Appendix G

Final Report for Rainbow River 2015 Aquatic Vegetation Coverage. Prepared by Water and Air Research, Inc. for the Southwest Florida Water Management District, Brooksville, Florida. 2015.

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Prepared for

Southwest Florida Water Management District
Brooksville, Florida

Prepared by

Water & Air Research, Inc.
6821 S.W. Archer Road
Gainesville, Florida 32608

February 9, 2016
15-7180-01

water & air RESEARCH, INC.

REAL PEOPLE • REAL SOLUTIONS

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Rainbow River 2015 Aquatic Vegetation Coverage Final Report
Contents

1.0 Introduction

1.1 Overview and Objective

The Rainbow River Aquatic Vegetation Coverage project was conducted for the Southwest Florida Water Management District (SWFWMD) using methods adapted from the previous vegetation surveys so that changes to the macrophyte communities can be evaluated. Water & Air Research, Inc. (Water & Air) conducted data collection and analysis of emergent and submergent vegetation and developed a GIS geodatabase that depicts 2015 vegetation conditions.

1.2 Previous Vegetation Characterization and Mapping

Previous vegetation assessment and mapping efforts have occurred sporadically along the Rainbow River since the late 1950's. Regular vegetation assessment started in 1996 (FDEP, 1996) and has continued since then in five year intervals for the years, 2000 (PBS&J, 2000), 2005 (PBS&J, 2007) and 2011 (Atkins North America, Inc. and Debra Childs Woithe, Inc, 2012). The 2015 effort builds on previous work and methods, so that the 2015 data can be compared to the 2011 data.

1.3 Project Area and River Description

The Rainbow River is located near Dunnellon, Florida in southwest Marion County and flows 6 miles (9.5 kilometers) from its source at Rainbow Springs to its confluence with the Withlacoochee River (Figure 1-1).

The Rainbow Springs Group and the river have significant recreational value, including swimming, kayaking and canoeing from the head springs and tubing on the river. Rainbow Springs has been a tourist destination since the early 20th Century, featuring glass-bottom boats. It continues to have economic significance to north-central Florida. The majority of the Rainbow River was designated as Rainbow Springs Aquatic Preserve in 1986 and an Outstanding Florida Waterway in 1987 due to its exceptional ecological and aesthetic characteristics. Rainbow Springs was acquired by the State of Florida in 1990 and the headspring, surrounding lands and portions of the spring run became Rainbow Springs State Park. The park contains approximately 1,084.58 acres (FDEP, 2002).

Rainbow Springs are among the world's clearest natural waters (Duarte and Canfield, 1990). However, water quality issues are affecting the Rainbow River with water clarity diminishing in the lower river due in part to increasing chlorophyll concentrations. SWFWMD has monitored water clarity at eight Rainbow River stations from river mile 0.04 to 5.60 over a nine-year period (2006 to 2014). In each year, water clarity decreased from upstream to downstream stations. Over the nine-year period average water clarity at the most upstream station was 221 feet and 32 feet at the most downstream station.

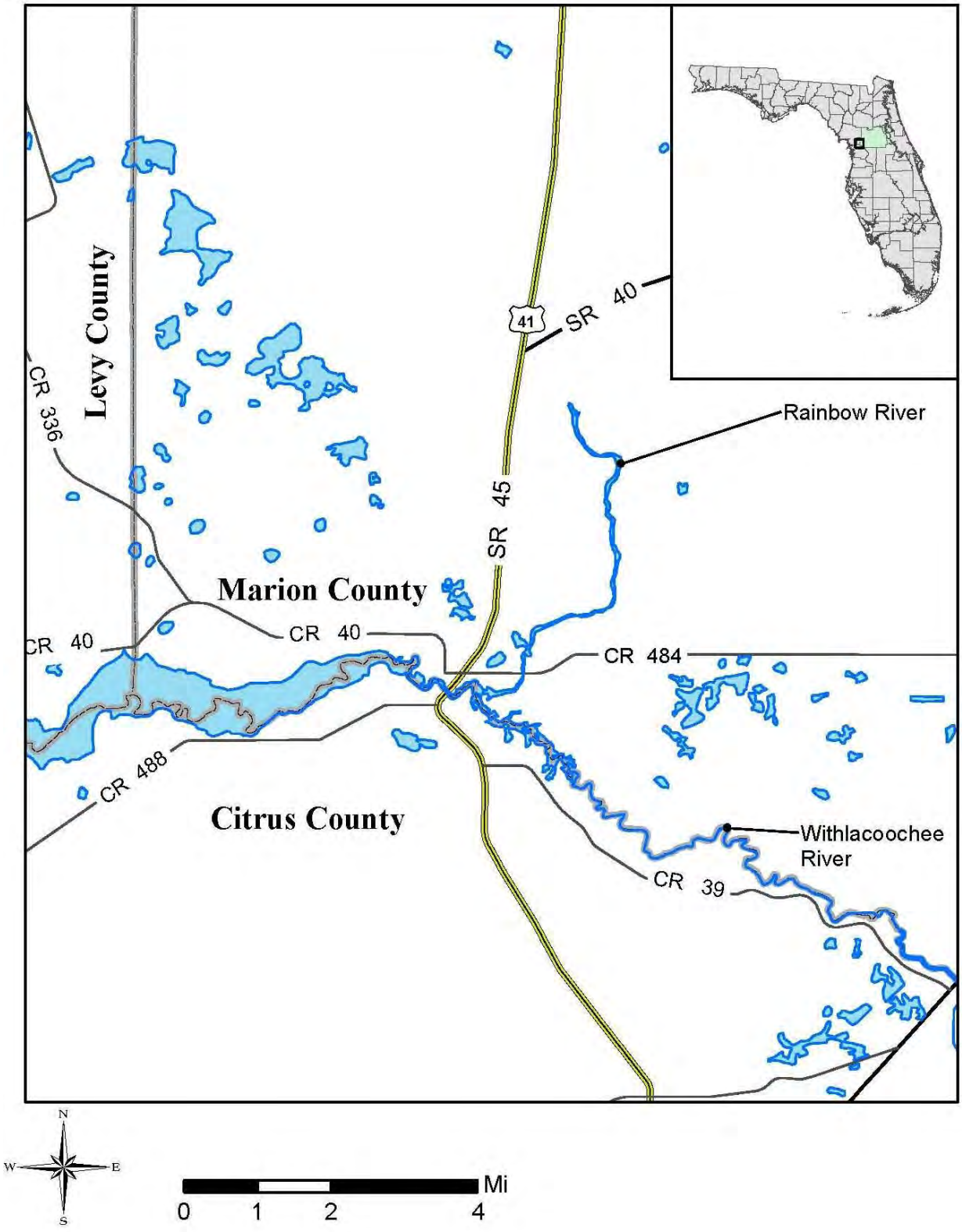

Figure 1-1. Rainbow River Region

Discharge of the river varies seasonally with minimal lag time between changes in rainfall and the response of the spring discharge (Jones, et al. 1996).The average discharge of the Rainbow River (at USGS 02313100 Rainbow River at Dunnellon, FL) in 2015 (based on available data for January through-March) is 667 cfs, the average discharge since the last mapping event (2011 through 2014) is 567.0 cfs, and the average discharge from 1965 through 2014 is 691 cfs. There has been increasing annual discharge from 2012 through 2014, although a period of record low (436 cfs) occurred in March, 2012 (USGS, 2015). Based on preliminary numbers for 2015, this increasing discharge trend may continue for 2015. Low flow for the calendar year 2015 occurred in early July, while peak flow occurred in the beginning of October 2015 (USGS, 2015).

Nitrate enrichment is the primary water quality issue of concern in a majority of Florida springs, including the Rainbow River. Nutrient enrichment stimulates aquatic plant abundance including the growth of phytoplankton, epiphytic algae and filamentous algae such as the nuisance species Lyngbya. Elevated levels of nitrogen, especially in the form of inorganic nitrate, occur in the Rainbow River far exceeding assumed historic concentrations of 0.1 mg/L. In 1995 one of the 4 spring vent monitoring stations on the Rainbow River had nitrate concentrations of 1mg/L and reached 2 mg/L in 2009 (SWFWMD, 2015). In 2010 FDEP added the Rainbow Springs Group and the Rainbow Springs Group Run to the Verified List of impaired waters for its high nitrate levels and algal mats. A TMDL was established in 2013 for nitrate reduction (FDEP, 2013).

Both land use proximal to the river and those within the springshed affect the quality of water in the Rainbow River. Land use along the river varies from Conservation and Recreation uses (Rainbow Springs State Park and other parks), to Urban and Built-up with single family homes with docks immediately adjacent to the river, and some agricultural lands in the vicinity. Significant land uses in 472,000 acre springshed include agriculture (38%), forestland (29%) and residential uses (14%)(SWFWMD, 2015). Analyses of the land uses and relative contribution of nitrogen by land use type identify agriculture and septic tanks as the primary sources of nitrogen to the Rainbow Springs BMAP area (FDEP, 2015).

Diverse and abundant emergent and submergent vegetation communities of the Rainbow River help to maintain the water quality, support fish and wildlife, stabilize banks and sediments and contribute to the river's scenic qualities. Regular monitoring of submerged aquatic vegetation (SAV) and emergent vegetation has occurred to document vegetation diversity, abundance and change through time (Section 1.2). Of concern is the decrease in cover of Sagittaria kurziana, a native species, and the occurrences of the exotic Hydrilla verticillata and the nuisance filamentous, blue-green algae, Lyngbya. The latter two species are especially prevalent in the lower river where high levels of chlorophyll have affected water clarity. In addition, both Hydrilla and Lyngbya have the ability to outcompete more desirable native SAV.

In addition to the effects of nutrient enrichment on SAV, recreational use of the river, especially during summer months, has caused damage to and loss of SAV principally from motor boat propeller damage and from other recreational uses (tubers and non-motorized boats). Thus, monitoring change of vegetation through time is one key indicator of the health of the Rainbow River and its response to management measures now in place to reduce nutrient loading, manage exotic vegetation, and curb impacts from recreational uses.

2.0 Methods

2.1 Project Area Base Map

The project area base map for the 2015 mapping effort was comprised of GIS files from the 2011 mapping effort. Water & Air received the 2011 GIS files from the SWFWMD in April 2015. The project area boundary generally defines the upland edge of the river system. As in previous years, all areas within the project boundary were mapped.

2.2 Field Methods and Mapping

2.2.1 General

The SWFWMD contracted with Water & Air to conduct the 2015 Rainbow River vegetation mapping and to refine and develop new field mapping methods. The 2015 project included mapping shoreline features and quantifying areas of herbaceous emergent vegetation, forested vegetation, SAV species, bare ground and filamentous algae. Data collected would then be compared to the previous (2011) mapping effort, where applicable.

Site reconnaissance was performed on the river in April-May to refine the methodology and field mapping strategy. A meeting was subsequently held with SWFWMD to discuss and further refine the proposed field methodology. Emergent vegetation and shoreline features (hardened shoreline and docks) were field mapped in May-June 2015. Field mapping for SAV, bare ground and algae was performed in June-August 2015.

Field mapping was conducted from an outboard-powered, aluminum boat. A laptop computer loaded with PC Mapper GIS software communicating with a SX Blue sub-meter GPS unit (< 3 ft accuracy) was used as a real-time moving map field work station. The field team utilized mapped boundaries from the 2011 mapping effort as a moving map background. Once identified, the vegetation boundaries and features of the 2015 data collection were drawn by hand on printed field maps that showed the 2011 mapped boundaries. By using the 2011 boundaries on both the real time digital map and the printed field maps, the field team was able to use the previous boundaries to register the 2015 boundaries. Once collected, the field maps and data were transferred to a digital format (digitized).

By agreement with the SWFWMD, a mix of metric and standard units was used to show distance and area. Throughout the report, acres (ac) will be the standard area unit. River Zones, in kilometers (km), have been historically used to define the river distances as measured downstream from the headsprings of the Rainbow River. A total of 95 River Zones (9.5 km) are identified with River Zone 1 located at the headspring and River Zone 95 located at the confluence of the Rainbow River with the Withlacoochee River.

2.2.2 Shoreline Features

Shoreline features, including hardened shoreline and dock structures, were mapped during the emergent vegetation mapping effort. Hardened shoreline is defined as any wood, concrete, rock, or other hard material used to retain the riverbank. The lengthwise extent of the hardened shoreline was mapped and data reported in linear feet. Locations of dock structures, mapped as points, were located at their interface with the shoreline. During the data collection, 2015 shoreline features were compared to the 2011 digital map. Any shoreline change was recorded by hand on a printed field map and then transferred to a digital format.

2.2.3 Emergent Vegetation

Emergent vegetation was mapped along with the shoreline features. There is no overlap of boundaries between the emergent vegetation and the SAV areas in 2015. The emergent GIS map layer included information about the emergent vegetation. Herbaceous emergent vegetation areas are non-woody plants rooted in the river bottom but with significant vegetative growth occurring above the water. Areas within the emergent map layer were classified as either herbaceous emergent or forested areas. Floating vegetation was also included as herbaceous emergent vegetation. Forested areas are defined as tree and shrub areas growing within the project boundary. Wetland forested areas make up the majority of the mapped forested areas. However, upland forested areas located within the project boundary were included in the mapped forested areas.

Field mapping of the 2015 emergent vegetation was similar to the 2011 mapping effort. Field mapping was done by navigating the boat along the perimeter of the area to be mapped. Then, by referencing the digital map, the emergent boundary was drawn by hand on a printed field map. Once an herbaceous emergent area had been mapped, the species of plants growing in the defined area were recorded on a field sheet as either dominant or present. A species was considered dominant if it occurred more than all other species in a given polygon. As a result, some polygons were noted as having more than one dominant species while other polygons had no dominant species. No species specific information was recorded for the forested areas. In general, patches of vegetation smaller than 15 ft x 15 ft or 225 square feet (sq. ft.) were not mapped and this is consistent with the 2011 methods. In general the 2011 emergent layer polygons were retained and used in the 2015 data collection, although small areas were combined into adjacent larger units, if appropriate.

2.2.4 Submerged Aquatic Vegetation

Field mapping of SAV was conducted following the data collection and digitization of emergent vegetation and shoreline features. The 2015 SAV mapping procedures differed somewhat from the 2011 SAV mapping effort by agreement with SWFWMD. The 2015 SAV attributes within a polygon grouped vegetation taxa and bare ground (sand, rock, shell) for cover determination. The 2011 mapping work defined separate polygons for SAV and non-vegetated areas (sand, rock, shell). The 2015 mapping effort grouped areas of similar river bottom habitats into single mapping units (polygons). In general, an effort was made to create mapping areas (polygons) no smaller than 30 ft x 30 ft or 900 sq. ft. for the SAV, although the 15 ft X 15 ft minimum for the emergent layer was retained from 2011.

Field mapping of the SAV was conducted by first identifying associations of similar areas of vegetation composition and bare ground. Landmarks on the riverbank (docks, hardened shoreline, trees, etc.) were used to aid in defining the boundaries. Once an area had been identified, the field team traveled the proposed boundary and drew the boundary by hand on a printed field map by referencing the digital map. A viewing bucket was used to facilitate a visual inspection of the vegetation and river bottom within each polygon area from the boat. The bottom composition and vegetation species cover for the polygon was identified visually and cover quantified using a modified Braun-Blanquet cover class. The midpoint assigned to each cover class was recorded by hand on a field data sheet for each SAV species or bare bottom type. Summed cover percentages for each polygon was approximately one hundred percent. Table 2-1 shows the modified Braun-Blanquet cover classes used for the 2015 SAV mapping effort.

Table 2-1. 2015 SAV and Bare Ground Cover Classes (SAV Species and Bare Ground)

SAV and Bare Ground Cover Classes	Midpoint / Value
Trace amount, >0 to 1%	0.10%
1 to 10%	5.00%
10% to 25%	17.50%
25% to 50%	37.50%
50% to 75%	62.50%
75% to 90%	82.50%
90% to 100%	95.00%

2.2.5 Algae

Algae cover was defined as filamentous algae growing on both vegetation and bare ground for the 2015 data collection. Algae cover was quantified as an attribute of the SAV polygon. Once the SAV polygon boundaries were drawn and bottom type for bare ground and SAV cover recorded, the algae cover was estimated and recorded on the printed field data sheet using modified Braun-Blanquet cover class. Table 2-2 shows the cover classes used for the 2015 algae data collection.

Table 2-2. 2015 Algae Cover Classes

Algae Cover Classes	Midpoint
>0% to 10%	5.00%
10% to 50%	30.00%
50% to 100%	75.00%

The 2015 field effort collected information on the relative cover for filamentous algae only within a given mapped SAV polygon. By contrast, the 2011 mapping effort defined distinct (separate) areas for benthic and epiphytic types of algae and made no distinction between filamentous and non-filamentous algae.

2.3 GIS Mapping

The 2015 GIS map files were created following the field data collection. GIS software was used to digitally draw (digitize) the polygon boundaries or edits made by hand on the printed field maps. For the emergent vegetation and shoreline features, both geometry and attributes were edited in the 2011 digital files to create the 2015 digital files. In contrast, the SAV polygons (including algae) were created as completely new digital files for 2015 due to method differences between the 2011 and 2015 data collection. As previously noted, there is no overlap of the emergent vegetation and SAV mapped boundaries in the 2015 GIS maps.

Field maps were digitized using PC Mapper GIS software. Geo-referenced, December 2014 high-resolution (1 ft) aerial images were acquired from the Land Boundary Information System (LABINS) and used to aid in digitizing the field maps.

Data collected in the field were entered into spreadsheets, imported and combined with the respective digitized maps using ARCMap GIS software. The resulting complete GIS data

files include vegetation and feature data with associated measures of area or lengths. Emergent and SAV GIS data files were then intersected by River Zone (0.1 km).

2.4 Data Compilation Methods

Water & Air received the 2011 digital data from the SWFWMD in April 2015. A quality assurance (QA) analysis was performed on the 2011 data to verify reasonable consistency (<5%) between the 2011 GIS data and 2012 report data tables to ensure that the results were reproducible (See Section 2.6 and Appendix A). The project boundary, 2011 vegetation map layers and River Zone boundaries were used as a field mapping reference and the basis for all comparisons with the 2011 data in this report.

Zone Group summaries were used for emergent, SAV and algae data compilation and comparisons. Zone Groups are comprised of ten River Zones and identified by the zones contained within the group (example Zone Group 1-10 or 11-20). All Zone Groups, except Zone Group 91 -95, are one kilometer of river length. The Zone Group provides a convenient measure to summarize data with reference to spatial distribution within the river system.

ArcMap was used to create and export spatial data to spreadsheets for compilation and data reduction. The data for emergent vegetation was exported from the GIS as an Excel workbook. The emergent vegetation map areas were designated as forested or “emergent” (aka herbaceous emergent). Total areas of forested and herbaceous emergent vegetation were calculated for the whole river, by River Zone and by Zone Group. The total areas of each category of emergent vegetation (forested or herbaceous) for the whole river, by River Zone and by Zone Group were used to calculate the percentage of polygon of emergent plants occupied by each category of vegetation (e.g. area of vegetation type/total Zone Group area * 100 = percentage). For emergent herbaceous species, the six most-dominant species were determined by ranking species by the number of polygons in which they were marked “dominant”. The top six species were those listed as “dominant" in the greatest number of polygons for the whole river.

The SAV data was exported from the GIS as an Excel workbook. The mapped areas (polygons) are the smallest unit that defines the vegetation cover.

For the purposes of clarity in discussion, the nomenclature of the SAV mapping effort is described here and will be used throughout the discussion of method and results. The “mapped” SAV refers to the GIS geodatabase layer that includes all SAV habitats; the submerged aquatic vegetation (SAV) species identified with coverage data and non-vegetated areas (bare ground). Examples of bare ground recorded in 2015 include sand, shell and rock. The SAV data refers to all of the information within the SAV GIS layer. The SAV data contains multiple “attributes” such as specific plants (SAV species) and bare ground (non-vegetated). In the case of the 2015 data, the algae data is also an SAV attribute because it uses the same polygon boundaries but with different cover classes (Section 2.2.5). However, the algae data is not summed with the other attributes, but kept separate. In contrast, the 2011 SAV classified separate polygons for SAV species, bare ground and algae. The 2015 SAV attributes include specific SAV species, various types of bare ground and the associated coverages (calculated from the cover class midpoint). To calculate the area for each 2015 SAV attribute, the midpoint of the cover category (Table 2-1) was multiplied by the area of the polygon. The result is an area of relative cover for each SAV attribute in the polygon.

Once the respective 2011 and 2015 SAV attribute areas were calculated, the procedures for summarizing the SAV attribute data for each data set are as follows. The SAV attribute area was determined for a polygon. Each SAV attribute area was then summed within a River Zone, Zone Group and for the whole river. The areas of the SAV attributes were then used to determine the percentage occupied by SAV species or bare ground for each River Zone, Zone Group and for the whole river using simple division (e.g. area of species/total Zone Group area times 100 equals the calculated percentage of the Zone Group with that SAV species). To determine the most abundant (dominant) SAV species, SAV species were ranked accordingly by the largest percent cover within a Zone Group or for the whole river.

The data for algae was exported from the GIS as an Excel workbook. The algae cover categories corresponded to percent cover ranges (Table 2-2). The midpoint of the cover category was multiplied by the polygon area to determine the algal cover area. The algae area was used to calculate the percentage of mapped submerged area occupied by algae (e.g. area of category/total Zone Group area times 100 equals the percentage). The calculated algae areas were then used to determine the percent cover of River Zone, Zone Group and river total. In both 2015 and 2011, the algae did not overlap with the emergent GIS layer.

2.5 Change Analysis Methods

In order to facilitate comparisons between years (2011 vs. 2015), summary tables and dominant species designations were compiled using the same methods for the 2011 data as for the respective 2015 data. The following information provides the methods used to develop the change analysis data sets of the Rainbow River Aquatic Vegetation Project.

2.5.1 Emergent Vegetation

The whole river areas occupied by herbaceous emergent and forested vegetation types were compared between years by subtracting the 2011 area from the 2015 area to show the increase or decrease of the total area occupied by that vegetation type. Similarly, the percent change in area occupied by each emergent vegetation type over the whole river between years was calculated as follows:

$$\text{Percent Change} = \frac{\text{New Value - Old Value}}{\text{Old Value}} \times 100$$

Herbaceous emergent species-level information was compiled for 2011 and 2015. The number of polygons where an herbaceous species was present or dominant was compiled for evaluation. In addition, whole river area of herbaceous species was compiled.

2.5.2 SAV and Bare Ground

The whole river total areas occupied by SAV and submerged bare ground were compared between years first by subtracting the 2011 area from the 2015 area to show the increase or decrease of the total area occupied by each. Similarly, the percent change in area occupied by each bottom type over the whole river between years was calculated as follows:

$$\text{Percent Change} = \frac{\text{New Value - Old Value}}{\text{Old Value}} \times 100$$

Whole river comparison of 2011 and 2015 SAV data should be done cautiously because the data allows different ways of summarizing SAV and bare ground areas due to varying SAV and bare ground field mapping methods and the cover classification system refinements.

The following information provides background regarding the 2011 SAV data including the field data as received by Water & Air in April 2015 and a description of data reduction options related to the SAV data. The 2011 SAV data defined areas (polygons) exclusively as bare ground or vegetated. The 2011 bare ground areas were uniquely classified and mapped with assigned ground categories (rock, sand etc.). These bare areas were assumed to have no cover of SAV species. The 2011 SAV areas classified as "SAV Present" had cover values assigned to the SAV species identified in the polygon. These areas are assumed to have no bare ground cover. The 2011 SAV species cover was calculated as a percent of the SAV polygon area.

The whole river 2011 SAV data can be used to determine the SAV area two ways with two different results: 1) sum the SAV data polygons classified as "SAV present" (species cover not considered) and 2) sum of all SAV species areas using cover class midpoint calculations. The preferred whole river SAV data comparisons use similar data reduction methods for the determination of area. The sum of the SAV midpoint cover provides the most reasonable methods for SAV data comparison.

Bare ground areas were recorded using different methods during the 2011 and 2015 field data collection. In 2011 the bare ground areas were unique polygons. These areas could be summed by Zone Group or for the whole river. The 2015 data recorded the bare ground cover by using cover class mid-points with the bare ground areas determined as a portion of the SAV polygon. The calculated bare ground areas, whether determined as the sum of polygon areas (2011) or a midpoint calculation (2015), were comparable between sampling events by Zone Group or for the whole river.

SAV species areas were calculated using different cover categories applied to the 2011 and 2015 SAV data. The following information is provided as background to summarize the process used to create data compatible for the SAV species change analysis.

The 2011 SAV data required several data reduction steps. To calculate the 2011 SAV cover for each SAV species, the cover class "codes" used in the GIS data file were converted to cover midpoint data (Table 2-3). The 2011 SAV species cover codes data provided by the SWFWMD represented the top end of the cover category for each polygon. Compared to 2015 field effort (Table 2-1), the 2011 cover classifications has fewer cover categories with all cover over 50% having a midpoint of 75%; and no species with a cover less than one percent included.

Table 2-3. 2011 SAV Cover Classes

Cover Range	Midpoint	GIS Code (2011)
0%	0%	0
1% to 10%	5%	10
10% to 50%	30%	50
50% to 100%	75%	100

The 2011 and 2015 areas of each SAV species were calculated by multiplying the midpoint of the cover category applied to each species present in the polygon to obtain the SAV species area. The SAV species areas were then summed within a Zone Group and for the whole-river for each SAV species. These SAV species areas within a Zone Group and over the whole river were then used to determine the percent cover by species of Zone Group

and the whole river area. Dominant SAV species were ranked by descending percent cover within a Zone Group and for the whole river.

The 2011 and 2015 change in total area occupied by all SAV species combined, as calculated by midpoint, was determined by subtracting the total SAV areas within Zone Group and for the whole river. The percent change in total SAV species cover area from 2011 to 2015 was then calculated to get the percent change in SAV cover for the whole river. Similarly, to calculate the whole river change and change within Zone Group area occupied by each SAV species between 2011 and 2015, the area occupied by each SAV species in 2011 in the Zone Group was subtracted from the 2015 species area within each Zone Group and for the whole river.

2.6 Quality Assurance and Quality Control Methods

Quality assurance (QA) checks and procedures were conducted on the 2011 Rainbow River vegetation data (Atkins Global, 2012) prior to starting the 2015 field data collection to help ensure the 2015 data is comparable with the previous effort. The goal of the QA review of the 2011 Rainbow River vegetation data was to determine if the GIS data received by the District from Atkins North America and Debra Childs Woithe, Inc. (SWFWMD 2012) can be used by Water & Air to recreate select summary data tables in the Atkins 2012 report. This is analysis referred to as the QA evaluation of the 2011 data and the methods used are documented in Appendix A. Water & Air was also tasked by SWFWMD to conduct quality control (QC) verification on a representative portion of the 2015 field survey of the river's SAV and emergent vegetation. The methods used for this analysis are discussed in Appendix A.

3.0 Results

Selected results are discussed below and supporting data provided in the associated data tables. The GIS database, metadata and generated pivot tables have been provided to the District and represent the delivery of the complete results of the 2015 Rainbow River vegetation data collection.

3.1 Project Boundary and Shoreline Features Comparisons between 2011 and 2015

For the 2015 mapping effort, the project boundary defines the total project area. (Figure 3.1) The project boundary provides a mapping limit and generally encompasses the area of the river proper and adjacent floodplain wetlands to the upland edge. The limits of the project boundary remained unchanged from 2011 to 2015. However, it was noted that portions of the project area base map include some upland forested habitat. By agreement with SWFWMD, these data were not segregated from the forested emergent layer assumed to be wetland forest. For example, upland forested habitats within the project boundary occur along the southern shore of River Zones 88, 89, and 90. A more detailed re-mapping of the project boundary is suggested if uplands are to be excluded from the project limits.

Shoreline features that were mapped include hardened shorelines such as retention walls or rip-rap and dock structures. The majority of hardened shoreline and dock structures occur along the western shoreline of the river. In 2011, 13,601.6 feet of hardened shoreline was mapped. By 2015, the amount of hardened shoreline had increased slightly to 13,853.2 feet. The addition of hardened shoreline occurred along the western shoreline in River Zones 16, 35, 36, 37, 39, and 40. No areas mapped as hardened shoreline in 2011 had

been removed by 2015. A total of 6 docks were added from 2011 to 2015. One dock each was added in River Zones 1, 14, 21, 30, 35, and 70.

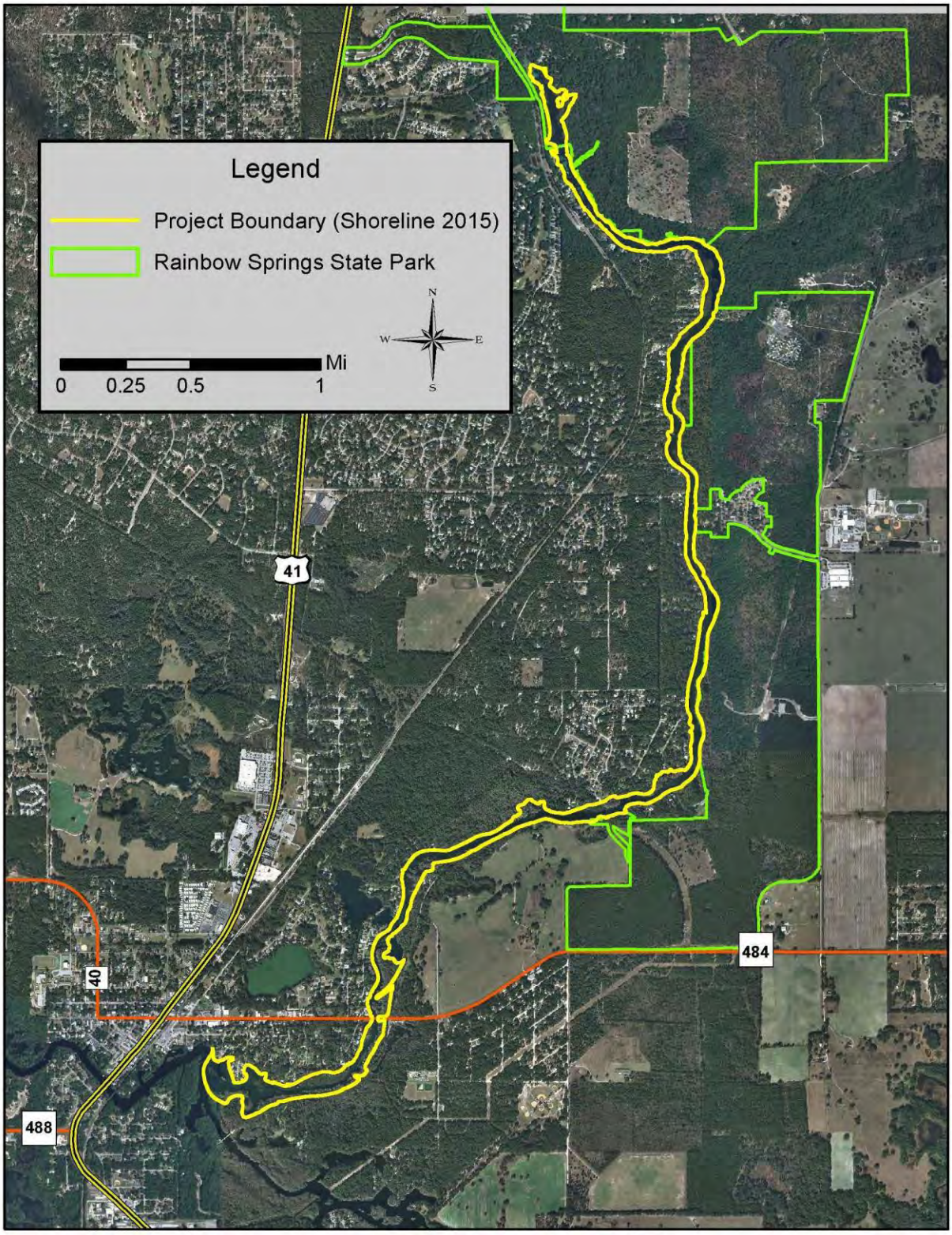

Figure 3-1. Rainbow River Study Area

3.2 2015 Whole River Results by Habitat Type

The total habitat area mapped in 2015 was 194.0 ac including emergent vegetation (herbaceous and forested) (69.7 ac) and SAV (including bare substrate) (124.3 ac) (Table 3-1). Figures 3-2.1 to 3-2.5 illustrate the location and extent of emergent and SAV habitats. The whole river SAV species covered the most area (91.1 ac). Forested emergent vegetation had the second most (36.9 ac), with bare submerged ground and herbaceous emergent vegetation occupying slightly smaller areas than forested (32.8 and 31.8 ac, respectively) (Tables 3-1 and 3-2). It is important to note that the areas of forested and herbaceous emergent plants are sums of the polygons areas, while areas of SAV and bare ground are based on calculations using the midpoints of cover categories assigned to individual SAV species and bare ground categories (Sections 2.4 and 3.10, Appendix A). Adding the SAV species and bare ground together will not exactly equal the total SAV polygon area.

Table 3-1. Habitat Areas 2011 and 2015 in the Rainbow River

Habitat Type	Area in 2011 (acres)	Area in 2015 (acres)	Change in Area from 2011 - 2015 (acres)	Percent Change from 2011 - 2015
SAV (including Bare)	136.865	124.320	-12.545	-9.17
Emergent (herbaceous)	31.443	32.789	1.345	4.28
Forested	25.981	36.896	10.915	42.01
Total River Area	**194.289**	**194.004**	**-0.285**	**37.124**

Note: These acreages represent the sum of the actual mapped areas within the project boundary.

Table 3-2. SAV Calculated Areas (2011 and 2015) for Rainbow River

Habitat Type	2011 Area (ac)	2015 Area (ac)	Change in Area from 2011 - 2015 (ac)	Percent Change from 2011 - 2015
SAV species	72.233	91.122	18.889	26.15
Bare Ground	*34.357	31.794	-2.563	-7.46
Total River Area	**106.59	**122.916	**16.326**	**18.690**

* For 2011, the areas of bare ground are the summed area of polygons marked with a substrate type as rock, shell or sand.

** For 2011 and 2015, the total river areas were calculated by multiplying the SAV species cover category midpoint (as a proportion) of the polygon area to obtain cover of each SAV species. The cover area for SAV species in a polygon were then summed to calculate the area of SAV (all species combined) in a polygon.

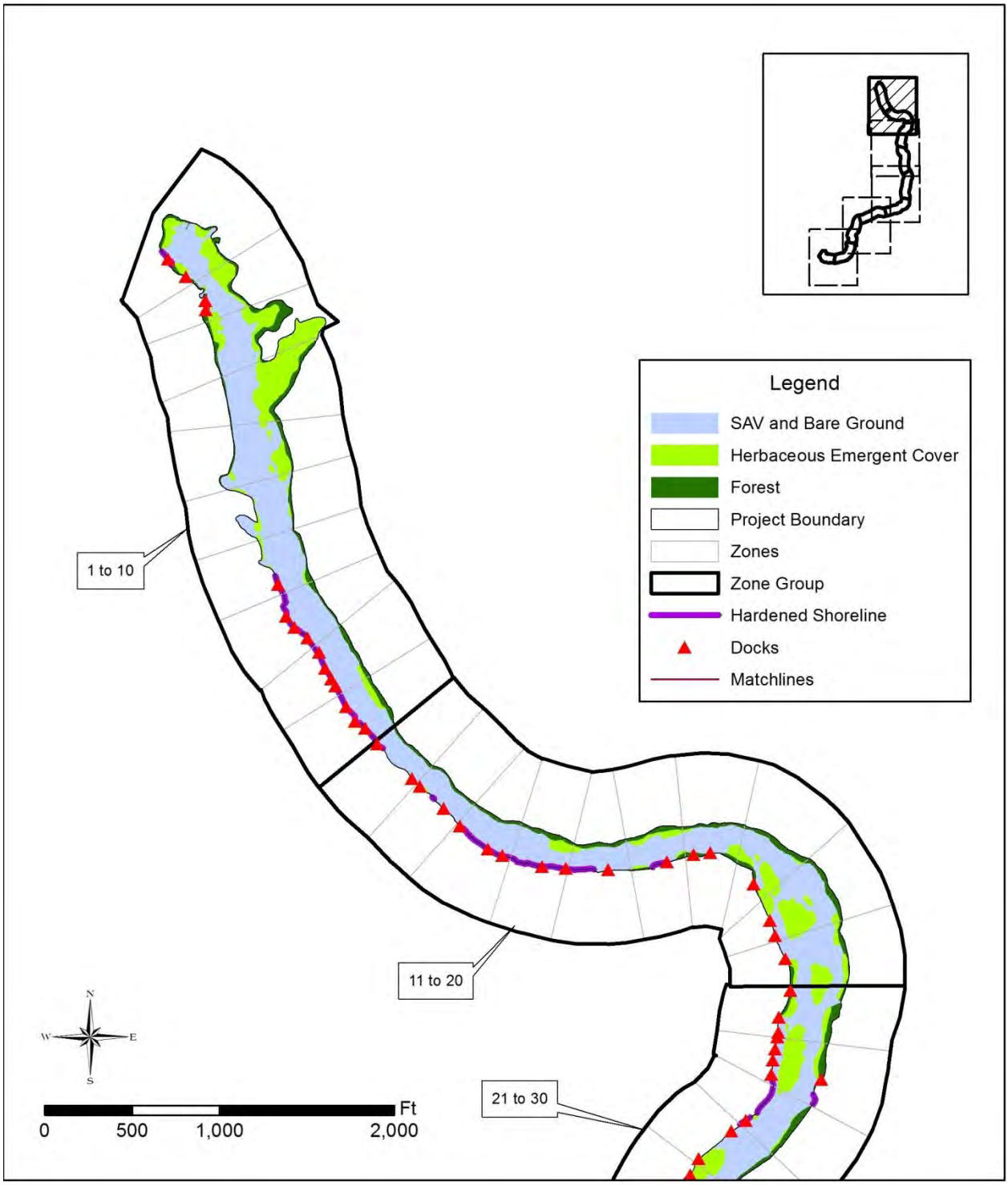

Figure 3-2.1. SAV, Forest, and Herbaceous Emergent Cover and Docks in 2015, Zones 1-20, Rainbow River, Marion County, Florida

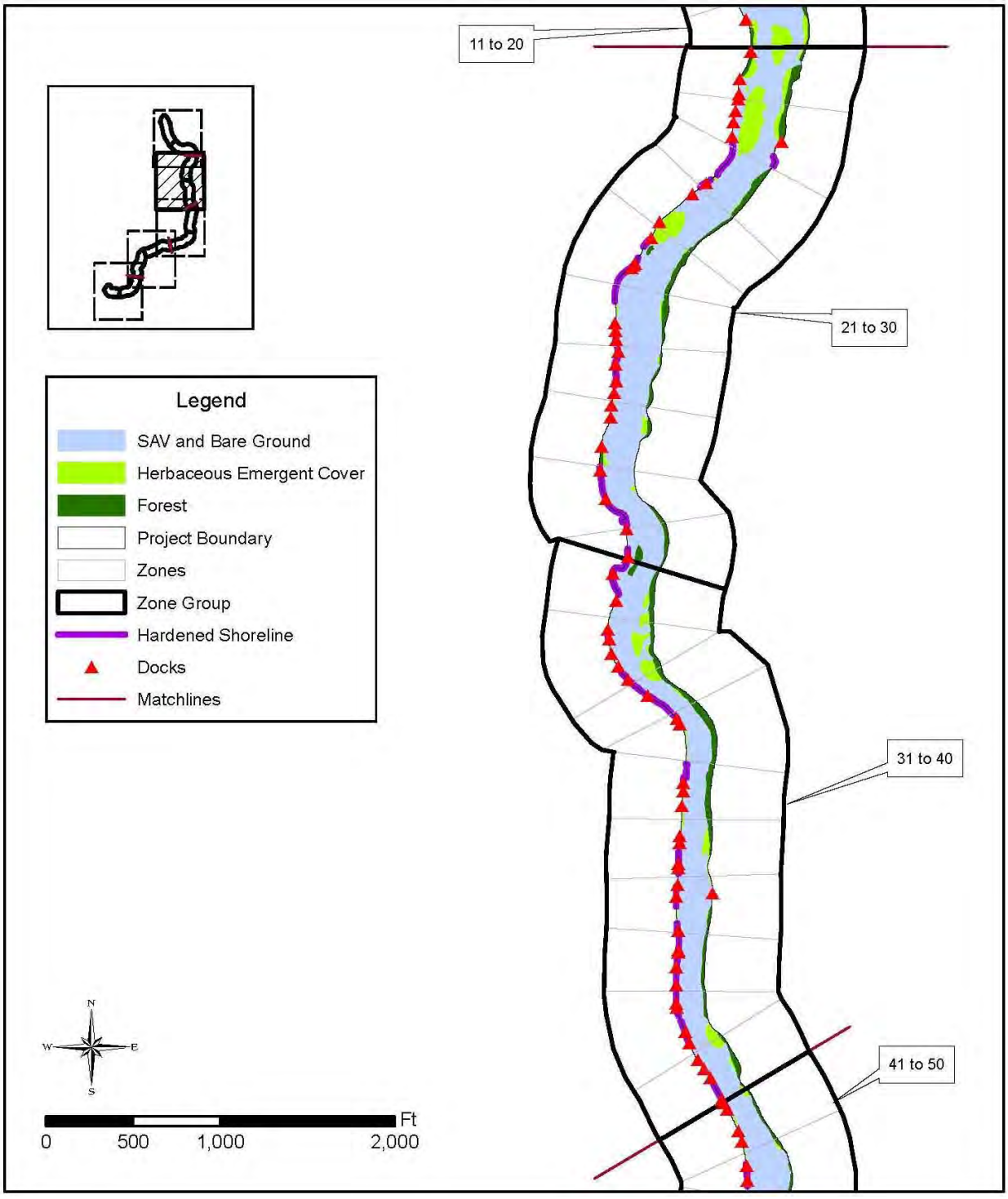

Figure 3-2.2. SAV, Forest, and Herbaceous Emergent Cover and Docks in 2015, Zones 21-40, Rainbow River, Marion County, Florida

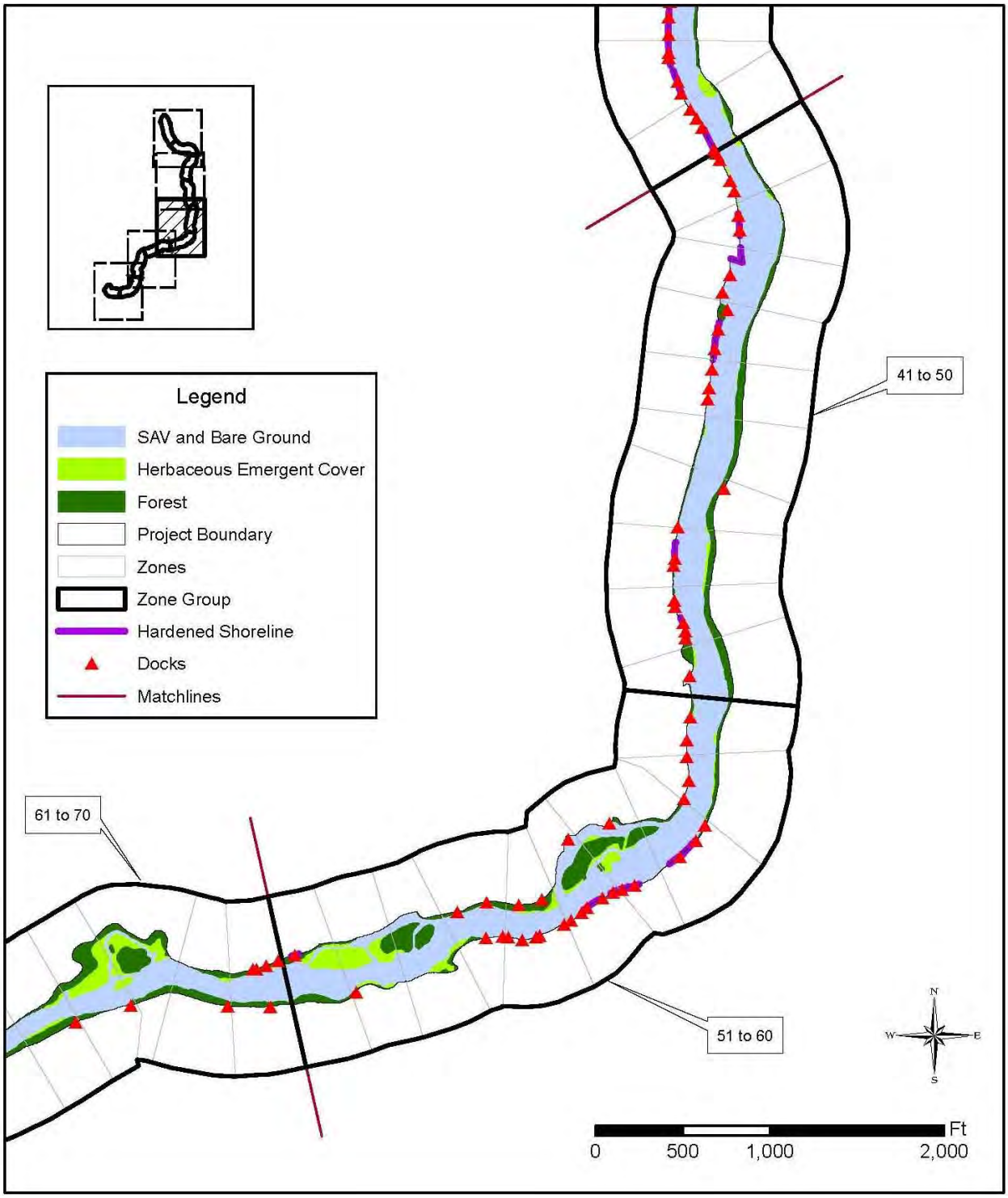

Figure 3-2.3. SAV, Forest, and Herbaceous Emergent Cover and Docks in 2015, Zones 41-60, Rainbow River, Marion County, Florida

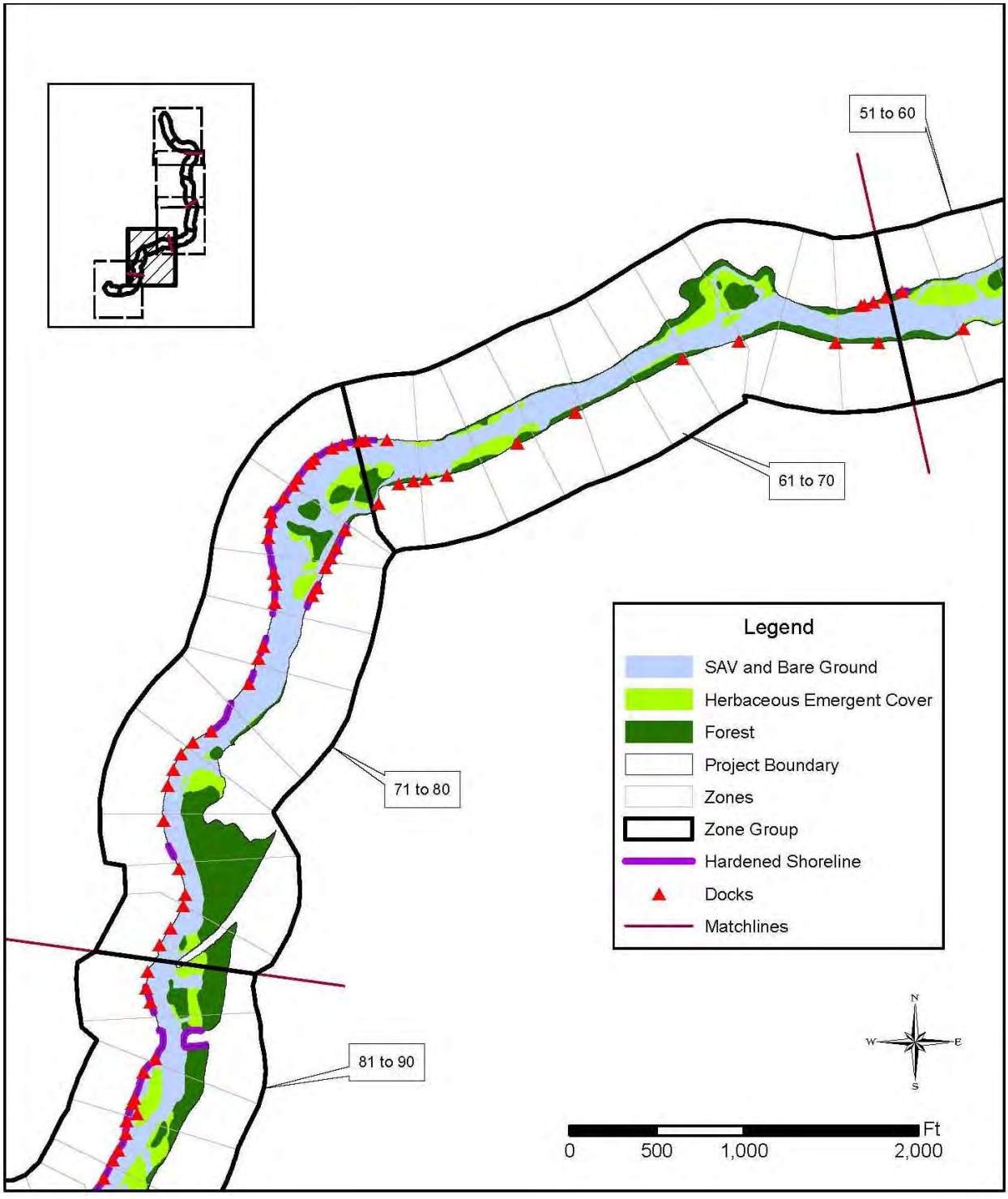

Figure 3-2.4. SAV, Forest, and Herbaceous Emergent Cover and Docks in 2015, Zones 61-80, Rainbow River, Marion County, Florida

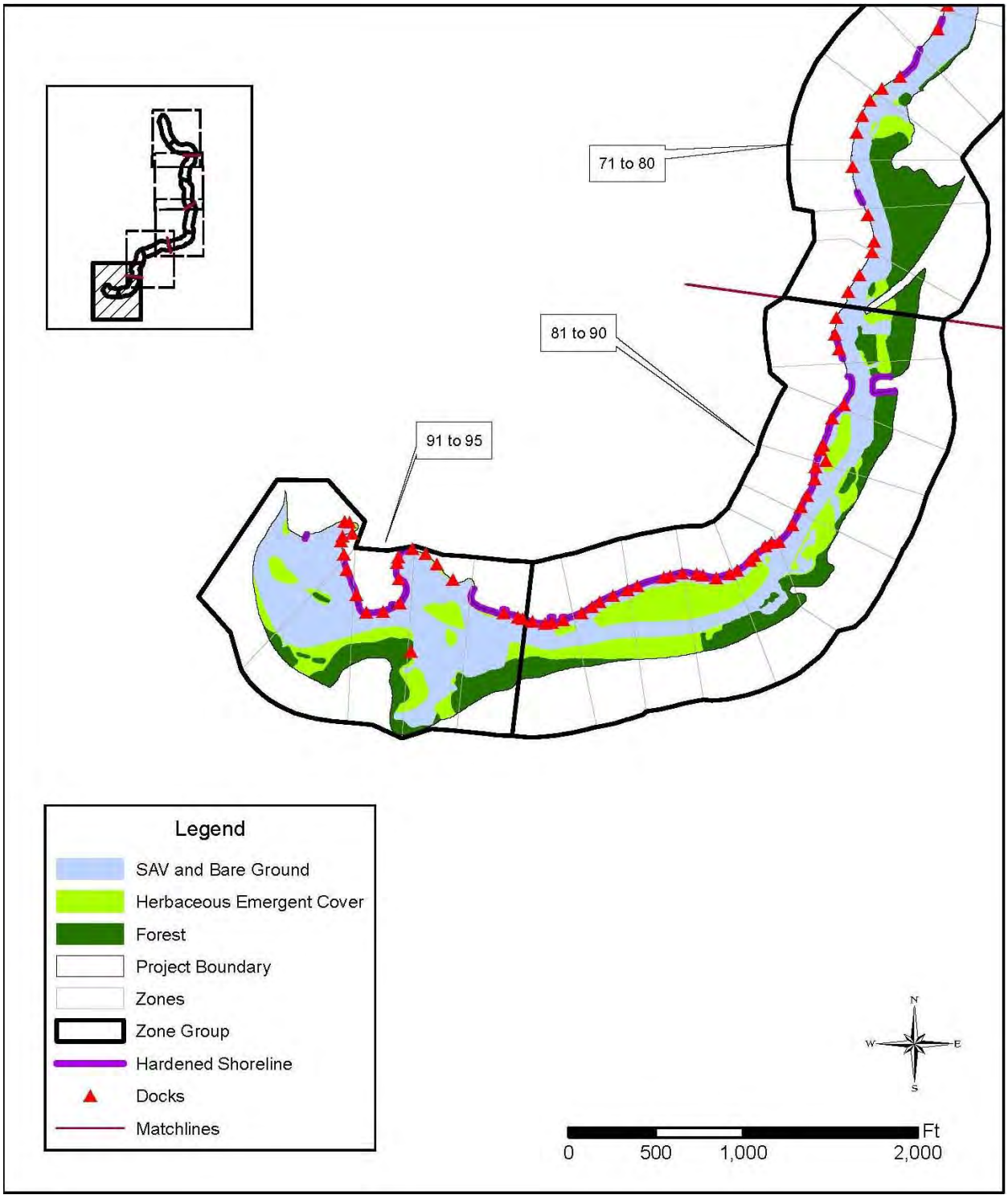

Figure 3-2.5. SAV, Forest, and Herbaceous Emergent Cover and Docks in 2015, Zones 81-95, Rainbow River, Marion County, Florida

3.3 Comparison of 2015 and 2011 Whole River Results by Habitat Type

Total areas mapped were very similar between years, with 194.3 ac overall mapped in 2011 compared with the 194.0 ac in 2015. The area occupied by the herbaceous emergent and bare ground habitats was similar between years (Tables 3-1 and 3-2). In 2015 data, the forested area increased (10.9 ac) when compared with 2011 (Table 3-1). The 2015 forested areas were mapped using aerial photo interpretation (API), field notes and GPS points taken in the field to assist with accuracy. These updated areas (polygons) along the eastern boundary of the project area reflect nearly all of the change in size in the forested area for the whole river. The newly mapped forested community replaces areas mapped in 2011 as SAV habitat. The herbaceous emergent areas are similar in 2011 (31.4 ac) and 2015 (32.9 ac).

Significant differences in the 2011 SAV areas were noted when comparing the mapped SAV areas with the midpoint calculated SAV areas for the 2011 GIS data. Table 3-3 illustrates the disparity of mapped polygons versus midpoint calculated areas for 2011 when compared with the 2015 data. When comparing the 2011 polygon areas and the midpoint calculated areas, the data varies by 22.1%. In contrast, a difference of 1.1% is observed between the same 2015 data.

Table 3-3. SAV Area Determinations

Year	Polygon (ac)	Midpoint calc (ac)	Difference (ac)	Percent Difference
2011	136.865	106.580	30.285	22.128%
2015	124.320	122.916	1.404	1.129%

As previously mentioned, a portion of the newly mapped forested community replaced area mapped as SAV habitat in 2011. This difference in available SAV habitat acreage (Table 3-2) necessitates species cover comparisons to be performed in terms of relative cover.

Whole river habitat change shows an increase in SAV species relative cover on the Rainbow River from 52.8% in 2011 to 73.3% in 2015 (Table 3-4); a difference of 20.5%.

3.4 Emergent Vegetation 2015

The whole river mapped emergent vegetation area consisted of the forested (36.9 ac) and herbaceous vegetation (32.8 ac) cover (Table 3-1). The highest percentages of forested cover as part of the emergent vegetation occurred in Zone Groups that include River Zones 41 – 80 (Table 3-5).

The area with the highest percentage of herbaceous vegetation area as part of the emergent vegetation cover was near the headspring (Table 3-5). Twenty-five herbaceous emergent taxa were recorded in 2015 (Table 3-6). The most dominant of those by area were Paspalum spp., Mikania scandens, Paspalidium geminatum, Panicum repens, Typha spp., and Hydrocotyle spp. (Table 3-7). Figures 3-3 through 3-8 illustrate the location of the herbaceous emergent vegetation that was identified as dominant and their spatial distribution along the river length.

Table 3-4.
Acreage and Percent Cover of SAV and Bare Ground by Zone Group for the Rainbow River (2011 and 2015).

	2011					2015				
Zone Group	Zone Group Area (ac)	Bare Ground Area* (ac)	SAV Area** (ac)	Percent Bare Ground	Percent Cover of SAV	Zone Group Area (ac)	Bare Ground Area (ac)	SAV Area** (ac)	Percent Bare Ground	Percent Cover of SAV
1 to 10	14.229	2.626	11.794	18.45%	82.88%	13.608	4.206	9.813	30.91%	72.12%
11 to 20	13.754	2.006	9.108	14.59%	66.22%	12.112	3.681	8.194	30.39%	67.66%
21 to 30	15.875	0.251	11.810	1.58%	74.40%	14.470	1.906	12.057	13.18%	83.32%
31 to 40	12.282	0.545	9.879	4.43%	80.43%	10.733	2.024	8.571	18.86%	79.85%
41 to 50	15.500	0.334	10.092	2.15%	65.11%	12.756	2.493	10.122	19.54%	79.35%
51 to 60	14.895	3.699	5.875	24.84%	39.44%	13.555	4.094	9.331	30.20%	68.84%
61 to 70	10.948	2.227	5.658	20.34%	51.68%	10.054	3.641	6.359	36.22%	63.25%
71 to 80	12.855	3.688	2.572	28.69%	20.01%	11.851	4.150	7.631	35.02%	64.39%
81 to 90	11.251	8.332	1.687	74.05%	14.99%	10.266	1.810	8.457	17.63%	82.38%
91 to 95	15.275	10.648	3.757	69.70%	24.59%	14.916	3.788	10.587	25.40%	70.98%
Total	**136.865**	**34.357**	**72.233**	**25.10%**	**52.78%**	**124.320**	**31.794**	**91.122**	**25.57%**	**73.30%**

Note: Each River Zone is 0.1 km of river length. Totals represent areas and percentages for the whole river.

* For 2011, the areas of bare ground presented here are the summed area of polygons marked with a substrate type as rock, sand or rock/sand.

** For both 2011 and 2015, SAV area for each species was calculated by multiplying the SAV species cover category midpoint (as a proportion) by the polygon area to obtain the cover area of each SAV species. The cover area for SAV species in a polygon were then summed to calculate the total area of SAV (all species combined) in a polygon.

Table 3-5.
Emergent Vegetation Area (Herbaceous or Forested) by Zone Group for the Rainbow River - 2011 and 2015.

	2011					2015				
Zone Group	Total Emergent (ac)	Herbaceous (ac)	Forested (ac)	Percent Herbaceous	Percent Forested	Total Emergent (ac)	Herbaceous (ac)	Forested (ac)	Percent Herbaceous	Percent Forested
1 to 10	6.426	5.300	1.126	82.48	17.52	7.062	4.969	2.093	70.36	29.64
11 to 20	3.095	2.697	0.398	87.13	12.87	4.602	2.709	1.894	58.85	41.15
21 to 30	2.738	2.424	0.314	88.52	11.48	4.163	2.413	1.750	57.96	42.04
31 to 40	1.440	1.406	0.034	97.64	2.36	2.989	1.343	1.646	44.93	55.07
41 to 50	0.509	0.251	0.258	49.40	50.60	3.248	0.338	2.910	10.41	89.59
51 to 60	4.915	2.688	2.227	54.69	45.31	6.263	2.252	4.012	35.95	64.05
61 to 70	6.875	2.966	3.909	43.14	56.86	7.769	2.978	4.791	38.33	61.67
71 to 80	8.582	1.787	6.796	20.82	79.18	9.568	2.167	7.401	22.65	77.35
81 to 90	14.468	7.064	7.382	48.83	51.02	15.253	8.998	6.255	58.99	41.01
91 to 95	8.398	4.861	3.537	57.88	42.12	8.765	4.622	4.143	52.73	47.27
Total	**57.446**	**31.443**	**25.981**	**54.74**	**45.23**	**69.684**	**32.789**	**36.896**	**47.05**	**52.95**

Note: Each zone is 0.1 km of river length. Totals represent areas and percentages for the whole river.

Table 3-6. Herbaceous Emergent Vegetation Taxa List for 2015 Rainbow River Aquatic Vegetation Coverage Assessment, Marion County, Florida.

Binomial	Common Name
*Alternanthera philoxeroides**	alligatorweed
Cicuta maculata	spotted water hemlock
Cladium jamaicense	sawgrass
*Colocasia esculenta**	wild taro
Crinum americanum	string-lily
*Cyperus papyrus**	papyrus
Hydrocotyle spp.	marshpennywort
Hymenocallis spp.	spiderlily
Mikania scandens	climbing hempvine
Nuphar spp.	spatterdock
Panicum hemitomon	maidencane
*Panicum repens**	torpedograss
Paspalum spp.	paspalum grass
Paspalidium geminatum	Egyptian paspalidium
*Pistia stratiotes**	water-lettuce
Polygonum spp.	knotweed
Pontederia cordata	pickerelweed
Rhynchospora inundata	narrowfruit horned beaksedge
*Ruellia simplex**	Mexican petunia
Sagittaria lancifolia	bulltongue arrowhead
Sagittaria latifolia	duck potato
Schoenoplectus tabernaemontani	softstem bullrush
Thelypteris spp.	maiden fern
Typha spp.	cattail
Zizania aquatica	wild rice

* indicates Listed Exotic Species
Common Name Source: http://florida.plantatlas.usf.edu/Default.aspx

Table 3-7. Herbaceous Emergent Polygon Areas by Species on the Rainbow River (2011 and 2015)

Species/Taxon	2011			2015		
	Area of Polygons Dominant (ac)	Area of Polygons Present (ac)	Total Area of Polygons with Species (ac)	Area of Polygons Dominant (ac)	Area of Polygons Present (ac)	Total Area of Polygons with Species (ac)
Alternanthera philoxeriodes	0.000	0.009	0.009	0.375	0.211	0.586
Cicuta mexicana	0.000	2.207	2.207	0.635	13.353	13.988
Cladium jamaicense	0.457	4.386	4.842	0.222	3.811	4.032
Colocasia esculenta	0.005	3.854	3.859	0.044	4.369	4.413
Crinum americanum	0.000	0.019	0.019	0.000	0.023	0.023
Cyperus papyrus	0.000	0.000	0.000	0.000	0.029	0.029
Hydrocotyle spp.	0.452	20.577	21.029	0.858	21.567	22.425
Hymenocallis spp.	0.000	0.682	0.682	0.021	1.294	1.315
Mikania scandens	6.445	22.553	28.998	9.271	18.842	28.112
Nuphar sp.	0.568	3.943	4.511	0.000	5.021	5.021
Panicum hemitomon	0.000	0.000	0.000	0.027	0.427	0.455
Panicum repens	0.095	2.568	2.663	0.203	6.530	6.733
Paspalidium geminatum	2.595	3.407	6.002	2.916	7.259	10.175
Paspalum spp.	20.627	10.390	31.017	11.572	17.012	28.583
Pistia stratiotes	0.000	4.890	4.890	0.000	11.250	11.250
Polygonum spp.	0.000	0.070	0.070	0.000	1.017	1.017
Pontederia cordata	1.744	0.295	2.040	0.067	1.897	1.964
Rhyncospora inundata	0.036	6.618	6.653	0.186	8.991	9.178
Ruellia simplex	0.000	0.000	0.000	0.000	0.019	0.019
Sagittaria lancifolia	0.239	4.034	4.274	0.300	9.959	10.259
Sagittaria latifolia	3.719	3.210	6.929	0.008	3.139	3.147
Schoenoplectus tabernaemontani	0.880	11.582	12.462	0.000	12.332	12.332
Thelypteris spp.	0.000	0.000	0.000	0.000	0.593	0.593
Typha spp.	0.475	14.367	14.841	6.161	10.041	16.202
Zizania aquatica	0.038	2.403	2.441	0.047	2.562	2.609

Note: Each herbaceous emergent species was documented as “dominant” and/or “present” in the Rainbow River based on visual assessment of cover in 2011 and 2015.

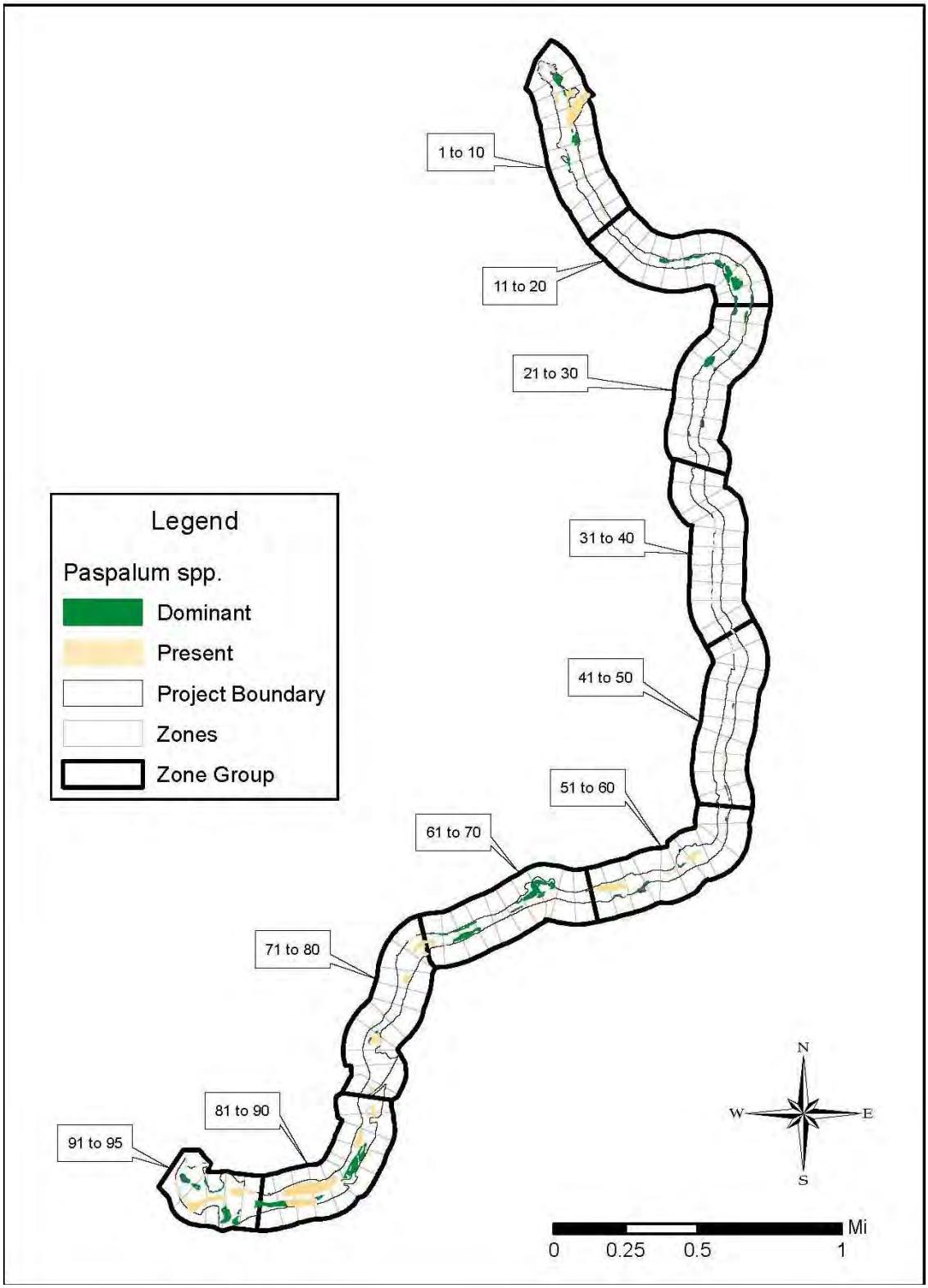

Figure 3-3. 2015 Herbaceous Emergent Species - Paspalum Grass (Paspalum spp.), Relative Cover by Zone, Rainbow River, Marion County, Florida

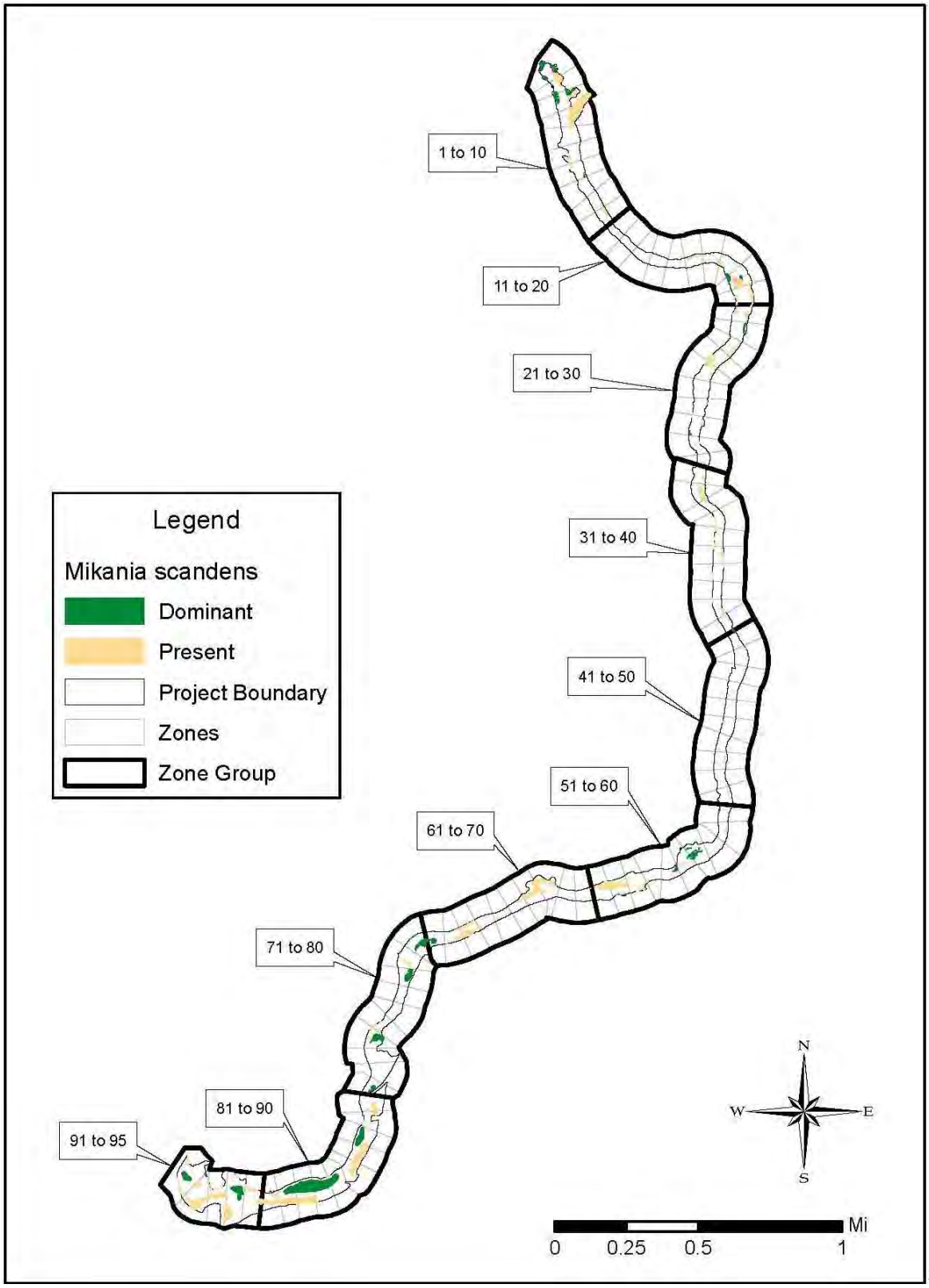

Figure 3-4. 2015 Herbaceous Emergent Species - Climbing Hempvine (Mikania scandens), Relative Cover by Zone, Rainbow River, Marion County, Florida

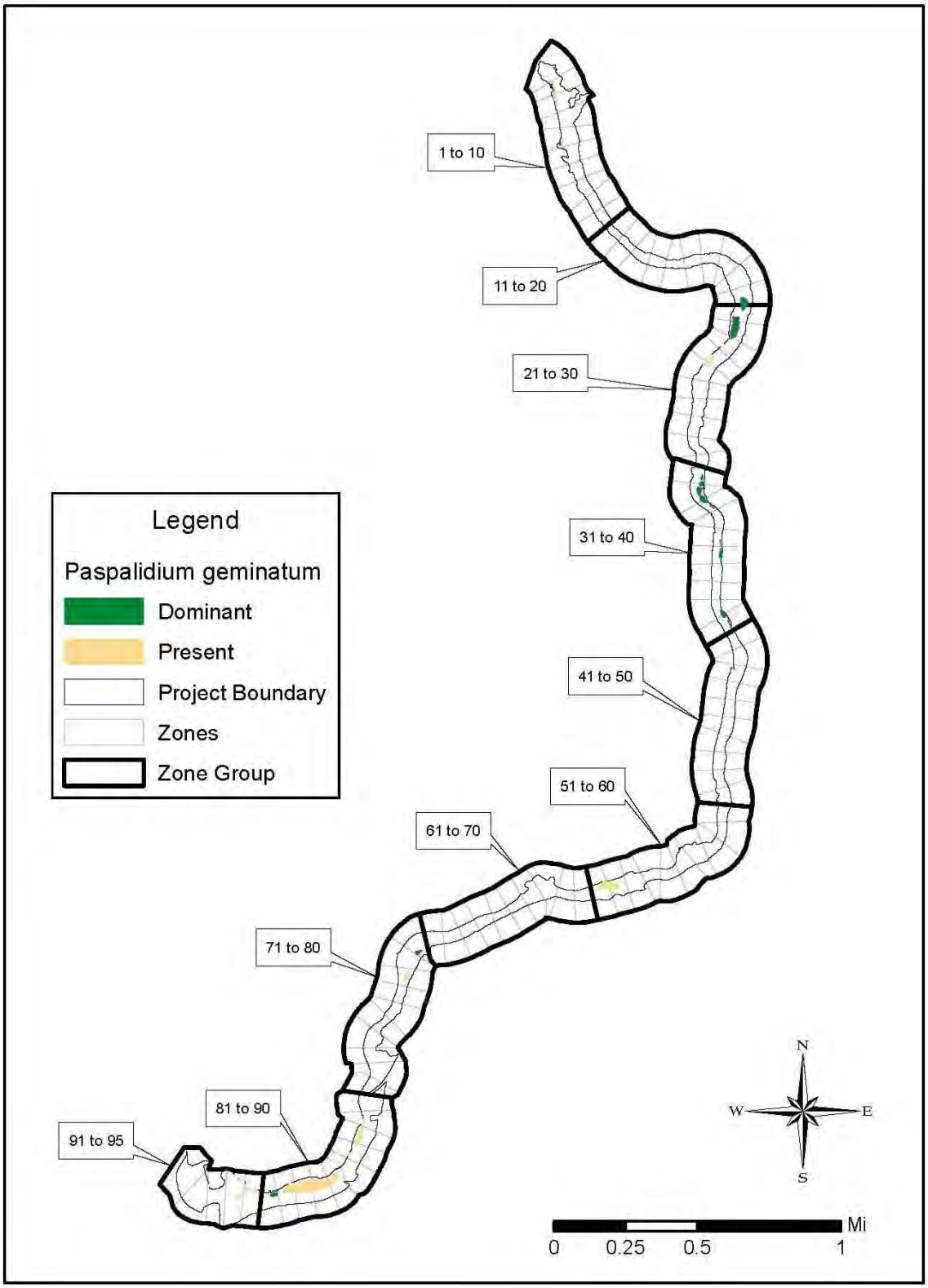

Figure 3-5. 2015 Herbaceous Emergent Species - Egyptian Paspalidium (Paspalidium geminatum), Relative Cover by Zone, Rainbow River, Marion County, Florida

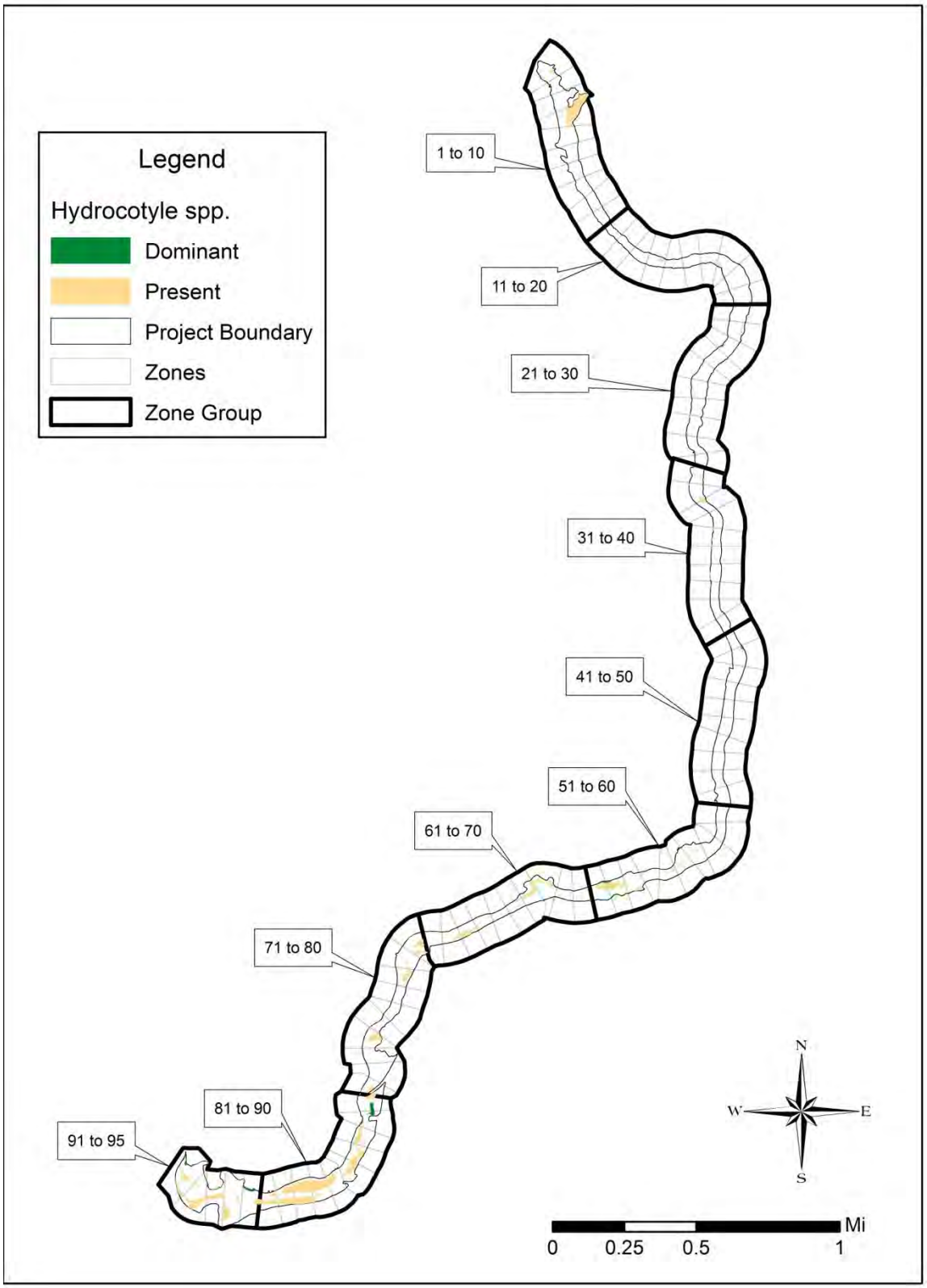

Figure 3-6. 2015 Herbaceous Emergent Species- Marshpennywort (Hydrocotyle spp.), Relative Cover by Zone, Rainbow River, Marion County, Florida

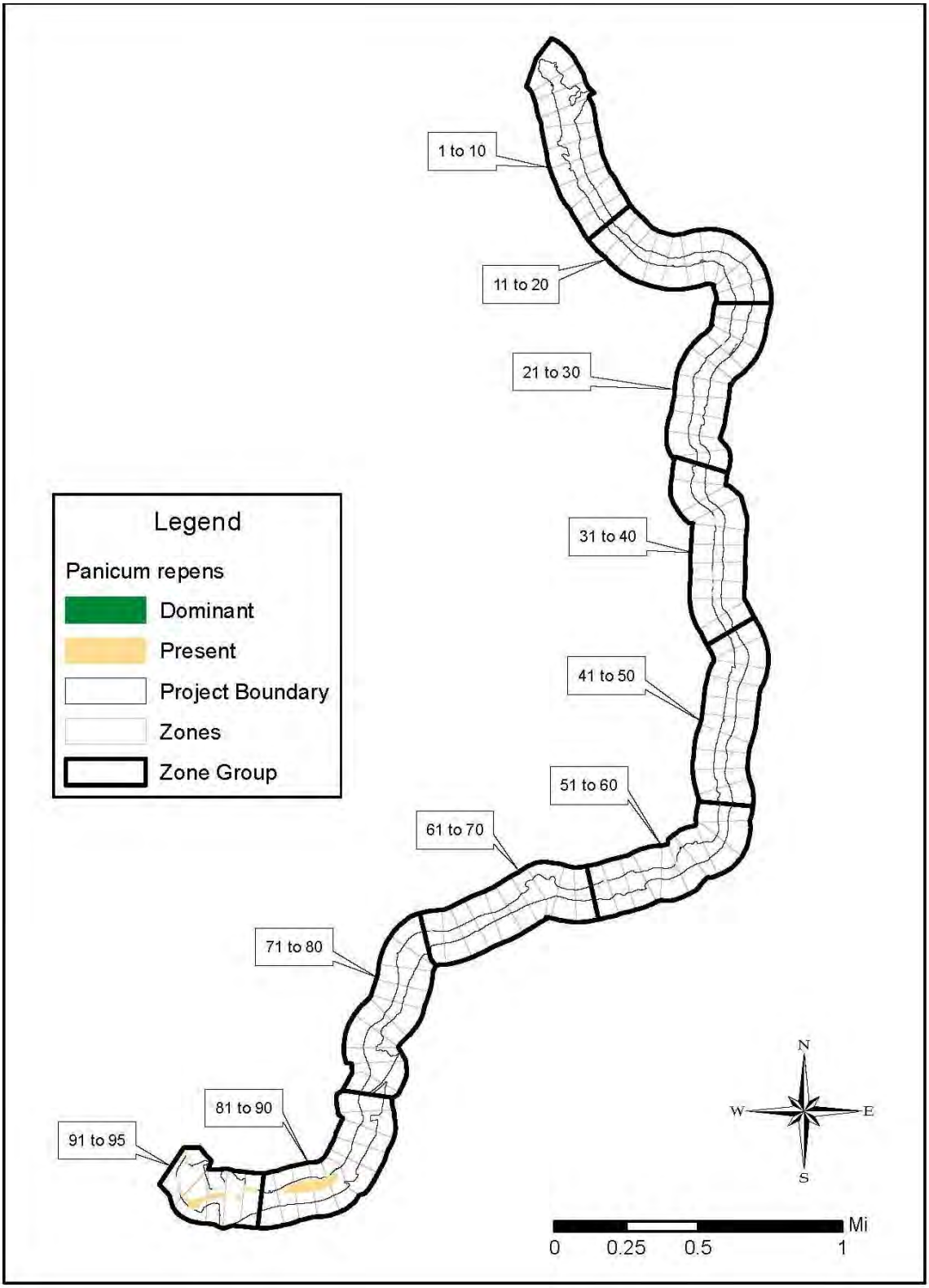

Figure 3-7. 2015 Herbaceous Emergent Species - Torpedograss (Panicum repens), Relative Cover by Zone, Rainbow River, Marion County, Florida

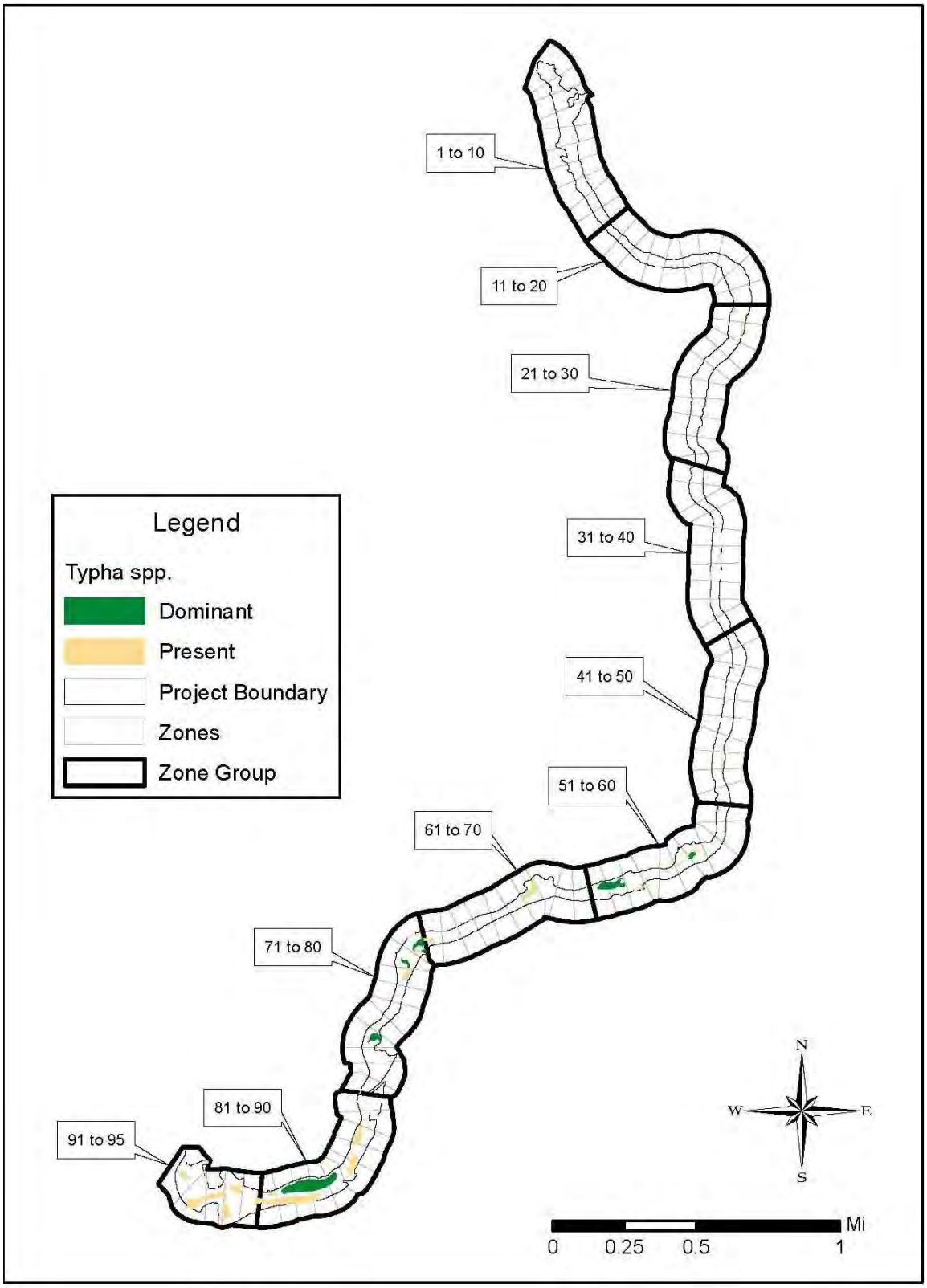

Figure 3-8. 2015 Herbaceous Emergent Species - Cattail (Typha spp.), Relative Cover by Zone, Rainbow River, Marion County, Florida

3.5. Emergent Vegetation Comparison between 2011 and 2015

Total area of all emergent vegetation types increased from 2011 to 2015 by 12.2 ac (Table 3-1). Most of the 2015 increase was in forested area (10.9 ac), but there was also a small increase (1.3 ac) in the herbaceous emergent vegetation area between years. Further discussion on this increase is discussed in Section 4.0.

Four additional herbaceous emergent taxa were recorded in 2015 compared to 2011. Three of these species (Thelypteris spp., Ruellia simplex, and Cyperus papyrus) were found in one polygon each. The fourth species, Panicum hemitomon, was identified in nine polygons (Tables 3-8a and 3-8b).

3.6. SAV 2015

In 2015, SAV species occupied 91.1 ac or 73.3% of the whole river mapped as SAV habitat (Table 3-4). Within the mapped SAV area, all Zone Groups had greater than 63% cover of SAV species with a maximum of 83.3% (Table 3-4). Sixteen SAV taxa were recorded in 2015 (Table 3-10). The highest diversity was found near the headspring (Table 3-8a). For 2015, the six most abundant SAV species river-wide in descending order were Sagittaria kurziana, Hydrilla verticillata, Vallisneria americana, Najas guadalupensis, Ceratophyllum demersum, and Potamogeton illinoensis (Figures 3-9 to 3-14 and Table 3-11a). Species composition and dominance changed with distance from the headspring. Sagittaria kurziana dominated the top half of the river and was replaced by Vallisneria americana in the middle and an invasive species, Hydrilla verticillata, in the lower river nearer the confluence of the Rainbow River with the Withlacoochee River (Table 3-11a).

3.7 SAV Comparison between 2011 and 2015

In general, the 2015 data shows an increase in the overall SAV species cover compared with the 2011 data (Table 3-4). In 2011 SAV cover in Zone Groups ranged from just under 15% to 82.9% (Table 3-4). Zone Groups in the lower half of the river had large increases in SAV species cover between these years. In the last 2.5 km, total SAV species cover more than doubled (Table 3-4). The order of the four most abundant species (Sagittaria kurziana, Hydrilla verticillata, Vallisneria americana, and Najas guadalupensis) remained the same between 2011 and 2015.

Sagittaria kurziana (Sagittaria) decreased in relative cover for the whole river by 5.27% between 2011 and 2015 (Table 3-12). This decrease was noted in six of the ten Zone Groups (Table 3-13) with the majority of the decline noted in the upper half of the river in three Zone Groups; 1-10, 11-20 and 31-40 (Table 3-13). Each of these Zone Groups saw a decrease in Sagittaria of more than 10% (Table 3-13). In 2011 Sagittaria was the most abundant species in all but the last two Zone Groups, while in 2015 it was the dominant species in only half the Zone Groups (Tables 3-11a and 3-11b).

Table 3-8a. Herbaceous Emergent Species Presence by Zone Group (2015) on the Rainbow River

	Zone Group									
2015 Species/Taxon	**1 to 10**	**11 to 20**	**21 to 30**	**31 to 40**	**41 to 50**	**51 to 60**	**61 to 70**	**71 to 80**	**81 to 90**	**91 to 95**
Alternanthera philoxeriodes				X					X	
Cicuta mexicana	X	X	X	X	X	X	X	X	X	X
Cladium jamaicense	X	X	X	X	X	X				
Colocasia esculenta			X	X	X	X		X	X	X
Crinum americanum								X		
Cyperus papyrus								X		
Hydrocotyle spp.	X	X	X	X	X	X	X	X	X	X
Hymenocallis spp.	X	X	X	X	X	X	X	X	X	
Mikania scandens	X	X	X	X	X	X	X	X	X	X
Nuphar sp.							X	X	X	X
Panicum hemitomon	X		X	X						X
Panicum repens		X	X	X	X	X	X		X	X
Paspalidium geminatum	X	X	X	X	X	X	X	X	X	X
Paspalum spp.	X	X	X	X	X	X	X	X	X	X
Pistia stratiotes						X	X	X	X	X
Polygonum spp.				X			X			X
Pontederia cordata				X					X	X
Rhyncospora inundata	X	X	X	X	X	X	X	X	X	X
Ruellia simplex								X	X	
Sagittaria lancifolia	X	X	X	X	X	X	X	X	X	X
Sagittaria latifolia	X					X			X	
Schoenoplectus tabernaemontani		X	X			X	X	X	X	X
Thelypteris spp.									X	
Typha spp.		X	X	X	X	X	X	X	X	X
Zizania aquatica	X	X	X							

Note: “X” denotes taxon presence. Each zone is 0.1 Km of river length.

Table 3-8b. Herbaceous Emergent Species Presence by Zone Group (2011) on the Rainbow River

	Zone Group									
2011 Species/Taxon	**1 to 10**	**11 to 20**	**21 to 30**	**31 to 40**	**41 to 50**	**51 to 60**	**61 to 70**	**71 to 80**	**81 to 90**	**91 to 95**
Alternanthera philoxeriodes			X							
Cicuta mexicana	X	X	X	X		X	X	X	X	X
Cladium jamaicense	X	X	X	X	X	X				
Colocasia esculenta				X	X	X		X	X	X
Crinum americanum	X									
Cyperus papyrus										
Hydrocotyle spp.	X	X	X	X	X	X	X	X	X	X
Hymenocallis spp.						X	X	X	X	
Mikania scandens	X	X	X	X	X	X	X	X	X	X
Nuphar sp.									X	X
Panicum repens			X	X	X	X		X	X	X
Paspalidium geminatum	X	X	X	X	X	X	X	X	X	X
Paspalum spp.	X	X	X	X	X	X	X	X	X	X
Pistia stratiotes					X	X	X	X	X	X
Polygonum spp.				X				X		X
Pontederia cordata									X	X
Rhyncospora inundata				X	X	X	X	X	X	X
Sagittaria lancifolia	X	X	X	X	X	X	X		X	
Sagittaria latifolia	X	X	X			X	X	X	X	X
Schoenoplectus tabernaemontani		X	X		X	X	X	X	X	X
Typha spp.			X	X		X	X	X	X	X
Zizania aquatica	X	X	X		X					

Note: “X” denotes Emergent species presence. Each zone is 0.1 km of river length.

Table 3-9. SAV Taxa List for 2015 Rainbow River Vegetation Aquatic Vegetation Coverage Assessment, Marion County, Florida.

Binomial	Common name
Ceratophyllum demersum	coontail
Chara sp.	muskgrass
Cyperaceae	sedge
Cyperus papyrus	Egyptian papyrus
Fontinalis sp.	water moss
Hydrilla verticillata	hydrilla
Hydrocotyle sp.	marshpennywort
Ludwigia repens	creeping primrosewillow
Myriophyllum sp.	watermilfoil
Najas guadalupensis	southern waternymph
Nasturtium sp	watercress
Potamogeton illinoensis	Illinois pondweed
Sagittaria kurziana	springtape
Sagittaria lancifolia	bulltongue arrowhead
Utricularia sp.	bladderwort
Vallisneria americana	American eelgrass
Zizania aquatica	wild rice

* indicates Listed Exotic Species

Common Name Source: http://florida.plantatlas.usf.edu/Default.aspx

Table 3-10a. SAV Species Occurrence by Zone Group in the Rainbow River 2015

	Zone Group									
2015 SAV Species	**1 to 10**	**11 to 20**	**21 to 30**	**31 to 40**	**41 to 50**	**51 to 60**	**61 to 70**	**71 to 80**	**81 to 90**	**91 to 95**
Ceratophyllum demersum	X	X	X	X	X	X	X	X	X	X
Chara sp.	X		X	X	X	X				
Cyperaceae	X									
Fontinalis sp.	X									
Hydrocotyle sp.	X									
Hydrilla verticillata	X	X	X	X	X	X	X	X	X	X
Ludwigia repens	X	X	X							
Myriophyllum sp.	X			X						
Najas guadalupensis	X	X	X	X	X	X	X	X	X	X
Nasturtium sp.	X									
Potamogeton illinoensis	X	X	X							
Sagittaria kurziana	X	X	X	X	X	X	X	X	X	X
Sagittaria lancifolia	X									
Utricularia sp.	X									
Vallisneria americana	X	X	X	X	X	X	X	X	X	X
Zizania aquatica			X	X	X	X	X	X		X
Number of Species	**15**	**7**	**9**	**8**	**7**	**7**	**6**	**6**	**5**	**6**

Note: “X” denotes species presence. Each zone is 0.1 Km of river length.

Table 3-10b. SAV Species Occurrence by Zone Group in the Rainbow River 2011

	Zone Group									
2011 SAV Species	**1 to 10**	**11 to 20**	**21 to 30**	**31 to 40**	**41 to 50**	**51 to 60**	**61 to 70**	**71 to 80**	**81 to 90**	**91 to 95**
Ceratophyllum demersum	X	X	X	X	X	X	X	X	X	X
Chara sp.		X		X	X	X	X	X		
Fontinalis sp.	X									
Hydrilla verticillata	X	X	X	X	X	X	X	X	X	X
Hydrocotyle sp.										
Ludwigia repens	X	X								
Myriophyllum sp.	X									
Najas guadalupensis	X	X	X	X	X	X		X	X	X
Nasturtium sp.										X
Potamogeton illinoensis	X	X								
Sagittaria kurziana	X	X	X	X	X	X	X	X		X
Utricularia sp.	X									
Vallisneria americana	X	X	X	X	X	X	X	X		X
Zizania aquatica			X				X	X		
Number of Species	**10**	**8**	**6**	**6**	**6**	**6**	**6**	**7**	**3**	**6**

Note: “X” denotes species presence. Each zone is 0.1 Km of river length.

Table 3-11a. Six Most Abundant SAV Species by Zone Group and Whole River in the Rainbow River for 2015

	Rank in 2015					
Zone Group	**1**	**2**	**3**	**4**	**5**	**6**
1 to 10	*Sagittaria kurziana*	*Potamogeton illinoensis*	*Vallisneria americana*	*Fontinalis* sp.	*Najas guadalupensis*	*Utricularia* sp.
11 to 20	*Sagittaria kurziana*	*Vallisneria americana*	*Hydrilla verticillata*	*Najas guadalupensis*	*Ceratophyllum demersum*	*Ludwigia repens*
21 to 30	*Sagittaria kurziana*	*Najas guadalupensis*	*Hydrilla verticillata*	*Vallisneria americana*	*Ceratophyllum demersum*	*Chara* sp.
31 to 40	*Sagittaria kurziana*	*Hydrilla verticillata*	*Najas guadalupensis*	*Vallisneria americana*	*Ceratophyllum demersum*	*Zizania aquatica*
41 to 50	*Sagittaria kurziana*	*Vallisneria americana*	*Hydrilla verticillata*	*Najas guadalupensis*	*Ceratophyllum demersum*	*Zizania aquatica*
51 to 60	*Vallisneria americana*	*Sagittaria kurziana*	*Hydrilla verticillata*	*Najas guadalupensis*	*Ceratophyllum demersum*	*Zizania aquatica*
61 to 70	*Vallisneria americana*	*Ceratophyllum demersum*	*Najas guadalupensis*	*Sagittaria kurziana*	*Hydrilla verticillata*	*Zizania aquatica*
71 to 80	*Hydrilla verticillata*	*Vallisneria americana*	*Najas guadalupensis*	*Ceratophyllum demersum*	*Sagittaria kurziana*	*Zizania aquatica*
81 to 90	*Hydrilla verticillata*	*Ceratophyllum demersum*	*Najas guadalupensis*	*Vallisneria americana*	*Sagittaria kurziana*	*Zizania aquatica*
91 to 95	*Najas guadalupensis*	*Hydrilla verticillata*	*Ceratophyllum demersum*	*Vallisneria americana*	*Sagittaria kurziana*	*Zizania aquatica*
Whole River	***Sagittaria kurziana***	***Hydrilla verticillata***	***Vallisneria americana***	***Najas guadalupensis***	***Ceratophyllum demersum***	***Potamogeton illinoensis***

Note: Each zone is 0.1 Km of river length. Species ranked by decreasing percent coverage.

Table 3-11b. Six Most Abundant SAV Species by Zone Group and Whole River in the Rainbow River for 2011

	Rank in 2011					
Zone Group	**1**	**2**	**3**	**4**	**5**	**6**
1 to 10	*Sagittaria kurziana*	*Utricularia* sp.	*Potamogeton illinoensis*	*Vallisneria americana*	*Hydrilla verticillata*	*Ludwigia repens*
11 to 20	*Sagittaria kurziana*	*Hydrilla verticillata*	*Vallisneria americana*	*Najas guadalupensis*	*Ceratophyllum demersum*	*Ludwigia repens*
21 to 30	*Sagittaria kurziana*	*Hydrilla verticillata*	*Najas guadalupensis*	*Vallisneria americana*	*Zizania aquatica*	*Ceratophyllum demersum*
31 to 40	*Sagittaria kurziana*	*Hydrilla verticillata*	*Najas guadalupensis*	*Vallisneria americana*	*Ceratophyllum demersum*	*Chara* sp.
41 to 50	*Sagittaria kurziana*	*Hydrilla verticillata*	*Vallisneria americana*	*Najas guadalupensis*	*Chara* sp.	*Ceratophyllum demersum*
51 to 60	*Sagittaria kurziana*	*Chara* sp.	*Vallisneria americana*	*Hydrilla verticillata*	*Ceratophyllum demersum*	*Najas guadalupensis*
61 to 70	*Sagittaria kurziana*	*Vallisneria americana*	*Chara* sp.	*Ceratophyllum demersum*	*Hydrilla verticillata*	*Zizania aquatica*
71 to 80	*Sagittaria kurziana*	*Vallisneria americana*	*Ceratophyllum demersum*	*Hydrilla verticillata*	*Najas guadalupensis*	*Chara* sp.
81 to 90	*Hydrilla verticillata*	*Najas guadalupensis*	*Ceratophyllum demersum*	N/A	N/A	N/A
91 to 95	*Najas guadalupensis*	*Sagittaria kurziana*	*Vallisneria americana*	*Hydrilla verticillata*	*Nasturtium* sp.	*Ceratophyllum demersum*
Whole River	***Sagittaria kurziana***	***Hydrilla verticillata***	***Vallisneria americana***	***Najas guadalupensis***	***Chara* sp.**	***Utricularia* sp.**

Note: Each zone is 0.1 km of river length. Species ranked by decreasing percent coverage.

Table 3-12. SAV Species Percent Change for the Whole River in the Rainbow River (2011 and 2015)

SAV Species	2015 Percent Cover *	2011 Percent Cover *	Difference in Percent Cover Between 2015 and 2011
Ceratophyllum demersum	5.60	1.33	4.27
Chara sp.	0.05	2.21	-2.15
Cyperaceae	**0.00	Not present	N/A
Fontinalis sp.	0.74	0.13	0.61
Hydrilla verticillata	17.84	7.36	10.49
Hydrocotyle sp.	**0.00	Not present	N/A
Ludwigia repens	0.31	0.17	0.14
Myriophyllum sp.	0.00	0.10	-0.10
Najas guadalupensis	11.45	4.16	7.29
Nasturtium sp.	**0.00	0.03	-0.02
Potamogeton illinoensis	1.19	1.09	0.10
Sagittaria kurziana	23.69	28.96	-5.27
Sagittaria lancifolia	0.02	Not present	N/A
Utricularia sp.	0.52	1.58	-1.06
Vallisneria americana	11.83	5.60	6.22
Zizania aquatica	0.05	0.08	-0.03

Note:

* Cover categories were different in 2011 and 2015 (see methods section for details).

** Trace amounts of this species were observed in 2015.

Table 3-13. SAV Species Percent Cover Change by Zone Group in the Rainbow River from 2015 and 2011

	Zone Group									
SAV Species	**1 to 10**	**11 to 20**	**21 to 30**	**31 to 40**	**41 to 50**	**51 to 60**	**61 to 70**	**71 to 80**	**81 to 90**	**91 to 95**
Ceratophyllum demersum	2.58	2.48	0.53	2.33	1.75	4.17	6.87	6.20	3.22	11.95
Chara sp.	0.00	-0.01	0.45	-0.18	-2.77	-8.70	-11.13	-0.37	0.00	0.00
Cyperaceae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fontinalis sp.	5.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrilla verticillata	-0.86	1.76	-6.91	3.20	2.42	8.97	0.33	21.46	66.61	19.06
Hydrocotyle sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ludwigia repens	0.27	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myriophyllum sp.	-0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Najas guadalupensis	5.54	5.45	6.53	5.93	5.02	10.47	12.61	9.79	-3.88	12.76
Nasturtium sp.	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.23
Potamogeton illinoensis	0.44	-0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sagittaria kurziana	-14.36	-13.57	4.79	-17.34	-5.00	2.18	-7.35	2.13	0.01	-2.71
Sagittaria lancifolia	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Utricularia sp.	-10.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vallisneria americana	1.32	4.31	3.99	5.22	12.79	12.28	10.28	5.18	1.43	5.55
Zizania aquatica	0.00	0.00	-0.44	0.26	0.03	0.03	-0.03	-0.01	0.00	0.00

Note: Each zone is 0.1 km of river length. Cover categories used differ between 2011 and 2015.

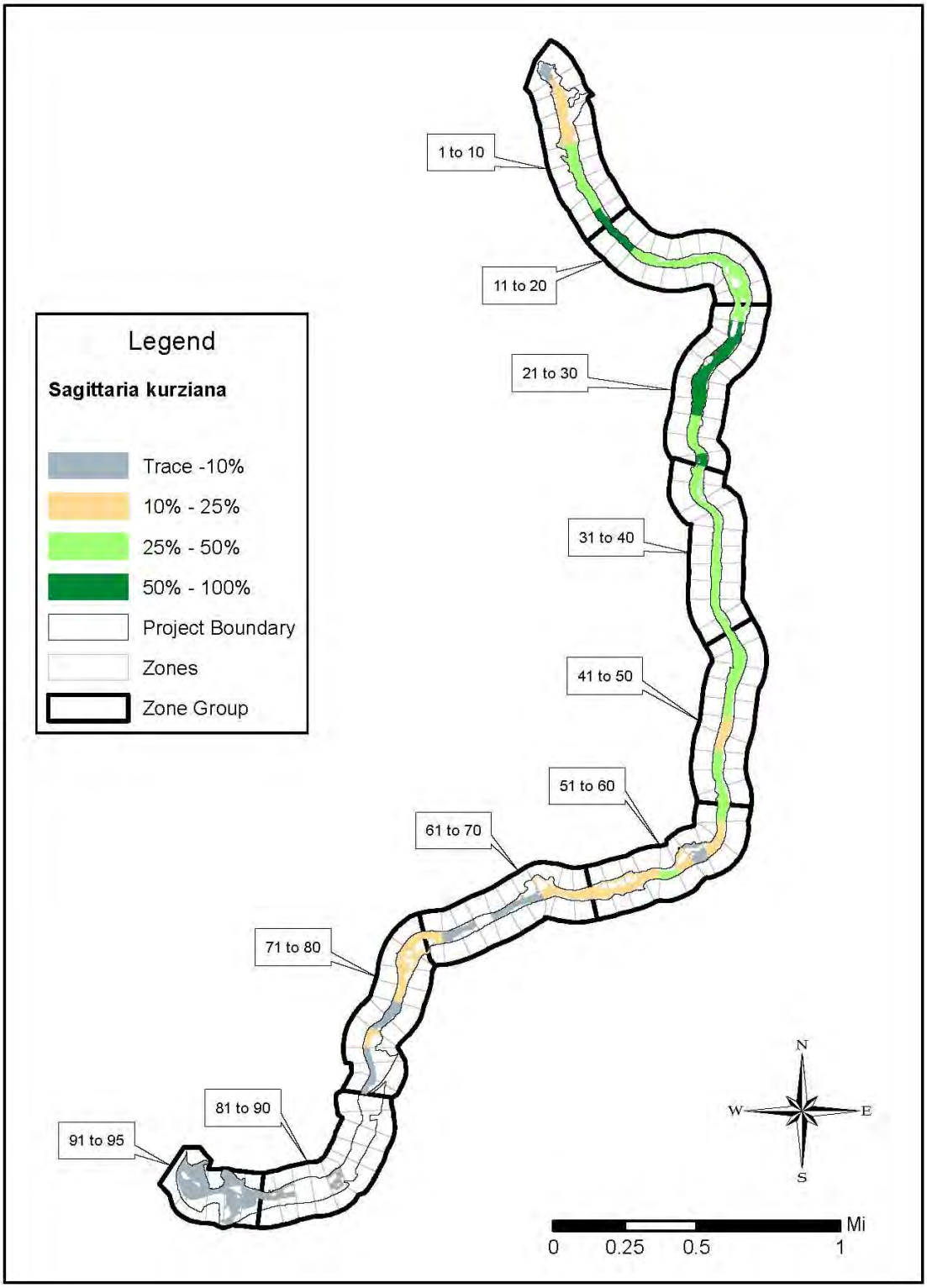

Figure 3-9. 2015 SAV Species - Springtape (Sagittaria kurziana), Relative Cover by Zone, Rainbow River, Marion County, Florida

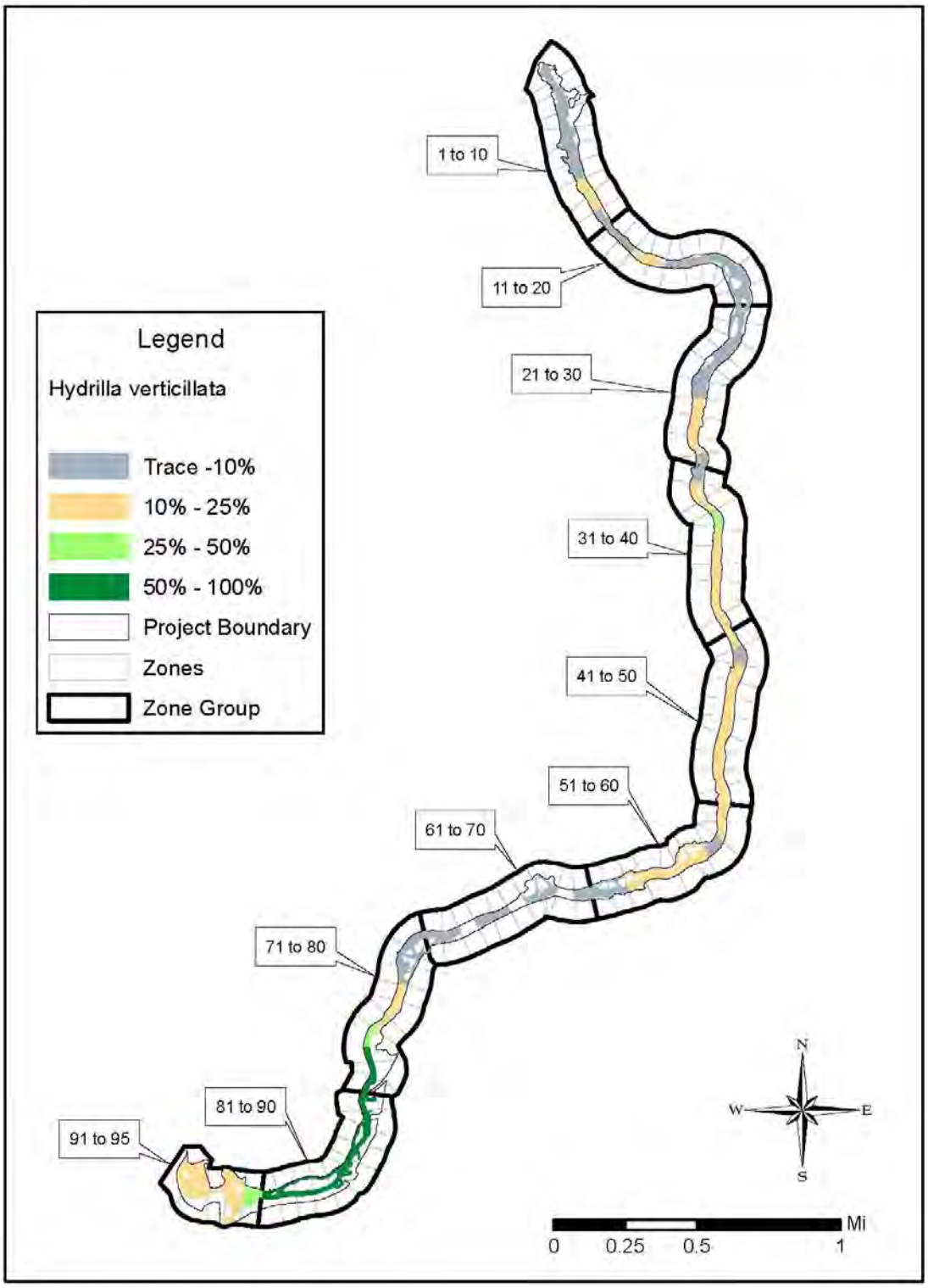

Figure 3-10. 2015 SAV Species - Hydrilla (Hydrilla verticillata), Relative Cover by Zone, Rainbow River, Marion County, Florida

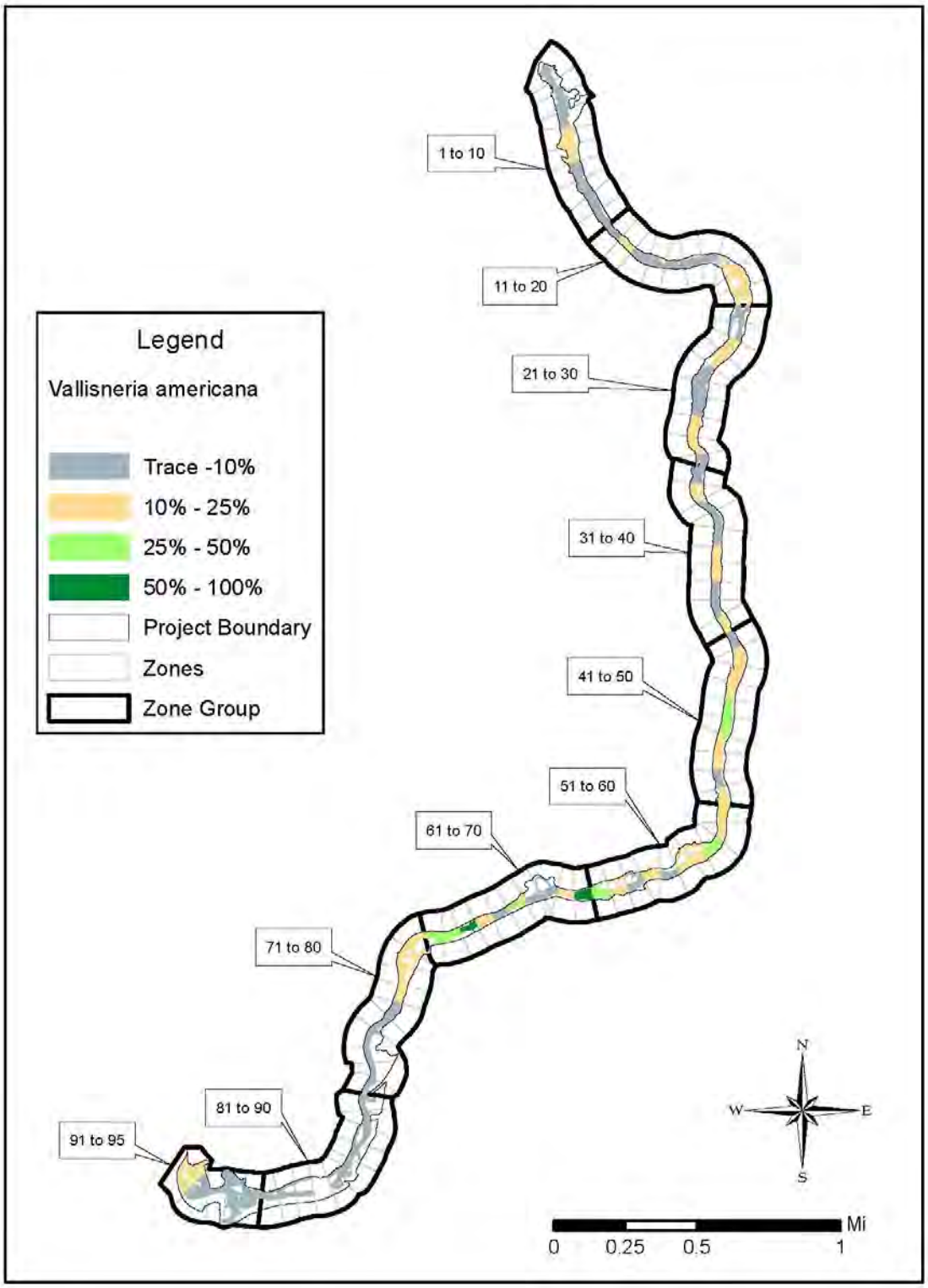

Figure 3-11. 2015 SAV Species - American Eelgrass (Vallisneria americana), Relative Cover by Zone, Rainbow River, Marion County, Florida

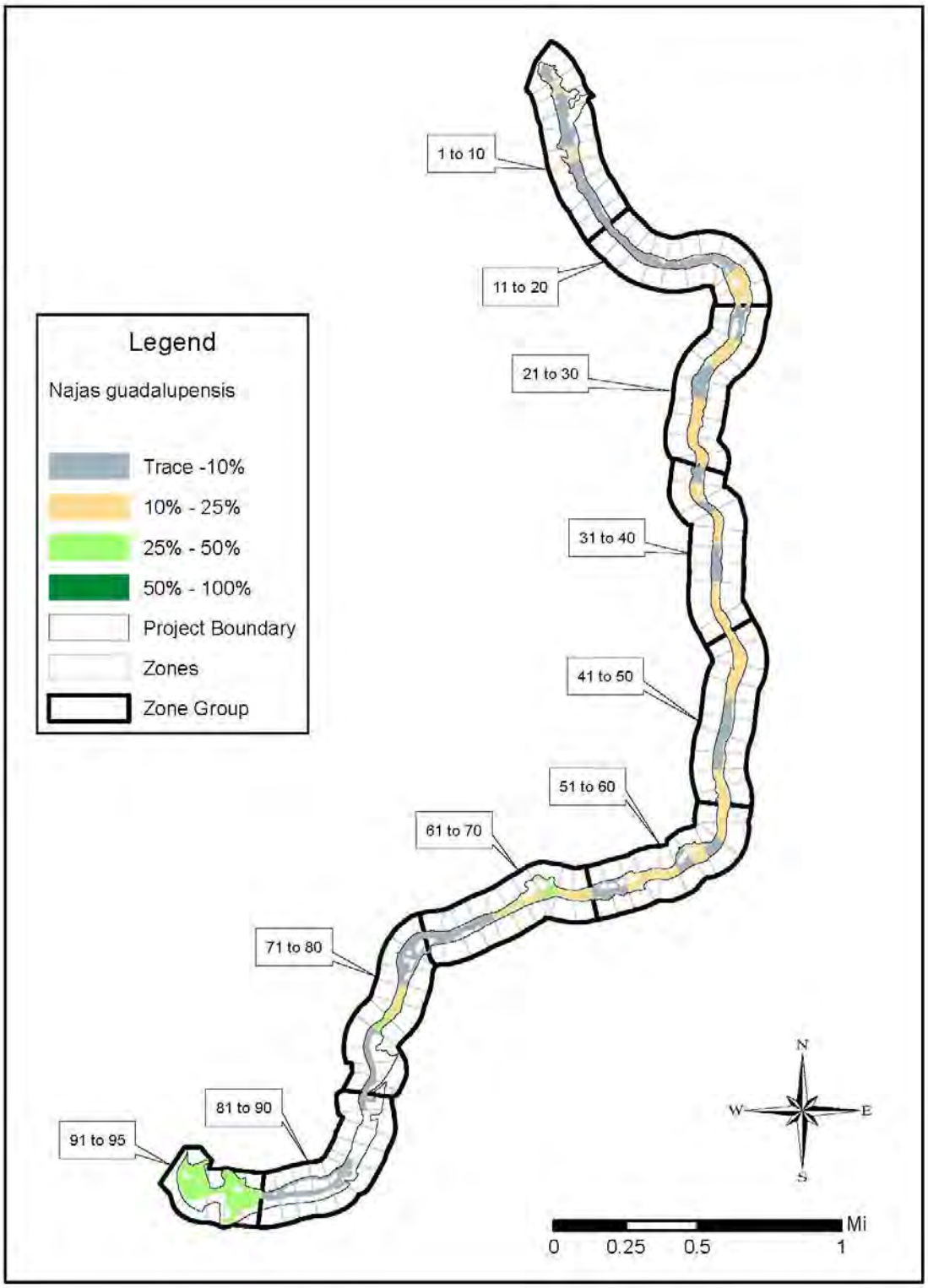

Figure 3-12. 2015 SAV Species – Southern Waternymph (Najas guadalupensis), Relative Cover by Zone, Rainbow River, Marion County, Florida

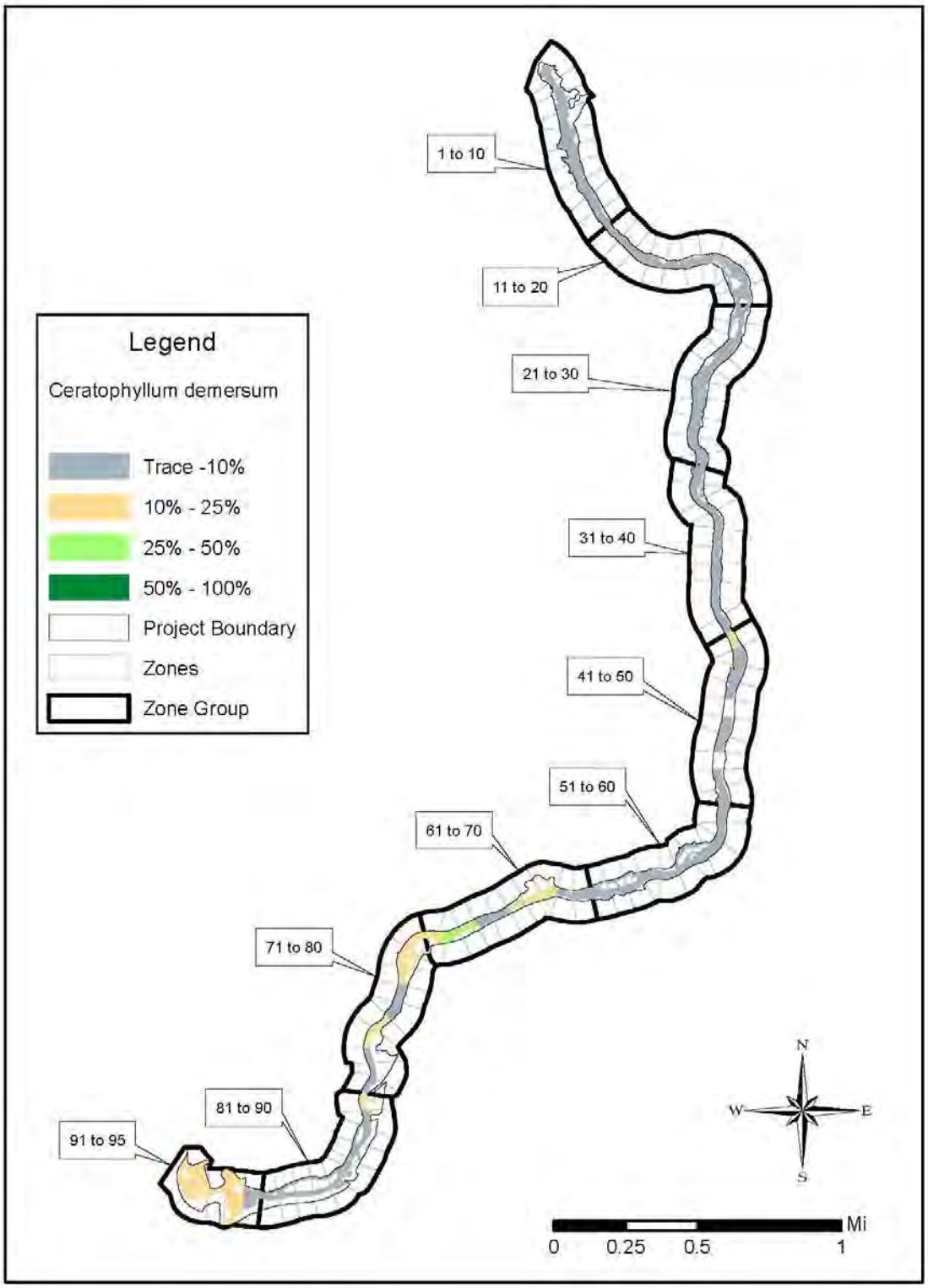

Figure 3-13. 2015 SAV Species – Southern Coontail (Ceratophyllum demersum), Relative Cover by Zone, Rainbow River, Marion County, Florida

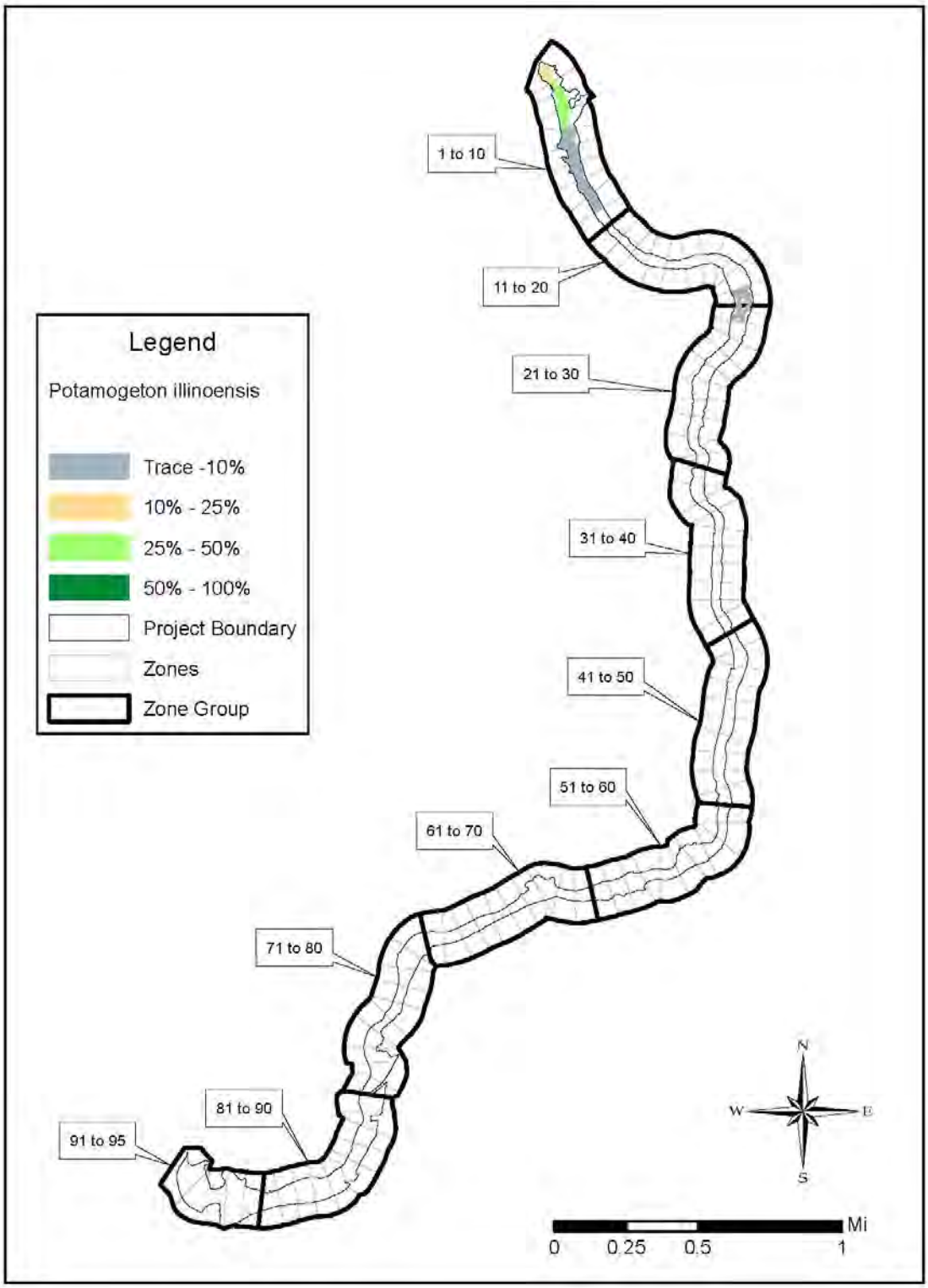

Figure 3-14. 2015 SAV Species – Illinois Pondweed (Potamogeton illinoensis), Relative Cover by Zone, Rainbow River, Marion County, Florida

Hydrilla verticillata (Hydrilla) had the largest percent cover increase of all species between 2011 and 2015 (Table 3-12). Overall, the relative cover of Hydrilla increased by 10.49%. However the vast majority of the increase occurred in three Zone Groups (Table 3-13). Two Zone Groups (71-80 and 91-95) saw approximately 20% more Hydrilla in 2015 (Table 3-13). One Zone Group (81-90) added 66.6% more Hydrilla in 2015 (Table 3-13). Hydrilla became the most abundant SAV species in two Zone Groups for 2015, while it was dominant in one Zone Group in 2011 (Tables 3-11a and 3-11b).

Vallisneria americana (Vallisneria) increased in overall cover area by 6.2% between 2011 and 2015 (Table 3-12). All 10 Zone Groups saw an increase in Vallisneria with the bulk occurring near the river middle of the river in three Zone Groups; 41-50, 51-60, and 61-70 (Table 3-13). Each of these Zone Groups increased in relative cover of Vallisneria by approximately 11% (Table 3-13). Vallisneria became the most abundant species in two Zone Groups for 2015, while it was not dominant in any Zone Groups in 2011 (Tables 3-12a and 3-12b).

Najas guadalupensis (Najas) increased in relative cover by 7.3% between 2011 and 2015 (Table 3-12). All 10 Zone Groups saw an increase in Najas with the bulk occurring in the lower half of the river in four Zone Groups; 51-60, 61-70, 71-80, and 91-95 (Table 3-13). Each of these Zone Groups increased in relative cover of Najas by approximately 11% (Table 3-13). For 2011 and 2015, Najas remained the most abundant species in one Zone Group; 91-95 (Tables 3-11a and 3-11b).

3.8 Algae 2015

The combined cover of filamentous epiphytic and benthic macroalgae in 2015 generally increased with distance from the headspring basin (Figure 3-15 and Table 3-14). River-wide, the algae midpoint cover class of 30% was applied to 48.0% of the submerged area mapped. The algae midpoint class of 75% encompassed 28.7% of the submerged area mapped and midpoint classification of 5% was given to 23.3% of the area. The midpoint class of 5% was not applied to any area in the downstream half of the river until the Zone Group 90-95 near the confluence where it was used to describe less than 1% of the area (Table 3-14).

Table 3-14. Algae Area Cover by Zone Group in the Rainbow in 2015

Zone Group	Zone Group Area (ac)	Cover (ac)	Percent Cover
1 to 10	13.608	2.387	17.54%
11 to 20	12.112	3.205	26.46%
21 to 30	14.470	1.941	13.42%
31 to 40	10.733	1.943	18.10%
41 to 50	12.756	4.049	31.74%
51 to 60	13.555	5.453	40.23%
61 to 70	10.054	4.388	43.65%
71 to 80	11.851	7.192	60.68%
81 to 90	10.266	7.185	69.99%
91 to 95	14.916	8.351	55.99%
Overall	124.320	46.094	37.08%

Note: Each zone is 0.1 km of river length. Totals represent areas and percentages for the whole river.

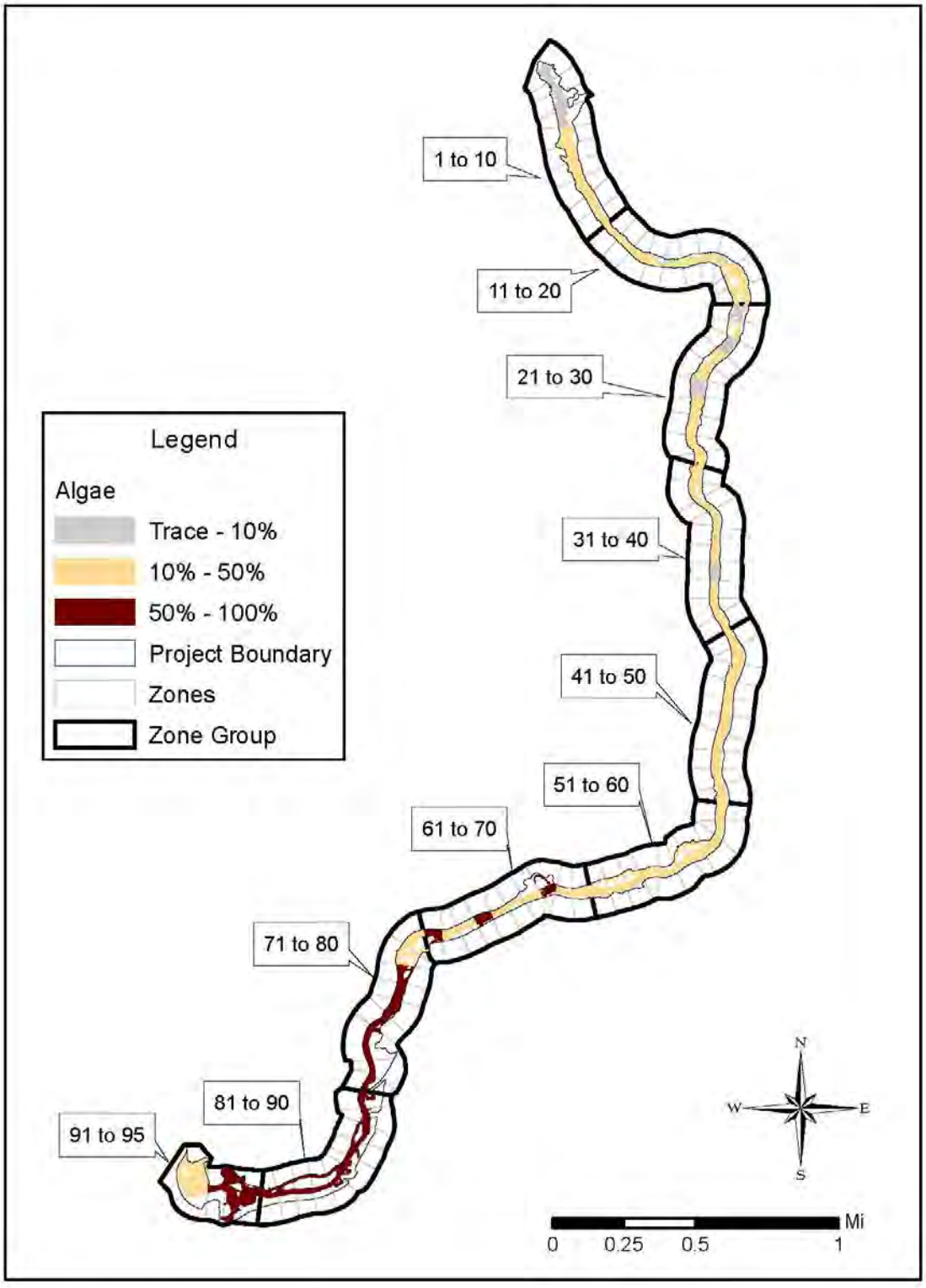

Figure 3-15. 2015 Algae Relative Cover by Zone, Rainbow River, Marion County, Florida

3.9 Algae Comparison between 2011 and 2015

A comparison of algae cover between 2011 and 2015 was not conducted because of differences in methods. An overview of some of the methods differences follows.

In 2015 both benthic mats growing directly on the substrate and epiphytic algae attached to SAV were recorded as a single variable and assigned one of three cover categories with the top category reaching a maximum of 100%. In 2011, the aforementioned two types of algae were recorded as two separate variables each with a maximum cover of 100%. Thus, no between-years comparison of algal cover can be made.

The 2015 methods for assessing algae quantifies cover in the same polygon as SAV and bare ground cover compared with the 2011 methods, where previously they were assigned to unique polygons (Atkins 2012). Although it is beyond the scope of this project, the 2015 algae data could be correlated with the 2015 SAV species data to determine if algae cover classes are more frequently found with certain SAV species or SAV cover classes. In addition low or heavy algae cover might correlate with SAV trends.

3.10 Quality Assurance and Control Evaluation Results

The results of the Quality Assurance and Control Evaluation are located in Appendix A.

3.11 Results Discussion

3.11.1 Mapping

Results of the 2015 Rainbow River vegetation project provided generally comparable results with the 2011 data. Whole river results showed similar total areas mapped in the two data sets, with 194.3 acres overall in 2011 compared with the 194.0 acres in 2015 (Table 3-1) consistent with the identical project boundary used for mapping. The total project area is split between vegetation types in the GIS data: SAV and emergent (herbaceous emergent and forested emergent) with no spatial overlap. The area occupied by the herbaceous emergent vegetation increased slightly from 31.4 acres in 2011 to 32.9 acres in 2015 (Table 3-1). The forested emergent mapped area increased 10.9 ac (5.6%) for the whole river in 2015 when compared with 2011 (Table 3-1). However, the change results in a decrease to the 2015 SAV polygon areas by the sum of the increases in emergent polygon areas.

A field comparison of the mapped polygons in the 2011 and 2015 GIS data clearly show mapped 2011 SAV polygons occurring in areas mapped as forested emergent in 2015. The emergent forest polygon cover extent was assumed not to have changed significantly in five years. These discrepancies occur not only along the emergent forest-SAV margins, but 2011 SAV layer was mapped well into the 2015 mapped emergent forest coverage.

Water & Air notified the District when this anomaly was first encountered in the field mapping process during the 2015 Recon. During subsequent field assessments, Water & Air field personnel took special care in documenting the boundary between 2015 emergent forested layer and the location relative to the 2011 SAV layer to ensure the 2015 polygons were accurate. The mapping discrepancy was not consistent river wide, but occurred in multiple locations. The largest discrepancies occurred in River Zones 1-60 (Table 3-5).

Because SAV layers and emergent layers have do not overlap, this results in an apparent loss of SAV habitat, by the same amount of gain of the 2015 emergent habitat (specifically the forested component). Although minor habitat change occurred, the District's aerial photography (confirmed by field verified mapping) supports the 2015 habitat coverage.

Therefore, a 10.9-acre discrepancy prevents an acre to acre comparison of SAV mapped totals in both 2011 emergent forested and SAV habitat with the 2015 data. However, comparisons of calculated areas of SAV habitat based on relative cover are meaningful.

3.11.2 Data Reduction

Whole river habitat comparisons based on calculated SAV areas in the Rainbow River show an SAV increase from 52.78% cover in 2011 to 73.30% in 2015 (Table 3-4). The 2011 SAV data varies by 22.1% when comparing the mapped SAV polygon areas to the midpoint calculated areas. In contrast, an area difference of 1.1% is observed for the 2015 data when comparing calculated cover to polygon areas.

Some of the 2015 increase in calculated SAV area may also reflect the introduction of cover categories with midpoints higher than 75% in 2015, and thus be an artifact of more refined quantitative assessments of cover.

3.11.3 Algae

In 2015, the combined cover of epiphytic and benthic filamentous macroalgae generally increased with distance from the headspring basin (Table 3-14). 2015 data show algae cover of 37% in the river, with cover above 50% in last three Zone Groups.

Methods differences between 2011 and 2015 algae assessments precluded direct comparisons in cover due to the focus on quantifying the cover of filamentous algae within the SAV polygons. Documentation of change in cover or abundance of algal mats is important in spring runs throughout Florida since the presence of significant benthic algae mats (in addition to nutrient enrichment) compete with SAV and are indicative of declining environmental quality. An adjustment to the methods in the future would yield comparable results to 2011 data by assessing benthic algal mats within the polygon similar to an SAV species (additive to SAV and bare areas). Epiphytic algae could be assessed as an overlay attribute on the SAV but not summed with other polygon components.

The 2015 methods, although similar to 2011 methods, generally provided improved data interpretation. The 2015 mapping effort created new SAV polygons based on a similar mix of river bottom habitats and species. The 2015 SAV polygons contained both vegetation taxa and bare ground (sand, rock, shell) attributes within the same polygon for cover determination. The 2011 mapping work defined separate polygons for SAV and non-vegetated areas (sand, rock, shell). The 2011 data did not directly account for bare ground within the SAV polygons. At the request of the District, the Braun–Blanquet cover classes were refined for 2015 SAV data collection to provide seven vegetation cover classes, rather than the four cover classes used in 2011 to better quantify the higher end cover ranges.

3.11.4 SAV Overview

The relative cover of SAV increased by more than 20% between 2011 and 2015. Zone Groups in the lower half of the river had large increases in SAV species cover in 2015. In a river wide species comparison of SAV in 2015, Hydrilla increased the most in relative cover (10.49%), followed by Najas (7.29%) Vallisneria (6.2%) and Ceratophyllum (4.27%) compared to 2011. The relative cover of Hydrilla, an invasive exotic species, increased river-wide compared to 2011, but it was especially significant in the lower river (River Zones 51-60 and 71-95). The relative cover of Ceratophyllum and Najas also showed a pattern of higher relative cover in the lower river as compared to the upper river. Vallisneria showed an increase in relative cover in all Zone Groups, with more significant increases in the middle river Zone Groups (River Zones 41-70) compared to 2011.

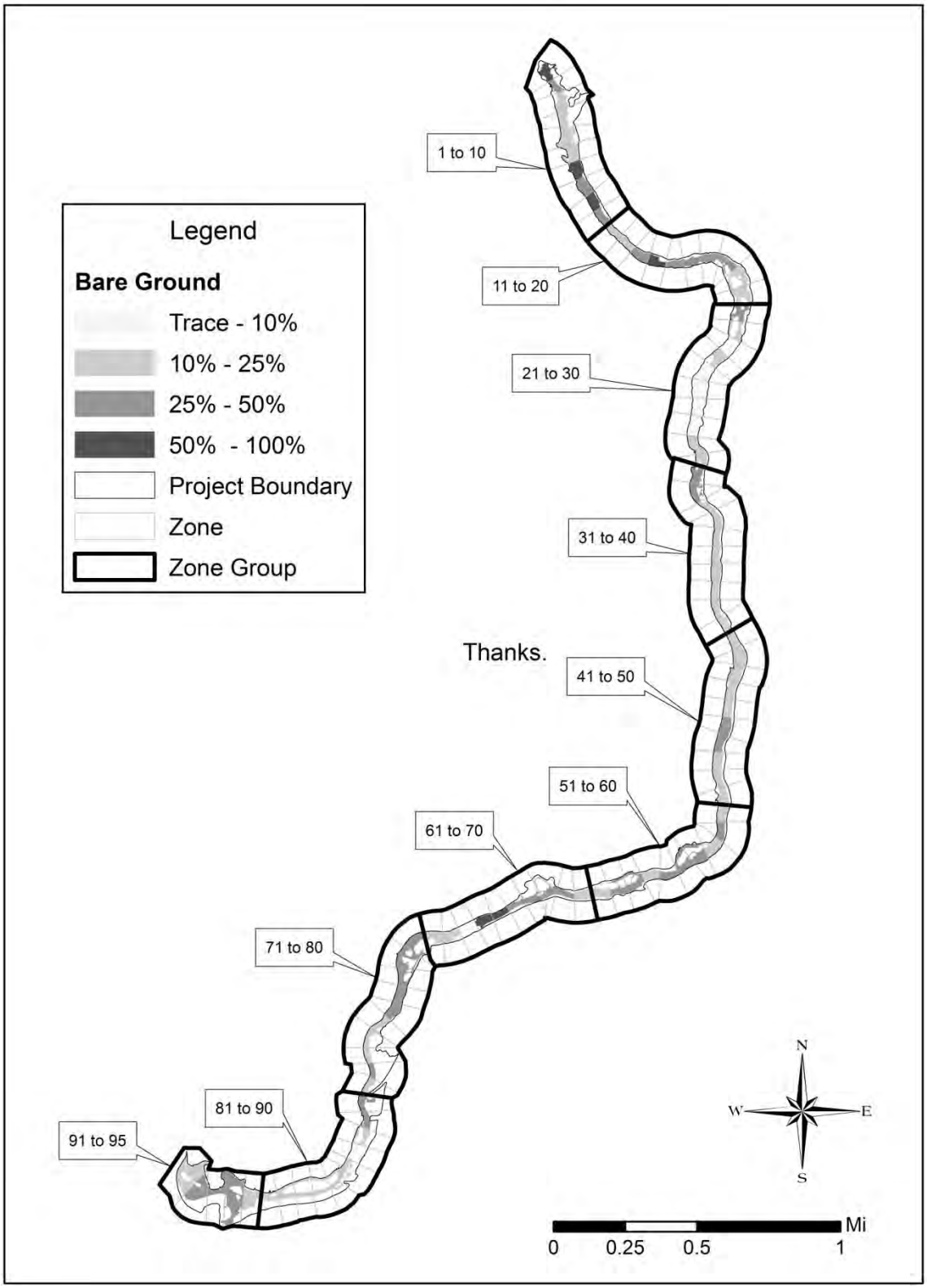

Figure 3-16. 2015 Bare Ground (Sand, Shell, and Rock) Relative Cover by Zone, Rainbow River, Marion County, Florida

The increase in cover of invasive exotic *Hydrilla* is a concern. The whole river *Hydrilla* cover increased by more than ten percent compared to 2011 levels with more significant increases occurring in River Zones 71-95 (Tables 3-12 and 3-13). An evaluation of the spatial data between 2011 and 2015 show that *Hydrilla* moved into areas previously classified as bare in the lower river. Data supports this observation. The increase in *Hydrilla* cover occurs in areas where significant loss of bare ground was noted (Zones 81-95) between 2011 and 2015 (Table 3-4). However, overall relative cover of bare ground remained similar from 2011 to 2015 but with increases in the upper river and losses in the lower river for 2015. (Figure 3-16)

Sagittaria kurziana, a characteristic spring run species, shows a river-wide decline of 5.27% (Table 3-12) since 2011 occurring in nearly all Zone Groups but especially in the upper river (Zone Groups 1-10, 11-20, and 31-40). Reduction of a key species like *Saggitaria* is cause for concern, especially when the historic data indicate a significant continuing decline since 2005. SAV cover moderately increased in the upper river for three other species: *Ceratophyllum demersum, Najas guadalupensis* and *Vallisneria americana* compared to 2011, making up for the reduction of *Saggittaria* in the first four Zone Groups.

The areas of *Sagittaria* loss were evaluated to see if the mapping issues between the 2011 SAV layer and the 2015 forested emergent layer (described earlier in this section) could account for this magnitude of difference. Analysis of 2011 SAV with 2015 forested emergent in one of the three Zone Groups indicates that approximately 1.5 acres of *Sagittaria* loss could be attributable mapped emergent/SAV issue, therefore actual loss of *Sagittaria* since 2011 is significant. In summary, the 2015 data support a continued decline of this important SAV species.

In summary, the 2015 vegetation assessment of the Rainbow River shows an increase in total relative cover of SAV species. Overall, there is a continued decline of some key native SAV species; increase of invasive, exotic SAV (especially in the lower river); and high algae cover of both benthic habitat and SAV. The results of the 2015 evaluation present continued challenges for the long term management of the Rainbow River, its watershed and springshed.

This work focuses on inventorying emergent vegetation and SAV because of its value in the maintenance of water and habitat quality of the Rainbow River. The high water clarity of the spring run allows the development of a diverse and abundant SAV community. Its beauty has attracted recreational uses of the spring and spring run for generations and its popularity has contributed in part to the changes in the aquatic vegetation. The 2015 aquatic vegetation assessment and others that preceded it allows assessment of the change in macrophytes during a time of declining water quality, riparian development and heavy recreational use. Understanding the trends in SAV diversity, abundance and distribution in the Rainbow River system will allow better identification of threats and successes in the on-going management of the river.

3.12 Summary of Findings

1. Overall mapped areas were consistent between the 2011 and 2015 data sets, varying by only 0.3 acres. However the spatial allocation between the mapped SAV layer and the emergent layer changed by 10.9 acres due to a mapping discrepancy. Due to the difference in acreages, relative cover was used for comparisons between the data sets when comparing the 2011 to 2015 SAV results

2. During a time of reduced residential development, hardened shoreline increased by almost 2% (251.6 feet), affecting six zones along the river since 2011. Six docks were added since the 2011 mapping event. The increase in hardened shoreline and new docks generally occurred in different zones.
3. The whole river herbaceous emergent areas were similar for 2011 and 2015 with an increase of 4.2% (1.3 acres) in 2015.
4. Whole river calculated (2015) and mapped (2011) bare ground cover was similar. Relative cover of bare ground in 2011 was 25.1% and 25.6% in 2015. However, the 2015 to 2011 Zone Group comparison data showed more bare ground in each of the River Zones 1-80, with significantly more in River Zones 1-50. In River Zones 81-95, there was a significant reduction in bare ground. The lower Zone Groups showed a loss of bare ground and replacement with *Hydrilla*. However, due to concerns about 2011 bare ground data anomalies (Appendix A) these results should be used cautiously.
5. Whole river SAV increased from 52.8% relative cover in 2011, to 73.3% with increases occurring river-wide. However the most significant increases occurred in the lower river within the last three Zone Groups.
6. A 22% difference was noted when comparing the mapped SAV areas with the midpoint calculated SAV areas for the 2011 GIS data. A similar analysis of the 2015 data shows a 1.1% discrepancy. This suggests that the 2015 approach better characterizes SAV conditions. However, the lack of information on how the 2011 methods and data accounted for small interspersed bare areas within the SAV polygon may explain the discrepancy and the inability to reconcile the 2011 bare area data noted in Appendix A.
7. There is an increase in 2015 SAV relative cover compared to 2011. Zone groups in the lower part of the river experienced larger increases than those in the upper part of the river. This somewhat coincides with locations where *Hydrilla* had substantial increases.
8. Relative cover of Sagittaria decreased in 2015 data by 5.27% with most of the decline noted in the upper half of the river. A significant decline in *Saggitaria* was also noted in previous years, between 2005 and 2011.
9. The whole river *Vallisneria* relative cover increased by 6.2% in 2015 compared to 2011, with most of the increases occurring mid-river (River Zones 41-70).
10. Whole River relative cover increased for *Najas* by 7.29%, with significant increases noted in River Zones 51-80 and 91-95. The exception was Zone Group 81-90 where there was a slight reduction in relative cover compared to 2011.
11. *Ceratophyllum* increased overall by 4.27% with increases in every Zone Group. More than 3% increase occurred in the lower river (River Zones 51-95).
12. Algae cover increased with increasing distance from the headspring. The whole river relative cover was 37%.

4.0 References

Atkins North America and Debra Childs Woithe, Inc. 2012. 2011 Rainbow River Vegetation Evaluation. Prepared for the Southwest Florida Water Management District. SWFWMD Tampa, FL.

Durante, C.M., and D.E. Canfield. 1990. Light absorption in Florida springs. Florida Scientist 53:118-122.

Florida Department of Environmental Protection (FDEP), 1996. Unpublished Electronic and Hard Copy Data Collected by FDEP Rainbow Springs Aquatic Preserve Staff Circa 1996. Rainbow River Aquatic Preserve. Florida Department of Environmental Protection, Bureau of Coastal and Aquatic Managed Areas.

Florida Department of Environmental Protection (FDEP), 2002. Rainbow Springs Unit Management Plan. FDEP Division of State Lands, Approved Plan dated December 5, 2002, Tallahassee, Florida.

Florida Department of Environmental Protection, 2013. Final Report Nutrient TMDL for Rainbow Springs Group and Rainbow Springs Group Run (WBIDs 1320A and 1320B). Ground Water Section, Tallahassee, Florida.

Florida Department of Environmental Protection (FDEP), 2015. Draft Basin Management Action Plan for the Implementation of Total Maximum Daily Loads for the Rainbow Springs Group and the Rainbow Springs Group Run. Prepared by the Division of Environmental Assessment and Restoration, Water Quality Restoration Program, Tallahassee, Florida.

Jones, G.W., S.B. Upchurch, and K.M. Champion. 1996. Origin of Nitrate in Ground Water Discharging from Rainbow Springs, Marion County, Florida. Ambient Ground-Water Quality Monitoring Program, Southwest Florida Water Management District. Brooksville, FL.

Nordlie, F.G. 1990. Rivers and Springs. Chapter 12, pp. 392-428 in R.L. Myers and J.J. Ewel (eds.) Ecosystems of Florida. University of Central Florida Presses. Orlando, FL.

PBS&J, 2000. Rainbow Springs Preserve 2000 Vegetation Mapping and Change Analysis Report. Prepared for the Florida Department of Environmental Protection, Bureau of Coastal and Aquatic Managed Areas. PBS&J, Tampa, FL.

PBS&J and Debra Childs Woithe, Inc. 2007. Rainbow River 2005 Vegetation Mapping and Evaluation Report. Prepared for the Southwest Florida Water Management District. SWFWMD SWIM Project #W419. PBS&J, Tampa, FL.

Southwest Florida Water Management District, 2015. Rainbow River SWIM Plan Final Draft: A Comprehensive Conservation Management Plan. Final draft dated 10/19/2015, Brooksville, Florida.

Water & Air Research, 1991. Diagnostic Studies of the Rainbow River. Report submitted to the Southwest Florida Water Management District. Surface Water Improvement and Management Program. Water & Air Research, Inc. Gainesville, FL.

Wetland Solutions, Inc. 2013. Rainbow Springs Restoration Action Plan. In cooperation with Howard T. Odum Florida Springs Institute, Report prepared for Rainbow River Conservation, Inc. dated August 14, 2013. Gainesville Florida.

US Geological Survey (USGS, 2015) http://waterdata.usgs.gov/fl/nwis/uv/?site_no=02313100&PARAmeter_cd=00065,00060

APPENDIX A

RAINBOW RIVER QUALITY ASSURANCE AND CONTROL EVALUATIONS

Appendix A
Rainbow River Quality Assurance and Control Evaluations

1.0 Introduction

Quality assurance (QA) checks and procedures were conducted on the 2011 Rainbow River vegetation data (Atkins Global, 2012) prior to starting the 2015 data collection to help ensure the 2015 data is comparable with the previous effort. The goal of the QA review of the 2011 Rainbow River vegetation data was to determine if the GIS data received by the District from Atkins North America and Debra Childs Woithe, Inc. (SWFWMD 2012) can be used by Water & Air to recreate select summary data tables in the Atkins 2012 report. An additional benefit of this procedure is to help to clarify methods used in the 2011 data acquisition to enable development of consistent, comparable and valid methods of data collection for the 2015 survey. This allowed improvement of field data collection measures without significant adverse affects on the comparability of the data. This is analysis referred to as the QA evaluation of the 2011 data throughout Appendix A.

Water & Air was also tasked by the SWFWMD to conduct quality control (QC) verification on a representative portion of the 2015 field survey of the river's SAV and emergent vegetation. This is discussed throughout this Appendix as the QC evaluation of the 2015 field data.

2.0 Methods Used in Quality Assurance and Quality Control Evaluations

2.1 Methods Used in Quality Assurance Evaluation of 2011 Rainbow River Vegetation Data

The data QA was performed using Excel spreadsheets extracted from the 2011 geodatabase and data checks were constructed using pivot tables. The initial data check was to determine the SAV and emergent vegetation coverage and confirm (within 5% accuracy) the summaries provided in the 2012 report using the geodatabase information for the whole river as defined by the shoreline.

The 2011 geodatabase was opened in ArcMap GIS 10. An intersection of the SAV, Emergent, and Algae layers with the river zone layer was performed to provide data coverage by river segment. These data were exported from ArcMap to Microsoft Excel and a pivot table was created to summarize and evaluate the spatial data. The spatial data summary was compared to the selected summary data tables in the 2012 report.

The SAV, Emergent and Algae spatial data were transformed to metrics that were comparable to the 2012 report summary tables.

The QA analysis assumed that the summary tables for the whole river reasonably represent the 2011 data. Water & Air did not test whether the detailed data by river zone could reproduce the report graphics. The data transformation was performed using the information provided in the geodatabase metadata. The SAV and Emergent areas summed to the total area within the project boundary. As a result, the assumption was that no overlap of SAV and Emergent areas occurred within the project boundary. The "relative area" of each SAV species was calculated by multiplying the midpoint of each modified Braun-Blanquet cover category (Tables 1 and 2) by the area of polygon. The areas occupied by the forested and emergent vegetation were calculated by summing the areas of the polygons containing each type of emergent layer data (forested of herbaceous emergent). The herbaceous emergent species dominance, as listed in the geodatabase, was summarized and checked against the appropriate summary report table. The summary of the emergent areas categorized by herbaceous emergent and forested vegetation were compared.

2.2 Methods Used in Quality Control Evaluation of 2015 Rainbow River Field Data Collection

Water & Air collected emergent and submergent vegetation data along the Rainbow River from May 15 through August 6, 2015. Following completion, Water & Air was tasked by the SWFWMD to repeat 2015 data collection along a representative portion of the river's SAV and emergent vegetation as a QC measure. This analysis reviewed some aspects of the quality of the 2015 field data collection by repeating the field data collection in selected polygons in a minimum of 10 zones in the river and comparing them to initial data collection.

Of the 95 zones established along the Rainbow River for collection of vegetation data, Water & Air recollected emergent and SAV data from a minimum of 10 zones selected from 15 randomly generated zone numbers. Each zone was revisited, and using the map created during the initial 2015 field work, each polygon present was evaluated to determine suitability for use in the QC evaluation. Selected polygons were resurveyed for the presence, absence and cover of SAV species and the presence, absence and dominance of herbaceous emergent species. The QC survey data was then compared to previous data collected for 2015.

Appendix A Table 1. Survey Results of SAV Braun Blanquet Cover Class (Midpoint) for Random Selected Zones of the Rainbow River during May - August 2015

Zone	*Polygon (OBJECTID)	Ceratophyllum	Chara	Fontinalis	Hydrilla	Ludwigia repens	Najas	Potamogeton	Sagittaria kurziana	Vallisneria	Zizaniopsis	Sand	Rock	Shell	Algae
7	148					17.5		17.5	17.5	37.5		5			H
7	149			T	5	T	5		17.5			82.5			M
7	150				17.5		37.5		5			37.5			M
7	151	T		T	5	T	5		37.5	5		62.5			M
8	144	5			5	5			62.5	5		17.5	17.5		M
8	146	5		5	17.5	5	5	5	37.5	5		5	5		M
8	147			5	17.5	T	T	T	37.5	5		37.5	5		M
9	145				17.5	5		T	17.5	5		62.5	5		M
21	100								T	5		95			L
21	101	T			5		5		17.5	17.5		17.5	17.5		L
21	102				5		5		17.5			5	62.5		L
21	103				T		T		T			95			L
21	104	T			5	T	17.5	T	62.5			5	17.5		L
21	107	17.5			5		17.5		37.5			17.5	5		M
29	27				17.5				17.5			62.5			H
29	28				T		T		95						L
29	29	5			5		37.5		17.5			37.5			H
29	30				17.5		17.5		62.5						L
29	31	5					5		37.5	62.5		T	T		L
29	32											82.5	17.5		L
29	33				37.5		17.5		17.5	37.5		5			M
30	43				5				82.5	5	5	T			M
30	44				5		5		62.5			17.5			L
30	45	17.5			5		37.5		37.5		T	T	5		L
51	332	T			5		17.5		17.5	37.5		17.5	5		M
51	333		T		17.5		17.5		37.5	5	T	17.5	5		M
67	273	T								T		95			H
67	274	5			T		5			5		82.5	T		H
81	230	17.5			62.5					T		17.5	T		H
81	231	17.5			62.5		5			5		17.5			H
81	232	5			5		5			T		82.5			H
81	233	5			82.5		T			T		5	T	T	H
86	214	T			95		T		T			5			H
86	215				17.5		17.5					62.5			H
86	227				82.5		T					17.5			H
86	228	5			95		T					5			H
91	191				17.5		62.5			5		17.5			H
91	192				5		17.5			17.5		62.5			H
91	193	5			82.5		5					5			H
91	194	17.5			62.5		17.5					T			H

* (OBJECTID) refers to the attribute name for polygons in the GIS database.

Modified Braun Blanquet Cover Classes and Midpoints:

Cover Class	Range	Midpoint or
1	0<1	T(race)
2	1<10	5
3	10<25	17.5
4	25<50	37.5
5	50<75	62.5
6	75<90	82.5
7	90-100	95

Abbreviations:
Algae
L=Low
M=Medium
H=High

Appendix A Table 2. Resurvey Results of SAV Braun Blanquet Cover Class (Midpoint) for Random Selected Zones of the Rainbow River, August 18-19, 2015

Zone	*Polygon (OBJECTID)	Ceratophyllum	Chara	Fontinalis	Hydrilla	Ludwigia repens	Najas	Potamogeton	Sagittaria kurziana	Vallisneria	Zizaniopsis	Sand	Rock	Shell	Algae
7	148	T			T	5	T	5	62.5	17.5	T	5			M
7	149	T			5		5		17.5	T		82.5	T		L
7	150				17.5		17.5		5			62.5			M
7	151	T		5	5	T	5		37.5	5		37.5	5		N/A
8	144	T			17.5	T	5		62.5	5		5	5		M
8	146	5			5	T	5	5	62.5	T	T	17.5	5		M
8	147			5	5	5	5	T	37.5	5		37.5			M
9	145				5	5	5	T	37.5	5		37.5	5		M
21	100									5		95			L
21	101	5			17.5		17.5		17.5	17.5		17.5	5		M
21	102	T			5		17.5		17.5			17.5	62.5		L
21	103				5		T		T			95			M
21	104	T			5		17.5		37.5	T		5	17.5		M
21	107	T			5		17.5		37.5	T		17.5	17.5		M
29	27				37.5		37.5		T		T	17.5	T		H
29	28	5			17.5		5		82.5			5			M
29	29	5			17.5		62.5		T			17.5			M
29	30				5		17.5		62.5	T			5		M
29	31	T					17.5		17.5	62.5		T	T		L
29	32				17.5		5		5	5		62.5	17.5		M
29	33	T			17.5		17.5		17.5	17.5		17.5			H
30	43				17.5				82.5			5			H
30	44				T		5		95				5		M
30	45	5			17.5		17.5		37.5		T	5	5		M
51	332	5			5		17.5		17.5	37.5		5	5		M
51	333	T			17.5		17.5		37.5	5	T	17.5	5		M
67	273	T			5					5		82.5			H
67	274	5			17.5		17.5		T		17.5	37.5	T		M
81	230	5			82.5		T			5		17.5	T	T	H
81	231	5			62.5		17.5					17.5		T	H
81	232	T			17.5		5			T		82.5			H
81	233	5			62.5					5		17.5		5	M
86	214	5			82.5		5					5			H
86	215	T			17.5		17.5					62.5			H
86	227				82.5		T					17.5			H
86	228				82.5		T					17.5			H
91	191	5			37.5		37.5			17.5		T			H
91	192				5		17.5			5		82.5			H
91	193				95							5			H
91	194	17.5			62.5		17.5		T	5		T			H

* (OBJECTID) refers to the attribute name for polygons in the GIS database.

Modified Braun Blanquet Cover Classes and Midpoints:

Cover Class	Range	Midpoint / Symbol
1	0<1	T
2	1<10	5
3	10<25	17.5
4	25<50	37.5
5	50<75	62.5
6	75<90	82.5
7	90-100	95

Abbreviations:
Algae
L=Low
M=Medium
H=High

Fifteen zones were randomly selected (www.random.org) with a minimum of ten zones to be resampled. Zones were rejected if they fell within areas containing non-representative factors (e.g., limited boat access). None of the randomly selected zones met these criteria. Vegetation data were collected in each zone for all Emergent and SAV areas if they met the criteria:

2.2 Methods Used in Quality Control Evaluation of 2015 Rainbow River Field Data Collection

Water & Air collected emergent and submergent vegetation data along the Rainbow River from May 15 through August 6, 2015. Following completion, Water & Air was tasked by the SWFWMD to repeat 2015 data collection along a representative portion of the river's SAV and emergent vegetation as a QC measure. This analysis reviewed some aspects of the quality of the 2015 field data collection by repeating the field data collection in selected polygons in a minimum of 10 zones in the river and comparing them to initial data collection.

Of the 95 zones established along the Rainbow River for collection of vegetation data, Water & Air recollected emergent and SAV data from a minimum of 10 zones selected from 15 randomly generated zone numbers. Each zone was revisited, and using the map created during the initial 2015 field work, each polygon present was evaluated to determine suitability for use in the QC evaluation. Selected polygons were resurveyed for the presence, absence and cover of SAV species and the presence, absence and dominance of herbaceous emergent species. The QC survey data was then compared to previous data collected for 2015.

Fifteen zones were randomly selected (www.random.org) with a minimum of ten zones to be resampled. Zones were rejected if they fell within areas containing non-representative factors (e.g., limited boat access). None of the randomly selected zones met these criteria. Vegetation data were collected in each zone for all Emergent and SAV areas if they met the criteria:

- If a polygon is >50% within the selected zone, it was acceptable for QC resurvey.
- If a polygon is >50% of the zone, it was used no matter how far it goes beyond the zone boundary.

The spatial relationship of the SAV and Emergent map layers was confirmed as part of the QC process. In the QC effort of the Emergent GIS data, the configurations of the forested and herbaceous emergent areas were examined relative to each other to confirm no overlap or gaps exist.

The QC survey data was compared to the original survey data to help determine the accuracy of vegetation data collection by examining whether the same species were

identified and the relative abundances were similar for the SAV and herbaceous emergent species.

3.0 Results of the Quality Assurance Evaluation and Quality Control Evaluation

3.1 Results of 2011 Data QA Evaluation

The analysis of the 2011 data can be summarized as follows:

- The Project Area, as defined by the shoreline polyline, and the sum of the SAV and Emergent areas had a difference of less than 0.2 percent.
- The SAV calculations confirmed similar "relative area" cover for the SAV. An example of the cover data by species can be seen in Table 3.2.1 of the Atkins 2012 report (Appendix B). Only very small size area cover (less than 0.02 ac) was above the 5% variance in our established QC limit. The minimal measurement unit specified in the 2011 mapping methodology was 225 sq. ft. or 0.005 ac. Since these deviations were small mapping units, the variance was not considered to be significant.
- The SAV calculation for “Bare” in Atkins 2012 Table 3.2.1 could not be reproduced. The Bare category was assumed to be the sum of the “Rock, rock/sand, rocks and sand” polygons in their dataset. The Bare area listed in Table 3.2.1 was 18.54 HA. The calculated area from their data was 14.23 HA.The difference of 4.31 hectares is greater than the 5% standard.
- The total forested and emergent coverage for the whole river was confirmed to be consistent with summary data in Table 3.2.1 of the Atkins 2012 report. The emergent vegetation cover by species in the database is consistent with the results presented in Table 3.4.1 of the Atkins 2012 report.

The data presented in the 2012 report data accurately portrays the geodatabase information supplied to Water & Air during the initiation of this work for SAV and emergent data, however there was an exception with the SAV “Bare” spatial data. Most analyses conducted on whole river data arrived at the same total coverage. In some instances the data varied slightly from that reported but the results differed by less than 5%.

None of the discrepancies found significantly compromises the 2011 data for comparison except for the SAV layer “bare areas” attributes. Examples of some of the minor discrepancies include:

- In comparing Sag (*Sagittaria* sp.) cover over the whole river, Water & Air calculated 39.63 acres, Atkins reported (in their Appendix D) 38.63 acres. This minor discrepancy may be a typographical error.
- A few minor coding errors were noted in the data.
- In the case of SAV "Bare" issue, Water & Air will rely on the data within the geodatabase, rather than report tables for comparative purposes. That assumes that the discrepancy was a result of processing or transcription, rather than the data itself. Since other similar metrics in that layer were consistent with the report tables, this seems to be a reasonable assumption and resolution to its use for future comparisons.
- It has also been suggested that the shortfall within the "Bare" category may be a result the imbedded "bare" areas within the SAV polygons but not accounted for directly in the data, but this could not be confirmed.

3.2 Other QA Procedures

In addition to documenting comparability of 2011 and 2015 data, general quality assurance procedures were used throughout the 2015 project including project specific checklists, standardized field data collection sheets for 2015 data collection, scanning rough field data sheets upon return from the field, and back-up of GIS data files on the Water & Air network. Once the field data were entered into a database, an independent reviewer checked the accuracy of the data entry and incorrect entries were flagged and corrected.

3.3 Results of 2015 Field Data Collection QC Evaluation

The following eleven zones were selected for QC resurvey: 7, 8, 9, 21, 29, 30, 51, 67, 81, 86, and 91. The vegetation resurvey occurred on the Rainbow River on August 18 and 19, 2015, and the original vegetation survey occurred during May through August 15.

Appendix A Tables 1 and 2 show the results of the vegetation data collection for SAV in 11 randomly selected zones on the Rainbow River. Appendix A Table 3 shows the results of comparisons of the SAV data collection by zone. The analysis only looks at ten of the commonly occurring species that were identified in the 11 zones. The analysis eliminated common river species that did not occur in these river zones and other incidental uncommon species.

Approximately 72% of the resurveyed observations in a "species by species" comparison over all eleven zones were identical to the original survey (Appendix A Table 3). Another 21% varied by only one cover class over all 11 zones. Six percent of the observations in the "species by species" comparison varied by more than one cover

class. Because the QC methodology was confined to certain river "zones", and the resurvey occurred only in portions of some polygons (since the polygons were split by zones), a somewhat higher variability is expected due to patchiness of species cover within a given polygon.

Appendix A Tables 4 and 5 show the results of the original survey and the QC resurvey respectively for the emergent vegetation by zone and by polygon. Only 8 of the 11 zones randomly selected contained herbaceous emergent species. Nineteen species of the 23 common herbaceous emergent species were represented in the eighteen polygons suitable to conduct comparisons. Approximately 83% of the resurveyed observations in "species by species" comparison over all eight zones matched the presence or absence data in the original survey (Appendix A Table 6). In approximately 8% of the species by species comparisons within the polygons, the species was not observed in the resurvey. In approximately 9% of the species by species comparisons, there was an addition of a new species not observed in the original survey in that polygon.

Seasonal shifts may account for some of the variability of herbaceous emergent vegetation. As the growing season progresses, species grow and cover more area, some gaining prominence while obscuring other species. Limited abundance information is available for the herbaceous emergent dataset because only presence, absence and dominance were scored. Overall, there was good evidence provided to authenticate reliable data collection of the SAV and emergent data from the 2015 Rainbow River vegetation survey. However, this effort falls somewhat short in providing a true quality assurance test of mapping and data collection due the temporal differences in the surveys, and the "zoned" approach to review. A better approach for future work might be to select random polygons throughout the river. However, the allowable time for this effort precluded using that approach in 2015.

4.0 Reference

Atkins North America and Debra Childs Woithe, Inc. 2012. 2011 Rainbow River Vegetation Evaluation. Prepared for the Southwest Florida Water Management District. SWFWMD Tampa, FL.

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Appendix A Table 3. Comparison Results of SAV Braun Blanquet (BB) Cover Class Changes by Species for Random Selected Zones of the Rainbow River from May - August 2015 Survey compared to the August 18 and 19, 2015 Resurvey

								Number of Level Changes in Zone by Species in BB Cover during Resurvey Relative to Survey***							
Zone	No. of Polygons Resurveyed**	Date of Surveys (Emergents, SAV)	Date of Resurvey	No. Species Observed in Survey	No. Species Observed in Resurvey	No. Species in Common	No. of Cover Comparisons	-3	-2	-1	0	1	2	3	Observations with no change in BB Level (%)
7	4	6/4/15, 7/9/15	8/18-19/15	8	9	8	40	0	0	6	26	7	1	0	65.0
8	3	6/4/15, 7/9/15	8/18-19/15	8	9	8	30	0	1	6	17	5	1	0	56.7
9	1	6/4/15, 7/9/15	8/18-19/15	5	6	5	10	0	0	1	7	1	1	0	70.0
21	6	6/4/15, 7/8/15	8/18-19/15	7	5	5	60	0	1	4	47	8	0	0	78.3
29	7	5/22/15, 6/11/15	8/18-19/15	5	6	5	70	0	2	6	47	8	5	1	67.1
30	3	5/22/15, 6/24/15	8/18-19/15	6	5	5	30	0	2	3	22	2	1	0	73.3
51	2	5/22/15, 8/5/15	8/18-19/15	7	6	6	20	0	0	1	17	2	0	0	85.0
67	2	6/3/15, 7/30/15	8/18-19/15	4	6	4	20	0	1	0	13	3	2	1	65.0
81	4	6/3/15, 7/22/15	8/18-19/15	4	4	4	40	0	1	5	28	6	0	0	70.0
86	4	6/3/15, 7/22/15	8/18-19/15	4	3	3	40	0	1	3	33	3	0	0	82.5
91	4	6/3/15, 7/21/15	8/18-19/15	4	5	4	40	0	2	2	30	4	2	0	75.0
Total*	**40**			**10**	**9**	**9**	**400**	**0**	**11**	**37**	**287**	**49**	**13**	**2**	**71.8**

* Total from all zones above

** Based on methodology, not all polygons in zone met criteria for resurvey

*** "-3" represents a three level decrease in BB cover levels (see below), "0" represents no change in BB cover level and "+3" represents a three level increase in BB cover levels

Modified Braun Blanquet Cover Classes:

Cover Class	Range of cover
1	0<1
2	1<10
3	10<25
4	25<50
5	50<75
6	75<90
7	90-100

Appendix A Table 4. Rainbow River Emergent Data Collected in Random Zones during May through August 2015

Zone	*Polygon (OBJECTID)	TYPE	Alternanthera	Cicuta	Colacasia	Hydrocotyle	Hymenocallis	Mikania	Nuphar	P.repens	Paspalum	Paspalidium	Pistia	Rhynchospora	S.latifolia	Scirpus	Typha	Zizaniopsis	Number of Species in Zone
7	21	em						P			D								6
7	23	em									D								
7	24	em		P				D			P			P	P			P	
21	43	em		P				P			D						P		7
21	48	em										D							
21	260	em		P				P			D				P			P	
28	56	em		P	P	P		D			D								7
28	57	em			P			P							D			P	
51	102	em		P				D		P	P			P			D		8
51	103	em									D			D					
51	363	em		P	D			D								P			
67	301	em				P	P	P			D		P		P				8
67	303	em							P		D						P		
81	184	em				P								P		P			11
81	188	em	D	D	P	D	P	P			P		P		P	P			
86	206	em		D		P						P	P						6
86	273	em		P		P		P		P			P						
91	267	em		D	P	D		P		P	P	P							7

* (OBJECTID) refers to the attribute name for polygons in the GIS database.

Abbreviations:
P = Present
D = Dominant
em = Emergent

Appendix A Table 5. Rainbow River Emergent Data Collected during QA Field Review in Random Zones, August 18 and 19, 2015

Zone	ID (polygon)	TYPE	Cicuta	Cladium	Colacasia	Hydcotle	Mikania	P. hemitomom	Paspalum	Pistia	Rhynchospora	S.lancifolia	S.latifolia	Scirpus	Typha	Zizaniopsis	No. Species in Zone
7	21	em	P			P	P		D		P	P					8
7	23	em					P		D								
7	24	em	P	P		P	P		P		P	P			P		
21	43	em					D		D			P			P		7
21	48	em							D								
21	260	em	P	P			P		D			P				P	
28	56	em	P		P		P		D								6
28	57	em		P			D					D					
51	102	em					P				P				D		6
51	103	em					P		P		P						
51	363	em			P									P			
67	301	em				P	P		D	P	P	P		P			7
67	303	em				P	P		D	P				P			
81	184	em				P	P		P	P	P			P			8
81	188	em	P			P	P		P	P	P	P					
86	206	em	P			P		P	P	P							7
86	273	em	P		P	P	P	P	P	P							
91	267	em	P		P	P	D	P	P	P			P				8

Abbreviations:
P = Present
D = Dominant
em = Emergent

Appendix A Table 6. Comparison Results of Emergent Species Presence/Absence for Random Selected Zones of the Rainbow River from May - August, 2015 Survey compared to the August 18 and 19, 2015 Resurvey

Zone	No. of Polygons Resurveyed in Zone	No. Species Compared Thoughout Zones	No. Species Occurences with Common Presence	No. Species Occurences with Common Absence	Loss of Species in Polygon	Gain of Species in Polygon	No. of Presence /Absence Comparisons
7	3	19	7	41	2	7	57
21	3	19	7	42	4	4	57
28	2	19	5	28	4	1	38
51	3	19	6	46	4	1	57
67	2	19	5	23	3	7	38
81	2	19	6	22	5	5	38
86	2	19	7	25	2	4	38
91	1	19	5	10	2	2	19
Totals			48	237	26	31	342
% Overall Common Presence/ Absence in Polygons Throughout QA Surveyed Zones							83%
% Overall Loss of a Species in a Polygon Throughout QA Surveyed Zones							8%
% Overall Gain of a Species in a Polygon Throughout QA Surveyed Zones							9%

APPENDIX B

SUPPLEMENTAL TABLES

Appendix B, Table 1. SAV Species Area Change for the Whole River in the Rainbow River (2011 and 2015)

SAV Species	2011 Area* (acres)	2015 Area* (acres)	Area Change 2011 - 2015 (acres)	Percent Change from 2011 - 2015
Ceratophyllum demersum	1.814	6.962	5.148	283.74
Chara sp.	3.020	0.068	-2.953	-97.75
Cyperaceae	Not Present	**0.000	N/A	N/A
Fontinalis sp.	0.179	0.916	0.736	410.38
Hydrilla verticillata	10.071	22.183	12.112	120.27
Hydrocotyle sp.	Not Present	**0.000	N/A	N/A
Ludwigia repens	0.232	0.391	0.159	68.35
Myriophyllum sp.	0.136	0.002	-0.134	-98.89
Najas guadalupensis	5.688	14.235	8.547	150.26
Nasturtium sp.	0.035	0.001	-0.033	-95.78
Potamogeton illinoensis	1.493	1.479	-0.015	-0.97
Sagittaria kurziana	39.633	29.451	-10.182	-25.69
Sagittaria lancifolia	Not Present	0.021	0.021	N/A
Utricularia sp.	2.157	0.646	-1.510	-70.03
Vallisneria americana	7.667	14.702	7.034	91.75
Zizania aquatica	0.108	0.066	-0.042	-38.89
Total	**72.233**	**91.122**	**18.889**	**26.15**

Note: Total areas represent all SAV species combined.

* Cover categories were differ in 2011 and 2015 (see methods section for details).

** Trace amounts of this species were observed in 2015.

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Appendix B, Table 2A. Area occupied by SAV species by zone group in the Rainbow River in 2015.

	Zone Group									
	1 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 95
2015 SAV Species	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)
Ceratophyllum demersum	0.3757	0.3490	0.0839	0.2977	0.2664	0.7634	1.4688	1.2048	0.3671	1.7850
Chara sp.	0.0004	0.0000	0.0646	0.0005	0.0015	0.0009	0.0000	0.0000	0.0000	0.0000
Cyperaceae	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fontinalis sp.	0.9157	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrocotyle sp.	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrilla verticillata	0.6129	1.0009	1.2458	1.9855	1.9150	1.7493	0.0815	2.8180	7.7094	3.0647
Ludwigia repens	0.2431	0.1478	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Myriophyllum sp.	0.0014	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Najas guadalupensis	0.7876	0.7194	1.4995	1.3712	1.2395	1.6104	1.2679	1.2282	0.2328	4.2783
Nasturtium sp.	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Potamogeton illinoensis	1.4785	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sagittaria kurziana	3.7476	4.7989	8.0679	3.8645	4.2870	2.3884	0.9504	1.1339	0.0009	0.2114
Sagittaria lancifolia	0.0210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Utricularia sp.	0.6463	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vallisneria americana	0.9812	1.1782	1.0663	1.0227	2.4089	2.8152	2.5903	1.2454	0.1465	1.2470
Zizania aquatica	0.0000	0.0000	0.0282	0.0284	0.0040	0.0035	0.0002	0.0010	0.0000	0.0004
Total SAV Area	**9.8135**	**8.1943**	**12.0567**	**8.5706**	**10.1222**	**9.3311**	**6.3590**	**7.6314**	**8.4567**	**10.5867**

Note: Each zone is 0.1 Km of river length.

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Appendix B, Table 2B. Area occupied by SAV species by zone group in the Rainbow River in 2011.

	Zone Group									
	1 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 95
2011 SAV Species	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)	Area (acres)
Ceratophyllum demersum	0.025	0.055	0.008	0.055	0.052	0.218	0.847	0.510	0.041	0.003
Chara sp.	0.000	0.001	0.000	0.023	0.432	1.297	1.219	0.048	0.000	0.000
Fontinalis sp.	0.179	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Hydrilla verticillata	0.763	0.895	2.463	1.879	1.951	0.585	0.053	0.298	0.955	0.228
Hydrocotyle sp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ludwigia repens	0.216	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Myriophyllum sp.	0.136	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Najas guadalupensis	0.035	0.068	0.609	0.841	0.728	0.210	0.000	0.073	0.692	2.432
Nasturtium sp.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.035
Potamogeton illinoensis	1.483	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sagittaria kurziana	5.963	7.316	8.092	6.552	5.985	2.299	1.840	0.956	0.000	0.631
Utricularia sp.	2.157	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Vallisneria americana	0.837	0.745	0.537	0.530	0.945	1.265	1.696	0.685	0.000	0.429
Zizania aquatica	0.000	0.000	0.102	0.000	0.000	0.000	0.004	0.002	0.000	0.000
Total SAV Area	**11.794**	**9.108**	**11.810**	**9.879**	**10.092**	**5.875**	**5.658**	**2.572**	**1.687**	**3.757**

Note: Each zone is 0.1 Km of river length.

Rainbow River 2015 Aquatic Vegetation Coverage Final Report

Appendix B, Table 3. SAV Species Area Change by Zone Group in the Rainbow River from 2011 and 2015

	Zone Group									
	1 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 95
SAV Species	Area Change (acres)	Area Change (acres)	Area Change (acres)	Area Change (acres)	Area Change (acres)	Area Change (acres)	Area Change (acres)	Area Change (acres)	Area Change (acres)	Area Change (acres)
Ceratophyllum demersum	0.3504	0.2938	0.0759	0.2426	0.2141	0.5456	0.6214	0.6951	0.3265	1.7821
Chara sp.	0.0004	-0.0015	0.0646	-0.0223	-0.4303	-1.2964	-1.2190	-0.0480	0.0000	0.0000
Cyperaceae	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fontinalis sp.	0.7363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Hydrilla verticillata	-0.1498	0.1057	-1.2175	0.1067	-0.0363	1.1639	0.0284	2.5197	6.7545	2.8370
Hydrocotyle sp.	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ludwigia repens	0.0270	0.1316	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Myriophyllum sp.	-0.1343	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Najas guadalupensis	0.7527	0.6518	0.8903	0.5304	0.5117	1.3999	1.2679	1.1548	-0.4589	1.8463
Nasturtium sp.	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0346
Potamogeton illinoensis	-0.0045	-0.0103	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sagittaria kurziana	-2.2150	-2.5176	-0.0238	-2.6877	-1.6975	0.0894	-0.8892	0.1777	0.0009	-0.4195
Sagittaria lancifolia	0.0210	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Utricularia sp.	-1.5102	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Vallisneria americana	0.1437	0.4332	0.5296	0.4931	1.4642	1.5503	0.8947	0.5608	0.1465	0.8182
Zizania aquatica	0.0000	0.0000	-0.0733	0.0284	0.0040	0.0035	-0.0037	-0.0012	0.0000	0.0004

Note: Each zone is 0.1 km of river length. Total SAV acreages differ between 2011 and 2015.

ATKINS TABLE

ATKINS NORTH AMERICA AND DEBRA CHILDS WOITHE, INC. 2012

Table 3.2.1. Change analysis of SAV, emergent and woody vegetation, and bare areas mapped in the Rainbow River 1996 to 2011. Relative areas calculated by transforming Braun-Blanquet categorical percent covers to hectares. River-wide species comprise 94% of total SAV coverage and are shown shaded in bold. Un-shaded species only occur in the headspring

RELATIVE AREAS												
	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	Hectares	%	%	%	%
SAV Species	1996 Relative Area	2000 Relative Area	2005 Relative Area	2011 Relative Area	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change
Sagittaria kurziana	**20.36**	**19.87**	**19.65**	**15.63**	**-0.48**	**-0.23**	**-4.02**	**-4.73**	**-2%**	**-1%**	**-20%**	**-23%**
Hydrilla verticillata	**9.67**	**10.43**	**10.90**	**4.05**	**0.76**	**0.47**	**-6.86**	**-5.63**	**8%**	**5%**	**-63%**	**-58%**
Vallisneria americana	**2.47**	**2.34**	**3.27**	**3.10**	**-0.13**	**0.93**	**-0.17**	**0.64**	**-5%**	**40%**	**-5%**	**26%**
Najas quadalupensis	**1.02**	**0.39**	**1.86**	**2.30**	**-0.63**	**1.47**	**0.45**	**1.29**	**-62%**	**376%**	**24%**	**126%**
Chara sp.	**0.57**	**0.84**	**0.39**	**1.22**	**0.27**	**-0.45**	**0.83**	**0.65**	**47%**	**-53%**	**213%**	**115%**
Ceratophyllum demersum	**1.06**	**0.63**	**1.09**	**0.73**	**-0.43**	**0.46**	**-0.36**	**-0.33**	**-40%**	**73%**	**-33%**	**-31%**
Utricularia sp.	0.40	0.06	0.51	0.87	-0.35	0.45	0.37	0.47	-86%	783%	73%	116%
Potamogeton illinoensis	0.23	0.29	0.27	0.60	0.06	-0.01	0.33	0.38	27%	-5%	120%	167%
Ludwigia repens	0.02	0.03	0.10	0.09	0.004	0.07	-0.01	0.07	16%	266%	-8%	291%
Fontinalis sp.	0.00	0.00	0.03	0.07	0.000	0.03	0.05	0.07			171%	
Myriophyllum sp.	0.00	0.01	0.00	0.05	0.005	0.00	0.05	0.05	125%	-51%	1228%	1365%
Zizania aquatica	0.00	0.00	0.01	0.04	0.000	0.01	0.03	0.04			267%	
Nasturitium sp.	0.001	0	0.003	0.01	-0.001	0.003	0.01	0.01	-100%	100%	399%	1207%
Hydrocotyle sp.	0.001	0	0.001	0	-0.001	0.001	-0.001	-0.001	-100%	100%	-100%	-100%
Total	**35.81**	**34.88**	**38.09**	**28.80**	**-0.92**	**3.21**	**-9.30**	**-7.01**	**-3%**	**9%**	**-24%**	**-20%**
Native Species	**26.13**	**24.45**	**27.19**	**24.75**	**-1.68**	**2.73**	**-2.44**	**-1.39**	**-6%**	**11%**	**-9%**	**-5%**
Exotic Species**	**9.67**	**10.43**	**10.90**	**4.05**	**0.76**	**0.47**	**-6.86**	**-5.63**	**8%**	**5%**	**-63%**	**-58%**
TOTAL AREAS												
	1996 Total Area	2000 Total Area	2005 Total Area	2011 Total Area	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change	96-'00 Change	00-'05 Change	05-'11 Change	96-'11 Change
Total SAV Occupied Area	52.92	51.15	53.57	41.48	-1.76	2.42	-12.09	-11.43	-3%	5%	-23%	-22%
Bare	7.11	8.87	6.45	18.54	1.76	-2.42	12.09	11.43	25%	-27%	187%	161%
Emergent	9.97	10.15	11.56	12.72	0.18	1.40	1.16	2.75	2%	14%	10%	28%
Forested	10.84	10.55	10.64	10.53	-0.28	0.08	-0.11	-0.31	-3%	1%	-1%	-3%
Total River Area	**80.84**	**80.73**	**82.22**	**83.27**	**-0.10**	**1.49**	**1.05**	**2.44**	**0%**	**2%**	**1%**	**3%**

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