Final Report & Recommendations
for GRDA Fish & Wildlife Mitigation Project

Oklahoma Water Resources Board
Lewisville Aquatic Ecosystems Research Facility

Feasibility of Establishing Native Aquatic Plants in Grand Lake

Table of Contents

PROJECT SUMMARY

Overview:

This Grand River Dam Authority (GRDA) project is a three-year contract with the Oklahoma Water Resources Board (OWRB) to evaluate best planting methods, species and elevations specific to Grand Lake. This evaluation was to provide a valid plan of action for establishing littoral plants throughout Grand Lake over the ensuing 20 years. The contract averaged $125,000/year for a project total of $375,000. The contract stipulated a minimum total of 5 acres of lake area planted with evaluations and recommendations reported.

OWRB subcontracted a portion of the work. The Lewisville Aquatic Ecosystem Research Facility (LAERF) provided expert consulting regarding field efforts, monitoring & nursery facilities. The Oklahoma Department of Wildlife Conservation (ODWC) furnished labor and nursery facilities.

Project Conclusions:

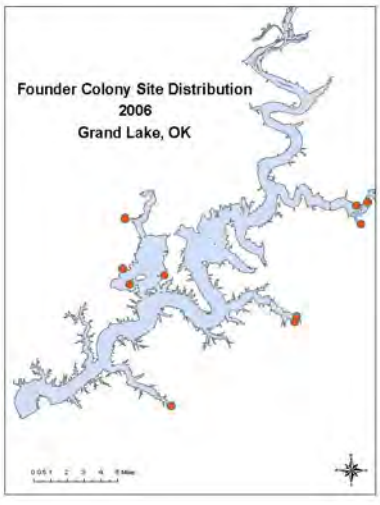
- Founder colonies can be successfully established in Grand Lake
- Site enhancement rather than expansion should be the focus for any subsequent work, as unprotected expansion by plants has not persisted beyond one season.
- We expect to see substantial surviving unprotected plants over the next 4 years with continued maintenance.

Project Recommendations:

A. Maintain and enhance current founder colonies for maximum seed and plant fragment production
B. Target Species focusing efforts at Target Elevations by encompassing ring cage founder colonies with large pens (see p. 26).
C. Monitor sites 4 times each year (corresponding to rule curve)
D. Survey areas remote to colonies checking for widespread establishment
E. Revegetation trial efforts should now begin on Hudson Lake. The successful establishment of founder colonies in Grand Lake suggests that Hudson Lake will likely accept plantings as well.

Project Performance:

A. 10 founder colonies in place over four arms of Grand Lake
B. 12+ acres planted exceeding the 5 acre commitment
C. 25 native aquatic plant species utilized; twelve emergent, three floating leaved, ten submersed
D. Challenges still remain:
    - Water Level fluctuations – Emergents were successful from 742’ to 744’ msl. Submersed plants work best in pens at 740’ to 741’ msl where cages are not overtopped by water.
    - Herbivory - Exclosures are critical. 2”x4” wire works for emergent plants while 2”x2” mesh needed for submersed plants. Shallow depths reduce herbivory pressure.



Supporting Pictures:

Figure 1: Typical founder colony layout; Site 5 "Honey Creek " 9-13-06 741.25' msl

Figure 2: Two-year emergent plant growth at Honey Creek Site 5; 11-8-05

Figure 3: Ten months later: Close up of *emergent* species spread at Honey Creek Site 5, 9-13-06

Figure 4: Successful *submersed* plant colony at Horse Creek Site 1; 9-13-06. Pen constructed 1-5-06

Figure 5: Examples of submersed plant reproduction at Site 1 “Bird Island” 9-14-06

Figure 6: Emergent plant establishment after *4 months of growth*; Site 8 "Cayuga", 9-13-06

FINAL REPORT

Background

Beginning in 2004 the Oklahoma Water Resources Board (OWRB) entered into an agreement with the Grand River Dam Authority (GRDA) to establish native aquatic vegetation in Grand Lake. This project was purposed to determine the feasibility for establishing aquatic plant growth lake-wide as a potential a long-term mitigation technique to populate the lake over 20 years. With funding from GRDA, OWRB contracted with LAERF for their technical expertise and enlisted ODWC for their assistance to establish protected plantings in the lake. The goals set were for a minimum of 5 acres planted over three years and to establish a long-term planting regime including plant species, protection methods and planting levels for the target species.

Approach

Aquatic vegetation does not become established easily in man-made reservoirs. Many species that may be suitable are often not found in the immediate vicinity of newly impounded reservoirs, and therefore no propagules are readily available for their establishment. The few propagules that may be brought in (by waterfowl, boaters, etc.) often face harsh environmental conditions (e.g., fluctuating water levels and/or high turbidities) or are predated upon by grazers such as common carp (*Cyprinus carpio*) and semi-aquatic turtles (mostly Emydids). In the meantime, absence of vegetation causes ecosystem components to suffer (e.g., poor fishery development), or provides open niches for invasion by exotic species, such as hydrilla (*Hydrilla verticillata*) or Eurasian water milfoil (*Myriophyllum spicatum*), which may result in degraded water quality, poor wildlife habitat, and interference with resource uses. Although natural establishment does sometimes occur in reservoirs in a relatively short period, it may take many, many years before it occurs in others (Grand Lake appears to be in this category): shortening the process of natural establishment of native aquatic plants will therefore greatly benefit a lake.

Because the large size of most reservoirs precludes full-scale establishment, in recent years the goal of native aquatic vegetation restoration has been the establishment of *founder colonies*. Founder colonies provide immediate small-scale habitat improvement and, more importantly, serve as sources of propagules for spread to other parts of a lake. Based upon studies conducted by LAERF in Texas reservoirs, founder colonies are capable of giving rise to significant lake-wide vegetation when provided maintenance for long-term viability. The product of this project was the establishment of founder colonies at various locations in the lake to serve as propagule sources for intra-lake spread in subsequent years.

Our approach to establishing native vegetation utilizes pioneer species (nearly all plants that we use are prolific seed and/or fragment producers), but more importantly addresses factors that influence many reservoirs' ecological state of equilibrium (e.g., turbid and lacking vegetation). Abiotic and biotic factors contribute to this state, and when these factors are overcome, a shift to a more desirable alternate state (e.g., clear and vegetated) can be reached. In the case of Grand Lake (and most southern reservoirs), two major limiting factors include water level fluctuations and herbivory. Fluctuating water levels in reservoirs are often exacerbated by human needs (e.g., flood control, power generation, municipal water supply, etc.), with high and low water periods occurring over greater periods and/or more frequently than might occur naturally, interrupting critical periods needed for plant establishment from limited propagule sources. At the same time, most reservoirs support significant populations of grazers, many of which are omnivorous and thrive in the absence of plants. When establishing founder colonies, we strive to overcome these limitations by planting mature propagules at multiple depths and protection with cages. These mature plantings are capable of withstanding harsher conditions than seedlings or other weak propagules, and are more likely to establish successfully. Once established, founder colonies then produce propagules of desirable species not otherwise available in the reservoir; once propagules are produced in sufficient quantities (e.g., seed bank development) and conditions are suitable (e.g. moderation of water level fluctuations conditions), natural colonization by both r- and k-selected species begins to occur.

LAERF's findings in Texas reservoirs suggests that founder colonies will successfully begin colonization once well established---those species maintained in founder colonies give rise to new, remote colonies covering larger areas than the founder colonies themselves. Although no models have been developed to predict large-scale spread, we do know that it has not occurred when founder colonies are allowed to diminish (cage degradation, etc.). Long-term maintenance appears to be critical for success. We do not know how large founder colonies need be, nor how many founder colonies are necessary for large-scale spread to occur. However, we do know that a single founder colony similar in size to each site in Grand Lake has consistently resulted in significant spread (spread of plants to more than double founder colony size) in large reservoirs, with increases to at least 25 times the areas planted in our studies in seven cases. While we assume (from smaller-scale systems) that greater numbers of colonies planted over a wide distribution will result in more rapid spread, we are not clear on time frames required for large-scale spread to occur. However, our experience suggests that it typically takes two or three years to establish founder colonies in larger systems, mostly due to figuring out which species, depths, and protection needs are most appropriate for a given system. Following successful establishment, we usually see spread begin in the 3rd to 7th year following initial plantings.

In our opinion, the current status in Grand Lake now is: after two and one half growing seasons, we have at least six well established sites of founder colonies, and likely ten---we define established founder colonies as those that exhibit recovery (re-growth) following seasonal variation (winter to spring) or ecological disturbance (e.g. changing water levels). Secondary to this definition is that an established founder colony produces propagules during appropriate times (most of the growing season), which appears to be occurring in Grand Lake. As long as these colonies are maintained (fix damaged cages, replant lost plants, etc.), propagule production will continue, and we anticipate spread to begin occurring within the next few years.

Plants

Table 1 below details the species planted in Grand Lake and denotes those that exhibited the best out of cage expansion, seed, fragment and vegetative reproduction. Moreover, it categorizes the plants into the species by their success in Grand Lake and includes a category for "volunteer plants" that, while desirable, were actually secondary non-targeted plants that came up within pots of the targeted plants. Native aquatic plant species, as opposed to introduced or exotic species, were selected because they provide suitable habitat for fish and other wildlife, and typically do not become problematic due to weedy overgrowth. In general, species selected for this project occur statewide, and many had been successfully introduced and established in other lakes in and around Oklahoma. A diversity of native plants was selected for initial (1^{st} year) testing in order to identify those species most suitable for establishment; additional species were added during the 2^{nd} year. Site expansion, addition, and re-plantings focused on species deemed most successful during the first two years.

Three aquatic plant growth forms (submersed, floating-leaved, and emergent) were used in this project. Submersed forms have leaves and stems found beneath or at the water surface and generally colonize 1 ft and deeper water up to about 10 ft. Floating-leaved forms generally do not have permanent subsurface leaves and typically occur in 2 to 6-ft water**.** Emergent forms are usually found in water less than 2-ft deep as well as moist soils.

Predominantly, well-established propagules were used in this project. Local plants were grown from shoot fragments, tubers, or bare root plants in 4- or 6-in diameter nursery pots in culture facilities for a period ranging from six weeks to one year. Experience has shown that potted plants offer the best chances of successful transplanting into reservoirs (as opposed to bare-root plants, tubers, fragments, or seed). Submersed potted plants included native volunteer species (southern naiad, horned pondweed, slender pondweed, and muskgrass) deemed desirable for Grand Lake. In addition, coontail (a non-rooted species) was transplanted from field-collected stem masses.

Plant Nursery at Porter

2,905 plants were produced in the nursery in 2006. Of those, 743 plants were provided for out-planting. Total capacity of the nursery is 3,432 plants in 6" pots. Total plant numbers by species and expenditures are found in the ODWC summary report in Appendix B. Not all plants were planted because the sites are limited by number of cages. Caging material is expensive and is a limiting factor. Maintaining and planting the 800+ cages currently in the lake is labor intensive and also limits the number of plants put into the lake.

The third year was a successful year in growing some submersed species, namely Potamogeton illinoensis, Potamogeton americana, Vallisneria americana and Heteranthera dubia. Emergent plants were large and healthy and performed well overall in the lake. LAERF provided bare root and apical tip propagules to ODWC for culture of potted plants at their Porter, OK facility. Development of this nursery provided a local source of suitable propagules for use in the project and relieved project dependence on LAERF for plants. In addition to plants, LAERF supplied instruction on construction and operation of the nursery facility, which was, by the third year, capable of producing most plants needed for the project.

Figure 7: Nursery ponds at ODWC Porter Office; Winter 2006

Table 1. Twenty-five native aquatic plant species planted in Grand Lake, Oklahoma.

Common name	Scientific name	Growth form	Years planted
Successful Species at most or all sites (Primary Target Species for future work)			
Bulltongue[1,2]	*Sagittaria graminea*	Emergent	1,2 & 3
Softstem bulrush[1,2]	*Schoenoplectus tabernaemontani*	Emergent	1,2 & 3
American pondweed[1,2]	*Potamogeton nodosus*	Submersed/floating-leaved	1,2 & 3
Illinois pondweed[1,2]	*Potamogeton illinoensis*	Submersed	1,2 & 3
Commonly Successful Species (Secondary Target Species for future work)			
River bulrush[2]	*Scirpus fluviatilis*	Emergent	2 & 3
Wild celery	*Vallisneria americana*	Submersed	1,2 & 3
Water stargrass[1]	*Heteranthera dubia*	Submersed/floating-leaved	1,2 & 3
Arrowhead[2]	*Sagittaria latifolia*	Emergent	1,2 & 3
Coontail[3]	*Ceratophyllum demersum*	Submersed	2 & 3
Less Successful Species			
Water willow	*Justicia americana*	Emergent	1,2 & 3
Pickerelweed[1]	*Pontederia cordata*	Emergent	1,2 & 3
Creeping burhead[2]	*Echinodorus cordifolius*	Emergent	2 & 3
Tall burhead[1]	*Echinodorus berteroi*	Emergent	1 & 2
Squarestem spikerush[2]	*Eleocharis quadrangulata*	Emergent	1,2 & 3
Flatstem spikerush[2]	*Eleocharis macrostachya*	Emergent	2
American bulrush[2]	*Schoenoplectus americanus*	Emergent	1,2 & 3
Water hyssop	*Bacopa monnieri*	Emergent	2 & 3
White water lily[2]	*Nymphaea odorata*	Floating-leaved	1,2 & 3
Spatterdock	*Nuphar luteum*	Floating-leaved	2
American lotus[2]	*Nelumbo lutea*	Floating-leaved	2
Sago pondweed	*Potamogeton pectinatus*	Submersed	1 & 2
Desirable Volunteer Species			
Southern naiad[1]	*Najas guadalupensis*	Submersed	1,2 & 3
Muskgrass	*Chara vulgaris*	Submersed	1,2 & 3
Slender pondweed	*Potamogeton pusillus*	Submersed	1,2 & 3
Horned pondweed	*Zannichellia palustris*	Submersed	1,2 & 3

[1] Exhibited substantial reproduction from seeds and/or fragments outside of cages
[2] Exhibited substantial vegetative spread outside of cages
[3] Coontail was not particularly successful, its ease of collection and propagation and the quality of habitat that it provides qualifies this plant as a “Target Species”.

Site selection

Five sites were selected in July 2004 for establishing founder colonies in Grand Lake, including four sites located in Horse Creek and one in Honey Creek. Two major criteria were used in selecting these sites: 1) protection from wind and wave action and 2) substrate texture. Waters associated with coves tended to be less turbid and afford greater light penetration, therefore allowing greater potential survival of submersed plants. Additionally, reduced wave action lessens the probability of newly planted propagules being washed out or being covered by shifting sediments. Substrates at sites selected ranged from sandy to muddy to permit rooting by plants; hard-packed clay and gravelly or rocky bottoms were avoided.

Five additional sites were selected and constructed in the 2nd and 3rd years of the project, including three in Elk River, one in Honey Creek, and one in Drowning Creek. Additionally, a small demonstration site was installed at Bernice State Park in the 3rd year.

Obstacles

Two major obstacles had to be overcome in order to establish aquatic vegetation founder colonies in Grand Lake: 1) water level fluctuations and 2) herbivory.

Water level fluctuations: Aquatic plants, dependent upon growth form---emergent, floating-leaved, or submersed--- establish most readily at shallow depths. We initially conducted multiple depth plantings of each species, placing most within the anticipated range of fluctuation due to the Federal Energy Regulatory Commission mandated rule-curve (mandated target lake levels) and actual historic water levels in the lake, with some planted deeper than likely to survive (unless full pool was not realized) and some planted shallower (in case water levels exceeded rule-curve elevations for significant periods). As the project progressed, elevation ranges for establishing each species were ascertained and subsequent plantings of each focused on those elevations.

For the most part, emergent species establish best in moist soil to very shallow water, usually less than 1-ft deep. Once well established, however, many of these plants can tolerate depths of 2 ft or more; emergent plants generally do not persist at depths of 3 ft or greater for long periods, and initial planting at depths greater than 1½ ft usually results in mortality. At the same time, emergent species are very tolerant of dry conditions, with many continuing to grow during periods of low water. In general, planting emergent species in shallow water, or even moist soil, is the best approach to establishing these species. However, we selected planting elevations outside the ideal depths regarding the rule-curve in Grand Lake to evaluate whether: 1) conditions in the lake were such that emergent plants could become established in depths outside our knowledge base, and 2) water levels did not match rule-curve goals, permitting establishment outside the normal range for these plants. Overall, we initially planted emergent species as deep as 740 ft msl (1-ft deep at lowest pool and 4-ft deep at highest pool) and as shallow as 744.5 ft msl (exposed at low pool and moist soil at high pool).

Floating-leaved and submersed plants are more suitable for deeper water and are generally less tolerant of dry conditions than emergent species. Both, however, establish best at relatively shallow depths (1 to 3 ft); once established these plants can thrive in deeper water. Unfortunately, planting within such a narrow depth range often subjects the plants to excessive flooding (sustained high water may starve plants by reducing light availability) or dry periods; both cases may result in loss of new plant colonies. While water levels in Grand Lake are generally more predictable than in many other reservoirs, variation from the lake's rule-curve was expected to occur, so plants were planted in a greater range of depths than that of ideal for their establishment. In general, these plants were installed from 742 ft msl to 738 ft msl. Shallower plantings (to 743 ft msl) of American pondweed, white water lily, and American lotus were made because of their ability to tolerate long-term exposure during low water periods. It was anticipated that these plants would flourish in shallow water during high pool, producing subterranean structures robust enough to survive low water periods.

Herbivory: Establishment of new colonies of aquatic plants in most reservoirs requires protection from herbivores, and Grand Lake was no exception. Large omnivores, most notably common carp and semi-aquatic turtles, often prove most problematic (along with terrestrial grazers during low water periods), and measures were taken to limit their impacts on vegetation. The majority of plantings in Grand Lake were protected from herbivores using several exclosure designs that have proven successful in other lakes. Some plants were left unprotected to evaluate overall herbivore impacts and establish the need to commit resources to building protective exclosures. Initially, the majority of plants were protected with 3-ft diameter ring cages constructed from 2-in x 4-in mesh, PVC-coated welded wire (Figure 1). Because the herbivore population in Grand Lake was unknown, a single ring cage of each submersed species was wrapped with finer mesh (1-in hexagonal wire) at each site to evaluate the need to protect from smaller grazers. Additional plants were protected with larger pens constructed from T-posts (15-ft x 30-ft) and 2-in x 4-in mesh PVC-coated welded-wire.

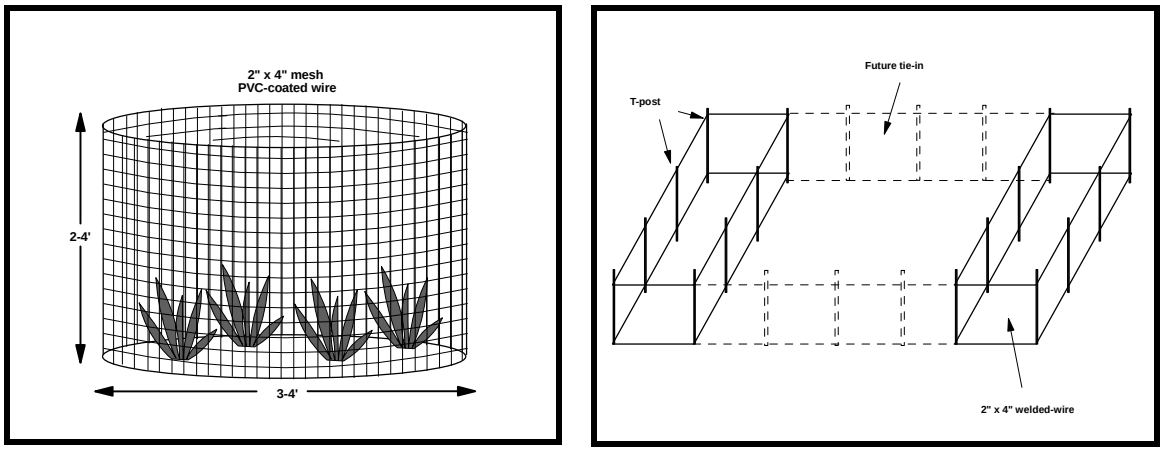


Figure 1. For the most part, plants were protected from herbivores with ring cages (left) and pens (right). In some cases, pens were installed around established ring cages to increase growing area propagule production.

As the project progressed, modifications were made to existing exclosures and new exclosure construction as determined by results from earlier plantings. In general, it was ascertained that emergent species could be adequately protected using larger mesh (2-in x 4-in) ring cages and pens; submersed and floating-leaves species were protected best using finer mesh (no larger than 2-in x 2-in mesh). In all cases, PVC-coated wire was most successful, as other materials tended to degrade within a single growing season.

General Evaluation

Previous annual reports (2004 and 2005) focused on ascertaining suitable species and methods for establishing them, as determined by growth factors reported. This evaluation regards longer-term establishment of species based upon their continued presence, general health (as determined by increase in biomass), and production of propagules, all signs of a mature plant colony; the measure of success in the third year was based upon maturity of founder colonies. Spread and establishment of propagules within and around founder colonies is also reported, as this is often indicative that propagule production is beginning to exceed factors limiting spread.

Overall, most plant species were established at the five original sites (Bird Island, Rabbit Island, Horse Creek, Fly Creek, and Honey Creek) by year three, and many appeared established at the two sites (Upper Honey Creek and Drowning Creek) constructed during the second year. While sites constructed in the third year could not yet be evaluated for successful establishment (seasonal recovery will not occur until next spring), three (Cayuga, Cowskin Island, and Upper Elk River) supported some species that appeared to be well established (prolific growth and seed production); only Bernice State Park exhibited poor establishment of all species. This site however was not planted until June 12, 2006 and hence had a very short growing season.

Typically, emergent species were established at elevations above 742 ft msl, despite periods of exposure to desiccation during late summer, fall, winter, and spring---the short period at which these elevations were inundated have apparently been sufficient (in conjunction with periodic rainfall) for establishment and propagule production. In contrast, most of the deeper plantings did not survive, with the two and one half month high water period too great (at a critical time of the growing season) for these species to tolerate. A notable exception to this was survival of bulltongue at depths as great as 740.5 ft msl; this species is highly tolerant of deeper conditions, even changing to a submersed form at depths greater than two feet.

Deviations between sites were attributed to soil types: those soils that wicked or held water longer (sandy and mucky) were more conducive to better establishment of emergent species. Rocky and heavy clay sites evidently dried to a greater degree, and plants at the highest elevations did not fair as well at such sites. Additional factors contributing to differences among sites included presence of herbivores (usually deer or waterfowl) and the presence of other plant species.

While not universal to every site, nearly all species of protected emergent plants, regardless of mesh size, established well in ring cages, and later in pens. There were however, signs of herbivory on plants reaching the edges of cages or those that had grown beyond cages. Most herbivory on emergent species appeared to be that of waterfowl, most likely geese, which occurred when emergent species were inundated or very near the shoreline; deer and other terrestrial grazers are thought to have contributed to herbivory during periods of low water. An exception was tall burhead, which did well only in small mesh cages but established poorly in large mesh cages, indicating a small herbivore was gaining access and feeding upon the plants---in several cases, small turtles were found inside cages planted with tall burhead. At some sites, moist, exposed flats that supported dense stands of vegetation such as *Cyperus* appeared to have "masked" emergent species from terrestrial grazers during low water periods and allowed some of the unprotected growth to occur. Although some survived and appeared to establish, unprotected emergent plants of nearly all species (water willow was the major exception) were either heavily grazed or gone within six weeks after planting, indicating a need for initial protection in order to establish them in founder colonies.

After three years, most submersed and floating-leaved plants were established at depths below 741.5 ft msl (excessive desiccation at higher elevations likely contributed to the failure of these species to establish), with American pondweed performing best overall. Wild celery, Illinois pondweed, and sago pondweed were established at depths greater than 741 ft msl, although sago pondweed was only marginally established at a few sites. American pondweed, white water lily, and American lotus planted at shallower depths (to 743.5 ft msl) cyclically grew and went dormant during high and low pools, respectively, indicating that these species were able to withstand prolonged exposure to desiccation in Grand Lake.

Submersed plants failed to establish without protection. Establishment in large mesh (2"x4") ring cages was poor; however, establishment was consistently high in small mesh (2"x2") cages, indicating that small herbivores were gaining access to at least some of the plants. It was ascertained (by grazing signs and actual capture of animals in some cages) that small turtles were responsible for most damage inside cages. At that time, large mesh cages were additionally wrapped with finer mesh materials and subsequent plantings were protected with finer mesh cages. Similar results were seen in large pens; some of these were later wrapped with finer mesh or a finer mesh ring cage was installed inside of them along with turtle ramps to allow escape of turtles trapped inside following high water periods. Once turtles were effectively excluded from submersed plants, survival and establishment increased dramatically. The outer pens at sites 1,2,3, & 5 set at roughly 739' msl have been overtopped each season allowing herbivores in to clean out the growth that had occurred there. To avoid this overtopping wire was added in October to all deep pens to raise pen height above the 745' msl level. In addition, these pens have fine mesh ring cages inside to protect seed colonies within in case of a breach.

Some plants (of most submersed species) failed to establish or were very weak in two types of cages constructed with finer mesh. Covered ring cages (2-ft diameter x 2-ft tall) were apparently suitable only for establishing wild celery, water stargrass, Illinois pondweed, and possibly coontail; other species had apparent difficulty growing through the mesh tops during periods of high water. Small diameter, tall ring cages (less than 2.5-ft diameter x 4 or 5-ft tall) also proved problematic for some species during periods of high water. We believe that some species (most notably American pondweed) elongate during high water, with the close proximity of the wire resulting in excessive stem abrasion, weakening and eventually killing the colony. Additionally, those stems that may survive are at risk of hanging up on the cages when water levels decline,

such as the drop from 744 ft msl to 741 ft msl in early August.

Seed production was observed at most sites by many of the plants, especially arrowhead, bulltongue, pickerelweed, bulrushes, spikerushes, burheads, and American pondweed. This indicated maturity of the founder colonies and that seed banks are increasing, which will ultimately lead to spread from the colonies.

Spread in and around founder colonies was noted, particularly at the two and three year-old colonies. This spread was apparently from both seeds and fragments, with seedlings and small colonies of bulltongue, pickerelweed, softstem bulrush, tall burhead, American pondweed, Illinois pondweed, and water stargrass observed. Contiguous spread (vegetative spread outside cages from protected plants) was also noted for most species, but most evidently by arrowhead, bulltongue, pickerelweed, bulrushes, spikerushes, water willow, white water lily, creeping burhead, American pondweed, and Illinois pondweed. While this spread did not increase the overall area encompassed by founder colonies, it did show the beginnings of each colony's potential to spread elsewhere.

Site-by-Site Evaluations

This section provides assessments of founder colony condition at each of the ten sites constructed over the three-year project. The small founder colony installed by volunteers at Bernice State Park in 2006 is not evaluated in this report.

Site 1: Bird Island (See Map in Appendix A)

Figure 8: Site 1 – "Bird Island"; 9-13-06 Lake level 741.25' msl

Overall assessment: this third-year founder colony is well established and producing propagules at all times during the growing season. Local herbivore populations are not consuming all seedlings, and spread to unprotected areas is beginning to occur. Small patches of water willow occur naturally near this site.
Founder colony distribution: 1.34 acres (5428 m^2)
Emergent species: good establishment at elevations above 742ft msl, especially by American bulrush, arrowhead, bulltongue, creeping burhead, squarestem spikerush, softstem bulrush, pickerelweed, river bulrush, and tall burhead. Exposed soils during low water remained moderately moist and continued to support growth of most species. Bulltongue was established at 740.5ft msl and above.
Submersed & floating-leaved species: excellent establishment at elevations below 742ft msl, most notably by American pondweed, Illinois pondweed, water stargrass, and wild celery. American pondweed and white water lily were also established up to 743.5ft msl.
Seed/fragment production: bulrushes, spikerushes, burheads, arrowhead, bulltongue, pickerelweed, American pondweed, Illinois pondweed, southern naiad, and horned pondweed supported flowers/seed heads.
Spread outside cages: seedlings/fragments of American pondweed, water stargrass, wild celery, southern naiad, and tall burhead scattered at elevations above 741ft msl. Cage jumping (species showing up in protected areas planted with other species) was observed by American pondweed, bulltongue, and tall burhead.
Herbivory: turtles and common carp appeared most problematic, with some evidence of waterfowl and terrestrial (e.g., deer) grazing noted.
Enhancements: Construction of small mesh, large pens around existing deeper cages will likely enhance this founder colony increasing biomass and propagule production. If the newly raised outer pens with internal ring cages are insufficient to protect submersed plants, new deep water pens with 2"x2" mesh may be constructed.

Site 2: **Rabbit Island** (See Map in Appendix A)

Figure 9: Site 2 "Rabbit Island" inside large pen; 9-13-06 Lake level 741.25' msl

Overall assessment: this third-year founder colony is well established and producing propagules at all times during the growing season. Secondary construction of pens around existing cages has permitted additional growth by emergent and submersed species, leading to greater production of propagules. Local herbivore populations are not consuming all seedlings, and spread to unprotected areas is beginning to occur. Small patches of water willow occur naturally near this site.
Founder colony distribution: 1.25 acres (5053 m^2)
Emergent species: good establishment at elevations above 742ft msl, especially by American bulrush, arrowhead, bulltongue, creeping burhead, squarestem spikerush, softstem bulrush, pickerelweed, river bulrush, water hyssop, water willow, and tall burhead. Exposed soils during low water remained moderately moist and continued to support growth of most species. Bulltongue was established at 740.5ft msl and above.
Submersed & floating-leaved species: excellent establishment at elevations below 742ft msl, most notably by American pondweed, Illinois pondweed, and wild celery; sago pondweed persisted at this site, and horned pondweed (volunteer from LAERF soils) was growing well in some cages American pondweed and white water lily were also established up to 743.5ft msl.
Seed/fragment production: bulrushes, spikerushes, burheads, arrowhead, bulltongue, pickerelweed, American pondweed, Illinois pondweed, southern naiad, and horned pondweed supported flowers/seed heads.
Spread outside cages: seedlings/fragments of American pondweed, water stargrass, bulltongue, southern naiad, and tall burhead were scattered at elevations above 741ft msl. Cage jumping was observed by American pondweed, bulltongue, and tall burhead.
Herbivory: turtles and common carp appeared most problematic, with some evidence of terrestrial (deer) grazing noted.
Enhancements: Construction of small mesh, large pens around existing deeper cages will likely enhance this founder colony increasing biomass and propagule production. If the newly raised outer pens with internal ring cages are insufficient to support submersed plants, new deep water pens with 2"x2" mesh may be constructed. Installation of fish/turtle release funnels should be considered. Move deeper larger mesh cages no longer supporting plants to elevations above 742ft msl and plant with emergent species. When needed, plant small diameter, tall ring cages and covered ring cages with submersed species other than American pondweed.

Site 3: **Horse Creek** (See Map in Appendix A)

Figure 10: Site 3 "Horse Creek" American pondweed in outer cage. These pens have been raised 1 ½ ft. to prevent lake overtopping up to 745' msl, thereby precluding the annual feeding frenzy by herbivores.

Figure 11: Site 3; New large pen installed in November 2006; Lake level 740.5' msl

Overall assessment: this third-year founder colony is well established and producing propagules at all times during the growing season. Local herbivore populations are not consuming all seedlings, and spread to unprotected areas is beginning to occur. Small patches of water willow occur naturally near this site.
Founder colony distribution: 2.55 acres (10,335 m^2)
Emergent species: good establishment at elevations above 742ft msl, especially by American bulrush, arrowhead, bulltongue, creeping burhead, softstem bulrush, pickerelweed, river bulrush, water hyssop, water willow, and tall burhead. Some plants appeared to suffer from excessive drying (heavy clay soils), but were surviving. Bulltongue was established at 740.5ft msl and above.
Submersed & floating-leaved species: excellent establishment at elevations below 742ft msl,

most notably by American pondweed, Illinois pondweed, and wild celery; water stargrass did well in only some cages in which it was planted. American pondweed and white water lily were also established up to 743.5ft msl.
Seed/fragment production: bulrushes, spikerushes, burheads, arrowhead, bulltongue, pickerelweed, American pondweed, and Illinois pondweed supported flowers/seed heads.
Spread outside cages: seedlings/fragments of American pondweed, water stargrass, bulltongue, and southern naiad were scattered at elevations above 741ft msl. Cage jumping was observed by American pondweed, bulltongue, and tall burhead.
Herbivory: turtles and common carp appeared most problematic, with some evidence of waterfowl and terrestrial (deer) grazing noted. Only two cages at this site were empty (both held turtles); turtles also breached the two deep pens.
Enhancements: Construction of small mesh, large pens around existing deeper cages will likely enhance this founder colony increasing biomass and propagule production. If the newly raised outer pens with internal ring cages are insufficient to support submersed plants, new deep water pens with 2"x2" mesh may be constructed. Installation of fish/turtle release funnels should be considered. Move some deeper larger mesh cages no longer supporting plants to elevations at or above 742ft msl and plant with emergent species. When needed, plant small diameter, tall ring cages and covered ring cages with submersed species other than American pondweed.

Site 4: **Fly Creek** (See Map in Appendix A)

Figure 12: Site 4 "Fly Creek" ; 9-13-06 741.25' msl

Overall assessment: this third-year founder colony is well established at some elevations and producing propagules at all times during the growing season. Local herbivore populations are not consuming all seedlings, and spread to unprotected areas is beginning to occur. Only ring cages have been constructed at this site. One native species not introduced during this project was establishing naturally at the site: round-leaf water hyssop (*Bacopa rotundifolia*).
Founder colony distribution: 0.80 acres (3246 m^2)
Emergent species: good establishment at elevations above 743.5ft msl, especially by American bulrush, creeping burhead, softstem bulrush, pickerelweed, river bulrush, water willow, squarestem spikerush, and tall burhead. Curiously, many plants at lower elevations (to 742ft msl), including bulltongue, appeared to suffer from excessive sediment build up---most of these plants were in the process of recovering at the time of final assessment (several weeks after the

lake was brought down to the 741ft msl range), but were not yet producing seeds. Soft, organic soils remained moist at higher elevations and plants continued to grow and produce seeds during low water.

Submersed & floating-leaved species: excellent establishment at elevations below 742ft msl, most notably by American pondweed, Illinois pondweed, water stargrass, and white water lily. American pondweed and white water lily were also established up to 743.5ft msl.

Seed/fragment production: bulrushes, spikerushes, burheads, arrowhead, bulltongue, pickerelweed, American pondweed, Illinois pondweed, and white water lily supported flowers/seed heads.

Spread outside cages: seedlings/fragments of American pondweed, bulltongue, and pickerelweed were scattered at elevations above 741ft msl. Cage jumping was observed by American pondweed, bulltongue, pickerelweed, arrowhead, and tall burhead.

Herbivory: waterfowl, turtles, and common carp were the most problematic grazers at this site.

Enhancements: Move deeper larger mesh cages no longer supporting plants to elevations at or above 742ft msl and plant with emergent species. When needed, plant small diameter, tall ring cages and covered ring cages with submersed species other than American pondweed. Construction of small mesh, large pens around existing cages may increase biomass and subsequently result in greater propagule production. The first pen was recently installed at this site, November 28, 2006.

Figure 13: Site 4 had prolific growth of all species – (pictured: softstem bulrush and pickerelweed)

Figure 14: New large pen at Site 4; Nov. 28, 2006; Lake at 740.5' msl

Site 5: **Honey Creek** (See Map in Appendix A)

Figure 15: Site 5 "Honey Creek" ; 9-13-06 741.25 msl

Overall assessment: this third-year founder colony is well established and producing propagules at all times during the growing season. Secondary construction of pens around existing cages has permitted additional growth, especially by emergent species, during low water periods, leading to greater production of propagules. Local herbivore populations are not consuming all seedlings, and spread to unprotected areas is beginning to occur.
Founder colony distribution: 2.18 acres (8815 m^2)
Emergent species: excellent establishment at elevations above 742ft msl, especially by American bulrush, arrowhead, bulltongue, creeping burhead, squarestem spikerush, softstem bulrush, pickerelweed, river bulrush, water hyssop, water willow, and tall burhead. Exposed soils during low water remained moderately moist and continued to support growth of most species. Bulltongue was established at 740.5ft msl and above.
Submersed & floating-leaved species: excellent establishment at elevations below 742ft msl, most notably by American pondweed, Illinois pondweed, and water stargrass. American pondweed and white water lily were also established up to 743.5ft msl.
Seed/fragment production: bulrushes, spikerushes, burheads, arrowhead, bulltongue, pickerelweed, American pondweed, Illinois pondweed, and water stargrass supported flowers/seed heads.
Spread outside cages: seedlings of bulltongue and pickerelweed were scattered at elevations above 741ft msl. Cage jumping was observed by bulltongue and pickerelweed. Contiguous growth by American lotus outside the pens in which it was planted was significant.
Herbivory: waterfowl, turtles, and common carp were the most problematic at this site.
Enhancements: Construction of small mesh, large pens around existing deeper cages will likely enhance this founder colony increasing biomass and propagule production. If the newly raised outer pens with internal ring cages are insufficient to support submersed plants, new deep water pens with 2"x2" mesh may be constructed. Installation of fish/turtle release funnels should be considered. This site must be closely watched for the presence of curlyleaf pondweed (*Potamogeton crispus*), an exotic species that at one time infested one larger pen. By opening the pen herbivores ate the curlyleaf. When needed, plant small diameter, tall ring cages and covered ring cages with submersed species other than American pondweed.

Site 6: **Upper Honey Creek** (See Map in Appendix A)

Figure 16: Site 6 "Upper Honey Creek" ; 9-13-06 741.25 msl

Overall assessment: this second-year founder colony appears to be well established and some species are beginning to produce propagules; significant recovery in spring 2007 should indicate successful establishment at this site. Secondary construction of pens around existing cages has permitted additional growth, especially by emergent and floating-leaved species, leading to greater production of propagules. Local herbivore populations are not consuming all seedlings, and spread to unprotected areas is beginning to occur.
Founder colony distribution: 2.35 acres (9,535 m^2)
Emergent species: excellent establishment at elevations above 742ft msl, especially by American bulrush, arrowhead, bulltongue, creeping burhead, squarestem spikerush, softstem bulrush, water hyssop, and pickerelweed. Exposed soils during low water remained moderately moist and continued to support growth of most species. Masking by terrestrial plants may be contributing to success of plants at higher elevations. Bulltongue was established at 741ft msl and above.
Submersed & floating-leaved species: excellent establishment at elevations below 742ft msl, most notably by American pondweed, water stargrass, white water lily, and American lotus. This is the only site at which spatterdock was planted and survived.
Seed/fragment production: bulrushes, spikerushes, burheads, arrowhead, bulltongue, pickerelweed, American pondweed, Illinois pondweed, white water lily, and American lotus supported flowers/seed heads.
Spread outside cages: seedlings of bulltongue and pickerelweed were scattered at elevations above 741ft msl. Cage jumping was observed by American pondweed, bulltongue, and pickerelweed.
Herbivory: turtles and common carp were the most problematic at this site.
Needs: Construction of small mesh, large pens around existing deeper cages will likely enhance this founder colony increasing biomass and propagule production. Some finer mesh cages are placed too deep (4.5 ft deep at low pool) for initial establishment---these cages may be combined to make 5-foot diameter cages and set at elevation 738' msl or shallower and replanted with submersed species other than American pondweed. Turtle ramps and/or release funnels should be installed in these pens.

Site 7: **Drowning Creek** (See Map in Appendix A)

Figure 17: Site 7 "Drowning Creek" ; 9-13-06 741.25 msl (large pen upper right corner)

Overall assessment: this second-year founder colony appears to be marginally established and a few species are beginning to produce propagules; significant recovery in spring 2007 should indicate successful establishment at this site. Spread outside protected areas has not yet been observed at this site. Fragments of a native aquatic buttercup (*Ranunculus*) and curlyleaf pondweed were observed at this site in late spring 2006.
Founder colony distribution: 0.85 acres (3449 m^2)
Emergent species: good establishment at elevations above 742ft msl by several species, including American bulrush, squarestem spikerush, bulltongue, softstem bulrush, and pickerelweed. Exposed soils during low water remained moderately moist and continued to support growth of these species. Bulltongue was established at 740.5ft msl and above.
Submersed & floating-leaved species: good establishment at elevations below 742ft msl, most notably by American pondweed, Illinois pondweed, white water lily, and wild celery. American lotus and American pondweed were possibly established at elevation 742.5ft msl (inside the large pen).
Seed/fragment production: bulrushes, spikerush, bulltongue, pickerelweed, American pondweed, Illinois pondweed, white water lily, and American lotus supported flowers/seed heads.
Spread outside cages: no spread outside cages was observed at this site.
Herbivory: turtles were the only apparent grazers at this site.
Enhancements: add emergent species, especially arrowhead, water willow, burheads, and more pickerelweed. Construction of small mesh, large pens around existing submersed cages should increase biomass and result in greater propagule production; turtle ramps and/or release funnels should be installed in these pens.

Site 8: **Elk River, Cayuga** (See Map in Appendix A)

Figure 18: Site 8 "Cayuga" Prolific growth in 4 months; 9-13-06 741.25 msl

Overall assessment: this first-year founder colony exhibited signs of good establishment, with most species surviving the high water period and producing propagules. This site was planted while the water was at 745' msl. This points out that emergent plants can grow well at the 742' msl, which is an elevation where the root system is rarely dry at Grand Lake. Plants grew well here all summer even while under two feet of water; significant recovery in spring 2007 should indicate successful establishment at this site. Spread outside protected areas was observed at this site.

Founder colony distribution: 1.36 acres (5494 m^2)

Emergent species: excellent establishment at elevations above 743ft msl by several species, including American bulrush, squarestem spikerush, arrowhead, bulltongue, softstem bulrush, and pickerelweed. Exposed soils during low water remained moderately moist and continued to support growth of these species; masking by terrestrial species (e.g., *Cyperus*) apparently contributed to establishment success.

Submersed & floating-leaved species: good establishment at elevations 738ft and 739ft msl by American pondweed and Illinois pondweed. Others (e.g., wild celery and water stargrass) were planted in September 2006 and have not yet been evaluated.

Seed/fragment production: bulrushes, spikerush, bulltongue, arrowhead, pickerelweed, American pondweed, and Illinois pondweed supported flowers/seed heads.

Spread outside cages: substantial vegetative spread (to more than double the protected area) outside cages by most emergent species was noted, likely due to masking by terrestrial vegetation.

Herbivory: turtles were the only apparent grazers at this site.

Enhancements: evaluate success of recently added species; add white water lily. Expand elevation plantings of emergent species. Construction of small mesh, large pens around existing submersed cages should increase biomass and result in greater propagule production turtle ramps and/or release funnels should be installed in these pens.

Figure 19: Site 8 "Cayuga" Prolific growth in 4 months; 9-13-06 741.25 msl

Site 9: Upper Elk River (See Map in Appendix A)

Figure 20: Site 9 "Upper Elk River" ; Prolific growth in most cages; 9-13-06 741.25 msl

Overall assessment: this first-year founder colony exhibited signs of good establishment, with most species surviving the high water period and producing propagules; significant recovery in spring 2007 should indicate successful establishment at this site. Spread outside protected areas was observed at this site. Only ring cages planted with emergent species were installed at this site.
Founder colony distribution: 0.23 acres (922 m^2)
Emergent species: excellent establishment at elevation 743.5ft msl by several species, including American bulrush, squarestem spikerush, arrowhead, bulltongue, softstem bulrush, and pickerelweed. Exposed soils during low water remained moderately moist and continued to support growth of these species; masking by terrestrial species (*Cyperus*) apparently contributed to establishment success.
Seed/fragment production: bulrushes, spikerush, arrowhead, bulltongue, and pickerelweed supported flowers/seed heads.
Spread outside cages: substantial vegetative spread (to more than double the protected area) outside cages by most emergent species was noted, likely due to masking by terrestrial vegetation.
Herbivory: no herbivory was noted at this site.
Ehancements: expand plantings of emergent species to greater depths. Add submersed and floating-leaved species deemed successful at site 8 (Cayuga) using similar cage types and planting elevations. Pen some cages if plantings are doing well.

Site 10: **Elk River, Cowskin Island** (See Map in Appendix A)
Overall assessment: this first-year founder colony exhibited signs of good establishment, with most species surviving the high water period and producing propagules; significant recovery in spring 2007 should indicate successful establishment at this site. Spread outside protected areas was not observed---only ring cages were installed at this site.
Founder colony distribution: 1.16 acres (4683m^2)
Emergent species: fair establishment at elevations above 743ft msl by squarestem spikerush and arrowhead. Although surviving, other species tested at this site appeared poorly established: exposed soils during low water were possibly too dry.
Submersed & floating-leaved species: good establishment at elevation 739ft msl by American pondweed and Illinois pondweed; sago pondweed also persisted at this depth. Deeper cages exhibited very poor establishment. Others (e.g., wild celery and water stargrass) were planted in September 2006 and have not yet been evaluated. White water lily was surviving at 743.5ft msl.
Seed/fragment production: American pondweed and Illinois pondweed supported flowers/seed heads.
Spread outside cages: no spread was observed.
Herbivory: turtles were the only apparent grazers at this site.
Enhancements: evaluate success of recently added species. Expand elevation plantings of emergent species (to 742ft msl). Construction of small mesh, large pens around existing emergent and submersed cages may increase biomass and subsequently result in greater propagule production; turtle ramps and/or release funnels should be installed in these pens.

Short Term Recommendations – (3 - 5 years)

Site enhancement rather than additional sites should be the focus for the next season or two as unprotected expansion by plants has yet to persist through a season. We believe the next step is to increase biomass substantially with large pens, maintain and monitor the existing cages and watch for successful unprotected colonies to appear in the vicinity of the sites. Evidence of persistent survival of unprotected plants signals the final stage of colonization through the founder colony method in Grand Lake.

In addition to specific recommendations provided in the Site-by-site section of this report, monitoring and maintenance of all sites is critical for long-term success of founder colony establishment. Monitoring should include periodic field evaluations: one in late spring (742 ft msl), one in mid-summer (744 ft msl), one in late summer (741 ft msl), and one in early fall (742 ft msl). Field evaluations should ascertain species presence (at each planted depth), growth (relative to previous evaluation), reproduction (flowers/seeds), vegetative spread from cages, and formation of new colonies in areas near founder colonies. A survey in areas remote to founder colonies should also be conducted (preferably during late summer) to document occurrences of widespread establishment in the reservoir.

These parameters should provide information necessary for maintenance, which will include construction of large pens around existing cages re-planting empty cages with more successful species at appropriate depths, increasing plantings of the most successful species at each site, repairing/modifying cages and pens as needed to limit herbivory.

A local nursery should be retained to provide plants for continued maintenance and expansion of the project; LAERF should be retained to participate in two of the field evaluations (late spring and late summer), give nursery technical support and provide backup plants for the aquatic plant nursery.

Long Term Recommendations – (Lake-wide site establishment; 5 – 20 years out)
Our experience in Grand Lake thus far has shown the fastest route for establishment of *substantial* colonies in the lake would be to focus planting those species that performed exceptionally well at all or nearly all sites over a narrow elevation band. Site layout should be large pens, i.e. 50'x100', surrounding ring cages set on 20' centers. Internal ring cages will act as insurance for founder colonies in case of a breach in the pen. These should be primarily planted with fast spreading target species (see below). These target species have shown that they can populate a large pen in just a season or two.

Elevations: Submersed target species should be planted in these pens at or near the 740' elevation. Emergent target species should be planted in large pens that will encompass the 742' elevation. Ideally these pens would extend across all target elevations and have both submersed and emergent plants, however some coves may need separate pens to cover the elevation change. While emergent plants grow well at the 742' level for half of the growing season, April, August and September, we speculate that plant expansion and even survival would be considerably better given a steady pool elevation. Given the current elevation rule curve, emergent plants are in two or more feet of water for most of the summer. While these plants usually survive at these depths they generally don't thrive and spread. Planting these plants higher leaves them dry for much of the year. A steady pool would provide an entire growing season for plants to mature and spread.

Primary Target Species: There were only four species that were consistently healthy and filling their cages at every site despite the differences of site characteristics (Table 1). Those species should be considered *"Primary Target Species"* to be planted liberally throughout every new and existing site. They are: softstem bulrush, bulltongue, American pondweed and Illinois pondweed. These plants were quick to spread vegetatively and survive the water fluctuation challenge brought by Grand Lake. These species promise to establish a pioneering wetland community that will furnish a stabilized root/soil matrix in which other species may come in later and succeed. As these plants create dense communities they may also furnish a masking of successional species to herbivores allowing them to establish.

Secondary Target Species: Additional *"Secondary Target Species"* should be planted to a lesser degree to create a more diverse community that will more adequately fill available niches. These plants were widely successful, to a lesser degree, as well in years one through three (Table 1). They are water stargrass, Vallisneria, arrowhead and river bulrush. Coontail, while not as successful has been added to this list due to its ease of collection and propagation.

All species used in this study should continue to be planted to some degree, especially at new sites, to increase diversity and learn if a site has a particular affinity for these other species. In particular this list should include: pickerelweed, tall burhead, creeping burhead, squarestem spikerush and water willow.

New Sites: Start-up of a new site would still begin with 4'-5' diameter ring cage founder colonies. These plantings, however, would focus on our Target Elevations and Species designed to fit within a 50'x100' or 100'x100' pen. Since pens are a more permanent system, penning of ring cages will only be instigated should the site prove conducive to cage plantings. By focusing on the most successful "Primary Target Species" we can quickly determine after a season's growth if more work at a site should be pursued. Once the large pens are installed many plants and species may be planted around the pen to increase diversity and expansion rate.

Installation of deeper pens should use a 2"x2" wire mesh to protect the submersed plants from small turtles and other herbivores that regularly bypassed the 2"x4" mesh. We found that upper level pens and rings cages may use the less expensive 2"x4" mesh as they rarely saw predation from small herbivores.

Sites currently targeted for future founder colonies include: Carey Cove, Wolf Creek Cove, Duck Creek Cove, Sycamore Creek and Lost Creek areas. The founder colony concept is that seeds and fragments will spread and colonize the entire lake over time. Experience in Grand Lake will eventually show us if environmental pressures will allow persistent colonies to appear in uncaged coves or if many of the coves will require a site of their own. Continued monitoring of this expansion will answer such questions and dictate what future work will be necessary.

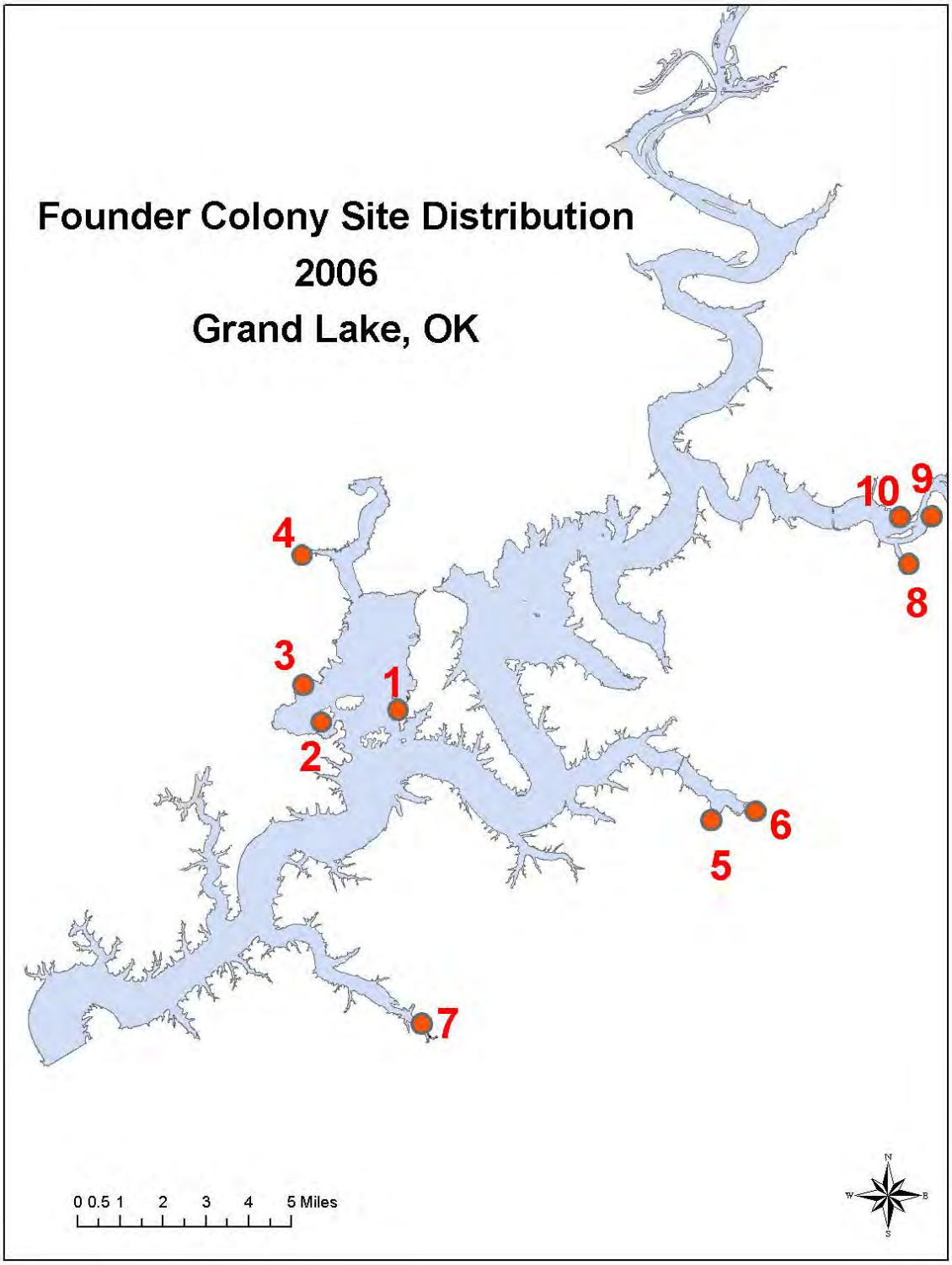
Because it appears that aquatic plant founder colonies can be successfully established in northeast Oklahoma using the techniques applied in Grand Lake, and the initial phase of spread (unprotected plants occurring in the vicinity of founder colonies) is beginning to occur after two and one half growing seasons, this approach is likely viable for other lakes in the Grand River system. We advocate founder colony trials begin in Hudson Lake in 2007 to determine target elevations, species and sites appropriate for a subsequent lake-wide mitigation effort.

Figure 21: Am. pondweed with one season of growth at the 740' msl

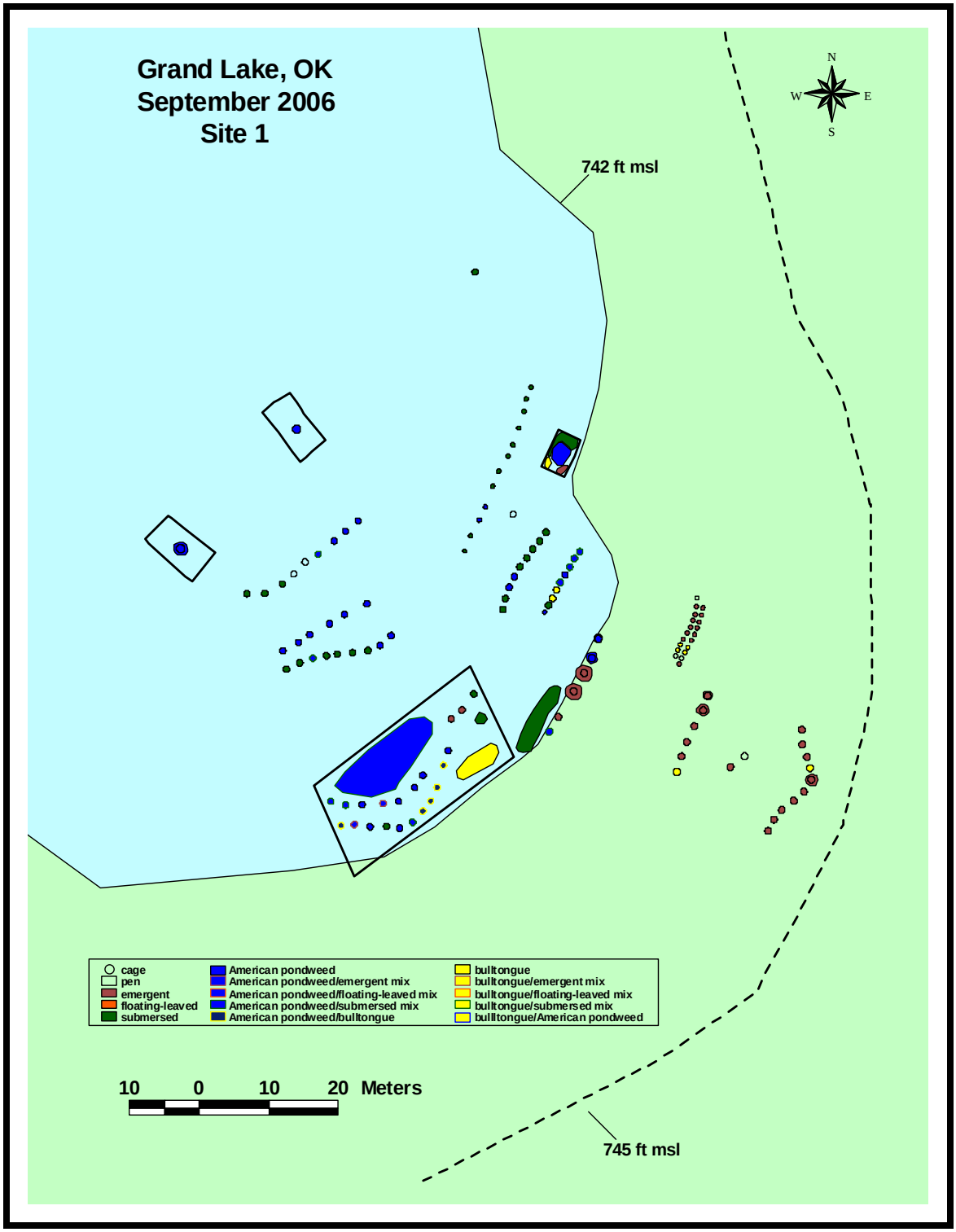
Figure 22: Arrowhead and pickerelweed with 4 mo. of growth at 742' msl at Site 8

Appendix A

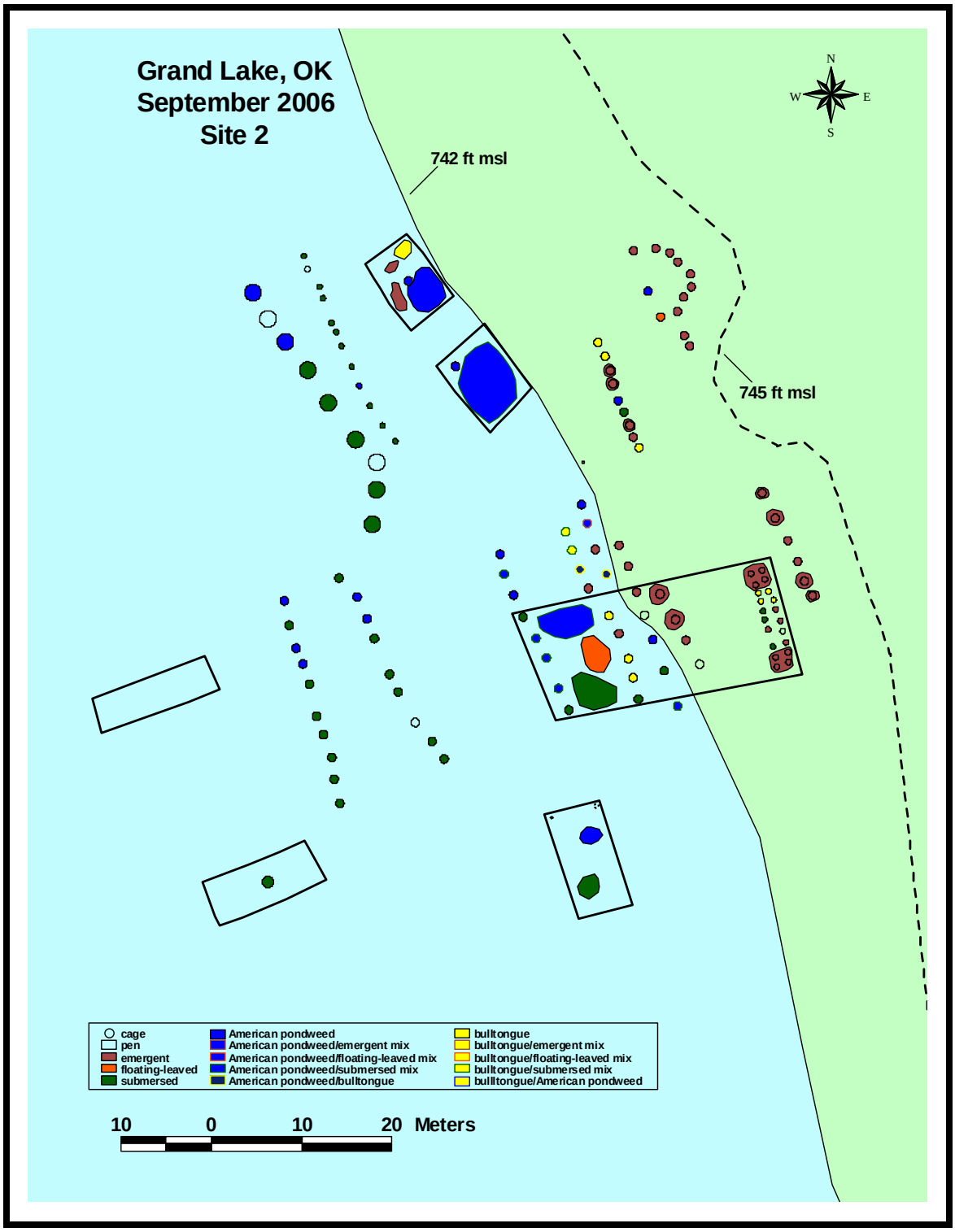
GPS mapping of aquatic vegetation establishment sites in Grand Lake, Oklahoma



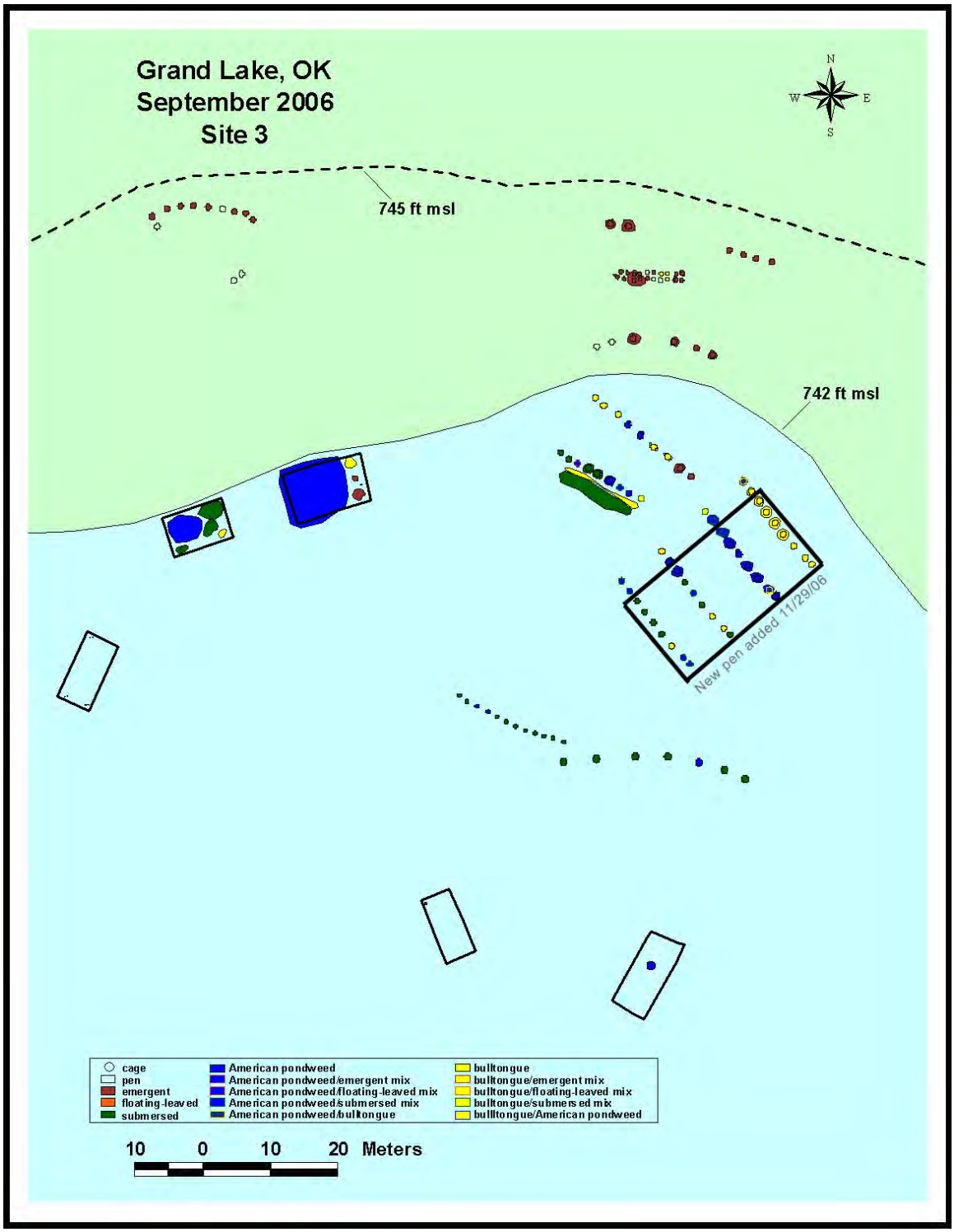
Lake-wide Distribution of Sites


Grand Lake, OK
September 2006
Site 1
N
W
E
S
742 ft msl
cage
pen
emergent
floating-leaved
submersed
American pondweed
American pondweed/emergent mix
American pondweed/floating-leaved mix
American pondweed/submersed mix
American pondweed/bulltongue
bulltongue
bulltongue/emergent mix
bulltongue/floating-leaved mix
bulltongue/submersed mix
bulltongue/American pondweed
10 0 10 20 Meters
745 ft msl

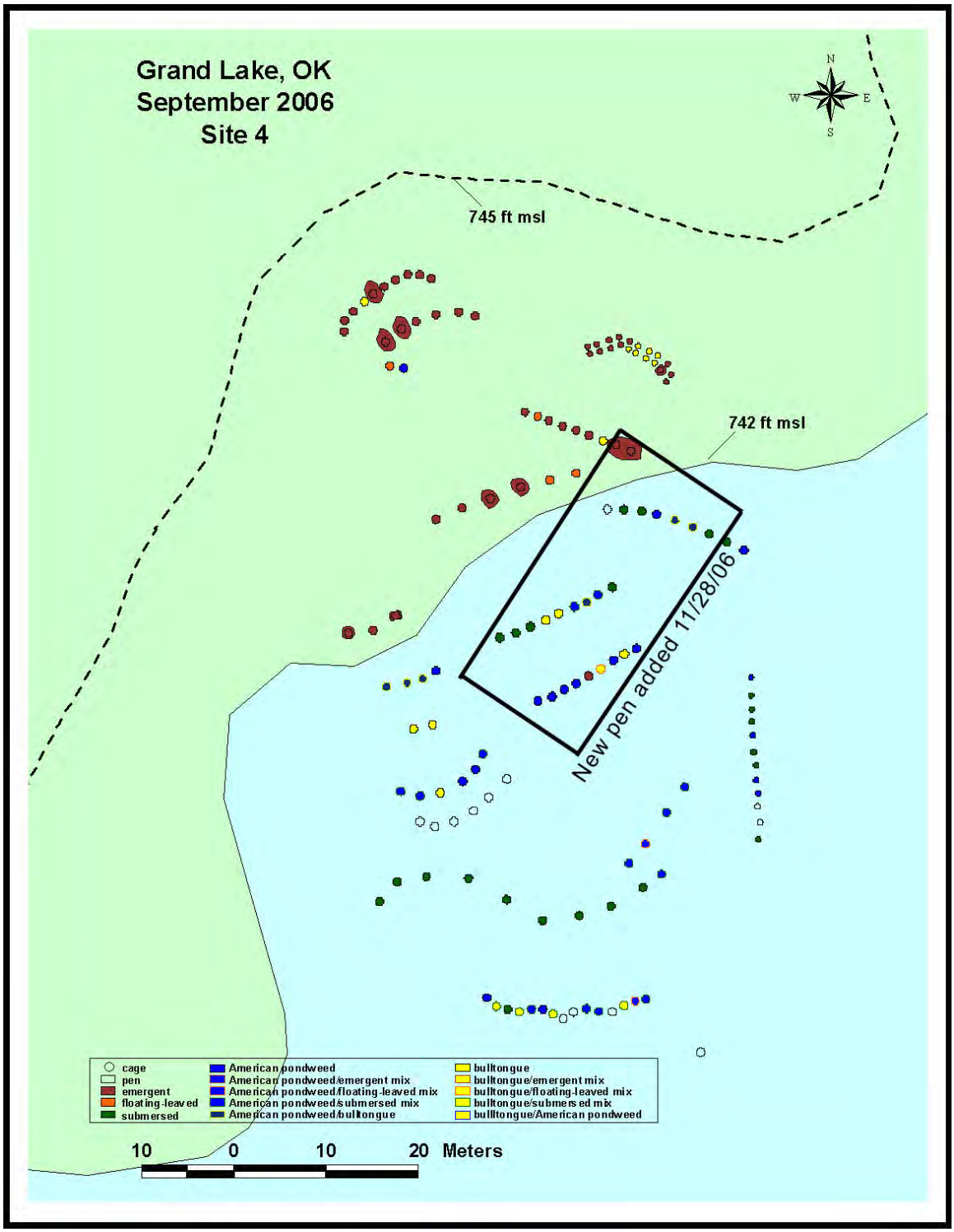
Bird Island



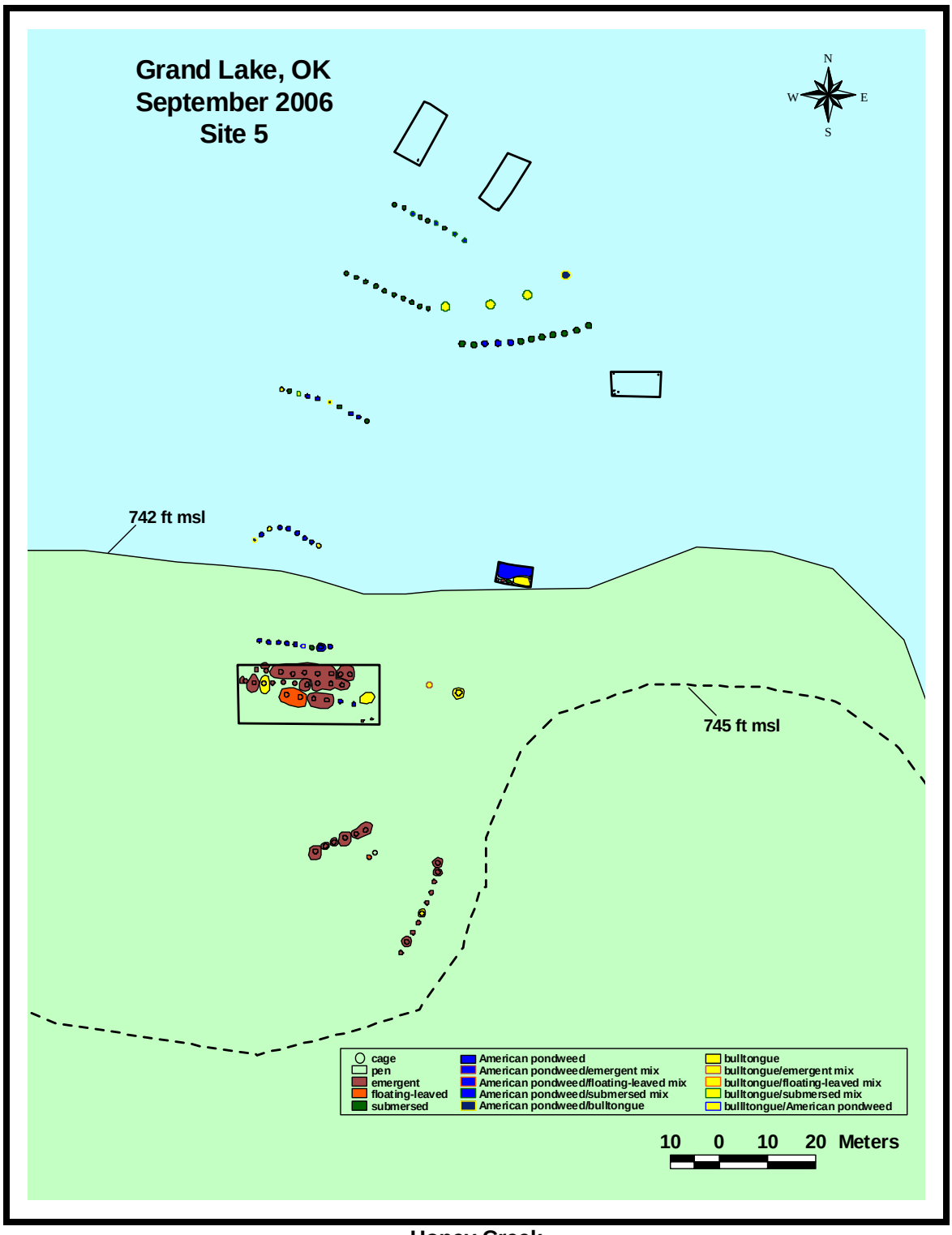
Rabbit Island

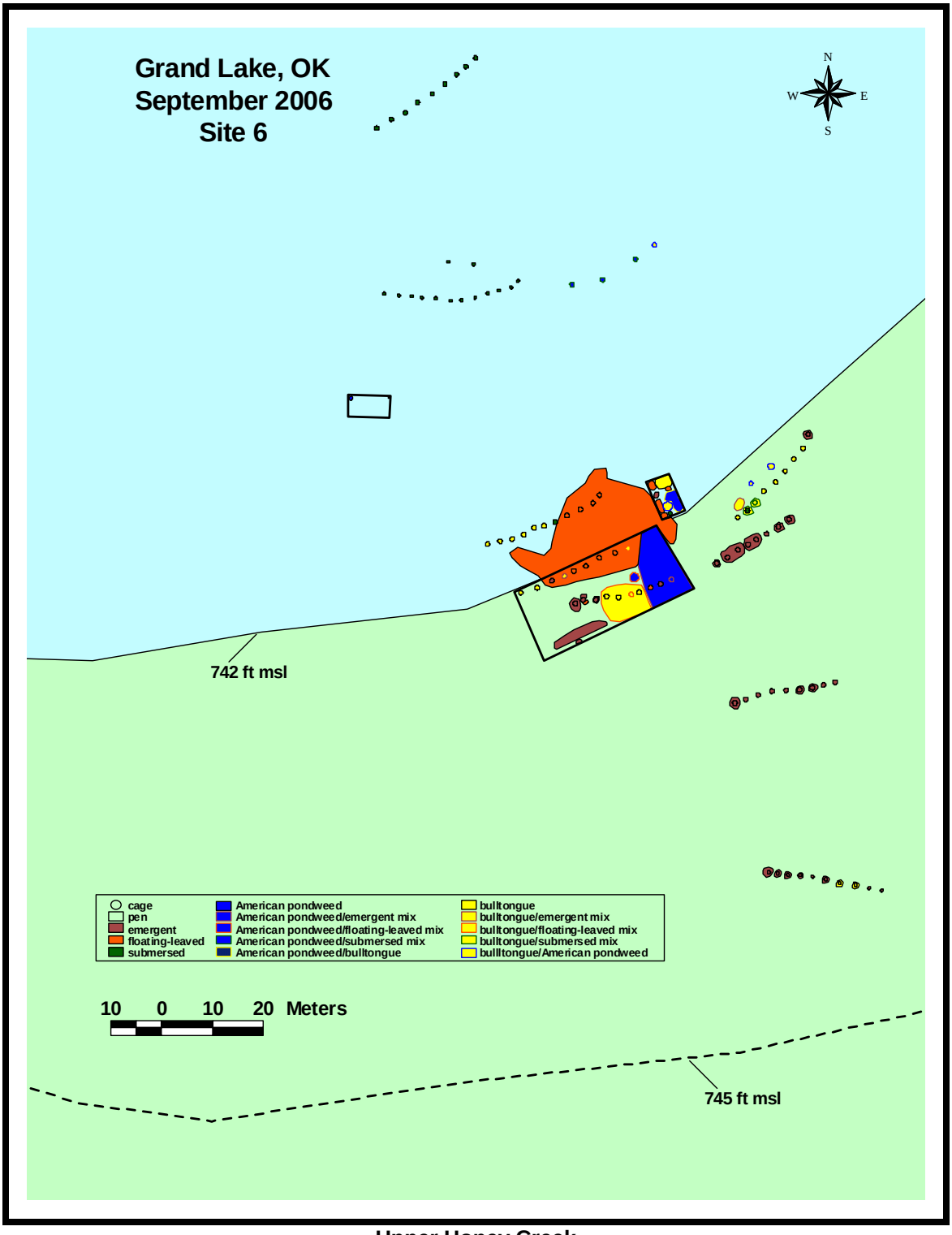

Grand Lake, OK
September 2006
Site 3
N
W
E
S
745 ft msl
742 ft msl
New pen added 11/29/06
cage
pen
emergent
floating-leaved
submersed
American pondweed
American pondweed/emergent mix
American pondweed/floating-leaved mix
American pondweed/submersed mix
American pondweed/bulltongue
bulltongue
bulltongue/emergent mix
bulltongue/floating-leaved mix
bulltongue/submersed mix
bullltongue/American pondweed
10 0 10 20 Meters

Horse Creek

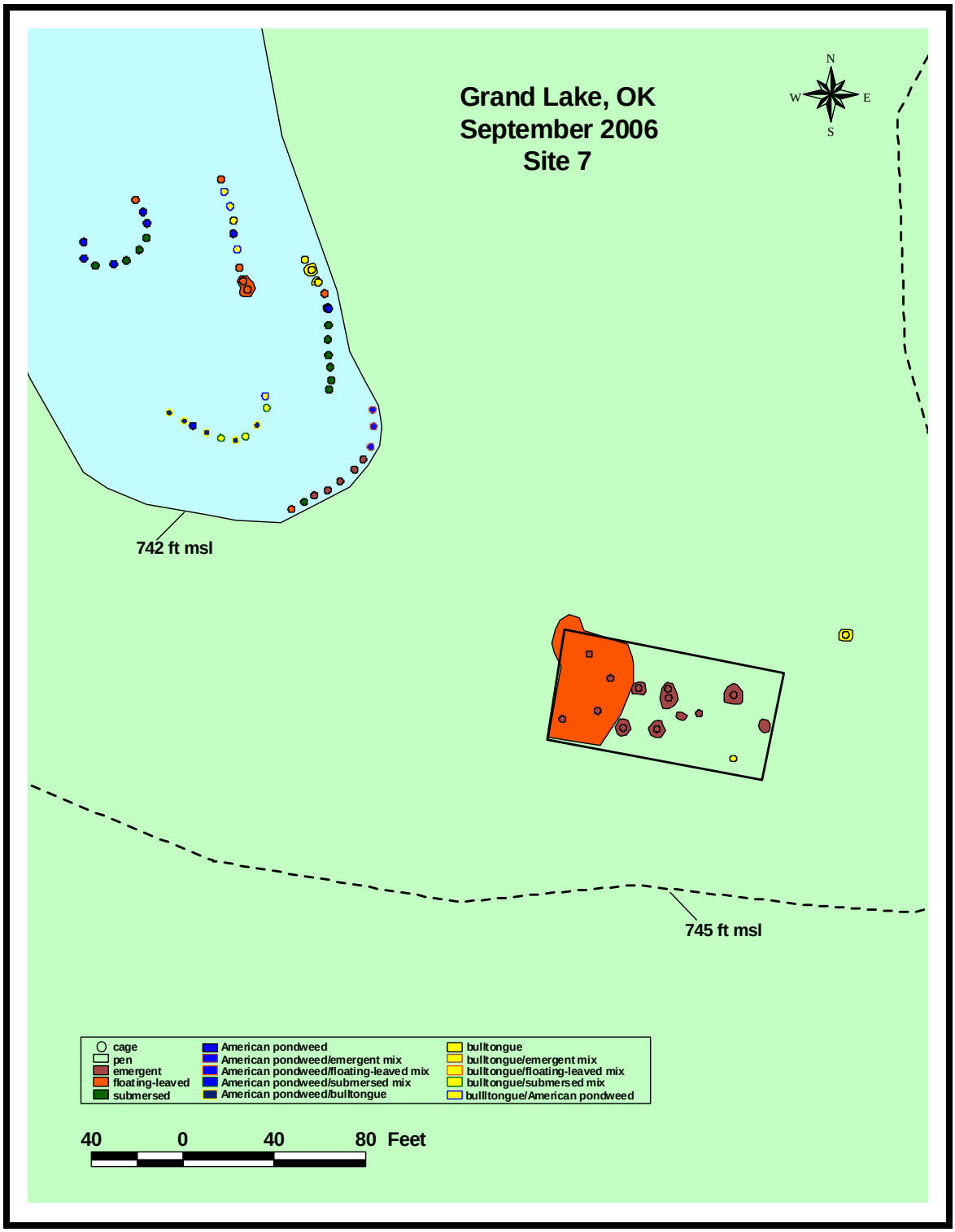

Grand Lake, OK
September 2006
Site 4
N
W
E
S
745 ft msl
742 ft msl
New pen added 11/28/06
cage
pen
emergent
floating-leaved
submersed
American pondweed
American pondweed/emergent mix
American pondweed/floating-leaved mix
American pondweed/submersed mix
American pondweed/bulltongue
bulltongue
bulltongue/emergent mix
bulltongue/floating-leaved mix
bulltongue/submersed mix
bullltongue/American pondweed
10 0 10 20 Meters

Fly Creek

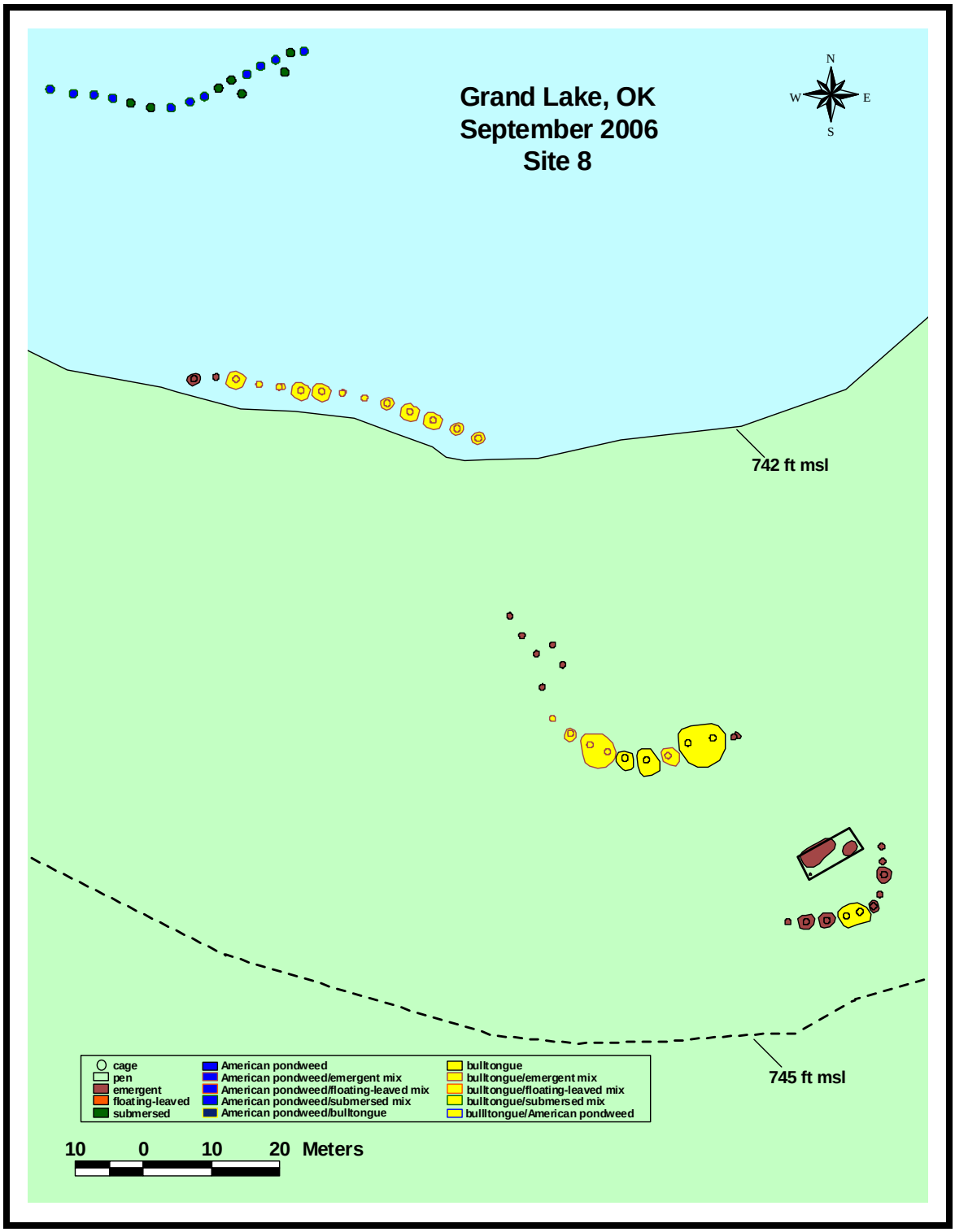

Grand Lake, OK
September 2006
Site 5
N
W
E
S
742 ft msl
745 ft msl
cage
pen
emergent
floating-leaved
submersed
American pondweed
American pondweed/emergent mix
American pondweed/floating-leaved mix
American pondweed/submersed mix
American pondweed/bulltongue
bulltongue
bulltongue/emergent mix
bulltongue/floating-leaved mix
bulltongue/submersed mix
bulltongue/American pondweed
10 0 10 20 Meters
Honey Creek



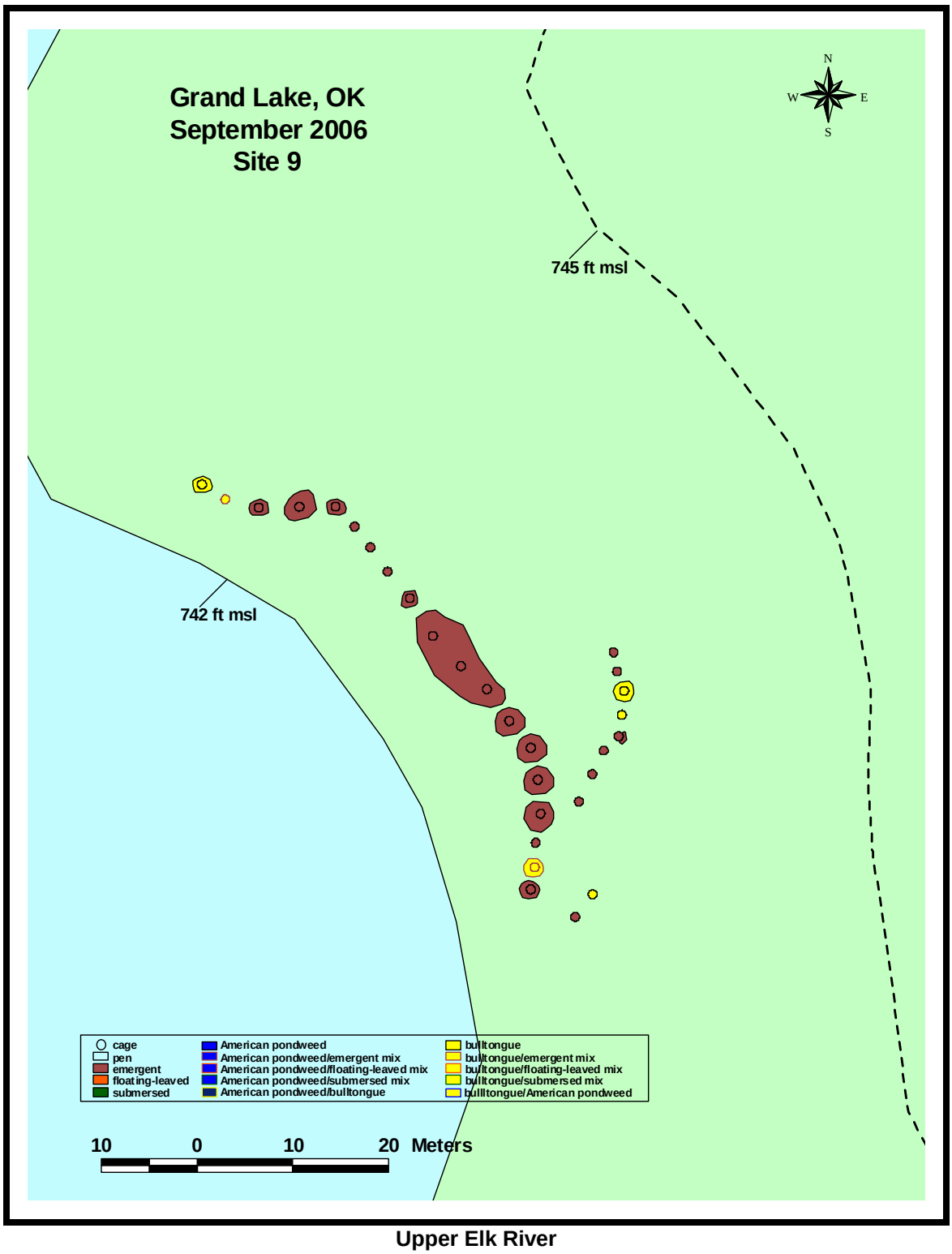
Upper Honey Creek



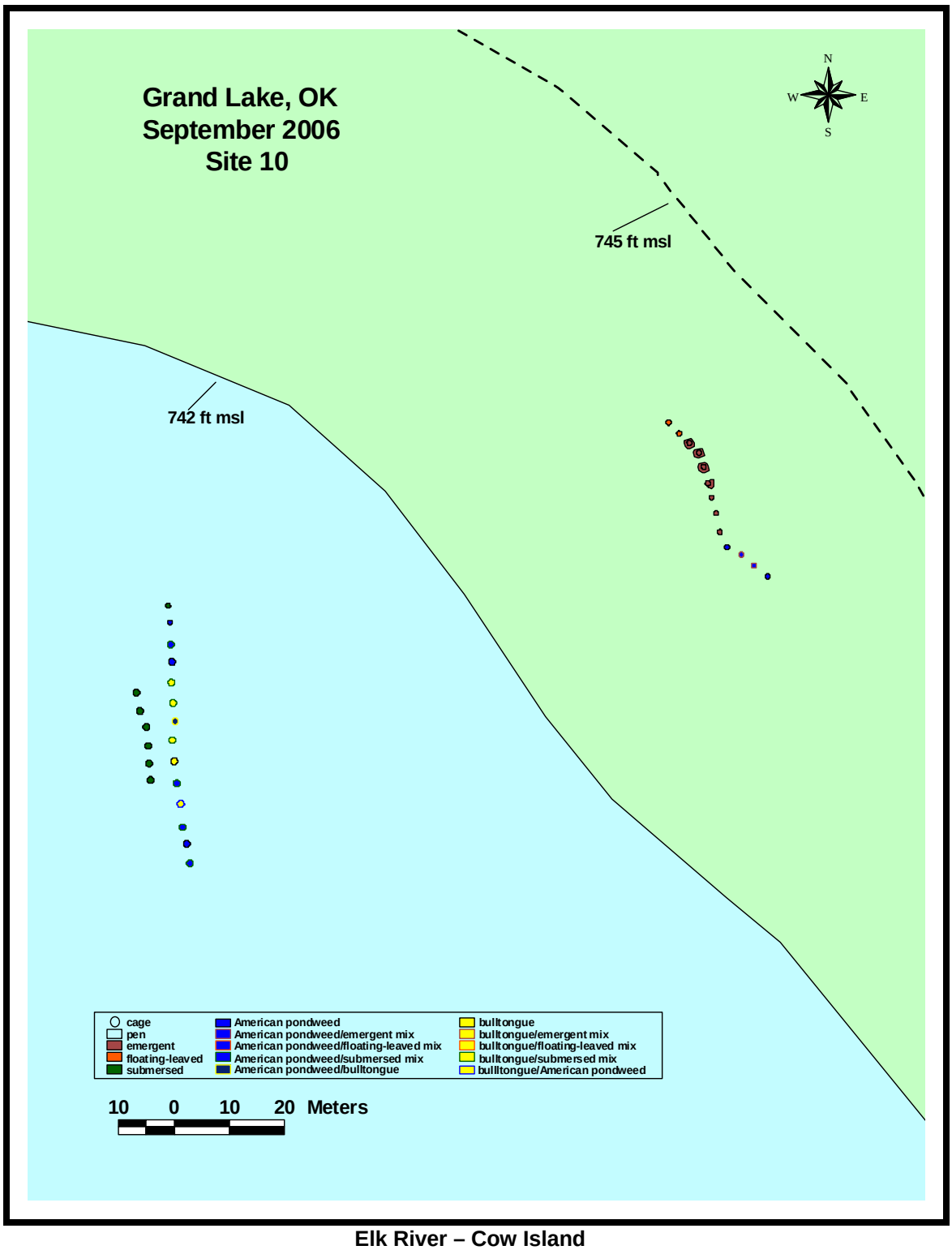
Drowning Creek



Elk River, Cayuga



Upper Elk River



Elk River – Cow Island

Appendix B

ODWC Report on Nursery Production and Expenditures
Porter Office

Jim Burroughs
N.E. Region Fisheries Supervisor

Summary of Expenditures by ODWC for expenses incurred and labor for the maintenance of the aquatic plant nursery and reservoir aquatic plant introductions.

Calendar Year 2006 (July 2005 through October 2006)

Material expenses included; pond liners, fertilizer, systemic, and other insecticides, boots for assessments and plantings, mosquito suits for maintaining nursery, miscellaneous supplies as needed.

Numbers of plants requested and provided for the Pensacola project….743 (plus coontail, unknown amount harvested offsite)

Star grass	120
Valsaneria	17
Sago	3
American Pondweed	96
Illinois Pondweed (pill)	36
Coontail (harvested)	large quantity, number undetermined
American Bullrush	105
Squarestem Bullrush	105
Bull Tongue	123
Arrowhead	99
Pickerel Weed	39

Estimated plants currently at nursery:

Star grass	84		
Valsaneria	144		
Sago	156		
American Pondweed			180
Illinois Pondweed (pill)	156		
American Bullrush			60
Squarestem Bullrush		96	
Bull Tongue	276		
Arrowhead	408		
Pickerel Weed	504		
Bacopa	84		
Softstem Bullrush	14		

Total = 2162 plants + 743 plants that were planted equals 2905 plants that were available for the Grand project this year. This number does not include the 180 planted in Ft. Gibson. If included, the GRAND TOTAL would be 3085.

Total capacity for at least 3432 plants was maintained at the Porter Office Nursery.