Florida Wildlife Corridor Water Benefits Report

An Independent Assessment Led by the University of Florida Water Institute

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Findings and opinions expressed herein are the collective work of the author team and are based solely on analysis of pre-existing scientific literature and data.

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Foreword

In 2021 the campaign to conserve the 18-million-acre Florida Wildlife Corridor accelerated with the unanimous passing of a state bill supporting the effort. Thereafter, it quickly became clear that understanding and communicating the varied benefits of land conservation and connectivity—for wildlife, but also for economies, people, and the services people get from nature—would be critical to motivating large-scale land conservation action. Chief among these considerations was water, writ large.

Florida is famous for its water. The state's iconic attractions include white sand Gulf beaches, the Everglades' swamps and sloughs, alligators, roseate spoonbills, clear water springs and both inland and coastal fisheries. Myriad at-risk aquatic species (especially fish and invertebrates) exist in the state's northern rivers and all 22 million Floridians require drinking water. Moreover, the state's vast agricultural economy requires extensive crop and livestock watering.

Perhaps because of water's ubiquity across the state, there has been a tendency for assumptions to be made about the benefits of land protection for water resources conservation. Given the immense interest in water statewide and the prominence of the Corridor effort, there was a clear need for authoritative information on the overlap between the Corridor and Florida's water resources.

To fill this gap, the conservation program at Archbold Biological Station (Venus, FL) approached the University of Florida Water Institute. As an independent ecological research facility with expertise in rare species and ecosystems and the agroecology of Florida ranching systems, Archbold has since 2021 led the convening of statewide conservation science for the Corridor campaign. Archbold has leveraged its network of researchers and conservation partners in agencies, aligned non-profits, and landowners to advance knowledge of the costs and benefits of Corridor conservation. At Archbold's request, the Water Institute's Director, Dr. Wendy Graham, organized an expert panel to assess overlaps between the Corridor's geography and the location of key hydrological values statewide.

The goal of the report was to gather a body of trustworthy information that conservation practitioners could confidently bring to decision-makers (e.g., agency and land trust leaders, landowners, and potential funders) and the public to motivate large-scale land conservation. With this report completed, Archbold, the Water Institute, and partners will work to make the large volume of work presented by the expert panel available through public media and outreach to conservation partners in the first part of 2023. The report also highlights outstanding unknowns about the intersection of water and land conservation in Florida with suggestions for future fruitful scientific efforts.

On behalf of the Corridor conservation community, we thank the Water Institute and the expert panel members for their time and commitment in compiling this first-of-its-kind report. We hope it will inspire future conservation success, establish a baseline for future monitoring of water resources conservation, encourage the continued interaction of ecologists, hydrologists, and conservation professionals to identify win-win opportunities for wildlife and water, and promote the utility of science for conservation planning.

Joshua Daskin, Ph.D. | Director of Conservation
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This report was generously funded by the Live Wildly Foundation.

Executive Summary

Background, Study Objectives, and Approach

The Florida Wildlife Corridor (FLWC) encompasses nearly 17.7 million acres (Figure 1), spanning from the Everglades in South Florida up to the northwestern-most part of the Panhandle. Over half (54%, 9.6 million acres) of the FLWC consists of existing conservation lands, whereas the remaining "opportunity areas" (46%, 8.1 million acres) do not yet have conservation status but would be prioritized for future conservation.

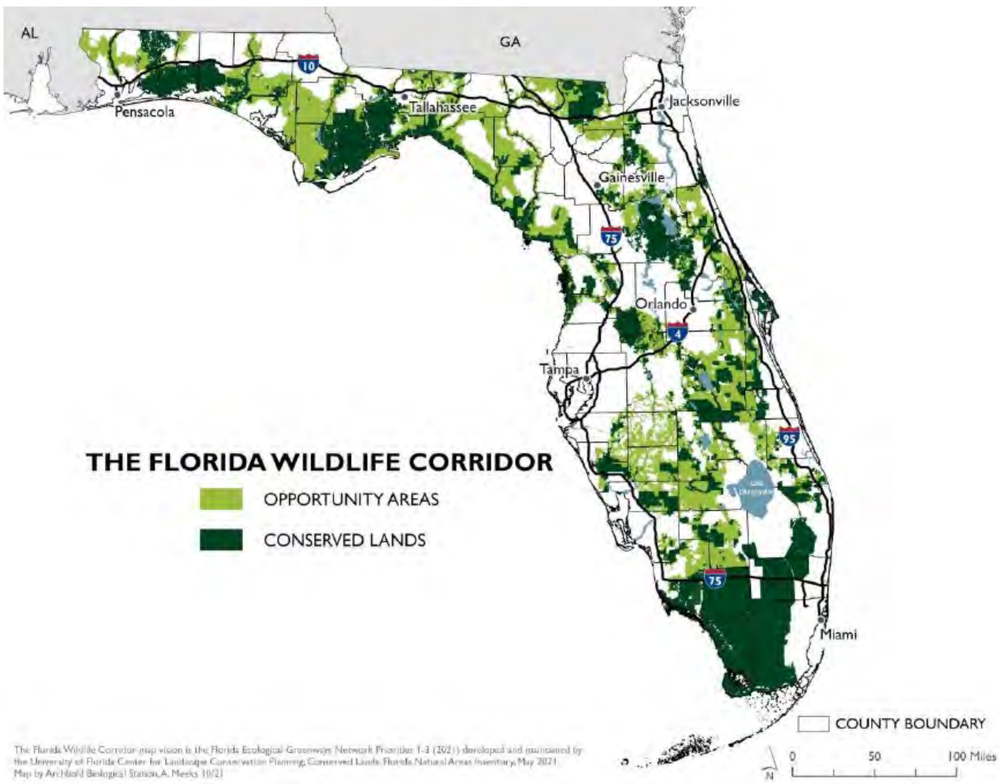

Figure 1. The Florida Wildlife Corridor Conserved lands and Opportunity areas. Map caption: The Florida Wildlife Corridor map vision is the Florida Ecological Greenways Network Priorities 1-3 (2021) developed and maintained by the University of Florida Center for Landscape Conservation Planning; Conserved Lands, Florida Natural Areas Inventory, May 2021. Map by Archbold Biological Station.

The FLWC was developed to protect functionally connected conservation lands on a landscape scale to promote ecological connectivity and establish wildlife corridors (Hoctor et al. 2015). The goals and design of the FLWC have evolved over the past four decades (Hoctor et al. 2001, 2015, and UF CLCP 2021), leading to the development of the Florida Ecological Greenways Network (FEGN), which is the basis of the current FLWC. The FEGN was developed at the University of Florida Center for Landscape Conservation and Planning (UF CLCP) and has been used by several state agencies to help prioritize state land acquisitions for recreational trails and conservation lands (e.g., the Florida Department of Environmental Protection's Office of Greenways and Trails and Florida Forever land acquisition and easement program).

Understanding how water was considered in the development and design of the FEGN is important for contextualizing the FLWC benefits to water resources across the state. While the FLWC incorporates some aquatic habitats and species considerations into its design, water resource benefits were not specifically targeted as a design objective for the FLWC. In addition, the design was intended to "identify and represent the most important statewide to regional corridors throughout Florida" (UF CLCP 2021) with an emphasis on wildlife movement, and therefore was not necessarily designed to maximize other conservation objectives such as water resource protections.

In June 2021, the Florida legislature passed the Florida Wildlife Corridor Act (2021), which encourages protection of the FLWC and mentions the following water-related benefits:

- "Protecting the headwaters of major watersheds, including the Everglades and the St. Johns River.
- Providing ecological connectivity of the lands needed for flood and sea-level rise resiliency and large-scale ecosystem functions, such as water management and prescribed burns essential for land management and restoration.
- Preserving and protecting land and waters that are not only vital to wildlife but are critical to this state's groundwater recharge and that serve as watersheds that provide drinking water to most Floridians and help maintain the health of downstream coastal estuaries."

The University of Florida Water Institute was approached by Archbold Biological Station to evaluate the state of the science regarding water-related benefits of the FLWC. The Water Institute was charged with selecting a panel of experts to review existing data and information to answer the following questions:

1. What are the water resources benefits from conservation of the Florida Wildlife Corridor?
2. What benefits are gained for water resources from a connected landscape beyond those from the total area conserved? Conversely, what are the consequences for water of not connecting the Corridor?
3. How can water resource benefits of future additional conservation lands be maximized?

We (the panel) first developed a list of potential water benefits of the FLWC to assess. The list of benefits considers the goals of the Florida Wildlife Corridor Act and input from water and conservation professionals during a virtual Water Science Exchange held by Archbold Biological

Station in March 2022 and a Corridor Summit hosted by the Florida Wildlife Corridor Foundation in April 2022. The list of potential water benefits of the FLWC includes:

- Protection of groundwater and surface water quality and quantity for humans, ecosystems, and species.
- Protection of aquatic ecosystem services including aquatic habitat, recreation and cultural values, and flood and sea level rise protection provided by springs, lakes, wetlands, rivers, and estuaries (as appropriate).
- Protection of imperiled species.

Our overall approach to assessing water benefits of the FLWC includes the following general components:

- Identification and justification of water benefit metrics
- Quantification of each metric within the FLWC
- Summary statistics and maps of the water benefits of the FLWC
- Geographic examples of high and low benefits, with recommendations for future conservation lands to augment each water benefit
- Discussion of additional benefits for water resources from a connected landscape (as appropriate)

We divided the State of Florida into four land categories for our analyses (Figure 2): FLWC existing conserved lands (***FLWC Conserved***) that comprise 27% of Florida's land area; FLWC opportunity lands (***FLWC Opportunity***) that are designated as part of the FLWC but are not yet conserved, which comprise 23% of Florida; other existing conserved lands located outside of the FLWC (***Other Conserved***) that comprise 4% of Florida's land area; and the remaining lands that are not conserved and not in the FLWC (***Not Conserved***), comprising 46% of the state.

To assess water benefits of the FLWC, we cross-referenced spatial datasets of the various water benefit metrics with the spatial extent of the four land categories and tabulated the metric in each land category (for a list of the water benefit metrics see Figure 3). The benefits from the FLWC were categorized as low-to-moderate or good-to-excellent in the following way:

- Good-to-excellent benefit (💧💧): greater than or equal to 50% of the statewide metric is within FLWC Conserved and Opportunity Areas.
- Low-to-moderate benefit (💧): less than 50% of the statewide metric is within FLWC Conserved and Opportunity Areas.

FLWC Conserved and Opportunity lands occupy 50% of the total state land area. We used this as a benchmark to establish the threshold between low-to-moderate and good-to-excellent benefits for water resources. For example, if less than 50% of total wetland habitat area lies within the FLWC, wetlands are underrepresented in the FLWC relative to statewide lands and would be designated as receiving “low-to-moderate” benefit. If 50% or more of total wetland habitat area lies within the FLWC, wetlands are well represented in the FLWC relative to statewide lands within the FLWC and would be designated as receiving “good-to-excellent” benefit.

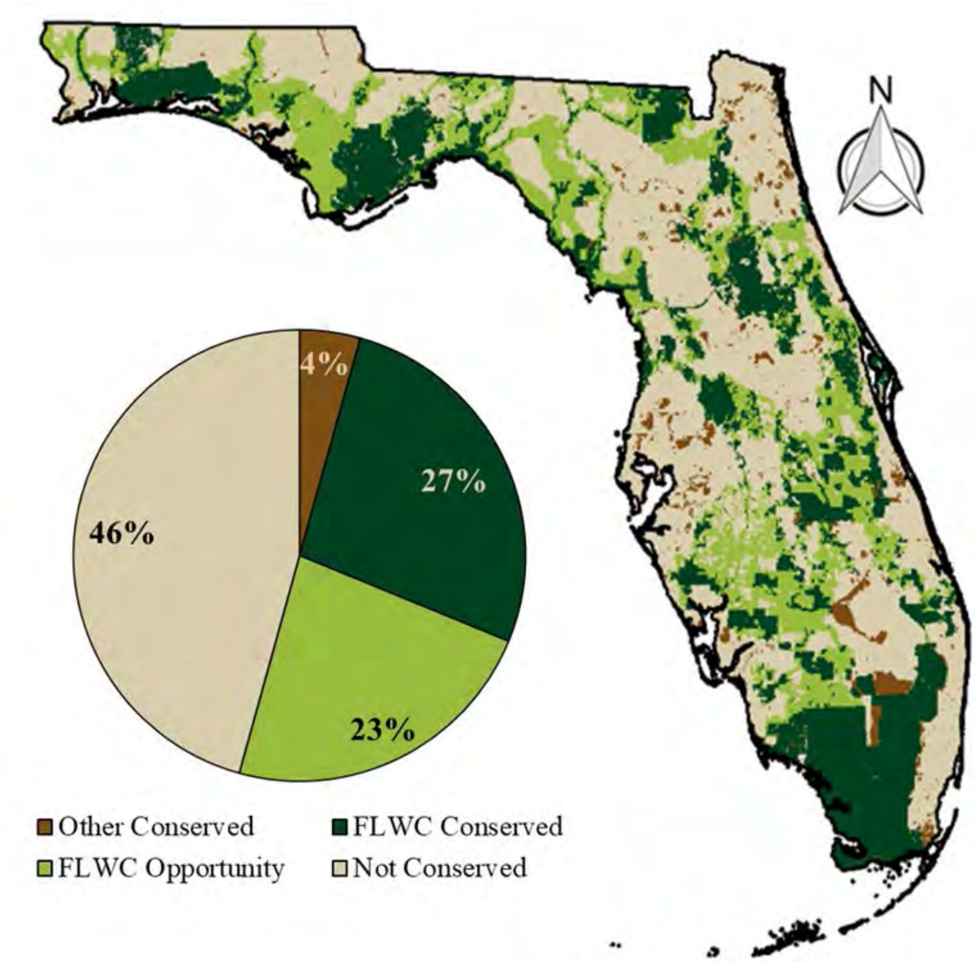

Figure 2. Percent of Florida’s land area within four land categories: Other Conserved, FLWC Conserved, FLWC Opportunity, Not Conserved.

Water Benefits of the Florida Wildlife Corridor

The benefits provided by the FLWC Conserved and Opportunity lands, based on evaluation of the entire suite of water-related metrics we developed, are presented in Figure 3 and are summarized in Table 1. Overall, we found that prioritizing land conservation within the proposed boundaries of the FLWC would provide significant benefits for Florida’s water resources. Our analyses suggest that together the FLWC Conservation and Opportunity lands would provide **good-to-excellent** benefits for spring vents, freshwater wetlands (both swamps and marshes), river corridors, river watersheds, and estuarine wetlands. Surface water and groundwater quality, groundwater recharge, surface water and groundwater supply, waterbody Minimum Flows and Levels (MFLs) and reservations, springsheds, lakes, coastlines, and fragile coastal uplands would be provided **low-to-moderate** benefit.

The FLWC is designed to conserve large terrestrial corridors that promote ecological connectivity throughout the state, which results in higher protection for some water benefits than others. For example, the FLWC design specifically incorporates river corridor and coastal-to-inland connectivity, functional wetlands, natural floodplains, and large wetland systems. Accordingly, river corridors and watersheds, wetland swamps and marshes, coastlines, and estuarine wetlands are provided good-to-excellent benefit by the corridor. Upland areas in central and north Florida tend to be excluded from the corridor, which means that many groundwater recharge areas, springsheds, and lakes are provided a low-to-moderate level of benefit.

Additionally, the FLWC design prioritizes “natural” areas and thus more developed areas including intensive agricultural areas (primarily irrigated crops) and urban areas such as the Tampa Bay region, southeast Florida, and Jacksonville area are excluded from the corridor. As a result, some vulnerable aquifer areas, high priority groundwater recharge areas, and urban coastal/estuarine areas receive low-to-moderate benefit. Similarly, limited benefit for permitted groundwater and surface water allocations is provided by the FLWC, principally because extraction sites tend to be located close to urban, industrial, and agricultural areas outside of FLWC lands. In general, groundwater quality and supply protection for wells in all aquifers throughout the state would be best protected by conserving the high-priority recharge areas and vulnerable aquifer areas which are under-represented in the current FLWC. Surface water quality and supply throughout the state would be best protected by conserving contributing watershed areas.

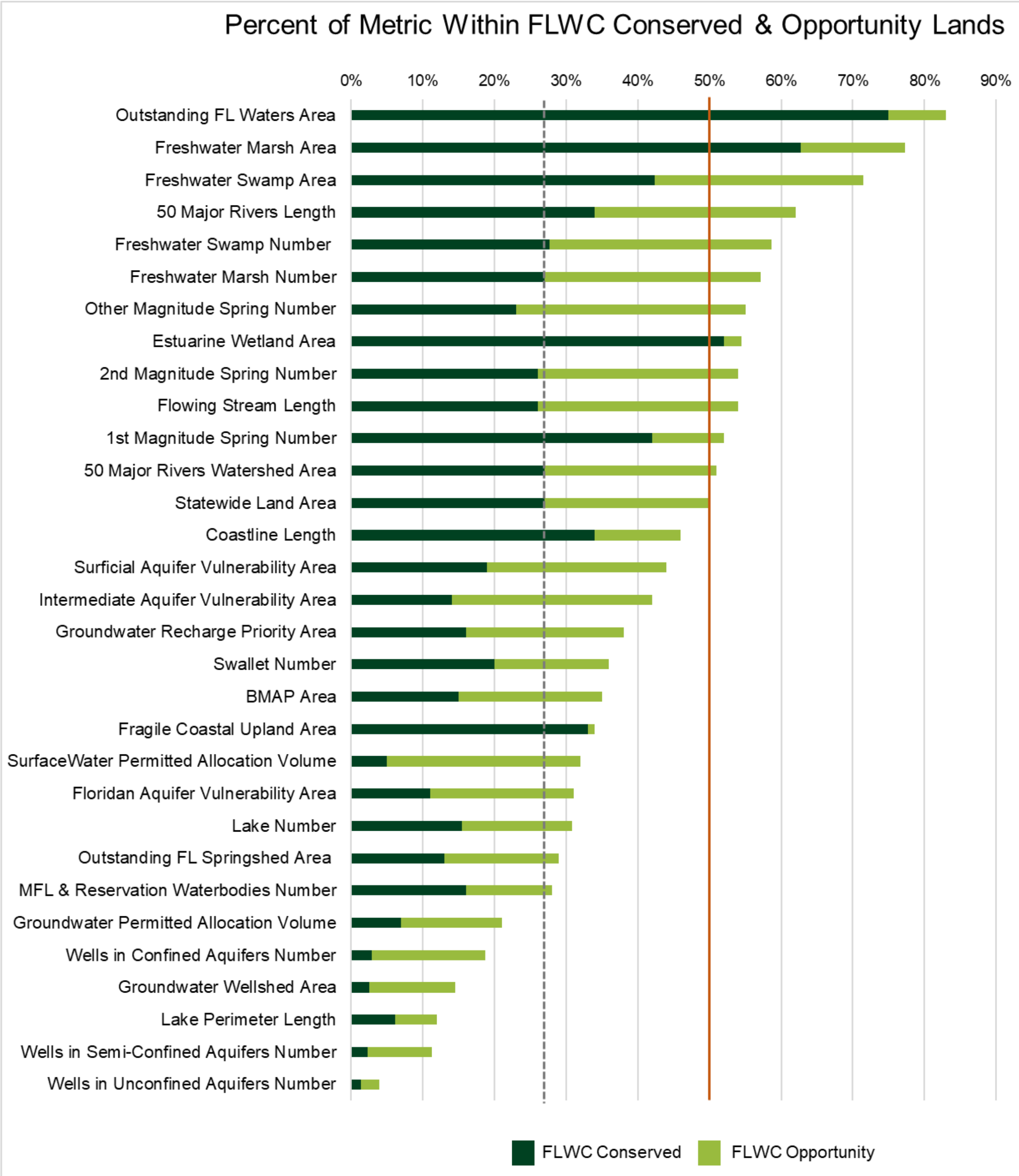

Figure 3. Percent of each water-related metric within FLWC Conserved and Opportunity areas. The orange line represents the statewide land area within the combined FLWC Conserved and Opportunity lands (the 50% threshold between low-to-moderate and good-to-excellent benefits), while the grey dashed line represents the statewide land area within only FLWC Conserved lands.

Table 1. Summary table of level of benefit provided by FLWC Conserved and Opportunity Areas to various water resources.

Water Resource	Level of Benefit Provided by FLWC Conserved & Opportunity Areas	
	💧 Low to Moderate	💧💧 Good to Excellent
Surface Water Quality	✓	
Groundwater Quality	✓	
Groundwater Recharge	✓	
Groundwater Supply	✓	
Surface Water Supply	✓	
MFLs & Reservations	✓	
Spring Vents		✓
Springsheds	✓	
Lakes	✓	
Freshwater Swamps		✓
Freshwater Marshes		✓
River Corridors		✓
River Watersheds		✓
Coastlines	✓	
Estuarine Wetlands		✓
Fragile Coastal Uplands	✓	

FLWC Opportunity lands double or nearly double benefits provided by existing FLWC Conserved lands for almost all water-related benefits and have the potential to greatly increase protection of some of the water resources that are currently provided the least benefit by FLWC Conserved and Other Conserved lands (Figure 3). Of note, Opportunity lands would more than double the conservation benefits currently provided by FLWC Conserved areas for lakes, springsheds, BMAP areas, groundwater recharge priority areas, and more vulnerable aquifer areas. Nevertheless, even with acquisition of FLWC Opportunity lands, overall conservation of these currently under-protected water resources would remain limited. This highlights the need for additional protection of these resources, perhaps from conservation programs complementary to the FLWC that strategically target functions and services that the FLWC was not designed for. For water resources and habitats already provided good benefit by FLWC Conserved and Other Conserved lands, such as 1st magnitude springs (74% conserved), estuarine wetlands (77% conserved) and fragile coastal uplands (74% conserved), the addition of FLWC Opportunity lands would only minimally increase benefit.

Several geographic regions stand out as priority areas for FLWC Opportunity land acquisition that would improve protection of various water benefits. Significant benefits to wetlands (fresh and estuarine), river corridors and watersheds, groundwater recharge areas and Outstanding Florida Springs (OFS) springsheds would be achieved with acquisition of FLWC Opportunity areas in the Panhandle (surrounding drainage and coastal areas of St. Joseph Bay, Choctawhatchee, Escambia, and Econfina River Basins), areas in the Suwannee River Basin, central Gulf Coast (Big Bend and Springs Coasts), and southwest Florida (Peace River, Myakka River, Fisheating Creek). Conservation of these areas would preserve important ecosystem services including buffering from sea level rise, water storage and flood protection, water quality protection and nutrient attenuation, carbon sequestration, and habitat for important and imperiled species.

There are also areas currently outside of the FLWC footprint (Conserved and Opportunity lands) that emerge as high priority for conservation of water benefits and appear to increase corridor connectivity. These include: 1) the Santa Fe River Basin (important for water quality, groundwater recharge, springsheds, wetlands, and river corridors, and could provide terrestrial connectivity between the Ocala National Forest area and the Suwannee River); 2) Nassau River Basin (important for wetlands, river corridors and could provide connectivity from the northeast Florida coast to the Okefenokee Swamp); and 3) several areas in the Panhandle where the corridor does not extend to state boundaries (important for springsheds, wetlands, river corridors, surface water quality, and could provide connectivity to conserved lands in Georgia and Alabama). Notably all three of these regions lie in Priority 4-5 regions of the Florida Ecological Greenways Network. Additionally, whereas urbanization in the Tampa Bay region may preclude significant corridor conservation, several rivers/stream networks and wetlands would benefit from additional measures of protection, particularly the Alafia and Hillsborough Rivers, which are also used for public water supply.

The water resource benefits of the FLWC will depend on how conserved lands are managed (EPA, 2022). Conservation easements that encourage land management practices that increase groundwater recharge, increase local storage of surface waters, reduce nutrient losses to ground and surface waters, increase nutrient attenuation in wetlands and riparian corridors, reduce water use, and reduce sediment losses should be considered for working lands within the FLWC. Examples of these types of practices for production forests include reduced planting densities, increased thinning, shorter rotations, improved nutrient and pesticide management, erosion control, and prescribed burns. Examples of practices for ranchlands include reduced stocking densities, prescribed grazing, improved nutrient and pesticide management, erosion control, wetlands restoration and water storage, and fencing of cattle out of waterways. For irrigated agricultural lands, management options may include converting irrigated areas to less water-intensive crops, silviculture, or ranchlands over time, and/or increasing water- and nutrient-use efficiencies for irrigated crops. For all FLWC working lands, buffers should be encouraged around depressional wetlands, lakes, sinkholes, and streams. Additionally, habitat values will benefit from appropriate management practices such as the widespread use of prescribed fire, removal of invasive species, restoration of landscape hydrology, and the adoption of wildlife best management practices.

The scope and ambition of the Florida Wildlife Corridor is exciting and globally noteworthy. The eminent biologist E.O. Wilson argued that the appropriate balance of conservation and development to achieve planetary protections for biodiversity and ecosystem function was 50-50, making the proposed 50% statewide footprint of the Florida Wildlife Corridor a landmark achievement, particularly in a state like Florida with such a remarkable development trajectory. At least as important as the total area dedicated to conservation is the design of a protected areas network that will maintain functional habitat connectivity, with attendant benefits for river corridors and wetland-rich landscapes. While there is variation in the extent to which the FLWC can provide all water-related benefits, with some such as groundwater recharge, OFS springsheds, MFL and reservation waterbodies, lakes, and water supply provided low-to-moderate benefit by current and proposed conservation efforts, the positive effects of the FLWC for water resources are unequivocal and should provide a source of considerable conservation optimism. These results demonstrate the potential to achieve multiple ecosystem service benefits through land conservation; this multi-objective approach can serve as a model for land conservation efforts beyond Florida.

Full Report

I. Introduction

Background

The Florida Wildlife Corridor (FLWC) encompasses nearly 17.7 million acres (Figure I-1), spanning from the Everglades in South Florida up to the northwestern-most part of the Panhandle. Over half (54%, 9.6 million acres) of the FLWC consists of existing conservation lands, whereas the remaining “opportunity areas” (46%, 8.1 million acres) do not yet have conservation status but would be prioritized for future conservation.

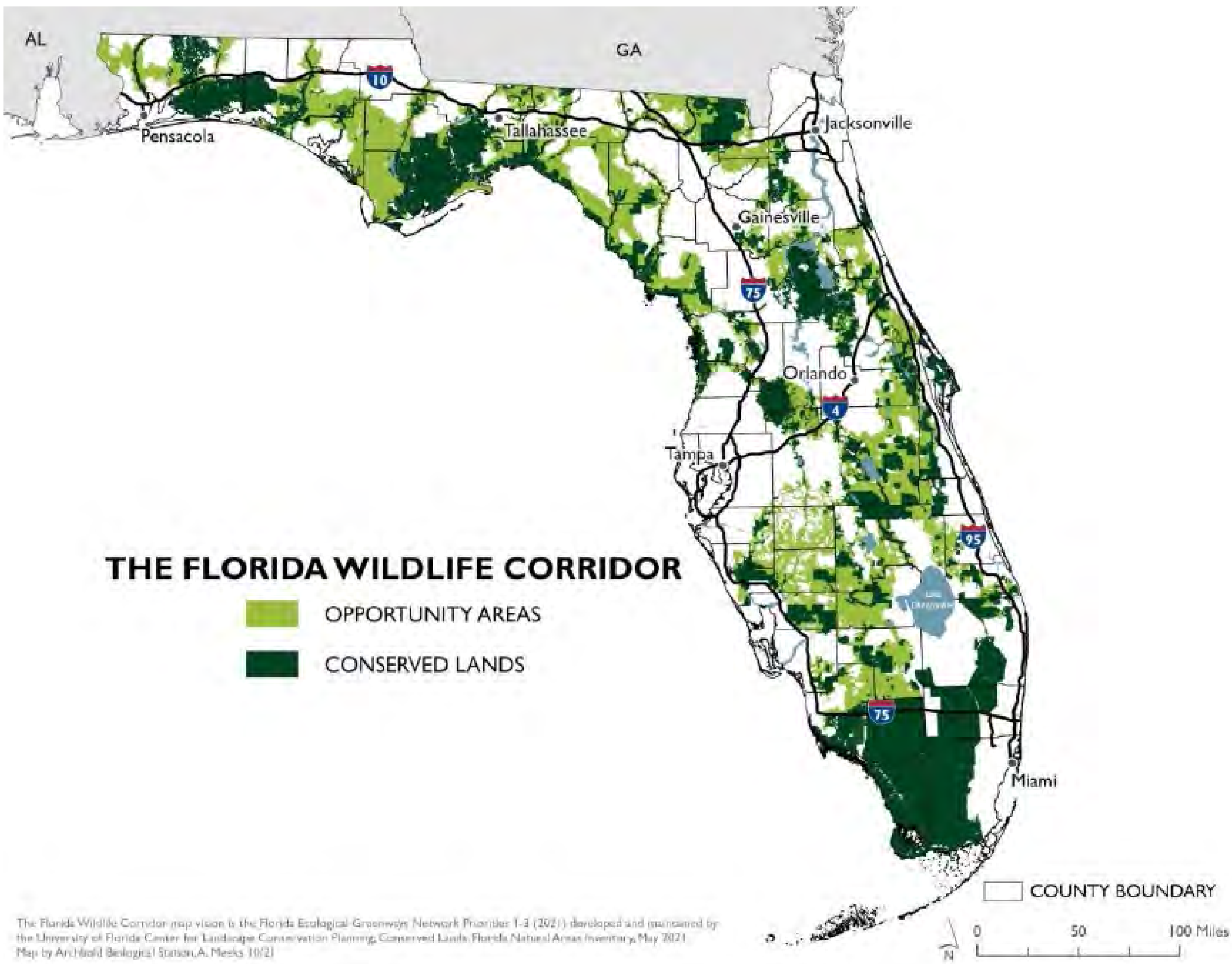

Figure I-1. The Florida Wildlife Corridor Conserved lands and Opportunity areas. Map caption: The Florida Wildlife Corridor map vision is the Florida Ecological Greenways Network Priorities 1-3 (2021) developed and maintained by the University of Florida Center for Landscape Conservation Planning; Conserved Lands, Florida Natural Areas Inventory, May 2021. Map by Archbold Biological Station.

The FLWC was developed to protect functionally connected conservation lands on a landscape scale to promote ecological connectivity and establish wildlife corridors (Hoctor et al. 2015). The goals and design of the FLWC have evolved over the past four decades (Hoctor et al. 2001, 2015, and UF CLCP 2021), leading to the development of the Florida Ecological Greenways Network (FEGN), which is the basis of the current FLWC. The FEGN was developed at the University of Florida Center for Landscape Conservation and Planning (UF CLCP) and has been used by several state agencies to help prioritize state land acquisitions for recreational trails and conservation lands (e.g., the Florida Department of Environmental Protection's Office of Greenways and Trails and Florida Forever land acquisition and easement program).

The FEGN is delineated and updated every 5-8 years through a process of GIS analyses and input from a Technical Advisory Group that:

1) identifies priority ecological areas (PEAs),
2) identifies hubs, which are larger connected areas of PEAs that can support wide-ranging or fragmentation-sensitive species,
3) assesses connectivity (including for Florida panther habitat, Florida black bear habitat, riverine corridors, coastal to inland connectivity, xeric habitat connectivity, integrated habitat connectivity, and general landscape connectivity),
4) combines hub and connectivity analyses results, and
5) classifies the resulting land areas into priorities 1-5 (previously 1-6).

The process results in a spatial designation of priorities 1-5 (P1-5) across the state, with 1 being the highest priority for conservation. P1 and P2 areas are considered to be critical hubs and linkages, whereas P3 areas are considered to represent connectivity alternatives and additional statewide priorities. The latest update of the FEGN was in 2021, and the 2021 FEGN P1-3 areas make up the current designation for the FLWC. For more information on the FEGN design and prioritization process see the UF CLCP website: http://conservation.dcp.ufl.edu/fegnproject/.

Understanding how water was considered in the development and design of the FEGN is important for contextualizing the FLWC benefits to water resources across the state. Various data layers were considered for the first step in the process of identifying PEAs, which include landscape species models, matrix-landscape natural communities, large species habitat and conservation zones, dark sky zones, strategic habitat conservation areas, existing conservation lands, and other layers developed by the Florida Natural Areas Inventory (FNAI). Of the datasets that went into developing the 2021 PEAs, the following include consideration of water-related habitats or species:

- Wood stork landscape species model (FNAI)

- Snail kite landscape species model (FNAI)
- Gulf sturgeon landscape species model (FNAI)
- Manatee landscape species model (FNAI)
- Matrix-landscape natural communities: larger wetland systems that are 500 acres or larger including swale, slough marsh, basin marsh, strand swamp, marl prairie, basin swamp and hydric hammock (Florida Cooperative Land Cover, FNAI modified version)
- Rare species habitat conservation priorities (FNAI)
- FL Forever Functional Wetlands (FNAI)
- FL Forever Natural Floodplains (FNAI)
- Potential Natural Areas (FNAI)
- Coastal Barrier Resources Act (CBRA) lands

In addition, connectivity analyses that incorporated water components include riverine corridors, coastal to inland connectivity, and the integrated habitat network (IHN) in the Peace River basin in west-central Florida. For the river corridor connectivity analysis, the "model buffers all Major Rivers and connected Special Outstanding Florida Waters by 800 meters [0.5 miles] with all connected compatible land uses including all natural, semi-natural, and pastureland uses" (UF CLCP 2021). For the coastal to inland connectivity analysis, "compatible areas of all natural and semi-natural land uses and with Landscape Integrity index scores of 5 or greater up to a mile beyond a projected 3 meter [10-foot] SLR [sea level rise] were included" (UF CLCP 2021). The IHN consists of a reclamation design for the 1.3-million-acre phosphate mining area in the Peace River Basin region in central-west Florida (FDEP 2020). The IHN connectivity analysis first identified National Hydrography Dataset flowlines (rivers, streams, and canals) within the IHN. A buffer was then established "to identify all natural, semi-natural, agricultural, and mining land uses connected to and within 200 meters [0.12 miles] of the IHN flowlines" (UF CLCP 2021).

The Florida Wildlife Corridor Act

In June 2021, the Florida legislature passed the Florida Wildlife Corridor Act (2021), which "creates incentives for conservation and sustainable development" by encouraging protection of the corridor (defined by the P1-3 areas of the FEGN). It mentions the following water-related benefits:

- "Protecting the headwaters of major watersheds, including the Everglades and the St. Johns River.
- Providing ecological connectivity of the lands needed for flood and sea-level rise resiliency and large-scale ecosystem functions, such as water management and prescribed burns essential for land management and restoration.

- Preserving and protecting land and waters that are not only vital to wildlife but are critical to this state's groundwater recharge and that serve as watersheds that provide drinking water to most Floridians and help maintain the health of downstream coastal estuaries."

Study Objectives, Water Benefits and Approach

The University of Florida Water Institute was approached by Archbold Biological Station to evaluate the state of the science regarding water-related benefits of the FLWC. The Water Institute was charged with selecting a panel of experts to review existing data and information to answer the following questions:

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We divided the State of Florida into four land categories for our analyses (Figure I-2): FLWC existing conserved lands (***FLWC Conserved***) that comprise 27% of Florida's land area (UF CLCP 2021); FLWC opportunity lands (***FLWC Opportunity***) that are designated as part of the FLWC but are not yet conserved, which comprise 23% of Florida (UF CLCP 2021); other existing conserved lands located outside of the FLWC (***Other Conserved***; based on FNAI Florida Conservation Lands, 2022) that comprise 4% of Florida's land area; and the remaining lands that are not conserved and not in the FLWC (***Not Conserved***), comprising 46% of the state.

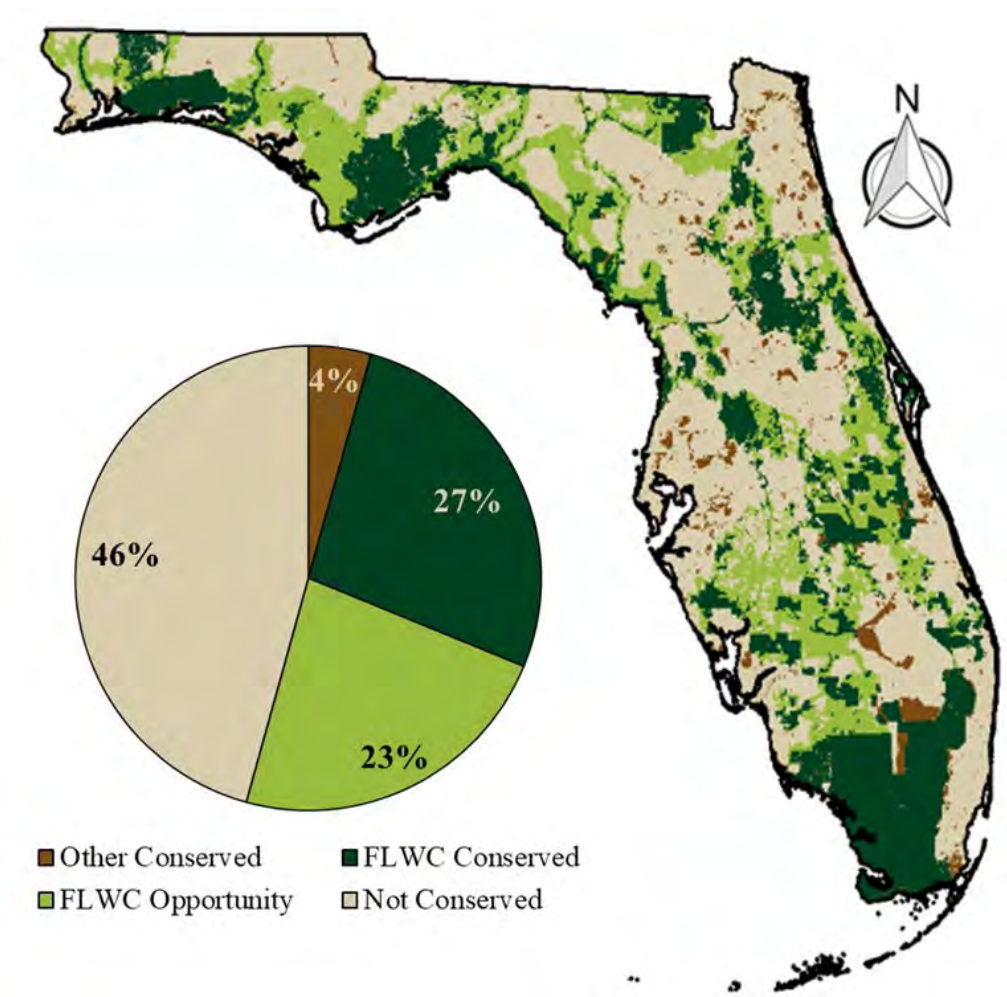

Figure I-2. Percent of Florida's land area within four land categories: Other Conserved, FLWC Conserved, FLWC Opportunity, Not Conserved.

To assess water benefits of the FLWC, we cross-referenced spatial datasets of the various water benefit metrics with the spatial extent of the four land categories and tabulated the metric in each land category. The benefits from the FLWC were categorized as low-to-moderate, good, or excellent in the following way:

- Good-to-excellent benefit (💧💧): greater than or equal to 50% of statewide metric is within FLWC Conserved and Opportunity Areas.
- Low-to-moderate benefit (💧): less than 50% of statewide metric is within FLWC Conserved and Opportunity Areas.

FLWC Conserved and Opportunity lands occupy 50% of the total state land area. We used this as a benchmark to establish the threshold between low-to-moderate and good-to-excellent benefits for water resources. For example, if less than 50% of total wetland habitat area lies within the FLWC, wetlands are underrepresented in the FLWC relative to statewide lands and would be designated as receiving “low-to-moderate” benefit. If 50% or more of total wetland habitat area lies within the FLWC, wetlands are well represented in the FLWC relative to statewide lands within the FLWC and would be designated as receiving “good-to-excellent” benefit.

Report Structure

The full report contains an introduction section and chapters divided by category of water benefit of the FLWC as follows: statewide water quality and quantity; water supply; springs; lakes; wetlands; rivers; estuaries; and imperiled species. Each chapter contains background information, metrics and justification, methods, results and discussion, and conclusions. Appendices A, B, and C provide additional details regarding water supply analyses. Abbreviations and references are provided at the end of the report.

II. Statewide Water Quantity and Quality

Background

Florida has a diverse system of water resources including 3 major aquifer systems and more than (>) 50 major rivers and streams, >700 springs, >7700 lakes, and >10 million acres of wetlands. Maintaining an abundant high-quality water supply to these resources is essential to protect ecosystem and human health, as well as economic prosperity in the state.

The vast majority of water that supplies these water resources falls as rainfall within the state of Florida. When rain falls on the land surface it may be evaporated or transpired back to the atmosphere; it may move over land through watersheds into streams, rivers, estuaries, lakes, and wetlands; or it may percolate through the soil to recharge aquifers that may subsequently feed rivers, lakes, wetlands, and springs.

Alteration of land cover within watersheds can reduce groundwater recharge, drain wetlands and floodplains, and change the flows, levels and hydroperiods of aquifers, rivers and streams, springs, lakes, and wetlands in ways that may be detrimental to ecosystem health. Overuse of water for public supply, agricultural irrigation, and industrial uses can result in similar detrimental changes. Likewise urban, agricultural, and industrial land uses can pollute Florida's water systems with nutrients, agricultural and industrial chemicals, and pharmaceuticals.

Conserving substantial portions of Florida's surface watersheds and aquifer recharge areas within the FLWC, along with appropriate management of water and land uses on conserved lands, has the potential to provide substantial benefits to Florida's statewide water quantity and quality for both humans and natural systems.

Metrics

We utilized the following metrics to assess the benefits of the FLWC to Florida's statewide water quantity and quality: the area of Florida's 50 major rivers' watersheds within FLWC Conserved and Opportunity lands; the area of Florida Department of Environmental Protection (FDEP) Basin Management Action Plan (BMAP) regions within FLWC Conserved and Opportunity lands; the area of high-priority aquifer recharge regions within FLWC Conserved and Opportunity lands; and the area of land designated as more vulnerable to aquifer contamination within FLWC Conserved and Opportunity lands.

The assessment of benefits to Florida's statewide water quantity and quality for both humans and natural systems is based on several assumptions:

- The area of Florida's 50 major watersheds within the FLWC translates proportionally to protections of flows, levels, hydroperiods, and water quality for rivers, springs, estuaries, lakes, and wetlands.
- The BMAP area within the FLWC translates proportionally to increased likelihood that Total Maximum Daily Loads[1] and Numeric Nutrient Criteria[2] will be achieved in the associated impaired water bodies, thus improving water quality.
- The high-priority aquifer recharge area within the FLWC translates proportionally to protection of aquifer recharge.
- The area of land designated as more vulnerable to aquifer contamination within the FLWC translates proportionally to protections of the quality of water recharging the aquifer.
- The degree of protection provided to Florida's watersheds and aquifer recharge areas will be dependent on how the FLWC conserved lands are managed.

Methods

We quantified statewide water quantity and quality benefit metrics by overlaying the following GIS coverages on the four statewide land categories of FLWC Conserved Areas, FLWC Opportunity Areas, Other Conserved Areas, and Not Conserved Areas:

- Florida's 50 major rivers as identified by the Florida Fish and Wildlife Conservation Commission (FWC)- Fish and Wildlife Research Institute (2020) https://www.arcgis.com/home/item.html?id=3158502d6e094de8b5871a9a9666bb18
- Florida Department of Environmental Protection Basin Management Action Plan (BMAP) areas (2022) https://fdep.maps.arcgis.com/home/webmap/viewer.html?webmap=1b4f1bf4c9c3481fb2864a415fbeca77
- Florida Natural Areas Inventory (FNAI) Critical Lands and Waters Identification Project (CLIP) Aquifer Recharge Map (2021) https://geodata.fnai.org/maps/aquifer-recharge-1/explore?location=27.726290%2C-83.734464%2C7.64
- Florida Department of Environmental Protection Floridan, Intermediate and Surficial Aquifer System Contamination Potential Maps (2022) https://geodata.dep.state.fl.us/datasets/FDEP::floridan-aquifer-system-contamination-potential/about

[1] A Total Maximum Daily Load (TMDL) is a scientific estimate of the maximum amount of a given pollutant that a surface water body can absorb and still meet the water quality standards that protect human health and aquatic life (https://floridadep.gov/DEAR/Water-Quality-Evaluation-TMDL)

[2] A Numeric Nutrient Criteria (NNC) is a scientific estimate of the maximum nutrient concentration in a water body that will not cause an imbalance in natural populations of aquatic flora or fauna (https://floridadep.gov/dear/water-quality-standards/content/numeric-nutrient-criteria-development)

We tabulated the areas and percent areas of major river watersheds, BMAPS, high-priority aquifer recharge areas, and more vulnerable aquifer contamination areas within FLWC Conserved, FLWC Opportunity, Other Conserved, and Not Conserved areas and plotted them as bar charts. Statewide water quality and quantity metrics were assigned to two categories: Good-to-Excellent (greater than or equal to 50% of the statewide benefit metric within the FLWC) and Low-to-Moderate (less than 50% of statewide benefit metric within the FLWC) as outlined in Section I.

Results and Discussion

Figure II-1 overlays Florida's 50 major river watershed areas over the FLWC Existing Conserved areas, FLWC Opportunity areas, Other Conserved areas, and areas that are Not Conserved. FLWC Conserved areas include 27% of major rivers watershed area, and FLWC Opportunity lands include an additional 24%, for a combined total of 51%. Thus, if all Opportunity lands were acquired, the Florida Wildlife Corridor would provide good benefit to Florida's major watersheds, at a rate slightly greater than the statewide land area in the FLWC (50%) (Figure II-1).

However, the major rivers watershed area within the FLWC varies around the state (Figure II-3). There are large land areas within the FLWC in the southern Everglades (>5,300 mi^2, 68%) and St. Johns River (>4,300 mi^2 ,45%) watersheds. On the other hand, the Nassau River watershed in Northeast Florida and the Hillsborough and Anclote River watersheds in West Central Florida are completely outside the FLWC. Very little area of the Alafia (~21 mi^2, 5%) and Little Manatee (~11 mi^2, ~5%) River watersheds in West Central Florida is included within the FLWC (Figure II-3).

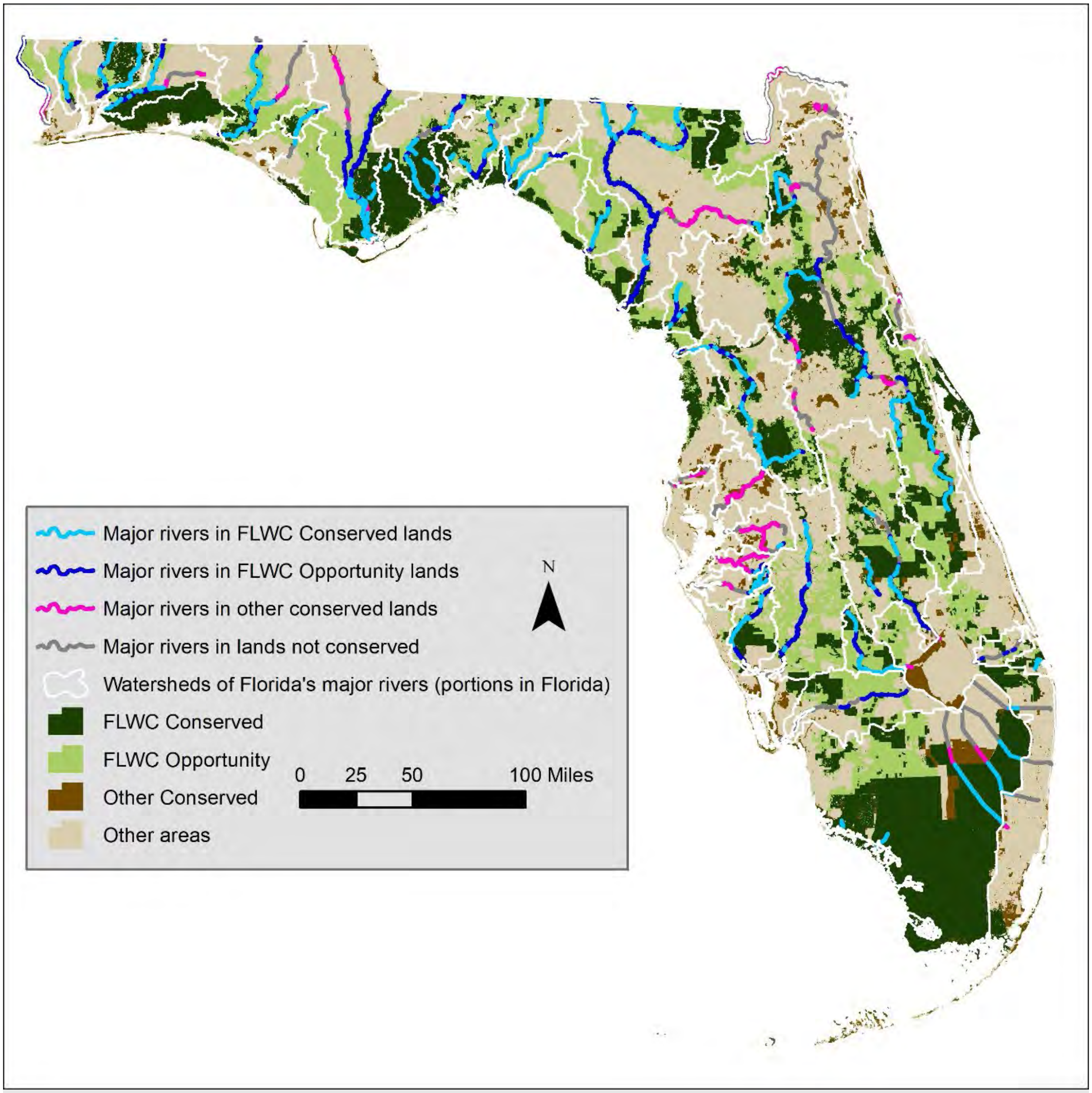

Figure II-1. Florida's 50 Major Rivers (as designated by FWC) overlain on the FLWC and Other Conserved areas.

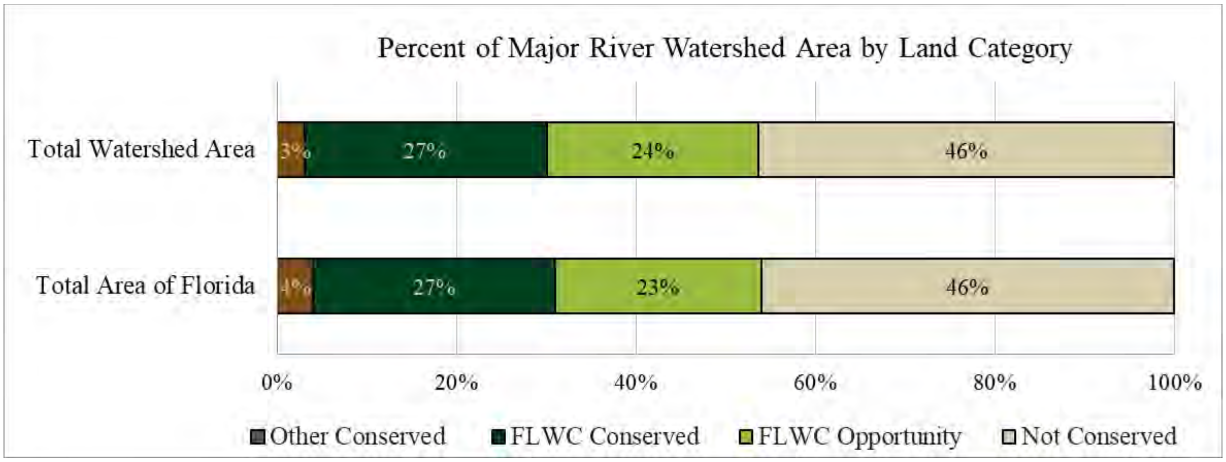

Figure II-2. Percent of total area of Florida's 50 Major River Watersheds by land category.

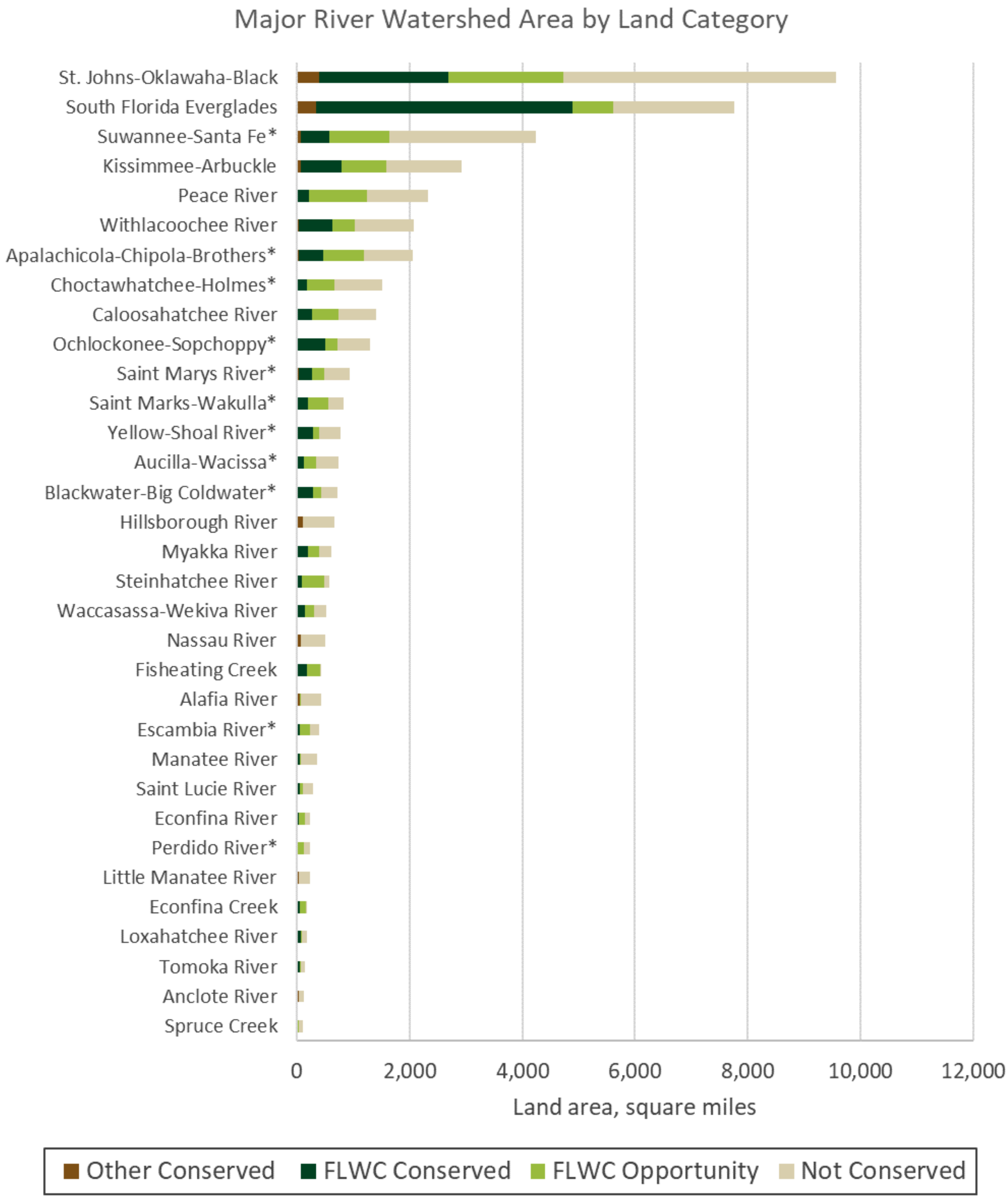

Figure II-3. Percent area of individual major river watersheds by land category. *Indicates that only the portion of the watershed in Florida was considered for the analysis.

Figure II-4 overlays Florida's BMAP areas over FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and areas that are Not Conserved. In total, FLWC Conserved areas include 15% of the BMAP area, and FLWC Opportunity areas include an additional 20%, more than doubling existing area. Together, FLWC Conserved and Opportunity areas would include 35% of the BMAP area statewide if all Opportunity lands were acquired. This is less than the 50% of statewide land area in the FLWC, indicating that overall, the FLWC would provide moderate benefit to Florida's BMAP areas and that BMAP areas are under-represented in the FLWC (Figure II-5).

As with major river watersheds, current BMAP areas within the FLWC differ around the state (Figure II-6). More than 75% of the Long Branch BMAP area in the Middle St. Johns River region is within FLWC Conserved and Opportunity areas, providing excellent benefit. Seven of the 33 BMAP areas have more than 50% of their land within FLWC Conserved and Opportunity areas and are thus provided good benefit (Caloosahatchee River, Wakulla Springs, Banana River, Middle St. Johns, Chassahowitzka-Homosassa, DeLong Spring, and the Everglades West Coast Region). Four of 33 BMAPs have between 40-50% of their land within FLWC Conserved and Opportunity lands and thus, are slightly underrepresented and provided moderate benefit (Wacissa, Lake Okeechobee, Orange Creek). However, 15 of 33 designated BMAPs have less than 20% of their land within FLWC Conserved and Opportunity areas (Jackson Blue Spring, Manatee River, Alafia River, the Hillsborough River, Lower St. Johns, Rainbow Springs, Lake Jesup, Central Indian River Lagoon, Bayou Chico, Wekiwa Springs, Volusia Blue Springs, Weeki Wachee Springs, Santa Fe River, Gemini Springs, and the Upper Ocklawaha River) and therefore receive low benefit. As new BMAPs are developed around the state they will likely accrue protection from the FLWC. For example, the Upper St. Johns River is slated for BMAP development and has a large portion of its drainage basin located within FLWC Conserved and Opportunity lands.

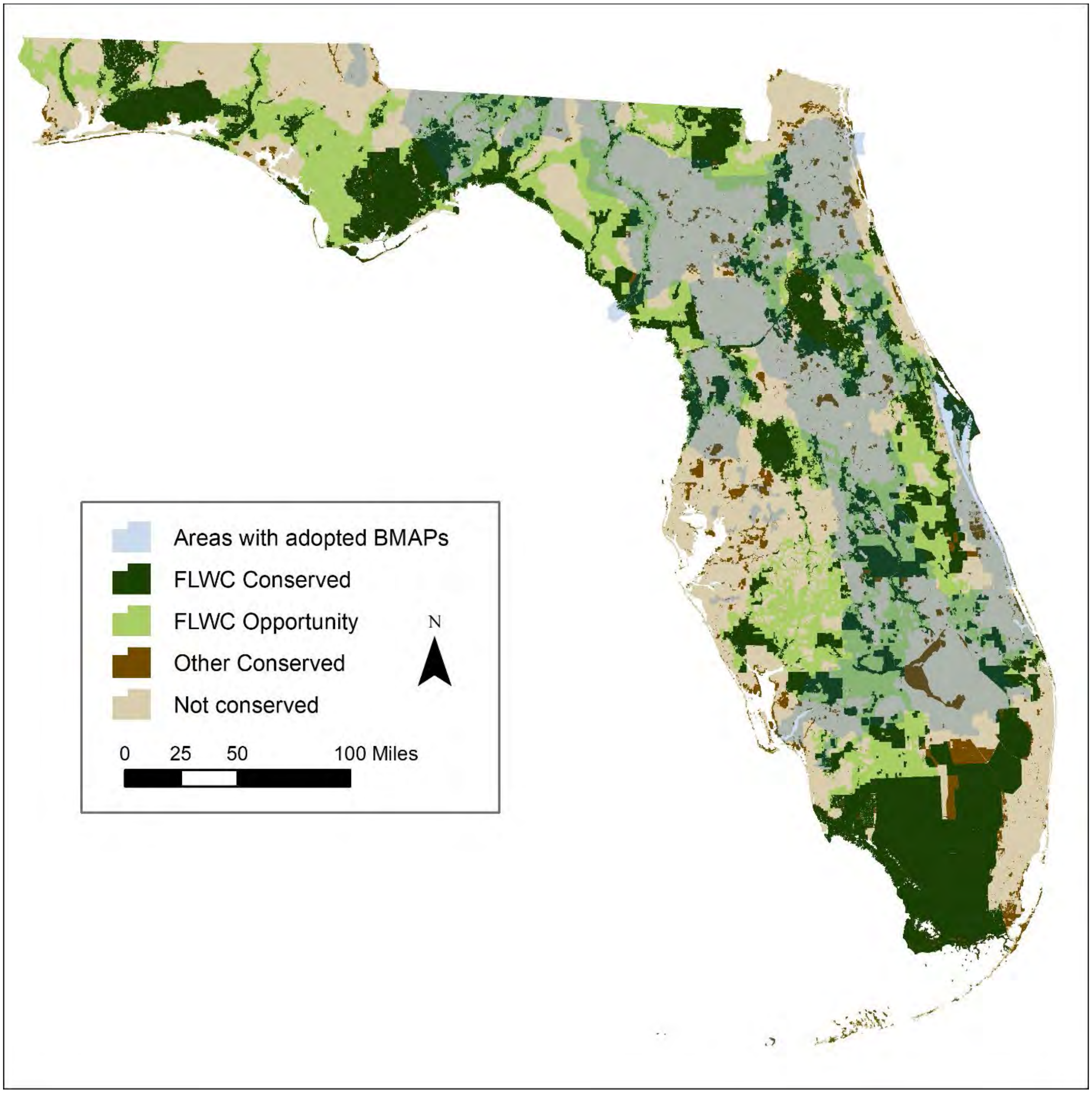

Figure II-4. FDEP BMAP areas overlain on the FLWC and Other Conserved areas.

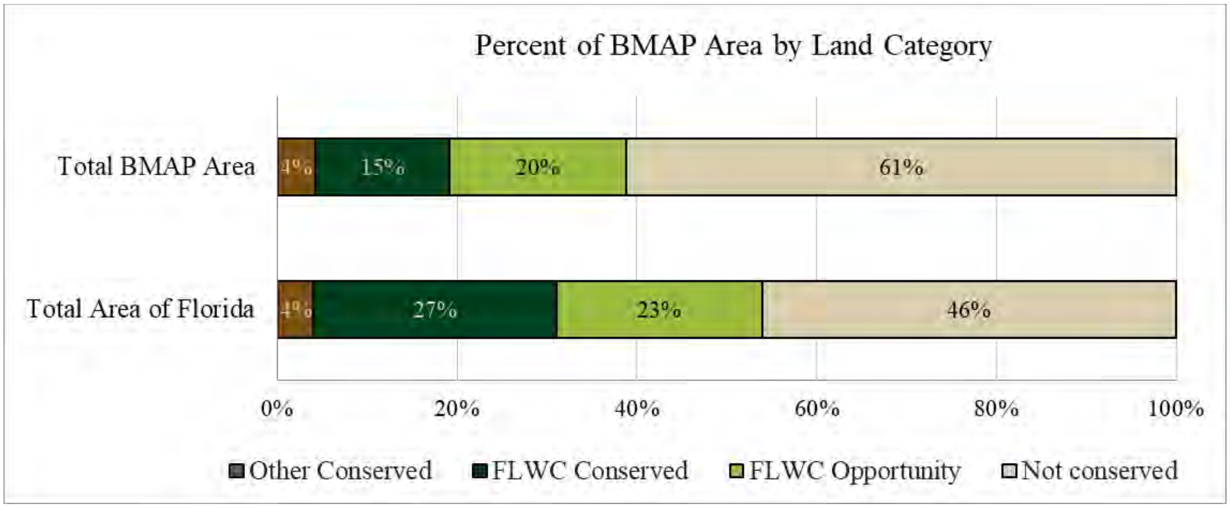

Figure II-5. Percent of total BMAP area by land category.

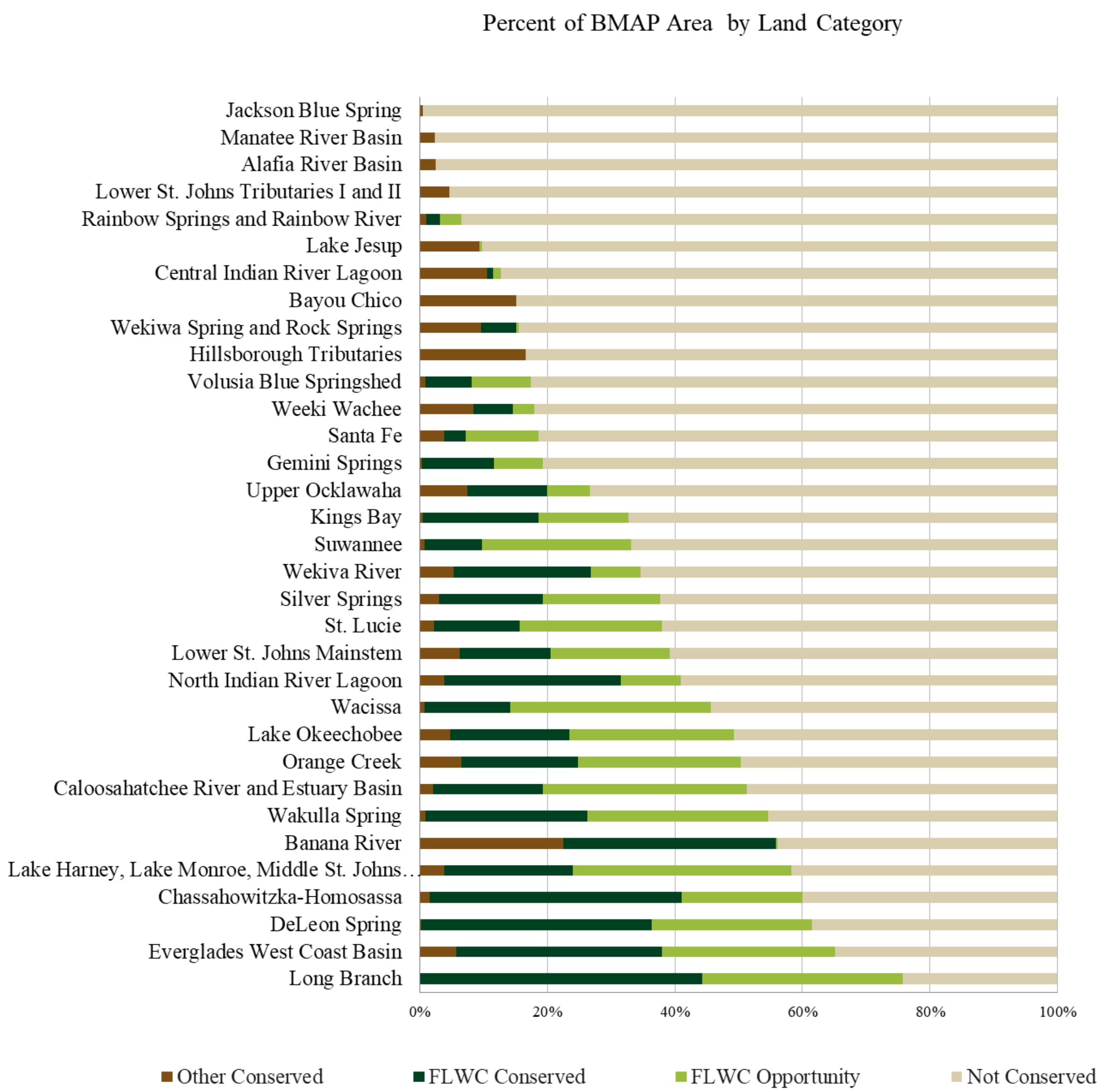

Figure II-6. Percent area of individual BMAPs by land category.

Figure II-7 overlays the CLIP-designated Priority 1-3 aquifer recharge areas over FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and areas that are Not Conserved. CLIP defines Priority 1-3 aquifer recharge areas to include the highest recharge areas in the state, as well as moderate recharge areas that overlap with current Springs Protection Areas, public water supply buffers, and/or swallets (Oetting et al. 2016). Lower-priority aquifer recharge areas (Priority 4-5) were not included in this analysis, and are defined as low, moderately low, and moderate recharge areas that do not overlap with current Springs Protection Areas, public water supply buffers, and/or swallets.

In total, FLWC Conserved areas include 16% of Priority 1-3 aquifer recharge areas, lower than the 27% of FLWC Conserved lands statewide. FLWC Opportunity areas include an additional 22%, more than doubling the existing area. Combined FLWC Conserved and Opportunity areas would include 38% of the Priority 1-3 aquifer recharge areas statewide, which is less than the 50% statewide land area in the FLWC. This indicates that overall, the FLWC would provide moderate benefit to Priority 1-3 aquifer recharge areas, and that these areas are underrepresented in the FLWC due to the small percentage of these lands included in the existing FLWC Conserved areas (Figure II-8).

Priority aquifer recharge areas that are provided good-to-excellent benefit by FLWC Conserved areas include the Ocala National Forest Area east of Lake George and the Green Swamp area in Central Florida. An area in Lafayette County, from Mallory Swamp and Steinhatchee Springs Wildlife areas north to I-10 would receive good benefit if the FLWC Opportunity areas were conserved. However, the priority recharge areas in Jackson County in the panhandle, the Suwannee Basin east of the Suwannee River, and the Tampa Bay and southeast Florida areas (that provide drinking water to more than 9 million Floridians) are provided no benefit by the FLWC.

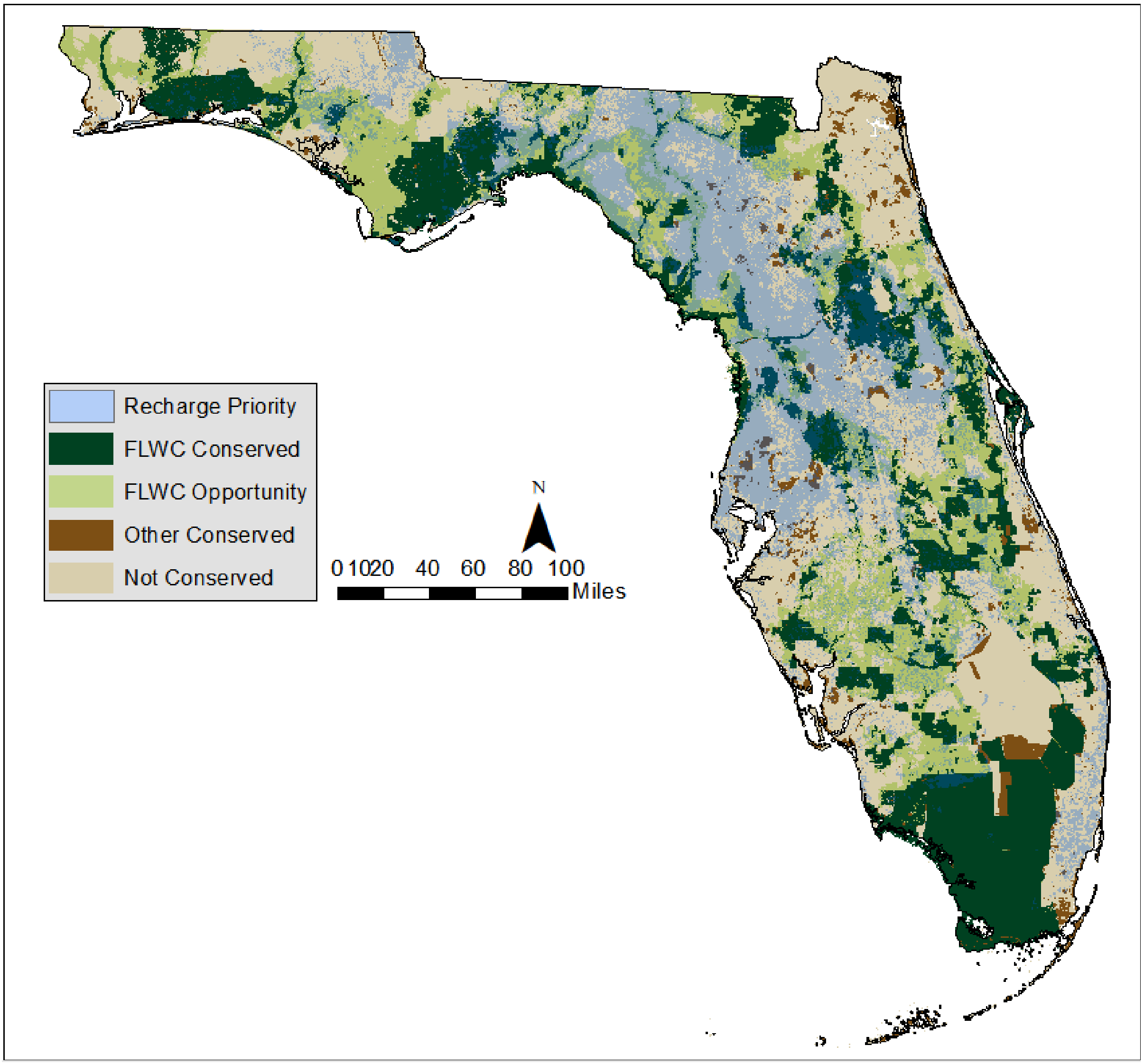

Figure II-7. CLIP Priority 1-3 aquifer recharge areas overlain on the FLWC and Other Conserved areas.

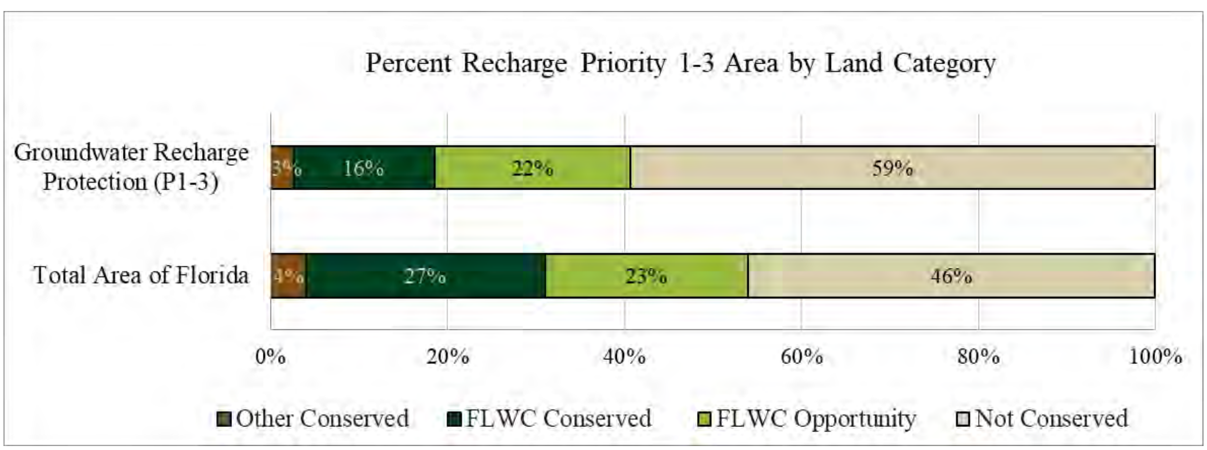

Figure II-8. Percent of CLIP Priority 1-3 aquifer recharge areas by land category.

Figures II-9-11 overlay regions of the Floridan aquifer, the Intermediate aquifer, and the Surficial aquifer designated by FDEP as more vulnerable to groundwater contamination with FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and areas that are Not Conserved.

FLWC Conserved areas include 11% of the more vulnerable regions for Floridan aquifer contamination. Opportunity FLWC areas include an additional 20%, almost tripling the existing area. Together FLWC Conserved and Opportunity areas would include 31% of more vulnerable Floridan aquifer regions statewide, indicating low-to-moderate benefit (Figure II-12).

FLWC Conserved areas include 14% of the more vulnerable regions for Intermediate aquifer contamination. FLWC Opportunity areas include an additional 28%, tripling the existing area. Together FLWC Conserved and Opportunity areas would include 42% of more vulnerable regions statewide, which represents moderate benefit for the Intermediate aquifer (Figure II-12).

FLWC Conserved areas include 19% of the more vulnerable regions for Surficial aquifer contamination. FLWC Opportunity areas include an additional 25%, more than doubling the existing area. Together FLWC Conserved and Opportunity areas would include 45% of more vulnerable regions statewide, indicating moderate benefit to the more vulnerable regions of the Surficial aquifer (Figure II-12).

The regions of higher aquifer contamination vulnerability are strongly driven by areas of higher groundwater recharge. Therefore, similar to the findings for priority aquifer recharge, aquifer contamination vulnerability regions of the Ocala National Forest Area east of Lake George and the Green Swamp area in Central Florida are provided good benefit by FLWC Conserved areas. The vulnerable region in Lafayette County, from Mallory Swamp and Steinhatchee Springs Wildlife areas north to I-10, would be provided good benefit if the FLWC Opportunity areas were conserved. However, the more vulnerable regions in Jackson County in the Panhandle, the Suwannee Basin east of the Suwannee River, the Tampa Bay region, and southeast Florida region are provided no benefit by the FLWC.

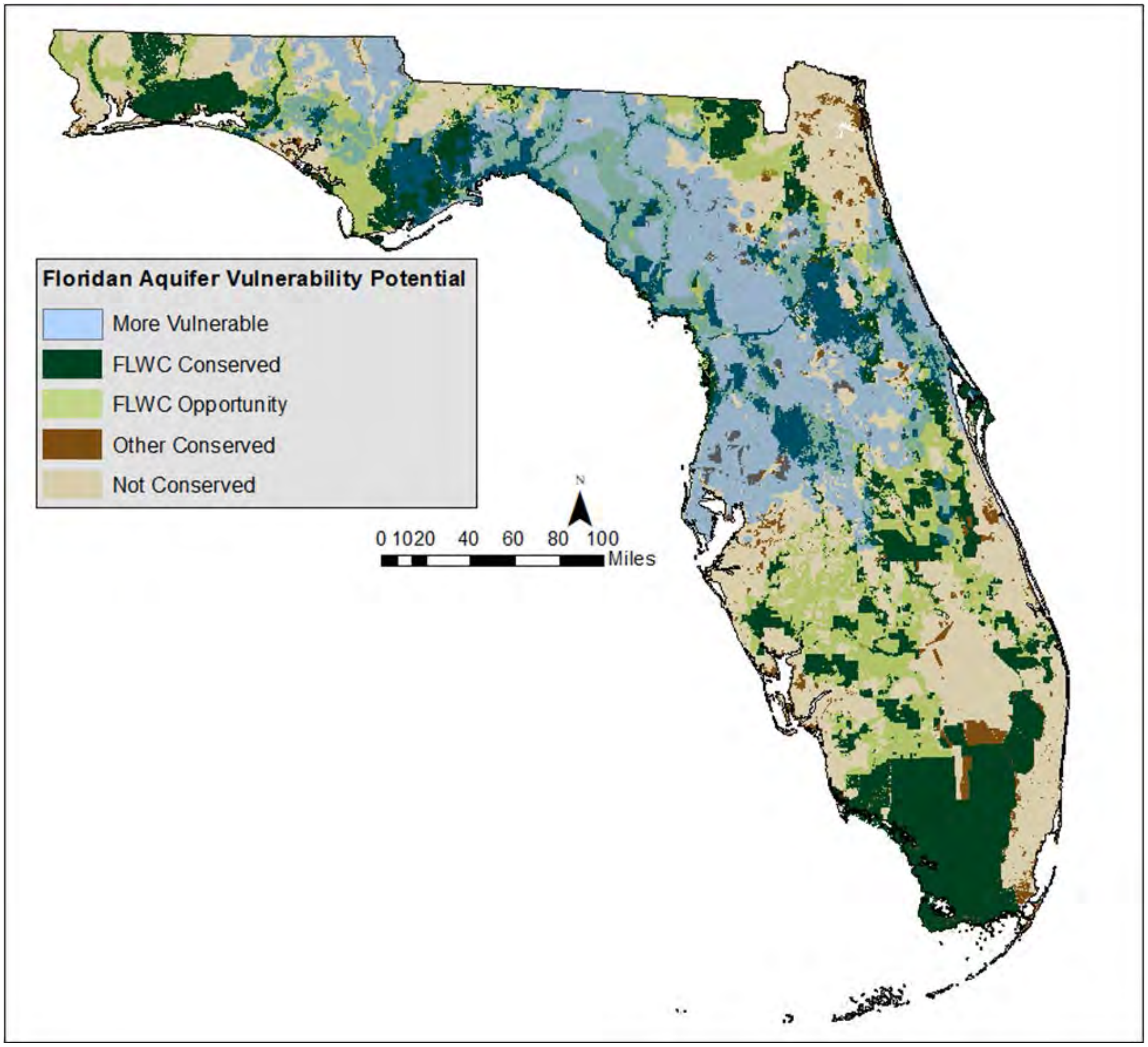

Figure II-9. Floridan aquifer regions that are more vulnerable to contamination overlain on the FLWC and Other Conserved areas.

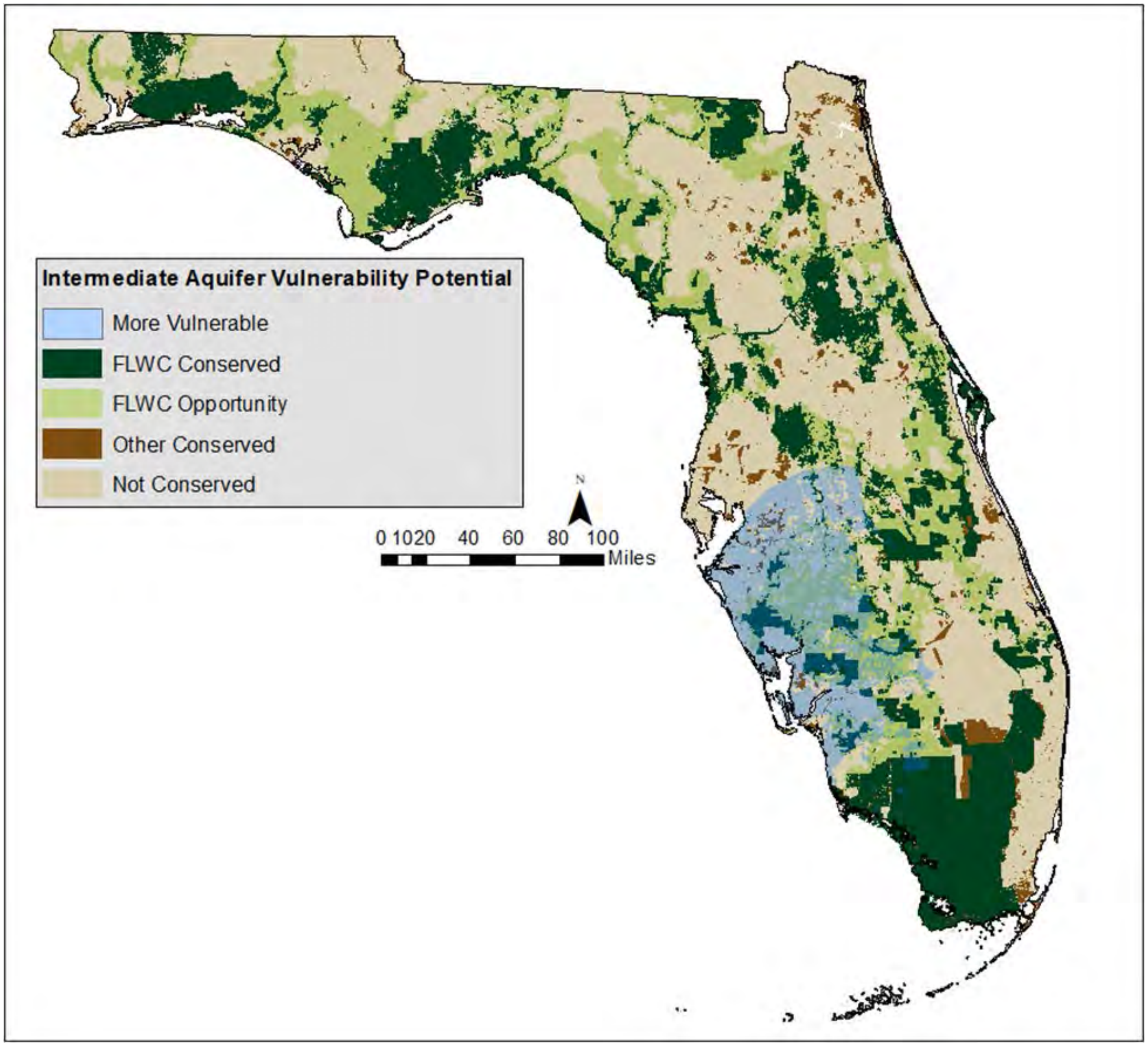

Figure II-10. Intermediate aquifer regions that are more vulnerable to contamination overlain on the FLWC and Other Conservation areas.

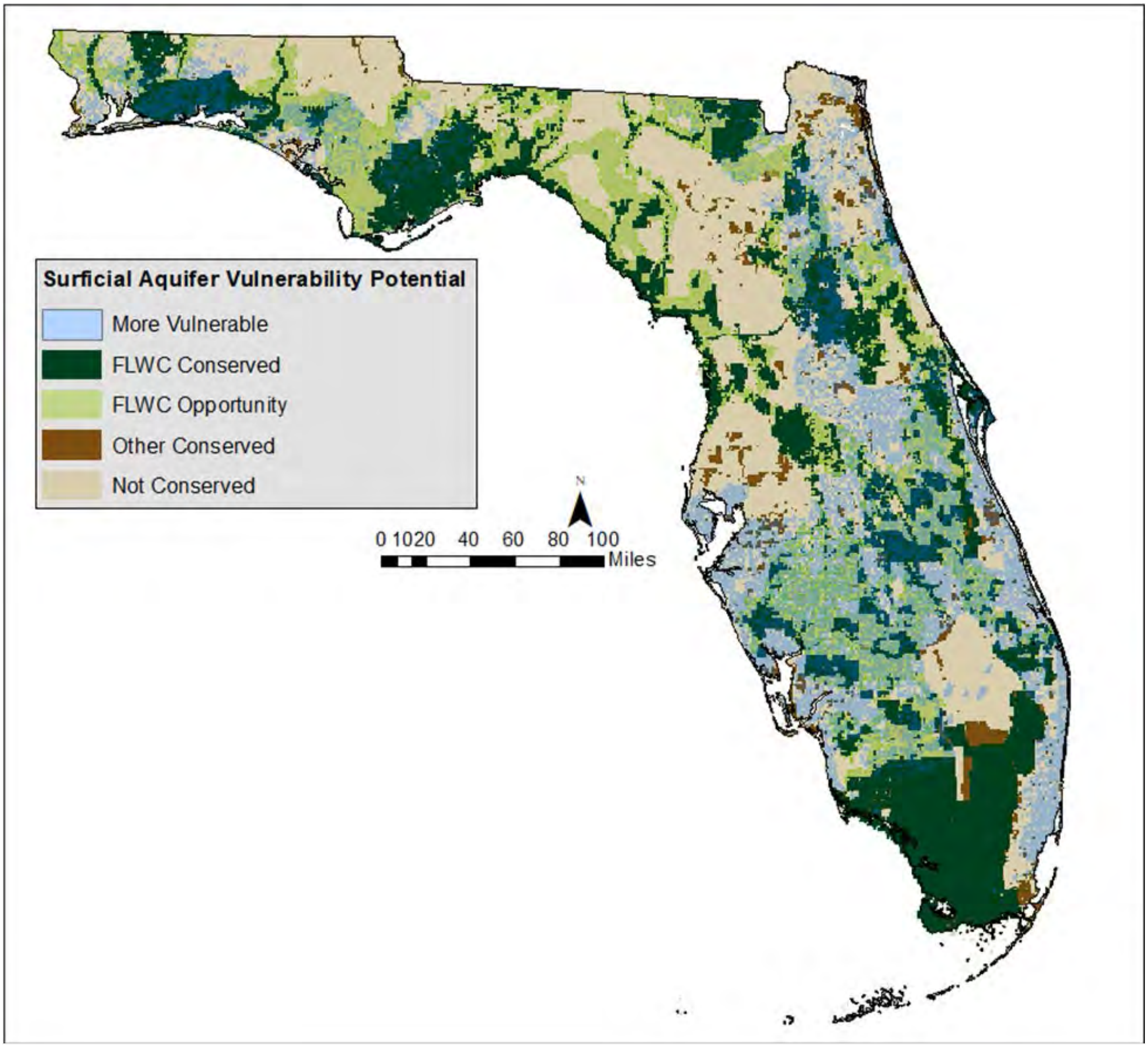

Figure II-11. Surficial aquifer regions that are more vulnerable to contamination overlain on the FLWC and Other Conserved areas.

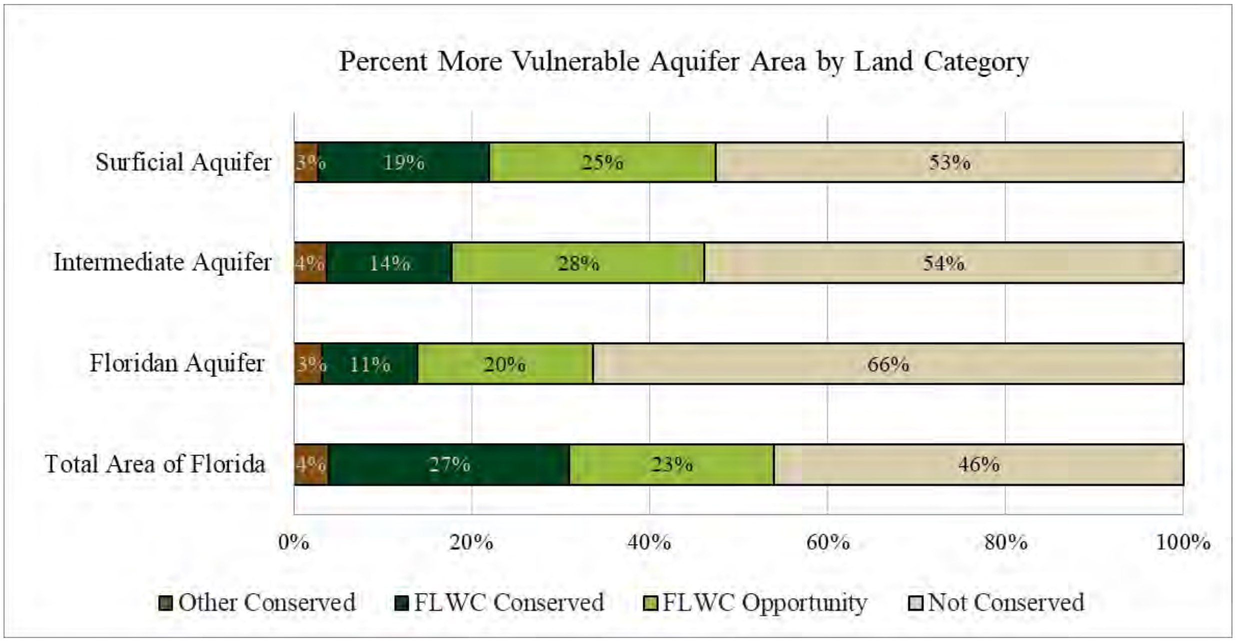

Figure II-12. Percent area of more vulnerable aquifer regions by aquifer and land category.

Conclusions

Florida's 50 major watersheds are provided a good-to-excellent level of benefit by the FLWC Conserved and Opportunity Lands, while BMAP areas are provided a low-to-moderate level of benefit. Averaged together, these results indicate that overall surface water quality is provided low-to-moderate benefit by the FLWC.

Regions of the Surficial, Intermediate, and Floridan aquifers that are more vulnerable to contamination and priority groundwater recharge areas are provided low-to-moderate benefit from the FLWC Conserved and Opportunity lands, but these benefits are underrepresented compared to the statewide percent land in the FLWC (50%). Thus, overall groundwater quality and groundwater recharge are both provided low-to-moderate benefit by the FLWC.

Priority FLWC Opportunity lands that could be acquired to increase statewide surface water quality and quantity benefit include areas in the Suwannee Basin, Upper St. Johns River Basin, and the Peace River Basin (Figure II-3). Opportunities to increase BMAP areas via acquisition of Opportunity lands occur throughout the state from the Everglades to the Panhandle (see Figure II-6 for BMAPs throughout the state with substantial areas in FLWC Opportunity lands). Additional priority conservation lands for BMAP areas beyond the FLWC include the Hillsborough, Alafia, and Manatee Rivers in southwest Florida (all of which are used for public water supply), as well as Jackson Blue Springs in the Panhandle and Wekiwa and Rainbow springs in central Florida.

Priority FLWC Opportunity lands that could be acquired to increase statewide groundwater quality and quantity benefit include high-priority recharge and more vulnerable areas of the Upper Floridan aquifer in the Suwannee River Basin, and high-priority recharge and more vulnerable areas of the Intermediate and Surficial aquifers in the Peace River Basin. Additional priority conservation lands for protecting groundwater quality and quantity beyond the FLWC include Jackson County in the Panhandle, the Suwannee Basin east of the Suwannee River, and the Tampa Bay and southeast Florida areas which provide drinking water to more than 9 million Floridians.

The assumptions underlying the metrics used to assess statewide water quantity and quality benefits (i.e., that conserving land areas that are the source of the surface and groundwaters that feed Florida’s streams, rivers, estuaries, lakes, wetlands, aquifers, and springs will benefit statewide water quality and quantity) are well-founded (EPA, 2022). However, determining the precise benefit of particular land conservation efforts for water quantity and quality in specific locations will require resource-specific monitoring and modeling studies.

It should be noted that the degree of protection achieved by the Florida Wildlife Corridor lands will be dependent on how those lands are managed. Conservation easements that specify land management should be considered for working lands within the FLWC.

Whereas there is no apparent advantage to groundwater recharge or groundwater quality benefit as a consequence of FLWC land connectivity, the surface watershed protection benefits are likely enhanced by connectivity between the conserved watershed land and the receiving water body.

III. Water Supply

Background

Florida has programs to ensure adequate water supply for current water use and future growth, while protecting the environment. Long-term water supply planning and permitting of the consumptive use of water is accomplished by the state's five Water Management Districts (WMDs, Figure III-1) together with the FDEP. Water demand is estimated by WMDs and tallied in six water-use categories: public supply, agriculture, domestic self-supply, recreational/ landscape irrigation, industrial/commercial/institutional and mining/dewatering, and power generation. The most recent annual report (2020) estimates that Florida's current water demand exceeds 6.4 billion gallons per day (BGD), and this is estimated to increase by nearly another 1 BGD by 2040 (FDEP 2021). Public supply, followed by agriculture, are the two largest water-use categories and together account for nearly 80% of the current water demand. Water is withdrawn from groundwater and surface waters and augmented with alternative supplies (e.g., desalination, water reclamation) to meet the demand. It should be noted however that statewide more than 90% of public water supply demand is met using groundwater (Marella 2020). Protection and management of source water is accomplished in a variety of ways, some of which are directly or indirectly related to land use. Land conservation is a powerful tool to protect surface and groundwater storage and recharge.

Ample water supply is also necessary to maintain healthy ecosystems. The permitting process for individual withdrawals, whether from groundwater or surface water, includes extensive analyses, including evaluating whether water resources and related ecosystems will be harmed by the water withdrawals. Florida statutes also provide mechanisms to protect these resources from significant harm caused by water withdrawals for consumptive use: Minimum Flows and Levels (MFLs), and Water Reservations. MFLs are utilized by all five WMDs, and generally involve field data collection, modeling, and a public rulemaking process. South Florida Water Management District (SFWMD) also utilizes Water Reservations. The Water Reservations process reserves water necessary for fish and wildlife and public health and safety, and this water is not available for consumptive use. Though similar to MFLs, SFWMD uses Water Reservations to readily align with federal requirements as part of the Comprehensive Everglades Restoration Plan (CERP) projects.

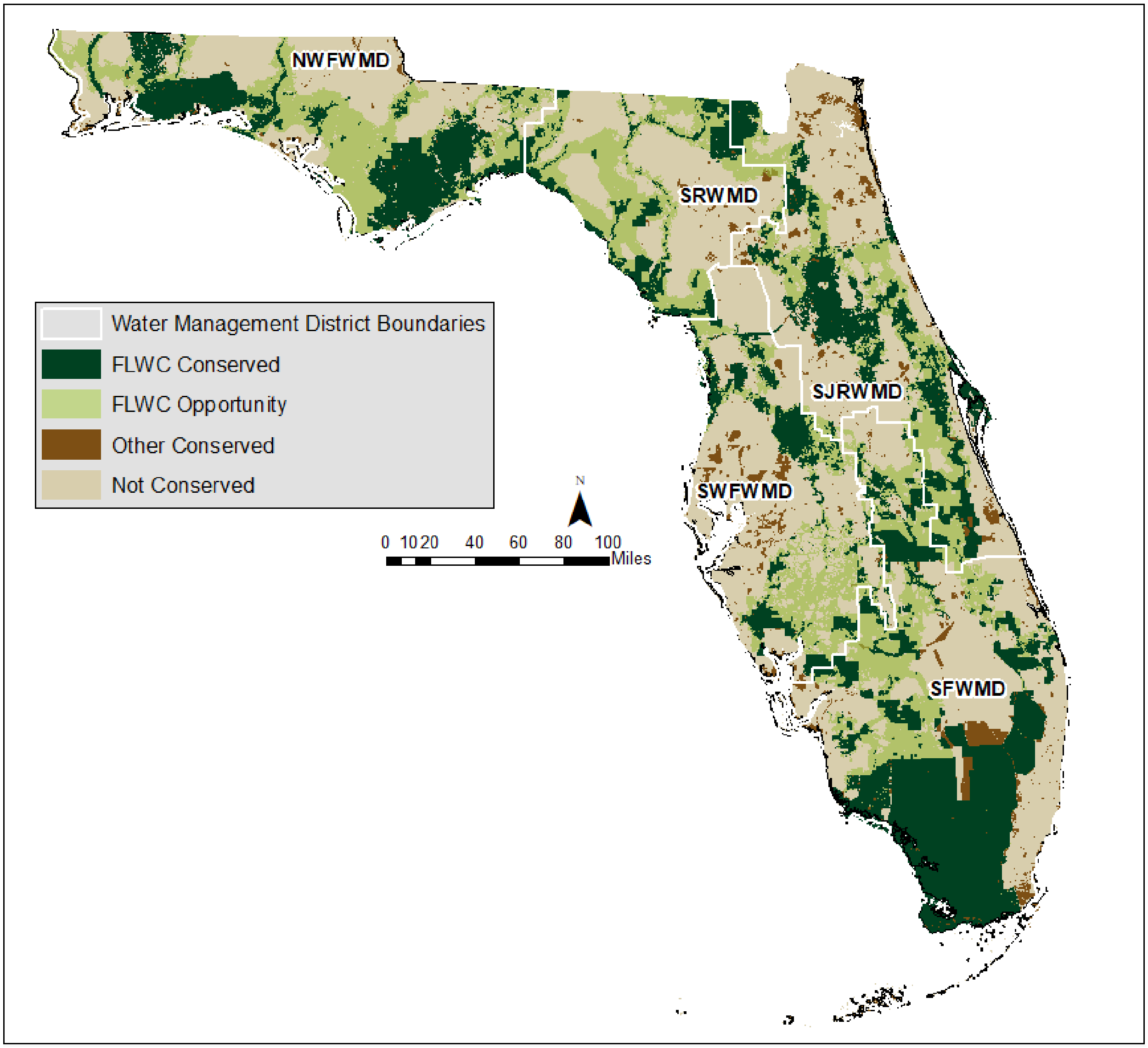

Figure III-1. Florida Water Management District boundaries overlain on the FLWC and Other Conserved areas. Water management districts include: Northwest Florida Water Management District (NWFWMD), Suwannee River Water Management District (SRWMD), St. Johns River Water Management District (SJRWMD), Southwest Florida Water Management District (SWFWMD), and South Florida Water Management District (SFWMD).

Metrics

Water supply-related ecosystem services include but are not limited to water supply for both human and non-human use. In Florida, water withdrawals from groundwater and surface water are regulated by permit to help ensure that non-human uses are protected. For this evaluation, we used the following water supply metrics: the percentage (by volume) of water allocations issued as individual permits for groundwater and surface waters; percentage (by area) of permitted groundwater allocation wellsheds (the approximate source area contributing to the pumped volume); percentage (by number) of permitted wells in unconfined, semi-confined, and confined aquifers; and percentage (by number) of MFL and Water Reservation water bodies. Here we provide statewide percentages for each of the four land categories as previously described in Section I. We present percentages by water management district in Appendix A (permitted groundwater and surface water allocations) and Appendix B (permitted groundwater allocation wellsheds).

Our assessment of water supply benefits provided by the FLWC is based on the following assumptions:

- Permitted wells within the FLWC will receive some degree of local wellhead protection (water quality protection) and groundwater supply protection.
- Wells within the FLWC that pump from unconfined and semi-confined aquifers receive more benefit than wells that pump from confined aquifers. For wells pumping from unconfined and semi-confined aquifers, captured water is primarily recharged from overlying lands. Conserving these lands will decrease the likelihood of 1) reductions in recharge that could lead to decreased water availability and 2) detrimental changes in pumped water quality.
- For wells that pump from confined aquifers, water captured by the well may be recharged at some distance from the well itself; thus, this water may not benefit from conserving directly overlying land. We present a simplified case study as an illustrative example in Appendix C, but full evaluation of confined aquifer well water sources would require analysis beyond the scope of this assessment.
- Groundwater quality and supply for wells in all aquifers (unconfined, semi-confined, and confined) are best protected by conserving high priority recharge areas and vulnerable aquifer areas as discussed in Section II.
- Permitted surface water withdrawals within the FLWC will receive some degree of local water quality and quantity protection, however surface water quality and quantity are best protected by conserving watershed contributing areas as discussed in Section II.
- The inclusion of MFL and Water Reservation waterbodies in the FLWC will increase the likelihood that MFL and Water Reservation targets are achieved. Adverse impacts to MFL or Water Reservation waterbodies caused by water withdrawals are typically estimated based upon proximity to those withdrawals and volume of withdrawals. Conserved areas (FLWC or Other) may result in fewer withdrawal points and/or reduced volumes of withdrawals, thus reducing harm and supporting water supply for these waterbodies.
- Acquisition of conservation properties may result in retiring water withdrawal points over time, or reducing water use from the withdrawal locations. This approach is commonly

used by state agencies and water management districts where conservation easement terms reduce water use and/or eliminate some or all permitted withdrawals.

Methods

Water Supply

To evaluate water supply protection metrics, we collected georeferenced individual water use permit data from the five WMDs. Each WMD Consumptive Use Permitting (CUP) Regulatory group provided current, specific individual CUP permit project and withdrawal point information including location, permitted allocation, source types, and use types in comprehensive spreadsheets. Permit information is also publicly available in database format through Florida's Water Permitting Portal (http://flwaterpermits.com). We overlaid locations of water withdrawals from both groundwater and surface water with the water management district boundaries and the four land categories: FLWC Conserved Areas, FLWC Opportunity Areas, Other Conserved Areas, and Not Conserved Areas. For groundwater, we mapped withdrawal locations covered by individual consumptive use permits for primary water supply aquifers (Floridan Aquifer, Sand and Gravel Aquifer, and Biscayne Aquifer; see Appendix A for additional detail). For surface water, we mapped withdrawal locations covered by individual consumptive use permits. We then converted permitted water demands (volume in million gallons per day, MGD) to volume-based percentages for each land category. In addition, we calculated source contributing areas, or wellsheds, for individual permitted groundwater allocations. Detailed assumptions and methods for calculating permitted groundwater allocation wellsheds are included in Appendix B.

Minimum Flows and Levels, and Reservations

We overlaid locations of adopted MFL waterbodies, obtained from review of FDEP and WMD rules (FDEP 2022: https://floridadep.gov/water-policy/water-policy/content/minimum-flows-and-minimum-water-levels-and-reservations), and Reservation waterbodies (point shapefile created from Florida Department of State Rule Chapter 40E-10, 2014) with the four land categories identified previously. We identified numbers and percentages of MFL and Reservation waterbodies within each land category.

Statewide water supply metrics were assigned to two categories: Good-to-Excellent (greater than or equal to 50% of the statewide benefit metric within the FLWC) and Low-to-Moderate (less than 50% of statewide benefit metric within the FLWC) as outlined in Section I.

Results and Discussion

Water Supply

Figure III-2 shows the statewide percent of permitted groundwater allocations and permitted wellshed areas within each land category, along with the statewide percentages of land area in each category for comparison.

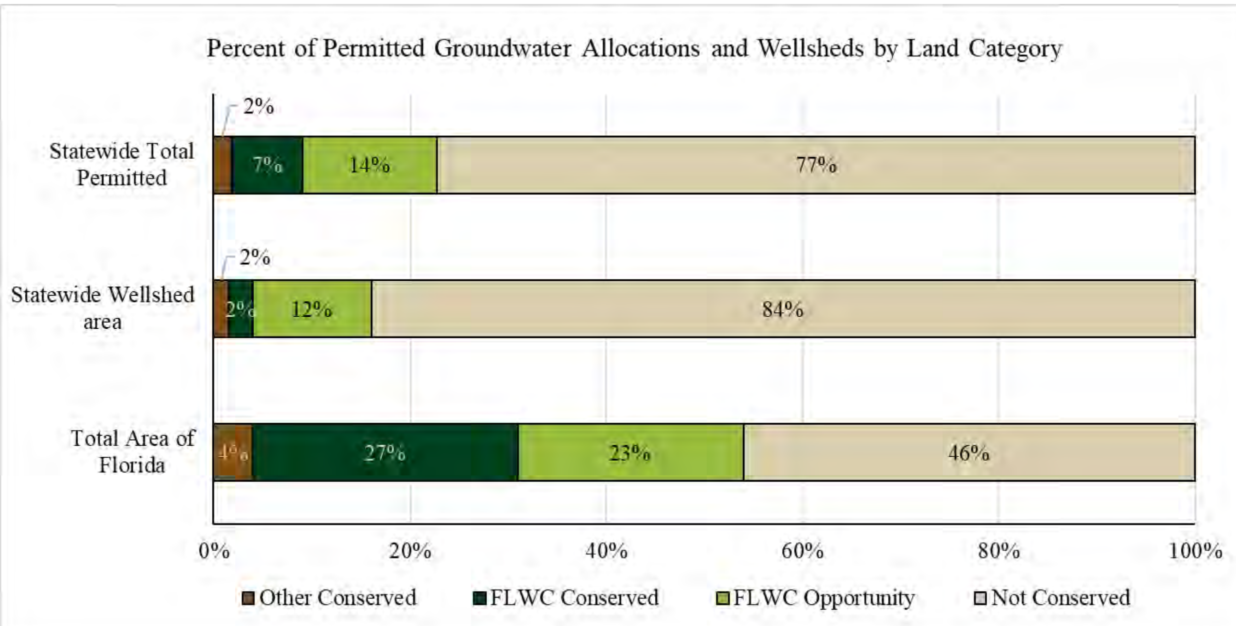

Figure III-2: Percent of permitted groundwater allocation (volume) wellshed area by land category.

Statewide, only 7% of permitted groundwater allocations (by volume) are within FLWC Conserved lands. FLWC Opportunity lands would add 14%, tripling the FLWC benefit if all Opportunity lands were acquired. An additional 2% of permitted groundwater allocations statewide are located within Other Conserved lands, leaving 77% in Not Conserved lands. Similarly, only 2% of estimated wellshed areas are within FLWC Conserved lands. FLWC Opportunity lands would add 12%, increasing the FLWC benefit sixfold if all Opportunity lands were acquired. Nevertheless 84% of the estimated wellshed areas remain in Not Conserved lands. These data indicate an overall low level of benefit for permitted groundwater allocations and wellsheds statewide, but nevertheless a substantial increase in benefits to both if all Opportunity lands were to be acquired. The difference in results between these two approaches is largely due to the difference in the treatment of non-consumptive water uses. For the volume-based method, only 5% of non-consumptive uses were included, whereas all permitted flow was used to estimate the wellshed areas.

More details regarding permitted groundwater allocation by water use type, aquifer source, and water management district are included in Appendix A. More details regarding wellshed area analysis by water management district are included in Appendix B. A case study that illustrates how the contributing area for confined Floridan aquifer wells in Northeast Florida can extend a considerable distance from a wellhead is included in Appendix C.

Figure III-3 overlays permitted well location by degree of aquifer confinement over FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and areas that are Not Conserved. Wells located in unconfined aquifers will be provided the most benefit by virtue of location within the FLWC because water captured by these wells is typically recharged from nearby overlying lands. Wells located in semi-confined aquifers will also be provided some benefit if they are within the FLWC because much of the water captured by these wells is also likely recharged from nearby overlying lands. Wells located in confined aquifers are likely provided less benefit if they are within the FLWC because recharge to these wells may originate at considerable distance away. Detailed analysis, beyond the scope of the current assessment, would be required to determine the recharge areas for these wells; however, an illustrative example is provided in Appendix C.

In total, only 1%, 2%, and 3% of permitted wells in unconfined, semi-confined, and confined aquifers, respectively, are located within FLWC Conserved areas (Figure III-4). An additional 3%, 9%, and 16% of permitted wells in unconfined, semi-confined, and confined aquifers, respectively, are located within FLWC Opportunity areas. The vast majority of permitted wells are located in Not Conserved areas because of their proximity to urban and irrigated agricultural lands. These data reinforce the findings above that, overall, the FLWC provides little wellhead or wellshed benefit to permitted wells throughout the state, but that the acquisition of all FLWC Opportunity lands would provide an improvement in overall water supply well benefits.

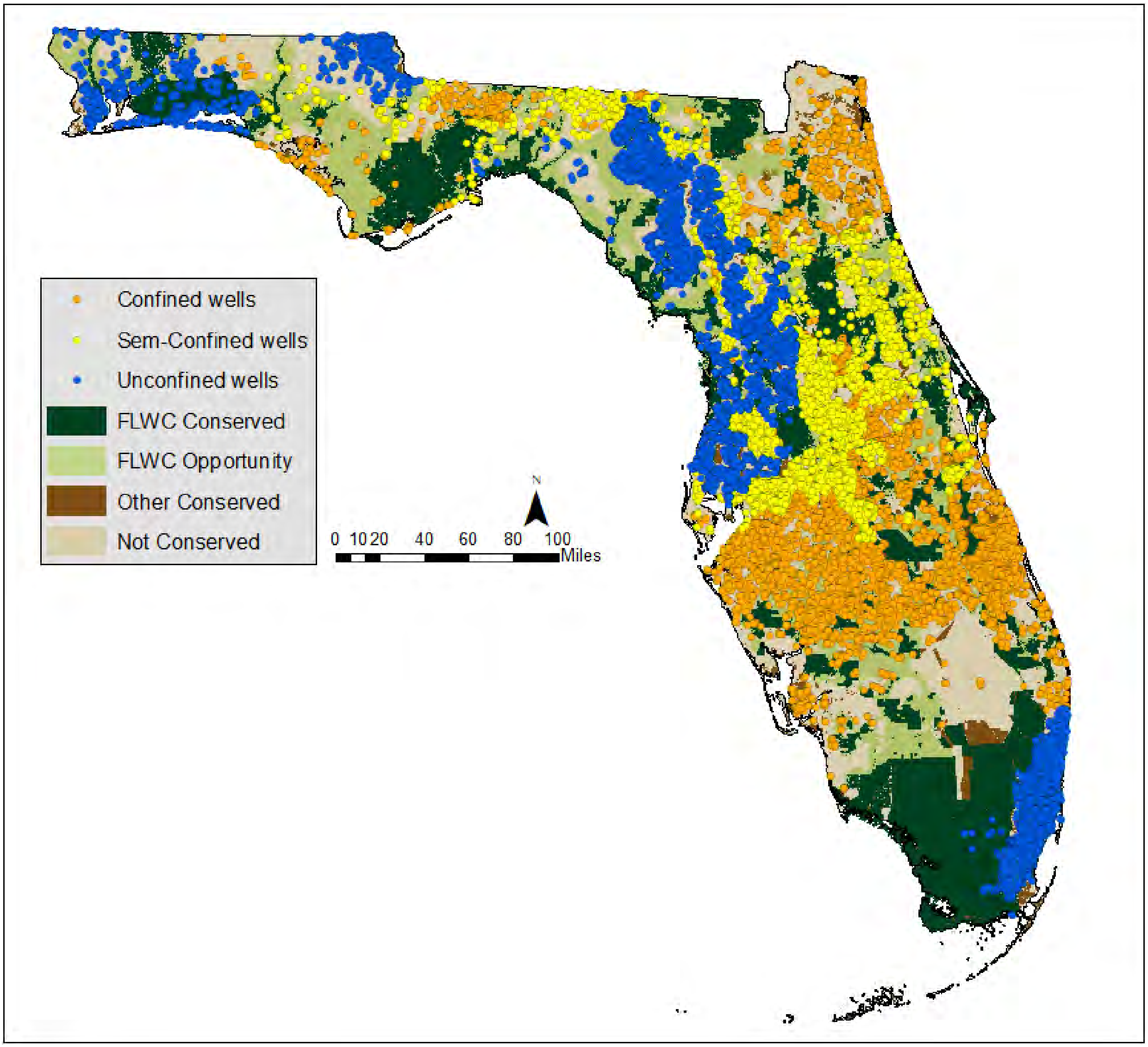

Figure III-3. Permitted groundwater wells by degree of aquifer confinement overlain on the FLWC and Other Conserved areas.

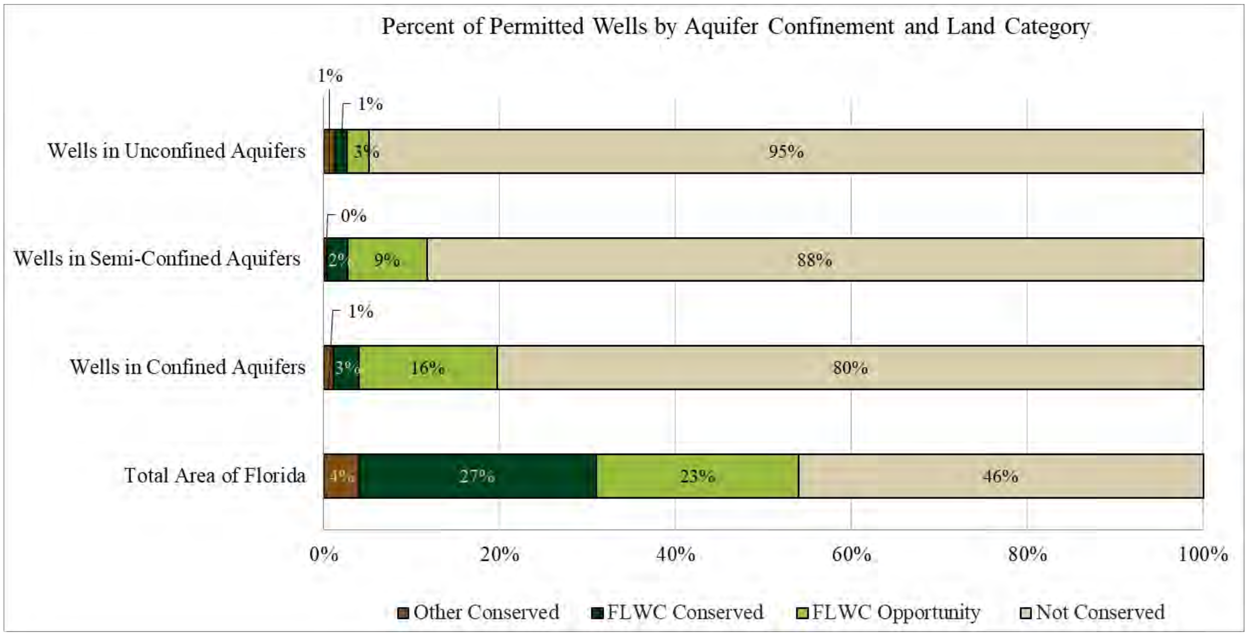

Figure III-4. Percent permitted groundwater wells by aquifer confinement and land category.

Figure III-5 shows the statewide percent of permitted surface water allocations within each land category. Five percent of permitted surface water allocations are within FLWC Conserved lands. If acquired, FLWC Opportunity lands would add 27% of permitted surface water allocations, increasing the total more than 5-fold to 32%. These data indicate an overall moderate level of benefit for permitted surface water allocations statewide, and that FLWC Opportunity lands would provide a marked improvement in overall surface water allocation benefits. More details regarding permitted surface water allocations by water use type and water management district are included in Appendix A.

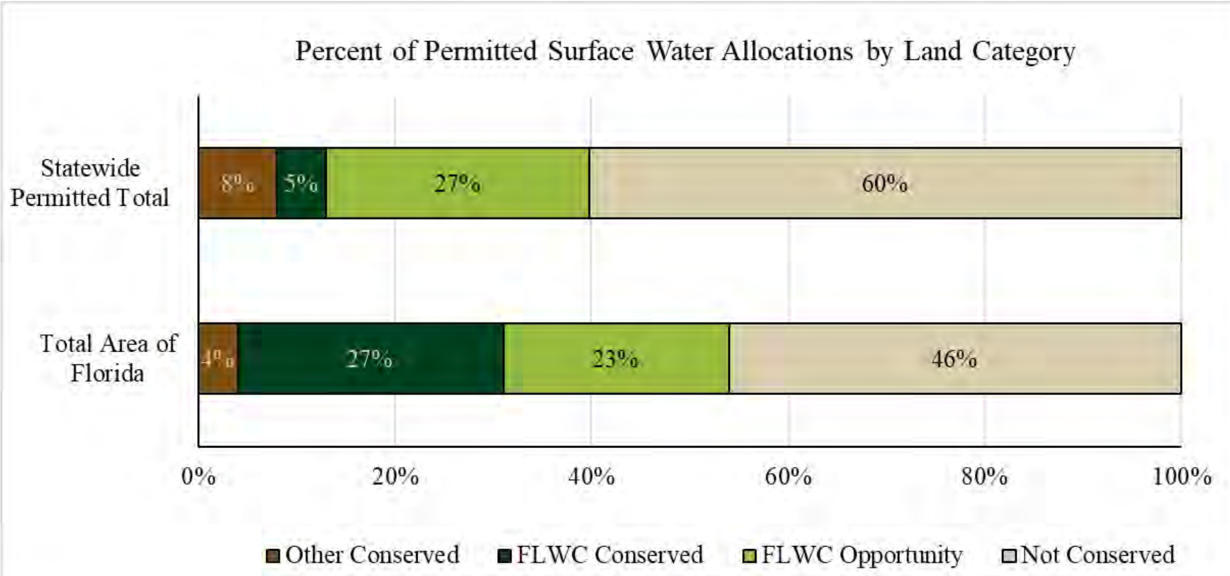

Figure III-5. Percent of permitted surface water allocation (volume) within each land category.

Minimum Flows and Levels and Water Reservations

Statewide, there are currently a total of 464 waterbodies with MFLs or protected by Water Reservations, including 36 waterbodies that make up the seven water reservations within SFWMD (Figure III-6). NWFWMD has the fewest (3) MFLs as this district only recently began using this protective measure. SWFWMD has the most, with nearly 200 MFLs. The majority of these were established several years ago and are within the Southern Water Use Caution Area to protect surface waterbodies including wetlands. SJRWMD has the second highest number of MFLs. Many of these were set on a series of lakes more than 20 years ago as a result of legal action. All Outstanding Florida Springs have adopted MFLs.

Figure III-7 shows that 58% of MFL and Water Reservation waterbodies throughout the state are in Not Conserved areas. This percentage is influenced by the numbers of Southern Water Use Caution Area MFLs and numerous lakes in SJRWMD in Not Conserved areas. Statewide there are 73 MFL and Water Reservation waterbodies (16%) located within FLWC Conserved lands, and 56 waterbodies (12%) located within FLWC Opportunity lands, for a total of 129 waterbodies (28%). These data indicate that the FLWC provides moderate benefit to MFL and Water Reservation waterbodies, and this benefit is underrepresented compared to the percent statewide land area in the FLWC (50%). It should be noted however that 20 of the 36 (56%) SFWMD Reservation waterbodies are in FLWC Conserved or Opportunity areas indicating good benefit for this subset of waterbodies.

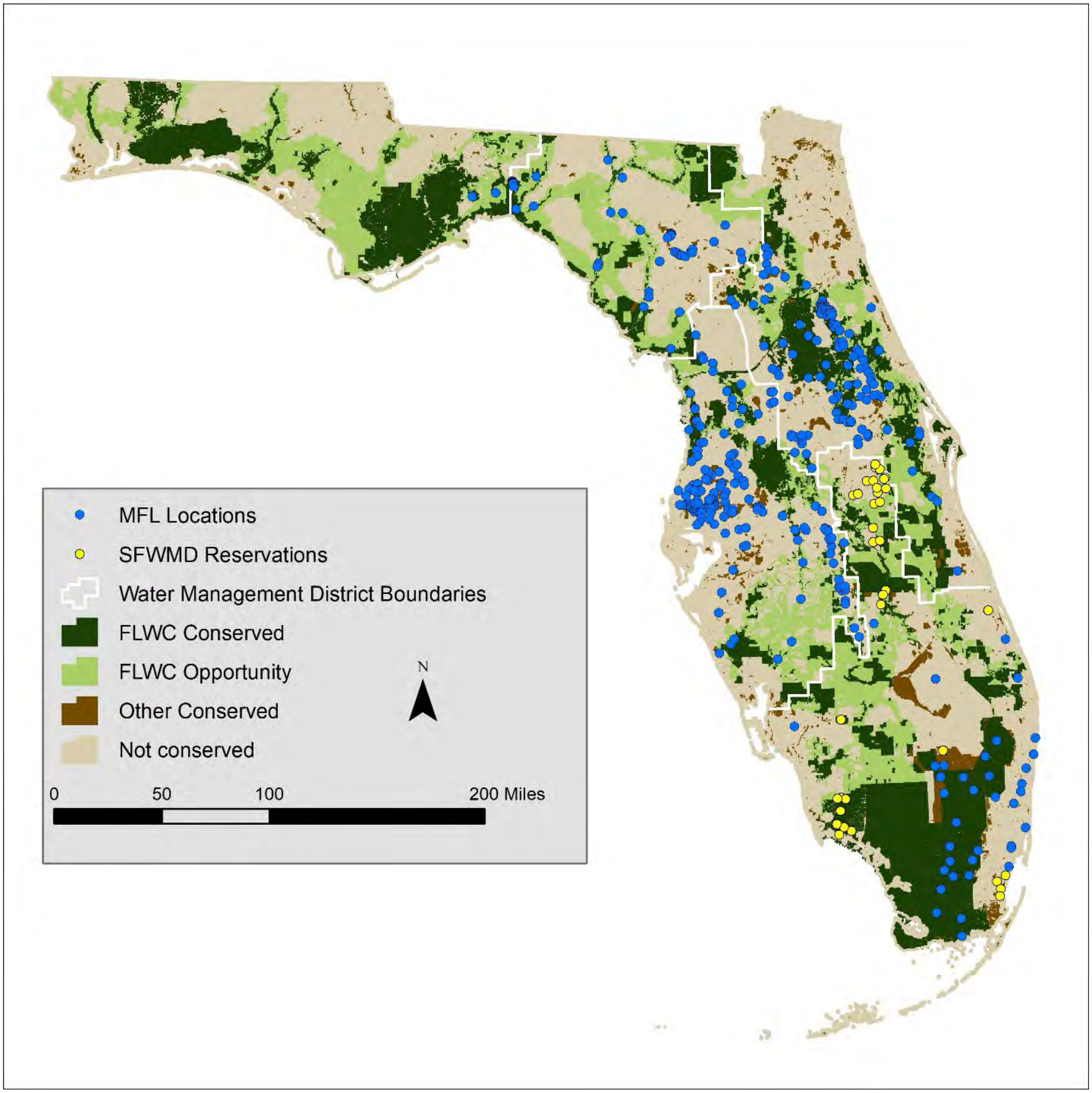

Figure III-6. MFL and Water Reservation Waterbodies overlain on the FLWC and Other Conserved areas.

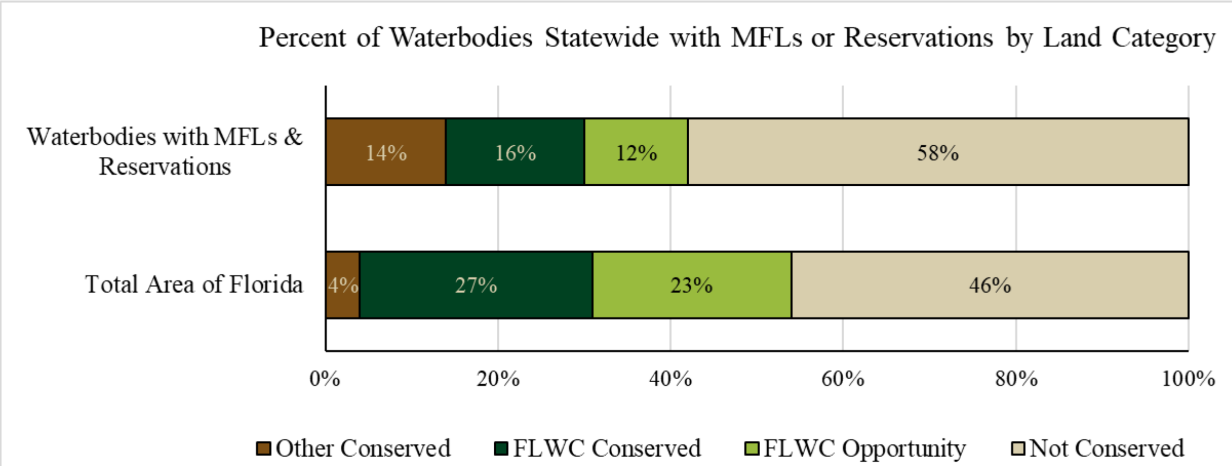

Figure III-7. Percent MFL and Water Reservation waterbodies by land category.

Conclusions

Statewide, FLWC Opportunity lands have the potential to increase the percent of permitted groundwater allocations within FLWC lands from 7% to 21%, and to increase the wellshed area within FLWC lands from 2% to 14%. The percent of permitted wells in unconfined and semi-confined aquifers within the FLWC would total 4% and 11%, respectively, if all FLWC Opportunity lands were acquired. These percentages are all substantially lower than the percent statewide land area within the FLWC (50%), indicating that permitted groundwater well number, allocation volumes, and wellsheds are substantially underrepresented in FLWC lands; therefore, overall groundwater supply receives low benefit. This finding is largely a consequence of the fact that permitted groundwater wells tend to occur near urban areas and irrigated agricultural lands, areas that were intentionally excluded from the FLWC. In general, groundwater quality and supply protection for wells in all aquifers throughout the state would be best protected by conserving the high-priority recharge areas and vulnerable aquifer areas presented in Section II.

While FLWC Opportunity lands have the potential to substantially increase the percentage of permitted surface water allocations within the FLWC from 5% to 32%, this represents only a moderate level of benefit for surface water supply. Surface water quality and supply throughout the state would be best protected by conserving contributing watershed areas as discussed in Section II.

Statewide FLWC Opportunity lands have the potential to almost double the number of MFL and Water Reservation waterbodies within the FLWC, however the resulting total percentage (28%) is lower than the percent statewide land area within the FLWC (50%) indicating this benefit is underrepresented in FLWC lands and thus receives a moderate level of benefit. A more complete analysis of MFL/Reservation waterbody protection would require delineation of the contributing areas to those water bodies, which may be available from individual WMDs for specific waterbodies but is beyond the scope of this effort.

The various assumptions underlying the metrics used to estimate groundwater supply benefits are good first estimates and yield consistent results. Similarly, the assumptions underlying the surface water supply and MFL/Reservation water body benefits are good first estimates. However, determining the precise benefit that particular land conservation efforts would provide to specific water supply benefits will require resource-specific monitoring and modeling studies. These types of studies are often produced to support the adoption or revision of MFL/Reservation waterbodies and may also be produced to provide supporting documentation for proposed CUP permits.

It should be noted that the degree of benefit provided to groundwater supply wells, surface water withdrawals and MFL/Water Reservation waterbodies will be dependent on how FLWC lands are managed. Conservation easements that specify land and water management should be considered for working lands within the FLWC.

Whereas there is no apparent advantage to groundwater supply wells as a consequence of FLWC land connectivity, the surface water supply and MFL/Water Reservation waterbody benefits are likely enhanced by connectivity between the conserved watershed land and the surface withdrawal point or receiving water body.

IV. Springs

Background

Florida has more than 700 springs that collectively discharge >8 billion gallons of water per day from the Upper Floridan aquifer into downstream spring-run and river ecosystems (USGS 1995). Of these springs, 33 have been recognized as first magnitude (flow >100 cfs or 64.6 MGD, Table 1), the highest concentration of first magnitude springs on Earth (Scott et al. 2002). Florida's springs are fed by groundwater from the Upper Floridan aquifer that originates both as diffuse recharge that infiltrates from the land surface through the vadose zone to the aquifer, and concentrated ("point-source") recharge from swallets, which are sinkholes that capture surface runoff and send it directly underground to the aquifer. As a result, the quality and quantity of water that emerges from springs is dependent on water and land uses within the springs recharge area, or springshed. Making the connection between land use and spring condition is complicated by the dominance of complex subsurface flowpaths and the decades-long median travel times of water through the aquifer.

Florida's springs provide habitat for a large and diverse number of plants and animals that are vulnerable to changes in spring water quantity and quality. The springs are highly productive ecosystems, and thus support a rich aquatic food web that includes iconic species of fish, turtles, amphibians, invertebrates, mammals, and reptiles (Odum 1957). These include threatened species such as manatees and other rare and endemic spring- and cave-dependent species (Florida Springs Task Force Report 2000). More than 10,000 years ago, Native Americans were drawn to springs for water supply and fishing. Today, both state residents and tourists visit the springs to participate in recreational opportunities such as wildlife and nature viewing, kayaking, snorkeling, tubing, and cave diving. Twelve of Florida's state parks are named for springs. Springs protection has emerged as one of several statewide water challenges, emphasizing the links between land use, water use, and aquifer condition. Spring protection efforts cross state and administrative boundaries.

Table IV-1. Spring Magnitude Definition

Magnitude	Flow Rate
1	≥ 100 cfs* (≥ 64.6 MGD**)
2	≥ 10 to100 cfs (≥ 6.46 to 64.6 MGD)
3	≥ 1 to 10 cfs (≥ 0.646 to 6.46 MGD)
4	≥ 100 gpm*** to 1 cfs (≥ 100 to 448 gpm)
5	≥ 10 to 100 gpm
6	≥ 1 to 10 gpm
7	≥ 1 pint/min to 1 gpm
8	< 1 pint/min

*cfs = cubic feet per second; **MGD = Million Gallons per Day; ***gpm = gallons per minute

Metrics

We used the following metrics to quantify the benefits of the FLWC to spring systems: the number of springs by magnitude; the recharge area of Outstanding Florida Springs[3] (OFS springsheds); and the number of swallets within the FLWC Conserved and Opportunity areas.

Our assessment of benefits to springs of the FLWC is based on several assumptions:

- Inclusion of lands that contain spring vents and spring-runs in the FLWC provides spring habitat benefits.
- Inclusion of OFS springshed areas in the FLWC translates proportionally to the quantity and quality of water emerging from the springs.
- Inclusion of swallets and their contributing areas in the FLWC benefits spring water quantity and quality.
- The degree of benefit provided to spring habitat, water quantity, and quality is dependent on how FLWC lands are managed.

Methods

To quantify the spring benefit metrics, we overlaid the Florida Department of Environmental Protection Geospatial Opendata GIS coverages of spring location (FDEP 2021: (https://hub.arcgis.com/datasets/FDEP::florida-springs-2016/explore?location=29.358841%2C-84.169952%2C8.04), OFS Springsheds (FDEP 2022: https://geodata.dep.state.fl.us/datasets/FDEP::outstanding-florida-springs-ofs-springsheds/), and swallet location (FDEP 2022: https://geodata.dep.state.fl.us/datasets/FDEP::florida-geologic-survey-fgs-swallets/) with the four land categories: FLWC Conserved Areas, FLWC Opportunity Areas, Other Conserved Areas, and Not Conserved Areas using GIS. We tabulated the numbers and percentages of springs, springshed areas, and swallets for each of the land categories and plotted metrics in bar charts.

Spring benefit metrics were assigned to two categories: Good-to-Excellent (greater than or equal to 50% of the statewide benefit metric within the FLWC) and Low-to-Moderate (less than 50% of statewide benefit metric within the FLWC) as outlined in Section I.

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[3] Section 373.802(4), Florida Statute defines “Outstanding Florida Springs” or “OFS” to include all historic first magnitude springs, as determined by the Florida Department of Environmental Regulation using the most recent Florida Geological Survey springs bulletin, and the following additional six springs: DeLeon, Peacock, Poe, Rock, Wekiva, and Gemini.

Results and Discussion

Figure IV-1 shows the location of mapped Florida Springs and spring-related waters (vents, karst windows and sinkholes) with respect to FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and Not Conserved areas. There are 376 springs of known magnitude within the FLWC Conserved and Opportunity areas. Of these, 171 are 1st or 2nd magnitude.

Forty-two percent of Florida's 1st magnitude springs, 26% of 2nd magnitude springs, and 23% of 3rd and smaller magnitude springs are located within existing FLWC Conserved areas. First magnitude springs receive good benefit from the FLWC Conserved areas, as their coverage is greater than 27% of total Florida land within the FLWC Conserved areas, suggesting they have been historically prioritized for protection. Second and smaller magnitude springs receive moderate benefit from FLWC Conserved lands.

If all Opportunity areas were acquired, an additional 10%, 28%, and 32% of Florida's 1st, 2nd, and 3rd and smaller magnitude springs, respectively, would be included within the FLWC. As a result, FLWC Opportunity areas would increase the number of 1st magnitude springs located within the FLWC by almost 25% and more than double the number of 2nd magnitude and lower-magnitude springs located within the FLWC. Overall, 55% of all mapped spring vents are located within FLWC Conserved and Opportunity areas, indicating that if all Opportunity lands were acquired, the FLWC would provide good-to-excellent level of benefit to spring vents. If Other Conserved lands are included with Conserved and Opportunity FLWC lands, 84% of 1st magnitude, and approximately 65% of 2nd magnitude and 64% 3rd and smaller magnitude Florida spring vents are located within conserved and Opportunity areas, indicating excellent benefit (Figure IV-2).

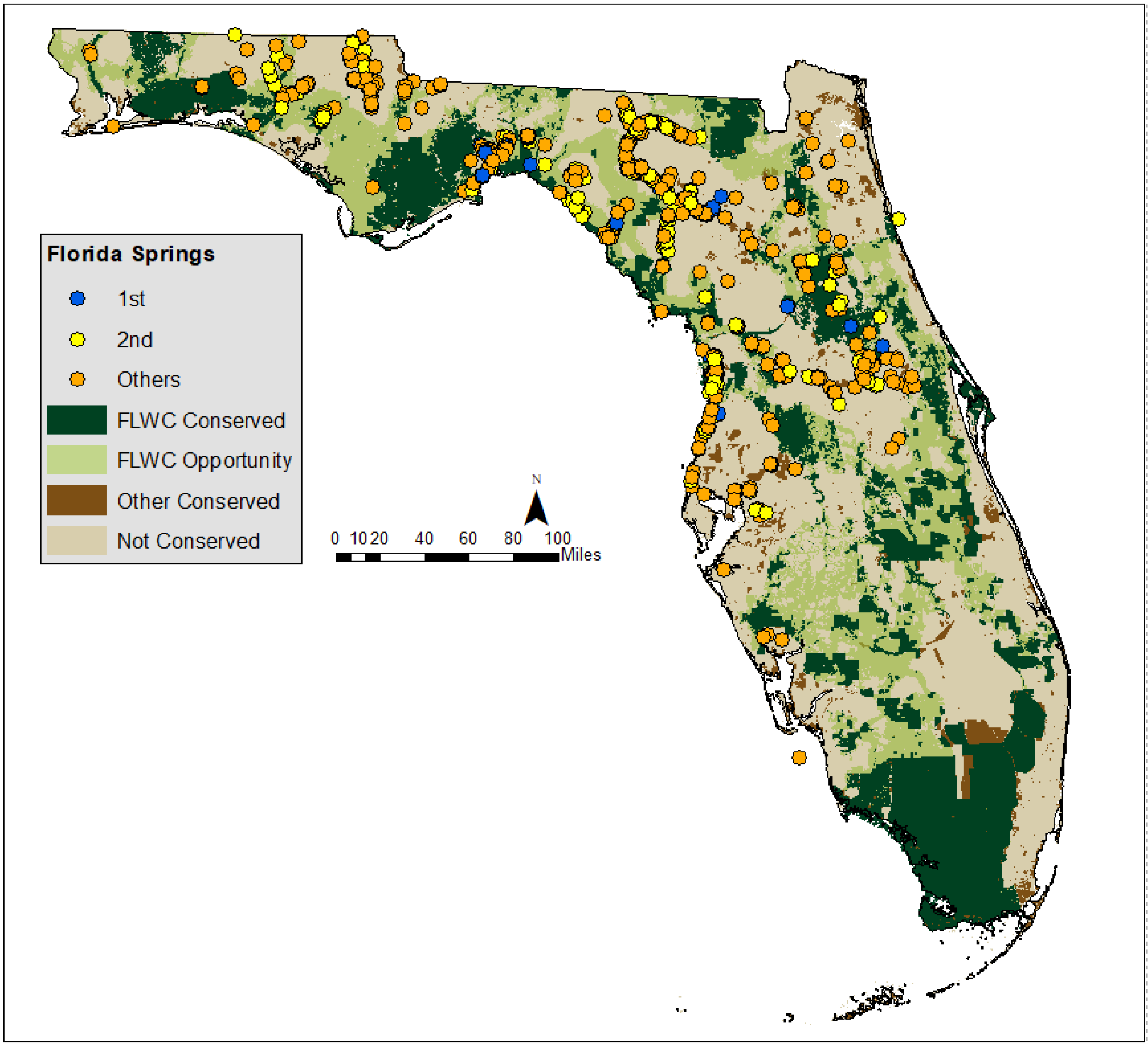

Figure IV-1. Florida springs and spring-related waters (FDEP: Florida Geologic Survey (FGS)) overlain on the FLWC and Other Conserved areas.

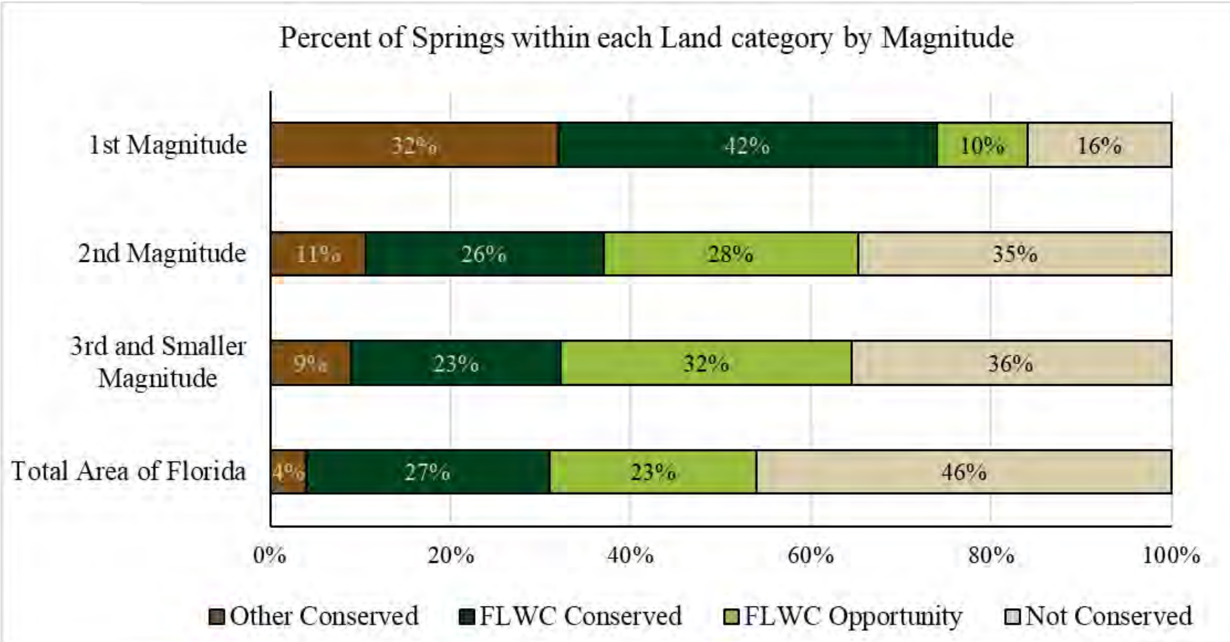

Figure IV-2. Percent of spring vent number by magnitude and land category.

Swallets are not as well protected by the FLWC as spring vents. Figure IV-3 shows the location of mapped swallets with respect to FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and areas that are Not Conserved. Existing FLWC Conserved and Opportunity areas include 20% and 16% of mapped swallets in Florida, respectively, for a combined total of 36%. This indicates that swallets are underrepresented in FLWC lands (less than the 50% of statewide land in the FLWC) and thus are provided moderate benefit.

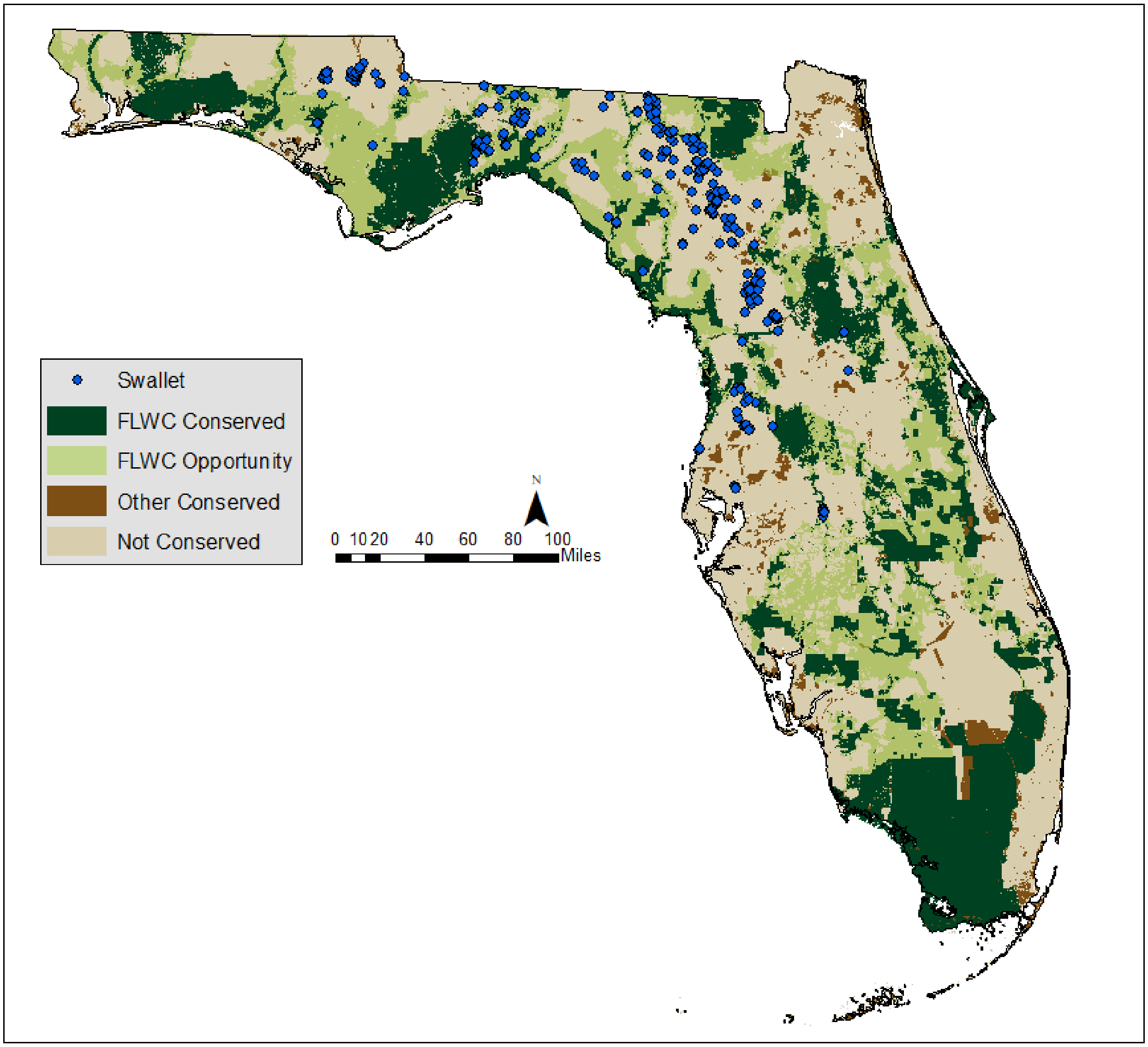

Figure IV-3. Swallet location (FDEP: FGS) overlain on the FLWC and Other Conserved areas.

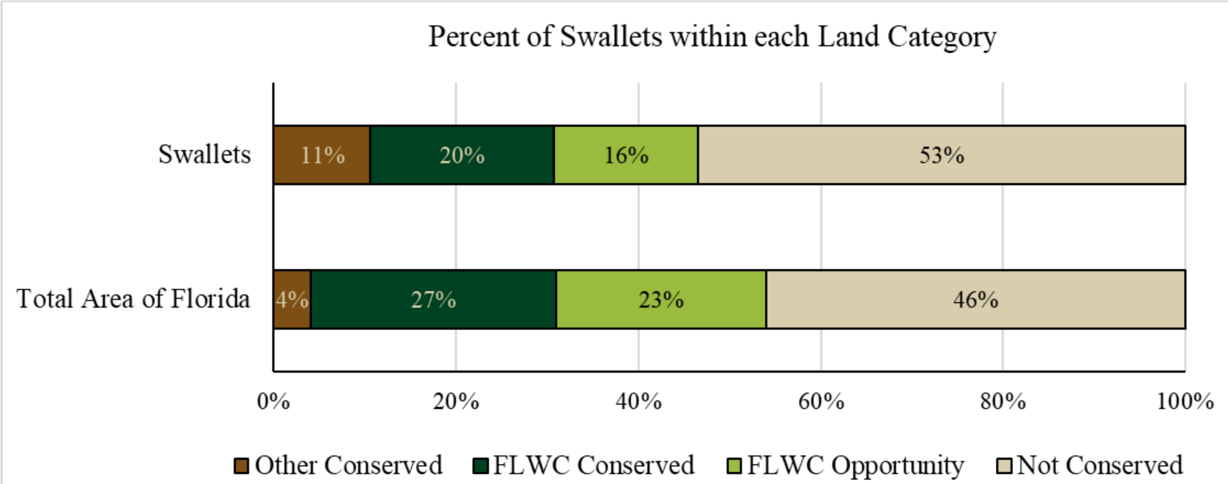

Figure IV-4. Percent of swallets within each land category.

OFS springshed areas are the spring metric provided least benefit by the FLWC. Figure IV-5 overlays the OFS springshed areas over the FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and areas that are Not Conserved. FLWC Conserved areas include only 13% of OFS springsheds. FLWC Opportunity areas more than double the OFS springshed area included within the FLWC, but still only include 16% of the OFS springshed areas. In total, the FLWC Conserved and Opportunity areas would include 29% of the total OFS springshed area if all Opportunity areas were acquired, indicating low-to-moderate benefit is provided to OFS springsheds. If Other Conserved lands are added to FLWC Conserved and all Opportunity lands, approximately 31% of OFS springsheds are within those lands (Figure IV-6). These data indicate OFS springsheds are substantially underrepresented in the FLWC and Other Conserved lands, highlighting a clear conservation need for OFS springsheds beyond the existing boundaries of the Florida Wildlife Corridor.

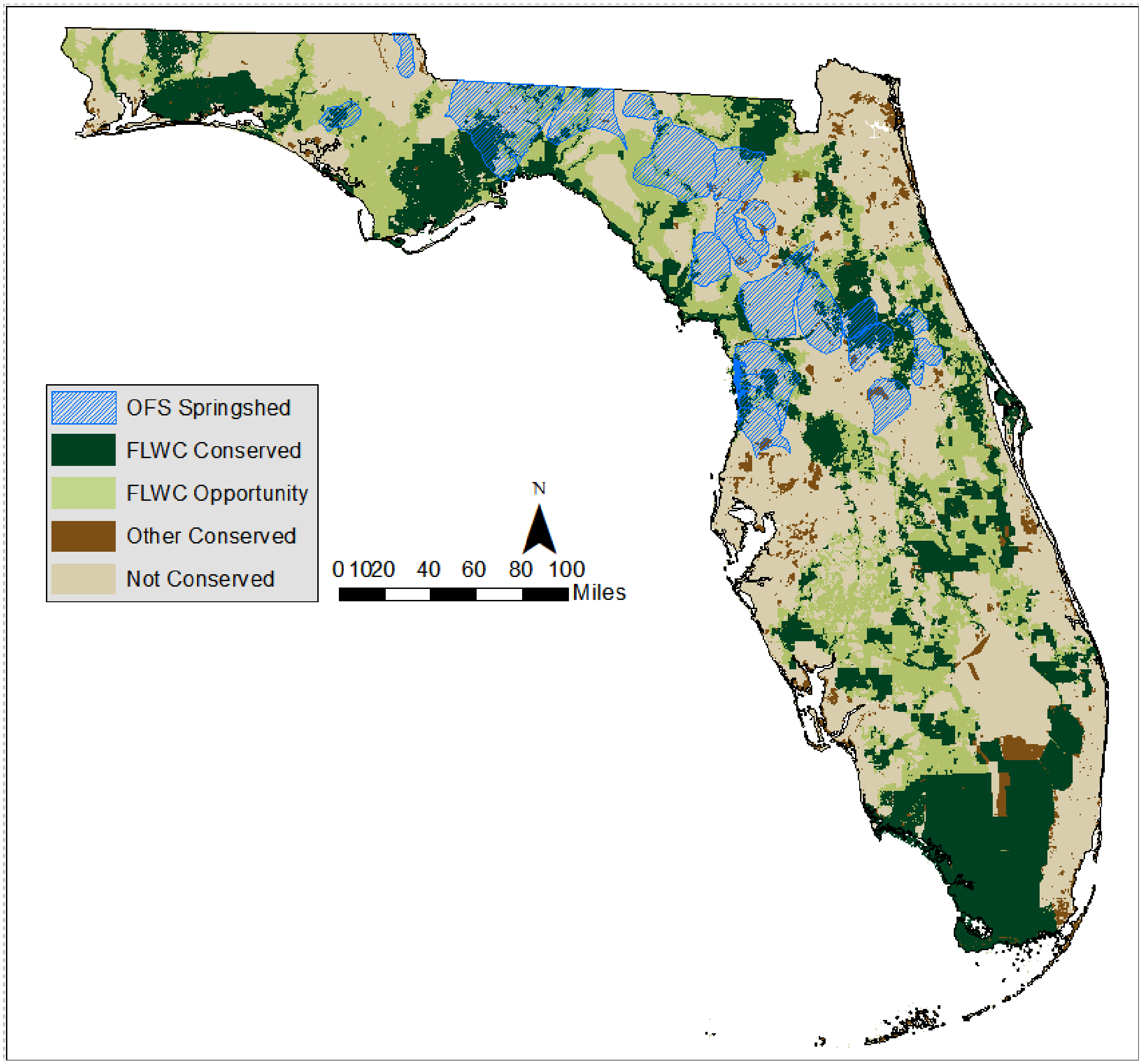

Figure IV-5. Outstanding Florida Springsheds (FDEP) overlain on the FLWC and Other Conserved areas.

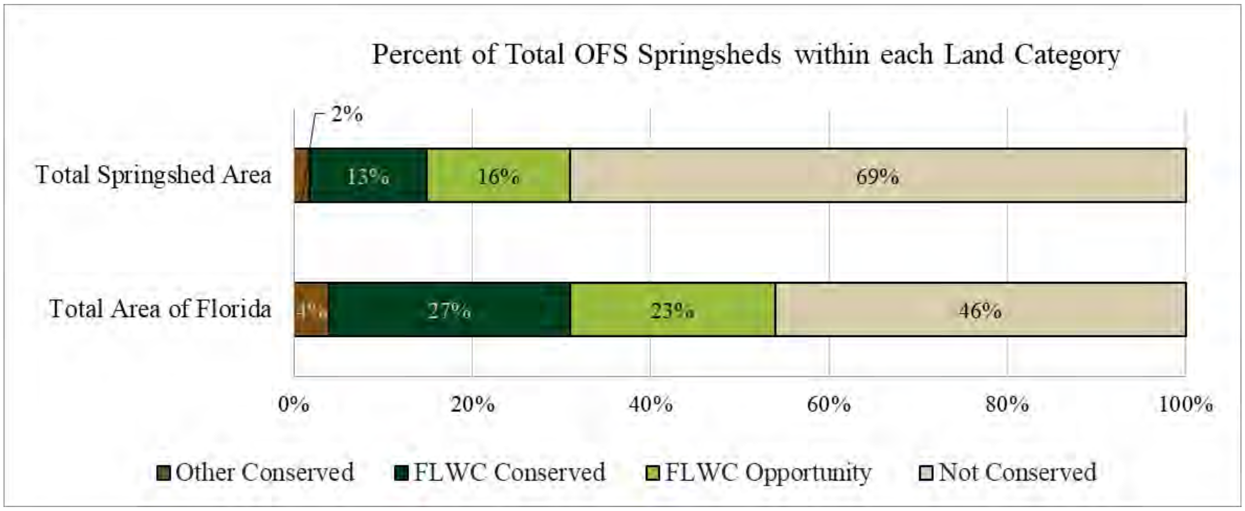

Figure IV-6. Percent OFS Springshed Area by land category.

The OFS springshed area protected by the FLWC differs throughout the state (Figure IV-7). For example, in the Ocala National Forest area, FLWC Conserved areas already provide approximately 65% protection for the Alexander Creek springshed and 85% protection for the Silver Glen springshed. Furthermore, if the FLWC Opportunity areas were conserved, FLWC protection for the DeLeon Spring springshed, in the Ocala National Forest area, would increase from 36% to 62%.

Several additional OFS springsheds would gain substantial benefit if FLWC Opportunity areas were acquired. For example, along the central Gulf Coast, Chassahowitzka and Homosassa Springs would both be more than 50% protected if FLWC Opportunity areas were added to existing FLWC Conserved areas. In the Florida Panhandle, the Gainer springshed would be more than 95% protected if FLWC Opportunity areas were added to existing FLWC Conserved areas, and the protection of the Wacissa and Wakulla springsheds would increase to 32% and 41%, respectively. In the Suwannee Basin, the Falmouth, Lafayette Blue, Peacock and Troy OFS springshed regions would increase from 4% to 27% protected, if the FLWC Opportunity areas were acquired.

However, there are substantial OFS springshed areas that are not included within the FLWC Conserved or Opportunity lands. An example is the Jackson Blue Springshed, which is completely outside the FLWC. Another area receiving low benefit is the Santa Fe Basin Springs region. None of the Devil's Ear, Hornsby, or Poe Springsheds in the Santa Fe Basin are included within FLWC Conserved and Opportunity areas and less than 20% of the Ichetucknee springshed is included. Lack of conservation in these OFS springsheds will make it difficult to achieve OFS MFLs, BMAPs, and ecosystem protection.

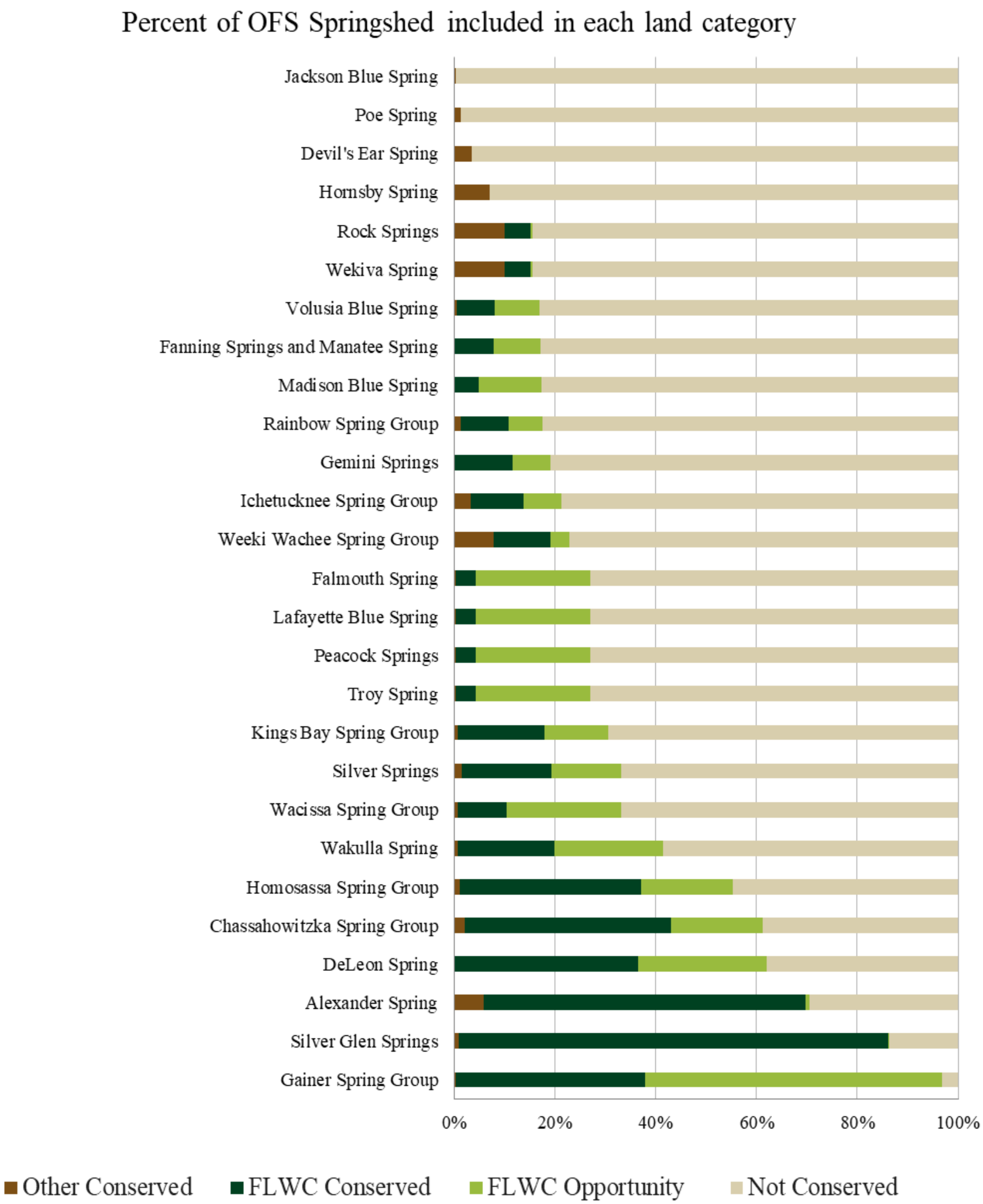

Figure IV-7. Percent individual OFS springshed area by land category.

Conclusions

Overall, Florida OFS springsheds and swallets receive low-to-moderate benefit from the FLWC Conserved and Opportunity areas, and these benefits are underrepresented compared to the statewide percent of land conserved by the corridor. Spring vents, however, are provided a good-to-excellent level of benefit, with 55% of 1st through 8th magnitude spring vents protected. This percentage exceeds the 50% of statewide land area within the FLWC indicating disproportionately large benefit for spring vents by corridor lands.

Priority FLWC Opportunity lands that could be acquired to increase OFS springshed protection include Panhandle lands surrounding the Gainer, Wacissa, and Wakulla springsheds, land surrounding DeLeon Springs near the Ocala National Forest, and lands surrounding Chassahowitzka and Homosassa Springs on the central Gulf coast. Additional priority conservation lands for protecting OFS springsheds, beyond the FLWC, include areas surrounding Devil's Ear, Poe, Hornsby, and Ichetucknee Springs in the Santa Fe River Basin, and the Jackson Blue Springshed in Jackson County.

The assumptions underlying the metrics used to assess springs benefits (i.e., that conserving spring vents, and swallet and recharge areas that are the source of the groundwaters that feed Florida's springs) are well-founded (EPA, 2022). However, making the connection between land and water use and spring condition is complicated by the dominance of complex subsurface flowpaths and the decades-long median travel times of water through the aquifer to spring vents. Determining the precise benefit that particular land conservation efforts would provide to specific springs will require resource-specific monitoring and modeling studies.

The degree of protection achieved by the FLWC lands will depend on how those lands are managed. Spring vent areas and spring runs should be managed to prevent ecosystem damage from recreation. Springshed lands and areas contributing to swallets should be managed to maximize groundwater recharge and minimize nutrient inputs. Conservation easements should be considered for working lands in springsheds.

There is no apparent advantage to spring water quantity or quality protection from FLWC land connectivity. Spring vent habitat, however, benefits from connectivity to spring-runs and downstream rivers and estuaries.

V. Lakes

Background

Florida has ~8000 permanent lakes, which cover ~3475 square miles (mi^2), or approximately 6% of the state's area (Brenner et al. 1990). There are a few large lakes in the state (e.g., Okeechobee, George, Kissimmee, Apopka, and Istokpoga) and innumerable smaller ones. The lakes are distributed heterogeneously across the landscape. Aptly named Lake County has more than 1300 lakes that are larger than 2.5 acres in size (Knochenmus and Hughes 1976), whereas Union, Baker, and Nassau counties, in northeast Florida, together have only seven lakes (Edmiston and Meyers 1983).

Florida lakes are relatively shallow. Many have maximum depths less than (<)16 ft (5m), and few have depths greater than 65 ft (20m). Lakes with the greatest surface areas are shallow (e.g., Okeechobee < 16 ft, Apopka ~11 ft), whereas the deepest are small sinkhole lakes such as Lakes Annie (69 ft [Gaiser et al. 2009]), Tulane (>72 ft [Grimm et al. 1993, 2006]), Sheelar (>65 ft [Watts and Stuiver 1980]), and appropriately named Deep Lake (95 ft [Gonyea and Hunt 1969]).

Lakes throughout Florida display a broad range of limnological characteristics with respect to pH, conductivity, dissolved color, nutrient and algal concentrations (trophic state), and biota (Shannon and Brezonik 1972; Canfield and Hoyer 1988; Brenner et al. 1990). Shallow lakes in Florida first filled with water in the early Holocene, *ca*. 9000-6000 years ago (Donar et al. 2009; Kenney et al. 2016; Larios Mendieta et al. 2018; Arnold et al. 2018), whereas at least some of the deep sinkhole lakes, like those mentioned above, have been shown to have held water continuously for tens of thousands of years, i.e., since the late Pleistocene. Thus, lakes in Florida have a long history of serving as habitat for aquatic flora and fauna and have been important resources for terrestrial wildlife and humans over many millennia.

Florida lakes continue to be vital aquatic ecosystems that provide essential services for wildlife and people. For instance, lakes provide habitat for many of the ~220 species of fish that occupy inland waters in the state (Robins et al. 2018), reptiles (aquatic turtles, water snakes, and the once-endangered alligator), and are homes or breeding sites for numerous amphibia (frogs, toads, salamanders, sirens/amphiumas). They also provide essential habitat and food for many species of resident and migratory aquatic birds, e.g., cormorants, ducks, herons, egrets, white pelicans, kingfishers, and raptors (ospreys, eagles). Littoral zones of lakes, along with nearby wetlands, are habitat areas for both native (*Pomacea paludosa*) and exotic (*Pomacea maculata*) apple snails, which are major food items for endangered snail kites (*Rostrhamus sociabilis*) (Cattau et al. 2017). Florida lakes also host aquatic mammals, including otters, muskrats, and beavers. In addition, lakes provide drinking water and/or protein for many terrestrial mammals, including, among others, panthers, bears, deer, and raccoons.

Florida's lakes also have a long history of providing environmental services for humans. Shallow lakes, which first filled with water in the Early Holocene, along with many springs that began to flow at the same time, were prime areas for early Indigenous settlement, providing reliable water sources for drinking and bathing, as well as abundant edible plants and animals (O'Donoughue 2017). Today, the state's lakes provide ecosystem services for the human population in many ways. Whereas some 90% of potable water used throughout Florida comes from underground aquifers, lakes in some areas also provide drinking water. Lakes also provide recreational opportunities and are sites for fishing, swimming, boating, and water skiing. Freshwater sportfishing attracts both resident and out-of-state anglers, and fishing generates jobs and income for the state (e.g., fishing licenses, boat and motor sales, hotel stays, restaurants). State residents typically pay premium prices for lakeside homes, and those higher costs mean greater property tax revenues for counties.

Lakes provide other ecosystem services, many of which are unacknowledged or underappreciated. For instance, the water-filled depressions intercept runoff and store water temporarily on the landscape, thereby providing flood protection. The high heat capacity of water also moderates temperatures on the surrounding landscape, which benefits local agriculture. Some citrus groves, for instance, are protected from freezes by lakes during winter months (Bill et al. 1979). Florida lakes also sequester organic carbon in their sediments at high rates (0.2 - 0.6 ounces per square foot per year; 63-177 grams per square meter per year), and those high burial rates, in combination with the extensive areal coverage of the lakes, indicate that carbon sequestration in these subtropical basins is an important component of carbon cycling and should be considered in global carbon models (Waters et al. 2019).

Human activities in Florida affect surface waterbodies in many ways. Many lakes, particularly small lakes on the Lake Wales Ridge and Trail Ridge, are surrounded by thick deposits of quartz sand, and are therefore poorly buffered against incoming acid precipitation. Some of these lakes, even in protected areas, displayed recent decreases in pH because of atmospheric inputs of acid rain (Sweets et al. 1990). Other such poorly buffered lakes experienced recent increases in pH, as well as other changes in chemistry because of runoff from calcium-bicarbonate-rich groundwater pumped into the watershed for residential and agricultural use (Whitmore et al. 2006), or to augment declining lake water levels (Martin et al. 1976; Dooris and Martin 1979). Some lakes have been subjected to inputs of toxic substances, such as arsenic, because of their proximity to golf courses, on which arsenical compounds were applied as herbicides (Whitmore et al. 2008). Whereas the local geology and soils are important influences on lake nutrient status (Bachmann et al. 2012), there is also ample evidence that many Florida lakes have undergone increases in trophic state (eutrophication) because of greater nutrient input from multiple sources, including direct sewage disposal, residential septic tank drainage, agricultural and residential fertilizer runoff, road construction, and phosphate mining (Brenner et al. 1993, 1995,1996, 1999; Schelske et al. 2005; Riedinger-Whitmore et al. 2005).

Metrics

One strategy for protecting lakes and maintaining their ecological integrity (biodiversity and natural functioning), is to conserve lands around them, i.e., to establish riparian buffer zones (Li et al. 2018; Wang et al. 2020). Such buffer zones intercept nutrients and particles that would otherwise be delivered to a lake. Establishment of buffer zones around Florida waterbodies is likely an effective strategy for conservation, given that nearly 70% of the state's waterbodies are hydrologically "closed," i.e., they lack overland inflows or outflows (Schiffer 1998). In such cases, most nutrients (e.g., nitrogen [N] and phosphorus [P]) and other inputs (e.g., heavy metals, pesticides) enter in surface runoff or subsurface inflow from the nearshore, riparian sector of the drainage basin. Thus, management initiatives designed to intercept incoming materials, including vegetated buffer areas around the lake periphery, can help conserve water quality and preserve ecological integrity.

Conserving lands as part of the FLWC has the potential to protect lakes from the negative consequences of riparian development. The potential value of the FLWC for lake protection was assessed in two ways. First, we looked at lake-perimeter lengths in the state by land type, i.e., shoreline lengths that fell into each of four land categories: 1) FLWC Conserved areas, 2) FLWC Opportunity areas, 3) Other Conserved areas, and 4) Not Conserved areas. That analysis was designed to address how much lake shoreline throughout the state of Florida falls into each of the four land categories and to evaluate whether substantial additional lake protection could be achieved by acquiring and conserving FLWC Opportunity lands. We also looked at the numbers of lakes that were in, or adjacent to, the four land categories to determine how much potential protection the lakes receive today and whether the acquisition of FLWC opportunity areas would substantially increase the number of lakes that could be conserved. Finally, we looked at the number of lakes in each land use category that receive various percentages of conservation. Our analysis reports statistics for the state-wide <u>population</u> of lakes. It does not address the conservation status of individual lakes, though a similar approach could be applied to individual waterbodies.

Interpretations of findings are predicated on several assumptions:

- Lake water quality and other measures of ecological integrity (biodiversity and lake functioning) are maximized when vegetation buffers along the lake perimeter are intact.

- Access to lake water for terrestrial animals (e.g., black bear, panther, deer) is improved in areas where lake riparian buffers are in place, by providing areas through which the fauna can safely move.
- Existing conserved lands inside and outside of the FLWC, as well as those that might come under future conservation (FLWC Opportunity areas), will be managed to establish or preserve riparian buffers, thereby enhancing conservation of both terrestrial and aquatic environments.
- Conservation of riparian buffer zones contributes to better water quality and thereby benefits both terrestrial and aquatic fauna.

Methods

We determined shoreline length and number of lakes in each land category by GIS analysis, using the USFWS National Wetland Inventory (NWI) (2018) Lakes and Ponds database. Water bodies included NWI lakes and ponds >5 acres (2 hectares) in area.

We used a buffer around lakes for the GIS analyses to eliminate error caused by slight mismatches between the lake polygons and the FLWC and Other Conserved layers. We conducted a sensitivity analysis was to assess buffer size impact on the analysis results. We found relatively minor differences in GIS analysis results when using a 33 ft (10 m) buffer versus a 1640 ft (500 m) buffer, and the conclusions for lake protections (low to moderate) were not impacted. However, zooming in to certain regions, it was clear the 33 ft (10m) buffer was introducing error due to the slight mismatches in GIS layers. Therefore, we used a 330 ft (100 m) buffer as this appeared to resolve much of the error while still providing an accurate representation of the lake perimeter.

We divided lake perimeters into 330 ft (100 m) segments with a 330 ft (100 m) wide buffer and assigned each to a land category. Figures V-1 to V-3 illustrate how we placed riparian buffer zones around the lake periphery and how we apportioned lengths among the four land categories.

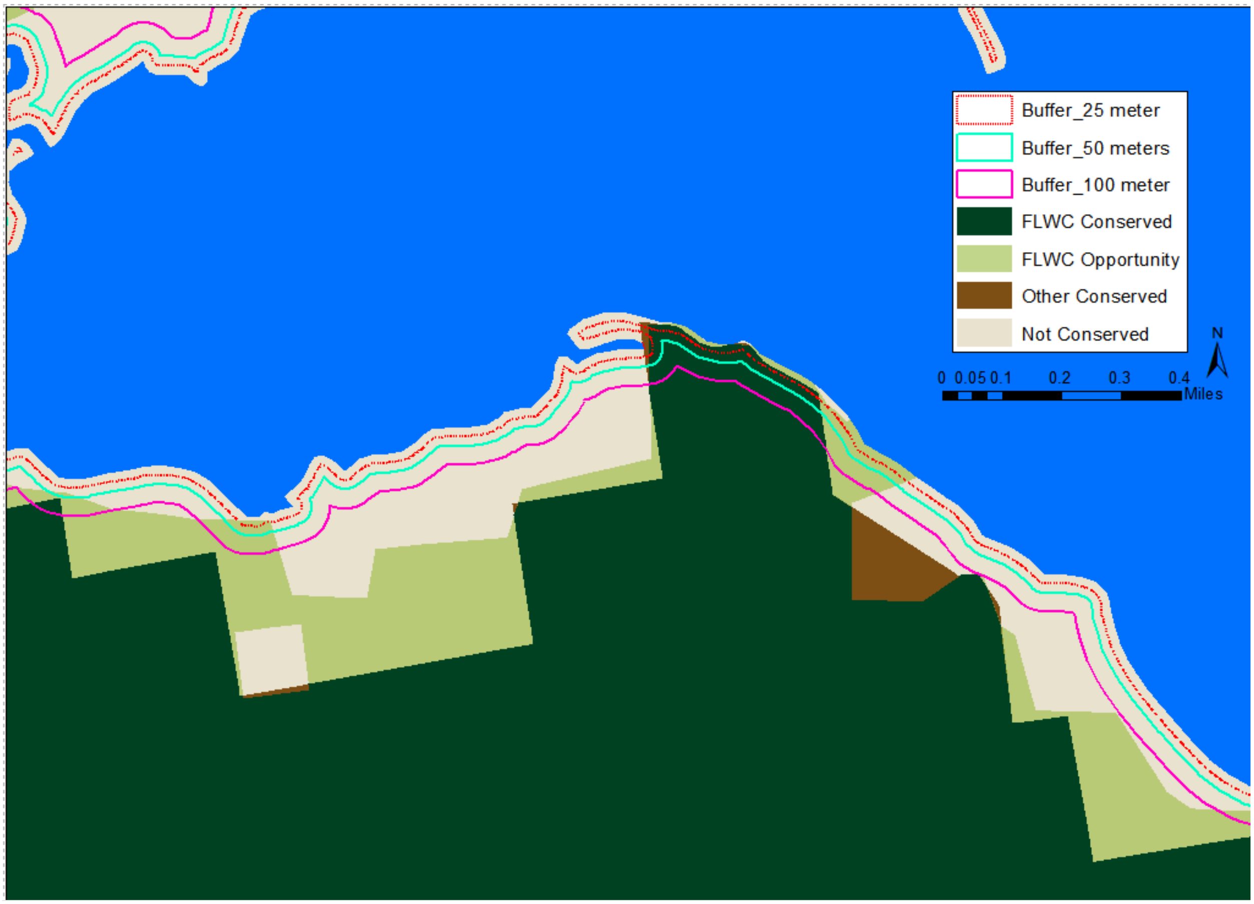

Figure V-1. Example lake perimeter, showing 82 ft, 164 ft, and 330 ft (25 m, 50 m, and 100m) buffer zones. The 330 ft buffer was used for analyses. The lake is depicted in blue.

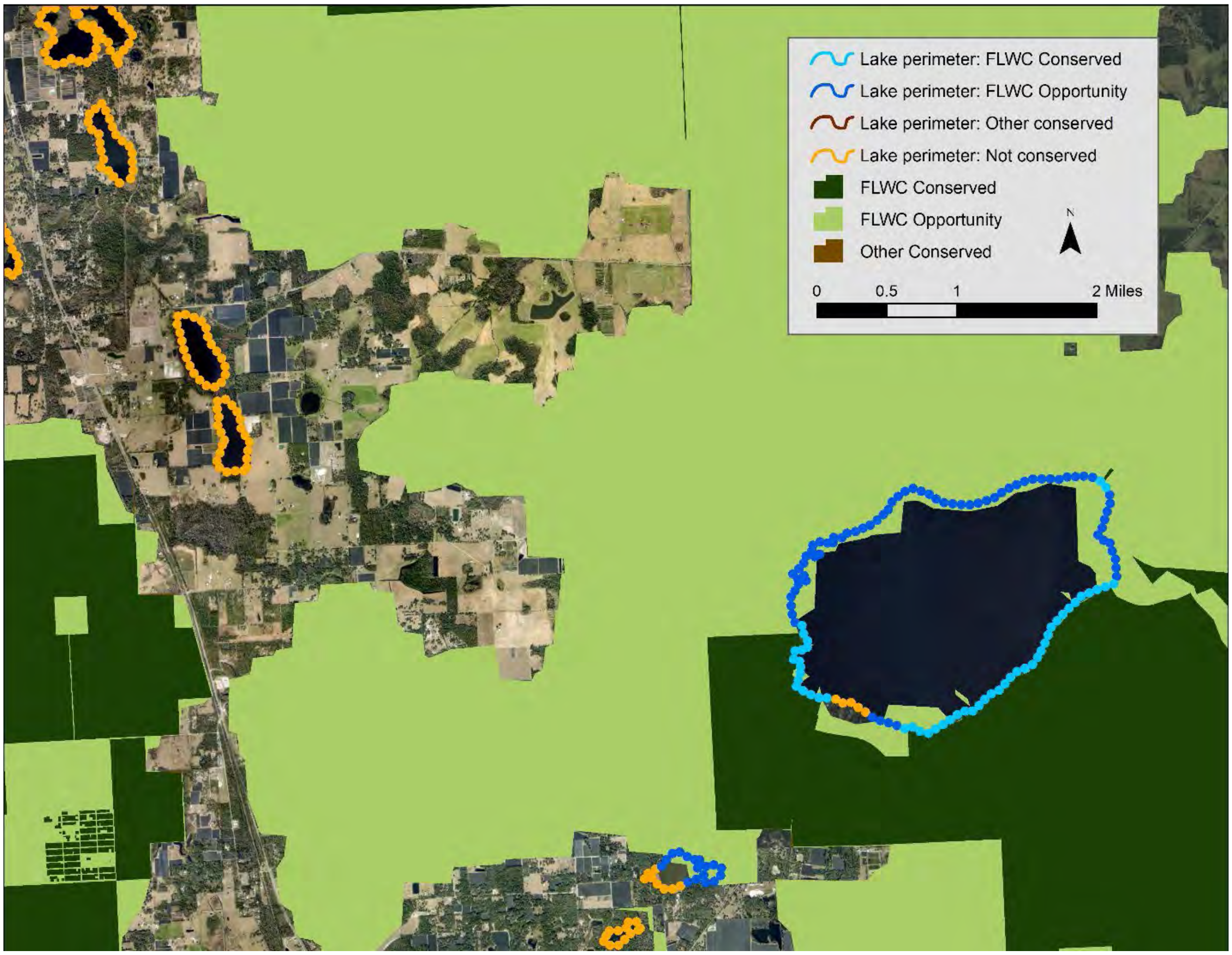

Figure V-2. This figure illustrates that some lakes are bordered by multiple land categories, as depicted by different color dots along the shoreline. Most of the small lakes on the left side of the figure are surrounded entirely by land that is not conserved, as depicted by dark brown dots. The south shore of the lake on the right of the figure was deemed to be surrounded by FLWC Conserved lands (light blue dots), i.e., already conserved lands, as much of the adjacent FLWC Opportunity area was within the lake. Dark blue dots on the north side of the lake show that bordering lands fall in the FLWC Opportunity area.

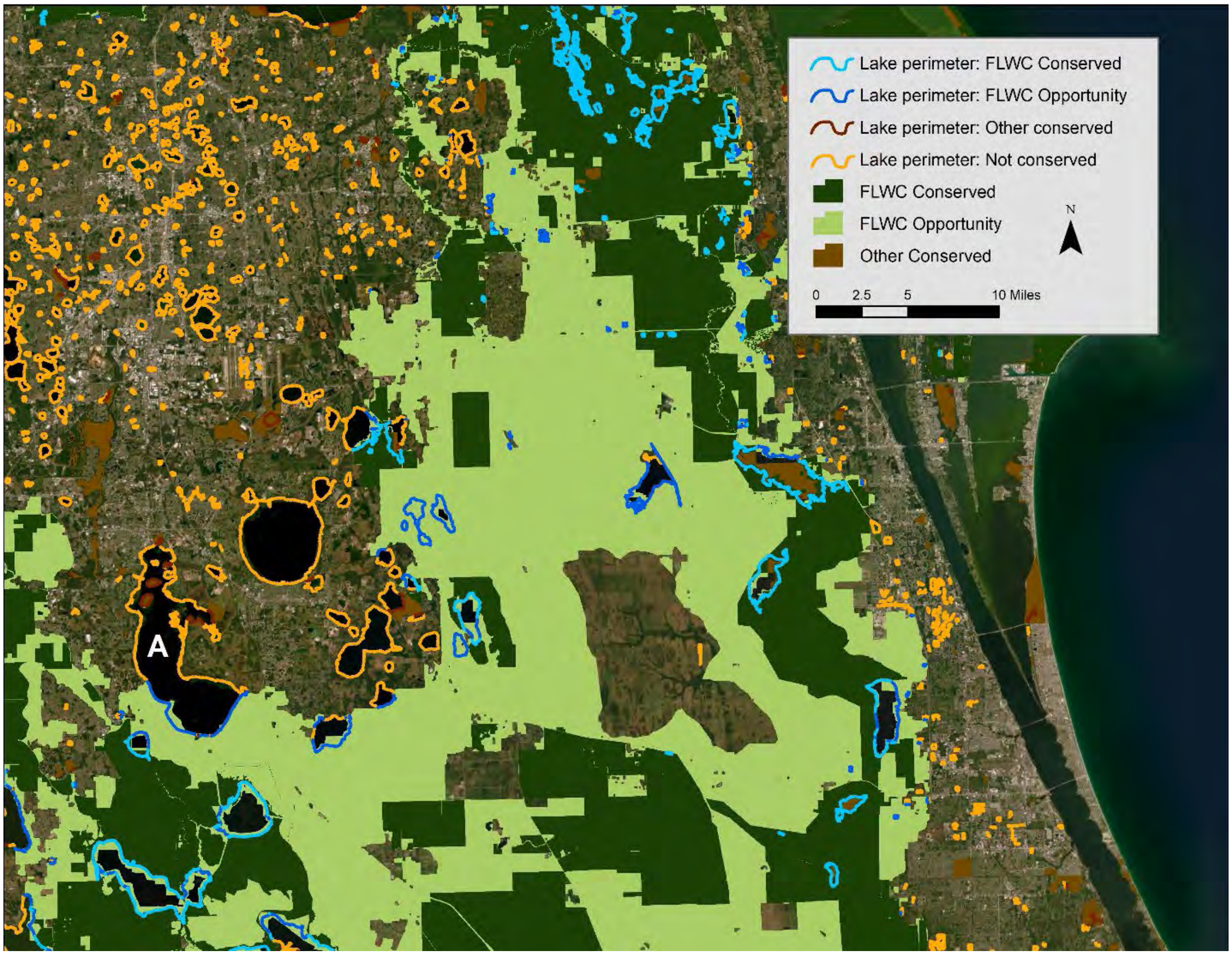

Figure V-3. In this view, it is apparent that many lakes have no conserved land area around their periphery, some are partially surrounded by conserved lands, and still others lie entirely within the FLWC. Note the large number of small lakes in the upper left of the figure that are surrounded by land that is 100% not conserved. Note also that a substantial portion of the shoreline around the lake marked “A” on the west side of the image could potentially be protected through acquisition and management of the FLWC Opportunity area south of the lake.

We assigned lake benefit metrics to two benefit categories: Good-to-Excellent (greater than or equal to 50% of the statewide benefit metric within the FLWC), and Low-to-Moderate (less than 50% of statewide benefit metric within the FLWC) as outlined in Section I.

Results and Discussion

Of a total of 15,729 miles (mi) of lake perimeter in Florida, some 618 mi are bordered by Other Conserved lands and about 959 mi are adjacent to FLWC Conserved lands (Figure V-4a). Shoreline length in FLWC Opportunity areas (915 mi) approaches that in FLWC Conserved areas. The overwhelming majority of lake shore length in Florida (~13,238 mi) is surrounded by lands that are Not Conserved. Acquisition of all FLWC Opportunity lands would nearly double the amount of lake shoreline within the FLWC to 12% and when combined with Other Conserved lands, would increase the potential for conserving lake shoreline from 1576 mi to 2492 mi, or ~16% of the state total (Figure V-4b). Together, FLWC Conserved and Opportunity lands protect approximately 12% of lake perimeters. Thus, lake perimeter is provided low benefit by FLWC Conserved and Opportunity lands, which is underrepresented compared to the overall percent of Florida land area within the FLWC (50%).

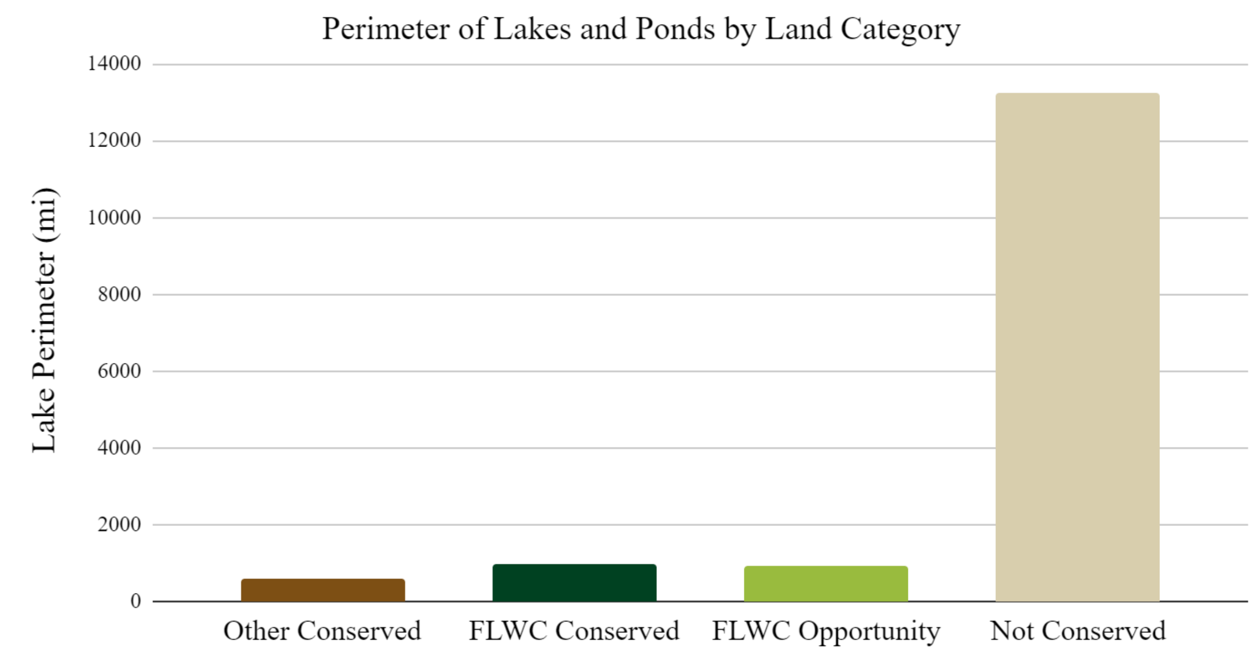

Figure V-4a. Bar plot showing the lengths of lake perimeter that lie within each of the land categories.

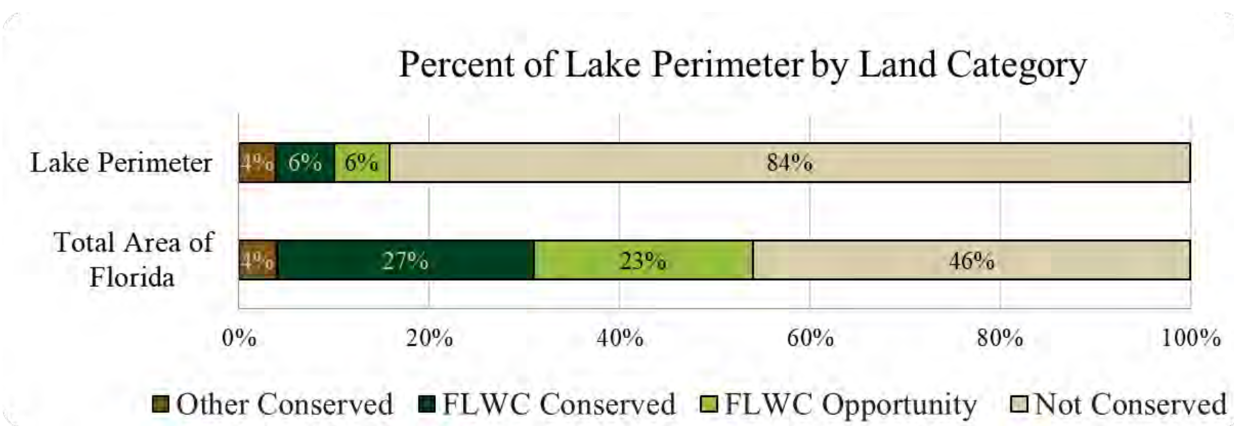

Figure V-4b. Percent of total lake perimeter within each land category.

Fifteen percent of lakes in Florida are surrounded by multiple land categories with respect to conservation status. Nevertheless, most Florida lakes (68%) are surrounded by land that holds no conservation status (Figures V-5a,b). Just as most lake shorelines throughout Florida abut lands that are Not Conserved (84%), the same holds true for numbers of lakes, i.e., many of the lakes are surrounded by lands that are not conserved in any way. Many such lakes are small and lie in urban areas where they are surrounded completely by residential and/or other development. Thus, lake number is also provided low benefit by FLWC Conserved and Opportunity lands.

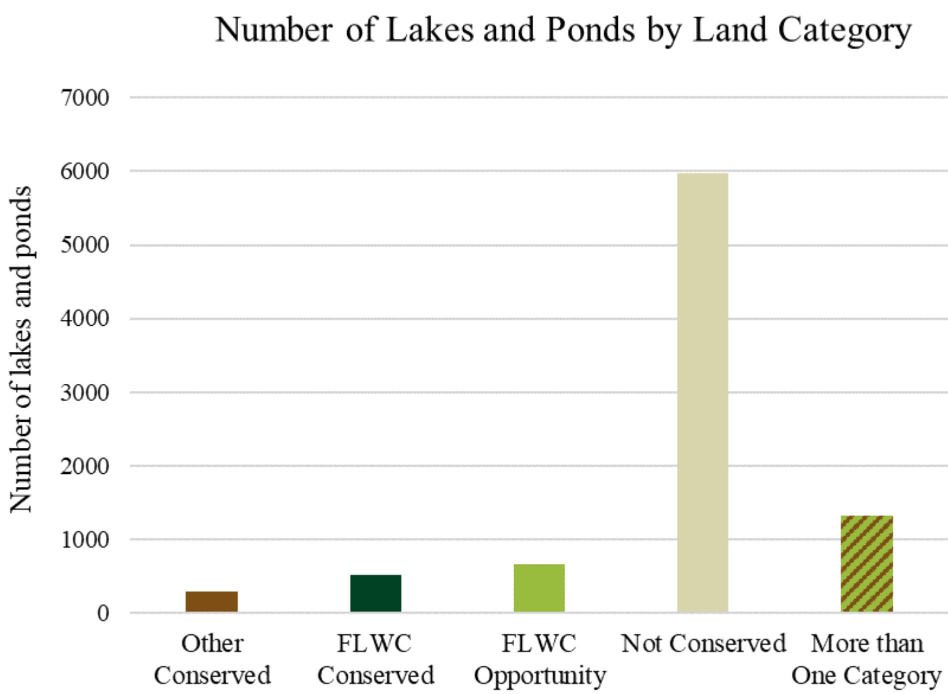

Figure V-5a. Number of Florida lakes within each land category.

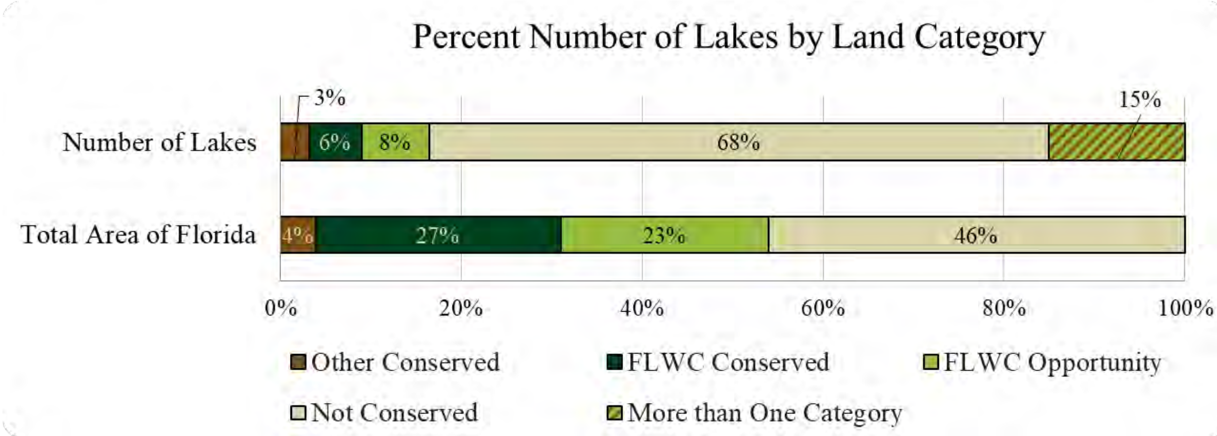

Figure V-5b. Percent of number of lakes within each land category.

Conclusions

Among surface waters, lakes enjoy far less existing and proposed conservation from the FLWC than do rivers or wetlands, whether lake conservation is assessed by length of shoreline or number of waterbodies in or adjacent to FLWC lands. This outcome is not unexpected, as the FLWC lands generally track the large river systems in the state, many of which have wetlands associated with them. In contrast, lakes are frequently "isolated" on the landscape. Many are located in upland areas, e.g., on or adjacent to the Lake Wales Ridge, and their watersheds are preferred sites for residential development and agriculture (Figure V-6). Despite the low-to-moderate benefit afforded lakes, those adjacent to or wholly within FLWC Opportunity lands have the potential to substantially increase the amount of shoreline and number of lakes under conservation.

Whereas connectivity between lakes is not frequently considered when conservation plans are developed, benefits to both terrestrial and aquatic fauna may accrue from maintenance of (or creation of) vegetation corridors among water bodies. Such vegetated zones, along with riparian buffers, may enable wide-ranging terrestrial animals to move across the landscape and access water and aquatic protein sources. Such an approach might be feasible in some areas, but clearly could not be applied in regions already characterized by dense residential development.

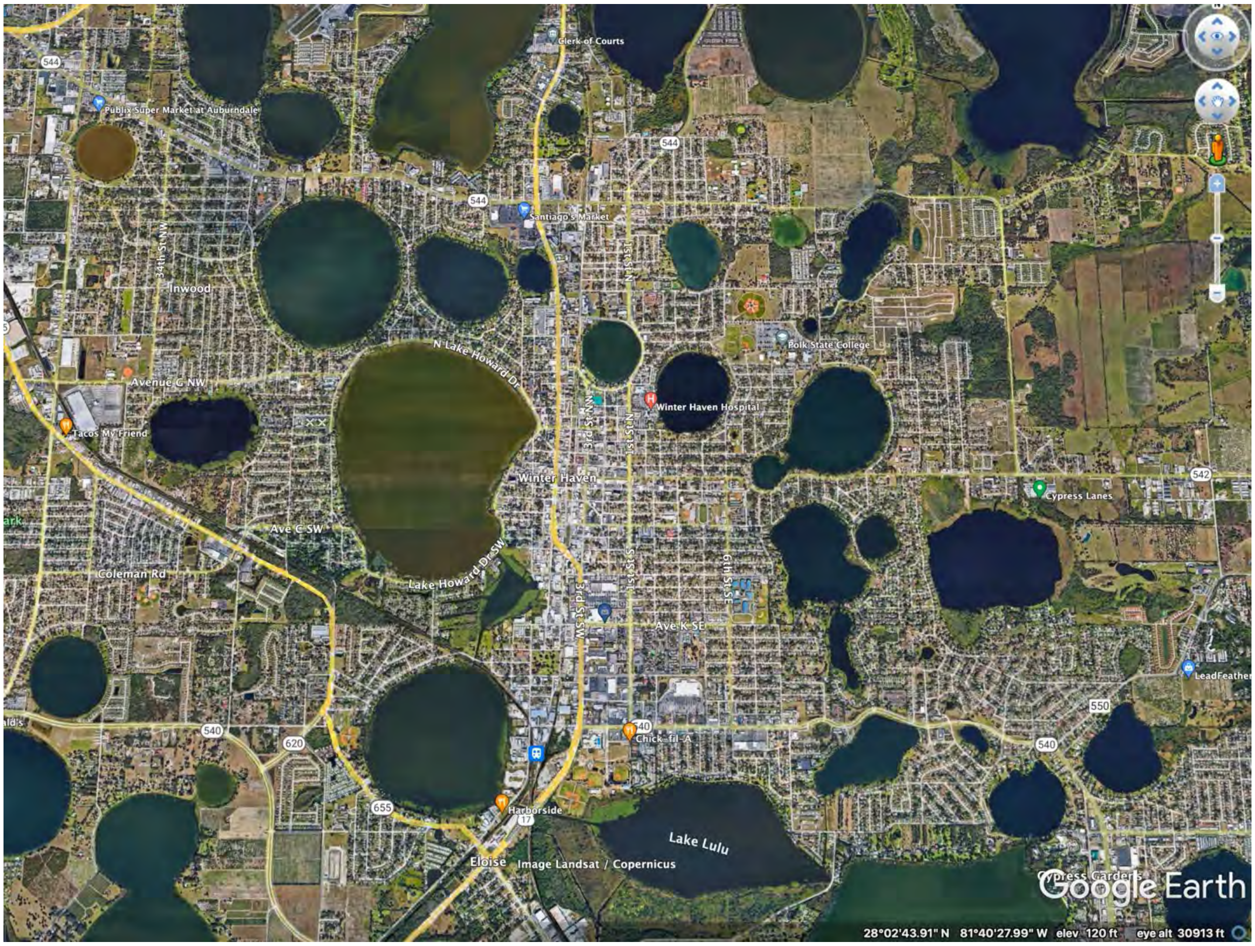

Figure V-6. Winter Haven (Florida) area, showing the extent of residential and agricultural development around the lakes in the region. Many of the waterbodies have no conserved land around the shoreline. Note that it would be difficult to conserve lands between waterbodies in this highly developed area.

A number of factors might be considered when prioritizing purchase of FLWC Opportunity lands, if lake conservation is a primary goal. First, an argument can be made for acquiring land tracts that possess multiple lakes, thereby achieving potential protection for many waterbodies. This may also make it possible to establish vegetation corridors between lakes, creating paths through which wildlife can move. Second, limnological characteristics of lakes might be used as criteria for deciding on land purchases. For instance, if clear-water, oligotrophic lakes are scarce in an area, protection of these lakes might guarantee that such waterbodies, home to a distinct biota and often preferred by local inhabitants for swimming, are maintained in a relatively undisturbed state. On the other hand, if highly productive (eutrophic) lakes are uncommon in an area, such waterbodies, which often host abundant wildlife and are good sportfishing sites, might be prioritized. Ideally, FLWC Opportunity lands that host an array of lake types could be targeted to enhance aquatic plant and animal diversity in the region.

When prioritizing land purchases for lake conservation, other issues may merit consideration. At the individual lake level, it might be helpful to assess how land acquisition and establishment of a riparian buffer might yield ecological benefits. For instance, one might evaluate how much more of the lake perimeter can be potentially protected by land acquisition, and whether that percentage is sufficient to afford conservation benefits. Whereas FLWC Opportunity lands are scarce in urban and suburban residential areas, such lands do host agriculture. In such cases, several questions might be addressed: 1) has historical land use already negatively impacted water quality? 2) are there legacy nutrients in basin soils, derived from agricultural fertilizers, that will continue to influence lake trophic status? 3) is there sufficient land around the lake(s) where vegetation buffers and corridors could enhance wildlife mobility?

As mentioned, lakes would not derive the same magnitude of conservation benefit from acquisition of FLWC Opportunity lands as would some of the other aquatic ecosystems. That is the case whether we consider the enhanced amount of shoreline protected or the larger number of lakes protected. Whereas this may be perceived as discouraging, it makes a strong argument for how critical it is to purchase such lands and extend protections to additional lakes. That is, the current situation affords such little conservation protection to lakes that acquisition of opportunity lands has the potential to considerably increase the proportion of lakes that are conserved.

VI. Wetlands

Background

Wetlands are important in Florida and beyond for their role in water storage, water quality improvement, habitat, carbon sequestration, and biological productivity (Zedler and Kercher 2005, Creed et al. 2017), all of which provide valuable but under-appreciated economic benefits (Barbier et al. 1997, Ghermandi et al. 2008). Historically, wetland area declined throughout North America (Dahl 2011; van Meter and Basu 2015), including Florida (Hefner and Brown 1984, Goldberg and Reiss 2016), and nearly 50% of wetland acreage has been lost. These losses necessitated preferential state and federal protections to ensure their functions are sustained, including mitigation for lost wetland acreage, buffers/setbacks for urban development, and best management practices for integrating wetlands in agricultural lands. Conservation of wetlands is an important priority at the state and national levels, but burgeoning human development and associated land use change, changing climate, and fragmentation of the landscape all imperil the sustained provision of the myriad services that wetlands provide.

Whereas all wetlands provide important functions, large wetlands are better protected than small wetlands, both in practice and law. This creates a critical conservation challenge, given emerging evidence on the disproportionate value of small wetlands for habitat (Cohen et al. 2016), hydrology (Rains et al. 2016), and biogeochemical functions (Marton et al. 2015, Cheng and Basu 2017). That is, small wetlands (and lakes) with large perimeter-to-area ratios (Cohen et al. 2016, Holgerson and Raymond 2016) provide greater functional value per area than larger, better conserved systems. For example, McLaughlin et al. (2014) demonstrate that wetlands with large perimeter-to-area ratios, or generally smaller wetlands, exert far greater control on water level variation in streams per unit area than much larger wetlands with less perimeter per area. Given the preferential loss of small wetlands (defined here as less than 20 acres) from many wetland landscapes, important changes have occurred in the portfolio of ecological functions that landscapes can provide (Cohen et al. 2016), particularly the resilience of wetland functions across diverse landscapes, given variation in hydrological controls (Wilcox et al. 2017, Boughton et al. 2010). Thus, in addition to protection acreage of wetlands for the intrinsic value of these ecosystems for humans and wildlife, there is a scientific imperative to focus on protections of smaller wetlands that often occur as part of “wetlandscapes” where landscape connectivity is a crucial factor in the functions that are provided (Thorslund et al. 2017, 2018). There are existing protections at the US Federal level, albeit imperiled by ongoing disagreement about the valid extent of Clean Water Act jurisdiction, and even better protections from State of Florida regulations (e.g., protections for all wetlands down to 0.5 acres). Although the strategic protections of smaller wetlands in wetlandscapes is not a priority, it appears to be an important frontier in both ecological science (Leibowitz 2003, Cohen et al. 2016, Bertasello et al. 2022) and conservation planning (Semlitsch and Bodie 1998, Cheng et al. 2020).

To assess wetland benefits of the FLWC, our primary questions were:

1) How effective is the FLWC (existing conserved and opportunity lands) for protecting Florida's freshwater wetlands? We explored this statewide and by large watershed.
2) How well does the FLWC conserve small wetlands?
3) What are the consequences of landscape connectivity for conserved wetland functions?
4) What are the priority areas for future wetland conservation across the state?

Metrics

To maintain the integrity of wetlands and wetland-rich landscapes, and preserve the watershed functions that those wetlands provide, requires conserving both individual wetland features, but also large swaths of land within which diverse wetlands connect and provide habitat heterogeneity (Thorslund et al. 2017). While most wetlands, especially small ones, are hydrologically closed (i.e., geographically isolated; Cohen et al. 2016), there is mounting evidence that these wetlands in Florida actually connect via surface flowpaths regularly and with important hydrological and biogeochemical implications (McLaughlin et al. 2019, Klammler et al. 2020). As such, conservation strategies aimed at enhancing both the overall acreage of wetlands, but also the diversity of wetlands within upland mosaics (i.e., wetlandscapes) are preferred. We used overall wetland area conserved as our primary metric, but also focus on the size of conserved wetlands, reasoning that added protections of small wetlands is useful given the legacy of small wetland losses and their outsized role in many landscape functions. We therefore assume that the services that wetlands provide are protected in proportion to the area of wetlands protected, and that protecting small wetlands enhances the overall wetland services that a landscape can sustain.

Conserving lands as part of the FLWC should protect wetlands from the negative consequences of development, including wetland filling, hydrological alterations and water quality impacts. The value of the FLWC for wetland protection was assessed in two ways. First, we looked at wetland area in the state sorted by land type, i.e., acres that fell into each of four land categories: 1) FLWC Conserved areas, 2) FLWC Opportunity areas, 3) Other Conserved areas, and 4) Not Conserved areas. This was done separately for forested (swamp) and herbaceous (marsh) systems. That analysis reveals the wetlands in each of the four land categories and, more specifically, quantifies the additional protections that would be achieved by acquiring and conserving FLWC Opportunity lands. We did a parallel analysis for small wetlands (i.e., those less than 5 acres). Our analysis reports statistics for the state-wide population of wetlands but does not address the conservation status of individual wetlands.

Interpretations of findings are predicated on several assumptions:

- Wetland function quality and other measures of ecological integrity (biodiversity and lake functioning) are maximized when wetlands remain surrounded by low intensity land uses, and when connectivity among adjacent wetlands is conserved.
- Landscape functions for fauna that use wetlands is maximized when the full portfolio of wetland types and sizes is conserved. Heterogeneity in individual wetland functions confers resilience on the overall provision of functions across landscapes.
- Existing conserved lands inside and outside of the FLWC, as well as those that might come under future conservation (FLWC Opportunity areas), will be managed to establish or preserve wetland conditions, thereby enhancing conservation of both terrestrial and aquatic environments.
- Conservation of wetlands of all types contributes to improved flood water storage functions and better water quality and thereby benefits both terrestrial and aquatic fauna in the wetlands and all the areas downstream.

Methods

We delineated lands into four categories statewide for this study (see Section I, Figure I-2). The FLWC consists of existing protected lands (FLWC Conserved) that comprise 27% of Florida's land area, and Opportunity lands that are currently not conserved but would be under current FLWC design comprising an additional 23% of Florida. Other Conserved lands, not part of the FLWC comprise 4% of Florida's land area, leaving 46% of the state area outside of the FLWC with no conservation status.

To assess the impacts to wetland resources from the strategic conservation of the FLWC, we cross-referenced the existing statewide inventory of wetlands from the US Fish and Wildlife Service National Wetlands Inventory (2018) with the spatial extent of the four land conservation classes (Not Conserved, FLWC Conserved, FLWC Opportunity, and Other Conserved). The NWI provides a seamless national database of wetland type, size, and extent that allows repeatable and reliable spatial inventories. Whereas there is evidence that NWI can undercount small wetlands (<0.25 acres, 1000 m^2) (Wu et al. 2019), it remains the most visible and well documented source of spatial wetland inventory information. For all of our analyses, we considered only wetland polygons in the NWI that exceeded 0.25 acres or 1000 m^2, which is roughly double the minimum mapped feature area, and close to the size at which topographic and image-derived delineations of wetlands diverge (van Meter and Basu 2015); in most cases this screened out several thousand polygons, but a trivial fraction of the total area.

The NWI reports wetland coverage across eight categories, six of which were omitted for this analysis of freshwater wetlands. Specifically, we focused on the wetland categories referred to as “freshwater emergent” (herein referred to as marshes) and “freshwater forested” (herein referred to as swamps). The former occupy nearly 17% of the total wetland area in the state of Florida, and 28% of all the individual wetland features, whereas the latter occupy 36% of the wetland area, and 45% of the features. Categories omitted from this analysis included: 1) estuarine wetlands (deep water and emergent wetland categories), which comprise 39% of total wetland area, and are discussed elsewhere in this report (Estuaries Section VIII), 2) lakes and ponds, which comprise 8% of the total mapped NWI area, and are also discussed elsewhere in this report (Lakes Section V), 3) riverine wetlands, which comprise 0.7% of the total mapped area and represent the flowing water footprint of Florida’s water resources, and are discussed elsewhere in this report (Rivers Section VII), and 4) other wetlands, which represent only 0.03% of the total NWI area, and appear to principally be human-made depressions.

Our analysis of the FLWC impacts on the statewide benefits to freshwater wetlands focuses on both the area (acreage) and number (count of individual polygons in the NWI dataset) withing FLWC Conserved and Opportunity lands. That is, we partitioned the existing NWI resource among the four land categories and report the benefits for both the number and area of wetlands. We focus on these metrics because we sought to consider both area-dependent wetland functions (e.g., water storage, C sequestration) and those functions (e.g., habitat provision, water quality improvement) that can be disproportionately provided by small wetlands (Cheng and Basu 2017, Cohen et al. 2016). Given the disproportionate importance of small wetlands for specific habitat and water quality functions, and the general conservation preference for protecting large iconic wetlands, the broad national trends of small wetland loss (e.g., van Meter and Basu 2015, Creed et al. 2017) present a significant challenge. Assessing the average size of wetlands in each of the land categories offers some insights into the protections afforded for these critically imperiled small aquatic habitats.

For each wetland type, we also evaluated the protections within each USGS Hydrologic Unit Code (HUC) at the 8-digit level (Figure VI-1). These basins are critical planning units for water quality and quantity, and wetland protections are crucial for a variety of watershed functions, including flood-water storage, water quality improvement, and ecological habitat. We sought to identify basins in which FLWC conservation efforts, especially via identification of FLWC Opportunity lands, would augment wetland protections, and, by complement, where wetland protections are weaker. Identification of basins that both contain a significant extent of wetland area, and that possess a large proportion of wetlands that fall outside current or proposed conservation, helps pinpoint locations where future wetland protections could be achieved, particularly basins that contain substantial wetland area abutting or connecting to existing conservation lands.

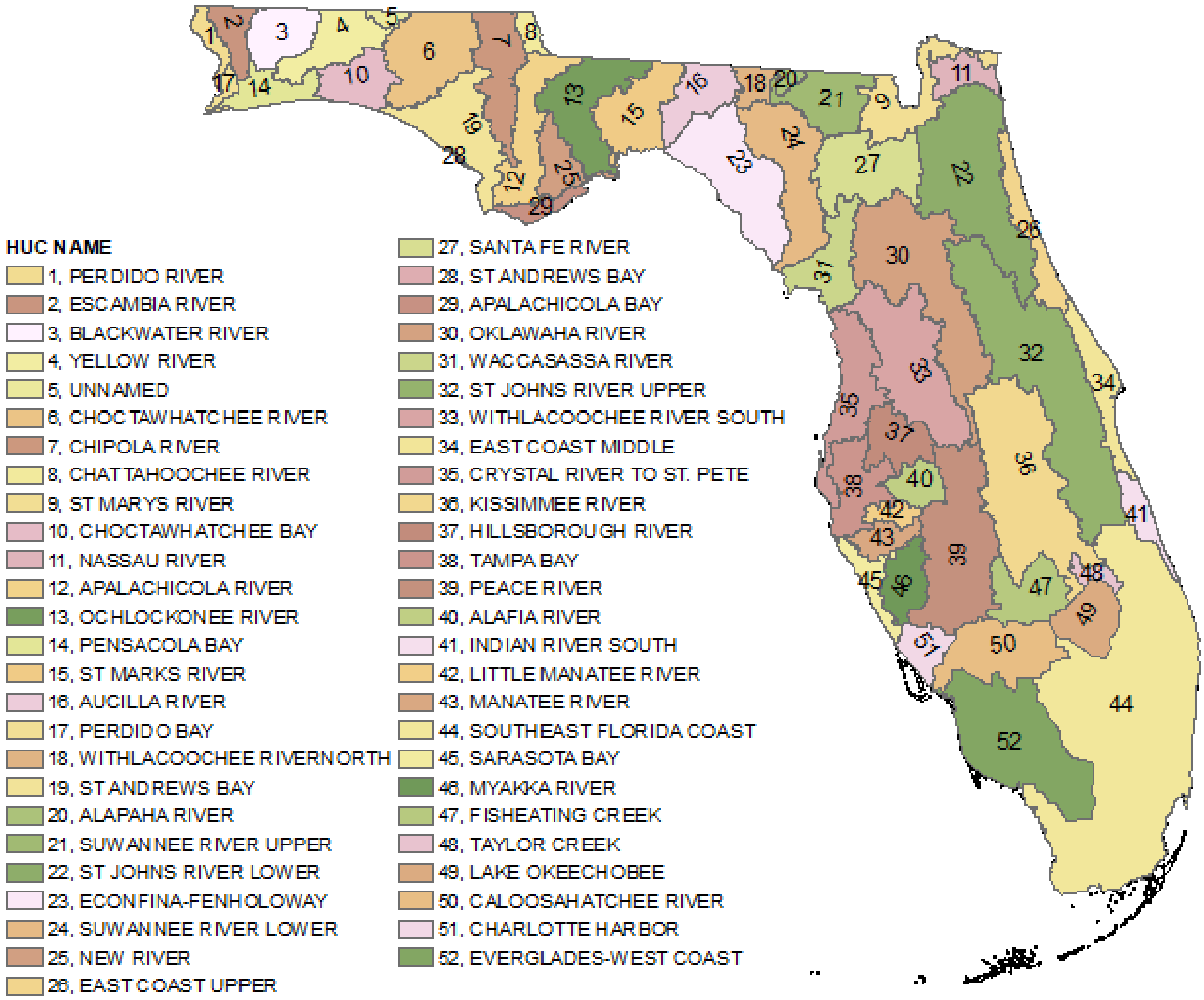

Figure VI-1. Hydrologic unit codes (HUC) at the 8-digit level for Florida. Statewide wetland protections (Figures IV-2 through 4) are variable across HUC8.

We assigned wetland benefit metrics to two benefit categories: Good-to-Excellent (greater than or equal to 50% of the statewide benefit metric within the FLWC), and Low-to-Moderate (less than 50% of statewide benefit metric within the FLWC) as outlined in Section I.

Results and Discussion

According to the National Wetlands Inventory, Florida has over 220,000 herbaceous emergent wetlands (marshes) with a total area of 5097 mi^2 (13,200 km^2), which represents about 8% of Florida's land area. This includes the large and iconic marshes of the Everglades but is still dominated in numbers by small marshes (77% of all wetlands are < 25 acres, 10 ha) that serve important local habitat and ecosystem functions. Similarly, Florida has 10,348 mi^2 (26,800 km^2) of forested wetlands (swamps) that cover 16% of the state.

Statewide Analysis

More than 77% of emergent wetland (marsh) area, and 57% of all individual wetland features (i.e., wetland number) are within FLWC Conserved and Opportunity lands (Figure VI-2). The incremental benefits of the FLWC provided by the Opportunity lands if acquired would be to conserve 15% of the total marsh area, which is 50% of currently unprotected marshes, and more than 30% of the total individual marsh features, which is nearly 45% of those that are currently unprotected.

Given the benchmark that 50% of statewide lands are within the FLWC, with Opportunity lands making up 23% of the state, the benefits for marshes provided by the FLWC are good-to-excellent, regardless of whether the protections are assessed on an area or feature count basis, although marsh area has a higher percentage in the FLWC than marsh number. The FLWC Opportunity lands include 30% more wetland features than expected based on the statewide area in Opportunity lands (23%). Whereas Opportunity lands include less marsh area than expected, this is largely because so much of the marsh area in Florida is already within FLWC Conserved lands. Strikingly, whereas 46% of Florida would remain without conservation status if Opportunity lands were acquired, only 14% of marsh area, and only 39% of marsh features would remain not conserved. Clearly, the FLWC Conserved and Opportunity lands greatly benefit Florida's herbaceous wetland resources.

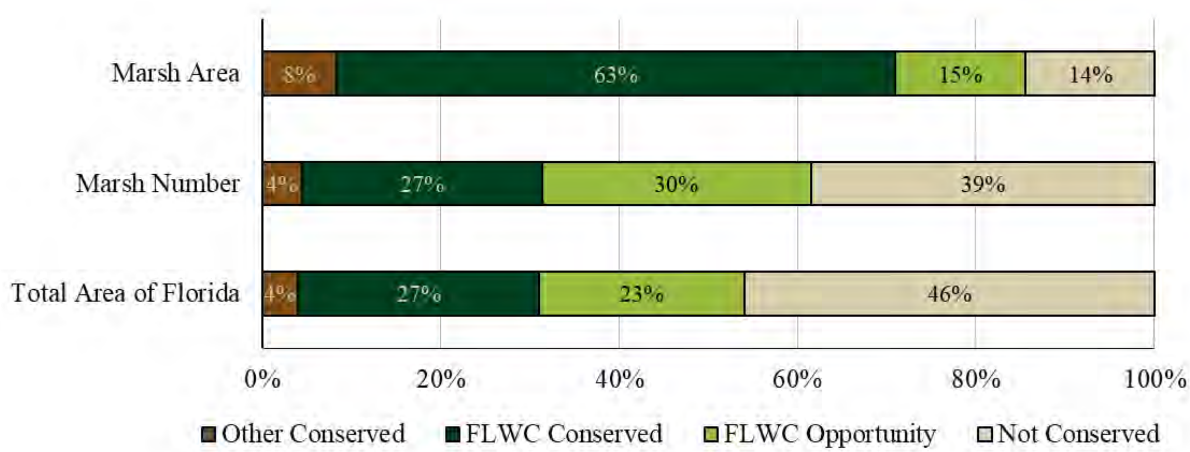

Figure VI-2. Summary of statewide protections for freshwater emergent wetlands (marshes) by total area (top) and total number of wetlands (middle) with reference to the statewide extent of the 4 land categories (bottom).

Similarly, 71% of forested wetland (swamp) area, and 58% of all individual swamp features are within FLWC Conserved and Opportunity lands, indicating good-to-excellent benefit (Figure VI-3). The incremental benefits that would be provided by acquisition of the Opportunity lands includes approximately 30% of both overall swamp area and total swamp features; this corresponds to more than half (55%) of the currently Not Conserved swamp area, and 45% of the currently Not Conserved swamp marsh features. Despite the Not Conserved land category occupying 46% of Florida, only 37% of swamp features and 24% of swamp area would be not conserved if FLWC Opportunity lands were acquired, which would be a remarkable and exciting achievement for statewide conservation of critical landscape functions derived from wetlands.

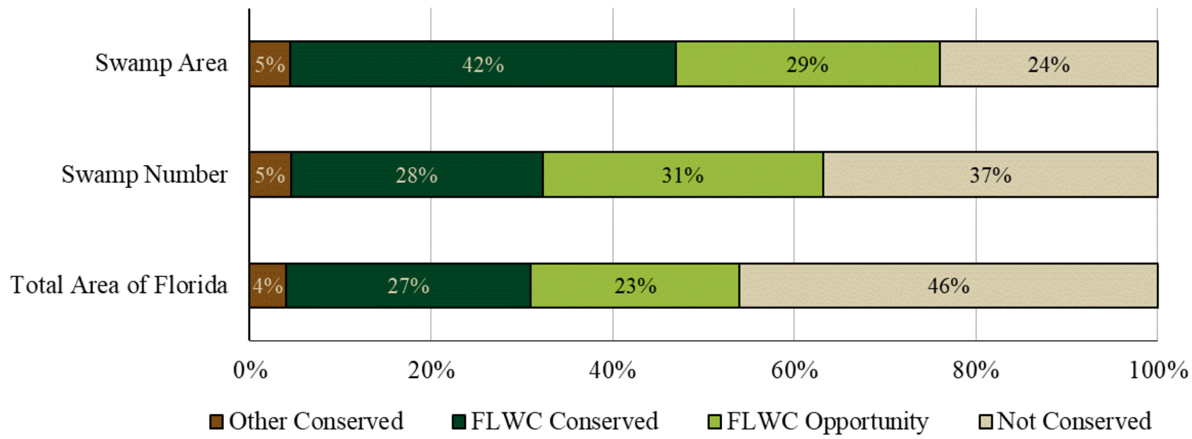

Figure VI-3. Summary of statewide protections for freshwater forested wetlands (swamps) by total area (top) and total number of wetlands (middle) with reference to the statewide extent of the 4 land categories (bottom).

We further considered impacts of the FLWC Conserved and Opportunity lands on distributions of wetland sizes. As explained above, some wetland functions accrue in direct proportion to wetland area; these include water storage and woody biomass storage. Other functions (water table variation, nutrient retention and C storage) are preferentially performed by small wetlands, making protections of small (often overlooked) wetlands a conservation priority. Our assessment of the NWI data for both marshes and swamps suggests that the mean area of wetland features in each class is an excellent proxy for the full distribution of wetland sizes. Notably, the mean area of swamps and marshes across the entire State of Florida is nearly identical, at 19.1 and 18.6 acres (7.7 and 7.5 hectares), respectively. Our analysis of mean wetland areas by land category (Figure VI-4 for marshes, Figure VI-5 for swamps) suggests that the FLWC Opportunity lands would substantially increase conservation for small wetland features if acquired. Specifically, the number of small marsh wetlands (i.e., those < 5 acres [2 ha]) in Opportunity lands would more than double the number currently in FLWC Conserved and Other Conserved lands. Likewise, the mean marsh size in existing conservation lands (within the FLWC or not) illustrates the strong preference for conserving large wetland features; the FLWC Opportunity lands are therefore notable in providing benefit for much smaller features, better aligned with the wetlands resources that are currently not conserved. Consider, for example, that existing conservation lands protect only 30% of the small marsh ecosystems around the state; doubling that to 60% with the FLWC Opportunity lands would translate into significant protections of key landscape functions.

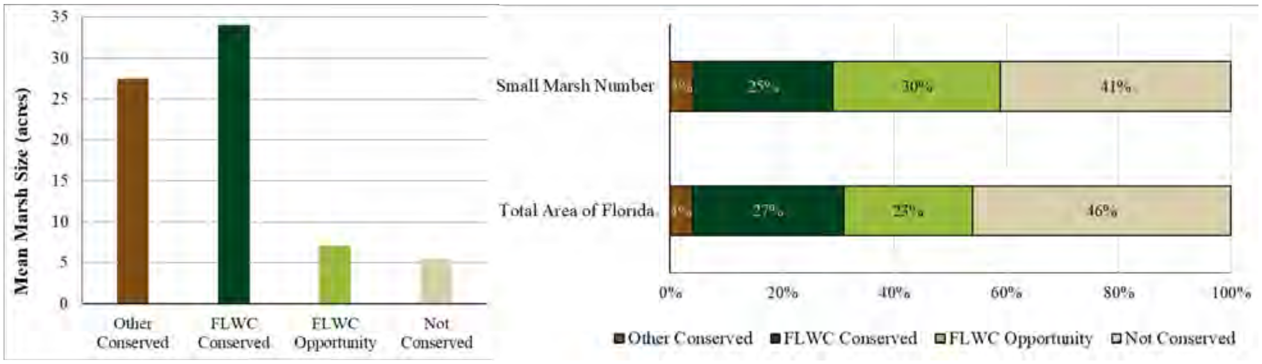

Figure VI-4. Protections for small (< 5 acres [2 ha]) emergent wetlands (marshes) by land conservation category.

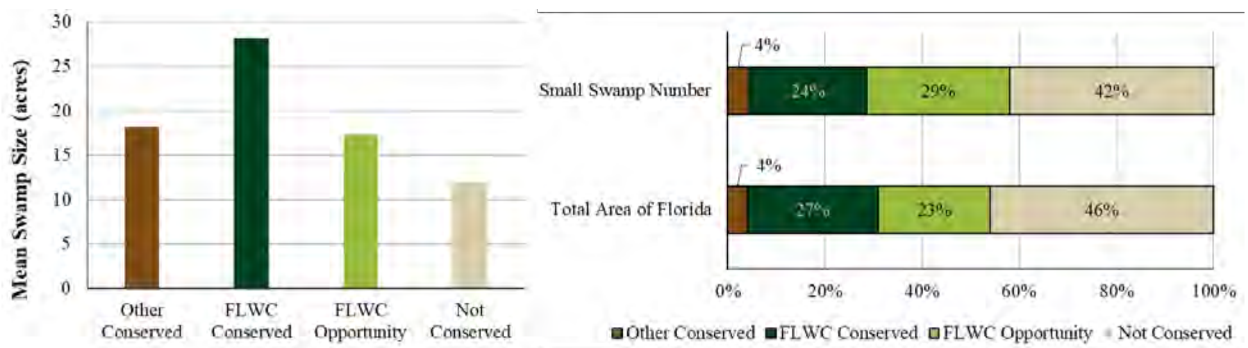

Figure VI-5. Protections for small (< 5 acres [2 ha]) forested wetlands by land conservation category.

FLWC Conserved areas protect larger swamps, whereas the swamp wetlands within the FLWC Opportunity lands are smaller (Figure VI-5). As a result, although existing conservation (both FLWC and Other Conserved areas) applies to less than 30% of small swamps, the addition of the FLWC Opportunity areas would more than double the statewide protections for small swamps, with a host of nuanced but important landscape function implications. When evaluated against the statewide area benchmarks for the FLWC, the protections that could be provided by the Opportunity areas if acquired stand out as particularly beneficial for small water bodies.

Basin-Specific Analysis

We evaluated wetland benefits by watershed (HUC8) in an effort to understand where the FLWC was particularly effective at ensuring wetland protections, and where future conservation efforts might be most effectively targeted.

We first summarize marshes by HUC8 and land category, ranked in Figure VI-6 by the proportion of the marsh area in each basin in the “Not Conserved” category. Several notable features of these disaggregated data emerge. First, the conservation status of marshes is highly uneven across the state; some basins have more than 90% of marshes within FLWC Conserved and Other Conserved lands (e.g., SE Florida Coast) while others have very few marshes currently conserved (e.g., Chipola River). Also notable is that even if all FLWC Opportunity lands were acquired, some basins would still have few marshes under conserved status. For example, the Chipola River is notable for nearly 0% current marsh conserved lands (FLWC or Other), and only a modest effect of adding the FLWC Opportunity lands. We note, however, that the area of marshes in the Chipola River is quite low (0.3% of the basin area), illustrating that further analysis (presented below) is warranted before using the information in Figure VI-6 to prioritize future conservation efforts. However, the most important inference from the HUC8 analysis is that the FLWC Opportunity areas can play a major, if spatially uneven, role in protecting marshes. Locations with particularly impressive marsh wetland conservation gains from Opportunity lands include the Escambia River, St. Andrews Bay, and the Econfina River in Florida’s Panhandle. Similarly, Fisheating Creek, Taylor Creek, and the Peace River emerge as clear beneficiaries of the FLWC Opportunity lands footprint in South Florida.

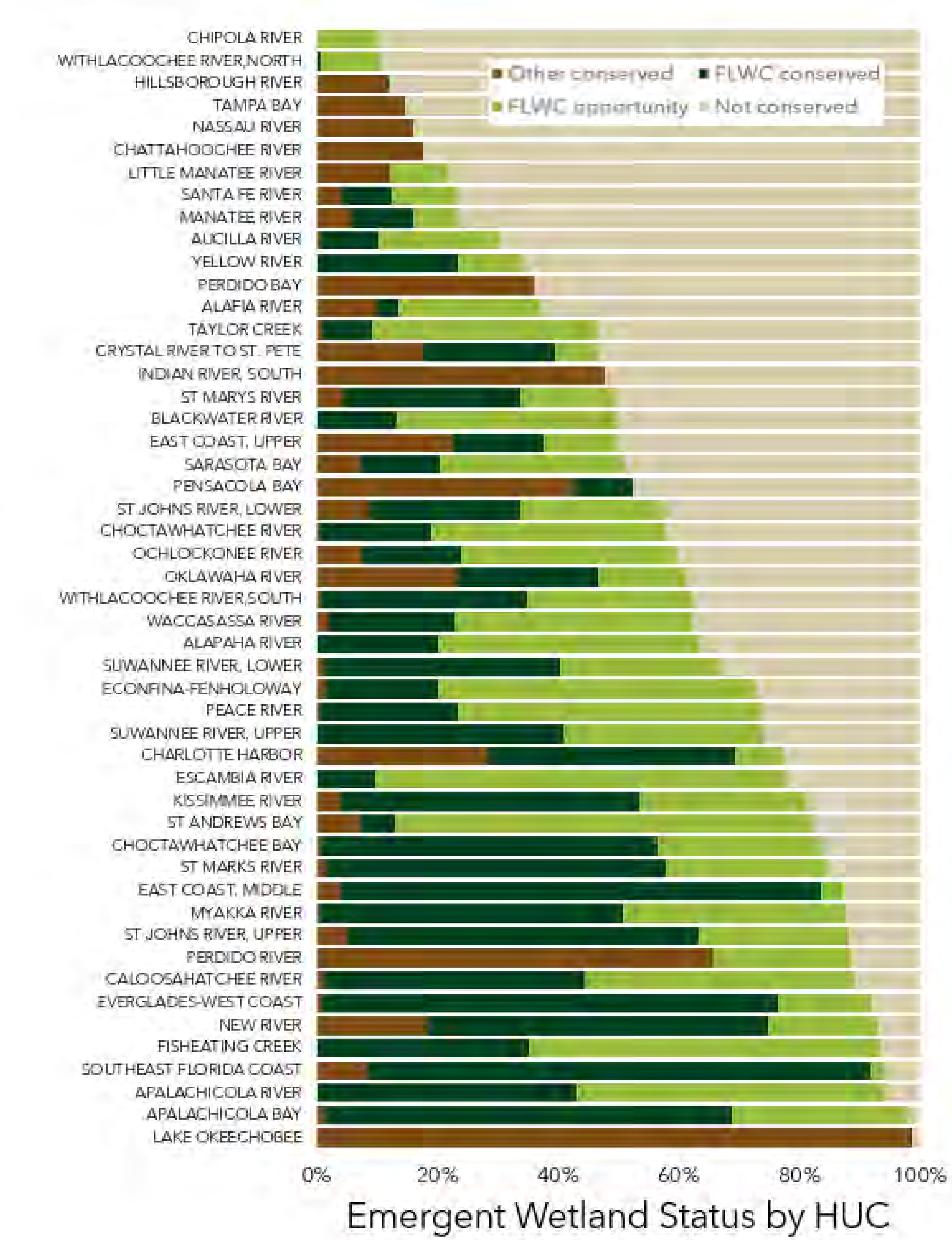

Figure VI-6. Conservation status of marsh wetlands across the HUC8 basins in Florida, ordered by the proportion of wetland area in the Not Conserved lands.

An additional way to visualize the data reported in Figure VI-6 is to plot the proportion of currently "Not Conserved" marshes that would be conserved by the adoption of the FLWC

Opportunity areas. This proportion varies from 0 to nearly 70%, with the basin exhibiting the most marked increase in proportional marsh conservation area located in Southwest Florida and the Panhandle (Figure VI-7). Marsh protections in Southeast Florida and the Tampa Bay region are particularly low, though in some cases this is because marsh conservation is already tremendously high (e.g., Southeast Florida) or density of marshes is low.

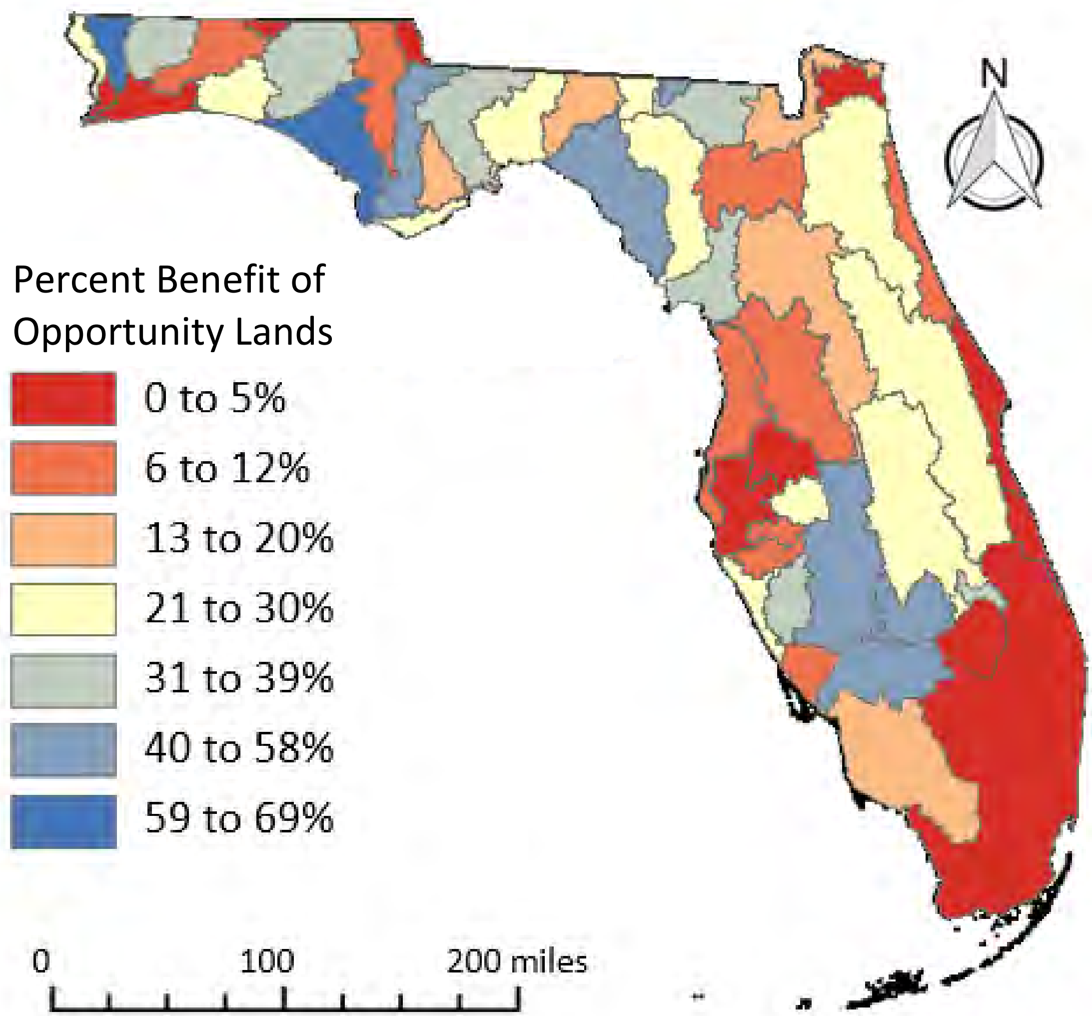

Figure VI-7. The percentage of marsh wetlands in each basin that is currently not conserved that would be conserved by the FLWC Opportunity lands if acquired.

The parallel analysis of swamp conservation by HUC8 (Figure VI-8) reveals similar patterns of statewide variation, with extensive FLWC Conserved lands in some basins (e.g., New River, Choctawhatchee Bay), but limited FLWC coverage even with consideration of FLWC Opportunity lands (e.g., Nassau River, Tampa Bay, Alafia River, Chattahoochee River). Given that the total swamp area is unclear from these proportional stacked bar plots, we reiterate that these data are not necessarily sufficient to design future conservation goals. However, it is clear that the impacts of the FLWC Opportunity lands are substantial in several key basins, including the Peace River, Fisheating Creek, Perdido River, St. Andrews Bay, and Waccasassa River.

As with marsh systems, the proportional protections (proportion of currently “Not Conserved” marshes that would be conserved by the adoption of the FLWC Opportunity areas) for swamps, summarized by basin (Figure VI-9), illustrate the enormous value of the FLWC Opportunity areas in the Panhandle and Central Florida, and the limited impact of the Opportunity areas in Northeast Florida and the Tampa Bay Region. Some of the variation in the proportional protections for swamps are a consequence of extremely small swamp areas (e.g., Lake Okeechobee or Fisheating Creek, where swamps are scarce), but some of the watersheds emerge as future conservation priorities. For example, the Nassau River, the Yellow River, the Aucilla River, the Hillsborough River, the Caloosahatchee River, and the Santa Fe River are basins with abundant swamp area but limited additional conservation value from the FLWC Opportunity areas. These are venues for future conservation investments to complement the tremendous value of the current corridor.

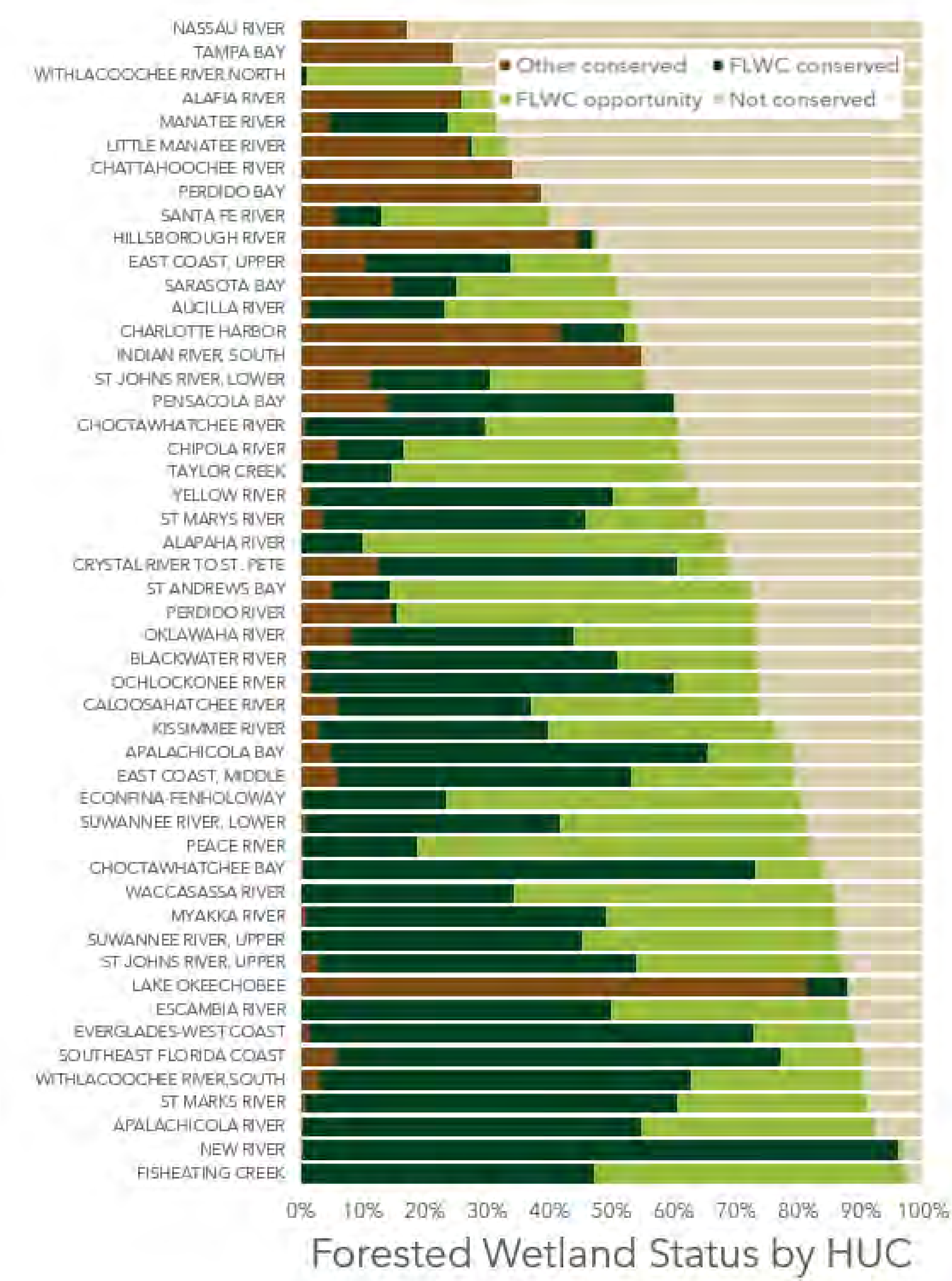

Figure VI-8. Conservation status of swamp wetlands across the HUC8 basins in Florida, ordered by the proportion of wetland area in the Not Conserved lands.

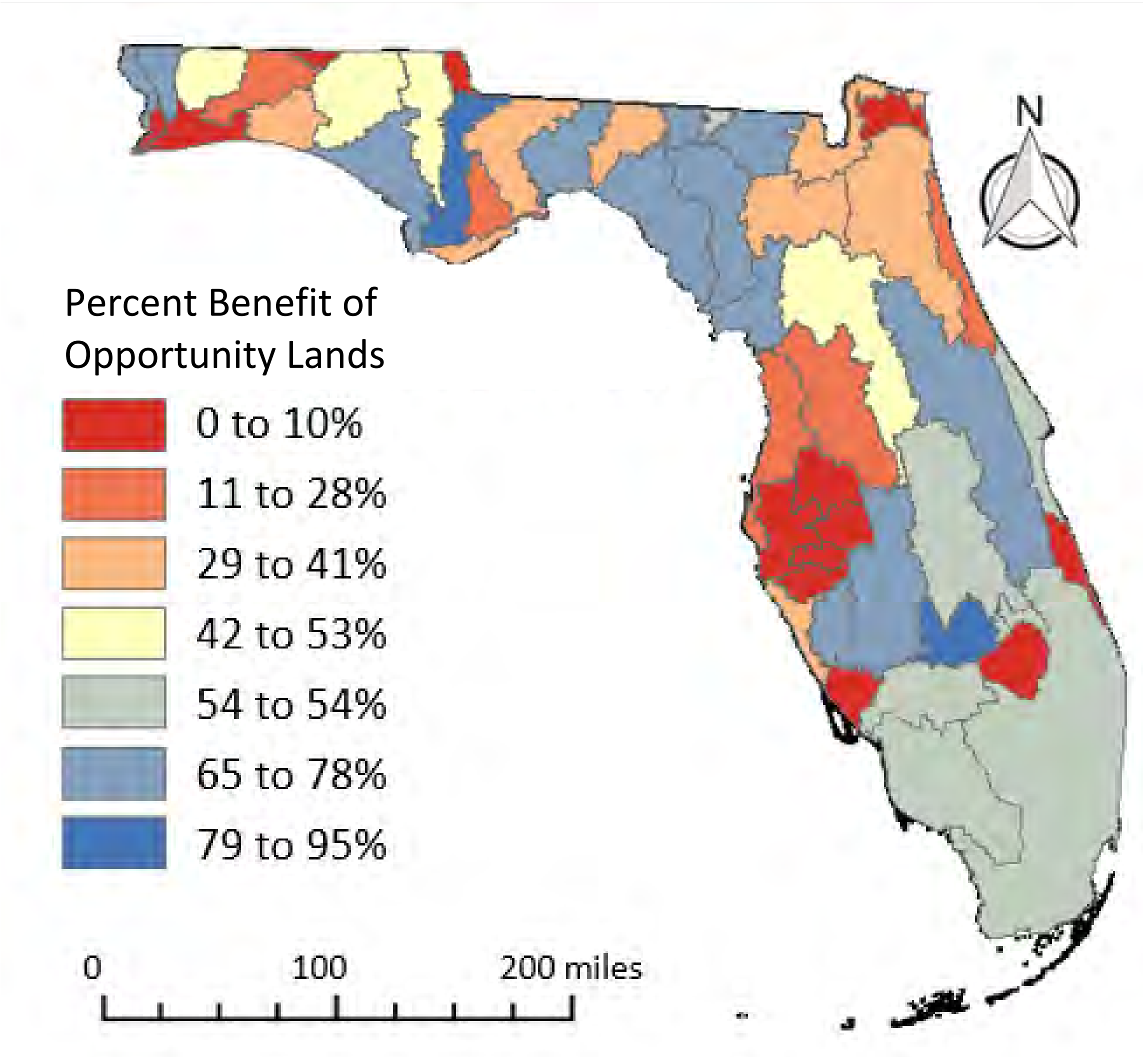

Figure VI-9. The percentage of swamp wetlands in each basin that is currently not conserved but would be conserved by the FLWC Opportunity lands if acquired.

As noted above, the analysis of the benefits of the FLWC Opportunity lands for swamps and marshes is sensitive to the area of each wetland type in each basin. In Figures VI-10 and 11, we seek to better visualize the impacts of the FLWC by watershed. To do so, we present each watershed as a circle in a bi-plot where the x-axis is the proportion of wetlands (marshes in Figure VI-10 and swamps in Figure VI-11) that are currently not conserved; that is, the proportion of wetlands that are not in the FLWC Conserved or Other Conserved lands. This captures the conservation challenge in each basin. The y-axis in these plots indicates the proportion of area currently Not Conserved on the x-axis that would be conserved by the FLWC Opportunity lands. In the plots, the dot size indicates the proportion of the basin area that is that wetland type, ranging from less than 2% to more than 60%. Watersheds that have few wetlands that are not conserved (to the left of the plot) are low priority for future conservation because most of the wetlands are already conserved. Watersheds towards the top right corner of the plot are those that have low current conservation status but where the FLWC Opportunity footprint would greatly increase wetland conservation. Watersheds located to the lower right of these plots, particularly those with substantial area of wetlands (larger dots), emerge as conservation priorities outside of the FLWC. For marshes (Figure VI-10) this includes the Hillsborough River, the southern Withlacoochee, Taylor Creek, and the Ocklawaha. For swamps, this includes the Nassau River, Hillsborough River, Santa Fe River, Yellow River, and Aucilla River.

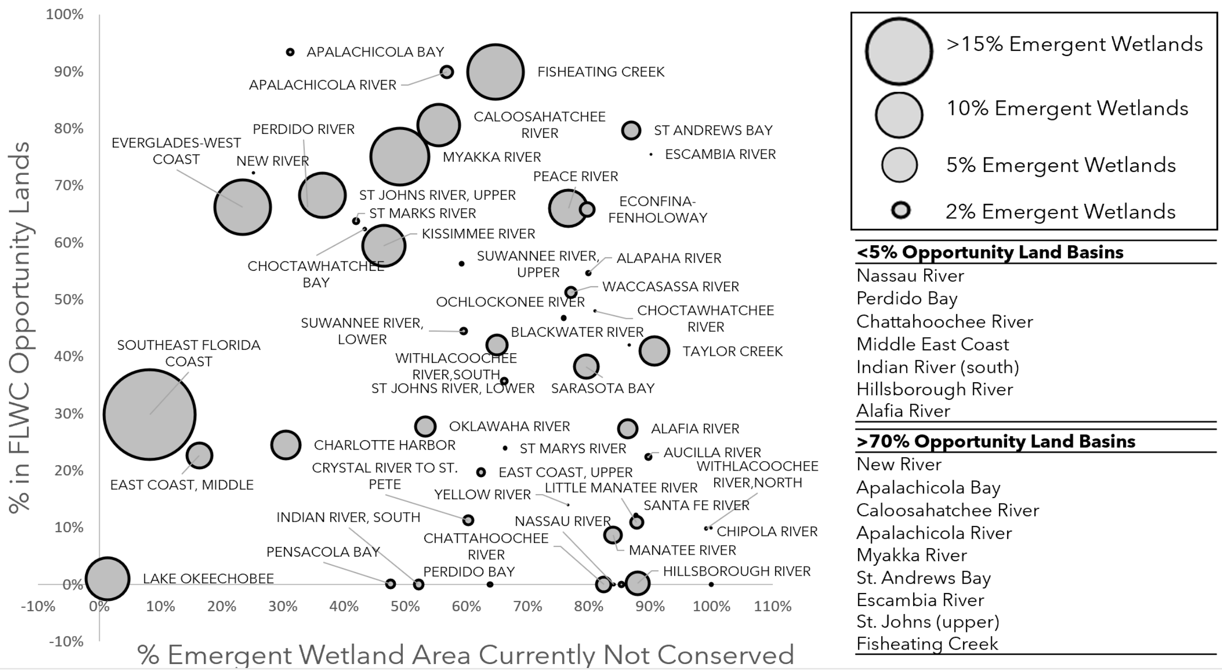

Figure VI-10. Summary of benefits of FLWC Opportunity lands to marshes by HUC8. The x-axis is % of marsh area in each basin currently not conserved; the y-axis shows the % of that marsh area that would be conserved by the FLWC Opportunity lands if acquired. Dot size denotes percentage of marsh area by basin. Basins where Opportunity lands would protect small (<5%) and large (>70%) fractions of currently unprotected wetland area are listed in the inset tables.

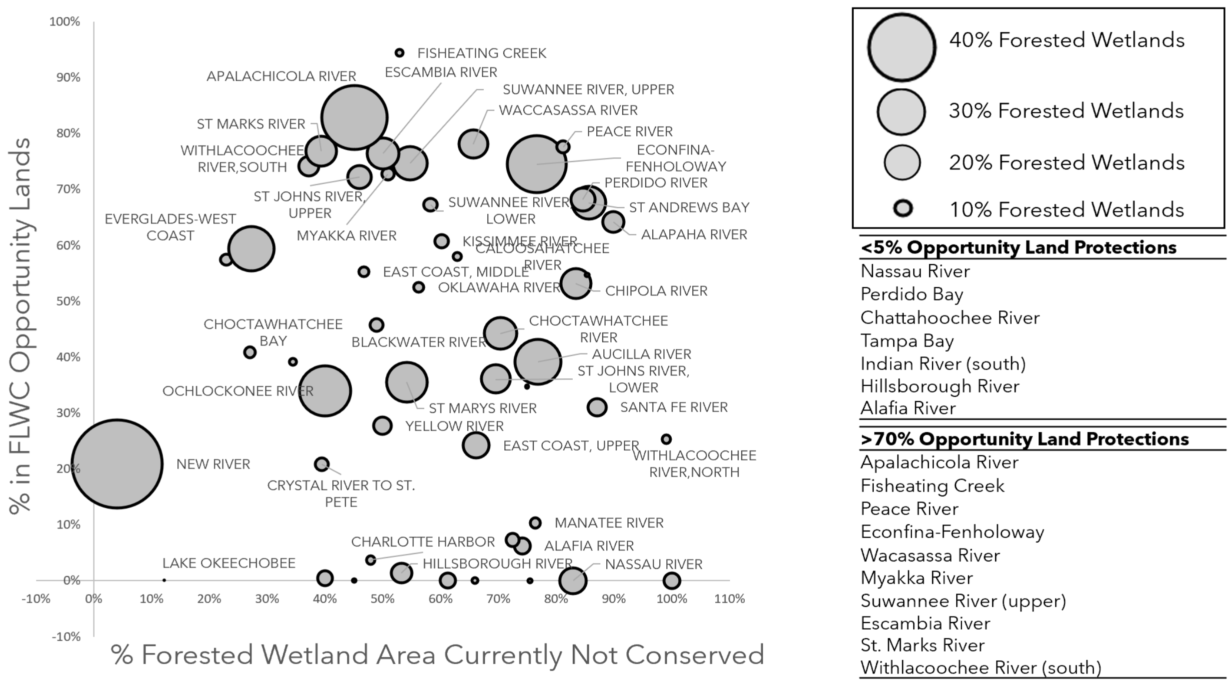

Figure VI-11. Summary of benefits of FLWC Opportunity lands to swamps by HUC8. The x-axis is % swamp area in each basin currently not conserved; the y-axis shows the % of that swamp area that would be conserved by the FLWC Opportunity lands if acquired. Dot size denotes percentage of swamp area by basin. Basins where Opportunity lands would protect small (<5%) and large (>70%) fractions of currently unprotected wetland area are listed in the inset tables.

Finally, we used information from Figures VI-10 and 11, along with qualitative assessment of the adjacency of FLWC lands to identify watersheds where key "wetlandscapes" remain but have limited area within the FLWC and/or Other Conserved lands (Figure VI-12). They include:

- the middle Yellow River adjacent to Eglin Air Force Base
- the eastern Aucilla River basin between the Aucilla River and the Econfina Conservation Area
- the entire Nassau River basin connecting the coast to the Okeefenokee
- the southern Withlacoochee region north of the Green Swamp
- the eastern Hillsborough River adjacent to the Green Swamp
- the upper Santa Fe (bounded by Osceola National Forest, Camp Blanding, and Santa Fe Swamp)
- the region of the Charlotte Harbor basin adjacent to the regions of Babcock Ranch.

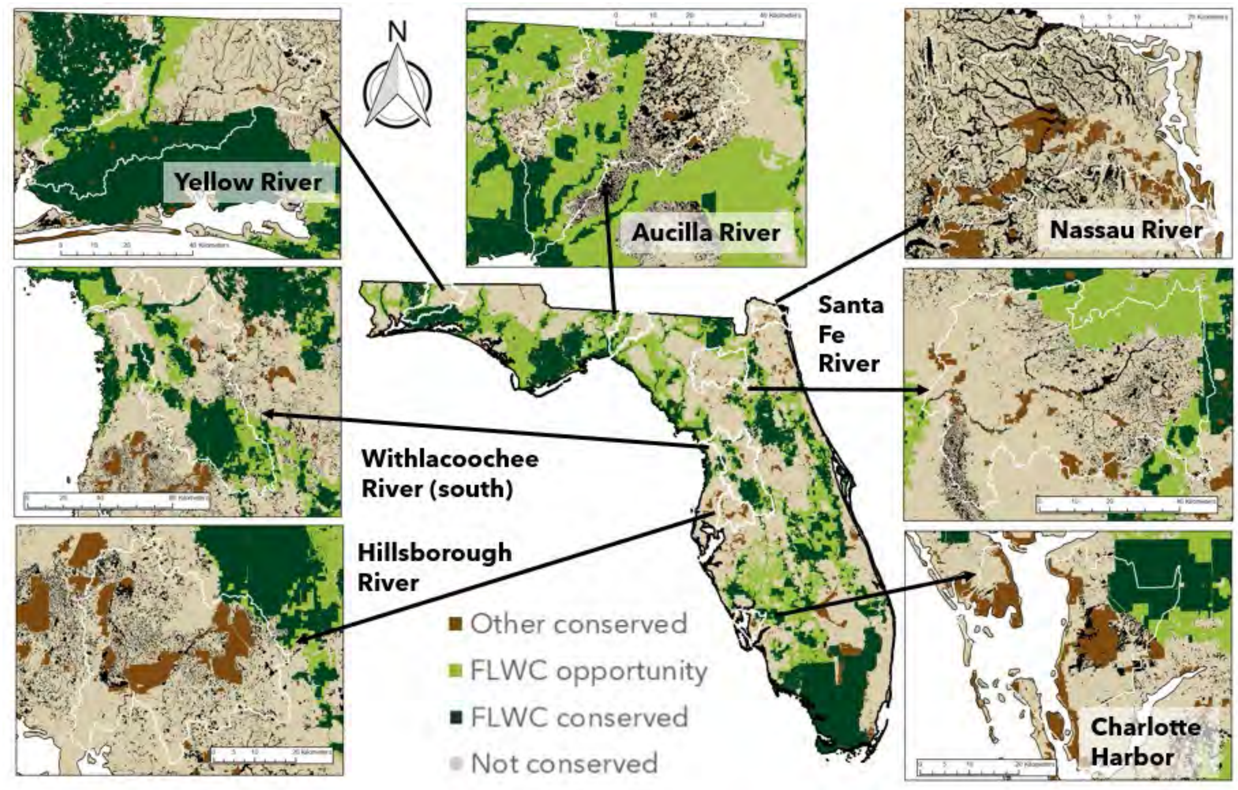

Figure VI-12. Watersheds with significant wetland area (gray polygons) that have significant areas outside of FLWC lands (Conserved and Opportunity). These basins were selected based on the proportions and areas outside of the FLWC and Other Conserved lands (Figs. VI-8-11), but also adjacency to the FLWC for consideration of potential linkages.

Conclusions

- Florida has ~380,000 swamps that cover more than 7 million acres, and >220,000 marshes that cover 3.3 million acres. Existing conserved lands (both within and outside the FLWC) cover 3.1 million acres of swamps and 2.3 million acres of marshes, with the latter dominated by protection of the Everglades.
- Existing FLWC Conserved lands **protect 63% and 42% of marsh and swamp area**, respectively, and 27% and 28%, respectively, of the total number of marshes and swamps in the state.
- The FLWC Opportunity lands **would dramatically improve conservation of both swamps and marshes** if acquired. FLWC Opportunity lands would nearly double the number of protected swamps and marshes and increase the protected area of swamps and marshes by 2 million and 500,000 acres, respectively.
- **Wetlands are provided excellent benefit** by the FLWC Conserved and Opportunity lands, including all metrics of swamp and marsh area and number.

- **If acquired, FLWC Opportunity lands would do a particularly good job of benefiting small wetlands** (<25 acres [10 ha]), in contrast to existing conservation, which has emphasized conservation of larger wetlands. This has important habitat and landscape implications.
- **Benefits of FLWC Opportunity lands for wetlands vary substantially among Florida's major watersheds**. If acquired, FLWC Opportunity lands would be particularly beneficial for wetlands in the following watersheds - New River, Apalachicola River, Myakka River, the Upper St. Johns River, and Fisheating Creek (for marshes) and the Apalachicola River, Peace River, Upper Suwannee River, the St. Marks River, and Fisheating Creek (for swamps).
- Watersheds currently outside of the FLWC identified for future conservation efforts, based on the extent of unconserved wetlands and proximity to FLWC Conserved or Opportunity lands, include the Yellow River, Nassau River, Santa Fe River, Hillsborough River, Aucilla River, southern Withlacoochee River, and the Charlotte Harbor basin.
- Decision-making by managers on all conserved lands is critical to ensure the hydrologic, water quality, and habitat functions of protected wetlands. Sufficient investments in land management are necessary to realize the water and habitat conservation potential of the Florida Wildlife Corridor.

VII. Rivers

Background

Rivers are enormously important for biodiversity and for supporting human wellbeing. Despite covering a small fraction of the earth's surface, rivers provide habitat for an incredible number of vertebrates, insects, fish, crustaceans, and mollusks (Tickner et al. 2020). Florida's rivers provide migration pathways for some of its most iconic wildlife such as manatees and Atlantic and Gulf sturgeon, as well as less-known endangered species such as endemic pigtoe mussels and several other types of bivalves. In addition to providing habitat for a variety of flora and fauna, floodplains that parallel rivers and creeks provide habitat for many animals and plants that benefit from the interface of terrestrial and aquatic-ecosystems. Rivers also sustain a wide range of provisioning, regulating, supporting, and cultural services (Gopal 2016). In Florida, recreation and other cultural services are of chief importance to Floridians (Shrestha et al. 2007, Chaikaew et al. 2017, Wu et al. 2018), thus emphasizing the need for good water quality; and other services are important as well. Because of Florida's low relief and periodically heavy rainfall, water frequently overfills stream channels and spills onto floodplains and adjacent lakes and wetlands (Leitman et al. 1984, Obeysekera et al. 1999, Light et al. 2002), delivering resources from the river such as silt and organic matter that are important for ecosystem services such as soil formation. This lateral connectivity also facilitates the removal of nutrients through plant uptake and denitrification in adjacent wetlands (Heffernan et al. 2010). Florida's rivers also play a critical role in maintaining the health of estuaries and other nearshore habitat: the freshwater carried by rivers maintains the balance of suspended matter and salinity (Zhou et al. 2021), which are critical to sustain fisheries and shellfisheries (Bergquist et al. 2006). River floodplains and adjacent areas also serve as important habitat for non-aquatic animals that benefit from the variations in topography, vegetation, and other resources in these areas that often become inundated during periods of high streamflow (Paolino et al. 2018, Larsen-Gray and Loehle 2022).

A river's drainage network is the principal mechanism that connects inland landscapes with the sea. Like most regions across the globe, Florida's rivers generally begin with small headwater streams that converge and grow increasingly large before reaching the Atlantic Ocean or Gulf of Mexico. The entire drainage network plays an important role in the health of river ecosystems. Small headwater streams comprise the majority of stream channels by length, owing to the dendritic nature of the drainage network (Leopold 1994), and as such, they play a critical role as sources and sinks of nutrients, fine sediment, and other pollutants, as well as habitat for a wide range of aquatic and riparian biota (Wohl 2017). Streams increase in size with distance downstream, providing important corridors for wildlife and mechanisms for transporting organic matter downstream (Vannote et al. 1980). Lateral connectivity and connectivity with adjacent riparian areas are important factors for sustaining aquatic ecosystem health in rivers and the waters they flow into (Jumani et al. 2020). Partial or full disruption in connectivity can halt these processes and have deleterious effects to biota and communities downstream (Perkin et al. 2015, Richter et al. 2010).

Metrics

Four key metrics were used to assess the benefits of the FLWC to rivers in Florida. These metrics focused on the major rivers and stream channels that carry water, as well as the areas that comprise their watersheds.

- ***Flowing Waters of Florida.*** The Florida Department of Environmental Protection has identified a statewide set of stream channels ("WMS Flowing Waters Resource"; FDEP 2022) ranging from small creeks to major rivers that transport water downstream. This spatial dataset may not include all the stream channels that carry water continuously or periodically, but it is recognized by FDEP's Watershed Monitoring Program as an agreed-upon and accurate set of stream channels (in coordination with Water Management Districts) derived based on similar and consistent methods across the state.
  This analysis determines the flowing waters drainage network as the length of stream channel by land category:
    1. FLWC Conserved (those channels in areas within the Wildlife Corridor that are in an existing conservation area),
    2. FLWC Opportunity (channels in FLWC Opportunity lands),
    3. Other Conserved (those channels in areas outside of the Wildlife Corridor but within an existing conservation area), and
    4. Not Conserved (those stream channels that are not in the Wildlife Corridor or any other conservation area).
- ***Major Rivers in Florida.*** The 1989 Florida Department of Natural Resources Florida Rivers Assessment (FDNR 1989, FWC 2020) identified 50 major rivers across the state. This analysis determines the length of major rivers by land category.
- ***Major River Watershed Area.*** The upstream areas of each of these 50 major rivers are classified by land category.
- ***Outstanding Florida Waters.*** Florida has designated more than 300 river corridors and adjacent areas as Outstanding Waters (FDEP 2022), those worthy of special protection by virtue of their special natural features. The goal of identifying water bodies as Outstanding is to protect existing water quality. These water bodies (often including adjacent areas) are classified by land category.

Interpretation of this analysis relies on four main assumptions:

1. Increased conservation along streams improves characteristics such as water quality and aquatic habitat. This study provides a comparison of the relative amounts and absolute amounts of land area and stream channel length that fall within categories of conservation status. It assumes that an increase in channel length or land in conservation will cause improvements in factors such as water quality and aquatic habitat that are important for aquatic ecosystems.

2. Flowing waters have equivalent ecological value through the drainage network and across the state. As described in more detail below, the drainage network of watersheds in Florida are comprised of small streams flowing into increasingly larger streams on the way to the Gulf of Mexico or Atlantic Ocean. Despite their variation in size, morphology, and adjacent riparian characteristics, all streams can serve as sources or sinks of nutrients, fine sediment, and other pollutants. Also, though the characteristics of streams in the northern part of the state may be substantially different from those in the southern part of the state, those differences do not diminish the local or regional value of streams in one part of the state any more than another.

3. Major rivers have equivalent value across the state. The list of major rivers across Florida varies considerably from south to north. Southern rivers such as Spruce Creek, the Loxahatchee river, and Tamaka river maybe much smaller in size then the Suwannee or Choctawhatchee Rivers to the north, but the southern rivers may be especially significant as habitat or drainage conduits for large inland wetlands during times of flooding. Thus, while they may be different in their scale, their regional significance may be just as great.

4. The conservation value of land is equivalent across a watershed. The analysis of watershed area does not consider variations in the value within the watershed. Lands closer to a drainage network may be of higher value ecologically or to the quality of water than land that is farther away from the drainage network. It may be more valuable to conserve land parallel with the river along a riparian corridor than it would to conserve the same amount of land as a square or rectangle farther from the drainage network, but that is not considered in this analysis.

Methods

Geographic information systems are critical tools for conducting quantitative assessments over the landscape. This analysis of rivers and their watersheds relies on several spatial datasets describing stream channels and watershed areas that have been created for Florida by other scientists. We obtained shapefiles characterizing data for Flowing Waters (line-type features) and for Outstanding Florida Waters (polygon-type features) from the FDEP Geospatial Open Data Library Portal (FDEP 2022: https://geodata.dep.state.fl.us/). This data portal does not include the 50 Major Florida Rivers; these were transcribed from the Flowing Waters line features in ArcMap 10.7 as depicted by the Florida Fish and Wildlife Commission (FWC 2020).

Once we identified the 50 Major Rivers in GIS, we derived their watersheds from US Geological Survey Hydrologic Unit Code (HUC) areas. HUC areas do not always characterize a watershed; they are intended to indicate areas of similar hydrologic characteristics and not watershed boundaries, and thus they often include more than one watershed or incomplete parts of watersheds. We gave special attention to create a representative watershed for each of the major Florida rivers (the portion within Florida) from HUC8, HUC10, and HUC12 area polygons. To do this, we combined HUC areas with a shared outlet to the Atlantic Ocean or Gulf of Mexico or an estuary so that they comprised a single watershed; for example, the list of 50 major rivers include the St. Johns River as well as the Wekiva River, Oklawaha River, Econlockhatchee River, and Black Creek; because they are all tributaries to the St. Johns River, we combined their HUC areas to create a St. Johns River watershed (and thus reducing the number of total watersheds accordingly). We treated major tributaries of other rivers such as the Apalachicola (including the Brothers and Chipola Rivers), Suwannee (including the Santa Fe, Alapaha, and Withlacoochee that flows south from Georgia), Choctawhatchee (which includes the Pea), Yellow (which includes the Shoal), Aucilla (including the Wacissa), and St. Marks (including the Wakulla) similarly to make a single watershed for each. Grouping reduced the total number of watersheds used for this analysis to 33.

We identified major rivers and other flowing waters via GIS overlay as being within one of four categories: FLWC Conserved areas, FLWC Opportunity areas, Other Conserved areas, and lands that are Not Conserved (henceforth “land categories”). We identified rivers and other flowing waters that had one or both sides of the line adjacent to or within a FLWC Opportunity area as being in Opportunity areas. We applied a 246 ft (75 m) buffer for identifying rivers in FLWC Conserved and Other Conserved areas because state conservation areas often exclude the channels of major rivers (as they are considered Waters of the State); based on iterative testing, a 246 ft (75 m) buffer sufficiently recognized rivers flowing through existing conservation areas as within those areas, without appreciable overcounting (for example, see Figure VII-1).

To identify the amount of each of the Major River watersheds and Florida Outstanding Waters within each of the land categories, we overlaid each feature with each of the four land categories. The amount of each Major River watershed was analyzed as a total area and as a percentage in each land category; Outstanding Waters were examined as a total sum of area within each land category.

We assigned river benefit metrics to two benefit categories: Good-to-Excellent (greater than or equal to 50% of the statewide benefit metric within the FLWC), and Low-to-Moderate (less than 50% of statewide benefit metric within the FLWC) as outlined in Section I.

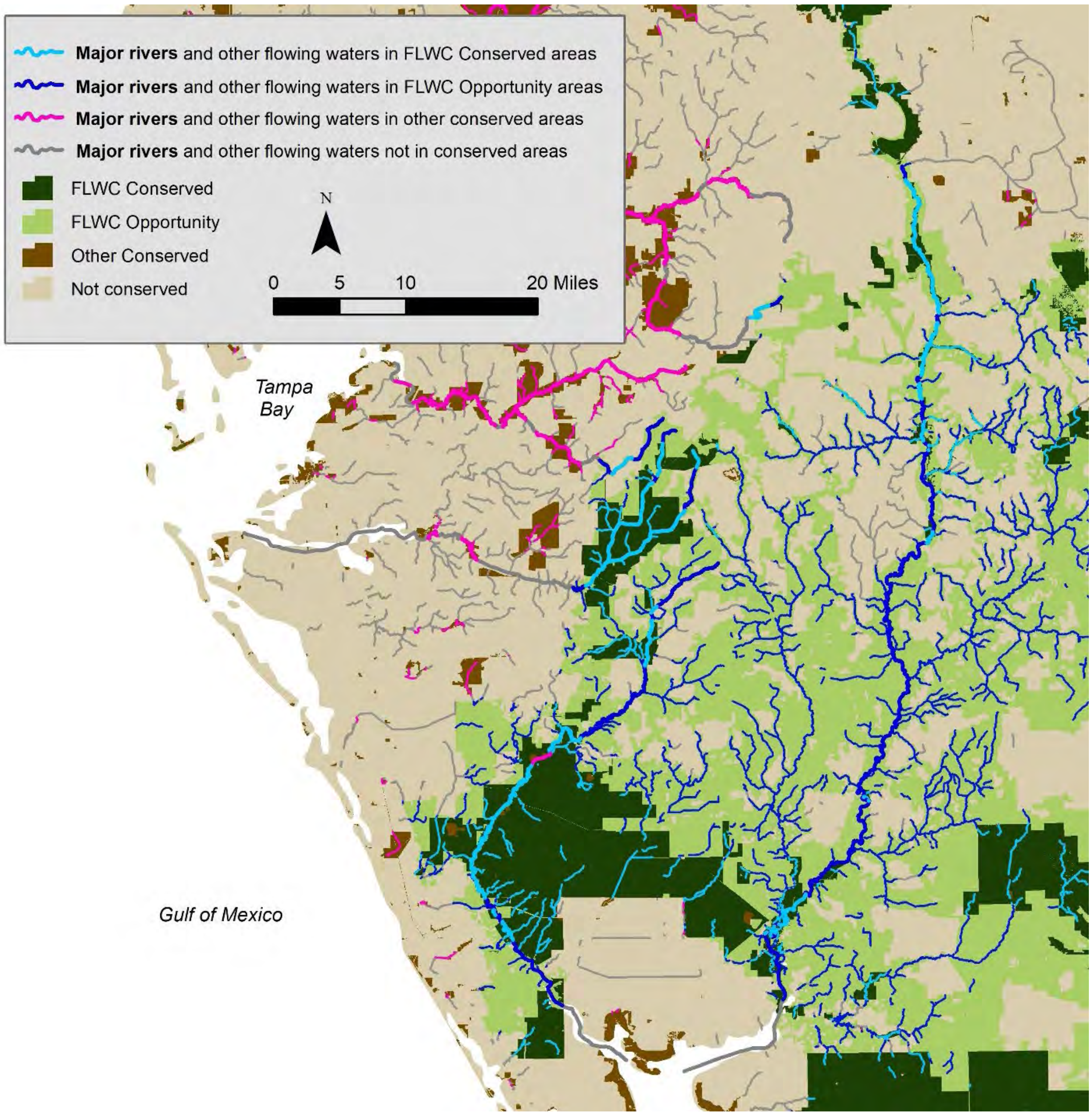

Figure VII-1. Example of major rivers (thick lines) and other flowing waters (thin lines) in southwest Florida, along with areas within the FLWC and Other Conserved areas.

Results and Discussion

Approximately 62% of the length of Florida's major rivers flow through the FLWC (Figure VII-2), roughly split between Opportunity and Conserved areas. This percentage is greater than the

50% threshold of statewide lands within the FLWC and highlights the intentional focus on river corridors in the design of the FLWC. This analysis also demonstrates the value of existing conservation efforts to protect major river corridors: 40% of the length of Florida's Major Rivers are already located in FLWC Conserved lands or Other Conserved lands. Major rivers flowing through Opportunity Areas are distributed across the state but are especially abundant in the south-central areas that are west and northwest of Lake Okeechobee (Figure VII-3). Furthermore, the extent of river length within FLWC Conserved and Opportunity lands varies from one major river to the next. Some rivers, like the Peace and Alapaha, have more than half of the river length within FLWC Opportunity areas; others, such as the Santa Fe, Palatlakaha, and Nassau, are afforded little protection by existing conserved land (FLWC Conserved or Other Conserved) nor potential benefit from FLWC Opportunity areas (Figure VII-4).

Figure VII- 2. Summary of statewide protections for major Florida rivers by length (top) compared to total statewide area (bottom), relative to the four land categories.

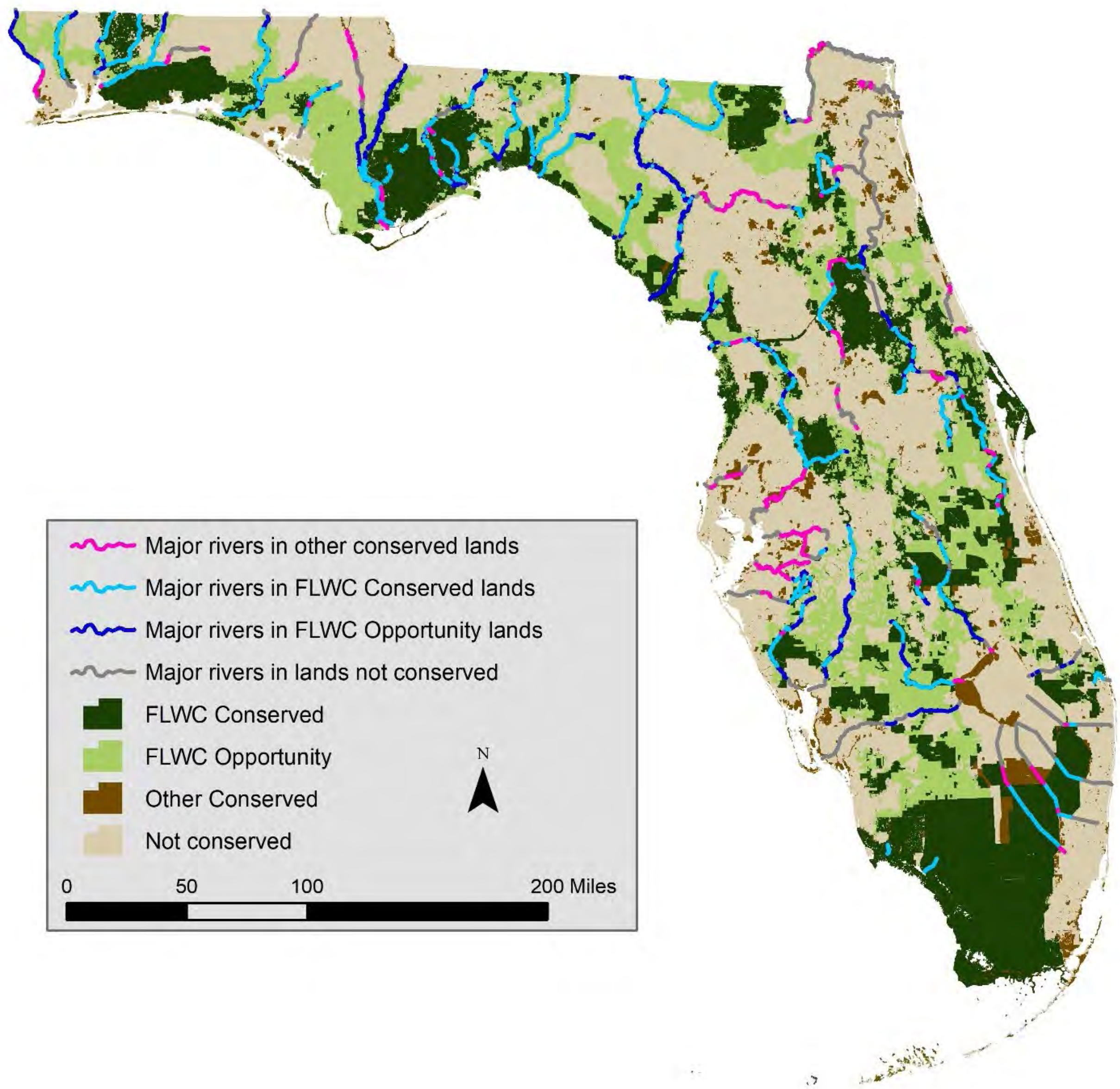

Figure VII-3. Distribution of major rivers of Florida and relative to the FLWC and Other Conserved areas.

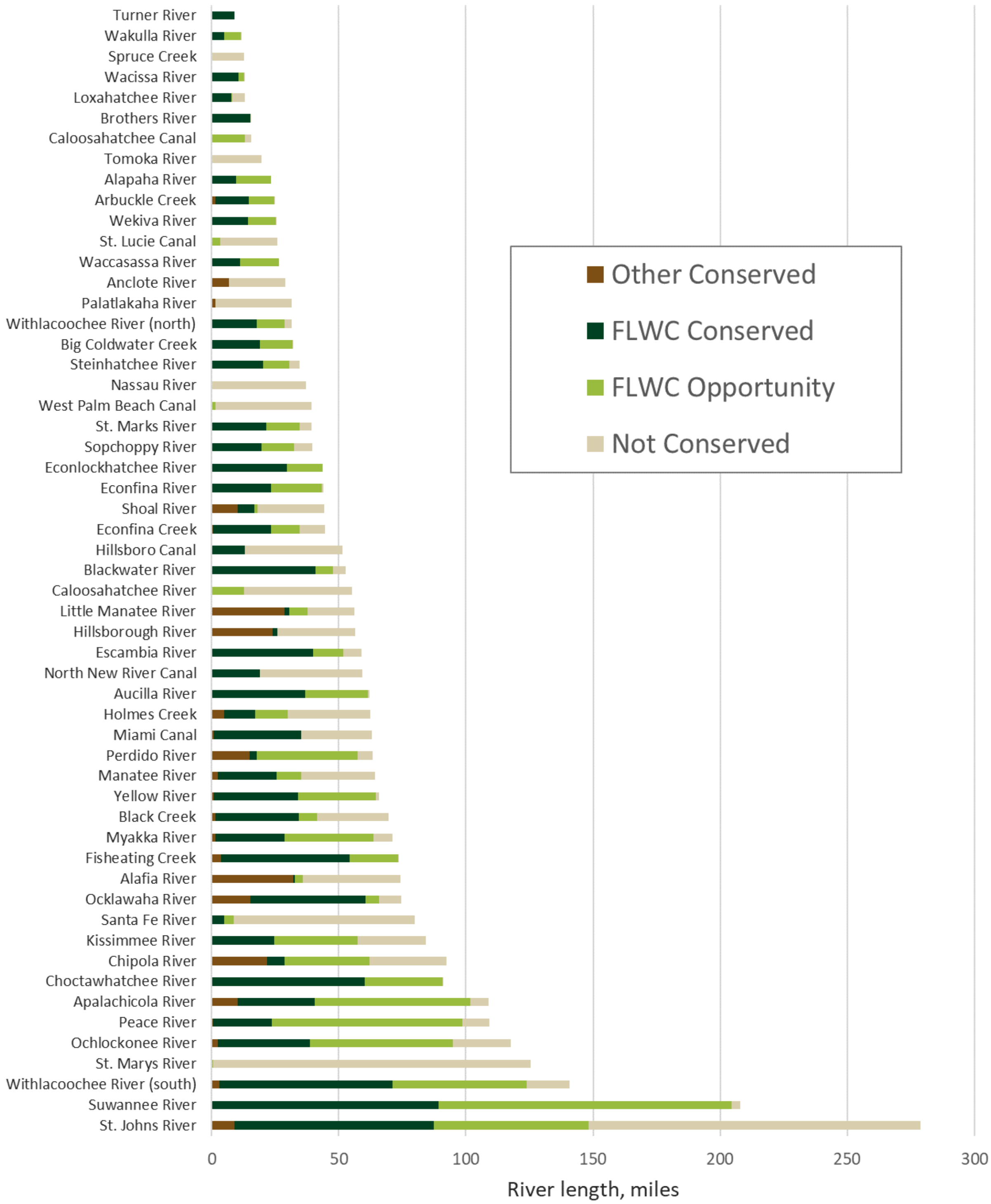

Figure VII-4. Length of major rivers (mi) by land category.

Among all streams recognized as flowing waters, the FLWC covers more than half of all channel length, with 27% of all channel length within FLWC Conserved lands and 28% within Opportunity Areas (Figure VII-5). As with major river length, this percentage is greater than the 50% indicating good benefit. However, like major rivers, stream channels within FLWC areas are not evenly distributed (Figure VII-6): some, such as the Peace River, Waccasassa River, and Myakka River, would have more than 90% of their recognized flowing drainage network within FLWC Conserved and Opportunity areas; others such as Hillsborough and Nassau River's flowing drainage networks would have little benefit from FLWC Conserved and Opportunity areas.

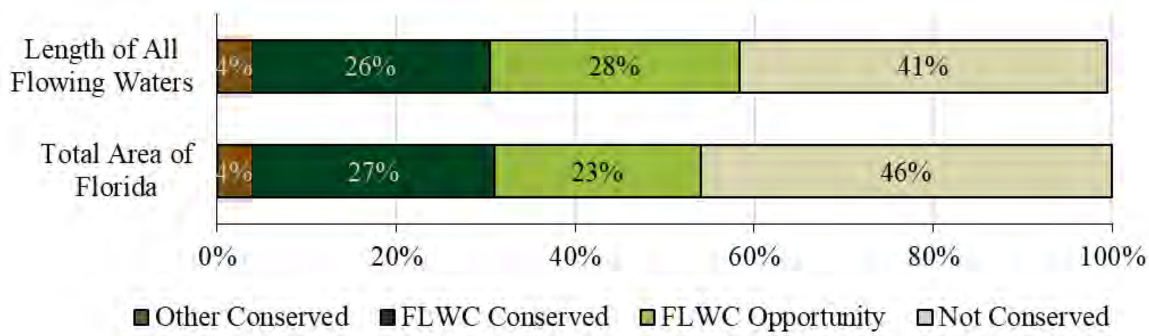

Figure VII- 5. Summary of statewide protections for flowing waters of Florida by length (top) compared to total statewide area (bottom), relative to the four land categories.

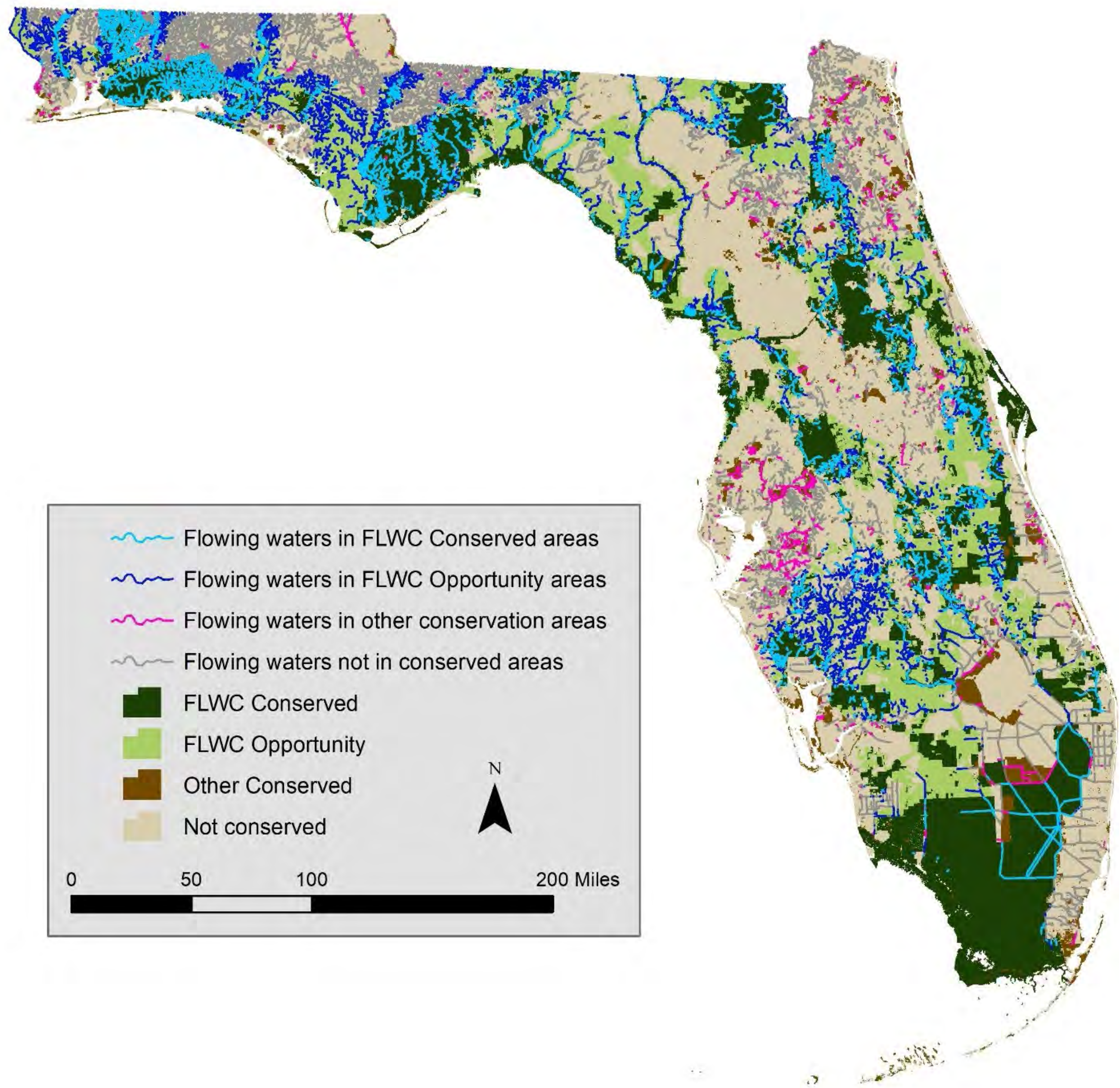

Figure VII-6. Distribution of flowing waters of Florida and relative to the FLWC and Other Conserved areas.

Florida's Outstanding Waters are predominantly located within the FLWC. More than 80% of Outstanding Waters are already within FLWC Conserved and Other Conserved areas (Figure VII-7); the FLWC Opportunity areas could add an additional 8% if acquired, leaving just 9% of remaining Outstanding Waters outside of the FLWC and Other Conserved areas, indicating excellent benefit of the FLWC. It should be noted that while the largest number of these Outstanding Waters in Opportunity areas are located along major river corridors in the northern part of the state, a substantial amount of FLWC Conserved area is comprised of the Everglades

(Figure VII-8). As indicated in the Springs Section (IV), only 29% of Outstanding Florida Springsheds in the north central part of the state are within the FLWC Conserved and Opportunity lands (low benefit), but spring vents are well represented among the designated Outstanding Florida Waters within the FLWC lands.

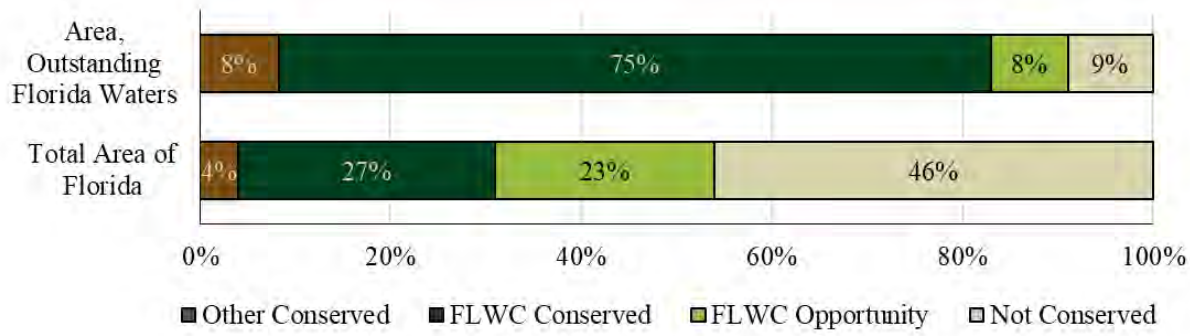

Figure VII- 7. Summary of statewide protections for Outstanding Florida Waters by area (top) compared to total statewide area (bottom), relative to the four land categories.

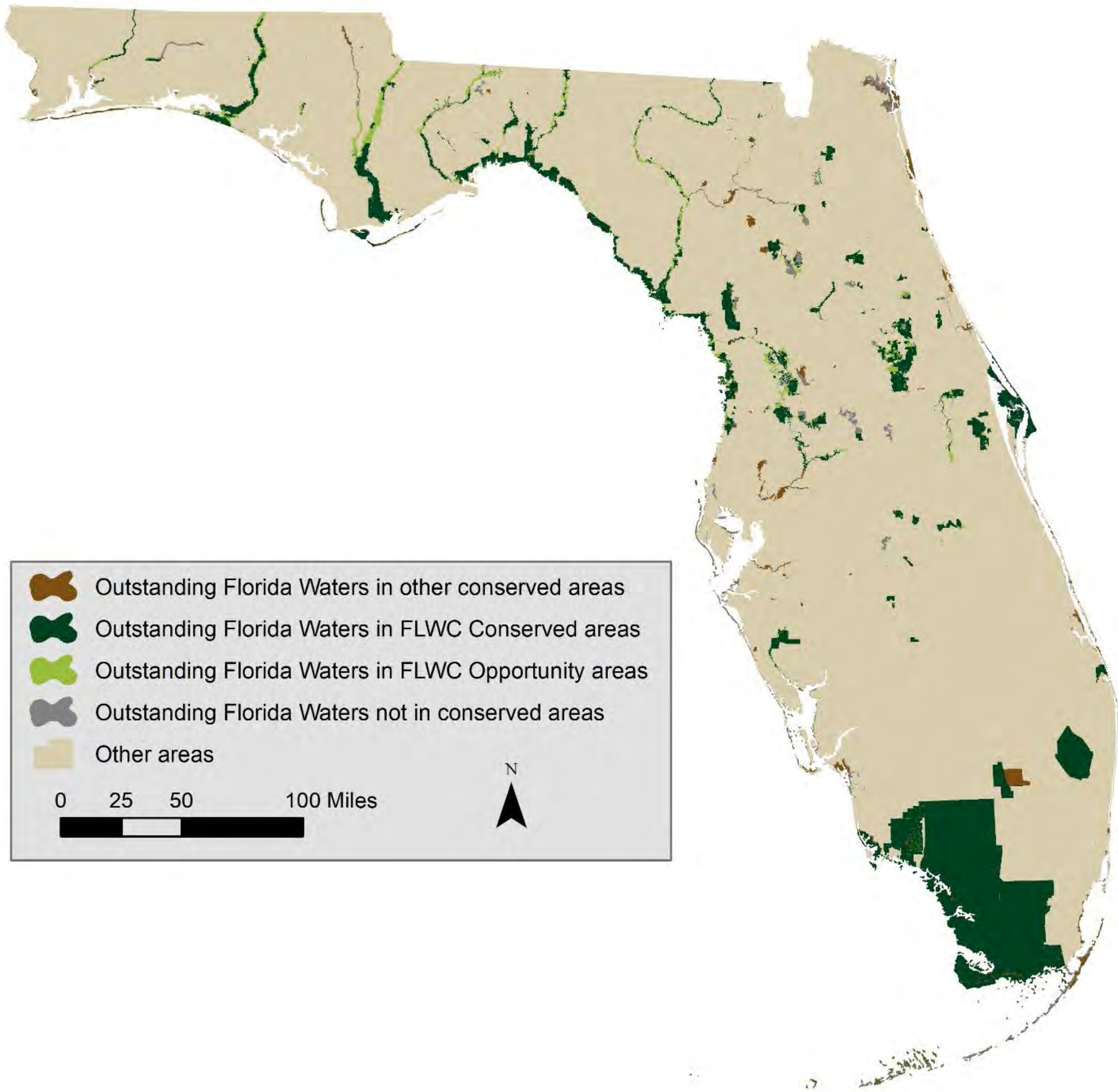

Figure VII-8. Distribution of inland Florida Outstanding Waters, relative to the FLWC and Other Conserved areas.

Watersheds, those areas of land that collect water toward a common point, of Florida's major rivers are also well-represented in the FLWC. FLWC Conserved areas protect 27% of major rivers watershed area, and an additional 24% lie within FLWC Opportunity lands. A total of 51% of the major river watershed area lies within the FLWC Conserved and Opportunity areas, which is greater than the 50% statewide threshold, indicating good protection for Florida's major watersheds. In some watersheds, like those of the Steinhatchee River, Econfina Creek, Fisheating Creek, and the Florida portion of the Perdido River watershed, 50% of the watershed area is within FLWC Opportunity areas (Figure VII-9). For three of those rivers, the FLWC Conserved and Opportunity areas comprise more than 80% of each watershed. In all, more than half of Florida's major rivers (18 out of 33) have at least 50% of their area within the FLWC. Like the other river metrics above, some of the watersheds of Florida's major rivers (e.g., Alafia River, Hillsborough River, Spruce Creek) have little to no area within the FLWC.

Whereas the percentage of watershed area in the FLWC and Other Conserved areas is a useful index to illustrate the value of the wildlife corridor for rivers and floodplains, it is also important to consider the magnitude of area within the FLWC (Figure VII-10). Comparing magnitudes of area creates a more complete picture of the amount of benefit the FLWC can provide as well as the level of investment needed to achieve meaningful conservation. For example, the Econfina and Peace Rivers have similar percentages of area within the FLWC (and within the FLWC, similar percentages in Conserved and Opportunity areas), but because the Peace River watershed is ten times as large as the Econfina River watershed, FLWC Opportunity areas can provide 10 times the habitat of new conserved areas as compared to the Econfina River. Such comparisons also highlight differences compared to percentages; for example, FLWC Opportunity areas may comprise 50% of the Perdido River watershed in Florida, a greater percentage than the Choctawhatchee or Caloosahatchee River watersheds (both have approximately one-third of their area within FLWC Opportunity areas), but those Opportunity areas in the Choctawhatchee and Caloosahatchee watersheds represent more than four times the amount of land area as the Opportunity areas in the Perdido watershed.

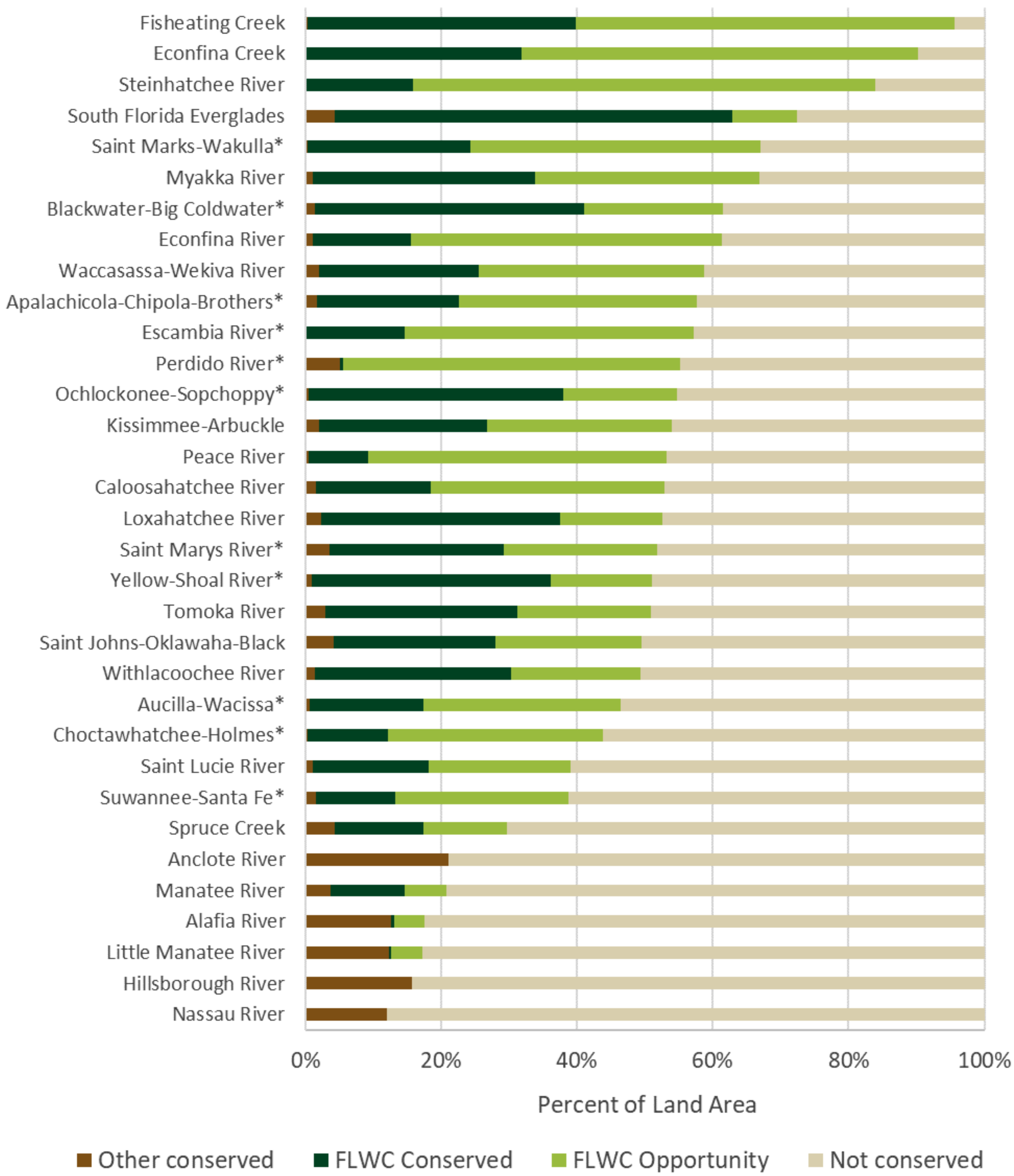

Figure VII-9. Percentage of watersheds of Florida's major rivers within the FLWC and Other Conserved areas. *Indicates only the portion of the watershed in Florida was considered for the analysis.

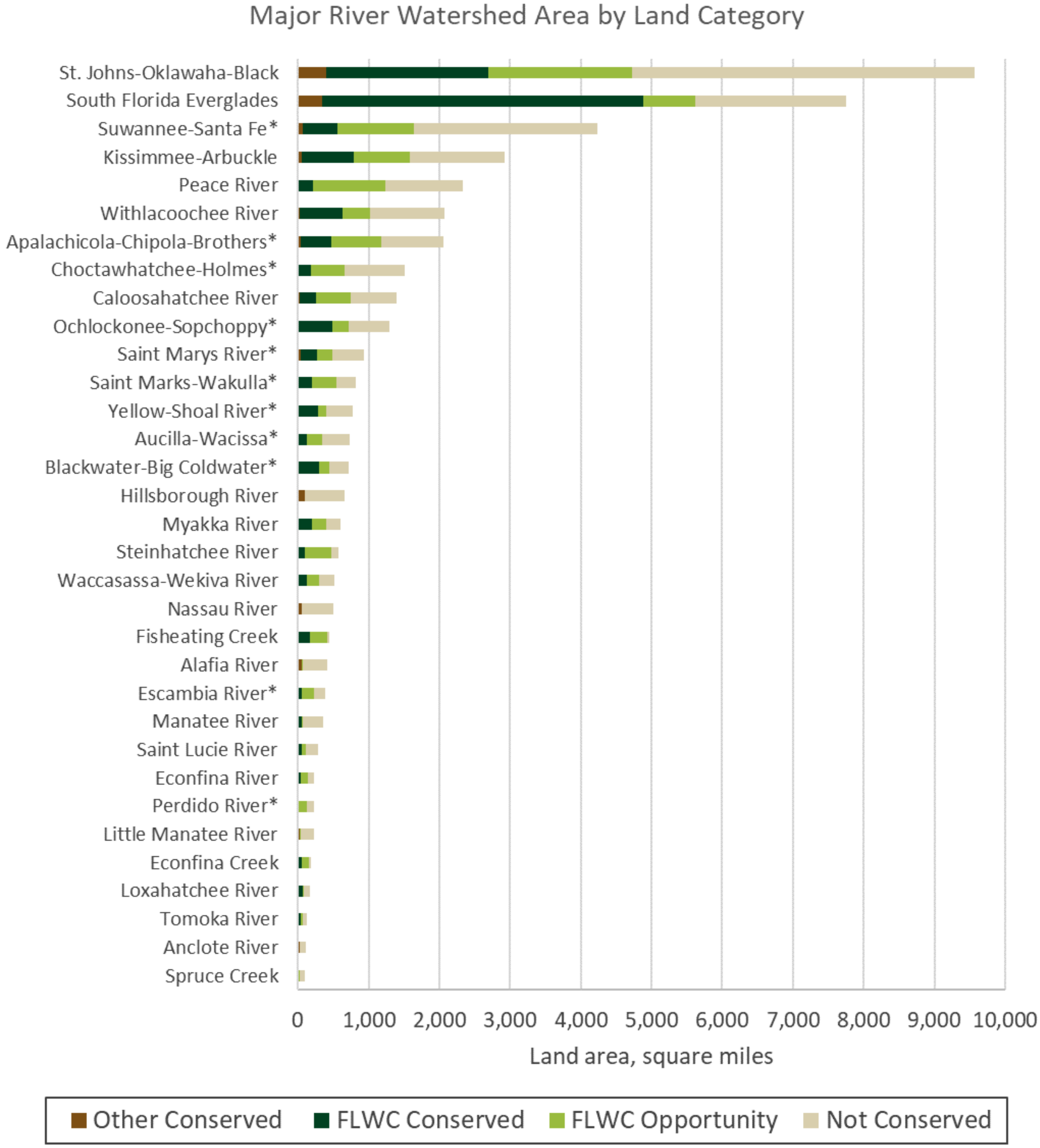

Figure VII-10. Magnitude of watershed area of Florida's major rivers within the FLWC and Other Conserved areas. * indicates only the portion of the watershed in Florida was considered for the analysis.

Overall, the FLWC would provide extensive benefits for rivers and smaller streams in Florida. Much of the length of major rivers within the FLWC (approximately 34%) are already conserved, with an additional 6% in Other Conserved areas; if acquired, the FLWC Opportunity areas would add an additional 28% of major river length to conserved areas. As noted in the analysis above, there are large parts of major rivers that are not within the FLWC (in particular, the lower St. Johns River, Nassau River, and St. Marys River), but many rivers would benefit from the FLWC Opportunity areas, such as the Perdido, Apalachicola, Suwannee, and Peace Rivers and the Caloosahatchee River Canal. Smaller streams also benefit from the FLWC, with a combined 54% of streams identified as flowing waters in Florida within the FLWC Conserved and Opportunity areas (and approximately 28% in the latter).

Large rivers and small streams are both important to river ecology and to the health of estuaries and lakes throughout the state (Toor et al. 2013, Longley et al. 2019). As illustrated in Figures VII-3b and 4b above, small streams can represent most of a river's tributary network; small stream channels extend across the landscape to collect water and deliver it downstream. Along with water, these stream channels carry dissolved materials and particulate matter that are important for river and estuarine food webs downstream (Vannote et al. 1980). Conserving areas around small streams sustains several ecological processes that can benefit nearby communities as well. Riparian zones and adjacent woodlands provide important buffers between developed areas, effectively withholding materials that stream channels can efficiently carry downstream (Roberts et al. 2018, Lyu et al. 2021, Dodds et al. 2022). Because developed areas often have amplified stormwater runoff and increased nutrient loads (from a wide range of sources including fertilizers, organic matter inputs, onsite sewage treatment, and atmospheric deposition), the capacity for riparian zones to slow water down and absorb nutrients represents a critical ecosystem service that is sustained by conserving land along small streams. Streams convey downstream both water as well as dissolved and particulate materials; the nutrients that enter small streams can be carried to lakes and estuaries, contributing to eutrophication and causing other related harmful outcomes such as harmful algal blooms (Phlips et al. 2020).

Conserving land alongside small streams provides another important ecological function and service to communities downstream. Small streams that are in areas of relatively high relief (even in Florida) are especially prone to erosion through gullying and headcutting (upward stream channel propagation and incision) (Witmer et al. 2009). Such effects are most common in places where watershed processes have changed, resulting in landscape hydromodification: instead of rainfall naturally infiltrating into the landscape and moving to stream channels through subsurface pathways, rainfall in a hydro-modified landscape is quickly moved off the land and efficiently moved to stream channels, resulting in more water in streams than they have historically accommodated (Freeman et al. 2019). As a result, the stream channel must widen or deepen to accommodate this new runoff. Even in small streams, these processes can cause large contributions to fine sediment loads in streams, which can smother fish spawning areas and cause stream channels to aggrade, and downstream areas to flood, because of reduced stream channel capacity (Kemp et al. 2011, Whitney et al. 2015). Further, these impacts can propagate downstream two larger rivers because they are connected via the drainage network.

This erosion of small streams can also contribute to reduced water clarity and associated ecosystem impacts in estuaries, such as loss of seagrass and declines in shellfisheries (Benham et al. 2016, Housego and Rosman 2016). Conserving areas along small streams can provide a buffer to reduce and slow surface water runoff, reducing the potential for these types of channel erosion and the adverse ecological effects of increased fine sediment downstream.

Conserving areas along river corridors is similarly important for large rivers. Development along large rivers can result in loss of riparian zones, which provide critical buffers to reduce nutrients and fine sediment in water downstream. High concentrations of fine sediment in large rivers can result in loss of in-channel habitat features, providing less habitat for organisms that live in rivers and utilize them as corridors to upstream areas. Healthy riparian zones along large rivers can also help to reduce nutrient and sediment inputs from upstream by accommodating floodwaters during moderate and high-flow periods: water spilling onto floodplains can deposit fine sediment, organic matter, and nutrient-enriched water. Wetlands in riparian zones can also play a role in reducing nitrate concentrations in surface water through denitrification.

The benefit of the FLWC for river systems is exemplified by these watersheds:

- ***Opportunity Areas within the Peace River and Myakka River watersheds***, if acquired, would extend conservation to land along major river corridors and the stream network throughout these watersheds (Figure VII-11). This is especially the case in the Peace River stream network, where an overwhelming majority of recognized stream network would be conserved. Conserving these areas would likely play a significant role in protecting aquatic resources in Charlotte Harbor. Although the FLWC may not conserve enough area to play a meaningful role in mitigating the effects of recent flooding in this area, such as what occurred as a result of Hurricane Ian (September 2022), additional development in areas adjacent to the Peace and Myakka River stream networks would certainly worsen the devastation along these river areas, causing damage to future development and increased flooding downstream.

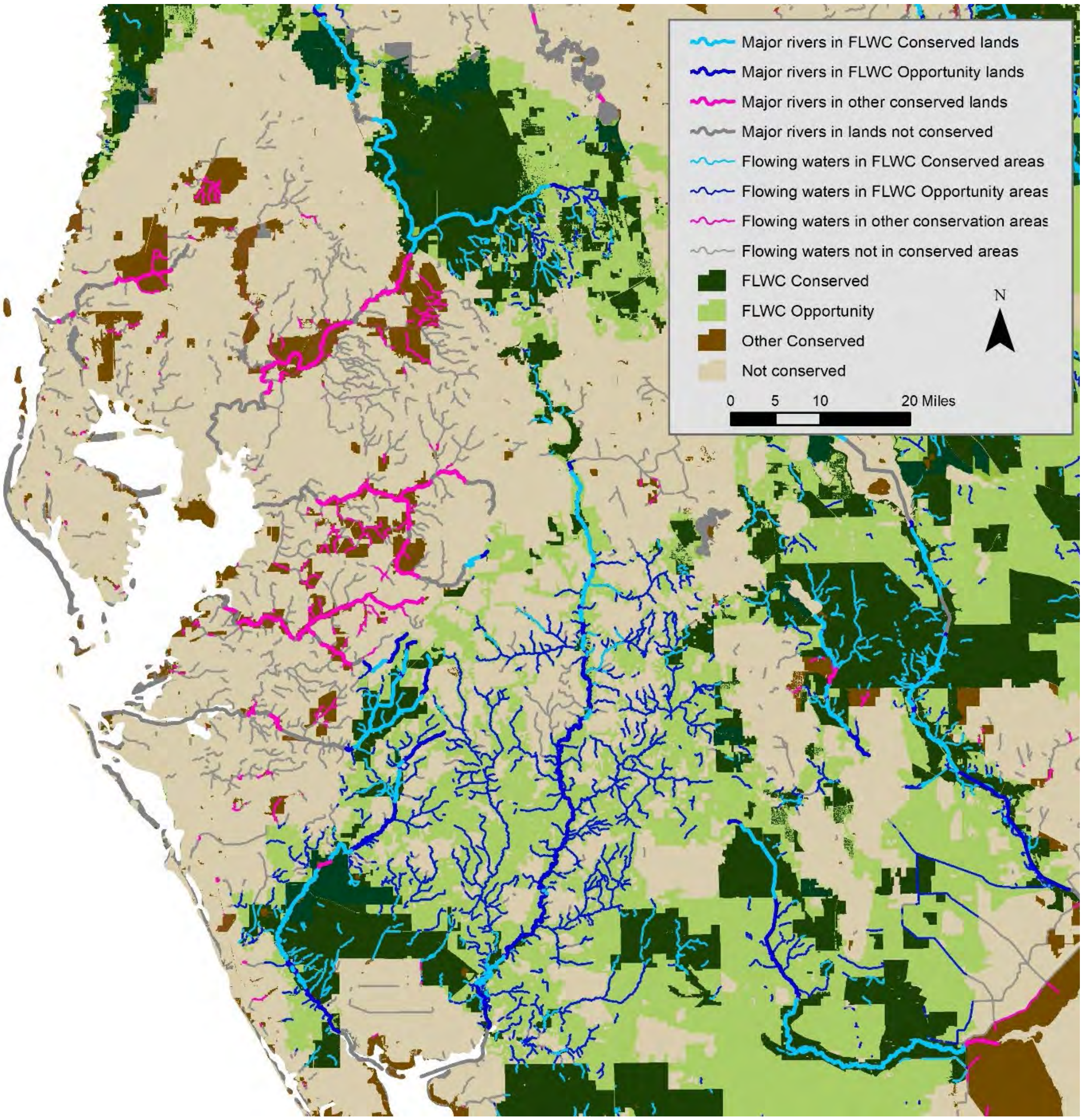

Figure VII-11 Wildlife Corridor areas and streams that flow through those areas in Southwest Florida.

- ***Opportunity Areas in the Florida Panhandle region***, if acquired, would extend conservation to substantial amounts of river channel networks (Figure VII-12). The density of officially recognized flowing waters is especially high in the Florida Panhandle, compared to elsewhere in the state, partly because of the relatively high relief and erosivity of the soils (NFWMD 2017). FLWC Conserved Areas in the Panhandle region such as Apalachicola National Forest, Tate's Hell and Blackwater River State Forests, Eglin Air Force Base, and several Northwest Florida Water Management District water management areas provide extensive conservation to stream channels. Opportunity

Areas would provide additional extensive conservation to streams and adjacent areas that flow into the Chipola River and upper parts of the Apalachicola River, as well as tributaries to the Choctawhatchee, Yellow, and Escambia Rivers. In addition to providing habitat for Gulf sturgeon, these rivers all provide important habitat for other endangered mussels including Fuzzy, Narrow, Oval, and Tapered pigtoe, Southern sandshell, Round ebonyshell, Southern kidneyshell, Choctaw bean, Shinyrayed pocketbook, Fat threeridge, Chipola slabshell and Purple bankclimber. Given the potential for erosion that additional development may cause, conserving lands along these Panhandle rivers, their adjacent riparian areas, and the streams that flow into them will be important for restoring native populations of these threatened organisms.

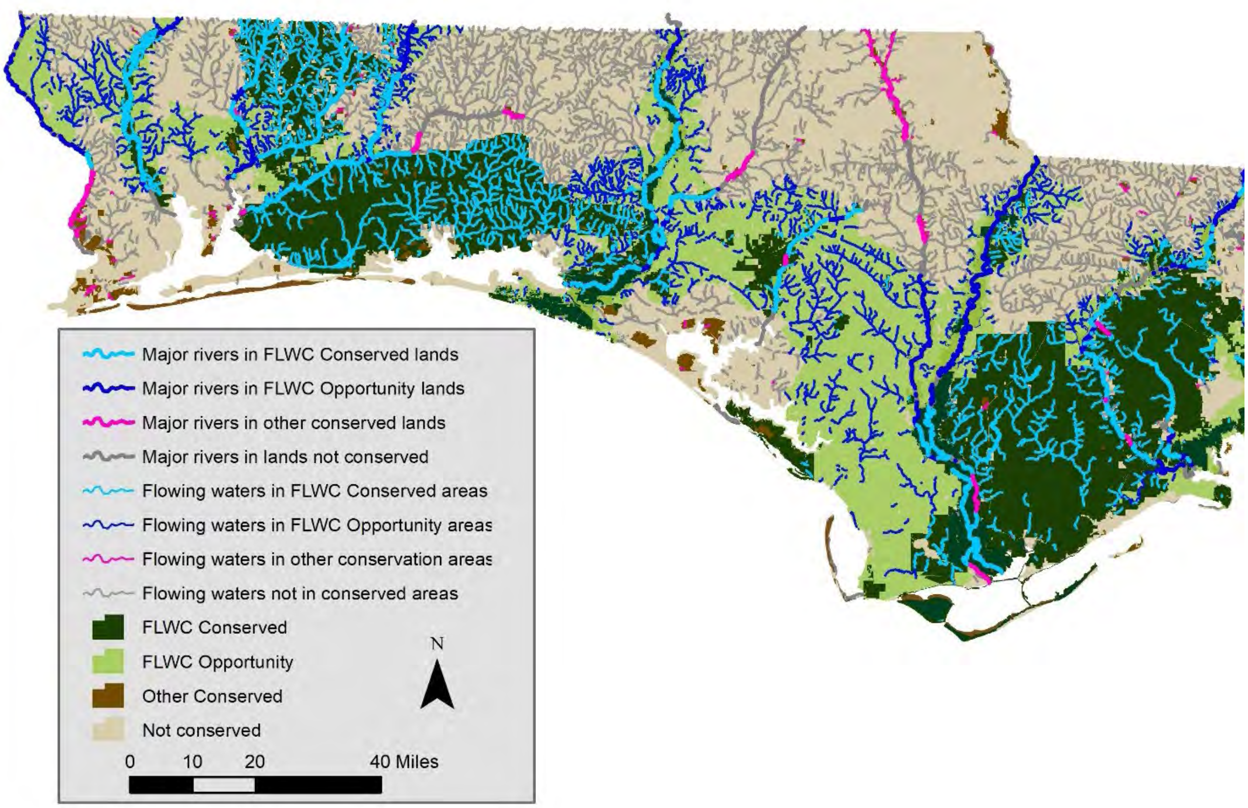

Figure VII-12. Wildlife Corridor areas and streams that flow through those areas in the northwest Panhandle region.

- ***Opportunity Areas near the upper Suwannee River***, if acquired, would provide extensive conservation to the stream channels that are close to the river (Figure VII-13). The streams that drain this river-adjacent landscape likely play an important role in their contribution of water and other matter to the river, so conserving this area is likely to have a meaningful role in sustaining current nutrient and sediment loads in the river. The upper Suwannee River is recognized as critical habitat for Gulf sturgeon, so conservation of these areas would also help to protect Gulf sturgeon habitat and other endangered species such as Suwannee moccasinshell mussels downstream.

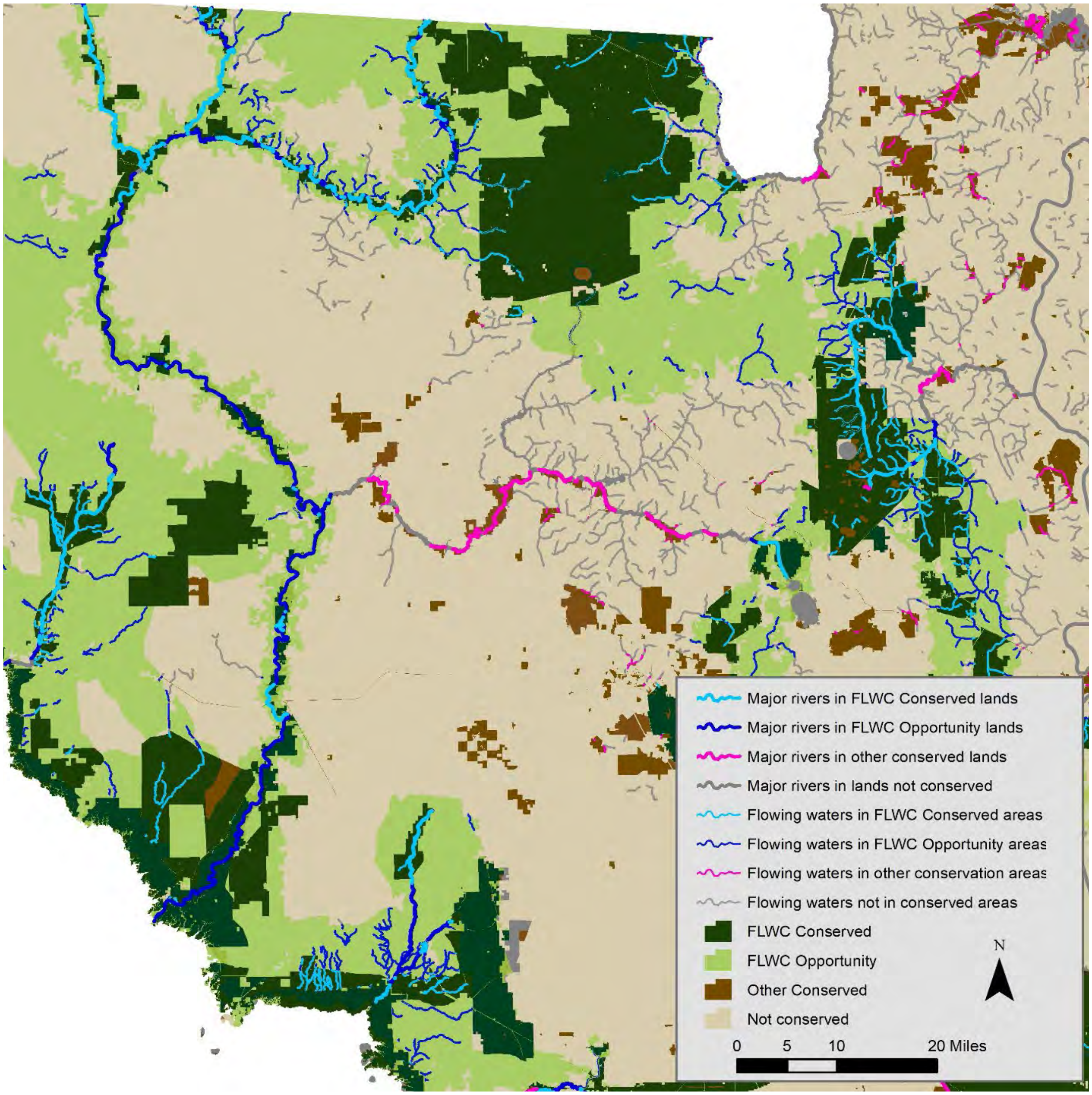

Figure VII-13. Wildlife Corridor areas and streams that flow through those areas in the Suwannee River watershed and nearby areas.

Each of these regions helps to explore the concept of connectivity in drainage networks. In river systems, connectivity refers to longitudinal (upstream-downstream) connections as well as lateral connections (from the river outward toward the floodplain and then terrestrial areas). Longitudinal connectivity is important because the movement of water transports materials downstream from the smallest of headwater streams through increasingly large streams to receiving waters such as estuaries, the ocean, or the Gulf of Mexico. Longitudinal connectivity is especially complex because of the variations in the movement of water, solutes, and particulate material, which can be strongly influenced by climate conditions (such as droughts and storm events) (Shields et al. 2008). In addition to providing downstream transport of materials by water, longitudinal connectivity also controls habitat availability and mobility among aquatic organisms, many of which migrate within and beyond drainage networks through their life cycle.

Lateral connectivity is important because riparian areas and adjacent terrestrial ecosystems provide inputs including nutrients and organic matter to river systems. In the northwest Panhandle region, the additional conservation of large Opportunity Areas along the lower Chipola River, upper Econfina Creek, and Choctawhatchee River would conserve large amounts of the drainage network, riparian zones, and upland areas that would likely help to sustain longitudinal and lateral connectivity. Within the Peace River Watershed in Southwest Florida, Opportunity Areas closely follow the drainage network in its entirety as well as some upland areas away from the drainage network. In this watershed, maintaining longitudinal connectivity would likely play a meaningful role in sustaining aquatic habitat, material transport, and other instream processes. Lateral connectivity is likely to be sustained in many areas as well, though perhaps not as extensively as if the entire watershed were conserved.

Conservation of land along the Suwannee River and its tributaries such as the Santa Fe would likely play a role in maintaining extensive longitudinal connectivity along the main river corridors, but predominantly unconserved areas along other parts of the drainage network beyond the main river may be more likely to adversely affect connectivity among headwaters, the Suwannee River, and Suwannee Sound. The Suwannee is further complicated by the general absence of drainage network in much of the area, a result of the predominantly karst landscape: water moves swiftly through the surface aquifer and few streams exist on the surface in of much of the region. A narrow band of riparian zone may be conserved in most of the Suwannee River, but inclusion of uplands that are currently not part of Opportunity Areas in future conservation planning would likely play a role in sustaining lateral processes and helping to sustain water quality within this system.

Although the FLWC Opportunity lands would provide extensive benefit to the regions described above, there are several regions where rivers and the small streams that feed them are not part of the FLWC conservation plans. These include:

- ***Several other parts of the Panhandle region*** where the FLWC does not extend, especially in the northern part of the region. The section above outlines several areas where Opportunity Areas would extend conservation; yet several nearby areas are omitted from the FLWC. This includes other parts of the Chipola River stream network, as well as most of the Shoal River network and streams that flow into Holmes Creek (tributary to the Choctawhatchee River), as well as Telogia Creek and other Ochlockonee River tributaries.

- ***Several rivers and their stream networks around Tampa Bay*** are not part of the FLWC. Omitting these areas for conservation could lead to additional erosion and fine sediment loading as well as increased nutrient loads into Tampa Bay in the future. Furthermore, the Alafia and Hillsborough Rivers in this region are used for public water supply. Omitting these areas has implications for both the quality and quantity of water for public supply.
- ***The Santa Fe and Nassau River stream networks*** as well as their adjacent floodplain areas are almost all outside of the FLWC. The streams that flow into the Santa Fe River play an important role in maintaining the health of ecosystems within the river itself, as well as the Suwannee River farther downstream, both of which are critical habitat for Gulf sturgeon and endemic mussel populations.

Conclusions

Florida's many rivers and smaller streams are likely to benefit from the Florida wildlife corridor. Additional land conservation will help to sustain water quality, aquatic habitat, and migration corridors along riparian zones that are critical for the continued function of ecosystems within these streams and rivers as well as the estuaries they flow into. As noted above, the FLWC does not include all rivers in the state, and as a result, there are some areas that will not benefit; but given the magnitude of the FLWC in many watersheds, its benefits are likely to be appreciable in many streams and estuaries across the state.

Connectivity is a key issue in many aspects of ecology, including the ecology of streams and rivers. As described above, one of the key benefits of FLWC is its capacity to include or enhance connectivity within drainage networks. The inclusion of entire drainage networks in opportunity areas represents a key benefit of the FLWC. Conserving land along drainage networks helps to sustain habitat along these aquatic- riparian corridors. Also, because of the importance of riparian and adjacent areas to water quality, conserving drainage networks can be especially important for maintaining water quality. Streams flow downstream continuously, and inputs from stream channels anywhere along this pathway will affect water quality, habitat, and other factors downstream. Thus, even small streams will affect downstream waters including lakes, larger rivers, and estuaries because they are connected with those water bodies through the drainage network.

Opportunity areas that add large amounts of area, such as those described above along areas including the Florida Panhandle, are one way to conserve land along entire drainage networks. In these cases, drainage networks and their entire watershed are included in Opportunity areas.

Another way to conserve land adjacent to drainage networks is to focus on conservation of land alongside stream channels, as described above for areas such as the Peace River. Because opportunity areas in the Peace River watershed follow the network of flowing waters, more of the drainage network is in conserved areas than would be if a similar amount of land in terms of area were conserved in a shape that did not so closely follow the drainage network. From the perspective of rivers, there could be value in following the drainage network in land conservation to maximize protections for water quality and instream habitat, as well as for enhancing the quality of estuaries downstream.

Additionally, management of conserved areas has a significant role in maintaining habitat and water quality in rivers and smaller streams. There are many ongoing restoration projects in Florida on state lands where historical land management is believed to have degraded water quality, requiring extensive and costly actions to reduce the impacts of unintended ecological processes such as woody vegetation encroachment in riparian zones. Other frequent impacts of management practices may include expansion of invasive species, which can propagate very quickly in Florida's riparian areas. Thus, management of conserved areas represents a critical issue to ensure that land conservation has benefits to streams and downstream estuaries that are intended. This is especially important for streams because of their connectivity across large distances via the drainage network.

All of these issues help to identify next steps that can improve our understanding of the relationships between land conservation through methods such as the FLWC and Florida's rivers and smaller streams. Field based research can help to explore the value of riparian zones on aquatic ecosystems, and while these values may be understood in some parts of the state, the diversity of stream ecosystems across the state suggests that their dynamics may vary across regions. The importance of connectivity in conserved riparian zones, specifically continuity with distance downstream, is also an important aspect for future consideration. How far sediment or nutrients travel, and the role of conserved adjacent lands, can be examined with fingerprinting and other contemporary analytical techniques.

In summary, river corridors (flowing stream length and 50 major rivers length) and river watersheds (50 major rivers watershed area and outstanding Florida waters) receive good-to-excellent benefit from the FLWC. Thus, additional conservation of land through the Florida Wildlife Corridor will make a major contribution to the health and sustainability of river ecosystems across Florida. Whereas some key areas may be omitted from its current proposed design, the FLWC will have substantial benefits to preserving the quality of water in major rivers, the habitat those rivers provide, and the habitats in estuaries that are fed by these rivers across much of the state.

VIII. Estuaries

Background

Florida has the longest coastline in the conterminous United States (Carter 1990), home to major coastal ecosystems such as seagrass beds, estuarine wetlands, dunes, and coastal strand. Florida's coastal resources and estuaries are threatened by impacts from a heavily developed coastline and poor water quality (Nagy et al. 2012, Lirman et al. 2019, Nichols et al. 2019). Therefore, protecting both Florida's shoreline and upstream watersheds is critical for maintaining Florida's unique estuarine systems.

Coastal ecosystems provide services to the surrounding communities, benefiting the citizens and the economy (Barbier et al. 2011). The conservation of natural shorelines provides recreation and cultural value to coastal communities (Harris and Defeo 2022). Ecosystems, such as estuarine wetlands and beaches, supply recreational fishing and water sports opportunities, as well as aesthetic and inspirational benefits (Friess et al. 2020). These systems also provide habitat and nurseries for aquatic organisms and important commercial and recreational fish species (Freiss et al. 2020, Harris and Defeo 2022). Seagrass beds, salt marshes and mangroves store buried carbon, trapping potential greenhouse gas emissions in the soil (Macreadie et al. 2021). Through intercepting water from uplands, estuarine wetlands filter nutrient pollution. In some situations, wetlands can be more effective at removing nutrients from upland water than crop management strategies (i.e., cover crops, land retirement; Hansen et al. 2018). Estuarine wetlands, dune, and coastal strand systems are critical to buffer coastal communities from coastal storms and erosion (Feagin et al. 2015, Temmerman et al. 2022). These ecosystem services are all important to Florida's citizens and the economy. Until this study, the impact of the FLWC Conserved and Opportunity lands on the conservation of these ecosystems and Florida's shoreline had not been quantified. We used a geospatial analysis to understand how the FLWC Conserved and Opportunity lands may benefit coastal ecosystems and thereby provide benefits to Florida.

Metrics

We used metrics that quantify benefits to Florida's coastline as well as the important coastal ecosystems within different conservation areas. For each metric, we measured its area or length within FLWC Conserved Areas, FLWC Opportunity Areas, Other Conserved Areas, and areas that are Not Conserved (see methods for details below). Within each of these areas, we calculated the length of shoreline that would fall within each category. Shorelines (referred to synonymously as coastlines in this section) are the interface between terrestrial and marine ecosystems, creating conditions for critical coastal ecosystems, such as salt marshes, mangroves, oyster beds, and coral reefs. Shorelines that are conserved are less likely to have impacts on adjacent coastal ecosystems. For example, conserved coastlines are less likely to have hardened shorelines that replace natural ecosystems.

We also calculated the amount of coastal wetland area within each land category. Coastal or estuarine wetlands are critical ecosystems, providing nurseries for natural and commercial fisheries, recreation, removal of nutrient pollution, carbon sinks, species habitat, and wave attenuation (Zedler and Kercher 2005, McLeod et al. 2011, Hansen et al. 2018). Through wave attenuation and absorption of water, estuarine wetlands can also provide some amount of mitigation of storm surge and sea level rise, depending on the storm and configuration of the estuary (Highfield et al. 2018, Temmerman et al. 2022). Finally, we determined the area of fragile coastal upland areas within each land category. These features include beach dunes, coastal grasslands, coastal strands, coastal scrub, and maritime hammock areas. Fragile coastal upland areas provide habitat for organisms as well as crucial wave attenuation and surge buffering during storms for coastal communities (Feagin et al. 2015, Morris et al. 2018). With these metrics, we assessed the benefit provided by the FLWC and proposed Opportunity lands for estuarine ecosystems.

Methods

To determine the effects of FLWC Conserved and Opportunity lands on estuarine ecosystems, we determined the length of shoreline, extent (area) of estuarine wetlands (marshes and mangroves), and extent (area) of fragile coastal uplands in each of the land conservation categories: 1) Other Conserved, 2) FLWC Conserved, 3) FLWC Opportunity, and 4) Not Conserved lands. We conducted a GIS analysis to determine these measures with the following files: 1) Shoreline - Cooperative Land Cover 3.5 (FWC 2021), 2) FLWC Conserved and Opportunity area files (UF CLCP 2021), 3) Conserved lands outside of Corridor (FNAI 2022), 4) Estuarine wetlands - National Wetlands Inventory (USFWS 2018), 5) Fragile coastal uplands - FNAI Fragile Coastal Resources (FNAI 2017), 6) Seagrass habitat - Seagrass habitat in Florida (FWC 2022), 7) State Manatee Protection Zones (FWC 2018).

We clipped each ecosystem file by the land category file to determine the amount (area, length) in each area. In order to determine the amount of estuarine ecosystem by water management district, we then clipped each file by the boundaries of the five water management districts (SFWMD 2016). To deal with mismatch between shoreline files and land conservation files, we buffered the land conservation files by 16.4 ft (5 m) to pick up all parts of the shoreline. Therefore, the “Not Conserved” lands are a slightly conservative estimate of shoreline length.

Our analysis is based on several assumptions. Here we identify the assumptions that might affect interpretations of this analysis:

- We assumed that a developed shoreline is detrimental to the surrounding estuarine waters and ecosystems. Therefore, a shoreline that is preserved and without development benefits the adjacent aquatic communities and water quality. An example of this benefit is that there are likely to be fewer boat strikes of manatees in areas without coastal development because of fewer boats. Our case studies rely on this assumption because seagrass ecosystems and manatees are aquatic organisms and do not benefit from the same protections as terrestrial organisms within the Wildlife Corridor. The protection afforded to them in this situation is purely from being adjacent to conserved land.
- Another assumption is that a coastal conserved land buffer improves estuarine water quality through the processing of nutrients through wetlands and/or the reduction of nutrient sources (i.e., no septic tanks in undeveloped land).
- We assume that this coastal buffer also provides some flood protection and helps buffer coastal storms. Therefore, areas with great amounts of conserved fragile uplands will benefit from these intact systems during hurricanes.
- One of our metrics, shoreline or coastline, is not an easily defined geographic feature. The mean high tide is constantly changing, and the coastline is fractal (Husain et al. 2021), meaning it has random detail at small scales. Depending on scale and purpose, agencies (e.g., NOAA) develop geospatial coastline files that reflect the amount of detail needed for the purpose of the file (i.e., navigation). Therefore, the coastline file we used in this analysis (FWC 2021) is a representation of the coastline and was chosen to complement the development of the geospatial data for the FLWC. To address this, we only report the percentage of coastline covered by each land conservation category, rather than raw numbers that may be more influenced by the chosen coastline dataset. Although we are more confident in the percentages, we are less confident in the absolute measure of the shoreline due to the factors outlined above.
- The degree of benefit provided to estuarine habitat, organisms, and waters is dependent on how adjacent FLWC lands are managed.

Estuarine ecosystem metrics were assigned to two benefit categories: Good-to-Excellent (greater than or equal to 50% of the statewide benefit metric within the FLWC), and Low-to-Moderate (less than 50% of statewide benefit metric within the FLWC) as outlined in Section I.

Results and Discussion

Shoreline Conservation

Coastlines are important areas that serve as the interface between land and sea. This critical junction between these two environments is home to important estuarine ecosystems and adjacent to estuarine waters. To understand how the FLWC benefits these environments, we determined the length of shoreline within each type of land category. We found that the FLWC Conserved and Opportunity areas cover 46% of Florida's shoreline, with the FLWC Conserved areas covering 34% of Florida's shoreline and FLWC Opportunity areas adding an additional 12% (Figure VIII-1). This incremental addition of the Opportunity lands would benefit 24% of the currently unconserved shoreline of Florida (i.e., combination of Not Conserved and FLWC Opportunity Lands). As discussed previously, 50% of Florida's land would be within FLWC Conserved and FLWC Opportunity lands. Thus at 46%, the shoreline length metric falls below the statewide percent of land within the FLWC Conserved and Opportunity areas, indicating a moderate level of benefit.

Across the state, we find regional differences in the percent of shoreline within the FLWC Conserved and Opportunity lands. Taking the water management district boundaries as broad regions across Florida, we compared the level of benefit for the coastline (Figure VIII-1). The length of coastline in the FLWC in the Suwannee River Water Management District (SRWMD; 92%: FLWC Conserved - 46%, FLWC Opportunity - 46%) far exceeds the 50% statewide benchmark because of the expansive conserved and undeveloped land in the Big Bend region, and thus is provided excellent conservation. The Northwest Florida Water Management District (NWFWMD; 50%: FLWC Conserved - 19%, FLWC Opportunity - 31%) also receives good benefit from the FLWC Conserved and Opportunity areas, while the South Florida Water Management District (SFWMD; 47%: FLWC Conserved - 46%, FLWC Opportunity - 0.4%), receives moderate benefit and is slightly underrepresented in the FLWC compared to the statewide percentage. Because of the configuration of the FLWC, other regions are less well conserved. Within the St. Johns River Water Management District (SJRWMD), 30% of the shoreline is within FLWC Conserved areas, with only 1% falling within FLWC Opportunity areas. Similarly, for the Southwest Florida Water Management District (SWFWMD) only 32% of the shoreline is currently within the FLWC Conserved (16%) and FLWC Opportunity areas (16%). Thus, for SJRWMD and SWFWMD, low-to-moderate benefit to coastline is provided, which is underrepresented compared to the statewide percentage of land within the FLWC.

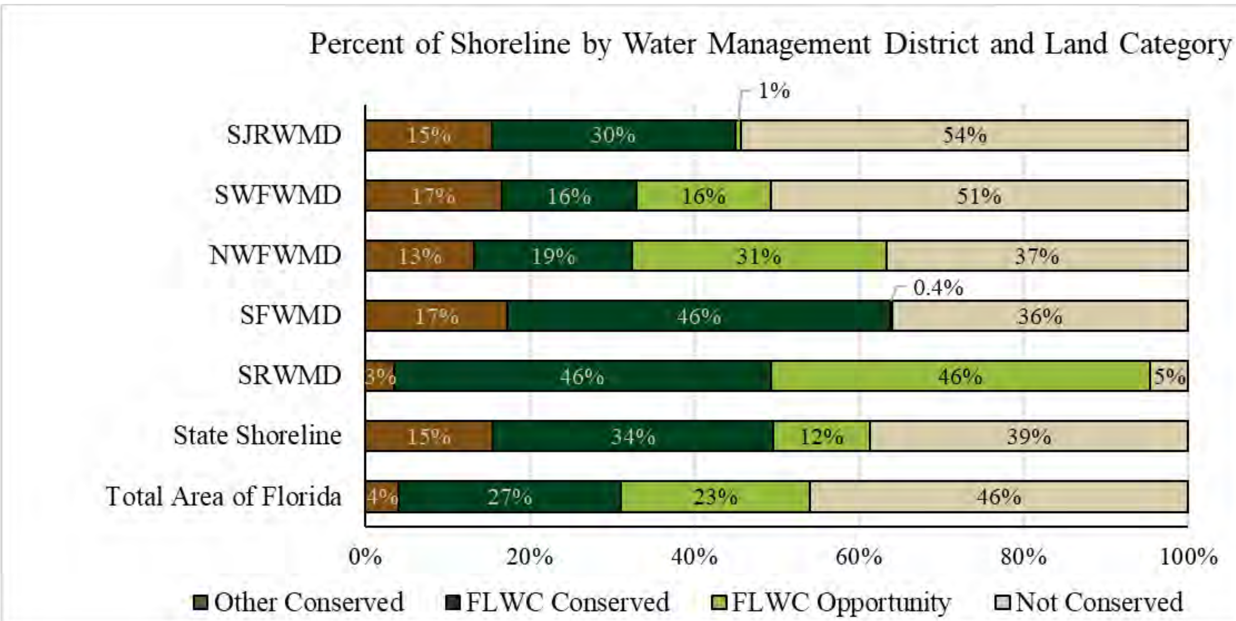

Figure VIII-1. Percent of Florida coastline covered by the different land categories across water management districts.

Estuarine Wetlands

Estuarine wetlands are a critical coastal ecosystem that serves as an important buffer between land and sea. Using the National Wetlands Inventory, we determined the amount of "Estuarine and Marine Wetland" that is within the different land categories. The National Wetlands Inventory defines estuarine and marine wetland as "Vegetated and non-vegetated brackish and saltwater marsh, shrubs, beach, bar, shoal or flat (U.S. Fish and Wildlife Service 2022). The boundaries of the FLWC are seaward of these intertidal systems, and therefore their extent is included in the boundaries. Because estuarine wetlands are seaward of the mean high-water line, they are considered sovereign submerged land. This distinction means that the Florida Department of Environmental Protection (or other regulatory agencies) have regulatory authority over these lands. Therefore, permission must be obtained before any alteration or destruction of these lands. In addition, all estuarine wetlands in the United States are covered by a "no net loss" policy of the federal government. These two additional protections mean that even the "Not Conserved" areas in the analysis have some regulation to limit the destruction of these resources.

We determined the amount of estuarine wetland area within each type of land conservation category. We found that the FLWC Conserved and Opportunity areas cover 55% of Florida's estuarine wetlands, overall providing a good level of benefit (Figure VIII-2). However, the FLWC Conserved area is 52% (1125 mi^2) of Florida's estuarine wetlands (2158 mi^2), and the FLWC Opportunity areas added only 2.5% (55 mi^2) to the estuarine wetland area. Thus, the

Opportunity areas will provide an incremental benefit of 11% of the currently unconserved land (Not Conserved land plus FLWC Opportunity areas).

When comparing coastal wetland coverage in Florida's water management districts, we found regional differences in the percent of estuarine wetlands in FLWC Conserved and Opportunity areas (Figure VIII-2). The area of estuarine wetlands within the FLWC Conserved and Opportunity areas in the SRWMD (92%) and SFWMD (63%) are the highest in the state and thus are provided excellent benefit. (Note that there is very limited coastal wetland area covered by Opportunity lands in SFWMD - 0.1%). Estuarine wetlands in NWFWMD also receive good benefit, with 59% of coastal wetland area either in FLWC Conserved or FLWC Opportunity areas. SJRWMD (12%) and SWFWMD (32%) receive low-to-moderate benefit, as they are below the statewide benchmark of 50%. Both of these districts also have very limited estuarine wetlands in the Opportunity areas (0.2% and 7%, respectively).

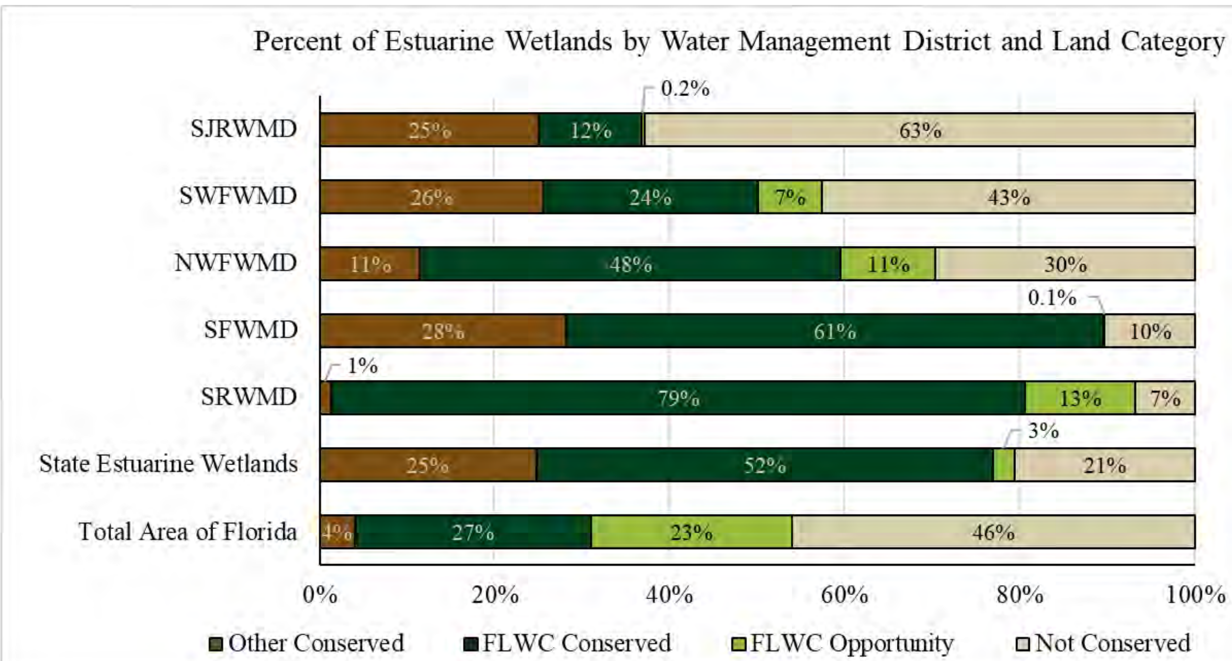

Figure VIII-2: Percent of estuarine wetlands covered by the different land categories across water management districts.

Fragile Coastal Uplands:

Coastal uplands such as dunes and coastal strand are important terrestrial ecosystems that serve as a barrier between estuarine waters and uplands. We used the FNAI Fragile Coastal Resources dataset and isolated the fragile coastal uplands for this analysis. This dataset includes beach dune, coastal grassland, coastal strand, coastal scrub, and maritime hammock ecosystems. Serving as a buffer between the ocean and coastal communities, these upland ecosystems can attenuate waves and absorb flooding during storms.

We determined the area of fragile coastal upland areas within each type of land category. The FLWC Conserved and Opportunity areas cover 34% of Florida's fragile upland ecosystems (Figure VIII-3). The FLWC Conserved area covers 33% (52 mi^2) of Florida's fragile coastal uplands (153 mi^2), and the FLWC Opportunity areas cover 1% (2 mi^2) of fragile uplands. If conserved, the Opportunity areas will provide an incremental benefit of 5% of the currently unconserved land (Not Conserved land plus FLWC Opportunity areas). Fragile coastal uplands are therefore provided moderate benefit, as the benefit is underrepresented compared to the statewide percentage of land within the FLWC (50%). This is in large part because so much fragile coastal land area is protected by Other Conserved lands (62 mi^2; 41%) that are not included in the FLWC.

Across Florida's water management districts, there are different levels of benefit for fragile coastal uplands (Figure VIII-3). The FLWC Conserved and Opportunity lands provide good-to-excellent benefit to fragile coastal uplands in the SRWMD and SJRWMD (90% and 52%, respectively). The other three water management districts, NWFWMD, SWFWMD, and SFWMD, are provided low-to-moderate benefit (30%, 18%, and 7%, respectively), as the benefit is underrepresented compared to total state land within the FLWC. The only water management district with considerable coverage of fragile coastal uplands in FLWC Opportunity lands is SRWMD (17%). The Big Bend region of the coast in the SRWMD is an area of the State with expansive conserved and undeveloped natural areas. The rest of the water management districts are provided very little proportional coverage of fragile coastal uplands by FLWC Opportunity lands (NWFWMD: 3%; SJRWMD: 1%; SWFWMD: 1%; and SFWMD: 0.002%). Although the FLWC does not have much Opportunity area land in these regions, many regions have substantial fragile coastal upland areas in Other Conserved areas (NWFWMD: 46%; SJRWMD: 28%; SWFWMD: 37%; SFWMD: 62%).

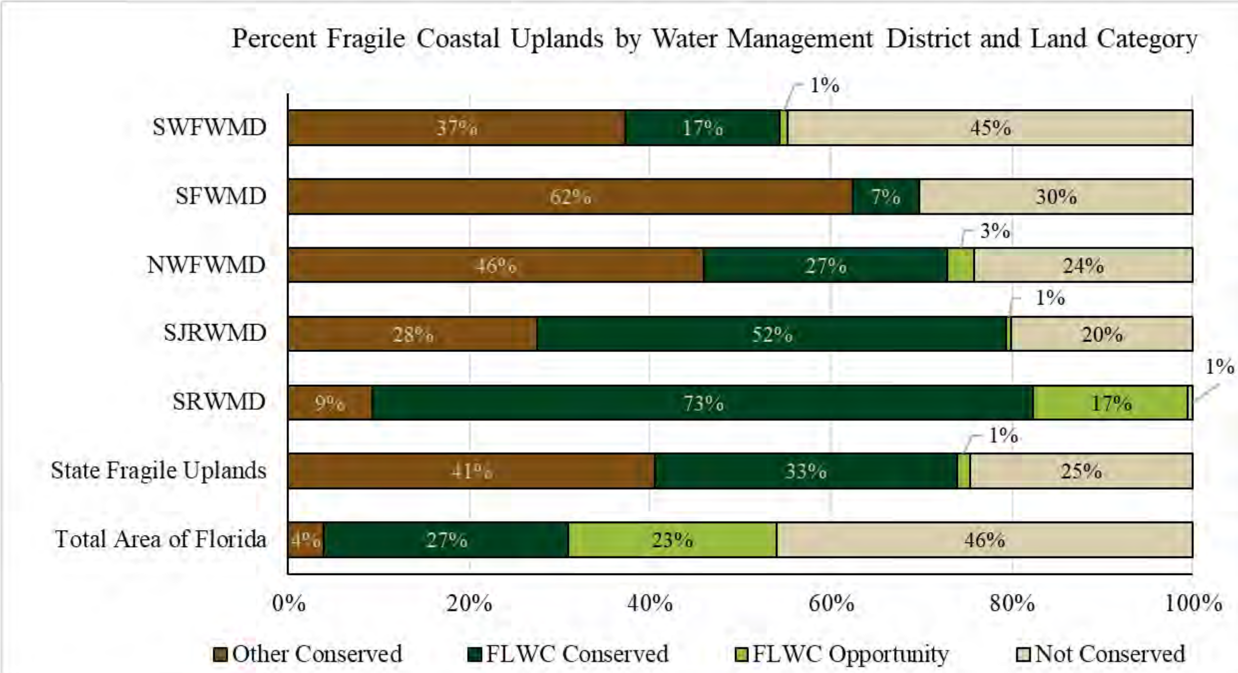

Figure VIII-3: Percent of Florida's fragile coastal upland ecosystems covered by the different land categories across water management districts.

Seagrass Case Study: Comparison of Tampa Bay and Crystal River

Seagrass ecosystems are important habitats for the coastal food web, including food fish species, sea turtles, and manatees (Cullen-Unsworth et al. 2014, de la Torre-Castro and Rönnbäck 2004). These seagrasses help settle the seabed and sequester carbon through burial (Fourqurean et al. 2012). In Florida, seagrasses exist throughout the coastal and estuarine areas of the state in subtidal environments found in protected bays, lagoons, and the Gulf of Mexico. There are seven seagrass species in Florida that live at depths where they can receive sunlight. Seagrass ecosystems require clear water for sunlight to reach the plants. Nutrients (algae) and dissolved and particulate matter in storm runoff can affect water clarity and therefore, seagrasses. In addition, propellers from boats can damage seagrass beds. Therefore, conservation of coastal uplands that surround seagrass ecosystems is important to their protection from physical damage and reduced water clarity.

We compared the seagrass extent (FWC 2022) and conservation around the areas of Tampa Bay and Crystal River. These areas vary in the extent of seagrass, but both have substantial seagrass habitat that supports animals such as manatees. The FLWC Conserved areas and FLWC Opportunity lands are located in areas that have good connectivity to existing conserved land and little human development. In our case study (Figures VIII-4, 5), it is clear that existing development plays a strong role in the selection of corridor lands along Florida's heavily developed coast (Figure VIII-4), with very little FLWC around Tampa Bay. Because of the large amount of development in Tampa, St. Petersburg, and other areas surrounding the Bay, pristine natural upland areas are rare and there are few places that the FLWC could consider for incorporation in Opportunity lands. Seagrass extent is more limited as a result of the impacts of runoff and nutrients from upland development on seagrass habitat (Carlson et al. 2010, Greening et al. 2014). In contrast, the Crystal River area of the Big Bend region of Florida has much less development and extensive conserved areas (Figure VIII-8). The extensive seagrass habitat in this area benefits from the undeveloped and conserved coastline. Because of the FLWC priority on contiguous “natural” lands and the heavily developed nature of much of Florida’s coastline, the FLWC Conserved areas and Opportunity lands will benefit some coastal submerged ecosystems more than others.

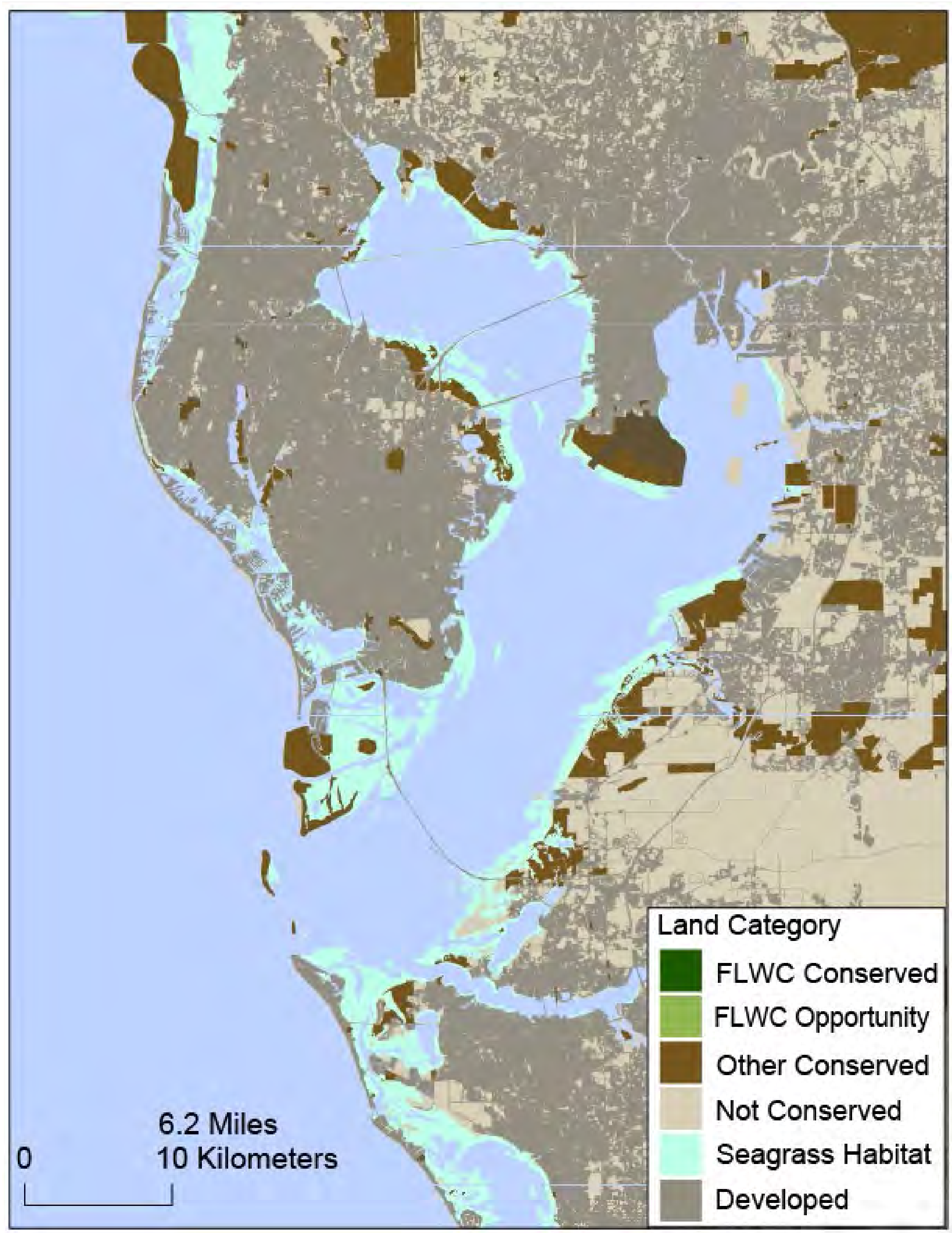

Figure VIII-4: Map of Tampa Bay region displaying different conservation categories, seagrass habitat, and development.

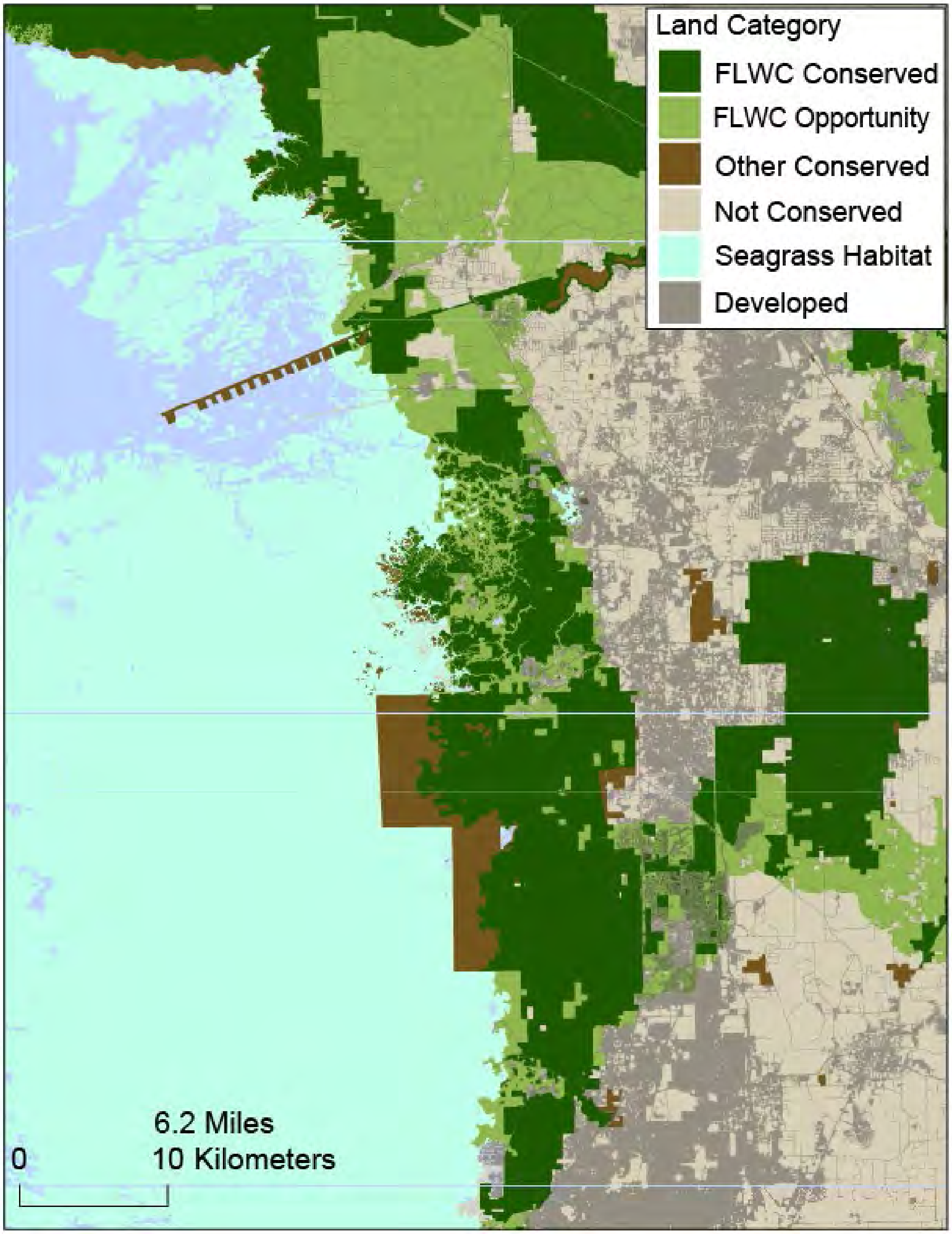

Figure VIII-8: Map of Crystal River region displaying different conservation categories, seagrass habitat, and development.

Manatee Case Study: Comparison of Indian River and Crystal River

Florida's iconic manatees rely on coastal and spring ecosystems (Laist and Reynolds 2006). They were reclassified from an endangered to a threatened species by the U.S. Fish and Wildlife Service in 2017. Manatees move easily between salty, brackish, and freshwater systems, migrating from coastal areas to inland springs, power plant outflows, or warm waters in the south in the winter. They exist in developed areas, with manatees frequently interacting with humans and boats. Eating seagrass and aquatic vegetation, manatees are dependent on healthy aquatic ecosystems, including seagrass beds. Manatees are threatened by boats, loss of habitat and food resources (decline of seagrass), marine debris, and changes in warm-water habitat resources (Allen et al. 2022). Therefore, less developed coastlines, including coastlines conserved by the FLWC, provide some degree of protection to these aquatic mammals.

We compared the State Manatee Protection Zone (FWC 2018) in the Indian River Lagoon and Crystal River areas of Florida (Figures VIII-9, 10). Both areas have extensive wintering grounds for manatees in Florida who are reliant on the warm-water refugia and food resources provided by these areas. In Indian River Lagoon, much of the coastline is developed, except for the conserved areas around Cape Canaveral and the Kennedy Space Center (Figure VIII-9). Few FLWC Conserved lands and Opportunity areas are adjacent to much of the Manatee Protection Zone. Aquatic species (e.g., manatees) are not bound to natural areas and can exist within urbanized areas. Therefore, manatees in the Indian River Lagoon will receive few benefits from the FLWC Conserved lands or acquisition of Opportunity lands. In Crystal River (Figure VIII-10), much of the land surrounding the manatee protection zone is Other Conserved, FLWC Conserved land, or FLWC Opportunity land. Therefore, manatees in these areas will benefit from undeveloped shorelines and fewer impacts from humans. This case study shows that because the FLWC prioritizes undeveloped, connected natural lands, manatees will have varied benefits from FLWC Conserved area and Opportunity lands across Florida’s coastline. In places with less development (e.g. Crystal River), manatees will benefit from fewer boats and better water quality. In places that are more urbanized (e.g. Indian River Lagoon), however, manatees will not benefit significantly from the addition of Opportunity lands and will continue to be threatened by diminishing habitat and food resources.

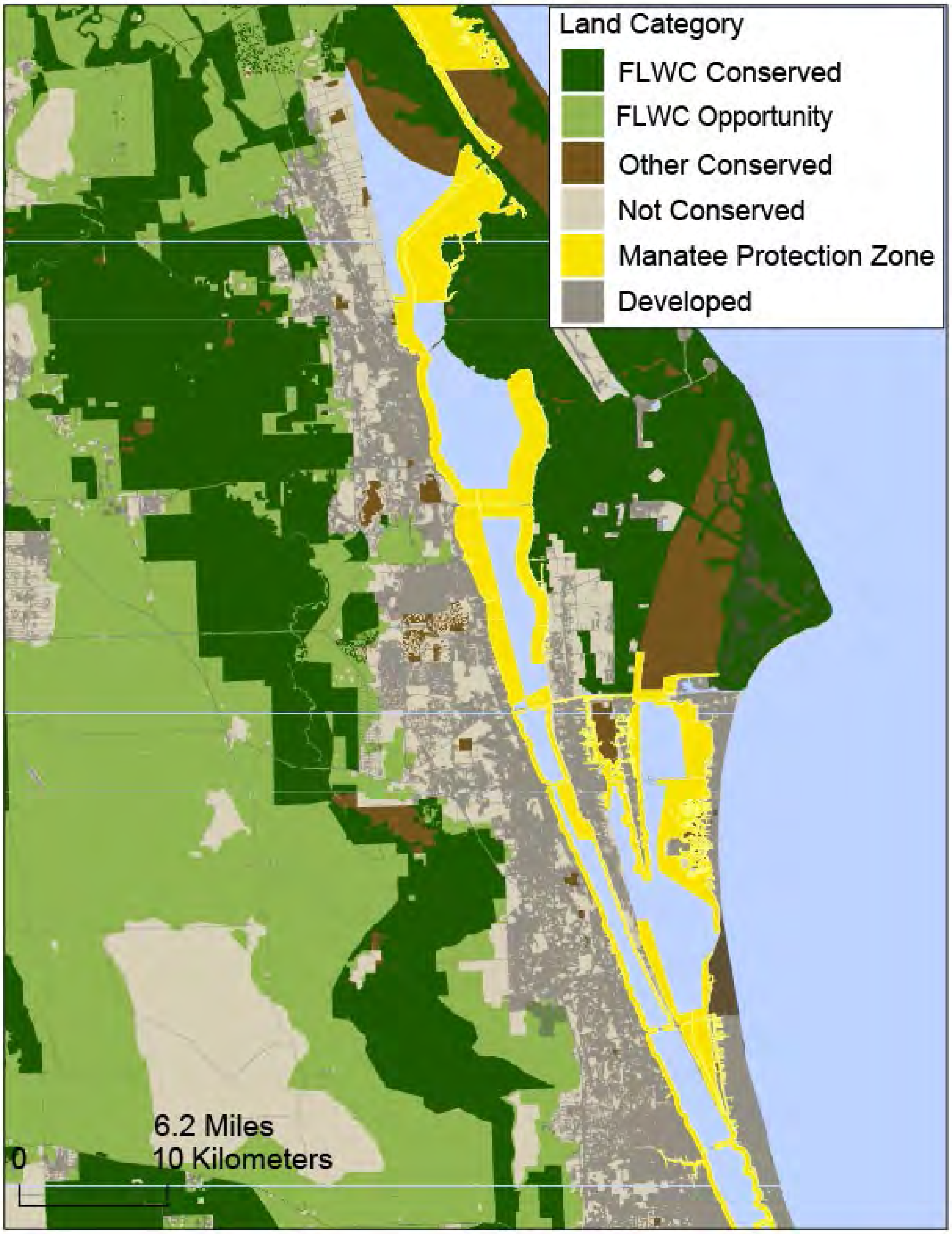

Figure VIII-9: Map of Indian River Lagoon region displaying different conservation categories, state manatee protection zones, and development. There are very few FLWC Conserved or Opportunity areas along the lagoon in this map.

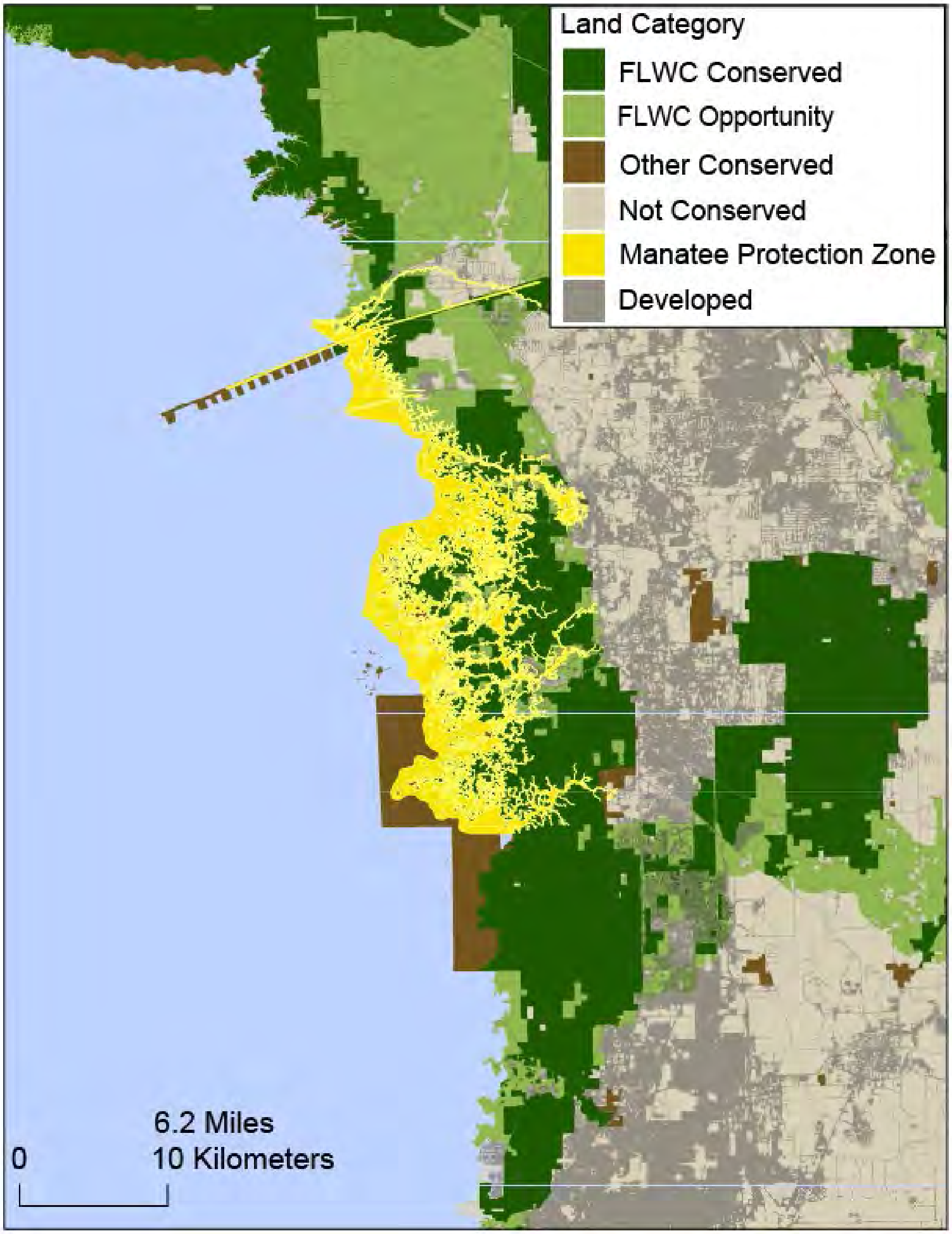

Figure VIII-10: Map of Crystal River region displaying different conservation categories, state manatee protection zones, and development. There are extensive FLWC Conserved and Opportunity lands along the shore in this area.

Conclusions

Florida has tremendous coastal and estuarine resources that are connected through the vast aquatic network across the state. Our analysis shows that the FLWC Conserved lands and Opportunity lands will provide varying degrees of benefit to estuarine resources. For the coastline as a whole, the coastline length within the FLWC Conserved and Opportunity lands falls below the 50% statewide benchmark, and thus is considered to receive moderate benefit. Estuarine wetlands, including salt marshes and mangroves, exceed the 50% benchmark and are provided good benefit. Fragile coastal uplands, which include dunes and coastal strand, are provided moderate benefit, with 35% within the FLWC Conserved and Opportunity areas. Estuarine wetlands and fragile coastal uplands do not have a high proportion of their area proposed to be FLWC Opportunity areas (2.5% and 1%, respectively), therefore FLWC Conserved lands provide the majority of the benefit for these resources. Thus, acquiring additional FLWC Opportunity lands will not dramatically improve the current situation for estuarine wetlands and fragile estuarine wetlands. Yet, 77% of estuarine wetland area and 74% of fragile upland area are already conserved through FLWC Conserved areas or Other Conserved areas. Thus, on the whole, these areas are well conserved, though underrepresented by the FLWC.

Regionally, we find that the FLWC Conserved lands and Opportunity areas vary by region with respect to coverage of estuarine resources. The SRWMD stands out as an area that significantly benefits from the FLWC. With a relatively undeveloped coastline and vast estuarine resources, the FLWC Conserved lands and potential acquisition of Opportunity lands would preserve aquatic habitat and minimize impacts to coastal resources. Other water management districts, NWFWMD and SFWMD, also have fairly good protection for estuarine resources in comparison to the state as a whole, especially if Other Conserved areas are considered. Although home to large cities and coastal communities, these water management districts also contain vast natural areas (e.g., Apalachicola National Forest and Everglades, respectively). This combination of land cover leads to conservation that reflects the mix of land use in the state. We find that even though existing Other Conserved and FLWC Conserved areas together provide good conservation, Opportunity areas are often small across these two management districts, particularly SFWMD. Therefore, the current situation will not be improved dramatically by the addition of Opportunity lands. Finally, we identified management districts that benefit less from the FLWC: SJRWMD and SWFWMD. These two regions have less estuarine related area in the FLWC than across the state as a whole. They also have several major metropolitan areas along their coastlines that inhibit connection of existing conserved lands to the larger FLWC.

Our regional trends and case studies point to the relationship of development, existing conserved areas, and placement of FLWC Opportunity areas. Coastal locations that are less developed and have more existing conservation land tend to benefit more from the FLWC Conserved and Opportunity lands than those that have a more developed coastline. Aquatic and coastal ecosystems often coexist with people across Florida's developed coastline. Ecosystems, such as seagrasses, can exist adjacent to coastal communities and in estuaries with mainly developed and hardened shorelines. In addition, aquatic organisms, such as manatees and fish, live and migrate through estuarine waters that are surrounded by developed areas. Therefore, the criteria set out by the FLWC to identify lands that benefit terrestrial animals do not always overlap with areas beneficial to estuarine ecosystems and coastal organisms.

These results have implications for ecosystem services provided by estuarine and coastal ecosystems. We found that Florida's shoreline will receive benefits from the conservation of natural shorelines that provide recreation and cultural value to coastal communities. Beaches, estuarine wetlands and seagrasses provide recreational fishing opportunities and water sports, as well as adding to the aesthetic and inspirational value of our coastal region. These ecosystems also provide habitat for aquatic organisms, filter nutrient pollution, increase flood and erosion protection, and are hotspots of carbon storage. Thus, these systems provide critical regulating ecosystem service benefits to Florida. The inclusion of coastal ecosystems in the FLWC, particularly coastlines and estuarine wetlands, will increase these benefits for the state. These benefits are unequally distributed across our coast, with more FLWC lands along more natural coastlines. While estuarine wetlands are well conserved, prioritizing coastal upland ecosystems that are critical to protecting our coast should be considered for future iterations of the FLWC, by acquiring FLWC Opportunity areas and/or incorporating more Other Conserved coastal uplands into the FLWC.

Conserving places that have natural shorelines is critical to protect pristine ecosystems and coastal water quality. Yet setting aside natural areas in a highly developed landscape can also accrue ecosystem service benefits for surrounding areas (Eigenbrod et al. 2009). The connectivity between estuaries and the upland watershed can affect the health of estuarine ecosystems and organisms. Surrounding uplands can affect habitat, biodiversity, and organism presence (Isdell et al. 2015, Warry et al. 2018). Therefore, the link between estuaries, river systems, and terrestrial uplands is critical to both conserving these water bodies and estuarine organisms. The results of our analyses indicate that the FLWC Opportunity areas do not accrue adequate additional benefits for estuarine ecosystems and organisms that are already imperiled because of development of the shoreline. Acknowledging the excellent coverage of coastal areas in less developed regions by the FLWC, we recommend that future iterations of the FLWC or other conservation frameworks consider estuarine resources in areas that are more developed, if preserving estuarine ecosystems and waters is a priority.

In summary we find:

- Florida has vast coastal resources, with the second longest shoreline in the United States. A total of 49% of the coastline is already conserved, with FLWC Conserved lands covering 34% and Other Conserved lands covering 15%. Estuarine wetlands, including salt marshes and mangroves, are already more than 77% conserved, with FLWC Conserved lands covering 52%, and Other Conserved Lands 25%. Fragile coastal upland ecosystems (e.g., dunes and coastal strand) that protect coastal communities are already 74% conserved, with 33% in FLWC Conserved lands and 41% in Other Conserved lands.
- If acquired, FLWC Opportunity lands would not dramatically increase the amount of conservation for the coastline and coastal ecosystems.
    - FLWC Opportunity lands would incorporate an additional 12% of the shoreline.
    - FLWC Opportunity lands would incorporate an additional 2.5% of estuarine wetland area.
    - FLWC Opportunity lands would incorporate an additional 1% of fragile coastal upland ecosystems.
- Across the coastal ecosystems, there are vast regional differences in the level of benefit provided by the FLWC. The SRWMD and SFWMD have extensive existing conservation because of the Big Bend and Everglades regions of Florida. The SJRWMD and SWFWMD have less coastal area in FLWC Conserved or Other Conserved lands, and little FLWC Opportunity land.
- Coastal ecosystems and related species often coexist with developed upland areas, for example manatees living in coastal estuaries such as the Indian River Lagoon. Through two case studies, we showed that areas without development will provide greater benefit to coastal ecosystems through the adjacent FLWC Conserved and Opportunity lands than areas with developed shorelines.

IX. Imperiled Species

Background

Florida is home to numerous imperiled species that are likely to benefit from the Florida Wildlife Corridor conservation initiative. The development and assessment of the FLWC has focused on functions and habitats, but recent work (Hamilton et al. 2022) enables high resolution assessment of the FLWC for protecting imperiled species. The dataset enables maps of richness and rarity across multiple taxonomic groups for the conterminous United States at roughly 1 km (0.62 mi) spatial resolution, yielding a novel tool for assessing the conservation value of the spatial configuration of the FLWC. Our goal in this section of the report was to document the impacts of the FLWC, spanning existing Conserved and Opportunity areas, for benefiting imperiled species across three taxonomic groups (plants, aquatic invertebrates, and vertebrates). Further disaggregation is possible (e.g., vertebrates include birds, fish, mammals, amphibians, and reptiles) with the publicly available data, but beyond the scope of this effort.

As with other water-related benefits analyses in this study, we evaluated the potential impacts on imperiled species with respect to the proportional area of the FLWC in Florida. That is, given that FLWC Conserved lands occupy 27% of Florida's total land area, and FLWC Opportunity lands 23%, we assessed the impact on imperiled species against those benchmarks. Where benefits exceed 50%, we inferred that the FLWC lands are spatially configured in a way that creates disproportionately large benefits.

Methods

We used the raster layers made publicly available from a published manuscript (Hamilton et al. 2022). Three data layers were obtained from the ArcGIS Living Atlas of the World (https://livingatlas.arcgis.com/en/browse/#d=2&q=mobi%20natureserve). We focused on raster representations of local imperiled species richness for vertebrates, aquatic invertebrates, and plants. In the published manuscript, the authors principally focused on range-size rarity maps and protection-weighted range size rarity to identify regions where imperiled species are currently poorly protected. Protection-weighting, in particular, identifies regions where imperiled species may be present, exist over narrow local ranges, and are poorly protected by conservation lands (e.g., state parks, military bases). However, the protection status maps used in Hamilton et al. (2022) were poorly aligned with existing conservation lands in Florida, necessitating our focus on imperiled species without protection-weighting. Furthermore, although range-size rarity is an important consideration for local conservation decision-making because it identifies individual species that exist over narrow geographic ranges and therefore require additional conservation attention, our analysis was aggregated across species. Since the footprint of the FLWC has been established, and our focus was on conservation of regions of Florida with high numbers of imperiled species, we focused on imperiled species richness maps as a measure of the benefits of the FLWC.

Raster layers for each taxonomic group list the number of imperiled species in each of the 146,660 cells that are mapped within the boundary of Florida. From the original citation (Hamilton et al. 2022), a species is included if it is listed as critically imperiled or imperiled on global conservation status ranks (Faber-Langendoen et al. 2012) or listed at the species-level under the US Endangered Species Act. The richness for these species across Florida ranges from zero to as high as 17 for plants, 11 for aquatic invertebrates, and 10 for vertebrates. For each taxonomic group, we summarized the proportion of cells at each level of imperiled species within each of the four land conservation classes (Other Conserved, FLWC Conserved, FLWC Opportunity, Not Conserved). We also report the number of cells for each level of imperiled species richness across the state.

To evaluate the benefits of the FLWC in relationship to lands with high imperiled species richness, we further summarized the impacts of both FLWC Conserved and FLWC Opportunity lands benchmarked to their overall area. For categories of “no imperiled species” (richness = 0), “any imperiled species” (richness > 0), and “many imperiled species” (richness > 4), we computed the ratio of the proportion of pixels in each land category to the expected proportion given the statewide extent of each land category. For example, where FLWC Opportunity lands conserve more pixels with “many imperiled species” than would be expected given the spatial extent of the FLWC Opportunity, this ratio would be greater than 1. Likewise, for the category of “no imperiled species” we expected that existing conserved lands would exhibit ratios less than 1, indicating that locations with few imperiled species have not been target areas for conservation. Of particular interest for our analysis was the proportion of pixels with different imperiled species richness that would be conserved by the FLWC Opportunity lands if acquired. Were imperiled species protections the only criterion for FLWC design, we would expect those areas with high imperiled species richness to fall within the FLWC Opportunity designation. Given that these imperiled species richness maps were not directly part of the FLWC design, this exercise is principally an effort to evaluate how well the FLWC aligns with those parts of Florida deemed to be most important for imperiled species conservation.

Results and Discussion

The high-resolution maps of imperiled species across Florida reveal several key hot-spots for imperiled species. Notably, the spatial configuration of implied conservation needs varies dramatically across the three taxonomic groups: plants (Figure IX-1a), vertebrates (Figure IX-2a, which include fishes, amphibians, reptiles, mammals, and birds); and aquatic invertebrates (Figure IX-3a). For plants (Figure IX-1), most pixels in Florida have no or very few imperiled species, but some hot-spots have more than 10, with key locations including the Lake Wales Ridge, the Apalachicola Bluffs, the Pine Rocklands, and Jennings State Forest. For vertebrates (Figure IX-2), most of the state has some imperiled species (the most common value is 2 imperiled vertebrate species per pixel; Figure IX-2b), but the highest concentration of imperiled vertebrates is in Florida's Western Panhandle, the Lake Wales Ridge, the Ocala National Forest, and the west coast of the peninsula (Figure IX-2a). In contrast, more than 90% of the state has no imperiled aquatic invertebrate species, particularly in the southern part of the peninsula (Figure IX-3a). For those organisms, the river corridors of the Panhandle and Big Bend emerge as the clear conservation focus.

The spatial distribution of imperiled species creates a clear conservation objective, which in some cases is well met. For example, for imperiled plants, the current conservation lands (FLWC Conserved and Other Conserved) preferentially protect those areas with high richness of imperiled plants (Figure IX-1b), while conserving less of the land where few imperiled plants are found. Whereas this association is likely both cause and effect (i.e., imperiled plants motivate conservation, but also thrive on conservation lands), it suggests that statewide protection for imperiled plants is already relatively effective, particularly for those lands incorporated in the Wildlife Corridor (FLWC Conserved). However, this pattern is reversed for vertebrates (Figure IX-2b), with existing conservation lands doing a relatively less effective of imperiled species protection, particularly for those locations with high richness of imperiled vertebrates. However, we note that the vertebrates included vary from small-bodied amphibians and fishes to large mammals and avifauna, rendering the spatial importance of an individual 0.62x0.62 mi (1x1 km) pixel uneven across species with respect to local conservation value. Specifically, the value of connected conservation corridors are likely to be far greater for species with large home-ranges than for those that are small or sessile. For aquatic invertebrates (Figure IX-3b), the pattern of imperiled species protections is more mixed, with existing conservation lands protecting many locations with 5 and 6 imperiled species, but few that are predicted to contain 3 or 4.

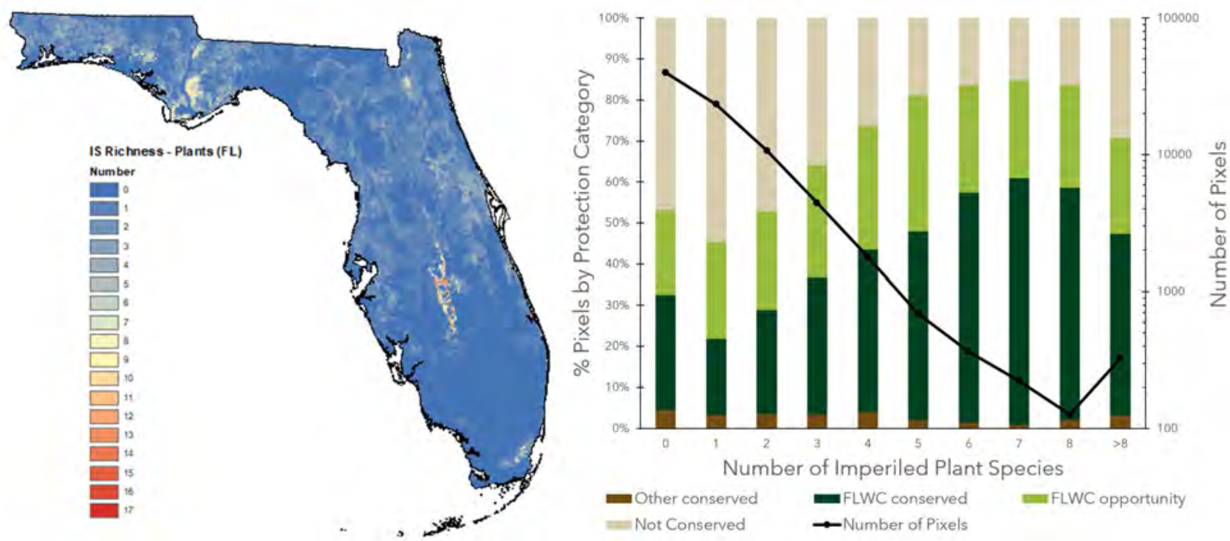

Figure IX-1a. Spatial distribution of imperiled plant species across Florida. b) The number of pixels for each imperiled species count (black line) and the proportion of those pixels in the four land categories.

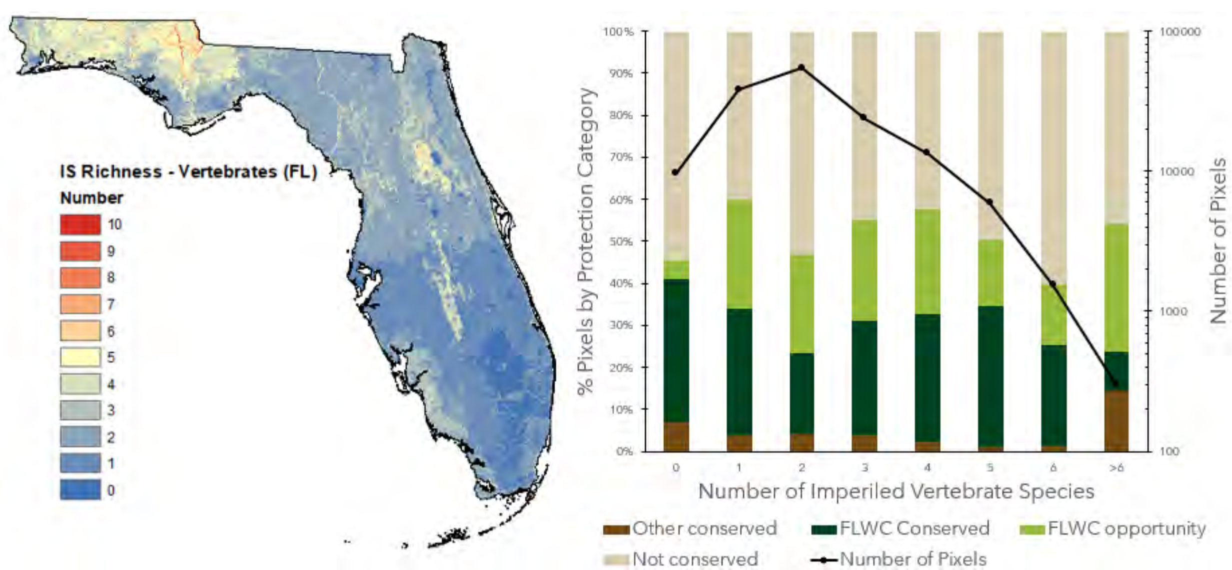

Figure IX-2a. Spatial distribution of imperiled vertebrate species across Florida. b) The number of pixels for each imperiled species count (black line) and the proportion of those pixels in the four land categories.

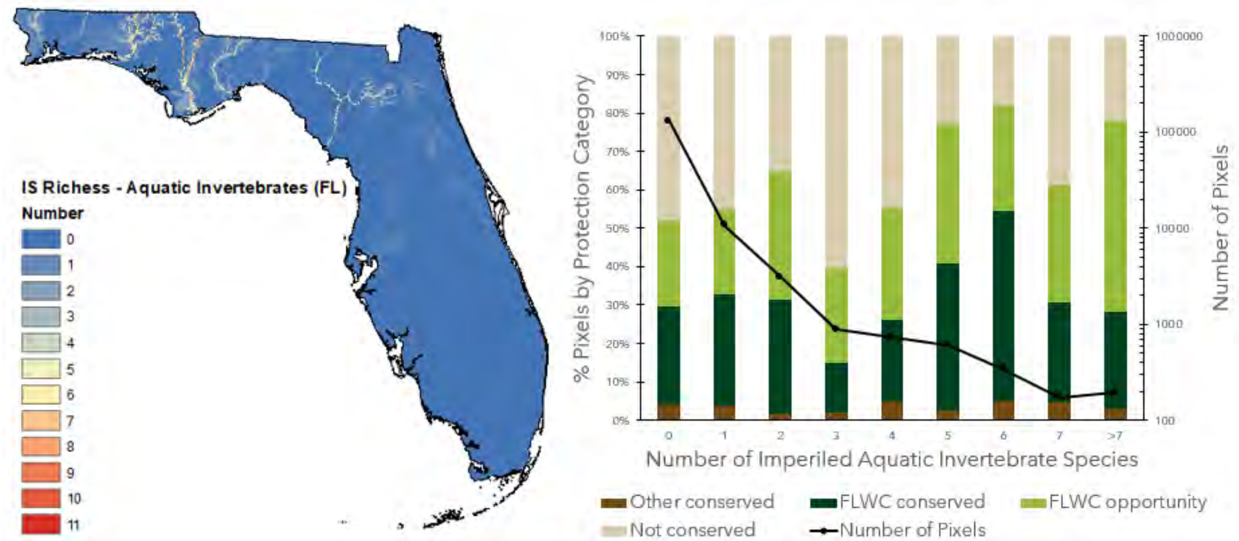

Figure IX-3a. Spatial distribution of imperiled aquatic invertebrate species across Florida. b) The number of pixels for each imperiled species count (black line) and the proportion of those pixels in the four land categories.

Another way to visualize the spatial patterns of existing FLWC Conserved lands (and later the FLWC Opportunity lands) is to reference the degree to which they overrepresent sites with high richness of imperiled species and underrepresent sites with few imperiled species. We note, again, that this specific spatial analysis of imperiled species was not a criterion for FLWC development, though other rare species and habitats were considered, making this analysis retrospective, albeit potentially useful. Ideally, existing conservation lands of the FLWC would overrepresent locations with high richness and underrepresent lands with few imperiled species; we define over- and underrepresentation based on the spatial proportion of FLWC Conserved lands in comparison with the spatial proportion of locations with high or low imperiled species. For each of three imperiled species richness categories (none, few, and many) and for each taxonomic group (vertebrates, aquatic invertebrates, plants), we computed the ratio of the proportion of pixels in each category (none, few, many) to the total proportion of pixels in the FLWC Conserved lands. Values greater than 1 indicate the FLWC Conserved lands overrepresent that category, and values less than 1 indicate underrepresentation. For example, if the proportion of pixels with many imperiled species protected by the FLWC Conserved lands is larger than the proportion of total pixels in the FLWC Conserved lands, the value of this "benefit ratio" will be greater than 1. For the category "none," we optimally expect values less than 1 (underrepresenting these low imperiled species richness lands) and for the category "many," we expect a value greater than 1, indicating these high richness pixels are preferentially selected. For the FLWC Conserved lands, the patterns are mixed (Figure IX-4), with clear evidence that the FLWC Conserved lands preferentially include locations with numerous imperiled plants but offer less dramatic preferential protections for other categories of imperiled species. Indeed, for vertebrates, the FLWC Conserved lands appear to overrepresent settings where no imperiled species are predicted to be found. We note, however, that the presence of corridors may enable dispersal into novel locations outside the existing core range, and that the current core range may change with changing climatic conditions.

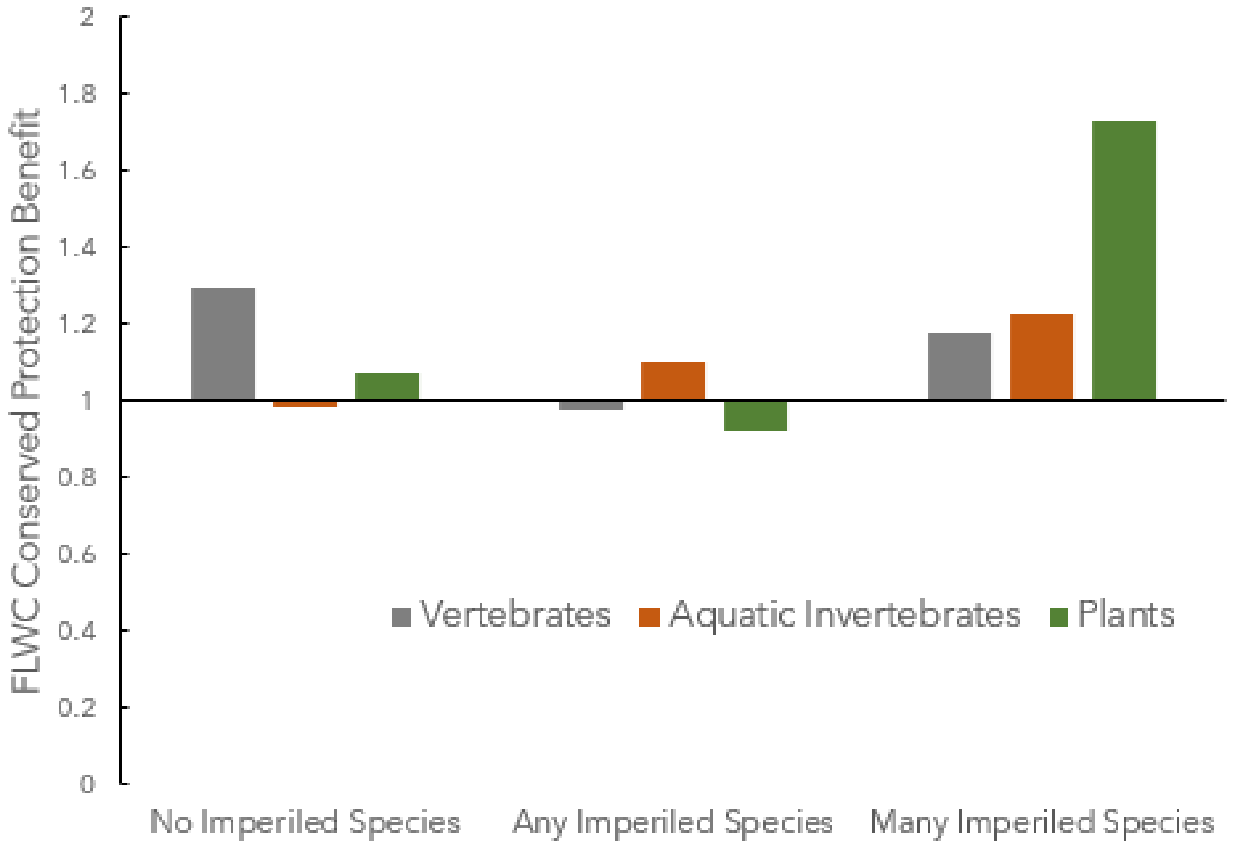

Figure IX-4. Relative benefit of FLWC Conserved lands for imperiled species across three taxonomic classes. Values of 1 indicate that the FLWC Conserved lands are protecting imperiled species at the expected rate given a random allocation of lands. Values greater than one indicate that FLWC Conserved lands do better than a random allocation for protecting imperiled species. The existing FLWC Conserved lands preferentially protect imperiled species only for locations where many imperiled species are present, and principally for plants.

This uneven pattern in protection derived from existing FLWC Conserved lands for imperiled species richness across taxonomic groups is somewhat reversed when we consider the impacts of the FLWC Opportunity areas. Across Figures IX-1b, 2b, and 3b, it is clear that, if acquired, the FLWC Opportunity lands would benefit locations with abundant imperiled species across all taxonomic groups, and further appear to avoid prioritizing regions where imperiled species richness is low (e.g., for plants Figure IX-1b and vertebrates Figure IX-2b). Given that the FLWC

Opportunity lands occupy 23% of Florida, there is clear evidence of preferential benefit (i.e., greater than 25% of the area) for regions with numerous imperiled vertebrates (Figure IX-2b) and aquatic invertebrates (Figure IX-3b). Moreover, the FLWC Opportunity lands include 20% or more of the areas of Florida with imperiled plants. The Opportunity lands are strongly preferentially situated to benefit imperiled species, particularly those locations with many imperiled species, and avoid inclusion of lands that without imperiled species. This is particularly true for plants and aquatic invertebrates (Figure IX-5). The specific protections for aquatic invertebrates, which arises from the protections of river corridors in the Big Bend and Panhandle areas of Florida, is of particular relevance as an impact of the FLWC on aquatic ecosystems.

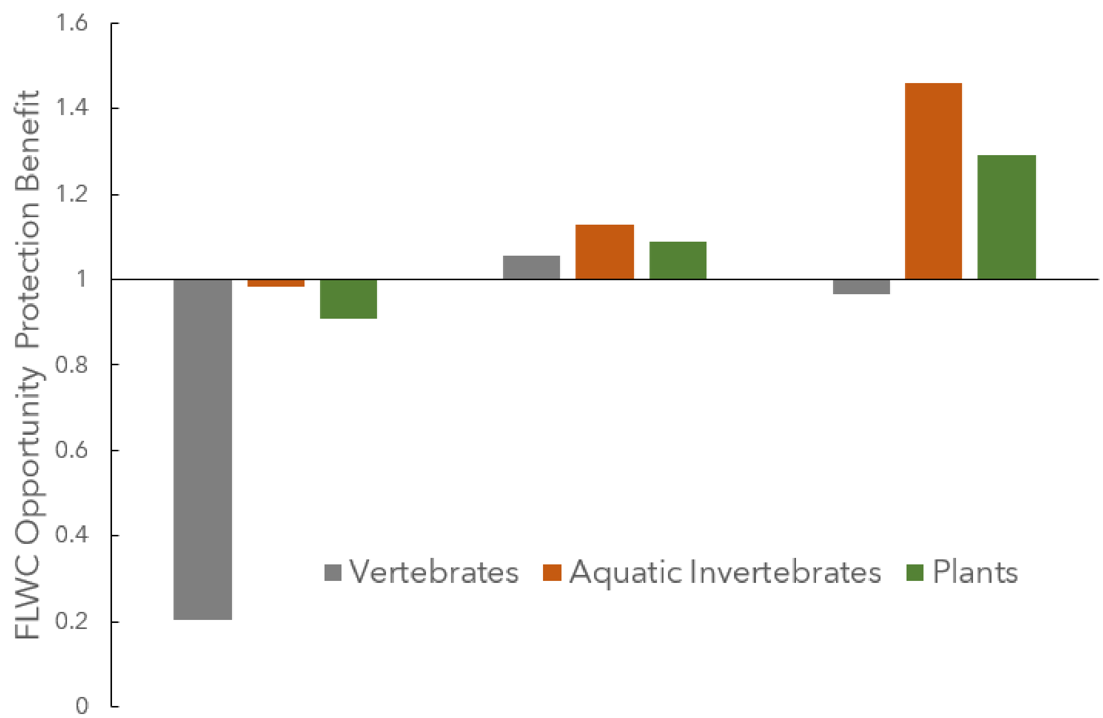

Figure IX-5. Relative benefit of FLWC Opportunity lands, if acquired, for imperiled species across three taxonomic classes. Values of 1 indicate that the FLWC Opportunity lands would protect imperiled species at the expected rate, given a random allocation of lands. Values greater than one indicate that the FLWC Opportunity lands if acquired do better than a random allocation for protecting imperiled species. The Opportunity lands are strongly preferentially situated to benefit imperiled species, particularly those locations with many imperiled species, and avoid inclusion of lands that without imperiled species. This is particularly true for aquatic invertebrates.

Finally, we note that the FLWC Opportunity lands, which occupy 23% of Florida, can play a disproportionate role in protecting lands that are currently unprotected, but may harbor high richness of imperiled species. The proportional contribution to conservation from FLWC Opportunity lands appears to be strongly related with the richness of imperiled species across all three taxonomic groups (Figure IX-6). That is, the design of the FLWC Opportunity lands appears remarkably well crafted to preserve the biological diversity of Florida, and protect species imperiled by habitat loss, invasive species, and climate change.

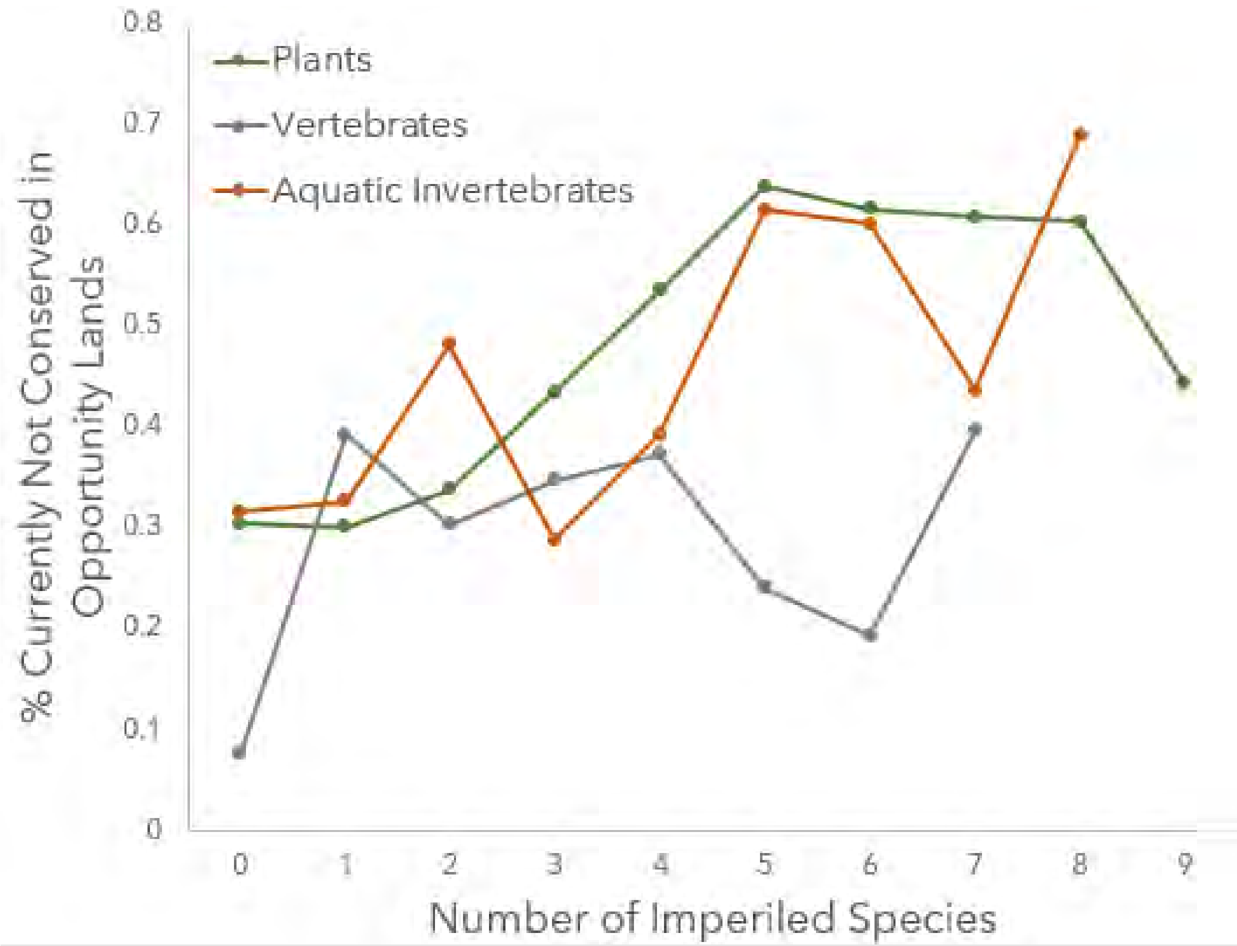

Figure IX-6. As the number of imperiled species increases (x-axis) across all three taxonomic groups, the proportional benefit of the FLWC Opportunity lands (y-axis) increases. This suggests that the FLWC Opportunity lands are well designed to improve conservation of imperiled species.

Conclusions

Imperiled species are one of the critical conservation challenges. Maps of imperiled species richness help focus the benefits of ambitious conservation initiatives like the Florida Wildlife Corridor. The recent development of detailed maps of imperiled species richness, aligned with the spatial configuration of the Florida Wildlife Corridor (existing Conserved lands and Opportunity lands), suggests that the FLWC can benefit imperiled species. Whereas this varies across taxonomic groups, with imperiled plants especially well protected, and imperiled vertebrates less well protected, the benefit of the FLWC Opportunity lands for all imperiled species was uniformly high.

Despite the overall protections that the FLWC Conserved and Opportunity lands (if acquired) provide, the analysis also revealed areas where future protections may need to be focused. Hot spots of plant diversity include the Lake Wales Ridge, the Pine Rocklands, Jennings State Forest, and the Apalachicola Bluffs. For vertebrates, the priority locations are the Lake Wales Ridge, the Ocala National Forest, and the western Panhandle. For imperiled aquatic invertebrates, hot spots include the river valleys of the Suwannee, Apalachicola, Ochlocknee, and Choctawhatchee Rivers. These areas are unevenly included within the FLWC, suggesting that an additional conservation framework may be needed.

The value of the FLWC Opportunity lands for imperiled species was particularly clear and notable. If acquired, the FLWC Opportunity lands appear well designed to preferentially protect locations with high richness of imperiled species across all three taxonomic groups and offer a crucial counterforce to the threats to these imperiled species from habitat loss, invasive species, and climate change.

X. Conclusions

Using existing knowledge and data we conducted analyses for this report to provide a high-level synthesis of the potential water benefits of the Florida Wildlife Corridor. We reported state-wide, population-level statistics for the following potential water benefits:

- Protection of groundwater and surface water quality and quantity for humans, ecosystems, and species.
- Protection of aquatic ecosystem services including aquatic habitat, recreation and cultural values, and flood and sea level rise protection (as appropriate) provided by springs, lakes, wetlands, rivers, and estuaries.
- Protection of imperiled species.

Overall, we found that prioritizing land conservation within the proposed boundaries of the FLWC would provide significant benefits for Florida's water resources. These results demonstrate the potential to achieve multiple ecosystem benefits through land conservation; this multi-objective approach can serve as a model for land conservation efforts beyond Florida.

Our analyses showed that conserving existing FLWC Conservation lands together with all Opportunity lands would provide good-to-excellent statewide benefits for spring vents, freshwater wetlands (both swamps and marshes), flowing rivers/streams, river watersheds, and estuarine wetlands. Low-to-moderate statewide benefits would accrue for surface water quality and supply; groundwater quality, recharge, and supply; waterbody Minimum Flows and Levels and reservations; springsheds; lakes; coastlines; and fragile coastal uplands. This report did not address FLWC benefits for individual springs, lakes, wetlands, rivers, estuaries, or specific water supplies for humans.

Of the water-related benefits specified in the 2021 Florida Wildlife Corridor Act, we determined that the Florida Wildlife Corridor (including existing Conserved lands and all Opportunity lands) would provide benefits to Florida's major river watersheds such as the headwaters of the Everglades and the St. Johns River; estuarine, marsh, and swamp wetlands that provide flooding and sea-level rise resiliency; and rivers, streams, and wetlands that are vital to wildlife and downstream estuaries. We found that the FLWC is less beneficial for protecting the state's groundwater recharge and drinking water supply. In general, groundwater quality and supply protection for wells in all aquifers throughout the state would be best protected by conserving the high-priority recharge areas and vulnerable aquifer areas which are under-represented in the current Florida Wildlife Corridor.

Next Steps

Assessing the statewide water resource benefits of the Florida Wildlife Corridor required several assumptions, particularly regarding the relationship between our metrics and the accrual of water-related ecosystem services. In addition, we found few existing studies or data that analyzed the benefits of land connectivity for water resources. Recommendations for next steps to address these limitations are included below.

1) Improving estimation of water benefits of the FLWC

Our assumptions underlying the water benefit metrics assessed in this report are generally well-supported based on existing data and studies (EPA 2022). However, determining the precise benefit that particular land conservation efforts would provide to specific water bodies or water supply locations will require monitoring and modeling studies to refine the metrics and accurately assess the resource-specific benefits. Maintaining and enhancing Florida Department of Environmental Regulation and Florida Water Management Districts' long-term monitoring of water quality, quantity, and aquatic ecology will be essential to the success of these efforts. Examples of potential future studies to improve estimation of water benefits of the FLWC include:

- Hydrologic-ecologic monitoring and/or modeling studies to better define surface and subsurface water and solute fluxes, flowpaths, and travel times from FLWC lands to specific resources such as springs, rivers, lakes, wetlands and estuaries, and to test assumptions regarding drivers and impacts of changes in these fluxes on receiving aquatic ecosystems.
- Leveraging existing, or undertaking new, hydrologic modeling studies to better define contributing areas to specific water supply wells and surface withdrawal points of interest, e.g., MODFLOW/MODPATH models for water supply wells and HSPF, SWAT or more complex coupled surface-groundwater models for surface withdrawals.
- Monitoring and modeling studies to test assumptions that lake water quality, along with lacustrine biodiversity and lake function, are maximized under conditions where riparian vegetation buffers are protected by surrounding conserved lands.
- Analysis of the relative importance of conserving river length and riparian corridor width versus river watershed area for hydrologic benefit.

2) Improving understanding of the effect of alternative land and water management systems on FLWC water benefits

The water resource benefits of the FLWC will depend on how conserved lands are managed. Conservation easements that encourage land management practices that increase water yield (surface flows and groundwater recharge), increase local storage of surface waters, reduce nutrient losses to ground and surface waters, increase nutrient attenuation in wetlands and riparian corridors, reduce water use, and reduce sediment losses should be considered for working lands within the FLWC. Additional studies are needed to better understand and quantify the impacts of FLWC land and water management in particular hydrogeologic settings for specific water benefits. Examples of potential studies include:

- Analysis of incremental improvement of water supply through FLWC Conservation Easements (CE) on working agricultural lands to better estimate how these CE terms may conserve water and improve water yield. This work would include silviculture, pasture/range lands, and actively irrigated agricultural properties, and utilize the Florida Statewide Agricultural Irrigation Demand (FSAID) geodatabase.
- Analysis of water constrained areas (see WMD water supply plans and statewide water plan) for ways to incrementally improve water availability through acquisition and management of FLWC lands.
- Development of a tool to estimate water yield for alternative forestry and ranchland management systems in the FLWC. The role of land management in modifying evapotranspiration (ET), and by extension water yield (i.e., rainfall minus ET, and thus all stream flow and aquifer recharge) is crucial for assessing the projected hydrological benefits of the FLWC, particularly considering that >75% of FLWC Opportunity lands are within current ranchlands and timberlands. Florida's hydroclimatic setting, wherein rainfall and ET are closely balanced, means small relative changes in ET can have substantial effects on the magnitude of runoff (McLaughlin et al. 2013). More recently Acharya et al. (2022) linked forest leaf area index reduction (e.g., via lower planting densities, forest thinnings or prescribed fire) to marked increases in water yield.

3) Quantifying the benefits of land connectivity for water resources

A specific charge to the panel was to consider the water resources benefits gained from a connected landscape beyond those from the total area conserved. In general, we agreed that benefits to surface watersheds and water bodies fed by overland flow systems are likely enhanced by connectivity between the conserved watershed land and the receiving water body. For example, large connected areas of undeveloped, naturally vegetated, surface watersheds allow surface runoff to move more slowly across the landscape resulting in reduced erosion, more infiltration to groundwater, and attenuated water and nutrient delivery to receiving surface water bodies such as lakes, wetlands, rivers, and estuaries. However, benefits to aquifers and waterbodies fed by groundwater are not as obviously enhanced by geographic connectivity of conservation lands. Examples of additional analyses needed to answer this question more completely include:

- A comprehensive literature review to synthesize the state of the science and determine next steps needed to better understand the benefits of land connectivity for water-related ecosystem services.
- An assessment of the importance of connectivity for sustaining ecological processes in river ecosystems. While the importance of lateral and longitudinal connectivity is widely recognized, connections between connectivity measures such as local or cumulative length of conserved channel shoreline and instream and riparian ecosystem processes are poorly understood (Jumani et al. 2022). Connectivity in river ecosystems is complicated by the variations inherent to the structure of drainage networks. Despite these complicating factors, research has also demonstrated the value of establishing linkages between connectivity measures and ecological processes (Perkin and Gido 2012, Jumani 2022). Research to quantify the value of longitudinal and lateral connectivity in Florida's river ecosystems, and to develop linkages with connectivity measures, represent important next steps to characterize the value of river corridor conservation in Florida.
- An assessment of the incremental impacts of land conservation for downstream estuaries. Upland drainage networks and terrestrial lands can impact the water quality of downstream estuaries, thereby impacting habitat and aquatic organisms. Through maintaining more natural land cover, conserved upland habitat should positively impact downstream estuaries. The impacts of incremental conservation and the amount of conserved land needed to ensure good water quality are not well understood. Future work should study the effects of terrestrial conservation on downstream systems.
- An assessment of the benefits of protecting connected wetlandscapes, not just individual wetlands. Throughout this report, we assume wetland functions accrue in proportion to area protected. However, a key benefit of connected large scale conservation is protection of complex landscape mosaics, or "wetlandscapes" that contain a diverse array of wetlands whose collective function, via landscape and hydrological interactions, is greater than their individual functions (Cohen et al. 2016). This arises because the functions of individual wetlands (e.g., habitat, water storage, C sequestration) interact with heterogeneous neighbor wetlands (varying in size, depth, and patterns of inundation and connectivity). Across Florida's wetlandscapes, overall landscape function (e.g., biodiversity support or C storage) arises both from the area and the variety of wetlands, making overarching protections of diverse landscape blocks favorable to piecemeal conservation. Improving the understanding and quantification of these integrated landscape functions is a key research frontier relevant to predicting water quality, water storage, and landscape C sequestration potential of the FLWC.

4) Maximizing water benefits through land conservation

- Development of a tool or platform that would allow users to select GIS layers of particular FLWC water benefit metrics and assign weights to each metric to determine which FLWC land areas achieve maximum aggregate benefit scores for desired water benefit outcomes. This platform could be integrated with other FLWC GIS analyses that assist in prioritization or screening of land acquisitions.
- An assessment of linkages of the FLWC to other conserved lands in bordering states (GA and AL) and the value of adding these areas to FLWC Opportunity lands to maximize water benefits as well as other conservation benefits through cross-state connections. Many of the FEGN Priority 4 and 5 areas already include these connections (e.g. the Nassau River watershed in northeast Florida and several areas in the northern portions of the panhandle).

5) Assessment of water benefits lost if FLWC Opportunity lands undergo development.

Urban development frequently has adverse impacts on water resources and aquatic ecosystems. If managed properly, land held in conservation can play an important role in sustaining ecosystem services that Floridians depend on for their wellbeing. While beyond the scope of this report, several quantitative tools and models could be used to develop a more detailed characterization of the benefits of Opportunity Areas targeted for conservation and the impacts that could occur if they were developed. Nutrient loads, groundwater recharge, stormwater runoff, and overall assessments of ecosystem services are all parameters that are commonly modeled to evaluate impacts of development. One novel aspect of such research relative to the FLWC has to do with the scale: characteristics such as relief, soil properties, climate, water resources, and plant communities vary considerably over the entire state, and thus the impacts of development could also be expected to vary as well. How these impacts vary, and why, could provide important insights on the relationship between of land conservation and water resources for future planning.

6) Analysis of climate and sea level rise resilience provided by the FLWC for all water resource benefits

These analyses would evaluate the potential benefits of land conservation for water-related resilience to climate change including green infrastructure/natural defenses in coastal and inland areas, mitigation of sea level rise (including salination of water supply), and coastal and inland flood storage and buffering (especially by living shorelines, wetlands/floodplains, and aquifer recharge potential). These analyses are not only important for the FLWC, but also for adjacent landowners and communities seeking to protect built infrastructure.

Appendix A: Analyses of Permitted Well and Surface Water Allocations by Water Management District

Background

General information for Florida's water supply is available from FDEP (2021), the most recent annual report available. Specific data for individual consumptive use permits (CUP) were collected from each of Florida's five water management districts (WMDs) and represents current (2022) information. Information utilized from these sources included CUP locations of withdrawal points (or permitted projects), primary water supply sources, permitted allocations (Million Gallons per Day, MGD) of surface water or groundwater primary sources, and water use type. Allocations are the average annual withdrawals (MGD) permitted at the end of permit. Actual water use is expected to be less, and in some cases, much less, dependent upon site-specific conditions and stage of permit. To simplify the groundwater analyses and focus on key source waters within or adjacent to the FLWC, groundwater analyses included combined data available for the Floridan Aquifer (upper Floridan, upper and lower Floridan (semi-confined, or undifferentiated)), the Sand and Gravel Aquifer (west FL Panhandle), and the Biscayne Aquifer (lower east peninsular FL). For some districts, individual permit allocations were provided by project total, not by individual locations. In these cases, withdrawal locations were mapped, and total project allocation was assumed to be equally distributed across the withdrawal locations. Surface water withdrawals may be from natural or constructed surface waters, but categories vary among water management districts. Thus, data for individual surface water categories were pooled. Water for power generation, frequently from surface water, is permitted for the entire withdrawal, although the potential impacts are derived from the water that is consumptively used (not directly returned to the waterbody after cooling, etc.) In these cases it was assumed that the consumptive use was approximately five percent of the allocation. Some permits, especially in agricultural or commercial/industrial use categories, may include conjunctive use, back-up allocations, and/or recycling of primary withdrawal water. Where possible to identify, these allocations were reduced to minimize redundancy while retaining locational information. Maps indicating the permitted water-use type were prepared and limited to Public Supply, Agriculture, Commercial/Industrial/Institutional and Mining/Dewatering, and Recreational/Landscape Irrigation. Power Generation was not mapped as a separate use because of consumptive use assumptions noted above and variations among water management districts. Domestic Self-Supply was not considered, as individual CUPs are not required.

Results

Northwest Florida Water Management District (NWFWMD)

Groundwater

The majority of the permitted groundwater allocations in NWFWMD are sourced from the Floridan Aquifer or the Sand and Gravel Aquifer (Figure A-1). Percentages from each of these sources across land categories are summarized in Figure A-2. Greater than 50% of the permitted allocations from both of these aquifers are in areas that are not conserved. However, the FLWC conserved lands already afford protection to approximately 21% and 7% of the groundwater allocations across the Floridan and Sand and Gravel aquifers, respectively.

Acquisition of FLWC opportunity land represents a potential to increase protection to 38% and 45%, respectively.

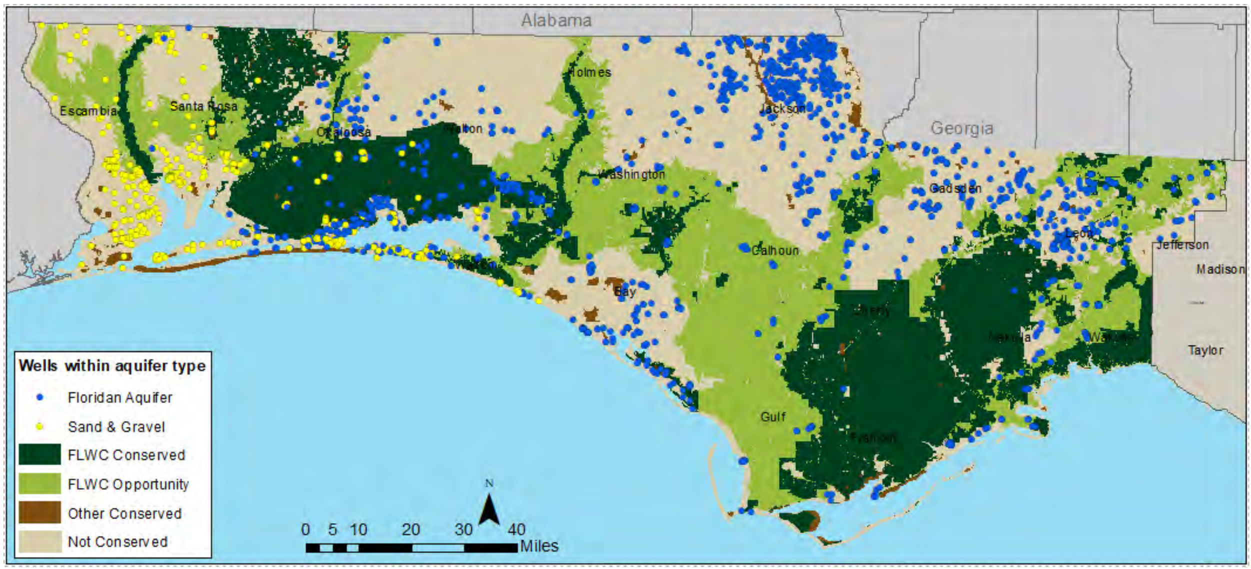

Figure A-1. NWFWMD permitted groundwater allocations by source and land category.

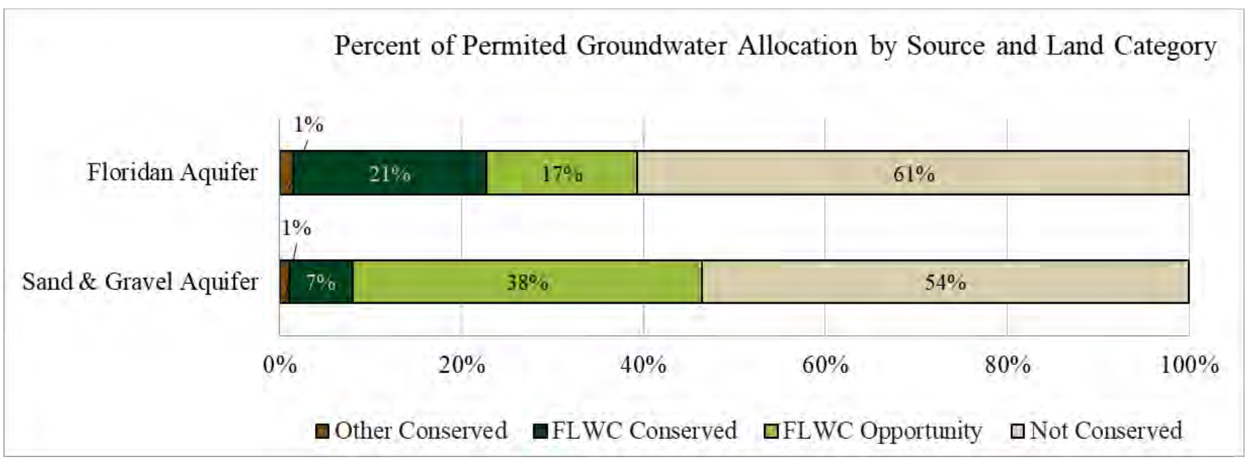

Figure A-2. NWFWMD percent of permitted groundwater allocation by source and land category.

Permitted groundwater withdrawal locations are shown by water-use type and land category in Figure A-3. Figure A-4 provides the percentage of total groundwater allocation from both aquifers in each of the four land categories. The largest groundwater-use type in NWFWMD is Public Supply, and while 42% falls on not conserved land, 17% is currently afforded protection by the FLWC conserved lands, with an additional 37% that could be protected by acquisition of FLWC opportunity lands. Commercial/Industrial permitted water consumption is approximately split between not conserved areas and FLWC opportunity land. In NWFWMD, less than 10% of permitted allocations for agriculture fall within FLWC conserved and opportunity lands.

Overall, 57% of the groundwater allocation from both aquifers is withdrawn from lands that are not conserved, and the FLWC (Conserved and Opportunity) together represent 42%.

Acquisition of FLWC Opportunity lands represents roughly two-thirds of this conservation opportunity.

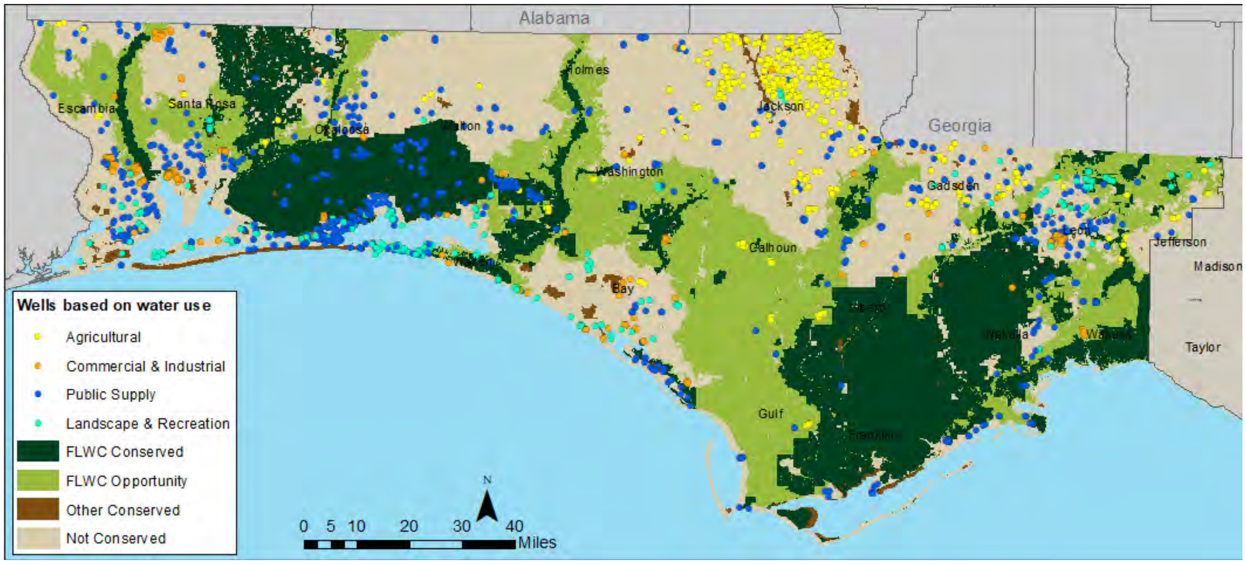

Figure A-3. NWFWMD permitted groundwater withdrawal locations by use type and land category.

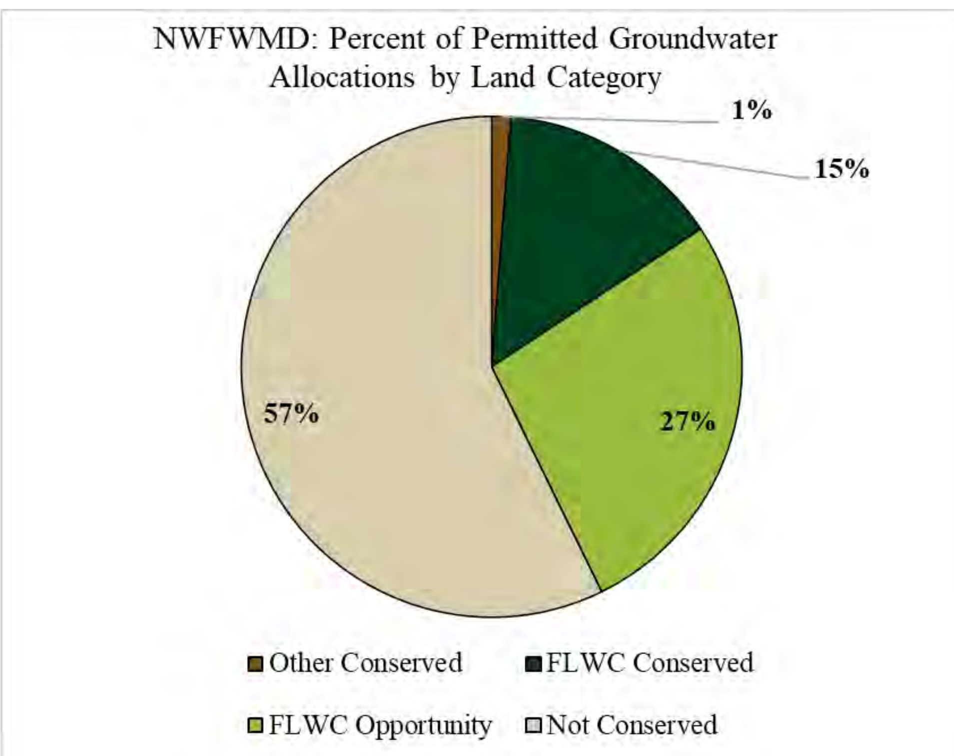

Figure A-4. NWFWMD percent of permitted groundwater allocations by land category.

Surface Water

Permits for withdrawals from surface water in NWFWMD are predominantly from river systems (Figure A-5). The vast majority (92%) of the locations of these permitted withdrawals allocations are on Not Conserved land (Figure A-6). However, FLWC Opportunity land acquisition could increase the percent of surface withdrawals located on conserved FLWC land from less than 1% to more than 6%.

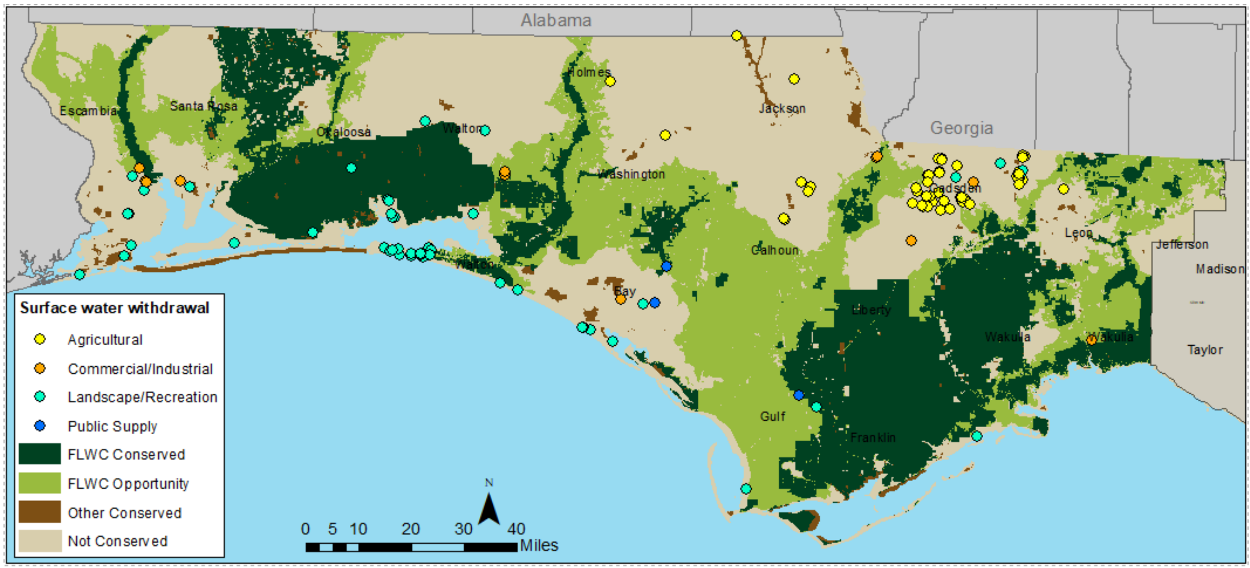

Figure A-5. NWFWMD permitted surface water withdrawal locations by land category and use type.

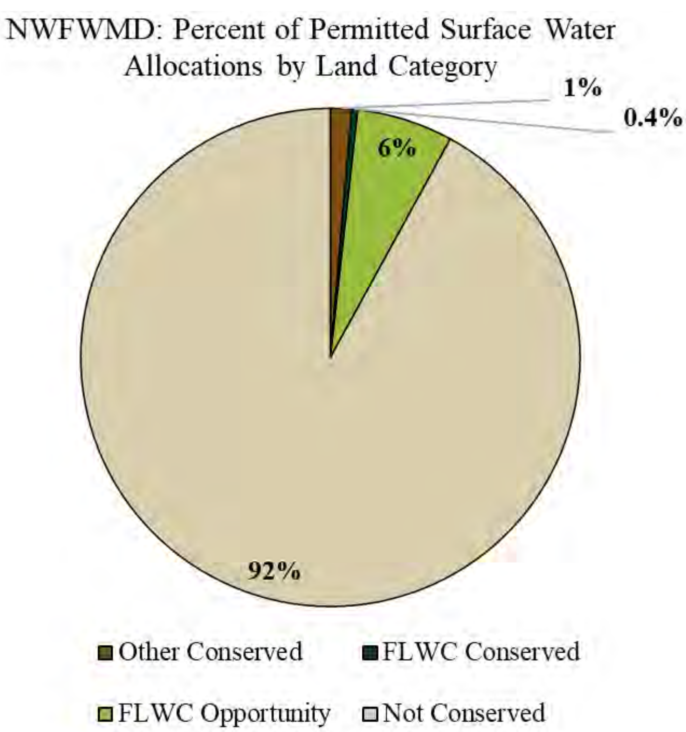

Figure A-6. NWFWMD percent of permitted surface water allocations by land category.

Suwannee River Water Management District (SRWMD)

Groundwater

The primary source of groundwater in SRWMD is the Floridan Aquifer. Water use is dominated by agriculture (Figure A-7). Regardless of use type, most withdrawals are not located within conservation lands, with more than 90% within Not Conserved lands (Figure A-8). Acquisition of FLWC Opportunity land, however, could increase current conservation from less than from 1% to more than 8%.

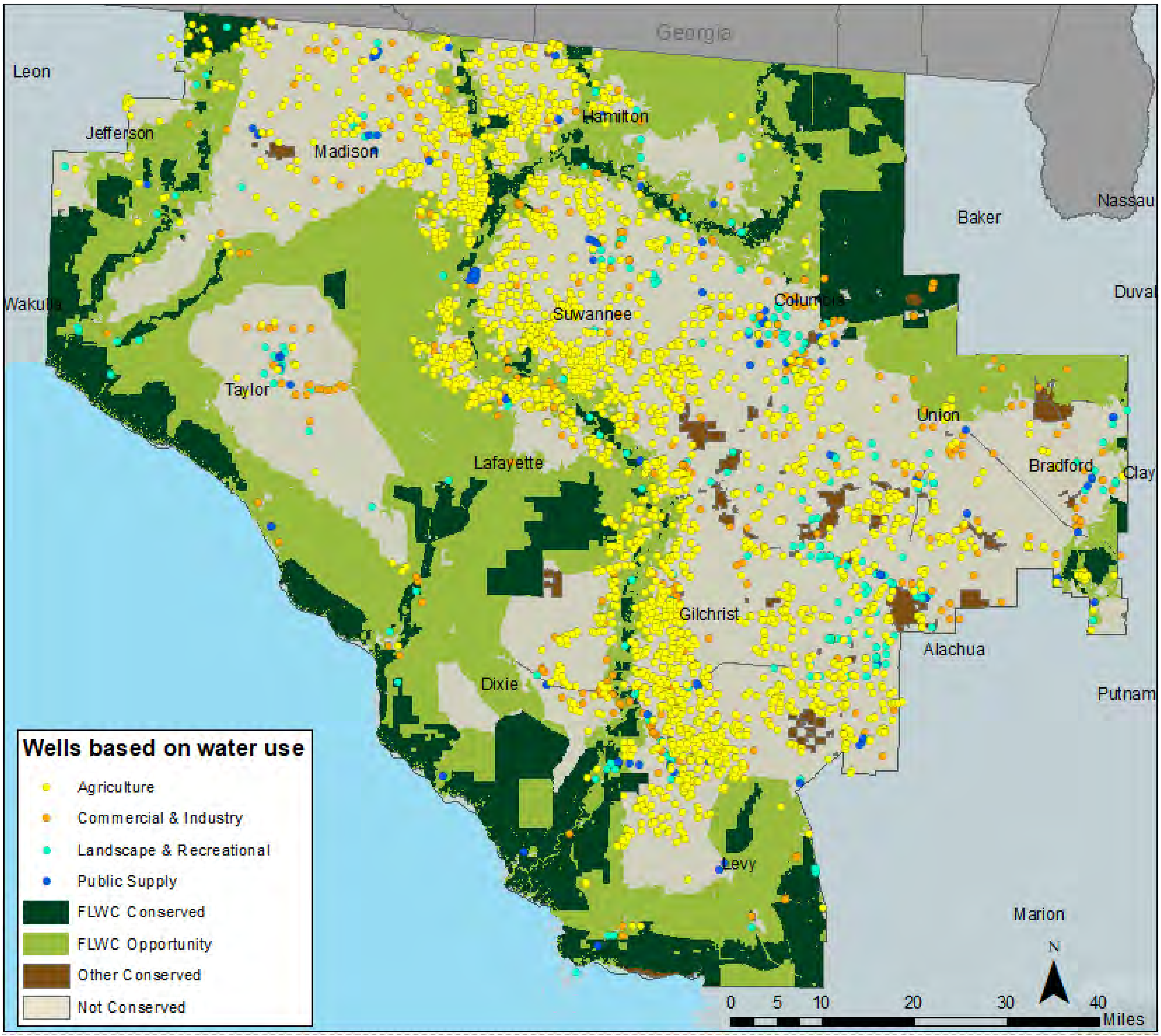

Figure A-7. SRWMD permitted groundwater allocation by land category and use type.

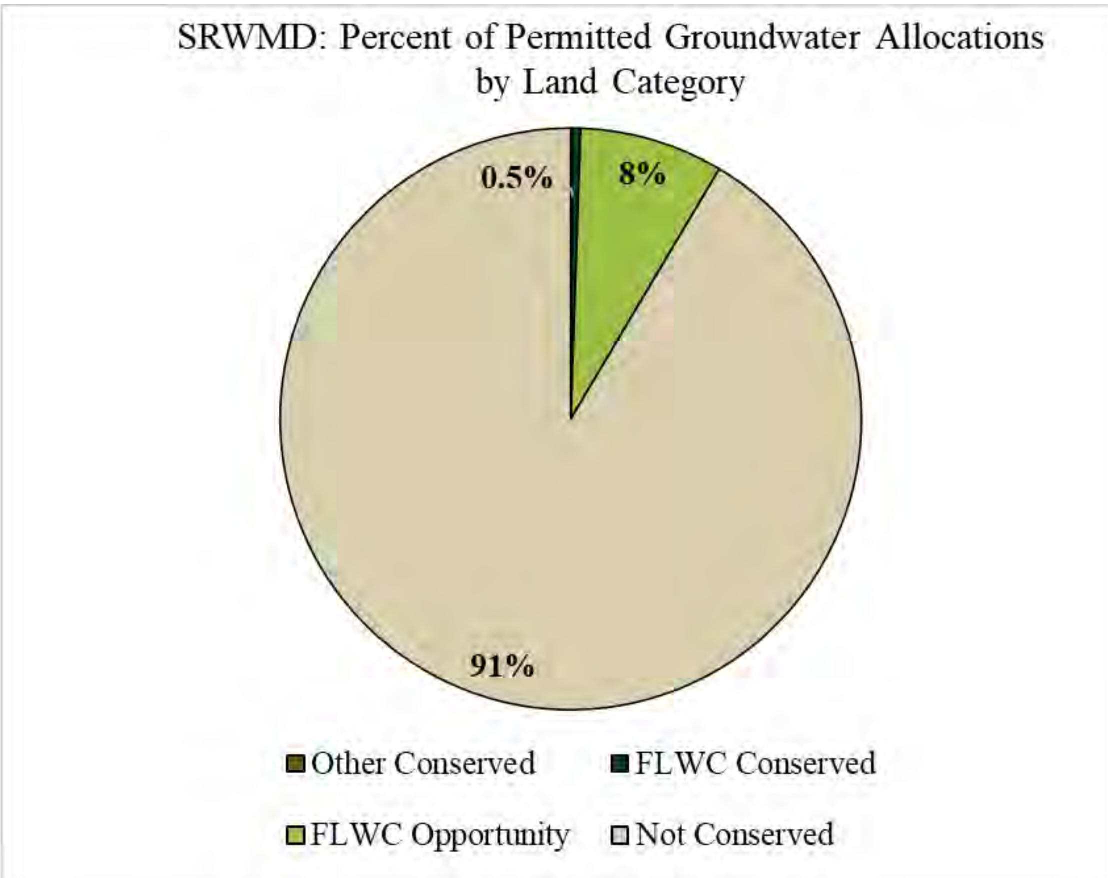

Figure A-8. SRWMD percent of permitted groundwater allocations by land category.

Surface Water

In SRWMD, Public Supply withdrawals are currently permitted only from groundwater. Agricultural withdrawals are also predominantly from groundwater (~70%), with a lesser amount (~30%) from surface water (Figure A-9). Approximately 15% of these agricultural allocations are within FLWC Opportunity Areas. A number of industrial (predominantly mining) uses are taken from surface water in SRWMD and combining these with the agricultural withdrawals brings the percentage in the FLWC Opportunity Area to 31% (Figure A-10).

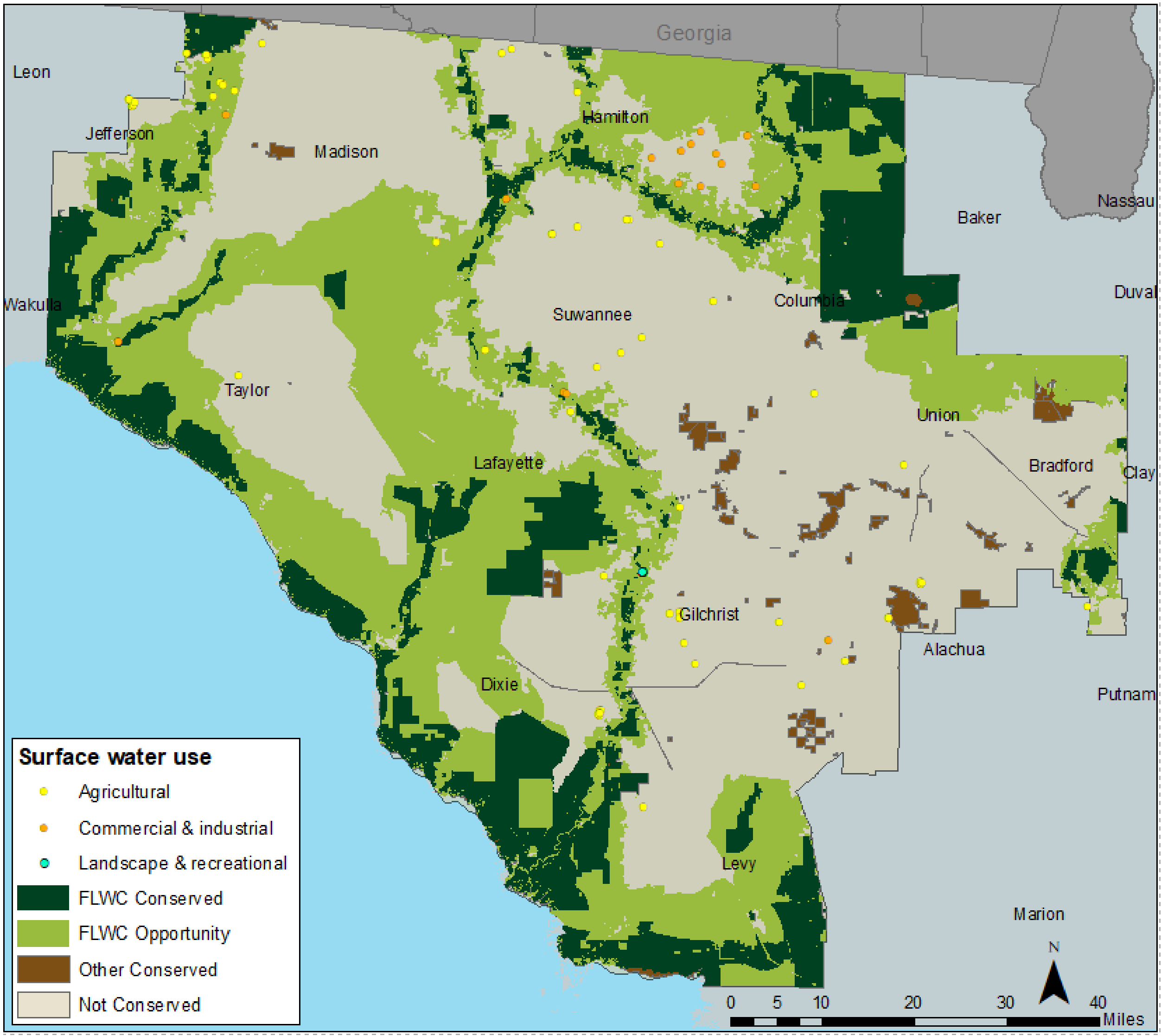

Figure A-9. SRWMD permitted surface water allocations by land category and use type.

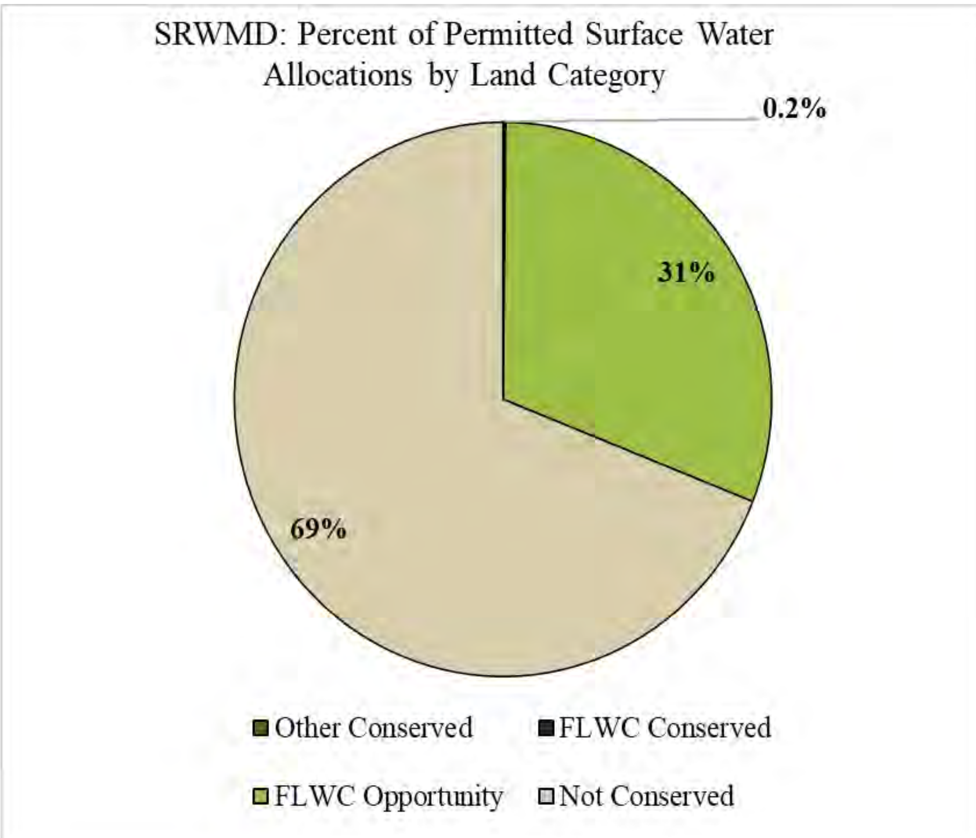

Figure A-10. SRWMD permitted surface water allocation by land category.

St. Johns River Water Management District (SJRWMD)

Groundwater

Permitted allocations of water in SJRWMD are primarily from groundwater. Public supply is more than half of the total permitted quantity, followed by agriculture at less than half the public supply amount. Throughout SJRWMD, and regardless of groundwater use type, the majority of the withdrawals (85%) are on lands that are Not Conserved (Figures A-11 and A-12). However, with the addition of all FLWC Opportunity lands, the total percentage of withdrawals on FLWC lands would increase from 3% to 13%. Agricultural wells are the majority of those that could be protected by the acquisition of FLWC Opportunity lands. There may be potential to reduce use from some agricultural wells through alternative land and water management options.

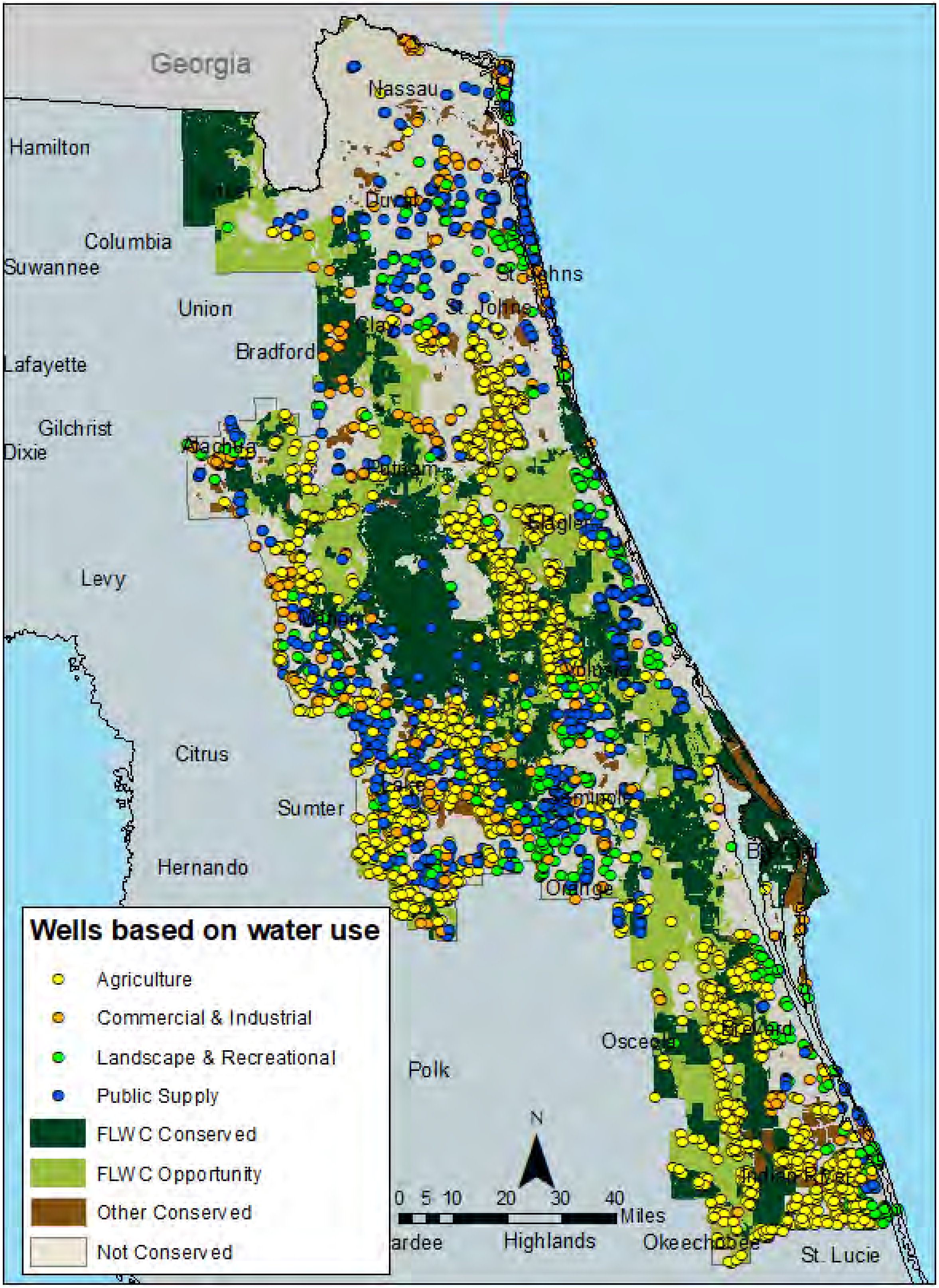

Figure A-11. SJRWMD permitted groundwater allocation by land category and use type.

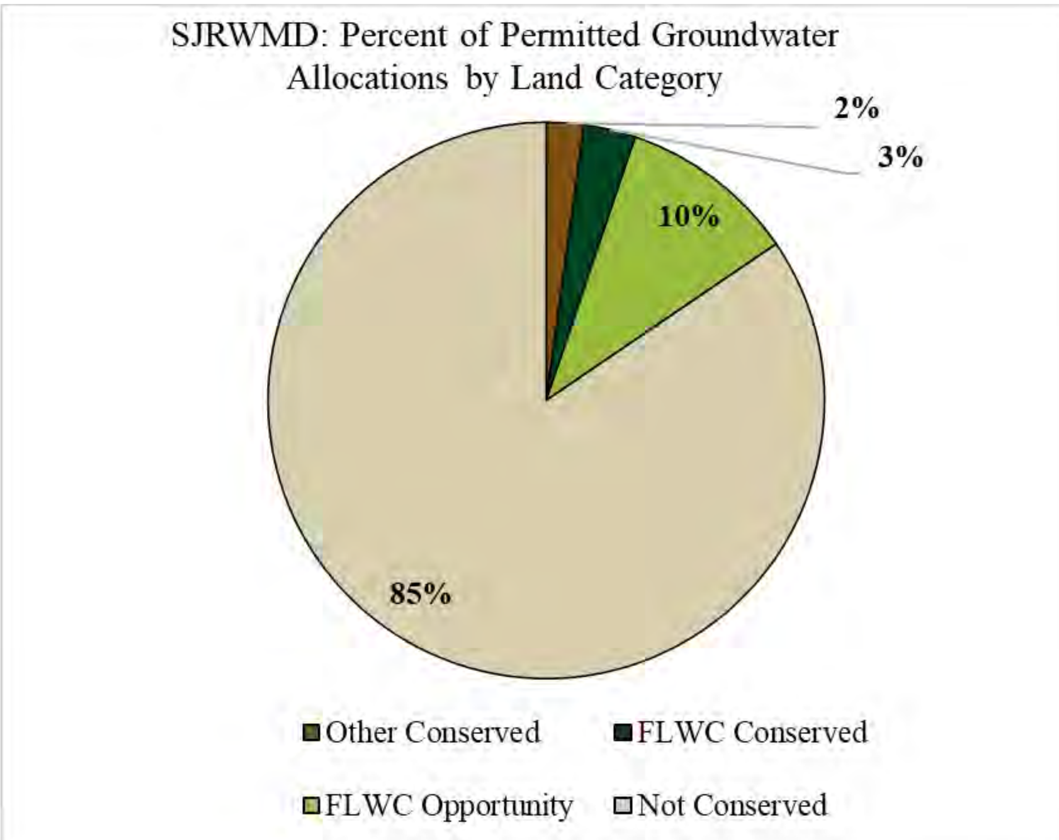

Figure A-12. SJRWMD percent of permitted groundwater allocations by land category.

Surface Water

In SJRWMD, although numerous surface water withdrawals are permitted, the water quantities are small compared to groundwater permits. Surface water withdrawal locations on FLWC Opportunity lands in the Upper and Middle St. Johns River Basin provide the best possibilities for conservation (Figures A-13 and A-14).

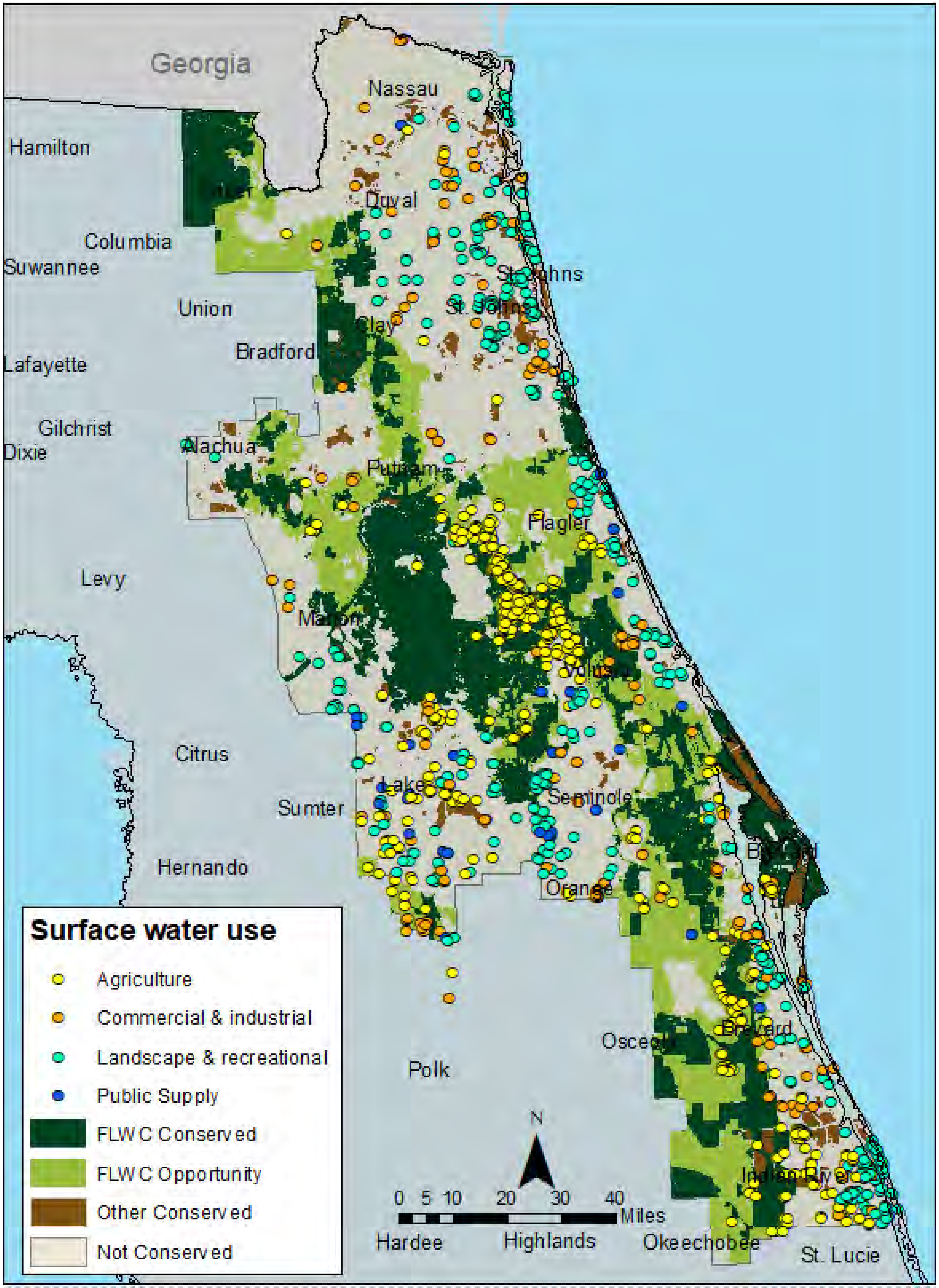

Figure A-13. SJRWMD permitted surface water allocation by land category and use type.

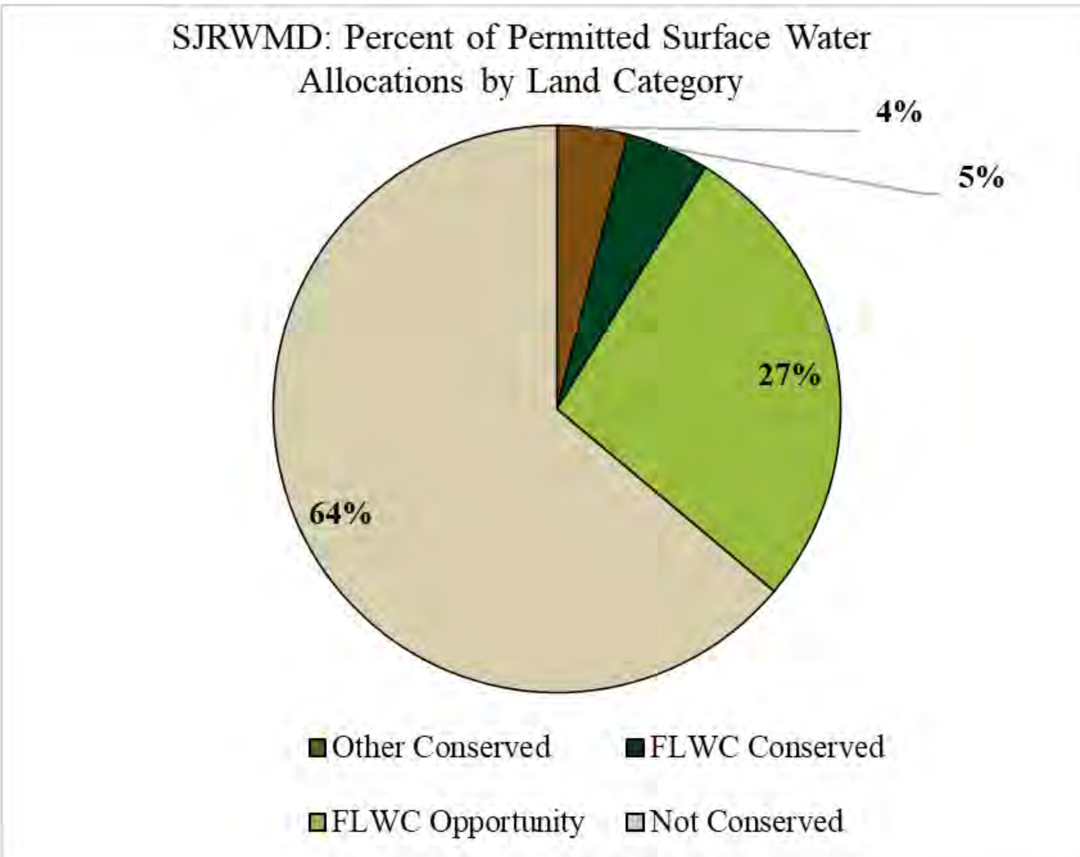

Figure A-14. SJRWMD percent of permitted surface water allocation by land category.

Southwest Florida Water Management District (SWFWMD)

Groundwater

Water supply allocations in SWFWMD are generally similar to those in SJRWMD. Figure A-15 shows the distribution of permitted groundwater withdrawals by water use type throughout the district. Agriculture is the largest use category, followed closely by water supply. Agricultural withdrawals represent the best opportunity for increased well protection and potential water use reduction on FLWC Opportunity lands. Figure A-16 provides the percentage of permitted groundwater allocations across the four land use categories. Overall, the percent of permitted groundwater allocations on FLWC Conserved and Opportunity lands could reach 20% if all opportunity lands were acquired.

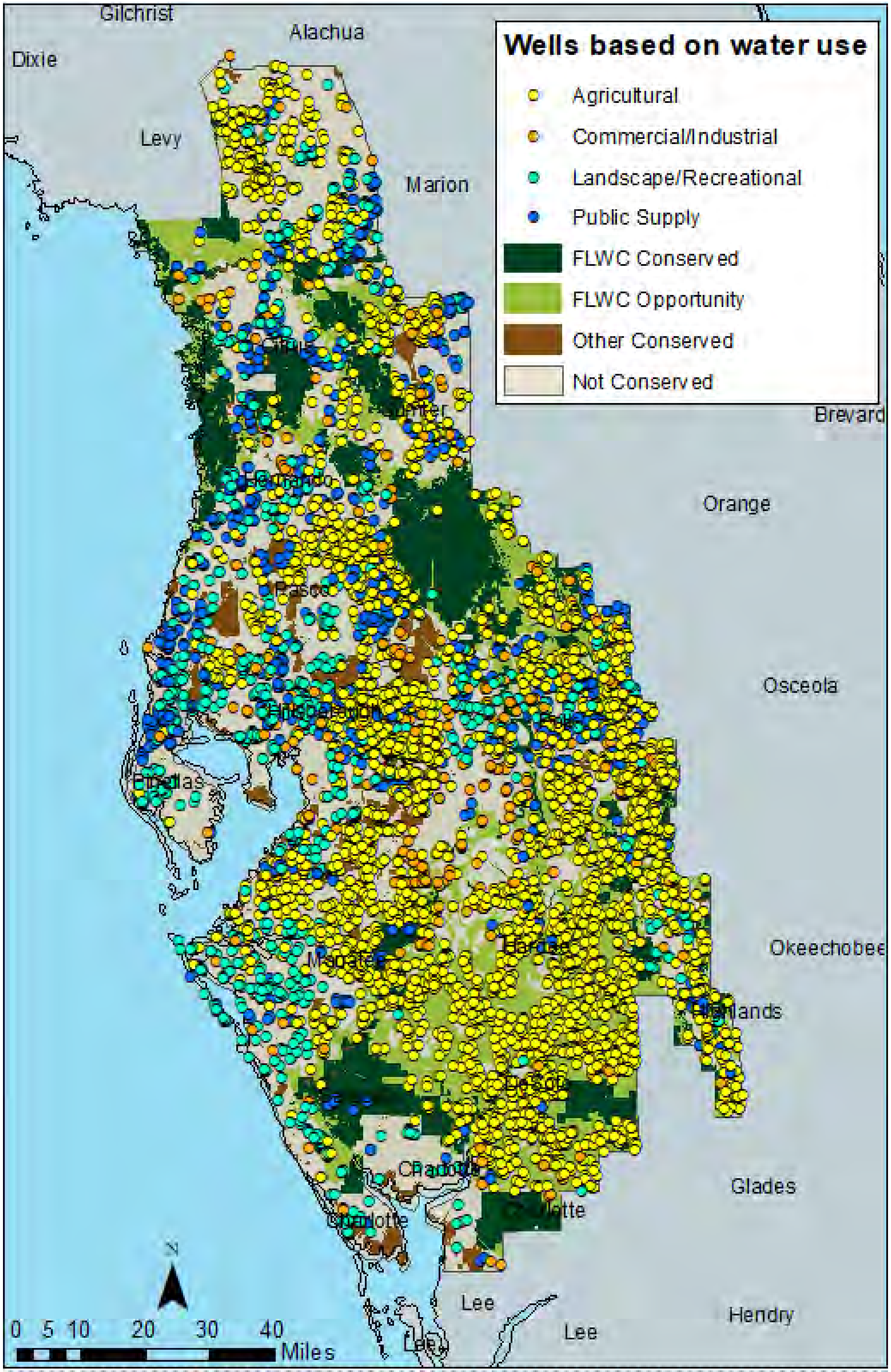

Figure A-15. SWFWMD permitted groundwater allocation by land category and use type.

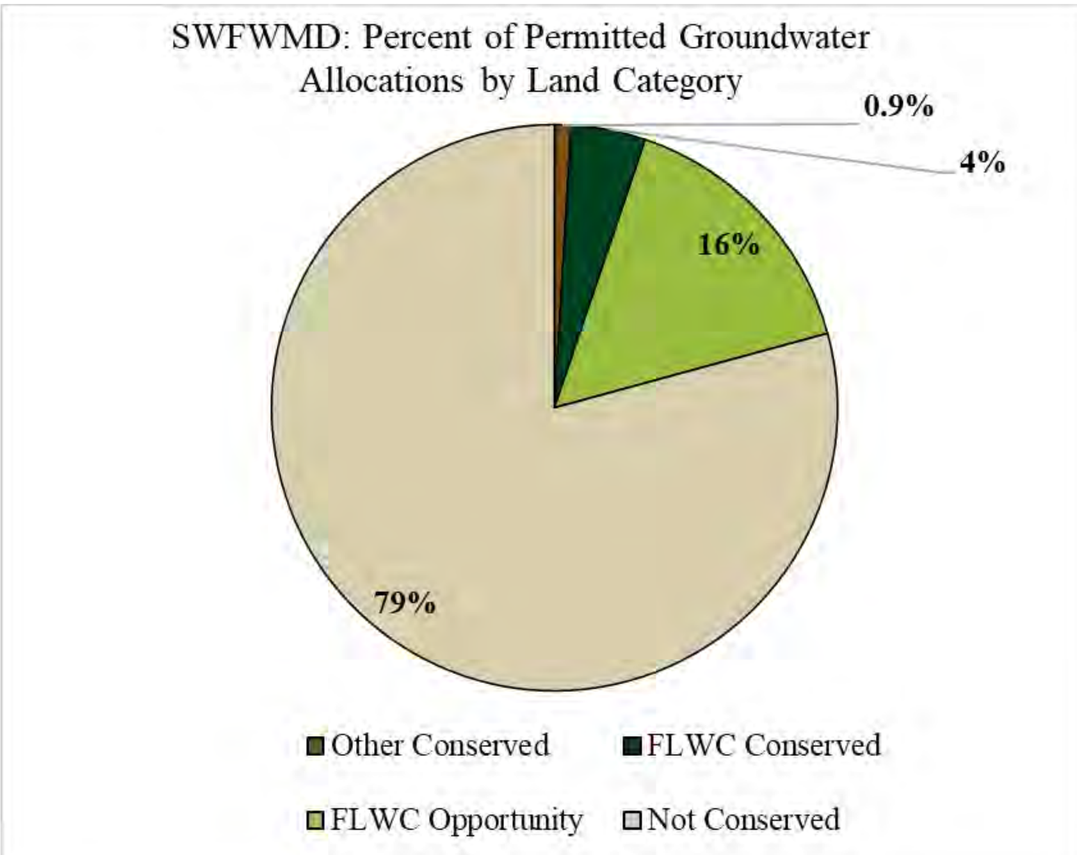

Figure A-16. SWFWMD percent of permitted groundwater allocations by land category.

Surface Water

In SWFWMD, a significant proportion (~90%) of the water withdrawn from surface water is for public water supply. Smaller permitted allocations are provided to the remaining use types. Few Public Supply withdrawal locations (0.4%) are found on existing FLWC conserved lands. Acquisition of all FLWC Opportunity lands would increase the surface water allocations located on FLWC lands to 11.4%. (Figures A-17 and A-18).

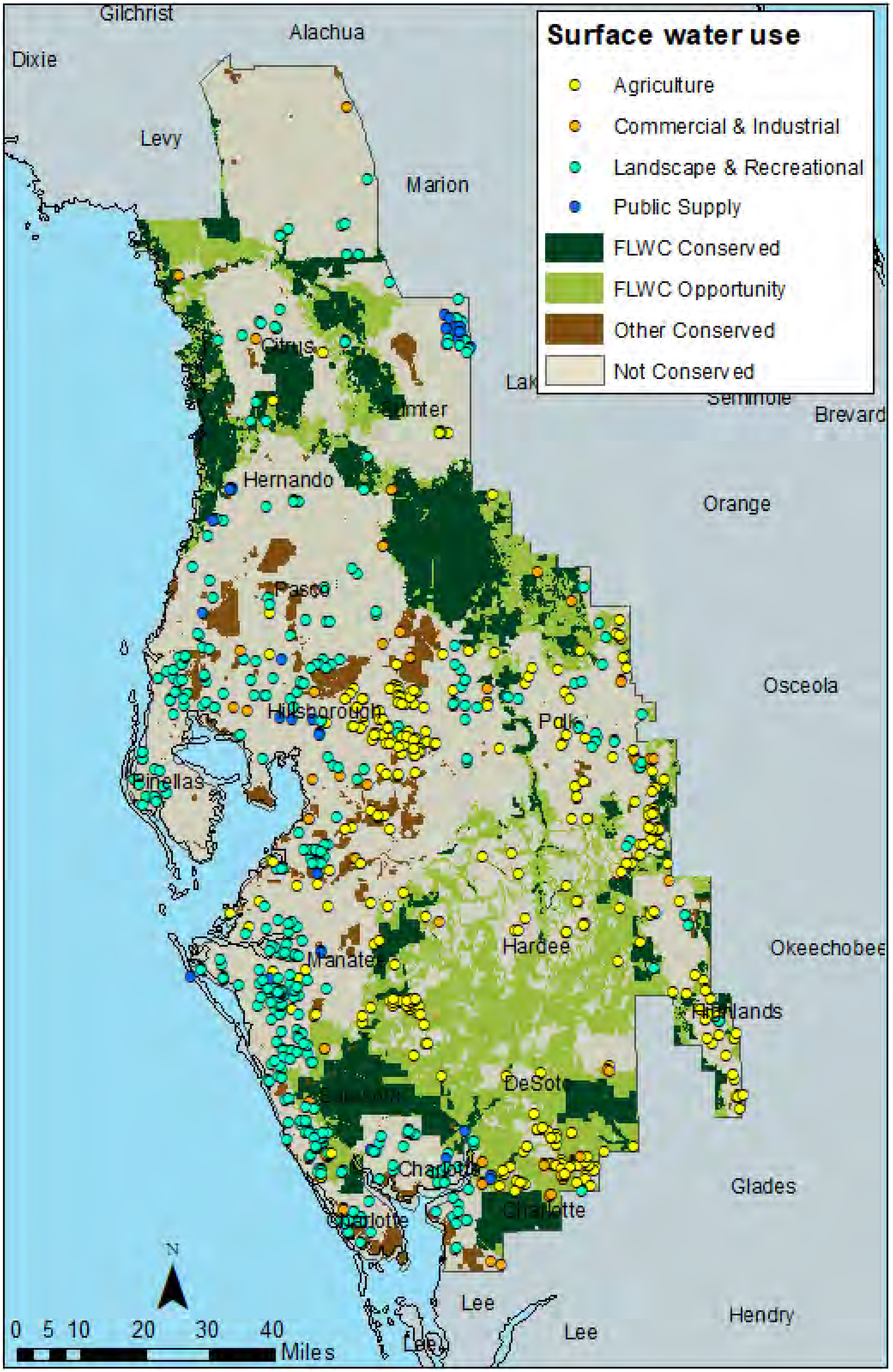

Figure A-17. SWFWMD permitted surface water allocation by land category and use type.

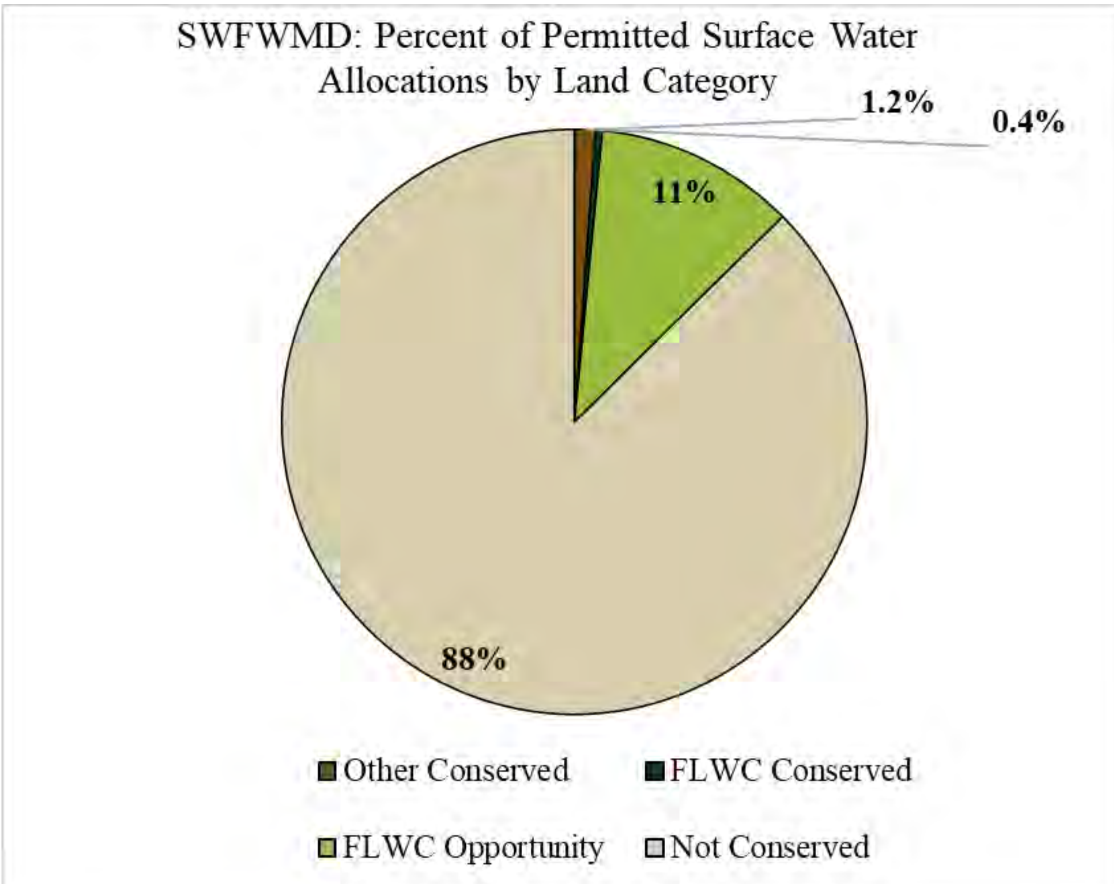

Figure A-18. SWFWMD percent of permitted surface water allocation by land category.

South Florida Water Management District (SFWMD)

Groundwater

SFWMD has the largest volume of permitted water allocations and the largest population. In this district, agriculture is the largest permitted use type. However, this district and NWFWMD permit allocations for more intense drought conditions than other WMDs, thus increasing the allocations. Two aquifers are dominant in SFWMD, the Biscayne Aquifer (primarily public supply along the southeast coast) and the Floridan Aquifer in the north (Figures A-19). More than 20% of the Floridan Aquifer withdrawals are already located on FLWC lands, and this number could reach >50% if all FLWC Opportunity Areas were acquired (Figure A-20).

District-wide 11% of permitted groundwater allocations are located in FLWC conserved lands, and an additional 14% are located in FLWC opportunity lands (Figure A-22). The vast majority of the wells in SFWMD Opportunity lands, however, are agricultural water supply wells in the deep, confined Floridan aquifer (Figure A-21). Thus, these wells are likely provided little protection by having overlying lands within the FLWC. Nevertheless, conservation easements on these properties would allow for the institution of land and water management options that continue farm operations while conserving water supply.

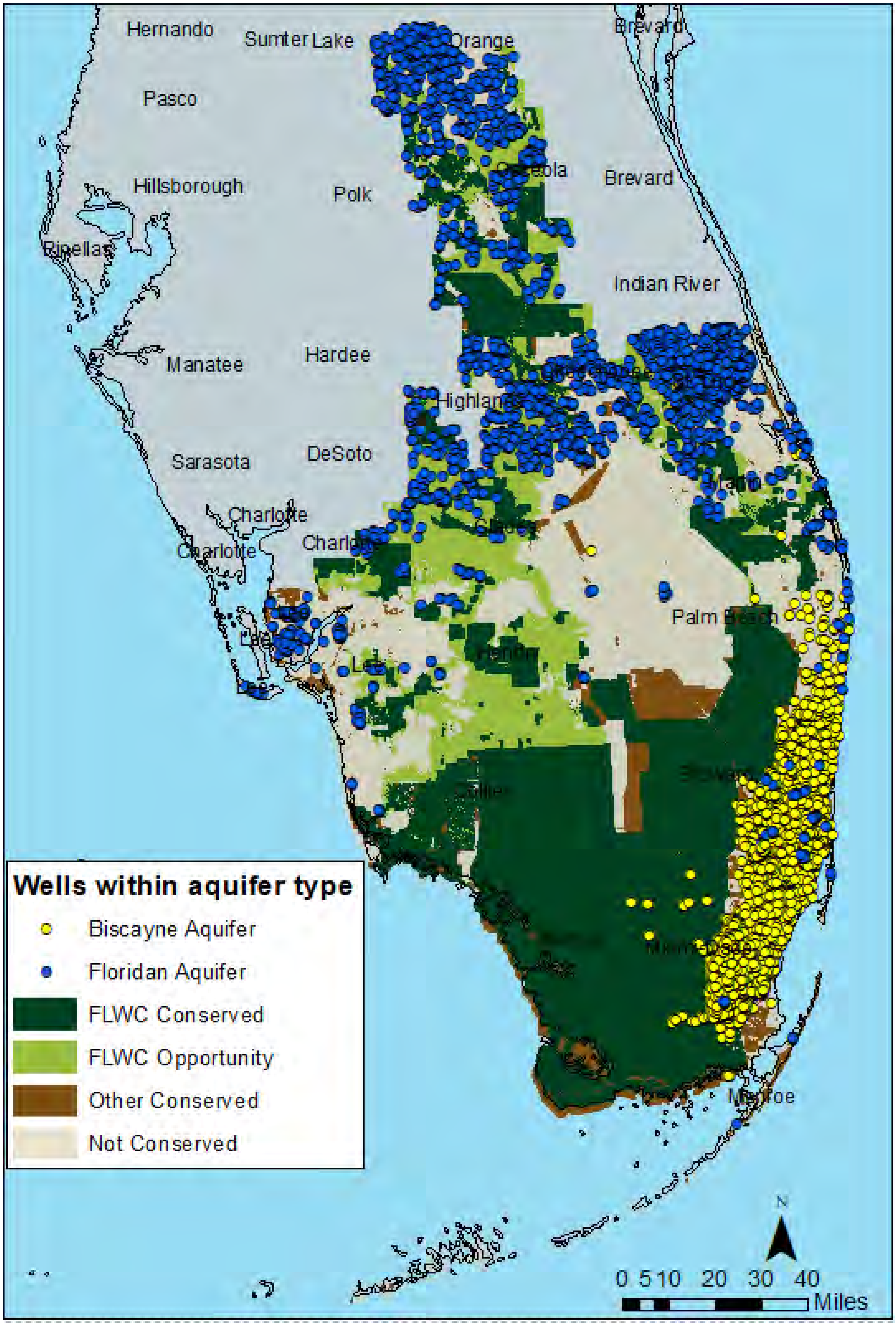

Figure A-19. SFWMD permitted groundwater allocation by source and land category.

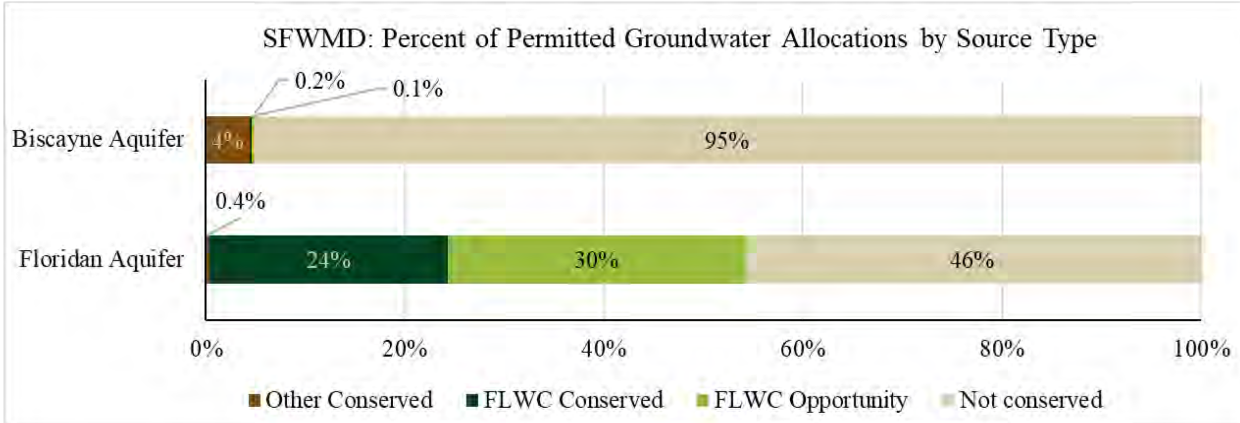

Figure A-20. SFWMD percent permitted groundwater allocation by source and land category.

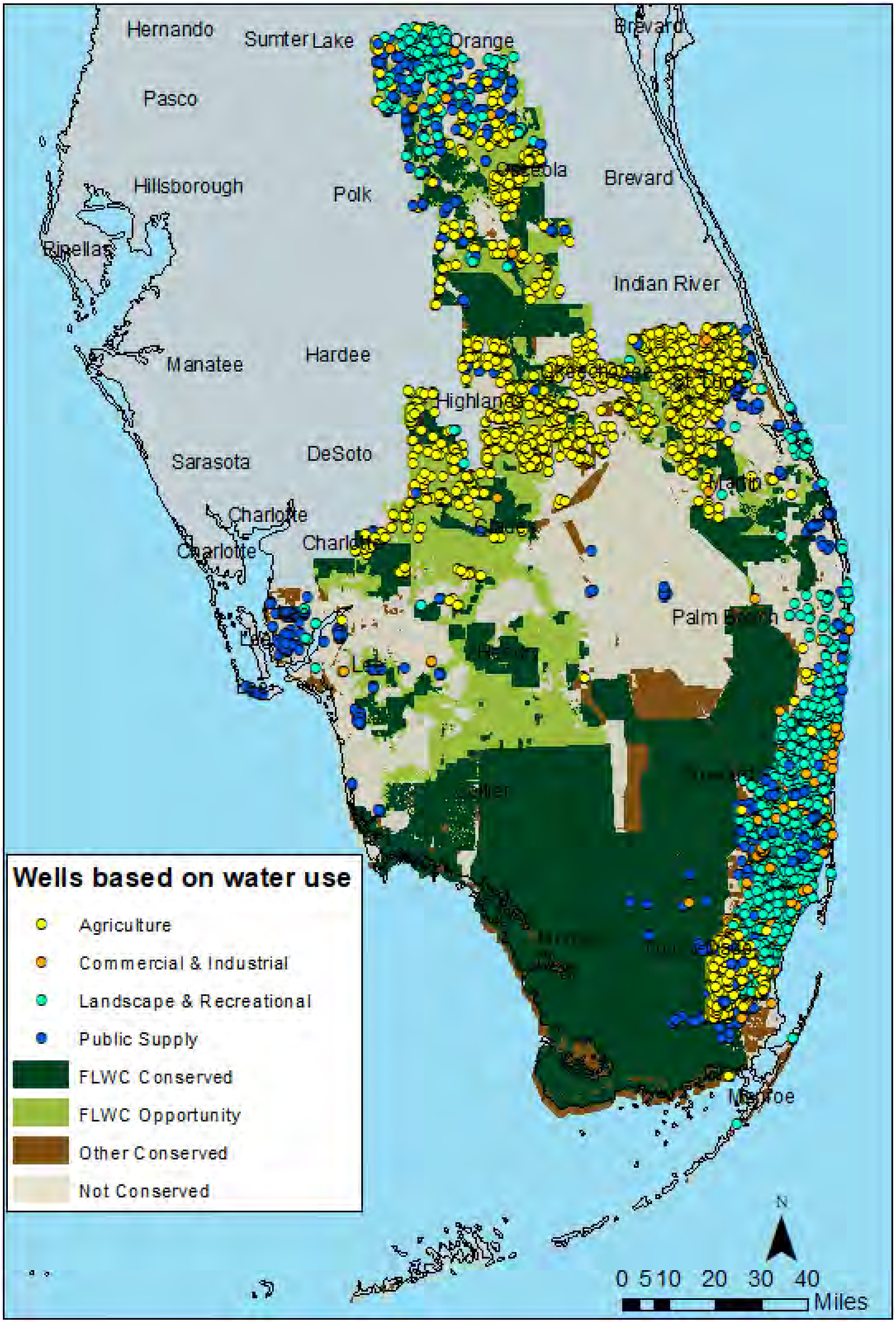

Figure A-21. SFWMD permitted groundwater allocation by land category and use type.

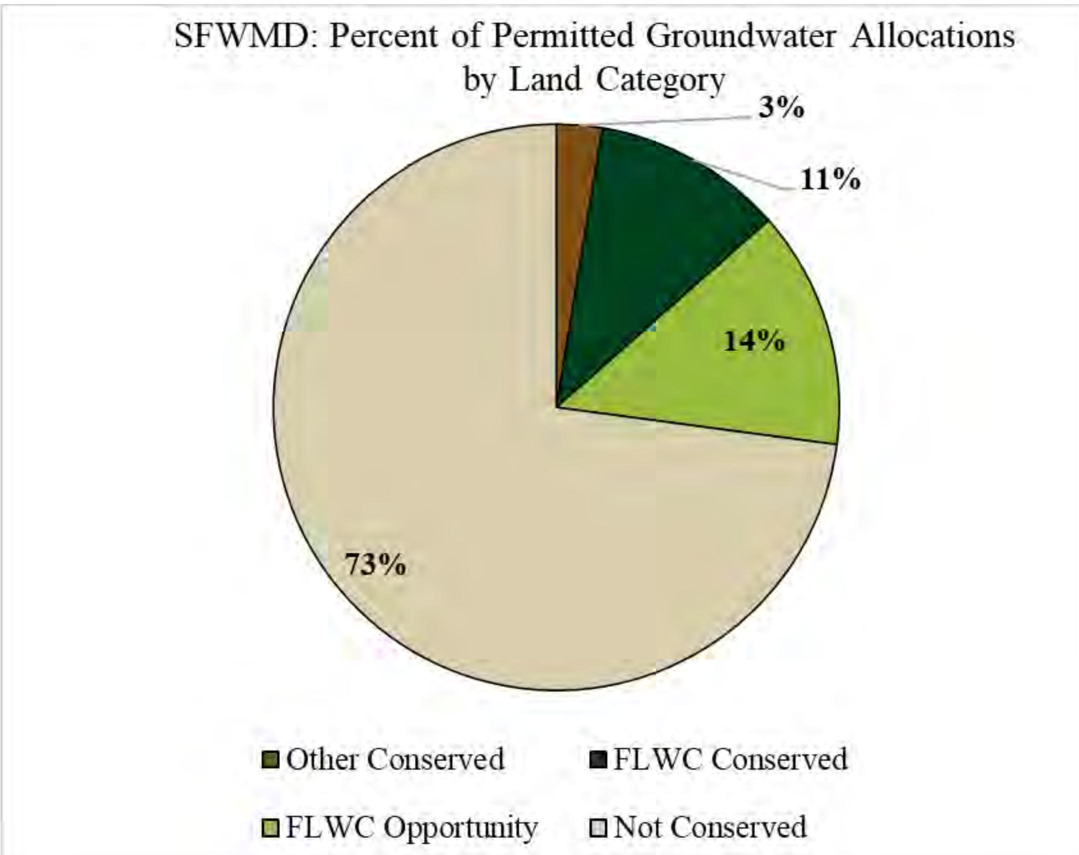

Figure A-22. SFWMD percent of permitted groundwater allocation by land category.

Surface Water

In SFWMD, surface water is drawn from canals and other surface sources throughout the system and is especially prevalent for uses other than public supply. For all surface water use 8% of permitted surface water allocations are located within FLWC conserved lands, and this could reach 42% if all FLWC opportunity lands were acquired. (Figures A-23 and A-24). Again, permitted agricultural allocations dominate those that would be protected by FLWC opportunity lands.

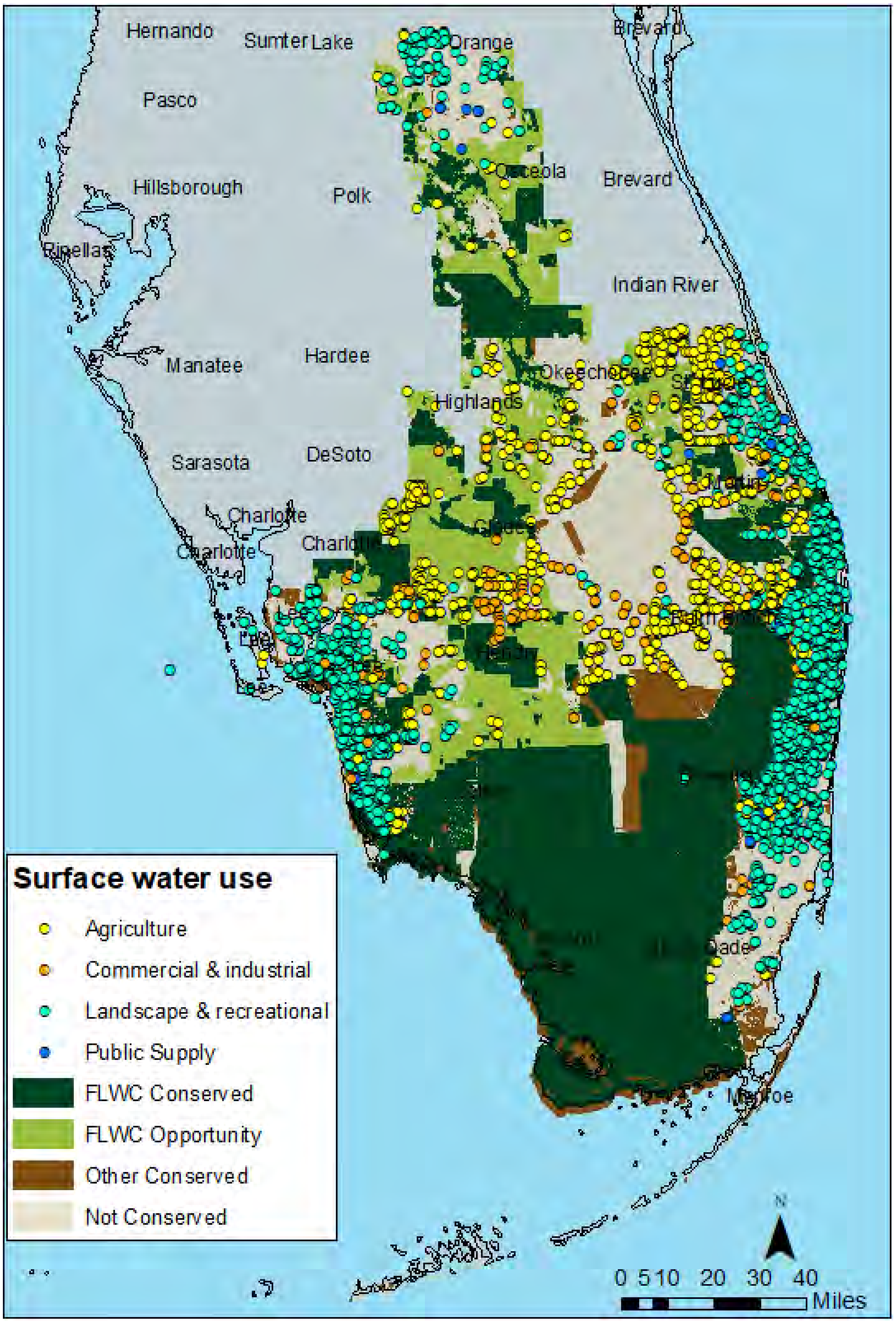

Figure A-23. SFWMD permitted surface water allocation by land category and use type.

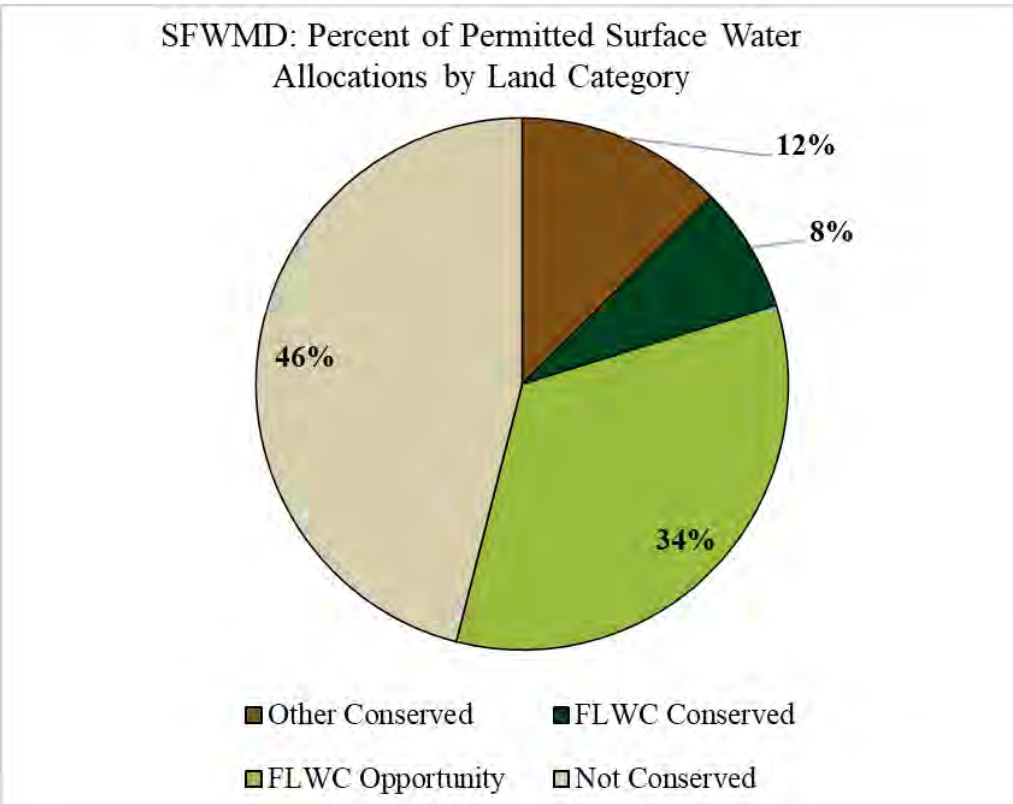

Figure A-24. SFWMD percent of permitted surface water allocation by land category.

Statewide Summary

NWFWMD has the highest percentage of permitted groundwater allocations in FLWC Conserved and Opportunity lands, at 15% and 27% respectively, for a total of 42%, indicating a moderate level of benefit in NWFWMD (Figure A.25). Benefits in this district are dominated by public water supply and commercial/industrial wells that could be protected if FLWC Opportunity Areas were acquired. SFWMD has 11% of permitted groundwater allocations in FLWC Conserved areas. FLWC Opportunity areas in SFWMD more than double this protection, adding an additional 14%, for a total of 25%. The vast majority of the wells in SFWMD Opportunity lands, however, are agricultural water supply wells in the deep, confined Floridan aquifer. Thus, these wells are likely provided little protection by having overlying lands within the FLWC.

SWFWMD, SJRWMD and SRWMD have smaller percentages of permitted groundwater allocations in FLWC areas, with totals of 20%, 13% and 8.5%, respectively, all of which are dominated by wells that could be protected if FLWC Opportunity Areas were acquired. Thus, for SFWMD, SWFWMD, SJRWMD and SRWMD, FLWC Conserved and Opportunity lands provide some protection to permitted groundwater allocations, but these benefits are substantially under-represented compared to total land areas conserved by the FLWC across the state.

Statewide, protection of groundwater permit allocation water in Florida would increase from 7% to 21% with implementation of the Florida Wildlife Corridor Opportunity Areas, a low-to moderate-level of benefit. The vast majority of Florida wells, however, would remain unprotected.

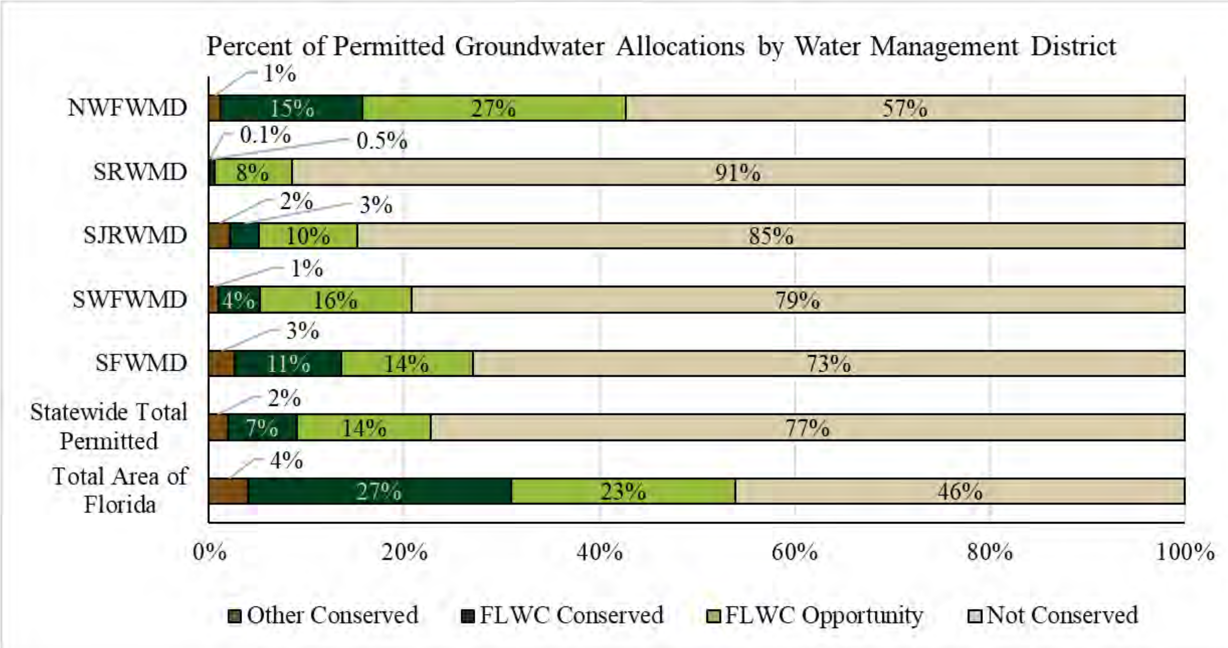

Figure A-25. Percent of permitted groundwater allocation by Water Management District and land category.

SFWMD has the highest percentage of permitted surface water allocations in FLWC Conserved and Opportunity lands, at 8% and 34%, respectively, indicating a moderate level of benefit in SFWMD (Figure A-26). Benefits in SFWMD are dominated by surface water permits for agriculture and commercial/industrial supplies that could be protected if FLWC Opportunity Areas were acquired.

SWFWMD, SJRWMD and SRWMD have smaller percentages of permitted surface water allocations in FLWC areas, all of which are dominated by surface water permits that could be protected if FLWC Opportunity Areas were acquired. For SWFWMD the total is 11% and is made up of primarily public water supply permits. For SJRWMD the total is 32% and is made up primarily of public water supply and commercial/industrial permits. For SRWMD the total is 31% and is made up primarily of commercial/industrial permits. Thus, for SFWMD, SWFWMD, SJRWMD and SRWMD, FLWC Conserved and Opportunity lands provide low-to-moderate protection to permitted surface water allocations, but these benefits are under-represented compared to total land areas conserved by the FLWC across the state.

NWFWMD has the lowest percentage of permitted surface water allocations in FLWC Conserved and Opportunity lands, at 0.4% and 6%, respectively, indicating a low level of benefit in NWFWMD. Benefits in NWFWMD are dominated by surface water permits for commercial/industrial uses that could be protected if FLWC Opportunity Areas were acquired.

Statewide, protection of surface water permit allocation water in Florida would increase from 5% to 32% with implementation of the Florida Wildlife Corridor Opportunity Areas; however, most of Florida’s surface water supplies would remain unprotected.

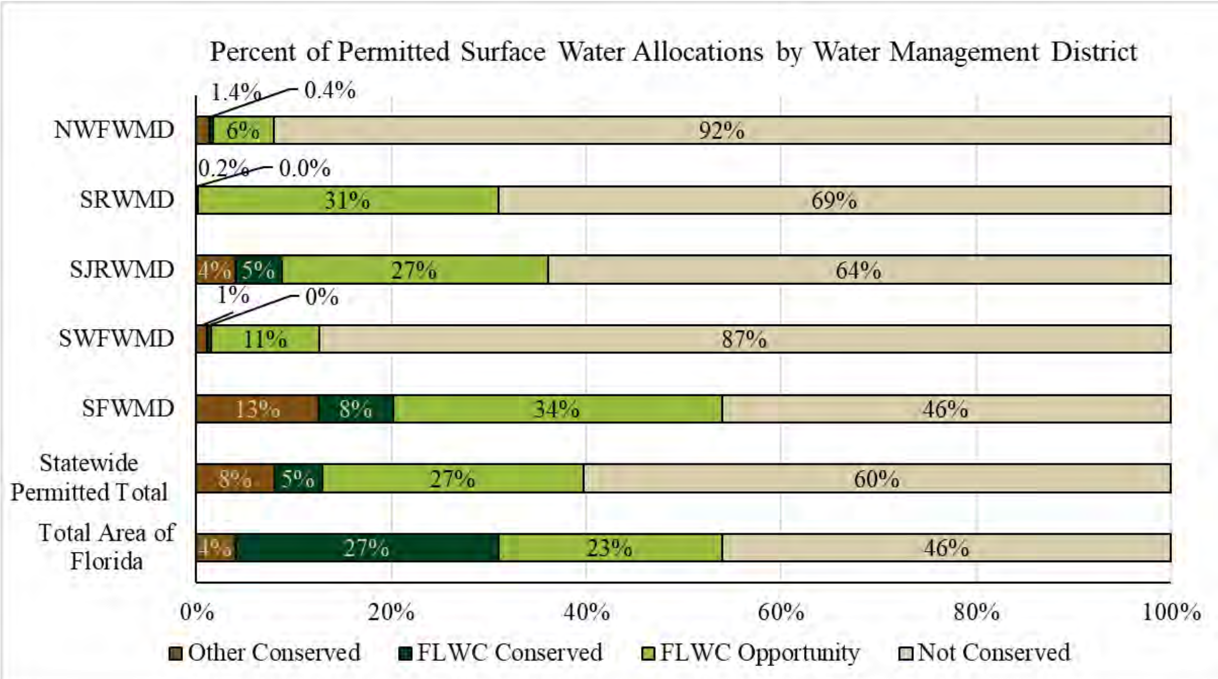

Figure A-26. Percent of permitted surface water allocation by Water Management District and land category.

Appendix B: Analysis of Wellshed Areas by Water Management District

Background

Groundwater supply source areas, or wellsheds, can be protected by land conservation. Both the quantity and quality of recharge water can be reduced by the types of land development that are rapidly spreading across Florida.

Metrics

The primary metric we used to assess the potential benefits of land conservation in this section is the estimated areas of wellsheds that fall into different land conservation categories. We assumed that:

- Permitted wells within the FLWC will receive some degree of wellshed protection.
- Wells located in unconfined and semi-confined aquifers receive more protection than wells in confined aquifers. For these wells, captured water is primarily recharged from overlying lands. Conserving these lands will reduce the likelihood of reductions in recharge that could lead to reduced water availability and will reduce the likelihood of detrimental changes in pumped water quality resulting from development.
- For wells in confined aquifers, water captured by the well may be recharged at some distance from the well itself; thus, this water may not be protected by conserving directly overlying land. We present a simplified case study as an illustrative example in Appendix C, but full evaluation of the source of confined aquifer well water sources would require analysis beyond the scope of this assessment.
- Where available and appropriate, we defer to Florida Department of Environmental Protection Source Water Assessment and Protection Program 5-year groundwater travel time areas to approximate wellshed areas.

Methods

We analyzed groundwater permit allocation data from Florida's five water management districts and approximate groundwater travel time data from the Florida Department of Environmental Protection Source Water Assessment and Protection Program (SWAPP; FDEP 2021) to assess the possible locations of the source areas of water supply withdrawals from groundwater. We overlaid estimated source areas on maps of the water management districts and added up the source areas falling into Florida Wildlife Corridor Conserved Areas, Florida Wildlife Corridor Opportunity Areas, Other Conserved Areas, and Not Conserved Areas. A related analysis based only on the allocated withdrawal point location itself is presented in Appendix A.

Wellsheds

The water supplied to wells ultimately comes from groundwater recharge, which is the infiltration of water into the aquifer from rainfall or surface water bodies such as lakes, streams or sinkholes. Depending on regional aquifer configurations - particularly the degree of confinement of an aquifer being tapped and the hydraulic gradients - this water can come from recharge near a well or from a considerable distance away, and its source area is a wellshed. We assume that wellsheds gain a degree of protection, both in terms of maintaining necessary recharge and water quality, if they are in FLWC lands. However most public supply wells are near the populations they serve and consequently outside the FLWC.

Pumping a supply well normally creates a cone of depression in which local gradients drive flow towards the well. If these gradients dominate the flow system, and if the aquifer being tapped is largely unconfined, then as an approximation, the flow from a well can be related to the land surface area required to provide the same flow of groundwater recharge. The relationship is given by $r = \sqrt{Q/(\pi\ Recharge)}$, where *r* is the radius of the circular wellshed, *Q* is the flow from the well or well field, and *Recharge* is the volume of recharge water per unit area and unit time, which is equivalent to the depth of recharge per unit time, in inches per year, like precipitation for example.

If a well taps a highly confined aquifer, the ultimate source of the water can potentially be a considerable distance away. As an end-member condition, if the aquifer is perfectly confined and there is no downward leakage, then the width of the flow zone contributing to the well is given by $W = Q/(Ti)$, where *Q* is the flow from the well, *T* is the aquifer transmissivity, and *i* is the hydraulic gradient. Under idealized conditions of constant gradient and transmissivity, the flow width would be maintained up-gradient until the end of the confining layer was reached. Then the area of recharge would be determined similar to the way it is computed for an unconfined aquifer. In reality, some leakage will occur, and the flow requirement of the well is often likely to be satisfied long before the edge of a confining layer is reached. A full analysis of the source of water for most confined wells would require detailed modeling that takes the geometry and properties of the aquifer system into account, which is beyond the scope of this assessment. Nonetheless, a case study of the confined aquifer near Jacksonville, based on leveraging preexisting modeling efforts, is described in Appendix C.

The DEP's SWAPP database includes 9513 public water supply systems and assigns an area with a 500-foot radius around noncommunity water systems, an area with a 1000-foot radius to small community systems, and an area with a 1000-foot radius plus the area represented by the five-year groundwater travel time for larger community water systems (FDEP 2021). These estimates generally appear to be independent of aquifer confinement status but provide another starting point for estimating wellshed areas. Thus, for small systems, DEP uses an even simpler approximation than the one we propose for unconfined aquifers above, i.e., depending on system type, either a 500- or 1000-foot-radius circular area surrounding a well is expected to encompass most potential contamination (and water) sources. For larger systems, estimation of the 5-year groundwater travel time generally involves more sophisticated approaches and here we defer to those calculations and their results as available in the SWAPP database. We incorporate the available SWAPP 5-year travel time areas as the source areas for all Public Supply wells in the SWAPP database with wellsheds larger than a 1000-foot radius. All other well source areas are estimated using the unconfined aquifer approximation described above, with the recognition that the actual source areas for confined aquifer wells may be located farther from the wells in directions that can only be determined through more detailed analysis.

Identification of Wellshed Land Classification

To assess the potential overlap of wellsheds with the various FLWC land classifications for wells that do not have more than a 1000-foot radius associated with them in the SWAPP database, we used permitted well flows and estimated recharge equal to 12 inches per year (approximately one-quarter of Florida average annual rainfall). The underlying assumption in using the simple approach here is that the wells capture their flow locally and in a circular area around the well. Applied to wells that do not include a 5-year travel time, our approach generally identifies a larger area than might be assigned by SWAPP, consistent with the full permitted flow. For example, a 1 MGD (700 gpm) permitted well would receive recharge from an area with a 4,300-foot radius.

As we show in Figure B-1 below, the 5-year travel time estimates for larger water systems are often shown as a line extending upgradient from a well. We note that the wells near Daytona Beach shown on Figure B-1 are completed in a semi-confined portion of the Floridan Aquifer (see inset). In some instances (Figure B-2), the 5-year travel time estimates are shown as sub-circular areas, as these examples from the Naples area illustrate.

We observed that not all wells in the SWAPP database that serve large communities appear to be assigned 5-year travel times. Notably, this includes Miami-Dade County, Palm Beach County, and likely other counties. In all, only about 960 of 9513 wells in the SWAPP database have areas larger than that associated with the 1000-ft radius threshold we applied. Moreover, many wells in the Water Management District databases are not public supply wells. Thus, the maps below are dominated by blue circular areas.

https://geodata.dep.state.fl.us/datasets/FDEP::source-water-assessment-and-protection-program-swapp-ground-water-areas-non-federal/explore?location=29.207595%2C-81.123943%2C11.51

Figure B-1. Daytona-area 5-year groundwater travel times for Floridan Aquifer wells (FDEP 2021).

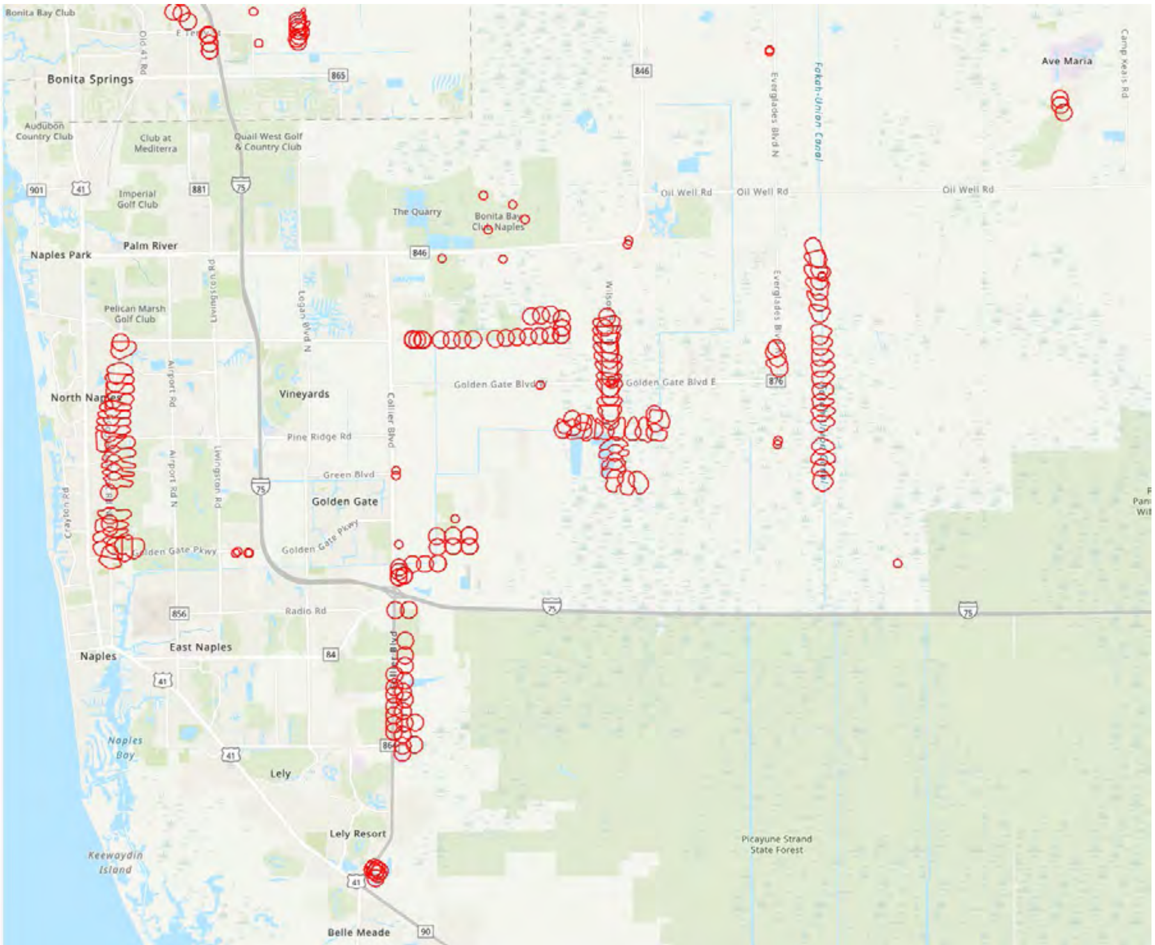

Figure B-2. Naples-area 5-year groundwater travel time areas (non-circular areas) for Intermediate Aquifer wells. (FDEP 2021).

Results

Figures B-3, B-6, B-9, B-12, and B-15 show the wellshed areas we estimated using the approaches outlined above based on full permitted well allocations in each of Florida's Water Management Districts (WMDs) and SWAPP 5-year groundwater travel-time data. Water Management District well allocations classified as Agriculture, Industrial/Commercial/ Institutional, Recreational/Landscape Irrigation, Mining/Dewatering, and Power Generation are included, whereas Domestic Self-Supply wells are not. Note that unlike the analysis in Appendix A, the full permitted allocation was used for all wells in this analysis because typically return flows from non-consumptive uses are not injected into the aquifer from which they were pumped. The wellshed areas (in square miles and as proportions of the totals) falling into the different land classifications are shown in Figures B-4, B-5, B-7, B-8, B-10, B-11, B-13, B-14, B-16, and B-17.

Northwest Florida Water Management District (NWFWMD)

Figure B-3 illustrates the results of our analysis for the NWFWMD. The district appears to be dominated by agricultural pumping in the Jackson County area, adjacent to the Alabama and

Georgia borders. SWAPP public supply well allocations with 5-year travel-time areas are evident primarily in the Tallahassee and Pensacola areas, but the map is dominated by well allocations that either are not covered by the DEP SWAPP database or fall below our 1000-foot SWAPP radius criterion. Most pumping allocation and SWAPP wellsheds are in lands categorized as Not Conserved.

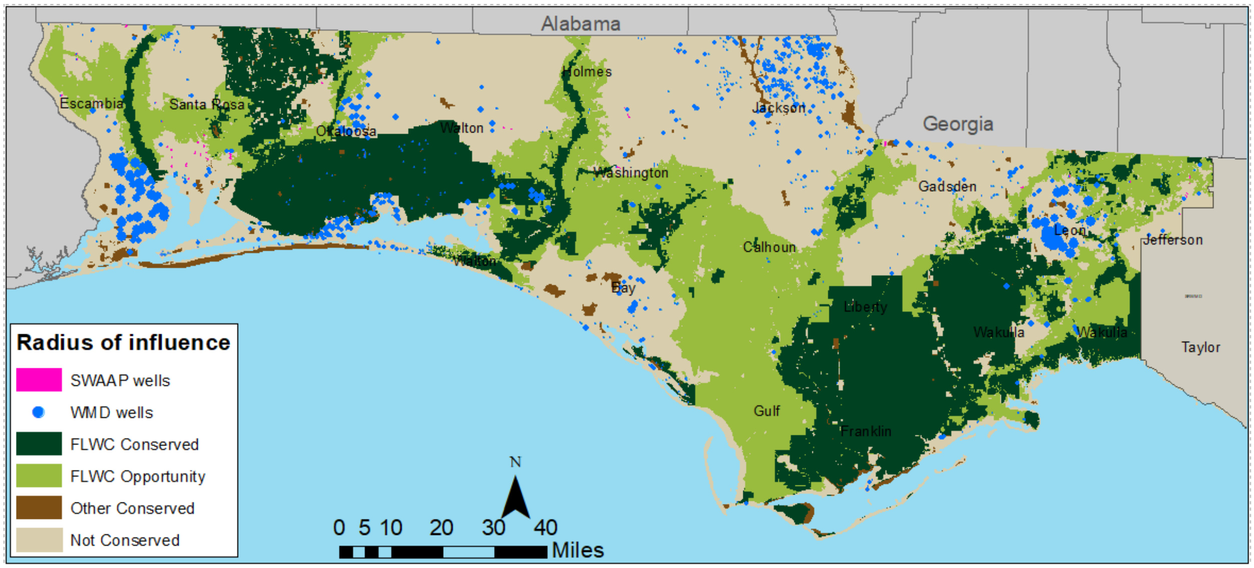

Figure B-3. Wellshed areas for Northwest Florida Water Management District wells.

In Figure B-4 we show the areas of allocation- and travel-time-based wellsheds in each of the FLWC land types. About 650 square miles of wellshed areas are in Not Conserved lands, whereas approximately 30 square miles of wellshed areas are in FLWC Opportunity lands and 10 square miles are in FLWC Conserved lands. Thus, although the vast majority of wellshed area is in Not Conserved lands, addition of the FLWC Opportunity lands would quadruple the FLWC protected wellshed areas.

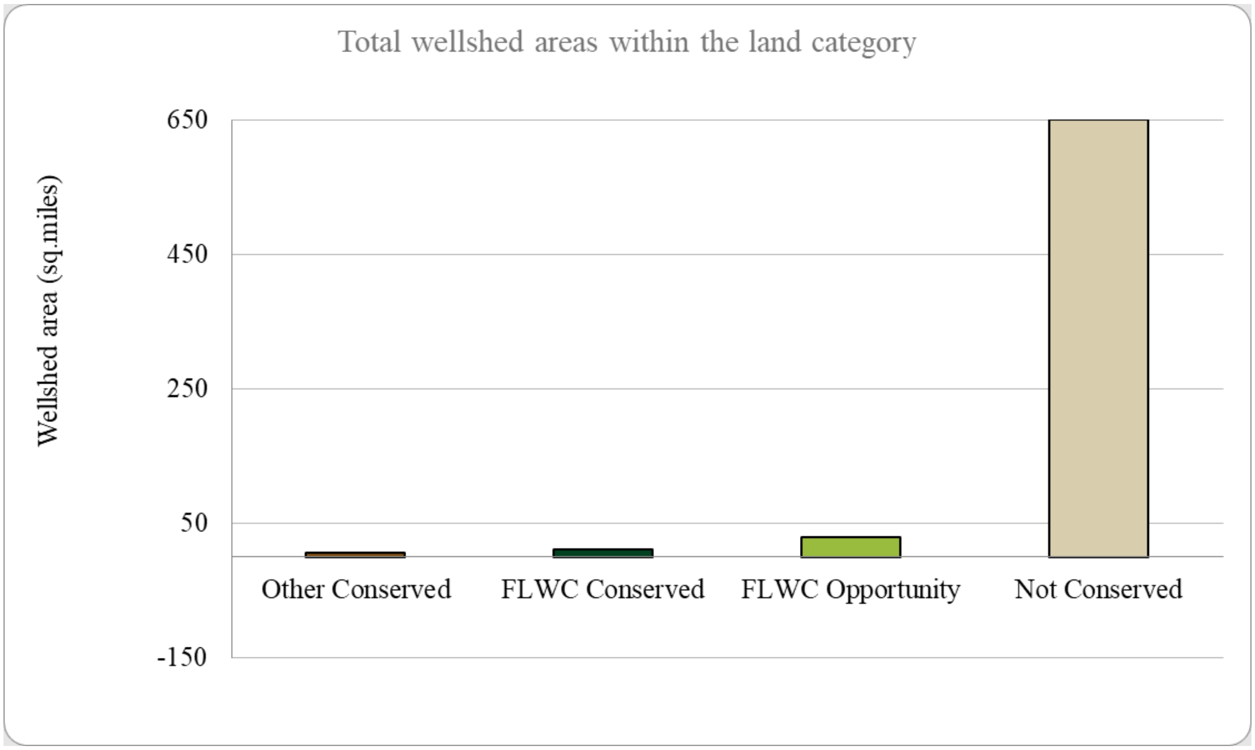

Figure B-4. Wellshed areas in different land categories for NWFWMD.

We present the proportions of wellshed areas in the different land categories in Figure B-5. All established conservation and Opportunity land accounts for less than 7% of the wellshed area and the Corridor is consequently considered to have low benefit for wellsheds in the NWFWMD.

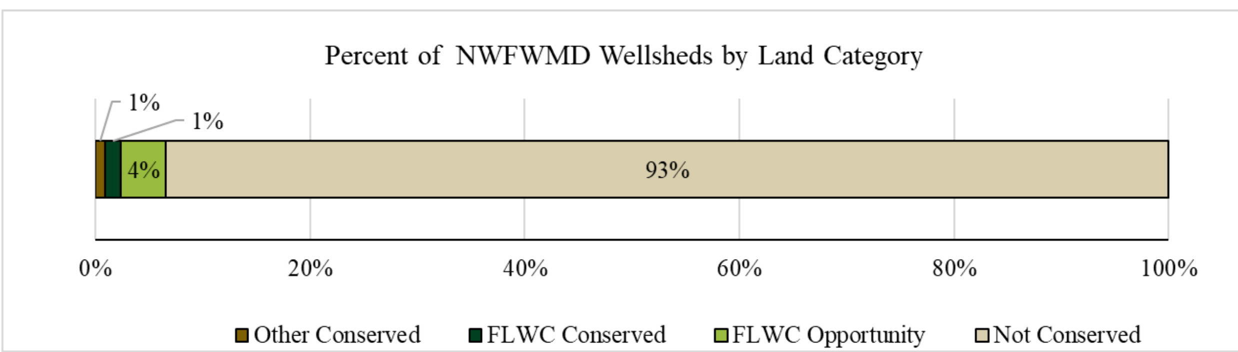

Figure B-5. Percent of wellshed areas in different land categories for NWFWMD.

St. Johns River Water Management District (SJRWMD)

We show wellshed areas for the SJRWMD in Figure B-6. We identified a considerable number of SWAPP wells that show 5-year travel-time areas, and among those are several that show their wellsheds extending into FLWC Conserved and Opportunity lands, particularly in the Deltona Beach/Volusia County area.

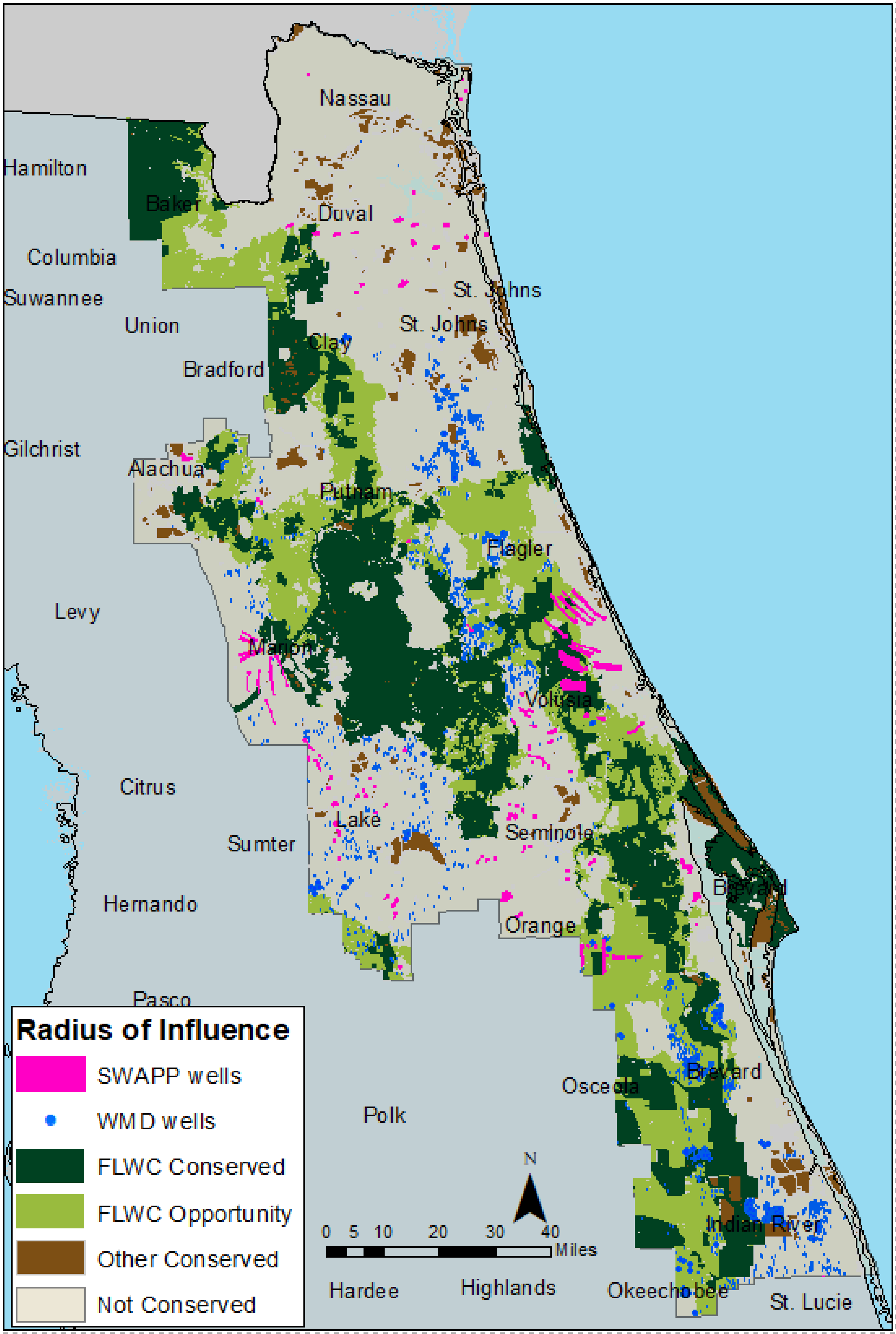

Figure B-6.
Wellshed areas for St. Johns River Water Management District.

Despite this, most travel-time- and allocation-based wellsheds fall into nearly 1400 square miles of Not Conserved lands, as we show on Figure B-7. Similar to our findings for the NWFWMD however, addition of the FLWC Conservation lands would roughly triple the protected wellshed areas from approximately 90 square miles to 260 square miles.

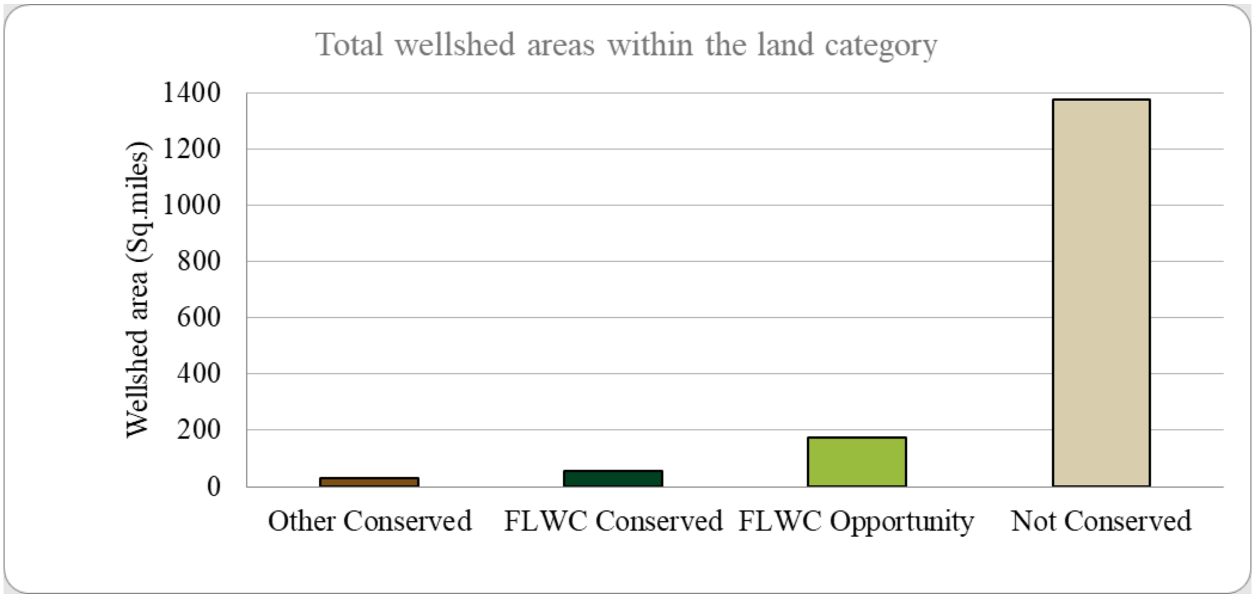

Figure B-7. Wellshed areas by land category for SJRWMD.

At 16%, the proportion of total protected wellshed area in the SJRWMD, if all Opportunity lands were conserved, is significantly greater than in the NWFWMD. We present the proportions of SJRWMD wellshed areas in Figure B-8. Accounting for just 14% of the wellshed area, together the FLWC Conserved and Opportunity lands provide low benefit to wellsheds in the SJRWMD.

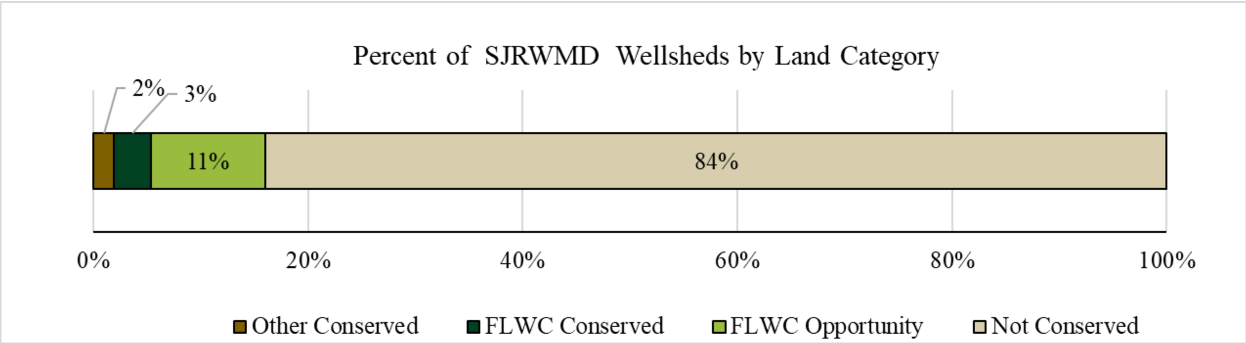

Figure B-8. Percent of wellshed areas in different Corridor land types for SJRWMD.

Suwannee River Water Management District (SRWMD)

We show the wellshed areas computed as described above for the SRWMD in Figure B-9 below. This map is dominated by well allocations that either are not covered by the DEP SWAPP database or fall below our 1000-foot SWAPP radius criterion. Most of the wellsheds are in Not Conserved land, reflecting the dominant use of these lands for irrigated agriculture.

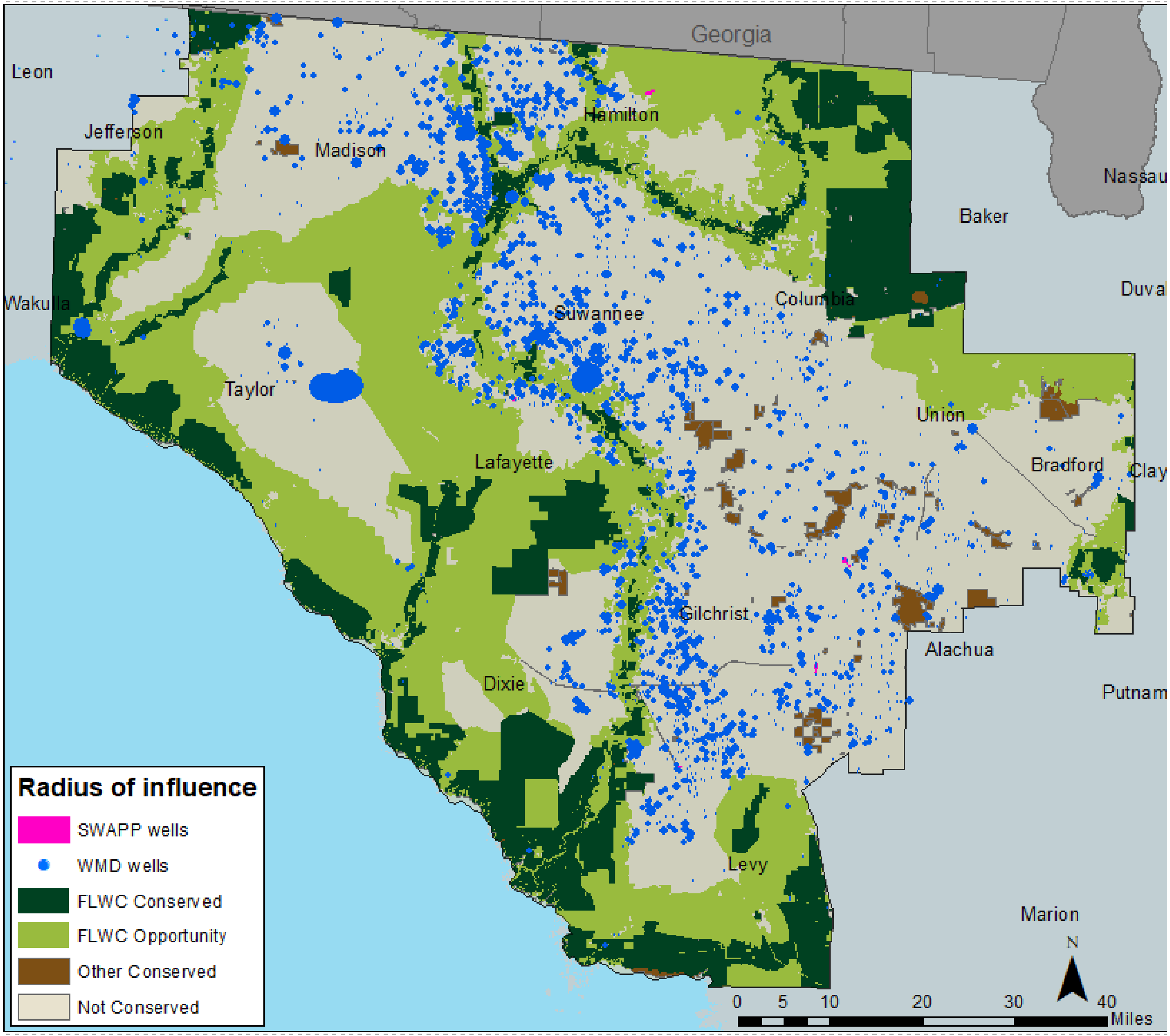

Figure B-9. Wellshed areas for Suwannee River Water Management District.

Figure B-10 shows the areas of wellsheds within the different land categories. About 550 square miles of wellshed lie in Not Conserved lands, whereas less than 40 square miles of wellshed are in all of the other classes.

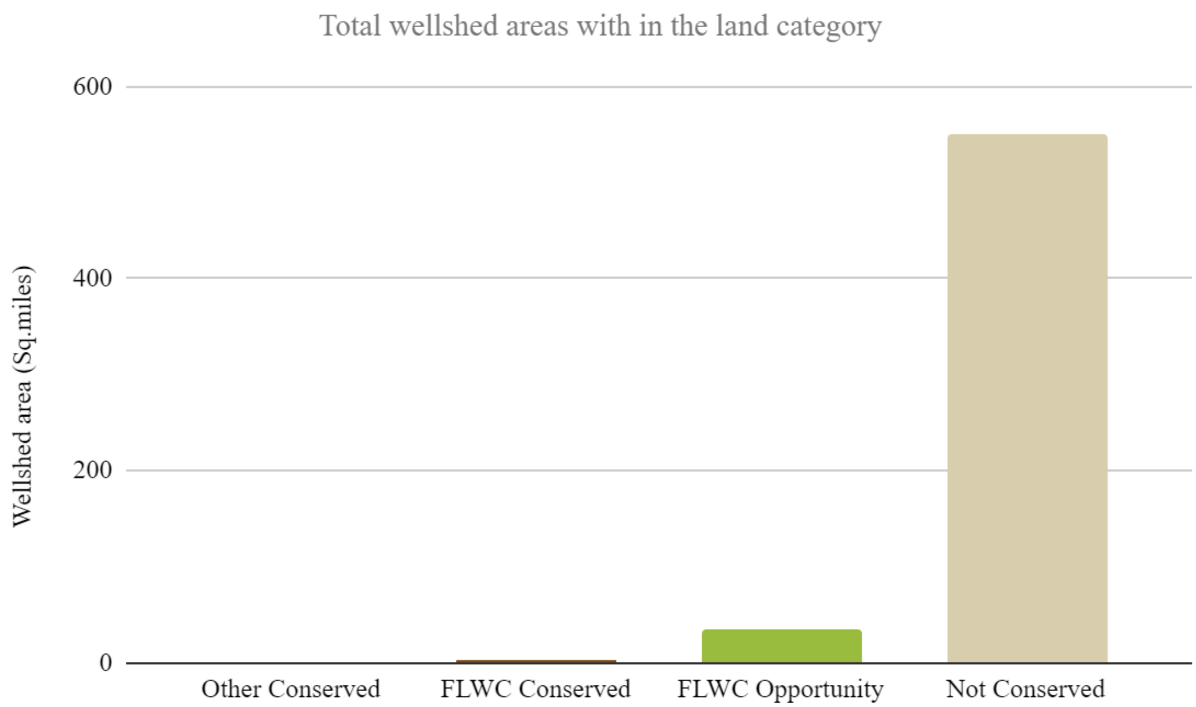

Figure B-10. Wellshed areas in different land categories for SRWMD.

With only about 6% of the wellshed area being offered protection by the FLWC Conserved, FLWC Opportunity and Other Conservation land (Figure B-11), the Corridor offers low protection to wellsheds in the SRWMD.

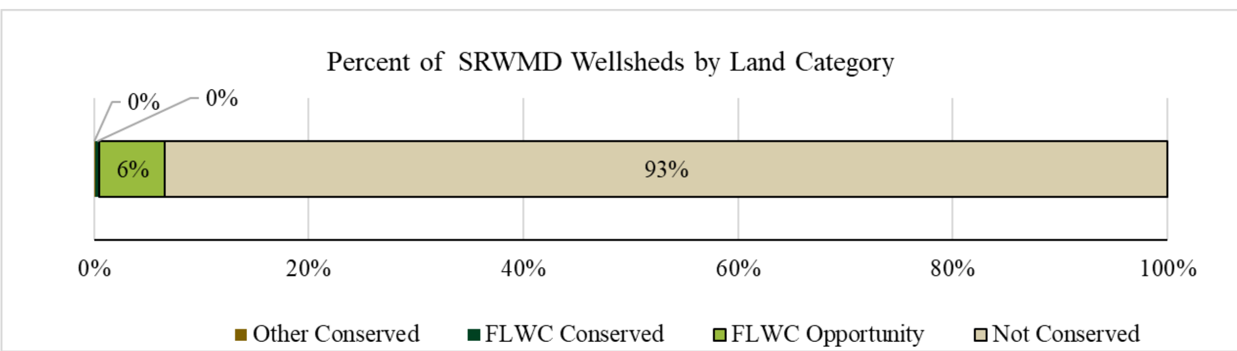

Figure B-11. Percent of wellshed areas in different land categories for SRWMD.

Southwest Florida Water Management District (SWFWMD)

Our map of wellsheds for the SFWMD (Figure B-12) is dominated by well allocations that either are not covered by the DEP SWAPP database or fall below our 1000-foot SWAPP radius criterion. There are a handful of SWAPP public supply wells with 5-year travel-time areas visible in Citrus, Polk, and Highlands counties. In general, there is a very strong tendency for wellsheds to fall in large tracts of Not Conserved lands, although wellsheds in the south of the District occupy areas largely surrounded by FLWC Opportunity lands, for example in Hardee and DeSoto counties.

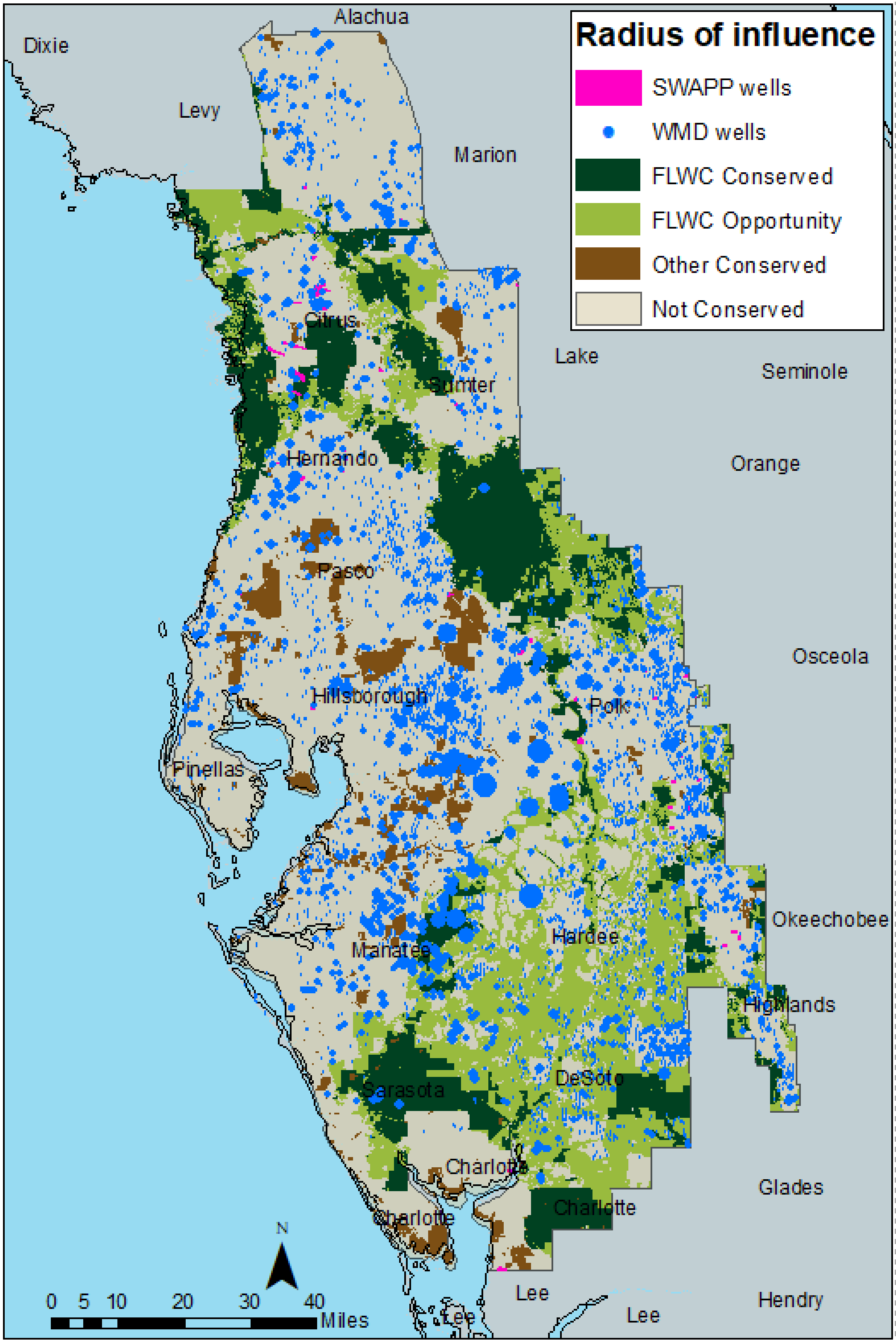

Figure B-12. Wellshed areas for Southwest Florida Water Management District.

Figure B-13 presents the areas of the wellsheds within each of the land classifications. More than 1300 square miles of wellsheds lie in Not Conserved lands. About 170 square miles of wellsheds are in FLWC Opportunity lands; there would be more than a 3-fold increase in protected wellsheds with conservation of the Opportunity lands.

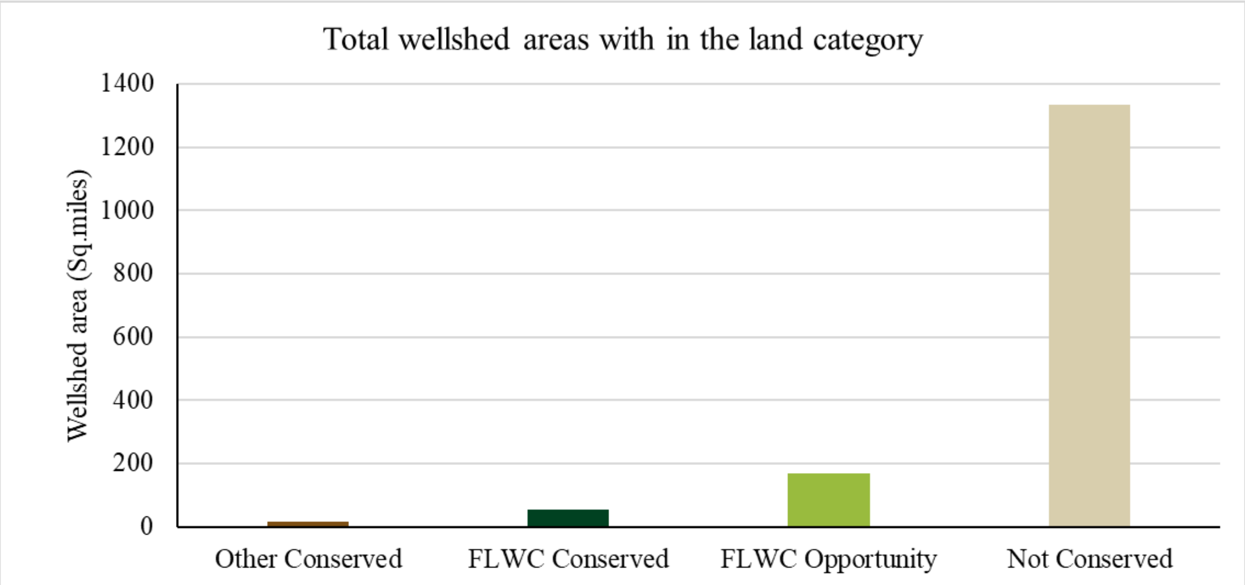

Figure B-13. Wellshed areas in different land categories for SWFWMD.

We give the proportions of wellsheds in each land class in Figure B-14. With 15% of the wellshed area within the existing conservation areas and the FLWC Opportunity lands, the SWFWMD would likely see the greatest benefit from conservation of the Opportunity lands if acquired. Overall, however, wellsheds in SWFWMD are provided low benefit by the FLWC.

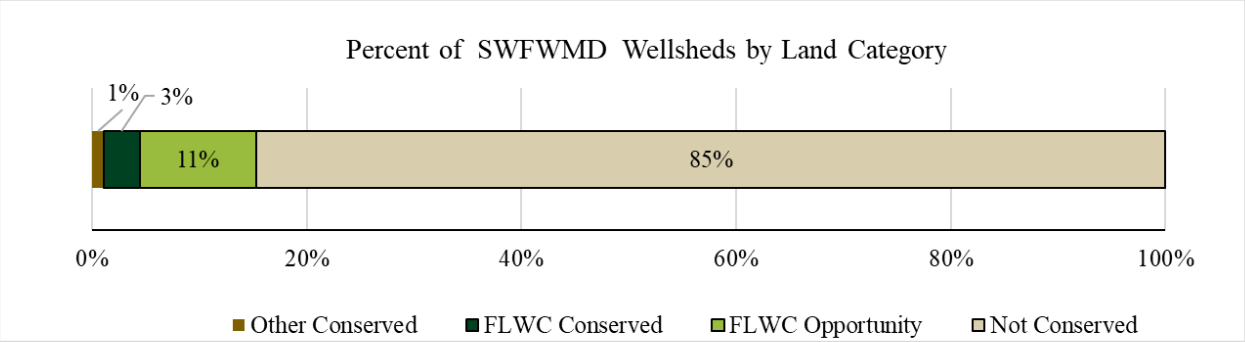

Figure B-14. Percent of wellshed areas in different land categories for SWFWMD.

South Florida Water Management District (SFWMD)

Figure B-15 shows that most permit allocation- and SWAPP-based wellshed areas fall into Not Conserved lands overlying the Biscayne Aquifer in Southeast Florida, and further north in St. Lucie and Orange counties. There appears to be considerable overlap of FLWC Opportunity areas and wellshed areas elsewhere in the District, however the wells in the opportunity areas are primarily pumping from the deep, confined Floridan Aquifer and thus may not receive substantial benefit from overlying conservation lands.

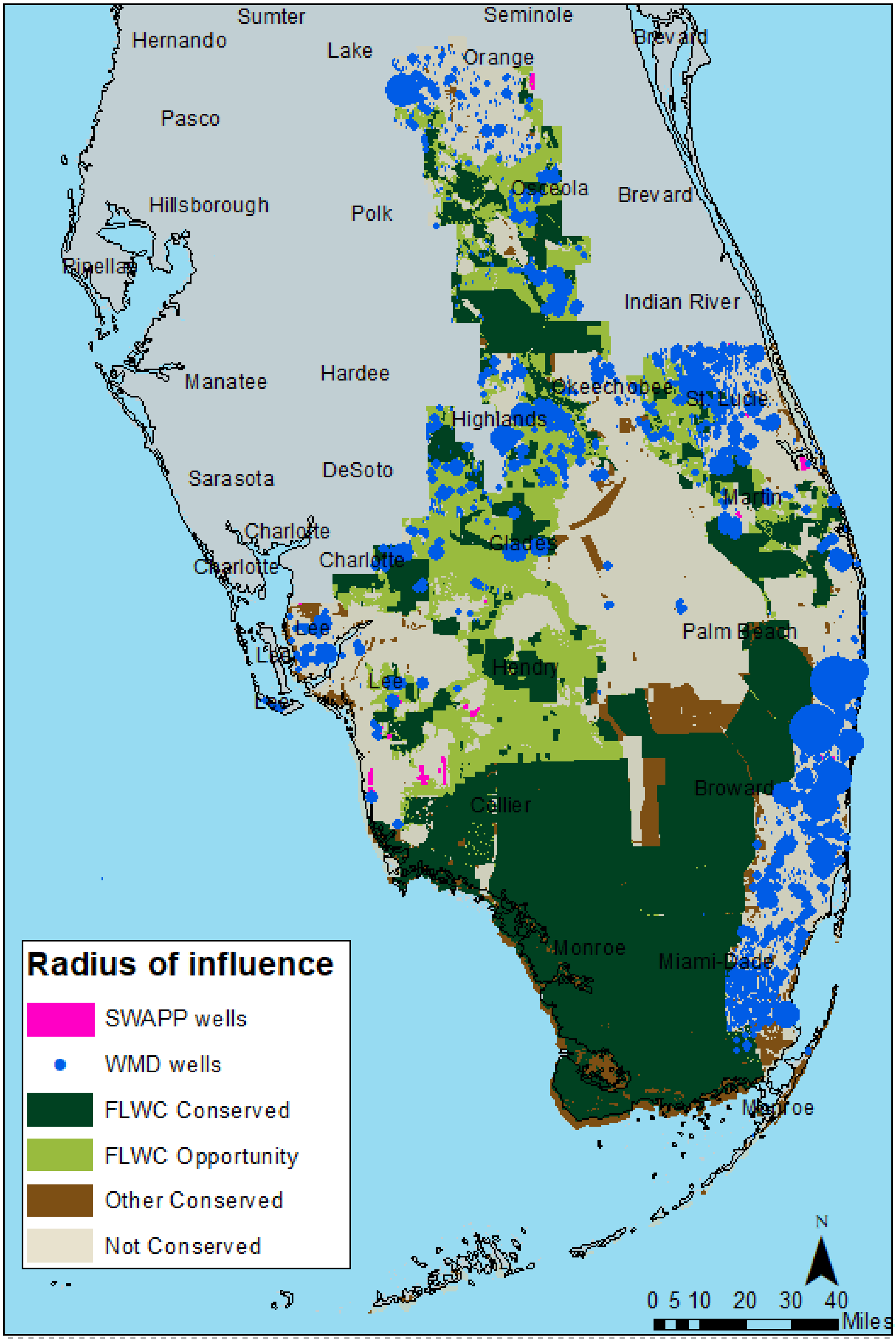

Figure B-15. Wellshed areas for South Florida Water Management District.

Figures B-16 and B-17 support these observations: 15% of the wellshed areas lie within FLWC Opportunity lands and 19% of wellshed areas would be protected by all conserved lands if all the FLWC Opportunity lands were also conserved, again a low level of benefit.

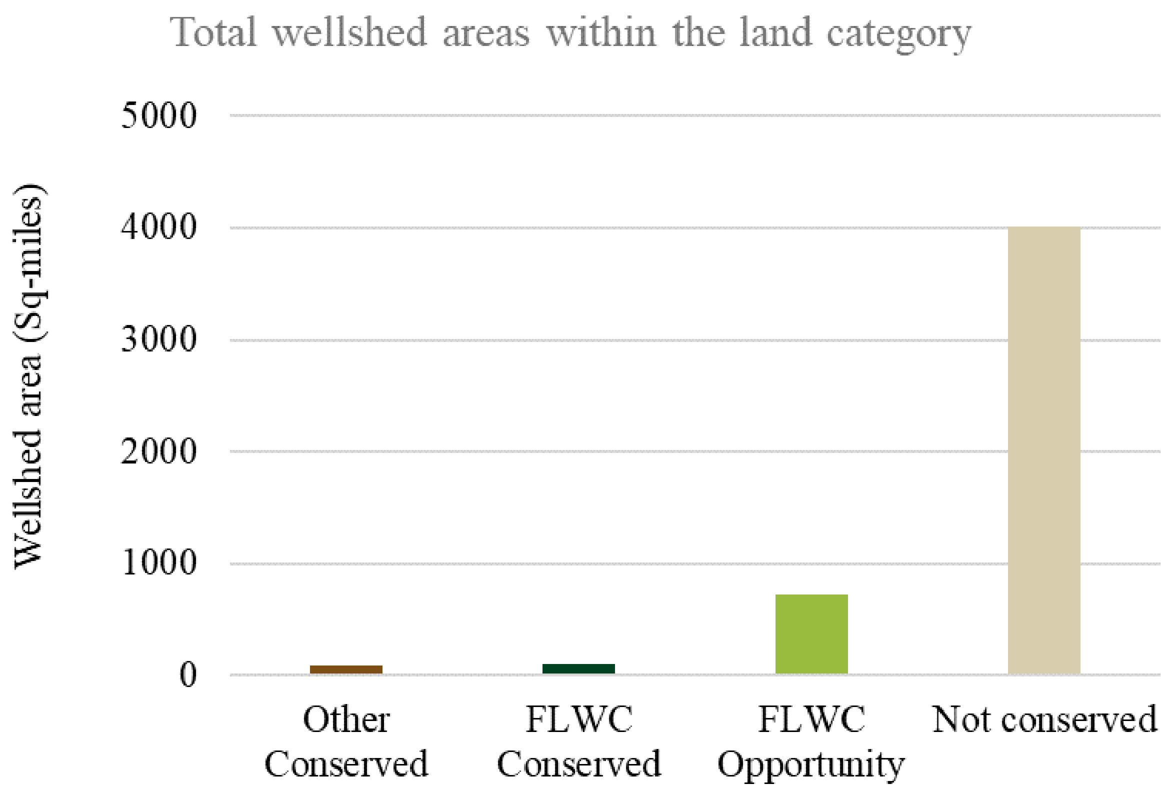

Figure B-16. Wellshed areas in different land categories for SFWMD.

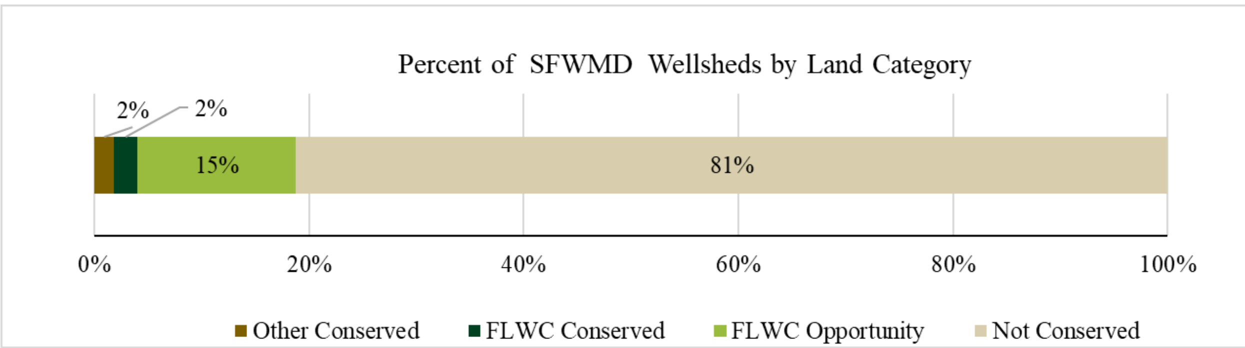

Figure B-17. Percent of wellshed areas in different land categories for SFWMD.

Statewide Summary

Figure B-18 below shows the total statewide wellshed areas that fall into the different land classifications. Although conservation of the FLWC Opportunity lands would quadruple the state's protected wellshed area from about 375 to 1500 square miles, most wellshed area - nearly 8000 square miles - falls in Not Conserved lands. Thus, statewide wellshed area is provided low benefit by the FLWC.

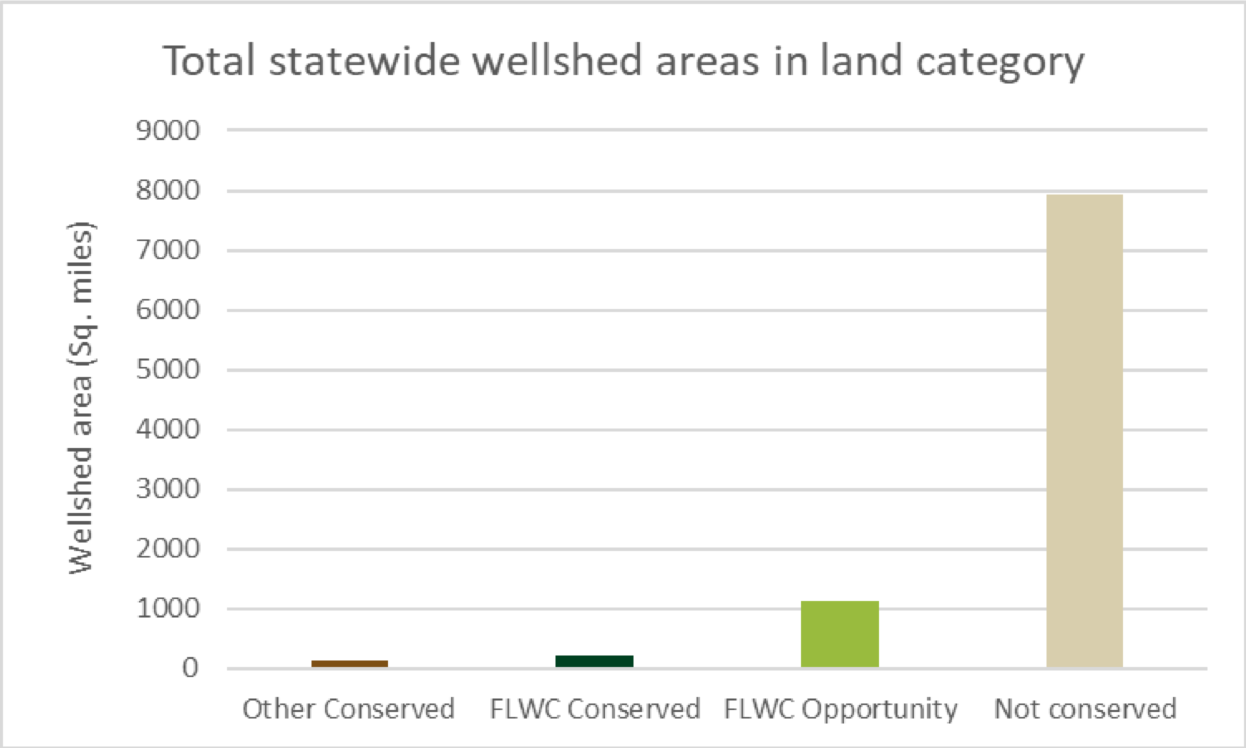

Figure B-18. Statewide wellshed areas by land category.

We show the same results as proportions that fall into the different land classifications in Figure B-19. Although most wellshed area is in Not Conserved land, addition of all FLWC Opportunity lands to other conserved and FLWC Conserved lands would increase protection from 4% to 16% of the nearly 10,000 square mile total wellshed area, a low level of protection.

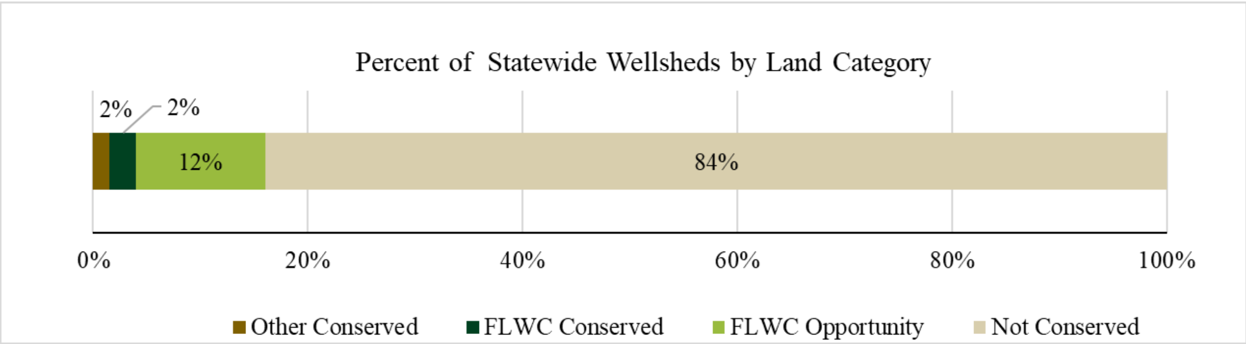

Figure B-19. Percent of statewide wellshed areas by land category.

Appendix C: Case Study on Confined Aquifer Wells

In order to further assess the approximation of using the available SWAPP (FDEP 2021) 5-year travel times for the confined aquifer wells, we reviewed results from the North Florida Southeast Georgia Groundwater Model (Durden et al. 2019). This model covers a large portion of northern Florida as shown in Figure C-1 below. Durdin et al. (2019) divided the active model area into groundwater basins as shown below and computed water balances for these basins.

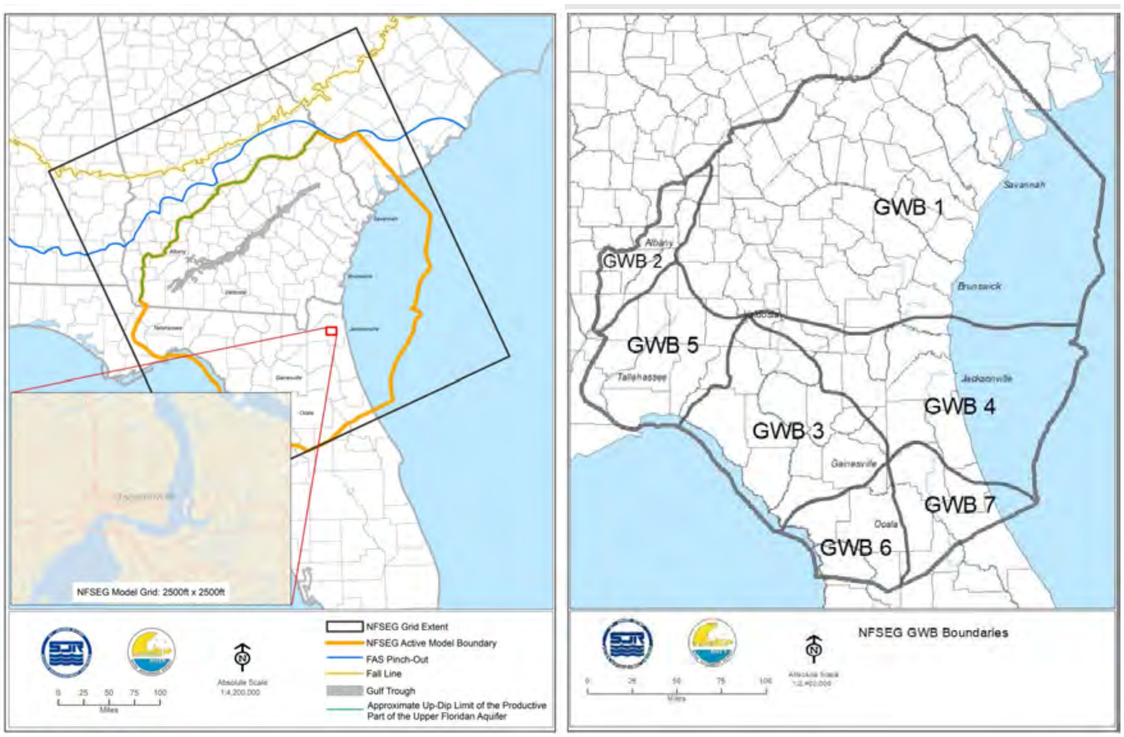

Figure C-1. North Florida Southeast Georgia (NFSEG) groundwater model extent and groundwater basins. From Durden et al. 2019.

We focused on Groundwater Basin 4 and model Layer 5, which represents the confined deeper Floridan Aquifer. In that basin "Well withdrawals are up to 4 times greater than the vertical flow of water into Layer 5. Lateral boundary flows make up any deficits in the mass balance of Layer 5." (Durden et al. 2019). A schematic mass balance for Groundwater Basin 4 that highlights the vertical leakage, lateral inflow, and pumpage in Layer 5 is shown in Figure C-2 below. Layer 5 has the largest pumping rate at 127 MGD and 70% of this pumping is met by groundwater inflows at the boundaries of the basin. Notably, these boundaries are at least 25, and up to more than 50, miles away from the primary pumping center near Jacksonville. Thus, a significant fraction of recharge supplying these wells may originate from a considerable distance away and could originate in Corridor conservation lands, for example.

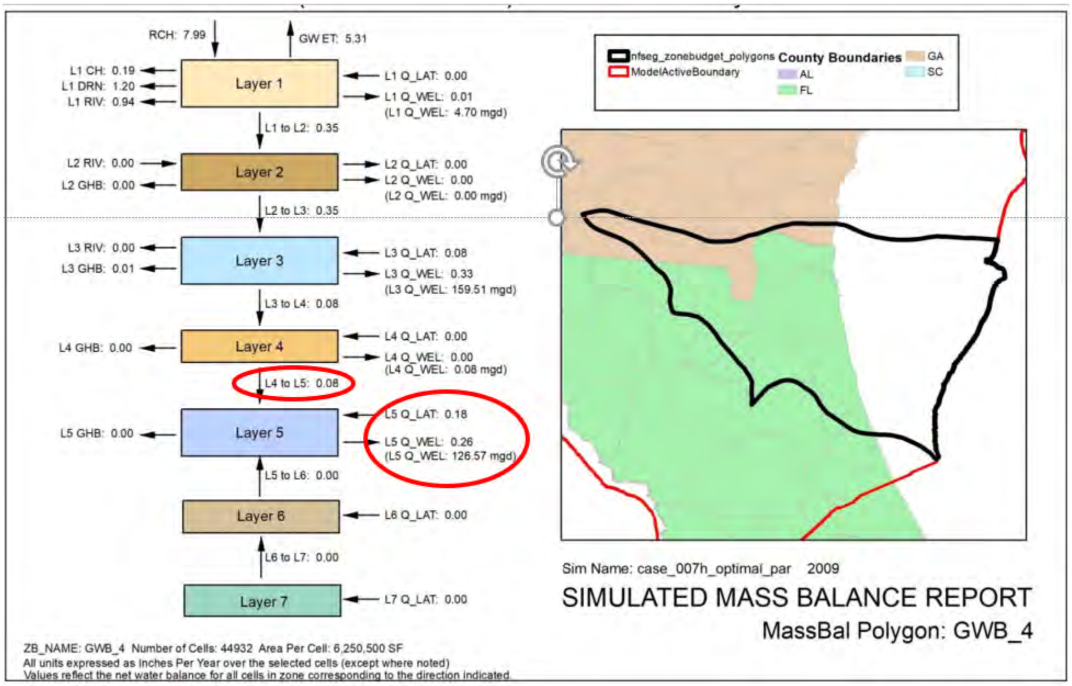

Figure C-2. Simulated mass balance for Groundwater Basin 4. Modified from Durden et al., 2019.

We used the model head results for Layer 5 to illustrate how the pathlines for groundwater flow can be calculated. In this simplified approach, we assumed that there is no leakage and that the aquifer is homogeneous and isotropic. Strictly based on the simulated heads, the groundwater gradients were computed and used to calculate flow pathlines starting at the cone of depression and tracking the flow up-gradient (Figure C-3). Under these assumptions, much of the flow to the deeper Floridan aquifer appears to come from the north and west in Groundwater Basin 1. The pathlines extend approximately 150 miles from the pumping center.

Several factors are likely to reduce the distance estimates based on both the basin-wide water balances (which led to the distance to the basin boundaries as the estimates) and the zero-leakage computation of flowpaths. In particular, the pumping-induced cone of depression in the Layer 5 potentiometric surface will induce more leakage from upper layers locally than is reflected by the average, while less leakage will occur elsewhere. Thus, some of the pumping demand will be met from the leakage. Only a fully 3-dimensional evaluation of the flowpaths that incorporates this leakage could more reliably estimate the recharge source areas that provide water to the pumping center. The availability of this preexisting model would allow such an evaluation of where the source areas are likely to be based on 3-dimensional flowpath analysis for individual wells or pumping centers. Similar analyses are also possible in other areas of the state, but are beyond the scope of this project.

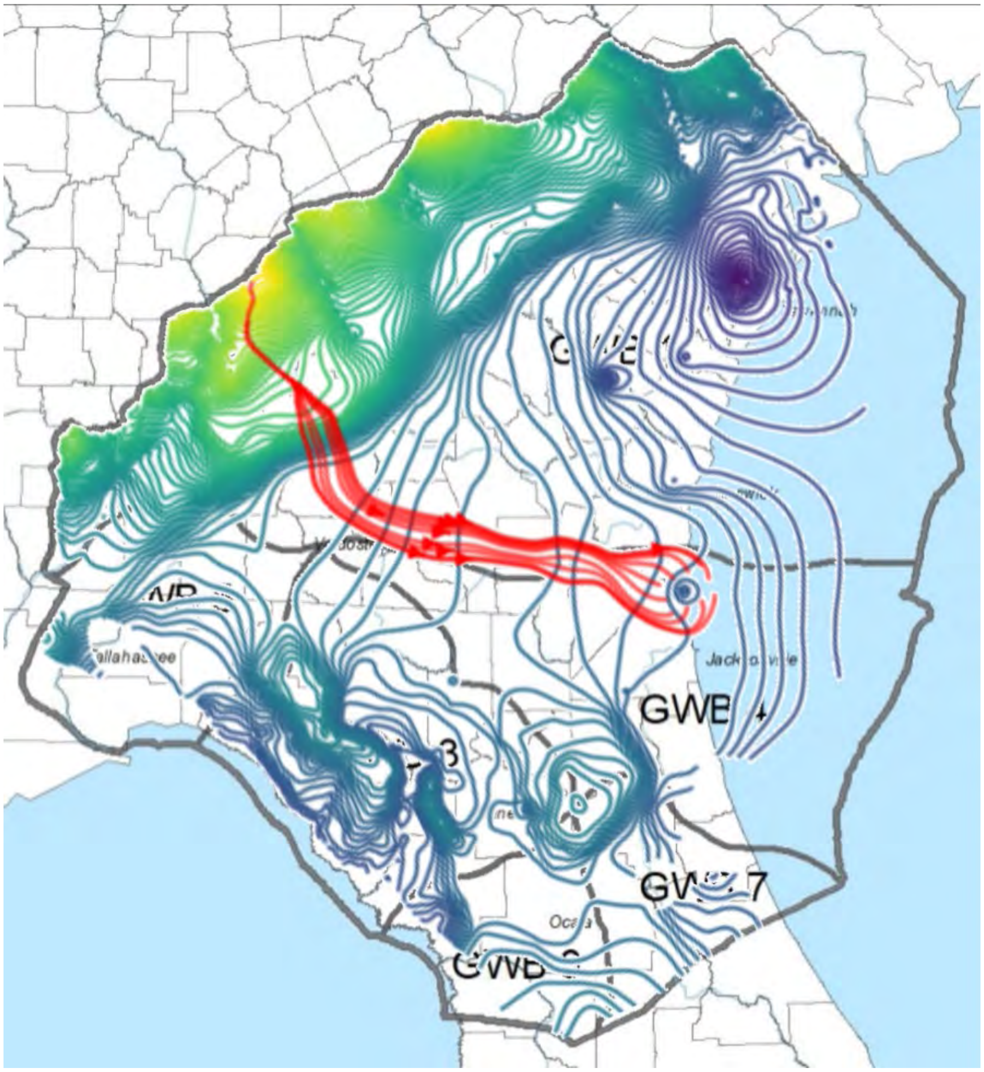

Figure C-3. Simulated heads from NFSEG Layer 5 (blues and greens, modified from Durden et al. 2019) and pathlines (red) for flow to the pumping center near Jacksonville.

Acronyms

BGD	Billion Gallons per Day
BMAP	Basin Management Action Plan
CBRA	Coastal Barrier Resources Act
CFS	Cubic Feet per Second
CUP	Consumptive Use Permitting
FDEP	Florida Department of Environmental Protection
FEGN	Florida Ecological Greenways Network
FWC	Florida Fish and Wildlife Conservation Commission
FLWC	Florida Wildlife Corridor
FNAI	Florida Natural Areas Inventory
GPM	Gallons Per Minute
HUC	Hydrologic Unit Code
IHN	Integrated Habitat Network
MFL	Minimum Flows and Levels
MGD	Million Gallons per Day
NWFWMD	Northwest Florida Water Management District
NWI	National Wetlands Inventory
OFS	Outstanding Florida Springsheds
PEA	Priority Ecological Area
SFWMD	South Florida Water Management District
SJRWMD	St Johns River Water Management District
SRWMD	Suwannee River Water Management District
SWFWMD	Southwest Florida Water Management District
TMDL	Total Maximum Daily Load
WMD	Water Management District
UF CLCP	University of Florida Center for Landscape Conservation and Planning

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