FY-07 104(b)(3)

EPA Grant CA# CD-966618-01 Project 2

Initiating a Vegetated Wetland throughout the Littoral Zone of Atoka Lake, Atoka County, Oklahoma

FINAL REPORT

Approved August 2011

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Agency: Oklahoma Water Resources Board (OWRB)

Project : 2

Location: Atoka Lake, WBID OK410400080020
Hydrologic Unit Code (HUC) 11140103, Muddy Boggy Watershed

Cooperators: Oklahoma City Water & Wastewater Utilities Department (OCWWUD)
Corps of Engineers at Lewisville (LAERF)

Acknowledgements

The U.S. Environmental Protection Agency funded 55% of this project, $112,553 making the planting of Atoka Lake a reality. Additional funding, labor and coordination came from the City of Oklahoma City who was supportive at every level to help make this a successful project.

Table of Contents

Table of Contents 4
Table of Figures: 5
Executive Summary 8
Integration with the Oklahoma Comprehensive Water Plan 9
Background 10
Site Description 11
Outline of Events 13
Meeting Project Objectives 15
Restoration of the shoreline to lacustrine wetlands: 15
Caged Plantings 17
Pen Plantings 17
Planting Scheme and Lake Elevations during the Project 22
Habitat Plantings with Trees 25
Volunteer (Preexisting) Plant Colonies 27
Additional Project Endeavors 28
Outreach 28
Presentation to Lake Atoka Reservation Association 29
Project Results 30
Cage Planting Results 31
Cage Survival 31
Cage Coverage 33
Pen Planting Results 42
Tree Planting Results 52
Volunteer (Preexisting) Plant Colonies 58
Accomplishing Workplan Objectives 60
Conclusion and Recommendations 62
Reconciliation with Data Quality Objectives 63
Decision Thresholds: 63
Decision Rule 64
Threshold Conclusions 64
Literature Cited 67
Appendix A – Lake Atoka Recommendation from the Lewisville Aquatic Ecosystem Research Facility at University of North Texas 1
Appendix B – Planting Data 1
Appendix C – Site Maps 1
Appendix D – Photo Monitoring 1
2008 2
2009 7
2010 12
Appendix E - Letter from Oklahoma Forestry Services regarding Tree Assessment 1
Appendix F – Water Quality Data 1

Table of Figures:

Figure 1: Scenic bluff at Atoka Lake July 2007 11
Figure 2: Existing colony of *Eleocharis spp.* (Spikerush) 11
Figure 3: Atoka Lake Map 12
Figure 4: Atoka Lake Site Map as of Final Assessment – fall 2010 16
Figure 5: Site 5 Spatterdock (*Nuphar lutea*) bursting out of its cage; and a shot of a typical caged site (Site 2), both taken at final assessment - September 2010 17
Figure 6: Construction and planting of a new pen in July, 2010 18
Figure 7: A canopy of *Potamogeton nodosus* (American Pondweed), *Nymphea Odorata* (White Water-Lily) and wire mesh provide outstanding cover for young age-class fish, fall assessment 2008 19
Figure 8: "Deeper" pen at site 4; September 2008 20
Figure 9: "Deeper" pen at site 4 two years later; September 2010. Developed community of *schoenoplectus tabernaemontani, nymphaea odorata, potamogeton nodosus, heteranthera dubia* and *vallisneria americana.* 20
Figure 10: "Deeper" pen has good growth of *schoenoplectus tabernaemontani, nymphaea odorata, potamogeton nodosus, heteranthera dubia* and *vallisneria americana*. September 2010. 21
Figure 11: "Shallow" pen at Site 4, has new sprouts of several different species *including sagittaria graminea, nuphar lutea, pontederia cordata,* and *sagittaria latifolia.* September 2010 21
Figure 12: Typical site layout by 2010 consisted of aquatic plant cages and pens, with tree cages and plots nearby 22
Figure 13: Plant Elevations in relation to Water Level elevations over project timeframe and growing seasons. 23
Figure 14: "Deeper" pen at Site 1, July 2010. More than half of the pen is under water. Later a "topper" was added to prevent the water from overtopping the "Deeper" pens… 24
Figure 15: Typical 2010 site layout with fewer deep cages and the addition of a Shallow pen at a higher elevation. 25
Figure 16: OWRB and City of Oklahoma City personnel planting tree seedlings March 2009 26
Figure 17: A *Quercus macrocarpa* (Bur Oak) sapling approximately 20 months after planting; and a *Platanus occidentalis* (American Sycamore) sapling approximately 8 months after planting, October 2010 27
Figure 18: Volunteer *Potamogeton spp.* (pondweed) and *Justicia americana* (water willow) Fall 2008 28
Figure 19: Owen Mills presenting first year results to the Lake Atoka Reservation Association (October 2008) 29
Figure 20: *Pontederia cordata* outgrowing its cage; 100% (site 3 September 2010) 34
Figure 21: *Schoenoplectus tabernaemontani* with average growth (September 2010). (50% Coverage) 35
Figure 22: *Nymphaea odorata* completely filling its cage at site 2; 100% coverage (September 2010) 36
Figure 23: A cage of *Pontederia cordata* with *exceptional growth* (75% coverage) at final assessment - fall 2010 37
Figure 24: *Thalia dealbata* causing its cage to tip over. (September 2010) 38

Figure 25: *Sagittaria graminea* with exceptional growth (≥75% coverage) both inside and outside of the cage (September 2010). 38
Figure 26: Lake-wide Average Coverage in Cages by Species 39
Figure 27: A full cage of *Thalia delbata* at site 3 during final assessment 2010. 40
Figure 28: Average Cage Coverage by Elevation 41
Figure 29: "Shallow" Pen at Site 5 - *Pontederia cordata, Schoenoplectus tabernaemontani, Justicia americana,* and *Eleocharis quadrangulata*. At final assessment fall 2010. 44
Figure 30: New propagules of *Pontederia cordata, Schoenoplectus tabernaemontani, Sagittaria graminea,* and *Nuphar lutea* along with *Justicia americana* are seen in this close-up shot from "Shallow" pen 5 at the final assessment – September 2010. 45
Figure 31: "Shallow pen" at Site 4. *Pontederia cordata, Schoenoplectus tabernaemontani,* and *Justicia americana* with new propagules of *Sagittaria graminea* at the final assessment – September 2010. 46
Figure 32: Another view of the "Shallow" pen at site 4. Final assessment 2010 46
Figure 33: "Deeper" Pen at Site 3 - final assessment, September 2010. 47
Figure 34: Site 5 "Deeper" pen with *Sagittaria graminea* and blooming *Nymphaea odorata* at the final assessment – September 2010. 48
Figure 35: Another view of the "Deeper" pen at site 5, September 2010. 48
Figure 36: New propagules of *Sagittaria graminea* at the boat ramp adjacent to site 2. Large stand of *Justicia americana* also visible. July 2010 50
Figure 37: Another view of new propagules of *Sagittaria graminea* at the boat ramp adjacent to site 2. July 2010 50
Figure 38: Relationship of Aquatic Plant site 2 to boat ramp (blue icon) where unprotected propagules were found reproducing. 51
Figure 39: Atoka Lake map with Tree sites and surrounding SSURGO soil types 56
Figure 40: "Shallow" pen at site 1 that has a large stand of Justicia americana growing in it. September 2010 58
Figure 41: Spread of *Justicia americana* at site 1, upper photo taken fall 2008, middle taken fall 2009, and lower taken fall 2010 59
Figure 42: Stand of *Ludwigia L. spp.* (Water Primrose) at Atoka Lake – July 2010 60
Figure 43: View of some of the cages at site 3 during the final assessment – September 2010 62
Figure 44: *Potamogeton nodosus* growing in a penned cage - final assessment, September 2010 63
Figure 45: Site 1 (Photo Point 1) 2008 2
Figure 46: Site 1 (Photo Point 2) 2008 2
Figure 47: Site 2 (Photo Point 1) 2008 3
Figure 48: Site 2 (Photo Point 2) 2008 3
Figure 49: Site 3 (Photo Point 1) 2008 4
Figure 50: Site 3 (Photo Point 2) 2008 4
Figure 51: Site 4 (Photo Point 1) 2008 5
Figure 52: Site 4 (Photo Point 2) 2008 5
Figure 53: Site 5 (Photo Point 1) 2008 6
Figure 54: Site 5 (Photo Point 2) 2008 6
Figure 55: Site 1 (Photo Point 1) 2009 7

Figure 56: Site 1 (Photo Point 2) 2009 7
Figure 57: Site 2 (Photo Point 1) 2009 8
Figure 58: Site 2 (Photo Point 2) 2009 8
Figure 59: Site 3 (Photo Point 1) 2009 9
Figure 60: Site 3 (Photo Point 2) 2009 9
Figure 61: Site 4 (Photo Point 1) 2009 10
Figure 62: Site 4 (Photo Point 2) 2009 10
Figure 63: Site 5 (Photo Point 1) 2009 11
Figure 64: Site 5 (Photo Point 2) 2009 11
Figure 65: Site 1 (Photo Point 1) 2010 12
Figure 66: Site 1 (Photo Point 2) 2010 12
Figure 67: Site 2 (Photo Point 1) 2010 13
Figure 68: Site 2 (Photo Point 2) 2010 13
Figure 69: Site 3 (Photo Point 1) 2010 14
Figure 70: Site 3 (Photo Point 2) 2010 14
Figure 71: Site 4 (Photo Point 1) 2010 15
Figure 72: Site 4 (Photo Point 2) 2010 15
Figure 73: Site 5 (Photo Point 1) 2010 16
Figure 74: Site 5 (Photo Point 2) 2010 16

Table of Tables:

Table 1: Pen Dimension and Area by Site 18
Table 2: Aquatic Plant Species planted throughout the project, by year planted. 30
Table 3: Cage Planting Survival from Final Assessment 32
Table 4: Cage Data of Species where n=30 or more 33
Table 5: Percent Coverage Breakdown for Caged Plants 34
Table 6: Lake-wide Averages of Plant *Coverage*, both inside and out of the Protective Cages 35
Table 7: Lake-wide totals for Growth and spread - Inside cages 36
Table 8: Lake-wide totals for growth observed outside of cages 37
Table 9: Final Pen Assessment Results - fall 2010 43
Table 10: Lake-wide Average Total for Survival within Pens 43
Table 11: Acres Planted at Atoka Lake 49
Table 12: 2009-2010 Tree Species Planted at Atoka Lake 53
Table 13: Final Assessment Results for Atoka Trees 53
Table 14: Tree Survival by Site 54
Table 15: Tree Survival by Species 54
Table 16: Species Survival by Site 55
Table 17: Species Survival by Soil Type 57

Executive Summary

Atoka Lake is currently not meeting its Fish and Wildlife Propagation (FWP) beneficial use due to turbidity. A 1981 Phase I Clean Lakes study recommended planting vegetation in its large shallow mud flats as a way to reduce the resuspension of solids from wave action. The City of Oklahoma City (OKC) has taken an initiative, along with the Oklahoma Water Resources Board (OWRB) and other agencies, to look for holistic treatments to their lake properties, including watershed Best Management Practices (BMP) and forest management options. The intention of this project was to work with Oklahoma City to initiate an ecological shift back towards a lacustrine fringe ecosystem. Protected plantings called *"Founder Colonies"* were established throughout the lake providing some 5.18 acres of high quality habitat. These areas are now sources of seed and shoots that have the potential to spread over the coming years. Due to the early success of emergent plant species the project scope was expanded to include floating leaved and submersed leaf plants. Because of the overall project success, continued maintenance of the founder colonies to allow for continued ecological shift is recommended.

From the summer of 2008 through the fall of 2010 the OWRB and its partners introduced 22 species of native obligate wetland (aquatic macrophyte) species to Atoka Lake in an attempt to revegetate, diversify and maintain the shorelines while creating habitat and improving water quality. In all, 17 species have survived in 350 cages and 9 large pens distributed over 5 sites across the lake. Emergent plant species that excelled were: *Pontederia cordata, Sagittaria latifolia, Sagittaria graminea, Thalia dealbata and Schoenoplectus tabernaemontani*. The submersed and floating leaved plants that were most successful were *Heteranthera dubia,* and *Nymphea odorata.* One plant, *Justicia americana* (Water-willow), did exceedingly well without any protection at all. By project end founder colonies were healthy and spreading well, with plants observed beyond founder colony sites. The following thresholds are the workplan measures set to indicate project success or failure. Conclusions based on the thresholds are in bold print.

Output Threshold was met; *a survival threshold of 50% or better within the protective cages indicates that the project has successfully established founder colonies*. Cage survival by project end was 67% over 350 cages. Founder colonies of obligate wetland plant species have been established. The substantive success rate gives OWRB confidence that with time and continued effort this lake can have a diverse aquatic macrophyte community.

Outcome Threshold, when plant coverage outside of the protective cages is equal to or exceeds the coverage within the protective cages, was not met with an average of 27% of cages exhibiting growth outside the cage, and a lake-wide average outside coverage of 17%. Since the 64% coverage was not met, the expected outcome is concluded as not secure. However, as the founder colonies have been established and significant growth outside of the cages was noted, the #2 Decision Rule is the best fit for the overall project conclusion as "***Output successful but Outcome Indeterminate***". Additional modifiers to this conclusion include the fact that Oklahoma City has expressed a commitment to continue maintenance on this project. This commitment increases the

likelihood of achieving the long-term outcome of an ecological shift in Atoka Lake toward a diverse lacustrine fringe wetland system.

Integration with the Oklahoma Comprehensive Water Plan

The mission of the Oklahoma Water Resources Board is to enhance the quality of life for Oklahomans by managing, protecting and improving the State's water resources to ensure clean, safe, and reliable water supplies, a strong economy, and a healthy environment. The guidance document for carrying out that mission is the Oklahoma Comprehensive Water Plan (OCWP), currently being updated to establish reliable water quantity and water quality for all Oklahomans through the next 50 years.

Aquatic plant revegetation along shorelines is one tool in the OCWP that can be utilized by lake managers to protect and enhance the water quality of Oklahoma lakes. This project represents a means for ensuring that improvements can be made to water quality so that Oklahoma lakes can fulfill their beneficial use designations.

Background

Atoka Lake is the largest reservoir owned by the City of Oklahoma City (OKC). It lies 110 miles southeast of Oklahoma City, in Atoka County. Water from Atoka Lake is transported via pipeline to one of Oklahoma City's municipal lakes, Stanley Draper. Raw water from Lake Stanley Draper is treated for potable consumption. Built in 1964 on the Muddy Boggy Creek, the Atoka impoundment is used primarily as a public water supply source. During times of extremely high use or low rainfall, the lake receives additional water pumped from nearby McGee Creek Reservoir.

Atoka Lake is listed as impaired for turbidity on the Clean Water Act 303(d) list. It is not currently meeting the Fish and Wildlife Propagation (FWP) beneficial use due to turbidity. It is only partially supporting FWP due to high true color values. The 2009 annual report of the Beneficial Use Monitoring Program (BUMP) gave an average lake-wide turbidity of 53 NTU with 85% of values greater than the Oklahoma Water Quality Standard (OWQS) of 25 NTU. Evidence (OWRB 1983) suggests that the high turbidity readings are natural due to local soil conditions. The predominantly colloidal clay soils do not easily settle out in the water column. The average Secchi disk depth was 33 cm and average lake-wide color was calculated at 160 units, which far exceeded the OWQS Aesthetic beneficial use for color of 70 units. Extremely high turbidity and color issues were a problem soon after impoundment of the reservoir. Interest in this problem prompted a 1981 Clean Lakes study by the Oklahoma Water Resources Board (OWRB) which recommended, among other things, to plant the extensive mudflats primarily located on the upper (north) end of the lake. The lake is prone to high waves and wave energy with straight long fetches running primarily north to south. To further intensify the problem, it is a shallow lake with an average depth of 18 feet and maximum depth of 60 feet. Creating a lacustrine wetland both in the upper flats and along the 70 mile perimeter can greatly reduce resuspension of solids in the lake and improve the lake's fishery.

The Oklahoma City Water & Wastewater Utilities Department (OCWWUD) is aware that littoral aquatic plants are a vital part of any natural lake and bring with them improved habitat and water quality while helping to stabilize shorelines and reduce turbidity.

Site Description

Figure 1: Scenic bluff at Atoka Lake July 2007

Atoka Lake (Figure 1) is a 5,700-acre lake with 70 miles of shoreline (Figure 3). The lake has many well-protected coves with easy access by boat or by truck. The substrate is generally colloidal clay. At project start some colonies or individuals of aquatic macrophytes were found. Namely Common Rush, Lovegrass, Spikerush (Figure 2), miscellaneous Sedges, Rosemallow, Buttonbush, Primrose and Water Willow as well as at least one floating leaved plant, a species of Pondweed (*Potamogeton spp.*) were intermittently distributed along and above the shoreline.

Figure 2: Existing colony of *Eleocharis spp.* (Spikerush)

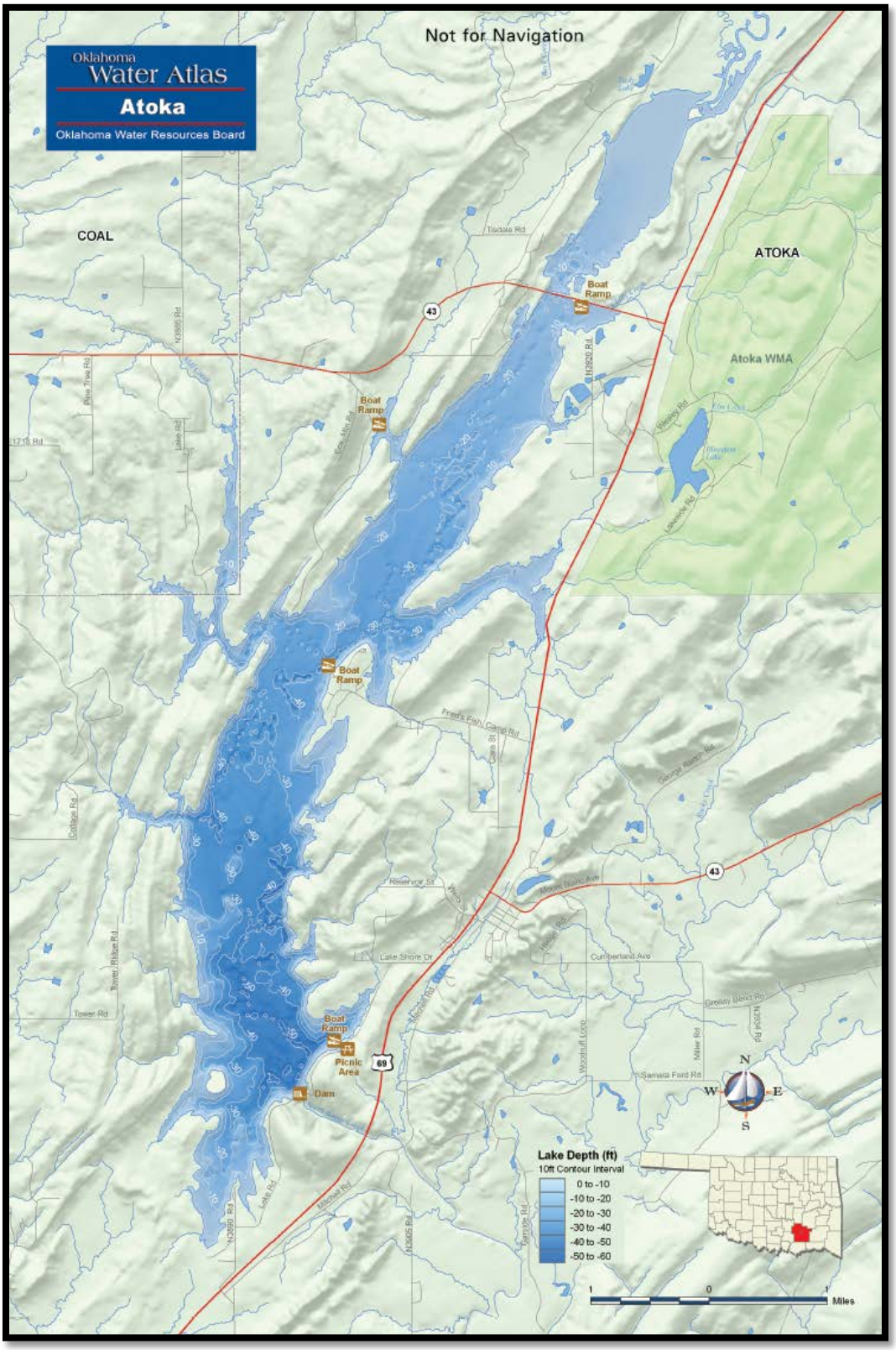

Figure 3: Atoka Lake Map

Outline of Events

The following outline is not meant to be an exhaustive list of events for the project but does help to give a picture of how the project proceeded.

2008

- May
  - Consultants from Lewisville Aquatic Ecosystem Research Facility (LAERF) visited Atoka to give planting recommendations/strategies.
  - Site selection.
- June – September
  - Constructed cages and pens then planted sites with assistance from City of Oklahoma City personnel.
  - First fall assessment conducted.
- October
  - Presentation of first year project results to the Atoka Lake Reservation Association. Results were well received by the managing board members.
- November – December
  - First year data analysis and mapping

2009

- January – March
  - First tree planting. Nine species amounting to approximately 1600 trees were planted at 8 sites.
- April – September
  - Spring assessment of plantings.
  - Replanted cages as needed.
  - Constructed 2 additional pens; making a total of 5 pens, one at each site.
  - Added Turtle Traps and Fish Funnels to each pen.
  - Added risers to the tops of all the pens.
  - Many cages were moved to higher elevations, due to sustained high water levels expected for the next few years.
  - Second fall assessment conducted.

2009 continued…

- October - December
  - Discovered that some tree sites had been damaged due to ATV activities in the area.
  - Second year data analysis and mapping

2010

- March
  - Second year of tree plantings. Approximately 1600 additional trees were planted at four new tree sites, making the total number of tree sites 12.
- April
  - Spring assessment of plantings.
- May - September
  - Installed an additional pen at 4 of the 5 sites for a total of 9 pens.
  - Last of plantings completed.
  - Some cages moved to higher elevations due to sustained high water levels
  - Added risers to pens that were inundated
  - Final Assessment of plantings
- November
  - Final Tree assessment

Meeting Project Objectives

Restoration of the shoreline to lacustrine wetlands:

From Project Workplan:

> *"By planting founder colonies of wetland species in key protected areas around the lake, natural spread will result in development of wetland habitat around much of the lake. This habitat will result in a healthier lake and more diverse ecosystem."*
>
> *"Plants will be distributed over at least 5 sites across the lake, providing immediate (3 year) wetland habitat in what is currently a poorly vegetated environment."*
>
> *"Following founder colony establishment (in the long term, 10+ years) these protected plants will create a seed bank and give off fragments that will over time populate the coves where sites are (located) and will spread to other parts of the lake as well."*
>
> *"Turbidity will be reduced as the colloidal clays fall out in the plant protected waters. Shoreline erosion will be curtailed by reduction of wave action and compaction of shoreline sediments by root systems. Emergent species such as bulrush, spike rush and duck potato will buffer the lake from upland erosion. Submersed species such as American pondweed and coontail will populate the deeper portions of the littoral zone."*
>
> *"Fish nursery habitat will be enhanced as the plants provide cover, macroinvertebrate habitat, and improved water quality."*

Outcome: 5 aquatic plant sites (Figure 4) were planted with 1,311 plants from 22 species over three seasons (Maps of each planted site can be found in Appendix C – Site Maps).

The lake currently has 350 cages and 9 pens with aquatic plants. The lake is well positioned to propagate many parts of the lake with several successful species. In time, with continued maintenance, the lake should establish diverse unprotected colonies of native wetland plants over a number of coves.

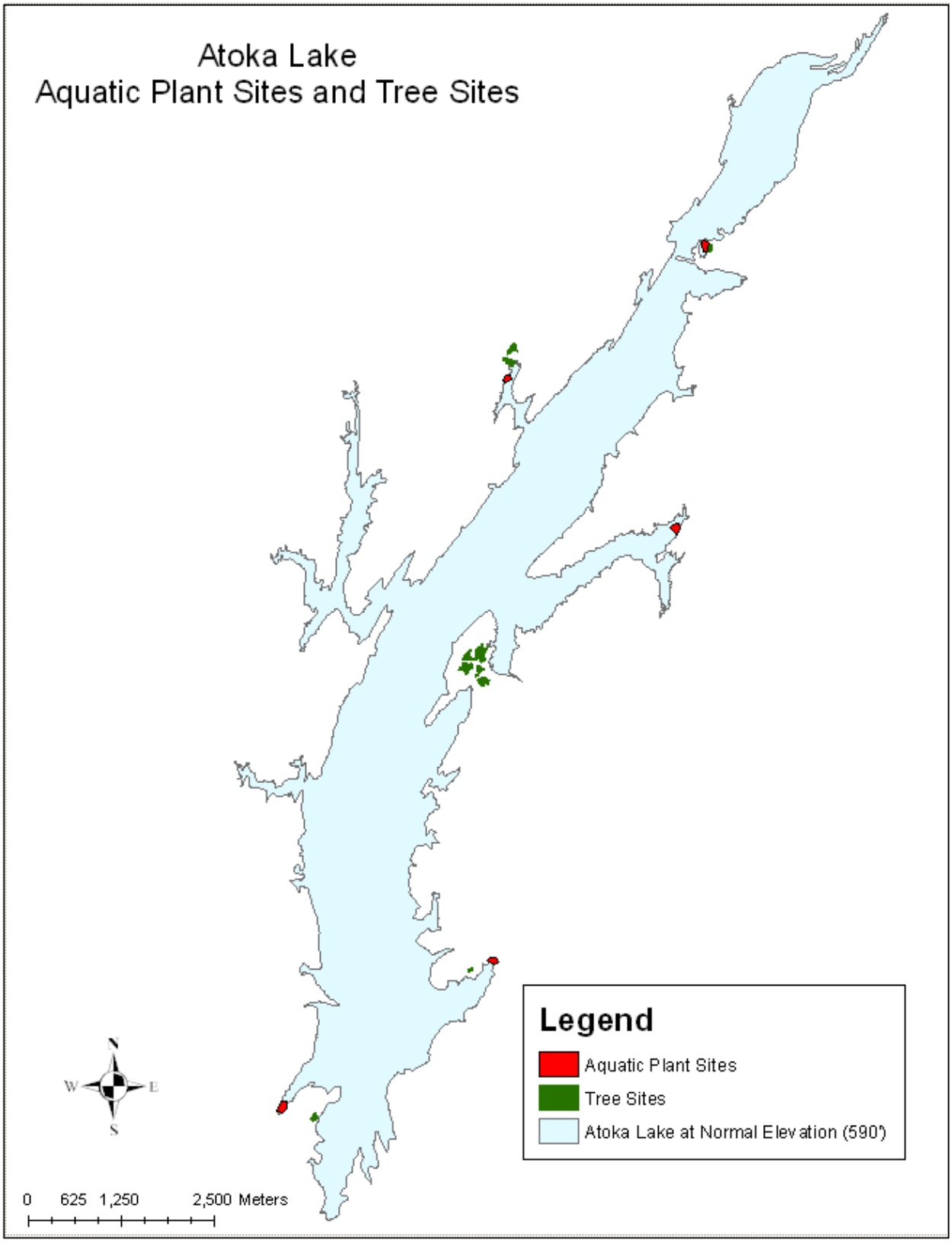

Figure 4: Atoka Lake Site Map as of Final Assessment – fall 2010

Caged Plantings

As of the 2010 fall assessment the lake had 350 cages of viable plants. Caged plantings are those plants put inside a plastic-coated wire mesh to protect them from herbivores. These cages were usually 3 feet in diameter and ranged from 3 feet in height for higher plantings to 5 feet in height for deeper plantings (Figure 5). Upper elevation plantings used a 2”x 4” mesh that is sufficient to control terrestrial grazers. Deeper plantings used a 2”x 2” mesh to filter out small turtles and fish. Tops were constructed for very deep plantings of submersed plants where cages were expected to be overtopped most of the time.

Figure 5: Site 5 Spatterdock (*Nuphar lutea*) bursting out of its cage; and a shot of a typical caged site (Site 2), both taken at final assessment - September 2010

Pen Plantings

Three pens were installed at sites 1, 2, and 4 in 2008, with two pens added in 2009 at sites 3 and 5; making a total of five pens, one at each site. In 2010, four additional pens were installed at four of the five sites (not site 3 due to the rocky substrate) giving Atoka Lake at total of 9 pens. Due to soil type and location layout, pen dimension varied at each site. Table 1 shows the dimensions and area of each pen.

Table 1: Pen Dimension and Area by Site

Site and Description	Pen Dimensions (ft.)	Pen Area (acres)
Site 1 – Deeper Pen	50 x 95	0.11
Site 1 – Shallow Pen	20 x 75	0.03
Site 2 – Deeper Pen	50 x 100	0.12
Site 2 – Shallow Pen	25 x 75	0.04
Site 3 – Deeper Pen	60 x 85	0.11
Site 4 – Deeper Pen	50 x 100	0.11
Site 4 – Shallow Pen	50 x 70	0.05
Site 5 – Deeper Pen	50 x 100	0.12
Site 5 – Shallow Pen	25 x 70	0.04

In the large area a pen provides, plant populations and their seeds can multiply beyond ring cage plantings by one or two orders of magnitude. The pen methodology was incorporated into this project due to the success of this method witnessed during previous founder colony projects including the EPA 104(b)(3) Lake Stanley Draper project and planting work done at Grand Lake. Figure 6 shows the installation of a pen in the summer of 2010.

Figure 6: Construction and planting of a new pen in July, 2010

Diverse plant communities can develop as well as habitat for younger age classes of fish. While not caught on camera, project staff witnessed on multiple occasions young fish darting in and out of the 2”x 4” mesh pens as staff approached. Pens have an outstanding ability to provide multiple levels of habitat and protection for younger age class fish (Figure 7).

Figure 7: A canopy of *Potamogeton nodosus* (American Pondweed), *Nymphea Odorata* (White Water-Lily) and wire mesh provide outstanding cover for young age-class fish, fall assessment 2008

Pens were placed in all five coves. Because the coves are well distributed around the lake, they are able to take into account differences in sediment types and water quality, and disperse seeds at various locations around the lake. Ring cages were also installed around many of the plantings within each pen to safeguard against breaches that can occur. These additional protection measures helped to assure that if a breach occurred, founder colonies remained to repopulate the pen.

In general, the pens did as expected; creating a mixed community of aquatic macrophytes. The caged and uncaged plants generally spread well, filling both their ring cages and the pen (Figure 8, Figure 9, Figure 10 and Figure 11).

Figure 8: "Deeper" pen at site 4; September 2008

Figure 9: "Deeper" pen at site 4 two years later; September 2010. Developed community of *schoenoplectus tabernaemontani, nymphaea odorata, potamogeton nodosus, heteranthera dubia* and *vallisneria americana.*

Most pens were not densely populated but had a diverse community of species. In fact, all nine pens had a minimum of five different "prominent" (at a minimum, a grouping of healthy macrophytes) species at the time of the final assessment. Figure 11 is an example of a shallow pen with multiple "prominent" species present.

Figure 10: "Deeper" pen has good growth of *schoenoplectus tabernaemontani, nymphaea odorata, potamogeton nodosus, heteranthera dubia* and *vallisneria americana*. September 2010.

Figure 11: "Shallow" pen at Site 4, has new sprouts of several different species *including sagittaria graminea, nuphar lutea, pontederia cordata,* and *sagittaria latifolia.* September 2010

Planting Scheme and Lake Elevations during the Project

A typical site consisted of aquatic plant cages and deep and/or shallow pens. Often times, tree sites were in close proximity to the aquatic plant sites. The initial plantings were done May through July of 2008 with both caged and pen plantings. A representative format is illustrated in Figure 12.

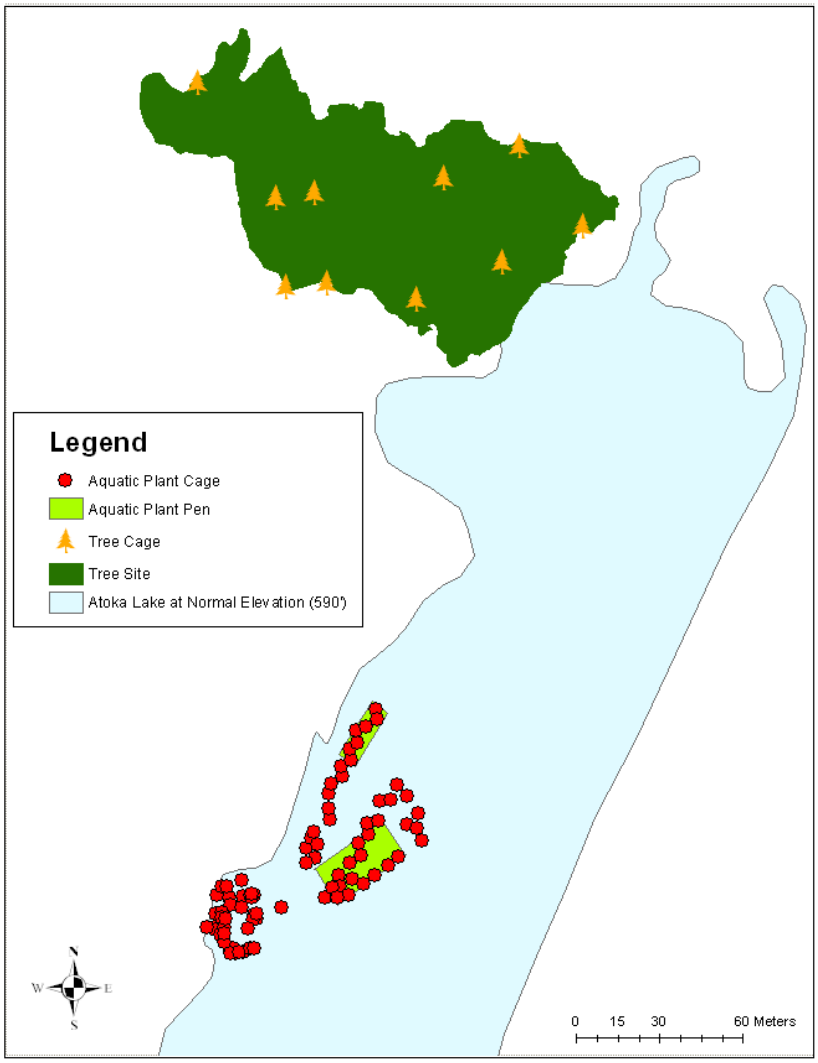

Figure 12: Typical site layout by 2010 consisted of aquatic plant cages and pens, with tree cages and plots nearby

In the first season, the plants experienced a steady drop in pool elevation. This was due to anticipated repairs on the Atoka pipeline that pumps water from Atoka Lake into Lake Stanley Draper. Lake Stanley Draper was filled higher than normal so that there would be

more water available to Oklahoma City as the pipeline repairs were being made. As a result, Atoka Lake was pumped down lower than normal in order to fill up Stanley Draper. When work began on the pipeline in 2009, Atoka Lake levels stayed above normal because there was not the usual drawdown from water being sent to Lake Stanley Draper due to the pipeline repairs. The water levels in Atoka Lake remained above the expected norm through the summer of 2010 as a result of the pipeline work. This was, at first, a very positive development for the emergent macrophytes, because the slow drawdown allowed them to follow the water. However, by the second season, as water levels during the growing season averaged 589.2' mean sea level (msl) the plants suffered from herbivory and inundation, with many of the cages and pen constructed in season one being overtopped and no longer providing protection. Planting elevations can be seen in Figure 13.

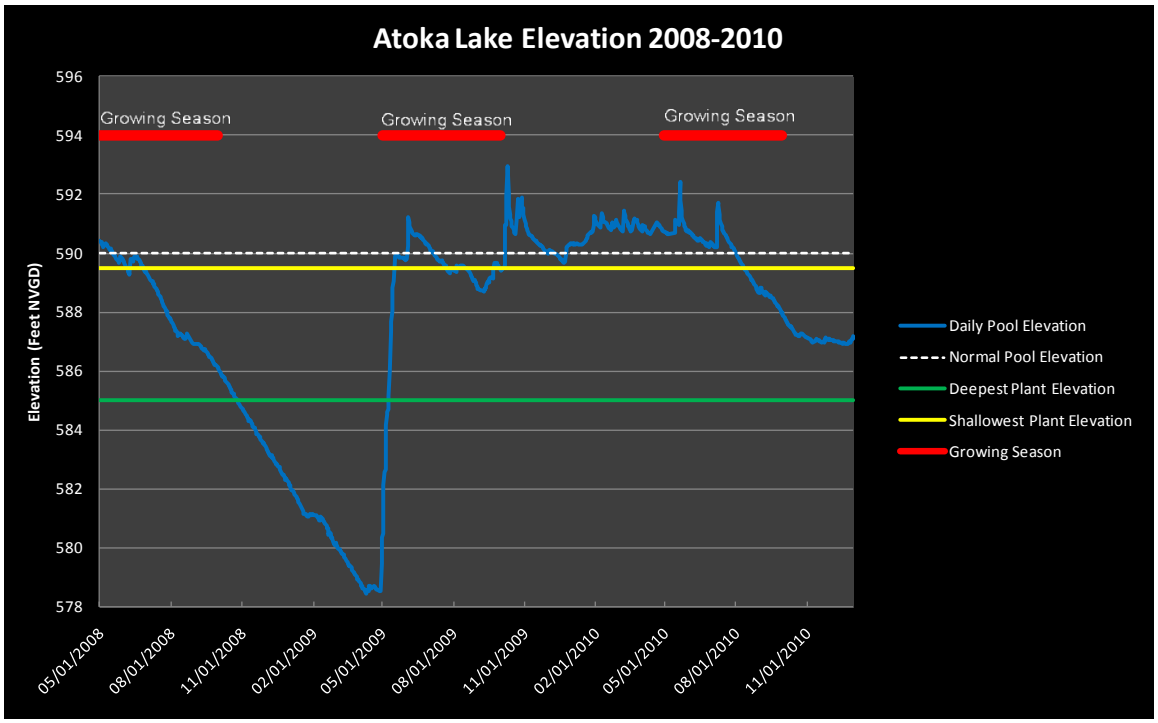

Figure 13: Plant Elevations in relation to Water Level elevations over project timeframe and growing seasons.

Emergent plants were assayed from 586' msl to 589.5' msl. Submersed and floating leaved species were assayed from 585.5' msl to 588' msl. The blue line on the graph in Figure 13 shows the lake elevation curve over the project period. Red lines at the top of the graph denote the growing season periods of May-September. The white dashed line delineates normal conservation pool elevation. The yellow line shows the shallowest elevation that plants were planted and the green line shows the deepest elevation that plants were planted. As can be seen, the water levels came up above normal pool elevation in season 2 and remained high throughout the summer of season 3. This inundation from high water put stress on the deeper plantings and overwhelmed many of the deeper emergent macrophytes.

By the second season, many of the sites were transformed; placing a few deep cages inside the pen, placing tops on deeper cages that had surviving plants to prevent herbivory and add an extra level of protection, and moving the majority of the deep cages that had experienced mortality to higher elevations. Eventually a “topper” was added to the “Deeper” pens (raising the top of the pen 1 ½ to 4 feet depending on the pen and elevation) to avoid overtopping by high water (Figure 14).

Figure 14: “Deeper” pen at Site 1, July 2010. More than half of the pen is under water. Later a "topper" was added to prevent the water from overtopping the “Deeper” pens.

By year three, “Shallow” pens had been constructed at four of the five sites to offer another area for founder colony development. The expectation was that the plants had a better chance of surviving the upper elevations and eventual drought conditions than lower elevations where they may be inundated for longer periods of time. Deep waters can lead to plants expending their energy on elongation rather than expansive growth. Therefore the majority of plantings were on higher ground with only submersed or floating leaved species planted at deep elevations. Figure 15 depicts what the typical site looked like by the end of 2010.

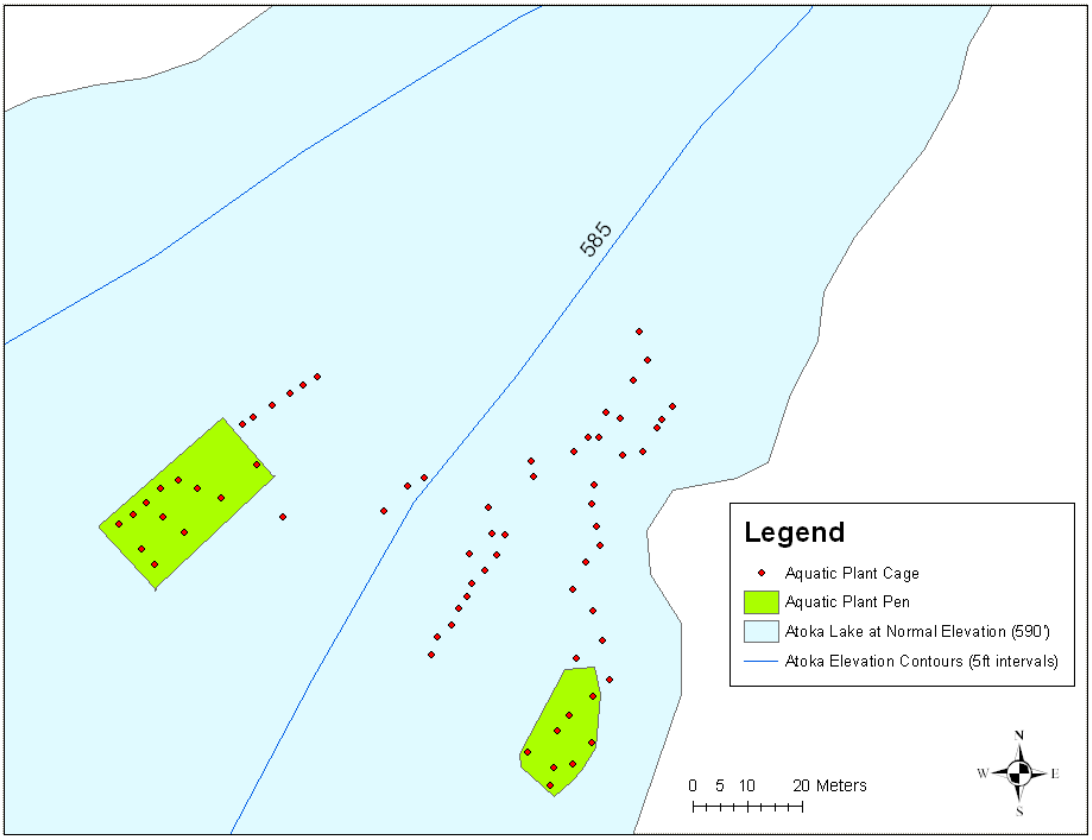

Figure 15: Typical 2010 site layout with fewer deep cages and the addition of a Shallow pen at a higher elevation.

Habitat Plantings with Trees

Trees were planted with assistance from Oklahoma City. Bare-root seedlings were purchased from the Albert Engstrom Forest Regeneration Center, operated by the Oklahoma Department of Agriculture, Food and Forestry, located in Goldsby, OK. Cages were placed around a select number of trees per site (depending on the size of the site) with 2x4 welded wire and flagged for visibility. These cages were placed around trees on the perimeter to delineate the site boundary and to make the areas more visible for the public. The caged seedlings were the only ones to be assessed, this was in part because finding the small seedlings once the tall grasses have grown around them was time consuming; even with flagging.

Tree plantings were designed, where possible, to compliment the aquatic plantings by providing wildlife habitat species, many of which could be classified as bottomland hardwoods such as *Carya illinoensis* (Native Pecan) and *Platanus occidentalis* (American Sycamore). These tree plots would provide exceptional browse, nesting and cover for multiple wildlife species. Figure 16 shows OWRB staff and City of Oklahoma City personnel planting trees in 2009.

Figure 16: OWRB and City of Oklahoma City personnel planting tree seedlings March 2009

In 2009, eight tree sites were selected, mainly in areas close to existing aquatic plant sites. City of Oklahoma City staff that work at Atoka Lake assisted in selecting suitable tree sites. One area in particular was selected because there had been a fire in the area a week before, and it was determined to be an ideal spot for new plantings. Each site had 5-10 trees caged around the perimeter, depending on the size of the site. An effort was made to place a cage around at least one of each species planted at that particular site. Nine different native species, totaling approximately 1,600 seedlings were planted over the eight sites in 2009.

In 2010, four more sites were selected that were nearby existing tree sites. These four sites each had ten trees caged per site, and again an attempt was made to get one of each species inside a cage. Approximately 1,600 additional trees were planted in 2010, for a total of roughly 3,200 total trees from nine different species over the two planting years.

Over the first year, it was discovered that all-terrain vehicles (ATV) had been driven through some of the areas where these trees were planted. The individuals responsible were identified and action has been taken by the City of Oklahoma City. All the tree plantings were located in areas where ATV use is prohibited. It was not determined exactly how many trees were damaged as a result of this incident. As of the fall tree assessment in 2010, none of the sites appear to have had any other issues.

Figure 17 shows two seedlings approximately 8 and 20 months after initial planting.

Figure 17: A *Quercus macrocarpa* (Bur Oak) sapling approximately 20 months after planting; and a *Platanus occidentalis* (American Sycamore) sapling approximately 8 months after planting, October 2010

Volunteer (Preexisting) Plant Colonies

Atoka Lake had existing plant colonies before the project began. In May of 2008, prior to the first season of planting, consultants from the Lewisville Aquatic Ecosystem Research Facility (LAERF) at the University of North Texas came - to Atoka Lake to assist in the development of an aquatic plant establishment strategy including site and planting recommendations for this project. In LAERF's report to the OWRB, they said the current "aquatic vegetation in the lake is restricted to a small number of native species that are moderately well established but offer only limited benefits to fish, aquatic wildlife, water quality, and erosion control." Existing species identified at Atoka Lake included emergent species such as Common Rush, Lovegrass, Spikerush, miscellaneous Sedges, Rosemallow, Buttonbush and Water Willow as well as at least one floating leaved plant, Pondweed (Figure 18).

Figure 18: Volunteer *Potamogeton spp.* (pondweed) and *Justicia americana* (water willow) Fall 2008

In the report from LAERF, the OWRB was given recommendations on site locations, species to supplement the aquatic plant community currently found in the lake, propagule selections, timing of planting, herbivore protection, planting depths and site maintenance. The full report from LAERF can be found in Appendix A – Lake Atoka Recommendation from the Lewisville Aquatic Ecosystem Research Facility at University of North Texas.

Over the course of the project, many of the preexisting plants were able to thrive when given protection from herbivory through the creation of pens and cages.

Additional Project Endeavors

Outreach

From Project Workplan:

> *State and Local participation will be instigated as OWRB and OKC work together to begin this wetlands program.*
>
> *OWRB will continue to actively promote the success of our wetland plantings and seek other agencies, municipalities and organizations willing to learn these methods to enhance their lakes with wetland plants.*

Presentation to Lake Atoka Reservation Association

In an effort to educate the public, especially those in the Atoka Lake area about the OWRB and OKC efforts to create a vegetated wetland in the littoral zone of Atoka Lake, then project manager Owen Mills made a presentation over first year project results to the Lake Atoka Reservation Association. The Association consists of an eight member board, comprised of the Mayors of Oklahoma City and The City of Atoka, the City Manager of Oklahoma City, the Chairman of the Oklahoma City Water Utilities Trust (OCWUT), one person appointed by the City of Oklahoma City for a two year period, and three citizens of Atoka County appointed by the City of Atoka. The Lake Atoka Reservation Association administers use of the Reservation, its resources and facilities.

The presentation was given in October 2008, and included information about the current vegetation in the lake, the new vegetation being added through the project as well as project goals and objectives, information on project sites and the timeframe and transfer of knowledge aspect of the project.

The intention of this presentation was to bring awareness, recruit involvement and create understanding of the project to the community and cooperators early on in the project. The presentation was well received by the managing board members. A photo taken during the presentation can be seen in Figure 19.

Figure 19: Owen Mills presenting first year results to the Lake Atoka Reservation Association (October 2008)

Project Results

There were three types of data that were tracked for the project: caged plantings, pen plantings and tree plantings. Caged plantings were by far the most numerous and will be heavily focused on, but important results were found from the other planting types as well.

Total aquatic macrophytes planted lake-wide = 1,311
Total aquatic species introduced = 22

Total trees planted lake-wide = approximately 3,200
Total tree species introduced = 9

The original project objective was to focus on emergent plant species to directly address the turbidity and color issues at Atoka Lake. As emergent plant species thrived in 2008 and 2009, emphasis was shifted toward floating leaved and submersed plant species to increase the diversity of the aquatic plant community and provide additional habitat for young of the year fish. This shift is particularly evident by 2010, as the majority of species that were planted (323 out of 592 total plants) were floating leaved or submersed species. Species planted throughout the project, by number and year, are listed in Table 2.

Table 2: Aquatic Plant Species planted throughout the project, by year planted.

Aquatic Plant Species Planted in Cages and Pens by Project Year					
2008		2009		2010	
Species	Number Planted	Species	Number Planted	Species	Number Planted
Bacopa monnieri	10	*Echinodorus berteroi*	14	*Sagittaria latifolia*	49
Echinodorus cordifolius	30	*Echinodorus cordifolius*	16	*Echinodorus cordifolius*	2
Eleocharis quadrangulata	5	*Heteranthera dubia*	35	*Heteranthera dubia*	121
Heteranthera dubia	14	*Hibiscus lasiocarpos*	30	*Nuphar lutea*	16
Hibiscus lasiocarpos	3	*Nuphar lutea*	7	*Nymphaea odorata*	72
Justicia americana	33	*Nymphaea odorata*	20	*Pontederia cordata*	57
Nuphar lutea	10	*Peltandra virginica*	10	*Potamogeton nodosus*	101
Nymphaea odorata	43	*Pontederia cordata*	15	*Sagittaria graminea*	87
Peltandra virginica	3	*Potamogeton nodosus*	20	*Saururus cernuus*	26
Pontederia cordata	23	*Sagittaria graminea*	40	*Schoenoplectus tabernaemontani*	47
Potamogeton nodosus	41	*Sagittaria latifolia*	14	*Thalia dealbata*	1
Sagittaria graminea	61	*Schoenoplectus tabernaemontani*	32	*Vallisneria americana*	13
Sagittaria latifolia	15	*Scirpus americanus*	10	***Total Species = 12***	**592**
Saururus cernuus	14	*Thalia dealbata*	27		
Schoenoplectus tabernaemontani	64	***Total Species = 14***	**290**		
Scirpus americanus	30				
Scirpus atrovirens	10				
Scirpus cyperinus	10				
Scirpus pallidus	10				
Total Species = 19	**429**				

Cage Planting Results

The Decision Thresholds set up in the QAPP largely deal with the *survival* of plants, but also take into account the *growth* or *coverage* within the protected area. Hence, both survival and growth are reported. It is noted on each table or topic what is being presented, Survival or Growth.

Survival of a cage is a simple binary rating: plant/no plant without accounting for size or vigor. *Growth* or *Coverage* refers to the percentage covered: a simplified percentage system to evaluate the loss or spread of plants within a ringed caged in relation to the initial plant condition. It is the coverage that accounts for the variation in size, vigor, and health of the plants inside and outside the protective cages and pens.

Cage Survival

The QAPP states *"a survival threshold of 50% or better within the protective cages indicates that the project has successfully established founder colonies at Lake Atoka"*.

By the final assessment in September 2010, a total of 350 cages were installed over the 5 sites at Atoka Lake. Survival at the final assessment was measured by visual observation of whether or not a plant was present in each cage.

Seventeen (17) out of the 22 species planted over the three year project had at least one surviving plant at the final assessment. A total of 866 plants were planted in cages over three planting seasons. On some occasions, more than one plant was planted in each cage, depending on plant availability. Five Hundred eighty four (584) plants were determined to be alive in cages at the final assessment conducted in September 2010. Cage survival by species is expressed in Table 3. Those species highlighted are plants that exceeded the 50% survival threshold set in place in the QAPP for the Decision Criteria. Thresholds are thoroughly explained in the Conclusions section below. The results in Table 3 are the cages in the water at the time of the final assessment. Keep in mind that the percentages and species listed in Table 3 take into account all species and total survival that occurred over the life of the project (all three seasons). There are many species that were attempted that did not perform as expected and were omitted from subsequent plantings in later years. Additionally, those cages that were found vacant at the final assessment were replanted at that time and therefore not considered a mortality. Plants that were in cages within a pen are included in Table 3, but plants that were free planted within a pen are not included. It is important to note that there are several species that have a very high percent survival ranking, but numbered very few cages. A small number of data points make results unclear, but these plants should be strongly considered for the next phase of the project.

Table 3: Cage Planting Survival from Final Assessment

(Species highlighted are plants that exceeded the 50% survival threshold from QAPP)

Caged Survival by Species - Final Assessment Fall 2010			
Species	**Number of cages planted**	**Number Survived**	**Total Survival**
Bacopa monnieri	10	0	0%
Echinodorus berteroi	14	2	14%
Echinodorus cordifolius	48	6	13%
Eleocharis quadrangulata	5	3	60%
Heteranthera dubia	55	60	100%
Hibiscus lasiocarpos	16	7	44%
Justicia americana	33	33	100%
Nuphar lutea	14	8	57%
Nymphaea odorata	88	52	59%
Peltandra virginica	3	3	100%
Pontederia cordata	60	60	100%
Potamogeton nodosus	98	33	34%
Sagittaria graminea	122	106	87%
Sagittaria latifolia	48	33	69%
Saururus cernuus	18	6	33%
Schoenoplectus tabernaemontani	111	95	86%
Scirpus americanus	27	1	4%
Scirpus atrovirens	10	0	0%
Scirpus cyperinus	10	10	100%
Scirpus pallidus	10	0	0%
Thalia dealbata	56	56	100%
Vallisneria americana	10	10	100%
Overall	866	584	67%

It is worthwhile to consider the data only looking at species that had a more practical "n" or sample set. Taking only those species that had 30 or more cages gives the following results in Table 4. Those species highlighted are plants that did not exceeded the 50% survival threshold set in place in the QAPP for the Decision Criteria.

Table 4: Cage Data of Species where n=30 or more

Caged Survival by Species - Species with n? 30 cages Survival by Species - Final Assessment Fall 2010			
Species	**Number of cages planted**	**Number Survived**	**Total Survival**
Echinodorus cordifolius	48	6	13%
Heteranthera dubia	55	60	100%
Justicia americana	33	33	100%
Nymphaea odorata	88	52	59%
Pontederia cordata	60	60	100%
Potamogeton nodosus	98	33	34%
Sagittaria graminea	122	106	87%
Sagittaria latifolia	48	33	69%
Schoenoplectus tabernaemontani	111	95	86%
Thalia dealbata	56	56	100%
Overall	719	534	74%

*** Highlighted species indicate survival percentage below the 50% decision threshold outlined in the QAPP.**

When looking at the more tested species (n≥30) the data gives a higher survival percentage than the overall picture at 74%, which is well over the survival threshold.

The overall survival of 584 plants out of 866 planted (67%) was significantly over the 50% survival threshold.

Cage Coverage

Percentage of cage coverage measurements were taken via visual estimate. Since this method could be highly subjective in its results, a method was developed to simplify the task and build consistency and understanding between sessions as well as between those making the assessments.

A guideline for assessing percent coverage of cages was outlined in the QAPP, and can be seen in Table 5.

Table 5: Percent Coverage Breakdown for Caged Plants

Initial Planting	
25%	Given to initial planted cage with 6” pot
15%	Given to initial transplant cage*
After Establishment	
0%	Dead or apparently dead plant(s)
10%	Loss of initial plant biomass and vigor, unhealthy
25%	No appreciable spread
50%	New shoots spread across ½ cage area
75%	New shoots spread across ¾ cage area.
100%	New shoots spread across entire cage area.
*	Note: Transplants are by definition less developed than the typical 6” potted plants with mature root systems and thus given a lesser coverage %.

Figure 20 shows a cage of *Pontederia cordata* that has completely filled its cage and has new shoots beginning to spread outside of the cage (100% cover) and Figure 21 shows a cage of *Schoenoplectus tabernaemontani* that has doubled in size since initial planting and was given a rating of 50% cover.

Figure 20: *Pontederia cordata* outgrowing its cage; 100% (site 3 September 2010)

Figure 21: *Schoenoplectus tabernaemontani* with average growth (September 2010). (50% Coverage)

Lake-wide overview statistics for caged planting growth and coverage can be seen in Table 6 below:

Table 6: Lake-wide Averages of Plant *Coverage*, both inside and out of the Protective Cages

	Coverage Inside of Cage	Coverage Outside of Cage
Lake-wide Average of Caged Plants	64%	17%

With initial plantings receiving a 25% coverage rating, a lake-wide average coverage of 64% shows that substantial growth occurred over three growing seasons. Outside coverage percentage was calculated by taking the average outside cage coverage of all 350 cages (many of which were 0; only 95 cages had any outside coverage at all). The result was an average of 17% coverage outside the protective cages. See further discussion of outside cage coverage later in this section.

Figure 22: *Nymphaea odorata* completely filling its cage at site 2; 100% coverage (September 2010)

In order to emphasize those cages that performed well, any cage that was rated at 50% coverage or better was considered to have *good growth.* While any cage that had 75% coverage or greater was considered to have *exceptional growth*. Table 7 shows the number of cages exhibiting *good* or *exceptional* growth at the final assessment.

Table 7: Lake-wide Totals for Growth and Spread - Inside cages

Total # of cages:	**350**
***Good growth*:** **(50% or better)**	**233 cages (67%)**
Exceptional *growth*: **(75% or better)**	**192 cages (55%)**

Of the total 350 cages, 233 cages (67% of the total) had good growth of 50% coverage or better and 192 cages (55% of the total) had exceptional growth with 75% coverage or better at the final assessment. Figure 23 is an example of a cage in which the plant has

survived and was determined to have 75% average coverage (*exceptional growth*) at the final assessment

Figure 23: A cage of *Pontederia cordata* with *exceptional growth* (75% coverage) at final assessment - fall 2010

There was also growth observed outside the ringed cages. Coverage outside the cages was measured by comparing the outside growth to the cage diameter. For example, 50% outside coverage would mean that the area of growth outside the cage was equivalent to 50% of the area inside the cage.

A total of 95 cages had plants growing outside of the original planted cage, 55 cages with good growth outside the cage and 34 cages that had exceptional growth outside of the cage as displayed in Table 8 below shows lake-wide totals for growth observed outside the cages.

Table 8: Lake-wide Totals for Growth Observed Outside of cages

Total number of cages with any outside growth:	**95 cages (out of 350 total cages, 27%)**
Total number of cages with Outside growth ranked "Good": (50% ranking or better)	**55 cages (out of 350 total cages, 16%)**
Total number of cages with Outside growth ranked "Exceptional": (75% ranking or better)	**34 cages (out of 350 total cages, 10%)**

Figure 24 shows a *Thalia dealbata* plant with the cage tipped over, but the plant continuing to grow well with new shoots, growing completely unprotected.

Figure 24: *Thalia dealbata* causing its cage to tip over. (September 2010)

Sagittaria graminea consistently showed growth inside and outside of its cage (Figure 25).

Figure 25: *Sagittaria graminea* with exceptional growth (≥75% coverage) both inside and outside of the cage (September 2010).

Coverage was also considered by species. Because the various species selected for the project grow at different rates and by different means (runners, rhizomes, tubers, etc.) variation in percent coverage by the final assessment was expected.

Lake-wide average coverage by species can be seen in Figure 26.

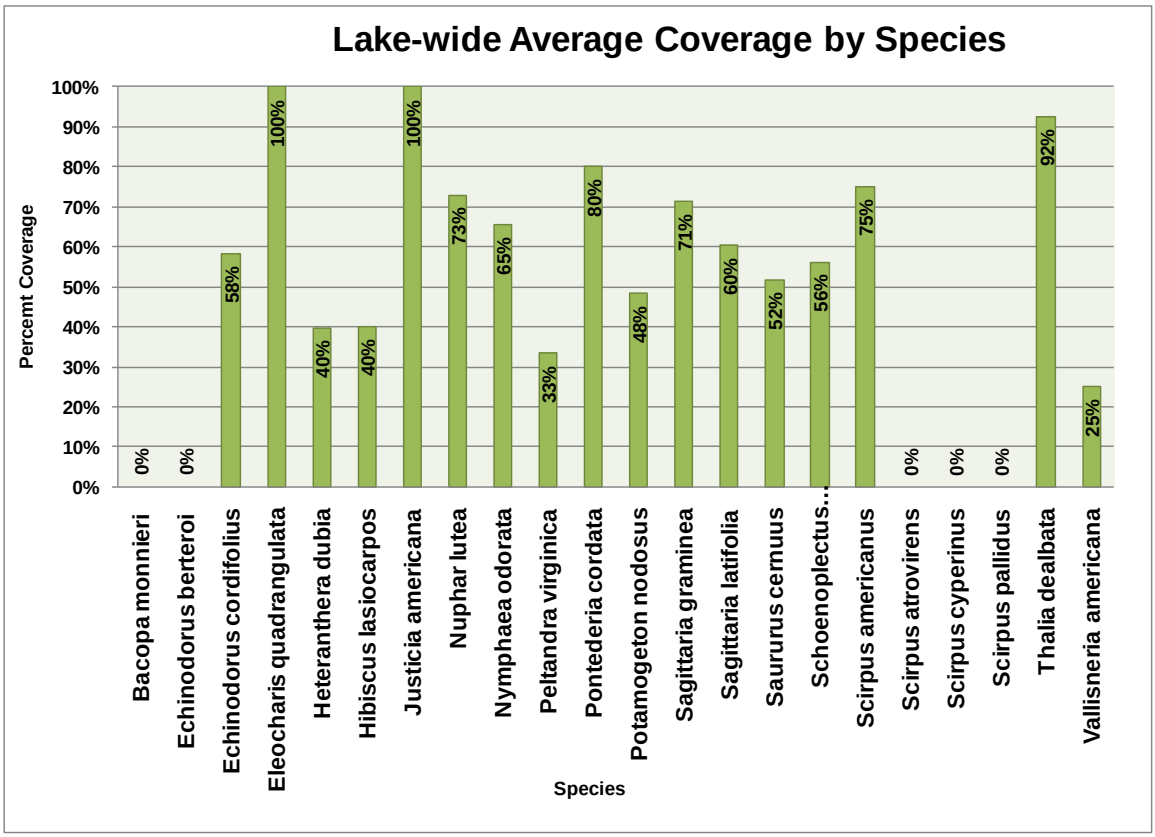

Figure 26: Lake-wide Average Coverage in Cages by Species

The maximum average coverage inside the cage for a species across the lake was 100% and was exhibited by two species: *Eleocharis quadrangulata* (Squarestem Spikerush), and *Justicia americana* (American Water-willow).

Several species, while not attaining 100% average coverage, did exhibit exceptional growth. These include: *Thalia dealbata* (Alligator Flag) at 92% (Figure 27), *Pontederia cordata* (Pickerelweed) at 80%, and *Scirpus americanus* (Three Square Bulrush) at 75%.

Figure 27: A full cage of *Thalia delbata* at site 3 during final assessment 2010.

One species, *Justicia americana*, was observed at the lake during the initial site selection, and was planted in cages during the 2008 season. By the final assessment, *Justicia americana* was so dominant throughout the sites that it was no longer necessary (or practical) to continue to assess all of it. Because it was native, it was popping up inside cages that were planted with other species, inside the pens, and along the shorelines. In fact, it can be seen in almost all the pictures included in this report, including in the background of Figure 20, Figure 21, and Figure 22. For the purpose of this report, we assigned a 100% coverage value to all 33 cages planted with *Justicia americana* in 2008. Those 33 cages were also planted with other species in subsequent years to try to increase diversity, when it was evident that the *Justicia americana* no longer needed protection.

As mentioned before, the coverage values also need to be considered by the number of plants in the subset. For example, *Eleocharis quadrangulata* had an average of 100% coverage, but there were only two cages that contained *Eleocharis quadrangulata* at the final assessment. Another species, *Scirpus americanus* had only one surviving cage at the final assessment, with coverage of 75%. So for both of these species, the few cages that did survive did well. With *Eleocharis quadrangulata* in particular, our plant nursery supplier was unable to provide this species in 2009 and 2010, so the plants that did survive were planted in 2008, and we expect that with replanting, this species would have performed well. However, both species may still need further evaluation to see if they can be successful at Atoka Lake.

Some species did not survive at all, namely *Bacopa monnieri* (Bacopa), *Echinodorus berteroi* (Tall Burhead), *Scirpus atrovirens* (Green Bulrush), *Scirpus cyperinus* (Woolgrass), and *Scirpus pallidus* (Cloaked Bulrush). At the end of each growing season, an assessment was conducted, and species that did not perform well that year were taken off of the purchase list for the next season. So the four species mentioned above were planted in 2008, and after poor performance over the 2008 growing season, were not replanted over the next two years. Similar scenarios occurred over the 2009 season as well.

Coverage also varied by the elevation of the cage. Because water level varied greatly between the 2008 season when cages were first installed, and the 2009 and 2010 seasons when the pipeline was being repaired, cages placed at higher elevations tended to do better than those at lower elevations. Cages at elevations below 586.0' (mean sea level) msl, primarily at site 5 (and one cage at site 2), where deep water submersed plantings are held. A vast majority of the project cages are between 586.0' and 589.0'msl. Since the plantings are designated at 25% initially, elevations that showed average coverage greater than 25% had positive growth. All of the elevations planted had over 25% average coverage, which indicates that elevations selected for this project are appropriate elevations for aquatic plants in Atoka Lake. Figure 28 shows average cage coverage taking into account the cage elevation.

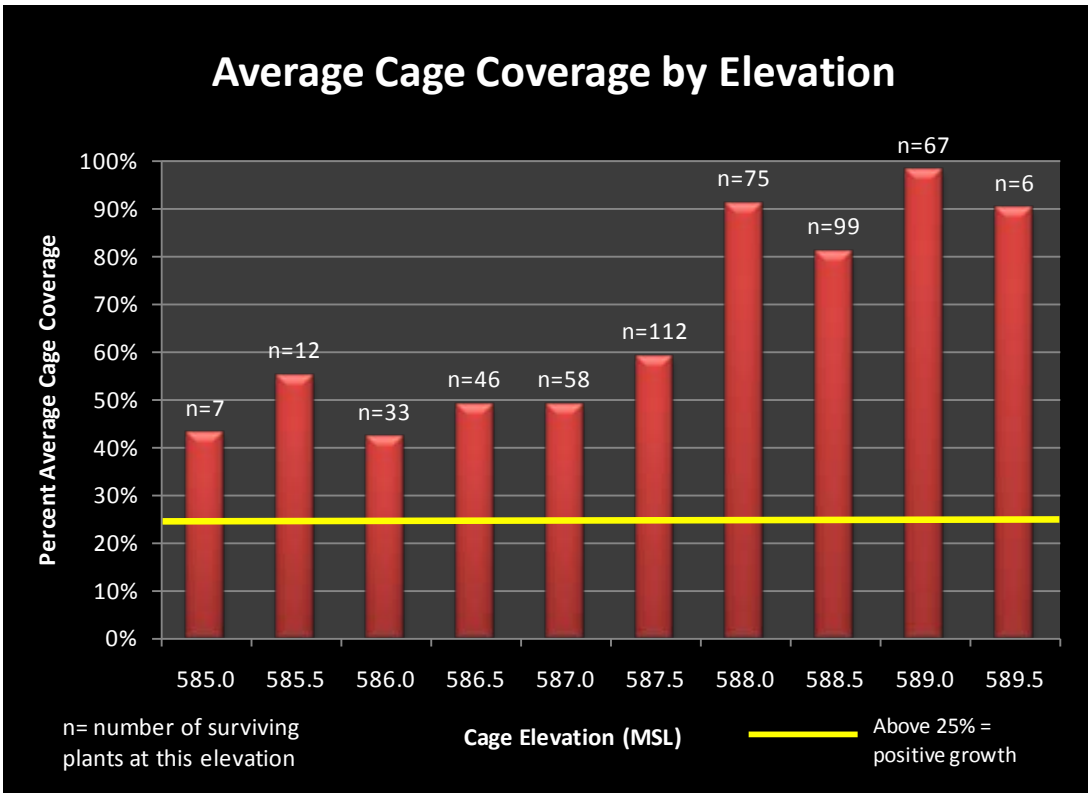

Figure 28: Average Cage Coverage by Elevation

Overall, shallow water cages seemed to do very well with 98% and 90% coverage for the shallowest cages at the final assessment. Deeper water cages had satisfactory growth, but the data suggests that the high water levels that started in May 2009 and continued through the 2010 growing season had a negative effect on plants at lower elevations. This is based on the fall 2008 assessment that showed the highest percent coverage in cages planted at lower elevations. When lake elevations return to normal over the next several years and the water level fluctuates more regularly (more than it did over the last two growing seasons), we may see a shift in which elevations have the best growth.

Pen Planting Results

As with caged plantings and plots, measurements were taken via visual estimate of a percentage of pen coverage (pC) maintaining the 0%, 10%, 25%, 50%, 75%, and 100% increments. Since this method would be highly subjective in its results, it was simplified to build consistency and understanding between sessions as well as between those making the assessments. Pens, being much larger than cages, will not likely fill to capacity and may still be healthy and spreading. Hence, giving purely a percent coverage would not accurately reflect the quality of a pen's plant community. For that reason, another metric was developed for pens called a Community Rating (CR) that better captured the quality of the pen's health and diversity. Between these two rating systems, a good measure of founder colony establishment is possible.

%Cover (pC) = visual estimation of total area coverage of all plants in the pen.

- Initial condition at time of planting = 25%

Community Rating (CR) = 0 - 4

0 = no aquatic macrophytes
1 = 1 species prominent – monoculture or aquatic macrophytes
2 = 2 species prominent
3 = 3 species prominent
4 = 4 or more species prominent

Prominent = at a minimum, a grouping of healthy macrophytes, i.e. an individual plant in the pen should not be considered prominent.

- Initial condition at time of planting = 4

The results were highly varied, due in large part to breaches or overtopping of pens. Pen placement was intended to cover roughly two or three feet of elevation change from the normal pool elevation. While this made it possible for the pen to house both emergent and submerged plants, it also created the possibility that high waters could overtop the 4 ½ foot tall fence on the deep end and expose the community to herbivory. With high water that began at the start of the 2009 growing season and continued though the end of the 2010 growing season, all of the "Deeper" pens were overtopped at some point, and

some were overtopped for extended periods of time. “Toppers” were added to the pens in 2009 and 2010 to increase the height, with the hopes of preventing further overtopping.

When the “Deeper” pens were originally installed, both emergent and submersed species could be planted in the same pen, due to the slight elevation change within the pen boundaries. But when water levels rose, and stayed up, the water was too high for many of the emergent species to survive in the “Deeper” pens. In 2010, four (4) new pens were constructed at higher elevations (“Shallow” pens) and were planted entirely with emergent species. In 2010, only floating leaved and submersed species were planted in the old, now called “Deeper”, pens, but a few emergent species did survive in the “Deeper” pens and helped to enhance the community rating of those pens. Table 9 lists the percent cover and community rating of each pen at the final assessment in the fall of 2010.

Table 9: Final Pen Assessment Results - fall 2010

Pen/Site #	Percent Cover	Community Rating	Elevation
1 Deeper	67%	4	585.5' -587.5'
1 Shallow	64%	4	587.5' - 589.0'
2 Deeper	25%	4	586.0' -587.5'
2 Shallow	75%	4	588.5' - 589.0'
3 Deeper	69%	4	586.5' - 587.5'
4 Deeper	25%	4	585.0' - 586.5'
4 Shallow	85%	4	588.0' - 588.5'
5 Deeper	63%	4	585.0 - 587.5'
5 Shallow	88%	4	588.5' - 591.0'
Total Average Coverage in Pens = 62%			

Pens had an overall community rating average of 4, while the average percent cover came to 62%. Percent cover varied by site, but the “Shallow”, emergent pens tended to have better coverage than the “Deeper” pens. This was most likely due to the breaches and overtopping that the “Deeper” pens sustained in 2009 and 2010.

Like the cages, the *survival* of plants within each pen was taken into account as well. Again, su*rvival* of a cage is a simple binary rating: plant/no plant without accounting for size or vigor.

The percent survival of plants within the pens was 84%. (Table 10)

Table 10: Lake-wide Average Total for Survival within Pens

	Total number of plants planted in pens	Total number surviving at final assessment	% Survival
Lake-wide Average of Pen Plants	392	328	84%

Figure 29: "Shallow" Pen at site 5 - *Pontederia cordata, Schoenoplectus tabernaemontani, Justicia americana,* and *Eleocharis quadrangulata*. At final assessment – fall 2010.

The most successful pen was the "Shallow" pen at site 5 (Figure 29) with a percent cover of 88%. At least seven (7) different species were prominent in this pen, giving it a community rating of 4. Species include: *Pontederia cordata, Schoenoplectus tabernaemontani, Eleocharis quadrangulata, Sagittaria graminea, Nuphar lutea, Saururus cernuus* and *Justicia americana*. The emergent species planted in this pen not only filled their cages, but also spread, with many new propagules (Figure 30) seen popping up throughout the pen.

Figure 30: New propagules of *Pontederia cordata, Schoenoplectus tabernaemontani, Sagittaria graminea,* and *Nuphar lutea* along with *Justicia americana* are seen in this close-up shot from "Shallow" pen 5 at the final assessment – September 2010.

Another pen that fared well was the "Shallow" pen at site 4 with percent cover of 85%. This pen had a community rating of 4, and included *Pontederia cordata, Schoenoplectus tabernaemontani, Sagittaria graminea, Sagittaria latifolia, Justicia Americana,* and *Thalia dealbata*. This pen was on a substrate of Deep Mud Organic and the higher elevation of this pen enabled so many emergent species to have successful growth within its protective boundary. Figure 31 and Figure 32 are photos taken at the final assessment of the "Shallow" pen at site 4.

Figure 31: "Shallow pen" at Site 4. *Pontederia cordata, Schoenoplectus tabernaemontani,* and *Justicia americana* with new propagules of *Sagittaria graminea* at the final assessment – September 2010.

Figure 32: Another view of the "Shallow" pen at site 4 – final assessment 2010

While the “Shallow” pens tended to have better percent cover than the submersed (Deeper) pens, the submersed pens still fared well despite a period of 15 straight months of high water. During the high water levels, the pens were often overtopped, allowing herbivory pressure as well as decreased light penetration in such deep water. The three “Deeper” pens that had the best results were pen 3 (69% cover), “Deeper” pen 1 (67% cover) and “Deeper” pen 5 (63% cover) each with a community rating of 4. Figure 33, Figure 34 and Figure 35 show “Deeper” pens at the final assessment.

Figure 33: “Deeper” Pen at site 3 at final assessment – September 2010.

Figure 34: Site 5 "Deeper" pen with *Sagittaria graminea* and blooming *Nymphaea odorata* at the final assessment – September 2010.

Figure 35: Another view of the "Deeper" pen at site 5 – September 2010.

Overall, between the inside and outside cage growth, as well as the pen plantings, a total of 5.18 acres were planted along the shorelines of the 5 sites at Atoka Lake. Table 11 shows the breakdown by site for cage and pen acres planted.

Table 11: Acres Planted at Atoka Lake

Acres Planted at Atoka Lake over all sites		
Site Number	**Portion**	**Acres Planted**
1	Cages (plot)	0.90
1	"Deeper" Pen	0.11
1	"Shallow" Pen	0.03
1	**Total**	**1.04**
2	Cages (plot)	0.77
2	"Deeper" Pen	0.12
2	"Shallow" Pen	0.04
2	**Total**	**0.93**
3	Cages (plot)	0.90
3	"Deeper" Pen	0.11
3	**Total**	**1.01**
4	Cages (plot)	1.02
4	"Deeper" Pen	0.11
4	"Shallow" Pen	0.05
4	**Total**	**1.18**
5	Cages (plot)	0.86
5	"Deeper" Pen	0.12
5	"Shallow" Pen	0.04
5	**Total**	**1.02**
Total		**5.18**

While 5.18 acres planted is relatively small when compared to the 70 miles of shoreline that surrounds Atoka Lake, spread of plants to areas outside of the site boundaries has already started to occur. New propagules of *Sagittaria graminea* were found at the boat ramp near aquatic plant site 2. Figure 36 shows the new plants on the north side (pictured on the right) of the boat ramp at site 2. Figure 37 shows another angle of the *Sagittaria graminea*, in this photo flowers are evident on the plant indicating that this plant is mature enough to spread seeds to this area of the lake. The way in which these plants spread to this area of the lake is unknown. It could be by seeds from site 2, or perhaps from fragments that broke off when loading and unloading the boat at this site. Regardless of how it happened, the plants look strong and at least one was already flowering, making the potential for a new founder colony in this location a likely possibility. Figure 38 is a map showing the distance between site 2 and the boat ramp. The closest cage at site 2 is 547 feet away from where the new plants were found.

Figure 36: New propagules of *Sagittaria graminea* at the boat ramp adjacent to site 2. Large stand of *Justicia americana* also visible – July 2010

Figure 37: Another view of new propagules of *Sagittaria graminea* at the boat ramp adjacent to site 2 – July 2010

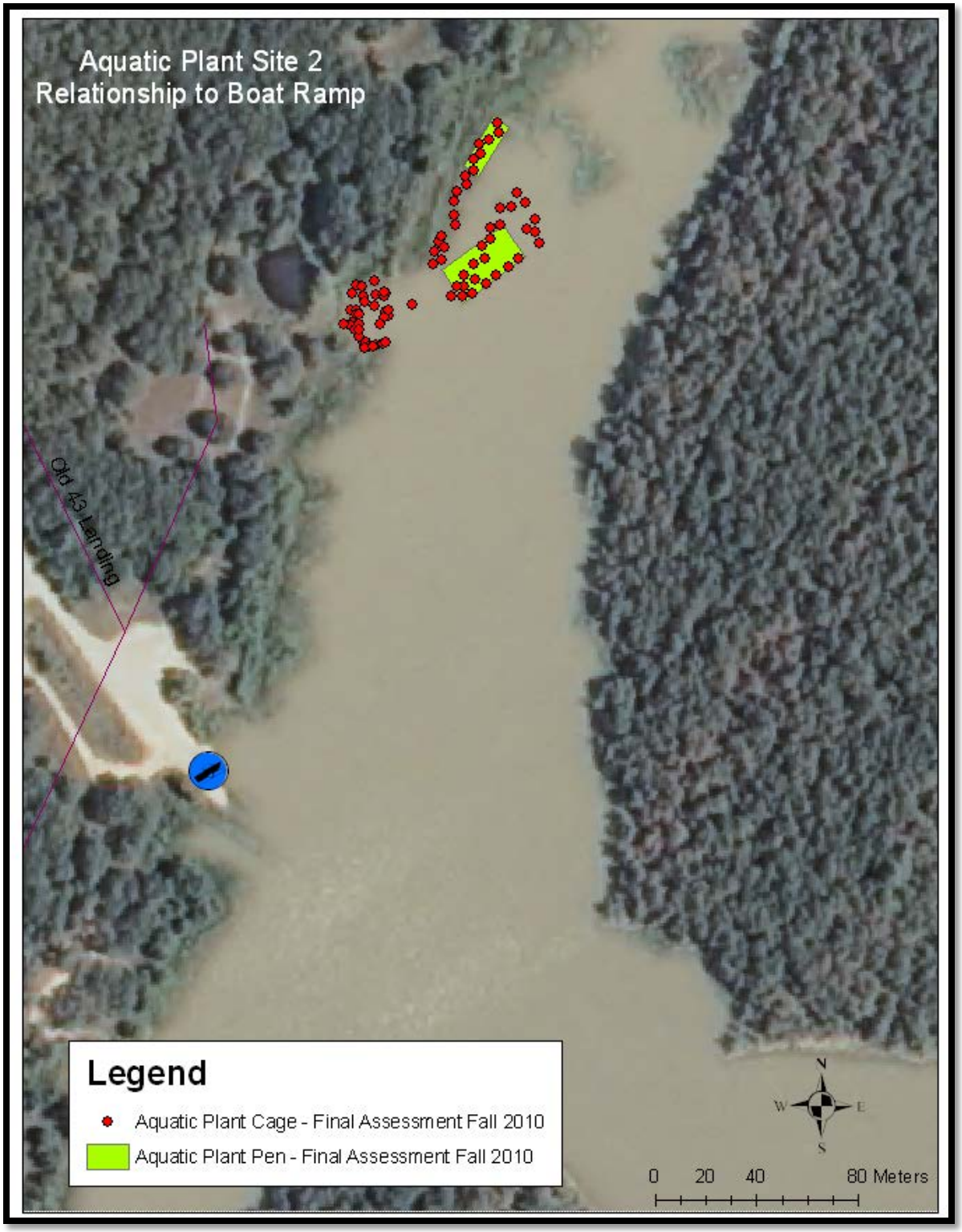

Figure 38: Relationship of Aquatic Plant site 2 to boat ramp (blue icon) where unprotected propagules were found reproducing.

Tree Planting Results

Because of the surrounding topography, particularly slope, there are very few places that would be suitable for new tree sites to be installed around Atoka Lake. Many locations around the lake were evaluated for suitability including the apparent soil conditions (texture, drainage, rocky areas, etc.), competition from other species, size of open areas, and slope. Very few suitable sites could be identified, and in the end, the 12 selected sites were the best available, even if they did not all have 100% of the desired characteristics.

Trees were initially planted in March 2009 with 57 caged trees logged by GPS for project assessment. In 2010, more trees were planted, 40 of which were caged, bringing the total number of caged trees to 97. The species planted can be found in Table 12.

In 2009, the area known as Fred's Fish Camp had some ATV activity that caused damaged to tree sites 1 and 2. The City of Oklahoma City identified the individuals responsible for the damage, and does not expect any further damage to the tree sites. One cage was removed due to the proximity of the cage to a fork in the road. The cage had been knocked over and, due to the damage inflicted when this occurred, it was not replaced. The tree planted in this removed cage could not be located and it was assumed that this tree did not survive.

Bare-root seedlings were planted

- 2009: Planted approximately1,600 trees on 8 sites located near aquatic plant sites
- 2010: Planted an additional 4 sites (also located near aquatic plant sites) with approximately 1,600 trees
- Species chosen were classified as "Wildlife" species
- Each site had a perimeter of trees that were flagged, caged, identified by species and marked with GPS points. The number of cages per site varied (minimum 4 to maximum 10) based on the size of the site and the number of trees planted at each site.
- Additionally, every fifth tree that each person planted was flagged and the species was written on the flagging material.

Table 12: 2009-2010 Tree Species Planted at Atoka Lake

Number of Trees planted by Species			
		Year Planted	
Scientific Name	Common Name	2009	2010
Carya illinoinensis	Native Pecan	200	200
Morus rubra	Red Mulberry	200	200
Quercus macrocarpa	Bur Oak	150	150
Celtis occidentalis L.	Common Hackberry	200	200
Plantanus occidentalis	American Sycamore	200	200
Fraxinus pennsylvanica	Green Ash	200	200
Cercis canadensis -upland only	Eastern Redbud	200	200
Cornus drummondii - upland only	Roughleaf Dogwood	150	150
Diospyros virginiana- upland only	American Persimmon	100	100
	Total by year	1,600	1,600
	Grand Total	3,200	

The final tree assessment was conducted in October 2010. Chris Joslin, a District 3 Area Forester from the Oklahoma Department of Agriculture, Food and Forestry, accompanied OWRB staff on the trip.

Table 13 shows the results of the final tree assessment conducted in November 2010.

Table 13: Final Assessment Results for Atoka Trees

Atoka Tree Assessment	Planted 2009		Planted 2010		All Trees	
	# Cages	%	# Cages	%	# Cages	%
Total Number Cages	57		39		96	
Survived	31	54 %	26	67%	57	59%

Overall survival was 59% over the two years. The Oklahoma Department of Agriculture, Food and Forestry stated that typical seedling survival rates range from 30%-99% depending on care in transporting and planting, species selected, soil conditions, competition from other species, herbivory, weather conditions, and other factors. Our tree seedlings were planted in areas with no site preparation prior to planting (other than the fire that had occurred naturally at sites 1 and 2 the week before planting), and no follow-up care. Several of the above mentioned factors could have had an effect on seedling survival. In particular, soil conditions, competition, herbivory, and weather most likely had the greatest impact on the trees planted at Atoka Lake.

Certain tree sites seemed to fare better than others. This could have been due to site soil type, other herbaceous cover at particular sites or additional factors. Site 9 had the highest survival rate with 75% and Site 3 had the next best with 71% of the caged trees surviving into 2010. Not only did this these sites have the highest percentage survival, but they were both planted in 2009; so all of the trees that survived at these sites had been in the ground for 20 months at the time of assessment. Sites 7, 10 and 11 (all planted in 2010) also had good survival rates (70%). Table 14 shows the survival rates by site.

Table 14: Tree Survival by Site

Survival of Caged Trees by Site Number												
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
Percent Survived	43%	60%	71%	60%	44%	50%	70%	40%	75%	70%	70%	56%
Number Survived	3	3	5	6	4	5	7	2	3	7	7	5
Total Number Caged	7	5	7	10	9	10	10	5	4	10	10	9

Table 15 shows survival number by species. Green Ash was the best performer, with 100% survival as of the 2010 fall assessment. Bur Oak also did well with 83% survival, as well as Dogwood with 78% survival. The species that struggled were Sycamores with only 31% survival and Redbud with 33% survival.

Table 15: Tree Survival by Species

Tree Species	Total Number Cages		Survived
Pecan	7	# of Cages	4
		%	57%
Hackberry	14	# of Cages	8
		%	57%
Redbud	9	# of Cages	3
		%	33%
Dogwood	9	# of Cages	7
		%	78%
Persimmon	8	# of Cages	4
		%	50%
Green Ash	12	# of Cages	12
		%	100%
Red Mulberry	9	# of Cages	4
		%	44%
Sycamore	16	# of Cages	5
		%	31%
Bur Oak	12	# of Cages	10
		%	83%

When evaluating how particular species did by site (Table 16), several things stand out. Site 3 seemed to have great results; 100% survival of all species with exception of the Sycamores, which did poorly at 5 out of 8 sites where they were planted. Green Ash, as mentioned above, had 100% survival at all sites; and Dogwoods also did well with the exception of site 10. Bur Oak did great at all sites, except site 4. Pecan also seemed to be affected by site location; sites 4, 7, 10 and 11 had 100% survival, while sites 5 and 6 had 0% survival.

Table 16: Species Survival by Site

Percent Caged Species Survived by Site												
Species	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**	**Site 8**	**Site 9**	**Site 10**	**Site 11**	**Site 12**
Bur Oak	100%	100%	100%	0%	100%					100%	67%	
Dogwood	50%	100%	100%	100%	100%					0%	100%	
Green Ash						100%	100%	100%	100%		100%	100%
Hackberry		0%	100%	100%	0%	50%	67%	100%				50%
Pecan				100%	0%	0%	100%			100%	100%	
Persimmon	0%			50%	50%					67%		
Red Mulberry						50%		0%	50%	67%		
Redbud	0%		100%		0%	50%	50%	0%				
Sycamore		0%	0%	33%	50%		67%			100%	0%	0%
***Greens indicate survival, with darker green representing 100% survival**												
										no caged Species		

Mr. Joslin, the area forester who accompanied us on the assessment, thought that several species seemed to be doing well and that site conditions played a role in the success of the seedlings. Mr. Joslin pointed out two factors that may have hindered the survival of trees at some sites. The first was soil type for each particular species and the second was existing herbaceous cover (grasses and weeds) at each site. Mr. Joslin said that area soils were not suitable for some of the species selected. He also said that a large amount of herbaceous cover can hinder tree establishment and survival, by robbing soil nutrients, water and sunlight from the seedlings. Mr. Joslin suggested that any replanting or future plantings focus on the species with good survival rates over the course of this project and be located at sites where herbaceous plants can be controlled while the new seedlings get established. The letter from Mr. Joslin is included in Appendix E - Letter from Oklahoma Forestry Services regarding Tree Assessment. Figure 39 shows the soil types surrounding Atoka Lake as classified in the Natural Resources Conservation Service's Soil Survey Geographic (SSURGO) Database.

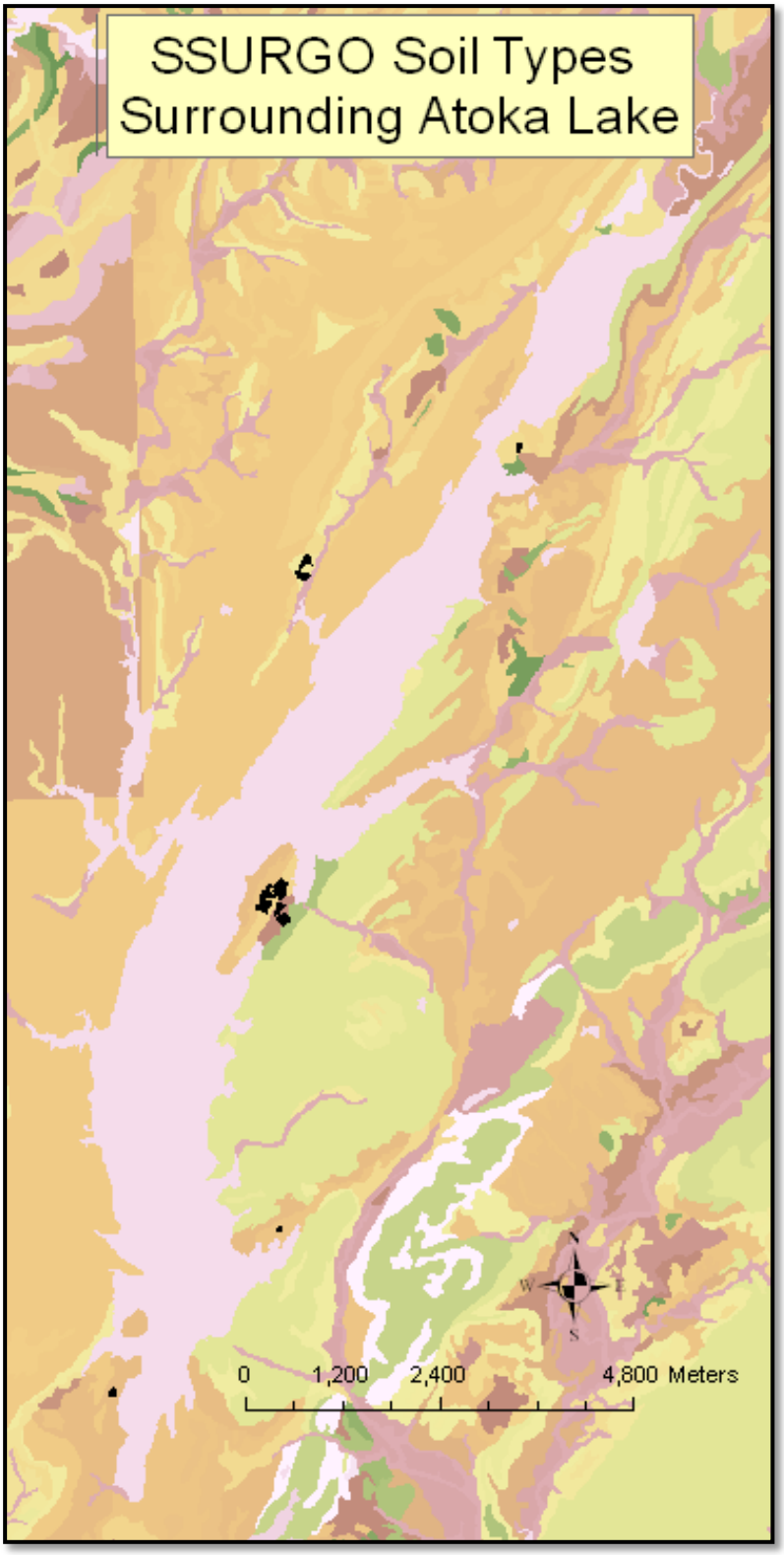

Figure 39: Atoka Lake map with Tree sites and surrounding SSURGO soil types

Table 17 shows how many of each species survived compared to the number planted when soil type is taken into consideration.

Table 17: Species Survival by Soil Type

Atoka Tree Species Survival by Soil Type								
		SSURGO Soil Type						
		Clearview fine sandy loam	Counts loam	Dennis loam	Dennis and Eram soils	Eram clay loam	Eram-Talihina complex	Parsons silt loam
Species	Pecan	1/2	0/1	1/1	0/1	1/1	1/1	n/a
	Hackberry	1/1	1/2	3/5	1/3	1/1	1/1	0/1
	Redbud	1/1	0/1	0/1	1/3	1/1	n/a	0/2
	Dogwood	n/a	n/a	1/2	1/1	1/1	2/2	2/3
	Persimmon	n/a	n/a	2/3	1/2	n/a	1/2	0/1
	Green Ash	3/3	n/a	8/8	n/a	1/1	n/a	n/a
	Red Mulberry	1/2	n/a	3/6	n/a	0/1	n/a	n/a
	Sycamore	2/2	0/1	1/4	1/2	0/4	1/3	n/a
	Bur Oak	n/a	n/a	1/2	1/1	4/4	0/1	4/4
fraction = number survived / total number planted (n/a - none planted in this soil type)								
Green = 100% survival, Brown = 0% survival								

Trees planted in Clearview fine sandy loam seemed to do best, while those planted in Counts loam did not have good survival. Other soil types had mixed results depending on the species. The sample size of each species at any particular soil type was relatively small, so results could be skewed based on this factor.

Because of the limited number of suitable tree site locations around Atoka Lake, the soil types associated with those locations, and the level of care that we were able to provide to the seedlings after planting (none), 59% overall survival was “real good” according to Albert Engstrom Forest Regeneration Center Nursery Manager Scott Huff.

While no designed objective assessment was done on the uncaged trees, areas where vegetation was less dense made it possible to distinguish surviving tree seedlings growing throughout the plots. These unmeasured observations gave the impression that most plots will survive at percentages relative to those observed in the cages. Given the 59% overall cage survival, if we expect similar numbers of the uncaged trees survived, then approximately 1,900 uncaged trees have survived initial planting at Atoka Lake from the 3,200 total trees planted.

Volunteer (Preexisting) Plant Colonies

Two preexisting species in particular are worth noting at Atoka Lake. The first, *Justicia americana* (American Water-willow) is a native species found in Atoka Lake, and it was identified at several locations throughout the lake by LAERF and Owen Mills during the site selection trip. *Justicia americana* was planted in year one of the project, but it was not planted in subsequent plantings, simply because there was no need to plant it. Over the course of the project, *Justicia americana* experienced tremendous growth at all project sites, and it was coming in on its own from the pre-existing seed bank, see Figure 40. At the final assessment not only was *Justicia americana* growing in the cages where it was planted, it was also a predominant species at all of the sites and was growing inside other cages, inside the pens and outside the protected areas. It's possible the three years of protection from predators allowed it to produce the numbers of propagules necessary to overcome the herbivory pressure. Another speculation is that the water levels over the project timeframe provided the perfect conditions for the proliferation of *Justicia americana*. Whatever the circumstances, we feel confident that *Justicia americana* has been successfully established at Atoka Lake. Figure 41 illustrates the spread of *Justicia americana* at site 1 over the course of the project.

Figure 40: "Shallow" pen at site 1 containing a large stand of Justicia americana – September 2010

Figure 41: Spread of *Justicia americana* at site 1; upper photo taken fall 2008, middle taken fall 2009, and lower taken fall 2010

The second preexisting species worth noting is *Ludwigia L. spp*. While this species was not a species that was planted as part of this project, it is also a species that was observed in the lake during the site selection trip. We kept an eye on this species over the three year project and much like *Justicia americana*, *Ludwigia L. spp.* has spread throughout several project coves and will most likely continue to spread to other coves in the lake (Figure 42). While we did not plant this species, perhaps the protection that project cages and pens provided was one of the reasons that *Ludwigia L. spp* is doing so well at Atoka Lake.

Figure 42: Stand of *Ludwigia L. spp.* (Water Primrose) at Atoka Lake – July 2010

Accomplishing Workplan Objectives

> *"By planting founder colonies of wetland species in key protected areas around the lake, natural spread will result in development of wetland habitat around much of the lake. This habitat will result in a healthier lake and more diverse ecosystem."*

Objective accomplished. 5 sites with 1,311 aquatic plants planted over three growing seasons. Average survival 67%, average cover 64%, and average outside growth 17%.

"Plants will be distributed over at least 5 sites across the lake, providing immediate (3 year) wetland habitat in what is currently a poorly vegetated environment."
Objective accomplished. A total of 5.18 acres of aquatic plant habitat created along the shorelines of Atoka Lake providing habitat for fish, nutrient uptake, shoreline stabilization, and filtration of runoff storm water.

"Following founder colony establishment (in the long term, 10+ years) these protected plants will create a seed bank and give off fragments that will over time populate the coves where sites are (located) and will spread to other parts of the lake as well."
Objective initiated. While spread to other parts of the lake was not assessed, it was observed that at one location (boat ramp at site 2) plant propagules were seen growing and producing flowers well outside the site boundaries. There is optimism from this observation the aquatic plants introduced in this project will spread to other parts of Atoka Lake.

"Turbidity will be reduced as the colloidal clays fall out in the plant protected waters. Shoreline erosion will be curtailed by reduction of wave action and compaction of shoreline sediments by root systems. Emergent species such as bulrush, spike rush and duck potato will buffer the lake from upland erosion. Submersed species such as American pondweed and coontail will populate the deeper portions of the littoral zone."
Objective initiated. While no improved water quality has been documented, the baseline data (BUMP 2007 and 2010) will allow future water quality data to be assessed for any observed improvements as a result of this project. A reduction in shoreline erosion should occur as aquatic plants continue to extend their boundaries along the littoral zone of Atoka Lake.

"Fish nursery habitat will be enhanced as the plants provide cover, macroinvertebrate habitat, and improved water quality."
Objective initiated. The creation of 5.18 acres of aquatic plant habitat along the shorelines of Atoka Lake provides immediate habitat for young fish and macroinvertebrates. While no improved water quality has been documented, the baseline data will allow future water quality data to be assessed for any observed improvements as a result of this project.

Conclusion and Recommendations

The primary focus of this project was to establish "founder colonies" that would, over time, produce quantities of seeds and fragments to disseminate across Atoka Lake creating wetland habitat along much of the shoreline. Because of the relatively high turbidity, the initial objective was to focus on emergent plant species as a means of controlling erosion. When the conditions are right, "bumper crops" are able to be produced and colonies can be established despite herbivore pressure. The quick success of emergent plants allowed efforts to assess the feasibility of floating leaved and submerged plant species in Atoka Lake to add to the diversity of the aquatic plant community, increase habitat and improve water quality within the lake. Figure 43 shows the successful emergent plants growing at site 3 in September 2010 and Figure 44 shows a cage of *Potamogeton nodosus*, at the final assessment.

Figure 43: View of the cages at site 3 during the final assessment – September 2010

Figure 44: *Potamogeton nodosus* growing in a penned cage - final assessment, September 2010

Reconciliation with Data Quality Objectives

Decision Thresholds:
(from QAPP)

1. ***Output Threshold**: a survival threshold of 50% or better within the protective cages indicates that the project has successfully established founder colonies at Lake Atoka.*

2. ***Outcome Threshold**: When plant coverage outside of the protective cages is equal to or exceeds the coverage within the cages the OWRB is confident this project will result in the predicted outcome; successful vegetation of the habitable littoral zone of Lake Atoka.*

Success of any of these parameters indicates that the project should be allowed an additional four years to verify actual establishment and quantify the resultant littoral community. OWRB may at that time request monies for 2 years of additional monitoring.

Decision Rule

(from QAPP)

"Decisions to be made will be based on first through third year data from the project. Plant establishment may take several additional seasons before significant expansion begins. Environmental conditions for the seeds and the colonies must be on target for exponential growth to occur. The "founder colony" concept works on the idea that the plants are always in place spreading seeds, fragments and propagules waiting for the optimal conditions for explosive growth to occur. Mindful of this concept, if wide expansion has not yet occurred by project end it may be premature to judge the project as failed.

1. *Output and Outcome Failure: No thresholds are met. At the end of year three, exceptional plant loss due to herbivory or other disturbance would indicate output failure and therefore outcome failure.*

2. *Output Successful but Outcome Indeterminate: Only Output Threshold is met. At the end of year three, if plants are surviving well within their cages but have not been able to grow beyond their cages OWRB will recommend that further monitoring up to year seven after project launch and may request monies for 2 years of additional monitoring to circumvent a False Negative Error.*

3. *Output Successful and Outcome Secure: Output Threshold is met. Barring severe drought or unforeseen calamity after project end, OWRB predicts that the habitable littoral zone will have substantial and permanent aquatic vegetation and viable seedbed in place by year seven after project launch. OWRB may request monies for 2 years of additional monitoring.*

4. *Output and Outcome Successful: All thresholds are met. The OWRB expects to initiate the ecosystem shift but not complete this shift within the project period. This scenario is not likely to occur within the three-year project window.*

Threshold Conclusions

The lake-wide average *survival* of protected plantings is 67% within the cages (Table 3) and 27% *growth* outside the cages (Table 8) or "unprotected".

The lake-wide average *coverage* of protected plantings is 64% (Table 6) within the cages and 17% *coverage* outside the cages (Table 6) or "unprotected".

The lake-wide average *survival* of protected pen plantings is 84% (Table 10)

The lake-wide average *percent cover* of protected pen plantings is 62% (Table 9)

The lake-wide average *community rating* for all pens is 4. (Table 9)

The lake-wide average *survival* of protected tree plantings is 59% (Table 13)

The Output Threshold states "*a survival threshold of 50% or better within the protective cages*". **This Output Threshold <u>has</u> been met** with a 64% average survival inside plant cages, an average of 84% inside the pens, and a 59% average inside tree cages. This success was definitive at 14% to 34% beyond the threshold for aquatic species, especially in the face of sustained flooding conditions for 15 months. This substantive success rate gives OWRB confidence that with time and continued effort, this lake can have a diverse aquatic macrophyte community. Success was also attained within tree cages which exceed the threshold by 9%.

The Outcome Threshold is "*When plant coverage outside of the protective cages is equal to or exceeds the coverage within the cages*". **This Outcome Threshold <u>has not</u> been met** with 17% average coverage outside of the cages being less than the 64% average coverage within the cages. Therefore, the OWRB cannot state with confidence that this project will succeed in its long-term goal of substantial littoral zone wetland colonization. While the 17% average coverage outside the cages is below the 64% within the ages, both numbers are quite significant achievements within the three-year project timeframe.

It is our opinion that the "founder colonies" have in fact been established and the #2 Decision Rule would be the best fit for the overall project conclusion of ***"Output successful but Outcome Indeterminate."*** While the 17% outside coverage is well below the inside coverage of 64%, the outside coverage is only taking into account the plants that were planted by the OWRB over the project duration. If the success of the volunteer (preexisting) plant colonies was also accounted for, in particular *Justicia americana* and *Ludwigia L. spp*, but also the native button bush, etc., the average outside coverage would increase exponentially, easily making the outside average coverage greater than the inside average coverage. It was most likely the added protection from pens and cages, as well as ideal water levels for several species, which allowed these volunteer colonies to develop and thrive. In addition one target species, *Sagittaria graminea*, was found outside of the founder colony, unprotected and reproducing through shoot and seed production.

Caged sites have been successful thus far and should continue to be used as a means of increasing the founder colony. Plants that have good or exceptional growth inside cages should have their cages removed, allowing them to continue their expansion. These removed cages should be relocated to areas where new propagules have sprouted, adding protection to the new plants.

Pen sites are perhaps the best solution for long term establishment of aquatic macrophytes in the lake. They provide more propagules, an immediate diversified wetland community (high CR) and excellent micro-habitat. As pens begin to reach 100% coverage, they too should be relocated within the site to protect new areas as the founder colony continues to expand.

Plantings should concentrate between 586' msl and 589' msl, where plants have been most successful. But as water levels return to a more normal fluctuation in the next few years, cages and pens may need to be relocated for continued success. Cages may be removed when the unprotected plants have clearly outgrown the plants within the cages and pens and have survived a full season. By 2017, cages should be removed from the lake regardless of the state of the plantings. This will ultimately be the decision of Oklahoma City.

The following species were the most successful by far and should be the primary species used in any subsequent plantings:

Heteranthera dubia (Water Star Grass)
Justicia americana (American Water-willow)
Nymphea odorata (White Water Lily)
Pontederia cordata (Pickerelweed)
Sagittaria latifolia (Arrowhead)
Sagittaria graminea (Bulltongue Arrowhead)
Schoenoplectus tabernaemontani (Softstem Bulrush)
Thalia dealbata (Alligator Flag)

The following species also showed success, but had limited numbers planted and therefore warrant further evaluation to determine their ability to thrive at Atoka Lake:

Eleocharis quadrangulata (Square-stem Spike Rush)
Scirpus americanus (Three Square Bulrush)
Nuphar lutea (Spatterdock)

With concentrated efforts using what has been learned from this project, and continued support from Oklahoma City, the chances greatly increase for ultimate success. As stated in the QAPP,

> "*Success of any of these parameters* (outcome or output thresholds) *indicates that the project should be allowed an additional four years to verify actual establishment and quantify the resultant littoral community. OWRB may at that time request monies for 2 years of additional monitoring."*

And with the attainment of Decision Rule #2,

> *"Output Successful but Outcome Indeterminate: Only Output Threshold is met. At the end of year three, if plants are surviving well within their cages but have not been able to grow beyond their cages OWRB will recommend that further monitoring occur (up to year seven after project launch) and may request monies for 2 years of additional monitoring to circumvent a False Negative Error."*

OWRB recommends further maintenance for the next 4 years to allow time for further establishment and spread of the resultant littoral community.

Because there have been multiple successes and lessons learned from this project combined with the commitment from OKC to continue with maintenance, the future success is greatly amplified. Given that there is funding from Oklahoma City to continue maintenance on this project, a positive outcome is very likely. Should Oklahoma City continue founder colony maintenance the OWRB will propose funding through the 104(b)(3) program for future monitoring to determine the longer term outcome of an ecological shift.

Literature Cited

1. Beneficial Use Monitoring Report; Oklahoma Water Resources Board; 2007
2. Beneficial Use Monitoring Report; Oklahoma Water Resources Board; 2010

Appendix A – Lake Atoka Recommendation from the Lewisville Aquatic Ecosystem Research Facility at University of North Texas

Received June 2008

Recommendations for establishing aquatic plant species in Lake Atoka, Oklahoma

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Background

Lake Atoka is a 5700-acre reservoir impounded to serve as water supply for Oklahoma City, Oklahoma. Water from the lake is pumped to supplement volume in Lake Stanley Draper, located approximately 100 miles away. The lake is considered variably mesotrophic to oligotrophic (moderate to low productivity) and exhibits high turbidity, due primarily to suspended clays. Aquatic vegetation in the lake is restricted to a small number of native species that are moderately well established but offer only limited benefits to fish, aquatic wildlife, water quality, and erosion control.

Oklahoma Water Resources Board (OWRB) recently received EPA funding for aquatic vegetation enhancement in the lake. Subsequently, OWRB requested assistance from the Lewisville Aquatic Ecosystem Research Facility (LAERF) in developing an aquatic plant establishment strategy. LAERF visited the lake in May 2008 to assist in site selection and provide planting recommendations for this project.

General Recommendations

LAERF recommends that OWRB focus on establishment of founder colonies to provide immediate habitat at a minimum of five sites within the lake and along lake shorelines. In addition to providing immediate but local habitat and other benefits, once well established, these founder colonies will serve to produce propagules (seeds, fragments, etc.) for natural spread to other areas of the lake, thereby improving the lake ecosystem overall.

First-year efforts should concentrate on identifying aquatic plant species most suitable for each site as well as ascertaining which will require protection from

herbivory in order to become initially established. All species suggested for use in this project should be planted at each site---this shotgun approach allows for selection of plants by their establishment success (or lack thereof), eliminating misjudgments regarding each site's potential to support particular plants. Additionally, each species should be planted with varied levels of protection at each site to evaluate herbivore influence on plant establishment: no protection and fine-mesh (2-in maximum) protection are recommended for Lake Atoka.

Second- and third-year efforts should focus on expansion of founder colonies using appropriate species and exclosures for each site. Additionally, continual maintenance of sites (exclosure repairs, replanting when necessary, etc.) should be conducted. Following this plan should result in full, diverse founder colony establishment by the end of the third growing season, as well as spread to areas remote to sites.

Specific Recommendations

1) Site Selection. OWRB and LAERF have identified seven potential sites for establishing founder colonies. Most sites currently support a low diversity of aquatic and riparian species, indicating they are suitable for founder colony establishment, but have not yet received natural inputs of many aquatic and riparian species that occur in Oklahoma.

2) Species Selection. Only species native to Oklahoma should be used in this project. Several species of native aquatic (*Potamogeton nodosus*), emergent (*Juncus* sp., *Justicia americana*, and *Eleocharis macrostachya),* and woody riparian (*Cephalanthus occidentalis* and *Salix nigra*) plants were observed at most of the sites.
We recommend using the following native Oklahoma species to supplement the aquatic plant community currently found in the lake:

Aquatic	Wild celery (*Vallisneria americana*)
	American pondweed (*Potamogeton nodosus*)
	Illinois pondweed (*Potamogeton illinoensis*)
	Water stargrass (*Heteranthera dubia*)
Floating-leaved	White water lily (*Nymphaea odorata*)
Emergent	Squarestem spikerush (*Eleocharis quadrangulata*)
	Slender spikerush (*Eleocharis acicularis*)
	Softstem bulrush (*Schoenoplectus tabernaemontani*)
	Tall burhead (*Echinodorus berteroi*)
	Creeping burhead (*Echinodorus cordifolius*)
	American bulrush (*Schoenoplectus americana*)

Pickerelweed (*Pontederia cordata*)
Bulltongue (*Sagittaria graminea*)
Arrowhead (*Sagittaria latifolia*)
Water hyssop (*Bacopa monnieri*)

3) Propagule Selection. We recommend using nursery-grown native plants. Such propagules are well suited for harsh conditions (such as water level fluctuations, herbivory, etc.) immediately following planting and generally prove most successful in long-term establishment when compared with plantings of bareroot plants or tubers. Additionally, using nursery-grown plants helps avoid accidental introductions of unwanted, noxious species. An exception to this recommendation is where species may be harvested locally (from within Lake Atoka and its watershed) without decimating existing colonies. Spread of those species by including bareroot transplants from other areas of the lake as part of each founder colony is an acceptable approach. Successful transplanting in this manner may increase cost-effectiveness of the project. However, if such attempts fail during the first year of plantings, we recommend discontinuation and sole use of potted nursery plants.

We generally do not recommend the use of tubers or seeds in aquatic vegetation establishment projects, primarily because both are difficult to procure and successful establishment from these propagules is inconsistent, at best. However, if OWRB can acquire locally produced tubers or seeds for any of the above species (or other *perennial* species deemed appropriate outside this recommendation), first year attempts might be made in order to evaluate their effectiveness and potential use for subsequent years.

4) Timing of Plantings. Most potted plants may be installed any time during the growing season, typically between the months of April and October, inclusive. Bareroot plants should be transplanted between May and September, inclusive. Tubers (if used) are generally available during late winter and should be planted prior to the growing season, or no later than May. Seeds (if used) may be available year-round, but should be planted in fall, winter, or early spring dependent upon species.

5) Herbivore Protection. The degree of herbivore effects on establishing plants in the lake are unknown, but the presence of aquatic herbivores including beaver, muskrats, crayfish, turtles, and common carp, as well as terrestrial grazers such as deer and rabbits, will likely impact any new plantings made in and around the lake. As mentioned in our General Recommendations, we suggest that initial plantings include two levels of protection for each species planted at each site: no protection and fine-mesh protection (2” mesh or finer).

Exclosures should be constructed from PVC-coated wire mesh to ensure durability. Ring cages measuring 3-ft to 4-ft in diameter x 2-ft or 4-ft tall should

be sufficient for herbivore protection in this lake. All cages should be well anchored to substrates using either T-posts or rebar. Larger mesh (up to 2-in x 4-in) pens or cages may be installed following first year evaluations to facilitate expansion of existing plant colonies. Pens should be constructed so that their tops are not underwater at conservation pool. Divided pens with deeper sections that may be inundated but shallower sections that will not be inundated are acceptable. Tall (5-ft or 6-ft) or covered ring cages should be installed in pens to provide additional protection for at least portions of the aquatic plant colonies should water exceed conservation pool. Turtle traps (floating, fall-in type) and release funnels should be installed in large pens to help remove herbivores that gain entry.

Plants that become established during the first year without protection will most likely require no protection during the remainder of the project, and subsequent plantings should be continued without exclosures unless significant herbivory is noted as the project progresses. Those requiring protection should not be excluded from additional plantings, but should continue to be planted with protection. These plants will eventually produce enough seeds (or other propagules) to overwhelm herbivores and begin to spread. Species that fail to establish with or without protection should be considered inappropriate for a given site (but not necessarily for the entire lake). Any species that fail to establish at all sites should be excluded from future plantings.

Cages that fail to support plants should be replanted with species that have successfully established but require protection at that site.

6) Planting Depths. Atoka Lake is prone to significant fluctuations, and plants should be installed within depth ranges most suitable to their growth during periods of high or low water, while at the same time considering high turbidity. We suggest two planting tiers for each major group of plants (aquatic and herbaceous riparian) based upon the following schematic:

Aquatic 3-ft below conservation and 4-ft below conservation (these cages may require covers)

Floating-leaved 2-ft below conservation and 3-ft below conservation

Emergent 0.5-ft below conservation and 2-ft below conservation

These depth tiers should ensure that plants of each group are actively growing at all times of the growing season and therefore potentially producing propagules by which they may spread from founder colonies. However, if water levels drop by more than 4-ft from conservation pool during the project, additional tiers should be added to ensure that at least some plants are at appropriate depths for active growth.

7) Site Maintenance. Sites should be visited regularly to ensure that cages remain intact (damage may come from wave action, floating debris, vandalism, etc.). Damaged cages should be repaired and replanted (if necessary) in a timely manner to ensure that each founder colony supports as many plants as possible.

Questions should be directed to:

Dr. Gary Owen Dick **garydick@laerf.org**	**ERDC/UNT** **Lewisville Aquatic Ecosystem Research Facility**
Ms. Lynde Dodd Williams **Lyndedodd@laerf.org**	**Lewisville, Texas** **972-436-2215**

Appendix B – Planting Data

See Excel Spreadsheet File on Enclosed CD

Appendix C – Site Maps

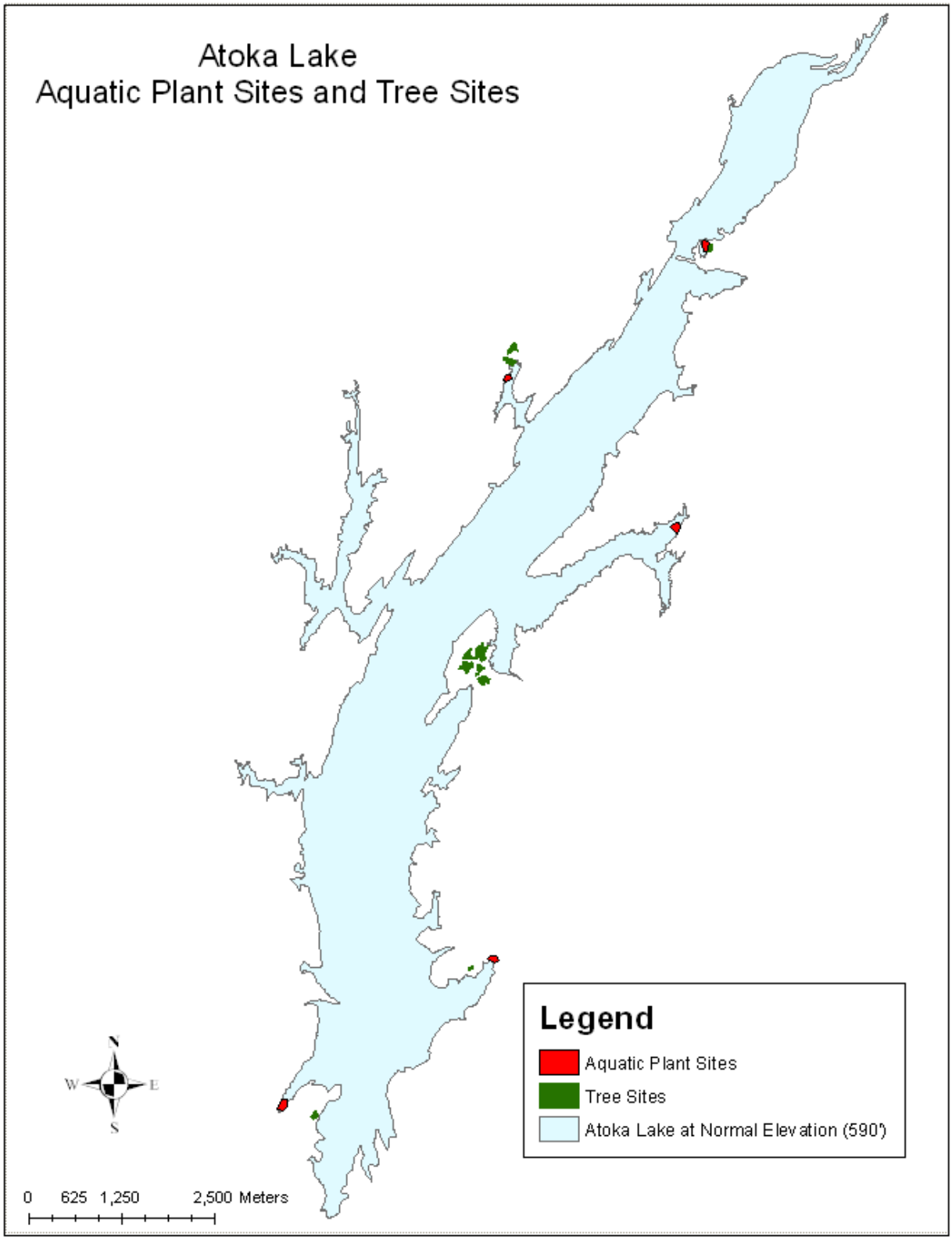
Plant species key for subsequent maps are as follows:

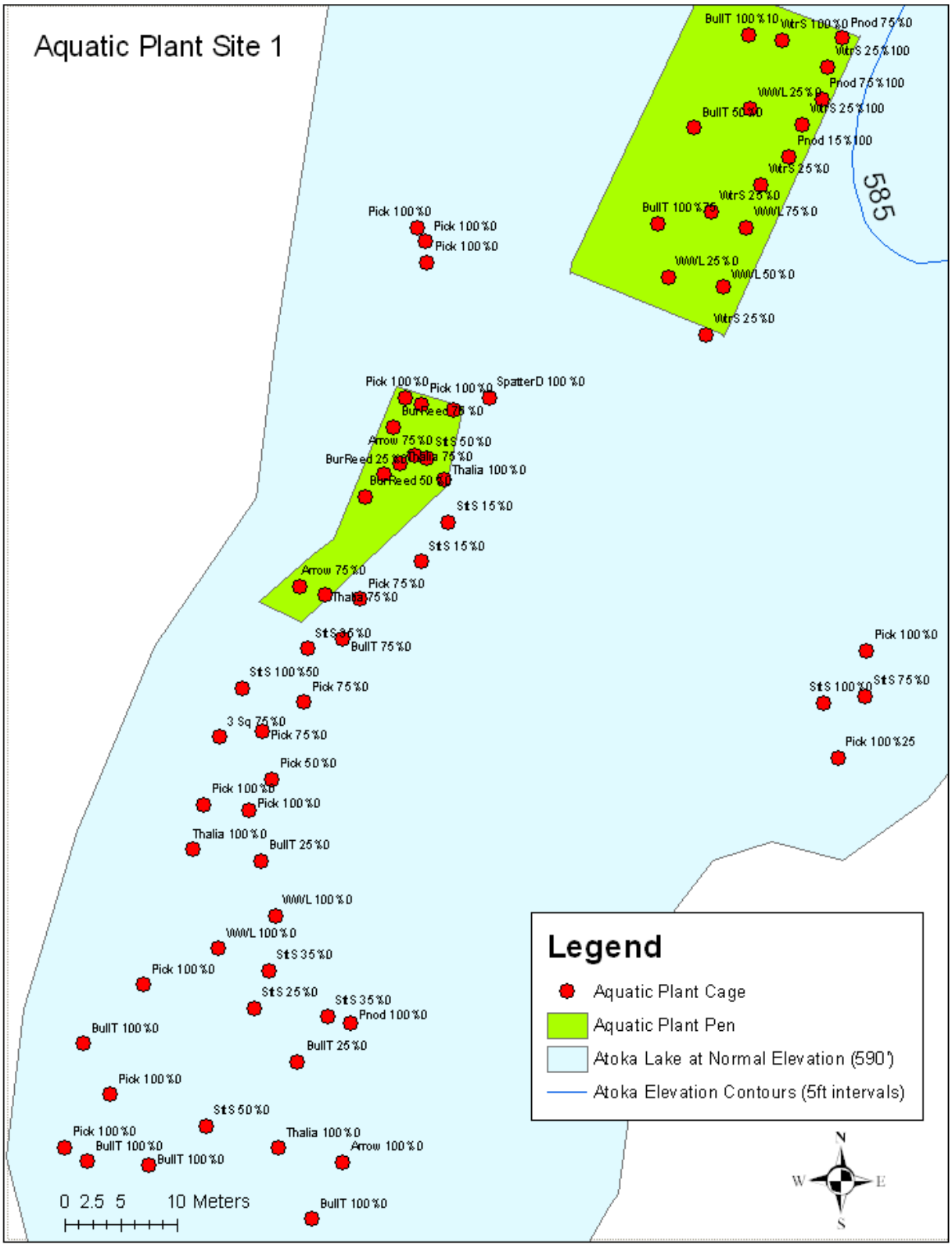
Species Key		
Species	Comon Name	Abbreviation
Scirpus americanus	Three Square Bulrush	3Sq
Sagittaria latifolia	Arrowhead	Arrow
Peltandra virginica	Green Arrow Arum	Aarum
Bacopa monnieri	Water hyssop	Bacp
Sagittaria graminea	Bulltongue Arrowhead	BullT
Scirpus pallidus	Cloaked Bulrush	ClkB
Echinodorus cordifolius	Creeping Burhead	CBH
Scirpus atrovirens	Green Bulrush	Gbull
Saururus cernuus	Lizard's Tail	Liz
Pontederia cordata	Pickerel Weed	Pick
Potamogeton nodosus	American Pondweed	Pnod
Hibiscus lasiocarpos	Rose Mallow	Rose
Schoenoplectus tabernaemontani	Softstem Bulrush	SftS
Nuphar luteum	Spatterdock	SpatD
Eleocharis quadrangulata	Square-stem Spike Rush	SqS
Echinodorus berteroi	Tall Burhead	TallB
Thalia dealbata	Alligator Flag	Thal
Vallisneria americana	Wild Celery, Tapegrass	Val
Justicia americana	American Water-willow	WW
Scirpus cyperinus	Woolgrass	Wool
Heteranthera dubia	Water Star Grass	WtrS
Nymphaea odorata	White Water Lily	WWL

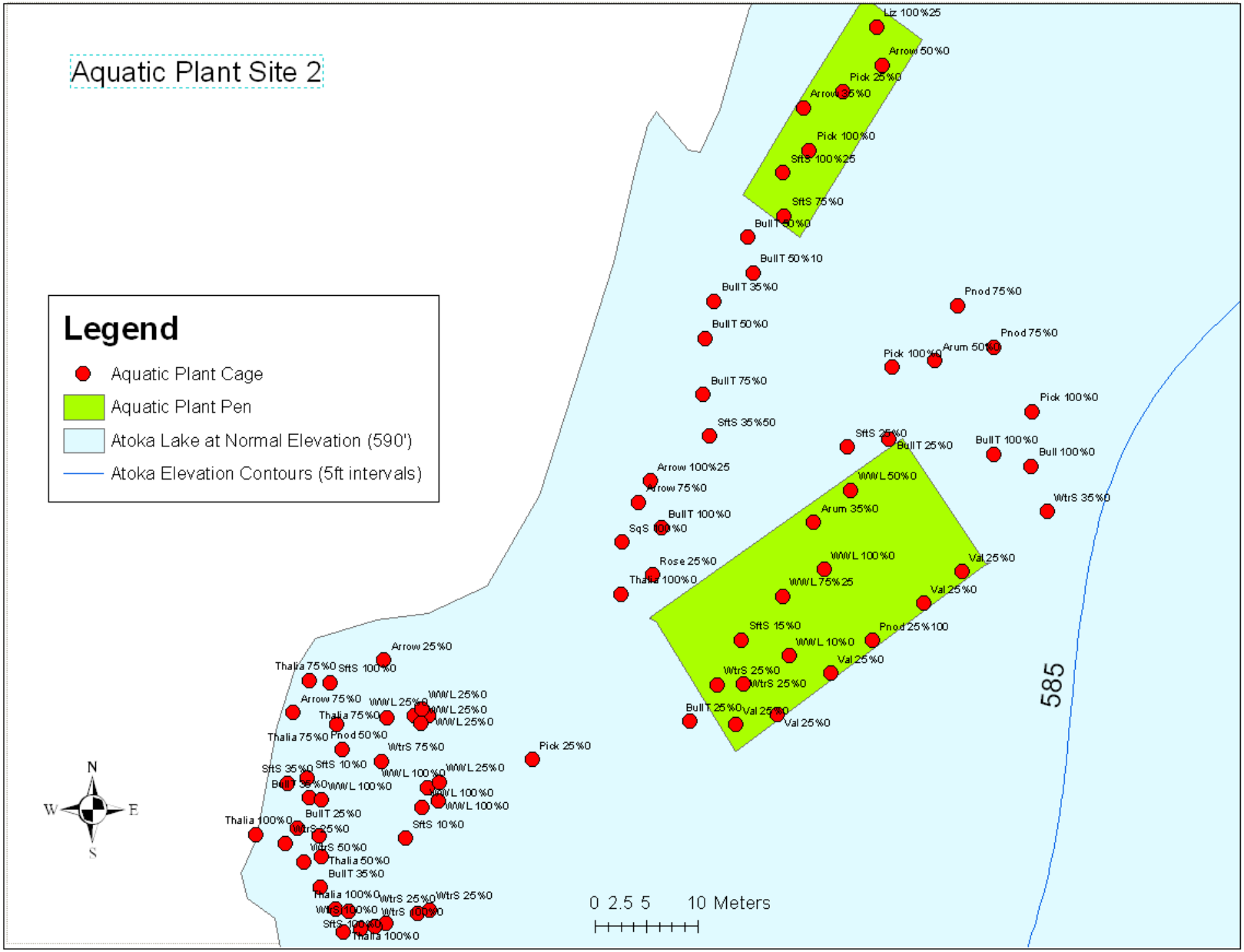
Assessment values for cage/plot coverage are denoted as follows:

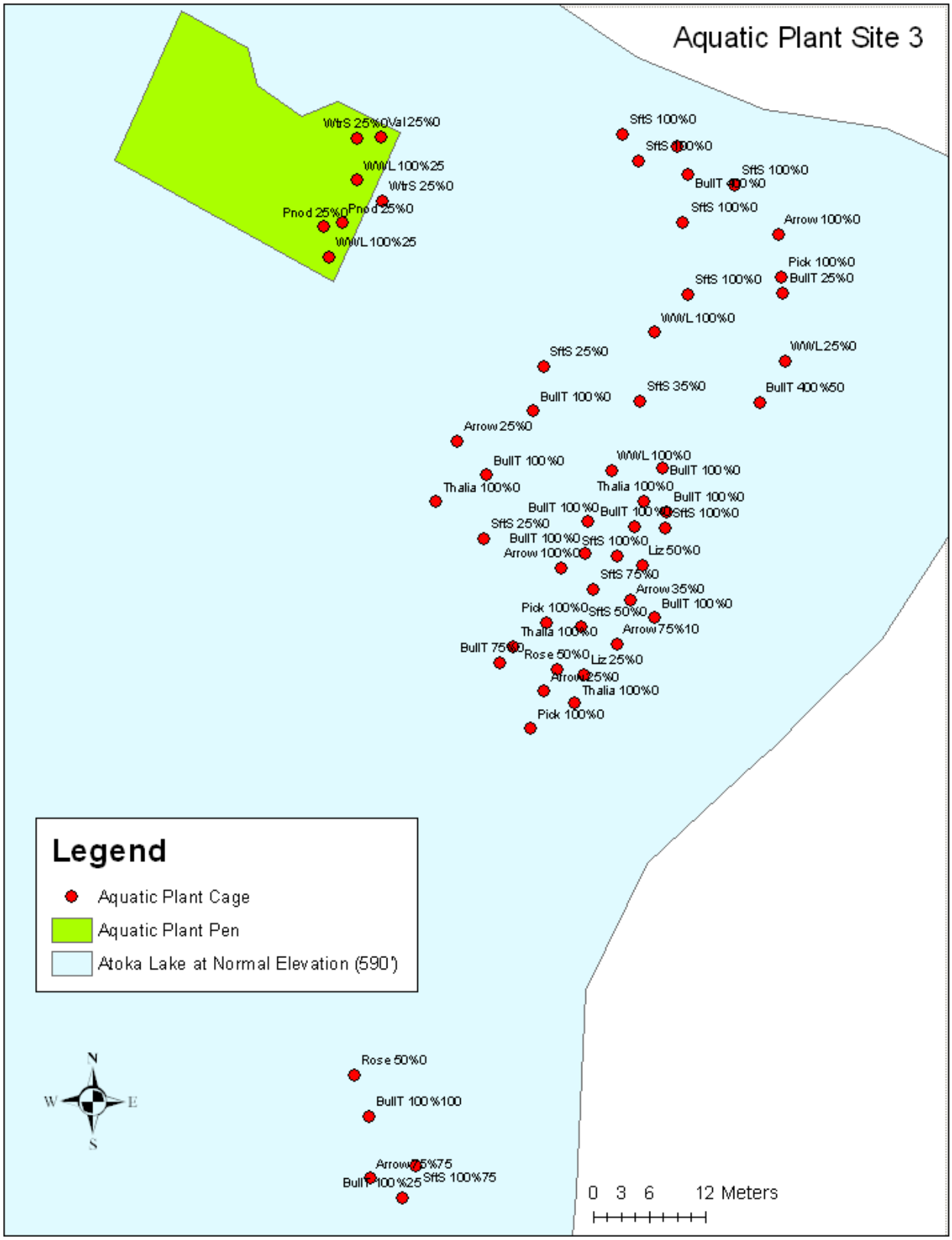
"**BullT 50%, 10%**" = (Species name % in cage or plot , % outside cage or plot)

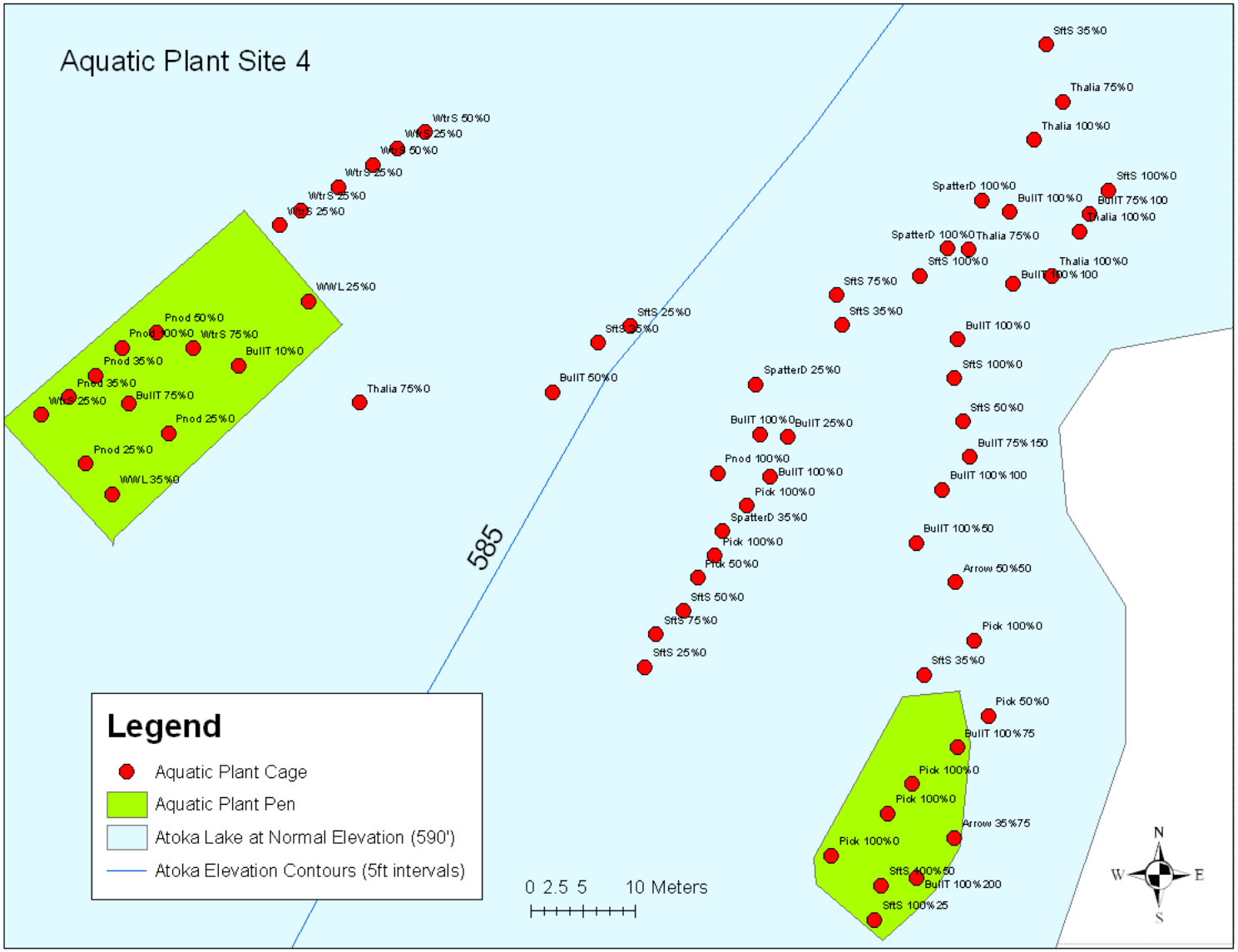
Tree Abbreviation Key		
Abbreviation	**Scientific Name**	**Common Name**
Pec	*Carya illinoinensis*	Native Pecan
Rmul	*Morus rubra*	Red Mulberry
Boak	*Quercus macrocarpa*	Bur Oak
Hack	*Celtis occidentalis L.*	Common Hackberry
Gash	*Fraxinus pennsylvanica*	Green Ash
Syc	*Plantus occidentalis*	American Sycamore
Rbud	*Cercis canadensis -upland only*	Eastern Redbud
Dog	*Cornus drummondii - upland only*	Roughleaf Dogwood
Per	*Diospyros virginiana- upland only*	American Persimmon

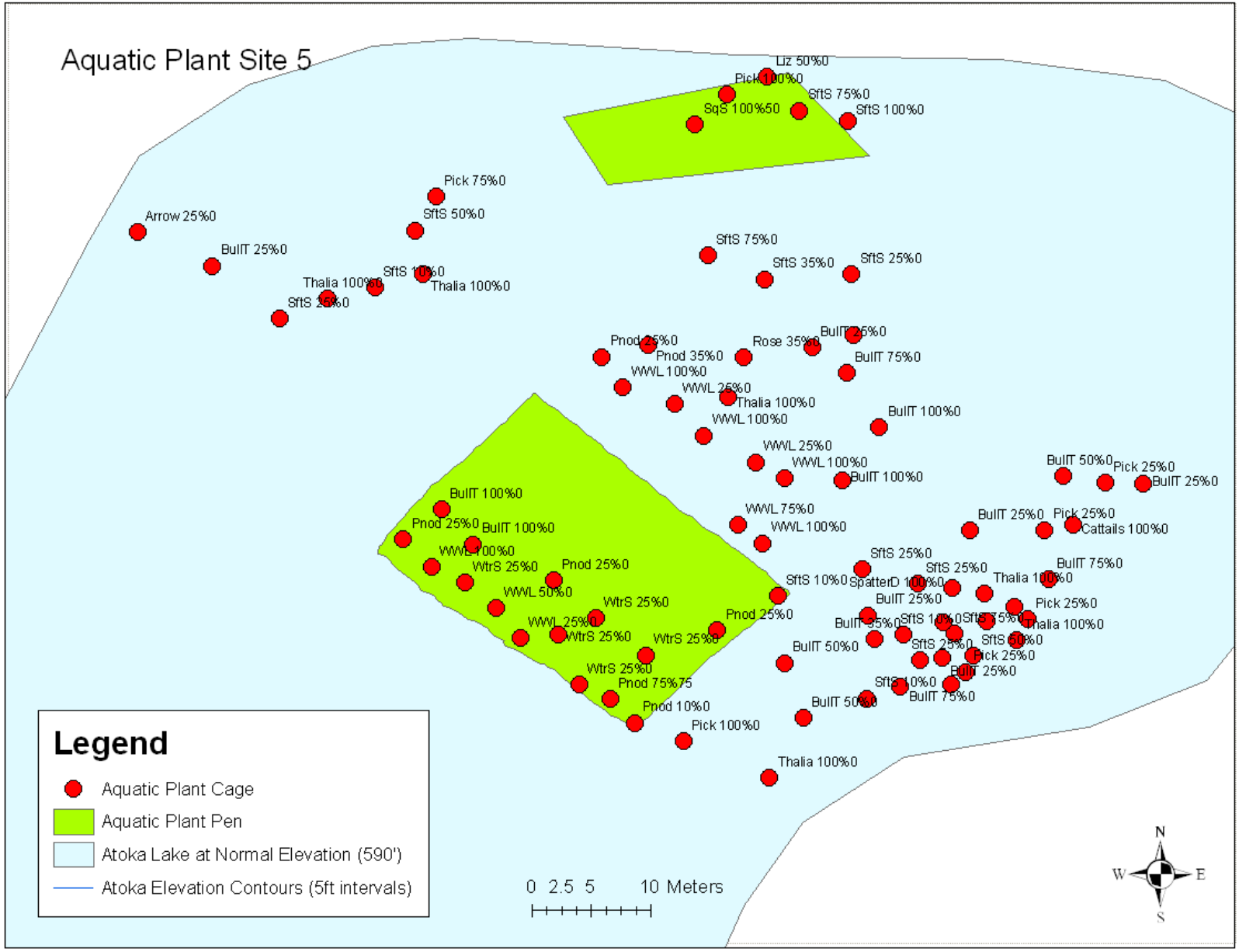

Atoka Lake
Aquatic Plant Sites and Tree Sites
Legend
Aquatic Plant Sites
Tree Sites
Atoka Lake at Normal Elevation (590')
N
W
E
S
0 625 1,250 2,500 Meters

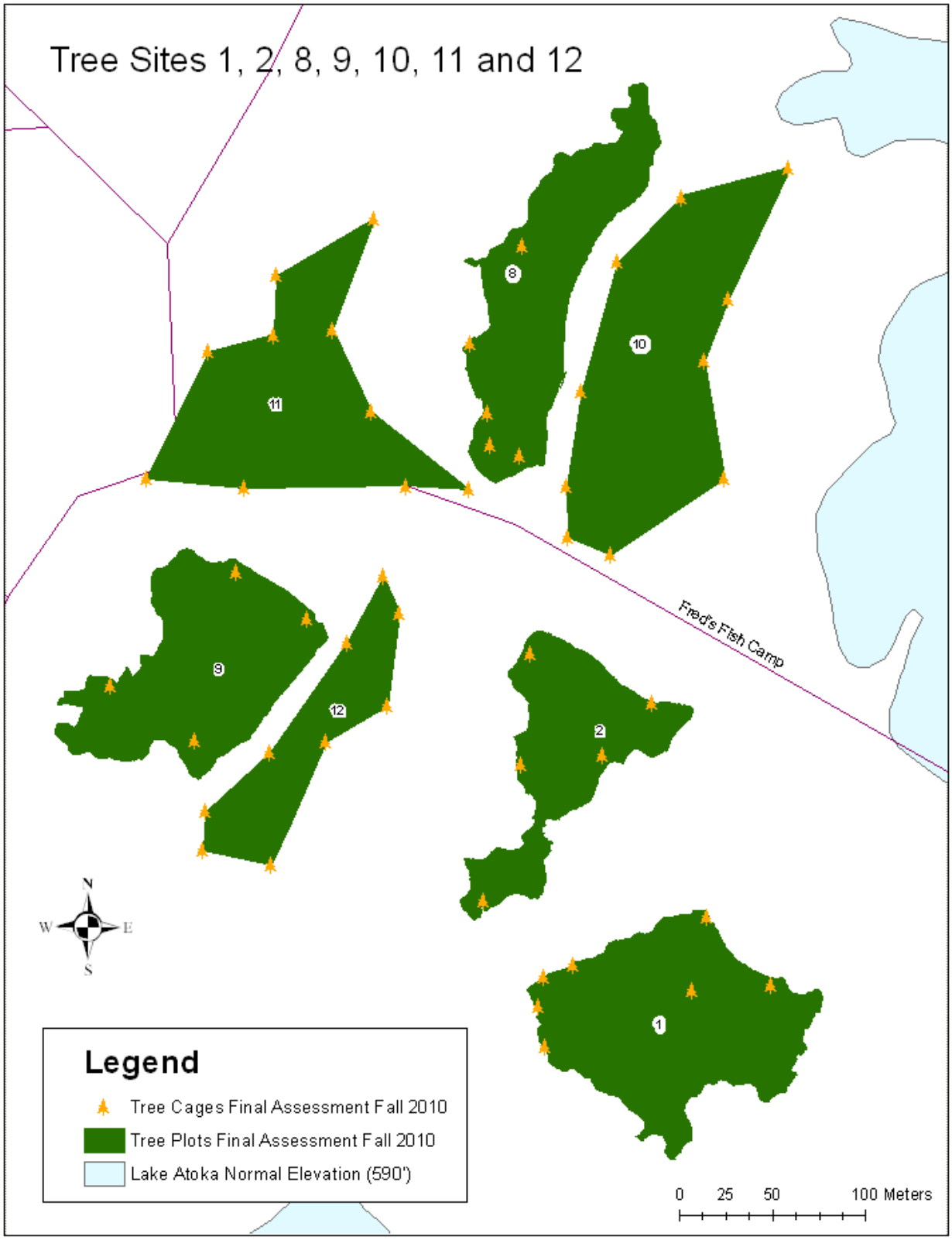

Aquatic Plant Site 1
585
Legend
Aquatic Plant Cage
Aquatic Plant Pen
Atoka Lake at Normal Elevation (590')
Atoka Elevation Contours (5ft intervals)
0 2.5 5 10 Meters
N
W
E
S

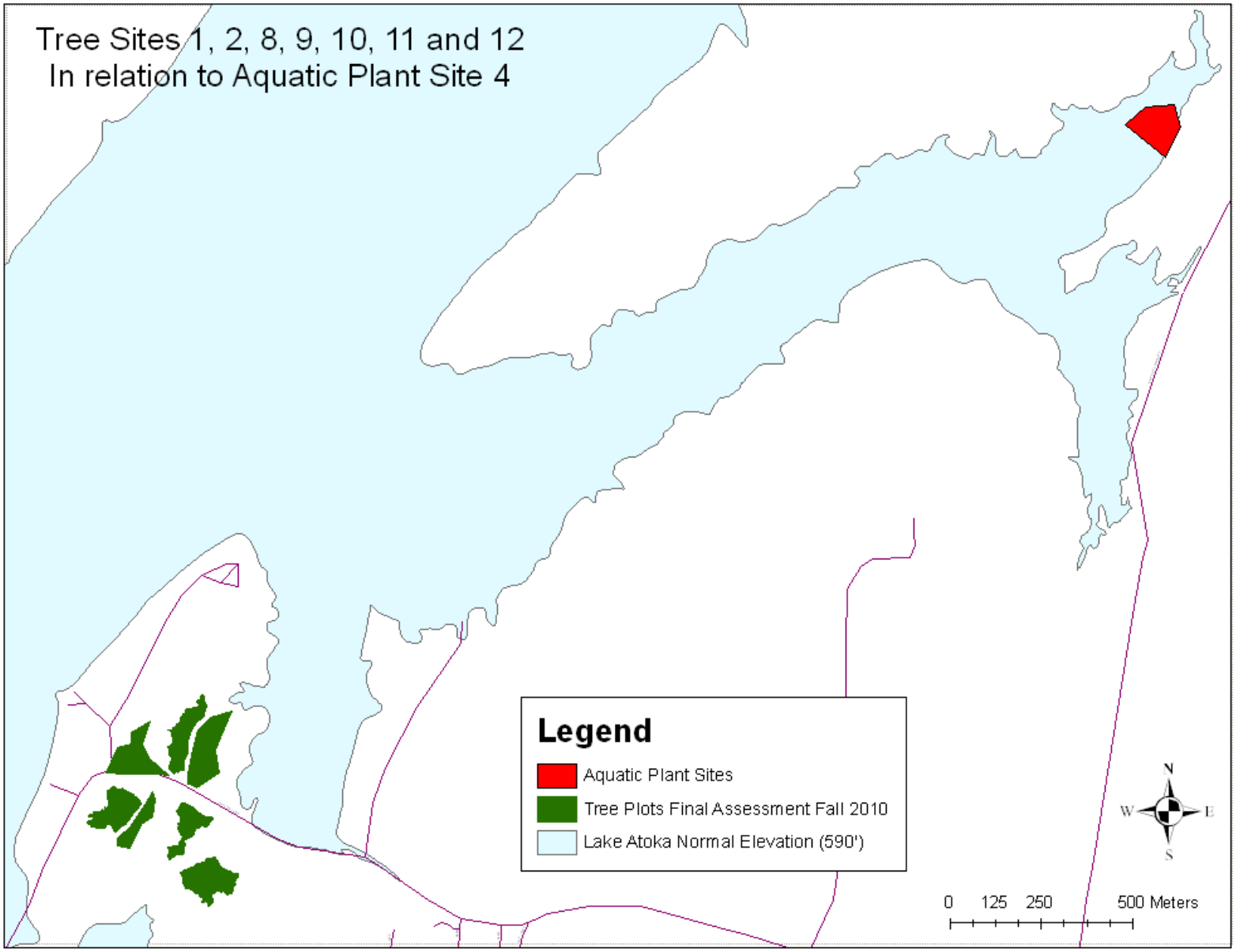

Aquatic Plant Site 2
Legend
Aquatic Plant Cage
Aquatic Plant Pen
Atoka Lake at Normal Elevation (590')
Atoka Elevation Contours (5ft intervals)
585
0 2.5 5 10 Meters
N
S
E
W

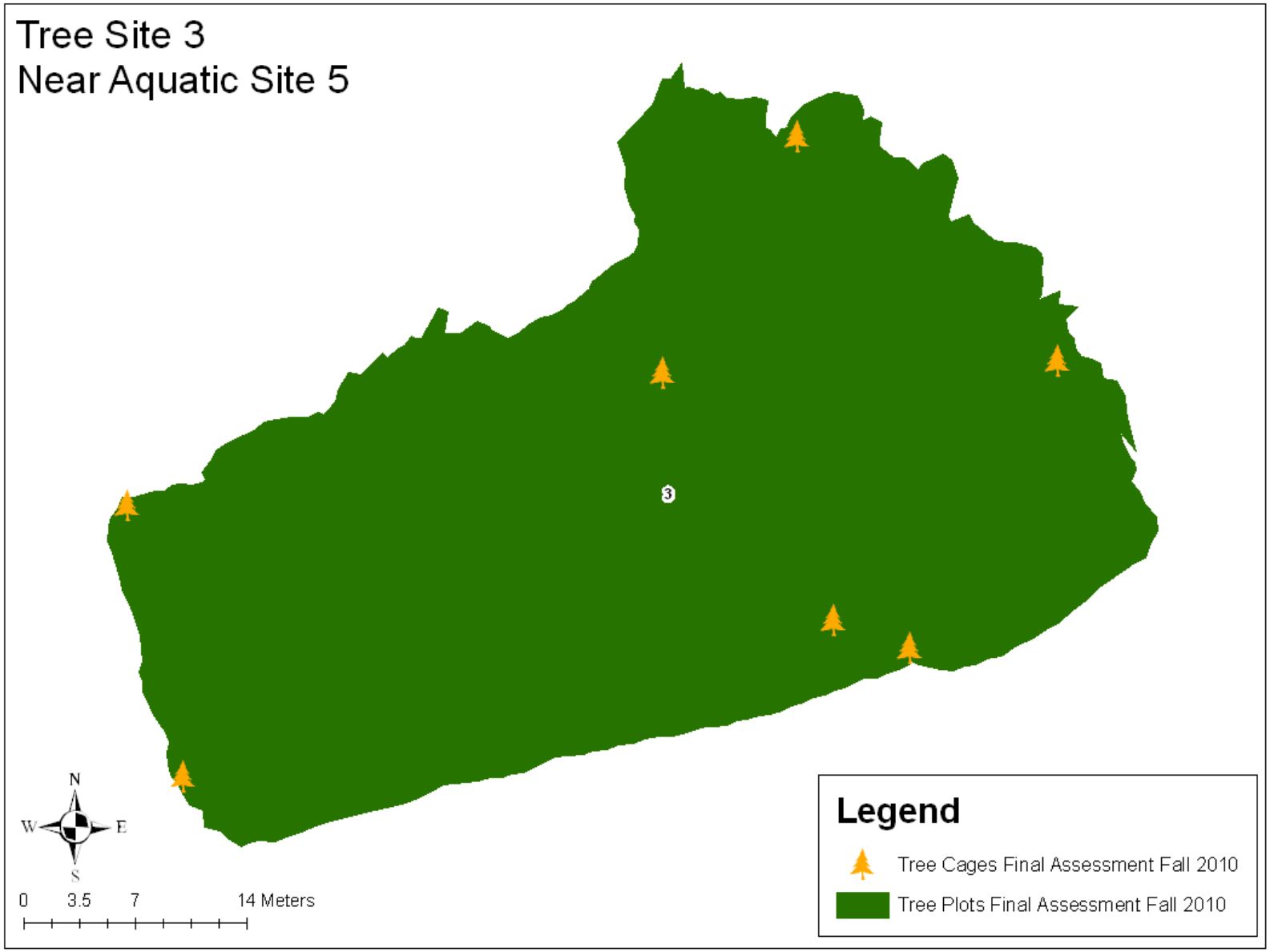

Aquatic Plant Site 3
WtrS 25%0
Val 25%0
WWL 100%25
WtrS 25%0
Pnod 25%0
Pnod 25%0
WWL 100%25
SftS 100%0
SftS 100%0
SftS 100%0
BullT 100%0
SftS 100%0
Arrow 100%0
Pick 100%0
BullT 25%0
SftS 100%0
WWL 100%0
WWL 25%0
SftS 25%0
SftS 35%0
BullT 400%50
BullT 100%0
Arrow 25%0
BullT 100%0
WWL 100%0
BullT 100%0
Thalia 100%0
Thalia 100%0
BullT 100%0
BullT 100%0
BullT 100%0
SftS 100%0
SftS 25%0
BullT 100%0
SftS 100%0
Arrow 100%0
Liz 50%0
SftS 75%0
Arrow 35%0
Pick 100%0
SftS 50%0
BullT 100%0
Thalia 100%0
Arrow 75%10
BullT 75%0
Rose 50%0
Liz 25%0
Arrow 25%0
Thalia 100%0
Pick 100%0
Legend
Aquatic Plant Cage
Aquatic Plant Pen
Atoka Lake at Normal Elevation (590')
N
W
E
S
Rose 50%0
BullT 100%100
Arrow 25%75
BullT 100%25
SftS 100%75
0 3 6 12 Meters

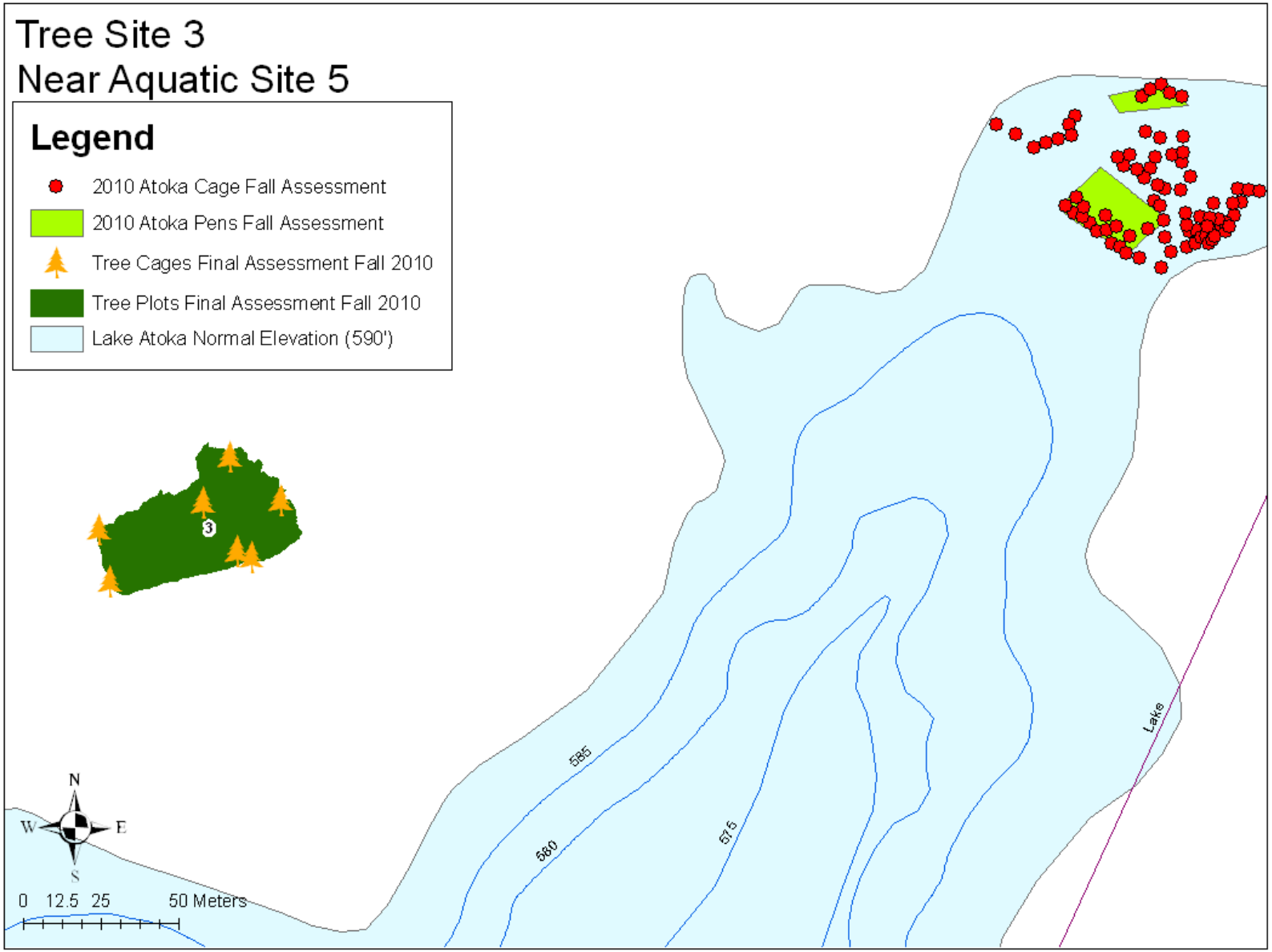

Aquatic Plant Site 4
WtrS 50%0
WtrS 25%0
WtrS 50%0
WtrS 25%0
WtrS 25%0
WtrS 25%0
WWL 25%0
Pnod 50%0
Pnod 100%0
WtrS 75%0
BullT 10%0
Pnod 35%0
Pnod 35%0
WtrS 25%0
BullT 75%0
Pnod 25%0
Pnod 25%0
WWL 35%0
Thalia 75%0
SftS 25%0
SftS 35%0
BullT 50%0
585
SftS 35%0
Thalia 75%0
Thalia 100%0
SftS 100%0
SpatterD 100%0
BullT 100%0
BullT 75% 100
Thalia 100%0
SpatterD 100%0
Thalia 75%0
SftS 100%0
Thalia 100%0
BullT 100% 100
SftS 75%0
SftS 35%0
BullT 100%0
SftS 100%0
SpatterD 25%0
SftS 50%0
BullT 100%0
BullT 25%0
BullT 75% 150
Pnod 100%0
BullT 100%0
BullT 100% 100
Pick 100%0
SpatterD 35%0
BullT 100%50
Pick 100%0
Pick 50%0
Arrow 50%50
SftS 50%0
SftS 75%0
SftS 25%0
Pick 100%0
SftS 35%0
Pick 50%0
BullT 100%75
Pick 100%0
Pick 100%0
Arrow 35%75
Pick 100%0
SftS 100%50
BullT 100%200
SftS 100%25
Legend
Aquatic Plant Cage
Aquatic Plant Pen
Atoka Lake at Normal Elevation (590')
Atoka Elevation Contours (5ft intervals)
0 2.5 5 10 Meters
N
W
E
S

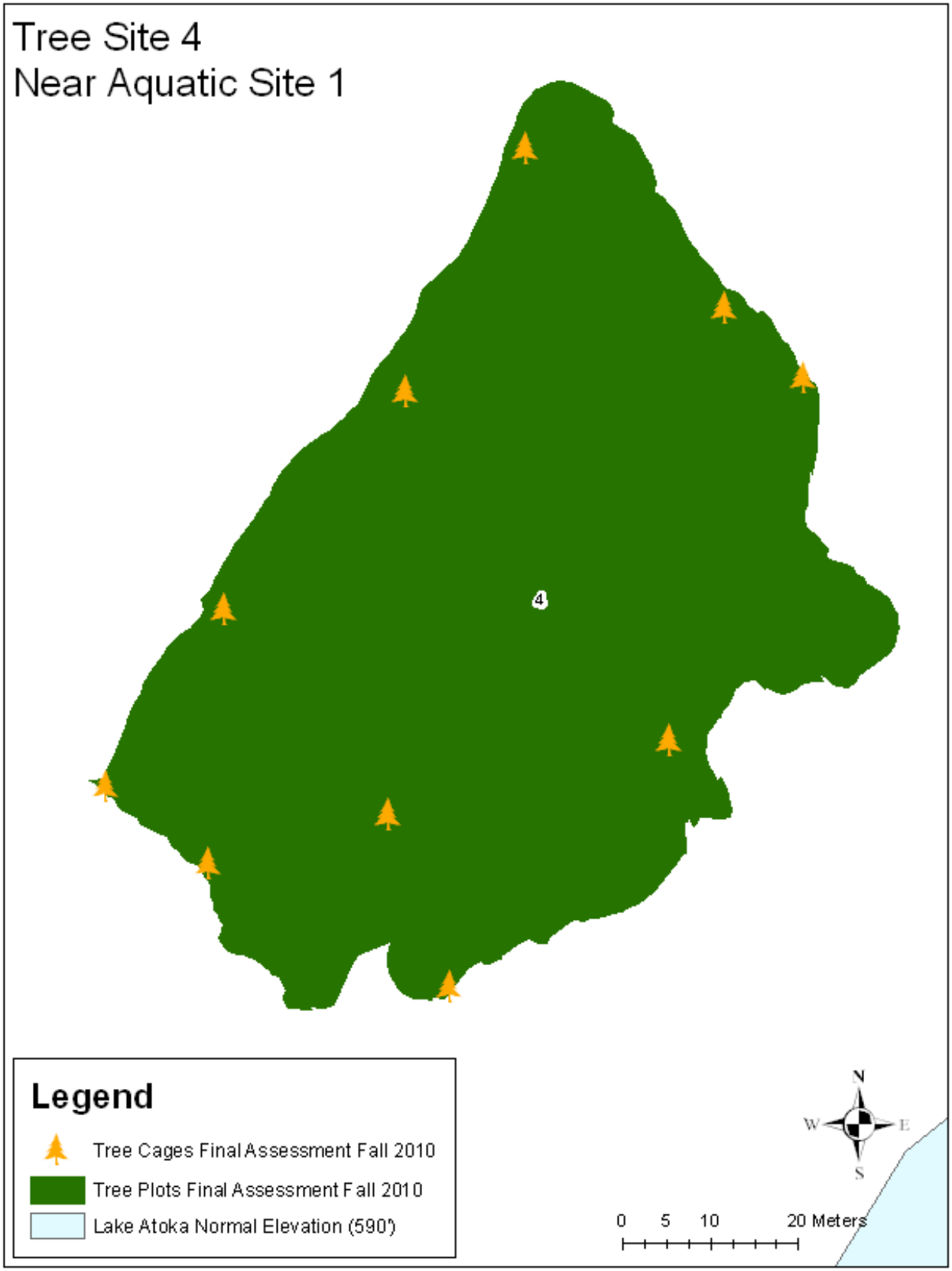

Aquatic Plant Site 5
Liz 50%0
Pick 100%0
SftS 75%0
SqS 100%50
SftS 100%0
Pick 75%0
Arrow 25%0
SftS 50%0
BulIT 25%0
SftS 75%0
SftS 35%0
SftS 25%0
Thalia 100%0
Thalia 100%0
Pnod 25%0
Rose 35%0
BulIT 25%0
Pnod 35%0
BulIT 75%0
WWL 100%0
WWL 25%0
Thalia 100%0
WWL 100%0
BulIT 100%0
WWL 25%0
WWL 100%0
BulIT 100%0
BulIT 50%0
Pick 25%0
BulIT 25%0
BulIT 100%0
WWL 75%0
WWL 100%0
BulIT 25%0
Pick 25%0
Cattails 100%0
Pnod 25%0
BulIT 100%0
WWL 100%0
WtrS 25%0
Pnod 25%0
SftS 25%0
SftS 25%0
BulIT 75%0
SftS 10%0
SpatterD 100%0
Thalia 100%0
WWL 50%0
BulIT 25%0
Pick 25%0
WtrS 25%0
Pnod 25%0
WWL 25%0
WtrS 25%0
WtrS 25%0
BulIT 50%0
SftS 25%0
Pick 25%0
WtrS 25%0
Pnod 75%75
BulIT 25%0
BulIT 75%0
Pnod 10%0
BulIT 50%0
Pick 100%0
Thalia 100%0
Legend
Aquatic Plant Cage
Aquatic Plant Pen
Atoka Lake at Normal Elevation (590')
Atoka Elevation Contours (5ft intervals)
0 2.5 5 10 Meters
N
W
E
S

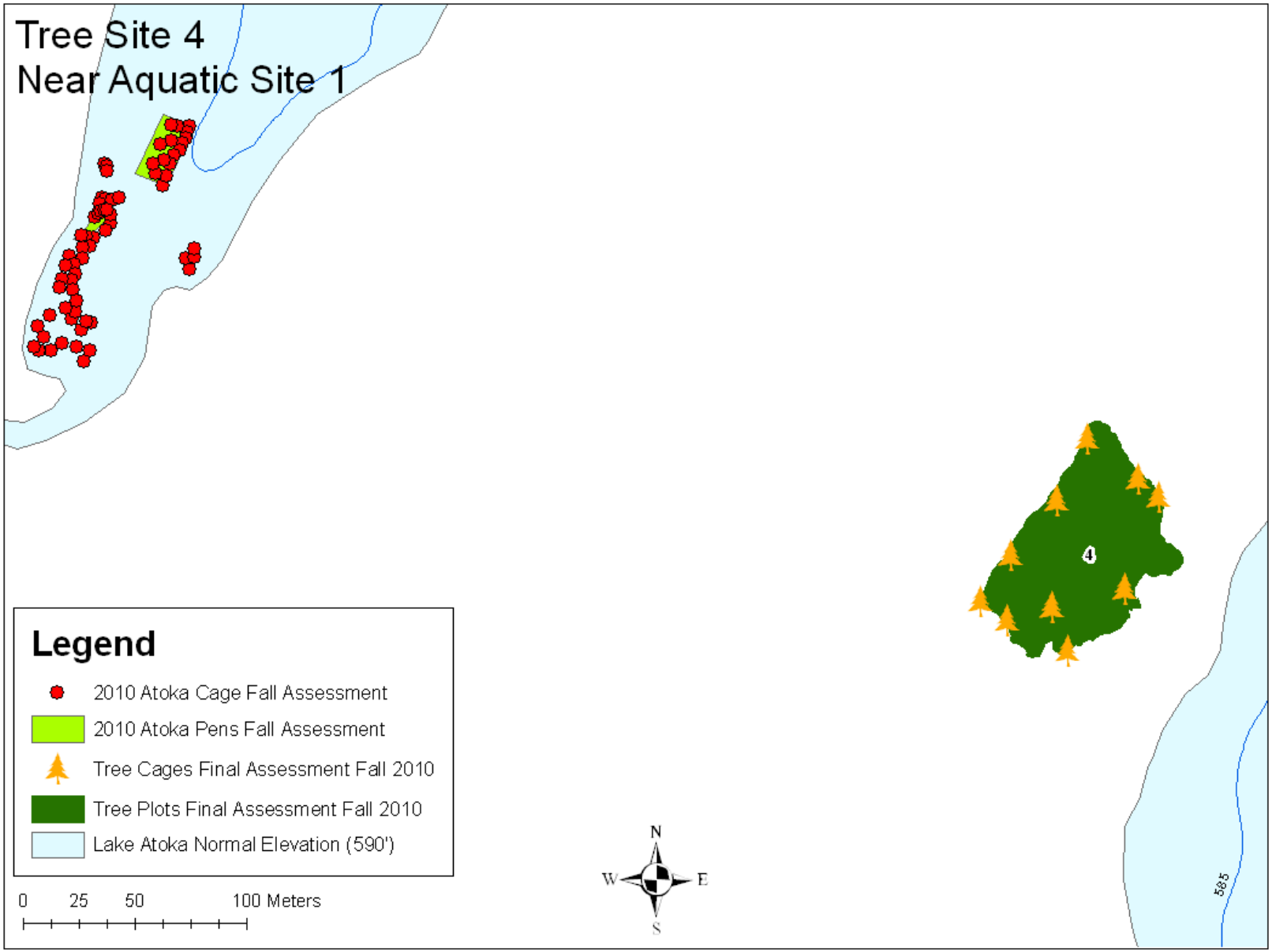

Tree Sites 1, 2, 8, 9, 10, 11 and 12
8
10
11
9
12
2
1
Fred's Fish Camp
N
W
E
S
Legend
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
0
25
50
100 Meters

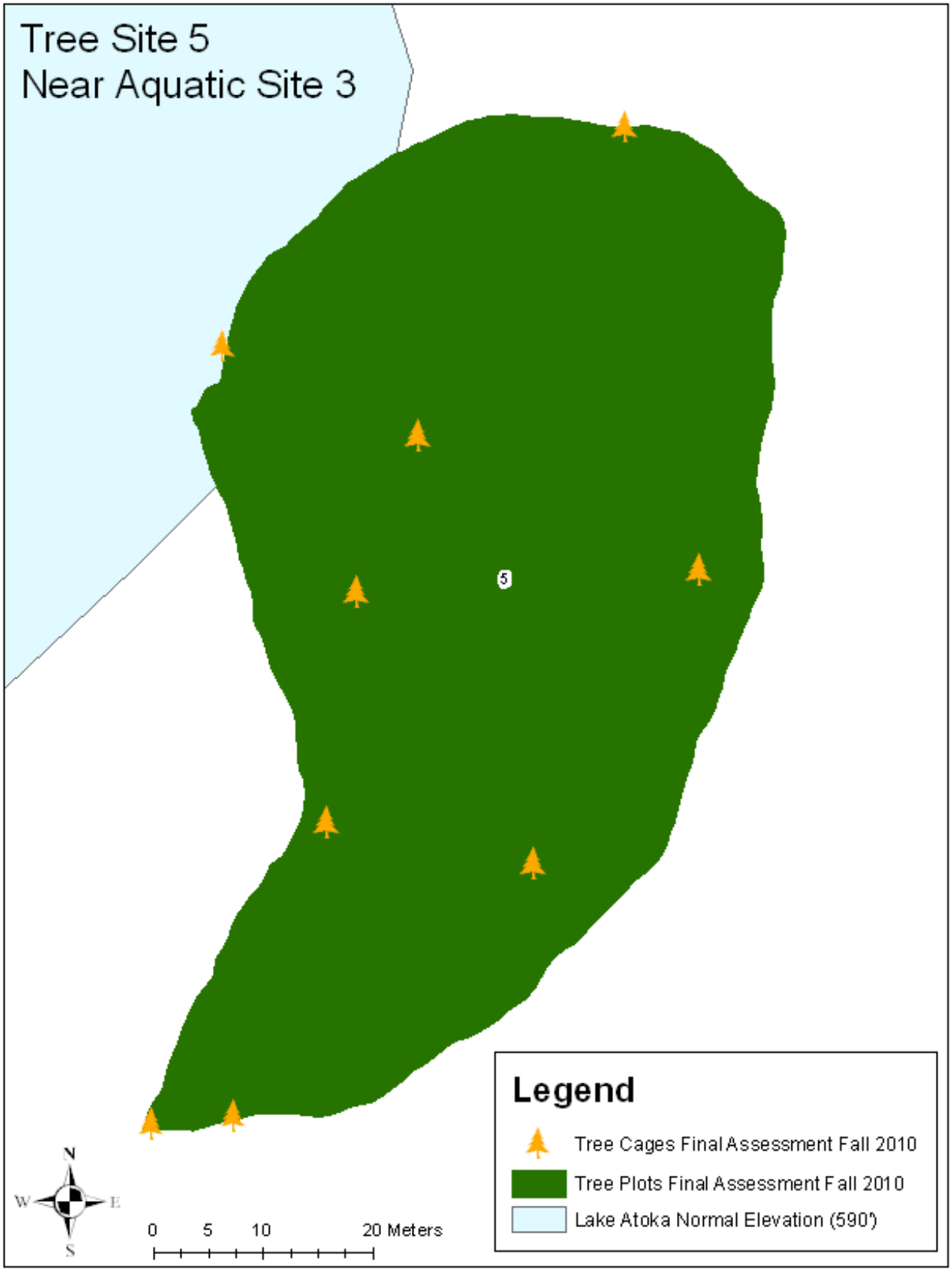

Tree Sites 1, 2, 8, 9, 10, 11 and 12
In relation to Aquatic Plant Site 4
Legend
Aquatic Plant Sites
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
N
W
E
S
0 125 250 500 Meters

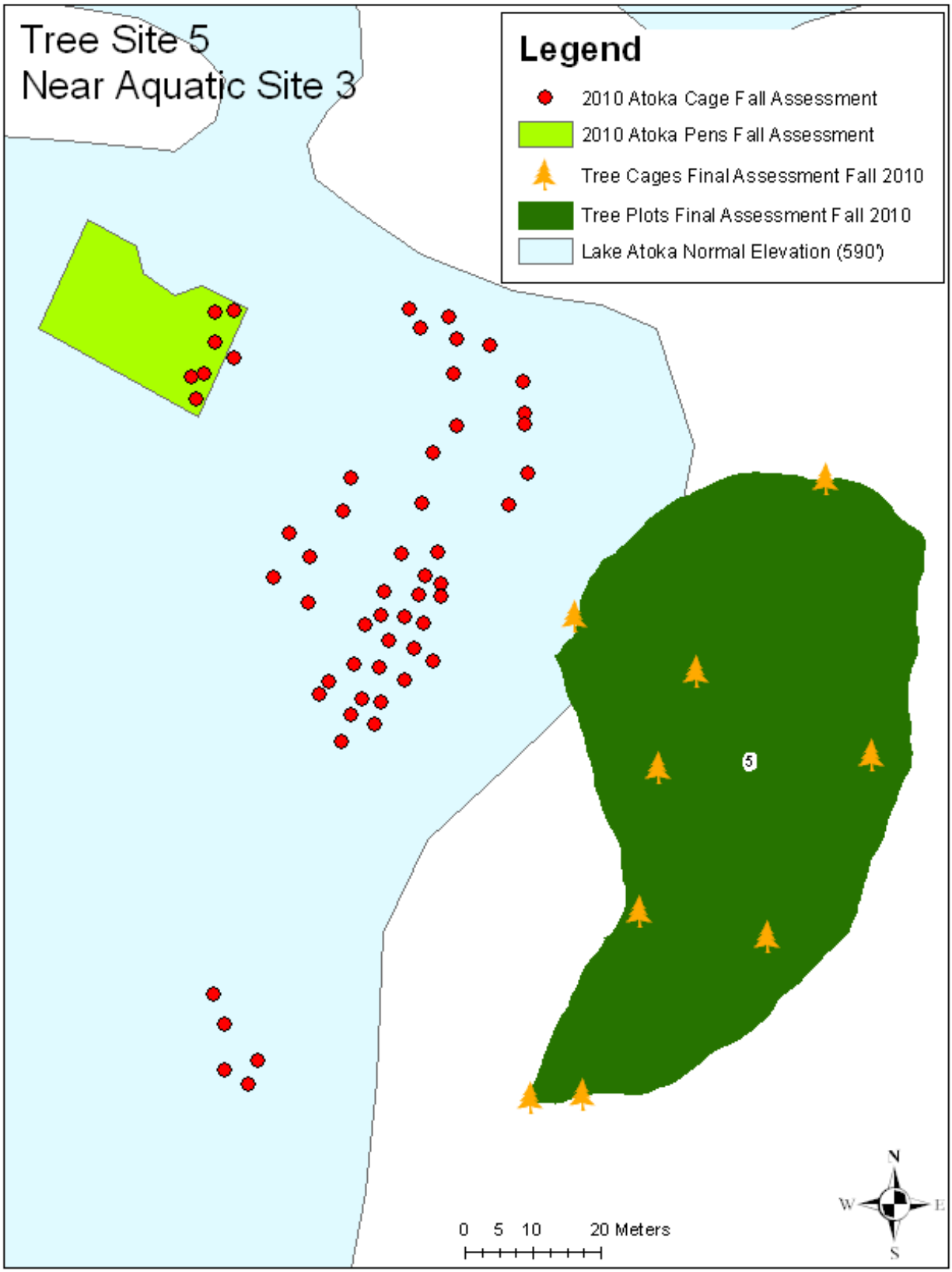

Tree Site 3
Near Aquatic Site 5
3
N
W
E
S
0
3.5
7
14 Meters
Legend
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010

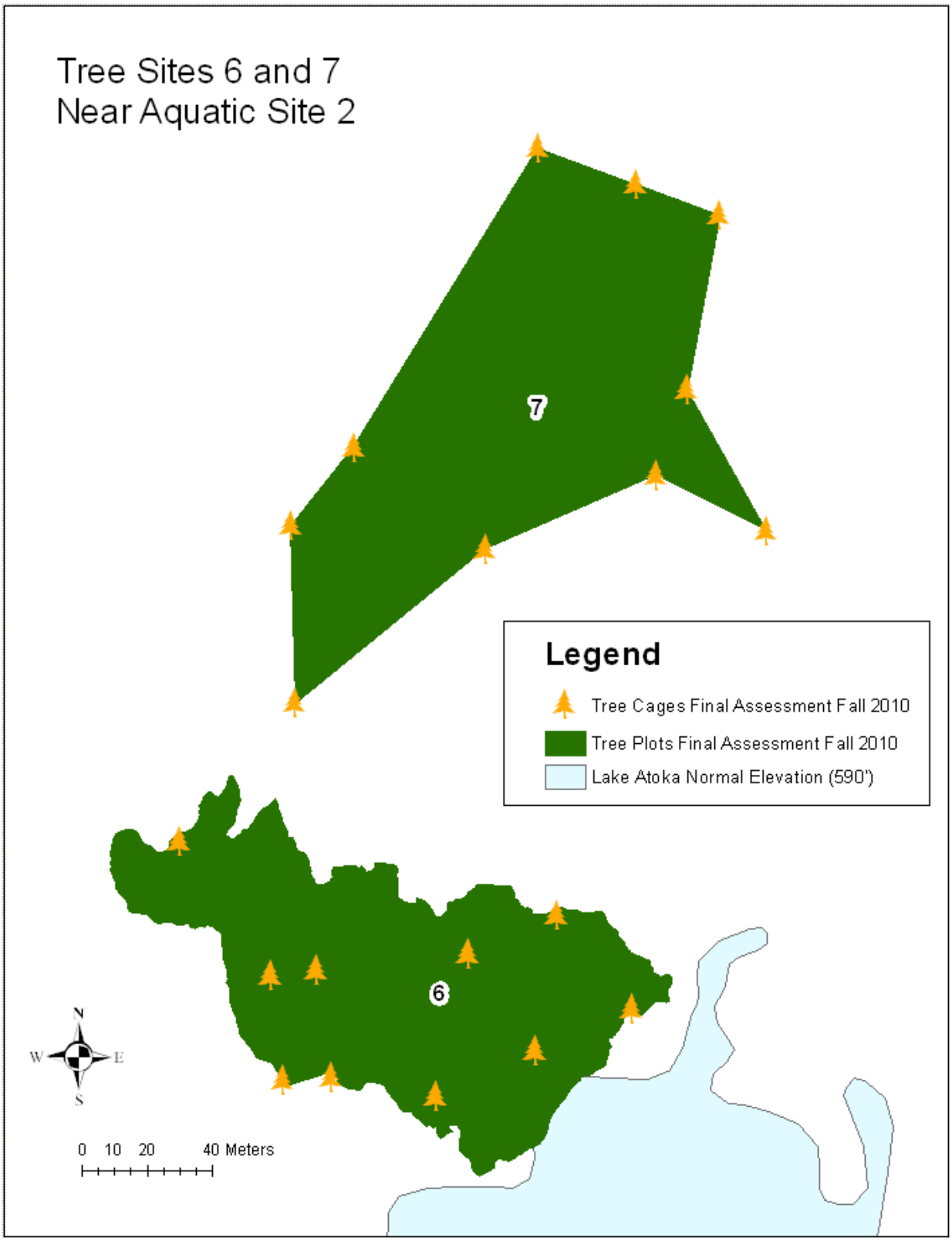

Tree Site 3
Near Aquatic Site 5
Legend
2010 Atoka Cage Fall Assessment
2010 Atoka Pens Fall Assessment
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
3
585
580
575
Lake
N
W
E
S
0 12.5 25 50 Meters

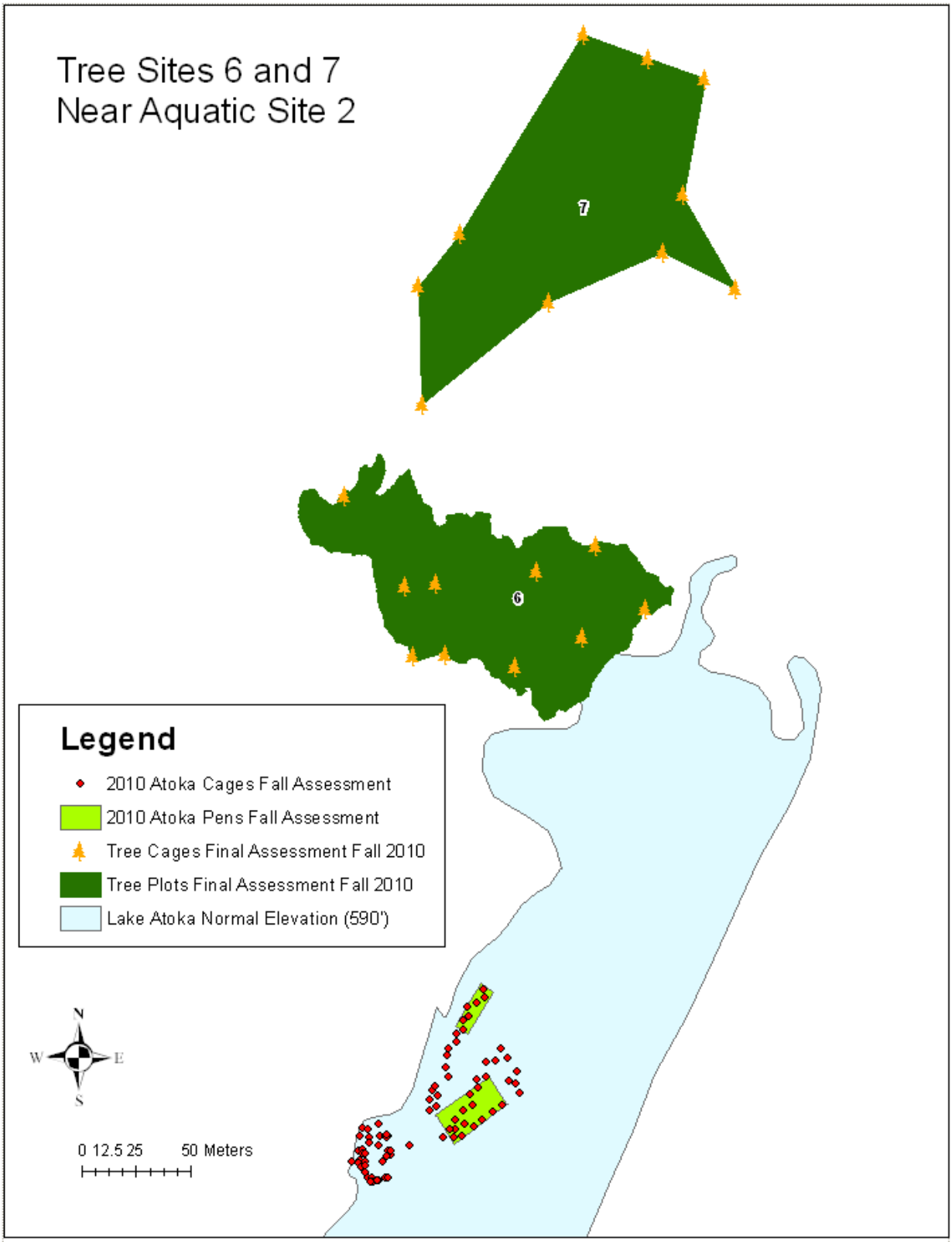

Tree Site 4
Near Aquatic Site 1
4
Legend
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
N
W
E
S
0 5 10 20 Meters


Tree Site 4
Near Aquatic Site 1
4
Legend
2010 Atoka Cage Fall Assessment
2010 Atoka Pens Fall Assessment
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
0 25 50 100 Meters
N
W
E
S
585


Tree Site 5
Near Aquatic Site 3
5
Legend
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
N
W
E
S
0
5
10
20 Meters


Tree Site 5
Near Aquatic Site 3
Legend
2010 Atoka Cage Fall Assessment
2010 Atoka Pens Fall Assessment
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
5
0 5 10 20 Meters
N
W
E
S


Tree Sites 6 and 7
Near Aquatic Site 2
7
6
Legend
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
N
W
E
S
0 10 20 40 Meters


Tree Sites 6 and 7
Near Aquatic Site 2
7
6
Legend
2010 Atoka Cages Fall Assessment
2010 Atoka Pens Fall Assessment
Tree Cages Final Assessment Fall 2010
Tree Plots Final Assessment Fall 2010
Lake Atoka Normal Elevation (590')
N
W
E
S
0 12.5 25 50 Meters

Appendix D – Photo Monitoring

Photo-monitoring results did not go as expected. There were several unanticipated events that made this monitoring more difficult than originally anticipated.

In essence, all sites had 2 photos taken at each fall assessment. Photo-points were staked, flagged, and logged by GPS at each site to ensure that a photo was captured from the same location, year after year. In each photo, a completed photo sign form was to be in the shot to properly document location, date, and time.

While this methodology sounded good in the planning stages, it became evident by the end of the second season that there were problems with the method. The lake came up several feet and remained up. This had several consequences on photo-monitoring.

- Water was high and completely covered plots that had previously been wholly visible;
- Terrestrials grown amongst the plots confounded any assessment early in the season.
- Flagging was washed out and no longer in place at many of the sites;
- Photo and Camera points were dependent on GPS which could be several feet off from actual and did not sufficiently help to find the exact flagged point;
- When GPS signal was unavailable, photos points could not be located;
- Photo sign forms were left behind for the final 2010 assessment, so documentation was carefully logged on paper and labels have been added to all 2010 photo-point images in the office (see photos below).

The 2008 photos can be seen in Figure 45 -Figure 54, the 2009 photos are in Figure 55 -Figure 64, and the final assesment photos from the fall of 2010 can been seen in Figure 65 -Figure 74.

2008

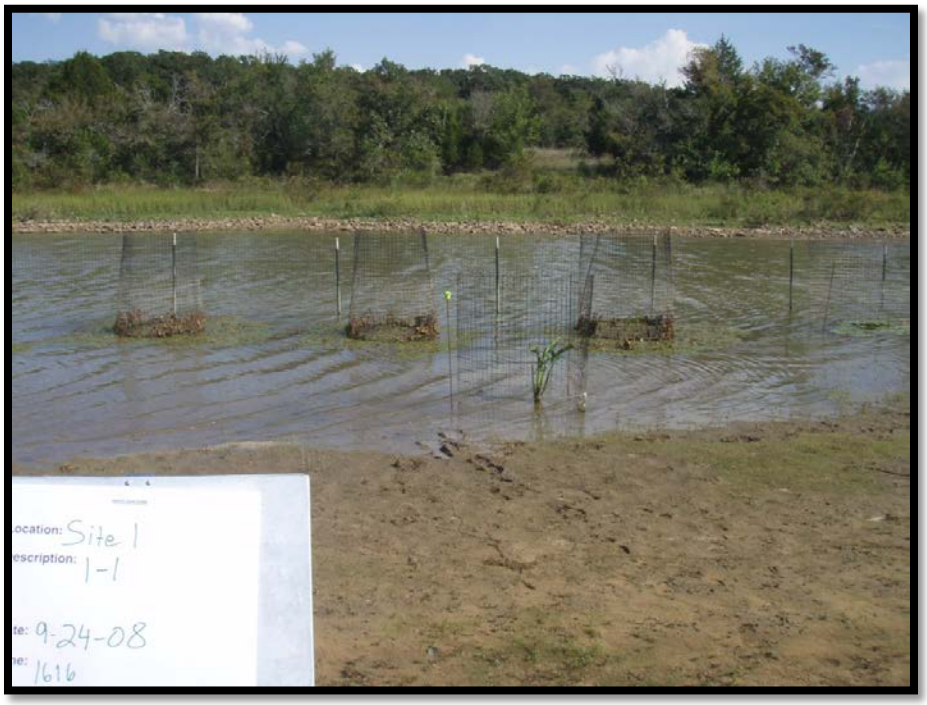


Figure 45: Site 1 (Photo Point 1) 2008

Figure 46: Site 1 (Photo Point 2) 2008

Figure 47: Site 2 (Photo Point 1) 2008

Figure 48: Site 2 (Photo Point 2) 2008

Figure 49: Site 3 (Photo Point 1) 2008

Figure 50: Site 3 (Photo Point 2) 2008

Figure 51: Site 4 (Photo Point 1) 2008

Figure 52: Site 4 (Photo Point 2) 2008

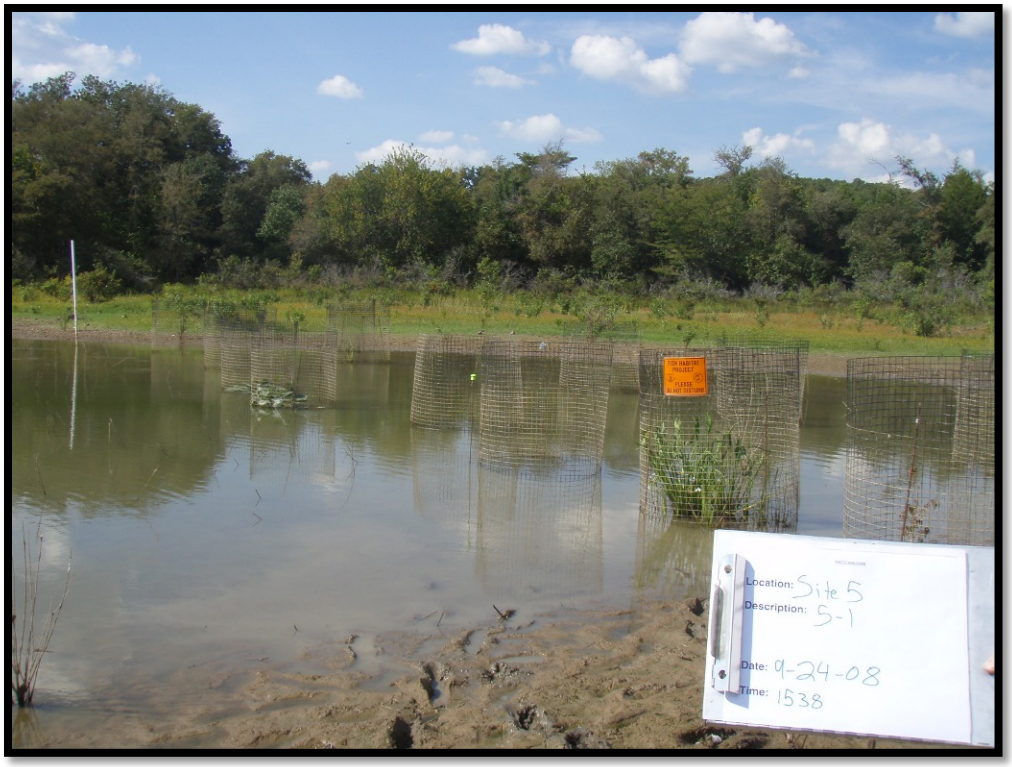


Figure 53: Site 5 (Photo Point 1) 2008

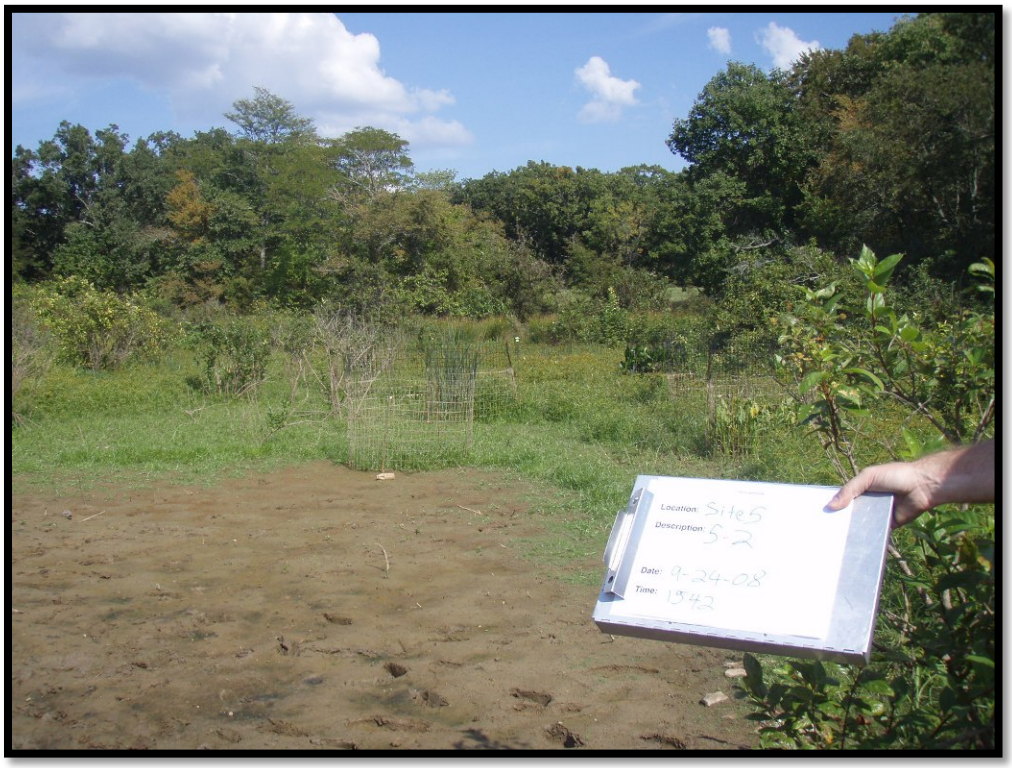


Figure 54: Site 5 (Photo Point 2) 2008

2009

Figure 55: Site 1 (Photo Point 1) 2009

Figure 56: Site 1 (Photo Point 2) 2009

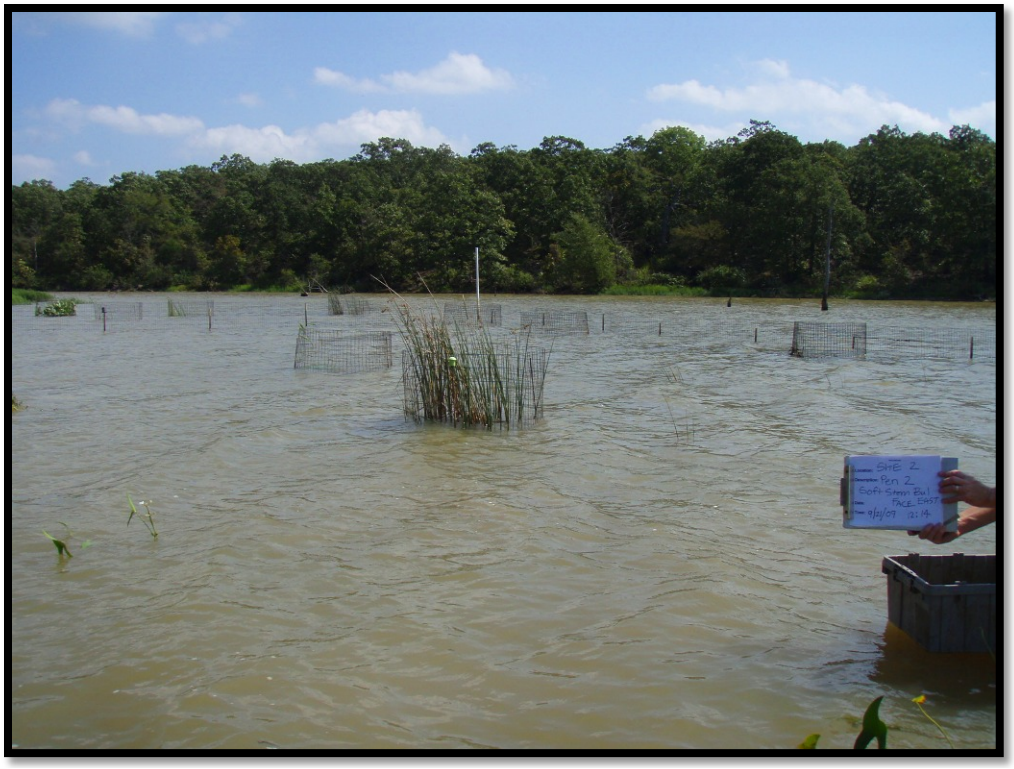


Figure 57: Site 2 (Photo Point 1) 2009

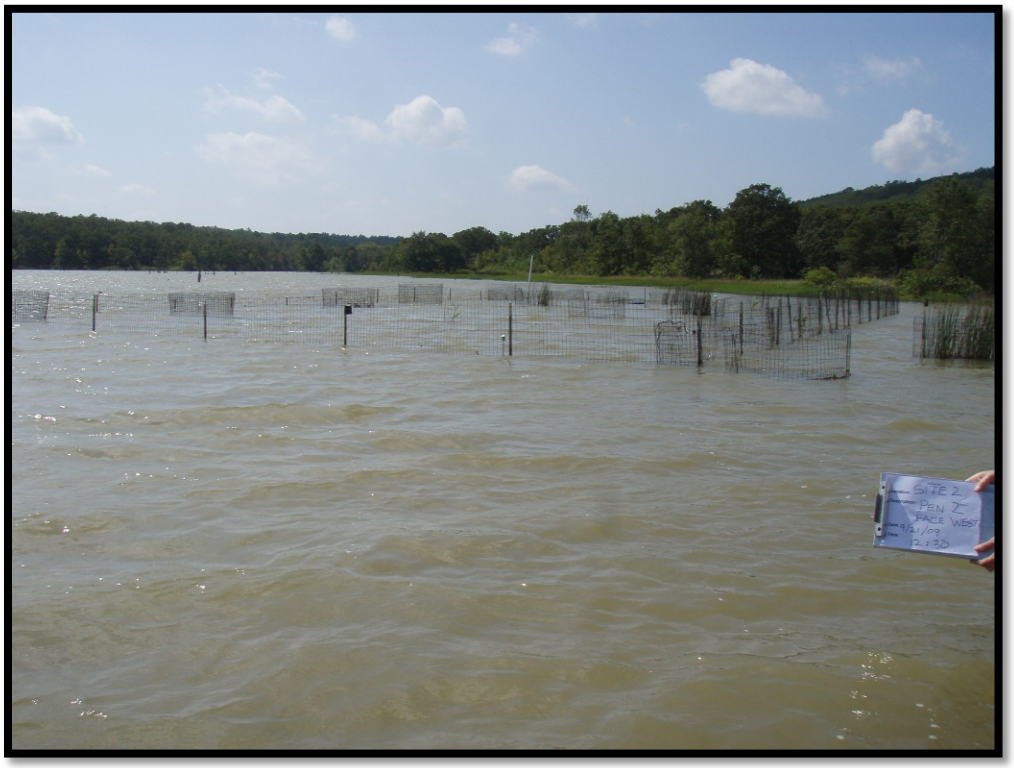


Figure 58: Site 2 (Photo Point 2) 2009

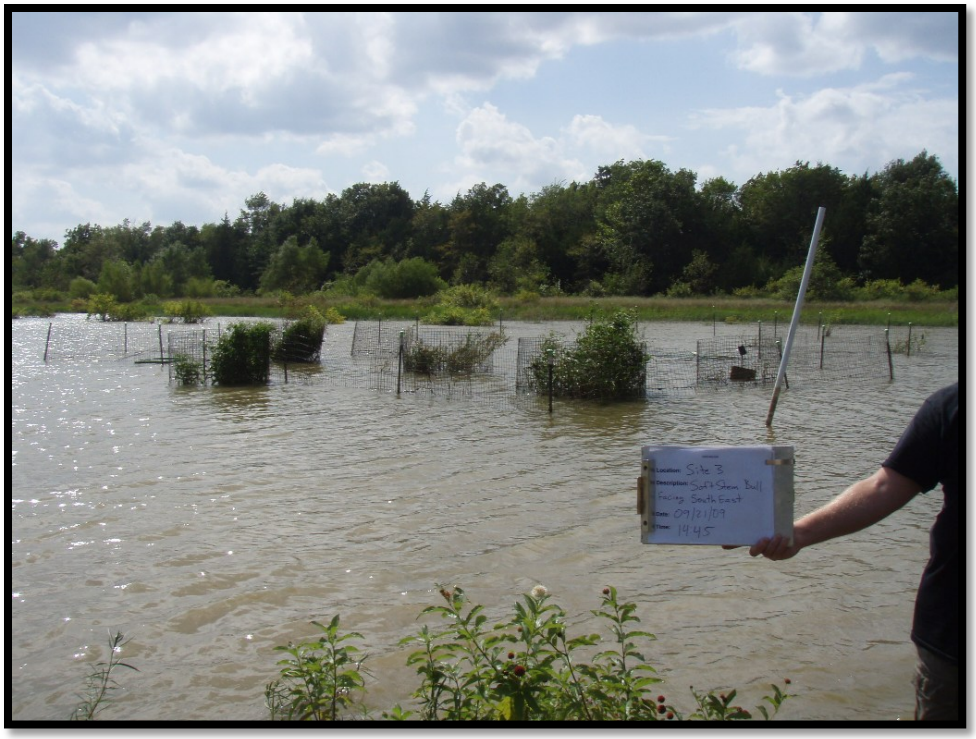


Figure 59: Site 3 (Photo Point 1) 2009

Figure 60: Site 3 (Photo Point 2) 2009

Figure 61: Site 4 (Photo Point 1) 2009

Figure 62: Site 4 (Photo Point 2) 2009

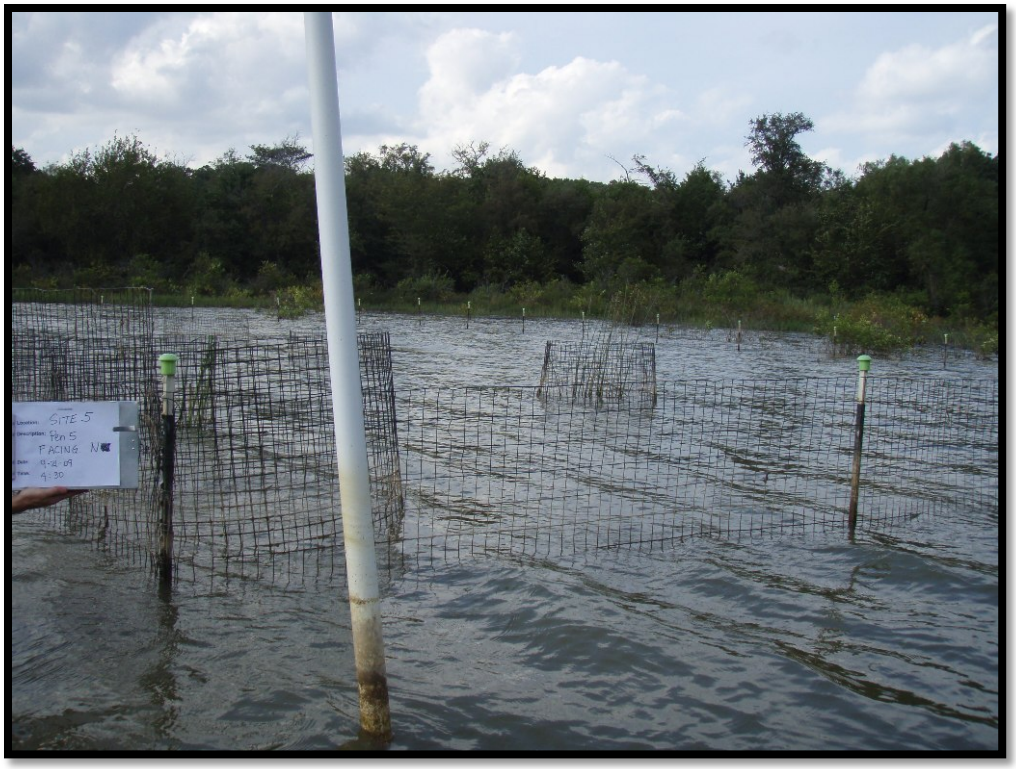


Figure 63: Site 5 (Photo Point 1) 2009

Figure 64: Site 5 (Photo Point 2) 2009

2010

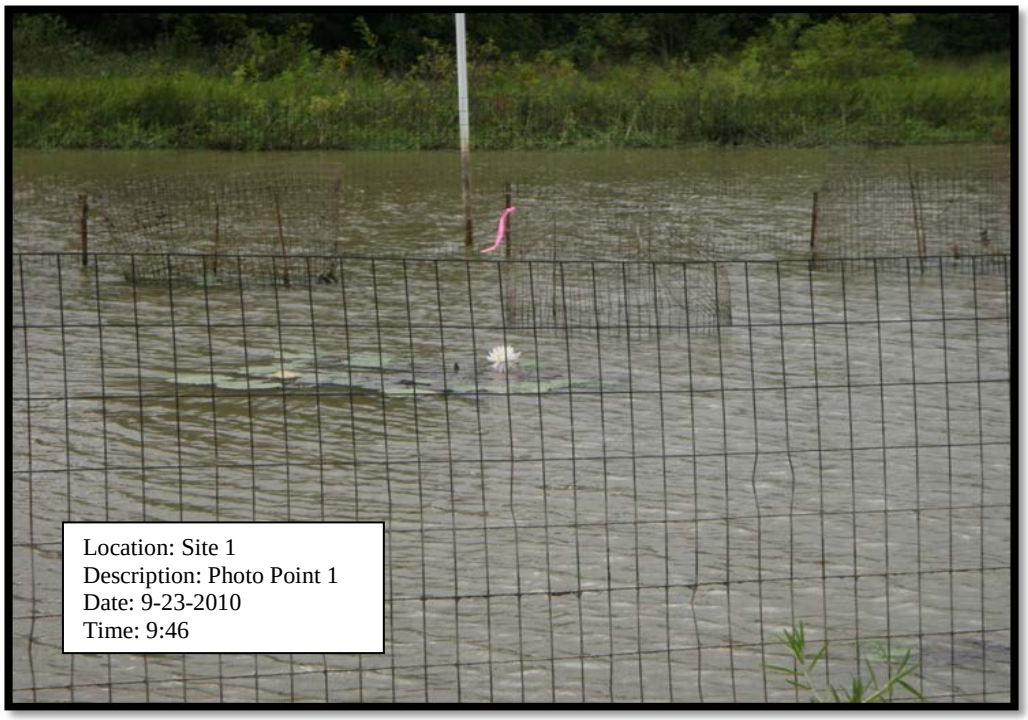


Figure 65: Site 1 (Photo Point 1) 2010

Figure 66: Site 1 (Photo Point 2) 2010

Figure 67: Site 2 (Photo Point 1) 2010

Figure 68: Site 2 (Photo Point 2) 2010

Figure 69: Site 3 (Photo Point 1) 2010

Figure 70: Site 3 (Photo Point 2) 2010

Figure 71: Site 4 (Photo Point 1) 2010

Figure 72: Site 4 (Photo Point 2) 2010

Photo Unavailable

Figure 73: Site 5 (Photo Point 1) 2010

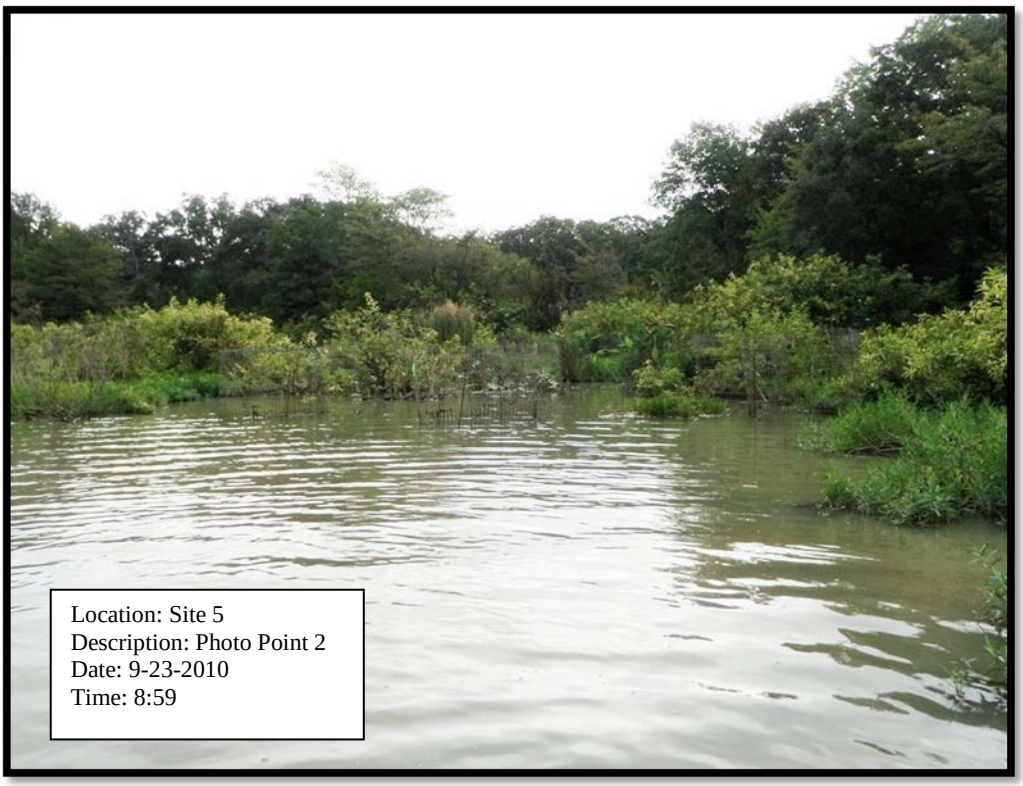


Figure 74: Site 5 (Photo Point 2) 2010

Appendix E - Letter from Oklahoma Forestry Services regarding Tree Assessment

RECEIVED
JAN 26 2011
Oklahoma Water Resources Board

State of Oklahoma
Department of Agriculture, Food, and Forestry

Mary Fallin
Governor

Jim Reese
Secretary of Agriculture

January 21, 2010,

Sara Ivey
Enviromental Specialist
Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, Ok. 73118

Sara,

I want to thank you for inviting me to go with your crew on the tree planting and survival assessment at Atoka Lake. A few things that I saw while we were doing the assessment that might have hindered the survival in some areas were as follows:

First, some of the areas soils were not suitable for the species of trees that were planted. We saw this in several areas, where some species were doing great and other were almost a 100% failure. If replanting these areas is an option, then you should use the research gathered from these plantings and survival checks to establish the types of trees to use.

Second, there seemed to be a large amount of herbaceous cover on these sites. Having a large amount of herbaceous cover (grasses & weeds) can hinder tree establishment and survival, by robbing soil nutrients, water and sunlight from the trees that you are trying to establish here. Before replanting there should be a plan in place to control these herbaceous plants while the new seedlings are trying to get established.

These are the major problems that I seen during the assessment and I know that your time and resources are limited. But I think with improving in these two areas, we could increase your survival greatly.

Again, I would like to thank you for letting me go with your crew that day and I hope the information I have provided can help with planting in the future. If there is anything else I can help you with in the future, just give me a call at 580-298-5255 or email me @ chris.joslin@oda.state.ok.us .

Sincerely,

Chris Joslin
Forester III
Antlers,Oklahoma, District 3-SE Area

2800 N. Lincoln, Oklahoma City, OK 73105 • (405) 522-5719
jim.reese@oda.state.ok.us

Appendix F – Water Quality Data

See Enclosed CD