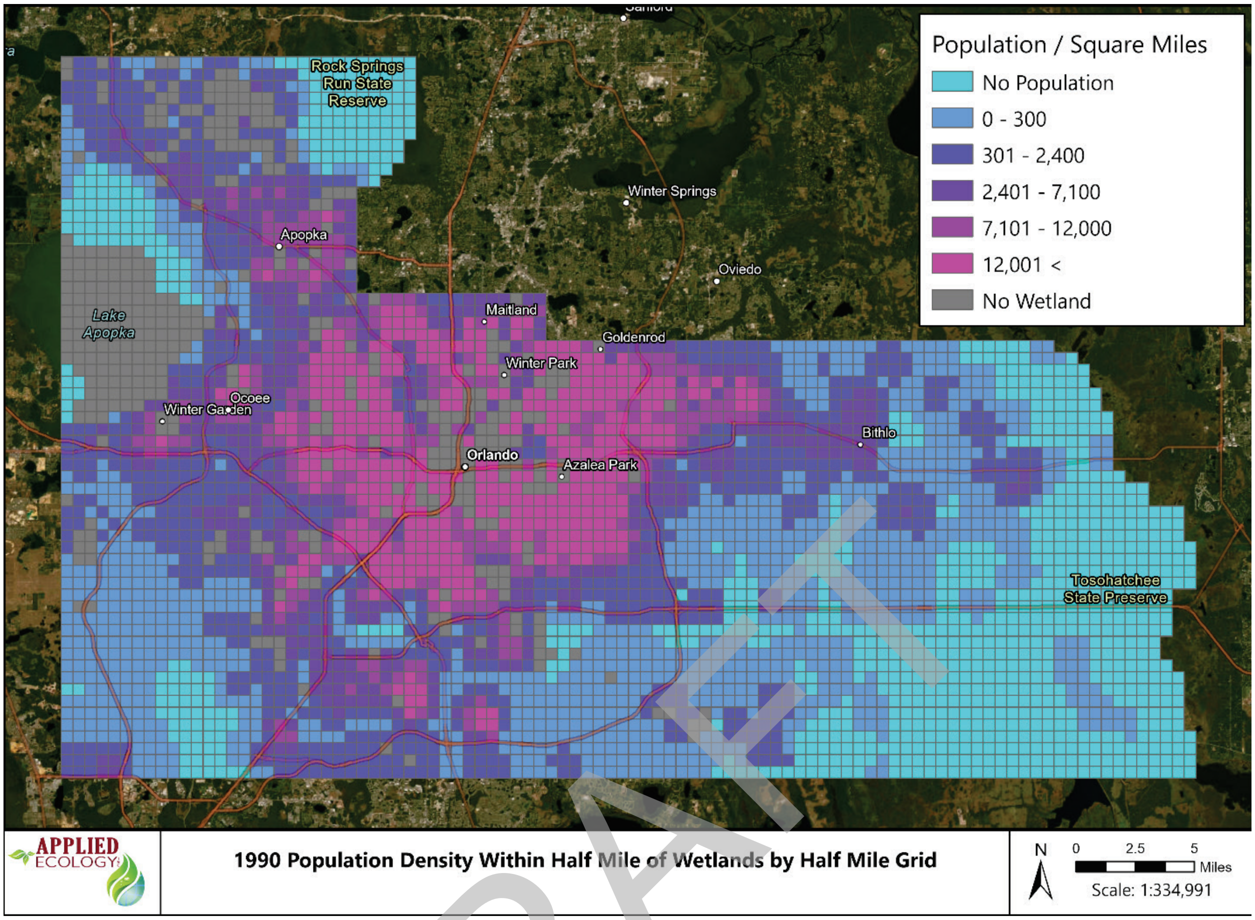

Figure 3-18. Distribution of population counts within a half mile of wetlands across Orange County, FL in 1990 as summarized by half mile grids.

Population and Wetland Change to 2022

The total change of wetland percent coverage across Orange County from 1990 to 2022 is depicted in **Figure 3-19**. The area of the largest increase in percent wetland cover was along the north shore of Lake Apopka, as the result of the Lake Apopka restoration project. There was an estimated 45% of the county which experienced wetland gains from 1990 to 2022, of which only 7% of the county experienced gains greater than 10%. Fifty-five percent of the county experienced wetland losses from 1990 to 2022 with only 10% of the county experiencing wetland losses greater than -10%. There were no large, contiguous areas of wetland lost but rather several small clusters across the county.

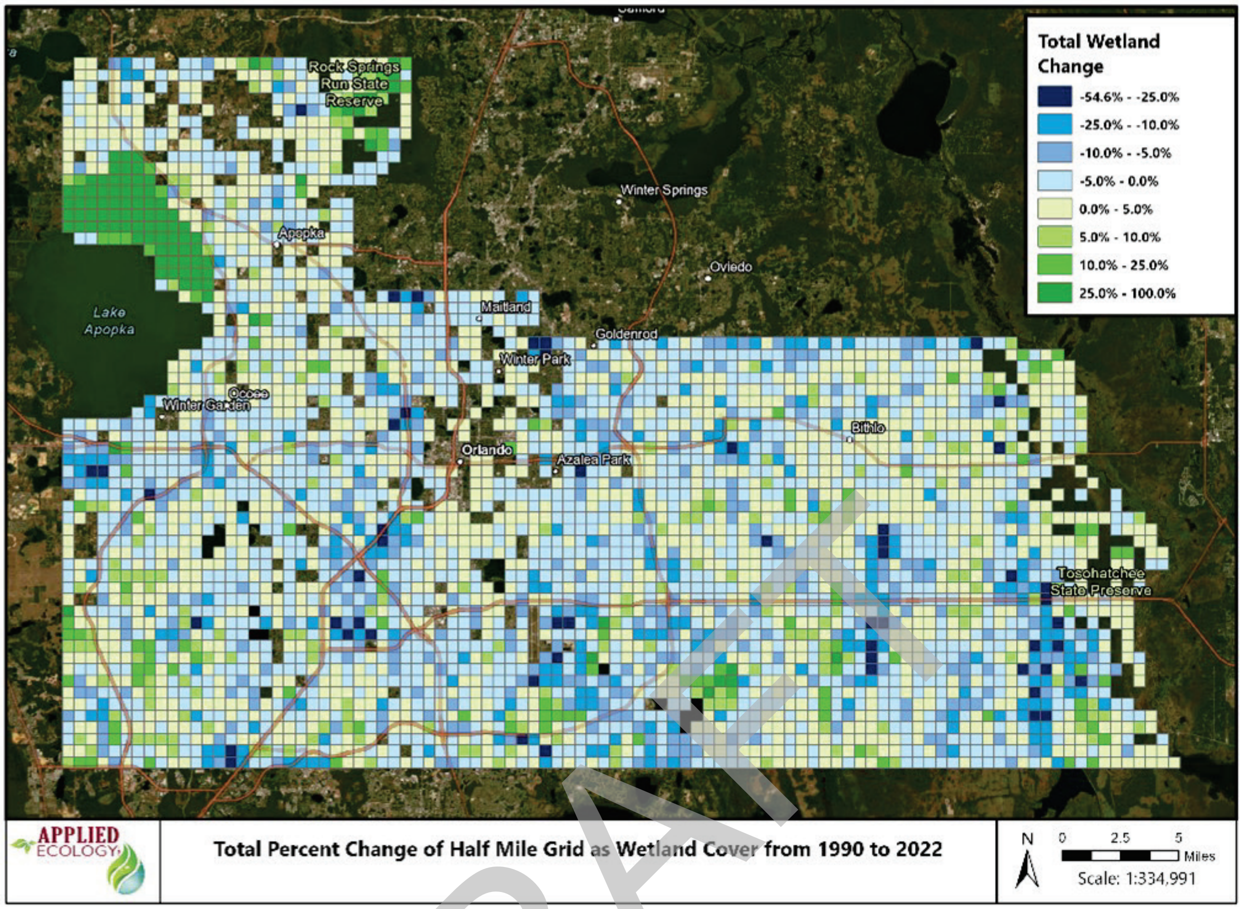

Figure 3-19. Total change of wetland cover across Orange County, FL as summarized by half mile grids from 1990 to 2022. Cells with no wetland change are not colored.

The results of a hotspot analysis on the total wetland change from 1990 to 2022 are depicted below in **Figure 3-20**. A hot spot is defined as a contiguous area of statistically significant higher values while a cold spot is a contiguous area of statistically significant lower values. For this analysis, a hot spot is a cluster of increasing wetland cover (wetland gains) while a cold spot is a cluster of decreasing wetland cover (wetland losses).

Overall, the identified hot spots of increasing wetland cover were typically outside of the more developed areas of the county. The largest hot spot of increase in wetland cover corresponded with the Lake Apopka restoration area. The largest cold spots were in the southeast of the county along State Roads 520 and 528.

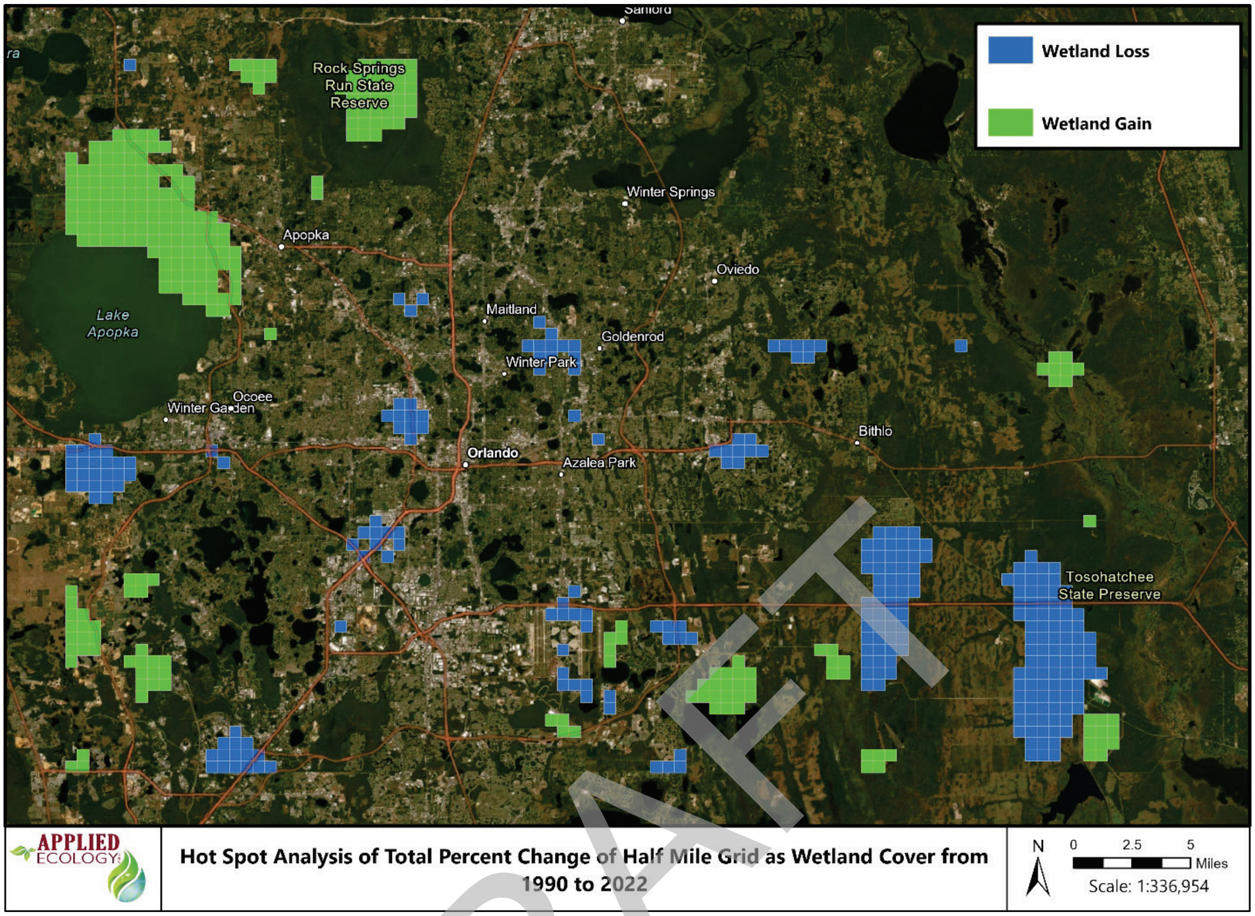

Figure 3-20. Hot Spot analysis of total change in percent wetland cover by half mile grid from 1990 to 2022.

The change in population density within a half mile of wetlands from 1990 to 2022 is presented in **Figure 3-21**. The areas of the largest decrease in population proximate to wetlands was likely the result of decreasing coverage of wetlands in more developed areas. Whereas the areas with the largest increase in population proximate to wetlands was most likely the result of increasing populations without wetland loss. In the southwestern portions of the county, there appears to have been a more spatially uniform increase in population proximate to the wetlands. The east of the county is split between areas of small increases or small decreases in population proximate to wetlands.

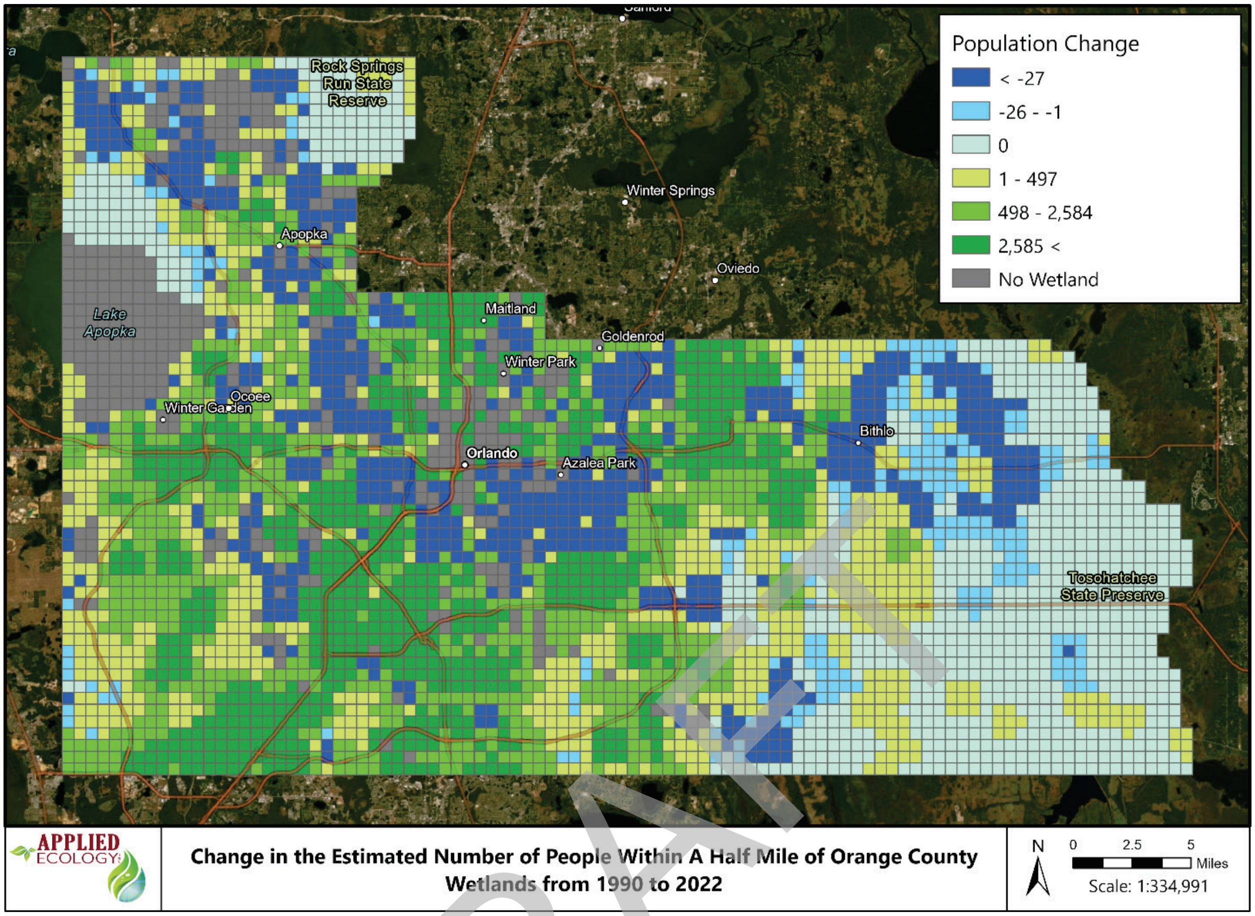

Figure 3-21. Total change in population density within a half mile of wetlands from 1990 to 2022.

The results of a hotspot analysis on the total change in population density within a half mile of a wetland from 1990 to 2022 are depicted in **Figure 3-22**. There were several large clusters of both hot and cold spots with several smaller clusters intermixed primarily in the Orlando area. The largest hot spots of increasing population density proximate to wetlands appeared to closely match the various main highways crossing Orange County. This may be indicative of development that either avoided filling wetlands or wetland restoration activities. The large cold spots may be related to a reduction in the population employed in the agricultural industries. For example, as the Lake Apopka restoration converted the croplands into wetlands, there may have been migration of population to other active agricultural areas.

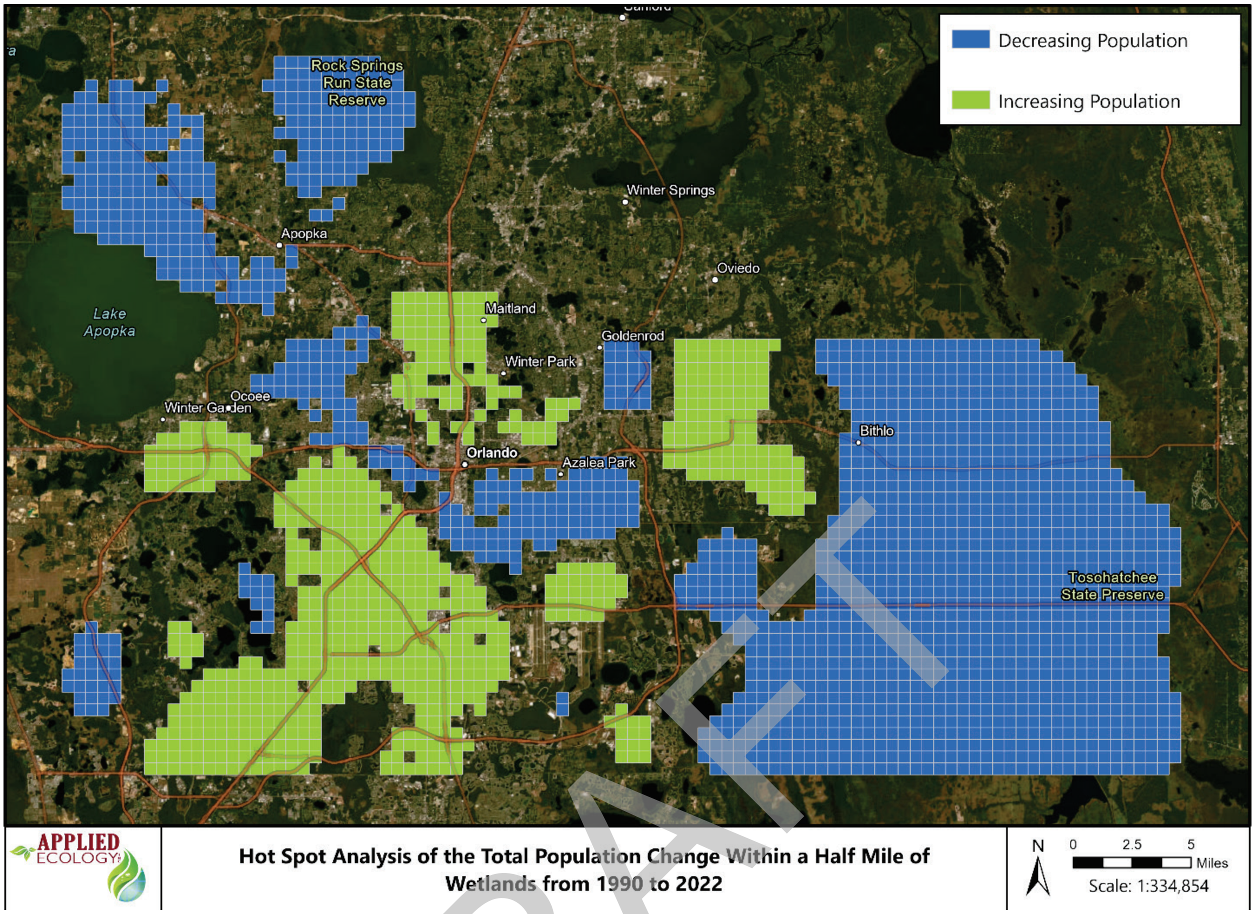

Figure 3-22. Hot spot analysis of total population change from 1990 to 2022.

Multivariate Cluster Analysis

The purpose of the Multivariate Cluster Analysis (MCA) is to identify and then group the grid cells to minimize the variability within each group included as part of this analysis: population density within a half mile of wetlands, change in the population estimate within a half mile of wetlands, wetland coverage within the grid, and wetland coverage change from 1990 to 2022. The result of this analysis identified that 8 clusters were able to adequately account for the variability in the data and is presented in **Figure 3-23**. The averages of the 4 metrics of each cluster are provided in **Table 3-8**.

Cluster ID 3 was the most encompassing of the county, representing 36.0% of all half-mile grid cells. These were areas that had on average 11.1% of wetland cover in 1990 which steadily decreased to 10.1% by 2022. The average population estimate in 1990 was approximately 353 and steadily increased to 980 people by 2022. When these half-mile grid cells are extrapolated over 36% of the total area of Orange County, we can infer that a large area of the county which experienced an increase in population within a half mile of wetlands also incurred a decrease in wetland coverage.

Table 3-8. Averages of population and wetland metrics by the 8 identified clusters.

Metric	Time	Cluster ID							
		1	2	3	4	5	6	7	8
Population Change	1990 to 2000	279	158	306	39	405	3,012	7,169	3
	2000 to 2010	-179	-107	-146	9	520	-2,290	-5,899	112
	2010 to 2022	435	155	466	36	-770	3,889	14,900	-107
Population Estimate	1990	124	28	353	174	4,184	1,099	1,352	12
	2000	402	186	659	213	4,588	4,111	8,521	15
	2010	223	79	513	222	5,108	1,821	2,622	126
	2022	659	234	980	258	4,338	5,710	17,522	19
Wetland Percent Change	1990 to 2000	0.1%	0.4%	-0.5%	2.1%	-1.2%	-1.0%	-2.2%	80.3%
	2000 to 2010	-1.1%	0.0%	-0.2%	3.7%	0.1%	-0.8%	-1.6%	8.6%
	2010 to 2022	1.1%	0.3%	-0.3%	-36.9%	-0.5%	-0.3%	-1.2%	2.7%
Wetland Percent Cover	1990	39.9%	87.4%	11.1%	61.6%	8.8%	16.2%	15.8%	2.8%
	2000	40.0%	87.8%	10.6%	63.7%	7.6%	15.2%	13.6%	83.1%
	2010	39.0%	87.7%	10.4%	67.3%	7.7%	14.5%	11.9%	91.7%
	2022	40.1%	88.1%	10.1%	30.5%	7.2%	14.1%	10.8%	94.4%
Percent of Orange County		20.7%	12.1%	36.0%	1.6%	12.0%	13.7%	2.4%	1.6%

Cluster ID 1 was the next largest, representing 20.7% of the all the grid cells in the county. Overall, the wetland coverage was stable between 1990 and 2022, with a 1.1% decrease between 2000 and 2010 which was followed by an equal increase of 1.1% between 2010 and 2022. There was also a gradual increase in population from 127 to 659 people by 2022. This may suggest that, in these locations, there was a small increase in development which did not result in wetland loss on average. These cells are mostly located in the unincorporated areas of Orange County which may be due to wetland restoration around existing residential areas between 2010 and 2022.

Cluster ID 6 was the third largest, representing 13.7% of all the grid cells, with most observed along the major highways of the county. This cluster started in 1990 with an average wetland coverage of 16.2% which decreased to 14.1% by 2022. The population estimates within these areas varied widely, starting at 1,099 in 1990 and then jumping to 4,111 in 2000, followed by a decrease to 1,821 in 2010, and then finally increasing again to 5,710. These locations may have had several factors influencing the population patterns, but overall maintained a steady decline in wetland coverage.

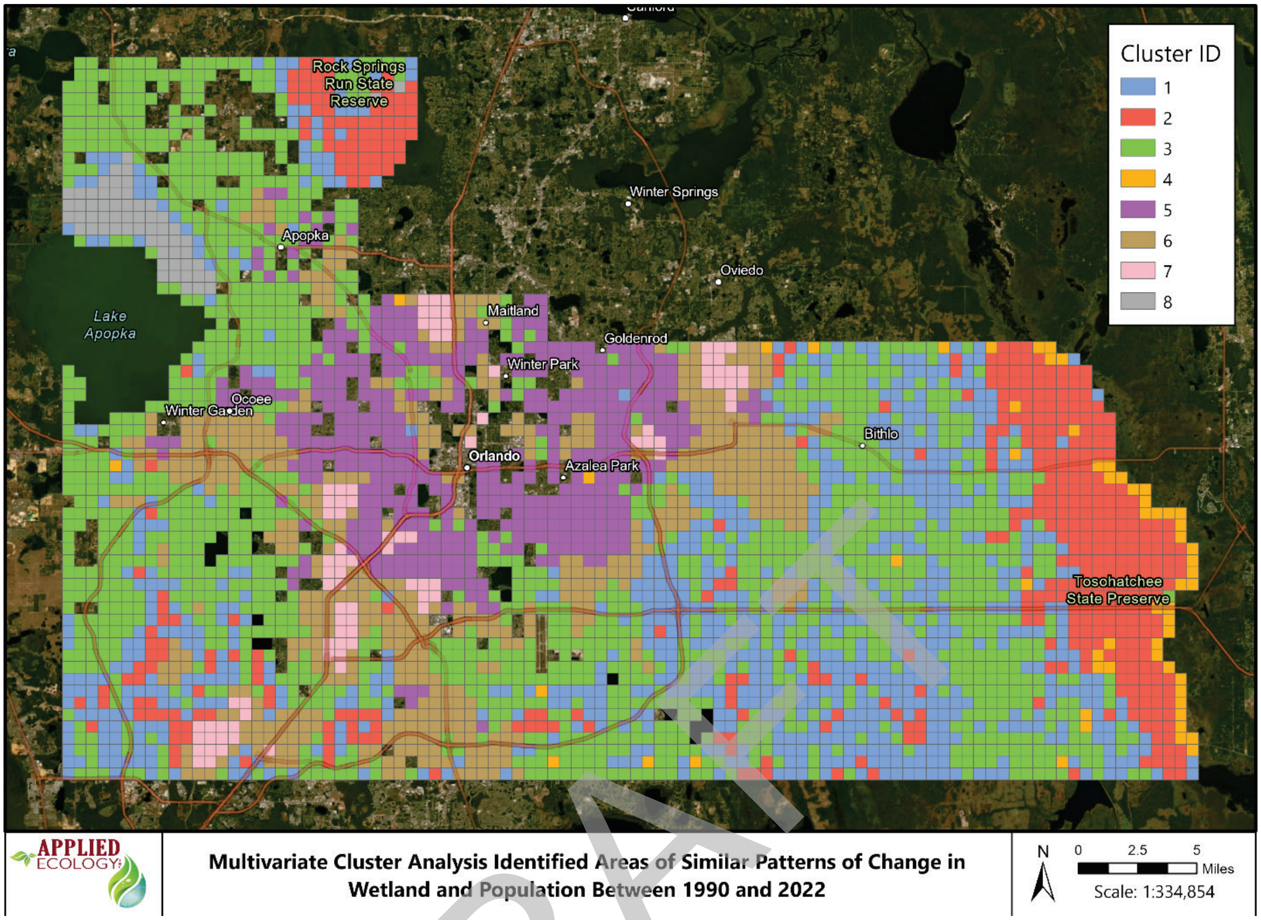

Figure 3-23. Multivariate Cluster Analysis (MCA) of change in wetland coverage and population density within a half mile of wetlands from 1990 to 2022

Cluster ID 2 was the fourth largest, representing 12.1% of all the grid cells in the county, and was primarily located in the Tosohatchee and Wekiva regions. This cluster was dominated by wetland cover with 87.4% in 1990 and increasing to 88.1% by 2022. This cluster largely coincides with protected natural areas. However, there was a moderate increase in the population from 158 people in 1990 to 234 people in 2022.

Cluster ID 5 was the fifth largest, representing 12.0% of all the grid cells in the county, and was primarily located around the City of Orlando. This cluster had little wetland cover with 8.8% in 1990 and decreased to 7.2% by 2022. The population of these areas started with an average of 4,184 people in 1990, increased to 5,108 by 2010, and then decreased to 4,338 by 2022.

The remaining clusters 4, 7, and 8 constituted 5.5% of the county. Cluster 4 was almost entirely within the Tosohatchee and was characterized by a small population near the wetlands but experienced a 36.9% decline in wetlands between 2010 to 2022. Cluster 7 was identified in proximity to clusters 5 and 6, characterized primarily by having the highest average number of people within a half mile of a wetland at 17,522 in 2022 accompanied by a decline in wetland coverage of 5% from 1990 to 2022. Lastly cluster 8 was entirely associated with the Lake

Apopka restoration project, with an 80.3% increase in wetland coverage between 1990 and 2000.

Projected 2050 Conditions

The projection of human population growth involves the modeling of births, deaths, and migration into and out of an area. Each of these components in turn are modeled based on a best estimate of the socioeconomic forces which act upon them. While events such as the 2020 COVID-19 Pandemic or the 2008 U.S. Housing Market Crash cannot be forecasted, within the model there are scenarios which can consider how future occurrences might influence the general pattern of population growth.

The University of Florida Bureau of Economic and Business Research (BEBR) generates county level population projections of Florida out to 2050. The current projected population growth for Orange County is from 1.457 million people in 2021 to a range between 1.559 million to 2.517 million in 2050, with a middle projection of 2.038 million (BEBR 2022). However, the fine scale spatial distribution of these projected new residents is not currently available.

The University of Maddison-Wisconsin Spatial Analysis for Conservation and Sustainability (SILVIS) Lab generated a projection of changes in housing units out to 2050. These projections have been used for long term planning, such as in the Narragansett Bay Estuary Program 2017 *State of the Bay* report. The SILVIS projection utilized the U.S. Census Bureau's housing counts and age data at the block level from 1940 to 2010 to calibrate a projection model.

The general pattern of housing unit change projected for Orange County is for the more densely populated areas of Orlando to either decline or not increase, while the suburban areas of Orlando may potentially experience increased development (**Figure 3-24**). As these are the bulk housing unit projections, they do not differentiate between the type of housing density, such as low-density single unit houses or high-density apartment blocks. Based on the previous population densities, one potential scenario is that the housing units built in the suburban areas may trend toward low density residential. However, these traditional development patterns may change based on the County's Vision 2050 planning efforts where urban infilling and densifying current urban areas may reduce future urban sprawl.

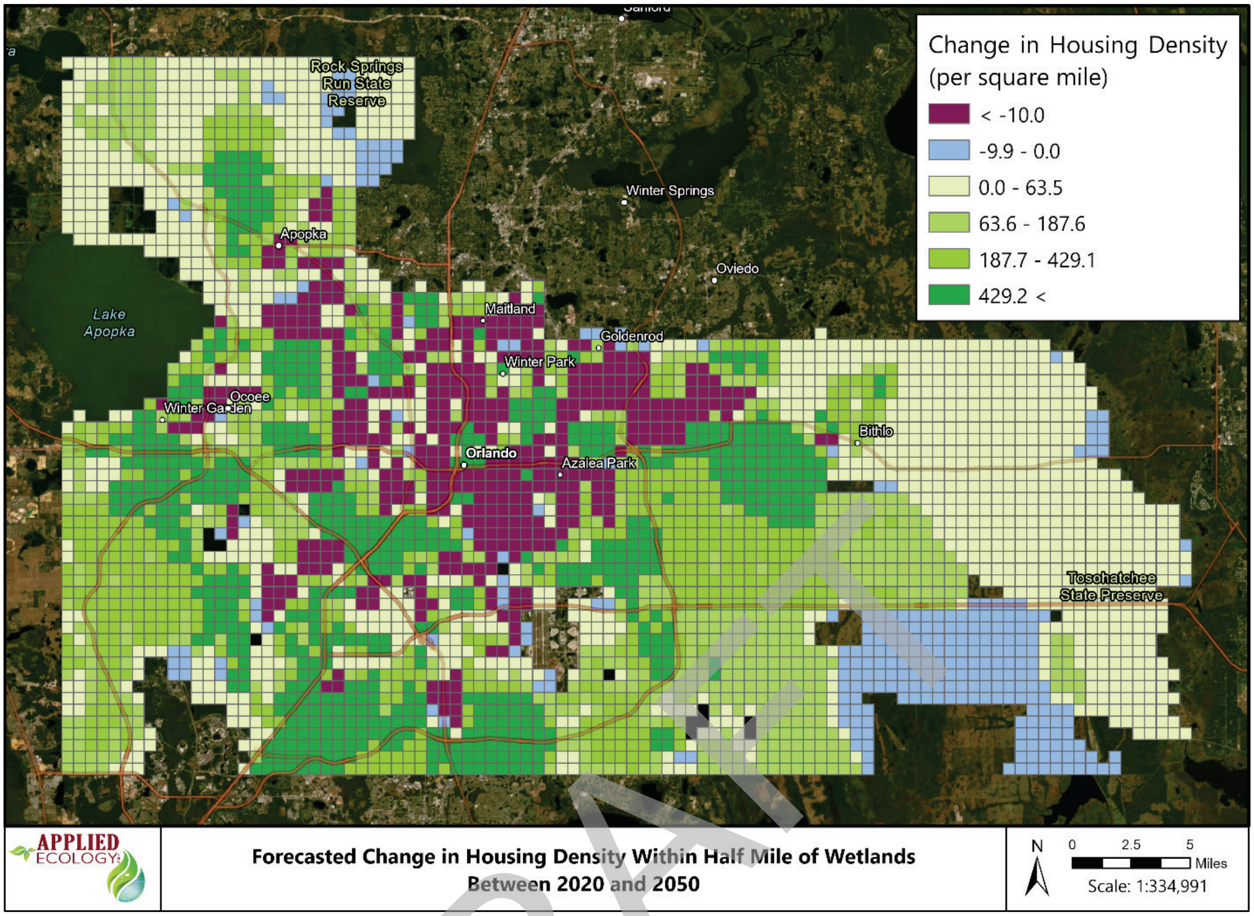

Figure 3-24. Silvis Lab forecasted change in the number of housing units from 2020 to 2050 by half mile grid.

A risk classification matrix was also created to identify areas of Orange County which may have a higher risk of wetland loss due to population changes (**Table 3-9**). In general, low risk of wetland loss was assigned to areas with little existing wetland coverage and the least amount of projected development. High risk was assigned to areas with more existing wetland coverage and elevated projected development, as well as areas with more than 50% current wetland coverage and low projected development.

Table 3-9. Risk matrix of potential wetland loss by 2050 based on the SILIVIS forecasted change in housing units from 2020 to 2050.

	Wetland Coverage				
Housing Unit Change	0.0-10%	10-25%	25-50%	50-75%	75-100%
Low Increase	Low	Low	Medium	High	High
Medium Increase	Low	Medium	Medium	High	High
Large Increase	Medium	Medium	High	High	High
Very Large Increase	Medium	High	High	High	High

In total, there is approximately 24.5% of Orange County which has a high risk of potential wetland loss between 2020 and 2050 (**Table 3-10**). There is also 33.2% with a medium risk of potential wetland loss and 24.0% of low risk of potential wetland loss. Just over 8% of the county's area falls in the high-risk category of very high development and 10-50% wetland coverage. Finally, a total of 9.6% of the high-risk area falls into the low development and over 50% wetland coverage category. These categories were assigned as high risk because even a limited increase in population density and/or development can have large impacts on the wetland habitats. For instance, one farm with only a few residents can have a large impact on the surrounding wetland habitats. As can be seen in **Figure 3-25** the high, medium, and low risk locations are intermixed across Orange County.

Table 3-10. The percentage of Orange County under each wetland risk category.

	Wetland Coverage				
Housing Unit Change	0.0-10%	10-25%	25-50%	50-75%	75-100%
Low Increase	11.2%	5.7%	4.8%	3.3%	6.3%
Medium Increase	7.2%	5.4%	3.8%	1.3%	0.3%
Large Increase	6.1%	4.1%	2.9%	1.0%	0.3%
Very Large Increase	9.0%	4.7%	3.4%	0.6%	0.4%

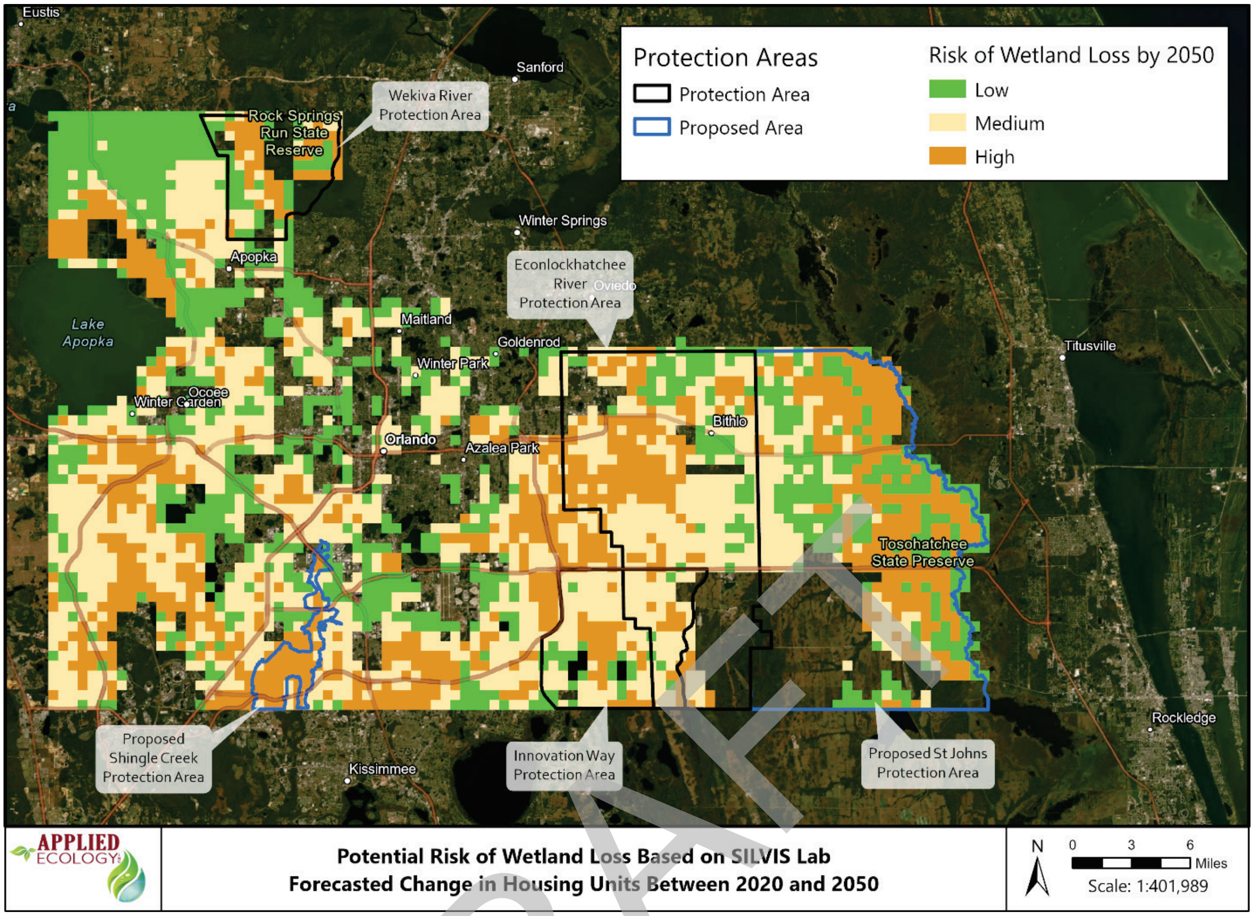

Figure 3-25. Potential wetland loss risk from 2020 to 2050 as determined by SILVIS Lab forecasted change in housing unit numbers by half mile grid.

3.4 Wetland and Land Use Conclusions and Recommendations

The wetland API mapping results reveal that wetland and water land cover categories have increased in area since 1990, with wetland land cover gaining 3,723 acres while water land cover increased by over 10,000 acres within the County. The largest factor responsible for the increase of wetlands from 1990 to 2022 in Orange County was the restoration of marsh habitat that occurred along the northern shores of Lake Apopka, which restored over 10,000 acres of freshwater marshes. This restoration area was not part of a mitigation process but was undertaken by the state to improve the water quality in Lake Apopka. Without the addition of the freshwater marsh land cover that this restoration effort provided, Orange County would have lost over 6,500 acres of wetland land cover since 1990. Freshwater marsh habitat alone would have declined by almost 1,900 acres.

These findings indicate that mitigation projects are not keeping pace with the loss of wetlands that is occurring due to urban development and other LULC changes. The extent of wetland mitigation credits that are purchased outside of Orange County to account for wetland losses within Orange County was not available for this analysis, so the overall adherence to the "no net loss" wetland policy, as defined under the Clean Water Act, have not been evaluated.

Out of the seven wetland land cover classifications that were included in the wetland API mapping, four increased in acreage – cypress (+16%), freshwater marshes (+34%), hydric pine flatwoods (+114%), and other wetlands (+131%). Three wetland types decreased in acreage, including mixed scrub-shrub wetlands (-17%), wet prairie habitats (-39%), and mixed wetland forests/hardwoods (-22%). These gains and losses of wetland types have changed the overall composition of wetlands in the County. For instance, in 1990, mixed wetland forests made up 46% of all wetland area in the county, but in 2022 they only comprised 35% of wetland habitat. On the other hand, freshwater marshes, which made up 15% of wetland cover in 1990, increased to 20% in 2022. These compositional changes can impact overall wetland health in the county, alter hydrology, and change biological diversity.

The mapping results also show that many of the wetland areas within the urban boundaries still exist. However, the upland habitats and buffer zones surrounding them have been diminished leaving many of these smaller wetlands isolated without clear hydrological or ecological connections to other wetlands and upland habitats. This ecological isolation could lead to functional loss in the wetland habitats if species important to maintaining wetland structure are impeded or blocked when moving between wetland patches and utilizing the surrounding uplands (Findlay & Bourdages, 2000; Roe et al., 2006; Roe & Georges, 2007; Uden et al., 2014)

Many of the changes that occurred within Orange County between 1990 and 2022 were driven by population growth and the subsequent land use and land cover changes that accompanied it. Urban and built-up land cover in the county increased by over 74,000 acres since 1990, led by an increase in residential medium and high-density housing as well as an expansion of the commercial and services sector. Additional impacts on wetland habitats have also occurred from the expansion of the infrastructure needed to support this growth (i.e., roads and highways, wastewater facilities, etc.) and have changed the wetland mosaic across the county.

Sixty-four percent of the county had a slow decline of wetland coverage between 1990 and 2022, averaging a rate of 0.8% loss of wetland cover per decade. This loss was also not exclusive to the developed Orlando area or the outlying suburbs of the city. However, amongst the less developed areas of the county, such as the Econlockhatchee and St. Johns watersheds, there were increases in population that did not coincide with an overall loss of wetlands. As the county is forecasted to continue to grow by potentially another half million residents over the next 30 years, there is a risk of net wetland loss in these areas. In response to this risk, the continued use of the protection areas and the growth planning of Vision 2050 will be instrumental in balancing future development with minimal wetland impacts.

4 TEMPORAL CHANGES IN WETLAND HEALTH AND FUNCTION

The previous section detailed how wetland acreage, extent, and distribution has changed over time. Although wetlands may persist through time in acreage, analyzing their health and function over time is also vital to fully understand the state of the wetlands in Orange County. To assess the health and function of wetlands in the county, a field validation effort focusing on 51 wetland sites in the County was undertaken to confirm wetland presence, wetland type, and provide a functional assessment using accepted protocols established under the Florida Uniform Mitigation Assessment Method (UMAM) that included a qualitative assessment of invasive species cover. Additionally, wetland buffers were also evaluated at each site to assess invasive species encroachment into the wetland. Hyperspectral imaging of fifteen of the 51 field visited wetland sites was also conducted to assess the wetland health indices and map community types using a separate, experimental methodology. Data from the literature review was used to inform the methods and approaches of the techniques employed and the recommendations provided in this section.

4.1 Field Assessments and Functional Ecosystem Analysis

A field assessment effort of 51 permitted mitigation wetlands was completed with three objectives:

1) To provide field validation of wetlands mapped using API in 2022

2) To determine the current wetland functionality of selected onsite mitigation locations within Orange County to assess if function is being preserved under the current County's wetland ordinance policies

3) To provide a case study for the use of innovative technology for wetland health assessments using UAV and HIS

The project team conducted field assessments on a total of 51 wetland mitigation sites that had previously been permitted by Orange County Environmental Protection Division (OCEPD). An experimental remote sensing assessment, using hyperspectral imagery analysis, of 15 of these sites was also conducted to evaluate the feasibility of remote functional assessment of wetlands, which is further described in Section 4.2. Each wetland was assessed for accuracy of the mapped wetland type, wetland size, wetland function (using the Uniform Mitigation Assessment Method or UMAM), and percent exotic cover. Each wetland was assigned an exotic category based on **Table 4-1**.

Table 4-1. Nuisance cover classes and corresponding percent cover.

Exotic Category	Percent Cover Ranges
1	< 1%
2	1% to 5%
3	5% to 25%
4	25% to 50%
5	> 50%

At least two experienced field ecologists visited each mitigation site and conducted thorough on-the-ground site assessments, which included an evaluation of the soils, hydrology, and vegetation found within the sites. These site inspections also allowed a comparison of the initial permit with a mitigation UMAM assessment value, or similar functional assessment or description (i.e., WRAP), found in the County's permit project files to the current functional conditions found during the site inspections conducted in 2022. All selected sites had been mitigated a minimum of five years ago, with most sites permitted ten or more years ago.

The current functional conditions found within each mitigation site were assessed using UMAM. UMAM provides a standardized procedure to assess a wetland's specific ecological functions through consideration of the current condition, hydrologic connection, uniqueness, location, fish/wildlife utilization, vegetative community, time lag, and mitigation risk. Most of these ecological functions are considered during both the initial, proposed mitigation area UMAM and the current condition UMAM; however, both time lag and mitigation risk are only considered during the initial site inspection and permitting process as they relate to future projections of the conditions expected to occur under mitigation and are not relevant to current condition assessments. Listed species information was also collected during the field effort. All data was collected using the appropriate UMAM forms and/or GPS data forms, which are provided as **Appendix C**.

The 51-field assessed wetland mitigation sites were also evaluated on whether they had established or maintained upland buffer zones surrounding them. The UMAM scores for each site were analyzed using a Wilcoxon signed-rank test, for both the buffered and unbuffered sites, to determine if there was a significant difference between the permitted UMAM scores and the new UMAM scores assigned to them during the field assessments. The Wilcoxon test, a non-parametric version of the paired T-test, is utilized to determine whether there is a statistically significant difference between two sets of dependent samples that does not require the data to be from a normal distribution. It was used for this analysis because the two UMAM scores (permitted and current conditions) are considered dependent samples because the buffered sites and non-buffered sites were analyzed independently of each other. In addition, because of the limited sample size, the data was found not to have a normal distribution (i.e., non-parametric).

In addition, a Mann-Whitney U-test was conducted on all the sites to analyze whether the sites with buffers had statistically significantly different UMAM scores than the sites without buffers. This was done by comparing the newly assessed UMAM scores between the buffered and non-buffered sites. The Mann-Whitney U-test is a non-parametric statistical test used to compare the differences between independent samples with small samples sizes. It was used to compare the differences in current UMAM scores between buffered and non-buffered sites, which are considered independent samples because they received different "treatments" (i.e., buffers or no buffers)

Because of the limited sample sizes (33 buffer and 18 no buffer) the P-values, which determine if the new UMAM scores differ significantly from the permitted scores, was not able to be directly computed for the two statistical tests that analyzed buffer and no buffer sites separately; however, the statistical program was able to compute an approximation of the P-values which are presented as approximate P-values in the results.

4.1.1 Wetland Selection Methodology

A selection of representative onsite mitigation areas or Conservation Area Impact (CAI) sites was carefully performed for field evaluation. Based on the County's available CAI permitted parcels spatial layer, as well as LULC data and other ancillary datasets described in Section 3.1, a ranking system was developed using a variety of readily available variables at the countywide scale. The ranking system developed for wetland site selection included the following parameters:

- wetland type,
- wetland size,
- distance to impaired waterbody,
- population change from 2000 to 2020, and
- impervious area within a 500' buffer of each wetland.

The 2015/2016 SJRWMD and 2017/2019 SFWMD LULC layers were utilized and all wetlands within the County were extracted. A spatial union was performed in GIS between the Water Management District's (WMD) wetlands layer and the County's CAI permitted parcels. These wetlands were then considered potentially impacted wetlands/mitigation sites that would be ranked based on the aforementioned ranking system for field evaluation.

The potentially impacted wetland types were then analyzed to evaluate which wetland types were most impacted by the CAI permits by acreage (**Table 4-2**). This analysis also guided the development of the simplified classification system implemented for the wetland inventory effort. Different LULC wetland codes were grouped together based on similarity of wetland community and habitat, reducing the number of wetland types to map and field assess. These aggregated wetland traditional LULC classes are called wetland groups. For example, the land use codes 6210, 6215, and 6216 were combined into a group called Cypress as all three land use codes classify cypress tree dominated wetland forested systems.

Table 4-2. Wetland types and total area (acres) within the County, wetland area within CAI permitted parcels, and the percentage of total acreage within the permitted parcels.

LULC Code	Wetland Type	Total County Wetland Acres	Total Wetland Acres within Permitted Parcels	% of Wetlands within Permitted Parcels
6410	Freshwater marshes	48,128	18,585	39%
6170[1]	Mixed wetland hardwoods	41,688	12,695	30%
6460[2]	Mixed scrub-shrub wetland	14,862	6,561	44%
6300[1]	Wetland forested mixed	26,886	6,525	24%
6210[3]	Cypress	19,383	5,489	28%
6250	Hydric pine flatwoods	11,550	3,705	32%
6440[4]	Emergent aquatic vegetation	5,387	1,192	22%
6430	Wet prairies	3,638	1,009	28%
6181[4]	Cabbage palm hammock	2,376	899	38%
6110[4]	Bay swamps	2,132	791	37%
6216[3]	Cypress - mixed hardwoods	3,531	554	16%
6172[2]	Mixed shrubs	4,284	369	9%
6215[3]	Cypress - domes/heads	1,067	100	9%
6182[4]	Cabbage palm savannah	165	77	47%
6200[4]	Wetland coniferous forest	40	31	78%
6111[4]	Bayhead	28	0.2	1%
6411[4]	Sawgrass marshes	2	0.00	0%
6500[4]	Non-vegetated wetland	1	0.00	0%

Table 3-3 Notes: Wetland classes with superscript (1) Combined to form the wetland type "Wetland Forested/Hardwood Mixed", (2) Combined to form the wetland type "Mixed scrub-shrub wetlands", (3) Combined to form the wetland type "Cypress", and (4) Combined to form the wetland type "Other wetlands". Light green highlighted rows indicate wetland classes used as "wetlands of interest".

Utilizing the percentage of total wetland acres impacted by CAI permits, five consolidated wetland types were prioritized for election based on how common these habitats appear to be impacted by CAI permitting. These wetland types include three forested systems (cypress, wetland forested/ hardwood mixed, and hydric pine flatwoods) and two herbaceous wetland systems (freshwater marshes and wet prairies). While scrub-shrub systems appear to be typically abundant, OCEPD has seen less of these types of wetlands being impacted or mitigated in comparison to hydric pine flatwoods. For mapping purposes, mixed scrub-shrub wetland systems were also included as a wetland class, with all other wetlands captured combined under a general "Other Wetlands" category.

For the field assessment effort, only wetlands located within unincorporated parts of Orange County were selected; this ensured that only wetland systems permitted under the Orange County wetland ordinance would be selected. The selected wetland types were then divided into two groups: large wetlands (>10 acres) and small wetlands (<10 acres).

To further narrow down the list of wetlands selected for field evaluation, three additional criteria were included: distance from the wetland to an impaired waterbody, population change from 2000 to 2020, and impervious area within a 500-foot buffer from the permitted wetland (**Table 4-3**). Wetlands that were 1,000-feet or less from an impaired waterbody were ranked higher priority for selection because these wetlands can provide critical services in terms of sediment and nutrient runoff potential into an already impaired waterbody. Wetlands more susceptible to anthropogenic impacts/development pressure were also prioritized for field assessments. This was performed by assigning population change values based on census data to every permitted wetland; those with a population change of greater than 147 people/km2 were considered a higher priority. Lastly, wetlands within urban settings were also prioritized for field assessments, since those are typically considered, according to ecological studies and literature review, to be at higher risk for functional losses. Wetlands surrounded by land uses with greater or equal to 30% impervious area (within 500-feet buffer of the wetland) were ranked higher priority for field selection due to the anticipated urbanization pressures on those wetlands.

Table 4-3. Criteria used for ranking wetlands to be considered for functional assessment.

Rank	Distance to Impaired Waterbody (feet)	Population Change 2000-2022 (people/km2)	Impervious Area within 500-feet
High	≤1,000	≥147	≥30%
Medium	-	>0 and ≤147	>10% and <30%
Low	>1,000	No Change	≤10%

Table 3-4 Symbol Key: "≤"= less than or equal to, "≥" = greater than or equal to, ">" = greater than, %=percent

Using the above criteria, a total of 200 wetlands, within the five consolidated wetland types described previously, were selected by AEI and provided to OCEPD for review. Wetlands selected were equally distributed across the five wetland types and County-defined size classes (Class I, II, and III) as much as possible. The 200 selected wetlands were evaluated individually by reviewing permit data from the County's permitting database. To be considered for the functional analysis, wetlands had to have been mitigation sites permitted a minimum 5 years ago (preferentially 10 years) with available UMAM, WRAP, or at minimum a field assessment report that would allow AEI staff to recreate historic functional scoring. Lack of historic functional assessment information precluded many of the selected sites because analyzing the change in functional scoring over time was one of the objectives of the field assessment effort.

Out of the original 200 wetland mitigation sites provided to the County, 29 were selected by consensus between the project team and OCEPD. These sites either had UMAM or equivalent assessment scores allowing them to be compared to the current field efforts. The remaining 22 sites were selected either by OCEPD or AEI staff based on availability of previous scoring (UMAM or WRAP), commissioner district location, wetland group/type, and/or previous knowledge of the CAI permit.

4.1.2 Functional Analysis of Selected Wetlands

The 51 mitigation sites that were selected and assessed for current function were each assigned a score based on UMAM after a thorough site investigation by ecological staff or a professional wetland scientist. During the field assessments, the project team used an opportunistic survey method to find areas within each site that best represented the site in its entirety. These representative areas were then thoroughly assessed using UMAM. All sites under ten acres that were completely accessible (i.e., not flooded) were walked and assessed over their total area. Sites that were not fully accessible and sites larger than 10 acres were assessed to the maximum degree possible and the resulting UMAM scores were extended (or extrapolated) to represent the entire mitigation area. The 51 mitigation sites that were selected and assessed for function were each assigned a score based on UMAM after a thorough site investigation by ecological staff or a professional wetland scientist. During the field assessments, the project team used an opportunistic survey method to find an area within each site that best represented the site in its entirety. The overall vegetative community, hydrology, wildlife access and usage, and location of the site were considered when developing the newly assigned UMAM score.

When assessing vegetation, the project team considered the permitted habitat type at each site and looked for key species that were historically documented utilizing that habitat. Having access to the initial permitted habitat type was key in understanding if the mitigation site had undergone ecological succession, or a regressive process caused by lack of land management, fragmentation, hydrologic disruption, or any other anthropogenic disturbance.

Vegetation was also assessed to calculate the percent of exotic/invasive species coverage at each site. Looking at exotic species coverage is beneficial in determining the overall health of a mitigation site. Sites with a higher presence of exotic species are typically suffering from habitat fragmentation, hydrology disruption, poor water quality, lack of land management practices and/or stress from nearby urban land use.

The project team assessed the hydrology at each site by examining water flows, historic water lines, soils, algal matting, aquatic plants, drift lines, lichen lines, plant adaptations, and hummocks. The wetland type listed on the permit documentation was acknowledged as an indicator of what the hydrology was at time of permitting. Signs of hydrologic stress on vegetation were noted, as this could be an indicator of altered hydrology.

Wildlife usage was assessed by the field ecologists who inspected each site for wildlife signs, particularly wildlife that depend on viable, healthy wetlands. Wildlife presence is an indicator of wetland functionality, and certain species, such as otters, indicate that there is appropriate hydrologic function and connectivity within the wetland system. Feral hog damage to the wetland was also recorded, if observed, as hogs can cause significant loss of plant and wildlife diversity if left untreated.

Additional location data was also collected at each site by the project team, including adjacent land use types and the presence or absence of connected wetland and/or wetland buffers (see

Section 3.2.3). This data was then used to assess if and how the surrounding habitats impacted the wetlands' functionality and health. Photographs taken at each site can be found in **Appendix B** along with a site description.

During the evaluation of the records associated with the permitted mitigation sites, it was noted that functional assessments that were older than 20 years tended to have projected a higher mitigation functional assessment score. These sites, which were permitted prior to 2004, were assessed before UMAM was enacted into Florida law to be the sole source of mitigation assessment. Of the 51 permitted sites that were field inspected, 13 permits were 20 years old or older and 29 were between 10 and 19 years old at the time of the current assessment. While reviewing the permitting documents, AEI found only WRAP assessments for eight of the permits and consequently performed a WRAP functional assessment for these sites. Functional assessments that were conducted less than 20 years ago tended to have lower anticipated mitigation scores for each of the permit sites. For instance, in 2000, a mixed wetland forested system was projected to have a 0.93 functional assessment, but the current condition was 0.81. Conversely, a functional assessment conducted in 2006 projected the wetland mixed forested system mitigation area to have a 0.63 functional assessment but the current condition was 0.73.

AEI acknowledges that prior to 2000, the functional assessments, especially for the location score, may have been anticipated to be far higher than current conditions. Staff experience, including staff training, compliance inspections on the mitigation areas, and a better understanding of how to conduct UMAM functional assessments appear to have led to more accurate functional assessments for those projects that are less than 20 years old. In addition, based upon the site inspections, AEI has identified that the location and community scores were far higher for the projects that were assessed over 20 years ago. The higher score to location could be attributed to experience conducting assessments or because historically many of the sites were surrounded by other natural systems that included buffers. Over the years, development has impacted the adjacent wetlands and led to a decline in the location score. It is most notable that the community scores for projects greater than 20 years scored lower in current conditions than in the permitted conditions. This is primarily due to the presence of invasive/exotic species. The lack of perpetual maintenance in the mitigation areas, especially the older mitigation locations, emphasizes the importance of implementing a perpetual maintenance requirement for invasive/exotic species removal.

4.1.3 Functional Analysis Results

The County and the project team selected 51 permitted mitigation sites (**Figure 4-1**), classified as one of the five wetland community types being analyzed, which had functional assessments in the County data files. These mitigation sites were all permitted and established for at least 10 years, with 13 of the mitigation sites in existence for over 20 years (**Table 4-4**). The types of wetlands and the number of assessments conducted on each classification are listed in **Table 4-5**.

Table 4-4. Year that selected mitigation site permits were issued and the number of permits by year.

Mitigation Permit Year	Number of Permits
1994	1
1996	1
1997	4
1998	3
1999	3
2003	1
2004	5
2005	5
2006	7
2007	3
2008	6
2010	10
2012	1
2013	1

Table 4-5. Wetland habitat classes and the number of each that underwent functional assessments, based on present day wetland habitat type.

Wetland Class	Number of Functional Assessments
Cypress	10
Freshwater Marsh	12
Hydric Pine Flatwoods	5
Mixed Wetland Forests/Hardwoods	19
Mixed Scrub-Shrub Wetlands	3
Wet Prairie	2

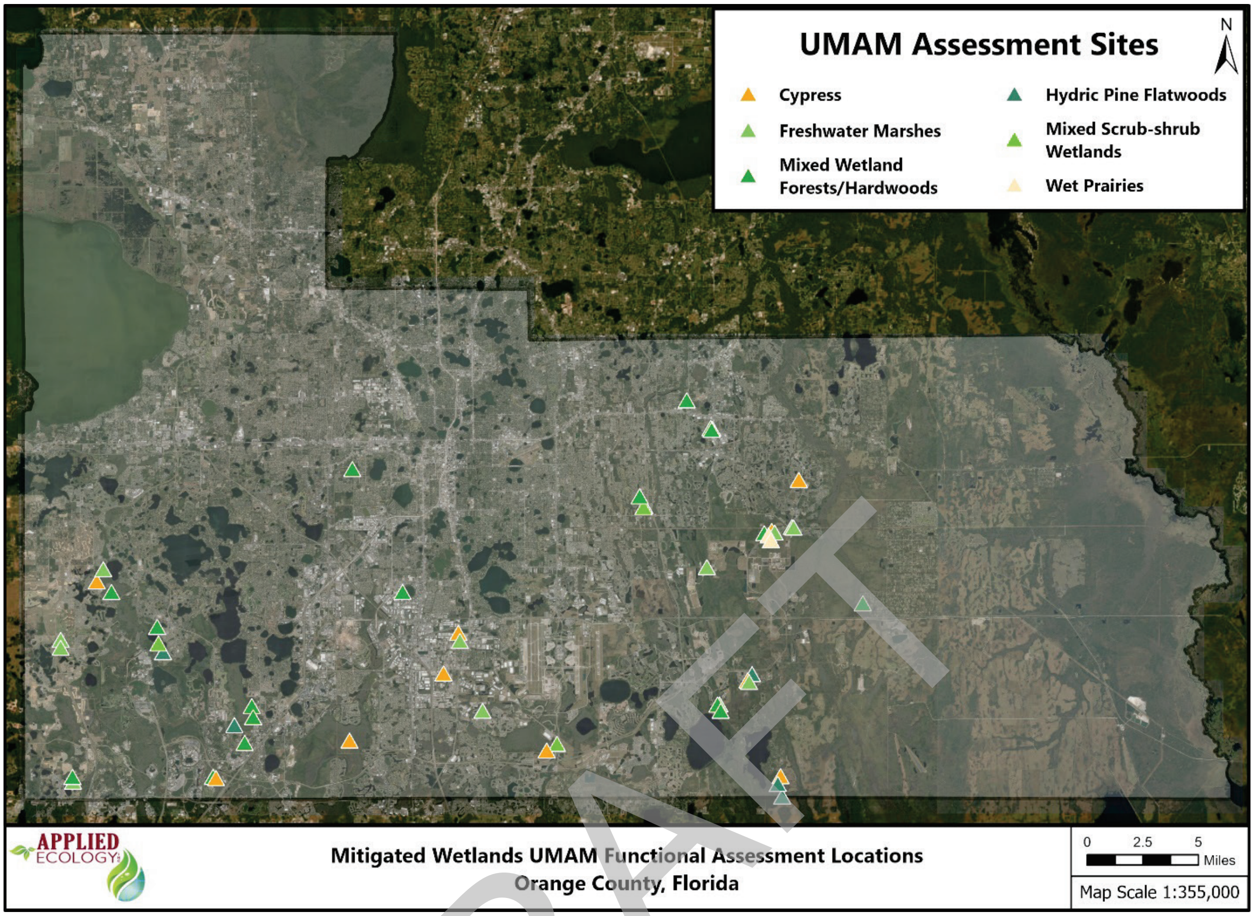

Figure 4-1. Previously permitted mitigation sites selected for field assessment efforts in Orange County, Florida.

4.1.3.1 Cypress

AEI conducted wetland assessments on ten cypress communities that had compensatory mitigation. Four of the cypress mitigation areas had a net higher functional assessment and four others had a net loss in functional assessment in comparison to the UMAM provided in the permit files. The remaining two cypress communities had no change in functional assessment between current condition and what was projected in the permit. The cypress communities that experienced functional loss were primarily due to the high presence of exotic vegetation. AEI also noted that the location of the mitigation areas, such as those located adjacent to industrial zoned areas, major roadways, and dense residential areas without buffers all tended to have a functional decline in the cypress community. Several of the cypress sites lacked hydrology and these systems contained a high percentage of exotic vegetation, ranging from 25% to 50% (exotic category 4). While two of the ten cypress sites were originally permitted as different habitat types. The difference between the initial permitted UMAM scores and the current assessment scores showed an averaged increase of 1.39%, with six sites gaining function and four losing function. Loss of function was generally attributable to a decrease in hydrological function and/or an increase in exotic species presence. Overall, there was considerable variability of the conditions seen among the assessed sites. The results of the 10 site assessments for cypress dominated wetlands are presented in **Table 4-6**.

Table 4-6. Cypress mitigation site assessment UMAM score comparison for current and previous functional assessments including percent exotic species cover.

AEI Site ID	Permit Year	Permit UMAM	Current UMAM	Difference Gain/Loss	% Change	Exotic Category	% Exotics Cover
1	2004	0.87	0.87	0	0	3	5 to 25
6	2007	0.8	0.87	0.07	8.75	2	1 to 5
7	2008	0.57	0.6	0.03	5.263157895	3	5 to 25
8	2006	0.8	0.73	-0.07	-8.75	4	25 to 50
17	2000	0.93	0.81	-0.12	-12.90322581	2	1 to 5
20	2007	0.6	0.58	-0.02	-3.333333333	4	25 to 50
21	2003	0.9	0.73	-0.17	-18.88888889	3	5 to 25
25	2005	0.7	0.85	0.15	21.42857143	2	1 to 5
30	1997	0.73	0.73	0	0	2	1 to 5
38	2005	0.76	0.93	0.17	22.36842105	2	1 to 5
				Median	0.00	2.50	
				Average	1.39	2.70	

4.1.3.2 Mixed Wetland Forests/Hardwoods

The project team conducted wetland assessments on 19 mixed wetland forested areas that included compensatory mitigation. A total of 13 of the 19 mixed wetland forested areas had a net loss in the functional assessment. Ten of the 13 mitigation sites had at least 5% of their area covered by exotic species, with two comprised of greater than 50% exotics (Category 5) and two with between 25% to 50% exotics cover (Category 4). The decline in the functional assessment from the time they were permitted to current conditions appears largely due to habitat fragmentation (i.e., lacking connectivity with other wetlands) and insufficient hydrologic function. Several of these mitigation areas lacked buffers which allowed garbage and exotics to encroach into the mitigation area. There were four sites that had a net gain in function. One of the sites was contiguous to a much larger wetland system that ultimately connects to the Florida Everglades. This system had buffers, good hydrology, wildlife usage and no invasive species present. In addition, its connectivity to adjacent wetlands helped preserve adequate hydrological function while providing important ecological connections to a larger wetland system. Surprisingly, seven of the mixed wetland forested systems that were located adjacent to residential settings contained less than 5% exotic vegetation. Several of these mitigation areas did have wetland buffers, but not all. The lack of exotics in these areas is largely due to the wetland's hydrology which was adequate to maintain the natural recruitment of desirable vegetation in the ground cover, shrub, and canopy strata.

The average functional change for all sites was a decline of 4.11%. Six of these Mixed Wetland Forested sites were originally permitted as a different habitat type. The results of these assessments are presented in **Table 4-7**.

Table 4-7. Mixed Wetland Forests mitigation site assessment UMAM score comparison for current and previous functional assessments including percent exotic species cover.

AEI Site ID	Permit Year	Permit UMAM	Current UMAM	Difference Gain/Loss	% Change	Exotic Category	% Exotics Cover
2	2004	0.67	0.7	0.03	4.47761194	3	5 to 25
4	2003	0.9	0.87	-0.03	-3.333333333	2	1 to 5
5	2006	0.63	0.73	0.1	15.87301587	2	1 to 5
10	2005	0.73	0.4	-0.33	-45.20547945	5	>50
11	2005	0.73	0.7	-0.03	-4.109589041	3	5 to 25
12	2005	0.73	0.57	-0.16	-21.91780822	3	5 to 25
13	2004	0.76	0.73	-0.03	-3.947368421	2	1 to 5
18	2000	0.87	0.77	-0.1	-11.49425287	2	1 to 5
19	2000	0.93	0.81	-0.12	-12.90322581	3	5 to 25
23	2008	0.87	0.67	-0.2	-22.98850575	3	5 to 25
24	1996	0.77	0.57	-0.2	-25.97402597	5	>50
27	2005	0.7	0.77	0.07	10	1	<1
31	1997	0.73	0.7	-0.03	-4.109589041	3	5 to 25
32	1998	0.77	0.73	-0.04	-5.194805195	2	1 to 5
35	2004	0.77	0.62	-0.15	-19.48051948	4	25 to 50
36	2009	0.77	0.99	0.22	28.57142857	1	<1
46	2008	0.73	0.77	0.04	5.479452055	1	<1
47	2008	0.77	0.7	-0.07	-9.090909091	4	25 to 50
48	2008	0.77	0.77	0	0	1	<1
				Median	-4.11	3	
				Average	-6.59	2.63	

4.1.3.3 Freshwater Marshes

The project team conducted wetland functional assessments on 12 freshwater marsh mitigation sites. Eleven of the 12 sites had a net loss in functional assessment from the time they were permitted to current conditions. Six of the ten sites had 5% or greater coverage of exotic vegetation (category 3 through 5) with one site consisting of over 50% exotic species. Only one of these six freshwater marsh systems had a buffer present, while all lacked appropriate hydrology, which appears to be a main contributing factor that caused such a high concentration of exotics in these mitigation areas. The one site that did not have a functional loss had a buffer and less than 1% exotic vegetation present. The average functional change across all sites was a loss of 10.44%. Two of the freshwater marsh sites were originally permitted as wet prairie systems. The results of the 12 freshwater marsh mitigation site UMAM assessments are presented in **Table 4-8**.

Table 4-8. Freshwater Marshes mitigation site assessment UMAM score comparison for current and previous functional assessments including percent exotic species cover.

AEI Site ID	Permit Year	Permit UMAM	Current UMAM	Difference Gain/Loss	% Change	Exotic Category	% Exotics
15	2000	0.93	0.72	-0.21	-22.5806	3	5 to 25
16	2000	0.93	0.87	-0.06	-6.45161	2	1 to 5
9	2004	0.76	0.43	-0.33	-43.4211	5	>50
26	2005	0.7	0.9	0.2	28.5714	1	<1
45	1994	0.77	0.71	-0.06	-7.79221	3	5 to 25
39	1997	0.87	0.8	-0.07	-8.04598	2	1 to 5
40	1997	0.87	0.79	-0.08	-9.1954	2	1 to 5
42	2008	0.7	0.62	-0.08	-11.4286	3	5 to 25
50	1997	0.8	0.67	-0.13	-16.25	3	5 to 25
51	1997	0.8	0.76	-0.04	-5	2	1 to 5
43	1999	0.87	0.79	-0.08	-9.1954	2	1 to 5
22	2003	0.9	0.77	-0.13	-14.4444	3	5 to 25
				Median	-9.19	2.50	
				Average	-10.44	2.58	

4.1.3.4 Wet Prairies

The project team conducted UMAM assessments on only two wet prairies mitigation sites, due to the very limited availability of wet prairie mitigation sites that fit the required conditions. Several sites that had initially been selected under this category, based on permit information, were found to be functioning as freshwater marshes at the time of the site assessment. The two assessed wet prairies both had a gain in function based on the UMAM scores of 0.13 from the time they were permitted to the current assessment. These two wet prairie sites had less than 1% exotic vegetation present within the community and were in a natural setting with large buffers and adequate hydrology. It was noted that one of the wet prairie sites was supposed to be larger in area; however, the buffer zone contained numerous pine trees which converted a portion of the wet prairie to wetland pine flatwood. The results of these UMAM assessments on wet prairie mitigation sites are presented in **Table 4-9**.

Table 4-9. Wet Prairies mitigation site assessment UMAM score comparison for current and previous functional assessments including percent exotic species cover.

AEI Site ID	Permit Year	Permit UMAM	Current UMAM	Difference Gain/Loss	% Change	Exotic Category	% Exotics
28	2005	0.7	0.83	0.13	18.5714	1	<1
29	2005	0.7	0.83	0.13	18.5714	1	<1
				Median	18.57	1	
				Average	18.57	1	

4.1.3.5 Hydric Pine Flatwoods

The project team conducted UMAM assessments on five hydric pine flatwood mitigation sites. Two of these sites had a net loss of function while three had a net gain in function. The three hydric pine flatwood communities that gained function had limited or no exotic vegetation, less than one percent, while the two wetlands found to have a functional loss had up to 25% exotic vegetation within the mitigation area. A lack of fire suppression and inadequate hydrology, combined with a lack of a buffer zone at one site, appears to be causing exotic species encroachment into these two mitigation areas. The average functional change for all sites was a gain of 4.66%. Two of the Hydric Pine Flatwoods sites that were visited were originally permitted as different habitats. The results of the hydric pine mitigation site assessments are presented in **Table 4-10**.

Table 4-10. Hydric Pine Flatwoods mitigation site assessment UMAM score comparison for current and previous functional assessments including percent exotic species cover.

AEI Site ID	Permit Year	Permit UMAM	Current UMAM	Difference Gain/Loss	% Change	Exotic Category	% Exotics
14	2000	0.87	0.81	-0.06	-6.89655	2	1 to 5
33	1999	0.77	0.7	-0.07	-9.09091	3	5 to 25
37	2005	0.76	0.93	0.17	22.3684	1	<1
41	2005	0.76	0.79	0.03	3.94737	1	<1
49	2008	0.77	0.87	0.1	12.987	1	<1
				Median	3.95	1	
				Average	4.66	1.60	

4.1.3.6 Mixed Scrub-Shrub Wetlands

The project team conducted UMAM assessments on three mixed scrub-shrub mitigation sites. All three mitigation areas had a slight loss in function which is largely due to the high presence of exotic vegetation. Two of the mixed scrub-shrub sites are located adjacent to residential areas that included buffers. However, lack of exotic vegetation management in the buffers has led to the presence of exotics in the mitigation areas. The third mixed scrub-shrub wetland area was originally permitted to be a wet pasture but has undergone successional community phasing into its current community as a mixed scrub-shrub. The adjacent upland berms to this area also have not been maintained so exotic vegetation encroachment has taken place in the wetland. The average functional loss for all sites was substantial at -12.81%. One of the Mixed Scrub-Shrub sites that were visited was originally permitted as a different habitat. The results of these assessments on mixed scrub-shrub wetland mitigation sites are presented in **Table 4-11**.

Table 4-11. Mixed Scrub-Shrub Wetlands mitigation site assessment UMAM score comparison for current and previous functional assessments including percent exotic species cover.

AEI Site ID	Permit Year	Permit UMAM	Current UMAM	Difference Gain/Loss	% Change	Exotic Category	% Exotics
3	2004	0.67	0.63	-0.04	-5.97015	4	25 to 50
34	1999	0.77	0.74	-0.03	-3.8961	3	5 to 25
44	2002	0.77	0.55	-0.22	-28.5714	3	5 to 25
				Median	-5.97	3	
				Average	-12.81	3.33	

4.1.3.7 Permit UMAM versus Current UMAM Analysis

To determine if there was a significant overall loss of function in the 51 mitigated wetlands between the time they were permitted and their present state, a one-sided Wilcoxon Signed-Rank test was conducted to compare the mean permitted UMAM scores with the current UMAM scores. The results of this statistical test are shown below in **Table 4-12** and **Figure 4-2**. Based on the results of the current field assessment, there was an overall loss of wetland function in the 51 mitigation sites from the time they permitted to the current assessment. Although the mean score of the permit UMAM of 0.78 was not much higher than the current UMAM score mean of 0.741, the difference was significant to the 0.05 level (approximate P-value=0.02). This indicates that there was a statistically significant loss of function in these wetlands overall. Although the variability in UMAM scores between the two series is similar, the current UMAM scores have several outliers, therefore the standard deviation is greater than the permit UMAM scores.

Table 4-12. Wilcoxon Signed-Rank test results using the initial permitted UMAM scores and newly assessed UMAM scores for the 33 wetland mitigation sites with buffers.

UMAM Scores	Minimum UMAM	Maximum UMAM	Mean UMAM	Standard Deviation
Permitted	0.57	0.93	0.778	0.086
Current	0.4	0.99	0.741	0.120

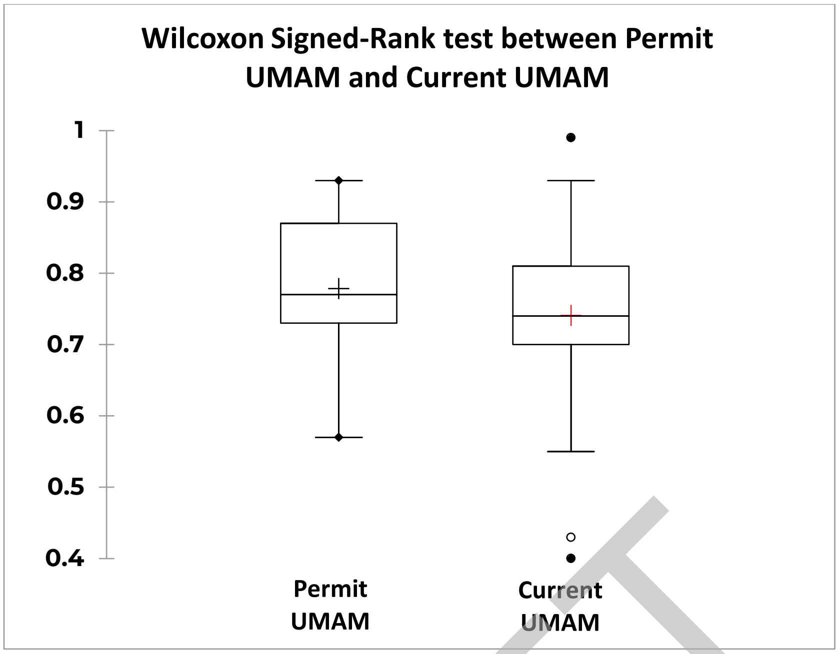

Figure 4-2. Wilcoxon Signed-Rank test box plots for the initial permitted UMAM scores and current UMAM scores for all 51 wetland mitigation sites.

4.1.4 Wetland Buffer Analysis Results

To determine if upland buffers around wetlands contribute to improvements or maintenance in wetland function over time, each mitigation wetland site was assessed to determine if an upland buffer zone around the wetland existed. Out of the 51 sites assessed sites, 33 had some form of undeveloped buffer zone around the wetland while 18 of the sites were mitigated without buffers.

A Wilcoxon Signed-Rank test was run individually for the (1) wetlands with buffers and (2) wetlands without buffers to determine if the UMAM scores that were calculated during the permitting process and the newly assessed 'current' UMAM scores were significantly different.

The wetland mitigation sites that had buffers did not show a significant difference (P-value = 0.543) between the permitted UMAM scores and the current scores. The mean of the UMAM scores given during the permitting process for the 33 wetland sites with buffers was 0.792, while the mean of the current UMAM scores was 0.780. Although the sites, on average, currently had lower UMAM scores than when they were permitted, the difference was not statistically significant. There was, however, more variability in the current UMAM scores as can be seen by an increase in the standard deviation. The results of the Wilcoxon rank sum test are presented below in **Table 4-13** and **Figure 4-3**.

Table 4-13. Wilcoxon Signed-Rank test results using the initial permitted UMAM scores and newly assessed UMAM scores for the 33 wetland mitigation sites with buffers.

UMAM Scores	Minimum UMAM	Maximum UMAM	Mean UMAM	Standard Deviation
Permitted	0.63	0.93	0.792	0.087
Current	0.55	0.99	0.780	0.100

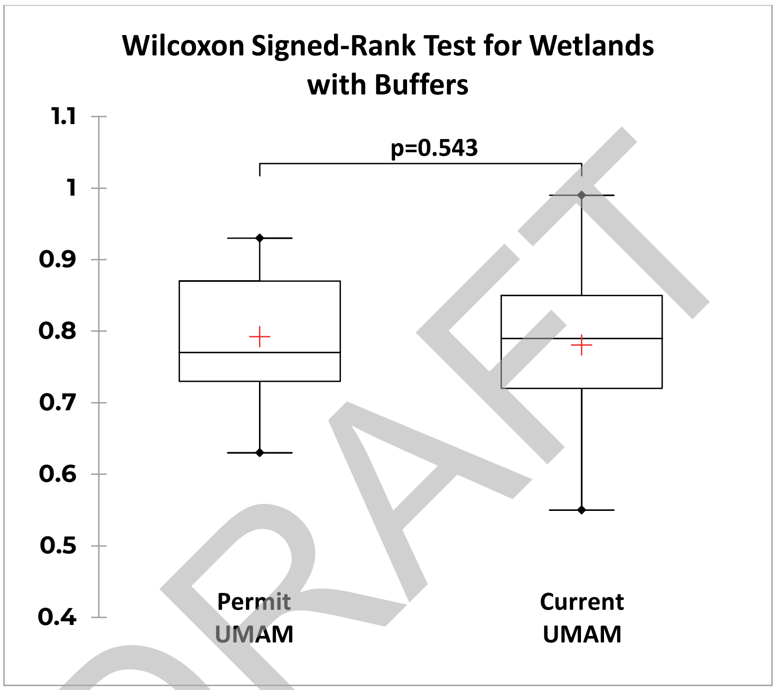

Figure 4-3. Wilcoxon Signed-Rank test box plots for the initial permitted UMAM scores and current UMAM scores for the 33 wetland mitigation sites with buffers.

The wetland mitigation sites without buffers did show a significant difference (P-value = 0.009) between the permitted UMAM scores and the current UMAM scores. The mean of the UMAM scores given during the permitting process for the 18 wetland sites without buffers was 0.753, while the mean of the current UMAM scores were significantly reduced to 0.668. On average, the current UMAM scores were 0.085 lower than the scores assigned during the permitting process. These results show a significant loss of wetland function for the wetland sites that did not have buffer zones, while the wetland mitigation sites with buffers were able to maintain function, highlighting the importance of establishing and maintaining upland buffers around wetlands. Like the results for the buffered wetlands, the current UMAM scores had a higher standard deviation, showing increased variability in the new UMAM scores. The results of the Wilcoxon Signed-Rank test for the wetlands without buffers are presented below in **Table 4-14** and **Figure 4-4**.

Table 4-14. Wilcoxon Signed-Rank test results using the initial permitted UMAM scores and current UMAM scores for the 18 wetland mitigation sites without buffers.

UMAM Scores	Minimum UMAM	Maximum UMAM	Mean UMAM	Standard Deviation
Permitted	0.57	0.90	0.753	0.081
Current	0.40	0.87	0.668	0.121

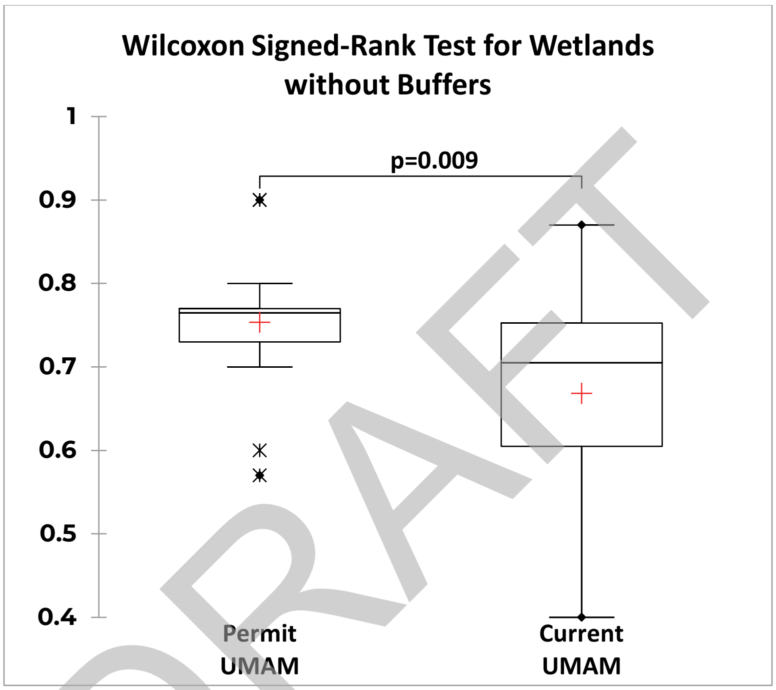

Figure 4-4. Wilcoxon Signed-Rank test box plots for the initial permitted UMAM scores and current UMAM scores for the 18 wetland mitigation sites without buffers.

All 51 wetland mitigation sites were then analyzed together using a Mann-Whitney U-test to determine if the current UMAM scores of the buffered sites were significantly different than the sites without buffers. The sites with wetland buffers had a mean UMAM score of 0.780 while the sites without buffers had a mean UMAM score of 0.668, showing a significant difference (P-value=0.002) between the buffered and unbuffered sites. The sites without buffers also had a higher standard deviation showing greater variability between the UMAM scores than the buffer sites. When the permitted UMAM scores were analyzed between the buffered sites and unbuffered sites they were not significantly different (P-value=0.281) with mean UMAM scores of 0.792 and 0.753, respectively. The results of the Mann-Whitney test on the current UMAM scores are presented below in **Table 4-15** and **Figure 4-5**.

Table 4-15. Results of the Mann-Whitney test between wetland mitigation sites with buffers and those without using the current UMAM scores.

Wetlands	Minimum UMAM	Maximum UMAM	Mean UMAM	Standard Deviation
No Buffer	0.40	0.87	0.668	0.121
Buffer	0.55	0.99	0.780	0.100

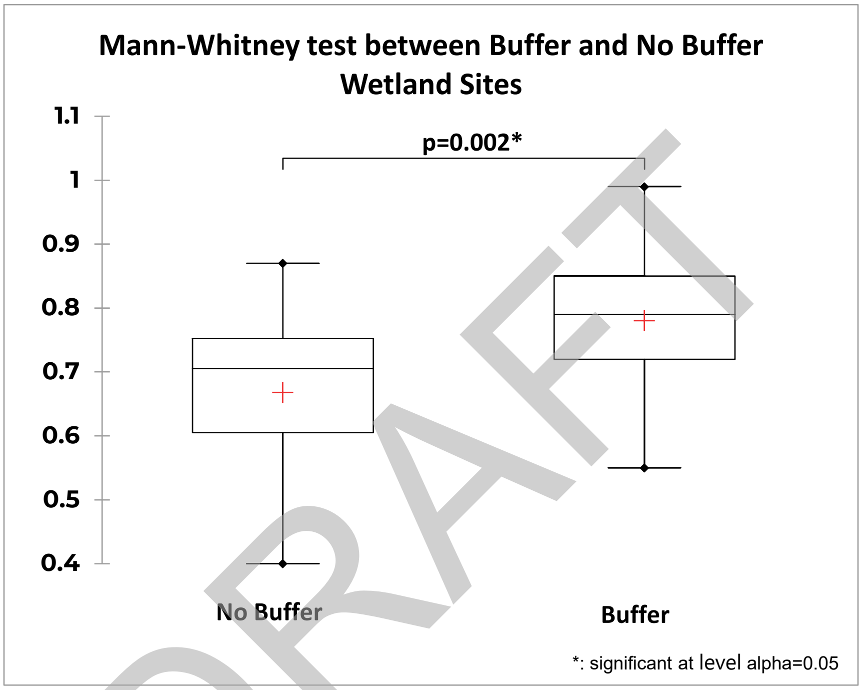

Figure 4-5. Mann-Whitney test box plots using the current UMAM scores for the 33 wetland mitigation sites with buffers and the 18 sites without buffers.

4.1.5 Wetland Functional Assessment Conclusions and Recommendations

Based upon the comparison of the functional assessments found in the permit files and current assessments, 35 of the 51 mitigation areas have lost functionality through time. Many of these functional losses are attributable to the compensatory mitigation location, connectivity, buffer, hydrology, and percentage of exotic vegetation found within the wetland and even in the adjacent buffers. Wetland mitigation areas located in adjacent industrial areas were more likely to decline in overall function. Many of these industrial wetland mitigation areas lacked buffers, showed signs of dumping or littering, lacked hydrologic connections, and had a high percentage of exotics.

A functional gain above what the corresponding permit projected was found in 13 of 51 mitigation areas. Functional gains in these cases were small, often negligible, and ranged from

0.03 to 0.22 depending upon the mitigation area. Of these 13 sites, all had a low percentage of exotic vegetation present. The wetland mitigation areas that had sufficient hydrology also tended to have less exotic presence.

Out of the 51 functional assessments, only three mitigation areas had a current functional score of 0.9 (very high function). The following conditions appear to have attributed to the higher functional assessment: location, established hydrologic connectivity to another larger wetland system, adequate buffer, extremely low exotic vegetation cover (< 1%), evidence of wildlife usage, appropriate hydrology, and native vegetative composition in each stratum.

The project team noted that several high-functioning compensatory mitigation sites had less than one percent exotic presence because the property owner was still performing exotic/nuisance species removal. The mitigation requirement of the permit had been attained years ago; however, the property owner chose to continue vegetative management of exotic species beyond the minimum permit requirements. The result of the ongoing exotic species removal is that the functional quality of the vegetative and structural habitats remains higher than other mitigation areas that were inspected.

On average, the current functional assessment of the 51 mitigation areas is 0.74. The functional assessments provided in the permit files for the 51 sites averaged 0.78. Out of the five communities that were assessed, the freshwater marsh and mixed scrub-shrub communities had the highest functional loss on average. One average, the wet prairie communities that were assessed had the highest overall functional gains, although the availability of wet prairie sites suitable for functional assessment was limited to two sites. Hydric pine flatwoods also had a slight functional gain overall, while cypress systems on average maintained function.

Sites with buffers tended to maintain function better over time compared to sites without buffers. The 33 sites with buffers had lower average UMAM scores under the current assessment compared to the permit values; however, the difference was not significant with mean permit scores of 0.79 versus 0.78 under the new assessment. Sites without buffers did show significantly lower scores under the current assessment compared with the permitted values. Non-buffered sites had permitted mean functional scores of 0.75 while the new assessment mean scores were 0.67, an average decline of 0.08. When the new assessment scores were compared between the buffered and non-buffered sites, there was a significant difference, with buffers sites scoring on average higher functional scores than the non-buffered sites.

The project team found that a comprehensive evaluation of the State of the Wetlands in Orange County as a result of the permitting process cannot be ascertained by looking exclusively at the permitting data because the database does not track the acreage of permitted wetland impacts nor the community types that have been authorized for impacts. The functional field assessment included only compensatory mitigation efforts that remained within the limits of Orange County, either onsite or offsite mitigation that was adjacent to or in close proximity to impact area, that included wetland enhancement and/or wetland preservation. Additional mitigation efforts include mitigation banking which can take place within or outside of the county boundaries. Based on the field assessment of selected mitigation sites, many of the mitigation areas that were included in this evaluation have a current condition that has degraded since the functional assessment was historically scored and described in the permit. Additional mitigation requirements in Article X, such as perpetual maintenance and monitoring, are needed to retain wetland function within Orange County and achieve a true "no net loss" objective. Despite the functional assessment rating, all the wetland mitigation areas offer an assortment of important ecological functions, including fish and wildlife habitat, nutrient uptake, flood protection/attenuation, climate regulation, groundwater recharge, and aesthetic and recreational enjoyment. The State of the Wetlands assessment evaluated only five general wetland types - cypress systems, mixed wetland forests, freshwater marshes, mixed scrub/shrub, and wet prairie habitats – that are found in Orange County. Wetlands provide valuable ecosystem services to the County, regardless of type, and help maintain the biological diversity that is vital to healthy and vibrant natural communities.

4.2 Drone Mapping and Data Analysis

AEI flew an Unmanned Aircraft System (UAS) mounted with a BaySpec OCI-F hyperspectral camera to collect imagery for the development of a wetland vegetation identification and characterization procedure. This experimental analysis was conducted to determine if remote sensing, using hyperspectral imagery, could be used to effectively identify wetland species, classify wetland habitats, and to access functional health using remotely operated vehicles. If remote sensing technology proves to be a viable method for level 1 and/or level 2 wetland assessments it could provide a lower cost alternative to on the ground assessment, especially over large areas, and allow for greater areal coverage at shorter time intervals than traditional methods.

A total of 15 flights across Orange County were flown from the 51 surveyed wetlands. These wetlands were selected to provide as diverse samples of all the wetland types found in Orange County as possible. Some of the 51 wetlands could not be flown due to airspace restrictions, inadequate launch locations, or other accessibility constraints. Each flight was performed by a certified FAA Part 107 pilot under fair weather conditions at an altitude of 400 feet, covering an average of 15 acres.

The BaySpec OCI-F collected 120 spectral bands between 400-1000 nanometers at a 1.5-inch spatial resolution. The OCI-F was calibrated with a 95% Spectralon sheet to calculate relative reflectance. The imagery was georeferenced by the BaySpec CubeCreator program and then processed to a GeoTIFF in ESRI ArcPro.

The vegetation identification process began with the selection of ground-truthed wetland species within the flight paths to extract representative spectral patterns for the species. A total of 8 representative samples were identified and then extracted from the GeoTIFF in ArcPro to Microsoft Excel. These 8 representative samples were then used to categorize an Unsupervised ISO Cluster Classification to increase the number of representative spectral patterns.

The representative samples were then used to inform an ArcPro Random Forest Supervised Classification model which was applied to the AEI 01 wetland flown on November 18, 2022. This wetland was selected as a case study for the use of the hyperspectral sensor to classify the co-dominant slash pine and cypress, then identify the potential stress resulting from the 2022 hurricanes Ian and Nicole.

The Random Forest classification was repeated until the training accuracy was at least 95%. Slash pine and cypress were targeted for the focus of classification as previous field efforts identified them as being the dominant vegetation of the site.

The hyperspectral imagery was also interpreted by the Enhanced Vegetation Index (EVI) and the Red-Edge Inflection Point (REIP) within ESRI ArcPro. Both algorithms are intended to provide an estimate of the general leaf density and vigor of vegetation, which are indicators of general wetland health. These were selected because they are compatible with the European Space Agency Sentinel-2 Multi-Spectral Imager sensor. The Sentinel-2 satellites have been collecting earth imagery since 2016 at a roughly 3-day revisit period at a 20 m practical resolution. This imagery is publicly available and has been extensively used across the globe to assess vegetation types and health, which in turn can be applied to all wetlands in Orange County.

The EVI (Equation 1) focuses primarily on the variation of reflected light in the NIR and is intended for use on landscapes with high biomass, exposed water or soil in the understory, and atmospheric interference (www.indexdatabase.de/db/i-single.php?id=16). The EVI is based on the Normalized Difference Vegetation Index (NDVI) which identifies healthy vegetation as reflecting more of the NIR spectrum. The REIP (Equation 2) is based on the impact that Chlorophyll has on the red to NIR spectrum, preferentially absorbing the red while reflecting the NIR spectrums (www.indexdatabase.de/db/i-single.php?id=139). Both these indices have been used to evaluate herbaceous and forested wetlands and their advantages are complementary. The EVI is more resistant to patchy canopies while the REIP is more resistant to oversaturation of a sensor in the NIR due to full canopies (Misra et al 2020).

Equation 1. Enhanced Vegetation Index (EVI) with Sentinel-2 band centers.

$$2.5\left(\frac{865\ nm - 705\ nm}{740\ nm + 6 * 655\ nm - 7.5 * 443\ nm + 1}\right)$$

Equation 2. Red-Edge Inflection Point (REIP) with Sentinel-2 band centers.

$$705 + 35\left(\frac{\left(\frac{665\ nm + 783\ nm}{2}\right) - 705\ nm}{740\ nm - 705\ nm}\right)$$

The resulting EVI and REIP processed imagery was then spatially interpreted using the ESRI ArcPro Optimized Hot Spot tool and then the resulting areas of high and low values were compared against the 2018 Florida Department of Emergency Management digital elevation model. The elevations were used as a proxy of wetland inundation and what impacts it may have on the distribution of the vegetation identified in wetland assessment site AEI 1.

4.2.1 Drone Mapping and Data Analysis Results

AEI performed a total of 15 UAS flights over a subset of the field inspected wetlands (**Table 4-16** and **Figure 4-6**). True color reference maps of each of the 15 flights are provided in **Appendix E**.

Table 4-16. Dates, IDs, and dominant wetland cover type for the 15 UAS flights performed.

AEI Wetland ID	Date	Wetland Type
18	9/26/2022	Mixed hardwood
19	9/26/2022	Forested Mixed
15	9/26/2022	Freshwater Marsh
4	11/17/2022	Mixed hardwood
21	11/17/2022	Cypress
22	11/17/2022	Freshwater Marsh
1	11/18/2022	Cypress
8	12/14/2022	Cypress
10	12/14/2022	Forested Mixed
50	12/16/2022	Freshwater Marsh
51	12/16/2022	Freshwater Marsh
5	12/16/2022	Forested Mixed
38	12/19/2022	Cypress
37	12/19/2022	Hydric Pine
36	12/19/2022	Forested Mixed

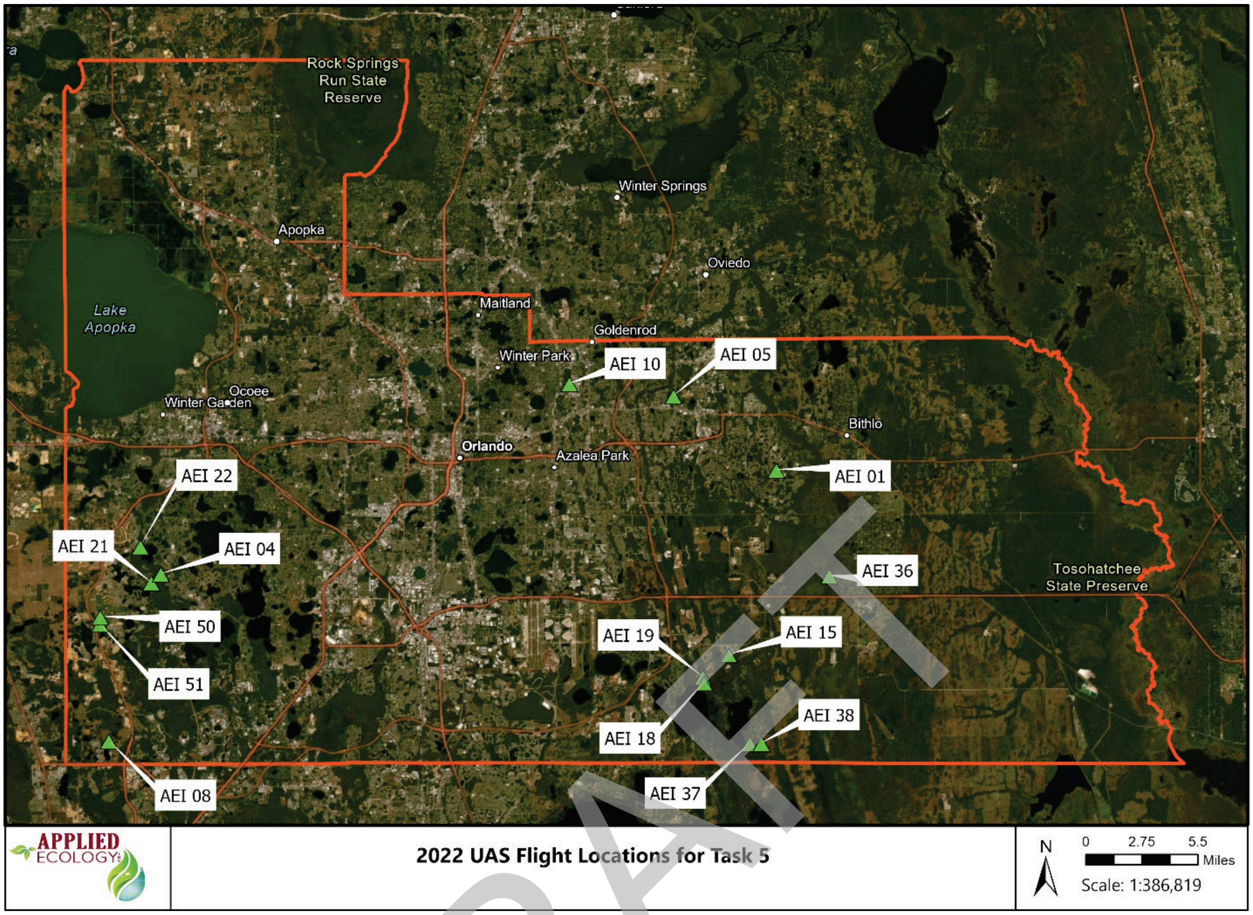

Figure 4-6. Locations of the 15 UAS flights performed in Orange County for Task 5.

4.2.1.1 Wetland Spectral Extractions

A series of ground-truthed herbaceous and woody wetland plants were identified and extracted from the BaySpec imagery to highlight both the variability between the species and their unique spectral fingerprints. The imagery was collected between September and December 2022, which captured the start to the Florida dry season as well as two hurricane events. Examples of the spectral signatures obtained from herbaceous (Figure 37) and woody (Figure 38) wetland plants are presented below. One of the key spectral differences between these types of plants is that woody plants with leaves or needles can reflect a larger percentage, up to 90%, of the Near InfraRed (NIR) spectrum (700-1300 nm) while herbaceous plants tend to reflect less than 30%. The visible light spectrum is provided in **Figure 4-7** for reference.

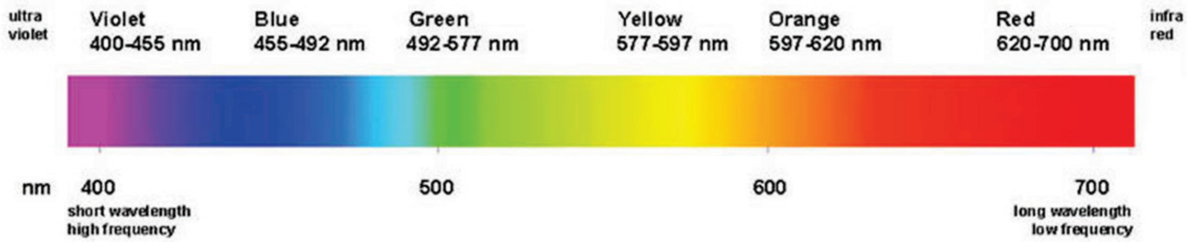

Figure 4-7. Visible light spectrum with color labels and nanometers (nm). Note: infrared spectrum is above 700 nm.

One example of an herbaceous wetland species, the waterlily, provides the most contrast. As seen in **Figure 4-8**, the spectral signature of the waterlily shows a decreasing reflectance of the NIR spectrum, which is indicative of the standing water that waterlilies are typically found in. As water will reflect in the blue part of the visible spectrum, it also absorbs the majority of the NIR light that reaches it. Additionally, waterlilies have a pronounced green reflectance which suggests a high Chlorophyll A content and healthy growth. Cordgrass and Cattail have a similar reflectance in the NIR, with most of the variation between these species occurring in the visible spectrum. Because cordgrass has a higher percent reflectance throughout the spectrum, as well as more reflectance in the red spectrum, it will generally appear to be brighter and brown to the human eye. Whereas cattails would tend to be darker with a greener hue. Lastly the bushy bluestem has the lowest reflectance of all the herbaceous wetland vegetation across the spectrum, which is likely due to the dark, rich organic soil it grows in.

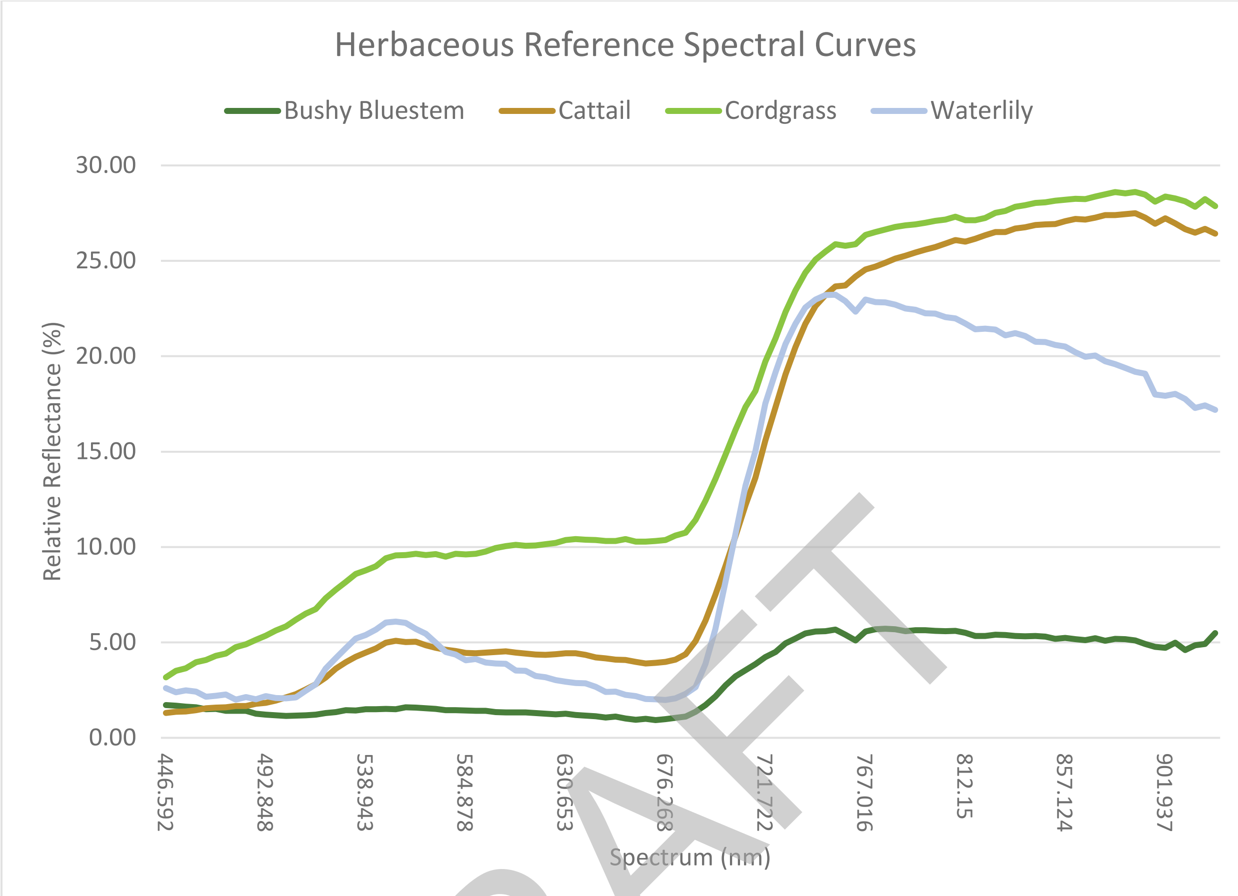

Figure 4-8. Reference spectra extracted from collected hyperspectral imagery for herbaceous wetland species.

In contrast, woody wetland and upland plants typically have a strong reflectance in the NIR spectrum (**Figure 4-9**). However, the Bald Cypress (*Taxodium distichum*) is an outlier in this instance, with the lowest NIR reflectance of the four woody species. This low reflectance may be the result of the seasonal changes that cypress undergoes, which typically turn brown in the fall. The cypress also has an elevated red reflectance relative to the green spectrum, as it was likely entering its fall state. The longleaf pine (*Pinus palustris*) and slash pines (*Pinus elliottii*) exhibit a similar reflectance in the lower wavelengths, with the longleaf pines exhibiting a brighter green than the slash pine. Because these are two closely related pines species, their reflectance throughout the spectrum is similar, showing only slight differences. Longleaf pine tends to have a higher reflectance in the NIR spectrum. Species that are closely related with similar reflectance values throughout the spectrum can present a challenge during assessment with multi-spectral sensors, however, under ideal conditions the differences can be recognizable. Lastly, the red maple (*Acer rubrum*), as its name would suggest, has a strong red reflectance due to its fall foliage. Timing data collection to correspond with the foliage change that occurs with the seasons can be beneficial when trying to identify specific species that undergo these transformations.

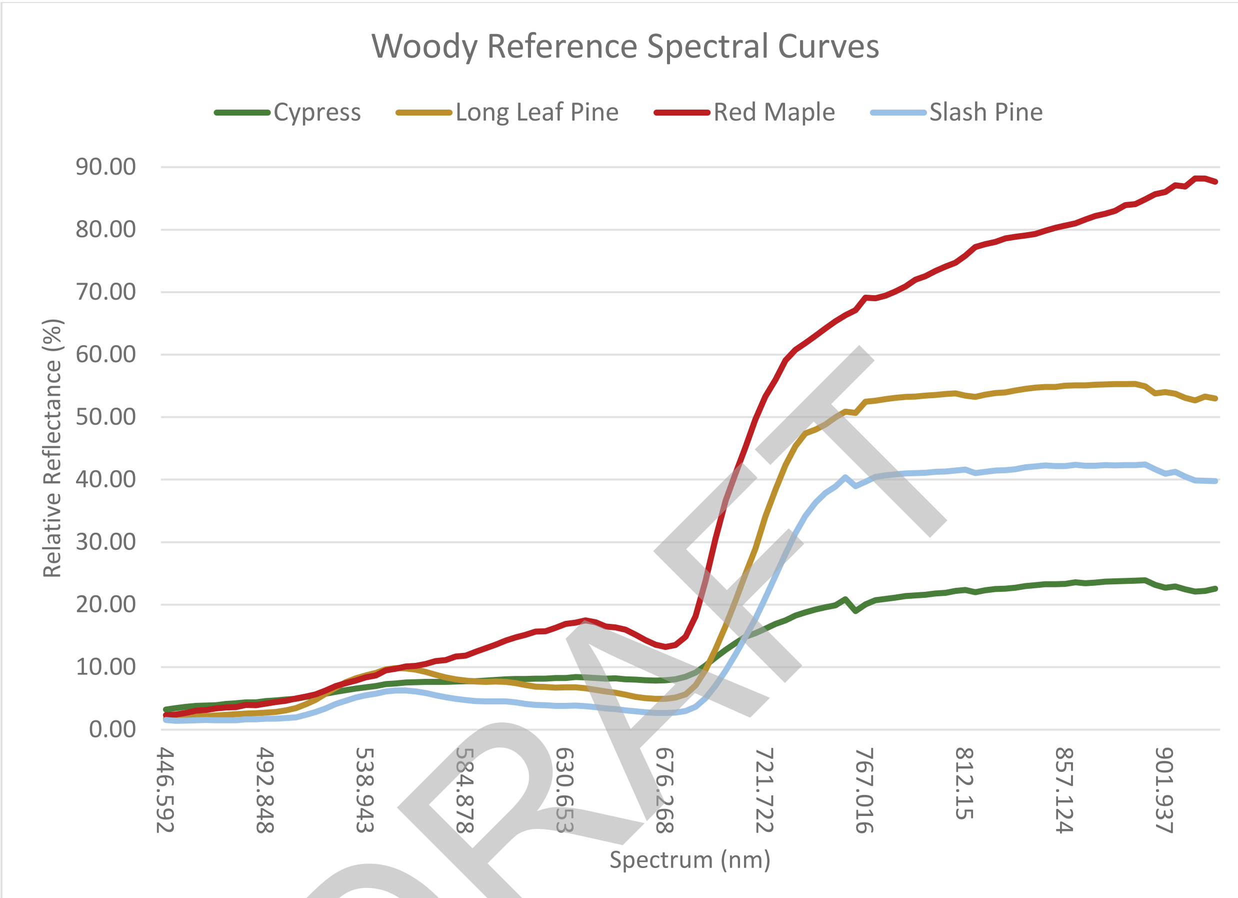

Figure 4-9. Reference spectra extracted from collected hyperspectral imagery for woody wetland species.

4.2.1.2 Wetland Classification

For illustrative purpose on the power of hyperspectral imaging using UAV for wetland community and wetland health mapping, the results of the analyses of the data collected for bald cypress and slash pine dominated wetlands (AEI 01) was flown on November 18th, 2022 covering approximately 15 acres (**Figure 4-10**). An initial field inspection of this site was conducted on August 26th of 2022. Between the field inspection and the actual data collection flight, hurricanes Ian and Nicole passed through the area.

Because the flight was performed before solar noon (i.e. when the sun is at its zenith in the sky), significant shading of the wetland understory occurred resulting in the collected imagery being more representative of the tree canopies.

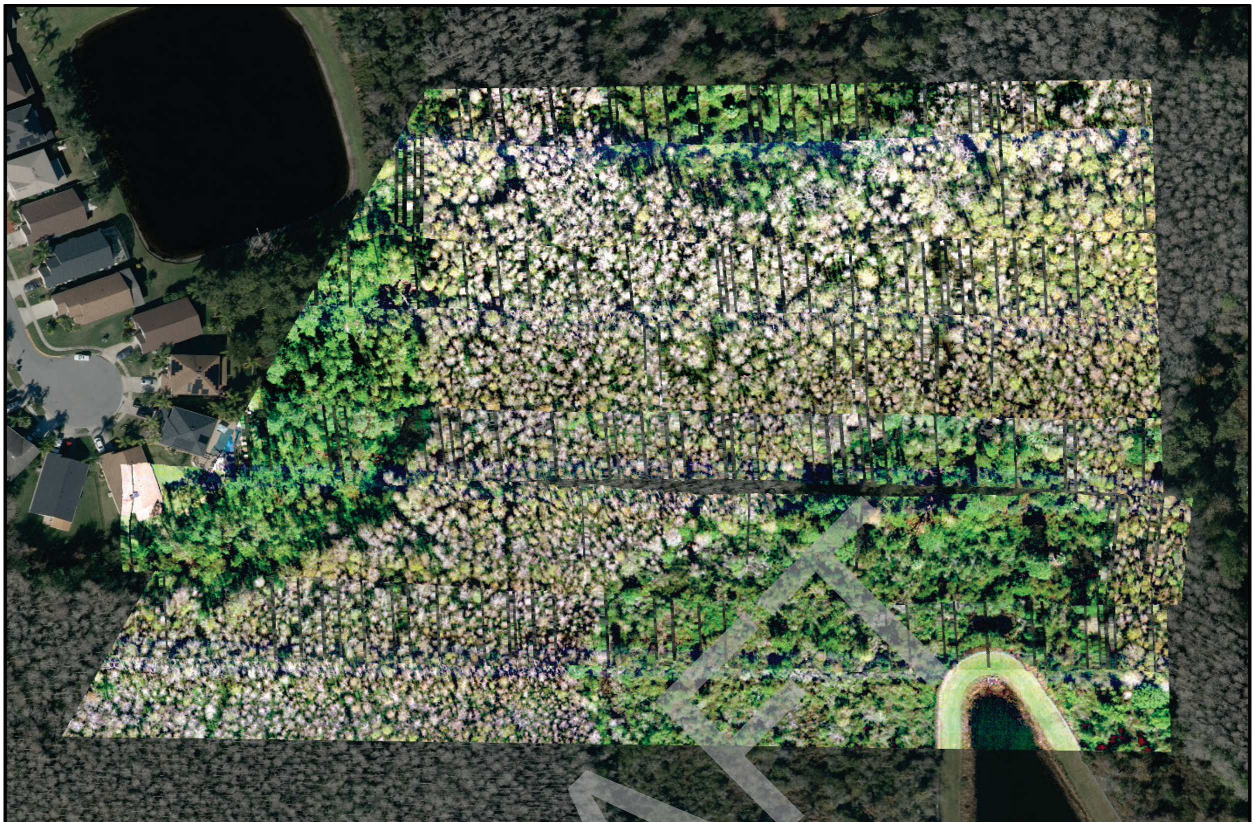

Figure 4-10. True color imagery of the AEI 01 wetland collected on November 18th, 2022.

4.2.1.3 Classified Imagery

The supervised classification of the hyperspectral imagery identified that the landscape was dominated by slash pines on the exterior with cypress occupying the interior of the AEI 01 wetland (**Figure 4-11**). There was a notable occurrence of slash pines amongst the cypress in the northern section of the flight area, however it is not uncommon for slash pines to encroach into cypress cores areas. Additionally, there were several likely cabbage palms (*Sabal palmetto*) identified amongst the slash pines on the exterior of the wetland.

The classification process also identified a split within the slash pine and cypress, with significantly different spectral curves (**Figure 4-12**). As the flight was performed in November, the slash pine and cypress had begun their transition to their reduced winter growth period. There was a general browning and dropping of some of their needles, which likely resulted in thinner canopy and more reflectance of the branches being captured by the hyperspectral camera. Additionally, the rate of browning and needle drop can be indicative of the stress that the tree was encountering (Wheeler et al 2020). This stress can be the result of temperature extremes, flooding, drought, or pests. There appears to be a concentration of the stressed slash pine and cypress trees in the northern section of the wetland, suggesting that both species could have been impacted by the same stressors.

The spectral difference between the healthy and stressed slash pines likely identified the shedding of needles. There was a shift observed between the green peak of the healthy pines around 550 nm to a more brownish color with somewhat equal reflectance between 550 and 666 nm. When slash pine shed their needles, the brown bark of the branches becomes the dominant reflected color. The spectral difference between the healthy and stressed cypress likely identified the trees that had begun to brown earlier or more rapidly than neighboring cypress. The increase of red reflectance around 666 nm would be perceived as a browner color to the human eye.

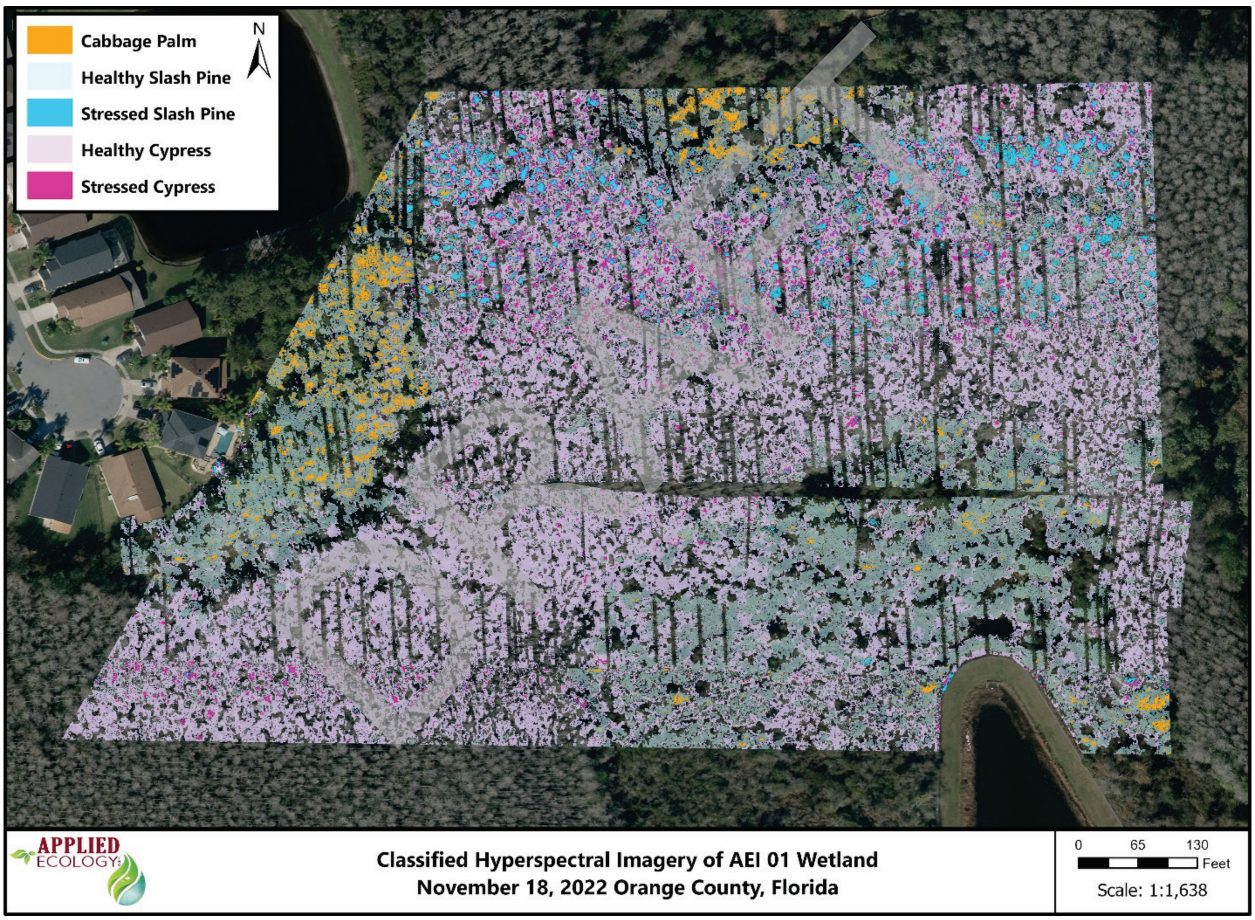

Figure 4-11. Results of the supervised classification of the AEI 01 wetland hyperspectral imagery collected on November 18th, 2022.

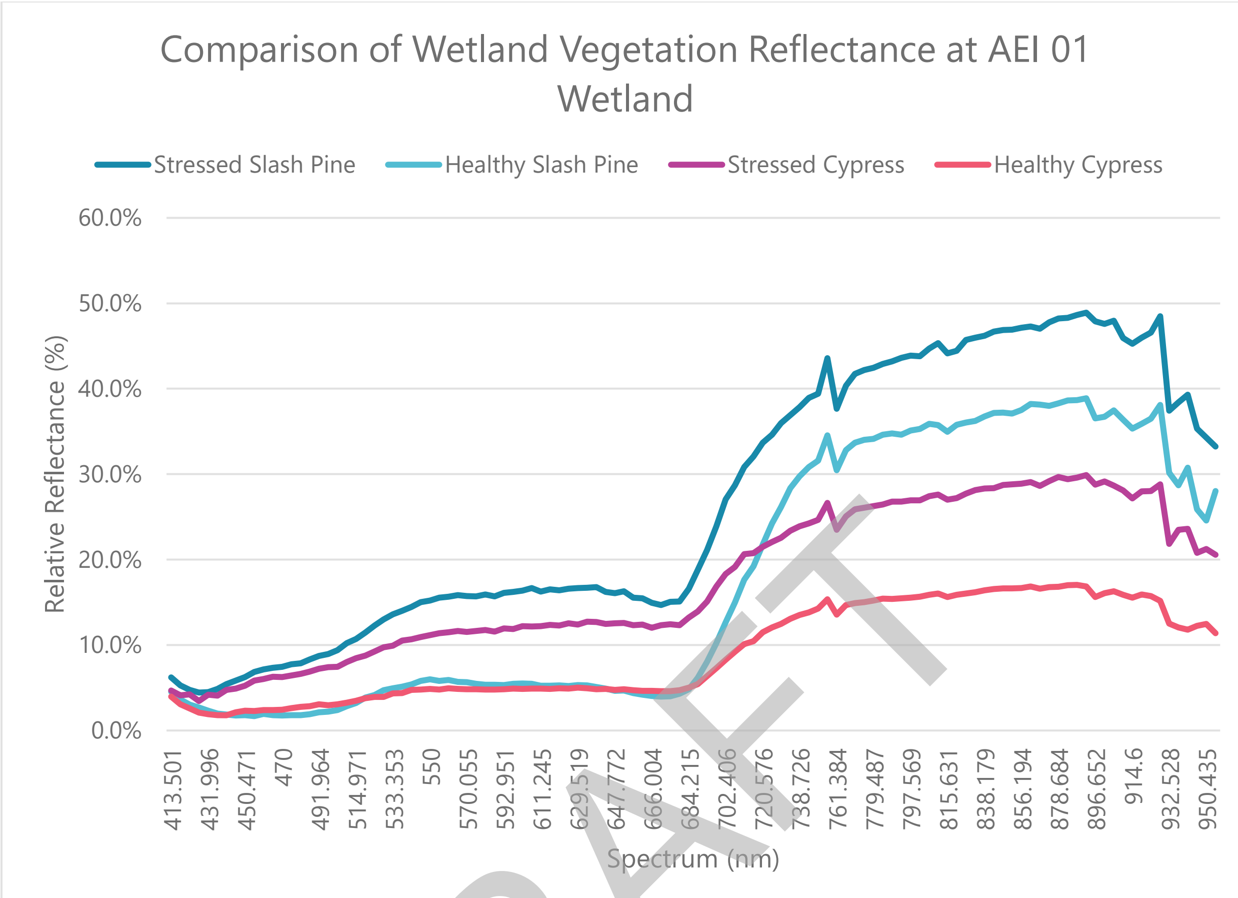

Figure 4-12. Comparison of the hyperspectral reflectance of wetland vegetation at the AEI 01 wetland on November 18th, 2022.

4.2.1.4 Enhanced Vegetation Index (EVI)

The Enhanced Vegetation Index (EVI) is based on the property of Chlorophyll A to strongly absorb light in the red spectrum and the physical structure of the leaves to reflect the NIR spectrum. The greater the difference between the reflectance of the NIR and red spectrums, the more likely the tree canopy has abundant leaves reflecting the presence of Chlorophyll A. These signatures likely indicate a healthy, unstressed tree. The inclusion of additional red and blue reflectance into the equation is intended to help reduce interference from the ground cover under the tree and a small amount of atmospheric interference. The higher the EVI value is, the more likely the vegetation is healthier and has a thicker canopy (Xue and Su 2017). Using an established index of vegetation health, such as EVI, can enable overall changes in wetland health to be captured at a broader landscape scale by leveraging available satellite sensors and can also be applied at a more local and refined scale using UAV platforms.

The EVI interpreted imagery from site AEI 01 generally appears to show the stands of slash pine to have the highest values, with a mixture of high and low values in the cypress dominated area (**Figure 4-13**). When EVI values are extracted for the slash pine and cypress, the healthy trees had a higher mean EVI compared to the stressed trees identified earlier (**Table 4-17**). Additionally, the cypress had a lower mean EVI than slash pine which was likely indicative of the seasonal browning that cypress trees experiences in November. Stressed slash pine trees (EVI of 1.112) also demonstrated a larger decrease in mean EVI scores from healthy slash pine (EVI of 2.076), compared to that of healthy and stressed cypress trees which had mean EVI values of 1.583 and 1.021, respectively. These differences in EVI values may be indicative that the stressed slash pine was responding more negatively to the preceding environmental conditions at AEI 01 on November 18th.

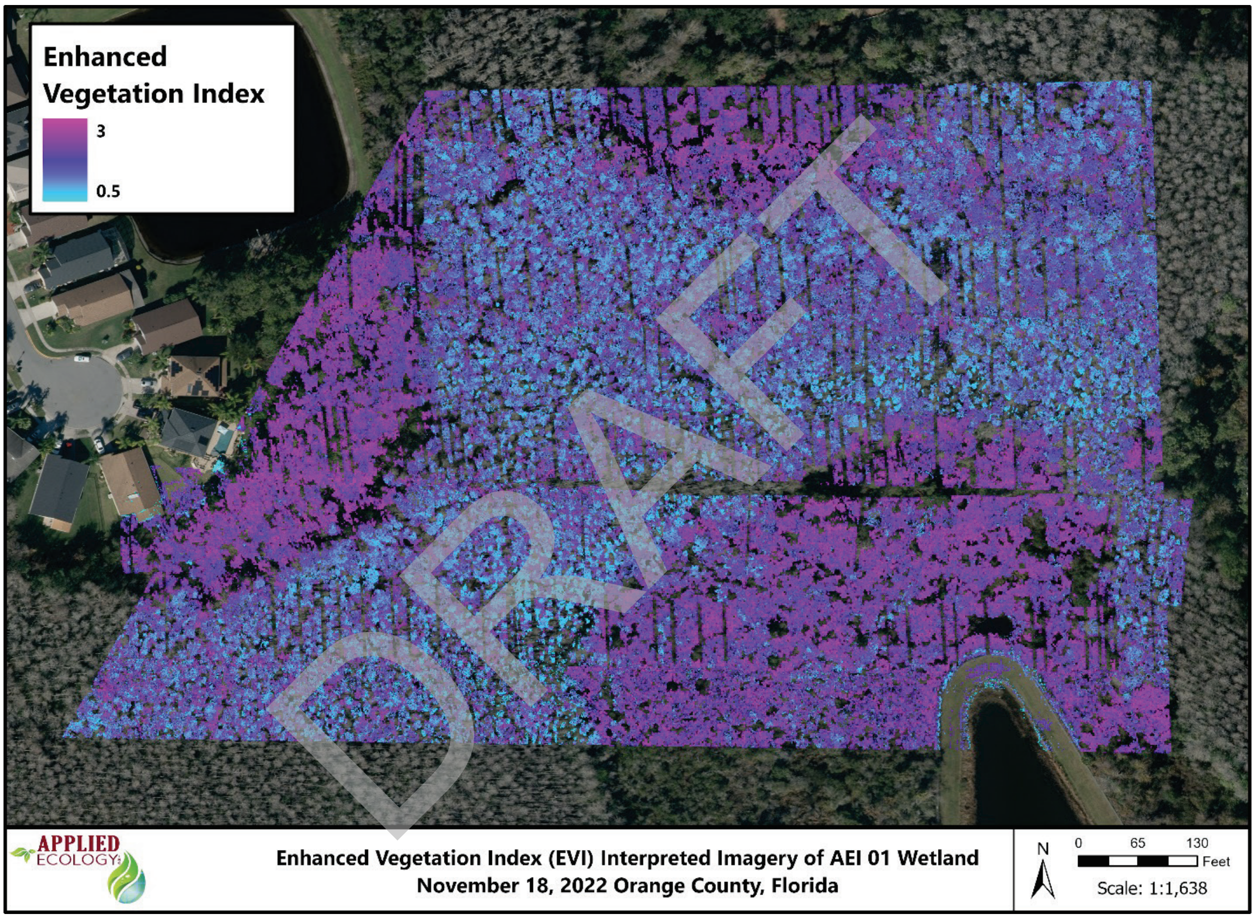

Figure 4-13. Enhanced Vegetation Index (EVI) interpreted imagery of AEI 01 wetland vegetation collected on November 18th, 2022.

Table 4-17. Summary statistics of Enhanced Vegetation Index (EVI) values of the classified vegetation covers (larger numbers represent higher Chlorophyll A content).

Vegetation	25th Percentile	Mean	Median	75th Percentile	Area
Healthy Cypress	1.049	1.583	1.371	1.800	36.3%
Stressed Cypress	0.840	1.021	0.977	1.148	1.6%
Healthy Slash Pine	1.722	2.076	2.035	2.500	19.2%
Stressed Slash Pine	0.952	1.112	1.090	1.247	1.5%
Cabbage Palm	1.940	2.140	2.125	2.292	1.3%

4.2.1.5 Red-Edge Inflection Point (REIP)

The Red-Edge Inflection Point (REIP) also leverages the spectral characteristics of Chlorophyll A and leaf structure but focuses on the behavior of the red-edge (665 nm to 783 nm) rather than the NIR of other vegetation indices. The red-edge is characterized by a low reflectance around 705 nm with high peaks on either side at 665 nm and 783 nm. This typically results in a more focused estimate of Chlorophyll A concentrations rather than canopy fullness, without the potential impact of over saturation of the sensor from the NIR range reflectance. This oversaturation in the NIR is observed in this dataset as the 705 nm absorption peak for has been shifted to approximately 680 nm (Main et al 2011). The resulting REIP interpreted image will likely have more contrast between vegetation and reduced noise leading to a clearer picture. The REIP also leverages a section of the visible spectrum which only recently can be captured with off the shelf multispectral cameras such as the MicaSense RedEdge or publicly available satellite imagery such as the European Space Agency Sentinel-2.

Like EVI, the highest REIP values, which indicate healthier trees, were observed amongst the slash pine dominated areas (**Figure 4-14** and **Table 4-18**). However, within cypress dominated areas there are more patches of elevated REIP values compared to the EVI distribution. These elevated REIP values are likely a clearer differentiation between the healthy and stressed cypress trees. As more of the cypress canopy branches are exposed in the fall, the reduced impact of the NIR reflection on the REIP allows for it to differentiate between cypress with reduced canopies but differing concentrations of Chlorophyll A in the remaining leaves.

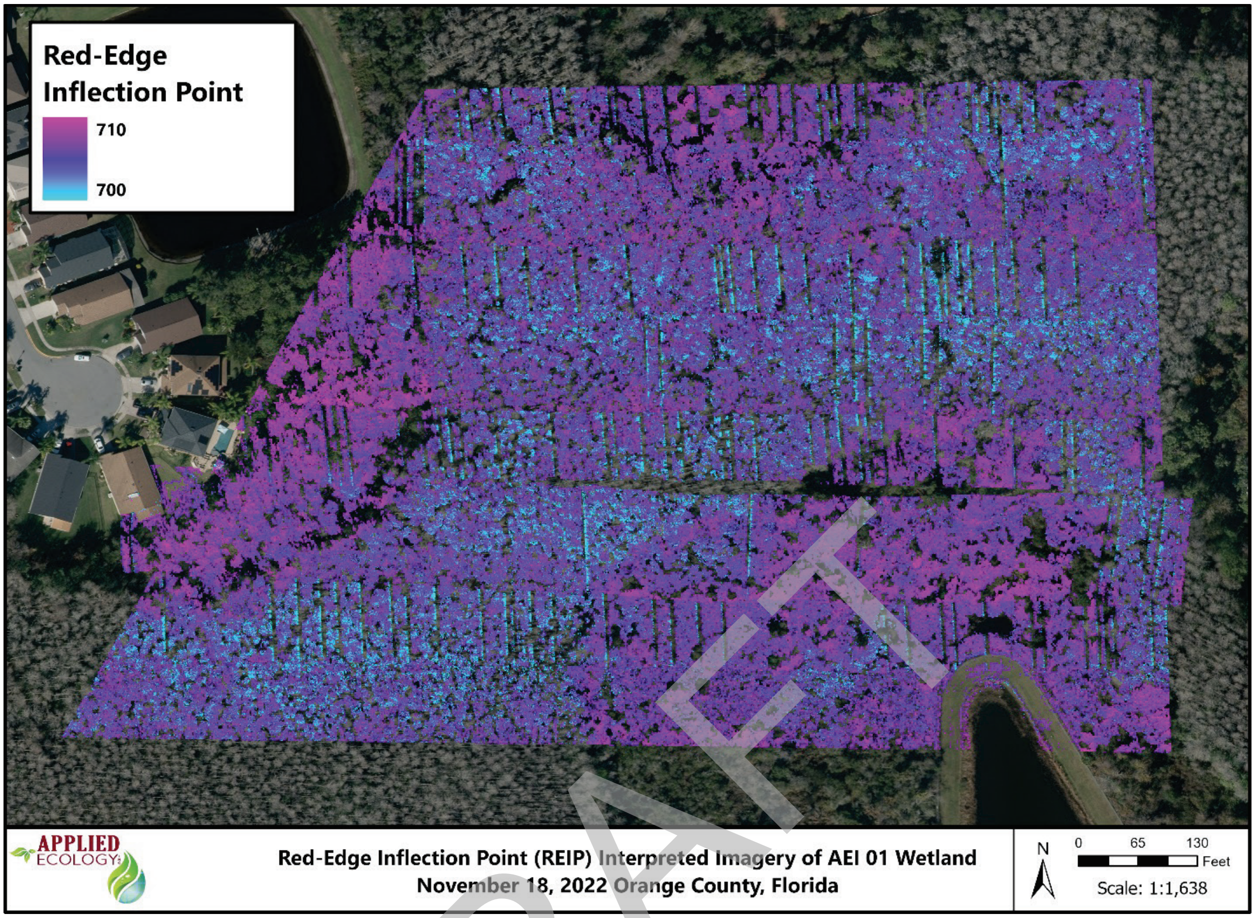

Figure 4-14. Red-Edge Inflection Point (REIP) interpreted imagery of AEI 01 wetland vegetation collected on November 18th, 2022.

Table 4-18. Summary statistics for Red-Edge Inflection Point (REIP) values of the classified vegetation covers (larger numbers represent higher Chlorophyll A content).

Vegetation	25th Percentile	Mean	Median	75th Percentile	Area
Healthy Cypress	709.63	713.02	713.85	717.33	36.3%
Stressed Cypress	704.62	707.88	708.89	712.38	1.6%
Healthy Slash Pine	714.05	716.61	717.09	720.00	19.2%
Stressed Slash Pine	705.41	708.30	709.00	712.17	1.5%
Cabbage Palm	716.39	718.31	718.51	720.56	1.3%

4.2.1.6 Hot Spot Analysis

A hot spot analysis was performed using the REIP interpreted imagery to identify patterns of REIP values for slash pine and cypress identified pixels. The hot spot analysis of the slash pines (**Figure 4-15**) identified that the likely stressed, low REIP value trees were predominately within the cypress dominated areas. The likely healthiest, high REIP value trees appeared to cluster with the slash pine dominated areas with 3 small clusters of high REIP values scattered in the cypress dominated area. While slash pine and cypress can occupy similar wetland conditions, the slash pines found amongst cypress may drop more needles or have less Chlorophyll A in their canopy.

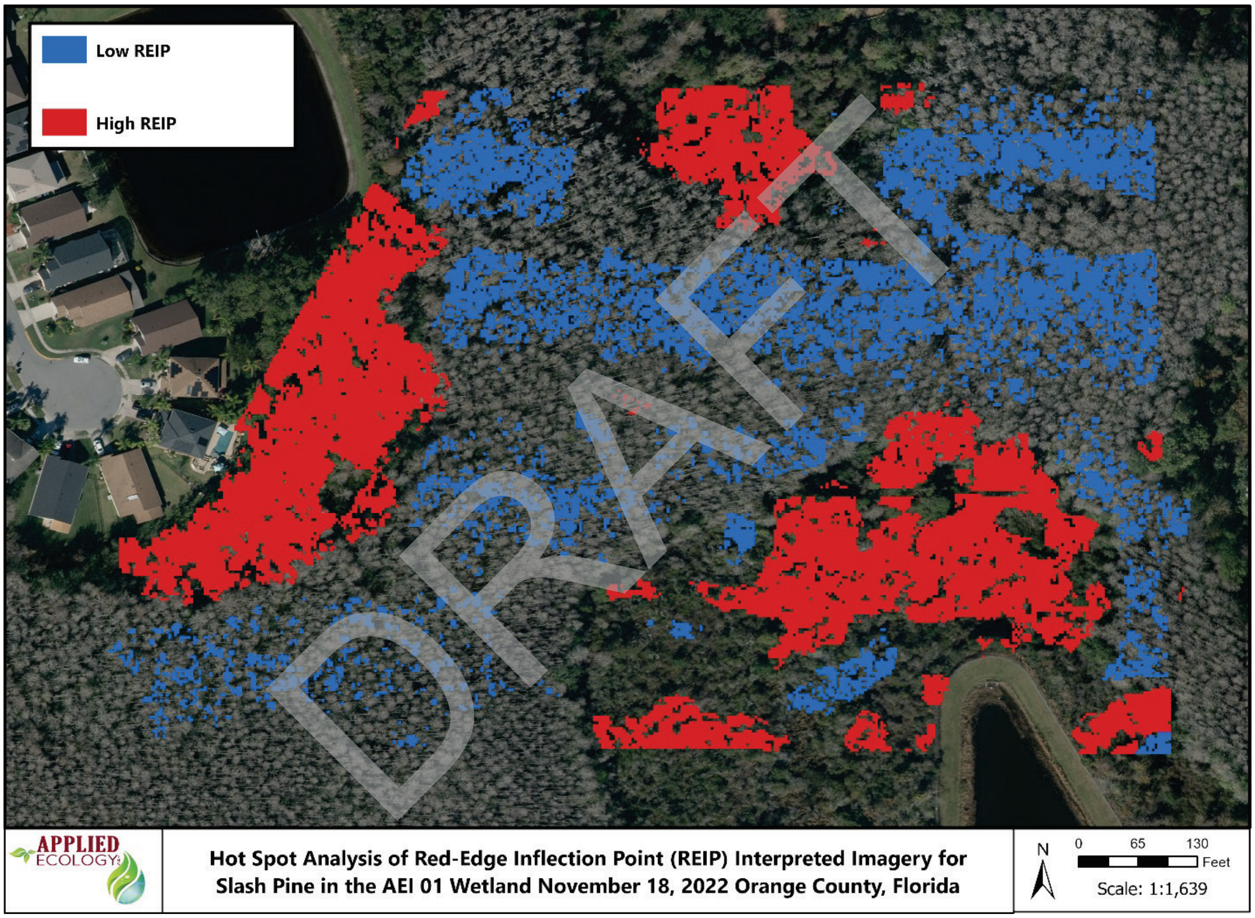

Figure 4-15. Hot spot analysis of Red-Edge Inflection Point (REIP) interpreted imagery for the slash pine trees identified by supervised classification in the AEI 01 wetland.

The hot spot analysis of the cypress (**Figure 4-16**) identified that the likely stressed, low REIP value trees were predominately within the cypress dominated areas intermixed with healthy, high REIP value trees. The scattering of healthy cypress amongst the southeast slash pine dominated area may be indicative of the cypress successfully occupying the understory. The low REIP value trees appear to cluster and share borders with one another.

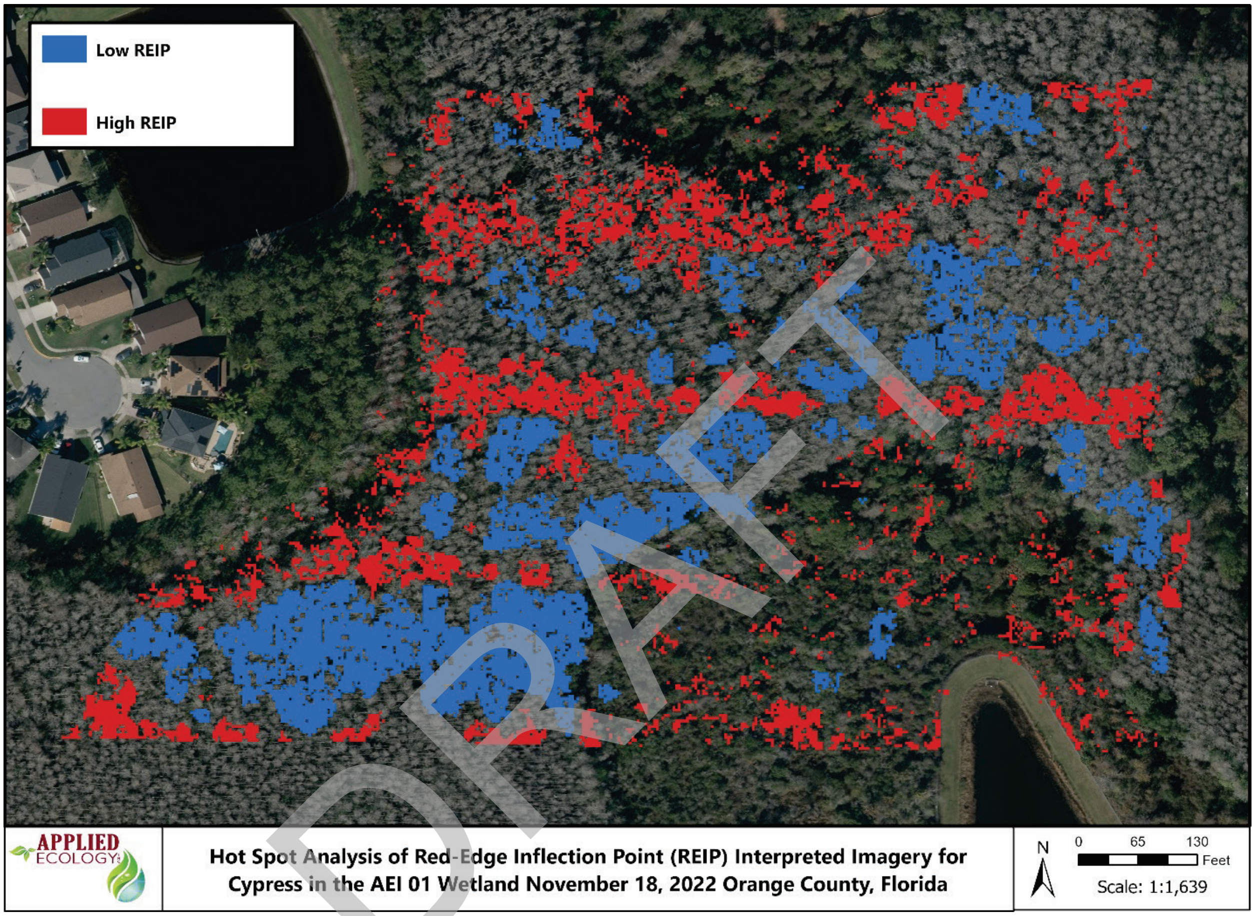

Figure 4-16. Hot spot analysis of Red-Edge Inflection Point (REIP) interpreted imagery for cypress trees from supervised classification in the AEI 01 wetland.

As over inundation following the two hurricanes was suspected to be a cause of stress, the hot and cold spots were then compared against the 2018 Florida Department of Emergency Management LiDAR derived elevations. Lower elevations were likely to have been inundated under deeper waters for a longer period. The high REIP slash pine hot spots were more likely to be found at the highest elevations in the area, followed by the high REIP cypress (Table 4-19). The low REIP cold spots for both slash pine and cypress were found at the lowest mean elevations. This could suggest that prolonged flooding of a mixed slash pine and cypress wetland may result in similar stresses for the two trees.

Table 4-19. Mean elevation in ft NAVD88 as estimated by the 2018 Florida Department of Emergency Management Peninsular LiDAR effort.

Vegetation	Elevation (ft NAVD88)	
	High REIP Hot Spot	Low REIP Cold Spot
Slash Pine*	64.294	62.985
Cypress*	63.372	62.974

* Significantly different hot spot and cold spot means at $p < 0.001$

4.2.2 Drone Mapping Conclusions and Recommendations

The value of remote sensing is in the ability to provide a snapshot of an entire landscape within a comparable time frame. It would be prohibitively resource intensive to capture a similar scale of information regarding wetland systems through field efforts. However, there can be more specificity in the data collected during intensive field efforts that, due to spatial or spectral resolution of the air or spaceborne sensor, can be impossible to determine from remote sensing alone, especially when considering ground cover under a forest canopy The investigational pilot run of the hyperspectral wetland mapping technology presented in this report highlights the value of adding remote sensing tools to the Orange County wetland management toolbox.

A UAS mounted camera, when used in parallel with field efforts, opens inaccessible wetlands for assessment through the characterization of the type and health of vegetation by analyzing the imperceptible variation in reflected light, and the creation of a mapped wetland product that can then be compared with other spatial data to help explain patterns and trends within the wetland. The AEI 01 wetland example provided in this report offers an example of this type of workflow. The UAS covered approximately 15 acres of the wetland in less than an hour, and the resulting imagery was processed to estimate the distribution of slash pine and cypress, as well as identify where the slash pines were encroaching upon the cypress. Then, with the application of spectral indices to interpret the imagery, areas of stressed trees were quantified and then compared against additional datasets to help explain the observed patterns. Following the hurricanes Ian and Nicole, Orange County experienced extreme inundation and the observations from the AEI 01 wetland suggest that cypress wetlands located in depressions that were flooded for an extended period could become an area of concern due to stress caused to the trees.

The AEI 01 wetland example also highlights the potential to leverage additional remote sensing assets such as the Sentinel 1 and 2 satellites to track changes in wetland conditions across the entire county, assets which are readily available without cost. The Red-Edge Inflection Point index was intently designed for the application to the Sentinel 2 A/B satellites, the only publicly available satellites that currently have the sensors to capture the required light spectrums. As wetland elevation and inundation patterns are another potential variable in characterizing wetlands, the Sentinel 1 A/B satellites with their Synthetic Aperture Radar (SAR) can provide estimates of both elevations and moisture content of wetlands. The fusion of these two data sources has been successfully utilized on wetlands across the world and in Florida (Mahdianpari et al 2018, Liao et al 2020, Slagter et al 2020). With Sentinel data availability beginning in 2016, there is a wealth of existing data that can be used to train advanced classification methods along with identifying potential seasonal and long-term patterns in wetland conditions.

5 WETLAND FRAGMENTATION ANALYSIS

5.1 Introduction to Fragmentation

Wetland fragmentation, or the breakdown in wetland connectivity across a landscape, is attributed to a loss in biodiversity and important wetland functions. Wetland fragmentation was analyzed across Orange County to evaluate the changes in wetland contiguity and distribution over time. The analysis was conducted on the four wetland land cover datasets (1990, 2000, 2010, and 2022) and run through FRAGSTATS, a spatial analysis program, with metrics computed for two different scales – Landscape and Wetland Class (Habitat Type), including Cypress, Freshwater Marsh, Hydric Pine Flatwoods, Mixed Wetland Forests/Hardwoods, Wet Prairies, and Mixed Scrub Shrub Wetlands. The methods used, results, and conclusions are addressed in the following sections.

5.2 FRAGSTATS Wetland Fragmentation Analysis

To determine if the wetlands in Orange County are becoming more fragmented over time, often considered a surrogate for wetland function at a landscape scale, a well-known open-source application for assessing the heterogeneity of a landscape called FRAGSTATS (version 4.2) was used. FRAGSTATS is a spatial pattern analysis program that was developed to quantify landscape structure (i.e., composition and configuration) (McGarigal, 2002). FRAGSTATS was designed to run using categorical land-cover datasets, like the ones developed through the API process. More information about the program and detailed explanations of the analysis methods and metrics can be found on the Fragstats website (https://fragstats.org).

To run the FRAGSTATS program, several processing steps had to be completed on the wetland API polygon feature classes prior to implementation. The API layers were converted to a metric-based spatial reference, required by FRAGSTATS, and then transformed into a categorical Georeferenced Tag Image File Format (GeoTIFF) raster dataset, consisting of 4 meter x 4 meter grid cells (approximately 13.1′ x 13.1′), using the eight API wetland and waterbody categories. This was the smallest grid size that could be applied, while still covering the entire county, due to memory and processing constraints imposed by the 32-bit processing environment employed by the FRAGSTATS program.

FRAGSTATS can analyze categorical land cover datasets at three different scales: Landscape, Class, and Patch. At the landscape scale, the entire area of interest, in this case Orange County, is analyzed as a whole without regard to the categorical data. The metrics that are selected and produced at the landscape scale are not relevant to smaller scales. At the class level, each categorical land cover class is analyzed throughout the entire landscape and the metrics produced at this level are only relevant to the summed area of the class and not to the individual patches of the class present. Patch level analysis includes metrics for each individual patch within each class and throughout the entire landscape (i.e., every individual wetland polygon is analyzed).

The analysis conducted on the four wetland land cover datasets (1990, 2000, 2010, and 2022) were run through FRAGSTATS with metrics computed for two different scales – Landscape and Wetland Class. Prior to running the model, a definition of the "landscape" is required, and four mandatory model parameters must be defined. These include:

1) Sampling Strategy
2) Neighborhood Rule
3) Aggregation/Proximity Search Radius
4) Edge Depth

For this analysis, the entirety of Orange County was considered the "landscape" in question, and the metrics produced are representative of the whole land cover dataset. Many of the analyses conducted using FRAGSTATS are primarily focused on one or more species' use of the habitats within the landscape. However, for the State of Wetlands Study, our analysis is focused solely on the wetland and waterbody land covers within Orange County and was not conducted with a particular species in mind. Therefore a "no-sampling" strategy was chosen as the sampling strategy for this analysis, as the entire county represents the sampling area. This sampling strategy considers the landscape as a whole and does not partition it during the analysis.

An eight-cell neighborhood rule was utilized to determine patch membership, meaning that each of the eight grid cells surrounding a center cell (i.e., 4 orthogonal and 4 diagonal) were analyzed in relation to the center cell (**Figure 5-1**). Every cell in the landscape is analyzed this way and any of the eight cells that are found to be the same wetland type as the center cell were then included in the same patch area.

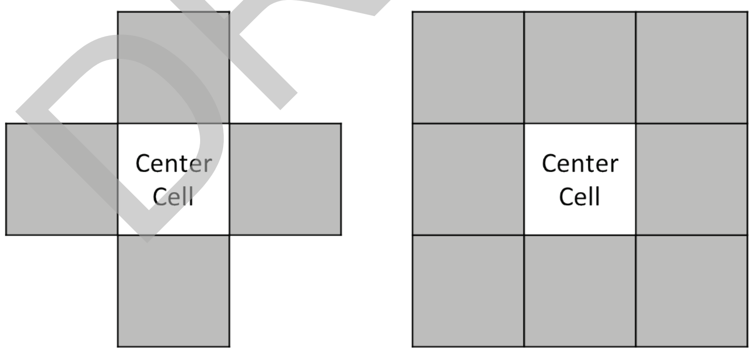

Figure 5-1. Neighborhood rules available for FRAGSTATS patch determination; the 8-cell rule (right) was selected for analysis.

The Aggregation/Proximity search radius defines the search radius that FRAGSTATS will apply to a focal patch when searching for neighboring patches of the same habitat type. The search radius was set to 500 meters for this analysis to provide a measure of habitat connectivity for species that may have poor dispersal patterns and/or are limited in the distance that they can travel between habitat patches, either by mobility or anthropogenic activities (e.g., roadways).

The last required model parameter, Edge Depth, represents the transition area or boundary between distinct habitat types (i.e., between a wetland forest and freshwater marsh). The transition from one habitat type to another can occur gradually in the area between the two habitats or it can be more abrupt with high-contrast edges, especially in urban and agricultural areas. Because our analysis focuses on the landscape and not on a particular species' use of the habitat, a constant edge depth of one grid cell, or 4 meters, was chosen as the model parameter. Areas of the land cover class inside the boundary areas are called "core" areas and are quantified to represent the actual land cover class without including the transition area between land cover types (**Figure 5-2**).

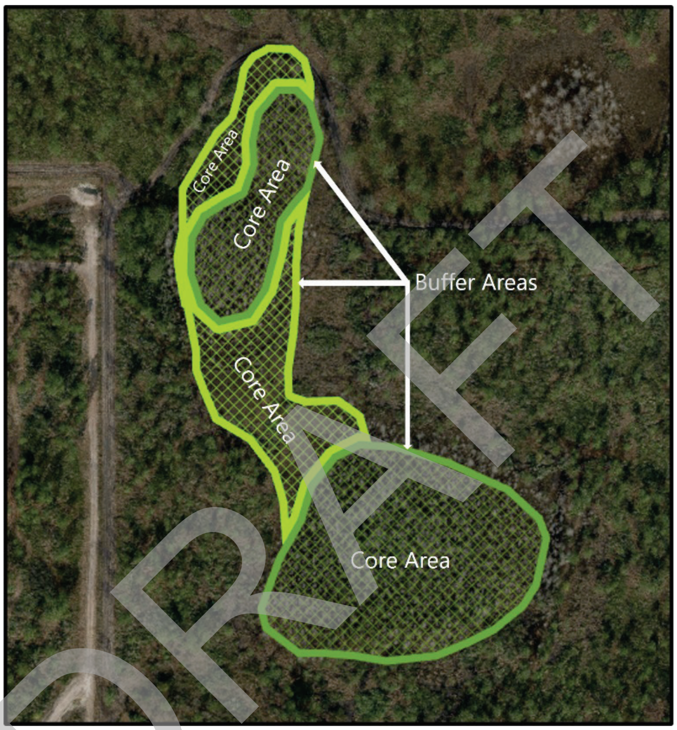

Figure 5-2. Core areas and buffer areas of a small wetland system, using a 4-meter (13.12 feet) buffer depth. One wetland (light green) shows a contiguous wetland with multiple core areas separated by a merged buffer region.

In addition to running the model across the entire landscape without regard to wetland classes (habitat types), the FRAGSTATS analysis was also conducted on the seven different wetland classes that were mapped during the API process. The class level fragmentation statistics analyze the wetland types independently, whereas the landscape level statistics evaluate fragmentation across the entire landscape, in this case Orange County, without regard to wetland classification. Class level results use the term patch(es) to identify distinct habitat areas of the same wetland types that do not share a common boundary. While at the landscape-level, patches refer to all distinct patches including patches of different wetland types that may share common boundaries. At the class level, some wetland types may show less fragmentation over time while others become more fragmented. It is important to note that this analysis does not address wetland function and health directly, it is only used to assess the fragmentation of habitats over time. Also, since these analyses were run using the rasterized versions of the API mapping results, the acreage values may vary slightly from those reported for the wetland API feature class totals.

FRAGSTATS was run independently for each of the four LULC years (1990, 2000, 2010, and 2022) and does not analyze the wetland API results concurrently or in a multi-dimensional format. This means that the results are a snapshot in time, independent of what is occurring before or after. FRAGSTATS does not look at the number of patches from one year then compare that to another year when calculating the metrics.

Wetlands classified as "Other wetlands" were included in both the landscape and the class level fragmentation analyses; however, they are not addressed in the discussion of the class-level results because this class includes an aggregation of several disparate wetland types, from emergent wetland types to other forested systems. Some categories may be less fragmented while others become more fragmented thus presenting the results as a combined aggregate could be misleading when trying to determine if a particular habitat type is undergoing fragmentation.

The metrics chosen to be analyzed at the landscape, class and patch level are shown in **Table 5-1**. A complete description of the program, metrics and the equations can be found at https://fragstats.org/.

Table 5-1. FRAGSTATS metrics that were calculated for the landscape scale and class level analyses.

Landscape Level Metrics	Class Level Metrics
Total Area (acres)	Class Area (acres)
Number of Patches (water included)	Percent of Landscape
Number of Wetland Patches	Number of Patches
Patch Density (#/100 acres)	Largest patch Index
Largest patch Index	Total Edge (miles)
Total Edge (miles)	Mean Patch Area (acres)
Landscape Shape Index	Shape Index (mean)
Mean Patch Area (acres)	Contiguity Index (mean)
Radius of Gyration (mean yards)	Total Core Area (acres)
Mean Shape Index	Core Area Percent of Landscape
Mean Contiguity Index	Number of Disjunct Core Areas
Total Core Area (acres)	Mean Core Area (acres)
Mean Core Area (acres)	Core Area Index (area-weighted mean)
Number of Disjunct Core Areas	Clumpiness
Contagion	Cohesion
Percentage of Like Adjacencies	Aggregation Index
Aggregation Index	Normalized Landscape Shape Index

A brief explanation is provided below for each of the landscape and wetland class level metrics. A more complete understanding of the metrics and the equations used to calculate them are referenced in **Appendix D**.

FRAGSTATS Landscape Level Metrics

Total Area (acres) – The sum of acres of all seven wetland habitats mapped in the API (water was not included in this analysis).

Number of Patches (water included) - Number of distinct habitat areas or "patches" that do not share a common boundary with another patch of the same habitat classification. A patch can share boundaries with other habitat types.

Number of Wetland Patches – Number of patches consisting of the seven wetland habitat types, excluding water.

Patch Density – The average number of distinct habitat patches in any 100 acres parcel of land throughout the landscape.

Largest patch Index **–** This metric equals percentage of the entire landscape made up of the largest patch of habitat regardless of classification.

Total Edge (miles) – The sum of all edge distances (i.e., perimeter), of all wetland patches in the landscape.

Landscape Shape Index – A standardized measure of total edge adjusted for the size of the landscape. Increasing values indicate more complex or irregular patch shapes with increasing habitat edge to area ratios.

Mean Patch Area – The mean patch area is the total wetland area divided by the number of wetland patches.

Radius of Gyration – A measure of patch extent calculated from the center of the patch to the boundary edge. Decreasing values indicated that wetland patches are losing core area over time as habitat edges get closer to the center of the patch.

Mean Shape Index – This is a straightforward assessment of shape complexity that is calculated using a square standard (i.e., the patch shape is compared to a square, which has a relatively small edge to area ratio). As the values increase the shape is becoming more complex with a higher edge to area ratio.

Mean Contiguity Index – This metric assesses spatial connectedness of the cells within a patch. The more compact the patch the more closely connected each cell is to the other cells in the patch (i.e., the more edges a cell shares with adjacent cells in the patch). As this value increases the cells are more contiguous to each other and the patch shape is more compact (i.e., a square or circle).

Total Core Area – This is a sum of the core areas of all wetland types. The core area of a patch equals the total area minus the area designated as the edge, or boundary areas. In this analysis a 4-meter (~ 13 feet) edge depth was set so all the area 4-meters inside the edge of every patch is subtracted from the total patch area to determine the core area.

Mean Core Area – This metric is the mean size in acres of the core areas of all patches in the landscape.

Number of Disjunct Core Areas – This represents the total number of disjunct core areas of all habitat types in the landscape. Habitat patches can have more than one core area if the patch is of irregular shape and the edge areas, when they come close together, separate the patch into several distinct core areas that do not have contiguity with each other.

Contagion – The contagion metric is a measure of patch aggregation across the landscape. This value approaches zero when habitat patches of the same classification are disaggregated and interspersed across the landscape (i.e., fragmented) and approaches 100 when they are maximally aggregated (i.e., one large patch).

Percentage of Like Adjacencies – This is another aggregation index that equals zero when patches are maximally disaggregated and there are no like adjacencies (i.e., patches of the same habitat type) and the habitats are more fragmented. As this number increases so does patch aggregation and the number of like adjacencies.

Aggregation Index – The aggregation index measures the amount of aggregation within patches, from 0 to 100. The more compact the shape, the more cells are aggregated, translates into a larger index number and less fragmentation.

FRAGSTATS Class Level Metrics

Class Area - The sum of acres for each of the seven different classes of wetland habitats mapped in the API (water was not included in this analysis).

Percent of Landscape – This metric is the percentage of the landscape (i.e., Orange County) that is covered by the specific wetland classification.

Number of Patches – The total number of patches found in the landscape for each wetland classification.

Largest patch Index - A standardized measure of total edge for each wetland classification adjusted for the size of the landscape. Increasing values indicate more complex or irregular patch shapes with increasing habitat edge to area ratios.

Total Edge – The sum of all edge lengths (i.e., perimeters) in the landscape for each class of wetland.

Mean Patch Area - The mean patch size of each class of wetland divided by the number of wetland patches in the landscape.

Mean Shape Index - This is a straightforward assessment of shape complexity within the wetland classification that is calculated using a square standard (i.e., the patch shape is compared to a square, which has a relatively small edge to area ratio). As the values increase the shape is becoming more complex with a higher edge to area ratio.

Contiguity Index - This metric assesses spatial connectedness of the cells within a patch of the specified wetland class. The more compact the patch the more closely connected each cell is to the other cells in the patch (i.e., the more edges a cell shares with adjacent cells in the patch). As this value increases the cells are more contiguous to each other and the patch shape is more compact (i.e., like a square or circle).

Total Core Area - This is a sum of the core areas of each wetland type found in the landscape. The core area of a patch equals the total area minus the area designated as the edge, or boundary areas. In this analysis a 4-meter (~ 13 feet) edge depth was set so all the area 4-meters inside the edge of every patch is subtracted from the total patch area to determine the core area.

Core Area Percent of Landscape – This number represents the percentage of the landscape occupied by the core areas of the wetland classification.

Number of Disjunct Core Areas - This represents the total number of disjunct core areas of each habitat type in the landscape. Habitat patches can have more than one core area if the patch is of irregular shape and the edge areas, when they come close together, separate the patch into several distinct core areas that do not have contiguity with each other.

Mean Core Area - This metric is the mean size in acres of the core areas of all patches within each wetland classification found in the landscape.

Core Area Index – This metric quantifies the total core area of a wetland classification as a percentage of the patch areas. Lower values represent core areas that are becoming smaller in relation to edge areas.

Clumpiness – Clumpiness is a measure of class aggregation that considers like adjacencies. When this metric equals -1 then the patch type is maximally disaggregated, when it equals 0 then the patches are distributed randomly around the landscape, when this it equals 1 then the patches are maximally aggregated (i.e., one large patch).

Cohesion – This metric, which has a range of 0 to 100, evaluates how connected patches of a corresponding class are distributed around the landscape. When this metric approaches zero it indicates that the patches are becoming increasingly sub-divided and less physically connected.

Aggregation Index - The aggregation index measures the amount of aggregation within patches of a specific class, from 0 to 100. The more compact the shape, the more cells are aggregated, translates into a larger index number and less fragmentation.

Normalized Landscape Shape Index – This is a simple measure, between 0 and 1, of aggregation and clumpiness which increases as patches become less aggregated and more spread out across the landscape.

5.3 Wetland Fragmentation Results

To assess the ecological changes that occurred in wetland and water land cover classes between 1990 and 2022 in Orange County, fragmentation analyses were conducted to analyze how wetland patches change over time in shape and complexity while assessing how the spatial pattern they exhibit across the landscape changes because of natural or anthropogenic disturbances. Evaluating how wetlands are aggregated, at both the landscape and wetland class level, can provide important information on whether habitat fragmentation is occurring.

5.3.1 FRAGSTATS Landscape Scale Results

The results of the FRAGSTATS landscape scale analysis are shown in **Table 5-2** with summaries of the results for each metric provided in the following section.

Table 5-2. FRAGSTATS analysis results at the landscape scale for the four wetland API maps created for this project that cover the years 1990, 2000, 2010 and 2022.

FRAGSTATS Metrics	1990 Wetlands	2000 Wetlands	2010 Wetlands	2022 Wetlands
Total Wetland Area (acres)	158,946	163,907	162,537	162,670
Number of Patches (water included)	15,258	17,926	20,340	20,867
Number of Wetland Patches	12,603	13,396	13,793	13,970
Patch Density (#/100 acres)	1.962	2.086	2.148	2.175
Largest patch Index	1.422	1.555	1.544	1.594
Total Edge (miles)	1665	1765	1877	2101
Landscape Shape Index	14.615	15.403	16.292	18.055
Mean Patch Area (acres)	12.614	12.238	11.784	11.644
Radius of Gyration (mean yards)	81.360	79.235	78.505	79.569
Mean Shape Index	1.632	1.653	1.696	1.765
Mean Contiguity Index	0.908	0.900	0.895	0.891
Total Core Area (acres)	148,175	152,797	151,138	150,773
Mean Core Area (acres)	11.757	11.406	10.958	10.793
Number of Disjunct Core Areas	13,495	14,735	16,055	17,434
Contagion	57.900	57.810	56.124	53.727
Percentage of Like Adjacencies	97.660	97.661	97.587	97.479
Aggregation Index	97.689	97.690	97.617	97.509

Number of Patches and Patch Density

Number of patches represents the simplest metric when looking at habitat fragmentation, if the amount of area remains relatively constant. Results from the API mapping show that the total area in Orange County covered by wetland habitats was 158,984 in 1990, and by 2022, there were 162,683 acres of wetland land cover, which represents a 2.33% increase. During this same time the total number of wetland patches in the county increased from 12,603 to 13,970 which is an increase of almost 11%. In this case, as the number of patches increase over time while the total area they occupy remains relatively constant, it is indicative of a more fragmented matrix of wetlands.

Patch density represents the average number of patches that occur in a 100-acre area of the landscape. This metric is directly related to the number of patches in this analysis since the total area of the landscape (i.e., Orange County) was the same for each time period, making it a legitimate way to compare changes per unit area between each year analyzed. In 1990, patch density was 1.962 patches/100 acres. Since 1990, patch density increased steadily over time through 2022 when it reached 2.175 patches/100 acres. This increase, although small, means that if you sample a random 100-acre parcel in 2022, it would, on average, have 0.213 more wetland patches than what was present in 1990 without an equivalent, corresponding increase in the amount of wetland acreage within that parcel.

Area Metrics - Mean Patch Area, Total Core Area, and Mean Core Area

The *mean patch area* within the county has decreased steadily from 1990 to 2022. In 1990, the mean wetland patch size was 12.61 acres. However, by 2022 the mean wetland patch size decreased by almost an acre to 11.64 acres. When you factor in the increase in the total number of patches over this same period, you get more patches with less average area, which is another indication that fragmentation is occurring.

The *total core area* represents the overall wetland area, of all seven wetland classes, that is inside the specified edge depth set prior to running the model, which was set at 4 meters for this analysis. Core areas are the internal wetland habitats that are less susceptible to impacts from edge effects (i.e., invasive species, pollution, etc.). From 1990 to 2022, the total core area remained relatively stable, with less than a 3% variation between all years. However, after increasing between 1990 and 2000 from 148,175 acres to 152,797 acres, due to the addition of the marsh restoration areas on the shores of Lake Apopka, the total core area has declined. Between 2000 and 2022, over 2,000 acres of core habitat has been lost in Orange County.

Another metric that indicates fragmentation is happening is the decrease from 1990 to 2022 in the *mean core area*. In 1990, the mean core area was 11.76 acres, while in 2022 it was one acre less on average. This translates into over an 8% decrease in core area size over the last 32 years. One positive factor to consider is that the rate at which fragmentation has been occurring has slowed down over the past twelve years from around 3% in 2010 to 1.5% currently.

Number of Disjunct Core Areas

The number of core areas at the landscape level is the sum of all distinct core areas, of every wetland type, within Orange County. A core area is defined as the area of habitat inside the edge boundary, which in this analysis was set at four meters in depth. Depending on its shape and edge depth, a single, contiguous wetland area can have more than one core area within its boundary. This occurs when a wetland patch becomes narrow enough that the opposite edges merge together and 'pinch' these core areas apart. For ecological purposes, these can be considered disjunct cores, acting as a separate, functionally distinct but smaller core area within a single patch of wetland.

As the number of disjunct cores increase in relation to the number of patches, it can be interpreted as a form of fragmentation because these disjunct cores can be functionally separated from other core areas within the patch, basically making them independent patches. In 1990 the number of disjunct core areas was 13,495, which was 7% higher than the number of actual patches. From 1990 to 2022, not only did the number of wetland patches increase, but the number of disjunct core areas also increased as a percentage of total patches. In 2000, there were 9% more disjunct cores than patches. In 2010, that number rose to over 16% and in 2022 there were almost 25% more disjunct core areas than total patches. When you consider this together with the total core area it implies that fragmentation is taking place and has been increasing since 1990.

Total Edge

The total edge metric is the sum, in length, of all edges from all wetland patches in Orange County. If total edge length increases while the area remains relatively constant, then we know the shapes of the patches are becoming more convoluted and irregular. In addition, if you break a large patch up into smaller patches, even if minimal area is lost, there will be more edge per area than before. When the amount of edge increases proportionally more than the area it signifies, the habitats under investigation are becoming more convoluted or fragmented and the habitat edges (boundaries) are getting closer to the internal, or core area, within the habitat. In 1990, the total miles of wetland edges in the county equaled 1665 miles. From 1990 to 2010, wetland edges increased by about 100 miles every ten years. Between 2010 and 2022, the amount of wetland edges in the county grew to 2,101 total miles, an increase of over 200 miles, even as the total wetland area basically did not change. This increase in edge length, without a corresponding increase in area, indicates habitat fragmentation is occurring. It's important to note, however, that when part of a contiguous wetland changes from one classification to another but remains a wetland, this is also considered fragmentation due to the difference in wetland function that occurs.

Mean Shape Index

Mean shape index is a unitless measure of shape complexity that compares a wetland patch shape, perimeter versus area, to a square standard (i.e., the perimeter/area ratio of a square). A higher mean shape index indicates more shape complexity as it deviates away from a more compact square shape, which has an index of 1. From 1990 to 2022, the mean shape index has steadily increased from 1.632 to 1.765. This increase represents an increase in shape complexity, which means wetland patches are becoming less compact, and although this index does not translate to a direct measure of fragmentation, it does indicate an increase in the amount of edge area in relation to core habitat area. This is another indication that habitat core areas, areas which experience less impacts from edge effects, are getting smaller over time in Orange County.

Largest Patch Index

The largest patch index is a metric that looks at the largest patch of a specific class of wetland habitat (i.e., mixed wetland forests) in the County, then quantifies it as a percentage of the entire landscape. In 2022 the largest contiguous patch of wetland habitat was the Lake Apopka restoration area which covered 1.594%, or 10,238 acres, of the County's entire area. This was an increase from 1990 where the largest patch of a single habitat type was 9,133 acres of mixed wetland forest in Wekiva Springs, covering 1.422% of the county. The Wekiva forest area was the single largest wetland habitat from 1990 through 2010, and the second largest in 2022. This metric doesn't necessarily mean that new wetland habitat was added. It could be that adjacent wetlands went through succession and changed to a different wetland class over time. Even when some parts of the County are showing an increase in fragmentation, this metric indicates that the Wekiva forest, the largest contiguous wetland habitat in the County from 1990 through 2010 and second largest in 2022 has largely remained intact. The wetland ordinances and protective status that have been put in place by the County, along with restoration efforts, are most likely the reason that these large tracts of wetlands are surviving.

Landscape Shape Index

Landscape shape index is a unitless, standardized measure of total edge that is adjusted for the size of the landscape that increases as total wetland edge length increases and wetland patches become more irregular or fragmented. Because the size of the landscape being analyzed is the same for each of the four time periods this metric provides a direct comparison between years. In 1990 the landscape shape index was 14.6. From 1990 to 2022 it increased steadily to 18.06 which indicates that fragmentation of wetland habitats has been occurring continuously since 1990, even though wetland area increased over the same period.

Radius of Gyration

The radius of gyration metric is a measure of patch extent, calculated based on the distance from the center of a wetland patch to its' edge. This metric denotes the mean distance from the center point to the edge for all wetland patches within the county. From 1990 to 2022 the mean distance from the center of a wetland patch to its edge decreased from 244 feet (81.36 yards) to 238 feet (79.57 yards), respectively. A radius of gyration that is decreasing indicates a reduction in overall patch size, which was also indicated by the mean patch area, but this metric provides a measure of average distance which can help in determining edge effects on core habitat. If the radius of gyration decreases over time, then the edges of the patches are getting closer to the core area. Although the difference between 1990 and 2022 might not seem like a significant difference it reflects a reduction in core habitat and an increasing possibility that edge effects could impact further into the interior of the habitat.

Mean Contiguity Index

Mean contiguity index assesses the spatial connectedness of the cells that make up each patch of wetland in the landscape. This metric considers each cell in a patch and its relation to the eight cells surrounding it to determine if they are also in the patch. This metric creates an index that relates a patch's boundary configuration and to its overall shape. As the index increases towards a value of 1 it signifies more connectedness between the cells and implies a more compact and less complex shape. The mean contiguity index in 1900 was 0.908 and by 2022 is it decreased to 0.891. While, in 2000 and 2010 it was 0.900 and 0.895, respectively. A continuous downward trend implies that over time the patches become more complex in shape and the cells within those patches are less connected to neighboring cells within the patch. Once again this is not a measure of fragmentation but rather an indication that the core areas are shrinking, in effect getting closer to the edges, which may make them more susceptible to negative edge effects.

Contagion

Contagion is a percent metric that utilizes adjacent patches to determine if a patch is aggregated (more connected) over the landscape or disaggregated (more fragmented).

Contagion approaches zero when the wetland types are maximally disaggregated (i.e., where every cell is a different wetland type) and interspersed (i.e., maximum diversity). As patches become more aggregated (larger) and closer to similar habitats, contagion increases until it reaches 100 when all patch types are maximally aggregated. In 1990, the contagion metric over the entire landscape was 57.9%, over 4% higher than what was found in 2022 (53.7%). . The largest change in contagion values, between consecutive time periods, occurred between 2010 and 2022 when it dropped by 2.4%. The decreasing trend in this metric indicates that the wetland habitats in Orange County are becoming more disaggregated (by wetland type) and interspersed with different habitat types over time. Disaggregation and interspersion are typically indicative of habitat disturbances, either natural or anthropogenic. Because dissimilar habitats provide different ecological functions and host different species assemblages small, interspersed wetland habitats may not provide the same level of overall wetland function as larger, contiguous wetland habitats.

Percentage of Like Adjacencies

The percentage of like adjacencies metric analyzes the frequency with which the different habitat types in the landscape appear next to each other on the map and the degree of aggregation that is occurring within the patch types. Larger patches with more compact shapes will have higher values than smaller patches with convoluted shapes. Unlike contagion, which also measures interspersion, this metric only measures aggregation over the entire landscape. Between 1990 and 2022 the percentage of like adjacencies dropped from 99.66% to 97.48%. As can be seen in the wetland maps the majority of wetland in Orange County can be found along the St. John's River and in the Wekiva Springs area. Since these large wetland areas have not changed much, the decline in this metric indicates that wetlands in other parts of the county are becoming less aggregated (i.e., more fragmented).

5.3.2 FRAGSTATS Wetland Class Level Results

The results of the FRAGSTATS wetland class level analysis are presented in the following section. As mentioned earlier, "Other wetlands" will not be discussed as a wetland class since the consolidated classification consists of disparate wetland types, making the resultant metrics unrelated to specific wetland function.

Cypress

Between 1990 and 2022, the number of cypress habitat patches increased by 359 while the mean patch size grew slightly, from 9.55 acres in 1990 to 9.65 acres in 2022 (**Table 5-3**). The largest patch of cypress also increased to cover 0.27% of the landscape, up from 0.14% in 1990.

While the area of cypress increased about 16% in the county, the total edge/perimeter of cypress habitats increased by over 30%, from 530 to 693 miles. This indicates that the patches are becoming more complex in shape (i.e., less compact). This finding is supported by an increase in the mean shape index from 1.48 to 1.54 between 1990 and 2022.

The contiguity index, which is a measure of spatial connectedness, decreased slightly over this period signaling that the cells within patches are becoming less connected to each other as the edge to area ratios grow. Another metric that reinforces this is the number of disjunct core areas found in 2022. In 1990, there were only 26 more disjunct cores than patch cores, which means that some of the patches had two or more core areas that were not "functionally" connected, even though they were within the same patch boundaries. In 2022, this number grew to 143, which means more patches have become irregular enough in shape to effectively cut off one area of the patch from another. This is also reflected in the decrease of the core area index from 92.28 to 92.07, which quantifies the core area as a percentage of the total patch area within the class.

The last four metrics – clumpiness, cohesion, aggregation index, and normalized landscape shape index – stayed relatively constant since 1990 and are not indicative that cypress habitats are becoming less spatially aggregated (i.e., more fragmented) throughout the landscape. When these metrics are analyzed together, the results indicate that cypress patches in Orange County, while increasing in area, have become less compact with less contiguity within patches. However, based on these results, they have not undergone significant fragmentation throughout the landscape.

Table 5-3. FRAGSTATS results at the wetland class level for cypress habitats.

FRAGSTATS Metrics	Cypress			
	1990	2000	2010	2022
Class Area (Acres)	22,520	23,905	22,106	26,210
Percent of Landscape	3.506	3.721	3.441	4.080
Number of Patches	2,358	2,655	2,556	2,717
Largest patch Index	0.136	0.129	0.130	0.268
Total Edge (Miles)	530	592	598	693
Mean Patch Area (Acres)	9.550	9.004	8.648	9.647
Mean Shape Index	1.480	1.481	1.496	1.542
Contiguity Index (Mean)	0.934	0.931	0.928	0.929
Total Core Area (Acres)	20,781	21,988	20,314	24,131
Core Area Percent of Landscape	3.235	3.423	3.162	3.757
Number of Disjunct Core Areas	2,384	2,688	2,614	2,860
Mean Core Area (Acres)	8.813	8.282	7.948	8.881
Core Area Index (Area Weighted Mean)	92.276	91.984	91.896	92.069
Clumpiness	0.973	0.971	0.971	0.972
Cohesion	98.874	98.805	98.782	98.904
Aggregation Index	97.349	97.248	97.217	97.277
Normalized Landscape Shape Index	0.027	0.028	0.028	0.027

Freshwater Marshes

Freshwater marsh habitat in Orange County increased from 24,524 to 32,871 acres between 1990 and 2022, due to the restoration efforts in north Lake Apopka, with mean patch size growing from 6.84 to 9.23 acres (**Table 5-4**). Unlike cypress habitats, the actual number of distinct freshwater marsh patches within the county decreased by 26 patches over this same period. However, after losing 142 patches between 1990 and 2000, they started to rebound in number gaining 39 patches between 2000 and 2010 and another 77 from 2010 to 2022. With the addition of over 10,000 acres from the Lake Apopka restoration efforts, the largest patch index also increased from 0.56% to 1.59%, with a corresponding increase in the percent of the landscape occupied by core areas of marsh habitat.

While freshwater marsh habitat increased 34% in area, the total edge/perimeter only increased by 30%, which is expected due to the large, contiguous marsh restoration area by Lake Apopka. However, in other areas of the county, marsh patches were changing and becoming more complex in shape and less compact, as indicated by the increase in the mean shape index, which rose continuously between 1990 and 2022 from 1.57 to 1.79. The contiguity index, which decreased from 0.89 to 0.85, also indicates that the spatial connectedness within patches is being reduced over time as the shapes become more complex. Another indication that marshes are becoming more complex in shape and less compact in other areas of the county can be found with the increase of disjunct core areas, which rose from 3,982 in 1990 to 5,163 in 2022 despite a decrease in the number of marsh patches over this time.

With the addition of over 7,000 acres of Lake Apopka marsh restoration area between 1990 and 2000, there was a corresponding increase in the core area index, cohesion, aggregation index and normalized landscape shape index which all indicate that fragmentation was not very prevalent in marsh habitats throughout the county. Since 2010, there has been a decrease in several of these indexes, a sign that there is some disaggregation and fragmentation occurring. With the addition of such a large restoration area of contiguous marshland since 1990 impacting the results, the change in these metrics indicates that fragmentation of marsh habitat is occurring in other parts of the county.

Table 5-4. FRAGSTATS results at the wetland class level for freshwater marsh habitats.

FRAGSTATS Metrics	Freshwater Marshes			
	1990	2000	2010	2022
Class Area (Acres)	24,524	31,126	33,562	32,871
Percent of Landscape	3.818	4.845	5.225	5.117
Number of Patches	3,588	3,446	3,485	3,562
Largest patch Index	0.562	1.014	1.187	1.593
Total Edge (Miles)	599	614	678	781
Mean Patch Area (Acres)	6.835	9.032	9.630	9.228
Mean Shape Index	1.566	1.583	1.642	1.786
Contiguity Index (Mean)	0.891	0.887	0.879	0.853
Total Core Area (Acres)	22,446	29,030	31,354	30,570
Core Area Percent of Landscape	3.494	4.519	4.881	4.759
Number of Disjunct Core Areas	3,982	3,889	4,317	5,163
Mean Core Area (Acres)	6.256	8.424	8.997	8.582
Core Area Index (Area Weighted Mean)	91.527	93.266	93.422	93.001
Clumpiness	0.970	0.976	0.976	0.975
Cohesion	99.340	99.415	99.409	99.444
Aggregation Index	97.087	97.705	97.758	97.600
Normalized Landscape Shape Index	0.029	0.023	0.022	0.024

Hydric Pine Flatwoods

Hydric pine flatwoods have shown the second largest increase in area, as a percentage, of all habitats growing 114% between 1990 and 2022 (**Table 5-5**). The number of hydric pine patches in Orange County has also grown significantly, from 134 in 1990 to 532 in 2022. The largest patch area did not increase while the mean patch size decreased markedly from 44.76 acres to just 24.14 acres in 2022, which is expected given the large increase in the number of patches (~400%) compared to the increase in acreage. Total edge length increased over 251% which is also expected given the large increase in patch numbers.

The hydric pine patches gained since 1990 were similar in terms of perimeter to area ratio to those that existed prior to 2022. The mean shape index did drop from 2.09 to 2.07, which indicates more shape complexity, however the contiguity index, or spatial connectedness within the patches, remained unchanged.

Despite the increase in patches and area coverage, the analysis indicates that the patches of hydric pine in the county are smaller and more spatially distant than the patches in existence in 1990. The core area index decreased from 94.84 to 93.33, while the aggregation indexes consisting of clumpiness, cohesion, aggregation and landscape shape all indicate that the patches have become more disaggregated and less connected than they were in the past.

Even though the results indicate that fragmentation is present in the landscape, the increase in hydric pine habitat/patches since 1990, despite how they are arranged on the landscape, are a sign that restoration and/or re-planting efforts may be having an impact. Some of these gains in hydric pine flatwoods may have come at the expense of wet prairie habitats. It was observed during the field assessments that some wet prairie habitats had pines planted around their buffers and over time the pines were encroaching into the wet prairie habitat, although how much this is occurring is currently unknown.

Table 5-5. FRAGSTATS results at the wetland class level for hydric pine flatwood habitats.

FRAGSTATS Metrics	Hydric Pine Flatwoods			
	1990	2000	2010	2022
Class Area (Acres)	5,998	6,822	9,627	12,841
Percent of Landscape	0.934	1.062	1.499	1.999
Number of Patches	134	135	267	532
Largest patch Index	0.264	0.319	0.299	0.273
Total Edge (Miles)	144	145	205	362
Mean Patch Area (Acres)	44.758	50.531	36.055	24.137
Mean Shape Index	2.092	2.079	2.035	2.070
Contiguity Index (Mean)	0.933	0.956	0.929	0.933
Total Core Area (Acres)	5,688	6,502	9,139	11,984
Core Area Percent of Landscape	0.886	1.012	1.423	1.866
Number of Disjunct Core Areas	136	142	317	623
Mean Core Area (Acres)	42.450	48.162	34.227	22.526
Core Area Index (Area Weighted Mean)	94.844	95.313	94.931	93.327
Clumpiness	0.983	0.985	0.983	0.977
Cohesion	99.510	99.583	99.504	99.311
Aggregation Index	98.307	98.463	98.326	97.756
Normalized Landscape Shape Index	0.017	0.015	0.017	0.022

Mixed Wetland Forests/Hardwoods

Mixed wetland forests showed the largest decrease in total acreage of all the seven wetland classes, losing over 16,000 acres of land cover between 1990 and 2022 (**Table 5-6**). As the amount of area declined, the number of patches increased throughout the county from 2,475 in 1990 to 2,550 in 2022, which is a strong indication that these wetlands are becoming increasingly fragmented over time. The largest patch of mixed wetland forests remained relatively unchanged and intact, however the mean patch size decreased by over seven acres between 1990 and 2022, dropping from 29.36 down to 22.07 acres.

Although only a slight increase in total edge length (16 miles) was observed, when considered together with a loss of 23% in area, it confirms that fragmentation is occurring and that the patches are becoming more complex in shape. This is evident in the increase from 1.71 to 1.79

of the mean shape index, with a corresponding decrease in the contiguity index and core area index over time. The number of disjunct core areas also increased between 1990 and 2022. In 1990, there were 33 more disjunct cores than patches; while in 2022, that number grew to 174, which means that more patches had multiple, isolated core areas in 2022 than in any of the previous years.

The aggregation metrics also indicate that patches of mixed wetland forests in Orange County are becoming less aggregated over the landscape. The aggregation index, clumpiness, and cohesion have all shown a downward trend over time. These metrics consider patch aggregation across the landscape within a single wetland classification, and lower values indicate disaggregation is occurring. This is also true for the normalized landscape shape index, a combined measure of clumpiness and aggregation, which shows an increasing trend from 1990 to 2022 that denotes patches are becoming less aggregated across the county. When all the metrics are considered together, mixed wetland forests are experiencing considerable losses and fragmentation in Orange County.

Table 5-6. FRAGSTATS results at the wetland class level for mixed wetland forest/hardwood habitats.

FRAGSTATS Metrics	Mixed Wetland Forests/Hardwoods			
	1990	2000	2010	2022
Class Area (Acres)	72,674	71,453	63,737	56,268
Percent of Landscape	11.313	11.123	9.922	8.759
Number of Patches	2,475	2,596	2,583	2,550
Largest patch Index	1.421	1.554	1.544	1.411
Total Edge (Miles)	948	987	977	964
Mean Patch Area (Acres)	29.363	27.524	24.676	22.066
Mean Shape Index	1.707	1.746	1.776	1.790
Contiguity Index (Mean)	0.916	0.912	0.910	0.903
Total Core Area (Acres)	69,160	67,833	60,280	53,018
Core Area Percent of Landscape	10.766	10.560	9.384	8.253
Number of Disjunct Core Areas	2,508	2,667	2,697	2,724
Mean Core Area (Acres)	27.944	26.130	23.337	20.791
Core Area Index (Area Weighted Mean)	95.166	94.935	94.575	94.225
Clumpiness	0.982	0.981	0.980	0.979
Cohesion	99.667	99.635	99.587	99.601
Aggregation Index	98.362	98.289	98.168	98.047
Normalized Landscape Shape Index	0.016	0.017	0.018	0.020

Wet Prairies

Wet prairie habitats have decreased in both land cover and number in Orange County since 1990, losing over 3,086 acres and 270 patches (**Table 5-7**). Mean patch area has also declined from 5.36 to 4.00 acres. In addition, while the total edge length has dropped from 260 miles to 216, the loss of 17% of habitat edge area does not parallel the 40% loss in acreage. This indicates that, along with habitat loss, wet prairie patches are becoming smaller and less compact in shape over time (i.e., higher perimeter to area ratios), which is reflected in the increase of the mean shape index and a decrease in both the contiguity index and core area index metrics.

The number of disjunct cores, as a percentage of total patches, have almost doubled from 1990 to 2022 rising from 14% more disjunct cores (than patches) to 26% more. This increase coupled with a decreasing aggregation index, which dropped from 95.80 to 95.06, are another indication that the patches are becoming more complex in shape and the cells within them are becoming more disaggregated over time.

Both the clumpiness and cohesion metrics also show a decreasing trend from 1990 to 2022, while the normalized landscape shape index has increased from 0.042 to 0.049. These three indices, which look at patch aggregation and connectivity between patches, all imply that patches are becoming more spread out and less physically connected across the county. Considering all the metrics in combination with the loss of area and a reduction in the number of patches, the results indicate that wet prairie habitats, in addition to experiencing losses, are undergoing significant fragmentation across the landscape.

Table 5-7. FRAGSTATS results at the wetland class level for wet prairie habitats.

FRAGSTATS Metrics	Wet Prairies			
	1990	2000	2010	2022
Class Area (Acres)	7,898	5,769	4,220	4,812
Percent of Landscape	1.229	0.898	0.657	0.749
Number of Patches	1,472	1,325	1,257	1,202
Largest patch Index	0.049	0.052	0.028	0.037
Total Edge (Miles)	260	233	204	216
Mean Patch Area (Acres)	5.365	4.354	3.357	4.004
Mean Shape Index	1.704	1.709	1.747	1.748
Contiguity Index (Mean)	0.890	0.885	0.879	0.881
Total Core Area (Acres)	6,921	4,970	3,528	4,114
Core Area Percent of Landscape	1.077	0.774	0.549	0.640
Number of Disjunct Core Areas	1,667	1,531	1,540	1,498
Mean Core Area (Acres)	4.702	3.751	2.806	3.423
Core Area Index (Area Weighted Mean)	87.629	86.146	83.602	85.491
Clumpiness	0.957	0.952	0.943	0.950
Cohesion	98.315	97.963	97.611	98.205
Aggregation Index	95.796	95.280	94.369	95.059
Normalized Landscape Shape Index	0.042	0.047	0.056	0.049

Mixed Scrub-Shrub Wetlands

The area covered by mixed scrub-shrub wetlands in the county has gone down from 19,490 acres in 1990 to 16,135 acres in 2022 (**Table 5-8**). Between 1990 and 2022, it fluctuated up and down, which is expected with a successional habitat. Despite losing land cover, the number of patches increased by almost 10% causing a decline in the mean patch area from 10.07 acres to 7.59 acres.

More patches with less area increased the total edge length of mixed scrub-shrub wetlands by 95 miles, which is reflected in the upward trend of the mean shape index from 1.69 to 1.80 and a downward trend in the contiguity index. This indicates that the shape of the patches is becoming less compact and the spatial connectedness of the cells within the patches are decreasing. This is also reflected in the number of disjunct core areas which have increased from 2,038 to over 2,500 even as the area of mixed scrub-shrub habitat shrinks. The core area index also declined from 91.47 to 89.53 between 1990 and 2022. These metrics all indicate that the habitat patches are becoming smaller and more complex in shape over time.

The four aggregation related metrics also indicate that mixed scrub-shrub wetlands in Orange County are becoming more fragmented over time. Clumpiness, a measure of class aggregation of like patches, decreased over time, although the decrease was minor. A decrease in the cohesion metric and the aggregation index, which dropped from 97.12 to 96.44, and an increase in the normalized landscape shape index all indicate that fragmentation of these habitats is occurring within the county.

Table 5-8. FRAGSTATS results at the wetland class level for mixed scrub-shrub wetland habitats.

FRAGSTATS Metrics	Mixed Scrub-Shrub Wetlands			
	1990	2000	2010	2022
Class Area (Acres)	19,490	18,622	21,588	16,135
Percent of Landscape	3.034	2.899	3.361	2.512
Number of Patches	1,935	2,344	2,629	2,126
Largest patch Index	0.208	0.160	0.081	0.071
Total Edge (Miles)	617	705	785	712
Mean Patch Area (Acres)	10.073	7.944	8.212	7.589
Mean Shape Index	1.694	1.712	1.734	1.801
Contiguity Index (Mean)	0.919	0.913	0.907	0.908
Total Core Area (Acres)	17,828	16,798	19,515	14,445
Core Area Percent of Landscape	2.775	2.615	3.038	2.249
Number of Disjunct Core Areas	2,038	2,555	3,020	2,529
Mean Core Area (Acres)	9.214	7.166	7.423	6.794
Core Area Index (Area Weighted Mean)	91.471	90.204	90.395	89.527
Clumpiness	0.970	0.966	0.966	0.964
Cohesion	99.008	98.748	98.755	98.586
Aggregation Index	97.108	96.664	96.728	96.437
Normalized Landscape Shape Index	0.029	0.033	0.033	0.036

5.4 Fragmentation Conclusions and Recommendations

The wetland fragmentation analysis results show an increasing trend towards more wetland habitat fragmentation at the landscape level. This is also apparent in the wetland API maps as more roadways have been constructed that bisect once contiguous wetlands and the number of distinct wetland patches has increased without a corresponding increase in wetland land cover. This has led to a decrease in the mean wetland patch size within the county. Smaller patches have increased edge to area ratios which means they can become susceptible to more negative edge effects like exotic species encroachment and pollution pressures. Fragmentation has also led to an increase in shape complexity, loss of contiguity, and an increase in disjunct core areas within some existing wetland patches. Loss of contiguity and more disjunct core areas indicates some wetlands are losing connectivity, not only to other neighboring wetland patches, but within contiguous wetland patches. All of which can lead to a net loss of wetland function within Orange County.

The large wetland habitats located in the Wekiva Special Protection Area and the Tosohatchee Wildlife Management Area have remained relatively intact since 1990 with even some wetland expansion occurring, especially around the Wekiva area. The protected wetlands along the Econlockhatchee River have also persisted without much change since 1990. For example, the large, contiguous wetland areas along the Econlockhatchee, from the northern county boundary to Highway 528, consisted of approximately 2,910 acres in 1990 and 2,741 acres in 2022. In these protected areas, along with the marsh restoration area north of Lake Apopka, fragmentation has been minimized. The FRAGSTATS model results imply that wetlands in other parts of the county are becoming increasingly disaggregated and interspersed. This is especially true in areas of the county that have seen an increase in urban and built-up land cover since 1990.

When FRAGSTATS was used to analyze fragmentation at the class level, which looks at the seven wetland classes independently across the landscape, the results were mixed. All the classes had some metrics that indicated disaggregation and fragmentation over time. Two of the seven wetland classes were found to have limited disaggregation and fragmentation impacts - cypress and freshwater marshes. One of the reasons freshwater marshes showed less fragmentation was the addition of the Lake Apopka restoration area, which is a large almost contiguous area that increased the mean patch size and decreased the total edge ratios. The five other classes – hydric pine flatwoods, mixed wetland forests, mixed scrub/shrub, wet prairies, and other wetlands - had model results that clearly indicated fragmentation and disaggregation were occurring, even as some of them were gaining area.

The results of the fragmentation analysis bring to light some important observations. Although the total acreage of wetlands (or wetland classes) in the county remains the same over time, or even increases, wetlands are still undergoing fragmentation and functional loss. For instance, wetland patches that become more complex in shape and less compact will be impacted by edge effects and hydrologic changes more readily (Ewers & Didham, 2008; Fletcher, 2005; Tabarelli et al., 2008). In addition, losing connectivity to other wetlands and upland habitats can impact the function of a wetland by limiting the biological and ecological interactions that naturally occur between connected habitats (Sawatzky et al., 2019; Semlitsch & Jensen, 2001; Zamberletti et al., 2018).

6 WETLAND SPATIOTEMPORAL ANALYSES

Following the completion of the background research/data collection, API mapping of wetlands for the selected years of interest, field assessments of 51 select sites using UMAM to compare past and present conditions, and UAS hyperspectral analysis of 15 of the 51 wetland sites, the project team performed a variety of data and statistical analyses to determine the ecological health of wetlands within the County and the effectiveness of wetland regulations.

These analyses included:

- Wetland change and persistence analysis that examined the persistence, gains, and losses of wetlands in the county.
- Ecological succession and reversion spatial analysis that analyzed the ecological changes or shifts that occurred between wetland habitat types.
- Spatial analysis of patterns in wetland change and environmentally sensitive areas such as flood prone areas, impaired waterbodies, groundwater recharge areas, and Outstanding Florida Waterbodies (OFWs).

The methods that were followed, relevant data inputs used, results, and conclusions are presented in the following sections.

6.1 Wetland Change and Persistence Analysis

Wetland change and persistence over time was analyzed using the four wetland maps developed during the API process for the years 1990, 2000, 2010 and 2022. Persistence refers to wetlands that have remained constant over space and time throughout the years analyzed. Each of the four feature classes were converted into a raster, or gridded, file format with a 5′ x 5′ grid pattern using the eight categorical land cover type listed in Table 3-5. During processing each raster, all of which have the same spatial extent, was aligned, or "snapped", to a reference grid which ensures that every grid cell within each raster will align perfectly with the spatially corresponding grid cell in the other three datasets. These initial raster datasets were used as the foundation for the various wetland change and persistence analyses included in this report.

The change and persistence of wetlands throughout Orange County from 1990 to 2022 was analyzed using several different methods. The first method looked at wetland/water persistence without regard to land cover type. For this analysis all wetland types, including water, were grouped into a single wetland category, and analyzed to spatially determine where wetlands and water were lost, gained, or persisted both spatially and temporally within the county. To determine this, the four wetland API rasters were overlayed, or "stacked", onto each other, creating a multidimensional array. Spatially matching grid cells that were coded for wetlands or waterbodies through all four time periods were categorized as "persistent". Grid cells coded for wetlands/waterbodies in 1990, 2000, and 2010 (or any combination thereof) that were not present in 2022 were considered "losses". While cells coded for wetlands in 2000 and/or 2010 that were also present in 2022, but not in 1990, were considered as wetland "gains". This same process was completed a second time without including water to show where only wetland habitats were lost, gained, or persisted from 1990 through 2022. In addition, maps were created to show where wetland losses and gains occurred during each of the three time periods – 1990 to 2000, 2000 to 2010 and 2010 to 2022. These analyses were conducted to show persistence, losses, and gains spatially without regard to land cover type or the ecological succession or reversion changes that may have occurred between 1990 to 2022 (i.e., where land cover classes change from one habitat type to another while remaining a persistent wetland).

In addition to analyzing how the total area of wetlands, regardless of type, changed or persisted over time, another multidimensional analysis was conducted using the categorical raster datasets to determine where in the county each of the seven wetland classes and water coverage persisted spatially without change, through each of the four temporal layers. For this analysis, all four wetland layers were loaded into a multidimensional (temporal) array and all grid cells that existed from 1990 through 2022 as the same wetland class (without change) were extracted into another raster dataset and quantified.

Because the wetland change and persistence analyses used raster datasets that were created from the four wetland API layers, this can result in many small areas (down to single 5′ x 5′ grid, or 25 sq ft.) that are classified as gains and losses which do not show up clearly on a map, primarily due to boundary modifications between years. The conversion from a feature class to a raster also resulted in differences of up to 2.4% in the areas calculated due to the polygon versus square grid boundary variations.

Results

Since 1990 in Orange County, wetlands have been both lost and gained throughout the county. While a large majority of them have persisted through time, many have changed from one wetland type to another or have had their boundaries change. As mentioned in the methods, "gain" refers to wetland areas that were not present in 1990 but are present in 2022, while "loss" refers to wetlands that were present in 1990, 2000 and/or 2010 but are no longer present in 2022. To be classified as "persistent" the wetland must have been in existence in both the 1990 and 2022 API feature classes.

From 1990 through 2022, Orange County has had approximately 135,384 acres of persistent wetlands, which means a wetland of one type or another has occupied the same spatial area in the county for the last 32 years. With water features included the area increases to 202,265 acres. The persistence, gain, and loss of wetlands and water, regardless of wetland type, are presented in **Figure 6-1**.

Persistence, gain and loss of wetlands, without water features, are shown in **Figure 6-2**. This map cleary shows that the majority of the persistent wetlands in the County are located in the Wekiva Springs area and wihtin the St. Johns River flood plain. The southwest portion of the county also has a considerable amount of wetlands that have presisted since 1990. Overall the western half of Orange Country contains the largest concentration of wetlands including those along the Econlockhatchee River and it's tributaries.

Over that same time period, Orange County gained approximately 27,268 acres of wetland outside of these persistent areas and over 35,300 acres when water is included. Persistent wetlands and wetlands gained equals the total wetland land cover in Orange County present in the 2022 aerial photography and included as features on the wetland API maps.

The areas shown as loss on these maps indicates spatially where wetlands once occurred in 1990, 2000 and/or 2010 that are no longer present in 2022. It's important to note that the losses shown on the maps are cumulative over time and show where wetlands once existed that are no longer in existence, regardless of when they were lost. Between 1990 and 2022 a total of 30,384 acres of wetlands were lost cumulatively, which includes wetlands that were gained after 1990 through 2010 but were subsequently lost by 2022. Out of these losses approximetely 23,600 were lost that were in existence in 1990, with the remaining 6,785 acres of losses coming from wetlands gained in 2000 and 2010 but lost prior to 2022. Whereas the gains (27,268 acres) include only those wetland areas that were added since 1990 that persisted into 2022. The overall wetland acres that were lost, gained or persisted between 1990 and 2022 are shown in **Table 6-1** (Note: because the persistence analysis was performed using raster data the acreage values will differ slightly from the values persented in the LULC analysis). These totals do not include the wetlands gained in 2000 and 2010 that were lost by 2022.

Table 6-1. Wetland losses, gains and persistence between 1990 and 2022.

Persistence Category	Acreage 1990 to 2022
Losses	**23,599**
Gains	**27,268**
Persistent	**135,384**

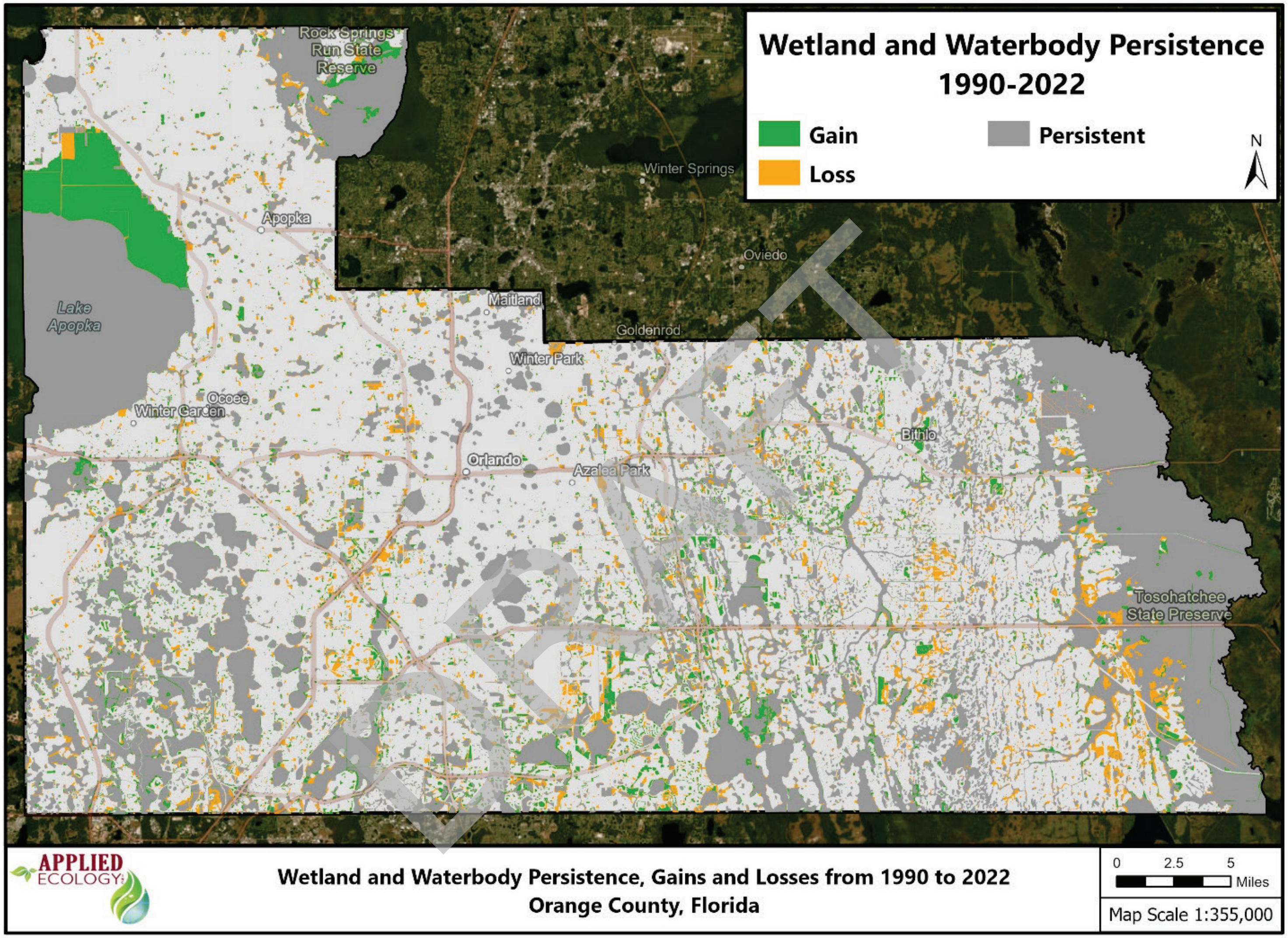

Figure 6-1. Wetland and water persistence, gains, and losses from 1990 to 2022 without regard to wetland types throughout Orange County, Florida.

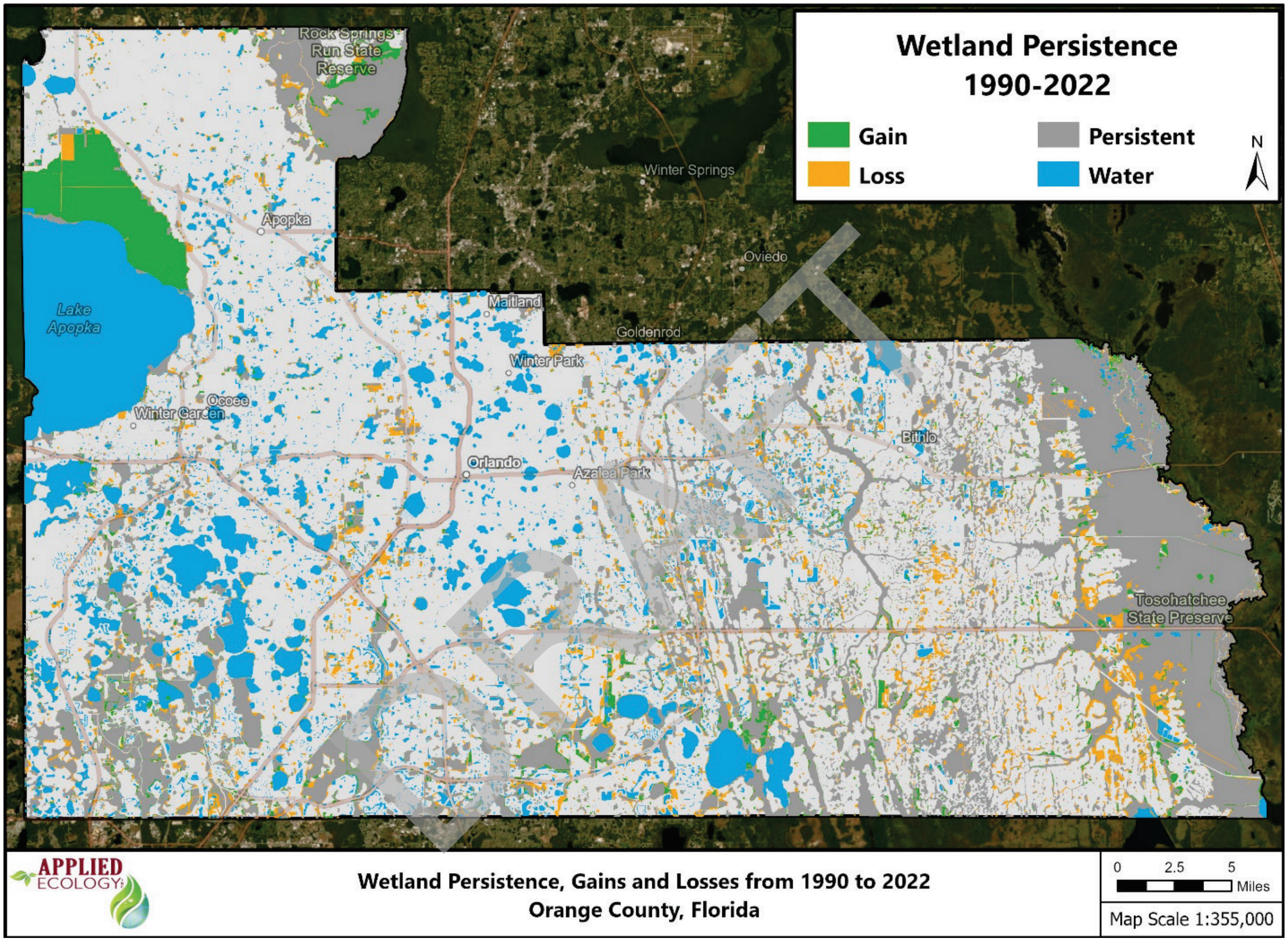

Figure 6-2. Wetland persistence, gains, and losses from 1990 to 2022 Orange County. Waterbodies are from the National Hydrography Dataset (NHD).

Persistence over time of the seven different wetland classes and water was also analyzed to show where wetland types remained spatially constant from 1990 through 2022 (**Table 6-2**). Of the 202,265 acres of wetland and water area that persisted from 1990 to 2022, just over 81,000 acres persisted as the same wetland types, in the exact same spatial location, throughout this period. Areas along the boundaries that may have changed from year to year are not included in these calculations. An additional 58,397 acres of water persisted in the same spatial location during the full 32-year period. Factoring in the habitats that did not change classification leaves roughly 62,800 acres of wetlands and water area that persisted but changed from one habitat type to another, or multiple different types, between 1990 and 2022. The mapping results for wetland class persistence from 1990 to 2022 are shown below in **Figure 6-3**.

Table 6-2. Wetland persistence from 1990 to 2022 in Orange County, Florida for the seven wetland classifications and water (in acres).

Wetland/Water Types	Persistent Acreage 1990 to 2022	% of 1990 Acreage
Cypress	15,566	69.12
Freshwater Marshes	13,578	55.36
Hydric Pine Flatwoods	3,250	54.19
Mixed Scrub-Shrub Wetlands	5,536	28.40
Mixed Wetland Forests/Hardwoods	40,838	56.19
Other Wetlands	1,719	29.42
Wet Prairies	581	7.36
Water	58,397	90.87

The wetland type that showed the least amount of persistence through time was wet prairies, with only 7.36% of the area they occupied in 1990 surviving through 2022. They were also the wetland class that lost the most area in the County, by percentage, during this period. However, this may be underestimating their actual persistence since they are the most difficult wetlands to map using API due to changing wet and dry conditions.

Mixed scrub-shrub wetlands were the second least persistent wetland class with just over 28% occupying the same spatial location through 2022. Freshwater marshes, hydric pines flatwoods, and mixed wetland forests persisted in roughly half of their 1990 footprints. While cypress systems showed the most persistence through time with over 69% of their original 1990 area remaining as cypress in 2022. Obviously, some of these wetland types increased in area based on the API mapping results since 1990, however, much of that expansion was in areas not previously occupied by that wetland type, either through succession/reversion or restoration.

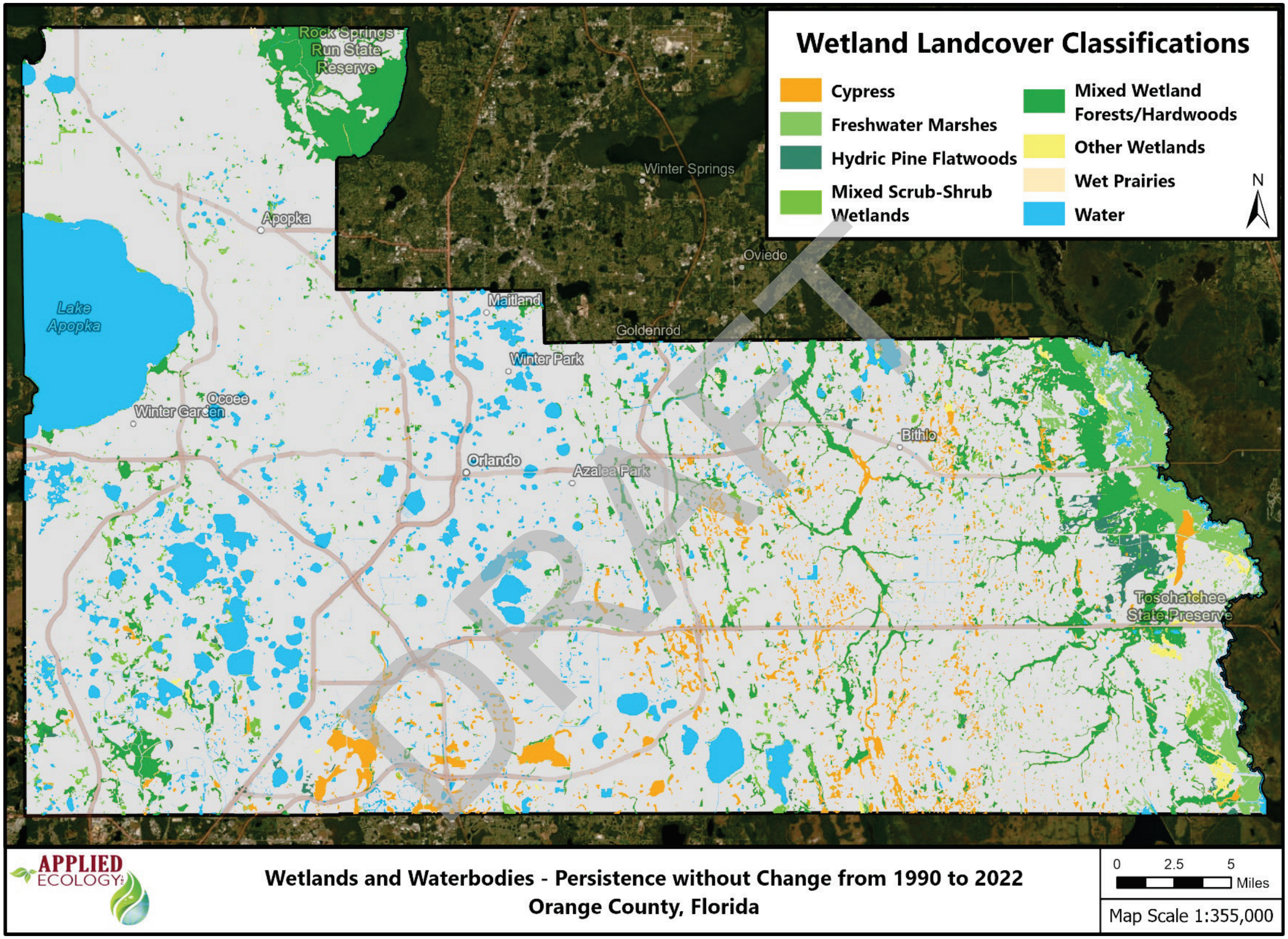

Figure 6-3. Wetland and water land cover that persisted without change from 1990 to 2022 in Orange County, Florida

6.2 Ecological Succession and Reversion Analysis

Once all the persistent wetlands were identified, each wetland area that changed from one category to another through time was analyzed to determine the direction of change that took place, in terms of ecological succession and reversion of habitat structure. This analysis applies a more historical view of ecological succession based on Frederic Clements view that succession in wetlands follows a relatively linear progression from colonization to climax communities and not the more circuitous route proposed by Henry Gleason (Middleton, 2016). The Clementsian theory of succession held that plant communities were predictable and deterministic, and that they would converge to a climatically determined stable climax community. While the Gleasonian view of succession, which was less deterministic, did not support the idea of coherent, stringently bounded community types. Instead, Gleason believed that plant species responded individually to environmental factors and not holistically as a single "organism", and that the composition of plant communities were more determinant on the responses of individual species.

6.2.1 Succession Analysis

For this analysis, the eight land cover classes were grouped into four categories listed below based on different stages of ecological succession.

1. Non-wetland habitats
2. Water habitats
3. Non-forested wetland habitats
4. Forested wetland habitats

To represent this abridged process of habitat succession used to map habitat change over time in Orange County, the linear progression goes from non-wetland and water habitats through "primary succession**"**, where non-wetland areas turn into non-forested wetlands, then through what is referred to as "climax succession**"**, as primary habitats turn into climax forest habitats. A simplified diagram of this progression is shown below, with examples, in **Figure 6-4**.

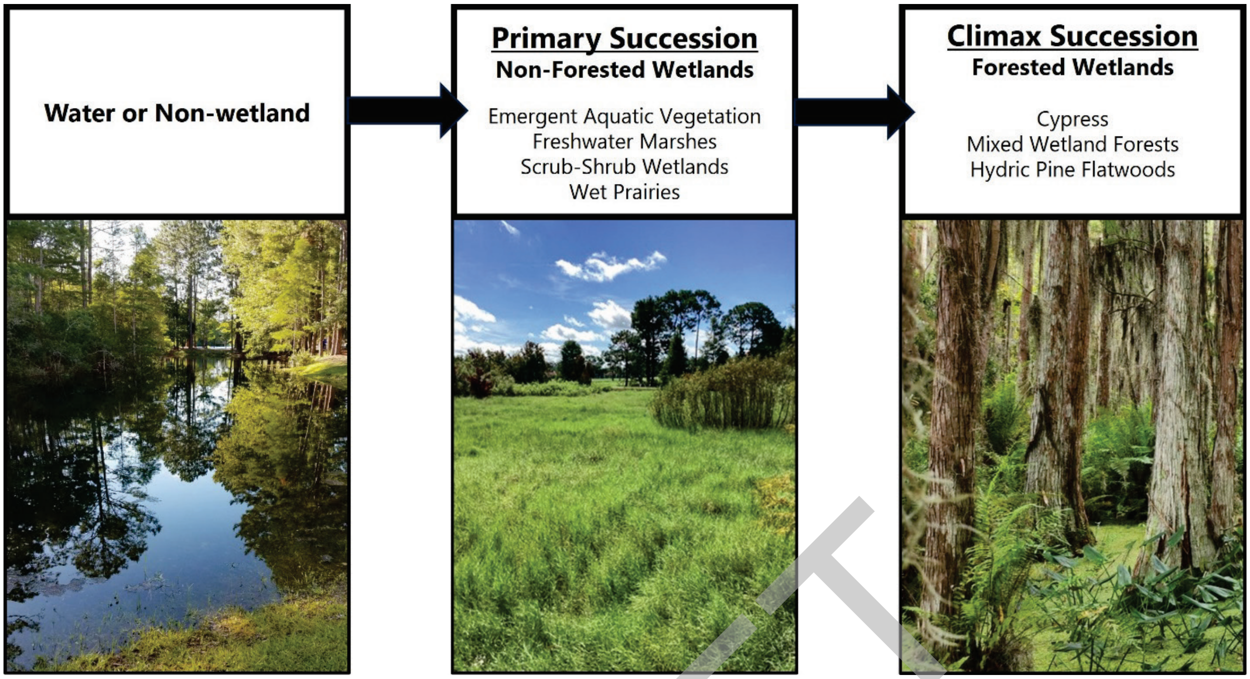

Figure 6-4. Linear stages of ecological succession used to analyze and map the change in wetland composition and structure over time in Orange County, FL.

Habitats also undergo changes in the reverse direction of succession, either through natural causes like fires or floods or through anthropogenic impacts (i.e., timber harvesting or development). This process is known as secondary succession and occurs when an established climax community is disturbed/altered and reverts to a successional stage. It can also be referred to as “reversion”, which is the term used in this analysis for habitats that change from forested wetlands to water or non-wetland habitats. In addition, a change from non-forested wetlands (primary habitat) to water or non-wetland habitats is also referred to as a reversion. “Primary reversion**”** is the term used in instances where a forested wetland reverts to a primary successional habitat. The succession and reversion pathways used in this analysis are outlined in **Figure 6-5**.

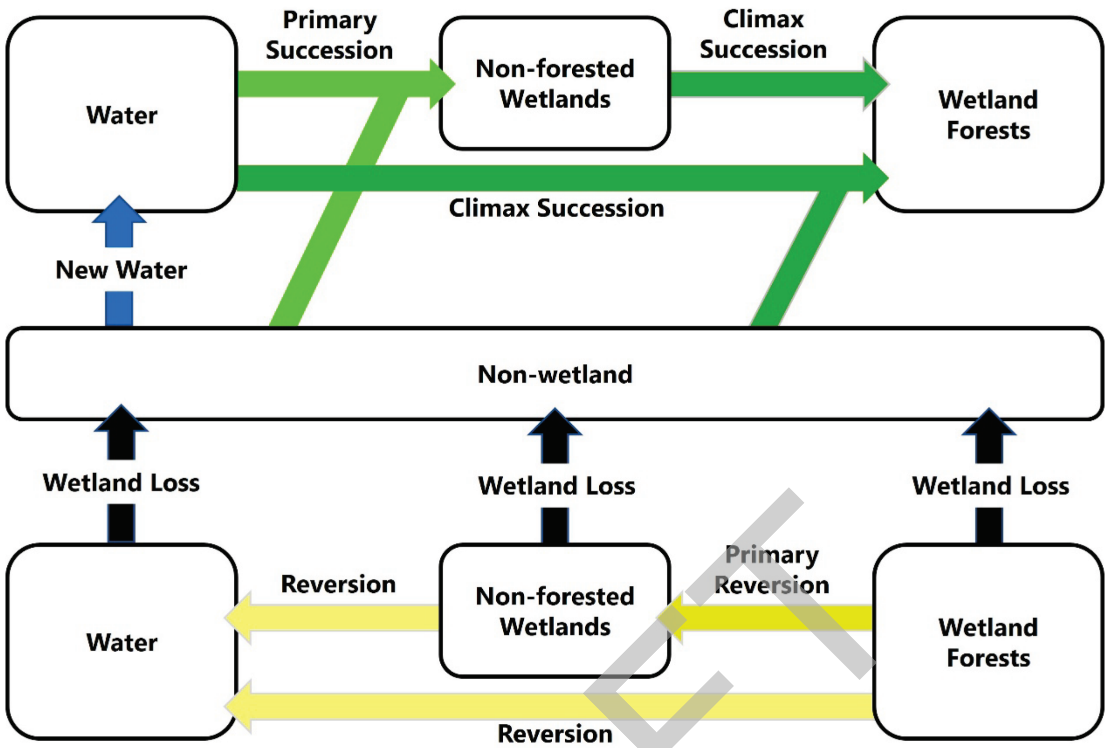

Figure 6-5. This diagram represents the succession and reversion pathways included in the wetland change analysis.

A simplified linear progression of succession and reversion was used for this analysis because a more complicated model that maps the changes over time for each of the seven wetland types and water results in over 60 different change categories, which makes it extremely difficult to represent in map form. By grouping wetland types into non-wetlands, water, primary habitats (i.e., wet prairies, freshwater marsh, and scrub-shrub) and climax habitats (i.e., cypress, mixed wetland forests, hydric pine flatwoods) the changes that occur and the ecological direction of those changes (i.e., succession and reversion) can be symbolized spatially. The specific changes that occur between non-wetland habitats, water, wetland habitats (i.e., non-forested) and forested wetland habitats are summarized in **Table 6-3** along with the succession/reversion categories that the changes were grouped under for this analysis.

Table 6-3. Wetland change types and the succession or reversion categories that each change type was associated with for the change analysis.

Wetland Change Type	Succession/Reversion Category
Non-wetland to Water	New Water
Forested Wetland to Water	Reversion
Non-forested Wetland to Water	Reversion
Forested Wetland to Non-forested Wetland	Primary Reversion
Non-wetland to Non-forested Wetland	Primary Succession
Water to Non-forested Wetland	Primary Succession
Non-wetland to Forested Wetland	Secondary Succession
Non-forested Wetland to Forested Wetland	Secondary Succession
Water to Forested Wetland	Secondary Succession
Forested Wetland to Non-wetland	Wetland Loss
Non-forested Wetland to Non-wetland	Wetland Loss
Water to Non-wetland	Wetland Loss
No Change	Stasis - No Change

6.2.2 Succession Results

The results of this analysis are provided below in **Figure 6-6** and the tabular results, that include wetland losses, are shown in **Table 6-4**. This table includes the total area (acres) that underwent change based on succession and reversion principles. It also includes the amount of land that was converted into water, the total area that did not undergo successional change, and the amount of wetland area that was lost to development or converted into non-wetland habitat during each period.

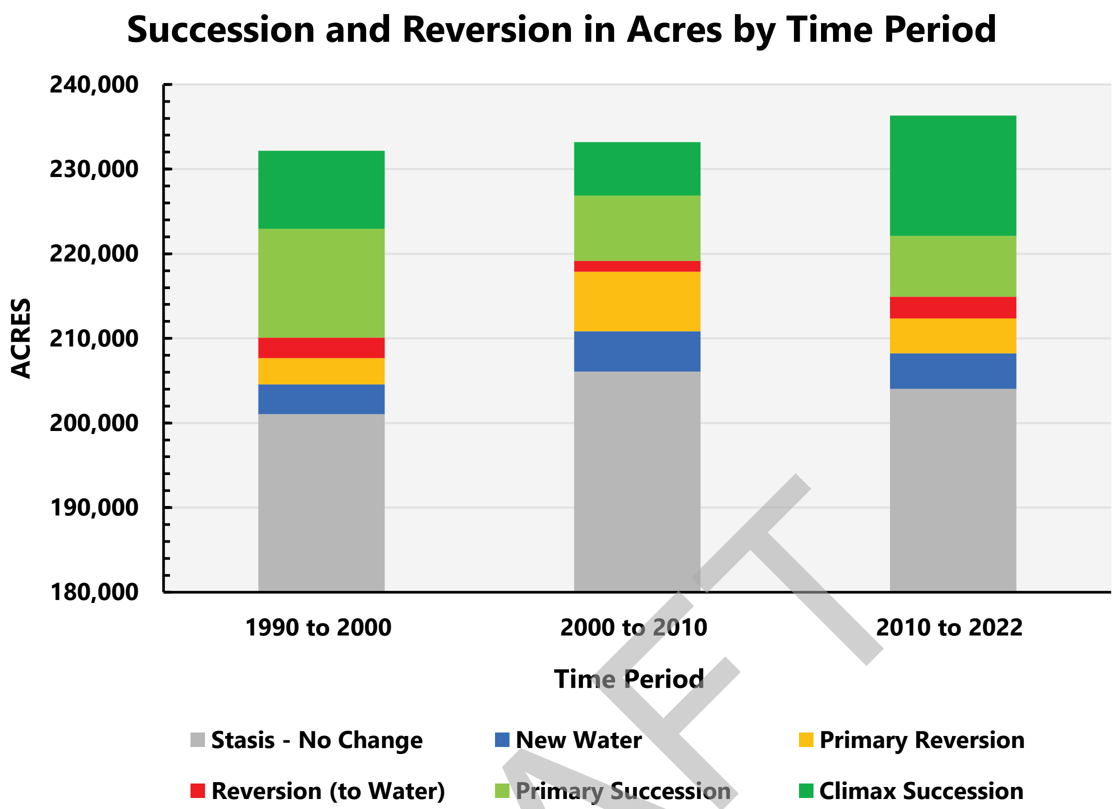

Figure 6-6. Habitat succession, reversion, and stasis for the time periods 1990 through 2000, 2000 through 2010, and 2010 through 2022.

The results for the full period between 1990 and 2022 are also presented in **Table 6-4** as a reference of the total changes, since they do not account for the successional changes that occurred between each of the time periods. Another important factor to consider is that the "losses" in this section refers to the spatial context of a wetland area. If a wetland is no longer in the same location, it is considered a loss. Gains in wetland acreage are due to primary succession, where non-wetlands or water are converted to non-forested wetlands, which offsets most of the wetland losses. Over time, the total amount of wetland area increases due to succession, however, wetland loss outpaces wetland gains by approximately 1,585 acres.

Table 6-4. Wetland succession, reversion, stasis and loss in acres that occurred between 1990-2000, 2000-2010, 2010-2022 and 1990-2022.

Change Category	1990 to 2000 Acres	2000 to 2010 Acres	2010 to 2022 Acres	1990 to 2022 Acres
New Water	3,512	4,776	4,190	11,033
Primary Reversion	3,105	7,023	4,110	6,738
Reversion	2,426	1,294	2,600	3,897
Primary Succession	12,829	7,715	7,176	19,016

Climax Succession	**9,253**	**6,312**	**14,213**	**17,229**
Stasis - No Change	**201,058**	**206,082**	**204,039**	**178,991**
Wetland Loss	**9,490**	**11,152**	**11,357**	**20,601**

Between 1990 and 2000 (**Figure 6-7**), a total of 22,082 acres of land in Orange County went through either primary succession (changing from non-wetland or water to non-forested wetlands) or climax succession (changing from non-wetland, water, or non-forested wetlands to forested wetlands). This period showed the largest amount of primary succession during any of the three time periods analyzed (excluding the cumulative 32-year period from 1990 to 2022). During this same period, 5,530 acres went through either primary reversion (forested wetlands to non-forested wetlands) or reversion (forested wetlands or non-forested wetlands to water). A total of 3,512 acres of new water area was gained while 9,490 acres of wetlands or water were lost to development or converted to a non-wetland land cover type.

From 2000 to 2010 (**Figure 6-8**), only 14,027 acres of land went through primary succession or climax succession, the least amount of any of the three regular time periods. However, this period had the highest total acreage that underwent either primary reversion or reversion, with over 8,300 acres. Wetland losses totaled 11,152 acres with 4,776 acres of new water area created. This ten-year period also had the greatest amount of wetland and water area, over 206,000 acres, that did not undergo succession (as defined in this analysis), although both the 1990-2000 and 2010-2022 periods were relatively close in this regard.

The period from 2010 to 2022 (**Figure 6-9**) had 21,389 acres go through succession, either primary or climax, with the highest level of climax succession occurring in any of the three time periods. Climax succession took place over 14,000 acres on land in the county, which equals 66% of the total successional change. At the same time, 6,709 acres went through reversion or primary reversion. This period also showed the highest wetland losses with 11,357 acres.

Overall, without considering the successional changes that occurred in the other time periods, the spatial analysis calculated that between 1990 and 2022 (**Figure 6-10**), a total of 20,601 acres of wetlands were lost. It is important to note that these losses are based on spatial locations and don't factor in wetlands (or water) that might have been gained in other locations where wetlands or water did not previously exist beginning in 1990. During this 32-year period, a total of 36,245 acres of land went through either primary or climax succession, while over 178,000 acres remained as wetlands in the same successional categories. Over 6,700 acres of wetlands went through primary reversion, moving from a higher successional category to a lower one (i.e., forest to scrub-shrub), while 3,897 acres of wetland reverted to water.

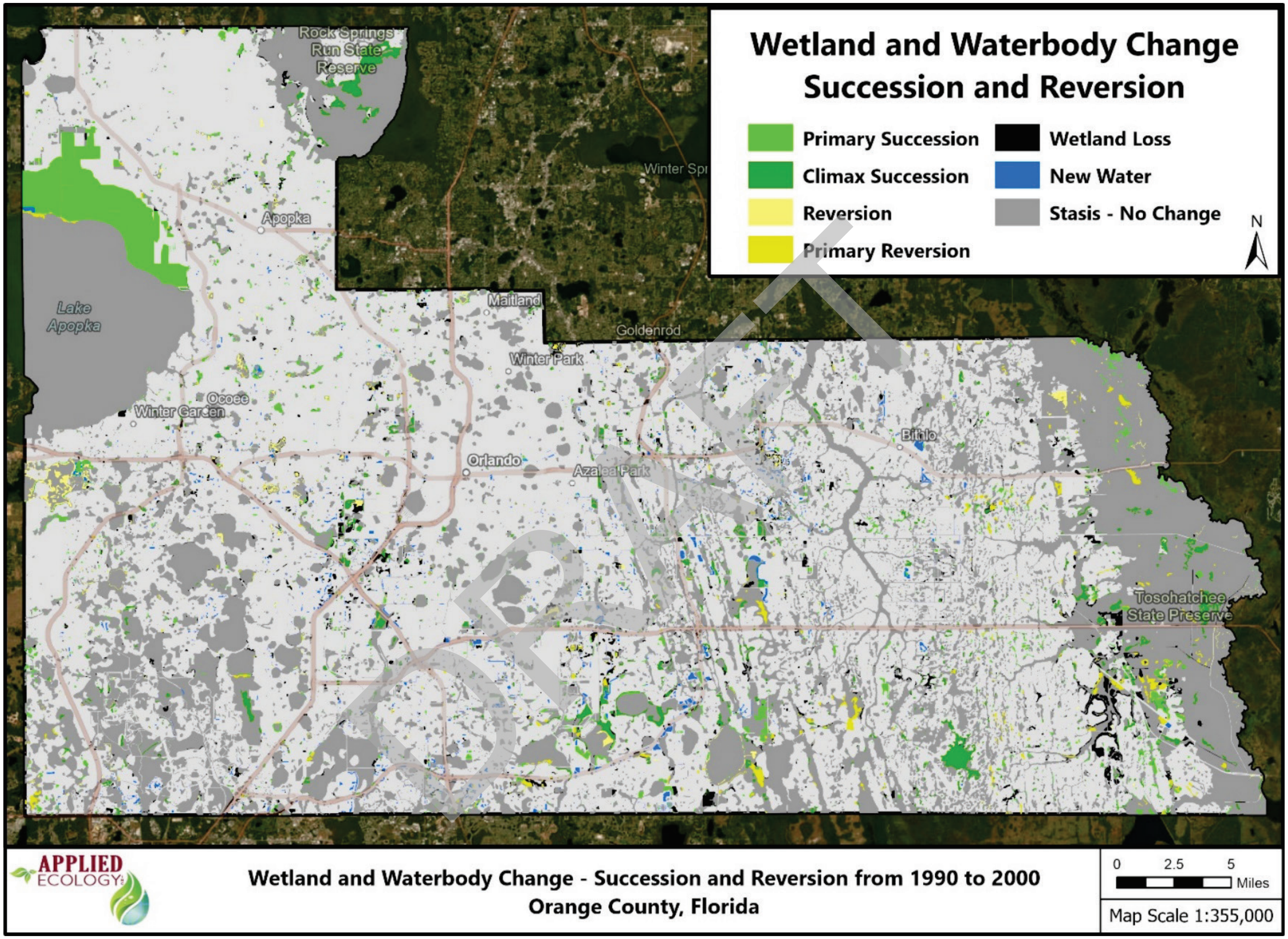

Figure 6-7. Wetland succession, reversion and loss that occurred between 1990 and 2000 in Orange County, Florida.

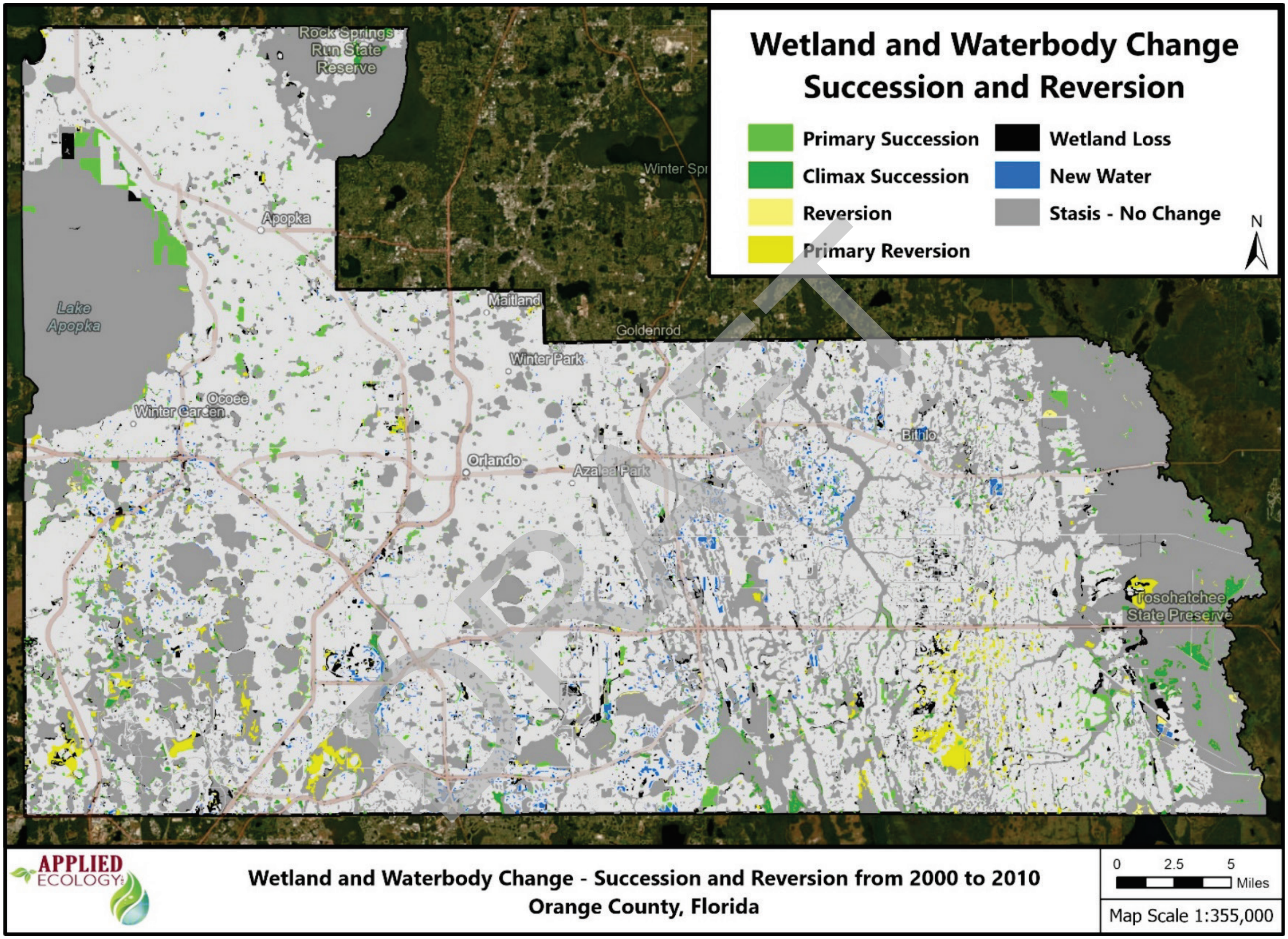

Figure 6-8. Wetland succession, reversion and loss that occurred between 2000 and 2010 in Orange County, Florida.

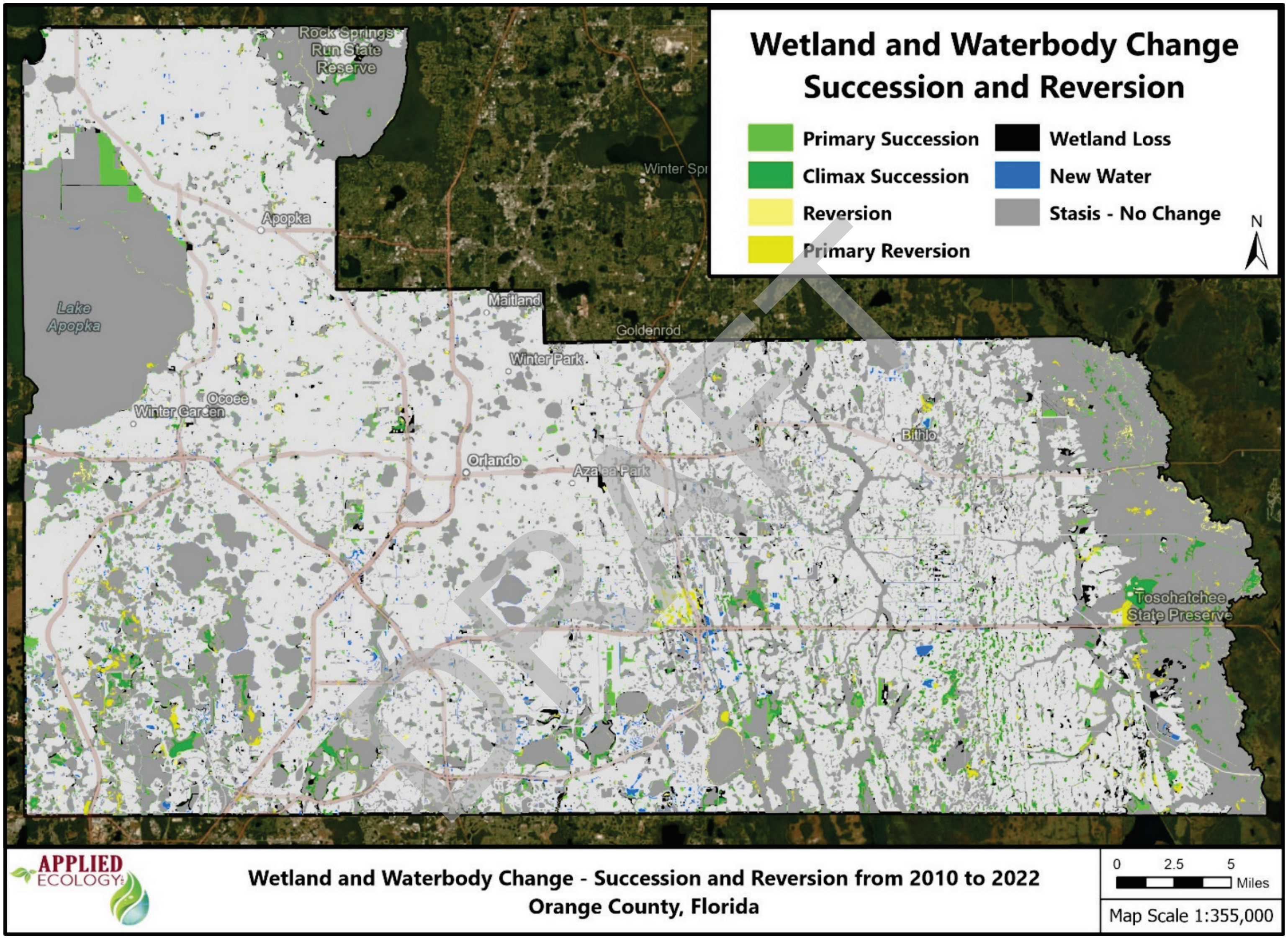

Figure 6-9. Wetland succession, reversion and loss that occurred between 2010 and 2022 in Orange County, Florida.

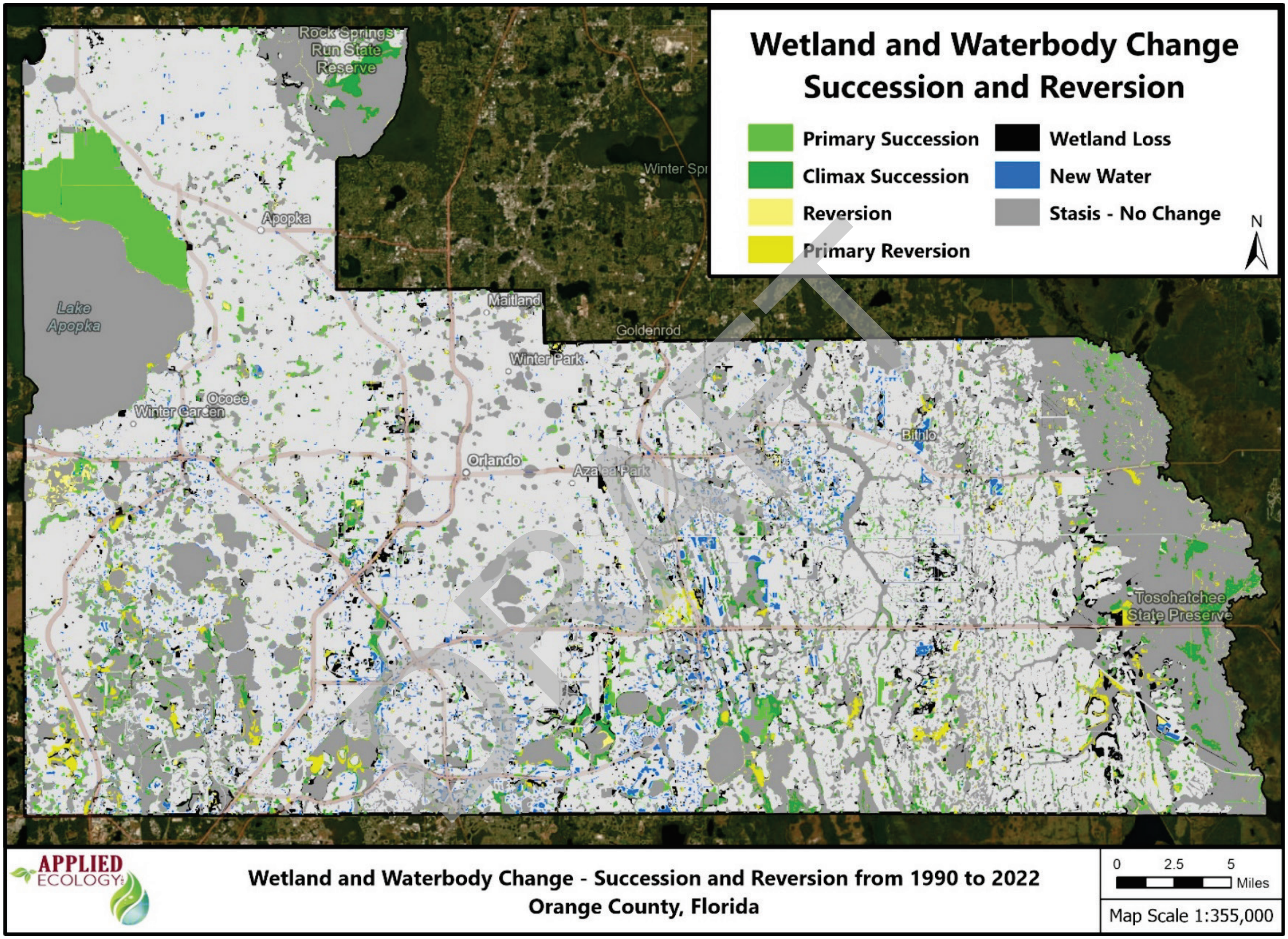

Figure 6-10. Wetland succession, reversion and loss that occurred between 1990 and 2022 in Orange County, Florida.

6.3 Wetland Changes and Environmentally Sensitive Areas

Drummond Carpenter performed a spatial evaluation of wetland changes within Orange County, to better understand how these changes may be related to other environmentally sensitive areas and/or practices of environmental concern. In general, areas with higher rates of wetland loss tended to be associated with areas of less regulatory protection. For example, wetlands designated as Low-Risk FEMA Flood Zones were lost at significantly higher rates than wetlands in High-Risk FEMA flood zone areas. Little-to-no relationship was observed between wetlands loss, aquifer recharge, and areas of groundwater withdrawal. This result may reflect that regulatory status, rather than hydrogeologic conditions, play the primary role in determining where wetland loss occurs in Orange County.

6.3.1 Spatial Patterns of Wetland Changes

Heatmaps of lost and gained wetlands areas were developed to help visualize the spatial distribution of wetland changes (**Figure 6-11** and **Figure 6-12**). To develop the heatmap, a hexagonal grid with 0.5 mile (mi.) spacing was used to sample the wetland preservation polygon and record the dominant wetland category (persistent, lost, gained) within each hexagon grid. A two-dimensional kernal density estimation with a 10,000-foot (ft.) search radius was then performed on hexagon centroids to help quantify areas of dense wetland gain or loss.

The resulting heatmaps highlight areas of Orange County where wetland changes have been concentrated. The gained wetland heatmap **(Figure 6-11**) demonstrates that new wetland areas are predominately located in the western half of Orange County. In addition to the LAN, many of the gained wetlands are found along major waterbodies such as Lake Hickorynut, Big Sand Lake, Lake Holden, Lake Jessamine, and Lake Orlando.

Wetlands losses are also primarily located in western Orange County (**Figure 6-12**). Dense concentrations of wetland loss are observed along the I4-corridor between Millenia and Dr. Phillips. Other dense wetland loss areas are found around the Interlachen Country Club, Orlando International Airport, Wedgefield, and Johns Lake.

Aquifer Recharge

To assess if there was a spatial relationship between areas of wetland change and aquifer recharge, Drummond Carpenter utilized GIS data for groundwater recharge available from the St. Johns Water Management District[1] (SJWMD) and the South Florida Water Management District[2] (SFWMD). Within Orange County, the SJWMD classifies recharge to the Upper Florida Aquifer as being either High, Medium, Low, or Discharge. SFWMD Upper Florida Aquifer GIS polygons were matched to this scheme based on provided recharge range values (**Figure 6-13**).

[1] https://data-floridaswater.opendata.arcgis.com/datasets/floridaswater::ufa-groundwater-recharge-2015-1/explore

[2] https://geo-sfwmd.hub.arcgis.com/datasets/precipitation-recharge-discharge-areas-floridan-sandstone-and-tamiami-aquifers/explore?location=28.444699%2C-81.425101%2C9.73

Wetland change polygons (Section 1) were assigned attributes of aquifer recharge classification (i.e., High, Medium, Low, or Discharge) based on the aquifer recharge classification with the largest aerial overlap for each wetland change polygon.

Wetland changes were aggregated based on the assigned aquifer recharge classification to determine if any systematic relationship exists between the two variables (**Figure 6-14**). Overall, there appears to be a weak relationship between aquifer recharge and wetland changes. Areas with High & Medium aquifer recharge lost nearly identical proportion of wetland areas (-11.6% and -11.7% respectively). Regions of Low aquifer recharge saw a net gain in wetland areas (+17.2%). This gain was largely driven by the LAN restoration area. If the LAN area was excluded, then Low recharge areas would have a similar proportion of wetland loss (-12.6%) to High & Medium recharge areas. Regions of aquifer discharge saw substantially lower rates of wetland loss (-1.4%) than all other wetland categories. This likely reflects a tendency for development to avoid areas of shallow groundwater.

Areas of Flooding

To assess if there is a spatial relationship between areas of wetland change and areas of flooding, Drummond Carpenter utilized GIS data available from Federal Emergency Management Agency (FEMA) Flood Insurance Rate Mapping[3] (**Figure 6-15**). Wetland change polygons were assigned attributes of flood risk zone (i.e., A, AE, X) based on the FEMA flood zone classification with the largest aerial overlap for each wetland change polygon.

Wetland changes were aggregated based on the assigned FEMA flood zone classification to determine if any systematic relationships exist between the two variables (**Figure 6-16**). Overall, there appears to be a strong relationship between areas of wetland loss and FEMA flood zone. High-risk flood zones A and AH saw similar rates of wetland loss (-1.5% and -2.9% respectively). High-risk flood zone AE saw a net gain (+10.0%). This zone included the LAN, which when excluded results in a slight wetland loss of -1.5%, similar to the other High-Risk zones. Comparatively, the Low-Risk X flood zone saw significantly higher rates of wetland loss (-35.1%). These results indicate that FEMA flood zone assignment is an important factor in determining wetland loss. Regulatory guidelines for High-Risk flood zones provide important protection from development. Wetlands in Low-Risk FEMA flood zones do not benefit from this protection and are at a higher risk for destruction.

Distance to Major Groundwater Withdrawal

To assess if there is a spatial relationship between areas of wetland change and areas of flooding, Drummond Carpenter utilized the major pumping well locations that are further discussed in Section 7. These major pumping locations represent point locations of significant groundwater withdrawal (**Figure 6-17**). For each wetland change polygon, the distance between the polygon edge and nearest major pumping well location was calculated.

Wetland changes were then binned by distance to pumping to determine if any systematic relationships exist between the two variables (**Figure 6-18**). Overall, there appears to be little-

[3] https://msc.fema.gov/portal/search?AddressQuery=orange%20county%20florida#searchresultsanchor

to-no relationship between areas of wetland loss and distance to major pumping locations. Between 0-1 miles, wetlands were lost at -8.7%. Similar rates were observed for the 2-3 mi. bin (-8.5%) and 3-4 mi. bin (-14.8%). Wetlands between 1-2 mi. from major pumping were the only distance-bin to see a net gain in wetland area (+21.3%). However, when the LAN is excluded, wetlands in this bin were lost at similar rates to other areas (-11.5%). At distances greater than 4 miles, rates of wetland loss were lower (3.5%). While this lower wetland loss rate at the furthest distance bin may reflect a relationship between wetland loss and distance to pumping, it may also be an artifact of many major pumping locations being located closer to infrastructure and development. Given the lack of clear relationship between distance to pumping and wetland loss, it is difficult to conclude that proximity to locations of major groundwater withdrawal is a major factor affecting wetland loss in Orange County.

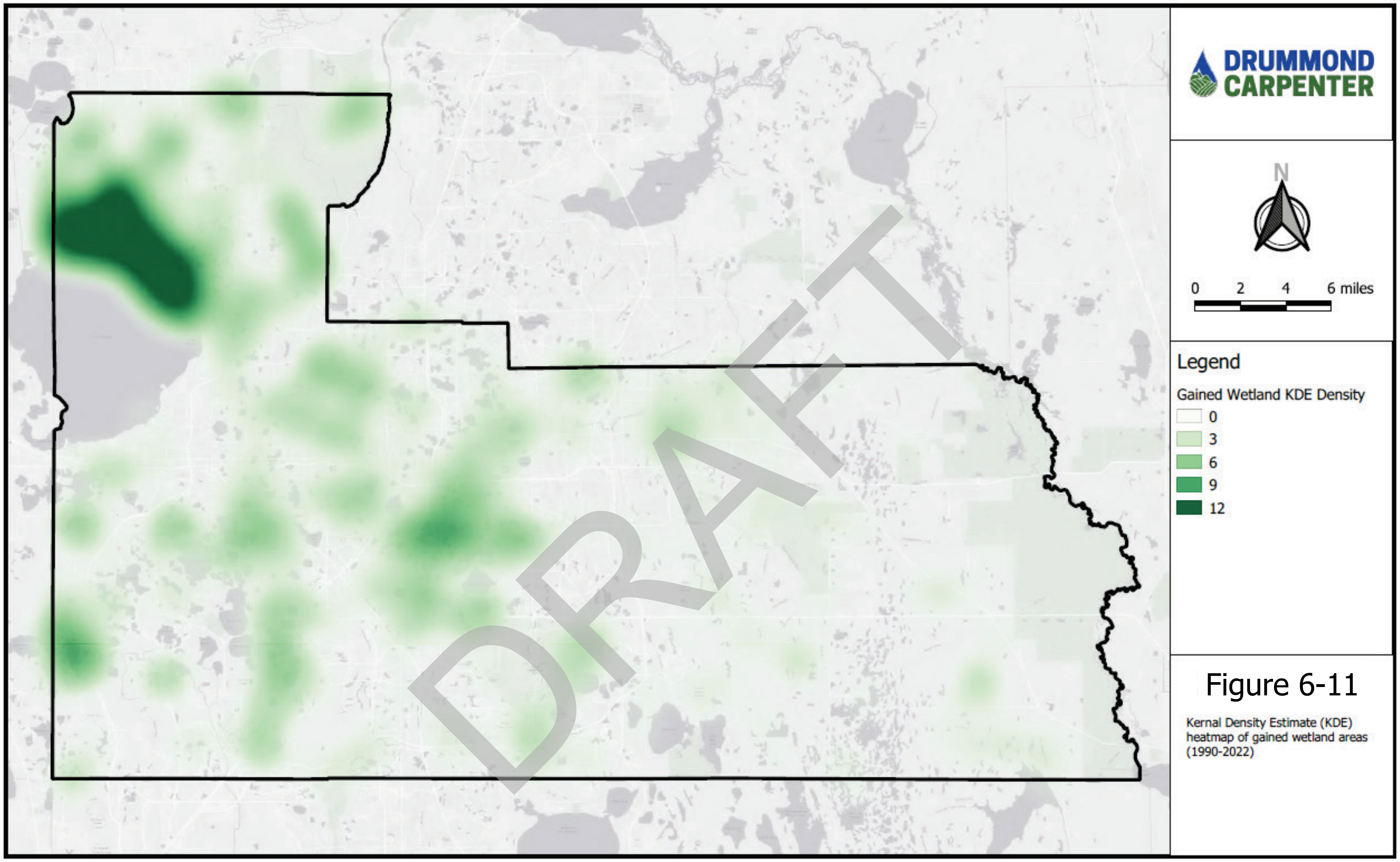

Figure 6-11. KDE Heatmap of Gained Wetland Areas (1990-2022).

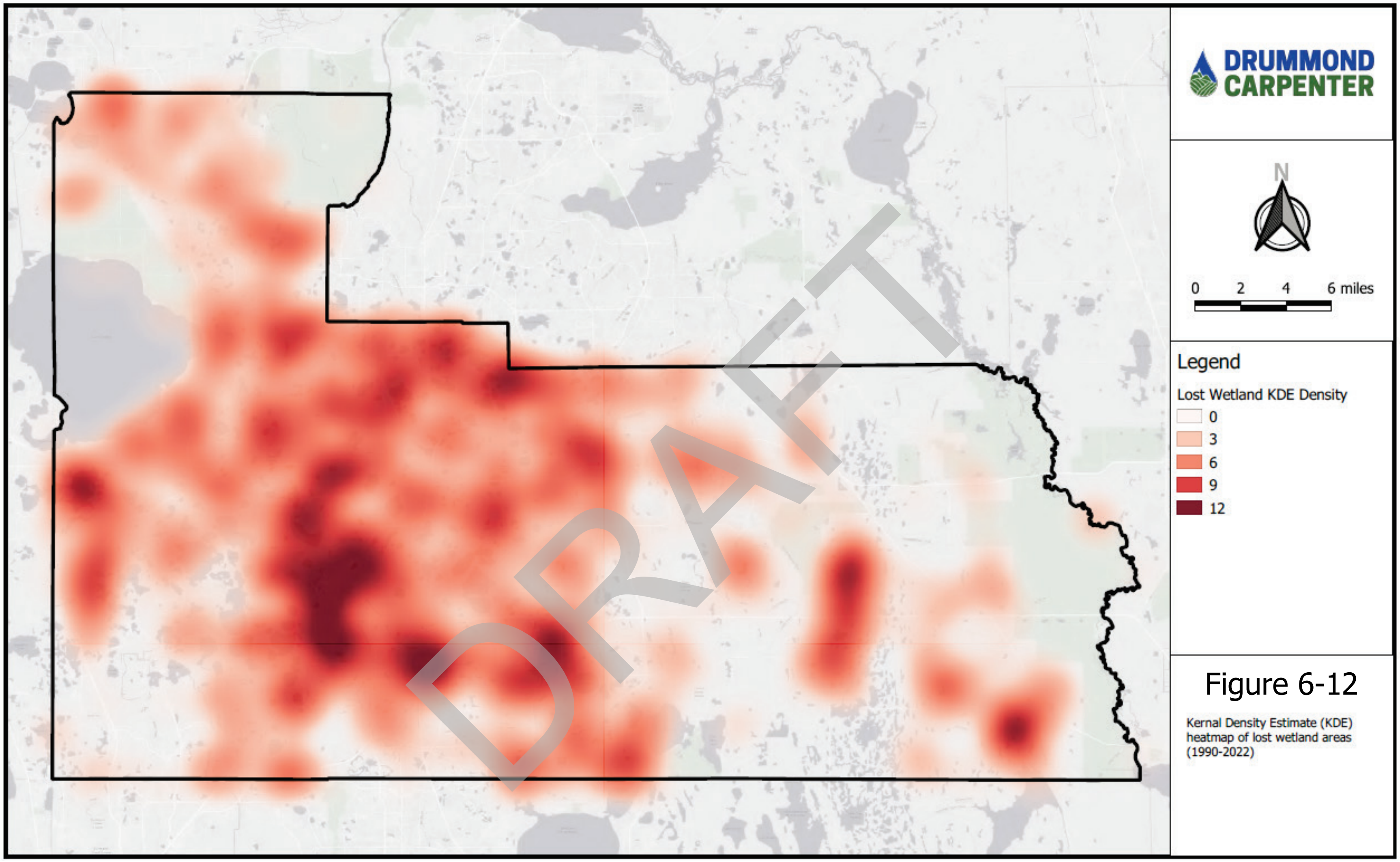

Figure 6-12. KDE Heatmap of Lost Wetland Areas (1990-2022)

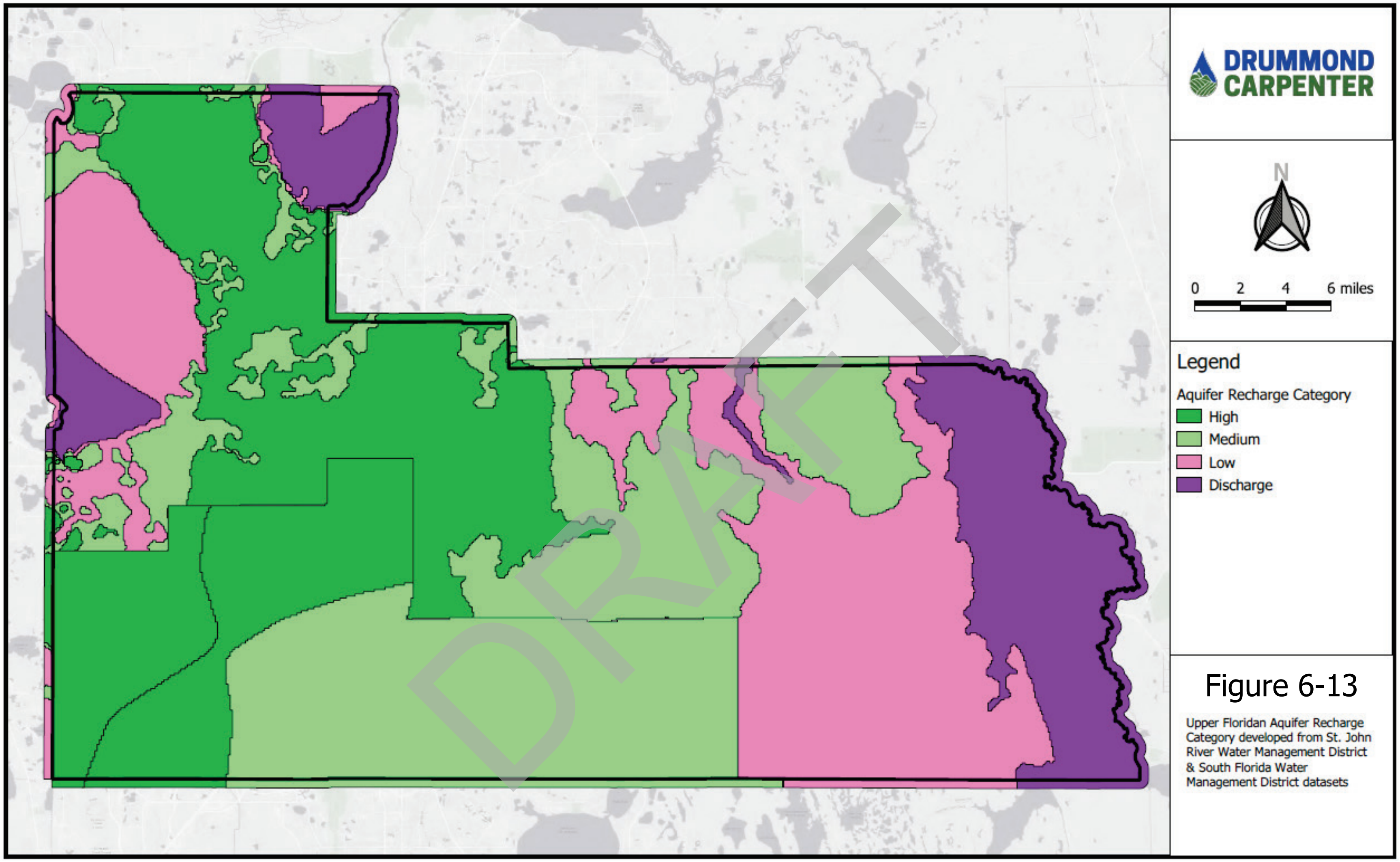

Figure 6-13. Aquifer Recharge Categories in Orange County.

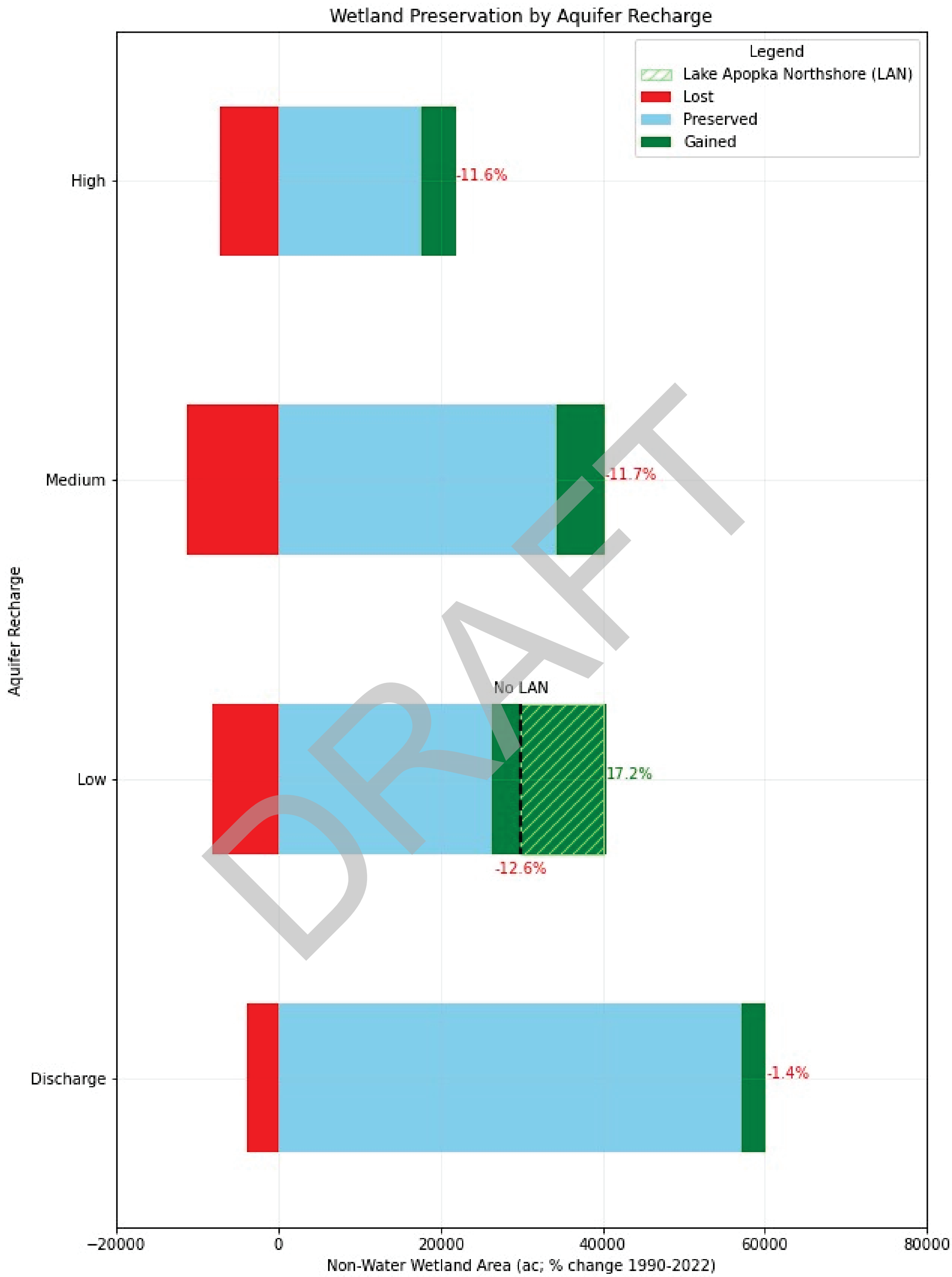

Figure 6-14. Wetland Preservation by Aquifer Recharge.

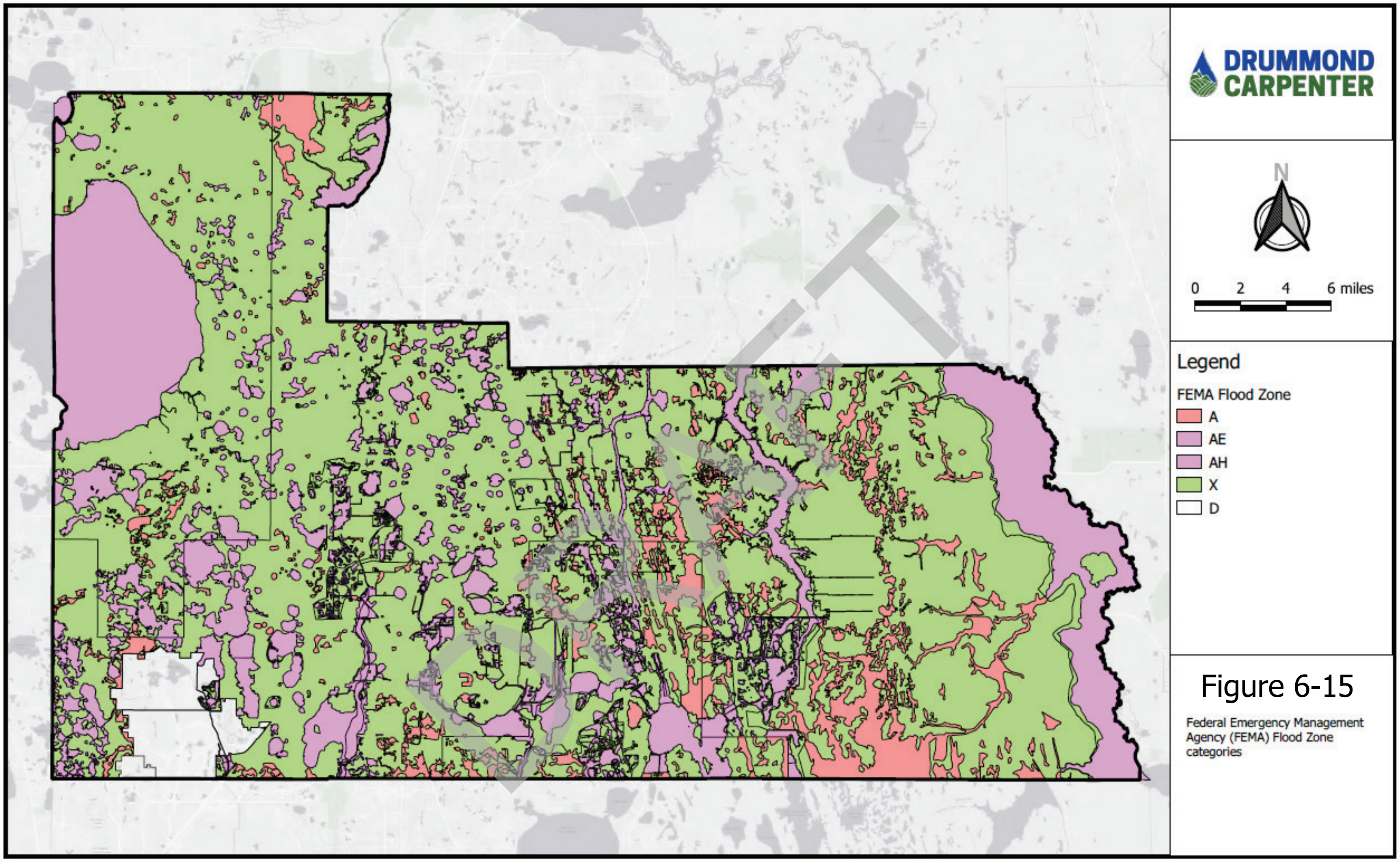

Figure 6-15. FEMA Flood Zone Categories in Orange County.

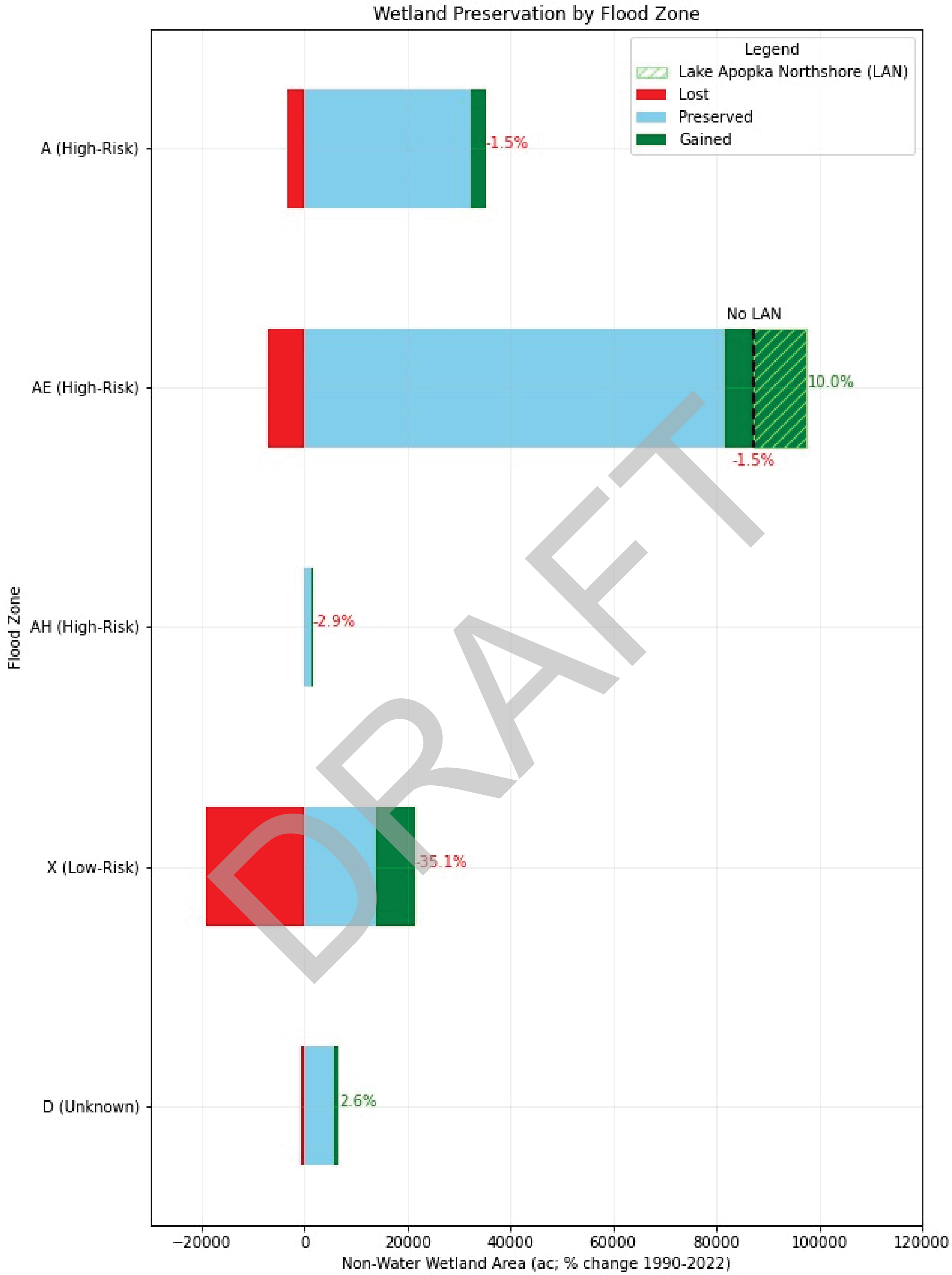

Figure 6-16. Wetland Preservation by Flood Zone.

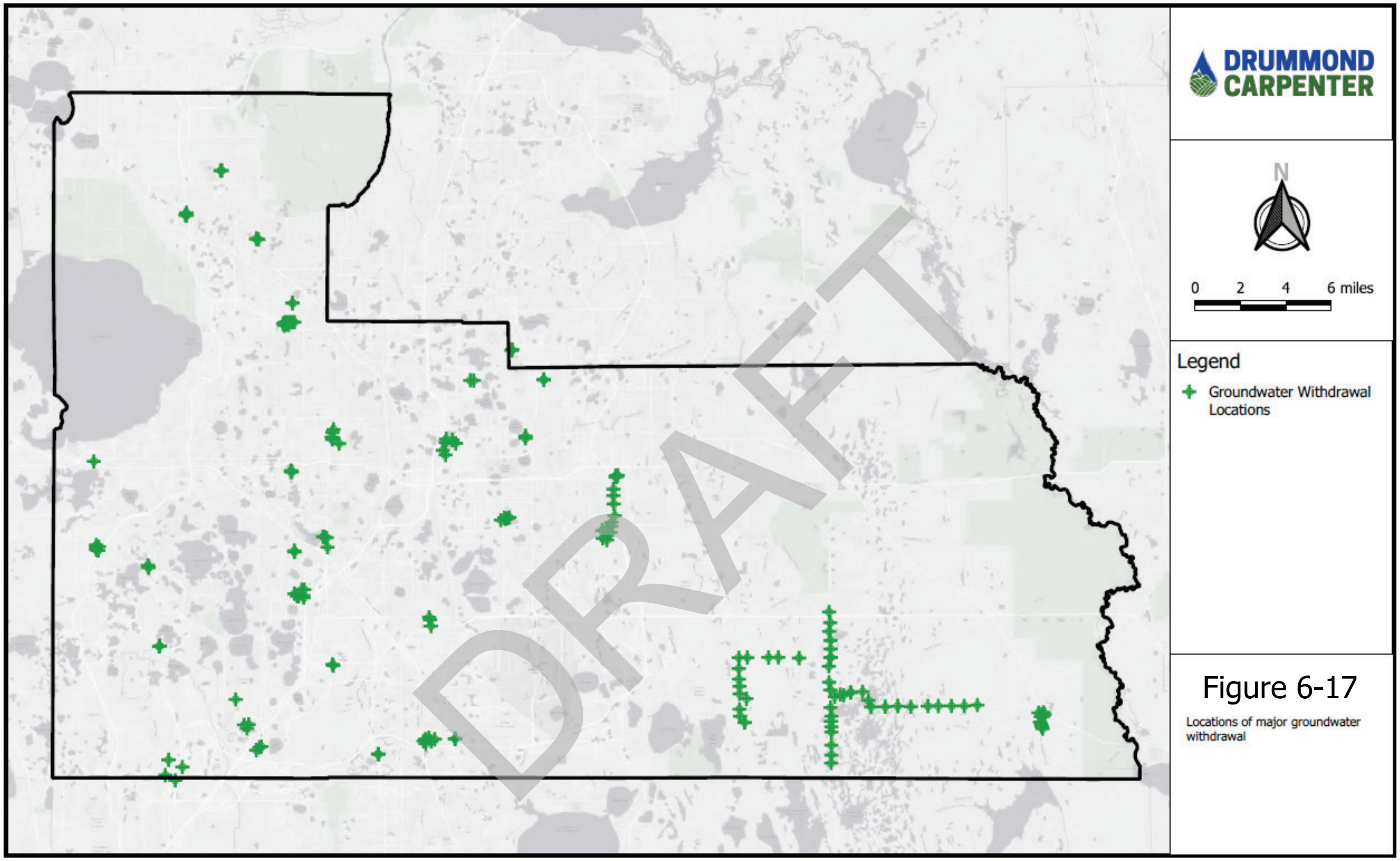

Figure 6-17. Locations of Major Groundwater Withdrawal.

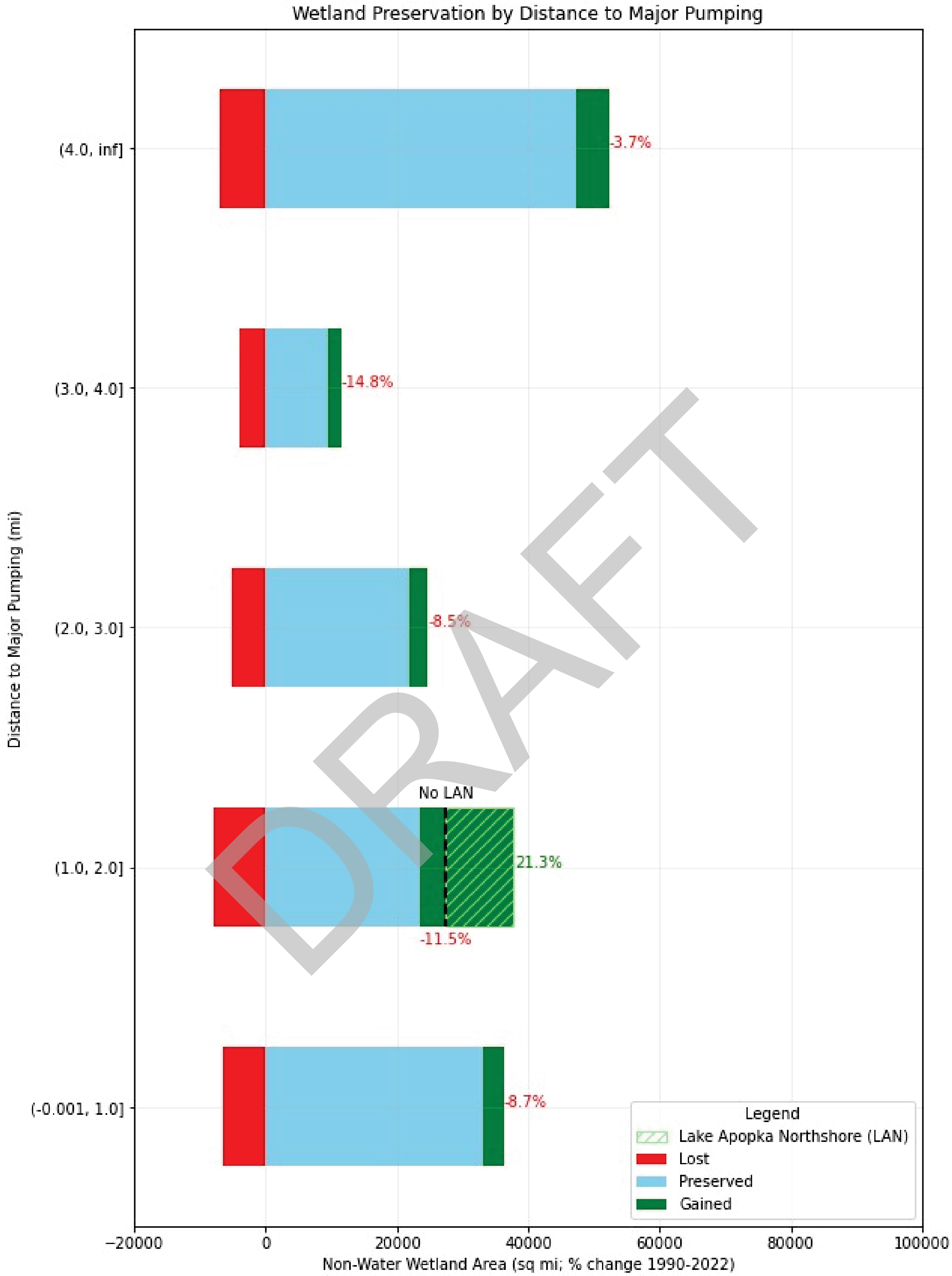

Figure 6-18. Wetland Preservation by Distance to Major Pumping Areas.

Outstanding Florida Waterbodies

To assess if there is a spatial relationship between areas of wetland change and proximity to Outstanding Florida Waters (OFWs; **Figure 6-19**), Drummond Carpenter utilized GIS data available from Florida Department of Environmental Protection (FDEP) Geospatial Open Data Portal[4]. Wetland change polygons were assigned an OFW status (OFW or non-OFW) based on if the wetland change polygon intersected and/or overlapped an OFW polygon in Orange County. Additionally, an edge-to-edge distance calculation was performed for each wetland change polygon to the nearest OFW polygon.

Wetland changes were aggregated based on OFW status and distance to nearest OFW to determine any systematic relationships between the variables (**Figure 6-20**). Overall, there was a relationship between OFWs and wetland changes. Wetland areas with non-OFW status had slightly higher rates of loss than OFW areas (-2.5% vs -0.6%). When LAN is excluded, this difference is highly pronounced with non-OFW wetland areas showing significantly higher rates of wetland loss (-11.4%) compared to OFW-proximal wetlands.

Wetland losses and distance to OFWs also show a relationship, where wetlands at an increasing distance from OFWs experienced higher rates of wetland loss (Figure 6-21). At the highest distance bin of >4 mi., wetlands are shown to have increased in area by 13.1%. However, this bin includes the LAN, which when excluded indicates a high rate of wetland loss for wetlands at this distance (-16.7%). Together, these results indicate that wetlands adjacent or close to OFW waterbodies are at less risk for loss than wetland areas that are distal from OFWs. This may reflect that much of the development in Orange County has been at a greater distance from OFWs and/or that OFW status provides regulatory protection to nearby surrounding wetlands.

Proximity to Impaired or Established TMDL Waterbodies

To assess if there is a spatial relationship between areas of wetland change and waterbodies with verified impairments or established total maximum daily loads (TMDLs), Drummond Carpenter utilized GIS data on hydrology[5], waterbody impairment[6], and TMDL status[7] from Orange County and FDEP (**Figure 6-21**). If a waterbody was listed as “Verified Impaired” or had a TMDL for bacteria, nutrients, or metals, then it was considered a TMDL waterbody for this analysis. ArcGIS hydrology tools were utilized to develop drainage basin extends for all hydrologic bodies in Orange County. Wetland change polygons were assigned a TMDL status (TMDL or non-TMDL) based on if they fell within the drainage basin of a TMDL waterbody.

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[4] https://geodata.dep.state.fl.us/maps/outstanding-florida-waters

[5] https://ocgis-datahub-ocfl.hub.arcgis.com/datasets/hydrology/explore?location=28.566896%2C-81.264900%2C11.59

[6] https://geodata.dep.state.fl.us/datasets/FDEP::verified-list-waterbody-ids-wbids/about

[7] https://geodata.dep.state.fl.us/datasets/FDEP::florida-total-maximum-daily-load-tmdl/explore?location=28.351395%2C-83.759550%2C7.00

Additionally, an edge-to-edge distance calculation was performed for each wetland change polygon to the nearest waterbody of the same TMDL status.

Wetland changes were aggregated based on TMDL status and distance to nearest waterbody to determine if any systematic relationships exist between the variables (**Figure 6-22**). Overall, there was a complicated relationship between the TMDL variables investigated here and wetland changes. Wetland areas in non-TMDL drainage basins experienced a loss of wetlands (-8.1%) while wetland areas in TMDL drainage basins experienced a net gain in wetland area (+1.3%). However, when the LAN is excluded from the calculations, the TMDL drainage basins show identical rates of wetland loss (-8.1%) to non-TMDL drainage basins.

For non-TMDL drainage basins, there did not appear to be any relationship between drainage distance and wetland loss (**Figure 6-23**). For wetland areas in TMDL drainage basins, there did appear to be a relationship between drainage distance and wetland loss, with wetlands exhibiting higher rates of loss at increasing distance from their drainage basin waterbody (**Figure 6-24**). The LAN is located within the 0-0.5 mi. distance bin. When the LAN is included, the bin reflects an 11.0% increase in wetland area. When the LAN is excluded, the bin reflects a -2.5% decrease in wetland area. The increase in wetland loss with increasing distance from TMDL waterbodies may reflect that regulatory agencies provide better protection to wetlands near impaired waters.

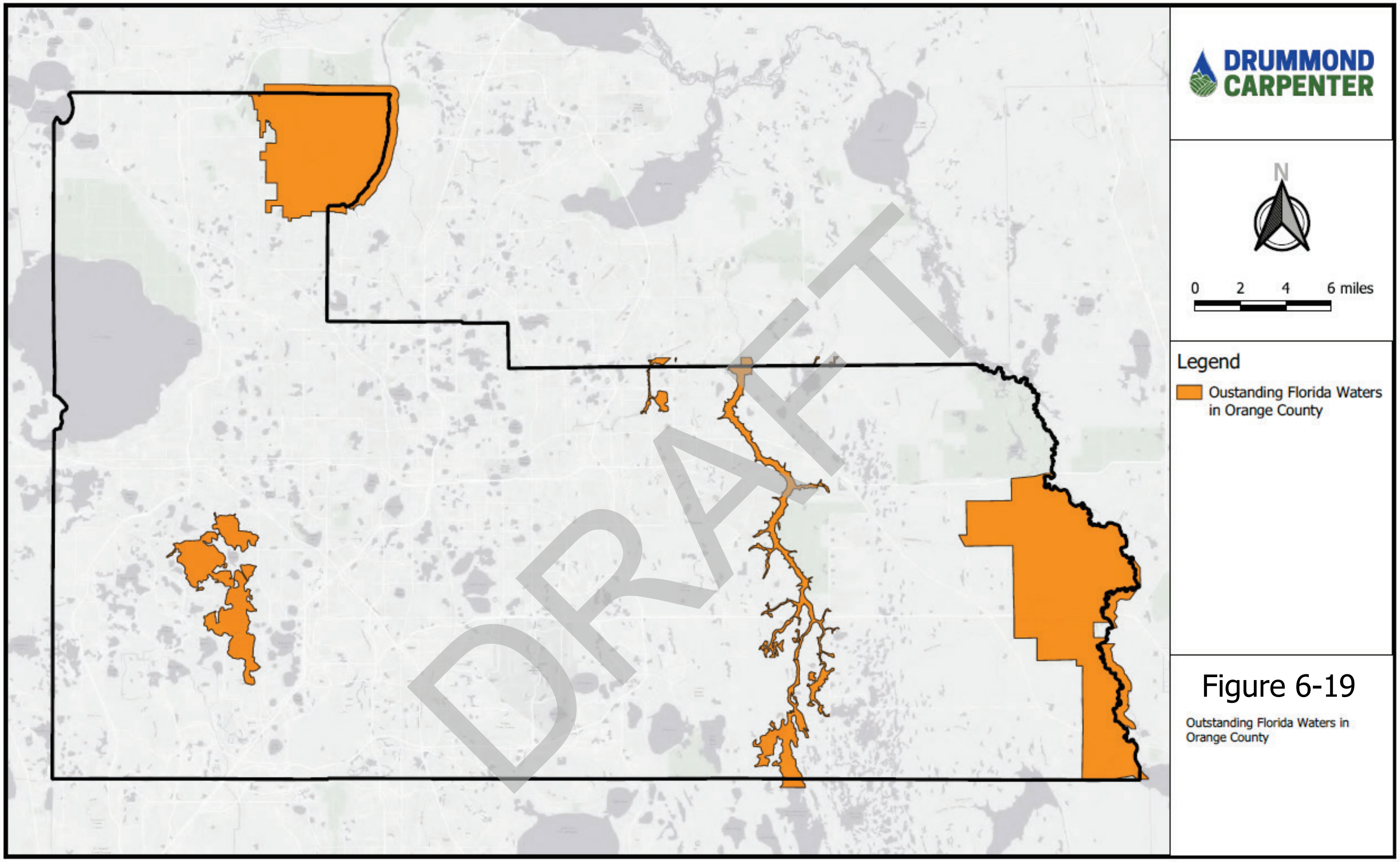


Figure 6-19. OFWs in Orange County.

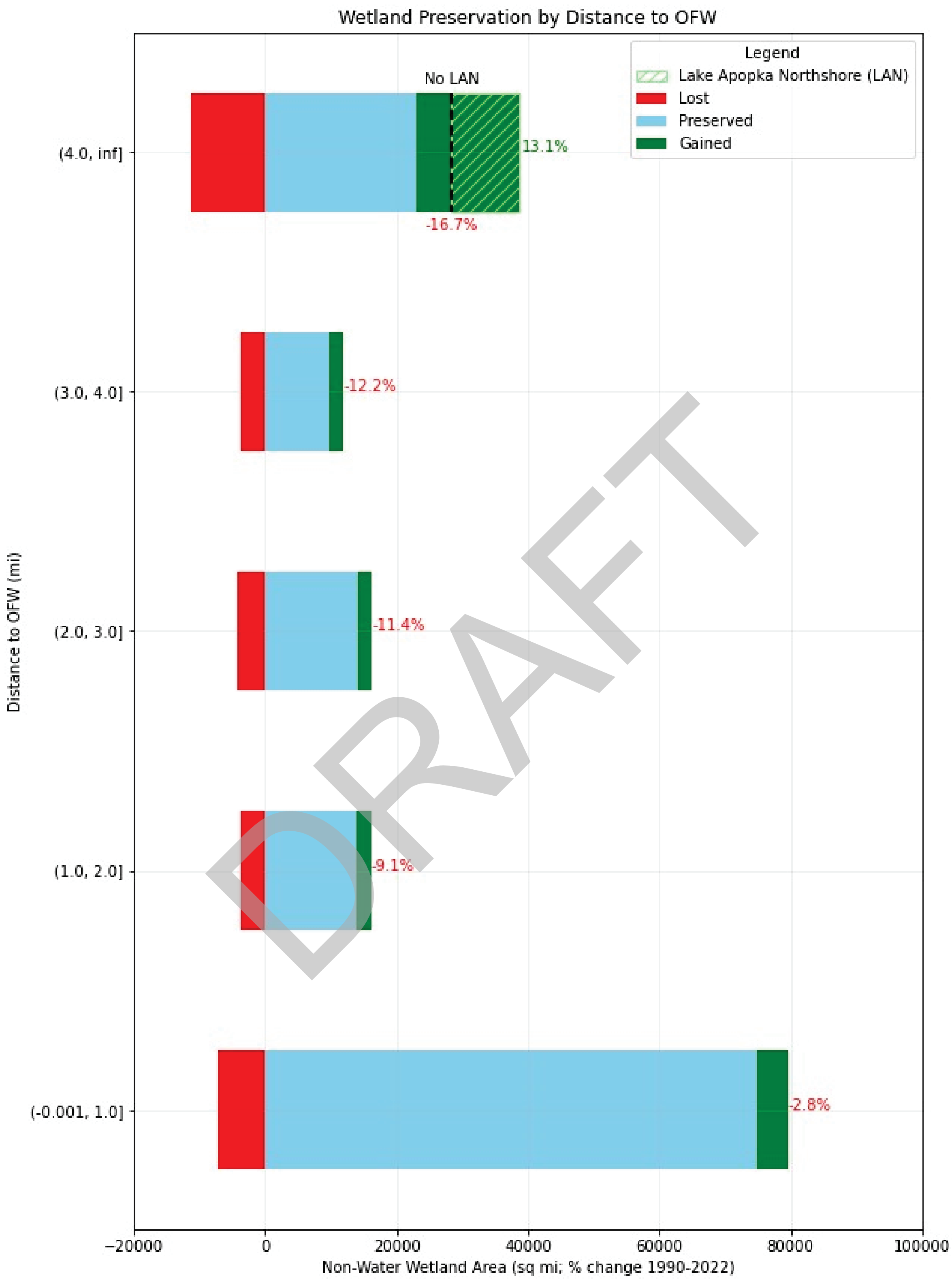


Figure 6-20. Wetland Preservation by Distance to OFW.

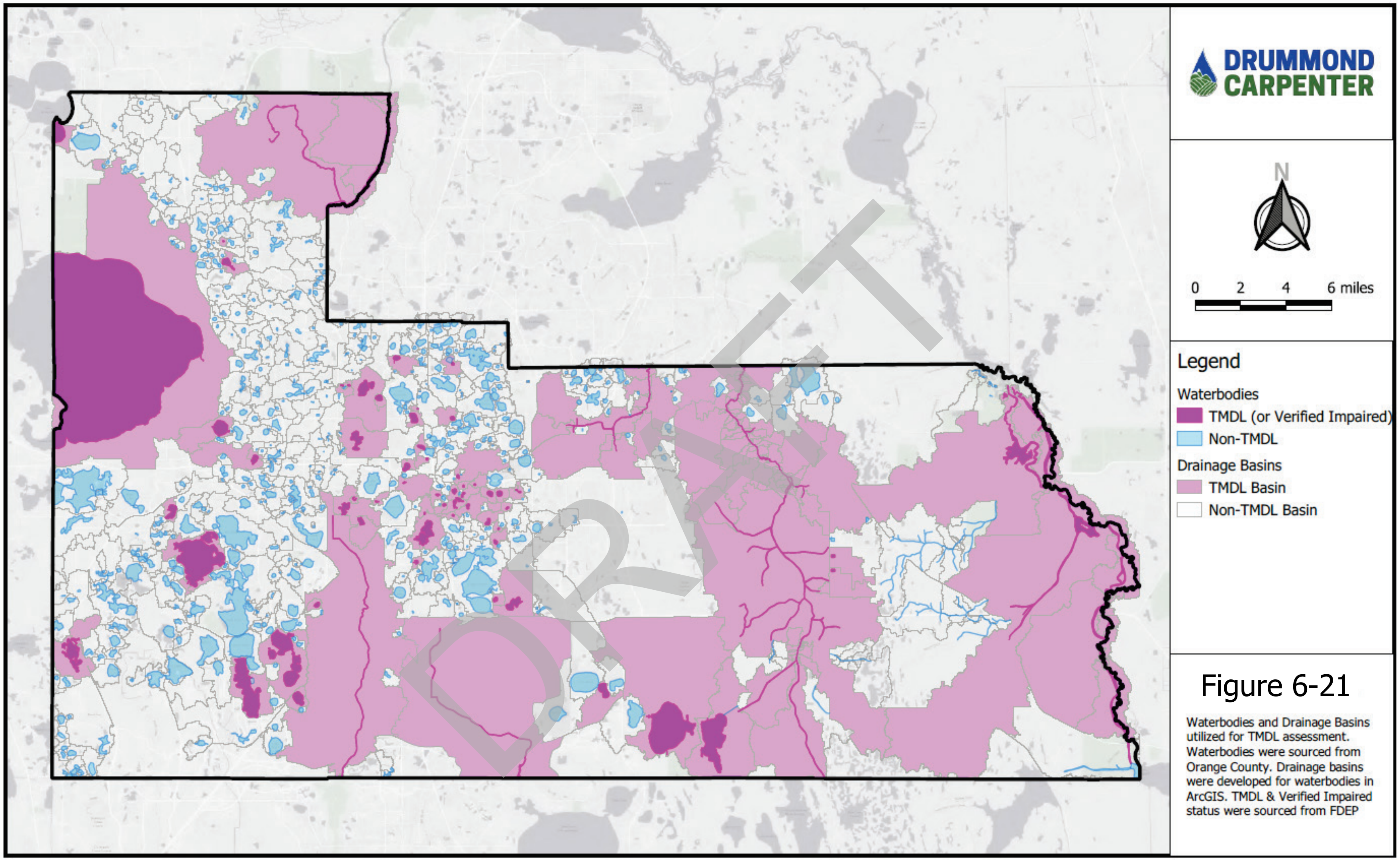


Figure 6-21. Waterbodies and Drainage Basins used for TMDL Assessment.

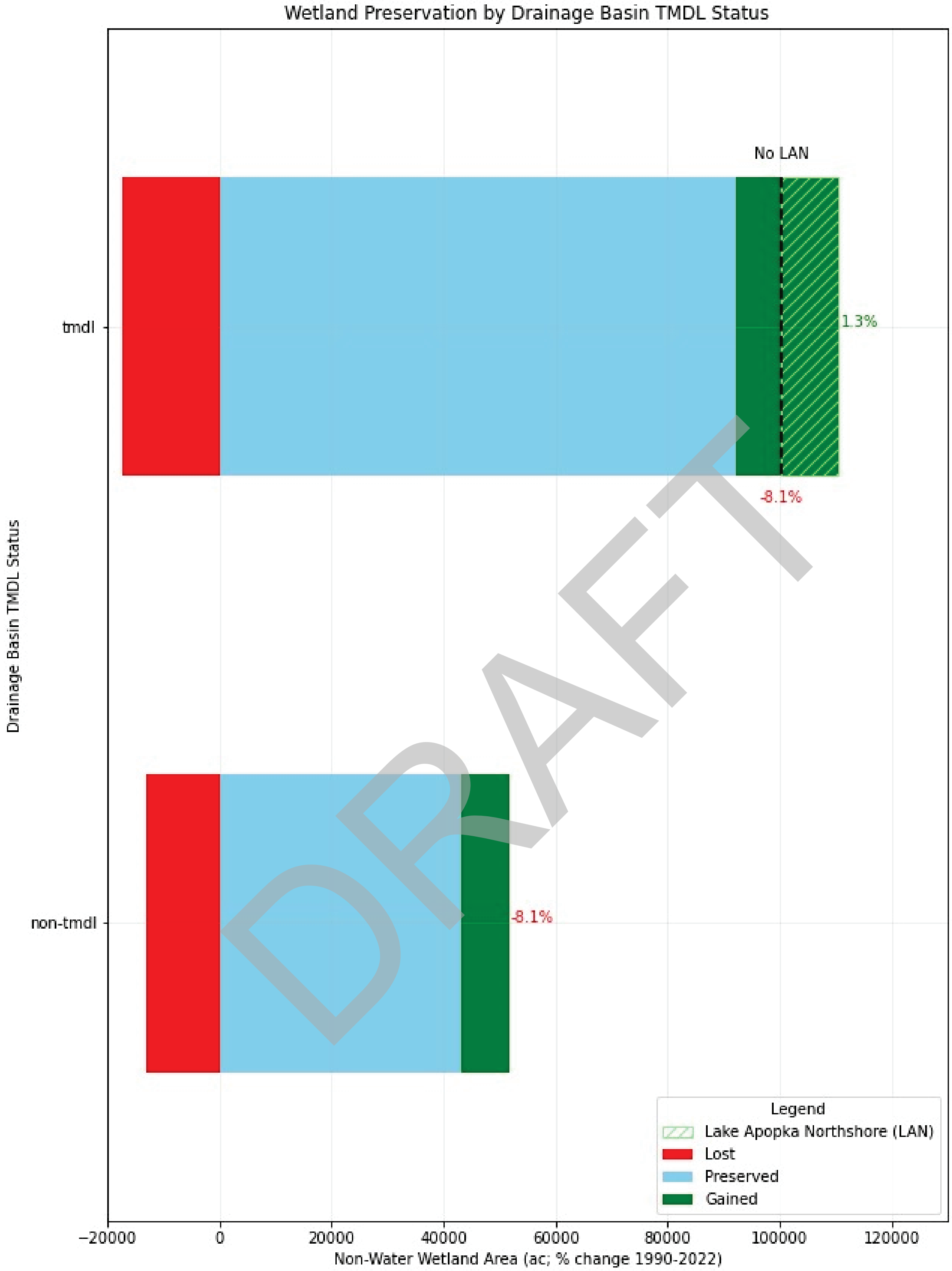


Figure 6-22. Wetland Preservation by Drainage Basin TMDL Status.

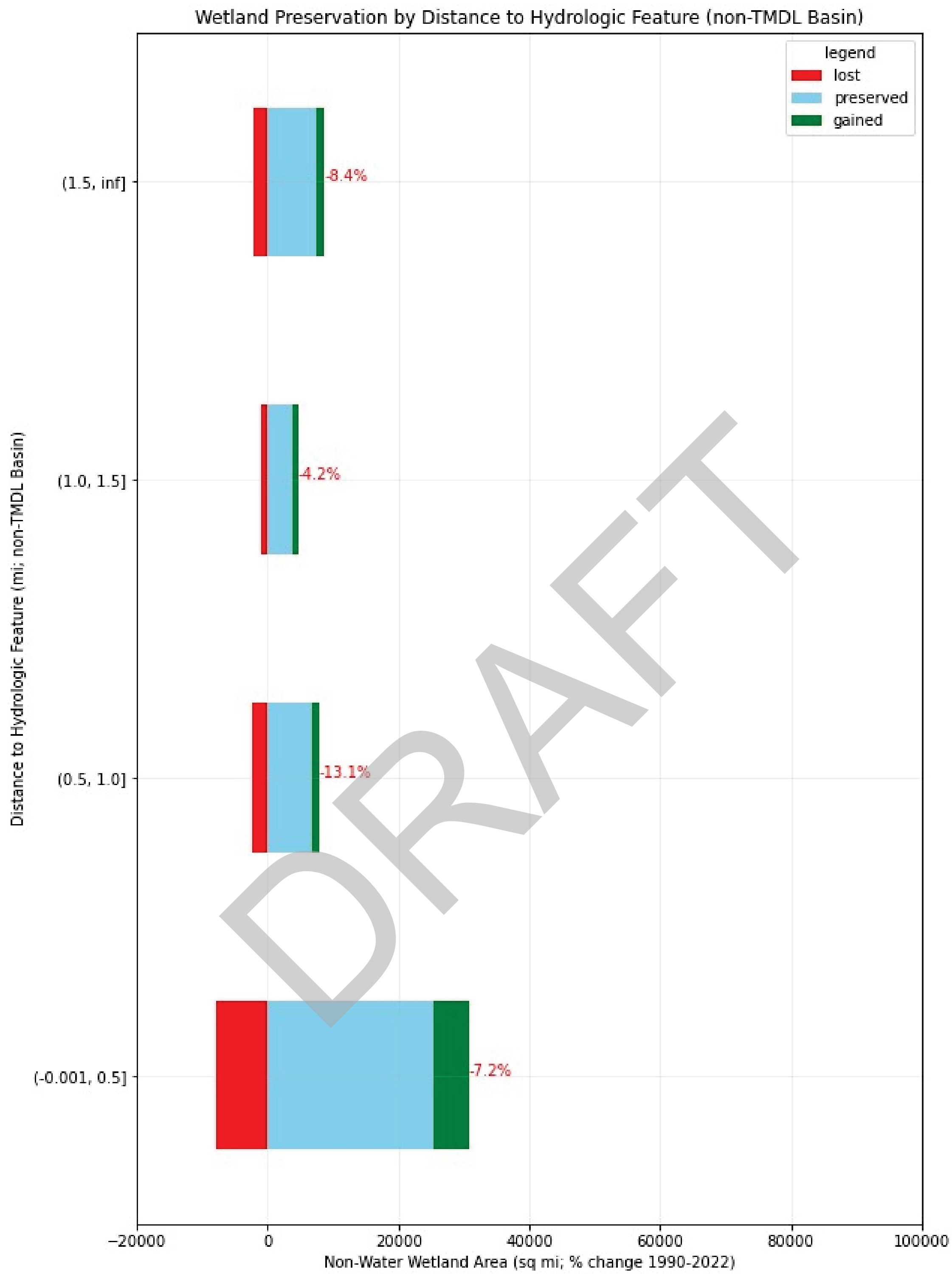


Figure 6-23. Wetland Preservation by Distance to Hydrologic Feature (non-TMDL Basin).

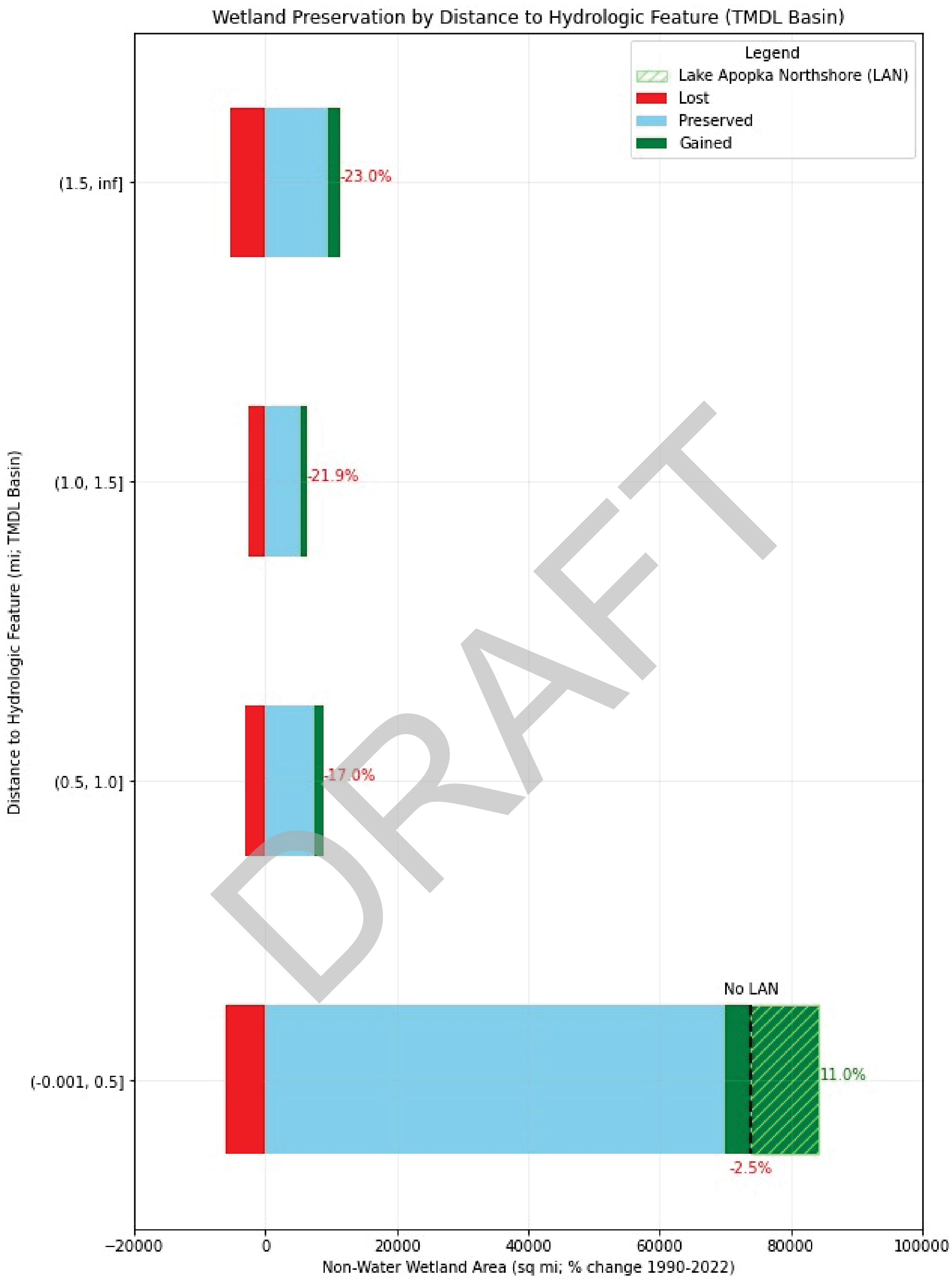


Figure 6-24. Wetland Preservation by Distance to Hydrologic Feature (TMDL Basin).

6.4 Conclusions

Results of the wetland persistence analysis reveal that about half of the wetlands in Orange County have remained the same wetland type in the same location from 1990 to 2022. And the majority of wetland land cover, over 80%, has persisted as one wetland type or another through the same 32-year period. Wetland area gains did occur throughout the county with the most significant gains concentrated in the northwest area of the county, north of Lake Apopka and in the Rock Springs Run State Reserve. Most of the gains in other areas of the county were limited in scope with some exceptions found in the south-central region.

The persistence analysis results also demonstrate that wetland losses have been spread out across the entire county and have not only been concentrated in the urban areas, with significant wetland losses in the eastern half of the county, especially along the western boundaries of the Tosohatchee State Preserve. During this same period, wetland habitats within the special protection areas have persisted and even expanded. Other areas, including the Shingle Creek area and wetlands in the southwestern corner of the County, have also persisted since 1990, although there have been some losses along the outside boundaries of the larger wetland areas. If urban development fueled by population growth continues in the county, preserving wetland areas will become more challenging, especially in the western parts of the county where most of the growth is occurring; however, wetland losses have already occurred in rural areas of the county well outside of urban land cover.

The wetland succession analysis demonstrates that ecological succession has been taking place in Orange County within wetland habitats and in areas of the county that were previously wetlands before conversion to other uses. Between 1990 and 2022, over 36,000 acres have undergone succession in the county with more than half transitioning from water or non-wetland land cover to wetlands. A significant portion of the successional changes were a result of restoration efforts by Lake Apopka that converted farmland into marshland and the creation of the Rock Spring Run State Reserve in 1983, which allowed previously de-forested wetlands to return to a natural forested state.

Wetlands around the county have also undergone reversion, from natural or anthropogenic disturbances, shifting from wetlands to water and non-wetland land cover or shifting from a higher ecological state to a lower one. Over 24,000 acres of wetlands were either lost or converted to water land cover, while almost 7,000 acres underwent ecological reversion to a lower ecological state. Some of the primary reversion, changing from a forested wetland to a non-forested wetland, occurred due to deforestation, while reversion from wetland to water occurred primarily due to development as stormwater ponds replaced many small wetland habitats.

While conducting the 51 functional assessments of the compensatory mitigation areas, the project team noticed that ecological succession was taking place on those wetland communities that did not have any management. For instance, lack of fire management was causing the pine flatwood communities to become more mixed forested wetland communities. In addition, planting of the buffer with pine trees adjacent to wet prairie habitat led to pine tree encroachment. This has caused an ecological shift in mitigation areas as wet prairies are undergoing successional changes into pine flatwoods.

Many factors may influence wetland loss in Orange County. Of those investigated in this spatial analysis effort, FEMA Flood Zones and OFW status showed the most consistent relationship with rates of wetland loss. This likely reflects that these factors provide important regulatory protection for wetland areas and help prevent their destruction. Aquifer recharge showed a weak relationship with wetland loss. While no major differences were observed between wetlands in High, Medium, and Low recharge zones, wetlands in regions of Discharge had much lower rates of loss. Distance from major groundwater withdrawal locations showed little-to-no relationship with patterns of wetland loss. TMDL status produced complicated results. Drainage basins associated with TMDLs had similar rates of wetland loss as drainage basins not associated with TMDL waterbodies. However, the distance between wetlands and TMDL waterbodies did show a monotonic relationship. This may reflect a preference for regulators to protect wetlands near impaired waterbodies.

7 WATER RESOURCES AND WETLAND VULNERABILITY

Wetlands provide various hydrologic benefits to the watersheds in which they reside, including aquifer or groundwater recharge and discharge, runoff velocity reduction, water storage, and evapotranspiration (Nilsson et al 2011, Bullock and Acreman 2003). Reductions in wetland groundwater recharge and ecological services can be caused by heavy pumping activity, increases in impervious surface area, and other anthropogenic alterations. Maintaining adequate groundwater levels is especially important for preserving local water supplies and wetland functions during periods of drought (Harbor 1994).

Pumping groundwater can lower shallow water levels, which can impact and stress wetlands. Within Orange County, most of the major groundwater withdrawals come from the Floridan Aquifer. Wetlands are typically connected to groundwater through the shallow water table of the Surficial Aquifer, which is separated from the Floridan Aquifer within Orange County by a hydrogeologic unit known as the Intermediate Aquifer System (IAS) or the Intermediate Confining Unit (ICU). The presence, thickness, and permeability of the IAS/ICU varies throughout Orange County.

Figure 7-1 shows a cross section through a representative Central Florida ridge lake, which could be considered generally analogous to a groundwater-dependent wetland in Orange County,2 where the IAS/ICU does not provide significant separation between the Surficial Aquifer and Floridan Aquifer.

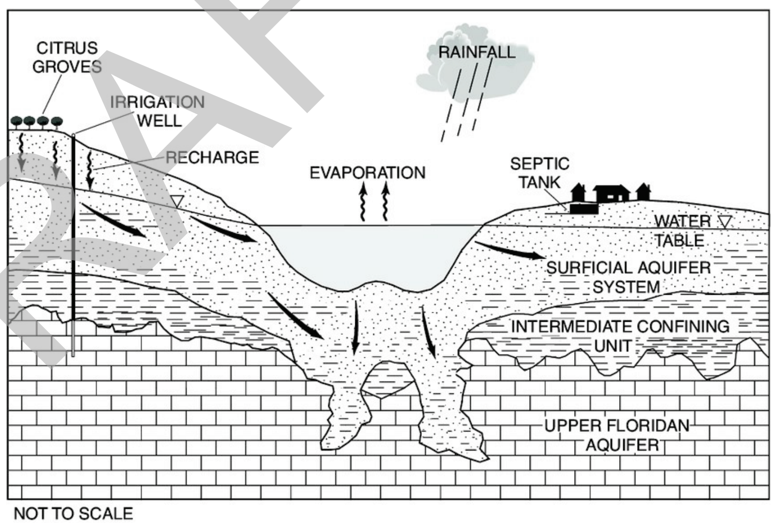


Figure 7-1. Cross section of a ridge lake in Central Florida (Lee, 2002).

Groundwater modeling simulations were conducted to evaluate the impacts of groundwater withdrawals in the Surficial Aquifer and Floridan Aquifer on water levels and groundwater-dependent wetlands within Orange County.

7.1 Model Configuration

A countywide groundwater flow model, termed Orange County's Enhanced East Central Florida Transient Expanded model (OCER ECFTX) in this study, was utilized to evaluate the impact of groundwater withdrawals on wetlands in Orange County. The OCER ECFTX model was previously developed by Drummond Carpenter through refinement of the regional East Central Florida Transient Expanded model (CFWI 2020d, Drummond Carpenter 2023). The ECFTX model uses United States Geological Survey code MODFLOW-NWT (Niswonger et al. 2011) to simulate regional groundwater flow. The ECFTX model domain encompasses peninsular Florida between the Gulf of Mexico and Atlantic Ocean from northern Volusia County to the Charlotte-DeSoto County line (**Figure 7-2**). Hydrogeologic units in the model are represented through 11 model layers with the Surficial Aquifer System (SAS) represented as Layer 1, the IAS/ICU represented as Layer 2, and the Upper Floridan Aquifer (UFA), a unit within the Floridan Aquifer, represented as Layers 3-6 (**Figure 7-3**).

To develop the OCER ECFTX model, Drummond Carpenter modified and refined the mesh of the regional ECFTX model using telescopic mesh refinement (TMR) in Groundwater Vistas Version 8 (Rumbaugh and Rumbaugh 2020), a graphical user interface and pre/post-processor for MODFLOW models. Utilizing TMR, (1) the regional the ECFTX model grid was refined to a desired resolution throughout an area extending just beyond Orange County and (2) water levels and existing boundary condition cells from the regional ECFTX model were extracted and applied as general head boundary conditions along the corresponding boundary cells of the refined OCER ECFTX model. The OCER ECFTX model was developed from the regional ECFTX model under 2003 steady-state hydrologic conditions. Therefore, the OCER ECFTX is a steady-state model generally representative of 2003 hydrologic conditions within the Orange County area.

The OCER ECFTX model domain includes portions Orange County and areas of Lake, Seminole, Volusia, Brevard, Polk, and Osceola counties (**Figure 7-2**). The model grid was refined from the original ECFTX model's 1,250 ft by 1,250 ft cell spacing to a 200 ft by 200 ft cell spacing. Model grid refinement was performed to facilitate simulation of groundwater flow throughout Orange County at an approximately 40x finer resolution than the regional ECFTX model, which provides the opportunity to better represent local groundwater flow conditions and surface waterbodies, such as rivers, lakes, and wetlands. For example, river and drain boundary conditions were modified to better represent the extent of surface water features at the refined grid resolution during OCER ECFTX model development (**Figure 7-2**) (Drummond Carpenter 2023).

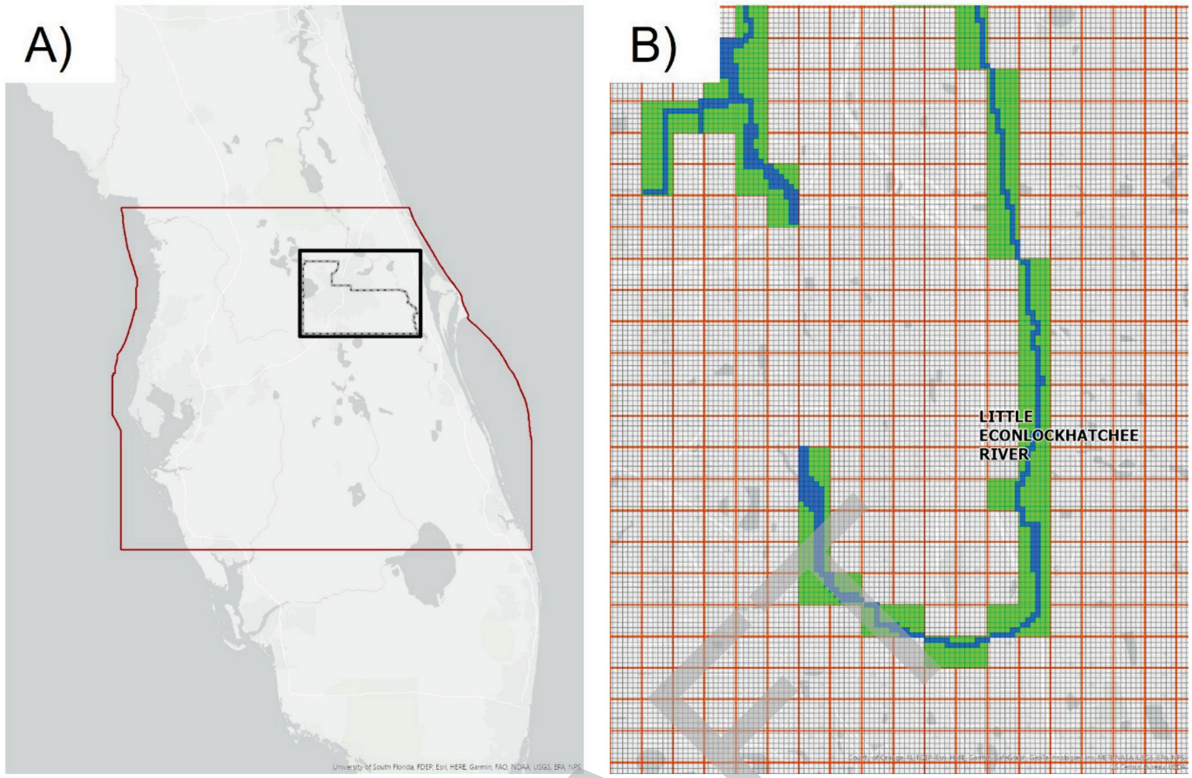


Figure 7-2. (A) Regional ECFTX (red) and the refined OCER ECFTX (black) model domains. (B) Example showing the regional ECFTX model grid (orange) and river boundary conditions (green) overlain with the refined OCER ECFTX grid (black) and river boundary conditions (blue).

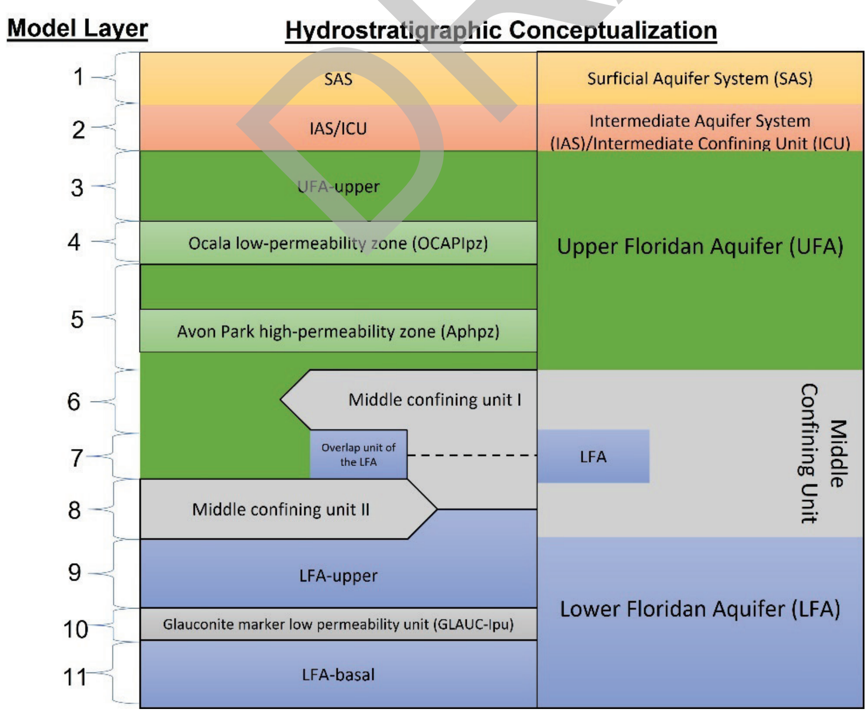


Figure 7-3. Layers in the ECFTX and OCER ECFTX model (Adapted from CFWI 2020d).

7.2 Modeled Scenarios

Groundwater-impacted wetlands are generally connected with the shallow water table (SAS) in Orange County. However, most major groundwater withdrawals in Orange County come from the Floridan Aquifer. The connectivity between the SAS and Floridan Aquifer varies based on the presence of the IAS/ICU. Two groundwater modeling scenarios were developed using the OCER ECFTX model to evaluate the spatial impact of groundwater withdrawals on wetlands within Orange County. Scenario 1 evaluated the impact of major pumping centers on groundwater levels and groundwater-impacted wetlands. Scenario 2 evaluated the impact of long-term groundwater withdrawals on groundwater levels and groundwater-impacted wetlands. Conceptual impacts to wetlands in Orange County from groundwater withdrawals and pumping centers are shown in **Figure 7-4** and **Figure 7-5**.

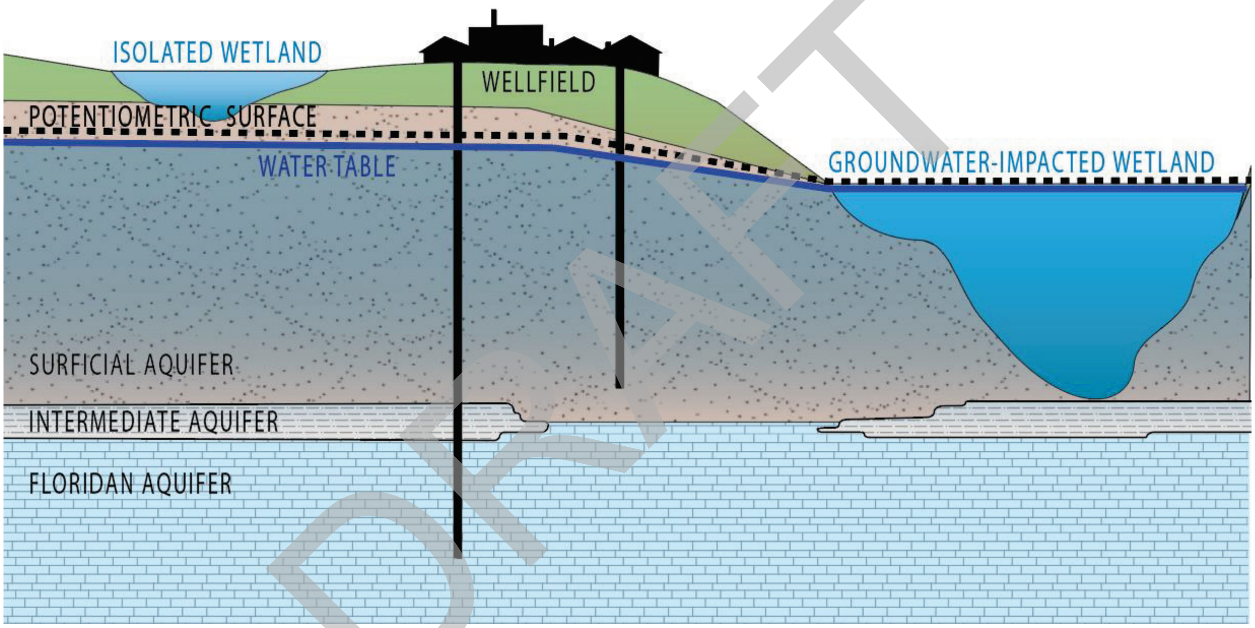


Figure 7-4. Conceptual cross section of wetlands in Orange County during a period of no pumping.

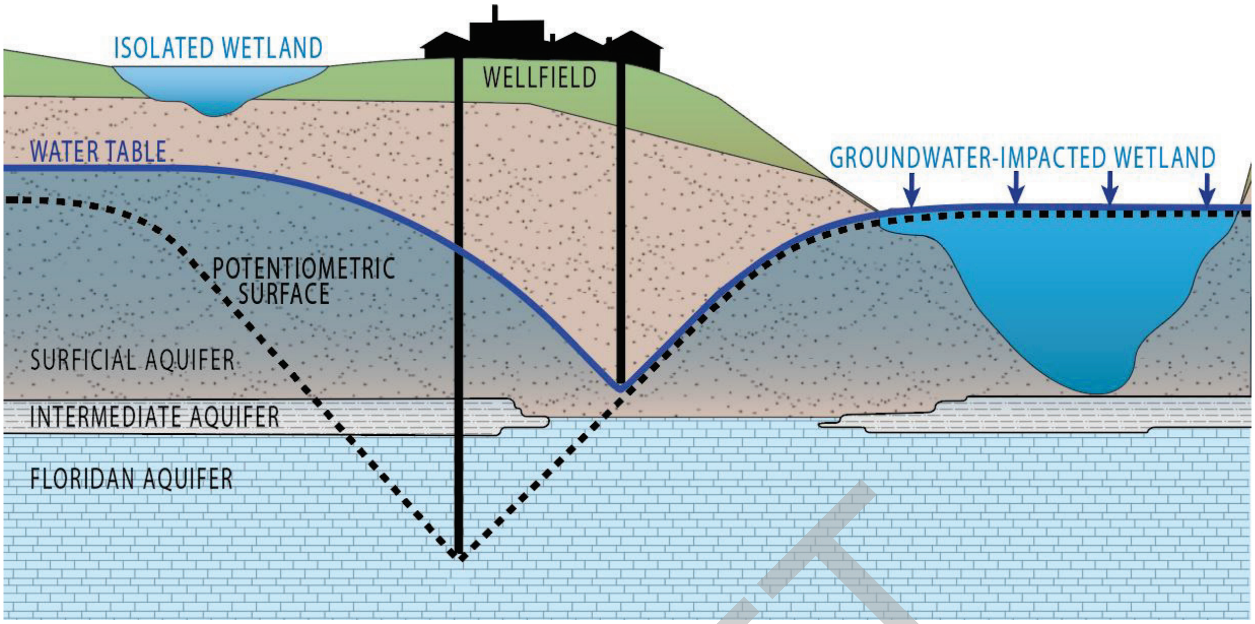


Figure 7-5. Conceptual cross section showing pumping impacts to wetlands in Orange County evaluated by the groundwater modeling scenarios in this study.

Scenario 1: Impacts of Major Pumping Centers

Scenario 1 represented a groundwater modeling simulation scenario that explored how major groundwater withdrawal sites within Orange County could impact surficial water levels and proximal wetlands. A review of available consumptive use databases and public water supply well information available through the SJRWD, SFWMD, and the FDEP, was used to identify six of the largest users in Orange County based on permitted annual allocated usage: Orange County Utilities Division, Orlando Utilities Commission, Reedy Creek Improvement District, City of Apopka, City of Cocoa, and the City of Winter Park (**Figure 7-6**). The locations of the wells/wellfields for these six major groundwater users, which are provided in FDEP's Public Water Supply Wells geodatabase[8], were used to delineate "Withdrawal Removal Areas" (**Figure 7-6** and **Figure 7-7**).

To explore the impact of the major pumping sites on groundwater levels and wetlands, a simulation was first conducted with no changes to the OCER ECFTX model. This simulation was considered the "Base Case" model simulation and represented pumping and groundwater levels under 2003 steady-state conditions. Pumping wells within the "Withdrawal Removal Areas" were then removed from the SAS (Layer 1) and UFA (Layers 3-6) for the Scenario 1 simulation (**Figure 7-7**). Injections wells, including those representing rapid infiltration basins (RIBs), were not

[8] Florida Department of Environmental Protection Geospatial Open Data Portal, Public Water Supply (PWS) Wells (Non-Federal), https://geodata.dep.state.fl.us/datasets/FDEP::public-water-supply-pws-wells-non-federal/explore

removed from the model. The "Withdrawal Removal Areas" (**Figure 7-6** and **Figure 7-7**) represent less than 5% of Orange County's area and 3% of the OCER ECFTX model area. However, removing SAS and UFA pumping wells from these locations reduced the overall withdrawal rate of the OCER ECFTX model by nearly 25%, indicating these locations adequately represented major pumping centers. Simulated groundwater levels with and without withdrawals from the major pumping centers (i.e., "Withdrawal Removal Areas") were compared to evaluate groundwater level and groundwater-impacted wetland impacts.

Scenario 2: Impacts of Long-Term Groundwater Withdrawal

Scenario 2 was developed as a groundwater modeling simulation scenario that explored how drawdown from long-term water withdrawals from the UFA could impact groundwater levels and wetlands. As part of the 2020 Regional Water Supply Plan, the CFWI developed a 2040 Withdrawal Condition scenario to simulate groundwater levels under projected 2040 pumping conditions in Central Florida using the regional ECFTX model (see Appendix D in CFWI 2020c). Simulated potentiometric datasets from the 2040 Withdrawal Condition groundwater modeling simulation conducted by CFWI were downloaded from the CFWI website[9] for use in Scenario 2.

As in Scenario 1, modifications were made to the Base Case model simulation to develop the Scenario 2 simulation. Potentiometric surfaces from the 2040 Withdrawal Condition simulation developed by the CFWI were applied as boundary conditions along the border of the OCER ECFTX Base Case model to develop the Scenario 2 simulation. No other changes to the Base Case model simulation were made. Therefore, the Scenario 2 simulation was considered a period of "low" UFA groundwater levels compared to a period of "high" UFA groundwater levels from the Base Case simulation, which represented groundwater conditions under 2003 steady-state conditions. Groundwater levels between the two simulations were compared to explore how temporal changes through long-term water withdrawals could impact groundwater levels and groundwater-impacted wetlands within Orange County.

[9] Central Florida Water Initiative Groundwater Modeling Results: Future Pumping Scenarios, ftp://ftp.cfwi.cfwiwater.com/pub/HAT/ECFTX_SCENARIOS/Results/Scenarios/

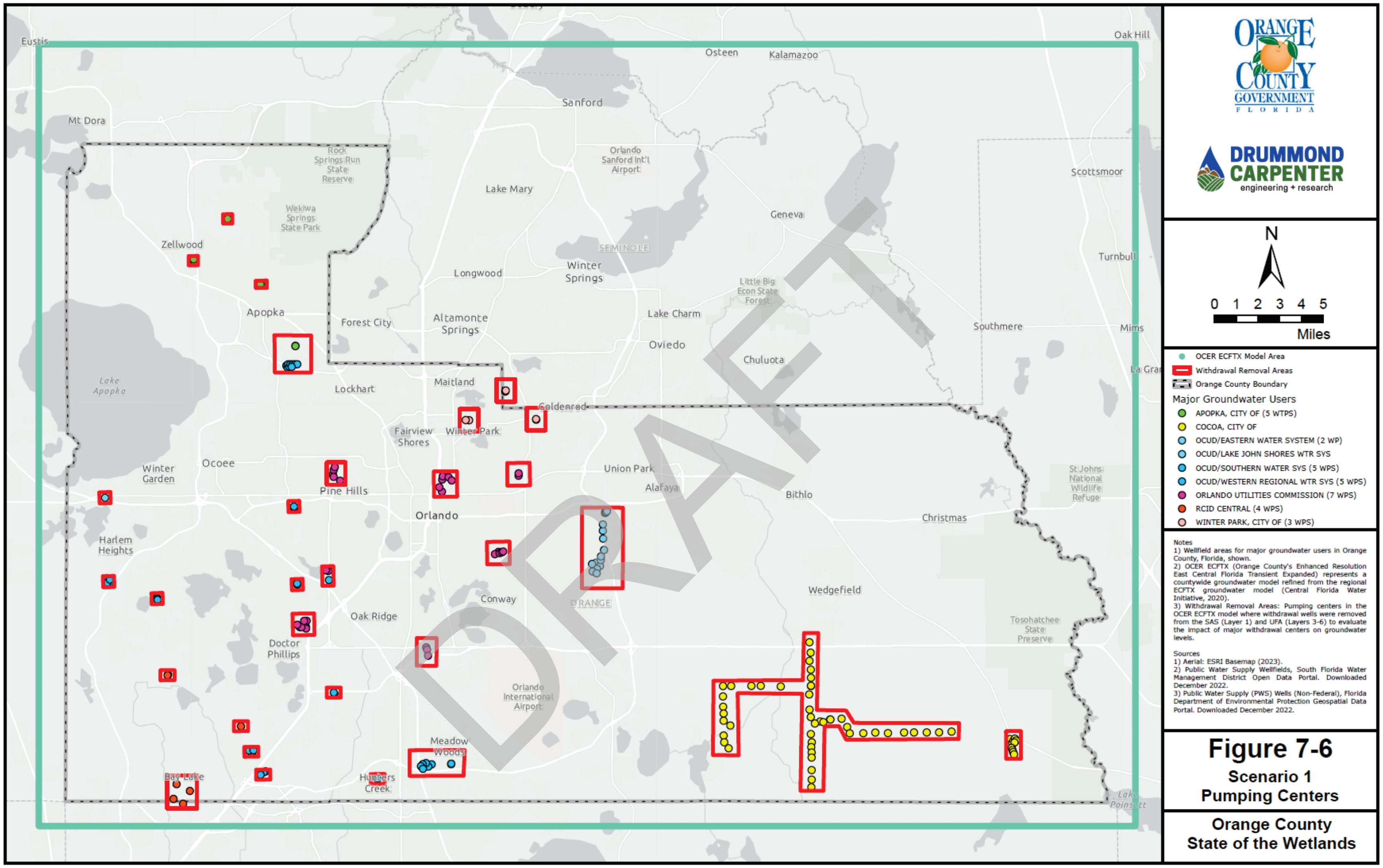


Figure 7-6. Scenario 1: Pumping Centers

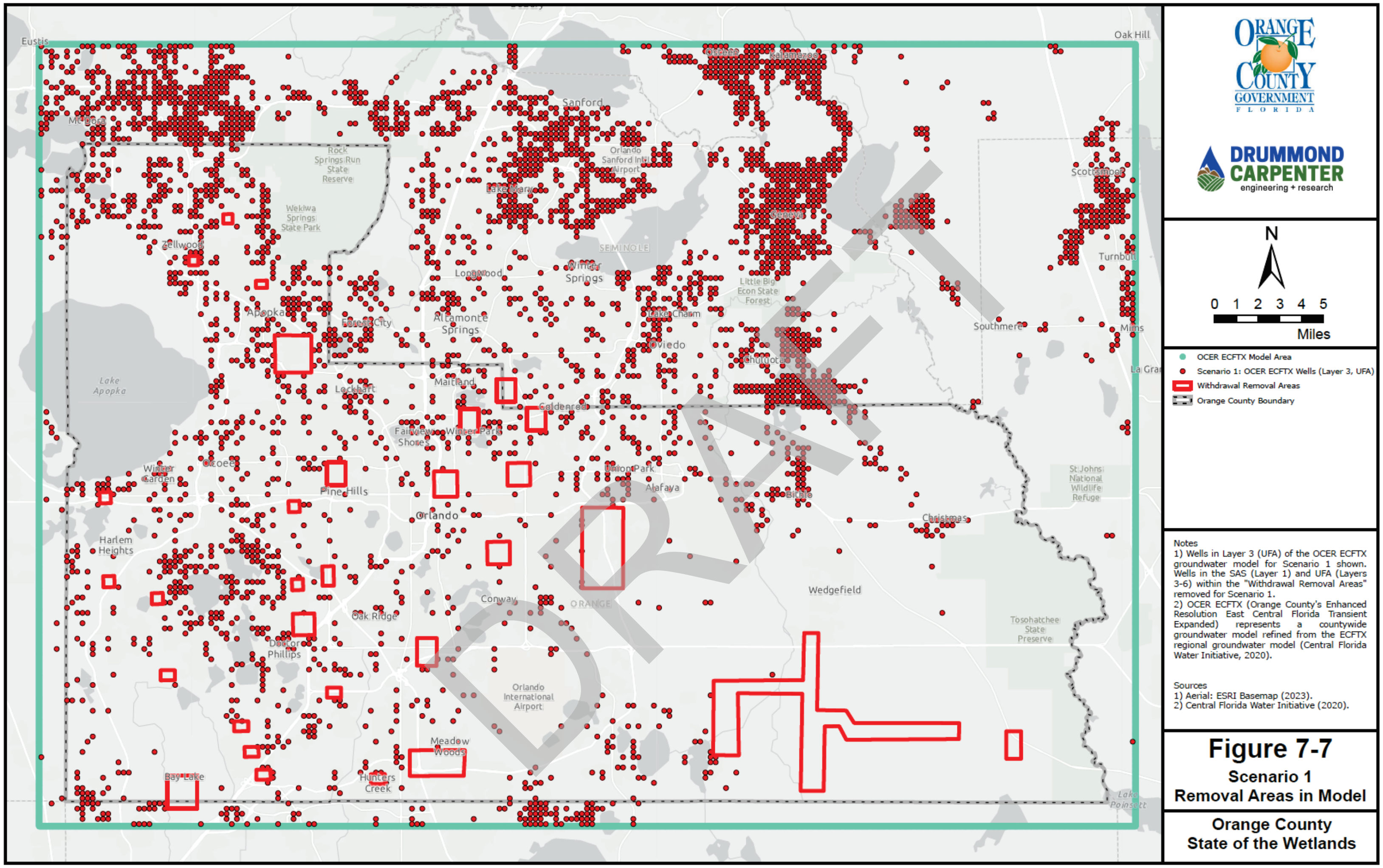


Figure 7-7. Scenario 1: Removal Areas in Model.

7.3 Results

Scenario 1: Impacts of Major Pumping Centers

Groundwater modeling suggests major pumping centers can impact groundwater levels throughout Orange County. **Figure 7-8** shows the head change (i.e., difference in groundwater levels) between the Base Case and Scenario 1 simulations in the UFA across Orange County. The only difference between the Base Case simulation and the Scenario 1 simulation is that pumping from the SAS and UFA in the "Withdrawal Removal Areas" (i.e., locations of major pumping centers) were removed from the model in Scenario 1. Positive head change suggests groundwater levels in the UFA rose across most of Orange County in Scenario 1 compared to the Base Case (Exhibit 3). Modeling results suggest that major pumping centers impact groundwater levels in the UFA across most of Orange County with over 0.5 foot of head change observed in the majority of the County and 3 feet or more observed in local areas.

Figure 7-9 shows the simulated head change between the Base Case and Scenario 1 simulations in the SAS across Orange County. While simulations indicate major groundwater centers impact UFA levels across most of the County (**Figure 7-8**), the impact to the SAS was more localized with the greatest impacts observed in the western portion of the County (**Figure 7-9**). In western Orange County, the SAS is generally more connected to the UFA (i.e., ridge regions) than in eastern Orange County where there is separation between the SAS and UFA by the IAS/ICU (i.e., plains regions). Major water users in the Orange County largely rely on the Floridan Aquifer, and modeling results from Scenario 1 suggests that the impact of major pumping centers on SAS groundwater levels are more closely tied to the locations where UFA and SAS are more connected rather than major pumping centers from within the SAS.

Groundwater-impacted wetlands are generally connected to the SAS and typically not directly located within the UFA. Therefore, modeling results from Scenario 1 suggests major pumping centers would have greater impacts on wetlands in the western portion of County than in the eastern portion the County. Head changes from impacted areas in the SAS generally ranged from 0.1 to 3 feet (**Figure 7-9**). Head changes on the order several feet can cause stress and wetland loss (CFWI 2020a). It should be noted that while modeling suggests major pumping centers largely impact UFA water levels, local pumping from within the SAS can still impact local SAS water levels and proximal wetlands. Site-specific SAS withdrawal impacts were not modeled as part of this evaluation.

Scenario 2: Impacts of Long-term Groundwater Withdrawal

Groundwater modeling suggests temporal changes and long-term water withdrawals from the UFA can impact groundwater levels throughout Orange County. **Figure 7-10** shows the head change (i.e., change in groundwater levels) between the Base Case and Scenario 2 simulations in the UFA across Orange County. For the Scenario 2 simulation, the potentiometric surfaces from the 2040 Withdrawal Condition simulation conducted by the CFWI were applied as boundary conditions along the model boundary. All other aspects of the Base Case model simulation were kept the same for Scenario 2 simulation. Therefore, Scenario 2 represented an application of 2003 conditions to a model utilizing 2040 water level boundary conditions representative of temporal changes in groundwater levels due to long-term future water withdrawals. Negative head change results are analogous to drawdown and suggest that long-term water withdrawals are projected to drawdown the UFA across Orange County (**Figure 7-10**). Groundwater levels in the UFA were at least one foot lower across most of Orange County in Scenario 2 compared to the Base Case with more pronounced decreases (>3 feet) simulated in the southwestern portion of the County.

Figure 7-11 presents the simulated head change between the Base Case and Scenario 2 simulations in the SAS across Orange County. Similar to Scenario 1, results from Scenario 2 suggests SAS water levels within the western portion of Orange County will be more impacted by temporal changes in UFA water levels due to long-term withdrawals as compared to the eastern portion of Orange County. Simulated drawdowns were more widespread and pronounced within the UFA (Figure 7-10) compared to the SAS (**Figure 7-11**) suggesting (1) long-term water withdrawals would have more pronounced impacts on UFA water levels than SAS water levels, and (2) impacted SAS water levels will be more impacted in areas where the SAS and UFA have greater connectivity due to the lack therefore of the IAS/ICU (confining unit).

Since groundwater-impacted wetlands are generally connected to the SAS, head changes in the SAS would be considered more likely to impact wetlands than UFA head changes. Water levels in impacted areas in the SAS generally decreased between 1 and 5 feet in Scenario 2 (**Figure 7-11),** which can lead to wetland stress and loss.

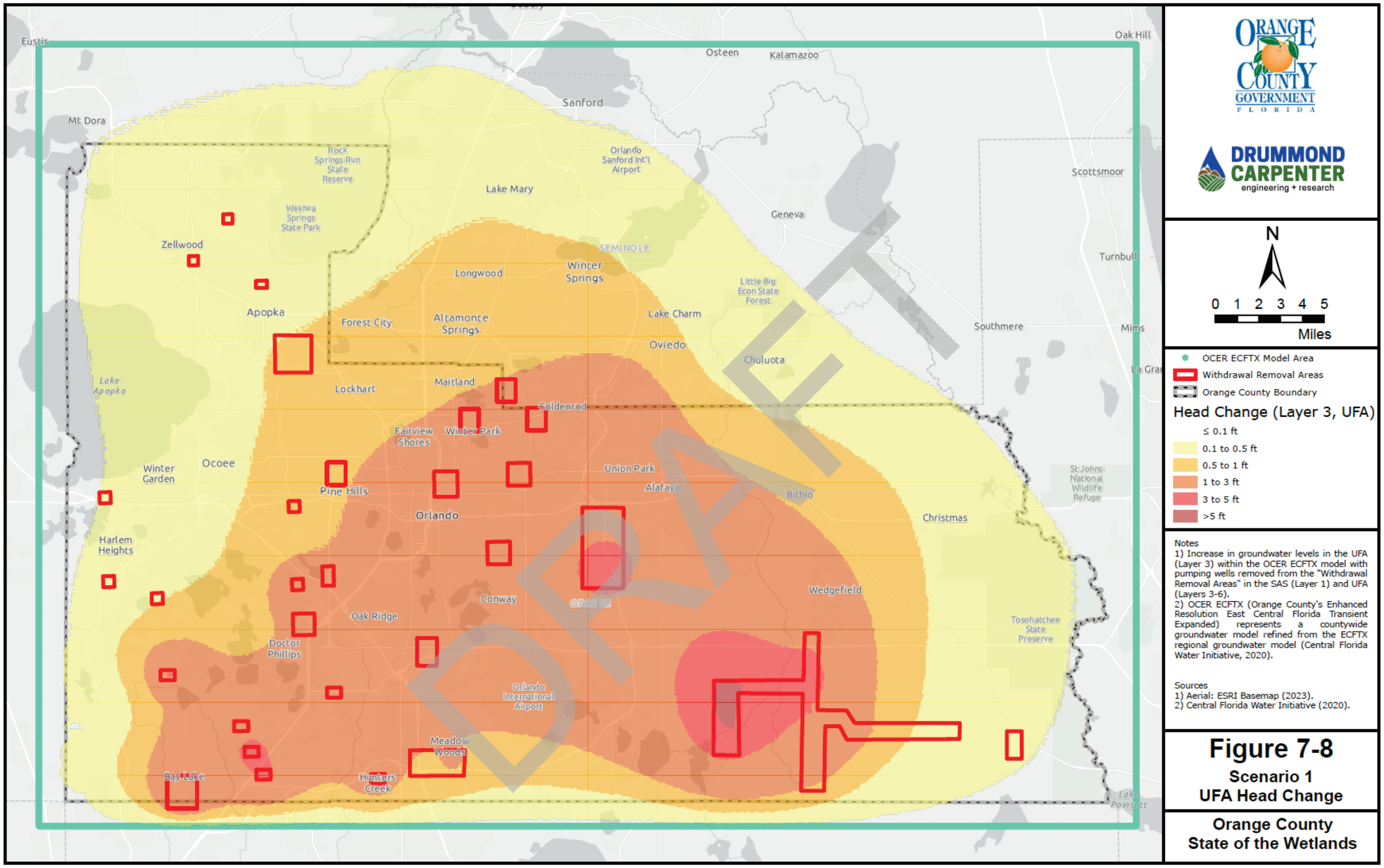


Figure 7-8. Scenario 1: UFA Head Change.

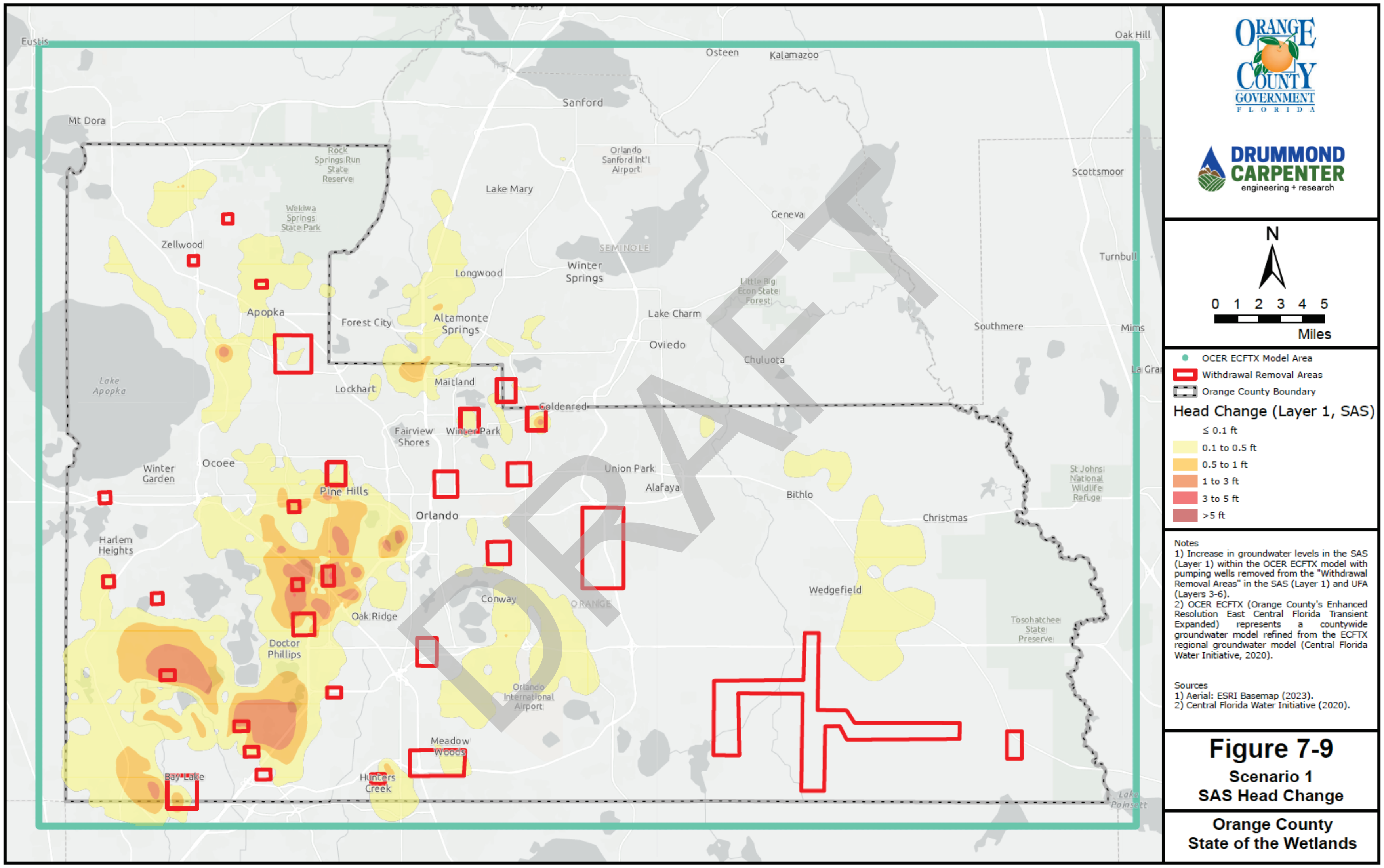


Figure 7-9. Scenario 1: SAS Head Change.

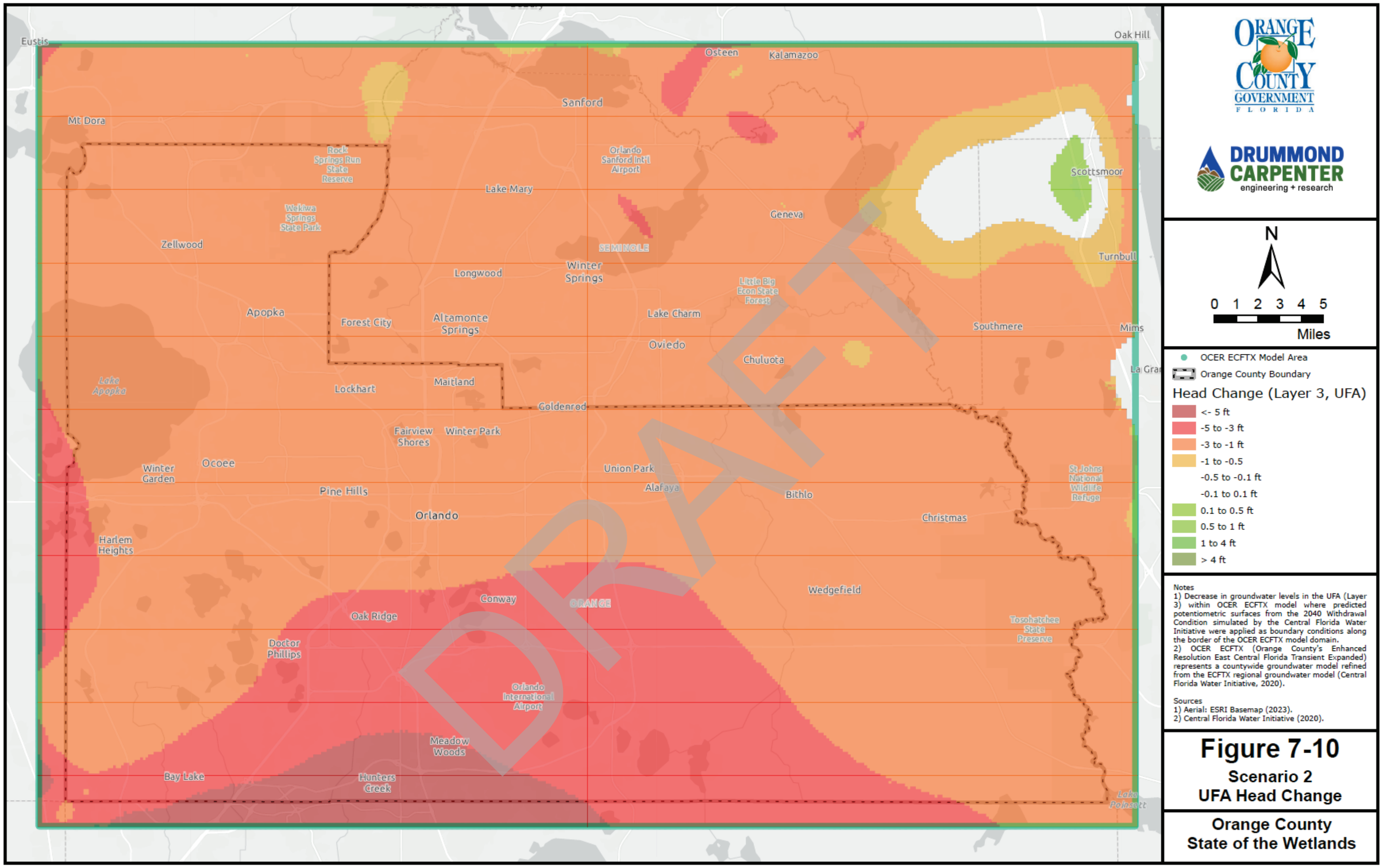


Figure 7-10. Scenario 2: UFA Head Change.

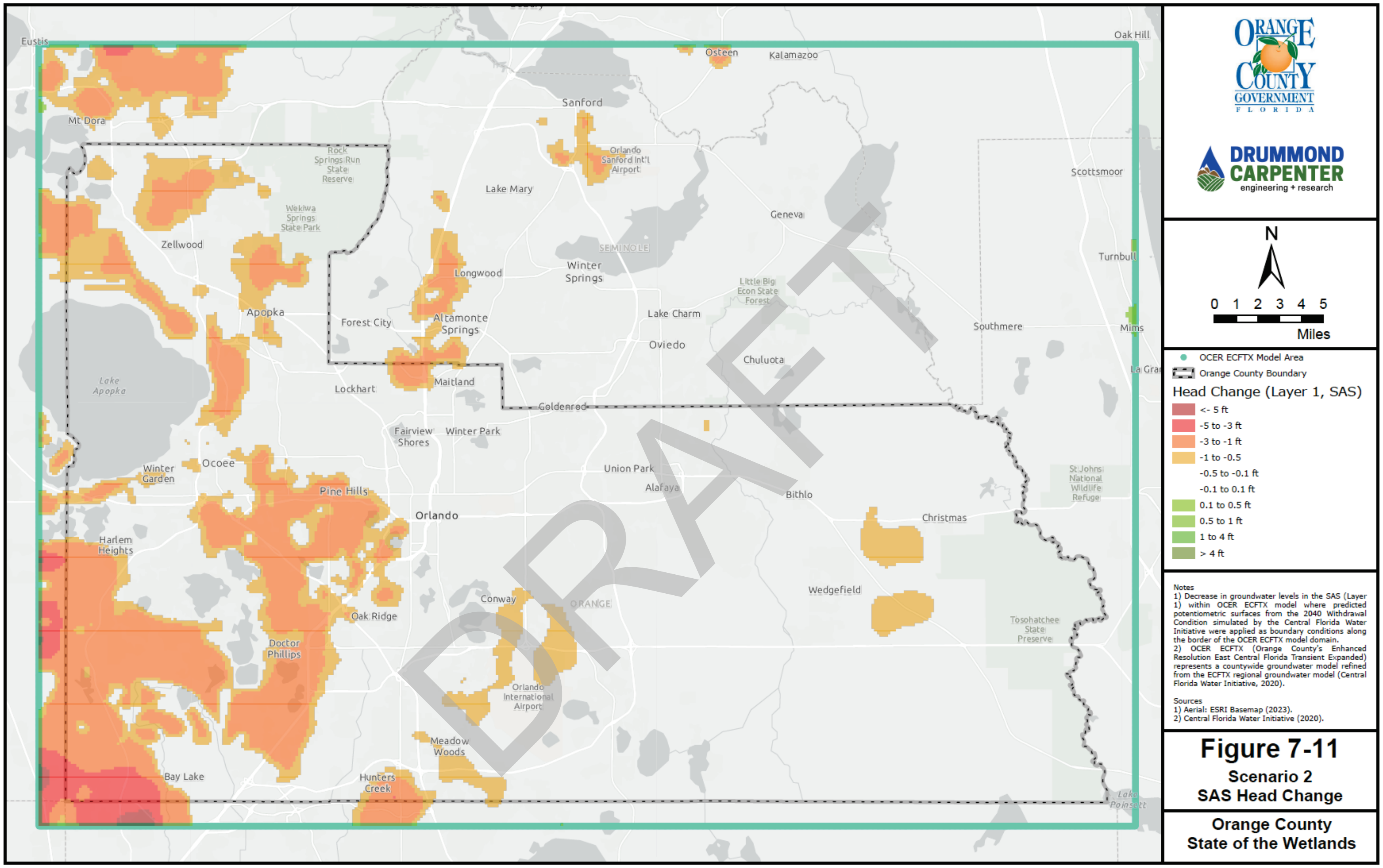


Figure 7-11. Scenario 2: SAS Head Change.

7.4 Groundwater Withdrawal Impacts on Wetlands

Modeling results suggest both major pumping centers and drawdown from long-term water withdrawals can impact wetlands in Orange County. Groundwater impacts were more pronounced and widespread in the UFA in both modeling scenarios. However, SAS groundwater levels were more impacted in the western portion of the County. The widespread UFA impacts and more localized SAS impacts indicate that withdrawals from within the SAS were not the primary driver for changes in groundwater levels in the shallow water table across Orange County. Instead, modeling suggests major pumping centers and long-term withdrawals have more impact on UFA levels with the greater impacts to the SAS felt in areas where there is more connectivity between the SAS and UFA. Therefore, groundwater-impacted wetlands in western Orange County would generally be expected to feel more of the effects of major pumping centers and long-term withdrawals as there is greater connectivity between the SAS and UFA in that portion of the County.

A 2020 hydrologic analysis performed by the CFWI predicted the increase in stress to primarily groundwater-dominated wetlands in Central Florida associated with increases in groundwater withdrawals. CFWI's hydrologic analysis, conducted by CFWI's Environmental Measures Team, is documented in the technical report "Assessment of Effects of Groundwater Withdrawals on Groundwater-Dominated Wetlands in the Central Florida Water Initiative Planning Area" (CFWI 2020a). The CFWI analysis used the regional ECFTX model to evaluate potential stress in identified groundwater-dominated wetlands based on historic water levels and projected groundwater level changes from a 2014 reference condition for future withdrawal conditions (2025, 2030, and 2040). In CFWI's assessment, groundwater-dominated wetlands in plains and ridge physiographic provinces were evaluated separately with predicted changes in SAS (Layer 1) water levels used to evaluate hydraulic stress for wetlands in plains regions, and both SAS (Layer 1) and UFA (Layer 3) water levels used to evaluate stress of wetlands in ridge regions. In Orange County, plains physiographic providences are generally located in the central and eastern part of the County with ridge physiographic provinces located primarily in the western portion of the County (see Figure 2 in CFWI 2013).

The CFWI report suggests that ridge physiographic provinces generally lack confining conditions between the SAS and UFA, while plains physiographic regions generally have a confining layer, the IAS/ICU, that restricts the exchange of water between the SAS and UFA. Therefore, assessing wetland stress via water level changes in the SAS for plains wetlands and both the SAS and UFA for ridge wetlands was considered appropriate and utilized in the 2020 CFWI study. However, the CFWI study notes that predicting future areas of stressed wetlands using changes in SAS water levels are "probably closer to reality than those based on UFA potentiometric elevations" (Appendix D of CFWI 2020a). Therefore, the use of the SAS to evaluate groundwater-impacted wetlands within Orange County in this study was reasonable.

Results of the CFWI 2020 analysis support the findings of this study and identified potential areas for stressed wetlands based on declines water levels in the western portion of Orange County. Simulated SAS head changes at locations of 2022 mapped wetlands from Scenarios 1 and 2 of this study (**Figure 7-12** and **Figure 7-13**) are similar to simulated SAS head changes on stressed, groundwater-dominated wetlands documented in the CFWI report (Figures 21, 23, and 25 in CFWI 2020a).

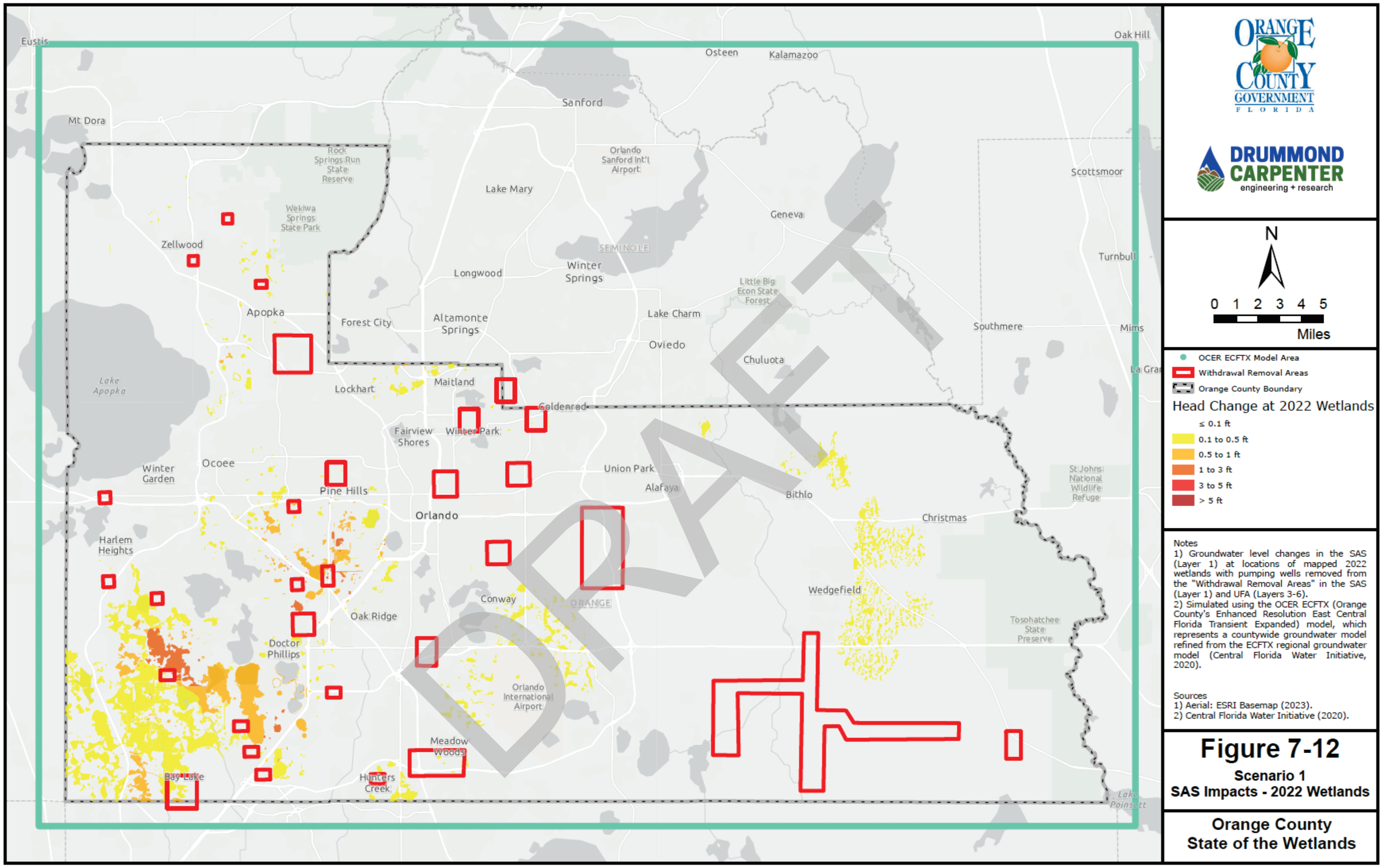


Figure 7-12. Scenario 1: SAS Impacts – 2022 Wetlands.

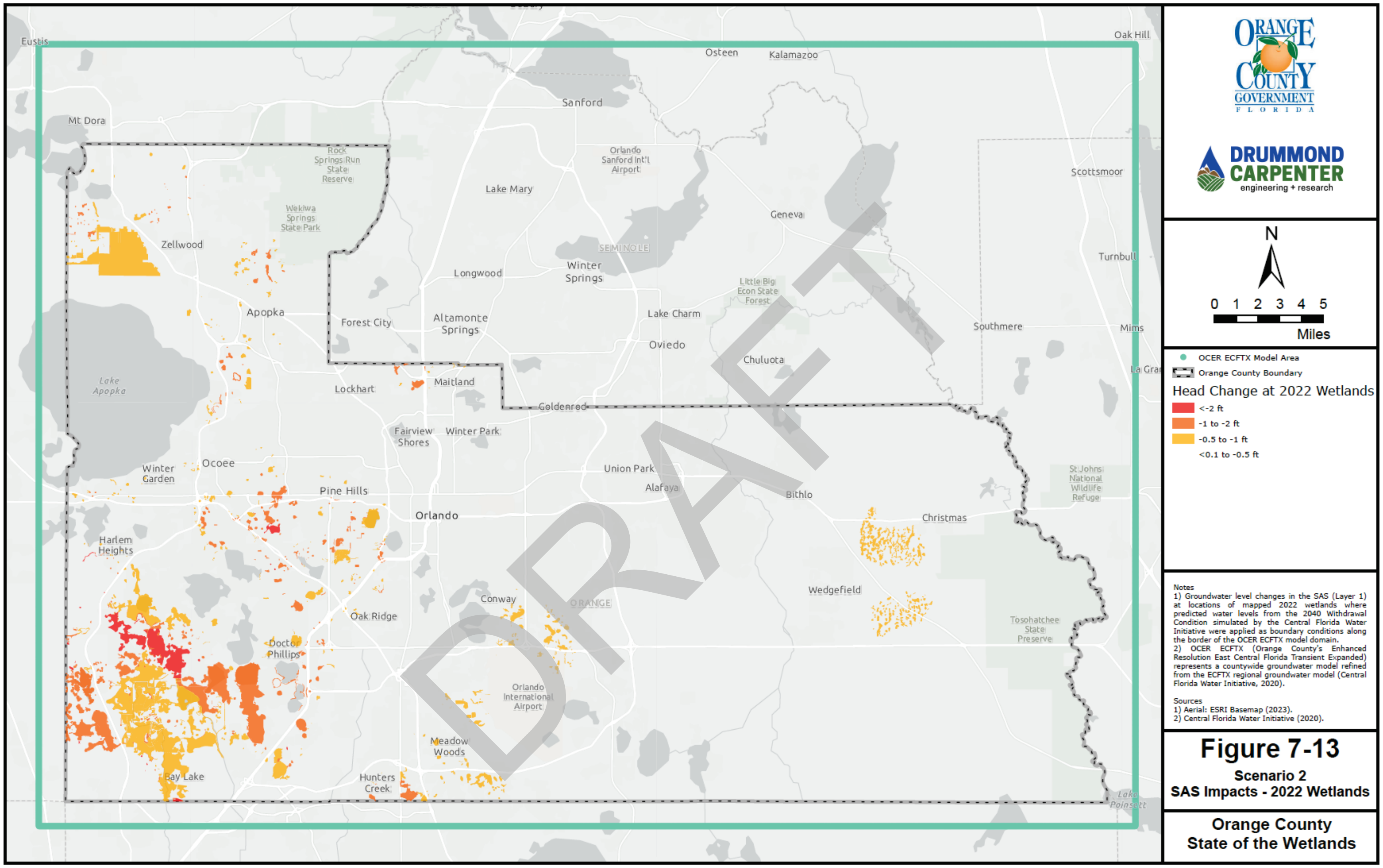


Figure 7-13. Scenario 2: SAS Impacts – 2022 Wetlands.

7.5 Recommendations

The groundwater modeling efforts conducted in this study focus on the impacts of groundwater level changes on wetlands within Orange County. This effort builds upon the efforts of CFWI's Environmental Measures Team effort evaluating the impact of groundwater changes on wetlands across the CFWI Planning Area. Based on results from this study's evaluation of the impact of groundwater level changes in Orange County and the previous efforts of the CFWI's Environmental Measures team, Orange County could consider the following policy recommendations:

1) **Develop the Orange County Water Use Caution Area (OCWUCA)**. Similar to findings from CFWI's wetland analyses (CFWI, 2013, 2020a), results of this study indicate groundwater withdrawals are more likely to impact wetlands in the southwestern portion of Orange County where there is greater connectivity between the SAS and UFA and UFA water levels are projected to decline due to projected future water withdrawals. Therefore, it is recommended Orange County consider developing the OCWUCA. As shown in Exhibit 9, the OCWUCA would be located in southwestern Orange County and bound by the County border, Interstate 4, State Road 408 and the Florida Turnpike. Within the OCWUCA the following practices could be considered by the County.

    a. Monitor wetlands in the area for changes in water level, stress state, and size. These wetlands should be outside of those already being monitored by the CFWI.

    b. Install monitoring wells and/or identify existing wells located in the SAS and monitoring water levels to evaluate potential SAS water level changes through time.

    c. Identify and conduct site specific studies on groundwater-impacted wetlands in the OCWUCA to evaluate how potential future changes in water levels could impact wetland health.

    d. Develop a "Wetland Protection Strategy" for the region using the "Recovery Strategy" developed for the 5,100 square mile "Southern Water Use Caution Area", which encompasses portions or all or Desoto, Hardee, Manatee, Sarasota, Charlotte, Highlands, Hillsborough, and Polk counties, as a general guide (https://www.swfwmd.state.fl.us/projects/southern-water-use-caution-area).

2) **Continue to incorporate regulations and guidance related to wetland impacts provided in the "Central Florida Water Initiative, Supplement Applicant's Handbook" effective as of January 5, 2022.** This handbook is incorporated by reference in subsection 62-41.302(1), F.A.C. and was developed for use in the CFWI by the FDEP, SJRWMD, and SWFWMD, and the SFWMD. The handbook was designed to provide a uniform regulatory framework for the allocation of groundwater resources

within the CFWI without causing harm to water resources and natural systems, such as wetlands.

3) **Promote the use of low-impact development (LID), other infiltrating BMPs (e.g., rapid infiltration basins), and the reduction of impervious surface areas, throughout the County to facilitate increased recharge to the SAS and UFA.** Increasing recharge to the SAS and UFA can help reduce the water level declines from future groundwater withdrawals. Such reductions in would in turn lead to reduced impacts to wetlands from water level changes.

8 CONCEPTUAL WETLAND IMPACT SCENARIOS

Wetlands provide vital environmental and ecological functions within the State of Florida and Orange County. Overall, wetland systems provide water quality improvement, flood storage, fish and wildlife habitat, recreational opportunities, and biological productivity. However, determining the value of individual wetlands can be difficult because they differ widely and do not all perform identical functions or perform those functions equally well (EPA, 2002). This causes uncertainty for authorities with jurisdiction over wetland activities when assessing the cost and repercussion of approving wetland impact permits.

Figure 8-1: Existing residential development surrounding wetland systems. Image from Google Earth.

This section analyzes incidental impacts associated with wetland loss from development activities. These incidental impacts include those to flooding (i.e., flood risk), aquifer recharge, water quality (e.g., nutrient loading), and hydroperiod change from a hypothetical land development project with direct wetland impacts typical to those which commonly occur within Orange County. Where practical, costs have been included to assign monetary values to the incidental impacts caused by the hypothetical development.

The goal of this effort is to demonstrate how wetland loss can cause incidental impacts that are largely unreported and unknown at the individual project level but are more easily observed when aggregated together at the regional or county scale. Water quality, offsite flood risk, and hydroperiod impact are often not directly analyzed because applications for land development and wetland impact activities are limited to what the governing regulations require. This review aims to better understand potential incidental impacts that could occur for projects that meet current environmental regulations. Incidental impacts are likewise analyzed in terms of current level of service (LOS) standards of Orange County.

8.1 Limitations of the Wetland Loss Scenarios

This work is based on hypothetical development assumptions, uncalibrated numerical stormwater, groundwater, and pollutant load modeling, as well as literature values and assumptions. As such this review should be considered a screening level of detail and not a comprehensive and detailed impact assessment. Field monitoring of actual constructed developments would be required to determine the true impact. However, this work has been prepared using standard industry practices and due diligence efforts to reasonably conceptualize and analyze the hypothetical development. These practices include:

- Utilizing the modeling tools commonly used by developer engineers when designing typical land development projects and when analyzing surface water and groundwater hydrodynamics.
- Coordination with the Orange County Planning staff on layout of the hypothetical development to ensure they are consistent with county zoning and permitting requirements.
- Coordination with Orange County Environmental Protection Division staff regarding the hypothetical amount of wetland impacts that could reasonably be authorized by the County.
- Utilizing the best publicly available environmental, hydrographic, and topographic information to represent an environment within Orange County.

8.2 Hypothetical Development

The hypothetical development (the Development) is envisioned as an approximately 50-acre mixed use Planned Development typical to those projects that would be permitted and constructed within Orange County. The Development is situated in a previously undeveloped area and would not be considered in-fill or redevelopment. Its undeveloped land (i.e., predevelopment condition) consists of a mixture of both uplands and natural wetlands.

To assess the impact of different site design approaches, three development scenarios were conceptualized, centered around an initial base scenario condition. Each scenario is envisioned to include identical amounts of development in terms of number of dwelling units, square footage of commercial building area, and number of parking stalls. Each scenario also has the same amount of proposed wetland impacts that are located at identical positions within the wetland mosaic. The base scenario, Scenario 1, includes a typical site design approach in terms of stormwater management and impervious surface area where all site drainage would be directed to a single wet detention pond. Discharge from the stormwater pond would be directed away from the wetland that normally receives runoff from the Development area, to assess the impacts of not mimicking hydrologic patterns.

Alternative Scenarios 2 and 3 are different versions of Scenario 1, where Scenario 2 includes a modified stormwater outfall that better mimics discharges to offsite wetlands. Scenario 3 is the same as Scenario 2, except that a low impact design (LID) approach would be utilized site-wide where infiltrating stormwater best management practices are deployed in lieu of wet detention, and multiple stormwater ponds are included.

Refer to Figures 8-2 through 8-5 for a depiction of Development Scenarios 1-3, as well as the existing site conditions and extent of wetland areas. **Figure 8-3** shows a detailed sketch of the general Development layout that is conceptualized. Simplified land-use based figures of each Scenario are shown on **Figure 8-4** and **Figure 8-5**. Note that the 50-acre Development is situated within a 500-acre region that extends beyond the Development footprint, which is seen on **Figure 8-2**. This is to assess the impact of surrounding wetland and off-site systems from the Development.

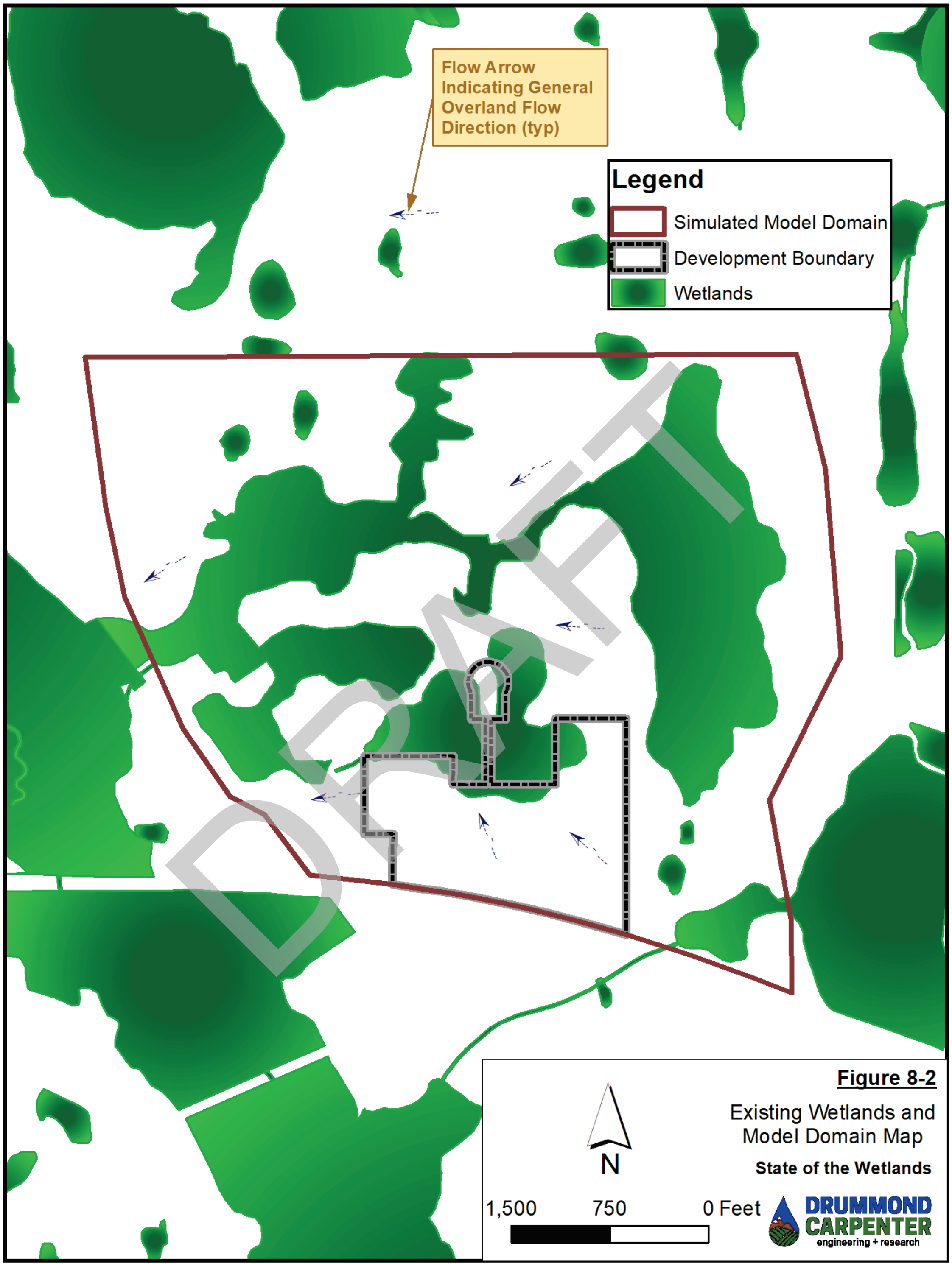


Figure 8-2. Existing Wetlands and Model Domain Map.

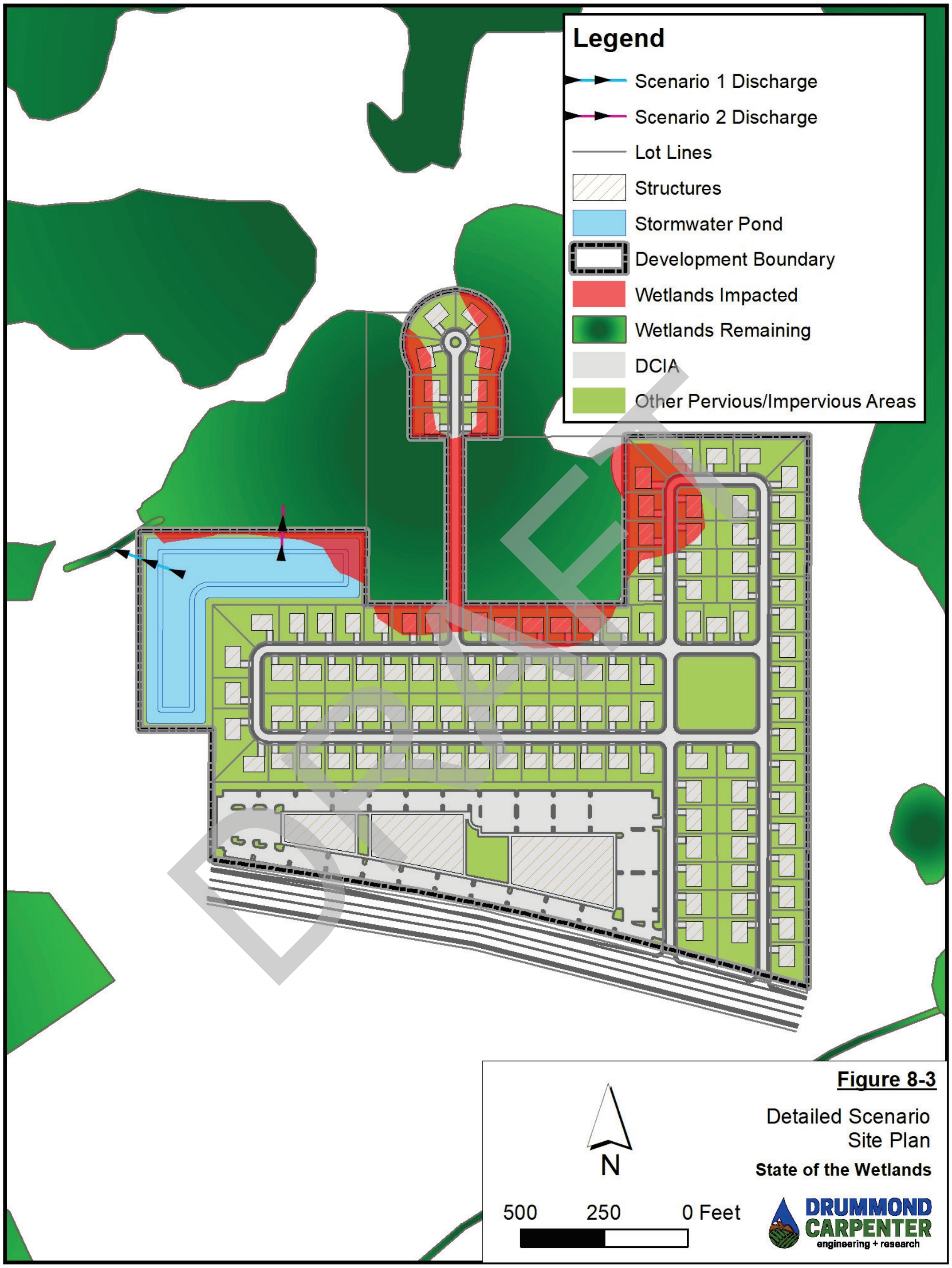


Figure 8-3. Detailed Scenario Site Plan.

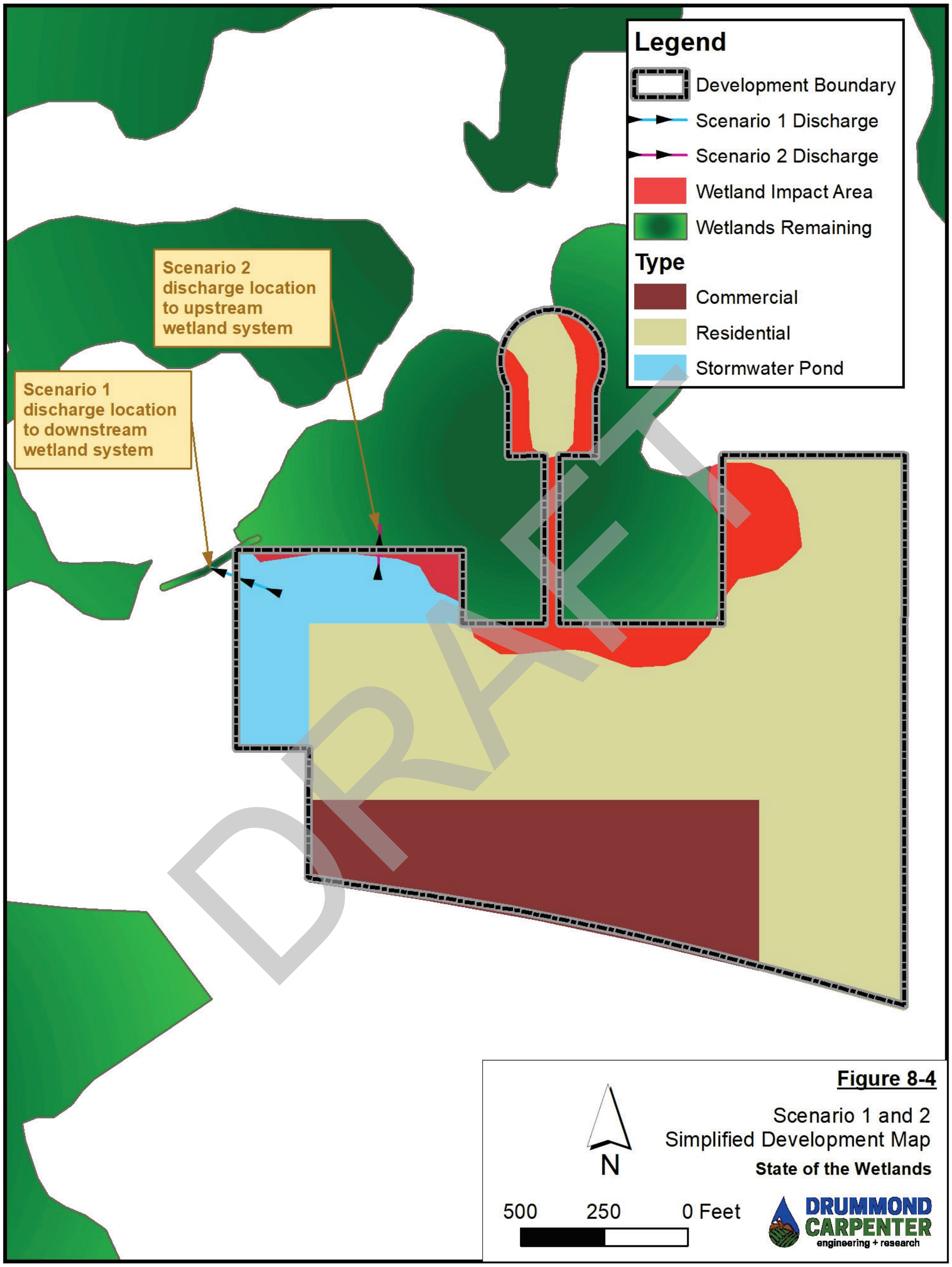


Figure 8-4. Scenario 1 and 2 Simplified Development Map.

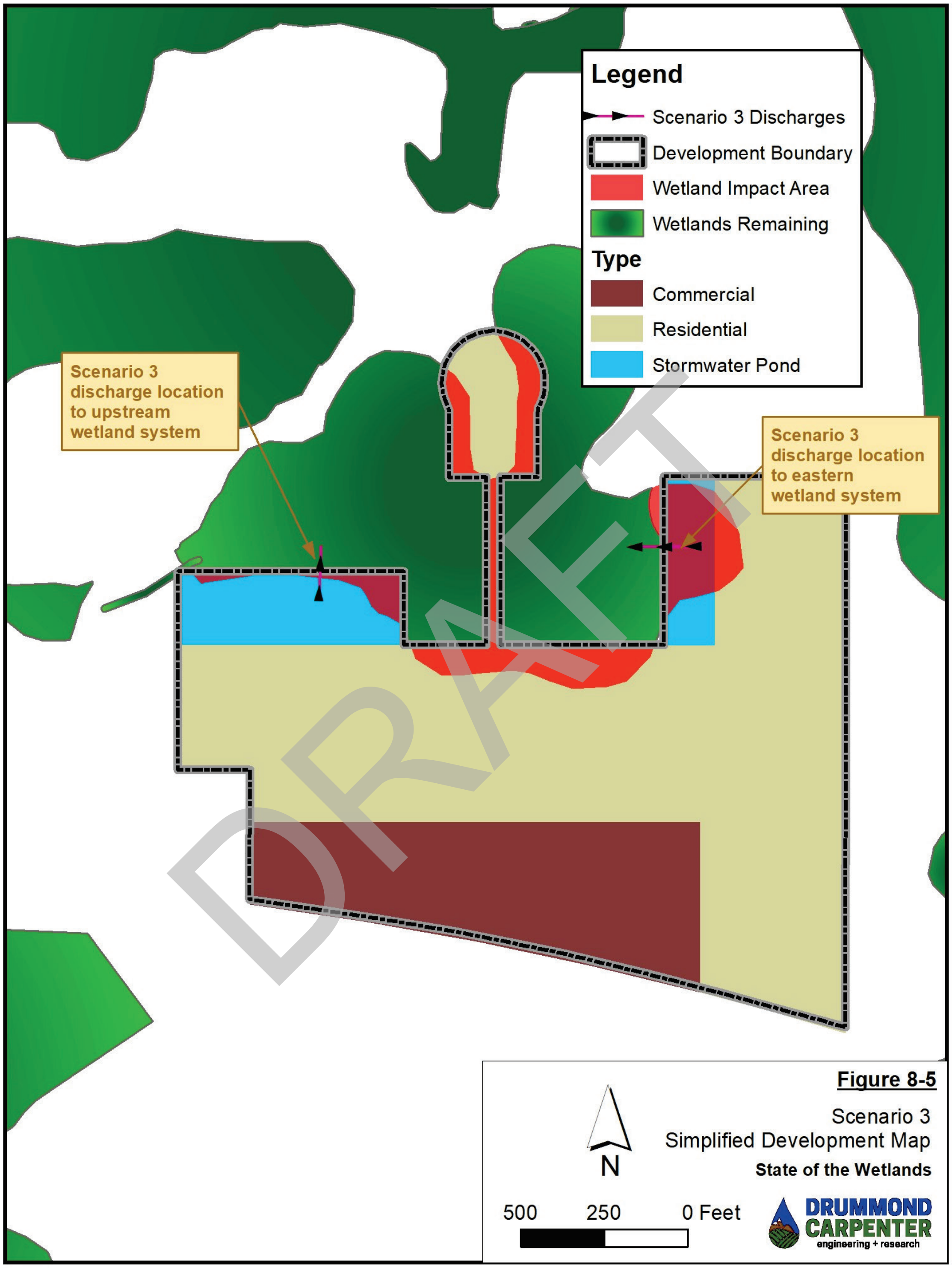


Figure 8-5. Scenario 3 Simplified Development Map.

8.3 Predevelopment Existing Conditions

The natural setting of the Development is an important consideration for this effort to ensure this analysis is representative of potential land development activity within the County. This analysis constitutes a predevelopment vs. post development (i.e., 'pre vs post') methodology. In other words, the Development's existing conditions are used as the basis to assess how the proposed Development Scenarios contribute to incidental impacts. These analyses require substantial amounts of information related to the physical condition of a site, including its topography, land cover type, presence of onsite wetlands, groundwater conditions, soil type, and more. All these factors are important to include when determining the predevelopment baseline condition.

The approach taken to establish the existing conditions was to select a real-world location within Orange County and to use the available information for that site to derive the parameters that would be used in subsequent analyses. The location of the site is not disclosed, as the intent is to assess a hypothetical site that is representative of Orange County. Physical site conditions, including the topography, soil conditions, and wetlands are based on publicly available information.

The size of the existing conditions extent was broadened beyond the footprint of the proposed Development, and totals approximately 500 acres. This was performed to limit numerical calculation biases caused by boundary conditions, and to include offsite areas in the incidental impacts review. The following summarizes relevant existing conditions information used.

Topographic Data

Topographic information is used in a hydrologic analysis to assess overland flow behavior and onsite depressional storage. A Digital Elevation Model (DEM) was developed based on publicly available Orange County 2008 5-ft DEM[10]. Minor changes to the DEM were made to better capture the storage capacity of low-lying wetland areas within the site area, and to remove perceived DEM artifacts from the dataset. In general, the site area drains from east to west along a gentle slope, with intervals of small to moderately sized storage areas intermixed within the region that generally align with the location of wetland systems (**Figure 8-6**).

Precipitation

Precipitation is a critical model input as it serves as the primary driver of surface water and groundwater processes within the site. Two types of precipitation datasets were incorporated: (1) design storm events based on regulated rainfall amounts and distributions, and (2) a one-year continuous simulation which utilized observed rainfall measurements in the vicinity of the project.

[10] https://geo-sfwmd.hub.arcgis.com/documents/18be98297bbb4889890e5a6d170128d2/about

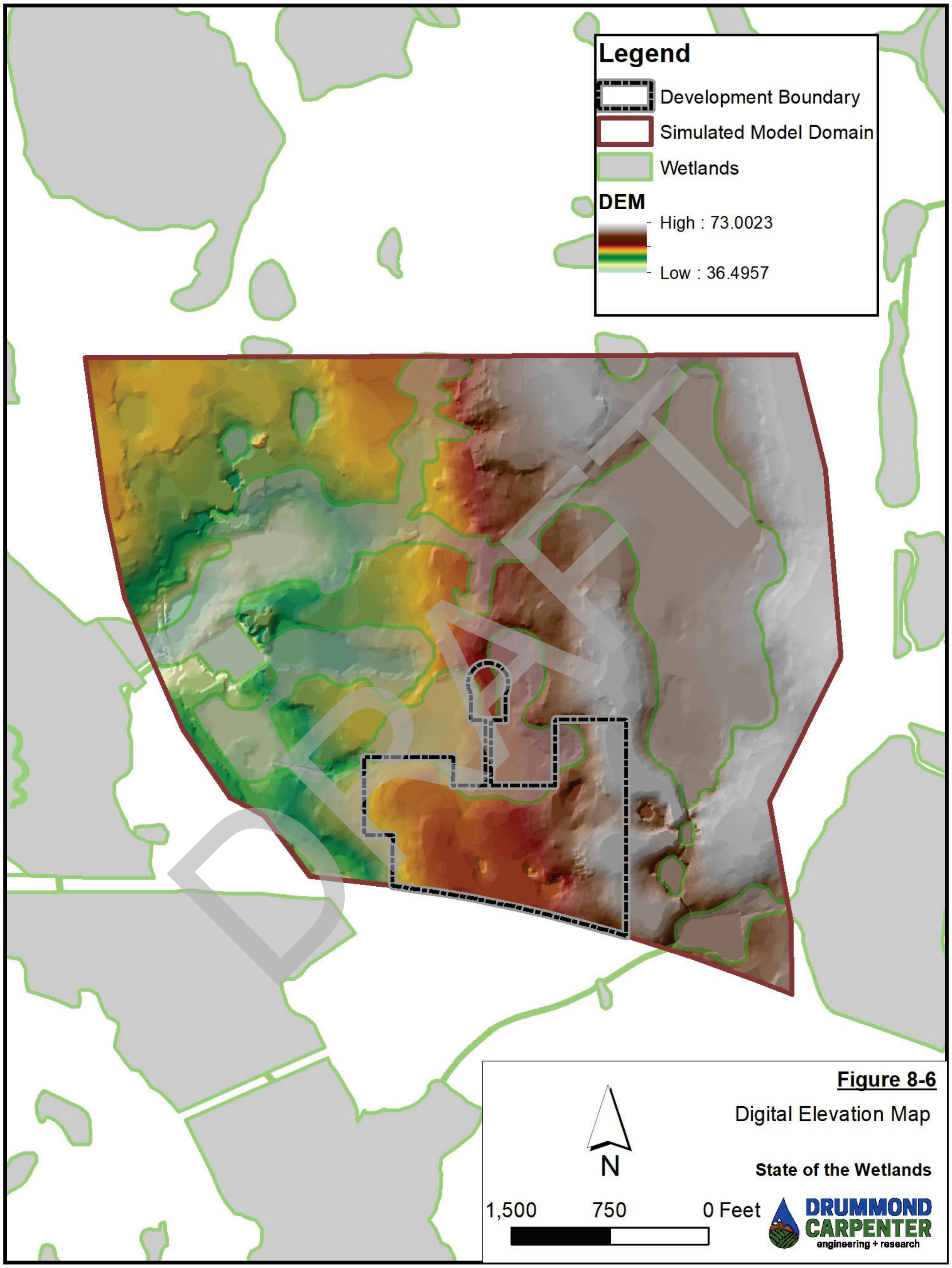


Figure 8-6. Digital Elevation Map.

Design storms were included as these are the regulated flood events that applicants must analyze when designing and permitting land development activities, which are important to adequately size hydraulic structures such as outlets and stormwater ponds. Design storms utilized in the model include the 25-year 24-hour, and 100-year 24-hour storm events. In general, the 25-year 24-hour design storm is used to calculate peak runoff rate discharging from a site and to ensure the post development peak runoff rate does not exceed the predevelopment rate. The 100-year 24-hour storm is used to assess peak flood stage to ensure onsite areas (pond top of bank, building footprints, etc.) are not exceeded, and is generally limited to a post development scenario.

Design storm rainfall distributions follow from the Orange County rainfall distribution. The magnitude of rainfalls for the 25-year 24-hour, and 100-year 24-hour storm events are 8.6 inches (in.) and 10.6 in., respectively. For the continuous simulations, daily rainfall records from the Orlando International Airport were obtained through the National Oceanic and Atmospheric Administration data portal[11]. The precipitation dataset encompassed a period from 2012-2020. The period from 1 January 2020 to 31 December 2020 was chosen for the continuous simulation due to its approximately average magnitude of annual precipitation (53.3 in.).

Reference Evapotranspiration

Potential evapotranspiration for the period from 2012-2020 was obtained from the United States Geologic Survey (USGS) Caribbean-Florida Water Science Center[12]. Evapotranspiration is an important consideration when analyzing long-term hydrologic processes, such as aquifer recharge and wetland hydroperiods. USGS provided Drummond Carpenter with the local evapotranspiration data via email. For the 2020 period of interest, 52.8 in. of potential evapotranspiration occurred.

Soils

Soil conditions play a major role in determining the hydrologic response to storm events. The soil types (e.g., sandy soils, clayey soils) and groundwater condition (e.g., depth to surficial aquifer) are primary factors in determining the amount of infiltration or runoff that occurs when it rains. Higher amounts of stormwater runoff are the main concern when estimating flood risk, but is also important in water quality calculations because more runoff contributes to higher surface water discharges and higher pollutant loading. Both the soil type and groundwater conditions are factors in determining the hydrologic soils group (HSG). HSGs represent the runoff potential of soils, where type 'A' indicates low runoff potential and 'D' indicates high runoff potential.

[11] https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00012815/detail

[12] https://www.usgs.gov/centers/cfwsc/science/reference-and-potential-evapotranspiration

The Soil Survey Geographic Database (SSURGO) soil information was downloaded from the U.S. Department of Agriculture Natural Resources Conservation Site website (https://websoilsurvey.sc.egov.usda.gov/). Based on the SSURGO data, the primary hydrologic soil condition throughout the study area is type 'A/D' or type 'A' (**Figure 8-7**). Hydrologic classification type A indicates well-draining soils with normal water tables in excess of two ft. below grade. Dual class 'A/D' soils indicate well-draining soils normally within a high groundwater table condition.

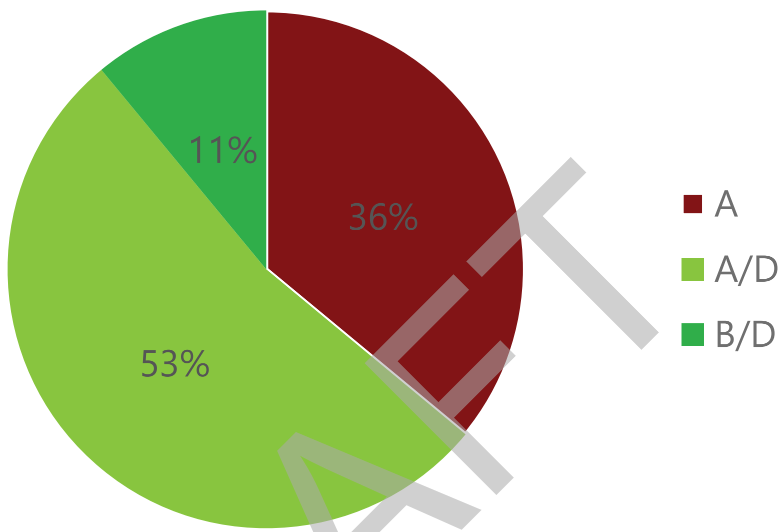


Figure 8-7. Soil Hydrologic Group Aerial Percentage of Project Area

Land Cover

Land cover is another important factor in assessing hydrologic runoff potential and pollutant loading associated with development activities. In general, undeveloped land has a lower runoff potential and pollutant loading than developed land. As development adds impervious surfaces and anthropogenic changes create additional pollution, the stormwater runoff and the pollutants within that runoff increase. Accurately assessing the change in land cover from predevelopment to post development enables these risk factors to be mitigated during the site design.

Land cover information was downloaded from the Florida Department of Environmental Protection's Geospatial Open Data Portal (http://geodata.dep.state.fl.us/). Land cover information for the existing conditions area was based on the period of 2013-2016. The general land cover conditions were noted as agriculture pasture fields and wetlands, which total approximately 90% of the study area (**Figure 8-8)**.

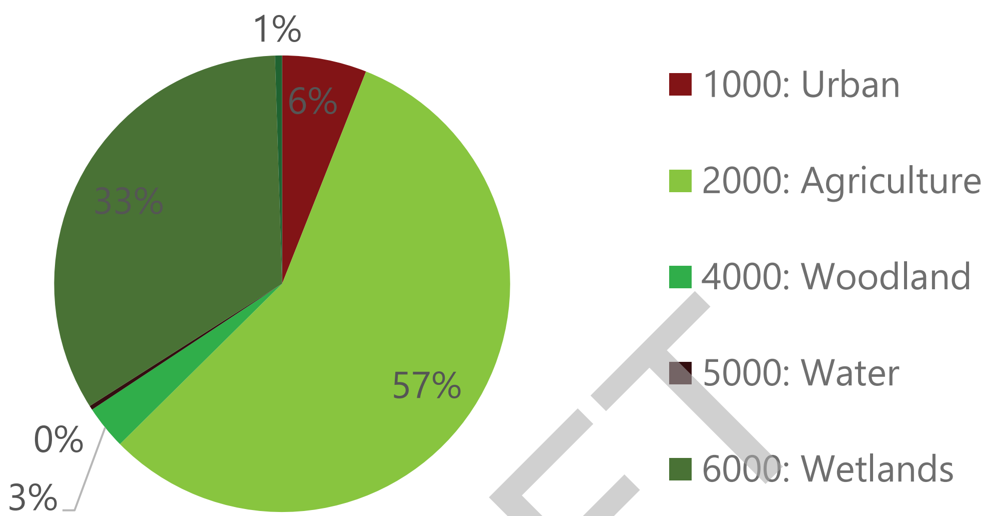


Figure 8-8. Land Use Aerial Percentage of the Project Area

Wetland Inventory

The existing wetland spatial coverage was used in the formulation of the proposed 50-acre Development footprint. The wetlands that are hypothetically impacted occur along the perimeter of the Development improvements. Wetland GIS coverages were obtained from the National Wetland Inventory database managed by the U.S. Fish & Wildlife Service. A total of 163 acres of wetlands from this dataset are present within the limits of the conceptual model domain. Refer to **Figure 8-2**.

Groundwater Table

The depth to surficial aquifer was used to assess the hydroperiod of the wetlands prior to and after the Development activities. Because the function of wetland systems depends largely on the established surface water and groundwater hydrology, developing a reasonable depth to groundwater was an important consideration.

A gridded surface representing the initial water table was developed in two stages. The first stage involved gridding elevation data suspected to be near the water table. The second stage included importing this data into a hydrodynamic stormwater and groundwater model (ICPRv4) and simulating groundwater flow in a pseudo-steady state condition to allow the water table to equilibrate. Because wetland systems are often positioned where the water table and land surface intersect, the elevations at the boundary of known wetlands can be used to generate an approximate water table. Elevations from DEM were extracted from the wetland boundaries and gridded by kriging to develop an initial water table approximation.

Following the development of the initial water table grid, the water table was loaded into ICPRv4 and allowed to equilibrate. This water table was used to establish initial groundwater condition for subsequent modeling and analysis.

8.4 Post Development Conditions

As noted above, the Development consists of three scenarios (**Table 8-1**). Each scenario assumes identical amounts of improvements that are important to land developers, including number of dwelling units, square footage of commercial buildings, and parking stalls. Similarly, an identical amount of wetland impacts is proposed for all scenarios. The only significant change between the scenarios is the approach to stormwater management, which has been performed to highlight the impact of design and regulatory considerations during the land development process.

Scenario 1

This includes the base condition scenario and incorporates a single wet detention stormwater pond and high amounts of impervious area. By including a single stormwater pond and offsite discharge location, all stormwater runoff that leaves the site would be focused to a point location. Where continuous wetland systems exist along flow ways, development activities can block historic drainage patterns that can provide a periodic water source that the wetland system relies on, disconnecting a portion of the wetland from its regional hydrology. For Scenario 1, the discharge location from the stormwater pond occurs offsite at the most downstream end of the offsite wetland. Scenario 1 assumes a high amount of impervious surface area for the residential and commercial areas.

Note that higher residential impervious areas are more common with apartments and other multifamily developments. The conceptual sketch on Figure 8-3 shows single family residential development which would be more associated with the impervious areas used in Scenarios 2 and 3.

Scenario 2

This scenario is a modification of Scenario 1. In this scenario, the design better mimics the predevelopment hydrology by discharging to an upstream portion of the off-site wetland to ensure that the Development does not hydrologically isolate remaining wetland systems. In addition, this scenario has a lower amount of impervious area than Scenario 1.

Scenario 3

In this scenario, the wet detention pond is replaced by multiple dry retention ponds and a low impact design (LID) system. LID is a design approach that typically encourages the infiltration of stormwater into soils and disconnecting impervious areas. While there are many types of LID technologies (e.g., rain gardens, pervious pavement, exfiltration) that can be applied, most of them operate in a similar way and are often distributed across a site development. For this project, the type of LID is not specified, but instead considered as an overall reduction in the amount of impervious area. Additionally, the stormwater management system is assumed to be purely retention-based.

Table 8-1. Development Scenarios

Details of the Development	Scenario 1	Scenario 2	Scenario 3
Total Area (ac)	52.5	52.5	52.5
Commercial Area (ac)	11.25	11.25	11.25
Residential and Open Space Area (ac)	36.5	36.5	36.5
Impervious Area (%)	73	58	45
DCIA (%)	59	45	32
Pervious Area (%)	27	42	55
Stormwater Management Tract Area (ac)	5.25	5.25	5.25
Wetland Impacts (ac)	5.6	5.6	5.6
Stormwater Management System and Design Approach	Single wet detention with point discharge at most downstream part of surrounding wetland system. High amount of impervious surfaces	Single wet detention with discharge locations better mimicking predevelopment flows. Moderate impervious area and DCIA	Dual dry retention system with LID practices to reduce DCIA. Low amount of proposed impervious surface area.

Stormwater Infrastructure

For each scenario, the primary stormwater infrastructure considered was the stormwater ponds. Stormwater conveyance infrastructure (catch basins, culverts, etc.) would be necessary to convey stormwater to the ponds, but these were not conceptualized directly as this infrastructure would not impact this analysis. The only hydraulic structures included in the analysis were the pond outfall control structures which regulate discharge to the off-site wetland system. For the wet detention scenarios, bleed down orifice devices were conceptualized and placed at the assumed normal water level for each pond. For retention ponds, no bleed down orifice was included with discharge only occurring after the treatment volume elevation was met.

For all scenarios, the required treatment volumes and permanent pool volumes exceed regulatory requirements. This is because matching pre vs. post development flow rates was the limiting factor in sizing the stormwater ponds, which caused the pond size to increase to better attenuate stormwater discharges.

Table 8-2 provides the regulatory parameters used for these ponds. For Scenario 3, the two retention ponds are combined with respect to their treatment volumetric totals. For consistency between the scenarios, the same pond volume was used.

Table 8-2. Development regulatory parameters.

Scenario	Treatment Volume Provided	Permanent Pool Volume
1	13 acre-feet	22 acre-feet
2	13 acre-feet	22 acre-feet
3	13 acre-feet	N/A

8.5 Modeling and Analysis

This analysis was performed to answer several questions to better understand incidental impacts from wetland loss, and how this understanding could be used to recommend potential revisions to the County land development rules and regulations. These questions include:

1. What is the potential impact of flood risk associated with wetland loss?
2. What is the potential impact of hydroperiod to remaining off-site wetlands after development?
3. What is the potential impact to water quality as a result of wetland loss?
4. How can the above impacts be accounted for in terms of monetary value from the loss of wetland systems?

To address these questions, multiple Development Scenarios were conceptualized, and environmental numerical modeling techniques were used to quantify potential incidental impacts. These analyses are based on an understanding of typical land development practices and current environmental regulations. It is important to note that there are considerably more potential scenarios that could exist than those considered in this section. The scenario parameters chosen were specifically made to highlight a diversity of outcomes that could be expected for similar developments that incorporate different design approaches.

8.5.1 Hydrologic Impact Analysis from Developments with Wetland Loss

A coupled surface water and groundwater hydrologic and hydraulic model was used to analyze the existing and proposed stormwater runoff, flooding, wetland hydration, surface water flow, and aquifer recharge for each Scenario. The modeling software chosen for this project is ICPRv4 [version 4.07.08], which is a comprehensive hydrodynamic surface water and groundwater modeling system.

Existing condition surface water features were modeled in a two-dimensional unstructured mesh to simulate overland flow and routing, with one-dimensional hydraulic node-link features to simulate channels, pipes, overland weirs, and depressional areas. Proposed condition Development scenarios were modeled using one-dimensional mapped basins to simulate onsite stormwater routing. The groundwater system for both existing and proposed development scenarios was modeled as a two-dimensional, single layer, triangular mesh with simulated saturated horizontal flow in the surficial aquifer. The two-dimensional (2D) groundwater mesh and surface water system interacted in several ways. This includes infiltration via recharge though the overlying unsaturated zone and seepage both into and out of the groundwater model where the water table intersects the ground surface.

Hydrologic processes were modeled using the Green-Ampt methodology, which more accurately reflects soil and groundwater interactions than the Curve Number method, and is suitable for both design storm and continuous simulation. The underlying soil properties were held consistent for all simulations, with the major difference limited to the amount of impervious surface and DCIA coverage for each scenario.

For the proposed condition improvements modeling, Scenarios 1 and 2 included a single mapped basin draining into the stormwater pond, which was modeled as a stage area node. A drop structure link was used to model the pond control structure, which included a bleed down orifice and overflow weirs connected to a discharge pipe link. The pipe link discharged into the surrounding 2-D overland flow mesh to simulate the point discharge to the receiving wetland system. For Scenario 3, two mapped basins and associated stage area nodes and drop structures were modeled to account for the two dry retention pond systems.

Both design storm and continuous simulations were performed for all scenarios. For development review purposes, the 25-year 24-hour design storm is a common synthetic storm event that is regulated by local authorities and the water management districts. Applicants proposing new development must typically demonstrate that the post development peak runoff rate (e.g., cubic feet per second of runoff) leaving the site is less than or equal to the pre-development rate from the same storm event. Achieving this standard is a typical way that proposed developments demonstrate reasonable assurance that their project will not cause adverse flood conditions. The 100-year 24-hour storm is also used to ensure that the stormwater runoff is safely stored within the stormwater pond and no pond overtopping occurs. Additional design storms can also be required, but this analysis is limited to the 25-year 24-hour storm and 100-year 24-hour storm events.

Continuous simulations were performed to assess the surface water and groundwater hydrology of the hypothetical site and Development based on actual environmental data, including precipitation and evapotranspiration rates for the 2020 year. Performing continuous simulations can better assess the response of a pre-development and post development site from routine, smaller storm events that occur throughout the year. These analyses are also helpful when calculating hydroperiod, groundwater recharge, and annual volumetric surface water discharges, which design storm-event based modeling cannot provide.

Refer to **Figures 8-9** to **8-11**, which depict the surface and groundwater modeling elements.

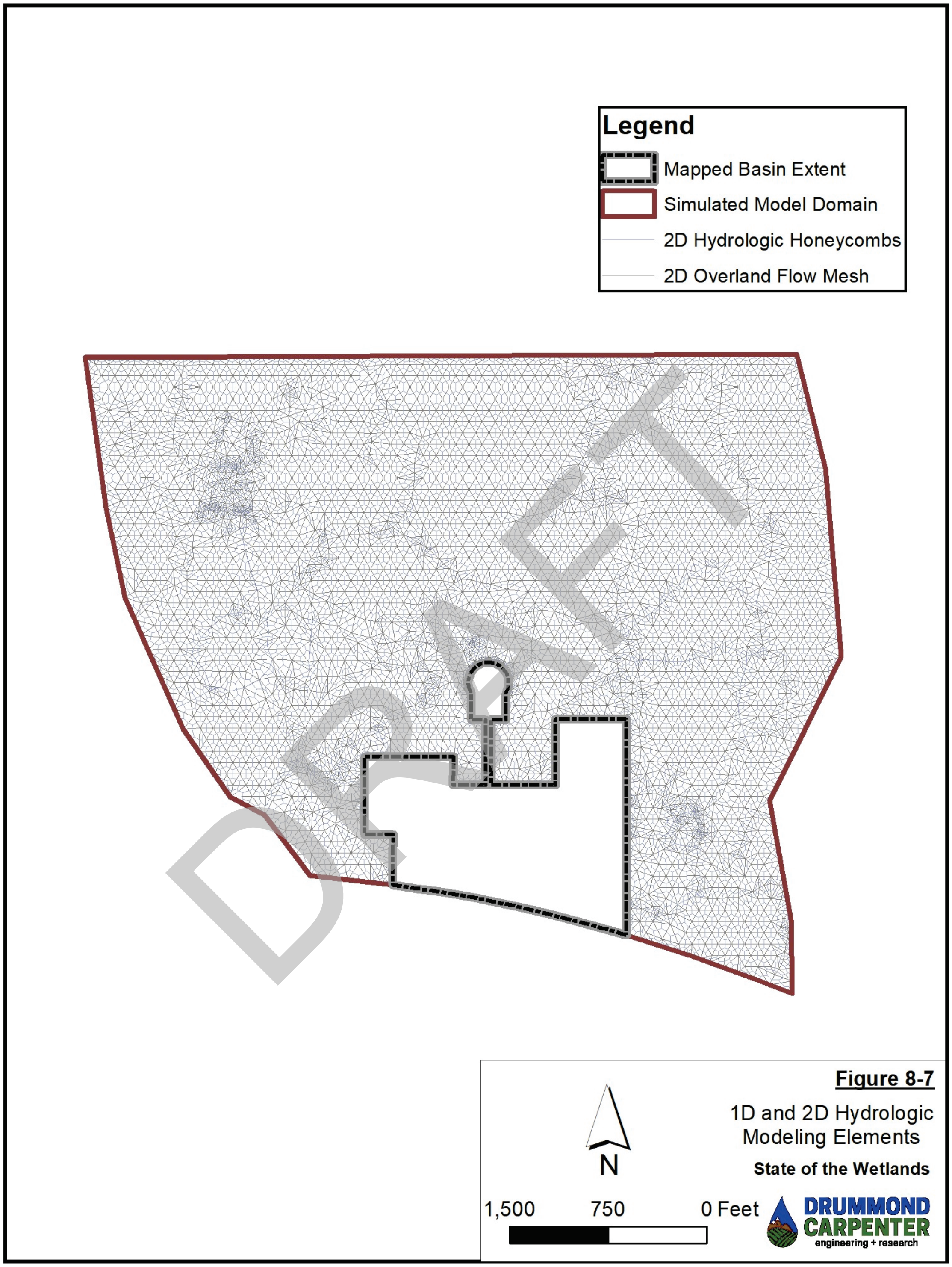


Figure 8-9. 1D and 2D Hydrologic Modeling Elements.

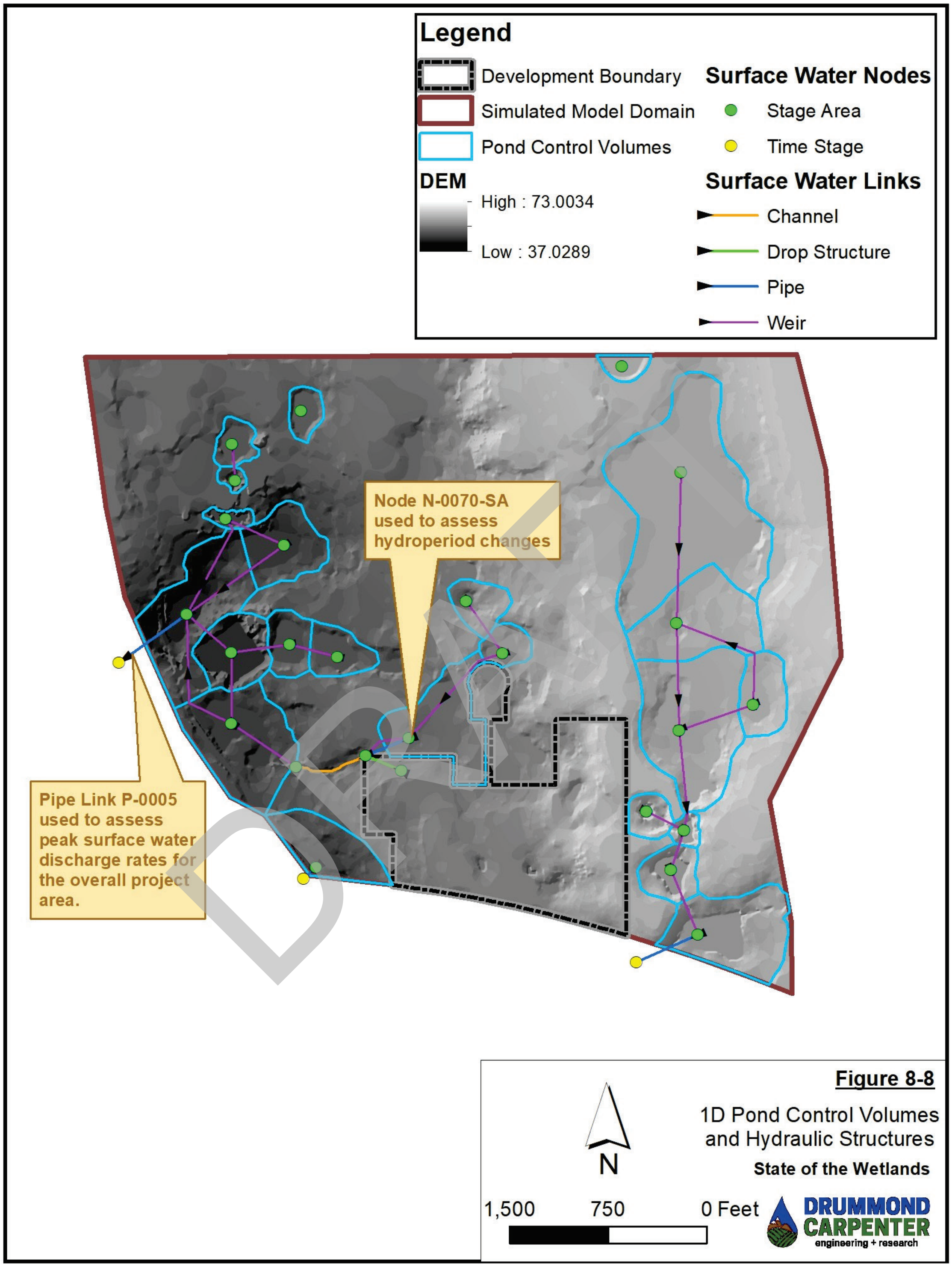


Figure 8-10. 1D Pond Control Volumes and Hydraulic Structures.

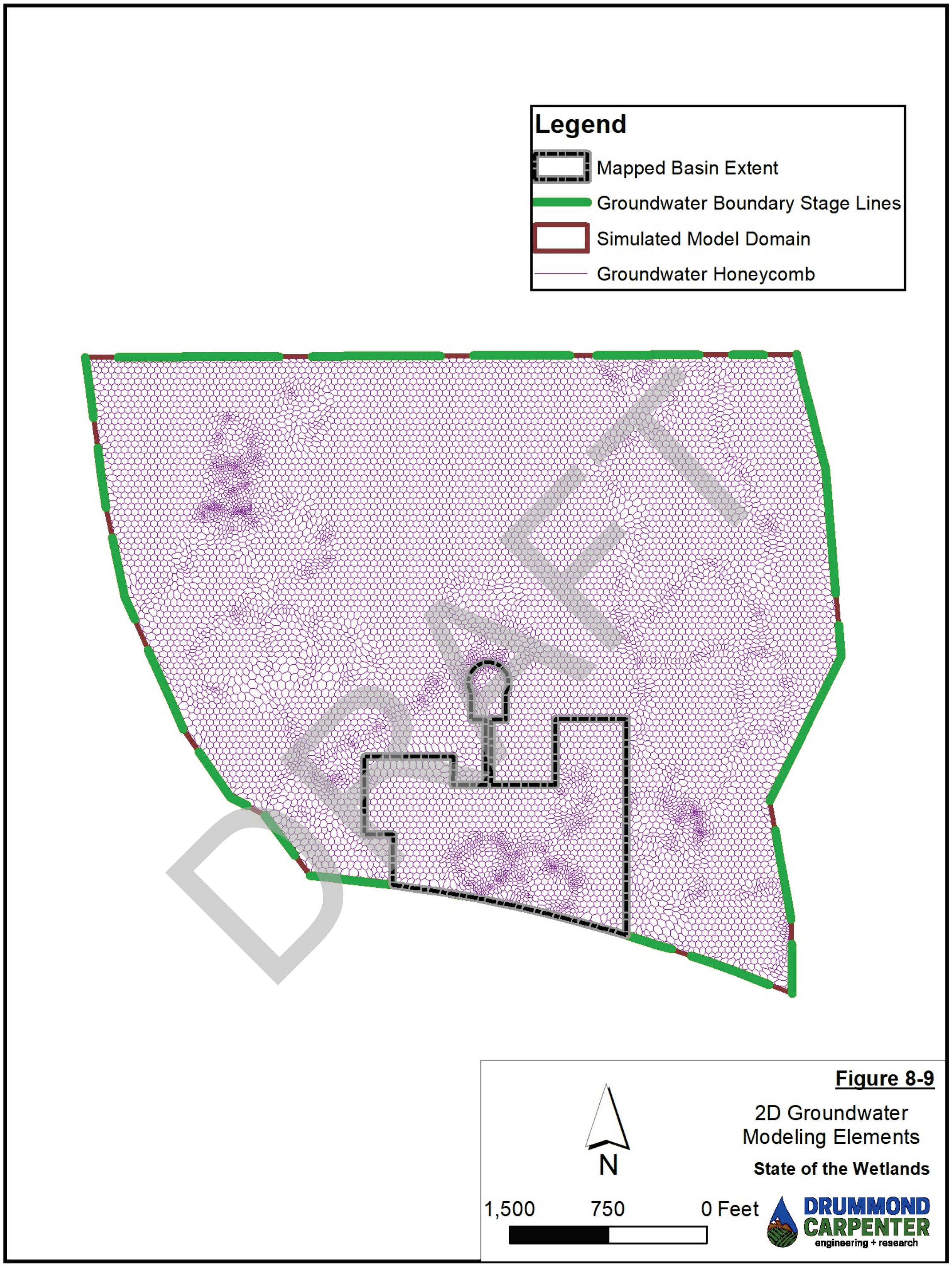


Figure 8-11. 2D Groundwater Modeling Elements.

8.6 Results

The Development removed 5.6 ac. of wetlands on the site, which was maintained for each scenario. Hydrologic impacts were assessed by comparing results from the existing and Development Scenarios. This comparison evaluated aquifer recharge, downstream discharge, wetland hydroperiods, and water quality. Results from this study suggest several potential indirect effects of the Development on the surrounding hydrologic system.

Aquifer Recharge

Aquifer recharge is an important consideration when assessing the impact of development activity. As new impervious areas are constructed, the ability of water to infiltrate and recharge the surficial and underlying aquifer is diminished. This reduction in recharge is balanced by an increase in stormwater runoff, which in open systems is conveyed to downstream waterbodies as surface water. The increase in surface water discharges can create potential flood risk considerations, as well as altering local groundwater elevations. This hydrologic shift can cause adverse impacts to local ecosystems and wetlands that depend on their established hydroperiods. Reductions in aquifer recharge are also a significant concern in western Orange County, where groundwater withdrawals are expected to significantly lower the surficial aquifer making those wetland systems more vulnerable to functional decline.

Aquifer recharge is defined in this analysis as the amount of rainfall that infiltrates into the soil from the overland flow layer into the underlying groundwater model layer and is calculated across the entire one-year continuous simulation. Where rainfall excess infiltrates into the soil layer, positive recharge occurs, and where elevated groundwater heads exceed the topographic surface, negative recharge (i.e., seepage) can occur and is recorded as part of the model's hydrologic mass balance.

Model results demonstrate the Development would have the adverse effect of decreasing aquifer recharge for all alternatives. The existing conditions model produced 20.29 in. of aquifer recharge over the one-year simulation period while the alternatives produced between 19.30 in and 20.14 in of aquifer recharge. Scenario 1 produced the greatest decrease in aquifer recharge, representing a 4.9% decrease for the model domain. Scenario 3 had the lowest amount of reduced recharge which is the result of the stormwater management design approach which assumed the complete use of infiltration-based stormwater best management practices (BMPs) such as dry retention ponds and LID practices, as well as a reduced amount of impervious area. Results are summarized in **Table 8-3**.

Table 8-3. Annual Aquifer Recharge and Stormwater Runoff

Scenario	Existing	Alternative 1	Alternative 2	Alternative 3
Aquifer Recharge (in)	20.29	19.30	19.37	20.14

Rainfall Excess Volume (in)	8.46	11.54	10.97	9.63

Downstream Discharge

Discharge flow rates are used as a basis to assess the flood risk of a development based on design storm simulations. If the proposed development matches or decreases the pre-development flow rate for the given design storm(s), then the project is assumed to have provided reasonable assurance against flooding.

Model results were compared at pipe link P-0005 to determine the effects of the Development under each of the three scenarios on downstream discharges. Link P-0005 is located at the model domain boundary and provides a suitable reference point for determining how offsite flow is impacted under each scenario. This culvert discharges to a regionally significant wetland and hydrologic system. Under each Scenario, site runoff is routed to one or more stormwater ponds and conveyed offsite via a pond control structure to a downstream wetland system, ultimately exiting via link P-0005.

The 25-year 24-hour design storm peak flow rate was assumed as the governing stormwater management criteria, where the post development must not exceed pre-development peak flow rates. Each of the three alternatives was simulated and compared to the existing condition to confirm the conceptual development met this criterion. As shown in **Table 8-4** below, the results demonstrate that the conceptual developments would meet current permitting criteria.

Table 8-4. Offsite Flows at P-0005 (25-year/24-hour event)

Scenario	Existing	Alternative 1	Alternative 2	Alternative 3
Peak Flow (cfs)	121.69	105.09	104.49	120.46

Groundwater Elevation and Wetland Hydroperiod

Drummond Carpenter evaluated the impact of the three alternative scenarios on the offsite groundwater table for the one-year model simulation. For the purposes of this analysis, the hydroperiod was assessed by analyzing seasonal elevation changes across the different scenarios, and how groundwater may elevate or decrease for different durations across the simulated year.

A 25% groundwater table exceedance probability (3 months a year on average) was extracted for each of the scenarios from ICPRv4. The project DEM minus 0.5 feet was then subtracted from the exceedance raster. This resulted in a dataset representing the extent of groundwater that is within 6 inches or higher of the surface for at least a 3-month period, and is used as the basis to assess seasonal hydroperiod extent of wetland systems. Only positive values were subsequently displayed to reflect the 25% exceedance probability of the groundwater table either at or above 6 inches below ground surface. **Figure 8-12** shows the results of this analysis.

As illustrated, Scenario 1 shows a significant reduction in the extent of the groundwater table that is within 6 inches of the ground surface for at least 3 months. This area is associated with an existing offsite wetland and suggests that this scenario could significantly alter the hydroperiod of this wetland. The cause of this reduction in groundwater table is because the proposed development does not mimic the predevelopment discharges. The discharge location of the stormwater pond occurs downstream of this depressional area, bypassing and hydrologically isolating this wetland.

Scenarios 2 and 3 show increases to the 25% groundwater exceedance area and isolated areas with a higher depth. This increase in groundwater table elevation is likely caused by the increased amount of runoff from the impervious area, and discharge locations that better mimic predevelopment flows to the existing wetland systems. For Scenario 3, the seepage from the adjacent stormwater ponds can be attributed to maintaining these elevated groundwater conditions.

Figure 8-13 shows a chart of water elevation exceedances between the existing conditions and Development Scenarios 1-3 at N-0070-SA. The horizontal line represents the calculated normal water line of the existing wetland. Consistent with the above, Scenario 1 shows a general water level decrease, whereas Scenarios 2 and 3 are above the existing condition baseline.

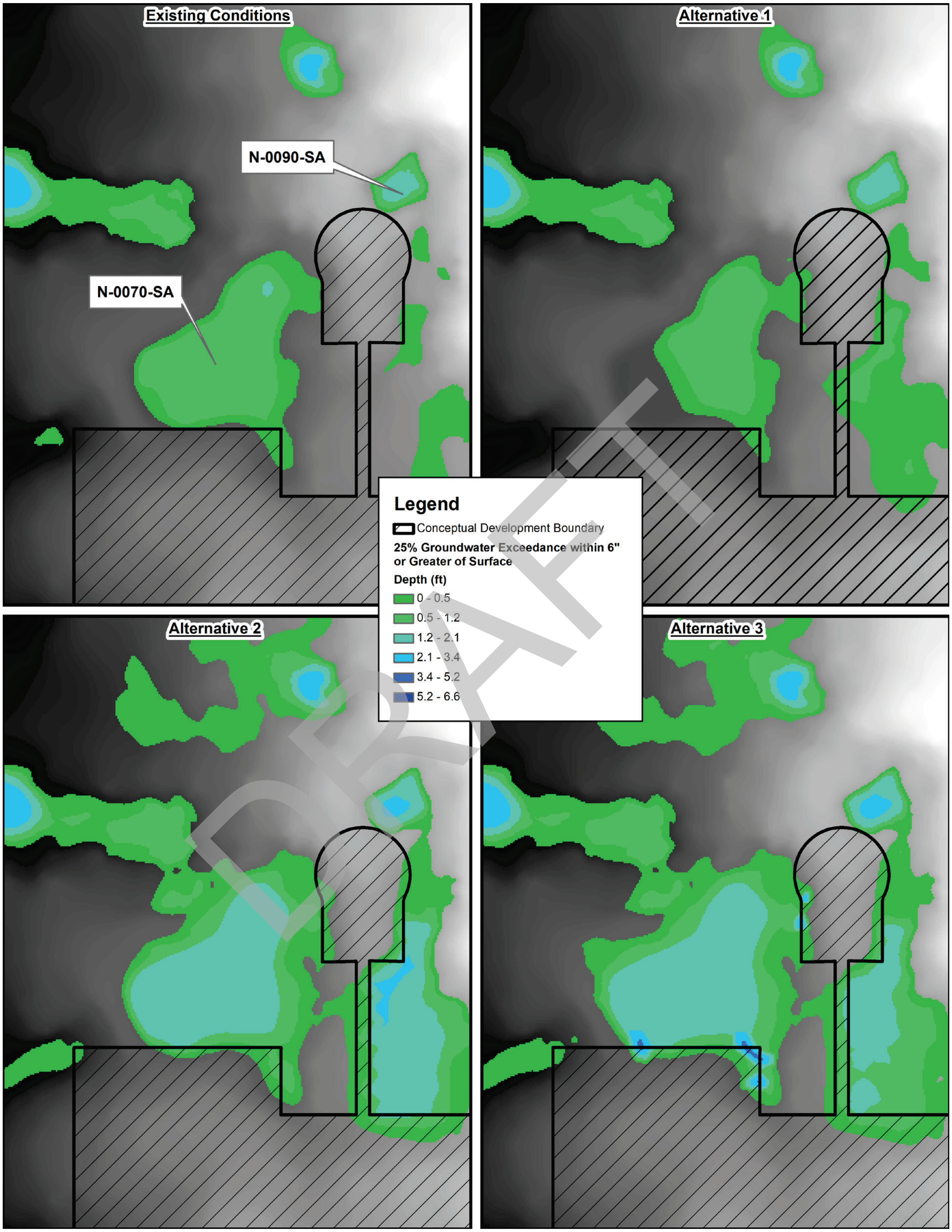


Figure 8-12. Spatial Extents of 25% Exceedance Groundwater Table

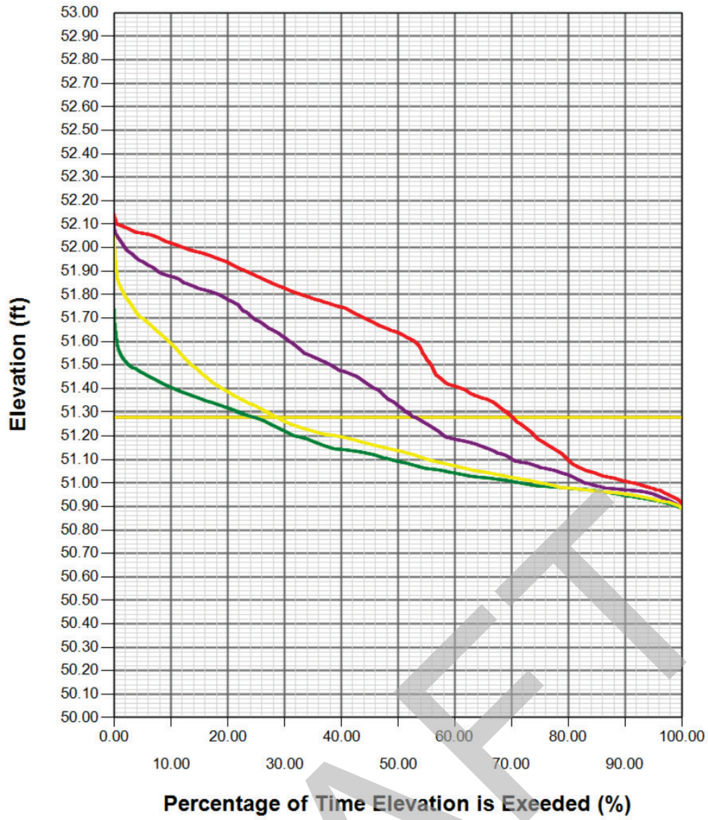


Figure 8-13. Wetland area (Node N-0070-SA) Stage Elevation % Exceedance where the yellow line represents existing conditions, green represents Scenario 1, purple represents Scenario 2, and red represents Scenario 3. The horizontal line represents the initial base water table condition.

Model results suggest that the conceptual development would affect wetland hydroperiod for the simulation period and model domain, either by increasing or decreasing water levels within wetland features. Wetland vegetation and wildlife are sensitive to changes in water levels and hydroperiods, as these changes can alter wetland community structure and reduce biodiversity. To determine if the Development scenarios affected wetland hydroperiods, stages from two wetland systems were compared between the existing and Development simulations. In general, the model results were similar between the simulations (**Figure 8-14** and **Figure 8-15**) but exhibited up to a 1-foot difference over existing conditions at certain times.

The wetland feature represented by Node N-0070-SA, located directly northwest of the conceptual development, showed the greatest impact from the alternatives. Wetland stages are generally lower in Scenario 1 over existing conditions and generally higher in Scenario 2 and 3. Similar results were observed at wetland feature N-0090-SA, located north of the conceptual development. Though stages and timing of peak water levels are similar at this wetland feature, differences between the conceptual and existing condition are up to 1-feet. Water level stages within wetland N-0090-SA are generally higher for all three alternatives than the existing condition. The highest changes in elevation at N-0090-SA are likely caused by the Development scenario impeding flow patterns, which cause periodic times where greater ponding occurs than did in predevelopment conditions. These conditions could be resolved with the placement of water control structures (e.g., culverts, flashboard risers) that could better convey surface water under the long north/south road through these wetland areas.

Figure 8-14. Wetland area (Node N-0070-SA) hydroperiod under existing versus conceptual developments.

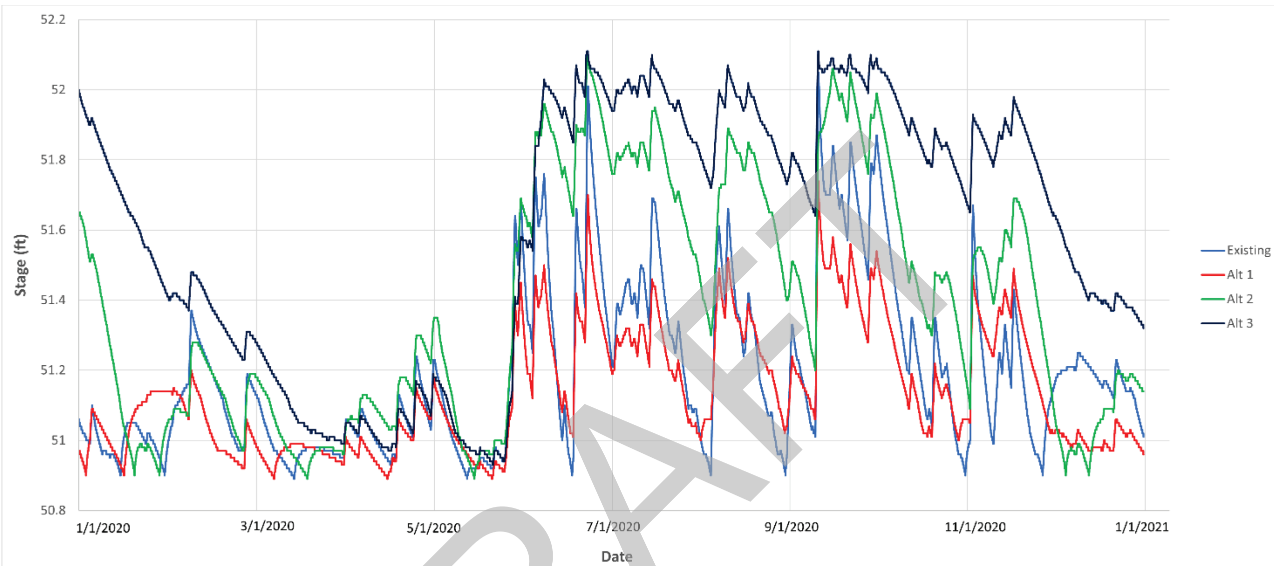
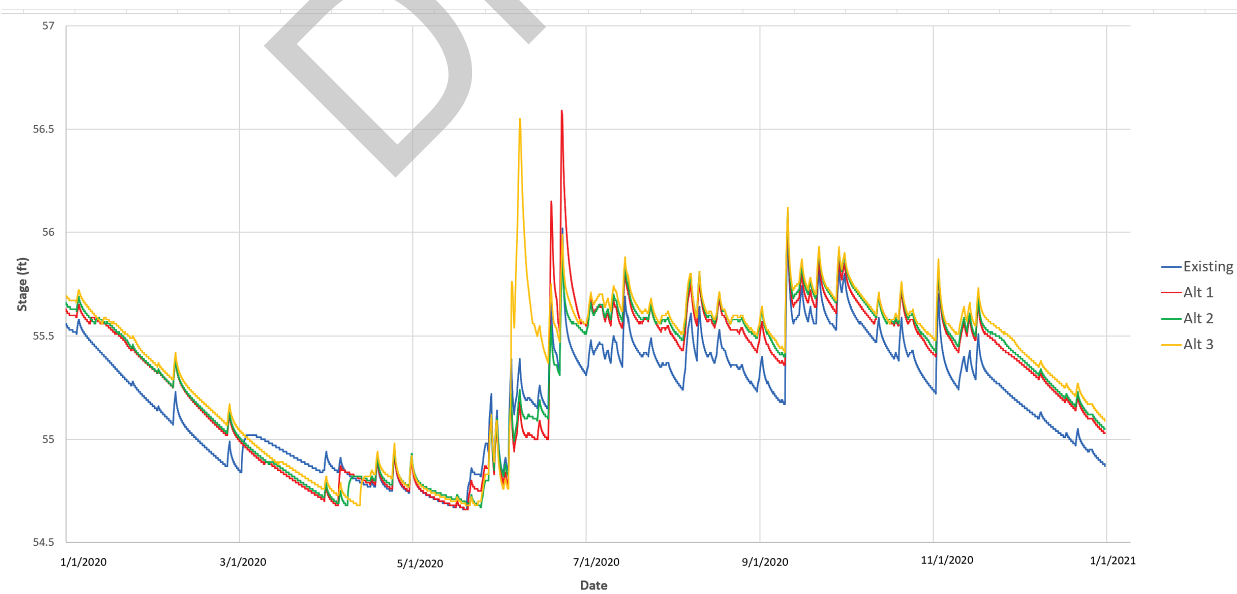


Figure 8-15. Wetland area (Node N-0090-SA) hydroperiod under existing versus conceptual developments.



Water Quality

For this assessment, total nitrogen (TN) and total phosphorus (TP) were calculated as the water quality parameters of interest. Nutrients, primarily TN and TP, are the primary pollutants of concern in Florida as they are responsible for most of the impaired waters within the state. Excess nutrients that discharge to receiving waters can contribute to algal blooms and eutrophication of waterbodies.

Water quality modeling was conducted using BMP Trains software[13]. Changes to water quality between the existing and Development Scenarios were assessed through a Net Improvement analysis. Catchment parameters utilized a weighted average approach based on the soils and land use of the existing and conceptual development conditions for each alternative.

Under each of the three Scenarios, the stormwater ponds were conceptualized as both wet detention and dry retention options. This doubled the number of water quality scenarios to six and has been performed to demonstrate the range in pollutant reduction values that can occur when managing stormwater runoff from the developed site.

For the dry retention option, the treatment volume was assumed to be between the orifice elevation and vertical control structure weir, resulting in a retention depth of 3 inches over the contributing area, which exceeds the typical amount of required water quality retention depth. For the wet detention option, the permanent pool was taken between the pond bottom and orifice elevation, resulting in a permanent pool volume of approximately 22 acre-feet, which exceeds the minimum residence time required for wet detention systems for each scenario. The overall area of the stormwater ponds in all scenarios is equivalent. The overall %DCIA for the developed condition of Scenarios 1, 2, and 3 is 59%, 45%, and 32%, respectively. A non-DCIA curve number (i.e. accounting for only non-DCIA impervious area and pervious area) was entered for each of the alternatives to avoid double counting imperviousness associated with DCIA.

Based on the results of the BMP TRAINS modeling, the existing conditions were calculated to have a TN loading rate of 35.65 kilograms per year (kg/yr) and TP loading rate of 1.88 kg/yr. The dry retention option of each alternative provides significantly higher pollutant reduction in a developed condition, with 95% removal efficiency or higher for TN and TP under each alternative. This results in a net improvement of water quality over existing conditions. The wet detention option provides only about 41-42% TN removal efficiency and 71-75% TP removal efficiency, resulting in net increases in nutrients discharged from the Development, which can have an adverse impact to water quality of the receiving waters.

In addition to the type of stormwater treatment provided, the amount of impervious area assumed under each scenario was a major factor in determining the amount of nutrient load

[13] https://stars.library.ucf.edu/bmptrains/

required to be reduced for each scenario. For example, Scenario 3 required over 100 kg/yr less TN reduction than Scenario 1 to meet its net improvement goal. This highlights the benefits that a LID approach can have at reducing the amount of stormwater treatment that is required. **Table 8-5** summarizes the results of the BMP Trains analysis.

Table 8-5. TN and TP Annual Loads by Scenario

Scenario	Scenario	TN Load (kg/yr)	TP Load (kg/yr)	TN Removal Efficiency (Post-Development)	TP Removal Efficiency (Post-Development)
Existing	Existing	35.65	1.88	--	--
1	Without Treatment	269.72	40.66	(87% Reduction Required)	(95% Reduction Required)
	Wet Detention Option	158.34	11.60	41%	71%
	Dry Retention Option	6.75	1.02	95%	97%
2	Without Treatment	218.00	32.97	(84% Reduction Required)	(94% Reduction Required)
	Wet Detention Option	126.87	8.745	42%	73%
	Dry Retention Option	4.5	0.68	98%	98%
3	Without Treatment	165.26	25.27	(78% Reduction Required)	(93% Reduction Required)
	Wet Detention Option	94.8	6.07	42%	76%
	Dry Retention Option	2.90	0.045	98%	98%

8.7 Costs

As described in the literature review in Section 2, wetlands provide valuable ecosystem services to their surrounding environment, including nutrient and carbon storage, flood attenuation, and aquifer recharge. These services also hold an economic value, and impacts to wetlands may result in economic losses due to several factors:

1) The decreased ability of the remaining wetland to provide services that are comparable to its pre-construction condition.
2) The inability of wetlands used as mitigation to replace 100% of the ecosystem services lost from the impacted wetland.
3) The discrepancies between wetlands and typical stormwater BMPs (i.e., ponds) in terms of nutrient removal and storage capability and/or efficiency.

The cost of water quality treatment on effluent exiting the proposed development can be estimated based on applicable industry standards, such as nutrient removal costs for typical stormwater BMPs. The University of North Carolina conducted a literature review on the cost-effectiveness of nearly 20 common nutrient removal strategies and stormwater BMPs, such as dry ponds, stormwater wetlands, wet ponds, infiltration systems, etc. When these BMPs were averaged together, the cost per pound of TP removal was $12,548.34, and the cost per pound of TN removal was $681.17 (McManus, 2019). **Table 8-6** below indicates the cost of TN and TP removal per Scenario compared to the existing condition. For simplification, this cost was converted to kilograms, and a rounded cost of $1500 per kilogram of TN and $27,600 per kilogram of TP were assigned to the removal efficiencies for each Scenario. Red costs indicate estimated additional costs incurred to remove nutrients compared to the existing condition. Green costs indicate a cost savings in nutrient removal compared to the existing condition.

Table 8-6. TN and TP Pollutant Loads and Removal Costs by Scenario.

Scenario	Scenario	TN Load (kg/yr)	TP Load (kg/yr)	TN Removal Cost (Relative to Existing)	TP Removal Cost (Relative to Existing)
Existing	Existing	35.65	1.88	--	--
1	Without Treatment	269.72	40.66	+$351,105	+$1,070,328
	Wet Detention Option	158.34	11.60	+$184,035	+$268,272

	Dry Retention Option	6.75	1.02	-$43,350	-$23,736
2	Without Treatment	218.00	32.97	+$273,525	+$858,084
	Wet Detention Option	126.87	8.745	+$136,830	+$189,474
	Dry Retention Option	4.5	0.68	-$46,725	-$33,120
3	Without Treatment	165.26	25.27	+$194,415	+$645,564
	Wet Detention Option	94.8	6.07	+$88,725	+$115,644
	Dry Retention Option	2.90	0.045	-$49,125	-$50,646

The dry retention options within each scenario provided generous cost savings as water quality resulted in a net improvement in these conditions compared to the existing condition. Alternatively, the wet detention options within each scenario resulted in a net loss of water quality treatment, the effects of which are magnified by the high cost of treating stormwater leaving the developed site, a burden which may be imposed on the taxpayer.

Evaluating the replacement costs of flood attenuation in each scenario is complex, as the downstream discharge rates in all development scenarios are less than the existing condition, as required by law and demonstrated in Table 2. Although the three scenarios would meet the current permitting criteria for flood risk mitigation, the literature has shown that wetland alteration is positively linked to increases in property damage associated with flooding. Brody et al. (2007) analyzed 383 flood events in coastal Florida counties over a 5-year period coupled with spatial trends in wetland loss. Results indicated that the greatest predictor of property damage was the amount of precipitation, followed by adjacent damages, and the third most powerful predictor was wetland alteration. However, Highfield and Brody (2006) showed that individual wetland alteration permits located inside a special flood hazard zone had a greater impact on flood damages than precipitation. Brody et al. (2007) also demonstrated that one wetland alteration permit increased the costs associated with each flood in Florida by approximately $1,596 USD/2020, on average (Brody et al., 2007; Goldberg and Watkins, 2020).

When these values were extrapolated per county over the course of one year, one wetland alteration permit increased the costs of flood damages by $908,581 USD/2020 annually (Goldberg and Watkins, 2020).

Patton et al. (2015) estimated the economic value of carbon storage in wetlands in the U.S. National Wildlife Refuge System using methodology developed in 2006 by the Intergovernmental Panel on Climate Change Guidelines for Greenhouse Gas Inventories. The study assessed the carbon value of the Okefenokee National Wildlife Refuge, which borders southern Georgia and northern Florida. Okefenokee is comprised of 45% scrub-shrub wetlands, 43% forested wetlands, and 12% emergent marsh (Patton et al., 2015). While the wetland community type within the proposed development is unknown, results described in Section 3 indicate that forested wetlands are among the most prevalent community type in Orange County, and the mosaic of wetlands within Okefenokee is generally similar to those within Orange County. According to the study, an average wetland acre within Okefenokee stores carbon within its soils and plants that are equivalent to 0.52 billion grams of CO_2, which is the unit of carbon stock evaluated for social economic purposes. That volume of carbon storage holds a U.S. value of approximately $389 USD/2010 per acre, and a global value of $4,615 USD/2010 per acre. When these values are extrapolated over the 5.6 acres of wetlands impacted by the proposed development in 2023 dollars, carbon storage lost equates to a U.S. value of $3,030 USD/2023 and a global value of $35,955 USD/2023.

8.8 Conclusions and Recommendations

A coupled 2D surface water-groundwater ICPRv4 model and a separate BMP Trains water quality model was developed to evaluate the potential incidental impacts of a typical Orange County development. The ICPRv4 model simulates both groundwater and surface water dynamics over a 500-acre site area which includes the proposed 50-acre Development to simulate both onsite and offsite conditions, whereas the BMP Trains model calculates nutrient loading and stormwater BMP performance over just the 50-acre Development site. Using ICPRv4, design storm simulations were conducted to ensure that the development met typical environmental regulatory requirements and was conceptualized to generally meet regulatory design standards. Continuous simulations were performed to calculate the incidental impacts associated with the proposed Development with wetland loss under various scenarios.

A comparison of the existing and hypothetical development conditions helped quantify changes to aquifer recharge, downstream discharge, wetland hydroperiod, and water quality. The following conclusions are drawn:

1. **Developments with wetland loss generally do not increase flood risk**. Because the governing stormwater management criteria requires a pre vs. post peak discharge analysis for open basin systems, applicants must demonstrate that this peak discharge rate will not be exceeded after development has been completed. This regulation requires development engineers to incorporate existing wetlands' storage capacity and

flood prevention function that they serve, regardless of whether they may be impacted.

a. This conclusion assumes that the 25-year 24-hour storm event (and similar design storms) adequately address flood risk. Back-to-back major storm events, or rainfall events with depths greater than the standard design storms have not been analyzed, as those storm events are currently not regulated by typical land development codes. Analyzing these more intense storm events may reveal increased flood risk from the loss of wetland area if they are evaluated.

b. If the engineer performing the pre vs post discharge analysis does not properly account for depressional storage in the existing conditions, then peak discharge may increase in the post development condition during the regulated design storms. Properly accounting for existing hydrologic function is important in the development engineering and permit review phases.

c. Increases in impervious surfaces often lead to overall total surface water volume increases, which can create antecedent hydrologic conditions that may increase flood hazards offsite. The evaluation of this within Orange County was outside of the effort included in this report.

2. **Developments with wetland loss may reduce aquifer recharge.** When adding high amounts of new impervious area, more rainfall becomes runoff than infiltrating into the underlying soil. This loss of recharge may cause changes in the water table over time, which can contribute to functional decline of remaining wetland systems. The Development Scenario that incorporates low impact design (LID) approaches, which promote infiltrating stormwater BMPs and lower amounts of impervious area, more closely match the undeveloped aquifer recharge condition.

3. **Developments with wetland loss can adversely impact wetland hydroperiod offsite.** When development designs impede surface water or groundwater flow patterns and alter local hydrology, wetland hydroperiods may be impacted. This impact can cause a reduction in groundwater levels that can lead to functional decline in wetland systems that rely on consistent hydroperiods. Developments that mimic predevelopment drainage patterns can maintain or increase the hydroperiod of offsite wetlands, which is more likely to avoid long-term off-site wetland functional decline.

4. **Developments with wetland loss can adversely impact water quality discharges off-site.** Current stormwater management requirements often do not require a pre vs. post nutrient discharge analysis. Developments are typically assumed to have provided reasonable assurances that water quality impacts are avoided by constructing standard stormwater management infrastructure. Wet detention stormwater ponds are generally insufficient at fully mitigating nutrient pollutants generated from new development. Projects that focus on infiltration and retention-based stormwater BMPs perform significantly better and can meet or reduce the pre-development nutrient load discharges.

Additionally, natural wetland systems are not known to provide perpetual water quality treatment of stormwater discharges. With respect to nutrient loading, natural wetlands reach a state of equilibrium over time and assimilate and discharge nutrients regularly. Thus, these systems may reduce or increase the amount of nutrients that discharge to them depending on the type of wetland and the concentration of nutrients in the stormwater discharge. As such, natural wetlands should not be relied upon for long-term, perpetual stormwater treatment. Water quality should instead be managed completely onsite with stormwater BMPs or managed offsite by a regional stormwater treatment system.

These results demonstrate that development activities that are compliant with governing environmental regulations may still cause adverse impacts to off-site systems. The amount of these incidental impacts can vary widely depending on the specifics of each site and development. However, the design approach used to achieve the development is important. Projects that incorporate LID or similar approaches can have a significantly smaller impact on the surrounding environment, while still meeting the goals of the underlying development. Regulations are therefore critical to guide responsible development activities.

Recommendations

The following regulatory recommendations are provided to improve the outcomes of development activities related to wetland function. These recommendations are intended to be associated with Orange County's wetland ordinance, Article X, and development review standards.

1. Require applicants seeking a wetland impact permit to provide detailed flow maps of the project site and any off-site wetlands within a specified boundary. Flow maps are commonly provided as part of engineering design submittals and would ensure that, to the extent practicable, existing hydrologic patterns are mimicked after construction. The flow maps should reference existing conditions, post-development conditions, and clearly indicate and describe any discrepancies between the two conditions.
2. Currently, the County's development review process for wetland impacts includes a review of potential wetland hydroperiods impacts. However, this review is not formally written in the Orange County code. Codifying this review process would require applicants to demonstrate that off-site wetland hydroperiods will not be significantly impacted by development activities. The County could also develop a more stringent hydroperiod review process for vulnerable wetlands, or wetlands that are rare or rapidly declining within Orange County. Through this State of the Wetlands study, it has been found that wet prairies are a vulnerable habitat within the County. Wet prairies rely on a consistent hydroperiod to sustain their unique composition of flora that provides habitat for a wide variety of wildlife species. Codifying wetland hydroperiod consistency requirements for development activities would aid in protecting these vulnerable wetland communities.
3. Wetlands used for on- or off-site mitigation to compensate for development activities should require groundwater monitoring and reporting for 5-10 years to assess long-term

hydroperiod effects. Applicants are currently required to monitor wetland function and maintain invasive species for mitigated wetlands for 5 years. Additionally, the updated wetland ordinance (Article X) will likely include new requirements for monitoring and maintenance in perpetuity. Therefore, requiring groundwater monitoring should result in only a moderate additional effort and cost for the applicant.

Data gained from these efforts would allow Orange County to study long-term groundwater trends in wetlands and evaluate whether wetland hydroperiods should be more strictly regulated. This data would be especially useful in southwestern Orange County, where the Central Florida Water Initiative and the State of the Wetlands Study have determined significant groundwater losses and vulnerability due to long-term groundwater withdrawals.

Ideally, having a groundwater data logger installed in the wetland monitoring well to capture daily or hourly groundwater levels would occur. This continuous data is very important to understand how groundwater levels fluctuate during and after storm events and can capture the periodicity of groundwater heads at a very fine resolution. Manually reading groundwater levels at quarterly inspections would likely not provide the County with actionable data. However, pressure transducers and data loggers are more expensive than manually reading groundwater depths during routine inspections. Therefore, the County may want to consider installing groundwater depth loggers at the County's expense using wells installed by applicants. This may include a permit condition that the County can access and monitor groundwater conditions.

4. Establish a wetland impact permitting incentive for applicants that incorporate Low Impact Design and achieve high pollutant reduction criteria in their project design. This incentive could be in the form of a permit review modifier that would reduce the number of permit approvals needed to obtain a permit and may therefore reduce the timeline for permit issuance. The incentivized modifier could also reduce the level of effort required by the applicant by reducing the number or intensity of analysis required to obtain a permit, such as a limited Cumulative Impact Assessment or the elimination of an Alternatives Analysis.

The County should evaluate the flood risk of wetland loss associated with more intense design storms than is currently performed. This analysis could assume back-to-back storms or storm events with a greater depth of rain, to assess the potential impact to floodplains under increasingly more intense rain events that the County is experiencing.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Summary of Results

This section of the report provides a synthesis of the results obtained in the State of the Wetlands study, particularly highlighting those that can provide guidance to the development of new wetland policy and monitoring approaches. Based on this comprehensive study, several significant:

- Total wetland area, not including water, within Orange County increased from 158,959 acres in 1990 to 162,683 acres in 2022, a 2.3% increase or 3,723 acres. It is important to note, however, that the total wetland area in 2022 includes over 10,000 acres of restored freshwater marshland from the Lake Apopka restoration area that took place between 1990-2000. Without this restoration effort, which is unrelated to a wetland mitigation effort or permitting, the county would have experienced a **loss of 4.09% in wetland area** from 1990 through 2022. These findings indicate that **mitigation projects are not keeping pace with the loss of wetlands** that is occurring due to urban development and other LULC changes.

- Out of the seven wetland land cover classifications that were included in the wetland API mapping, four increased in acreage – cypress (+16%), freshwater marshes (+34%), hydric pine flatwoods (+114%), and other wetlands (+131%). Three wetland types decreased in acreage, including mixed scrub-shrub wetlands (-17%), wet prairie habitats (-39%), and mixed wetland forests/hardwoods (-22%). These **compositional changes can impact overall wetland health in the county, alter hydrology, and change biological diversity**.

- Based upon the comparison of the functional assessments found in the permit files and current assessments, **35 of the 51 mitigation areas have lost functionality through time**. Many of these functional losses are attributable to the compensatory mitigation location, connectivity, buffer, hydrology, and percentage of exotic vegetation found within the wetland and even in the adjacent buffers. **Sites with buffers tended to maintain function better over time compared to sites without buffers**. Wetland mitigation areas located in adjacent industrial areas were more likely to decline in overall function. Many of these industrial wetland mitigation areas lacked buffers, showed signs of dumping and littering, lacked hydrologic connections, and had a high percentage of exotics.

- The wetland fragmentation analysis results show an **increasing trend towards more wetland habitat fragmentation at the landscape level**. Fragmentation has also led to an increase in shape complexity, loss of contiguity, and an increase in disjunct core areas within some existing wetland patches. Loss of contiguity and more disjunct core areas indicates some wetlands are losing connectivity, not only to other neighboring wetland patches, but within contiguous wetland patches. All of which can lead to a net loss of wetland function within Orange County.
- Two of the seven wetland classes were found to have limited disaggregation and fragmentation impacts - cypress and freshwater marshes. The five other classes – hydric pine flatwoods, mixed wetland forests, mixed scrub/shrub, wet prairies, and other wetlands - had model results that clearly indicated fragmentation and disaggregation were occurring, even as some of them were gaining area.
- Based on hotspots of wetland losses and analyses of potential future risk of wetland loss, **the most vulnerable remaining wetland areas within Orange County include**:
    - **St. Johns River – upper and lower portions**
    - **Shingle Creek**
    - **Cypress Creek**
- Results of the wetland persistence analysis reveal that **about half of the wetlands in Orange County have remained the same wetland type in the same location from 1990 to 2022**. And the majority of wetland land cover, over 80%, has persisted as one wetland type or another through the same 32-year period.
- Many factors may influence wetland loss in Orange County. Of those investigated in this spatial analysis effort, **FEMA Flood Zones and OFW status showed the most consistent relationship with rates of wetland loss. This likely reflects that these factors provide important regulatory protection for wetland areas and help prevent their destruction**.
- Groundwater modeling results suggest both major pumping centers and drawdown from long-term water withdrawals can impact wetlands in Orange County. Results suggest major pumping centers and long-term withdrawals have more impact on Upper Floridian Aquifer levels with the greater impacts to the Surficial Aquifer System felt in areas where

there is more connectivity between the SAS and UFA. Therefore, **groundwater-impacted wetlands in western Orange County would generally be expected to feel more of the effects of major pumping centers and long-term withdrawals** as there is greater connectivity between the SAS and UFA in that portion of the County.

- Results from the conceptual development scenarios demonstrate that development activities that are compliant with governing environmental regulations may still cause adverse impacts to off-site systems. The amount of these incidental impacts can vary widely depending on the specifics of each site and development. However, the design approach used to achieve the development is important. **Projects that incorporate LID or similar approaches can have a significantly smaller impact on the surrounding environment, while still meeting the goals of the underlying development**. Regulations are therefore critical to guide responsible development activities.

9.2 Conclusions and Recommendations

Many of the changes that occurred within Orange County between 1990 and 2022 were driven by population growth and the subsequent land use and land cover changes that accompanied it. Additional impacts on wetland habitats have also occurred from the expansion of the infrastructure needed to support this growth (i.e., roads and highways, wastewater facilities, etc.) and have changed the wetland mosaic across the county. As the county is forecasted to continue to grow by potentially another half million residents over the next 30 years, there is a risk of net wetland loss in less developed areas of the county, such as the Econlockhatchee and St. Johns watersheds. If urban development fueled by population growth continues in the county, preserving wetland areas will become more challenging, especially in the western parts of the county where most of the growth is occurring; however, wetland losses have already occurred in rural areas of the county well outside of urban land cover. In response to this risk, the continued use of the protection areas and the growth planning of Vision 2050 will be instrumental in balancing future development with minimal wetland impacts.

Additionally, maintaining a "no net loss" objective is dependent on ensuring longevity of the County's mitigation areas. Based upon the field functional assessments, the project team noted that the following make a significant difference in the success of the compensatory mitigation: location, buffers, buffer size, buffer management, hydrology, connectivity, exotic/nuisance species removal, fire management, buffer planting, and perpetual maintenance especially of exotic/nuisance species. The compensatory mitigation failures appear to be attributed to project location, hydrology, and the high percentage of invasive species present regardless of community type. The greatest non-successful mitigation areas were found in industrial areas, golf courses, and commercial areas, especially those that lacked buffers. In addition, the project team noted that those mitigation areas that are being regularly utilized by humans have the greatest amounts of trash and exotic presence within the disturbed areas. The most successful mitigation areas were those that had large upland buffers, those whose upland buffers and wetlands were periodically burned with prescribed fire, and those that were directly connected to larger natural areas through hydrologic features and/or uplands.

Based on the comprehensive analyses of the wetland mapping, functional analysis, and spatial assessments, several recommendations have been formulated that can provide guidance to the development of wetland policy countywide:

- The project team noted that several buffer areas were planted with slash pine trees (*Pinus elliottii*). **If buffer plantings are recommended in the future, they should not include slash pine trees unless the adjacent community is a hydric pine flatwood that also contains slash pine**. Planting buffer areas with slash pines has led to the encroachment of pine into the adjacent communities, especially the freshwater marsh and wet prairie mitigation areas, changing the succession of the community from a diverse herbaceous system into a pine dominated wetland. Slash pine, based on its relatively fast germination rate, and moisture tolerability, is capable of quickly dominating herbaceous wetlands, such as wet prairie, resulting in a loss of biodiversity, particularly within the herbaceous groundcover. Given that fire, a tool that can be used to limit the invasion of slash pines, may not be logistically feasible for many of the non-forested wetland mitigation areas, slash pines should not be planted within the mitigation area or the upland buffers. If plantings are needed along the upland buffers of non-forested wetland systems, species associated with upland grassland/dry prairies that are readily available at native nurseries should be selected, such as wiregrass (*Aristida stricta*), saw palmetto (*Serenoa repens*), lopsided Indiangrass (*Sorghastrum secundum*), bluestem broomsedge (*Andropogon virginicus*), narrowleaf silkgrass (*Pityopsis graminifolia*), coastal plain staggerbush (*Lyonia fruticosa*) and/or toothache grass (*Ctenium aromaticum*).
- **All project sites that serve as compensatory mitigation should include perpetual maintenance if wetland function is a mitigation priority.** Perpetual maintenance should include exotic/nuisance species removal throughout the entire mitigation area and upland buffer, trash removal, and fire management as necessary. This perpetual management should not only emphasize the removal of invasive species, but also take into consideration the wetland habitat that was present during permitting and **remove vegetation that would not be found naturally within these habitat types**. This would include, for example, the removal of intruding shrub and canopy species in non-forested wetland systems, the removal of intruding pines in cypress systems, and the removal of intruding shrub and hardwood species in pine dominated systems, even if these species are native to Florida. Though native, species such as laurel oak, slash pine, wax myrtle, elderberry, and many more can alter the biodiversity of wetlands when not adequately controlled. For example, laurel oak can out compete young pines and herbaceous

ground cover when not controlled in hydric pine flatwoods, which can result in the loss of biodiversity.

- Invasive/exotic control efforts in mitigation areas should **maintain less than 5% exotic/nuisance species on any property, upland or wetland buffer, mitigation area or remaining wetland area**. Although less than 1% invasive/exotic coverage would be more desirable, implementing a 5% rule would be easier to enforce and is likely to be more politically acceptable. Based upon the site inspections and review of the mitigation monitoring reports, permit success in the past may have been achieved with less than 5% or 10% exotics in the wetland mitigation area. However, over time, the 5% to 10% exotic species presence, without appropriate long-term maintenance, would quickly exceed this threshold. This process was observed during the filed assessments with many sites containing 25% to over 50% exotics throughout the mitigation area. To obtain a no net loss of wetland function, it is vital that the County include perpetual property management, in the form of maintenance of the associated wetland areas within the permit boundaries and an associated upland buffer.
- If a wetland is permitted in an unnatural state for mitigation, such as a wet pasture, the permittee should be required to research and find the historic habitat type that was present prior to any anthropogenic impacts and plan on restoring the wetland based on these findings. The research should consider historic aerials, soil types, neighboring habitats, historic maps, current vegetation, etc., when determining the historic habitat type.
- Based on results from the groundwater modeling effort discussed in Section 7, several policy recommendations have been formulated:
    - **Develop the Orange County Water Use Caution Area (OCWUCA)**, which would be located in southwestern Orange County and bound by the County border, Interstate 4, State Road 408 and the Florida Turnpike. **On-site practices would include monitoring wetland hydrology, installing groundwater monitoring wells to evaluate water level changes over time, investigate identified groundwater-impacted wetlands, and develop a "Wetland Protection Strategy"** for the region using the "Recovery Strategy" developed for the 5,100 square mile "Southern Water Use Caution Area", which encompasses portions or all or Desoto, Hardee, Manatee, Sarasota, Charlotte, Highlands, Hillsborough, and Polk counties, as a general guide (https://www.swfwmd.state.fl.us/projects/southern-water-use-caution-area).
    - Continue to incorporate regulations and guidance related to wetland impacts provided in the "Central Florida Water Initiative, Supplement Applicant's Handbook" effective as of January 5, 2022.

  - **Promote the use of low-impact development (LID), other infiltrating BMPs (e.g., rapid infiltration basins), and the reduction of impervious surface areas** throughout the County to facilitate increased recharge to the SAS and UFA. Increasing recharge to the SAS and UFA can help reduce the water level declines from future groundwater withdrawals. Such reductions in would in turn lead to reduced impacts to wetlands from water level changes.

- The following regulatory recommendations, which are further discussed in Section 8, are provided to improve the outcomes of development activities related to wetland function. These recommendations are intended to be associated with Orange County's wetland ordinance, Article X, and development review standards:
  - **Require applicants seeking a wetland impact permit to provide detailed flow maps of the project site and any off-site wetlands** within a specified boundary to indicate differences between pre- and post-construction conditions.
  - Codify the County's development review process for hydroperiod review, which would require applicants to demonstrate that off-site wetland hydroperiods will not be significantly impacted by development activities.
  - Wetlands used for on- or off-site mitigation to compensate for development activities should **require groundwater monitoring and reporting for 5-10 years to assess long-term hydroperiod effects**.
  - Establish a wetland impact permitting incentive for applicants that incorporate Low Impact Design and achieve high pollutant reduction criteria in their project design.
  - **Evaluate the flood risk of wetland loss associated with more intense design storms** than is currently performed. This analysis could assume back-to-back storms or storm events with a greater depth of rain, to assess the potential impact to floodplains under increasingly more intense rain events that the County is experiencing.

Additional Recommendations:

- Require a significantly sized natural upland buffer to be established and appropriately managed, including providing an allowable list of plant species by wetland type.
- Protecting small wetlands, particularly those most vulnerable due to significant losses in the past 30 years (i.e. wet prairies), which is critical to maintaining biodiversity.
- Incorporate protection for uplands, as wetlands are inter-connected ecologically to upland habitats and fragmentation and isolation of these habitats will impact both wetland and upland ecological function.
- Consider the impacts of new development and infrastructure projects on the fragmentation and disaggregation of larger, contiguous wetlands and the impacts that edge effects can have on sensitive wetland habitats.

- Develop permitting policies that promote the retention of wetland connectivity.
- Include boundary length to area ratios in policy decisions that maintain compactness and interconnectedness of wetlands to promote the preservation of larger core areas that will improve function and increase resilience.
- Maintain high functioning wetland systems, increase their footprints, and limit further fragmentation to benefit all wetlands and help maintain biodiversity.
- Expand the assessment and the use of remote sensing technologies including UAS and satellite data (Sentinel 1 and 2) in classifying wetlands and assessing wetland function and health.
- Institute a monitoring system on a regular schedule (i.e., every 5 years) to assess wetland function in mitigation areas, or Countywide, including hydrology, connectivity, buffers, fragmentation, biodiversity, and exotics/invasive species cover. This can be achieved by the combined use of remote sensing techniques (updating wetland inventory, wetland health assessment) with field assessment for selected sentinel wetlands.
- Update and improve wetland permitting procedures and file management systems to include all relevant data for each permit, to provide the County with a wealth of data to assess and track wetland impacts over time:
    - Update relational database with GIS capabilities that would allow the access/viewing of permitting information by location.
    - Database improvements that include proposed acreage impacts, avoided/minimized wetland acreage, permitted acreage impacts, community type(s), mitigation type and acreage, final permit status, conservation easement status, and compliance issues

10 REFERENCES

Ameli, A. A., & Creed, I. F. (2019). Groundwaters at risk: wetland loss changes sources, lengthens pathways, and decelerates rejuvenation of groundwater resources. JAWRA Journal of the American Water Resources Association, 55(2), 294-306.

An, S. & Verhoeven, J. (2019). In A. Shuqing, & T. A. Jos (Eds.), Wetlands: Ecosystem services, restoration and wise use, 1st edn. Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-030-14861 -4.

Beck, T. J., Gawlik, D. E., & Pearlstine, E. V. (2013). Community patterns in treatment wetlands, natural wetlands, and croplands in Florida. The Wilson Journal of Ornithology, 125(2), 329-341.

Bonds, M. H., & Pompe, J. J. (2003). Calculating wetland mitigation banking credits: adjusting for wetland function and location. Natural Resources Journal, 961-977.

Brody, S. D., Zahran, S., Maghelal, P., Grover, H., & Highfield, W. E. (2007). The rising costs of floods: Examining the impact of planning and development decisions on property damage in Florida. Journal of the American Planning Association, 73(3), 330-345.

Brody, S. D., Davis, S. E., Highfield, W. E., & Bernhardt, S. P. (2008). A spatial-temporal analysis of section 404 wetland permitting in Texas and Florida: Thirteen years of impact along the coast. Wetlands, 28, 107-116.

Brown, M. T., Schaefer, J. M., and Brandt, K. H. (1990). Buffer Zones for Water, Wetlands and Wildlife in East Central Florida. Florida Agricultural Experiment Stations Journal Series: T-00061. Accessed via 21-Buffer-Zones-for-Water-Wetlands-and-Wildlife-in-East-Central-Florida.pdf (unioncounty-fl.gov)

Bullock, A., & Acreman, M. (2003). The role of wetlands in the hydrological cycle. Hydrology and Earth System Sciences, 7(3), 358-389.

Cassani, J. R., Croshaw, D. A., Bozzo, J., Brooks, B., Everham III, E. M., Ceilley, D. W., & Hanson, D. (2015). Herpetofaunal community change in multiple habitats after fifteen years in a southwest Florida preserve, USA. PLoS one, 10(5), e0125845.

Castelle, A. J., Conolly, C., Emers, M., Metz, E. D., Meyer, S., Witter, M., Mauermann, S., Erickson, T. &. Cooke, S. S. (1992). Wetland Buffers: Use and Effectiveness. Adolfson Associates, Inc., Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, Pub. No. 92-10.

Central Florida Water Initiative's Environmental Measures Team. (2020a). Assessment of Effects of Groundwater Withdrawals on Groundwater-Dominated Wetlands in the Central Florida Water Initiative Planning Area. Accessed via EMT_Final_Report_08-24-2020.pdf (cfwiwater.com).

Central Florida Water Initiative (CFWI). (2020b). 2020 Regional Water Supply Plan.

Central Florida Water Initiative (CFWI). (2020c). 2020 Regional Water Supply Plan, Appendices.

Central Florida Water Initiative (CFWI). (2020d). Model Documentation Report East-Central Florida Transient Expanded (ECFTX) Model.

Central Florida Water Initiative's Environmental Measures Team. November 2013. Development of Environmental Measures for Assessing Effects of Water Level Changes on Lakes and Wetlands in the Central Florida Water Initiative Area. Accessed via https://cfwiwater.com/pdfs/CFWI_Environmental_Measures_finalreport.pdf.

Chasmer, L., Mahoney, C., Millard, K., Nelson, K., Peters, D., Merchant, M., ... & Cobbaert, D. (2020). Remote sensing of boreal wetlands 2: methods for evaluating boreal wetland ecosystem state and drivers of change. Remote Sensing, 12(8), 1321.

Cheesman AW, Dunne EJ, Turner BL, Reddy KR. (2010). Soil phosphorus forms in hydrologically isolated wetlands and surrounding pasture uplands. J Environmental Quality. 39:1517–1525.

Chen, T. S., & Lin, H. J. (2011). Application of a landscape development intensity index for assessing wetlands in Taiwan. Wetlands, 31(4), 745-756.

Clewell, A. F., Goolsby, J. A., & Shuey, A. G. (1982). Riverine forests of the South Prong Alafia River System, Florida. Wetlands 2:21-72.

Cohen, M. J., Creed, I. F., Alexander, L., Basu, N. B., Calhoun, A. J., Craft, C., ... & Walls, S. C. (2016). Do geographically isolated wetlands influence landscape functions? Proceedings of the National Academy of Sciences, 113(8), 1978-1986.

Collins, J. P. (2010). Amphibian decline and extinction: what we know and what we need to learn. Dis Aquatc Organ. 92:93–99.

Costanza, R., Pérez-Maqueo, O., Martinez, M. L., Sutton, P., Anderson, S. J., & Mulder, K. (2008). The value of coastal wetlands for hurricane protection. Ambio, 241-248.

Davila, A., & Bohlen, P. J. (2021). Hydro-ecological Controls on Soil Carbon Storage in Subtropical Freshwater Depressional Wetlands. Wetlands: Official Scholarly Journal of the Society of Wetland Scientists, 41(5). https://doi-org.portal.lib.fit.edu/10.1007/s13157-021-01453-2.

DeLotelle, R. S., Epting, R. J., Costa, R., Leonard, D., Morris, V., & NeSmith, K. (2018). The Red-cockaded Woodpecker in South Central Florida: ecology, habitat, and behavior. Florida Scientist, 81(4), 126-156.

Dertien J.S., Self S., Ross B.E., Barrett K., & Baldwin R.F. (2020). The relationship between biodiversity and wetland cover varies across regions of the conterminous United States. PLoS ONE 15(5): e0232052. https://doi.org/10.1371/ journal.pone.0232052

Donnelly, J. P., Moore, J. N., Casazza, M. L., & Coons, S. P. (2022). Functional wetland loss drives emerging risks to waterbird migration networks. Frontiers in Ecology and Evolution, 10, 844278.

Dooley, J. M., & Brown, M. T. (2020). The quantitative relation between ambient soundscapes and landscape development intensity in North Central Florida. Landscape Ecology, 35(1), 113-127.

Dunne, E. J., Coveney, M. F., Marzolf, E. R., Hoge, V. R., Conrow, R., Naleway, R., ... & Battoe, L. E. (2012). Efficacy of a large-scale constructed wetland to remove phosphorus and suspended solids from Lake Apopka, Florida. Ecological Engineering, 42, 90-100.

Drummond Carpenter, PLLC. (2023). Orange County Groundwater Vulnerability Assessment. Final Report developed for Orange County' Environmental Protection Division. Orange County, FL.

Environmental Law Institute. (2003). Conservation Thresholds for Land Use Planners. Environmental Law Institute, Washington D.C. Accessed via Conservation Thresholds (eli.org)

Environmental Law Institute. (2008). Planner's Guide to Wetland Buffers for Local Governments. Environmental Law Institute, Washington D.C. Accessed via Planner's Guide to Wetland Buffers for Local Governments | Environmental Law Institute (eli.org).

Environmental Protection Commission of Hillsborough County. (2006). Developing Scientifically-Based Ecological Buffers to Protect the Watersheds in Hillsborough County, Florida. Accessed via Tech-Memo-Buffers-01-25-2006.pdf (usf.edu).

Ewers, R. M., & Didham, R. K. (2008). Pervasive impact of large-scale edge effects on a beetle community. Proceedings of the National Academy of Sciences, 105(14), 5426-5429.

FDEP (Florida Department of Environmental Protection). (2022). Summary of the wetland and other surface water regulatory and proprietary program in Florida. Tallahassee, FL. http://www.dep.state.fl.us/water/wetlands/docs/erp/overview.pdf

Findlay, C. S., & Bourdages, J. (2000). Response time of wetland biodiversity to road construction on adjacent lands. Conservation Biology, 14(1), 86-94.

Fletcher Jr, R. J. (2005). Multiple edge effects and their implications in fragmented landscapes. Journal of Animal Ecology, 74(2), 342-352.

Florida Fish and Wildlife (FWC). (2022). https://myfwc.com/conservation/freshwater/wetland-habitat/.

Frohn, R. C., Autrey, B. C., Lane, C. R., & Reif, M. (2011). Segmentation and object-oriented classification of wetlands in a karst Florida landscape using multi-season Landsat-7 ETM+ imagery. International Journal of Remote Sensing, 32(5), 1471-1489.

Giannetti, B. F., Barrella, F. A., & Almeida, C. M. V. B. (2006). A combined tool for environmental scientists and decision makers: ternary diagrams and emergy accounting. Journal of cleaner production, 14(2), 201-210.

Goddard, Nathaniel L. (2010). "Bird Communities of Isolated Cypress Wetlands Along an Urban Gradient in Hillsborough County, Florida" Graduate Theses and Dissertations. https://scholarcommons.usf.edu/etd/1643

Goldberg, N. & Reiss, K.C. (2016). Accounting for wetland loss: wetland mitigation trends in northeast Florida 2006–2013. Wetlands 36:373–384

Goldberg, N. & Watkins, R.L. (2021). Spatial comparisons in wetland loss, mitigation, and flood hazards among watersheds in the lower St. Johns River basin, northeastern Florida, USA. Natural Hazards, 109:1743-57.

Gross, F.E.H. (1987). Characteristics of small stream floodplain ecosystems in North and Central Florida. MS Thesis (CFW-87-01). Gainesville, FL. University of Florida, pp. 167.

Haag, K. H., Lee, T. M., & Water, T. B. (2010). Hydrology and ecology of freshwater wetlands in central Florida: a primer. Reston, VA, USA: US Geological Survey.

Harbor, J. M. (1994). A practical method for estimating the impact of land-use change on surface runoff, groundwater recharge and wetland hydrology. Journal of the American Planning Association, 60(1), 95-108.

Hart, R. (1984). Evaluation of methods for sampling vegetation and delineating wetlands transition zones in coastal West-Central Florida, January 1979-May 1981.

Highfield, W. E., & Brody, S. D. (2006). Price of permits: Measuring the economic impacts of wetland development on flood damages in Florida. Natural Hazards Review, 7(3), 123-130.

Highfield, W. E., Norman, S. A., & Brody, S. D. (2013). Examining the 100 ‐ year floodplain as a metric of risk, loss, and household adjustment. Risk Analysis: An International Journal, 33(2), 186-191.

Houlahan, J. E., & Findlay, C. S. (2003). The effects of adjacent land use on wetland amphibian species richness and community composition. *Canadian Journal of Fisheries & Aquatic Sciences*, 60(9), 1078–1094. https://doi-org.portal.lib.fit.edu/10.1139/f03-095

Hu, T., Liu, J., Zheng, G., Zhang, D., & Huang, K. (2020). Evaluation of historical and future wetland degradation using remote sensing imagery and land use modeling. Land Degradation & Development, 31(1), 65-80.

Jacobs, A. D., Kentula, M. E., & Herlihy, A. T. (2010). Developing an index of wetland condition from ecological data: an example using HGM functional variables from the Nanticoke watershed, USA. Ecological Indicators, 10(3), 703-712.

Jones, Edmunds, and Associates, Inc. (JEA). (2000). Calculating Buffer Zone Widths for Protection of Wetlands and other Environmentally Sensitive Lands in St. John's County. Accessed via JEA_Brown_Hamann_2000_CalculatingBufferZoneWidths-ProtectWetlands-StJohnsCty.pdf (ufl.edu).

Kayranli, B., Scholz, M., Mustafa, A., & Hedmark, Å. (2010). Carbon storage and fluxes within freshwater wetlands: a critical review. Wetlands, 30, 111-124.

Kim, H. W., & Park, Y. (2016). Urban green infrastructure and local flooding: The impact of landscape patterns on peak runoff in four Texas MSAs. Applied geography, 77, 72-81.

Klemas, V. (2011). Remote sensing of wetlands: case studies comparing practical techniques. Journal of Coastal Research, 27(3), 418-427.

Klemas, V. (2013). Remote sensing of emergent and submerged wetlands: An overview. International Journal of Remote Sensing, 34(18), 6286-6320.

Kurz, D. J. (2013). Restored wetlands can support mammalian assemblages comparable to those in nonmitigated reference wetlands. The American Midland Naturalist, 170(2), 260-273.

Lane, C. R., & Autrey, B. C. (2016). Phosphorus retention of forested and emergent marsh depressional wetlands in differing land uses in Florida, USA. Wetlands ecology and management, 24(1), 45-60.

Lane, C. R., & D'Amico, E. (2010). Calculating the ecosystem service of water storage in isolated wetlands using LiDAR in North Central Florida, USA. Wetlands, 30(5), 967-977.

Larkin, J. L., Maehr, D. S., Hoctor, T. S., Orlando, M. A., & Whitney, K. (2004, January). Landscape linkages and conservation planning for the black bear in west-central Florida. In Animal Conservation forum (Vol. 7, No. 1, pp. 23-34). Cambridge University Press.

Lee, T. M. (2002). Factors Affecting Ground-Water Exchange and Catchment Size for Florida lakes in Mantled Karst Terrain. Water Resources Investigations Report 02-4003. U.S. Department of the Interior, U.S. Geological Survey. Prepared in Cooperation with the Southwest Florida Water Management District and the St. John's River Water Management District.

Lee, T. M., Haag, K. H., Metz, P. A., & Sacks, L. A. (2009). Comparative Hydrology, Water Quality, and Ecology of Selected Natural and Augmented Freshwater Wetlands in West-Central Florida. U.S. Geological Survey. Accessed via pp1758_lowrez.pdf (usgs.gov).

Levrel, H., Scemama, P., & Vaissière, A. C. (2017). Should we be wary of mitigation banking? Evidence regarding the risks associated with this wetland offset arrangement in Florida. Ecological Economics, 135, 136-149.

Liao, H., Wdowinski, S., & Li, S. (2020). Regional-scale hydrological monitoring of wetlands with Sentinel-1 InSAR observations: Case study of the South Florida Everglades. Remote Sensing of Environment, 251, 112051.

Ma, Z., Cai, Y., Li, B., & Chen, J. (2010). Managing wetland habitats for waterbirds: an international perspective. Wetlands, 30(1), 15-27.

Main, R., Cho, M. A., Mathieu, R., O'Kennedy, M. M., Ramoelo, A., & Koch, S. (2011). An investigation into robust spectral indices for leaf chlorophyll estimation. ISPRS Journal of Photogrammetry and Remote Sensing, 66(6), 751-761.

Mahdavi, S., Salehi, B., Granger, J., Amani, M., Brisco, B., & Huang, W. (2018). Remote sensing for wetland classification: A comprehensive review. GIScience & Remote Sensing, 55(5), 623-658.

Mahdianpari, M., Salehi, B., Mohammadimanesh, F., Homayouni, S., & Gill, E. (2018). The first wetland inventory map of newfoundland at a spatial resolution of 10 m using sentinel-1 and sentinel-2 data on the google earth engine cloud computing platform. Remote Sensing, 11(1), 43.

McCauley, L. A., Jenkins, D. G., & Quintana-Ascencio, P. F. (2013). Isolated Wetland Loss and Degradation Over Two Decades in an Increasingly Urbanized Landscape. Wetlands: Official Scholarly Journal of the Society of Wetland Scientists, 33(1), 117–127. https://doi-org.portal.lib.fit.edu/10.1007/s13157-012-0357-x

McClellan, M., Comas, X., Benscoter, B., Hinkle, R., & Sumner, D. (2017). Estimating belowground carbon stocks in isolated wetlands of the Northern Everglades Watershed, central Florida, using ground penetrating radar and aerial imagery. Journal of Geophysical Research: Biogeosciences, 122, 2804–2816. https://doi.org/10.1002/ 2016JG003573

McGarigal, K. (2002). FRAGSTATS: Spatial Pattern Analysis Prog-ram for Categorical Maps. Computer software program produced by the authors at the University of Massachuse-tts, Amherst. www. umass. edu/landeco/research/fragstats/fragstats. html.

McKinney, M. L. (2008). Effects of urbanization on species richness: a review of plants and animals. Urban ecosystems, 11(2), 161-176.

McLaughlin, D. L., & Cohen, M. J. (2013). Realizing ecosystem services: wetland hydrologic function along a gradient of ecosystem condition. Ecological Applications, 23(7), 1619-1631.

McManus, C., Kirk, E., & Rosenfeld, C. (2019). Literature Review: Cost-Effectiveness of Nutrient Removal Practices. University of North Carolina, School of Government, Environmental Finance Center. Accessed via Literature-Review_Cost-Effectiveness-of-Nutrient-Removal-Practices.pdf (unc.edu).

Middleton, B. (2016). Succession in Wetlands. In: , et al. The Wetland Book. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-6172-8_1-2

Miller, K. M., Mitchell, B. R., & McGill, B. J. (2016). Constructing multimetric indices and testing ability of landscape metrics to assess condition of freshwater wetlands in the Northeastern US. Ecological Indicators, 66, 143-152.

Misra, G., Cawkwell, F., & Wingler, A. (2020). Status of phenological research using Sentinel-2 data: A review. Remote Sensing, 12(17), 2760.

Mitchell, M. G., Bennett, E. M., & Gonzalez, A. (2013). Linking landscape connectivity and ecosystem service provision: current knowledge and research gaps. Ecosystems, 16(5), 894-908.

Nestlerode, J. A., Hansen, V. D., Teague, A., & Harwell, M. C. (2014). Application of a three-tier framework to assess ecological condition of Gulf of Mexico coastal wetlands. Environmental Monitoring and Assessment, 186(6), 3477-3493.

Nilsson, K. A., Rains, M. C., Lewis, D. B., & Trout, K. E. (2013). Hydrologic characterization of 56 geographically isolated wetlands in west-central Florida using a probabilistic method. Wetlands Ecology and Management, 21, 1-14.

Northwest Florida Water Management District. (2017). Ochlockonee River and Bay Watershed: Surface Water Improvement and Management Plan. Accessed via SWIM Plan Updates: 2015 - 2017 | Northwest Florida Water Management District (nwfwater.com).

Novitski, R. P. (1985). The effects of lakes and wetlands on flood flows and base flows in selected northern and eastern states. Proc. Conf. on Wetlands of the Chesapeake, Easton, Maryland: Environmental Law Institute, pp 143-154.

Odum, H. T. (1996). Environmental Accounting: Emergy and Environmental Decision Making. John Wiley and Sons, New York.

Ogden, J. C., Baldwin, J. D., Bass, O. L., Browder, J. A., Cook, M. I., Frederick, P. C., ... & Lorenz, J. J. (2014). Waterbirds as indicators of ecosystem health in the coastal marine habitats of southern Florida: 1. Selection and justification for a suite of indicator species. Ecological indicators, 44, 148-163.

Olsen, A. R., Kincaid, T. M., Kentula, M. E., & Weber, M. H. (2019). Survey design to assess condition of wetlands in the United States. Environmental Monitoring and Assessment, 191(1), 1-16.

Owley, J. (2015). Preservation Is a Flawed Mitigation Strategy. Ecology L. Currents, 42, 101.

Ozesmi, S. L., & Bauer, M. E. (2002). Satellite remote sensing of wetlands. Wetlands ecology and management, 10, 381-402.

Patton, D., Bergstrom, J. C., Moore, R., & Covich, A. P. (2015). Economic value of carbon storage in US National Wildlife Refuge wetland ecosystems. Ecosystem Services, 16, 94-104.

Rains, M.C., Landry, S., Rains, K.C., Seidel, V. & Crisman, T.L. (2013). Using net wetland loss, current wetland condition, and planned future watershed condition for wetland conservation planning and prioritization, Tampa Bay Watershed, Florida. Wetlands, 33(5), 949-963.

Reiss, K. C. (2006). Florida Wetland Condition Index for depressional forested wetlands. Ecological Indicators, 6(2), 337-352.

Reiss, K. C., & Brown, M. T. (2007). An evaluation of Florida depressional wetlands: application of US EPA levels 1, 2, and 3 assessment methods. EcoHealth, 4, 206–218.

Reiss. (2008). Wetland Mitigation: Which Function. *Water Resources IMPACT*.

Reiss, K. C., Hernandez, E., & Brown, M. T. (2009). Evaluation of permit success in wetland mitigation banking: a Florida case study. Wetlands, 29(3), 907-918.

Reiss, K. C., Hernandez, E., Brown, M. T., & Preserve, K. P. (2007). An evaluation of the effectiveness of mitigation banking in Florida: ecological success and compliance with permit criteria. Final report. Florida Department of Environmental Protection (# WM881), Tallahassee, FL and US Environmental Protection Agency (# CD96409404-0), Washington, DC.

Reiss, K. C., Hernandez, E., & Brown, M. T. (2014). Application of the landscape development intensity (LDI) index in wetland mitigation banking. Ecological modelling, 271, 83-89.

Rodewald, P. G., & Matthews, S. N. (2005). Landbird use of riparian and upland forest stopover habitats in an urban landscape. *The Condor*, *107*(2), 259-268.

Roe, J. H., & Georges, A. (2007). Heterogeneous wetland complexes, buffer zones, and travel corridors: landscape management for freshwater reptiles. Biological Conservation, 135(1), 67-76.

Roe, J. H., Gibson, J., & Kingsbury, B. A. (2006). Beyond the wetland border: estimating the impact of roads for two species of water snakes. Biological Conservation, 130(2), 161-168.

Romañach, S. S., D'Acunto, L. E., Chapman, J. P., & Hanson, M. R. (2021). Small mammal responses to wetland restoration in the Greater Everglades ecosystem. Restoration Ecology, 29(3), e13332.

Salas, E. A. L., & Henebry, G. M. (2013). A new approach for the analysis of hyperspectral data: Theory and sensitivity analysis of the Moment Distance Method. Remote sensing, 6(1), 20-41.

Sarah A. Stankavich, Gregory A. Smith, David J. Kurz, A. Justin Nowakowski, & Nicholas A. McGinty. (2013). Restored Wetlands Can Support Mammalian Assemblages Comparable to Those in Nonmitigated Reference Wetlands. The American Midland Naturalist, 170, 260–273. https://doi-org.portal.lib.fit.edu/10.1674/0003-0031-170.2.260

Sawatzky, M. E., Martin, A. E., & Fahrig, L. (2019). Landscape context is more important than wetland buffers for farmland amphibians. Agriculture, Ecosystems & Environment, 269, 97-106.

Semlitsch, R. D., & Jensen, J. B. (2001). Core habitat, not buffer zone. National wetlands newsletter, 23(4), 5-6.

Slagter, B., Tsendbazar, N. E., Vollrath, A., & Reiche, J. (2020). Mapping wetland characteristics using temporally dense Sentinel-1 and Sentinel-2 data: A case study in the St. Lucia wetlands, South Africa. International Journal of Applied Earth Observation and Geoinformation, 86, 102009.

Tabarelli, M., Lopes, A. V., & Peres, C. A. (2008). Edge‐effects drive tropical forest fragments towards an early‐successional system. Biotropica, 40(6), 657-661.

Talukdar, S., Eibek, K. U., Akhter, S., Ziaul, S. K., Islam, A. R. M. T., & Mallick, J. (2021). Modeling fragmentation probability of land-use and land-cover using the bagging, random forest and random subspace in the Teesta River Basin, Bangladesh. Ecological indicators, 126, 107612.

Tozer, D. C., Nol, E., & Abraham, K. F. (2010). Effects of local and landscape-scale habitat variables on abundance and reproductive success of wetland birds. Wetlands Ecology and Management, 18(6), 679-693.

Uden, D. R., Hellman, M. L., Angeler, D. G., & Allen, C. R. (2014). The role of reserves and anthropogenic habitats for functional connectivity and resilience of ephemeral wetlands. Ecological Applications, 24(7), 1569-1582.

U.S. EPA (2006). Elements of a State Water Monitoring and Assessment Program for Wetlands. Washington, DC: US EPA. http://www.epa.gov/owow/wetlands/pdf/Wetland_Elements_Final.pdf.

Vaissière, A. C., & Levrel, H. (2015). Biodiversity offset markets: What are they really? An empirical approach to wetland mitigation banking. *Ecological Economics*, *110*, 81-88.

Vickers, C. R., Harris, L. D., & Swindel, B. F. (1985). Changes in herpetofauna resulting from ditching of cypress ponds in coastal plains flatwoods. Forest Ecology and Management, 11(1-2), 17-29.

Waddle, J. H., Glorioso, B. M., & Faulkner, S. P. (2013). A quantitative assessment of the conservation benefits of the Wetlands Reserve Program to amphibians. Restoration Ecology, 21(2), 200-206.

Waddle, J. H., Glorioso, B. M., & Faulkner, S. P. (2013). A quantitative assessment of the conservation benefits of the Wetlands Reserve Program to amphibians. Restoration Ecology, 21(2), 200-206.

Wheeler, K. I., Levia, D. F., & Vargas, R. (2020). Visible and near-infrared hyperspectral indices explain more variation in lower-crown leaf nitrogen concentrations in autumn than in summer. Oecologia, 192(1), 13-27.

Whigham, D. F., Chitterling, C., & Palmer, B. (1988). Impacts of freshwater wetlands on water quality: a landscape perspective. Environmental management, 12, 663-671.

Widney, S., Kanabrocki Klein, A., Ehman, J., Hackney, C., & Craft, C. (2018). The value of wetlands for water quality improvement: an example from the St. Johns River watershed, Florida. Wetlands Ecology and Management, 26(3), 265-276.

Wu, W., Zhou, Y., & Tian, B. (2017). Coastal wetlands facing climate change and anthropogenic activities: A remote sensing analysis and modelling application. Ocean and Coastal Management, 138, 1–10. https://doi-org.portal.lib.fit.edu/10.1016/j.ocecoaman.2017.01.005

Xue, J., & Su, B. (2017). Significant remote sensing vegetation indices: A review of developments and applications. Journal of sensors, 2017.

Zakaria, M., & Rajpar, M. N. (2014). Assessing the habitat suitability of two different artificial wetland habitats using avian community structures. American Journal of Applied Sciences, 11(8), 1321.

Zamberletti, P., Zaffaroni, M., Accatino, F., Creed, I. F., & De Michele, C. (2018). Connectivity among wetlands matters for vulnerable amphibian populations in wetlandscapes. Ecological Modelling, 384, 119-127.

11 APPENDICES

Appendix A – Data Sources

Table A-1. Availability of the United States Census Bureau decennial census block groups for Orange County, FL. The 1970-2010 censuses have been made available by the University of Florida Geocenter with all available demographic information. The 2020 census block groups were acquired from the US Census Bureau and then joined with the available population data tables.

Year	Data Category	Spatial Type	Description	Source	Link to Data Source
1990	Census	Polygon	Demographic and socioeconomic data	UF Geocenter	https://www.fgdl.org/
2000		Polygon	Demographic and socioeconomic data	Oak Ridge National Laboratory	https://landscan.ornl.gov/
2010		Polygon	Demographic and socioeconomic data	Oak Ridge National Laboratory	https://landscan.ornl.gov/
2020		Polygon	Demographic and socioeconomic data	Oak Ridge National Laboratory	https://landscan.ornl.gov/

Table A-2. Availability of aerial orthophoto imagery of Orange County, FL. All imagery listed below is available as a georeferenced raster product.

Data Name	Year	Data Category	Source	True Color	CIR	Data Resolution	County Coverage
USGS NHAP	1984	Aerial Imagery	USGS Earth Explorer	N	Y	1 ft	100%
USGS Aerial Photo Single Frames	1990	Aerial Imagery	USGS Earth Explorer	N	N	1 ft	20%
LABINS Aerial Imagery	1995	Aerial Imagery	LABINS	N	Y	1 ft	100%
LABINS Aerial Imagery	1999	Aerial Imagery	LABINS	N	Y	1 ft	100%
FDOT Aerial Imagery	2009	Aerial Imagery	APLUS	Y	Y	1 ft	100%
Orange County Aerial Imagery	2022	Aerial Imagery	Orange County	Y	N	1 ft	100%

Table A-3. Availability of Land Use Land Cover (LULC) spatial data for Orange County, FL.

Data Name	Year	Data Category	Source	Data Type	Data Resolution	County Coverage
SFWMD 1995 Land Use	1995	Land Use	SFWMD	Polygon		35%
SJRWMD 1995 Land Use	1995	Land Use	SJRWMD	Polygon		80%
SFWMD 1999 Land Use	1999	Land Use	SFWMD	Polygon		30%
SJRWMD 1999 Land Use	1999	Land Use	SJRWMD	Polygon		80%
SFWMD 2004 Land Use	2004	Land Use	SFWMD	Polygon		30%
SJRWMD 2004 Land Use	2004	Land Use	SJRWMD	Polygon		80%
SJRWMD 2009 Land Use	2009	Land Use	SJRWMD	Polygon		80%
SFWMD 2008/2009 Land Use	2009	Land Use	SFWMD	Polygon		35%
SJRWMD 2014 Land Use	2014	Land Use	SJRWMD	Polygon		80%
SFWMD 2017 Land Use	2017	Land Use	SFWMD	Polygon		35%
NWI	2022	Wetlands	US Fish & Wildlife	Polygon		100%
Green PLACE Boundaries	Unknown	Unknown	Orange County	Polygon		
Green PLACE Natural Communities	Unknown	Unknown	Orange County	Polygon		
CAD Data	1994-2011	Unknown	Orange County	Polygon		

Appendix B – Wetland Functional Assessment Summaries

State of the Wetlands – Orange County, Florida

SITE 1

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

8/26/2022

Description

The mitigation area was in a residential setting which had sufficient buffers to support wildlife usage. The water environment was extremely good as a majority of the wetland had evidence of hydrology and the cypress areas were inundated with 18" of water at the time of inspection. Additional water marks were found on the trunks to the cypress trees. The wetland vegetative community along the periphery includes exotics such as blackberry, Chinese tallow, and Brazilian pepper. The wetland community beyond the initial periphery of the system included desirable vegetation such as pond and bald cypress, red maple, pickerelweed, duck weed, swamp fern and chain fern. A rare species, the jingle bell orchid, was identified in several cypress trees.

State of the Wetlands – Orange County, Florida

SITE 2

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

9/2/2022

APPLIED ECOLOGY INC

Description

The mitigation area is in a residential setting that had sufficient buffers and connectivity to other systems to support wildlife. The hydrology was appropriate for the wetland, with mucky soils and buttress roots. There was no standing water in the mixed hardwood habitat, though the down slope mixed-scrub shrub wetland had standing water. There were scattered invasive species around the upland buffer of the wetland, however the interior of the wetlands was dominated by native species such as royal fern, Carolina willow, water oak, lizard's tail, red maple, tupelo, and American elm.

State of the Wetlands – Orange County, Florida

SITE 3

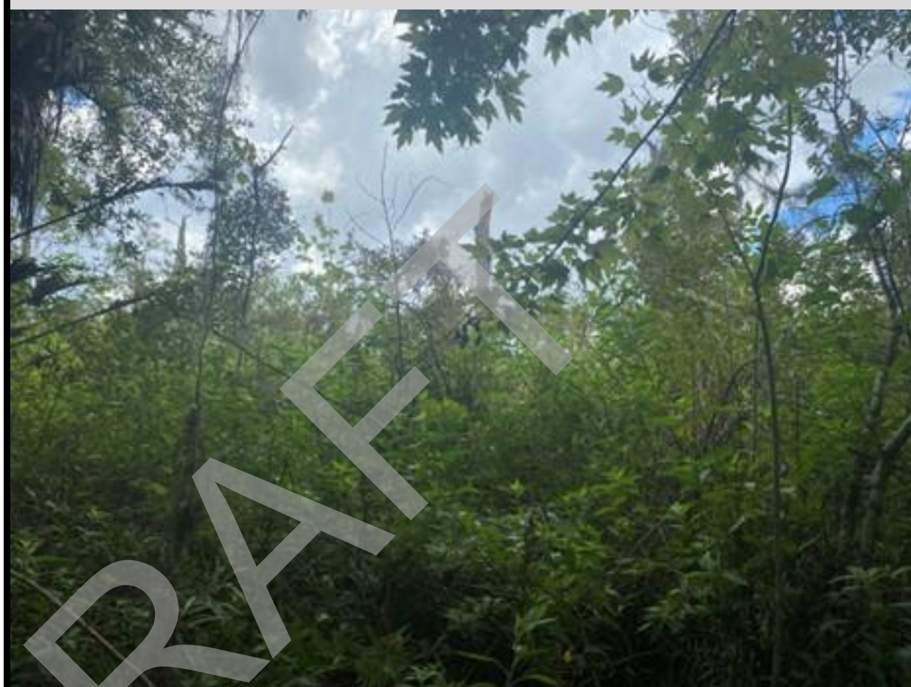
Mitigated Wetland Functional Assessment

Community Type

Mixed Scrub-Shrub Wetlands

Picture Date

9/2/2022



Description

The mitigation area is in a residential setting that had sufficient buffers and connectivity to other systems to support wildlife. The hydrology was appropriate for the wetland, with standing water, mucky soils, and adventitious rooting. The wetland was largely infested with Peruvian primrose willow throughout, with roughly 25-50% of the study area being covered by invasive species. Native vegetation includes wax myrtle, Carolina willow, Virginia chain-fern, American groundnut, and red maple.

State of the Wetlands – Orange County, Florida

SITE 4

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

9/21/2022

Description

The mitigation area is primarily surrounded by residential areas, with a community sports park to the south. The wetland is part of a much larger wetland system that has good hydrological connectivity. The hydrology is appropriate, with standing water present down slope towards a bordering cypress swamp. There is a sufficient upland buffer to allow for good wildlife usage and support. There are minor amounts of caesar weed around the edge of the site. Most of the vegetation coverage is native, including long leaf pine, laurel oak, red bay, sabal palm, saw palm, swamp fern, and sweet bay.

State of the Wetlands – Orange County, Florida

SITE 5

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

8/26/2022

Description

The mitigation area is primarily surrounded by residential areas to the east, and the Little Econ to the west. The wetland is part of a much larger wetland system that has good hydrological connectivity. Water levels seem low considering the vegetation, with no standing water evident. There are areas of sphagnum moss that display signs of seepage. There is a sufficient upland buffer to allow for good wildlife usage and support. There are minor amounts of caesar weed around the edge of the site, and large swaths of grape vine around the edges that are choking out desirable species. Most of the vegetation coverage within the core of the wetland is native, including long leaf pine, water oak, sweet gm, pond pine, swamp bay, loblolly bay, wax myrtle, saw palmetto, centella, and cinnamon fern.

State of the Wetlands – Orange County, Florida

SITE 6

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

8/29/2022

Description

The mitigation area is surrounded by managed natural communities, with a large pine flatwoods community to the south, and a large continuous cypress community in all other directions. The system is connected to Shingle Creek which allows for adequate habitat for hydrologically dependent wildlife. The water level is appropriate, with much of the site having 2-3ft of standing water. Most of the trees have buttress roots and "knees" or pneumatophoress. Vegetative species found within the mitigation area include bald cypress, pond cypress, dahoon holly, pond pine, duck potato, pickerel weed, swamp smartweed, spider orchid, little blue maiden cane, and cattail.

State of the Wetlands – Orange County, Florida

SITE 7

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

8/29/2022

Description

The mitigation area is surrounded entirely by industrial usage. There is little-to-no hydrological connectivity to surrounding wetlands. There was no evidence of wildlife utilization. The water level seemed very low for the habitat type, and time of year. Vegetation, such as Brazilian pepper, Chinese tallow, and elderberry, found within the core of the cypress system shows that there are minimal periods of inundation. The edge of the system has dense amounts of Brazilian pepper and Caesar weed. Other vegetation found within the core includes bald cypress, tupelo, royal fern, sabal palm, red maple, and dahoon holly.

State of the Wetlands – Orange County, Florida

SITE 8

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

8/31/2022

Description

The mitigation area is surrounded by natural communities to the west and north, and vacant land and major roadways to the east and south. Despite being connected to a very large wetland system, there is very little natural upland buffer for the mitigation area. Hydrology is sufficient, with connectivity to other wetland areas, and appropriate amounts standing water, and water flow, There are very high percentages of invasive coverage throughout the site, primarily strawberry guava, and Peruvian primrose willow. Dominant native vegetation including cypress, tupelo, dahoon holly, red maple, fetterbush, royal fern, swamp fern, and cinnamon fern.

State of the Wetlands – Orange County, Florida

SITE 9

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

8/31/2022

Description

The mitigation site is surrounded by a golf course and residential setting. There is minimal connectivity to other wetland features through culverts present within the golf course. Water levels are appropriate for wetland type with roughly 18″ of standing water. There are signs of nutrient runoff within the wetland, with algal blooms seen along the edges of the marsh. The vegetation found within the wetland was nearly entirely invasive, with the dominant species being torpedo grass. Other species found are Peruvian primrose willow, Carolina willow, young bald cypress around the edges.

State of the Wetlands – Orange County, Florida

SITE 10

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

9/9/2022

Description

The mitigation area is surrounded by residential and industrial areas. The system is very isolated, with no connectivity to outside water systems. Hydrology was minimal, with no standing water other than a ditch along the western boundary of the mitigation area. The upland buffer is sufficient in size, though invasive species are still prevalent throughout the entire site. Invasive species coverage is roughly 50%, with large amounts of air potato, Caesar weed, climbing fern, skunk vine, and tuberous sword fern. Native dominant vegetation includes slash pine, pond pine, laurel oak, live oak, saw palm, sabal palm, red maple, and elderberry.

State of the Wetlands – Orange County, Florida

SITE 11

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

8/26/2022

Description

The mitigation area is bordered by retail development to the north, east, and south, and residential to the west. The system is largely isolated, with only minor connectivity through culverts and roadside ditches. Hydrology is appropriate with standing water, mucky soils, stain lines, and adventitious rooting. The upland buffer is sufficient in size, though invasive species are still found throughout the entire site, along with garbage and construction debris. Invasive species found onsite include Brazilian pepper, Peruvian primrose willow, showy rattlebox, camphor tree, and Caesar weed. Native vegetation within the wetland includes Virginia chain fern, royal fern, dahoon holly, loblolly bay, sweet bay, fetterbush, slash pine, red maple, and Carolina willow.

State of the Wetlands – Orange County, Florida

SITE 12

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

10/31/2022

APPLIED ECOLOGY INC

Description

The mitigation area is bordered by retail development to the north, east, and south, and residential to the west. The system is largely isolated, with only minor connectivity through culverts and roadside ditches. The upland buffer is sufficient in size, though invasive species are still found throughout the entire site, along with garbage and construction debris. Hydric and muck soils were found within this community type, though there was no standing water found. Invasive species found on site includes Brazilian pepper and Caesar weed. Dominant native vegetation includes slash pine, pond pine, red maple, loblolly bay, saw palm, wax myrtle, gallberry, and swamp fern.

State of the Wetlands – Orange County, Florida

SITE 13

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

9/9/2022

Description

The mitigation site is surrounded by a golf course and residential setting. There is minimal connectivity to other wetland features through culverts present within the golf course. Water levels are appropriate for wetland type with roughly 18" of standing water, and this portion of the mitigation area is large enough to support hydrologically dependent wildlife species. Other signs of hydrology are buttress roots, mucky soils, and stain lines. There was evidence of hog rooting surrounding the edges of the mitigation area. Invasive coverage was minimal, with only small populations of tuberous sword fern present. Dominant native vegetation includes red maple, dahoon holly, sweet bay, cypress, and tupelo.

State of the Wetlands – Orange County, Florida

SITE 14

Mitigated Wetland Functional Assessment

Community Type

Hydric Pine Flatwoods

Picture Date

9/19/2022

Description

This mitigation area was originally permitted as a wet prairie. The compensatory mitigation included a requirement for slash pines to be planted within the buffer. The slash pines that were planted around the upland buffer have begun to encroach into the wetland, and now this species has become the dominant canopy and sub-canopy species. This will likely lead to the loss of native groundcover diversity. The increased density of pines seems to be altering the hydrology. There was no standing water during the site inspection, though there was evidence of historic standing water with hummocks and stain lines. This community is an entirely isolated depression. The upland buffer is very good and is large enough to support a population of gopher tortoises. Dominant vegetation is maiden cane, wax myrtle, slash pine, red maple, chain fern, and small populations of the endangered hooded pitcher plant.

State of the Wetlands – Orange County, Florida

SITE 15

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

9/19/2022

Description

The mitigation area has residential settings to the north and west, and open land and natural areas to the south and east. The wetland is an isolated depression marsh. The historically non-woody and herbaceous marsh shows signs of slash pine intrusion – likely due to lack of fire history, and potentially due to hydrology alterations. There were mucky soils, standing water, and hummocking present. Dominant vegetation found in the freshwater marsh included red root, chalky blue stem, and camphor weed.

SITE 16

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

9/19/2022

Description

The mitigation area has residential settings to the north and west, and open land and natural areas to the south and east. The wetland is an isolated depression marsh. The historically non-woody and herbaceous marsh shows signs of slash pine intrusion – likely due to lack of fire history, and potentially due to hydrology alterations. There were mucky soils, standing water, and hummocking present. Hog rooting was evident during the site assessment. The dominant vegetation found included red root, xyris, chalky blue stem, rhexia, red maple, and cinnamon fern.

State of the Wetlands – Orange County, Florida

SITE 17

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

9/19/2022

Description

The mitigation area has residential settings to the north and west, and open land and natural areas to the south and east. The wetland is an isolated cypress swamp. The hydrology is very good for the system, with standing water at roughly 2-3", buttress roots, mucky soils, stain lines, and "knees" or pneumatophores were all present. Little blue heron was seen during site visit. There were a couple Chinese tallow present, though overall, invasive coverage was minimal. Dominant vegetation includes bald cypress, dahoon holly, tupelo, pickerelweed, Virginia chain fern, swamp fern, cinnamon fern, wax myrtle, carex and grape vine.

State of the Wetlands – Orange County, Florida

SITE 18

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

9/19/2022

Description

The mitigation area is surrounded by a public park to the north, natural lands to the east, and residential to the west and south. The site was originally permitted as wet pasture, though since permitting, there has been successional growth of hardwoods. The hydrology seems to have been altered with the creation of berms along the east side of the wetland, which disconnects the site from a very large marsh. There was no standing water during the site inspection, though mucky soils were present. The canopy was nearly entirely red maple. The canopy coverage was very dense, shading out much of the understory. Other vegetation found on site included sweet bay, loblolly bay, Virginia chain fern, swamp fern, cinnamon fern, wax myrtle, and grape vine.

State of the Wetlands – Orange County, Florida

SITE 19

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

9/19/2022

Description

The mitigation area is surrounded by a public park to the south, pasture to the east and west, and natural lands/stormwater pond to the north. This site was originally permitted as pond pine, though likely due to fire suppression, the site now has a large presence of hardwood species coverage. There is moderate connectivity to surrounding wetlands through culverts. The soils during the site inspection were mucky, and there were scattered areas with standing water. Deer and evidence of hog rooting were observed during the site assessment. Dominant vegetation includes pond pine, red maple, swamp bay, long leaf pine, dahoon holly, water oak, Virginia chain fern, cinnamon fern, wax myrtle, and lizard's tail.

SITE 20

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

9/21/2022

Description

The mitigation area is in an industrial area, with an eight-lane highway to the north, and a pond to the east. There is minor connectivity with other wetlands through culverts and ditches, though this is the only natural community within the immediate area. There is standing water, though the level is lower than expected for the time of year the assessment was done. Other hydrological indicators found during the site inspection included mucky soils, stain lines, and buttress roots. A box turtle was seen within the mitigation area. There were high levels of invasive species coverage throughout much of the site. Vegetation found on site included cypress, tupelo, live oak, elephant ear, Virginia chain fern, cinnamon fern, royal fern, Brazilian pepper, fetterbush, button bush, and wax myrtle.

State of the Wetlands – Orange County, Florida

SITE 21

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

9/21/2022

Description

The mitigation area is primarily surrounded by residential areas, with natural areas to the east, on the opposite side of a two-land road. The wetland is part of a much larger wetland system that has been fragmented by a roadway. Hydrology was appropriate; water levels at the time of the site inspection was roughly 2-3 ft deep, and the cypress trees had buttressed roots. There is no upland buffer for this mitigation area. Invasive species coverage is very high around the edges of the system, primarily Peruvian primrose willow. Dominant vegetation includes cypress, Carolina willow, wax myrtle, long leaf pine, dahoon holly, Virginia chain fern, and red maple.

State of the Wetlands – Orange County, Florida

SITE 22

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

9/21/2022

Description

The mitigation area is in a residential setting. The wetland is entirely isolated apart from a culvert that connects the marsh to a lake roughly 100 ft away. There is no upland buffer between the mowed grassy areas and the mitigation area. The hydrology is appropriate, with no signs of vegetative stress, and normal water level, which allows for usage by hydrologically dependent wildlife. There are minor amounts of Peruvian primrose willow around the edges of the mitigation area. Dominant vegetation includes swamp fern, cattail, water lily, wax myrtle, Mexican primrose willow, pickerelweed, duck potato, and Carolina willow.

State of the Wetlands – Orange County, Florida

SITE 23

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

9/21/2022

Description

The mitigation area is located in a residential setting, with development to the north and south, a lake to the east, and natural communities to the west. The mitigation area is part of a much larger wetland system, which allows for the presence of hydrologically dependent wildlife. The water level during the site assessment appeared to be lower than normal. There are other signs of healthy hydrology, including the presence of mucky soils and adventitious rooting. The site was permitted as hydric pine, though due to fire suppression, the canopy now consisted of large amounts of hardwood species. Peruvian primrose willow coverage was very high in the sub-canopy. Other vegetation found within the mitigation area includes slash pine, sweet bay, swamp bay, dahoon holly, slash pine, Virginia chain fern, and royal fern.

SITE 24

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

10/31/2022

Description

The mitigation area is in an industrial setting, with warehouses to the west and a lake to the east. The site is a forested edge of a natural lake. There was no upland buffer. The edge of the development and wetland was covered in garbage. The water level was low considering the time of year of the site visit, though the soils were mucky. There were large amounts of dead vegetation within the mitigation area. Invasive species were dominant throughout the wetland, particularly along the edge nearest the warehouses, which was entirely comprised of Brazilian pepper and grape vine. Vegetation found within the core of the mitigation area included bald cypress, red maple, sweet bay, dahoon holly, wax myrtle, swamp fern, water oak, ear pod tree, climbing fern, and cogon grass.

State of the Wetlands – Orange County, Florida

SITE 25

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

11/8/2022

Description

The mitigation area is largely within a natural setting. To the north is a utility corridor and pine flatwoods. To the south and west are varying natural communities, and to the east is an apartment complex. There are large upland buffers surrounding the entire cypress swamp. The water environment was extremely good as a majority of the wetland had evidence of hydrology and the cypress areas were inundated with 18" of water at the time of inspection. Additional water marks were found on the trunks to the cypress trees. The vegetation community was comprised entirely of native species, including bald cypress, dahoon holly, tupelo, fetterbush, wax myrtle, swamp fern, Virginia chain fern, and grape vine.

State of the Wetlands – Orange County, Florida

SITE 26

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

11/8/2022

Description

The mitigation area is surrounded by pine flatwoods. The wetland was originally permitted as wet prairie, though based on our site assessment, the community was an isolated marsh system. The dense coverage of Peelbark St. John's wort (Hypericum fasciculatum) indicated that inundation periods were more aligned with freshwater marsh than wet prairie. The mitigation area is very small, less than an acre in size. There was no standing water during the site inspection, though there were hummocks and mucky soils. Dominant vegetation included Peelbark St. John's wort, slender flattop goldenrod, Aristida sp., and bushy bluestem.

State of the Wetlands – Orange County, Florida

SITE 27

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

11/8/2022

Description

The mitigation area is surrounded by pine flatwoods. This wetland area is a riverine system that connects to cypress swamps. Given the surrounding natural communities, the mitigation area offers ample upland buffer and habitat for wildlife. The hydrology was good during the time of visit, though it appeared that periods of high-water level may be causing canopy tree die off. The soils were mucky, and there was buttressing of roots. There were signs of hog rooting during the site inspection. Dominant vegetation was entirely native, including red maple, tupelo, laurel oak, water oak, saw grass, wax myrtle, saw palm, and swamp fern.

State of the Wetlands – Orange County, Florida

SITE 28

Mitigated Wetland Functional Assessment

Community Type

Wet Prairie

Picture Date

11/8/2022

Description

The mitigation area is surrounded by pine flatwoods, to the south and west, upland hardwoods to the east, and a utility corridor to the north. Given the surrounding natural communities, the mitigation area offers ample upland buffer and habitat for wildlife. Historically, the mitigation area was a larger wet prairie, though with fire suppression woody vegetation began encroaching. Now the mitigation area is roughly an acre in size. Hydrology seemed appropriate for the time of year and the habitat type. There was no standing water during the site inspection, though there were mucky soils and hummocking. Dominant vegetation includes bog buttons, peelbark St. John's wort, endangered hooded pitcher plant, xyris, bushy blue stem, and gallberry along the edges.

State of the Wetlands – Orange County, Florida

SITE 29

Mitigated Wetland Functional Assessment

Community Type

Wet Prairie

Picture Date

11/8/2022

Description

The mitigation area is surrounded by wetland hardwoods to the north, south, and west, with cypress to the east. Given the surrounding natural communities, the mitigation area offers ample upland buffer and habitat for wildlife. Historically, the mitigation area was a larger wet prairie, though with fire suppression woody vegetation began encroaching. Now the mitigation area is roughly an acre in size. Hydrology seemed appropriate for the time of year and the habitat type. There were small spots of standing water, mucky soils, and hummocking. Dominant species includes bog buttons, peelbark St. John's wort, coreopsis, xyris, bushy blue stem, pink sundew, wiregrass, and wax myrtle.

State of the Wetlands – Orange County, Florida

SITE 30

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

11/14/2022

Description

The mitigation area is within a busy urban area near multiple roads, highways, hotels, and restaurants. The wetland is bound between two berms and a channelized canal. Despite the development, there is appropriate hydrological connectivity through culverts. The wetland system is large enough to support large amounts of wildlife species. Wildlife documented while onsite includes wood stork, great white heron, great blue heron, wren, red bellied woodpecker, pileated woodpecker, cardinal, mockingbird, and deer. Water depth during the site inspection was roughly 18". There wasn't an upland buffer surrounding the cypress mitigation area. There were scattered amounts of invasive species, including Peruvian primrose willow. Most of the site was dominated by desirable native species, including cypress, dahoon holly, sweet bay, red maple, wax myrtle, lizard's tail, swamp fern, and cinnamon fern.

State of the Wetlands – Orange County, Florida

SITE 31

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

11/14/2022

Description

The mitigation area is within a busy urban area near multiple roads, highways, hotels, and restaurants. The wetland is bound between two berms and a channelized canal. Despite the development, there is appropriate hydrological connectivity through culverts. The wetland system is large enough to support large amounts of wildlife species. Wildlife documented while onsite includes wood stork, great white heron, great blue heron, wren, red bellied woodpecker, pileated woodpecker, cardinal, mockingbird, and deer. There were roughly 5-25% coverage of invasive species and noxious weeds, including Caesar weed, Virginia creeper, and grape vine. It was noted that there were multiple dead pine trees within the mitigation area. Dominant vegetation includes pond pine, dahoon holly, sweet bay, cabbage palm, red maple, wild coffee, beauty berry, wax myrtle, lizard's tail, swamp fern, and cinnamon fern.

SITE 32

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

11/21/2022

Description

The mitigation area is in a very residential area. There is a school to the north, and single-family houses in all other directions. This was a very isolated system with little-to-no connectivity. Despite the isolated nature, the hydrology was appropriate with normal water levels, mucky soils, and buttress roots. There was an appropriate upland buffer. The vegetation was nearly entirely native; species included red maple, tupelo, cypress, slash pine, laurel oak, sabal palm, highbush blueberry, Virginia willow, swamp fern, and cinnamon fern.

State of the Wetlands – Orange County, Florida

SITE 33

Mitigated Wetland Functional Assessment

Community Type

Hydric Pine Flatwoods

Picture Date

11/21/2022

Description

The mitigation area is in a residential setting, with high density residential to the west, and single-family homes to the east. To the north is a small lake, and to the south is a two-lane road that fragments the mitigation area from a neighboring wetland system. The wetland, though fragmented, is hydrologically connected through culverts to a much larger wetland system that ultimately flows south to the Everglades. The hydrology was appropriate with a normal water level, buttress roots, and hummocking. Given that the mitigation area neighbors a lake, there is good habitat for hydrologically dependent wildlife. The hydric pine community has an appropriate canopy coverage, though fire suppression has resulted in a nearly impenetrable subcanopy of saw palmetto. There is little-to-no upland buffer beyond the fill associated with the development. Along the edges of the mitigation area are tall stands of elderberry and Caesar weed. Dominant species within the core of the site are slash pine, red maple, loblolly bay, laurel oak, sweet bay, swamp bay, and wax myrtle.

State of the Wetlands – Orange County, Florida

SITE 34

Mitigated Wetland Functional Assessment

Community Type

Mixed Scrub-Shrub Wetland

Picture Date

11/21/2022

Description

The mitigation area is in a residential setting, with high density residential to the west, and single-family homes to the east. To the north is a small lake, and to the south is a two-lane road that fragments the mitigation area from a neighboring wetland system. The wetland, though fragmented, is hydrologically connected through culverts to a much larger wetland system that ultimately flows south to the Everglades. The hydrology was appropriate with a normal water level, buttress roots, and hummocking. Given that the mitigation area neighbors a lake, there is good habitat for hydrologically dependent wildlife. There is a large upland buffer bordering the wetland. The buffer is largely dominated by nuisance species such as black berry and grape vine. The core of the wetland has roughly 25% coverage of Peruvian primrose willow. Other dominant vegetation includes Carolina willow, wax myrtle, and swamp fern.

State of the Wetlands – Orange County, Florida

SITE 35

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

11/22/2022

Description

The mitigation area is within a residential setting and is completely isolated with no connectivity. There is a berm that runs north/south through the center of the wetland that is used as a utility corridor. Despite the isolation there is adequate hydrology and water levels. Lots of frogs were noted within the mitigation area. There are large amounts of invasive species along the edges of the system, particularly near the residential areas. Invasives include Brazilian pepper, Caesar weed, Chinese tallow, and cogon grass. Dominant vegetation within the mitigation area includes Carolina willow, wax myrtle, dahoon holly, red maple, Peruvian primrose willow, royal fern, Virginia chain fern, saw grass, and torpedo grass.

State of the Wetlands – Orange County, Florida

SITE 36

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

11/22/2022

Description

The mitigation area is surrounded by rural and natural landscapes. To the east is low density residential, to the west is varying managed natural communities. The mitigation area is a part of a much larger riverine system that is hydrologically connected to the Everglades. There are appropriate upland buffers for this mitigation area that provides adequate filtration from the neighboring rural communities. Given the size and unimpeded connectivity of the wetland there is adequate resources to support hydrologically dependent wildlife. The hydrology was very good and had appropriate flow, water level, mucky soils, stain lines, algal matting, buttress roots, and hummocks. There were no invasive species seen during the site inspection. Dominant vegetation include cypress, tupelo, American elm, red maple, sweet gum, Walter's viburnum, sabal palm, saw palm, lizard's tail, and wood oats.

State of the Wetlands – Orange County, Florida

SITE 37

Mitigated Wetland Functional Assessment

Community Type

Hydric Pine Flatwoods

Picture Date

11/30/2022

Description

The mitigation area is within a managed natural community. The hydric pine flatwoods community has upland pine flatwoods to the east, and wetland forested mixed to the east. The mitigation area is a part of a much larger wetland system that is hydrologically connected to the Everglades. There are appropriate upland buffers from the neighboring upland pine flatwoods. The size and health of the mitigation area provides appropriate resources to hydrologically dependent wildlife. The hydrology was appropriate with occasional spots of standing water, mucky soils, and hummocking. Scorch marks are found on most of the pines, showing that routine burns are done in the area when necessary. The lack of dense understory shows that the burns are successful in maintaining a healthy understory. No invasive species were seen during the site inspection. Dominant vegetation includes slash pine, long leaf pine, chalky bluestem, cinnamon fern, wire grass, and gallberry.

State of the Wetlands – Orange County, Florida

SITE 38

Mitigated Wetland Functional Assessment

Community Type

Cypress

Picture Date

11/30/2022

Description

The mitigation area is within a managed natural community that has upland pine flatwoods to the east, and wetland forested mixed to the east. Low density residential/rural lands are found 100 ft to the north. It is a part of a much larger wetland system that is hydrologically connected to the Everglades. There are appropriate upland buffers from the neighboring upland pine flatwoods. The size and health of the area provides appropriate resources to hydrologically dependent wildlife. The hydrology was appropriate with roughly 12" of standing water, mucky soils, buttress roots and "knees" or pneumatophores. Scorch marks on the edge cypress trees shows periodic prescribed burns were creeping in. This appeared to be beneficial, as there was high diversity of herbaceous species and minimal subcanopy coverage. There were minimal amounts of climbing fern on some cypress trees. Dominant species found within the mitigation area includes cypress, tupelo, dahoon holly, slash pine, fetterbush, saw palm, pipewort, Andropogon, Xyris, nodding club moss, and wax myrtle. Also present were three endangered species: hooded pitcher plant, jingle bell orchid, and northern needleleaf air plant.

State of the Wetlands – Orange County, Florida

SITE 39

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

12/5/2022

Description

The mitigation area is within a residential setting, with high density residential in all directions. The marsh is isolated in nature, and is bordered by upland forested mixed habitat, which provides appropriate upland buffering. The hydrology is appropriate, with normal standing water roughly 18" in depth, mucky soils, and adventitious rooting. The mitigation area and upland buffers are adequate in size and provide appropriate resources for wildlife. During the site assessment, evidence of hog rooting was noted. No invasive plant species were seen during the site visit. Dominant vegetation includes peelbark St. John's wort, maiden cane, pickerelweed, wax myrtle, Carolina willow, and button bush. Wax myrtle seems to be spreading within the mitigation area.

State of the Wetlands – Orange County, Florida

SITE 40

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

12/5/2022

Description

The mitigation area is within a residential setting, with high density residential in all directions. The marsh is isolated in nature, and is bordered by upland forested mixed habitat, which provides appropriate upland buffering. The hydrology is appropriate, with normal standing water roughly 18" in depth, mucky soils, and adventitious rooting. No invasive plant species were seen during the site visit. Dominant vegetation includes peelbark St. John's wort, maiden cane, pickerelweed, wax myrtle, Carolina willow, and button bush. It was noted that wax myrtle seems to be spreading within the mitigation area.

State of the Wetlands – Orange County, Florida

SITE 41

Mitigated Wetland Functional Assessment

Community Type

Hydric Pine Flatwoods

Picture Date

12/5/2022

Description

The mitigation area is within a managed natural community. The hydric pine flatwoods community has upland pine flatwoods and cypress to the south, and wetland forested mixed to the north. The mitigation area is a part of a much larger wetland system that is hydrologically connected to the Everglades. There are appropriate upland buffers from the neighboring upland pine flatwoods. The size and health of the mitigation area provides appropriate resources for hydrologically dependent wildlife. The hydrology of this area was appropriate considering it was towards the upper edges of the wetland. There were no invasive species seen, however there was stress to canopy species, with several dead pine trees present. The slash pine trees were extremely dense as you got deeper into the hydric pine community, which resulted in the shading out any subcanopy and groundcover vegetation. Dominant vegetation, primarily along the upper edges of the hydric pine, includes slash pine, bushy bluestem, Virginia chain fern, cinnamon fern, sugarcane plume grass, and grape vine.

State of the Wetlands – Orange County, Florida

SITE 42

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

12/5/2022

Description

The mitigation area is in an industrial area, with an eight-lane highway to the north, and a pond to the northeast. There is minor connectivity with other wetlands through culverts and ditches, though this is the only natural community within the immediate area. There is standing water, though the level is lower than expected for the time of year the assessment was done. Other hydrological indicators found during the site inspection included mucky soils, stain lines, and buttress roots. There is little-to-no upland buffer. There is sediment found on the leaves of the bordering shrub, likely originating from nearby industrial activities. Dominant vegetation includes pickerelweed, cattail, Andropogon, wax myrtle, Carolina willow, and Peruvian primrose.

State of the Wetlands – Orange County, Florida

SITE 43

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

12/5/2022

Description

The mitigation area is in an urban setting with industrial usage to the north and single-family housing to the south. The wetland is largely isolated and fragmented; only hydrologically connected through culverts under roadways. The wetland is large enough to support hydrologically dependent wildlife. There are little-to-no upland buffers surrounding the mitigation area. The hydrology was appropriate with 2-3′ of standing water, mucky soils, and buttress roots. There were minor amounts of climbing fern around the edges of the mitigation area. Dominant vegetation includes peelbark St. John’s wort, swamp fern, Virginia chain fern, xyris, sugarcane plume grass, wax myrtle, bald cypress, and slash pine creeping around the edges.

State of the Wetlands – Orange County, Florida

SITE 44

Mitigated Wetland Functional Assessment

Community Type

Mixed Scrub-Shrub Wetland

Picture Date

12/7/2022

Description

The mitigation area has natural communities to the north, and high density residential to the south. The mitigation area is a part of a much larger system that is hydrologically connected via canals and lakes to the south, and ultimately to the Everglades. The water level seemed low during the site visit, considering the time of year. The wetland was originally permitted as wet pasture, though has begun to go through successional phasing and is currently mixed scrub-shrub. There are adequate upland buffers, however they are primarily comprised of noxious weeds such as grape vine and black berry. There are berms that disconnect the upland buffer from the mitigation area. The edge of the wetland contains large amounts of Caesar weed and Chinese tallow. The core of the mixed scrub-shrub wetland is primarily comprised of wax myrtle and Peruvian primrose willow, with a ground cover of Virginia chain fern, and creeping primrose willow.

State of the Wetlands – Orange County, Florida

SITE 45

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

12/7/2022

Description

The mitigation area is primarily surrounded by a natural landscape, though there is a small two-lane road directly to the south of the site. The wetland is part of a much larger wetland system that is fragmented by roadways. The system ultimately flows south and is hydrologically connected to the Everglades. East of the site is hydric pine flatwoods, west of the site is a forested riverine system. Hydrology was very good and has an appropriate water level roughly 1-2 ft deep, mucky soils, and buttress roots. The hydrology and size of the system provides adequate resources for hydrologically dependent wildlife. Along the edge of the system, where the road runs, are small amounts of climbing fern and Caesar weed. Vegetation found within the wetland includes Virginia chain fern, swamp fern, duck potato, bald cypress, and wax myrtle and slash pine creeping in along the edges.

State of the Wetlands – Orange County, Florida

SITE 46

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

12/12/2022

Description

The mitigation area is in a largely urban landscape, surrounded by hotels and resorts. The wetland is entirely isolated, and only hydrologically connected by stormwater ditches and culverts. The location likely limits usage by hydrologically dependent wildlife. The water level was appropriate, soils were mucky, and vegetation had hummocking. There were no signs of invasive species during the site assessment. Dominant vegetation includes sweet bay, long leaf pine, red maple, Virginia chain fern, cinnamon fern, royal fern, swamp fern, Florida rein orchid, and lizard's tail.

State of the Wetlands – Orange County, Florida

SITE 47

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

12/12/2022

Description

The mitigation area is in a residential setting. There is single-family housing to the east and a large mixed scrub-shrub wetland to the west that is associated with a small lake. The wetland was originally permitted as hydric pine flatwoods, however due to fire suppression hardwood species have begun to dominate the canopy. The mitigation area was notably dry for the season, although there were signs of hydrology with stain lines and adventitious rooting. No standing water was seen during the site inspection. There was an upland buffer dominated by noxious weeds such as black berry, grape vine, and poison ivy. Vegetation within the mitigation area includes dahoon holly, red maple, water oak, pond pine, Chinese tallow, Peruvian primrose willow, Carolina willow, swamp fern, sword fern, Caesar weed, and cogon grass. Most of the dahoon hollies were covered in grape vine. The density of the vegetation may limit wildlife usage.

State of the Wetlands – Orange County, Florida

SITE 48

Mitigated Wetland Functional Assessment

Community Type

Mixed Wetland Hardwoods

Wetland Forested Mixed

Picture Date

12/12/2022

Description

The mitigation area is in a residential setting. There is single-family housing to the east and a large mixed scrub-shrub wetland to the west that is associated with a small lake. There is no upland buffer present. The hydrology was very good with 2-3 ft of standing water, buttress roots, algal matting, water stains, and adventitious rooting. The size of the system and hydrology should provide the necessary resources to support hydrologically dependent wildlife. Small fish were seen during the site assessment. There were minor amounts of Peruvian primrose willow within the mitigation area. Dominant vegetation includes dahoon holly, sweet bay, red maple, tupelo, slash pine, and swamp fern.

SITE 49

Mitigated Wetland Functional Assessment

Community Type

Hydric Pine Flatwoods

Picture Date

12/12/2022

Description

The mitigation area is within an urban setting, bordered by a four-lane road to the east, and west. On either side of the roads are forested wetlands. The wetland is hydrologically connected to larger systems, though they are fragmented by the roadways. The water environment of the mitigation area is very good with 1-2 ft of standing water, lichen lines, adventitious rooting, and mucky soils. A slight flow of water was noted running through the wetland. The size of the system and hydrology connection with other systems should support hydrologically dependent wildlife. Snakeskin and small fish were seen during the site inspection. There were very minor amounts of Peruvian primrose willow seen within the wetland. Dominant vegetation found includes pond pine, slash pine, dahoon holly, sweet bay, red maple, saw palmetto, wax myrtle, cinnamon fern, royal fern, and swam fern.

State of the Wetlands – Orange County, Florida

SITE 50

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

12/8/2022

Description

Mitigation is in a largely disturbed, unnatural setting. All surrounding landscapes are mowed and used for utilities. The uplands surrounding the marsh were historically sandhill. The wetland is an isolated depressional system. The water levels at the time were high, though there had recently been large rain events. The uplands surrounding the marsh are usually uninterrupted by human disturbances, so they support multiple gopher tortoises. Given the surrounding land use and open nature of the marsh, usage by hydrologically dependent wildlife is expected. Stands of invasive torpedo grass were scattered surrounding and within the marsh. Dominant vegetation includes bushy blue stem, little blue maidencane, duck potato, salt bush, Carolina willow, pickerelweed, xyris, bog buttons, and cattail.

State of the Wetlands – Orange County, Florida

SITE 51

Mitigated Wetland Functional Assessment

Community Type

Freshwater Marsh

Picture Date

12/8/2022

Description

Mitigation is in a largely disturbed, unnatural setting. North and east of the wetland is a golf course. South and west of the wetland are unimproved pastures. The uplands surrounding the marsh were historically sandhill. The wetland is an isolated depressional system. The water levels at the time were high, though there had recently been large rain events. There was no upland buffer. There were minor amounts of Peruvian primrose willow within the wetland. Dominant vegetation includes cattail, soft rush, duck potato, pickerelweed, dollar weed, Mexican primrose willow, and red maple.

Appendix C – UMAM Worksheets

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 1
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	TD, NE, JB	August 26, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	8		This wetland CE area is located within the Avalon Park community with portions located behind the Orange Technical College, Avalon Campus. The CE area is not fenced, however due to its semi-remote location trash was not found within the area. The CE area is a distance from Avalon Park Blvd and some development so the location is greater than moderate. The location provides support for wildlife and there was little to no invasive found beyond the edge of the wetland CE areas. Deer scat was noticed in this wetland system.
.500(6)(b)Water Environment (n/a for uplands)	9		A majority of the wetland had evidence of hydrology and the cypress areas were inundated with 18 inches of water at the time of inspection. Additional water marks were found on the trunks to the trees.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	9		The vegetation found along the periphery of this CE area includes blackberry, Chinese tallow, water primrose, Brazilian pepper and wax myrtle. The community beyond the toe of slope includes swamp fern, chain fern, red maple, button bush, pond and bald cypress, lemon bacopa, duck weed, pickerelweed, false nette, whisk fern and wax myrtle. The jingle bell orchid, a rare species, was identified within the cypress dome.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.87	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 2
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, TD	August 26, 2022

Scoring Guidance
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed

Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Description
.500(6)(a) Location and Landscape Support w/o pres or current: with: 6	The site is located between Econolockhatchee Trail and Faith Assembly and beyond that SR 417. The CE area is not fenced but has signage denoting the area is CE. Wildlife such as birds (brown thrasher, crows, cardinals) were noticed within the CE area. The site has a moderate amount of invasive species and currently no adverse effects.
.500(6)(b)Water Environment (n/a for uplands) Current: Permit: 7	The site is located between Econolockhatchee Trail and Faith Assembly and beyond that SR 417. The CE area is not fenced but has signage denoting the area is CE. Wildlife such as birds (brown thrasher, crows, cardinals) were noticed within the CE area. The site has a moderate amount of invasive species and currently no adverse effects.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community Current: Permit: 8	Vegetation found within this CE included royal fern, beauty berry, Carolina willow, american ground nut vine, water oak, lizard's tail, false willow, red maple, tupelo and american elm. The UMAM score projected for the site was Location/landscape - 6, Water - 6, and Community - 8. Total project score was projected to be 0.67. Current condition was 0.70 (mixed hardwood)

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.7

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 3
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	TD, NE, JB	August 26, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	Current	Description
.500(6)(a) Location and Landscape Support		6	The site is located between Econolockhatchee Trail and Faith Assembly and beyond that SR 417. The CE area is not fenced but has signage denoting the area is CE. Wildlife such as birds (brown thrasher, crows, cardinals) were noticed within the CE area. The site has a moderate amount of invasive species and currently no adverse effects.
.500(6)(b)Water Environment (n/a for uplands)		7	The CE area has hydric soils and the presence of muck is found in the wetlands. The area has extensive water stains on the red maple trees. Many portions of the wetland were inundated above the surface.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		6	Vegetation found within this CE included royal fern, beauty berry, Carolina willow, american ground nut vine, water oak, lizard's tail, false willow, red maple, tupelo and american elm. The UMAM score projected for the site was Location/landscape - 6, Water - 6, and Community - 8. Total project score was projected to be 0.67. Current condition was 0.63 within the mixed shrub habit area.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0	0.63

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
AEI 4		
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	NE, JB	September 21, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Description
.500(6)(a) Location and Landscape Support w/o pres or current: with: 8.4	Wetland is part of a much larger system, though there is a roadway to the south that fragments the wetland. Good sized upland buffer. Upland buffer edge with minimal invasive coverage. Upland buffer shows signs of fire suppression due to oak regeneration and large duff layer.
.500(6)(b)Water Environment (n/a for uplands) Current: Permit: 9	Water level appropriate. Minimal signs of stressed vegetation.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community Current: Permit: 8.6	Invasive coverage in wetland minimal. Minimal signs of stress to plants. Upland buffer is shaded by oak coverage, causing lack of diversity amongst strata.

Score = sum of above scores/30 (if uplands, divide by 20)

Current	Permit
0	0.86667

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 5
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	TD, NE, JB	August 26, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	8		Project is located within the Econ River RHPA; Entire CE has a locked chain link fence and CE signage. Little to no litter found within the CE. Location provides for wildlife access. Little invasive species present beyond the initial fenceline.
.500(6)(b)Water Environment (n/a for uplands)	6		Majority of site has lower water levels within the wetlands. Mosses found on trunk and bases of trees indicative of lack of hydrology. Community structure in ground, shrub and canopy is good, with natural recruitment of desirable species.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	8		The vegetation in this CE area included the following: Long leaf pine, water oak, sweet gum, pond pine, swamp bay, loblolly bay, wax myrtle, saw palmetto, centella, caesar weed, grape vine and cinnamon fern. The UMAM score in the project file projected the site to be: Location/Landscape - 6, Water Environment - 7 and Community - 6 for a Total of 19/30 = 0.63 Actual Current condition is 0.73

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.73333	0.63333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 6
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	August 29, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	9		Strong connectivity with nearby and distant water features through Shingle Creek. Area is protected by SJRWMD. Invasives are mostly limited to landscape edges through edge effect.
.500(6)(b)Water Environment (n/a for uplands)	8		Water is at a healthy/normal level. Consistent flow from surrounding uplands. The community is dominated by desireable natives. Recruitment and stand succession is strong. No signs of prolongued dry spells.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	9		The community is dominated primarily by bald cypress, with the occasional pond cypress, dahoon holly, and pond pine around the edges. Sub canopy contains like species, as well as wax myrtle and fetterbush. Ground cover includes duck potato, pickerel weed, swamp smartweed, spider orchid, little blue maidencane, and cat tail. Surrounding uplands seem to have standard support from prescribed fire. The UMAM score in the project file projected the site to be: Location/Landscape - 8, Water Environment - 8, and Community - 8 for a total of 24/30 = 0.80. Actual Current Condition is 0.87.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.86667	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 7
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	August 29, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	6		Invasives primarily found along edges of site. Minor coverage of invasives in core. Little to no site connectivity.
.500(6)(b)Water Environment (n/a for uplands)	6		No standing water on site. Little to no water connectivity to off site areas. Burm placed around edges of site.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	6		Invasives primarily found along edges of site. Minor coverage of invasives in core. No standing water makes cypress germination minimal. Invasives, including brazillian pepper, and china berry found in core of cypress dome. Elderberry also found at core of dome, indicating minimal inundation periods. The UMAM score in the project file projected the site to be: Location/Landscape - 6, Water Environment - 7 and Community - 6 for a Total of 19/30 = 0.63 Actual Current condition is 0.73

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.6	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 8
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	August 30, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	8		Location is an important ecological stepping stone for many widlife species. Many birds were seen foraging while on site. Dense invasive species coverage is likely making it difficult for the movement of small mamals, and is also likely limiting foraging for many other species.
.500(6)(b)Water Environment (n/a for uplands)	8		Water environment was mostly healthy, though aqautic and wetland invasive species were smothering many portions on-site.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	6		Invasives were prevelent through much of the site. Strawberry Guava and Peruvian Primrose were limiting stand germination and growth through many portions of the cypress dome. The UMAM score in the project file projected the site to be: Location/Landscape - 8, Water Environment - 8, and Community - 8 for a total of 24/30 = 0.80. Actual Current Condition is 0.73.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.73333	

If preservation as mitigation,

Preservation adjustment factor =

Adjusted mitigation delta =

For impact assessment areas

FL = delta x acres =

Delta = [with-current]

If mitigation

Time lag (t-factor) =

Risk factor =

For mitigation assessment areas

RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 9
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions (Freshwater Marsh)	NE, JB	September 9, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Comments
.500(6)(a) Location and Landscape Support	6		Site is surrounded by development. Waterways minimally connected - other than small culverts through the golf course. Nearly eniterly dominated by invasives.
.500(6)(b)Water Environment (n/a for uplands)	5		Water in wetlands are at appropriate levels. Signs of nutrient runoff along edges of wetlands with algal blooms present. Wetland systems entirely dominated by invasives.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	2		Invasive plant species were dominant along all stratum. Algal blooms present. Minimal value for wildlife. The UMAM score in the project file projected the site to be: Location/Landscape - 7, Water Environment - 8, and Community - 8 for a total of 24/30 = 0.76. Actual Current Condition is 0.43.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.43333	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 10
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, KB	September 9, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Comments
.500(6)(a) Location and Landscape Support	5		Very isolated system, surrounded by development. Invasive presence is very high through site. Minimal water presence other than small ditch that runs N/S along apartment complex.
.500(6)(b)Water Environment (n/a for uplands)	5		Very isolated system, surrounded by development. Invasive presence is very high through site. Minimal water presence other than small ditch that runs N/S along apartment complex.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	2		Very isolated system, surrounded by development. Invasive presence is very high through site. Minimal water presence other than small ditch that runs N/S along apartment complex. Invasive species are limiting recruitment of desirable species. Canopy pines are heavily suppressed by invasive coverage. The UMAM score in the project file projected the site to be: Location/Landscape - 7, Water Environment - 7, and Community - 8 for a total of 24/30 = 0.73. Actual Current Condition is 0.4.

Score = sum of above scores/30 (if uplands, divide by 20)

current or w/o pres	with
0.4	

If preservation as mitigation,

Preservation adjustment factor =

Adjusted mitigation delta =

For impact assessment areas

FL = delta x acres =

Delta = [with-current]

If mitigation

Time lag (t-factor) =

Risk factor =

For mitigation assessment areas

RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 11
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	TD, NE, JB	August 26, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	6		This mitigation area is located behind a shopping center on the west side of Alafaya Trail.The CE area was denoted with CE signage but not protected with any type of fence. The CE area has a 3:1 slope with the top of bank planted with crepe myrtle, pine and magnolia trees and lantana. Trash has blown into the initial edge of the CE area. It was noted that irrigation PVC was found within the CE most likely left from initial construction of the shopping center.
.500(6)(b)Water Environment (n/a for uplands)	7		Evidence of hydrology is found throughout this CE area.Hydric soil and the presence of muck was present within the wetlands. Evidence of hydrology included noted: channelized areas, water above the surface, water marks on tree trunks, and adventitious roots were seen.There was natural recruitment of desireable vegetation in the ground, shrub and canopy.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	8		The vegetation within this wetland CE area included the edge effect had Brazilian pepper, water primrose, showy rattlebox, camphor, caesar weed, wax myrtle and vines. Beyond the toe of slope the vegetation within the wetland area included Virginia chain fern, royal fern, dahoon holly, loblolly bay, fsweet bay, fetterbush, slash pine, red maple, and Carolina willow. The UMAM score projected for the project site: Location/Landscape - 7, Water - 7 and Community - 8 Total score projected to be 0.73. Actual current condition is 0.70.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.7	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 12
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	NE, JB & TD	October 31, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	4	5	Location is an important ecological stepping stone for many widlife species. The eastern side of the mixed forested wetland is located behind shopping center with parking lot. The location of this wetland is not ideal as it is bound to the east w/ commercial development and a 6 lane roadway. The western portion of the preservation area comprises of a cypress dome that is accessible from Oberry Hoover Road. There is a powerline easement located on the western edge of the parcel and the location of this community functions slightly higher because of location. The CE signs are posted along both east and west sides of the CE. It is noted that trash was found within the eastern side of the CE area, primarily with the upland buffer, and this area is heavily used by homeless.
.500(6)(b)Water Environment (n/a for uplands)	7	7	Water environment is in moderate condition. Hydric, muck soils were found in both the mixed wetland and cypress dome communities. It is noted that the mixed wetland has experienced fire supression, so the pond pine community will be adversely affected due to the lack of fire. Some areas of the wetland were very dry.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	6	8	The vegetation found within the Mixed Forested community (eastern side) consits: planted side slope leading into a buffer overgrown w/ vines. The wetland includes saw palmetto, slash pine, pond pine. wax myrtle, gallberry, loblolly bay and red maple. The cypress community (western side) off of Oberry Hoover road consists of bald cypress, sweet bay and tupelo. The UMAM score in the project file projected the mitigation site to be: Location/Landscape - 7, Water Environment - 7, and Community - 8 for a total of 22/30 = 0.73. Actual Current Condition for the Mixed Forested Community is 0.57 and the Cypress Community 0.67

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.56667	0.666666667

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 13
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions (Mixed Wetland Hardwoods)	NE, JB, KB	September 9, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	6		Site is surrounded by development. Waterways minimally connected - other than small culverts through the golf course.
.500(6)(b)Water Environment (n/a for uplands)	8		Water in wetlands are at appropriate levels to support veg communities and wildlife. Some signs of nutrient runoff along edges of wetlands.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	8		Community was apparently healthy, with appropriate levels of desirable species recruitment. Minimal invasives along edges of wetland system. The UMAM score in the project file projected the site to be: Location/Landscape - 7, Water Environment - 8, and Community - 8 for a total of 23/30 = 0.76. Actual Current Condition is 0.73.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.73333	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

Project: *AEI 14* **date:** 9/19/2022

Impacts :	Habitat type	Wildlife Utilization before	after	Wetland Overstory Shrub Canopy before	after	Wetland Vegetative Groundcover before	after	Adjacent Upland/ Wetland Buffer before	after	Wetland Hydrology before	after	Water Quality & Input Treatement before	after	Acres	Functional units lost	Total Impact Acres	Total Enhancment Acres	Total Preserve Acres	Total Creation Acres
																0.43	0.00	0.00	0.00
W7	641	3.00	2.50	2.50	2.00	2.50	2.50	3.00	2.50	3.00	2.50	2.40	2.63	0.43	0.04				
X2															0.00				
X3															0.00				
X4															0.00				
X5															0.00				
X6															0.00				
X7															0.00				
X8															0.00				
X9															0.00				
X10															0.00				

Total Functional Units lost	**Total Functional Units gained**	**Total Mitigation Acres gained**
0.042	**0.000**	**0.00**

Mitigation Type	Habitat Type	Wildlife Utilization w/o	w	Wetland Overstory Shrub Canopy w/o	w	Wetland Vegetative Groundcover w/o	w	Adjacent Upland/ Wetland Buffer w/o	w	Wetland Hydrology w/o	w	Water Quality & Input Treatment w/o	w	time lag	risk factor	Preservation Adjustment Factor	Relative Functional Gain	Acres Provided	Functional Units gained
creation																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
enhance																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
area4														1.00	1.00	1.00	0.0000		0.0000
preserve																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area 3														1.00	1.00	1.00	0.0000		0.0000
area 4														1.00	1.00	1.00	0.0000		0.0000

WRAP Assessment used with the before = the anticipated Preservation WRAP score provided during permitting
and the after = current condition during site inspection conducted on 9/19/2022

Wildlife: active gopher tortoise burrows in adj uplands
Canopy: slash pine and couple red maple
Ground cover: young slash pine & RM, chain, wax myrtle, pitcher plants,
Buffer: signage but not fenced; wall along private single family homes
Hydrology: evidence of altered hydrology especially with the pine recruitment in the ground cover & canopy
WQ: good

Project: *AEI 15* **date:** 9/19/2022

Impacts :	Habitat type	Wildlife Utilization before	Wildlife Utilization after	Wetland Overstory Shrub Canopy before	Wetland Overstory Shrub Canopy after	Wetland Vegetative Groundcover before	Wetland Vegetative Groundcover after	Adjacent Upland/ Wetland Buffer before	Adjacent Upland/ Wetland Buffer after	Wetland Hydrology before	Wetland Hydrology after	Water Quality & Input Treatement before	Water Quality & Input Treatement after	Acres	Functional units lost
W13	641	3.00	2.50	2.50	2.00	2.50	2.75	3.00	2.50	3.00	2.50	3.00	3.00	0.76	0.07
X2															0.00
X3															0.00
X4															0.00
X5															0.00
X6															0.00
X7															0.00
X8															0.00
X9															0.00
X10															0.00

Total Impact Acres	Total Enhancment Acres	Total Preserve Acres	Total Creation Acres
0.76	0.00	0.00	0.00

Total Functional Units lost	**Total Functional Units gained**	**Total Mitigation Acres gained**
0.074	**0.000**	**0.00**

Mitigation Type	Habitat Type	Wildlife Utilization w/o	Wildlife Utilization w	Wetland Overstory Shrub Canopy w/o	Wetland Overstory Shrub Canopy w	Wetland Vegetative Groundcover w/o	Wetland Vegetative Groundcover w	Adjacent Upland/ Wetland Buffer w/o	Adjacent Upland/ Wetland Buffer w	Wetland Hydrology w/o	Wetland Hydrology w	Water Quality & Input Treatment w/o	Water Quality & Input Treatment w	time lag	risk factor	Preservation Adjustment Factor	Relative Functional Gain	Acres Provided	Functional Units gained
creation																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
enhance																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
area4														1.00	1.00	1.00	0.0000		0.0000
preserve																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area 3														1.00	1.00	1.00	0.0000		0.0000
area 4														1.00	1.00	1.00	0.0000		0.0000

WRAP Assessment used with the before = the anticipated Preservation WRAP score provided during permitting
and the after = current condition during site inspection conducted on 9/19/2022

Wildlife:
Canopy: young slash pine
Ground cover: dominated with red root, chalky blue stem ,camphor-weed/Pluchea
Buffer: barb wire fence
Hydrology: evidence of hydrology above surface
WQ: good

Project: *AEI 16* **date:** 9/19/2022

Impacts :	Habitat type	Wildlife Utilization before	Wildlife Utilization after	Wetland Overstory Shrub Canopy before	Wetland Overstory Shrub Canopy after	Wetland Vegetative Groundcover before	Wetland Vegetative Groundcover after	Adjacent Upland/ Wetland Buffer before	Adjacent Upland/ Wetland Buffer after	Wetland Hydrology before	Wetland Hydrology after	Water Quality & Input Treatement before	Water Quality & Input Treatement after	Acres	Functional units lost	Total Impact Acres	Total Enhancment Acres	Total Preserve Acres	Total Creation Acres
																0.81	0.00	0.00	0.00
W14	641	3.00	2.00		2.00	2.50	3.00	3.00	2.50	3.00	3.00	3.00	3.00	0.81	-0.05				
X2															0.00				
X3															0.00				
X4															0.00				
X5															0.00				
X6															0.00				
X7															0.00				
X8															0.00				
X9															0.00				
X10															0.00				

Total Functional Units lost	**Total Functional Units gained**	**Total Mitigation Acres gained**
-0.045	**0.000**	**0.00**

Mitigation Type	Habitat Type	Wildlife Utilization w/o	Wildlife Utilization w	Wetland Overstory Shrub Canopy w/o	Wetland Overstory Shrub Canopy w	Wetland Vegetative Groundcover w/o	Wetland Vegetative Groundcover w	Adjacent Upland/ Wetland Buffer w/o	Adjacent Upland/ Wetland Buffer w	Wetland Hydrology w/o	Wetland Hydrology w	Water Quality & Input Treatment w/o	Water Quality & Input Treatment w	time lag	risk factor	Preservation Adjustment Factor	Relative Functional Gain	Acres Provided	Functional Units gained
creation																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
enhance																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
area4														1.00	1.00	1.00	0.0000		0.0000
preserve																			
														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area 3														1.00	1.00	1.00	0.0000		0.0000
area 4														1.00	1.00	1.00	0.0000		0.0000

WRAP Assessment used with the before = the anticipated Preservation WRAP score provided during permitting
and the after = current condition during site inspection conducted on 9/19/2022

Wildlife: rutting by hogs
Canopy: suppose to be a marsh but recruitment of slash pine has occurred
Ground cover: red root, xyris, chalky blue stem, rhexia, RM & cinnamon fern
Buffer: good
Hydrology: good
WQ: good

Project: *AEI 17* **date:** 9/19/2022

Impacts :	Habitat type	Wildlife Utilization before	Wildlife Utilization after	Wetland Overstory Shrub Canopy before	Wetland Overstory Shrub Canopy after	Wetland Vegetative Groundcover before	Wetland Vegetative Groundcover after	Adjacent Upland/ Wetland Buffer before	Adjacent Upland/ Wetland Buffer after	Wetland Hydrology before	Wetland Hydrology after	Water Quality & Input Treatement before	Water Quality & Input Treatement after	Acres	Functional units lost	Total Impact Acres	Total Enhancment Acres	Total Preserve Acres	Total Creation Acres
																2.37	0.00	2.37	0.00
W7	621	3.00	2.50	3.00	3.00	3.00	3.00	3.00	2.00	3.00	2.50	2.40	3.00	2.37	0.18				
X2															0.00				
X3															0.00				
X4															0.00				
X5															0.00				
X6															0.00				
X7															0.00				
X8															0.00				
X9															0.00				
X10															0.00				

Total Functional Units lost	Total Functional Units gained	Total Mitigation Acres gained
0.184	-0.184	2.37

Mitigation Type	Habitat Type	Wildlife Utilization w/o	Wildlife Utilization w	Wetland Overstory Shrub Canopy w/o	Wetland Overstory Shrub Canopy w	Wetland Vegetative Groundcover w/o	Wetland Vegetative Groundcover w	Adjacent Upland/ Wetland Buffer w/o	Adjacent Upland/ Wetland Buffer w	Wetland Hydrology w/o	Wetland Hydrology w	Water Quality & Input Treatment w/o	Water Quality & Input Treatment w	time lag	risk factor	Preservation Adjustment Factor	Relative Functional Gain	Acres Provided	Functional Units gained
creation																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
enhance																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
area4														1.00	1.00	1.00	0.0000		0.0000
preserve																			
W7	621	3.00	2.50	3.00	3.00	3.00	3.00	3.00	2.00	3.00	2.50	2.40	3.00	1.00	1.00	1.00	-0.0778	2.37	-0.1843
area 2														1.00	1.00	1.00	0.0000		0.0000
area 3														1.00	1.00	1.00	0.0000		0.0000
area 4														1.00	1.00	1.00	0.0000		0.0000

WRAP Assessment used with the before = the anticipated Preservation WRAP score provided during permitting
and the after = current condition during site inspection conducted on 9/19/2022

Wildlife: little blue heron
Canopy: Bald cypress dome, dahoon holly, tupelo, couple tallow
Ground cover: pickerelweed, chain, swamp & cinnamon ferns, wax myrtle, vitus,
Buffer: ok
Hydrology: good hydrology within the cypress dome extending to periphery of
WQ: good

Project: *AEI 18* **date:** 9/19/2022

Impacts :	Habitat type	Wildlife Utilization before	Wildlife Utilization after	Wetland Overstory Shrub Canopy before	Wetland Overstory Shrub Canopy after	Wetland Vegetative Groundcover before	Wetland Vegetative Groundcover after	Adjacent Upland/ Wetland Buffer before	Adjacent Upland/ Wetland Buffer after	Wetland Hydrology before	Wetland Hydrology after	Water Quality & Input Treatement before	Water Quality & Input Treatement after	Acres	Functional units lost	Total Impact Acres	Total Enhancment Acres	Total Preserve Acres	Total Creation Acres
																12.06	0.00	0.00	0.00
W20	630	2.50	2.00		2.50	2.50	3.00	2.50	1.50	2.50	1.50	2.50	3.00	12.06	-0.67				
X2															0.00				
X3															0.00				
X4															0.00				
X5															0.00				
X6															0.00				
X7															0.00				
X8															0.00				
X9															0.00				
X10															0.00				

Total Functional Units lost	Total Functional Units gained	Total Mitigation Acres gained
-0.670	**0.000**	**0.00**

Mitigation Type	Habitat Type	Wildlife Utilization w/o	Wildlife Utilization w	Wetland Overstory Shrub Canopy w/o	Wetland Overstory Shrub Canopy w	Wetland Vegetative Groundcover w/o	Wetland Vegetative Groundcover w	Adjacent Upland/ Wetland Buffer w/o	Adjacent Upland/ Wetland Buffer w	Wetland Hydrology w/o	Wetland Hydrology w	Water Quality & Input Treatment w/o	Water Quality & Input Treatment w	time lag	risk factor	Preservation Adjustment Factor	Relative Functional Gain	Acres Provided	Functional Units gained
creation																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
enhance																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
area4														1.00	1.00	1.00	0.0000		0.0000
preserve																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area 3														1.00	1.00	1.00	0.0000		0.0000
area 4														1.00	1.00	1.00	0.0000		0.0000

WRAP Assessment used with the before = the anticipated Preservation WRAP score provided during permitting and the after = current condition during site inspection conducted on 9/19/2022

Wildlife:
Canopy: Red maple (RM) (dome/canopy), sweet bay, loblolly, lots of fallen RM
Ground cover: young RM, chain, swamp & cinnamon ferns, wax myrtle, vitus, grape
Buffer: small, adjacent to stormwater pond, no signage & not fenced
Hydrology: evidence of hydrology above surface in some areas; evidence of altered hydrology
WQ: Adj to stormwater pond, soccer field and natural areas

Project: *AEI 19* **date:** 9/19/2022

Impacts :	Habitat type	Wildlife Utilization before	Wildlife Utilization after	Wetland Overstory Shrub Canopy before	Wetland Overstory Shrub Canopy after	Wetland Vegetative Groundcover before	Wetland Vegetative Groundcover after	Adjacent Upland/ Wetland Buffer before	Adjacent Upland/ Wetland Buffer after	Wetland Hydrology before	Wetland Hydrology after	Water Quality & Input Treatement before	Water Quality & Input Treatement after	Acres	Functional units lost	Total Impact Acres	Total Enhancment Acres	Total Preserve Acres	Total Creation Acres
																15.61	15.61	0.00	0.00
W19	622	2.50	2.00	3.00	2.00	2.50	3.00	3.00	2.50	2.50	2.00	3.00	3.00	15.61	1.73				
X2															0.00				
X3															0.00				
X4															0.00				
X5															0.00				
X6															0.00				
X7															0.00				
X8															0.00				
X9															0.00				
X10															0.00				

Total Functional Units lost	Total Functional Units gained	Total Mitigation Acres gained
1.734	-1.734	15.61

Mitigation Type	Habitat Type	Wildlife Utilization w/o	Wildlife Utilization w	Wetland Overstory Shrub Canopy w/o	Wetland Overstory Shrub Canopy w	Wetland Vegetative Groundcover w/o	Wetland Vegetative Groundcover w	Adjacent Upland/ Wetland Buffer w/o	Adjacent Upland/ Wetland Buffer w	Wetland Hydrology w/o	Wetland Hydrology w	Water Quality & Input Treatment w/o	Water Quality & Input Treatment w	time lag	risk factor	Preservation Adjustment Factor	Relative Functional Gain	Acres Provided	Functional Units gained
creation																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
enhance																			
W19	622	2.50	2.00	3.00	2.00	2.50	3.00	3.00	2.50	2.50	2.00	3.00	3.00	1.00	1.00	1.00	-0.1111	15.61	-1.7344
area 2														1.00	1.00	1.00	0.0000		0.0000
area3														1.00	1.00	1.00	0.0000		0.0000
area4														1.00	1.00	1.00	0.0000		0.0000
preserve																			
area 1														1.00	1.00	1.00	0.0000		0.0000
area 2														1.00	1.00	1.00	0.0000		0.0000
area 3														1.00	1.00	1.00	0.0000		0.0000
area 4														1.00	1.00	1.00	0.0000		0.0000

WRAP Assessment used with the before = the anticipated Preservation WRAP score provided during permitting
and the after = current condition during site inspection conducted on 9/19/2022

Wildlife: deer, ruts from hogs,
Canopy: pond pine, Red maple (RM), swamp bay, dahoon holly, water oak
Ground cover: extensive fern coverage (chain & cinnamon ferns), wax myrtle, lizards tail
Buffer: planted pine which is now encroaching into wetlnad
Hydrology: evidence of hydrology at and above surface in many areas
WQ: good

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
AEI 20		AEI 20
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	September 21, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current	with / Permit	Comments
.500(6)(a) Location and Landscape Support (w/o pres or current / with)		4.7	Rather isolated system with industrial landscape surrounding. Invasives abundant around edges.
.500(6)(b)Water Environment (n/a for uplands)		6.4	Water level lower than expected. Well below assumed seasonal high. Water rather stagnant. Box turtle seen.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		6.4	Invasive vegetation found in core that interfered with recruitment . Low water levels causing moderate amounts of stress on ferns and buttonbush.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.58333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 21
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, TD	September 21, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with / Permit	Description
.500(6)(a) Location and Landscape Support		8	Wetland is part of a much larger system, though there is a roadway to the south that fragments the wetland.
.500(6)(b)Water Environment (n/a for uplands)		7	Water level appropriate. Minimal signs of stressed vegetation. Fragmentation from historic waterflow.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		7	Severe invasive coverage, especially along edge of road. Primarily peruvian primrose willow.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.73333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 22
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, TD	September 21, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with / Permit	Description
.500(6)(a) Location and Landscape Support		7	Site is entirely isolated and surrounded by development. Though it is connected by culvert to lake that is roughly 100 ft away.
.500(6)(b)Water Environment (n/a for uplands)		8	Water environment is appropriate. Standing water. No signs of vegitative stress. Connected to Lake by culvert.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		8	There are minimal invasives around edges. The core is very healthy. Actual Current Condition is 0.77.

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Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.76667

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 23
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
Mitigation site EXISTING Conditions	NE, JB & TD	October 31, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	7		System is located west of Lake Spar, and has development to the north and south. West of the site is a much larger system.
.500(6)(b)Water Environment (n/a for uplands)	8		Water environment appears to be drier than normal. Hydric soils within the wetland area along with the presence of muck. Portions of the wetland were inundated with water.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	5		Site appears to have been historically hydric pine. Now has assortment of pine, holly, bay, and oak. Actual Current Condition is 0.67.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.66667	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 24
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions at Mitigation Site	NE, JB & TD	October 31, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	4		Location is an important ecological stepping stone for many widlife species and during the site inspection there was no sound from any birds. This mitigation area is located behind the Sysco building. There are a series of warehouses that front the wetland mitigation area. No CE signs were posted at the site. In addition, there is little to no buffer between the fill associated with the development and the beginning of the mitigation area. Any upland area is being utilized by the homeless. There is an extensive amount of trash along the perifery of the mitigation area.
.500(6)(b)Water Environment (n/a for uplands)	7		Water environment appears to be drier than normal. Hydric soils within the wetland area along with the presence of muck. Portions of the wetland were inundated with water.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	6		This mitigaton area has a wall of Brazilian pepper along with extensive grapevine and poison ivy. The heart of the wetland consists of bald cypress, red maple, sweet bay, dahoon holly, wax myrtle, sword fern, water oak, and ear pod tree. It was noted that cogon grass was found along the outer edge of the mitigation area. Actual Current Condition is 0.57.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.56667	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 25
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	NE, JB, TD	November 8, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

.500(6)(a) Location and Landscape Support	w/o pres or current:	with: 8	Cypress dome located adjacent to apartments with a a large upland buffer. Minimal invasives and good hydrology
.500(6)(b)Water Environment (n/a for uplands)	Current:	Permit: 9	Water levels appropriate
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	Current:	Permit: 8.4	Primarily native vegitation. Scattered invasive mermaid weed.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.84667

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 26
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	NE, JB,	November 8, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with / Permit	Notes
.500(6)(a) Location and Landscape Support		9	Marsh that was once wet prairie. No non natives. Adjacent to road
.500(6)(b)Water Environment (n/a for uplands)		9	No standing water but appears appropriate
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		9	Veg appropriate. Primarily consistent with remnant wet prairie, though hypericum

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.9

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 27
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	NE, JB	November 8, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Notes
.500(6)(a) Location and Landscape Support		8	Evidence of hog rooting. Roadway to the south. Good upland buffer.

Indicator	Current	Permit	Notes
.500(6)(b)Water Environment (n/a for uplands)		8	Water depth appropriate. May be periods of high water that is killing canopy.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		7	Tree stratum is starting to dwindle with more shrub growth starting to occur

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Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.76667

If preservation as mitigation,

Preservation adjustment factor =

Adjusted mitigation delta =

For impact assessment areas

FL = delta x acres =

Delta = [with-current]

If mitigation

Time lag (t-factor) =

Risk factor =

For mitigation assessment areas

RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 28
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	November 8, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support		8	Adjacent to power lines and hardwood species starting to encroach into the feature. Habitat is a fragment of what it used to be.

Indicator	Current	Permit	Description
.500(6)(b)Water Environment (n/a for uplands)		8	Water appropriate for area. No standing water, though soil is very saturated and mucky. Consistent with wet prairie.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		9	Encroachment of hardwoods into feature, though wet prairie species still present in core.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.83333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 29
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	November 8, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current	With/Permit	Description
.500(6)(a) Location and Landscape Support (w/o pres or current / with)		9	Power lines roughly 30 yrds away and hardwood species starting to encroach into the feature. Habitat is a fragment of what it used to be.
.500(6)(b)Water Environment (n/a for uplands) (Current / Permit)		8	Water levels appropriate. Adjacent cypress dome fully inundated.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community (Current / Permit)		8	Woody species encroaching into wet prairie areas.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.83333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 30
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, TD	November 14, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Description
.500(6)(a) Location and Landscape Support w/o pres or current: 7 — with: 7	This preservation area is located adjacent to Bonnet Creek Canal. The wetland has two berms one on the east side adjacent to Bonnet Creek and the second runs east/west from Chelonia Parkway to Bonnet Creek. Culvrts were noticed within the berm and were functional. An assortment of birds including wood stork, great white heron, great blue herons, wrens, red bellied woopecker, pileated woodpecker, cardinal and mocking birds were seen utilizing the wetlands. In addition, deer scat was found.
.500(6)(b)Water Environment (n/a for uplands) Current: 8 — Permit: 8	Water environment was good during the time of inspection. The cypress dome portion of the wetland was inundated 18" above the ground surface.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community Current: 7 — Permit: 7	Within the edge of the wetland adjacent to the berms the vegetation found within the wetland includes exotics such as caesar weed, Virgina creeper, poison ivy and grape vine. The vegetation include a canopy of cypress, holly, bay and red maple trees It was noted that there are numerous dead cypress within this community. Ground cover and shrub layer includes wax myrtle, lizards tail, swamp and cinnamon ferns and water primrose. The UMAM score in the project file projected the site to be: Location/Landscape - 7, Water Environment - 8, and Community - 7 for a total of 22/30 = 0.73. Actual Current Condition is 0.73. Our functional assessment did not change from that which was permitted. The overall exotic presence in this wetland community is less than 5%.

Score = sum of above scores/30 (if uplands, divide by 20)

Current	Permit
0.73	0.73

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 31
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, TD	November 14, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Scores	Description
.500(6)(a) Location and Landscape Support	w/o pres or current: 7; with: 7	This preservation area is located adjacent to Bonnet Creek Canal. The wetland has two berms one on the east side adjacent to Bonnet Creek and the second runs east/west from Chelonia Parkway to Bonnet Creek. Culvrts were noticed within the berm and were functional. An assortment of birds including wood stork, great white heron, great blue herons, wrens, red bellied woopecker, pileated woodpecker, cardinal and mocking birds were seen utilizing the wetlands. In addition, deer scat was found. There is no buffer to the adjacent development which can be seen from within this portion of the community.
.500(6)(b)Water Environment (n/a for uplands)	Current: 7; Permit: 8	Water environment was good during the time of inspection. The entire community was inundated during the inspection with some areas the water 6" above the ground surface.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	Current: 7; Permit: 7	Within the edge of the wetland adjacent to the berms the vegetation found within the wetland includes exotics such as caesar weed, Virgina creeper, poison ivy and grape vine. The vegetation include a canopy of rement pond pine, holly, bay, cabbage palmand red maple trees. It was noted that there are numerous dead pine trees and little to no recruitment of pine within this community. Ground cover and shrub layer includes wild coffee, beauty berry, wax myrtle, lizards tail, swamp and cinnamon ferns and water primrose. The UMAM score in the project file projected the site to be: Location/Landscape - 7, Water Environment - 8, and Community - 7 for a total of 22/30 = 0.73. Actual Current Condition is 0.73. Our functional assessment changed slightly from that which was permitted due to the decline in the pine community and the presence of exotics. The overall exotic presence in this wetland community is less than 15%.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0.70	0.73

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 32
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	November 21, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Comments
.500(6)(a) Location and Landscape Support		8.1	Standing water present. Depth and duration seem appropriate.
.500(6)(b)Water Environment (n/a for uplands)	Current:	Permit: 6.5	Surrounded by development. Minimal connectivity.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	Current:	Permit: 7.4	Limited exotics - good community structure.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.73333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 33
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	November 21, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current / w/o pres or current	Permit / with	Comments
.500(6)(a) Location and Landscape Support		8	Part of large wetland system that flows south to the everglades. Though there is high density development to the east and west.
.500(6)(b)Water Environment (n/a for uplands)		6.7	Water levels appropriate. Adjacent to Lake Sharp. Though vegitation limits usage by animal species and ground cover species.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		6.3	Vegetation could use burn, saw palm very dense - limiting recruitment.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.7

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 34
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	November 21, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with / Permit	Comments
.500(6)(a) Location and Landscape Support		7.6	Part of large wetland system that flows south to the everglades. Though there is high density development to the north and south. High density of invasive.
.500(6)(b)Water Environment (n/a for uplands)		8.1	Water level appropriate. Limiting factor for wildlife would be veg density. Adjacent to Lake Sharp.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		6.5	Large percentage of invasives. Primarily Peruvian primrose. Pines creeping in to habitat. A lot of downed woody debris. Upland mitigation area largely covered by nuisance species.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.74

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 35
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	November 22, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Comments
.500(6)(a) Location and Landscape Support		4	Isolated system. Large amounts of invasives found near bordering developments.

Indicator	Current	Permit	Comments
.500(6)(b)Water Environment (n/a for uplands)		8	Appropriate water level. Observed many frogs dependent on the system. Hummocking, water staining.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		6.9	Habitat has edge effect with invasives. Minimal upland mitigation area. Trash on edges of system.

Score = sum of above scores/30 (if uplands, divide by 20)

Current	Permit
0	0.63

If preservation as mitigation,

Preservation adjustment factor =

Adjusted mitigation delta =

For impact assessment areas

FL = delta x acres =

Delta = [with-current]

If mitigation

Time lag (t-factor) =

Risk factor =

For mitigation assessment areas

RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
Archer Ave	09-009	AEI 36
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	NE, JB, TD	November 22, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current	With / Permit	Description
.500(6)(a) Location and Landscape Support (w/o pres or current / with)		10	Appropriate water level. Slight flow due to connectivity with Econ River.
.500(6)(b)Water Environment (n/a for uplands) (Current / Permit)		9.8	Part of large wetland system. Surrounded by preserve and low density housing.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community (Current / Permit)		10	No invasives in habitat. Vegetation appropriate across all strata.

Score = sum of above scores/30 (if uplands, divide by 20)

Current	Permit
0	0.99

Delta = [with-current]

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

If mitigation
Time lag (t-factor) =
Risk factor =

For impact assessment areas
FL = delta x acres =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 37
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions of Mitigation site	NE, JB & TD	November 28, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	10		Location is an important ecological stepping stone for many widlife species. The project site is located east of Lake Mary Jane and east of Lake Mary Jane Road in SE Orange County. Access to the site is by way of 4-wheel drive vehicle as there are no roadways only natural trails within the property. As a result of the remote location, there is full support to wildlife within the property with no barriers for wildlife.
.500(6)(b)Water Environment (n/a for uplands)	9		Water environment was appropriate throughout the project site. There is no evidence of soil erosion or depostion. Muck soils are found within the wetland. Evidence of hydrology is found within the site with water just above the surface in many areas and just below the ground in other portions.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	9		This pine flatwood community consists of a canopy of slash and long leaf pine trees. The shrub layer consists of gall berry. Ground cover is dominated with cinnamon ferns and saw palmetto The UMAM score in the project file projected the site to be: Location/Landscape - 8, Water Environment - 7, and Community - 8 for a total of 23/30 = 0.76. Actual Current Condition is 0.93.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.93333	

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 38
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	November 30, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with / Permit	Comments
.500(6)(a) Location and Landscape Support		8.8	Location is ideal. Low density development north of site.
.500(6)(b)Water Environment (n/a for uplands)		9.7	Water level appropriate. Vegetation present that shows signs of good water quality (pitcher plants, club moss, etc)
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		9.3	Vegetation looks very healthy and well managed.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.92667

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 39
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, KB	December 5, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support		7.6	Location suffers from fragmentation by roadway. Though ultimately water is able to flow to Econ river.

Indicator	Current	Permit	Description
.500(6)(b)Water Environment (n/a for uplands)		8.3	water levels appropriate for system
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		8.1	Vegetation mostly appropriate. Pine and wax myrtle intrusion from lack of fire history.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.8

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 40
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, KB	December 5, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Scores	Comments
.500(6)(a) Location and Landscape Support	w/o pres or current: ; with: 7.6	Location suffers from fragmentation by roadway. Though ultimately water is able to flow to Econ river.
.500(6)(b)Water Environment (n/a for uplands)	Current: ; Permit: 8.3	water levels appropriate for system
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	Current: ; Permit: 7.9	Vegetation mostly appropriate. Pines and wax myrtles spreading due to lack of fire.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.79333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 41
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, KB	December 5, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with / Permit	Description
.500(6)(a) Location and Landscape Support		8.9	Location is nearly perfect, with the small downside being that much of the habitat to the south is improved pasture.
.500(6)(b)Water Environment (n/a for uplands)		7.7	Water levels appropriate. Lack of plant diversity seems to stem from minimal burns in area. Soil was moist and mucky - representative of an ecotonal hydric flatwoods system.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		7.1	Vegetation mostly native, though recruitment of desirable species is limited due to lack of fire history and large amount of downed woody debris.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.79

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 42
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, KB	December 5, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current / w/o pres or current	Permit / with	Description
.500(6)(a) Location and Landscape Support		4.1	Location is very isolated. Completely surrounded by industrial structures and busy roads.
.500(6)(b)Water Environment (n/a for uplands)		7.6	Water levels appropriate. Many invasives and undesirable species along edge of wetland that may signify poor water quality.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		6.9	No upland buffer. Many plants are covered in silt and dust from industrial uses nearby.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.62

If preservation as mitigation,

Preservation adjustment factor =

Adjusted mitigation delta =

For impact assessment areas

FL = delta x acres =

Delta = [with-current]

If mitigation

Time lag (t-factor) =

Risk factor =

For mitigation assessment areas

RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 43
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, KB	December 5, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support		7	Wetland system is largely surrounded by housing development, though wetland is connected through streams and canals through to other wetlands. Minimal upland buffers.

Indicator	Current	Permit	Description
.500(6)(b)Water Environment (n/a for uplands)		8.6	Water level is appropriate. Lack of fire history is evident with the intrusion of shrub and canopy species.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		8.1	Vegetation mostly appropriate, though lack of fire is evident with the impeding wax myrtle and slash pine along edges

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.79

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 44
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	December 7, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Scores	Notes
.500(6)(a) Location and Landscape Support	w/o pres or current: ; with: 6.3	Frequent berms surrounding wetland. Invasives very prevalent outside wetland. Site a part of much larger system.
.500(6)(b)Water Environment (n/a for uplands)	Current: ; Permit: 5.8	Water level seemed low. No species present that would indicate a healthy system.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	Current: ; Permit: 4.4	Monoculture of wax myrtle. Minimal land management done to keep habitat healthy.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.55

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 45
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	December 7, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current	With/Permit	Description
.500(6)(a) Location and Landscape Support (w/o pres or current / with)		7.4	Site is connected to a much larger system that ultimately flows south to the everglades. Site borders landfill. Landfill entrance road is directly to the south of the site.
.500(6)(b)Water Environment (n/a for uplands)		7.1	Water level seems slightly higher than ususal. Most herbaceous species were dead, likely from increased inundation following two hurricanes.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		6.9	Vegitation appropriate, though young slash pine are starting to encroach into system.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.71333

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 46
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, TD	December 12, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	7	7	This project site is located off of Grand Cypress Bouldvard. The systemed only has a culvert connection to off-site wetlands and is disconnected by development. Conservation area is not fenced off and conservation easement signage is posted along the easement area.
.500(6)(b)Water Environment (n/a for uplands)	8	7	Water environment was good as there were appropriate water levels found within the community. Hydric soils, hummocking of pines and water stains on the trees were evident through the system.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	8	8	The canopy contained minimal pond and slash pine and appears to be transitioning to a mixed hardwood sytem. The species found in the canopy included bay trees, red maple and pond pine. The ground cover and shrub communities included lizard tail, FL rain orchid, wax myrtle, cinnamon, royal and swamp ferns. This site has minimal invasive species with less than 1% present. The property owner continues to perform invasive/exotic species removal within this site. The UMAM score in the project file projected the site to be: Location/Landscape - 7, Water Environment - 7, and Community - 8 for a total of 22/30 = 0.73. Actual Current Condition is 0.77. Based upon the functional assessment the preserved community is in a slight better condition and has a slightly higher functional value than that anticipated for the project. Net gain in functional value with success of hydrology and exotic/nuisance species removal ongoing beyond the permit requirements.

Score = sum of above scores/30 (if uplands, divide by 20)

current or w/o pres	with
0.77	0.73

If preservation as mitigation,

Preservation adjustment factor =

Adjusted mitigation delta =

For impact assessment areas

FL = delta x acres =

Delta = [with-current]

If mitigation

Time lag (t-factor) =

Risk factor =

For mitigation assessment areas

RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 47
Impact or Mitigation	Assessment conducted by:	Assessment date:
EXISTING Conditions	NE, JB, TD	December 12, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current	Permit	Description
.500(6)(a) Location and Landscape Support	8	8	This community is located behind Hidden Valley Mobile Home Park (MHP) off of Apopka Vineland Road, north of CR 535 and south of Hidden Village Boulevard. This wetland community is part of a more extensive system.The conservation easement is located behind the lots to the MHP. The lots slope down into the wetland conservation area which is not fenced off from the development. Conservation easement signage is posted along the easement area.
.500(6)(b)Water Environment (n/a for uplands)	7	7	Water environment was fair. Some evidence of hydrology was found with adventious roots, water stains on trees, however there was no presence of standing water above the ground surface. Currently water levels are below surface.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	6	8	Holly, red maple, water oak, pond pine, and chinese tallow are found in the canopy. The ground cover and shrub layer has water primrose, Carolina willow, swamp fern, sword fern, aster, grape vine, caesar weed, blackberry, cogon grass and poison ivy. It was noted that grape vine is taking over the holly trees. It was noted that the vegetative community in this area has an extensive amount of exotic/nuisance vegetation present. The UMAM score in the project file projected the site to be: Location/Landscape - 8, Water Environment - 7, and Community - 8 for a total of 23/30 = 0.76. Actual Current Condition is 0.70. The results of the functional assessment are lower due to the presence of exotic species and the decline of the canopy. Current condition is lower than that projected by the permit.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0.70	0.77

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 48
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, TD	December 12, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Description
.500(6)(a) Location and Landscape Support	8	8	This community is located behind Hidden Valley Mobile Home Park (MHP) off of Apopka Vineland Road, north of CR 535 and south of Hidden Village Boulevard. This wetland community is part of a more extensive system. The conservation easement is located behind the lots to the MHP. The lots slope down into the wetland conservation area which is not fenced off from the development. Conservation easement signage is posted along the easement area.
.500(6)(b)Water Environment (n/a for uplands)	8	7	Water environment was good. Evidence of hydrology was found with adventious roots, water stains on trees, and presence of standing water above the ground surface. The water was clear, juvenile fish seen along with slight flow as the system connects to Cypress Creek.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	7	8	It was noted during the site inspection that the canopy in this community is very thin within the conservation easement area. The ground cover and shrub layers are more prodominate with the presence of water primrose.Holly, red maple and tupelo,sweet bay and a few pond pine are found in the remaining canopy. The ground cover and shrub layer has water primrose, swamp fern, sword fern, aster, grape vine and poison ivy. The UMAM score in the project file projected the site to be: Location/Landscape - 8, Water Environment - 7, and Community - 8 for a total of 23/30 = 0.76. Actual Current Condition is 0.77. The scores differed on the Water and Community assessments, however the overall score is the same as that in the permit.

Score = sum of above scores/30 (if uplands, divide by 20)	
current or w/o pres	with
0.77	0.77

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 49
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB, TD	December 12, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	Current	Permit	Description
.500(6)(a) Location and Landscape Support	8	8	This project site is bordered on one side by CR 535 (Apopka Vineland Road) and the internal roadway (Silk Oak Circle/Jacaranda) associated by Grand Cypress on another side. Despite the roadways, the site supports wildlife and lacks invasive species. Fish (juvenile) were noted in the water, scat and a snake skin along the ground. Conservation area is not fenced off and conservation easement signage is posted along the easement area.
.500(6)(b)Water Environment (n/a for uplands)	9	7	Water environment was very good. The water levels were appropriate for this pond pine community. Hydrology evident with standing water in the system, lichen lines, swollen lentices, adventious roots. Noted a slight flow of water within the system westward.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	9	8	The dominante species within this community canopy is pond pine. The canaopy also contained holly, slash pine, sweet bay, red maple. The ground cover and shrub layers were healthy with cinnamon, royal and swamp ferns, saw palmetto, water primrose, wax myrtle, sweet bay, holly all present. Exotic vegetation within this system is less than 1%! It is noted that exotic species removal continues within the system by the owner. The UMAM score in the project file projected the site to be: Location/Landscape - 8, Water Environment - 7, and Community - 8 for a total of 23/30 = 0.77. Actual Current Condition is 0.87. Based upon the functional assessment the preserved community is in better condition and has a higher functional value than that anticipated for the project. Net gain in functional value with success of hydrology and exotic/nuisance species removal ongoing beyond the permit requirements.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0.87	0.77

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 50
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	December 8, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Comments
.500(6)(a) Location and Landscape Support		5	Area is largely disturbed. Development surrounding most of site. Wetland is surrounded by hitoric sandhill community that had been cleared.
.500(6)(b)Water Environment (n/a for uplands)	Current:	Permit: 7.9	Water level temporarily high following hurricanes. Some stress along edges of wetland that typically are not inundated.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community	Current:	Permit: 7.2	Torpedo grass creeping into wetland. Other vegetation appropriate.

Score = sum of above scores/30 (if uplands, divide by 20)	
Current	Permit
0	0.67

If preservation as mitigation,
Preservation adjustment factor =
Adjusted mitigation delta =

For impact assessment areas
FL = delta x acres =

Delta = [with-current]

If mitigation
Time lag (t-factor) =
Risk factor =

For mitigation assessment areas
RFG = delta/(t-factor x risk) =

Form 62-345.900(2), F.A.C. [effective date 02-04-2004]

PART II – Quantification of Assessment Area (impact or mitigation)
(See Sections 62-345.500 and .600, F.A.C.)

Site/Project Name	Application Number	Assessment Area Name or Number
		AEI 51
Impact or Mitigation	**Assessment conducted by:**	**Assessment date:**
EXISTING Conditions	NE, JB	December 8, 2022

Scoring Guidance	Optimal (10)	Moderate(7)	Minimal (4)	Not Present (0)
The scoring of each indicator is based on what would be suitable for the type of wetland or surface water assessed	Condition is optimal and fully supports wetland/surface water functions	Condition is less than optimal, but sufficient to maintain most wetland/surface waterfunctions	Minimal level of support of wetland/surface water functions	Condition is insufficient to provide wetland/surface water functions

Indicator	w/o pres or current	with	Comments
.500(6)(a) Location and Landscape Support		6	Surrounded by golf course. Slightly connected to other features.

Indicator	Current	Permit	Comments
.500(6)(b)Water Environment (n/a for uplands)		8.3	Water level appropriate. Location may limit usage by animals with hydrologic needs.
.500(6)(c)Community structure 1. Vegetation and/or 2. Benthic Community		8.5	Vegetation appropriate. Little to no upland mitigation.

Score = sum of above scores/30 (if uplands, divide by 20)

Current	Permit
0	0.76

If preservation as mitigation,

Preservation adjustment factor =

Adjusted mitigation delta =

For impact assessment areas

FL = delta x acres =

Delta = [with-current]

If mitigation

Time lag (t-factor) =

Risk factor =

For mitigation assessment areas

RFG = delta/(t-factor x risk) =

Appendix D - FRAGSTATS Metrics

The metrics provided in this appendix, which were used in the FRAGSTATS fragmentation analysis, were published in the following article:

McGarigal, K.S., Cushman, S., Neel, M. & Ene, E. (2002). FRAGSTATS: Spatial pattern analysis program for categorical maps.

Available at -
https://www.researchgate.net/publication/259011515_FRAGSTATS_Spatial_pattern_analysis_program_for_categorical_maps

FRAGSTATS Mean and Area-weighted Mean Statistics

$MN = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij}}{N}$	MN (Mean) equals the sum, across all patches in the landscape, of the corresponding patch metric values, divided by the total number of patches. MN is given in the same units as the corresponding patch metric.
$AM = \sum_{i=1}^{m}\sum_{j=1}^{n}\left[x_{ij}\left(\frac{a_{ij}}{\sum_{i=1}^{m}\sum_{j=1}^{n} a_{ij}}\right)\right]$	AMN (area-weighted mean) equals the sum, across all patches in the landscape, of the corresponding patch metric value multiplied by the proportional abundance of the patch [i.e., patch area (m^2) divided by the sum of patch areas]. Note, the proportional abundance of each patch is determined from the sum of patch areas rather than the total landscape area, because the latter may include internal background area not associated with any patch.

FRAGSTATS Patch Level Metrics (used for Mean and Area-weighted Mean calculations)

(P1) Area	
$AREA = a_{ij}\left(\frac{1}{10,000}\right)$	a_{ij} = area (m^2) of patch ij.
Description	AREA equals the area (m^2) of the patch, divided by 10,000 (to convert to hectares).
Units	Hectares
Range	AREA > 0, without limit. The range in AREA is limited by the grain and extent of the image; in a particular application, AREA may be further limited by the specification of a minimum patch size that is larger than the grain.
Comments	The *area* of each patch comprising a landscape mosaic is perhaps the single most important and useful piece of information contained in the landscape. Not only is this information the basis for many of the patch, class, and landscape indices, but patch area has a great deal of ecological utility in its own right. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

(P2) Shape Index	
$SHAPE = \frac{.25\ p_{ij}}{\sqrt{a_{ij}}}$	p_{ij} = perimeter (m) of patch ij. a_{ij} = area (m^2) of patch ij.
Description	SHAPE equals patch perimeter (m) divided by the square root of patch area (m^2), adjusted by a constant to adjust for a square standard.
Units	None
Range	SHAPE ≥ 1, without limit. SHAPE = 1 when the patch is square and increases without limit as patch shape becomes more irregular.
Comments	*Shape index* corrects for the size problem of the perimeter-area ratio index (see previous description) by adjusting for a square standard and, as a result, is the simplest and perhaps most straightforward measure of shape complexity.

(P1) Core Area	
$$CORE = a_{ij}^{c}\left(\frac{1}{10{,}000}\right)$$	a_{ij}^{c} = core area (m^2) of patch ij based on specified edge depths (m).
Description	CORE equals the area (m^2) within the patch that is further than the specified depth-of-edge distance from the patch perimeter, divided by 10,000 (to convert to hectares). Edge segments along the landscape boundary are treated like background (as specified in the edge depth file) unless a landscape border is present, in which case the boundary edge types are made explicit by the information in the border.
Units	Hectares
Range	CORE ≥ 0, without limit. CORE = 0 when every location within the patch is within the specified depth-of-edge distance from the patch perimeter. CORE approaches AREA as the specified depth-of-edge distance(s) decreases and as patch shape is simplified.
Comments	*Core area* represents the area in the patch greater than the specified depth-of-edge distance from the perimeter. Note, that a single depth-of-edge distance can be used for all edges or the user can specify a edge depth file that provides unique distances for each pairwise combination of patch types.

(P3) Core Area Index	
$$CAI = \frac{a_{ij}^{c}}{a_{ij}}(100)$$	a_{ij}^{c} = core area (m^2) of patch ij based on specified edge depths (m). a_{ij} = area (m^2) of patch ij.
Description	CAI equals the patch core area (m^2) divided by total patch area (m^2), multiplied by 100 (to convert to a percentage); in other words, CAI equals the percentage of a patch that is core area.
Units	Percent
Range	0 ≤ CAI < 100 CAI = 0 when CORE = 0 (i.e., every location within the patch is within the specified depth-of-edge distance(s) from the patch perimeter); that is, when the patch contains no core area. CAI approaches 100 when the patch, because of size, shape, and edge width, contains mostly core area.
Comments	*Core area index* is a relative index that quantifies core area as a percentage of patch area (i.e., the percentage of the patch that is comprised of core area).

(P3) Radius of Gyration	
$$\text{GYRATE} = \sum_{r=1}^{z} \frac{h_{ijr}}{z}$$	h_{ijr} = distance (m) between cell ijr [located within patch ij] and the centroid of patch ij (the average location), based on cell center-to-cell center distance. z = number of cells in patch ij.
Description	GYRATE equals the mean distance (m) between each cell in the patch and the patch centroid.
Units	Meters
Range	GYRATE ≥ 0, without limit. GYRATE = 0 when the patch consists of a single cell and increases without limit as the patch increases in extent. GYRATE achieves its maximum value when the patch comprises the entire landscape.
Comments	*Radius of gyration* is a measure of patch extent; thus it is effected by both patch size and patch compaction. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

(P5) Contiguity Index	
$$\text{CONTIG} = \frac{\left[\frac{\sum_{r=1}^{z} c_{ijr}}{a_{ij}^{*}}\right] - 1}{v - 1}$$	c_{ijr} = contiguity value for pixel r in patch ij. v = sum of the values in a 3-by-3 cell template (13 in this case). a_{ij}^{*} = area of patch ij in terms of number of cells.
Description	CONTIG equals the average contiguity value (see discussion) for the cells in a patch (i.e., sum of the cell values divided by the total number of pixels in the patch) minus 1, divided by the sum of the template values (13 in this case) minus 1.
Units	None
Range	0 ≤ CONTIG ≤ 1 CONTIG equals 0 for a one-pixel patch and increases to a limit of 1 as patch contiguity, or connectedness, increases. Note, 1 is subtracted from both the numerator and denominator to confine the index to a range of 1.
Comments	*Contiguity index* assesses the spatial connectedness, or contiguity, of cells within a grid-cell patch to provide an index on patch boundary configuration and thus patch shape (LaGro 1991).

FRAGSTATS Class Level Metrics

(C1) Total (Class) Area	
$$CA = \sum_{j=1}^{n} a_{ij} \left(\frac{1}{10,000} \right)$$	a_{ij} = area (m^2) of patch ij.
Description	CA equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by 10,000 (to convert to hectares); that is, total class area.
Units	Hectares
Range	CA > 0, without limit. CA approaches 0 as the patch type becomes increasing rare in the landscape. CA = TA when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch.
Comments	*Class area* is a measure of landscape composition; specifically, how much of the landscape is comprised of a particular patch type. In addition to its direct interpretive value, class area is used in the computations for many of the class and landscape metrics.

(C2) Percentage of Landscape	
$$PLAND = P_i = \frac{\sum_{j=1}^{n} a_{ij}}{A}(100)$$	P_i = proportion of the landscape occupied by patch type (class) i. a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2).
Description	PLAND equals the sum of the areas (m^2) of all patches of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, PLAND equals the percentage the landscape comprised of the corresponding patch type. Note, total landscape area (A) includes any internal background present.
Units	Percent
Range	0 < PLAND .,; 100 PLAND approaches 0 when the corresponding patch type (class) becomes increasingly rare in the landscape. PLAND = 100 when the entire landscape consists of a single patch type; that is, when the entire image is comprised of a single patch.
Comments	*Percentage of landscape* quantifies the proportional abundance of each patch type in the landscape. Like total class area, it is a measure of landscape composition important in many ecological applications. However, because PLAND is a relative measure, it may be a more appropriate measure of landscape composition than class area for comparing among landscapes of varying sizes.

(C8) Number of Patches	
$NP = n_i$	n_i = number of patches in the landscape of patch type (class) i.
Description	NP equals the number of patches of the corresponding patch type (class).
Units	None
Range	NP ≥ 1, without limit. NP = 1 when the landscape contains only 1 patch of the corresponding patch type; that is, when the class consists of a single patch.
Comments	*Number of patches* of a particular patch type is a simple measure of the extent of subdivision or fragmentation of the patch type. Although the number of patches in a class may be fundamentally important to a number of ecological processes, often it has limited interpretive value by itself because it conveys no information about area, distribution, or density of patches. Of course, if total landscape area and class area are held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret. Number of patches is probably most valuable, however, as the basis for computing other, more interpretable, metrics. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

(C3) Largest Patch Index	
$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A}(100)$	a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2).
Description	LPI equals the area (m^2) of the largest patch of the corresponding patch type divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the landscape comprised by the largest patch. Note, total landscape area (A) includes any internal background present.
Units	Percent
Range	0 < LPI .,; 100 LPI approaches 0 when the largest patch of the corresponding patch type is increasingly small. LPI = 100 when the entire landscape consists of a single patch of the corresponding patch type; that is, when the largest patch comprises 100% of the landscape.
Comments	*Largest patch index* at the class level quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

(C4) Total Edge	
$$TE = \sum_{k=1}^{m} e_{ik}$$	e_{ik} = total length (m) of edge in landscape involving patch type (class) i; includes landscape boundary and background segments involving patch type i.
Description	TE equals the sum of the lengths (m) of all edge segments involving the corresponding patch type. If a landscape border is present, TE includes landscape boundary segments involving the corresponding patch type and representing 'true' edge only (i.e., abutting patches of different classes). If a landscape border is absent, TE includes a user-specified proportion of landscape boundary segments involving the corresponding patch type. Regardless of whether a landscape border is present or not, TE includes a user-specified proportion of internal background edge segments involving the corresponding patch type.
Units	Meters
Range	TE ;:, 0, without limit. TE = 0 when there is no class edge in the landscape; that is, when the entire landscape and landscape border, if present, consists of the corresponding patch type and the user specifies that none of the landscape boundary and background edge be treated as edge.
Comments	*Total edge* at the class level is an absolute measure of total edge length of a particular patch type. In applications that involve comparing landscapes of varying size, this index may not be as useful as edge density (see below). However, when comparing landscapes of identical size, total edge and edge density are completely redundant.

(C1) Total Core Area	
$$TCA = \sum_{j=1}^{n} a_{ij}^{c} \left(\frac{1}{10{,}000} \right)$$	a_{ij}^{c} = core area (m^2) of patch ij based on specified edge depths (m).
Description	TCA equals the sum of the core areas of each patch (m^2) of the corresponding patch type, divided by 10,000 (to convert to hectares).
Units	Hectares
Range	TCA ≥ 0, without limit. TCA = 0 when every location within each patch of the corresponding patch type is within the specified depth-of-edge distance(s) from the patch perimeters. TCA approaches total class area (CA) as the specified depth-of-edge distance(s) decreases and as patch shapes are simplified.
Comments	*Total core area* is defined the same as core area (CORE) at the patch level (see Core Area), but here core area is aggregated (summed) over all patches of the corresponding patch type.

(C2) Core Area Percentage of Landscape	
$CPLAND = \frac{\sum_{j=1}^{n} a_{ij}^{c}}{A}(100)$	a_{ij}^{c} = core area (m^2) of patch ij based on specified edge depths (m). A = total landscape area (m^2).
Description	CPLAND equals the sum of the core areas of each patch (m^2) of the corresponding patch type, divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, CPLAND equals the percentage the landscape comprised of core area of the corresponding patch type. Note, total landscape area (A) includes any internal background present.
Units	Percent
Range	$0 \leq CPLAND < 100$ CPLAND approaches 0 when core area of the corresponding patch type (class) becomes increasingly rare in the landscape, because of increasing smaller patches and/or more convoluted patch shapes. CPLAND approaches 100 when the entire landscape consists of a single patch type (i.e., when the entire image is comprised of a single patch) and the specified depth-of-edge distance(s) approaches zero.
Comments	*Core area percentage of landscape* is defined the same as core area (CORE) at the patch level (see Core Area), but here core area is aggregated (summed) over all patches of the corresponding patch type and computed as a percentage of the total landscape area, which facilitates comparison among landscape of varying size.

(C3) Number of Disjunct Core Areas	
$NDCA = \sum_{j=1}^{n} n_{ij}^{c}$	n_{ij}^{c} = number of disjunct core areas in patch ij based on specified edge depths (m).
Description	NDCA equals the sum of the number of disjunct core areas contained within each patch of the corresponding patch type; that is, the number of disjunct core areas contained within the landscape.
Units	None
Range	$NDCA \geq 0$, without limit. NDCA = 0 when TCA = 0 (i.e., every location within patches of the corresponding patch type are within the specified depth-of-edge distance(s) from the patch perimeters). NDCA > 1 when, due to patch shape complexity, a patch contains more than 1 core area.
Comments	*Number of disjunct core areas* is defined the same at the patch level (see Number of Core Areas), but here it is aggregated (summed) over all patches of the corresponding patch type. Number of disjunct core areas is an alternative to the number of patches when it makes sense to treat the core areas as functionally distinct patches.

(C4) Clumpiness Index

$$Given\ G_i = \left(\frac{g_{ii}}{\sum_{k=1}^{m} g_{ik}} \right)$$

$$CLUMPY = \begin{bmatrix} \frac{G_i - P_i}{1 - P_i} \ for\ G_i \geq P_i \\ g \\ \frac{G_i - P_i}{1 - P_i} \ for\ G_i < P_i;\ P_i \geq .5 \\ \frac{P_i - G_i}{-P_i} \ for\ G_i < P_i;\ P_i < .5 \end{bmatrix}$$

g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the *double-count* method.

g_{ik} = number of adjacencies (joins) between pixels of patch types (classes) i and k based on the *double-count* method.

P_i = proportion of the landscape occupied by patch type (class) i.

Description	CLUMPY equals the proportional deviation of the proportion of like adjacencies involving the corresponding class from that expected under a spatially random distribution. If the proportion of like adjacencies (G_i) is greater than or equal to the proportion of the landscape comprised of the focal class (P_i), then CLUMPY equals G_i minus P_i, divided by 1 minus P_i. Likewise, if $G_i < P_i$, and $P_i \geq 0.5$, then CLUMPY equals G_i minus P_i, divided by 1 minus P_i. However, if $G_i < P_i$, and $P_i <$ 0.5, then CLUMPY equals P_i minus G_i, divided by negative P_i. Note, all background edge segments are included in the sum of all adjacencies involving the focal class, including landscape boundary segments if a border is not provided. Cell adjacencies are tallied using the *double-count* method in which pixel order is preserved, at least for all internal adjacencies (i.e., involving cells on the inside of the landscape). If a landscape border is present, adjacencies on the landscape boundary are counted only once, as are all adjacencies with background. Note, P_i is based on the total landscape area (A) including any internal background present.
Units	Percent
Range	$-1 \leq CLUMPY \leq 1$ Given any P_i , CLUMPY equals -1 when the focal patch type is maximally disaggregated; CLUMPY equals 0 when the focal patch type is distributed randomly, and approaches 1 when the patch type is maximally aggregated. Note, CLUMPY equals 1 only when the landscape consists of a single patch and includes a border comprised of the focal class.

Comments	*Clumpiness index* is calculated from the adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type) appear side-by-side on the map. Clumpiness is scaled to account for the fact that the proportion of like adjacencies (G_i) will equal P_i for a completely random distribution (see previous discussion). The formula is contingent upon G_i and P_i because the minimum value of G_i has two forms which depend on P_i. Specifically, when $P_i \leq 0.5$, $G_i = 0$ when the class is maximally disaggregated (i.e., subdivided into one cell patches) and approaches 1 when the class is maximally clumped. However, when $P_i \geq 0.5$, $G_i = 2P_i - 1$ when the class is maximally disaggregated and approaches 1 when the class is maximally clumped. Note, when $G_i > P_i$, the formula given above assumes a maximum value of $G_i = 1$ (i.e., maximum clumping). This is not strictly true. In fact, the maximum value of G_i asymptotically approaches 1 as P_i increases to 1. At very small P_i, the maximum value of G_i is somewhat less. However, the bias is only nontrivial when the focal class consists of only a few cells. As the number of cells increases, the bias rapidly decreases and becomes trivial. Hence, when $G_i > P_i$ CLUMPY is slightly biased low. That is, the computed degree of clumping is slightly less than the actual degree of clumping, but again, the difference is trivial under most conditions. This approach of assuming that a maximum value of $G_i = 1$ is necessary because it is impossible to calculate the true maximum value of G_i, taking into account potential like adjacencies of perimeter cell surfaces of the focal class when maximally clumped into a single compact patch. Recall that FRAGSTATS allows for the existence of a landscape border, which may consist of cells of the same class as the neighboring patches inside the landscape proper (a situation virtually guaranteed to occur in a moving window analysis). Unfortunately, there is no way to calculate the expected number of perimeter cell surfaces adjacent to the landscape boundary given any P_i–this depends on the exact configuration and positioning of the focal class when maximally clumped. Note, the maximum like adjacencies computed for the aggregation index does not include perimeter cell surfaces. Thus, calculating maximum G_i based on this approach will always underestimate the true value. The use of 1 as the maximum G_i guarantees a theoretical maximum (upper limit) value of 1 for CLUMPY.

(C7) Patch Cohesion Index		
$$\text{COHESION} = \left[1 - \frac{\sum_{j=1}^{n} p_{ij}^{*}}{\sum_{j=1}^{n} p_{ij}^{*}\sqrt{a_{ij}^{*}}}\right] \cdot \left[1 - \frac{1}{\sqrt{Z}}\right]^{-1} \cdot (100)$$		p_{ij}^{*} = perimeter of patch ij in terms of number of cell surfaces. a_{ij}^{*} = area of patch ij in terms of number of cells. Z = total number of cells in the landscape.
Description	COHESION equals 1 minus the sum of patch perimeter (in terms of number of cell surfaces) divided by the sum of patch perimeter times the square root of patch area (in terms of number of cells) for patches of the corresponding patch type, divided by 1 minus 1 over the square root of the total number of cells in the landscape, multiplied by 100 to convert to a percentage. Note, total landscape area (Z) excludes any internal background present.	
Units	None	
Range	0 < COHESION < 100 COHESION approaches 0 as the proportion of the landscape comprised of the focal class decreases and becomes increasingly subdivided and less physically connected. COHESION increases monotonically as the proportion of the landscape comprised of the focal class increases until an asymptote is reached near the percolation threshold (see background discussion). COHESION is given as 0 if the landscape consists of a single non-background cell.	
Comments	*Patch cohesion index* measures the physical connectedness of the corresponding patch type. Below the percolation threshold, patch cohesion is sensitive to the aggregation of the focal class. Patch cohesion increases as the patch type becomes more clumped or aggregated in its distribution; hence, more physically connected. Above the percolation threshold, patch cohesion does not appear to be sensitive to patch configuration (Gustafson 1998).	

(C3) Aggregation Index		
$$AI = \left[\frac{g_{ii}}{max \rightarrow g_{ii}} \right] (100)$$	g_{ii} =	number of like adjacencies (joins) between pixels of patch type (class) i based on the *single-count* method.
	max-g_{ii} =	maximum number of like adjacencies (joins) between pixels of patch type (class) i (see below) based on the *single-count* method.

Description	AI equals the number of like adjacencies involving the corresponding class, divided by the maximum possible number of like adjacencies involving the corresponding class, which is achieved when the class is maximally clumped into a single, compact patch; multiplied by 100 (to convert to a percentage). If A_i is the area of class i (in terms of number of cells) and n is the side of a largest integer square smaller than A_i, and $m = A_i - n^2$, then the largest number of shared edges for class i, max-g_{ii} will take one of the three forms: max-g_{ii} = 2n(n-1) , when m = 0, or max-g_{ii} = 2n(n-1) + 2m -1, when m ≤ n, or max-g_{ii} = 2n(n-1) + 2m -2, when m > n. Note, because of the design of the metric, like adjacencies are tallied using the *single-count* method, and all landscape boundary edge segments are ignored, even if a border is provided.
Units	Percent
Range	0 ≤ AI ≤ 100 Given any P_i , AI equals 0 when the focal patch type is maximally disaggregated (i.e., when there are no like adjacencies); AI increases as the focal patch type is increasingly aggregated and equals 100 when the patch type is maximally aggregated into a single, compact patch. AI is undefined and reported as "N/A" in the "basename".class file if the class consists of a single cell.
Comments	*Aggregation index* is calculated from an adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type) appear side-by-side on the map. Aggregation index takes into account only the like adjacencies involving the focal class, not adjacencies with other patch types. In addition, in contrast to all of the other metrics based on adjacencies, the aggregation index is based on like adjacencies tallied using the *single-count* method, in which each cell side is counted only once. Consequently, the tallies given in the "basename".adj output file are not correct for this metric. Further, because of the design of the metric, landscape boundary edge segments are ignored, even if a border is provided FRAGSTATS handles this case by distinguishing between internal like adjacencies (i.e., like adjacencies involving cells *inside* the landscape) and external like adjacencies (i.e., like adjacencies between cells *inside* the landscape and those in the border). Only internal like adjacencies are used in the calculation of this metric; a landscape border has no affect on this metric. The aggregation index is scaled to account for the maximum possible number of like adjacencies given any P_i. The maximum aggregation is achieved when the patch type consists of a single, compact patch, which is not necessarily a square patch.

(C6) normalized Landscape Shape Index

$$nLSI = \frac{e_i - \min e_i}{\max e_i - \min e_i}$$

e_i = total length of edge (or perimeter) of class i in terms of number of cell surfaces; includes all landscape boundary and background edge segments involving class i.

min e_i = minimum total length of edge (or perimeter) of class i in terms of number of cell surfaces (see below).

max e_i = maximum total length of edge (or perimeter) of class i in terms of number of cell surfaces (see below).

Description

nLSI equals the total length of edge (or perimeter) involving the corresponding class, given in number of cell surfaces, minus the minimum length of class edge (or perimeter) possible for a maximally aggregated class, also given in number of cell surfaces, which is achieved when the class is maximally clumped into a single, compact patch, divided by the maximum minus the minimum length of class edge. If a_i is the area of class i (in terms of number of cells) [note, this is equivalent to the sum of patch areas across all patches of class i] and n is the side of the largest integer square smaller than a_i (denoted) and $m = a_i - n^2$, then the minimum edge or perimeter of class i, min-e_i, will take one of the three forms (Milne 1991, Bogaert et al. 2000):

min-e_i = 4n, when m = 0, or

min-e_i = 4n + 2, when $n^2 < a_i \leq n(1+n)$, or

min-e_i = 4n + 4, when $a_i > n(1+n)$.

If A is the landscape area, including all internal background (in terms of number of cells), B = number of cells on the boundary (perimeter) of the landscape, Z = total length of landscape boundary (perimeter) given in number of cell surfaces, and P_i = proportion of the landscape comprised of the corresponding class, then the maximum edge or perimeter of class i, max-e_i, will take one of the three forms:

max-e_i = $4a_i$, when $P_i \leq 0.5$, or

max-e_i = $3A - 2a_i$, when A is even; $0.5 < P_i \leq (0.5A + 0.5B)/A$, or

max-e_i = $3A - 2a_i + 3$, when A is odd; $0.5 < P_i \leq (0.5A + 0.5B)/A$, or

max-e_i = $Z + 4(A - a_i)$, when $P_i > (0.5A + 0.5B)/A$

Note, the formula for max-e_i recognizes the fact that as P_i increases beyond 0.5, the maximum total length of edge is achieved when the cells of the focal class fill in first along the boundary of the landscape. Unfortunately, the formulas given above for $P_i > 0.5$ are only an approximation for this effect. An analytical solution is not possible given the infinite number of landscape shapes possible. In addition, the formula for min-e_i assumes that the maximally aggregated class is a single square or almost square patch. However, if the landscape shape is highly irregular, then as the proportional class area P_i approaches 1, the shape of the landscape will constrain the minimum class edge possible (i.e., the actual min-e_i << the theoretical min-e_i) and nLSI will biased high (i.e., the class will appear to be relatively less aggregated than it actually is). However, for square or rectangular landscapes, or classes with P_i << 1, there is either no bias or it is trivial.

Range	0 ≤ nLSI ≤ 1 nLSI = 0 when the landscape consists of a single square or maximally compact (i.e., almost square) patch of the corresponding type; LSI increases as the patch type becomes increasingly disaggregated and is 1 when the patch type is maximally disaggregated (i.e., a checkerboard when $P_i \leq 0.5$). Note, nLSI is undefined and reported as N/A in the output files whenever max-e_i = min-e_i, which exists when the class consists either of a single cell, comprises all but 1 cell, or comprises the entire landscape, because it is impossible to distinguish between clumped, random and dispersed distributions in these cases.
Comments	*Normalized Landscape shape index* is the normalized version of the landscape shape index (LSI) and, as such, provides a simple measure of class aggregation or clumpiness. The normalization essentially rescales LSI to the minimum and maximum values possible for any class area. When the patch type is relatively rare (say $P_i < 0.1$) or relative dominant (say $P_i > 0.5$), the range between the minimum and maximum total edge (or perimeter) is relatively small; whereas when the patch type is intermediate in abundance (say $P_i = 0.5$), the range is quite large. nLSI essentially measures the degree of aggregation given this variable range. Note, just as LSI and the Aggregation Index (AI) are closely related, the normalized versions of these metrics are related, in fact perfectly so. For this reason, the normalized version of AI is not computed since it is completely redundant with nLSI. In addition, given the considerations given above regarding the computational method that assumes a square or almost square shape for a maximally compact class and the bias this creates if the landscape is highly irregular and the percentage of the landscape comprised of the focal class is high, it is advisable to avoid using this metric under these conditions of bias. Also, for these reasons, this metric is not available in the Moving Window analysis mode when a circular window shape is selected.

FRAGSTATS Landscape Metrics

(L1) Total Area	
$TA = A\left(\frac{1}{10{,}000}\right)$	A = total landscape area (m^2).
Description	TA equals the total area (m^2) of the landscape, divided by 10,000 (to convert to hectares). Note, total landscape area (A) includes any internal background present.
Units	Hectares
Range	TA > 0, without limit.
Comments	*Total area* (TA) often does not have a great deal of interpretive value with regards to evaluating landscape pattern, but it is important because it defines the extent of the landscape. Moreover, total landscape area is used in the computations for many of the class and landscape metrics.

(L7) Number of Patches	
$NP = N$	N = total number of patches in the landscape.
Description	NP equals the number of patches in the landscape. Note, NP does not include any internal background patches (i.e., within the landscape boundary) or any patches at all in the landscape border, if present.
Units	None
Range	NP ≥ 1, without limit. NP = 1 when the landscape contains only 1 patch.
Comments	*Number of patches* often has limited interpretive value by itself because it conveys no information about area, distribution, or density of patches. Of course, if total landscape area is held constant, then number of patches conveys the same information as patch density or mean patch size and may be a useful index to interpret. Number of patches is probably most valuable, however, as the basis for computing other, more interpretable, metrics. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

(L8) Patch Density	
$PD = \frac{N}{A}(10{,}000)(100)$	N = total number of patches in the landscape. A = total landscape area (m^2).
Description	PD equals the number of patches in the landscape, divided by total landscape area (m^2), multiplied by 10,000 and 100 (to convert to 100 hectares). Note, PD does not include background patches or patches in the landscape border, if present. However, total landscape area (A) includes any internal background present.
Units	Number per 100 hectares
Range	PD > 0, constrained by cell size. PD is ultimately constrained by the grain size of the raster image, because the maximum PD is attained when every cell is a separate patch.
Comments	*Patch density* is a limited, but fundamental, aspect of landscape pattern. Patch density has the same basic utility as number of patches as an index, except that it expresses number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size. Of course, if total landscape area is held constant, then patch density and number of patches convey the same information. Like number of patches, patch density often has limited interpretive value by itself because it conveys no information about the sizes and spatial distribution of patches. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

(L2) Largest Patch Index	
$LPI = \frac{\max(a_{ij})}{A}(100)$	a_{ij} = area (m^2) of patch ij. A = total landscape area (m^2).
Description	LPI equals the area (m^2) of the largest patch in the landscape divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percent of the landscape that the largest patch comprises. Note, total landscape area (A) includes any internal background present.
Units	Percent
Range	0 < LPI :, 100 LPI approaches 0 when the largest patch in the landscape is increasingly small. LPI = 100 when the entire landscape consists of a single patch; that is, when the largest patch comprises 100% of the landscape.
Comments	*Largest patch index* quantifies the percentage of total landscape area comprised by the largest patch. As such, it is a simple measure of dominance.

(L3) Total Edge	
TE = E	E = total length (m) of edge in landscape.
Description	TE equals the sum of the lengths (m) of all edge segments in the landscape. If a landscape border is present, TE includes landscape boundary segments representing 'true' edge only (i.e., abutting patches of different classes). If a landscape border is absent, TE includes a user-specified proportion of the landscape boundary. Regardless of whether a landscape border is present or not, TE includes a user-specified proportion of internal background edge.
Units	Meters
Range	TE ;:, 0, without limit. TE = 0 when there is no edge in the landscape; that is, when the entire landscape and landscape border, if present, consists of a single patch and the user specifies that none of the landscape boundary and background edge be treated as edge.
Comments	*Total edge* is an absolute measure of total edge length of a particular patch type. In applications that involve comparing landscapes of varying size, this index may not be as useful as edge density (see below). However, when comparing landscapes of identical size, total edge and edge density are completely redundant.

(L5) Landscape Shape Index	
$LSI = \frac{.25\ E^*}{\sqrt{A}}$	E^* = total length (m) of edge in landscape; includes the entire landscape boundary and some or all background edge segments. A = total landscape area (m^2).
Description	LSI equals .25 (adjustment for raster format) times the sum of the entire landscape boundary (regardless of whether it represents 'true' edge or not, or how the user specifies how to handle boundary/background) and all edge segments (m) within the landscape boundary, including some or all of those bordering background (based on user specifications), divided by the square root of the total landscape area (m^2). Note, total landscape area (A) includes any internal background present.
Units	None
Range	LSI ≥ 1, without limit. LSI = 1 when the landscape consists of a single square patch; LSI increases without limit as landscape shape becomes more irregular and/or as the length of edge within the landscape increases.
Comments	*Landscape shape index* provides a standardized measure of total edge or edge density that adjusts for the size of the landscape. Because it is standardized, it has a direct interpretation, in contrast to total edge, for example, that is only meaningful relative to the size of the landscape.

(L2) Number of Disjunct Core Areas	
$NDCA = \sum_{i=j}^{m} \sum_{j=1}^{n} n_{ij}^{c}$	n_{ij}^{c} = number of disjunct core areas in patch ij based on specified edge depths (m).
Description	NDCA equals the sum of the number of disjunct core areas contained within each patch in the landscape; that is, the number of disjunct core areas contained within the landscape.
Units	None
Range	NDCA $\geq$ 0, without limit. NCA = 0 when TCA = 0 (i.e., every location within every patch is within the specified depth-of-edge distance(s) from the patch perimeters); in other words, when there are no core areas. NDCA > 1 when, due to patch size and shape, at least one core area exists.
Comments	*Number of disjunct core areas* is defined the same at the patch level (see Number of Core Areas), but here it is aggregated (summed) over all patches. Number of disjunct core areas is an alternative to the number of patches when it makes sense to treat the core areas as functionally distinct patches.

(L1) Contagion Index

$$\mathrm{CONTAG} = \left[1 + \frac{\displaystyle\sum_{i=1}^{m}\sum_{k=1}^{m}\left[P_i \cdot \frac{g_{ik}}{\displaystyle\sum_{k=1}^{m} g_{ik}} \right] \cdot \left[\ln\left(P_i \cdot \frac{g_{ik}}{\displaystyle\sum_{k=1}^{m} g_{ik}} \right) \right]}{2\ln(m)} \right] (100)$$

P_i = proportion of the landscape occupied by patch type (class) i.
g_{ik} = number of adjacencies (joins) between pixels of patch types (classes) i and k based on the *double-count* method.
m = number of patch types (classes) present in the landscape, including the landscape border if present.

Description	CONTAG equals minus the sum of the proportional abundance of each patch type multiplied by the proportion of adjacencies between cells of that patch type and another patch type, multiplied by the logarithm of the same quantity, summed over each unique adjacency type and each patch type; divided by 2 times the logarithm of the number of patch types; multiplied by 100 (to convert to a percentage). In other words, the observed contagion over the maximum possible contagion for the given number of patch types. Note, CONTAG considers all patch types present on an image, including any present in the landscape border, if present, and considers like adjacencies (i.e., cells of a patch type adjacent to cells of the same type). All background edge segments are ignored, as are landscape boundary segments if a border is not provided, because adjacency information for these edge segments is not available and the intermixing of the classes with background is assumed to be irrelevant. Cell adjacencies are tallied using the *double-count* method in which pixel order is preserved, at least for all internal adjacencies (i.e., involving cells on the inside of the landscape). If a landscape border is present, adjacencies on the landscape boundary are counted only once as are all adjacencies with background. Note, P_i is based on the total landscape area (A) excluding any internal background present.
Units	Percent
Range	$0 < \mathrm{CONTAG} \le 100$ CONTAG approaches 0 when the patch types are maximally disaggregated (i.e., every cell is a different patch type) and interspersed (equal proportions of all pairwise adjacencies). CONTAG = 100 when all patch types are maximally aggregated. CONTAG is undefined and reported as "N/A" in the "basename".land file if the number of patch types is less than 2, or all classes consist of one cell patches adjacent to only background.
Comments	*Contagion* is inversely related to edge density. When edge density is very low, for example, when a single class occupies a very large percentage of the landscape, contagion is high, and vice versa. In addition, note that contagion is affected by both the dispersion and interspersion of patch types. Low levels of patch type dispersion (i.e., high proportion of like adjacencies) and low levels of patch type interspersion (i.e., inequitable distribution of pairwise adjacencies results in high contagion, and vice versa.

(L3) Percentage of Like Adjacencies	
$PLADJ = \left(\dfrac{\sum_{i=1}^{m} (g_{ii})}{\sum_{i=1}^{m} \sum_{k=1}^{m} (g_{ik})} \right) (100)$	g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the *double-count* method . g_{ik} = number of adjacencies (joins) between pixels of patch types (classes) i and k based on the *double-count* method.
Description	PLADJ equals sum of the number of like adjacencies for each patch type, divided by the total number of cell adjacencies in the landscape; multiplied by 100 (to convert to a percentage). In other words, the proportion of cell adjacencies involving the same class. PLADJ considers all patch types present on an image, including any present in the landscape border, if present. All background edge segments are included in the denominator, including landscape boundary segments if a border is not provided. Cell adjacencies are tallied using the *double-count* method in which pixel order is preserved, at least for all internal adjacencies (i.e., involving cells on the inside of the landscape). If a landscape border is present, adjacencies on the landscape boundary are counted only once, as are all adjacencies with background.
Units	Percent
Range	$0 \leq PLADJ \leq 100$ PLADJ equals 0 when the patch types are maximally disaggregated (i.e., every cell is a different patch type) and there are no like adjacencies. PLADJ = 100 when all patch types are maximally aggregated (i.e., when the landscape consists of single patch and all adjacencies are between the same class), and the landscape contains a border comprised entirely of the same class. If the landscape consists of single patch but does not contain a border, PLADJ will be less than 100 due to the background edge segments along the boundary included in the tally of all adjacencies. PLADJ is undefined and reported as "N/A" in the "basename".land file if the landscape consists of a single non-background cell.
Comments	*Percentage of like adjacencies* is calculated from the adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type) appear side-by-side on the map. PLADJ measures the degree of aggregation of patch types. Thus, a landscape containing larger patches with simple shapes will contain a higher percentage of like adjacencies than a landscape with smaller patches and more complex shapes. In contrast to the contagion index at the landscape level, this metric measures only dispersion and not interspersion. Note, regardless of how much of the landscape is comprised of each class, this index will be minimum if all patch types are maximally dispersed (or disaggregated), and it will be maximum if all patch types are maximally contagious.

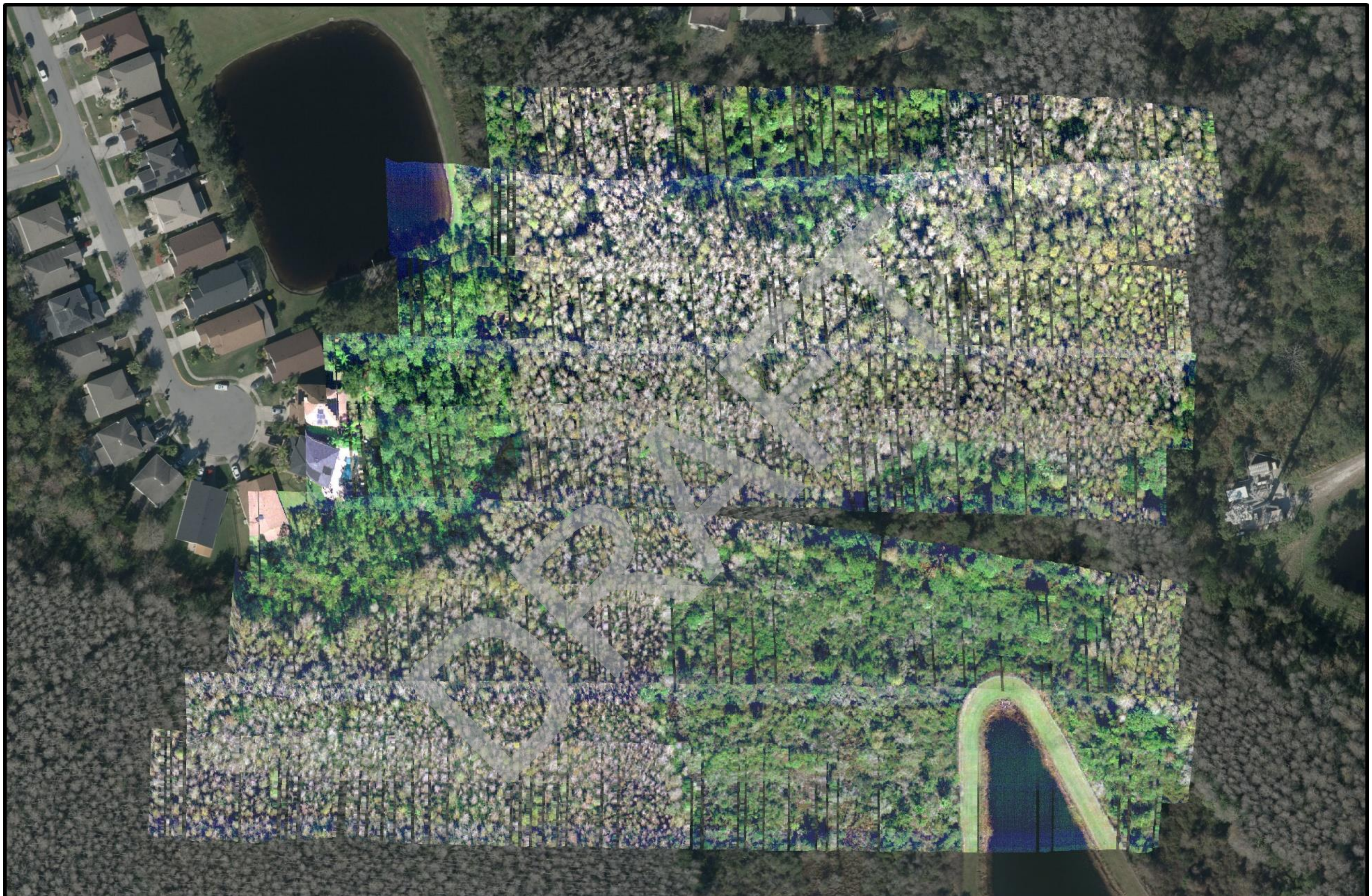
(L4) Aggregation Index

$$AI = \left[\sum_{i=1}^{m} \left(\frac{g_{ii}}{\text{max}\rightarrow g_{ii}} \right) P_i \right] (100)$$

g_{ii} =	number of like adjacencies (joins) between pixels of patch type (class) i based on the *single-count* method.
max-g_{ii} =	maximum number of like adjacencies (joins) between pixels of patch type (class) i (see below) based on the *single-count* method.
P_i =	proportion of landscape comprised of patch type (class) i.

Description	AI equals the number of like adjacencies involving the corresponding class, divided by the maximum possible number of like adjacencies involving the corresponding class, which is achieved when the class is maximally clumped into a single, compact patch, multiplied the proportion of the landscape comprised of the corresponding class, summed over all classes and multiplied by 100 (to convert to a percentage). If A_i is the area of class i (in terms of number of cells) and n is the side of a largest integer square smaller than A_i, and $m = A_i - n^2$, then the largest number of shared edges for class i, max-g_{ii} will take one of the three forms: max-g_{ii} = 2n(n-1), when m = 0, max-g_{ii} = 2n(n-1) + 2m -1, when m ≤ n, or max-g_{ii} = 2n(n-1) + 2m -2, when m > n. Note, because of the design of the metric, like adjacencies are tallied using the *single-count* method, and all landscape boundary edge segments are ignored, even if a border is provided. Also, P_i is based on the total landscape area (A) excluding any background present.
Units	Percent
Range	0 ≤ AI ≤ 100 Given any P_i , AI equals 0 when the patch types are maximally disaggregated (i.e., when there are no like adjacencies); AI increases as the landscape is increasingly aggregated and equals 100 when the landscape consists of a single patch. AI is undefined and reported as "N/A" in the "basename".land file if each class consists of a single cell (and hence is undefined).
Comments	*Aggregation index* is calculated from an adjacency matrix at the class level (see class-level AI comments). At landscape level, the index is computed simply as an area-weighted mean class aggregation index, where each class is weighted by its proportional area in the landscape. The index is scaled to account for the maximum possible number of like adjacencies given any landscape composition.

Appendix E - Hyperspectral Imagery



18 November 2022
AEI Wetland 1

N
0 0.01 0.03
Miles
Scale: 1:2,080

APPLIED ECOLOGY

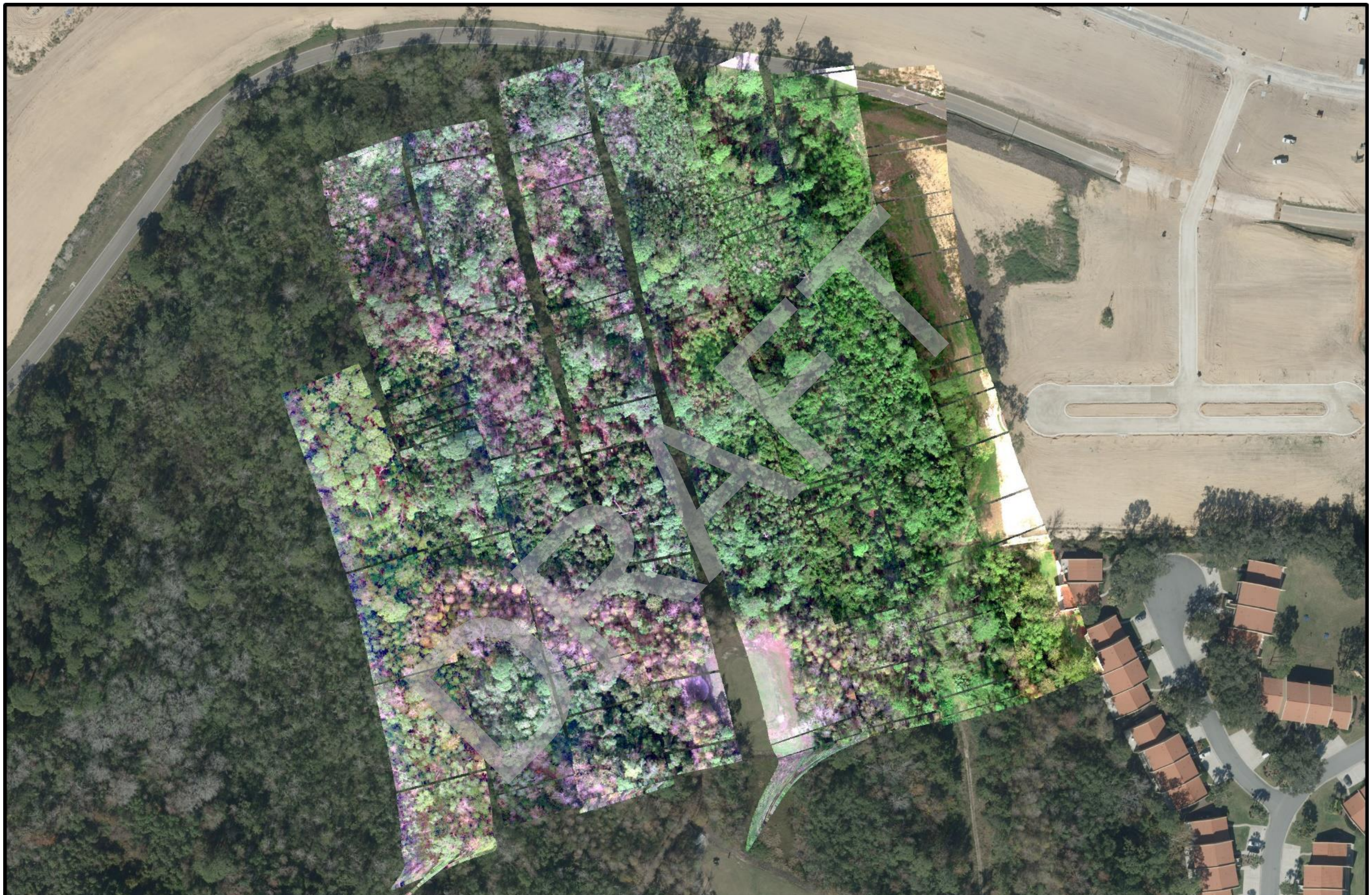
17 November 2022
AEI Wetland 4

N
0 0.01 0.01 Miles
Scale: 1:1,100

APPLIED ECOLOGY

16 December 2022
AEI Wetland 5

N
0 0.01 0.02 Miles
Scale: 1:1,600



APPLIED ECOLOGY

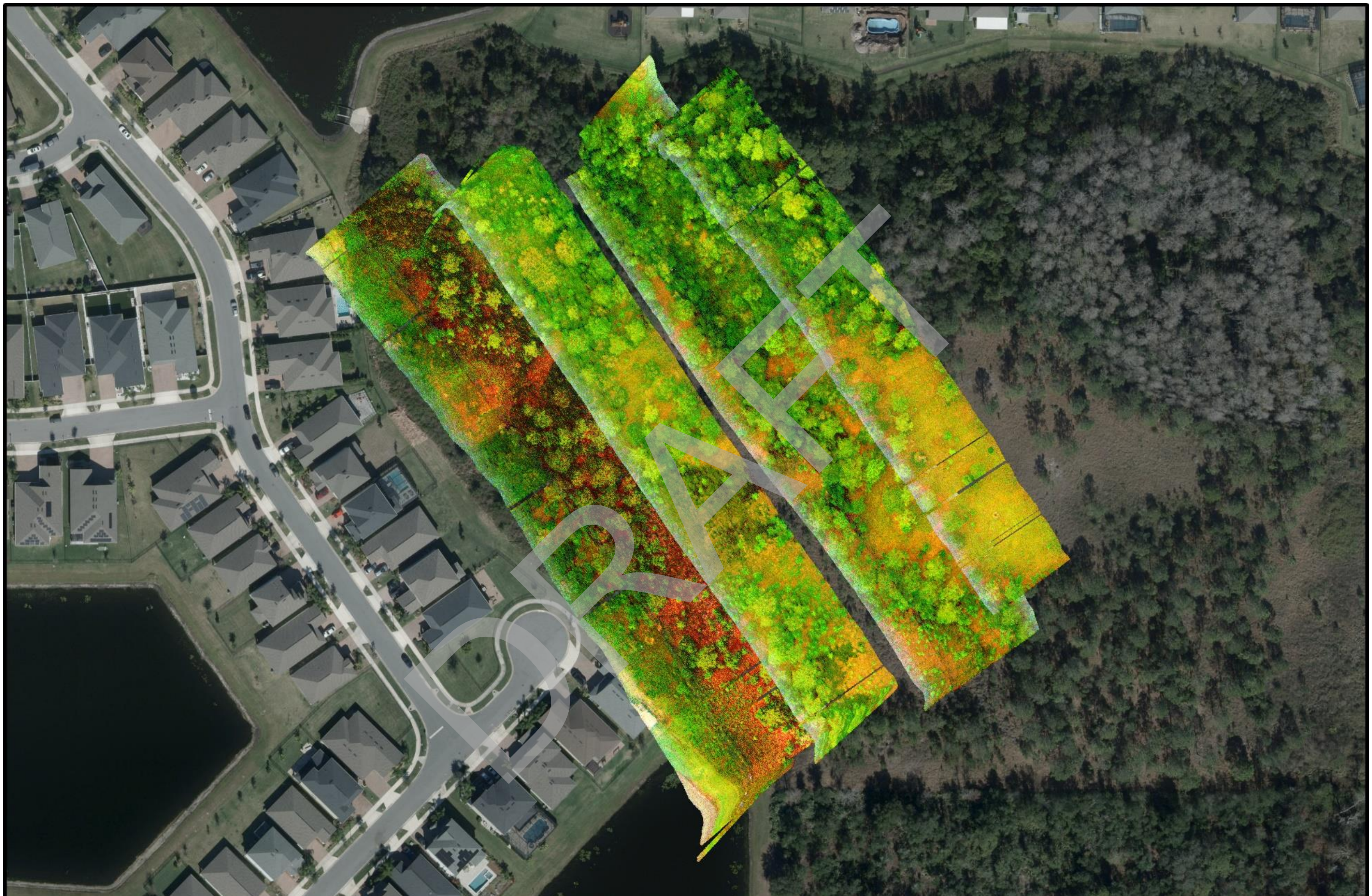
14 December 2022
AEI Wetland 8

N
0 0.02 0.04 Miles
Scale: 1:2,500

APPLIED ECOLOGY

14 December 2022
AEI Wetland 10

N
0 0.02 0.04 Miles
Scale: 1:3,250



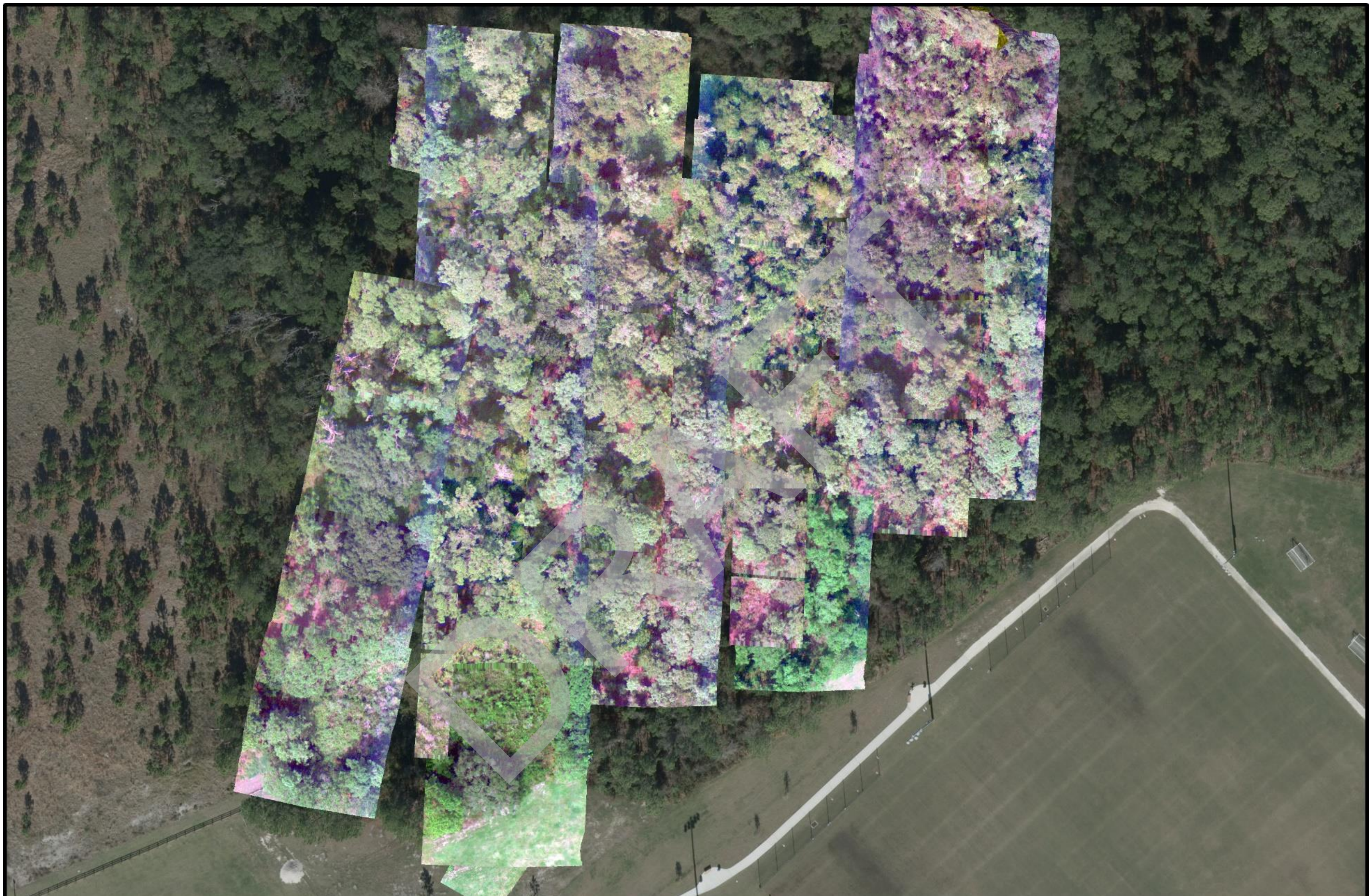
APPLIED ECOLOGY

26 September 2022
AEI Wetland 15

N
0 0.01 0.03
Miles
Scale: 1:2,077

26 September 2022
AEI Wetland 18

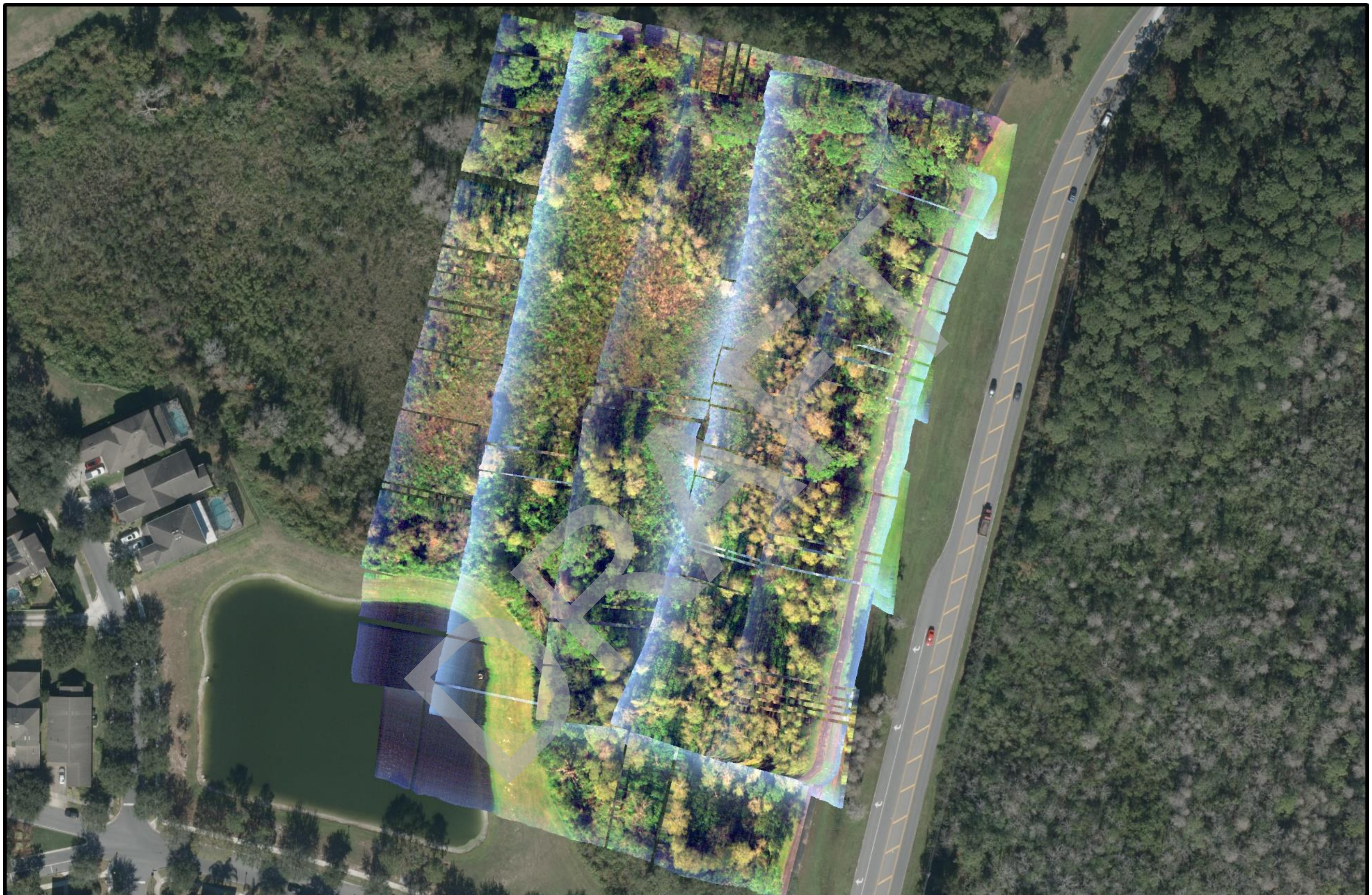
N
0 0.01 0.02
Miles
Scale: 1:1,400



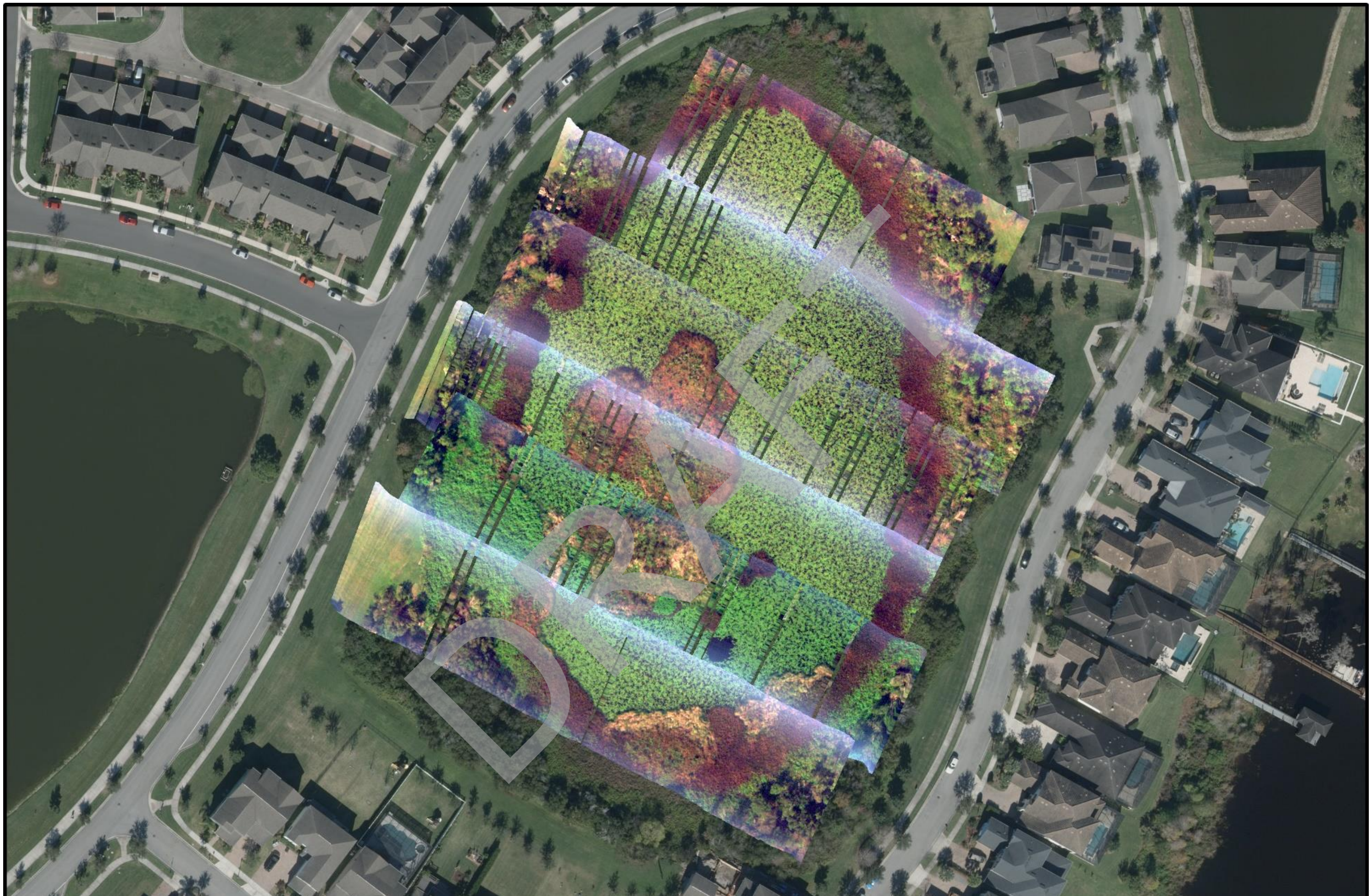
APPLIED ECOLOGY

26 September 2022
AEI Wetland 19

N
0 0.01 0.02 Miles
Scale: 1:1,500



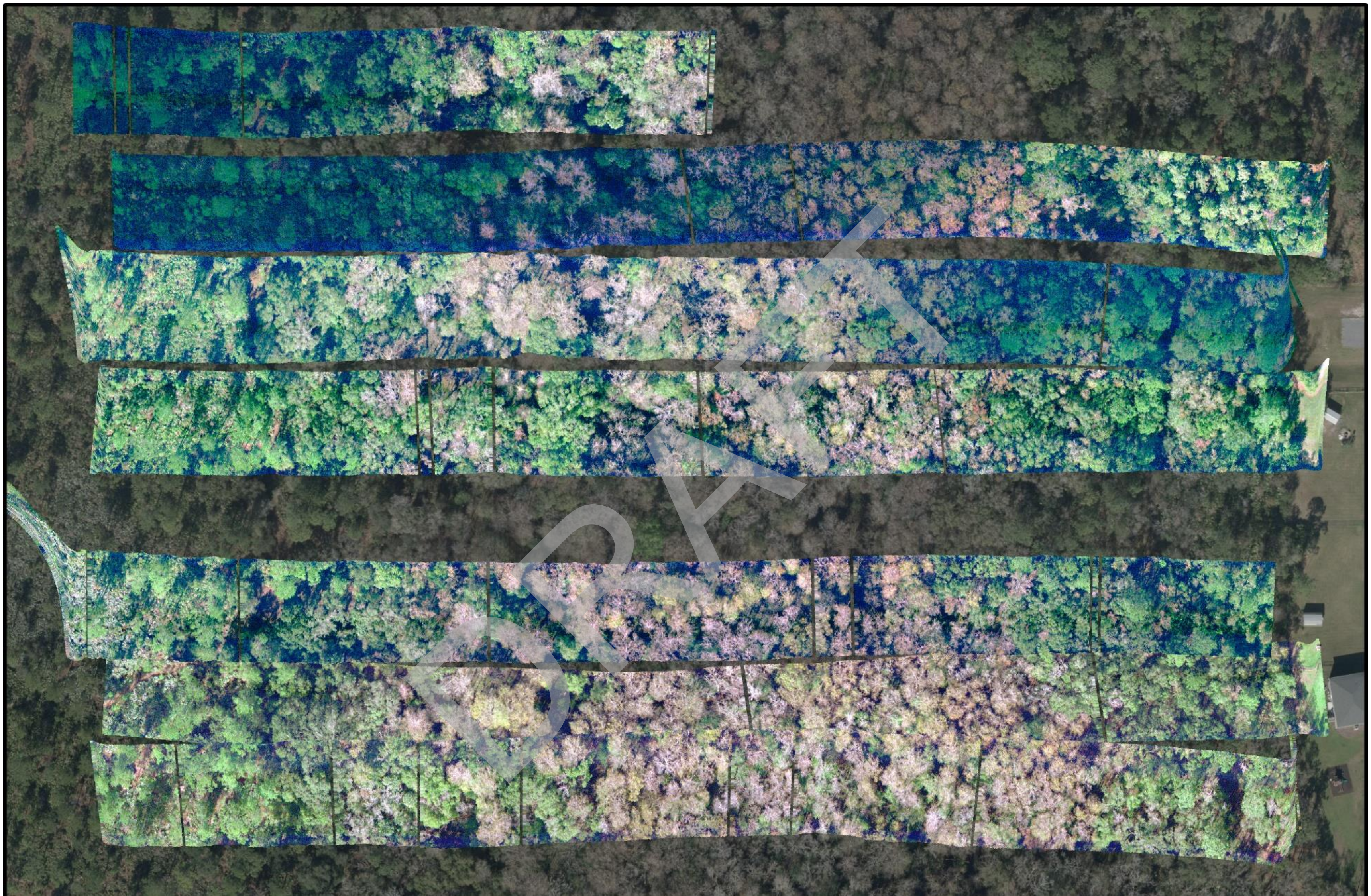
APPLIED ECOLOGY	**17 November 2022** **AEI Wetland 21**	N 0 0.01 0.03 Miles Scale: 1:1,800



APPLIED ECOLOGY

17 November 2022
AEI Wetland 22

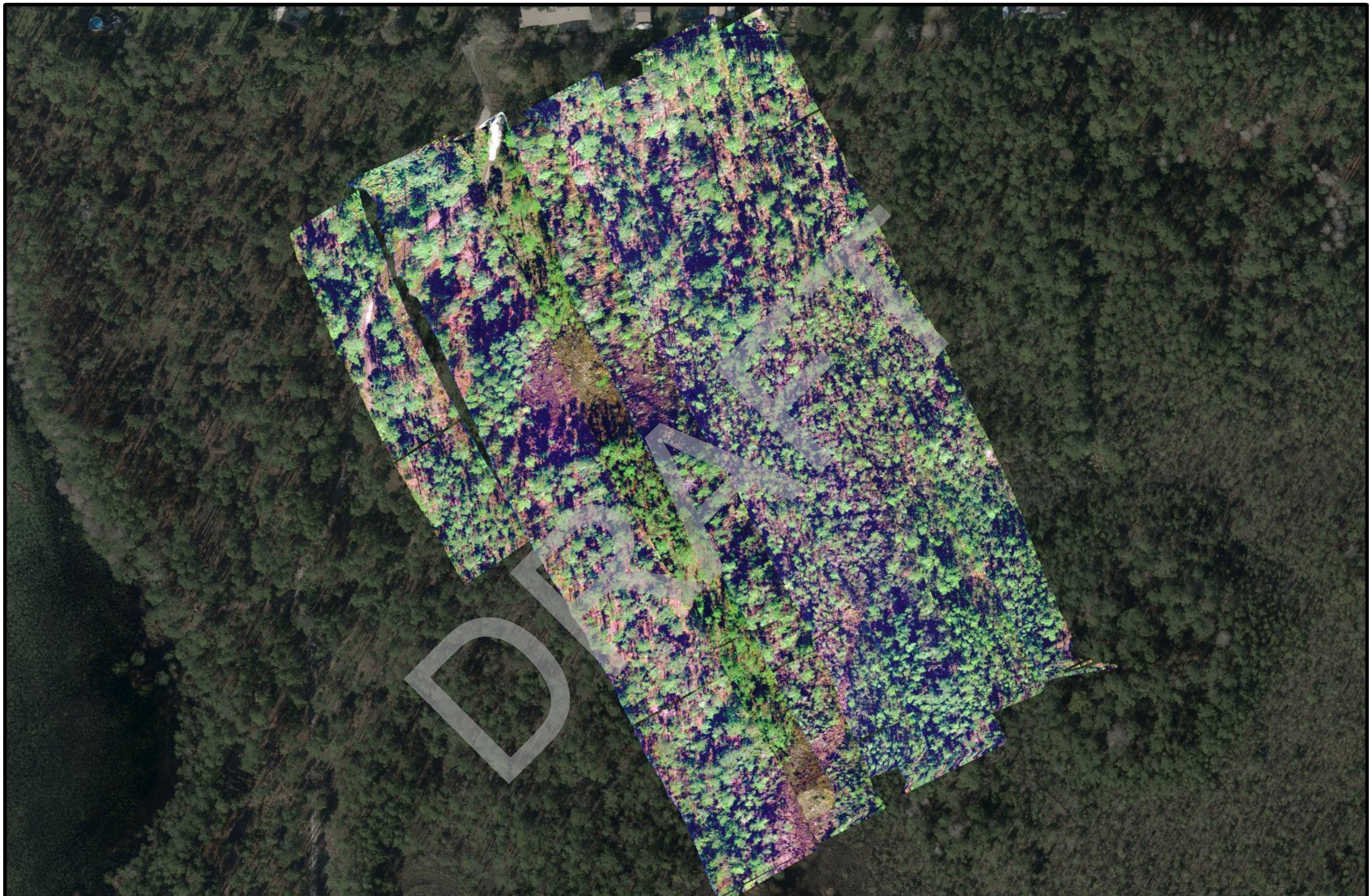
N
0 0.01 0.02 Miles
Scale: 1:1,649



APPLIED ECOLOGY

19 December 2022
AEI Wetland 36

N
0 0.01 0.03 Miles
Scale: 1:2,000



APPLIED ECOLOGY

19 December 2022
AEI Wetland 37

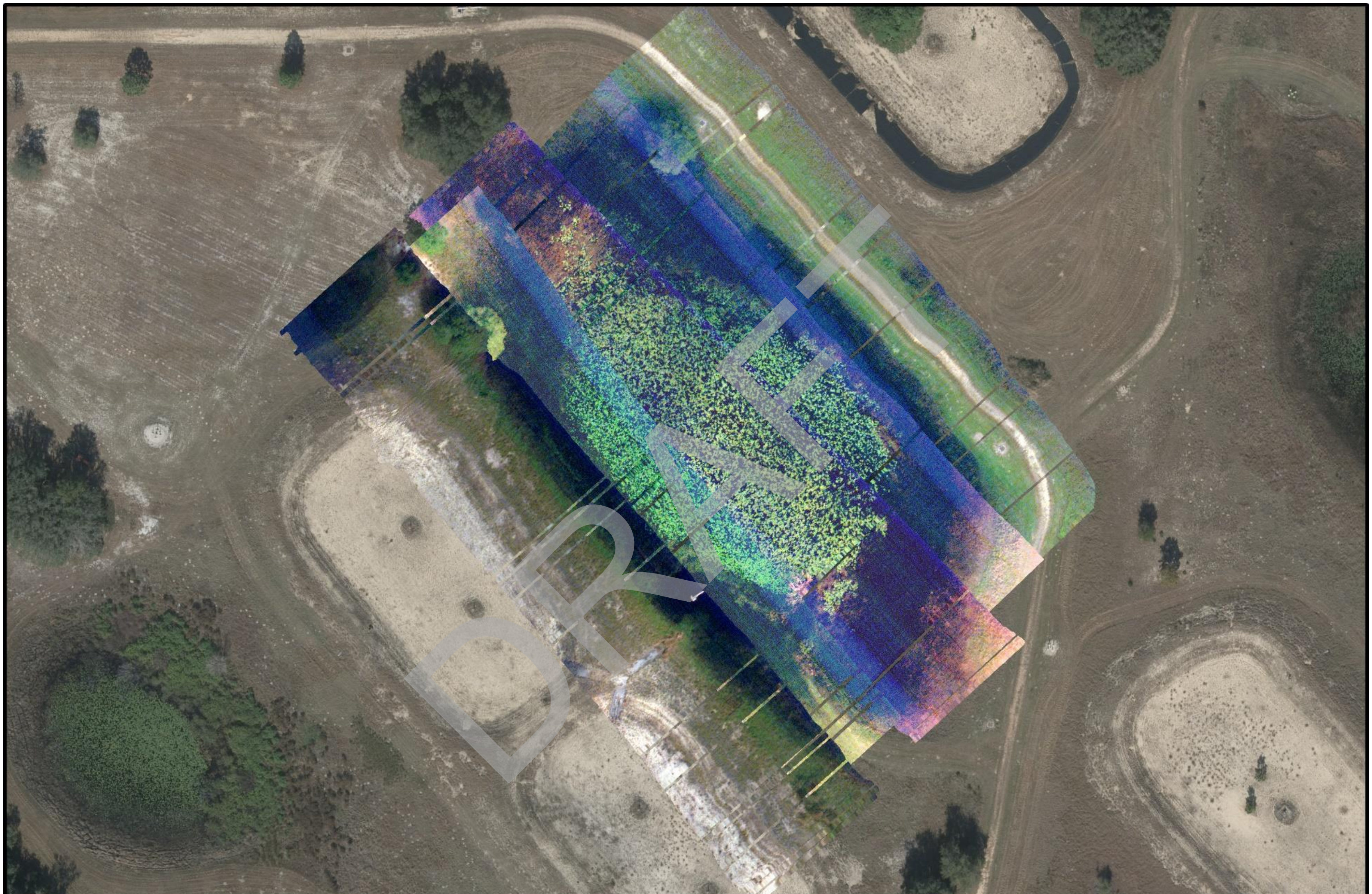
N

0 0.02 0.04 Miles

Scale: 1:2,600

19 December 2022
AEI Wetland 38

N
0 0.01 0.03
Miles
Scale: 1:2,250



APPLIED ECOLOGY

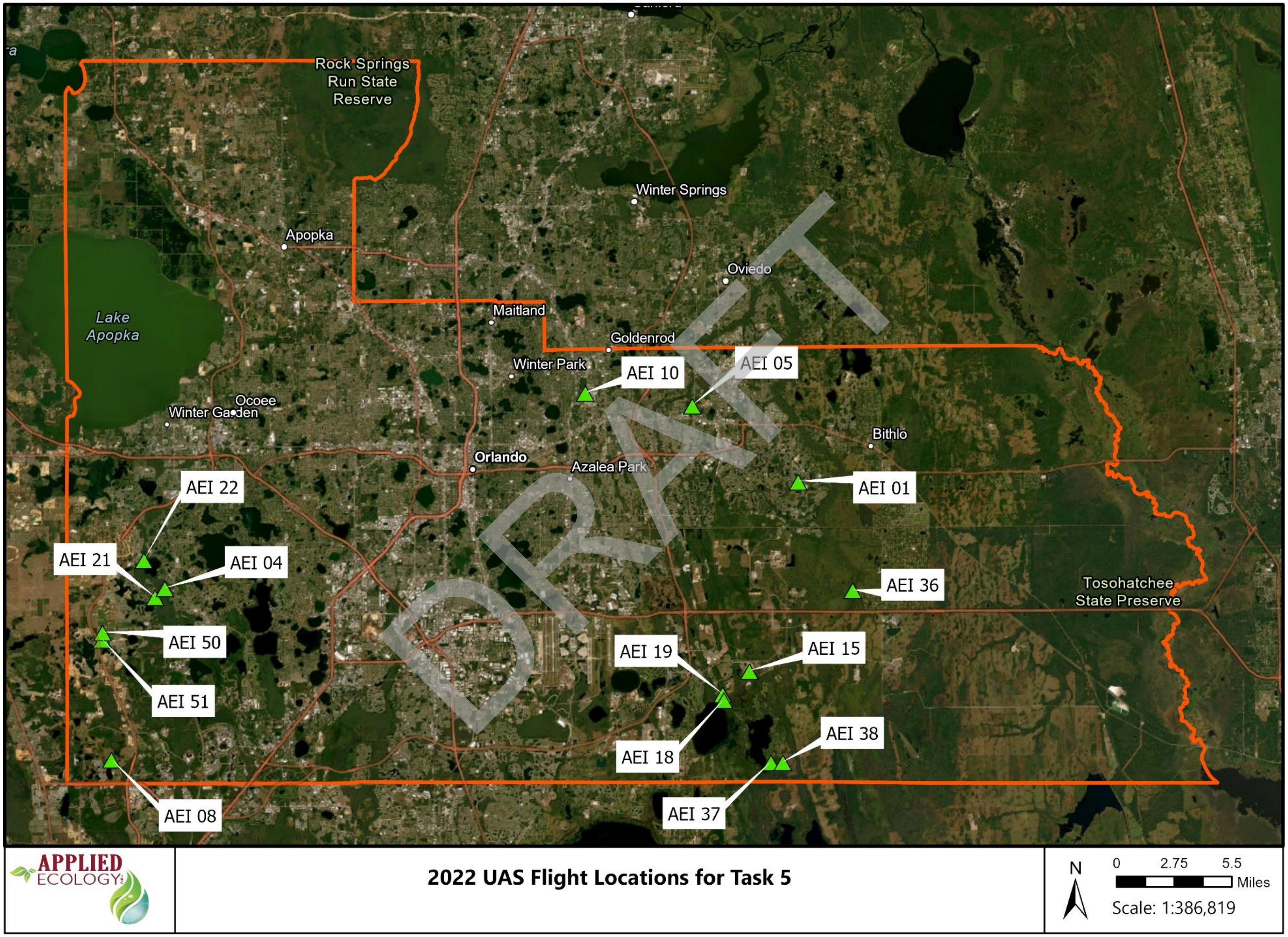
16 December 2022
AEI Wetland 50

N
0 0.01 0.03 Miles
Scale: 1:1,750

APPLIED ECOLOGY

16 December 2022
AEI Wetland 51

N
0 0.01 0.01
Miles
Scale: 1:900



2022 UAS Flight Locations for Task 5