Dallas Floodway Extension

Lower Chain of Wetlands and Grasslands Ecological Management and Monitoring

Status Report to U.S. Army Corps of Engineers
Fort Worth District
March 2015

Gary Owen Dick, Lynde L. Dodd, Aaron N. Schad, Dian H. Smith and Chetta S. Owens
USACE ERDC Lewisville Aquatic Ecosystem Research Facility
Lewisville, Texas
972-436-2215

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Background

The Dallas Floodway Extension (DFE) includes a chain of wetlands designed to permit unimpeded overflow of floodwaters along the west side of the Trinity River from the Dallas Floodway to Loop 12, while at the same time provide quality wetland and grassland habitat during periods of normal water flow. The project was fully authorized for flood control by Section 301 of the River and Harbor Act of 1965 (79 Stat. 1091) and modified by Section 351 of the Water Resources Development Act of 1996 (110 Stat. 3724), which authorized inclusion of non-Federal levees. The authorization was further modified to add environmental restoration and recreation as project purposes by Section 356 of the Water Resources Development Act of 1999 (Public Law 106-53). In initial planning, ecosystem restoration following construction would result in 271 acres of habitat improvement, including 123 acres of emergent wetlands, 45 acres of open water, and 102 acres of grasslands.

The USACE Fort Worth District (SWF) requested assistance from the Corps' Engineer Research and Development Center's (ERDC) Lewisville Aquatic Ecosystem Research Facility (LAERF) in planning and implementation of native aquatic plant establishment in the project. ERDC provided general guidelines for wetland cell construction to maximize vegetation establishment and ecosystem function while maintaining the system's hydraulic capacity. ERDC also provided locally collected and grown wetland and grassland plants, their installation, long-term monitoring, and development of long-term management strategies for the project. The overall goal from ERDC's perspective has been to produce wetland and grassland habitat for waterfowl and other wildlife during normal flow periods by way of development of significant native vegetation communities.

The first phase of the project called for construction of four wetland cells, designated as D, E, F, and G, known collectively as the Lower Chain of Wetlands (LCOW); construction on Cell D was completed in 2004, and plant establishment and ecosystem management began thereafter. Construction of Cells E, F, and G was completed in late fall 2008; establishment of native wetland plants and ecosystem management was initiated soon after the wetland cells were filled to test pumping/filling systems and levee integrities. Three additional wetland areas have been included in the project since Cell D was constructed: Rochester Park Lake (planted 2005-2007) and Cells E-West and F-North (construction completed in winter 2008 as part of the LCOW). Additional cells, A, B, and C (Upper Chain of Wetlands, UCOW) have recently entered construction phase and will be included in ERDC ecosystem management as they are completed.

In addition to establishing and monitoring wetland vegetation, SWF engaged ERDC to monitor several components of wetland function, including sedimentation (filling in of cells), macro-invertebrate community development, fishery development, and use by aquatic and semi-aquatic wildlife, primarily shorebirds and waterfowl. SWF also requested that ERDC conduct efforts to establish vegetation in rip-rapped and other hard-armored areas, most notably the river channel below Interstate 45 and the outfalls of Cell F and Cell G. In 2010, ERDC initiated assessment of previous seeding and planting efforts in grasslands adjacent to the wetland cells. Following results of this evaluation, which showed poor native grassland community development, ERDC proposed in its 2011 Scope of Work to employ methodologies including modifications of basic methods used to successfully establish wetland vegetation for repairing and improving the grassland community. This report summarizes work conducted on the LCOW wetlands and grasslands, with focus on vegetation establishment and ecosystem monitoring and management up to and during 2014. A summary of specific tasks undertaken through 2014 are provided in Appendix A.

Wetland Vegetation Community Establishment Approaches

ERDC began transplanting containerized native wetland plants into Cell D during late 2004 using techniques developed by ERDC researchers for establishing aquatic vegetation in lakes and reservoirs, and followed similar procedures as construction of the remaining LCOW cells were completed. In addition to planting, management strategies were developed and employed in Cell D to improve conditions for native plant establishment and spread. ERDC then applied successful strategies to other cells, with cell-specific modifications made to methodologies as needed to maximize plant establishment and diversity in each.

Aquatic and wetland plants used in this project were primarily containerized specimens grown from locally collected stock and cultured at LAERF in Lewisville, Texas. Typically, a variety of species and growth forms (emergent, floating-leaved, and submersed) were planted in each cell following construction, with results from initial plantings used to identify the most suitable approaches for establishment and expansion of plants on a cell-by-cell basis. Longer-term results (e.g., vegetation response to intentional water level manipulations, overbanking events, etc.) were used to further refine plant establishment strategies. ERDC used ongoing results (plant establishment response) to identify needs for further action or changes in current action (adaptive management), and was thus better able to apply available management tools to the system. By manipulating certain environmental conditions (e.g., accounting for herbivory, changing water levels, changing flow rates, controlling nuisance species, etc.) at the proper times, ERDC was able to steer the development of the plant community in the LCOW to one that was favorable to meet project goals.

It was expected that feeding activities of aquatic or terrestrial animals would impede establishment of plants in the cells, as is the case in many waterbodies in North Texas. Therefore, initial planting designs in each cell included evaluations of protected versus unprotected areas in order to ascertain which, if any, plants species would require protection for successful establishment. Initial plantings of emergent wetland species in all cells readily established and spread with and without protection from herbivores. Subsequent plantings of those species were, for the most part, made without protection, which enabled a shift in resources to focus on installing more plants, rather than fewer plants with protection. This hastened the process of full vegetative coverage in areas suitable for emergent plants in the cells. On the other hand, initial plantings indicated that herbivory, primarily by turtles and crayfish, could prevent establishment of submersed and floating-leaved vegetation, and that their establishment would require protection. Subsequent plantings of those species were made using exclosures to prevent herbivores from feeding on transplants. Despite additional efforts needed to establish herbivory-prone species, their importance as components of the aquatic portion of the wetland ecosystem merited their continued inclusion in the project. Once established in protected areas, most plant species were able to grow and spread to unprotected areas in most cells. In addition to protecting transplants, live-trapping/removal of herbivores and water level manipulations were used to modify herbivore populations, both of which improved establishment and spread of some submersed and floating-leaved species.

In addition to installing and protecting plants, water levels in the LCOW cells were manipulated to encourage growth of desirable volunteer wetland species such as smartweeds and sedges, as well as grasses and forbs in riparian areas. This strategy resulted in development of plant communities comprised of a combination of species that provide high quality habitat for waterfowl and other aquatic wildlife. In general, water levels were lowered during the spring through fall growing period to expose large areas of moist soil, which encouraged growth of both wetland and grassland plants. At the same time, obligate wetland and aquatic species were able to grow in permanently flooded shallows. Following plant community development and seed production, water levels were raised to maximum pool during late fall and winter, inundating vegetated areas and providing access to food and cover for invertebrates, fish, waterfowl and other aquatic wildlife. To further diversify LCOW habitats, variations in timing and water level fluctuations were made between cells.

Managing nuisance species has been a critical component of establishing native vegetation in the LCOW. In addition to changing water levels seasonally to prevent or reduce establishment of some nuisance plants when properly timed, combinations of mechanical, chemical, and biological control methods have been applied when deemed necessary. In general, weed management has followed an early detection/rapid response approach, and techniques have focused on management of targeted species, as opposed to non-selective, broad-spectrum control. By placing pressures specifically on nuisance plants, desirable plants have been able to better compete for available resources and resist re-infestations once control has been achieved. While management of weedy species will be an ongoing management requirement, resources needed to achieve control are much reduced when continuous pressures are applied to undesirable species.

Monitoring has been critical for ongoing evaluation of vegetation community dynamics, and has included assessments of plant community development in and around the wetland cells. Additionally, basic water quality (pH, dissolved oxygen, conductivity, and temperature) and sedimentation in the cells have been monitored at prescribed stations. Moreover, further biological monitoring (fish and macro-invertebrates) was initiated in 2009 to help define project success, and includes not only the wetland chain but a stretch of the Trinity River just beneath IH-45. Monitoring of the adjacent grasslands and planting efforts to establish vegetation in rip-rap areas were initiated in 2009, and have included small scale test plantings, serial larger-scale plantings, and nuisance plant management.

Wetland Plantings

Plant establishment was initiated in Cell D in 2004, in Rochester Park Lake in 2005, in Cells E, F, and G in 2008. Planting began in E-West, F-North, the Wood Duck Pond (and several small water features associated with Cell G) in 2009 and continued with supplemental plantings throughout 2014. Table 1 provides the thirty-one species of aquatic plants that have been transplanted into the cells as of 2014. These include nine submersed species, three floating-leaved species, and nineteen emergent species. Most of these species are perennial and capable of year-to-year recovery following periods of dormancy due to cold temperatures, dry periods, or periods of excessive inundation; all additionally spread from seed.

Table 1. Thirty-one species of native aquatic plants representing three growth forms have been transplanted in the LCOW since October 2004.

Scientific name	Common name	Growth form
Acmella oppositifolia	Opposite leaved spot flower	emergent
Bacopa monnieri	Water hyssop	emergent
Carex cherokeensis	Cherokee sedge	emergent
Ceratophyllum demersum	Coontail	submersed
Chara vulgaris	Muskgrass	submersed
Echinodorus berteroi	Tall burhead	emergent
Echinodorus cordifolius	Creeping burhead	emergent
Eleocharis acicularis	Slender spikerush	emergent
Eleocharis macrostachya	Flatstem spikerush	emergent
Eleocharis quadrangulata	Squarestem spikerush	emergent
Heteranthera dubia	Water stargrass	submersed
Juncus effusus	Soft rush	emergent
Justicia americana	American water-willow	emergent
Najas guadalupensis	Southern naiad	submersed
Nelumbo lutea	American lotus	floating-leaved
Nymphaea mexicana	Yellow water-lily	floating-leaved
Nymphaea odorata	American white water-lily	floating-leaved
Peltandra virginica	Arrow arum	emergent
Phyla lanceolata	Lance-leaf frog-fruit	emergent
Polygonum hydropiperoides	Swamp smartweed	emergent
Pontederia cordata	Pickerelweed	emergent
Potamogeton illinoensis	Illinois pondweed	submersed
Potamogeton nodosus	American pondweed	submersed
Potamogeton pusillus	Slender pondweed	submersed
Sagittaria platyphylla	Delta arrowhead	emergent
Sagittaria latifolia	Broadleaf arrowhead	emergent
Schoenoplectus pungens	American bulrush	emergent
Schoenoplectus californicus	Giant bulrush	emergent
Schoenoplectus tabernaemontani	Softstem bulrush	emergent
Vallisneria americana	Wild celery	submersed
Zannichellia palustris	Horned pondweed	submersed

Wetland Plantings, Monitoring, and Management Results To Date

Moist soil management and plant establishment

Design and construction of Cell D (and later, most other cells) resulted in three general inundation depths at full pool: a shallow shelf (approximately one-foot deep), a deep shelf (approximately three-feet deep), and a flood conveyance channel (approximately seven feet deep). Our original planting strategy called for moist soil management in which water levels were to be held at two elevations dependent upon time of year: Full pool (winter pool) would be held between late fall and late winter to provide habitat access for waterfowl and other aquatic wildlife on the shallow shelf; low pool (summer pool) was scheduled for between late winter and late fall to encourage establishment, growth, and spread of both emergent aquatic and terrestrial plants on the shallow shelf. Submersed, floating-leaved, and deepwater emergent species would be established from the grade between shallow and deep shelf, and on the deep shelf itself; no plants would be established in the channel or grade between deep shelf and channel. Some species were expected to grow as deep as four or five feet along the slopes leading to the channel.

The original planting strategy was not followed in late 2004 in order to reduce possible erosion of the newly excavated wetland slopes during Trinity River overbank events. Water levels were held at winter pool rather than summer pool, with test plantings of emergent species conducted at the winter pool shoreline and floating-leaved and selected submersed plants installed at the drop-off to the three-foot deep shelf. Because plants grew (albeit slowly) throughout the 2004-2005 winter, we continued planting at winter pool through late spring, 2005. Some submersed plant species were also planted on the deep shelf during that time.

In 2006 and 2007, we lowered Cell D to summer pool according to our prescribed schedule and planted the majority of emergent plants at the water's edge and submersed and floating-leaved plants on the deep shelf, which was 2-ft deep at the time of plantings. These plantings, combined with volunteer colonization by desirable vegetation, resulted in full coverage over the shallow shelf and partial coverage on the deep shelf, meeting the goals of aquatic plant establishment set for Cell D by the end of the 2008 growing season (Figure 1). Many of the species planted combined with desirable volunteer wetland species including sedges (*Carex spp.*), water primrose (*Ludwigia repens*), annual smartweeds (*Polygonum spp*.), flatsedge (*Cyperus acuminatus*), rushes (*Juncus spp*.), buttercup (*Ranunculus* sp.), and rattlebox (*Sesbania* sp.) were well established by 2008 and continued to thrive between 2009 and 2014.

Figure 1. Vegetation has become widespread along the shoreline and in the shallows of LCOW cells, meeting the overall goals of aquatic plant establishment in the wetlands.

In addition to scheduled water level manipulations, we periodically attempted to inundate exposed areas during hot and dry periods when emergent species showed signs of stress to ensure that adequate moisture was available to sustain survival and growth of wetland species. Water is supplied to Cell D via a moderately small electric submersed pump (Figure 2) managed by the City of Dallas Central Waste Water Treatment Plant (CWWTP), and during the heat of summer, this pump proved inadequate to inundate the shallow shelf in a timely manner, taking as long as three weeks when pumping 24-hours per day. Despite this limitation, plants were able to recover following periods of desiccation on exposed areas of the shallow shelf. The worst periods of exposure occurred during the summers of 2008 and 2010. In 2008, unknown persons lowered the weir gate to lowest managed pool setting (3-ft below full pool) on two occasions, exposing all plants to desiccation. In 2010, an extended period under which the water supply pump was not working resulted in water levels dropping below the 3-ft deep shelf, with all plant colonies exposed to summer heat and desiccation for a significant portion of the growing season. This resulted in a major but temporary setback to the wetland plant community in Cell D. Plants recovered dramatically in late summer/early fall following pump repair

Figure 2. Water is supplied to Cell D by the pump pictured above, and to Cells E and E-West by a larger pump installed in a nearby vault.

and refilling to summer pool. The plant community showed few signs of long-term damage from these events except for increases in invasive species (specifically alligatorweed, *Alternanthera philoxeroides*) following these events, indicating that the established community was resilient and capable of withstanding harsh environmental conditions.

Although initially viewed as inhibitory to our goals, uncontrolled/unauthorized lowering of water levels resulted in expansion of many desirable species. Combined with substantial recovery of other plant species when the cell was refilled, the event showed that manipulating water levels during the growing season could be used to increase growth and spread of the wetland plant community to lower elevations, resulting in more of the cell occupied by beneficial plants. We used this information to alter the moist soil management schedule by adding a water level change event: following the dry heat of summer (September 2008), we lowered the cell to one foot below summer pool, where it remained until the schedule called for winter pool in late October/early November. This timing (after summer heat) manipulation resulted in additional growth of emergent species onto lower elevations, increasing colony sizes and overall vegetative coverage in the cell, without causing damage to other more water-obligate species. Just as importantly, the timing of this drawdown did not appear to benefit invasive species (primarily alligatorweed), but did provide habitat for migrating shorebirds. As this project emphasizes adaptive management, we decided to incorporate a late summer to fall drawdown below summer pool in an effort to increase habitat value and usage by migratory birds.

Between 2011 and 2014 we investigated additional season manipulation of water levels to provide better habitat for overwintering waterfowl and shorebirds in Cell D. Eight or so weeks after the cell was raised to full pool in late fall to inundate wetland and grassland areas, water levels were lowered by six inches to one foot to expose mudflats where terrestrial vegetation had declined, thereby benefitting shorebirds and making made deeper vegetated areas available to dabbling ducks and wading birds. A moist soil management schedule for Cell D was formulated as:

- **Winter pool (392-ft ASL, full pool): November to March**
- **Mid-winter pool (391.5-ft ASL, 0.5-ft below full pool): February**
- **Late winter pool (392-ft ASL, full pool): March**
- **Spring pool (390.5-ft ASL, 1.5-ft below full pool): April and May**
- **Summer pool (391-ft ASL, 1-ft below full pool): June to September**
- **Summer saturation pool (392-ft ASL, full pool): As needed June to September**
- **Fall pool (390-ft ASL, 2-ft below full pool): October**

Deviation from this schedule was applied when environmental conditions were not conducive to intended results of water level manipulations, or when additional benefits might be realized. For instance, sustained drought or hot weather in October has circumvented lowering the cell to fall pool. Results of vegetation community development in Cell D following moist soil strategies are shown in Figure 3. Plant communities were well-established substantially by 2008 and have persisted through 2014 (Appendix B).

Figure 3. A diversity of emergent, floating-leaved, and submersed vegetation has been established in Cell D as a result of combinations of planting and water level manipulations.

We began applying a similar moist soil management schedule to other cells as planting was initiated in each, with slight variations made to produce more diverse habitats within the LCOW. While this schedule has produced desirable results, deviations can also provide further benefits. For instance, lowering water levels in Cell E and Cell G in winter 2013 for a short period permitted freezing of alligatorweed stem bases and attracted waterbirds that had not otherwise been using the cells. Monitoring results of changes made is therefore important to document ecosystem responses and whether or not the change is benefitting the project. The following section outlines moist soil management differences and plant community responses between 2009 and 2014 in the remaining cells.

Cell E-West was initially managed with two water levels in 2009, including a winter pool and summer pool. However, since 2010 water levels have been maintained as stable in the cell (no moist soil management) at a permanent pool. Installed plants were well-established by 2012, with no additional plantings required since that time. This cell was built with steeper slopes than most other cells, and lacks planting shelves, which has resulted in establishment of a thin band of mixed wetland/grassland plants along its perimeter. An island located in the western half of the cell increases overall wetland plant coverage. Emergent plants are well-established and are represented by a combination of planted and volunteer species, with spikerushes, sagittaria, bulrushes, and smartweeds the most commonly encountered. Submersed and floating-leaved species are marginally established in the cell in 2014.

Cell E has been managed to produce a mixed wetland vegetation/mudflat habitat similar to that in Cell D since late 2008. Late winter pool (full pool) is lowered by 1-ft to achieve summer pool, and then lowered another 0.5-ft to achieve fall pool, thereby providing habitat for migrating shorebirds and mudflat-loving waterfowl such as shovelers (*Anas clypeata*) and teal (*Anas* spp.). Plants installed between 2010 and 2013 were well established and had spread throughout most of the cell by 2014, resulting in no need for additional plantings. Moist soil management in this cell has resulted in establishment of large stands of sagittaria, pickerelweed, smartweeds, water primrose, sesbania, bulrushes, and spikerushes.

Cell F-North has been managed as a partial ephemeral wetland since 2009. Wetland species appropriate for those conditions were planted between 2009 and 2013, with water levels not managed other than to prevent elevation from dropping below levels that would cause loss of fish and other aquatic wildlife. Full pool for the cell is set using the dam board box to permit overflow from runoff before inundation of the islands occurs, preserving the islands as nesting habitat for mallards and other resident ground-nesters. Emergent plants, especially water smartweed, water primrose, sedges, bulrushes, and water-lilies were well-established and spreading along the perimeter of this cell by the end of the 2014 growing season.

Beginning in late 2008, Cell F was managed similarly to Cell D, with water level changes including an early winter pool (full), mid-winter pool (½-ft below full), late winter pool (full), spring pool (1.5-ft below full), summer pool (1-ft below full), and fall pool (another 1 ½ to 2-ft below full) to further encourage establishment of mixed wetland and grasslands to provide better winter habitat for species that use flooded terrestrial areas, such as mallards (*Anas platyrhynchos*). ERDC planted the westernmost portion of this cell, designated F (West), with wetland plants between 2009 and 2012 (Figure 8). Planting in easternmost half, designated Cell F (East), was delayed in order to manage a significant cattail infestation occurring in that cell; planting was initiated in 2010 and completed in 2013. Additional plantings were made in large expanses of full pool inundated areas associated with F (West) and F (East) in order to hasten plant community establishment in mixed wetland/grassland zones. As of 2014, emergent species such as bulrushes, sesbania, sagittaria, spikerushes, and sedges were abundant around these cells.

Cell G has been managed with winter pool (full) and summer pool (1 ½-ft below full). This has given similar results as in other cells, but has resulted in better establishment of submersed species, particularly pondweeds and water stargrass. Greater water level fluctuations results in inundation of more expansive areas supporting grassland species, providing additional food and cover for dabbling ducks. Plants installed between 2009 and 2013 responded well to this plan, with further plantings not required in 2014.
In addition to submersed species, Cell G supports large stands of bulrushes, pickerelweed, sagittaria, spikerushes, sedges, sesbania, and others.

Planting was also conducted in the Wood Duck Pond, an approximately 4-acre sump area adjacent to and connected by culvert to Cell G. The pond was planted primarily with floating-leaved species, including American lotus (*Nelumbo luteum*), to produce habitat for wood ducks (*Aix sponsa*) and other waterfowl (Figure 4). Additional species established include spikerushes, sagittaria, and bulrushes. To diversify emergent vegetation species, additional plantings were made in 2014.


Figure 4. Aquatic plants are well-established in the Wood Duck Pond at the southwest side of Cell G. Nest boxes were installed in 2012 for wood ducks and hooded mergansers.

Table 2 provides a list of wetland plant species observed in the LCOW (on the 1-ft deep shelf or below) since 2005. Many are desirable native plants that had been transplanted by ERDC or had naturally established as volunteers from seed banks. In addition to these plants, many grassland species grow intermingled with wetland species as a result of moist soil management practices discussed earlier in this report. Aquatic vegetation meander surveys conducted in 2014 indicated that most planted species and many desirable volunteer species were well established and spreading in the wetland cells, throughout the LCOW. Undesirable species that have become established in the LCOW are discussed later in this report.

Table 2. Forty-nine plant species have been observed in the wetlands between 2005 and 2014 (T = transplanted and V = volunteer). Species highlighted in bold are considered invasive and have been managed by ERDC.

Scientific name	Common name	Source	D	E-W	E	F-N	F-W	F-E	G
Acmella oppositifolia	Opposite leaved spot flower	V	X		X		X		X
Alternanthera philoxeroides	**Alligatorweed**	**V**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Azolla caroliniana	Mosquito fern	V		X					X
Bacopa monnieri	Water hyssop	T	X	X	X	X	X	X	X
Carex cherokeensis	Cherokee sedge	T & V	X	X	X	X	X	X	X
Carex crus-corvi	Ravenfoot sedge	T & V	X	X	X	X	X	X	X
Ceratophyllum demersum	Coontail	T	X		X		X	X	
Chara vulgaris	Muskgrass	T	X		X				X
Cyperus sp.	Flatsedge	V	X	X	X	X	X	X	X
Echinodorus berteroi	Tall burhead	T	X	X	X		X		
Echinodorus cordifolius	Creeping burhead	T	X	X	X		X		X
Eleocharis acicularis	Slender spikerush	T	X	X	X	X	X	X	X
Eleocharis macrostachya	Flatstem spikerush	T	X	X	X	X	X	X	X
Eleocharis quadrangulata	Squarestem spikerush	T	X	X			X		X
Fraxinus caroliniana	**Green ash**	**V**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Heteranthera dubia	Water stargrass	T	X	X	X			X	X
Hibiscus sp.	Hibiscus	V				X			X
Hydrocotyle sp.	Pennywort	V	X	X	X	X	X	X	X
Juncus effusus	Soft rush	T	X		X	X	X	X	X
Juncus sp.	Rush	V	X	X			X	X	X
Justicia americana	American water-willow	T		X		X			X
Lemna sp.	Duckweed	V	X	X	X	X	X	X	X
Ludwigia repens	Water primrose	V	X	X	X	X	X	X	X
Najas guadalupensis	Southern naiad	T	X	X	X	X	X		X
Nelumbo lutea	American lotus	T & V							X
Nymphaea mexicana	Yellow water-lily	T	X	X	X	X	X	X	X
Nymphaea odorata	American water-lily	T	X	X	X	X	X	X	X
Paspalum distichum	Jointgrass	V	X	X	X	X	X	X	X
Peltandra virginica	Arrow arum	T	X	X		X			
Phyla lanceolata	Lance-leaf frog's fruit	T & V	X		X	X	X	X	X
Phyla nodiflora	Turkey tangle frogfruit	T & V	X	X	X	X	X	X	X
Polygonum hydropiperoides	Swamp smartweed	T	X	X	X	X	X	X	X
Polygonum spp.	Smartweeds	V	X	X	X	X	X	X	X
Pontederia cordata	Pickerelweed	T	X	X	X	X	X	X	X
Populus deltoides	**Cottonwood**	**V**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Potamogeton illinoensis	Illinois pondweed	T	X	X	X	X	X	X	X
Potamogeton nodosus	American pondweed	T	X	X	X	X	X	X	X
Potamogeton pusillus	Slender pondweed	T	X	X	X	X	X	X	X
Ranunculus sp.	Buttercup	V	X	X	X	X	X	X	X
Sagittaria latifolia	Broadleaf arrowhead	T	X	X	X	X	X	X	X
Sagittaria platyphylla	Delta arrowhead	T	X	X	X	X	X	X	X
Salix nigra	**Black willow**	**V**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Sesbania herbacea	Bigpod sesbania	V	X	X	X	X	X	X	X
Schoenoplectus pungens	American bulrush	T	X	X	X	X	X		X
Schoenoplectus californicus	Giant bulrush	T	X	X	X	X	X		X
Schoenoplectus tabernaemontani	Softstem bulrush	T	X	X	X	X	X	X	X
***Typha* sp.**	**Cattails**	**V**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Vallisneria americana	Wild celery	T	X	X	X				X
Zannichellia palustris	Horned pondweed	T	X		X				X

Herbivory

Plantings at the LCOW consisted primarily of emergent species, and few of those, if any, have been affected by herbivores at any point during vegetation establishment. Because protection for emergent plants was largely not needed, ERDC was able to shift resources from construction of protective exclosures to production and transplanting of more plants, which hastened the process of establishing native desirable vegetation in the wetlands.

However, emergent plants are not the only growth form needed to provide high quality habitat (and benefits) in the LCOW. Floating-leaved and submersed species are important components of most aquatic ecosystems, providing significant benefits such as structural habitat for fish and their prey, water column nutrient-load reduction, and food for waterfowl and other aquatic wildlife. Survival and growth of floating-leaved and submersed species have required protection in the LCOW, primarily from turtles. Whenever planting these species, ERDC used protection, such as ring cages, to ensure their establishment (Figure 5). Once established, many species of floating-leaved and submersed species were capable of spreading beyond protected areas, thereby providing larger-scale benefits to the system. In addition to using ring cages for protection, ERDC installed several larger pens (approximately 10-ft x 20-ft) for protection of submersed species in some of the cells in order to increase overall plant colony size and seed production, and thereby speed the process of spread to unprotected areas.

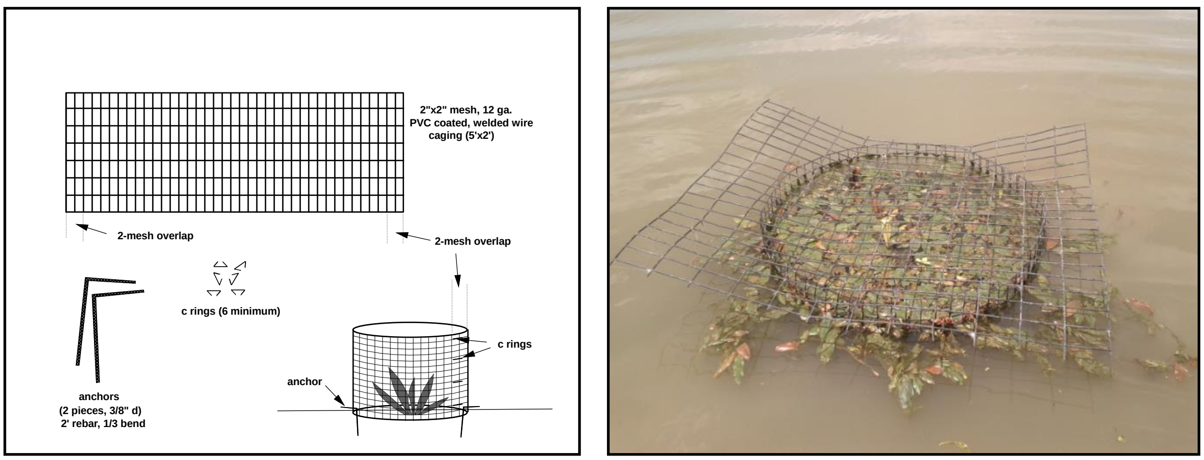


Figure 5. Ring cages were installed to serve as protection for newly establishing submersed and floating-leaved vegetation from grazing by turtles, common carp, and other herbivores. In cases where cages were regularly overtopped by rising water, covers were installed to prevent herbivores from swimming inside. The photo at the right shows that once plants fill cages (in this case American pondweed), they begin to spread to unprotected areas.

Turtles: The principal herbivore encountered in the LCOW has been semi-aquatic turtles, mostly red-eared sliders (*Trachemys scripta elegans*), but includes river cooters (*Pseudemys* sp.) and map turtles (*Graptemys* sp.). While emergent species have only been moderately affected by turtles, submersed and floating-leaved species have been hard-hit on occasions. Beginning in 2006, ERDC began deploying fall-in live traps in Cell D to capture and relocate turtles to the Trinity River or LAERF (located upstream on the Trinity River) (Figure 6). We reasoned that a reduction in turtle population density would in turn reduce grazing pressure on newly establishing vegetation, thereby enabling spread of plants from protective exclosures. Between 2006 and 2014, over 1,250 turtles were captured from Cells D, E, F and G and relocated, and following initiation of this practice several species, including American pondweed, water stargrass, American water-lily, and yellow water-lily, exhibited greater spread outside of protected areas. Additionally, volunteer species such as water primrose spread significantly throughout the cells in conjunction with turtle management. Inexplicably, we have only encountered moderate problems with turtles in other cells following initial planting and protection: once plants are established inside exclosures in those cells, they are able to grow beyond protection. Turtle relocations have not been required in those cells.

Figure 6. Fall-in live traps have proven successful for capture and relocation of grazing turtle species in several LCOW cells (left). Red-eared sliders dominate the turtle population in the LCOW, and are voracious consumers of aquatic vegetation, as seen by grazing damage on American pondweed (right).

Common carp: In late 2006, we observed that adult common carp (*Cyprinus carpio*) were present in Cell D and in subsequent years that common carp were in all cells. While successful reproduction in any cell has not been verified as of this report, we did observe spawning behavior in Cell E in spring 2010 and in other cells between 2011 and 2014. Because common carp can have devastating impacts on aquatic vegetation and aquatic ecosystems in general, we installed eight pens (10-ft x 10-ft x 4-ft tall) designed to trap and contain carp (and turtles) until they can be removed in Cell D (Figure 7). Traps were planted with submersed species to act as attractants, and several carp and numerous turtles have been caught using this methodology since their installation. Overall herbivory damage has lessened in Cell D since turtle and carp traps have been installed, but low numbers of carp removed appear to indicate that turtles are the primary grazers in the cells. Portable carp funnel traps were tested near inflows of other cells in 2012 and 2013, but were not successful in capture or removal of carp, although some turtles were captured. No substantial damage by common carp was noted in any of the cells during 2014.

Figure 7. Carp live traps were constructed in Cell D to help reduce carp densities provided limited results, but were effective at live trapping turtles for removal from the cell.

Invertebrates: Grazing by other herbivores has periodically caused problems during the project. While evident in all cells since their filling, crayfish (*Procambarus clarkii* and others) did not appear to cause significant problems for plants until spring 2010, when submersed plants in Cell E, Cell G, and the Wood Duck Pond were heavily damaged and required replantings on two occasions (Figure 8). A moderate number of finer mesh ring cages were installed to protect founder colony plants in those two cells to ensure their presence in the face of crayfish herbivory. Additionally, we lowered water levels in both cells by six inches to simulate drying conditions, which may have triggered burrowing activity by the crayfish and lessened their impacts on new plantings. Lower water levels may also have left the crayfish more susceptible to predators such as herons and egrets. Although crayfish and their chimneys are frequently observed to date in and around all cells, no significant damage to plants by crayfish has been observed in any cells since 2010.

Other invertebrates have been observed feeding on desirable plants, but these typically do only limited damage and should be considered important ecosystem components, helping to prevent any one plant species from taking over the plant community. Examples include water-lily leafcutter moths (*Synclita* sp.) feeding on floating-leaved and some emergent species (Figure 9), and seasonal populations of native flea beetles (*Lysathia ludoviciana*) that damage water primrose. A number of these species are generalist feeders, and may help keep nuisance plants such as alligatorweed in check.

Figure 8. Crayfish burrows (and individuals) were frequently encountered around all LCOW cells. In some cases, populations become dense enough to impact establishing submersed vegetation.

Figure 9. Water-lily leafcutter moth damage on American pondweed.

Waterfowl: Although a highly desirable component of the ecosystem, dabbling ducks have contributed to plant loss during winters in all cells, primarily in the form of uprooted sagittarias and rushes, but long-term damage to plant populations by overwintering waterfowl appears to be minimal. Because native plants and overwintering waterfowl have co-evolved, waterfowl feeding typically does not significantly damage plant populations, and in fact may benefit regrowth of some species the following spring by enabling higher germination and sprouting rates of seeds and tubers that remain. However, if resident populations of waterfowl establish in DFE wetlands (Figure 10), their effects on the plant community may become problematic. Fortunately, other than occasional reproduction by small numbers of resident mallards, we have seen no evidence as of 2014 that a significant resident waterfowl population is developing at the LCOW. In the event that resident populations do begin to develop, a plan for their management will have to be formulated.

Figure 10. Migrating dabbling ducks feed heavily on aquatic plants during cooler seasons in the LCOW, but have not excessively damaged plant colonies to date. Development of large populations of resident ducks or geese, such as these mallards, could inflict significant damage on vegetation communities in the LCOW.

Mammals: Beavers (*Castor canadensis*) have been observed in several cells and beginning in 2010 have caused some damage to American and yellow water-lilies and possibly bulrush colonies. While some recovery of damaged plants had occurred by late 2011, supplemental plantings were made in 2012 to ensure those species are present in the cells in which damage occurred, most notably Cell D and Cell E. While beaver damage was occasionally noted in 2013 and 2014, vegetation appears to be established well enough to withstand their presence.

To date, beaver activity in other cells has not included noticeable damage to plants, although issues have occasionally occurred at the outfalls of Cell E and Cell G, where beavers have brought materials (mostly willow twigs, alligatorweed, and mud) to dam the weir gate boxes (Figure 11). Ongoing efforts to discourage dam-building have included hand removal of materials, short-term stoppage of pumping to prevent water from flowing over weir gates (which triggers beaver dam-building behavior), and restricting water flow to morning daylight hours when beaver are less likely to be active. Although potentially labor-intensive, these efforts have provided reasonably good results and beaver activity has been manageable through 2014.

Beavers have also burrowed in and around several weir structures, with most burrowing occurring at the dam board weir box in Cell E-West, the weir gate box in Cell E, and the flow through from the Cell E weir gate box into Cell F (West). Burrows did not appear to be extensive enough to cause significant problems as of 2014, but they should be monitored periodically to ensure the earthen areas around these structures are not overly damaged.

If beavers continue to be problematic or their activity increases to the point of preventing weir gate operation or causing levee integrity failure, trapping and relocation may be required. Alternatively, because recolonization will likely become an ongoing issue, consideration of modifications to the outlet weirs and other structures prone to beaver activity may be necessary. For instance, fencing off areas to prevent beaver from constructing dams has proven successful in some situations, although maintenance of fencing may be high in the LCOW, where periodic significant water flow may result in excess debris (trash, logs, mats of vegetation, etc.) preventing flow to the weirs and/or damaging fencing. Alternative beaver discouragement methods might include installation of sound producing devices (predator calls or unpleasant sonic pulses) or electrical barriers to keep beaver away from sensitive areas. A test in 2013 using over-the-counter sonic repulsion devices designed to manage moles provided modestly positive results in beaver deterrence, but did not prevent dam or lodge building.

Figure 11. Beavers periodically build dams at the outlet weirs in some of the LCOW cells. In this case, beaver damming has been supplemented by rafts of alligatorweed, potentially clogging flow through the weir.

Nutria (*Myocastor coypus*) were observed in one cell (E-West) in 2010, but feeding on plants has not yet been seen, and nutria have not apparently established in the LCOW. Because nutria have the potential to significantly damage belowground portions of bulrushes and other rhizatomous species, as well as damage levees when burrowing, monitoring their occurrence is highly important at the LCOW, and if observed, control measures will have to be devised. Nutria have not been observed since the initial sighting in 2010.

Feral pigs (*Sus scrofa*) tracks and rooting have been observed along the shorelines and adjacent grasslands of Cells F (East), F-North and G, with some damage to shoreline plants such as sagittaria and flatstem spikerush occurring in 2011 and grassland plants in 2012 and 2014. If excessive activity is noted in wetland or grassland areas, animal control may have to be applied to remove the animals, or at least reduce their densities in the area. No damage by feral pigs was observed in 2013, possibly due to reductions in numbers along the Trinity River as a result of a COD contract with a hog removal specialist during part of that year, but observations of damage in 2014 may indicate a recovery of hog populations in the area.

Water quality

Water quality was monitored periodically beginning in 2005, with intensive evaluations including several water chemistry parameters made in 2013. In general, water quality remained suitable for supporting plants, fish, and invertebrates throughout the project, with infrequent occurrences of high pH due to excessive algal growth, mostly occurring in Cell D and Cell E-West soon after their construction and filling. Previously reported results of water quality monitoring through 2013 are given in Appendix C. Although the LCOW was not constructed to moderate nutrient loads in CWWTP effluents, substantial decreases in nitrogen and phosphorus were documented, attributable to vegetation establishment within the chain.

Effects of overbanking on wetland plants

Numerous overbanking events have occurred since completion of Cell D, with the most severe occurring during summer 2007, when continuous overbanking occurred for about six weeks in June and July (during the active growing season). Complete submersion of plants combined with high turbidities damaged both planted and volunteer plant species, but recovery was noted for nearly all species within four weeks of overbanking cessation. Plants that were most severely impacted due to this event included the submersed species wild celery and Illinois pondweed. Shorter-term overbanking events, usually lasting only several days to a few weeks, have occurred during all years of the project except for 2014, but have had only minimal direct impacts on wetland plants in any of the cells. In some cases, protective exclosures have been washed away or damaged by floating debris and have required replacement or repair. The three overbanking events occurring in 2012 had minimal impacts on vegetation communities and exclosures in the LCOW; the single, short-term event occurring in 2013 appeared to have no impacts on plants or exclosures.

Indirectly, flushing of nutrients (and planktonic algae) that build up when adding effluent has sometimes improved water quality and benefitted growth of some plants in the cells, particularly soon after their construction, before plants had established. Typically, if the system appears to be on the brink of an algal bloom (e.g., water starting to green up), overbanking effectively replaces that water with river water. While not of pristine quality, river water is generally lower in nutrients than CWWTP effluent.

Overbanking has also served as a natural stocking mechanism for fish, other aquatic wildlife, and volunteer plant species. No fish or other aquatic animals were intentionally stocked in any of the cells after their construction, but populations and communities of these organisms developed rapidly in each cell following initial overbanking events.

Monitoring of sedimentation due to silt deposition during overbanking and other causes was initiated in 2008 in Cell D and in other cells in 2009, continuing through 2013. Monitoring was not undertaken in 2014 due to an absence of overbanking during that year. Results of this effort are given in Appendix D.

Effects of water supply disruption on wetland plants

ERDC regularly manipulates water levels to encourage growth of desirable plants. However, these fluctuations are moderate and are carefully controlled and monitored to ensure that potential negative effects are avoided. Drying emergent plants too quickly or at the wrong time of year, for instance, could damage existing stands, just as lowering of the water at any time could expose submersed species and lead to their mortality. Several events have occurred since the LCOW was constructed in which water levels dropped unexpectedly. In the first case, unauthorized lowering of the weir gate to its lowest setting resulted in water levels falling to 3-ft below full pool during mid-summer, exposing many plants to desiccation. We were able to refill the cell using the CWWTP pumps within a few weeks, but many plants exhibited signs of damage before water levels returned to summer pool. A few weeks after refilling, the water level was lowered again by the same amount and in the same manner (unauthorized), and again refilled. Fortunately, plant colonies suffering from this double-drawdown proved highly resilient and most had recovered before the end of that growing season. Part of ERDC's management of the entire LCOW since that time has been to monitor water levels and weir gate elevations to make sure prescribed conditions are met to prevent unnecessary damage to wetland plant communities.

CWWTP pump failures have occasionally interfered with our ability to maintain water levels, resulting in sometimes profound negative effects on the wetland plant community. The most notable occurred in 2010, when pump failures in the winter resulted in cells holding significantly less water than normal during the spring (most had fallen 3 to 4 feet below full pool by June, when pumps were repaired) (Figure 12). Ecologically, this event represented a major disturbance, with the

Figure 12. Periods of low water have occurred periodically due to unauthorized lowering of weir gates and CWWTP pump failure, damaging wetland plant communities.

resultant exposed mud banks providing an ideal situation for rapid expansion of an undesirable species, alligatorweed, and increased germination and seedling growth success of black willows (*Salix nigra*) and cattails (*Typha* sp.). Up to that time, these species were being held in check using several management strategies (see Weed management section, below), including water level management. Since the prolonged pump failure, more intensive management has been required to keep the invasive plants under control. Short term pump failures in the winter of 2011/2012 and spring 2012 resulted in slight interruption of moist soil management, but repairs were timely enough to prevent excessive water losses, damage to existing plant communities, or a repeat of rapid expansion of nuisance plants. Both pumps were down in for a portion of 2013, but were brought back online before plants (or cells) suffered from excess water loss. Pumps remained functional throughout 2014, enabling consistent moist soil management application and avoidance of unplanned ecosystem disturbances. In addition to lack of overbanking, stability in the vegetation community between 2013 and 2014 is likely attributable to absence of unmanaged flood/drought events.

Weed management

A critical but often overlooked component of vegetation establishment projects is management of nuisance species, which is especially important in new construction projects such as the LCOW. Beginning as early as 2005, several undesirable species began growing as volunteers in Cell D, and began establishing in other cells as their construction was completed. Problematic species included cattails, black willows, and cottonwoods (*Populus deltoides*), present in area seedbanks, and alligatorweed, its source the CWWTP channel that is used to supply water to the LCOW (Figure 13). Although cattails are native to north Texas and are good contributors to wetland function via nutrient abatement and structural habitat, the species is aggressive and tends to crowd out other wetland species that provide a wider range of benefits to wetland-dependent wildlife. Cattails growth is permitted in the wetlands to utilize its benefits, but spread is periodically kept in check to limit it's propensity towards taking over as a monoculture. Likewise, black willows and cottonwoods are native species that provide certain benefits to wetlands, but are woody and can impede water flow, which is not compatible with the flood conveyance requirements of the project. Several small patches of willows have been left intact to provide habitat, but occurrence outside of these areas is controlled. Alligatorweed is a nuisance species introduced to the U.S. from South America that is capable of expansive growth that degrades wetland function and can impede water flow, especially through structures such as the weir gate boxes. Because these (and other) nuisance species were capable of significant disruption of project goals, ERDC began efforts to manage them to minimize their impacts on establishing desirable vegetation and flood conveyance, and to avoid larger-scale and expensive efforts to control them if left unconstrained.

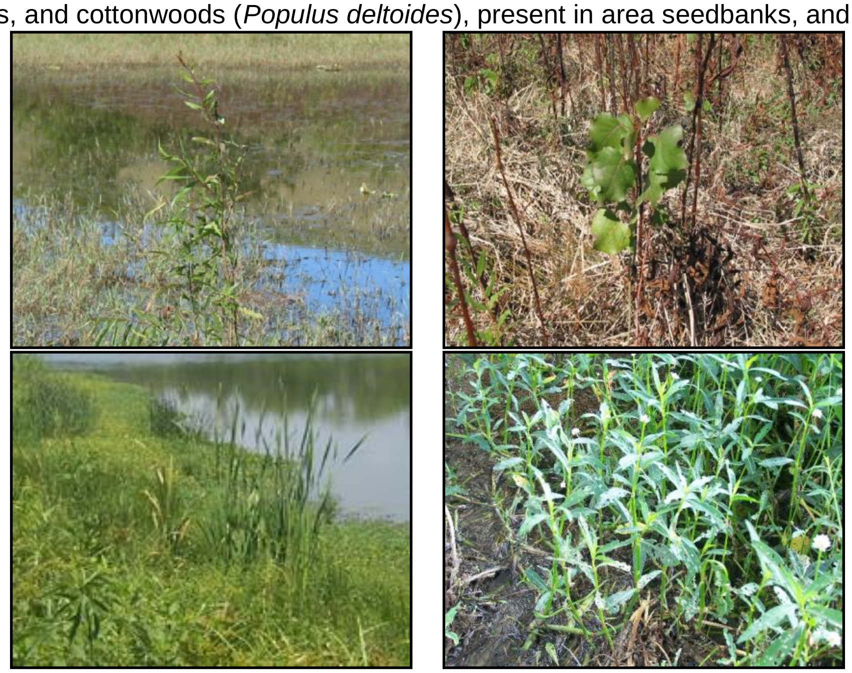


Figure 13. Black willows (top left), Eastern cottonwoods (top right), cattails (bottom left), and alligatorweed (bottom right) are the primary undesirable wetland species being managed in the LCOW.

When encountering cattails and tree saplings, ERDC staff initially hand-pulled them in order to prevent their growth and spread. While these efforts met with moderate success, they did not provide the level of control desired due to extensive seed banks of the two species in the areas. Spot-treatments with non-selective glyphosate (cattails and trees) and later with selective triclopyr (trees) were therefore implemented. Spot-treatments were used to minimize damage to non-target species, and included wicking and foliar application with a small tank sprayer. An additional benefit of using triclopyr over glyphosate for trees was its ineffectiveness on monocots (grasses and most herbaceous wetland species planted around the LCOW). Treatment in this manner has been highly successful on cattails, black willows, and cottonwoods, with only limited impacts on desirable vegetation. ERDC continued management of cattails and tree saplings as needed in all cells through 2014. At the time of this report, cattails occur in small colonies in most cells, with a few stands left untreated to provide food for beavers (as an alternative to them feeding on planted bulrushes) and as nesting and cover habitat for several bird species. Trees are near-absent or uncommon in most cells, with the exception of small stands of black willows adjacent to Cell F (East), Cell G, and the Wood Duck pond. These trees are not of concern for flow impediment and are therefore being retained to provide additional habitat in the LCOW. Additionally, as beaver cut and feed on these trees, the stands have diminished somewhat in coverage since 2009. Table 3 provides an overview of nuisance plant management strategies that have proven successful in the LCOW; herbicide applications are made as needed, generally twice yearly.

Table 3. Overview of nuisance plant management efforts undertaken at the LCOW through 2014.

Cell	Cattails	Willows & cottonwoods	Alligatorweed
D	Glyphosate as needed; currently no infestation	Triclopyr as needed; small currently no infestation	Triclopyr as needed; alligatorweed insects four times in spring and summer; infestation greatly diminished
E	Glyphosate as needed; small infestation remains	Triclopyr as needed; small infestation remains	Triclopyr as needed; alligatorweed insects four times in spring and summer; infestation greatly diminished
E-West	Glyphosate as needed; currently no infestation	Triclopyr as needed; currently no infestation	Triclopyr as needed; alligatorweed insects four times in spring and summer; infestation greatly diminished
F (West)	Glyphosate as needed; currently no infestation	Triclopyr as needed; currently no infestation	Triclopyr as needed; alligatorweed insects four times in spring and summer; infestation greatly diminished
F (East)	Glyphosate as needed; currently no infestation	Triclopyr as needed; currently no infestation	Triclopyr as needed; alligatorweed insects four times in spring and summer; infestation greatly diminished
F-North	Glyphosate as needed; currently no infestation	Triclopyr as needed; small infestation remains	Triclopyr as needed; alligatorweed insects four times in spring and summer; infestation greatly diminished
G	Glyphosate as needed small infestation remains	Triclopyr as needed; small infestations await decision-making	Triclopyr as needed; alligatorweed insects four times in spring and summer; infestation greatly diminished
Wood Duck pond	Glyphosate as needed small infestation remains	Triclopyr as needed; some are left purposefully as habitat	No alligatorweed infestation
CWWTP channel	N/A	N/A	Alligatorweed insects four times in spring and summer; triclopyr at water intake as needed; infestation greatly diminished

Alligatorweed remains established in all LCOW cells, but declined significantly between 2012 and 2014. Alligatorweed easily spreads by fragments and is believed to have first been introduced into Cell D in 2005, by both overbanking events and pumping from the infested CWWTP channels. Initial treatments included hand-pulling, but unintentional low-water events beginning in 2008 provided opportunities for explosive spread. Pump failure and delayed repairs during the growing seasons of several years prevented ERDC from adjusting water levels in a manner that may have stymied the spread of alligatorweed. Large mud flats exposed at those times provided suitable conditions for alligatorweed to aggressively spread into available niches, with no means to slow the spread by inundating the mud flats. In addition to treating infestations with glyphosate, which provided only temporary control, ERDC began introducing biocontrol agents, alligatorweed flea beetles (*Agasicles hygrophila*) and stem-boring moths (*Arcola malloi*), in Cell D during 2008, in an effort to manage the infestation before other LCOW cells were completed (Figure 14). While the combination of the two can devastate alligatorweed populations, each alone provides only limited control and did not reduce the problem. By 2010, despite single-time yearly introductions when the beetles were available from the COE Jacksonville District, flea beetle populations had not become established and alligatorweed continued to thrive. In 2011, ERDC began using triclopyr in conjunction with biological control, which provided the best control results since the infestation began. However, the four native species that occupy similar niches as alligatorweed (water primrose, water smartweed, opposite leaved spot flower, and lance-leaf frog-fruit) are also susceptible to triclopyr, and alligatorweed remained dominant following recovery because control was not selective in this particular case. ERDC and SWF recognized that managing alligatorweed would require more effective (but selective) control and in 2012 began making multiple releases of alligatorweed flea beetles acquired from multiple sources: Jacksonville District and a population started in cultures at the LAERF. Earlier-in-the-year releases combined with four (or more) release dates resulted in substantial declines in alligatorweed in the LCOW and increases in native plants growing in the same general areas. ERDC also released beetles in the CWWTP channels to reduce the likelihood of re-infestations. In addition to releasing insects, areas without populations of plants capable of competing with alligatorweed were planted with water smartweed, frog-fruit, and spot flower. Additional stocking of flea beetles were made in 2013 and 2014 to sustain momentum of control and enable better growth of native plantings. In those years, alligatorweed declined from occurring along approximately 90% of the shorelines of the cells to less than 10%, indicating that the combinations of flea beetles releases and native plantings were providing control.

It remains uncertain if alligatorweed flea beetles will survive winters in the north Texas area. We did not find evidence of recovery of populations following the winters in 2012 or 2013, resulting in additional 2013 and 2014 releases made. If areas now dominated by native vegetation cannot compete against alligatorweed in the absence of flea beetles, it is likely that periodic reintroduction of beetles will be required as a part of a long-term management strategy.

Figure 14. Alligatorweed flea beetles (top left) acquired from USACE Jacksonville District and those reared at LAERF cultures were released multiple times between 2008 and 2014 (top right) in a successful effort to control alligatorweed infestations at the LCOW. Establishment of these biocontrol agents can provide sustained management of alligatorweed in the wetland cells and adjacent areas, but whether or not the beetles are established remains unknown. Potential re-infestations of alligatorweed come from the nearby wastewater treatment plant and the Trinity River.

Armored areas plantings

Several areas prone to erosion were identified by SWF and ERDC in 2009: the outfall from Cell F to Cell G and the outfall from Cell G into Honey Springs Branch (Figures 15 and 16); additionally, water flowing into Cells E-West and F-North just prior to and during overbanking by the Trinity River had caused some erosion problems (Figures 17 and 18). And, finally, areas adjacent to hard-armored slopes of the Trinity River just below the IH-45 Bridge were deemed of concern (Figure 19). SWF contracted repairs of hard armored areas at the Cell F to G outfall (2009), the Cell G outfall (2010) and the riverbank (2009). Following repairs, SWF took additional measures by engaging ERDC to plant an array of plants, both terrestrial and wetland, to improve performance of armoring at these sites as well as at cuts associated with Cell E-West and Cell F-North. Large-scale plantings at these sites were conducted in 2010 and 2011, with supplemental plantings made as-needed in 2012 and 2013. Assessments in 2014 indicated that additional plantings were not necessary in these areas, with establishment of planted and volunteer vegetation considered satisfactory.

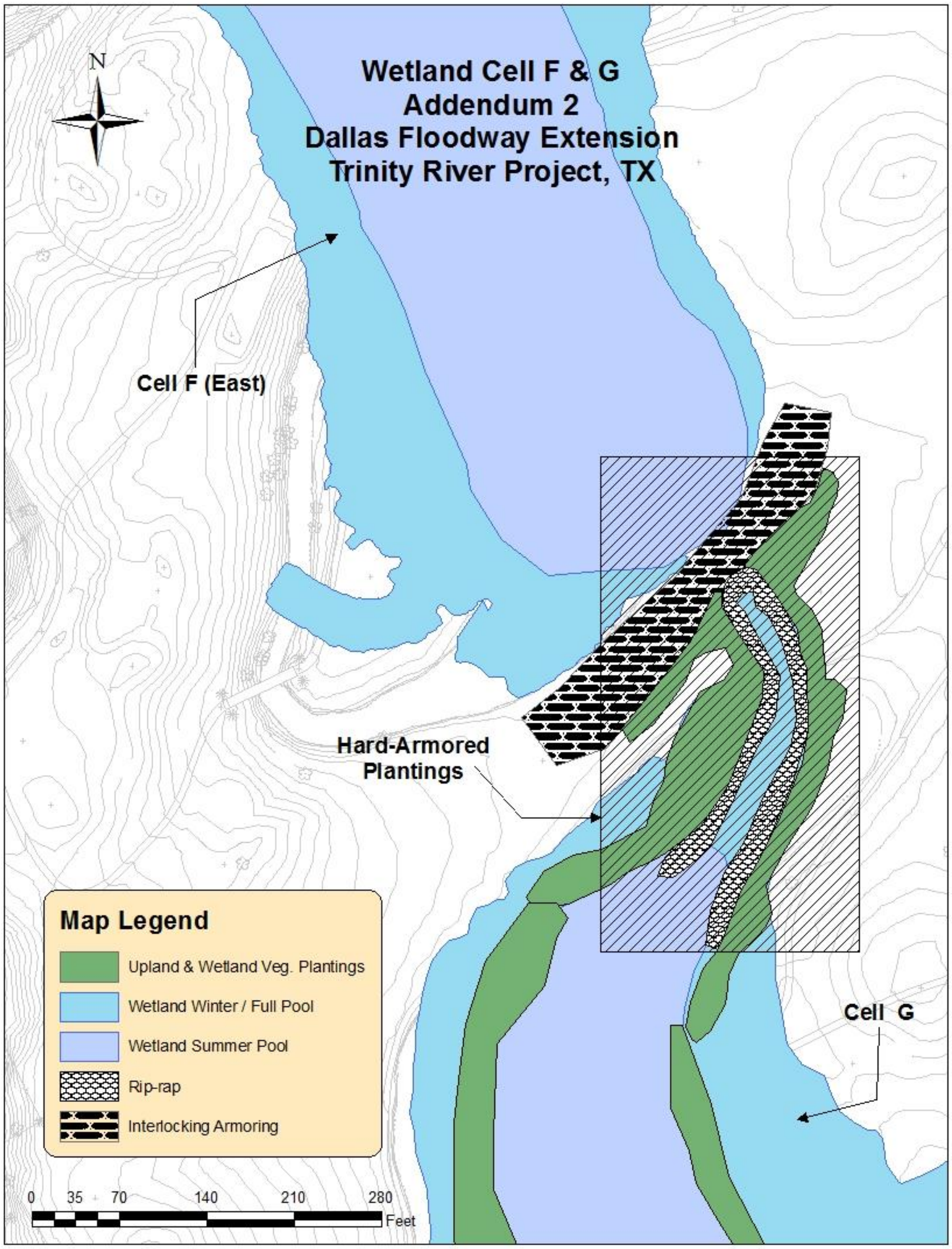


Figure 15. Hard armored areas at the outfall of Cell F into Cell G have been planted to improve performance of armoring. Plantings were initiated in 2010 and completed in 2012.

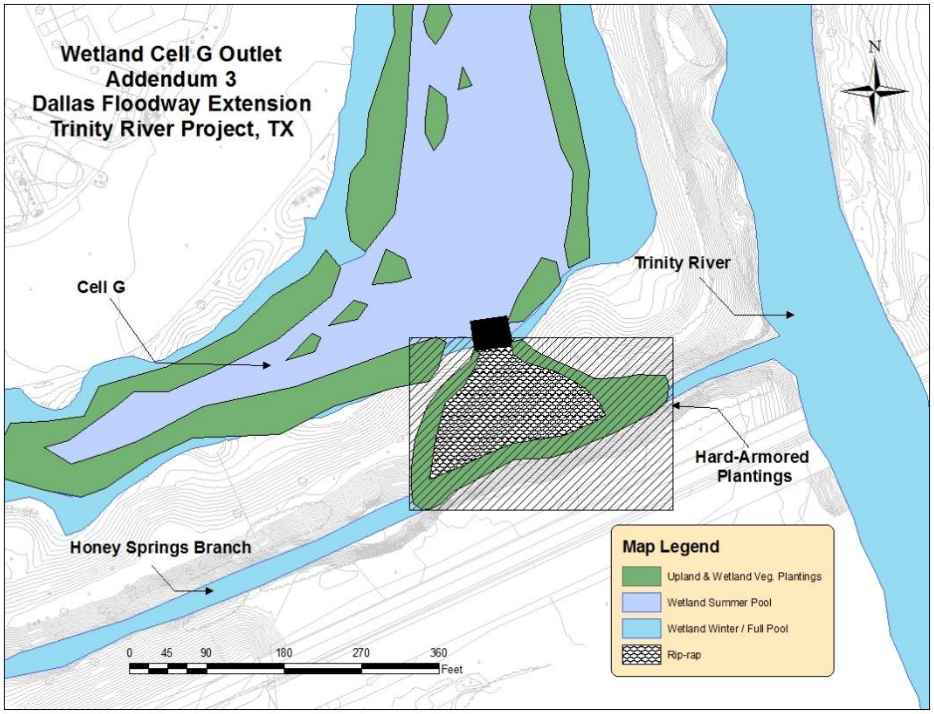


Figure 16. Hard armored areas at the outfall of Cell G were planted to improve performance of armoring. Plantings were initiated in 2011 following completion of repairs and completed in 2012.

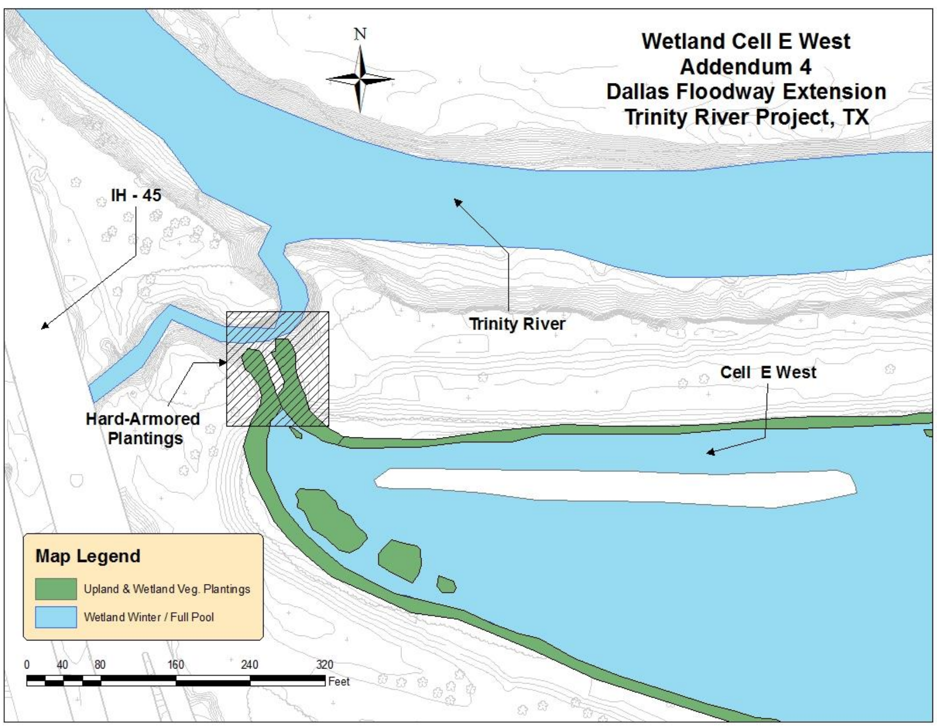


Figure 17. A moderately hard armored cut at the northwest corner of Cell E-West was planted to improve performance of armoring and reduce overall erosion. Plantings were initiated in 2010 and completed in 2012.

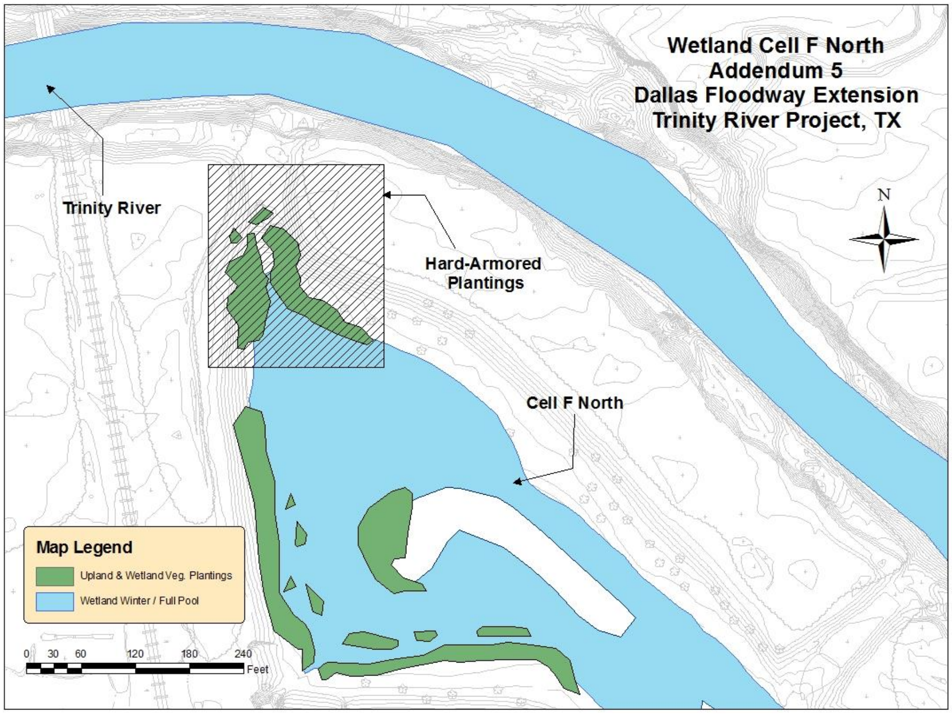


Figure 18. A moderately hard armored cut at the northwest side of Cell F-North was planted to improve performance of armoring and reduce overall erosion. Plantings were initiated in 2010 and completed in 2012.

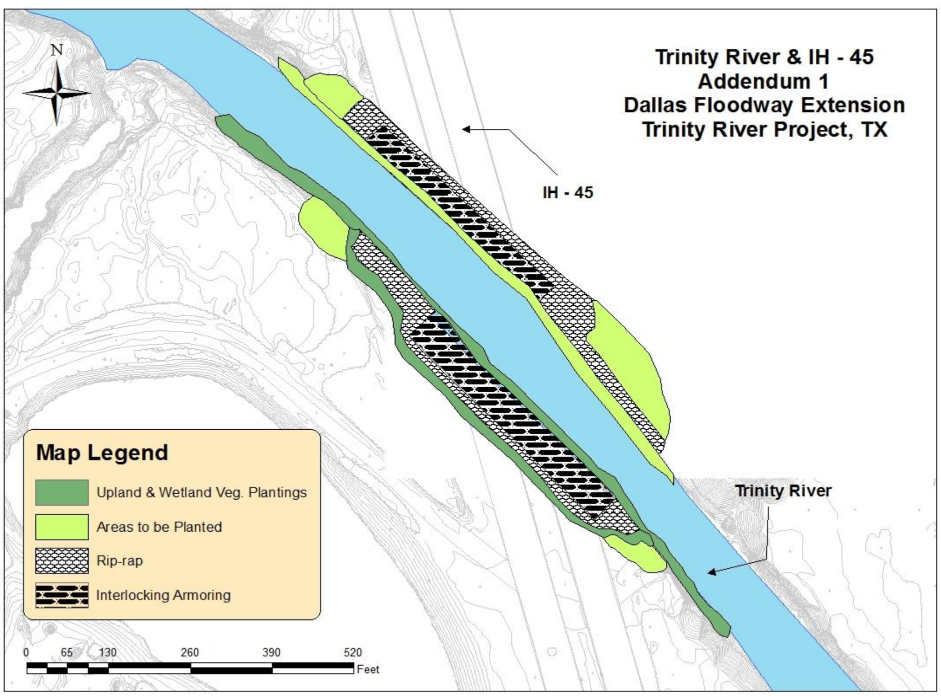


Figure 19. Hard armored areas along the river channel below the IH-45 bridge have been planted to improve performance of armoring. Plantings were initiated in 2010 and completed in 2013. Additional planting was required to compensate for damage to plantings made by repeated erroneous mowing. While vegetation has persisted in this area, no further plantings were made during 2014.

Results to date: Plant production for armored areas began at LAERF in FY2010, with test plantings conducted at all sites later in the year except for the Cell G outfall, which was under construction. Planting was initiated at the Cell G outfall and continued at other areas during FY2011 and FY2012. Plantings were made in summer, fall, winter, and spring to evaluate species selection and timing of establishment. Fall and winter plantings were the most successful, with peppervine (*Ampelopsis arborea*), trumpet creeper (*Campsis radicans*), winecup (*Callirhoe involucrata*), Dakota mock vervain (*Glandularia bipinnatifida*), vine mesquite (*Panicum obtusum*), and Turkey tangle frogfruit (*Phyla nodiflora*) establishing well along higher elevation rip-rap areas at all sites. Likewise, American water-willow, spikerushes, and frog-fruit established well near the water's edge, particularly in the rip-rap along the river's shoreline. However, repeated mowing (4 times observed) of plants along the river, including weed whacking of plants in the rip-rap at the river's edge, resulted in poor establishment performance of some individual plants in that area. Despite this damage, a large portion of the plants did survive (estimated at 70%), but growth was limited (Figure 20). ERDC has worked with the City of Dallas and provided no-mow area instructions, and began replanting areas damaged by mowing in FY2012. While the intense heat and drought of both 2011 and 2012 may have contributed to setting plants back at all sites, recovery of most had occurred by mid-fall (except under the I-45 overpass, where recovery was low). No significant mowing issues occurred in 2013, and supplemental planting made at the river showed high success, particularly nearest the water, where American water-willow has established and spread (Figure 20). As of 2014, several species were well-established along the outfalls F and Cell G, as well as at the cuts at Cell E-West and F-North. We believe vegetation is well established all of these areas, and that over time full coverage of planted and desirable volunteer species will provide soft-armoring benefits to the project (Table 4).

Figure 20. American water-willow established among riprap along the Trinity River channel under the I-45 bridge (above). Although repeatedly mowed during initial establishment stage, turkey tangle frogfruit and Turk's cap survived (right) and have persisted through 2014, serving as soft armor at the edge of riprap directly under the I-45 bridge and in other armored areas around the LCOW.

Table 4. Native wetland and grassland plants were installed between 2011 and 2013 around several hard-armored areas at the LCOW to improve performance of erosion control.

Species	Common name	Growth form	Established in 2014
Ampelopsis arborea	Peppervine	Woody vine	Yes
Ampelopsis cordata	Heart-leaf peppervine	Woody vine	Yes
Bacopa monnieri	Water hyssop	Perennial herb	Yes
Callirhoe involucrata	Winecup	Perennial herb	Marginal
Campsis radicans	Trumpet creeper	Woody vine	Yes
Carex cherokeensis	Cherokee sedge	Perennial sedge	Yes
Eleocharis (3+ spp.)	Spikerushes	Perennial rush	Yes
Glandularia bipinnatifida	Dakota mock vervain	Perennial herb	No
Hibiscus (2+ spp.)	Mallows	Shrub	No
Juncus effusus	Needle-rush	Perennial rush	Yes
Justicia americana	American water-willow	Perennial herb	Yes
Malvaviscus drummondii	Turk's cap	Shrub	Yes
Panicum obtusum	Vine mesquite	Perennial grass	No
Passiflora incarnata	Passion flower	Woody vine	No
Phyla nodiflora	Turkey tangle frogfruit	Perennial herb	Yes
Schoenoplectus (3+ spp.)	Bulrushes	Perennial rush	Yes
Smilax (2+ spp.)	Green briar	Woody vine	Yes
Vitis mustangensis	Mustang grape	Woody vine	Yes

Biological monitoring

ERDC began monitoring fish and macro-invertebrate populations in 2008 for a five-year period along the stretch of modified Trinity River just north of Cell D at IH-45, Cell D, and the other LCOW cells following their filling in 2009. Fish and invertebrates were not monitored in 2014, but data collected through 2013 and summaries of that data are provided in Appendices E and F. In addition to fish and macro-invertebrates, ERDC has kept records of higher vertebrates encountered in the wetland chain. This report includes all vertebrate species that ERDC researchers have observed in the wetlands, grasslands, and woodland areas along the LCOW from Cell D to Cell G between 2005 and 2014.

ERDC has observed numerous mammals (17 species), birds (133 species), reptiles (19 species), and amphibians (7 species) to date (Table 5). Identifications have been made with and without the aid of binoculars and pertinent field guides. In some cases, identifications have been made from tracks or other signs such as hog rooting or beaver cuttings, etc. Surveys and general observations were initiated in fall 2005 on Cell D, and in other cells beginning in late 2008. Soon after filling in late 2008, mammals, waterbirds, reptiles, and amphibians began utilizing cells E-West, E, F-North, F, and G, sometimes in large numbers (especially waterfowl and gulls). Since its construction, the LCOW has attracted a number of waterbirds and other standing-water dependent species not likely to have occurred prior to conversion to herbaceous wetlands with permanent inundation (Figure 21).

Typically, several species not previously recorded by ERDC researchers at the LCOW are observed every year. For instance, spiny softshell turtles (*Apalone spinifera*) and a single least shrew (*Cryptotis parva*) were observed for the first time in 2014. Several factors influence the occurrence of new species, including yearly changes in migratory patterns, but it is likely that management of the LCOW wetlands and grasslands is resulting in better habitat and therefore is attracting more wildlife.

Although comparative data is not available, we suspect that the vertebrate diversity and species richness is vastly different between the LCOW and the more common grassy swales with the boundaries of the Trinity River flood conveyance. As an example, water level manipulations appear to be benefitting waterfowl. During most years, migratory waterfowl begin utilizing the cells in early to mid-November, with submersed, floating-leaved, and emergent vegetation serving as a food source or habitat for their food source (e.g., macro-invertebrates) adequate to hold their numbers. In late November to early December, cells are raised to winter pool, inundating mixed wetland and grassland vegetation and providing additional food sources for many waterfowl species. An added benefit was observed in Cell D in the winters of 2011, 2012, 2013, and 2014. Inundation of grasses and forbs when the cell was raised to winter pool led to a significant copepod bloom, which in turn drew in hundreds of northern shovelers and undoubtedly provided significant forage for the fishery (Figure 22). This same phenomenon occurred in Cell G during 2013 and 2014.

Table 5. Vertebrate species (excluding fish) observed in the LCOW since September 2005. Those listed in bold font were observed for the first time during 2014. Observations include grassland and forested areas associated with the wetland cells.

Common name	Scientific name	Area
	Mammals	
Beaver	*Castor canadensis*	Wetlands
Coyote	*Canas latrans*	Wetlands/grasslands
Bobcat (tracks)	*Lynx rufus*	Grasslands
Mink	*Neovison vison*	Wetlands
Feral pig (tracks & rooting)	*Sus scrofa*	Wetlands/grasslands
Fox squirrel	*Sciuris nigra*	Woodlands
Eastern cottontail	*Sylvilagus floridanus*	Grasslands/woodlands
Harvest mouse	*Reithrodontomys sp.*	Grasslands
Hispid cotton rat	*Sigmodon hispidus*	Grasslands
Least shrew	***Cryptotis parva***	**Grasslands/woodlands**
Nine-banded armadillo	*Dasypus novemcinctus*	Wetlands/grasslands
Nutria	*Myocastor coypus*	Wetlands
Raccoon	*Procyon lotor*	Wetlands
River otter	*Lontra canadensis*	Wetlands
Striped skunk	*Mephitis mephitis*	Wetlands/grasslands
Woodland vole	*Microtus pinetorum*	Woodlands
Virginia opossum	*Didelphis virginiana*	Wetlands
	Birds	
American bittern	*Botaurus lentiginosus*	Wetlands
American coot	*Fulica americana*	Wetlands
American crow	*Corvus brachyrhynchos*	Wetlands/grasslands/woodlands
American goldfinch	*Carduelis tristis*	Woodlands
American kestrel	*Falco sparverius*	Grasslands
American pipit	*Anthus rubescens*	Wetlands/grasslands
American robin	*Turdus migratorius*	Grasslands/woodlands
American swallow-tailed kite	*Elanoides forficatus*	Woodlands/grasslands
American white pelican	*Pelecanus erythrorhynchos*	Wetlands
American wigeon	*Mareca americana*	Wetlands
Anhinga	*Anhinga anhinga*	Wetlands
Bald eagle	*Haliaeetus leucocephalus*	Wetlands/grasslands
Barn swallow	*Hirundo rustica*	Wetlands/grasslands/woodlands
Barred owl	*Strix varia*	Woodlands
Belted kingfisher	*Megaceryle alcyon*	Wetlands
Bewick's wren	*Thryomanes bewickii*	Woodlands/grasslands
Black vulture	*Coragyps atratus*	Grasslands
Black-necked stilt	*Himantopus mexicanus*	Wetlands
Blue jay	*Cyanicutta cristata*	Woodlands
Blue-gray gnatcatcher	***Polioptila caerulea***	**Woodlands**
Blue-winged teal	*Anas discors*	Wetlands
Bonaparte's gull	*Larus philadelphia*	Wetlands
Brewer's blackbird	*Euphagus cyanocephalus*	Grasslands/woodlands
Brown-headed cowbird	*Molothrus ater*	Grasslands
Brown thrasher	*Toxostoma rufum*	Woodlands
Budgerigar	*Melopsittacus undulatus*	Grasslands
Bufflehead	*Bucephala albeola*	Wetlands
Canada goose	*Branta canadensis*	Wetlands
Canvasback	*Aythya valisneria*	Wetlands
Carolina chickadee	*Parus carolinensis*	Woodlands
Carolina wren	*Thryothorus ludovicianus*	Woodlands
Cattle egret	*Bubulcus ibis*	Wetlands/grasslands
Cedar waxwing	*Bombycilla cedrorum*	Woodlands
Chimney swift	*Chaetura pelagica*	Wetlands/grasslands
Chipping sparrow	***Spizella passerina***	**Grasslands**

Birds continued		
Common barn owl	*Tyto alba*	Woodlands
Common goldeneye	*Bucephala clangula*	Wetlands
Common grackle	*Quiscalus quiscula*	Grasslands/woodlands
Common merganser	***Mergus merganser***	**Wetlands**
Common moorhen	*Gallinula chloropus*	Wetlands
Common nighthawk	*Chordeiles minor*	Grasslands
Cooper's hawk	*Accipiter cooperii*	Woodlands
Crested caracara	*Polyborus plancus*	Grasslands
Dark-eyed junco	*Junco hyemalis*	Woodlands
Dickcissel	*Spiza americana*	Grasslands
Double-crested cormorant	*Phalacrocorax auritus*	Wetlands
Downy woodpecker	*Picoides pubescens*	Woodlands
Eastern bluebird	*Sialia sialis*	Grasslands/woodlands
Eastern kingbird	*Tyrannus tyrannus*	Grasslands
Eastern meadowlark	*Sturnella magna*	Grasslands
Eastern phoebe	*Sayornis phoebe*	Wetlands/grasslands/woodlands
Eastern wood-pewee	*Contopus virens*	Woodlands/grasslands
European starling	*Sturnus vulgaris*	Grasslands
Franklin's gull	*Larus pipixcan*	Wetlands
Gadwall	*Anas strepera*	Wetlands
Great blue heron	*Ardea herodius*	Wetlands
Great crested flycatcher	*Myiarchus crinitus*	Grasslands
Great egret	*Ardea alba*	Wetlands
Greater yellowlegs	***Tringa melanoleuca***	**Wetlands**
Great-tailed grackle	*Quiscalus mexicanus*	Grasslands
Green-backed heron	*Butorides virescens*	Wetlands
Green-winged teal	*Anas carolinensis*	Wetlands
Hairy woodpecker	*Picoides villosus*	Woodlands
Hooded merganser	*Lophodytes cucullatus*	Wetlands
House sparrow	***Passer domesticus***	**Woodlands**
Inca dove	*Columbia inca*	Grasslands
Indigo bunting	*Passerina cyanea*	Grasslands
Killdeer	*Charadrius vociferus*	Wetlands/grasslands
Lark sparrow	***Chondestes grammacus***	**Grasslands**
Least sandpiper	*Erolia minutilla*	Wetlands
Least tern	*Sternula antillarum*	Wetlands
Lesser scaup	*Aythya affinis*	Wetlands
Lesser yellowlegs	*Tringa flavipes*	Wetlands
Little blue heron	*Florida caerulea*	Wetlands
Loggerhead shrike	*Lanius ludovicianus*	Grasslands
Long-billed dowitcher	*Limnodromus scolopaceus*	Wetlands
Mallard	*Anas platyrhynchos*	Wetlands
Marbled godwit	***Limosa fedora***	**Wetlands**
Marsh wren	*Cistothorus palustris*	Wetlands
Mississippi kite	*Ictinia mississippiensis*	Grasslands/woodlands
Mourning dove	*Zenaida macroura*	Grasslands
Northern cardinal	*Cardinalis cardinalis*	Woodlands
Northern flicker	*Colaptes auratus*	Grasslands/woodlands
Northern harrier	*Circus cyaneus*	Wetlands/grasslands
Northern mockingbird	*Mimus polyglottos*	Grasslands/woodlands
Northern pintail	*Anas acuta*	Wetlands
Northern rough-winged swallow	*Stelgidopteryx serripennis*	Wetlands/grasslands
Northern shoveler	*Spatula clypeata*	Wetlands
Osprey	***Pandion haliaetus***	**Wetlands (flyover)**
Painted bunting	*Passerina ciris*	Grasslands/woodlands
Pied-billed grebe	*Podilymbus podiceps*	Wetlands
Pine siskin	***Carduelis pinus***	**Woodlands**
Purple finch	***Carpodacus purpureus***	**Woodlands**

Birds continued		
Purple martin	*Progne subis*	Wetlands/grasslands
Redhead	*Aythya americana*	Wetlands
Red-bellied woodpecker	*Melanerpes carolinus*	Woodlands
Red-shouldered hawk	*Buteo lineatus*	Grasslands/woodlands
Red-tailed hawk	*Buteo jamaicensis*	Grasslands/woodlands
Red-winged blackbird	*Agelaius phoeniceus*	Wetlands/grasslands
Ring-billed gull	*Larus delawarensis*	Wetlands
Ring-necked duck	*Aythya collaris*	Wetlands
Rock pigeon	*Columbia livia*	Grasslands
Ruby-crowned kinglet	*Regulus calendula*	Woodlands
Ruby-throated hummingbird	*Archilochus colubris*	Grasslands
Ruddy duck	*Oxyura jamaicensis*	Wetlands
Sandhill crane	*Grus canadensis*	Wetlands (flyover)
Savannah sparrow	*Passerculus sandwichensis*	Grasslands
Semipalmated sandpiper	***Calidris pusilla***	**Wetlands**
Scissor-tailed flycatcher	*Tyrannus forficatus*	Grasslands
Snowy egret	*Leucophoyx thula*	Wetlands
Sora	*Porzana carolina*	Wetlands
Spotted sandpiper	*Actitis macularia*	Wetlands
Swainson’s hawk	*Buteo swainsoni*	Wetlands/grasslands
Tree swallow	*Tachycineta bicolor*	Wetlands/grasslands
Tricolored heron	*Egretta tricolor*	Wetlands
Tufted titmouse	*Baeolophus bicolor*	Woodlands
Turkey vulture	*Cathartes aura*	Grasslands
Upland sandpiper	*Bartramia longicauda*	Wetlands/grasslands
Vesper sparrow	*Pooecetes gramineus*	Grasslands
Western kingbird	*Tyrannus verticalis*	Grasslands
White ibis	*Eudocimus albus*	Wetlands
White-crowned sparrow	*Zonotrichia leucophyrs*	Woodlands
White-eyed vireo	***Vireo grisus***	**Woodlands**
White-faced ibis	*Plegadis chihi*	Wetlands
White-throated sparrow	*Zonotrichia albicollis*	Woodlands
White-winged dove	*Zenaida asiatica*	Grasslands
Willet	*Catoptrophorus semipalmatus*	Wetlands
Wilson’s phalarope	*Phalaropus tricolor*	Wetlands
Wilson’s snipe	*Gallinago gallinago*	Wetlands
Wood duck	*Aix sponsa*	Wetlands
Yellow-bellied sapsucker	*Sphyrapicus varius*	Woodlands
Yellow-crowned night-heron	*Nycticorax violaceus*	Wetlands
Yellow-rumped warbler	*Dendroica coronata*	Grasslands/woodlands
Reptiles		
Blotched water snake	*Nerodia erythrogaster*	Wetlands
Broad-banded water snake	*Nerodia fasciata*	Wetlands
Broadhead skink	*Eumeces laticeps*	Woodlands
Common snapping turtle	*Chelydra serpentina*	Wetlands
Diamondback water snake	*Nerodia rhombifer*	Wetlands
Green anole	*Anolis carolinensis*	Grasslands
Ground skink	***Scincella lateralis***	**Woodlands**
Mississippi map turtle	*Graptemys kohnii*	Wetlands
Mud turtle	*Kinosternum subrubrum*	Wetlands
Red-eared slider	*Trachemys scripta*	Wetlands
River cooter	*Pseudemys concinna*	Wetlands
Rough green snake	***Opheodrys aestivus***	**Grasslands**
Southern painted turtle	*Chrysemys dorsalis*	Wetlands

Reptiles continued		
Spiny softshell	***Apalone spinifera***	**Wetlands**
Texas rat snake	*Elaphe obsoleta*	Grasslands
Texas spiny lizard	*Sceloporus olivaceus*	Woodlands
Three-toed box turtle	*Terrapene carolina*	Woodlands
Western ribbon snake	*Thamnophis proximus*	Wetlands
Yellow-bellied racer	***Coluber constrictor***	**Grasslands**
Amphibians		
American bullfrog	*Lithobates catesbeiana*	Wetlands
Blanchard's cricket frog	*Acris crepitans*	Wetlands
Bronze frog	*Lithobates clamitans*	Wetlands
Green treefrog	***Hyla cinerea***	**Wetlands**
Gulf coast toad	*Bufo valliceps*	Wetlands
Southern leopard frog	*Lithobates utricularia*	Wetlands
Upland chorus frog	*Pseudacris triseriata*	Wetlands

Figure 21. Waterbirds observed at the LCOW since 2005 include the black-necked stilt (top left), American bittern (top right), Wilson's phalarope (bottom left), and white ibis (bottom right).

Figure 22. Northern shovelers flock to and filter-forage copepod blooms associated with decomposing vegetation in winter-inundated wetlands in Cell D.

Wetlands Summary

Wetland vegetation has become well-established in the LCOW and currently covers most of the perimeters of all cells and significant portions of the shallow planting shelves found in some cells. A dynamic planting schedule, water level manipulation, herbivore trapping and relocation, and management of nuisance plant species have facilitated development of a desirable native plant community that includes obligate and facultative wetland species, rather than stands of willows and cattails typical in disturbed wet areas in north Texas. Concurrently, fish and macro-invertebrate communities have developed and show evidence of stabilization, leading to usage by a variety of waterbirds and shorebirds, including ducks, sandpipers, egrets, and herons. In order to ensure that the wetlands are in their best possible ecological condition when SWF hands the LCOW over to the City of Dallas (anticipated to occur sometime in 2015), ERDC staff will continue to monitor and manage the ecosystem until management changes are implemented.

LCOW Adjacent Grasslands

ERDC conducted assessments of seeding efforts by contractors in grasslands adjacent to the wetland cells in 2009. Following results of this evaluation, which showed poor native grassland community development, ERDC proposed to test modifications of basic methods used to establish vegetation in the LCOW wetland cells for improving the grassland community, focusing primarily on species selection (perennials vs. annuals, grasses vs. forbs), propagules (seeds versus containerized), and post-planting management (mowing vs. no mowing). Following initial evaluations, ERDC proposed to begin large-scale establishment of grassland vegetation using results from tests. This section describes grassland plant community improvements conducted between 2009 and 2014.

Grassland evaluations

Surveys were conducted in 2009 and 2010 to identify, categorize and enumerate the plant communities in seeded grassland areas surrounding the LCOW. These areas had been drill-seeded over a period of time between 2007 (Cell D) and 2009 (remaining LCOW). Plugging of several grass species was also conducted at Cell D in 2009. Meander surveys conducted in late 2009 and early 2010 focused on locating species that had been seeded at the site, and suggested that most of the seeds and some of the species did not germinate or that germinated seedlings did not survive; instead, the grasslands appeared to be dominated by nuisance species such as giant ragweed (*Ambrosia trifida*). Of 45 species identified, ten were nonnative and six of those were considered undesirable (e.g., Johnsongrass, *Sorghum halepense*). Of the 32 native species identified, six were undesirable in grasslands, and included aggressive forbs (e.g., giant ragweed) and woody species (e.g., cedar elm, *Ulmus crassifolia*). Fifteen of the native species observed were included in drill-seeding, but none of these appeared to occur in significant numbers. A list of plant species observed during surveys is given in Table 6.

Table 6. Plant species observed during informal surveys made in 2010. Status: N = native; NS = native, seeded (highlighted in bold); I = introduced. Category: U = undesirable; D = desirable; A = acceptable.

Scientific Name	Common name	Status	Category
Ambrosia trifida	Giant ragweed	N	U
Andropogon gerardii	Big bluestem	NS	D
Arundo donax	Arundo	I	U
Baccharis halimifolia	Eastern baccharis	N	U
Bothriochloa ischaemum	King Ranch bluestem	I	U
Centaurea americana	American basketflower	NS	D
Chamaecrista fasciculata	Partridge pea	NS	D
Convolvulus equitans	Bindweed	N	D
Coreopsis tinctoria	Plains coreopsis	NS	D
Coreopsis lanceolata	Lanceleaf coreopsis	NS	D
Cucurbita foetidissima	Wild gourd	N	D
Cuscuta sp.	Dodder	N	D
Cynodon dactylon	Bermudagrass	I	U
Dalea purpurea	Purple prairie clover	NS	D
Erodium cicutarium	Redstem stork's bill	I	A
Eustoma exaltatum	Texas bluebells	N	D
Fraxinus pennsylvanica	Green ash	N	U
Helianthus maximiliani	Maximilian sunflower	NS	D
Heliotropium indicum	Indian heliotrope	I	A
Iva annua	Marsh-elder	N	D
Lamium amplexicaule	Henbit	I	A
Ludwigia alternifolia	Seedbox	N	D
Melia azederach	Chinaberry	I	U
Oenothera speciosa	Pink evening primrose	NS	D
Panicum virgatum	Switchgrass	NS	D
Phalaris sp.	Canary grass	I	A
Phlox drummondii	Drummond phlox	NS	D
Pyrrhopappus pauciflorus	Texas dandelion	N	D
Ranunculus macounii	Buttercup	N	D
Ritibida columnifera	Mexican hat	NS	D
Salvia azurea	Pitcher sage	NS	D
Salvia coccinea	Scarlet sage	NS	D
Secale cereale	Rye	I	D
Sesbania drummondii	Rattlebox	N	U
Setaria macrostachya	Large-spike bristlegrass	N	D
Sida ciliaris	Bracted fanpetals	N	D
Solanum rostratum	Buffalobur	N	D
Sorgastrum nutans	Indiangrass	NS	D
Sorghum halepense	Johnsongrass	I	U
Sporobolus sp.	Dropseed	N	D
Stellaria media	Common chickweed	I	A
Tridens albescens	White tridens	N	D
Tripsacum dactyloides	Eastern gamagrass	NS	D
Ulmus crassifolia	Cedar elm	N	U
Vernonia sp.	Ironweed	N	D

A transect survey was conducted in late spring 2010 to quantify meander survey observations and ascertain whether or not additional efforts would be needed to establish beneficial vegetation in specified areas. Seventeen permanent transects (GPS-recorded) were placed around the LCOW for evaluation of the grassland communities (Figure 23). A 1-m x 1-m sampling plot was placed every 25 feet along each transect, with species presence (frequency) and estimates of percent cover recorded. Voucher specimens were collected and returned to LAERF for final identification. Similar surveys along the same transects were used to evaluate the status of subsequent efforts to improve the grasslands in spring 2011, 2012, 2013 and 2014; supplemental meander surveys to identify summer- and fall-blooming species were also conducted those years.

The 2010 spring transects survey identified 70 plant species in the LCOW grassland areas, with 60 of those considered desirable or acceptable; the remaining 10 species are considered undesirable and are either nonnative or aggressive (Appendix G). Only eleven drill-seeded or plugged species were identified in the transect survey. Percent cover estimates showed that undesirable species (including bare areas and unknown species) covered 53.5% of the grasslands while desirable and acceptable species combined to cover 46.5%. Undesirable species were dominated by giant ragweed, with an estimated cover of over 25% of the entire surveyed area and representing almost half the area dominated by undesirable species. Desirable species coverage was dominated by volunteer species (73%) as opposed to seeded species (27%). Seeded species represented just over 5% of total grassland cover and most notably included 3% clasping coneflower (*Dracopis amplexicaulis*), 1% Illinois bundleflower (*Desmanthus illinoensis*) and 1% plains coreopsis (*Coreopsis tinctoria*). Acceptable species were nonnative but not considered to have potential for dominating the ecosystem.

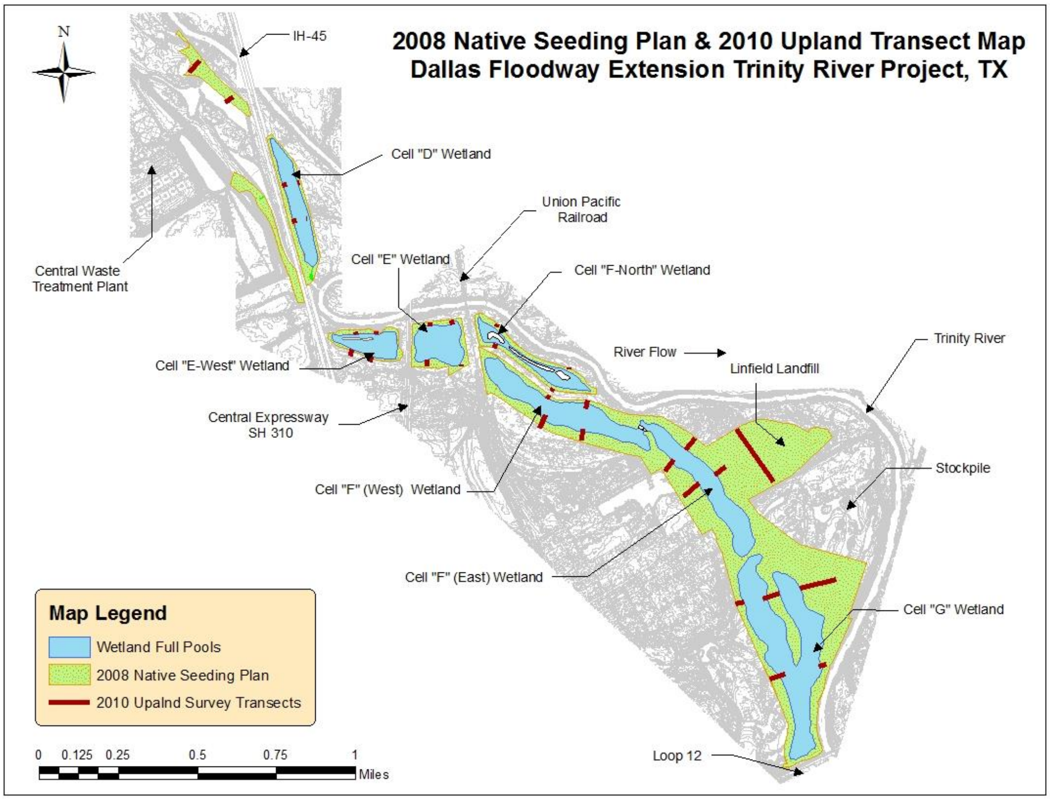


Figure 23. Seventeen transects were placed around the LCOW for evaluating the plant communities within drill-seeded areas.

Following the spring 2010 survey, it was decided that improvements could be made to the grassland vegetation community, but that establishing more desirable plants would require a change in strategy from drill seeding, which had provided low success (other than cereal rye cover crop establishment) following two efforts. Because undesirable vegetation was well established and dominated substantial portions the grasslands by 2010, grassland improvement would require inclusion of management of at least some of those species, most notably giant ragweed. ERDC requested and SWF complied with engaging a contractor for scheduled mowing in an effort to target giant ragweed and some of the other nuisance grassland plants to reduce competition with desirable plants. Properly timed mowing would further benefit by preventing production of new seeds of nuisance species, thereby reducing the weedy seedbank. In concert with management by mowing, ERDC began the process of determining the best approach to improving the species diversity and overall grassland plant community composition at the LCOW.

Grassland test plantings

A multi-year effort was formulated for establishing plant communities in the grasslands surrounding the LCOW. First year efforts included conducting test plantings to evaluate differences between application of seeds and installation of containerized plants of a variety of annual and perennial grasses and forbs. Two test locations were selected: Cell F (West) between the lower end of the cell and the Trinity River, and Cell D between the wetland cell and Interstate Highway 45. Twelve native grassland plants, including six perennial grasses and six perennial or annual forbs, were selected for the tests based upon their predicted suitability for establishment under conditions that occur in the LCOW (Table 7).

Table 7. Twelve grassland species were selected for test plantings at two locations in the LCOW.

Scientific name	Common name	Growth form
Andropogon gerardii	Big bluestem	Perennial grass
Chamaecrista fasciculata	Partridge pea	Annual forb
Dracopis amplexicaulis	Clasping coneflower	Annual forb
Desmanthus illinoensis	Illinois bundleflower	Perennial forb
Helianthus maximiliani	Maximilian sunflower	Perennial forb
Oenothera speciosa	Pink evening primrose	Perennial forb
Panicum virgatum	Switchgrass	Perennial grass
Salvia coccinea	Scarlet sage	Annual/perennial forb
Schizachyrium scoparium	Little bluestem	Perennial grass
Sorghastrum nutans	Indiangrass	Perennial grass
Tridens albescens	White tridens	Perennial grass
Tripsacum dactyloides	Eastern gamagrass	Perennial grass

Containerized plants grown from locally obtained stock were produced at LAERF culture facilities during fall and winter 2010/2011 and transplanted into the field in late winter 2011. Six individuals of each of the twelve species were transplanted on 5-ft centers within each containerized plant treatment plot (one at Cell D, two at Cell F (West)). Seeds of the same species were broadcast in adjacent plots, which were then harrowed to improve soil contact in seeded plots. The areas were cordoned off with t-posts and survey tape to prevent unintentional mowing or other mechanical disturbance to the plots. Plots were not irrigated after planting.

Plant establishment was monitored periodically to evaluate the treatments. Few, if any, plants established from seeds at either test site by the end of the growing season. Because the seeds had proven viable (ERDC produced many of the containerized plants using the same seed stock), it appeared that they either failed to germinate or did not survive following germination. While overbanking did not occur (silt cover has been implicated in failure of seed drilling at the LCOW), 2011 spring and summer were particularly dry, which may have contributed to seed failure. Considering the poor performance of seeding in this test (and previous seeding efforts) and uncertainties of environmental conditions at the LCOW grasslands, ERDC concluded that establishing vegetation from single-effort seeding would have the lowest probability of success and therefore would not be relied upon substantially in large-scale plant establishment efforts.

Containerized perennials fared much better, with survival estimates for most species in excess of 70% at both locations. Most annual forbs, however, did not appear to survive (Table 8). Several factors likely contributed to survival between containerized plant treatments. Each species likely responded differently to growing conditions during the spring and summer of 2011, with perennial grasses exhibiting the highest survival as a group. Annuals and forbs fared poorly under those conditions, indicating that transplanting them (without subsequent irrigation) would not be successful during dry years in the LCOW grasslands. Drought conditions may have also affected accuracy of survival estimates for some perennial species, which may have gone into stress dormancy. And, the presence of other foliage (most notably giant ragweed), may have made it difficult to find some species (of any type) during assessments.

Table 8. Containerized perennial grasses are the most likely to survive conditions in the LCOW grassland areas.

Common name	Cell F (West) % survival	Cell D % survival
Big bluestem	75	90
Partridge pea	0	0
Clasping coneflower	0	0
Illinois bundleflower	0	0
Maximilian sunflower	100	100
Pink evening primrose	0	0
Switchgrass	70	80
Scarlet sage	0	25
Little bluestem	40	100
Indiangrass	80	70
White tridens	60	90
Eastern gamagrass	98	70
Mean	**44**	**52**

Basis for mean differences in survival rates between Cell F (West) and Cell D were not clear, although survival rates in Cell D, which were generally higher, could have been due to higher soil moisture content: measurements in late summer showed that portions of the plots at Cell F (West) held 3% or less moisture, where all plants, including volunteers, appeared to have died due to drought stress---those areas looked as though they had been treated with broad spectrum herbicides. Other areas within the plots held considerably more soil moisture (10% and greater), and plants, although appearing stunted, remained alive. Soil moisture in all portions of the plots at Cell D remained above 10% during the same period.

Considering that containerized, perennial species (all the grasses and one forb, Maximilian sunflower, *Helianthus maximiliani*), exhibited the highest survival, ERDC decided to focus on that group of plants for establishing the basis of a sustainable native grassland plant community in the LCOW. The idea was that by establishing colonies of these plants, rhizatomous spread and annual seed production would ultimately result in full-scale establishment of beneficial species, much as had occurred with aquatic species planted in and around the wetlands.

Grassland large-scale plantings

Large-scale grassland plantings were initiated during the winter of 2011/2012 using containerized plants produced at the LAERF. Ten grassland species were selected for planting, including grasses and several perennial forbs that had proven successful in 2010 plot tests; because smaller numbers of untested perennial species were available at that time, they were included in the plantings (Table 9).

Table 9. Numbers of ten perennial species and the areas in which they were selected for large-scale planting in the grasslands adjacent to the LCOW. IH-45 represents an area just west of Interstate Highway 45.

Scientific name	Common name	IH-45	E-West	E	F-North	F (West)	F (East)	G	TOTAL
Amsonia tabernaemontana	Eastern bluestar		6	24					30
Andropogon gerardii	Big bluestem	50	25	24	12	24	24	48	207
Carex crus-corvi	Crow foot sedge		10	24					34
Helianthus grosseserratus	Sawtooth sunflower							50	50
Helianthus maximiliani	Maximilian sunflower	50	10	10					70
Panicum virgatum	Switchgrass	100		0		12		36	148
Schizachyrium scoparium	Little bluestem	50	25	24	12	24	24	48	207
Sorghastrum nutans	Indiangrass		30	30	12	96	96	72	336
Tridens albescens	White tridens	50		4		48	48	120	270
Tripsacum dactyloides	Eastern gamagrass	100	50	50	100	200	200	450	1150
	TOTAL	**400**	**156**	**190**	**136**	**404**	**392**	**824**	**2502**

Grasslands slated for improvement in the ERDC 2010 SOW totaled 48 acres, and included areas immediately surrounding most of the wetland cells and a section of grassland just south of the Trinity River and west of Interstate Highway 45. ERDC additionally supplemented grassland plantings around Cell D, bringing the total grassland improvement area to approximately 55 acres (Figure 24). Several desirable grass species were already established in some areas, with those species that appeared sufficient for further natural colonization considered when laying out planting schematics. For instance, switchgrass (*Panicum virgatum*) was fairly well established around portions of Cell E-West, E, F-North, and F (West), and therefore no additional planting of that species was planned for those areas. In all, four general planting areas were identified within the turfing area.

1. Seven+ acres west of IH-45. This area was dominated by Bermudagrass (*Cynodon dactylon*) and Johnsongrass. Efforts focused on overplanting the existing nuisance species-dominated grassland with large, robust species, including big bluestem (*Andropogon gerardii*), eastern gamagrass (*Tripsacum dactyloides*), little bluestem (*Schizachyrium scoparium*), Maximilian sunflower, switchgrass, and white tridens (*Tridens albescens*). Planting began in 2011 (fall).

2. Eight+ acres surrounding Cell D. Eastern gamagrass and switchgrass had been established from plugs in some areas. Supplemental planting with other grass species and forbs was initiated in 2011/2012 (winter).

3. Fifteen acres surrounding portions of Cell E-West, E, F-North, and F (West). All species except for switchgrass (which was moderately established in these areas) were planted, beginning 2011/2012 (winter).

4. Twenty-five acres surrounding portions of all cells (except Cell D). All species were planted in those areas, beginning in 2011/2012 (winter).

In addition to species already established, considerations were given to elevations, and ultimately, soil moisture in each planting area. Those species thought least likely to survive drought conditions (e.g., Eastern gamagrass) were planted nearest the wetland cells, where the water table was expected to provide higher soil moisture to sustain growth even under drought conditions. Species more tolerant of drought conditions (e.g., switchgrass) were planted at higher elevations.

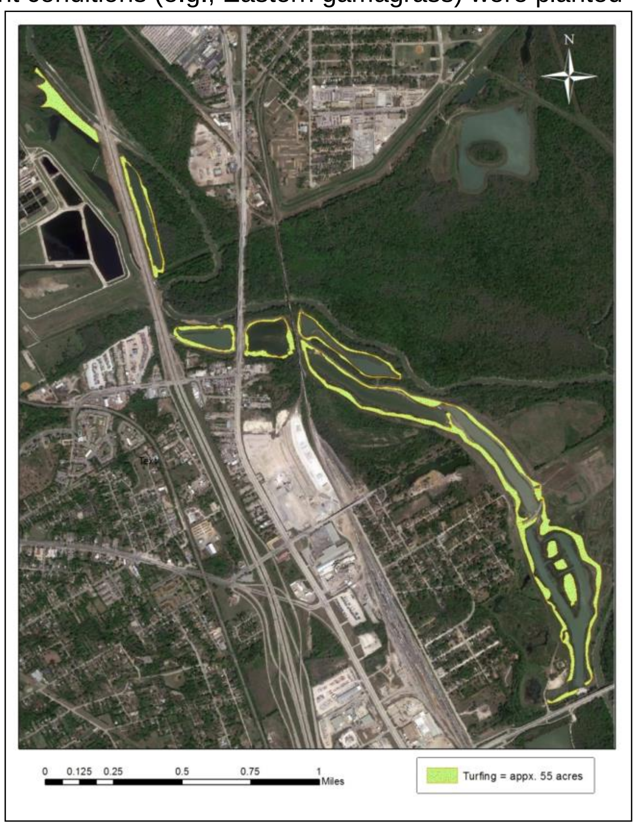


Figure 24. Turfing map highlights areas undergoing grassland vegetation community improvements that began in 2011.

Plantings were made on multiple transects running parallel with wetland cell shorelines and placed approximately 30-ft apart. This resulted in tiers of plantings at different elevations, with tiers closest to the wetland cell at lowest elevation and those farthest from the wetland cell at the highest elevation. Dependent upon the turfing area dimensions, one to three tiers were installed around the LCOW. An exception was the IH-45 area, where 6 tiers were installed, all at about the same elevation. Plantings were made on 30-ft centers along each tier, resulting in an approximate 30-ft on center distribution of plants in the turfing area. Approximately 2,500 containerized plants were transplanted into the grasslands during that time.

Evaluations of large-scale plantings were made periodically, with a final evaluation made near the end of the first growing season (September 2012), when ERDC was able to locate approximately 21% of the plants installed (Figure 25). While this number appears to imply low survival, it is more a reflection being able to locate individual plants in mixed communities of existing vegetation following. Although each transplant was marked with a survey flag, most flags were destroyed by mowing that took place twice during that year. And, because some species are slow to establish, even when planted from containers, they may remain difficult to locate for two or three years.

Several species were more easily found than others, including switchgrass, Eastern gamagrass, and white tridens. However, some of all species were located with the exception of Eastern bluestar. Documented survival under harsh growing conditions (the summer of 2012 suffered drought conditions similar to those occurring in 2011) provided ERDC with additional information for continuing to formulating plantings strategies for 2013 and 2014.

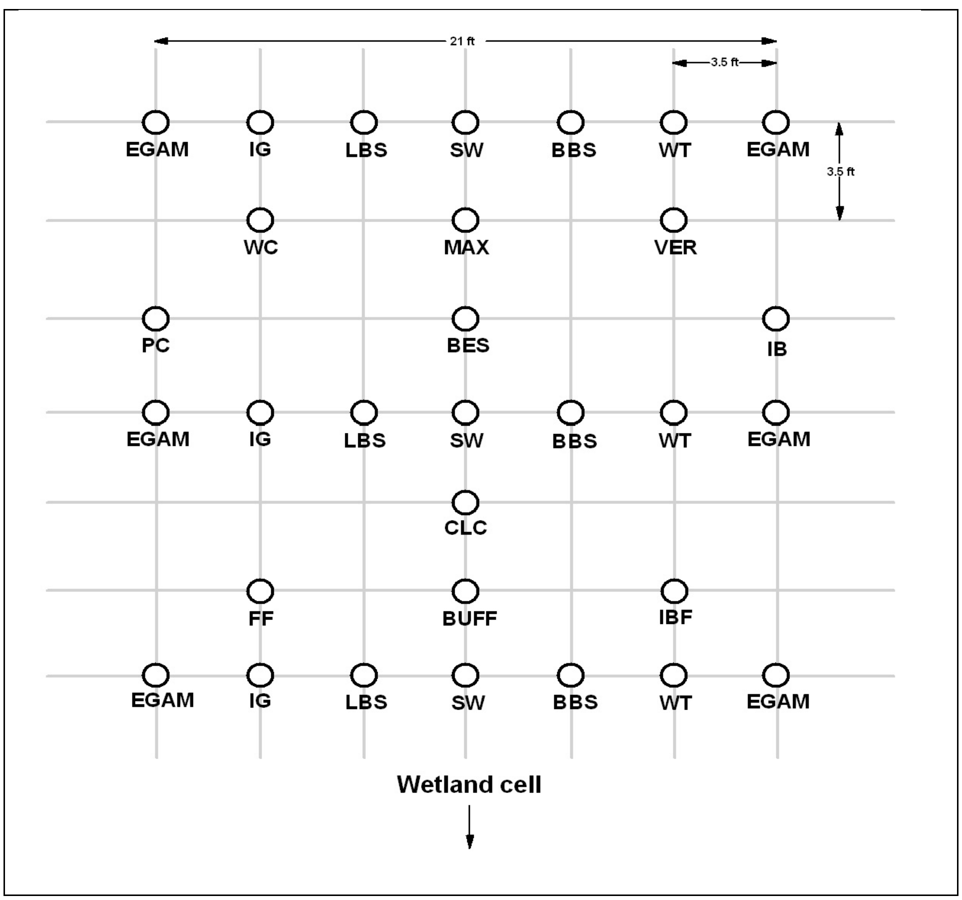
Figure 25. White tridens (above) and Eastern gamagrass (right) were planted during the 2011/2012 winter. By September 2012, both species were well-establishing and producing seeds. Additional plantings of these species were made in subsequent years.

ERDC altered its approach for the second year of large-scale planting. Instead of continuing to plant individuals to fill in the 30-ft on center layout already planted, as was originally intended, we opted instead to plant “founder colonies” or “islands” of grasslands species to serve as seed sources for natural spread in later years. Plots were widely distributed around the turfing areas in which multiple species were planted. In total, 65 plots were set up and planted. This approach was taken in order to address three goals: 1) increase desirable species coverage, 2) increase number and distribution of desirable species, and 3) identify additional techniques for greater establishment success.

Plots measured approximately 21-ft x 21-ft and were placed around each wetland cell and the area west of I-45. After selection and marking with survey flags, plots were treated with 2% a.i. glyphosate to kill nuisance vegetation, primarily Bermudagrass and Johnsongrass, which might interfere with newly establishing transplants. The primary focus of the plots was to establish perennial grasses and forbs that had proven successful in previous plantings, but included species that had begun to establish naturally in the grasslands but have not yet become widespread; 16 species were planted in each of the 65 plots (Table 10 and Figure 26). Eleven perennial grasses and forbs were planted during their dormancy in winter 2012-1013 and five annual forbs were planted in spring 2013. The effort to plant annual species, despite failure of annuals to establish in earlier tests, was included to evaluate whether or not additional steps could be made when planting to increase survival and establishment.

Table 10. Species selected for the second year of large-scale plantings in the LCOW grasslands.

Planted winter 2012/2013	
Scientific name	**Common name**
Andropogon gerardii	Big bluestem
Bouteloua dactyloides	Buffalograss
Callirhoe involucrata	Winecup
Glandularia bipinnatifida	Dakota mock vervain
Helianthus maximiliani	Maximilian sunflower
Lippia nodiflora	Turkey tangle frogfruit
Panicum virgatum	Switchgrass
Schizachyrium scoparium	Little bluestem
Sorghastrum nutans	Indiangrass
Tridens albescens	White tridens
Tripsacum dactyloides	Eastern gamagrass
Planted spring 2013	
Coreopsis tinctoria	Plains coreopsis
Desmanthus illinoensis	Illinois bundleflower
Dracopis amplexicaulis	Clasping coneflower
Gaillardia pulchella	Indian blanket
Rudbeckia hirta	Blackeyed Susan



EGAM (Eastern gamagrass)

IG (Indiangrass)

LBS (little blue stem)

SW (switchgrass)

BBS (big bluestem)

WT (white tridens)

WC (winecup)

MAX (Maximilian sunflower)

VER (Dakota mock vervain)

FF (turkey tangle frogfruit)

BUFF (buffalograss)

PC (plains coreopsis)

IB (Indian blanket)

IBF (Illinois bundleflower)

CLC (clasping coneflower)

BES (blackeyed Susan)

Figure 26. Sixty-five plots were laid out around the LCOW and each planted with 16 grassland species (winter 2012/2013). Several planting treatments were evaluated.

Installing large a number of plots enabled ERDC to conduct additional evaluations of techniques for establishment of grassland plants in the LCOW. Several methods designed to improve transplant success were evaluated. This information would be incorporated into LCOW grasslands plantings made in the 2013/2014 winter, and will be valuable in developing planting strategies for the Upper Chain of Wetland's grasslands areas once they are constructed.

Plots were installed during winter 2012/2013 and spring 2013 and monitored periodically thereafter (Figure 27). Planting layouts were flagged with color-coded survey stakes to match species to-be-planted for consistency between plots; planting pits were dug to a depth and width (diameter) of 6 inches using gasoline-powered augers. Several amendments/planting methods were evaluated among plots to determine which planting methods were most suitable for which species:

- Plots were irrigated immediately after planting, and then on an as-needed basis, when plants showed desiccation stress such as drooping leaves
- Backfilling of planting pits in a portion of plots was amended with commercially-acquired sandy topsoil to reduce voids common in backfilling with clay soils
- Soils in planting pits in a portion of plots were amended with Terra-Sorb™ to provide a longer-term water source between watering events
- Root balls of plants installed in a portion of plots were inoculated with commercial mycorrhizal fungi to improve transplant performance

Thirty plots received varying combinations of amendments (including six with no amendments) while the remaining 35 received all amendments.

Figure 27. Grassland plots were installed using several planting treatments during the 2012/2013 winter and spring 2013 to increase native grassland vegetation, then monitored to evaluate which species and planting treatments were best suited for additional plantings.

Selected weeds occurring in the plots were hand-pulled or cut throughout the growing season to reduce competitive interference during first year establishment. Giant ragweed, Johnsongrass, and annual bastardcabbage (*Rapistrum rugosum*) were the most commonly encountered weeds in plots, although some plots additionally supported Bermudagrass, which was not removed. Additional irrigation was implemented only one time during the growing season (June), when plants showed signs of water stress in some of the plots.

Plots were evaluated four times during 2013, and later in 2014. Percent survival and fitness of planted species were assessed and recorded in April, May, June, and October 2013. Survival was determined by observable presence or absence of planted species at the survey flag to which it was assigned for planting. Fitness scores for each species ranged from 0 to 3, with criteria provided below:

0 *Dead or aboveground biomass absent*

1 *No significant change from initial planting size or decrease in planting size but not dead*

2 *Some new growth as compared to initial plant but not robust in nature*

3 *Robust new growth, size increase as compared to initial planting size, flowering, etc.*

Results of plot analyses (ANOVA) indicated no significant differences (p = 0.1) between treatments for grass species except for big bluestem, which occurred in the June assessment. No differences were detected for amendments of Terra-Sorb™, mycorrhizal fungi or commercial top soil, or combinations of treatments for the remaining grasses. This implied that, for most species, simply digging a pit, backfilling with local soils, and watering immediately, combined with as-needed watering during the first growing season, would be adequate for their establishment in the LCOW. However, as a precaution, we have opted to include sandier-than-local topsoils as part of backfill to reduce voids as standard planting practice at the LCOW. Treatments did not appear to affect survival and growth of most forbs tested, but significant differences were found for several. Perennial forb turkey tangle frogfruit and annual plains coreopsis exhibited differences in initial survival by treatment in April, but not for May, June or October; mostly annual, but sometimes short-lived perennial wildflower black-eyed Susan showed differences in mean fitness only in June. By October, most forbs, both annual and perennial, were naturally senescing due to their seasonal life cycles (Appendix G, Figures G-4 through G-9).

Areas around the wetland cells exhibit differences in soil type, shade, soil moisture, elevation in relation to full pool of wetlands, invasive species, and human access. In an effort to ascertain which perennial species did best at different locations within the LCOW grasslands, evaluations were made of their fitness based upon location of plots grouped together by their association with a particular wetland cell. Fitness by species was reanalyzed following this criteria with ANOVA ($\alpha = 0.1$) for the October assessments, which reflected seasonal establishment success following their cool season planting. While most species showed no significant differences in fitness regardless of wetland cell, big bluestem, switchgrass, Maximilian sunflower and white tridens did, exhibiting significantly lower fitness around Cell F-North. Many other species also exhibited lower fitness around that cell, but the differences from fitness around other cells were not significant. Poor performance of plants around Cell F-North were attributed to several factors, including shading by trees, a substantial Johnsongrass infestation, and unauthorized vehicles driving directly over several of the plots.

In general, perennial grasses and forbs perennial species including big bluestem, Indiangrass, buffalograss, little bluestem, Eastern gamagrass, switchgrass, white tridens, Maximilian sunflower, turkey tangle frogfruit, and Dakota mock vervain exhibited the highest survival and fitness of species planted in 2012/2013 (Figure 28). These species comprised the focus of additional grassland plantings at the LCOW during the winter of 2013/2014, but not to the exclusion of other species. Additional surveys of existing test plots and plots to-be-planted were slated for evaluations to provide information for planting techniques to-be-used in later years.

Figure 28. Maximillian sunflower and Illinois bundleflower (left) with white tridens, Dakota mock vervain and Eastern gamagrass (right) pictured during surveys of plots in 2013.

New plots were established during the winter of 2013/2014 based on results of the 2013 plot assessments---our greatest focus was on transplanted species that had exhibited highest survival and fitness rates, but included additional species that, based upon experience and observation, appeared suitable for each area planted. Plot locations and species composition were formulated from results of adjacent plots so that those species known to be most likely to survive and thrive in a given area were selected for planting in that same area. Criteria used for species selection for planting between existing plots included high survival rates and an average fitness of 2 or greater, although variations to these requirements were made for several species/plots. One hundred and five new plots were established between the original plots, with one, two or three new plots positioned on approximately 110-ft centers between existing plots. Each plot was planted with two to twelve appropriate species (singly or in combination) on approximate 6-ft centers during December 2013 (Table 11). As prior soil amendments of Terra-Sorb^{TM}, mycorrhizal fungi, or combinations of amendments revealed no significant differences in survival rates, top soil was the only amendment added during this planting to ensure adequate soil around the new plants. No watering was needed due to a rain event which occurred immediately post-planting.

Table 11. Additional grassland plots were installed during winter 2013/2014, consisting of combinations of 1 to seven plant species selected based on survival and fitness assessments made in 2013.

Cell	New Plots	Buffalograss	Eastern gamagrass	Indiangrass	Little bluestem	Switchgrass	Dakota mock vervain	White tridens	TOTAL
E-West	14	1	40	0	10	24	0	8	**83**
E	8	1	28	0	5	16	0	0	**50**
F (East)	17	17	20	17	13	30	4	34	**135**
F-North	9	1	32	8	0	0	0	0	**41**
F (West)	8	7	32	8	1	8	2	6	**64**
G	49	38	196	49	26	98	20	78	**505**
Totals	**105**	**65**	**348**	**82**	**55**	**176**	**26**	**126**	**878**

New plots were evaluated in July 2014 for percent survival and fitness using the same criteria as in 2013 assessments of original plots. Switchgrass had the greatest survival rate (80%), followed by Indiangrass (50%), buffalograss, Eastern gamagrass and white tridens (40%), and little bluestem and Dakota mock vervain (30% each). The grand mean survival rate for the new plots was 51%. While this number may seem low relative to previous plantings, identifying newly planted grass species in existing mixed communities can be difficult, and that actual survival may be considerably higher than is reported here. And, because transplants used in this project have well-developed root systems, it is anticipated that recovery from underground stock will occur. Surviving plants of each species had a fitness of score of 2 or greater with the exception of little bluestem, which averaged 1.6. Mean fitness score of 2.2 was observed for all surviving plants (Table 12).

Table 12. Percent survival and fitness of seven grassland species planted near wetland cells in December 2013. Not all species were planted around all wetland cells.

Cell	Assessment parameter	Buffalograss	Eastern gamagrass	Indiangrass	Little bluestem	Switchgrass	Dakota mock vervain	White tridens
E-West	Percent survival	0	15	-	30	100	-	25
	Survivor fitness	0	2.3	-	1.0	2.0	-	2.5
E	Percent survival	0	0	-	20	94	-	
	Survivor fitness	-	-	-	2.0	2.33	-	
F (East)	Percent survival	24	50	41	54	80	0	62
	Survivor fitness	1.8	1.0	1.7	1.1	1.4	0	1.3
F-North	Percent survival	0	59	63	-	-	-	
	Survivor fitness	0	2.11	1.80	-	-	-	
F (West)	Percent survival	17	50	63	0	50	0	67
	Survivor fitness	2.0	1.9	1.4	0	2.0	0	1.5
G	Percent survival	47	49	45	31	69	35	29
	Survivor fitness	2.7	2.6	2.4	2.3	2.4	2.9	2.7
Overall Percent Survival		**40**	**40**	**50**	**30**	**80**	**30**	**40**
Overall Survivor Fitness		**2.5**	**2.3**	**2.1**	**1.6**	**2.1**	**2.9**	**2.0**

Wetland cell may have continued to play a role in survival. For instance, 100% of switchgrass at Cell E-West survived, followed by Cell E (94%), Cell F (East) (80%), Cell G (69%) and Cell F (West) (50%). As previously stated, differences in soil, occurrences of nuisance or other plants, and human activity such as driving over plots likely played a role in some of these differences.

As a follow up to the previous year's evaluations of the original plots and to acquire information on longer-term success of the test plantings, plots installed during the winter of 2012/2013 (and spring 2013) were evaluated again in July 2014 (Appendix G, Figures G-10 through G-13). Analyses of community survival revealed no significant difference between wetland cells, which averaged greater than 80% survival 1-year post-installation (2013; $p=0.32$); however, by 2014 significant differences between the wetland cells were observed ($p<0.00$) with the survival rate decreasing to between 39% and 67%. Community fitness analyses of surviving plants for 2013 and 2014 revealed that fitness scores were wetland cell-related but with most wetland cells having fitness scores averaging above 2. The exceptions were Cell F-North (both years) and of I-45 in 2014, which had lower values.

2014's assessment of Cell E revealed that the community survival had decreased to a mean of 50%, but retained a mean fitness rate of 2.2. Big bluestem, Eastern gamagrass, Indiangrass, switchgrass, white tridens and turkey tangle frogfruit appeared well adapted for this cell as their survival and fitness ratings were above average. Community survival around Cell E-West had decreased to approximately 40%, but retained a fitness rating of 2.3. Species most suitable to this cell included Big bluestem, Eastern gamagrass, Indiangrass, little bluestem, switchgrass, and Maximilian sunflower. Community survival decreased to approximately 65% for the grassland surrounding Cell F (East), but retained a fitness rating of 2.5. Big bluestem, buffalograss, Eastern gamagrass, Indiangrass, switchgrass, Maximilian sunflower, Dakota mock vervain, white tridens, and turkey tangle frogfruit were found to be persisting well in this area. Cell F-North community survival rate decrease to 41% by the 2014 assessment and continued to have a low fitness rate (1.8). Species most adaptable to the grassland surrounding this cell include big bluestem, buffalograss, Eastern gamagrass, Indiangrass, switchgrass, and turkey tangle frogfruit. Assessment of Cell F (West) revealed that community survival had decreased to 57%, but retained a fitness rate of 2.3. Big bluestem, buffalograss, Eastern gamagrass, Indiangrass, switchgrass, Maximilian sunflower, white tridens and turkey tangle frogfruit appear well adapted for this cell. Cell G's 2014 assessment found that community survival had decreased to approximately 62%, but retained a fitness rating of 2.5. Big bluestem, buffalograss, Eastern gamagrass, Indiangrass, switchgrass, Maximilian sunflower, Dakota mock vervain and turkey tangle frogfruit appear best suited to this area. Finally, community mean survival decreased to approximately 48% for the grassland of the I-45 site while the mean fitness rating decreased to 1.8. Big bluestem, buffalograss, Eastern gamagrass, Indiangrass, switchgrass, and Maximilian sunflower appear suited for this grassland area as their survival and fitness ratings were above average. However, as discussed later in this report, mowing in addition to our management efforts has been difficult to direct in that area. Overall, while survival seems to decline over time, fitness is increasing around most cells. This has two implications:

1) Some grassland species are not suitable for all areas around all wetland cells and are not able to survive even when transplanted from robust, containerized propagules. This may, at least in part, explain poor and inconstant establishment from seeds during initial turfing efforts.

2) All grassland species tested are suitable for some areas of the wetland cells when transplanted from robust, containerized propagules. Knowing this, it is clear that our approach will provide the greatest likelihood of site-wide establishment of desirable vegetation: continuous production of seeds by each species in areas in which they are best suited will lead to development of communities dominated by desirable plants. While distribution of diversity around the LCOW grasslands may not be random, patches of desirable vegetation will provide the same benefits to the grassland ecosystem.

In late 2012, SWF expressed concern about poor grassland vegetation coverage and potential erosion during rain events in two areas outside the turfing area. These areas included the hillsides on either side of Cell F (East) that correspond with a cut through the old Linfield Landfill. ERDC conducted a precursory evaluation of the areas and submitted a SOW addressing the issue. The SOW called for additional seeding and planting containerized plants to help fill in bare areas. Although seeding the LCOW was not largely successful in previous efforts due to overbanking events and absence of irrigation in previous attempts, these hillsides are largely above the areas prone to overbanking, and the potential cost effectiveness and benefits of success suggested it should be used in this effort. That success would depend, in large part, upon unpredictable weather conditions that could occur in the area during fall, winter and spring of 2012/2013 and beyond. We also recognized that mowing too closely to the ground on the hillsides was impacting existing cover crops, and determined to halt mowing until stable vegetation communities could develop.

A seed mix comprised of cover crop and dry-condition suitable grass species was broadcast at 22 lbs. per acre over the two hillsides in November 2012 (Table 13). Soils were harrowed as seeds were broadcast to increase seed contact with soil. In addition to seeding, the hillsides were planted with containerized plants in winter 2012/2013.

Table 13. Grass seeds were broadcast over two hillsides just outside the LCOW turfing area in an effort to fill in bare spots.

Species	Pounds per acre	X10 acres (in lbs.)
Cereal rye	12	120
Buffalograss	3	30
Sideoats grama	3	30
Switchgrass	4	40
White tridens	<1 (4 packs)	40 packs

Two different planting patterns were used for the hillside planting with approximately 300+ containerized plants installed in areas supporting little to no vegetation. On the eastern slope, sixty-five triangular plots were planted with three plants each on 6-ft centers. All plots received one switchgrass, one Eastern gamagrass and one each of Indiangrass, white tridens or little bluestem. On the western slope, 7 plots selected based upon poor vegetation coverage were each planted with sixteen plants on 6-ft centers. Plant were randomly distributed within plots, and included four Eastern gamagrass, four switchgrass, four white tridens, one Indiangrass, one turkey tangle frogfruit, one winecup, and one Dakota mock vervain.

Only occasional patches of cereal rye, switchgrass, and white tridens were identifiable from seeding during 2013, but planted species exhibited high survival and many appeared to have become well established by the end of the growing season. Volunteer species present on the hillsides recovered reasonably well with the halting of mowing, and by the end of 2013, most bare areas were occupied by plants. While no significant rain or overbanking events occurred to enable us to gage the success of the reseeding/planting efforts in terms of reducing or preventing erosion, recovery of the vegetation community was encouraging. Plant community development continued to improve in 2014, with results from seeding being more obvious in that year, and by November the hillsides were well-vegetated, in large part by increases in switchgrass and sideoats grama (*Bouteloua curtipendula*).

A supplemental planting of containerized perennial sunflowers (Maximilian and sawtooth) was made in June 2013 to increase wildflower diversity in some areas. As both species are rhizomatous, large in stature (3-ft to 10-ft tall) and form large monotypic stands, suitable locations were chosen adjacent to wetland cells F and G to allow for expanded growth. Planting pits were amended with Terra-Sorb™, although irrigation was not continued past an initial watering at the time of planting. Twelve plots each consisting of four mature potted plants of either Maximilian or sawtooth sunflower were planted on 6-ft centers around Cell G (five plots) and the south side of Cell F (seven plots) at elevations conducive to growth for these species. Plants did not establish strongly during 2013 due to dry conditions, but they recovered during spring 2014 and grew to expand during that year. Full flowering patches are expected to occur during 2015.

Effects of management on the grasslands

Following drill-seeding at Cell D, intermittent mowing was conducted in association with mowing under and along the right-of-way of I-45. However, establishment of native grasslands was not considered when mowing schedules were set, resulting in several undesirable species, primarily Johnsongrass and giant ragweed, dominating the area. No mowing was conducted in the remaining LCOW grasslands after drill-seeding in 2008 and 2009, resulting in giant ragweed rapidly becoming the dominant species there.

In addition to supplementing the native grassland plant community with containerized plantings as described above, ERDC recommended that SWF initiate a scheduled, and as-needed, mowing program to help control nuisance plants while at the same time permit growth and spread (primarily by seed) of desirable species. A general schedule was followed to target the two dominant problem plants, typically calling for one or two mows per year, depending upon conditions. Two mows were made in 2010 and 2011, but only a single mow was required in 2012, 2013 and 2014:

1) Mid-summer mow---targets giant ragweed for mowing before setting seeds. Because this is an annual species, preventing seed production can significantly reduce the seedbank, resulting in fewer plants the following year. Waiting until mid-summer also permits most spring annuals a chance to set seed, and provides long enough remaining growing season for seed production by many fall annuals.

2) Late summer to early fall mow---targets Johnsongrass to further reduce seed production and weaken rootstock, especially during dry periods. Many native grasses (e.g., switchgrass) can tolerate this mow and have already set seeds, minimizing damage to them.

In 2013, ERDC recommended and directed a shift to selective mowing by SWF contractors. Mowing in previous years had greatly reduced giant ragweed coverage by that time, and only a single mow was needed during that year. Only areas supporting giant ragweed or dominant stands of Johnsongrass were mowed, reducing total area mowed by an estimated 50%. Further, we trained mowers to target giant ragweed and Johnsongrass while making efforts to avoid substantial stands of desirable vegetation, such as switchgrass and Illinois bundleflower. We reasoned that areas not infested with nuisance plants would benefit from a full season of seed production, hastening the process of spread and increasing cover of desired plants. Additionally, this strategy left better cover for grassland wildlife during the following winter. While results of selective mowing will not be known for several years, ERDC is recommending it be continued by the City of Dallas once they begin management.

Selective mowing continued into 2014 for annual control of giant ragweed and Johnsongrass. Mowing was conducted in summer (August), prior to seed formation to ensure control of targeted invasive plants without impacting desirable native vegetation. ERDC provided additional direction and plant identification training to the mowing contractor to improve selective mowing results. We also provided a generalized map as further guidance and remained on-site during the mow (Figure 29).

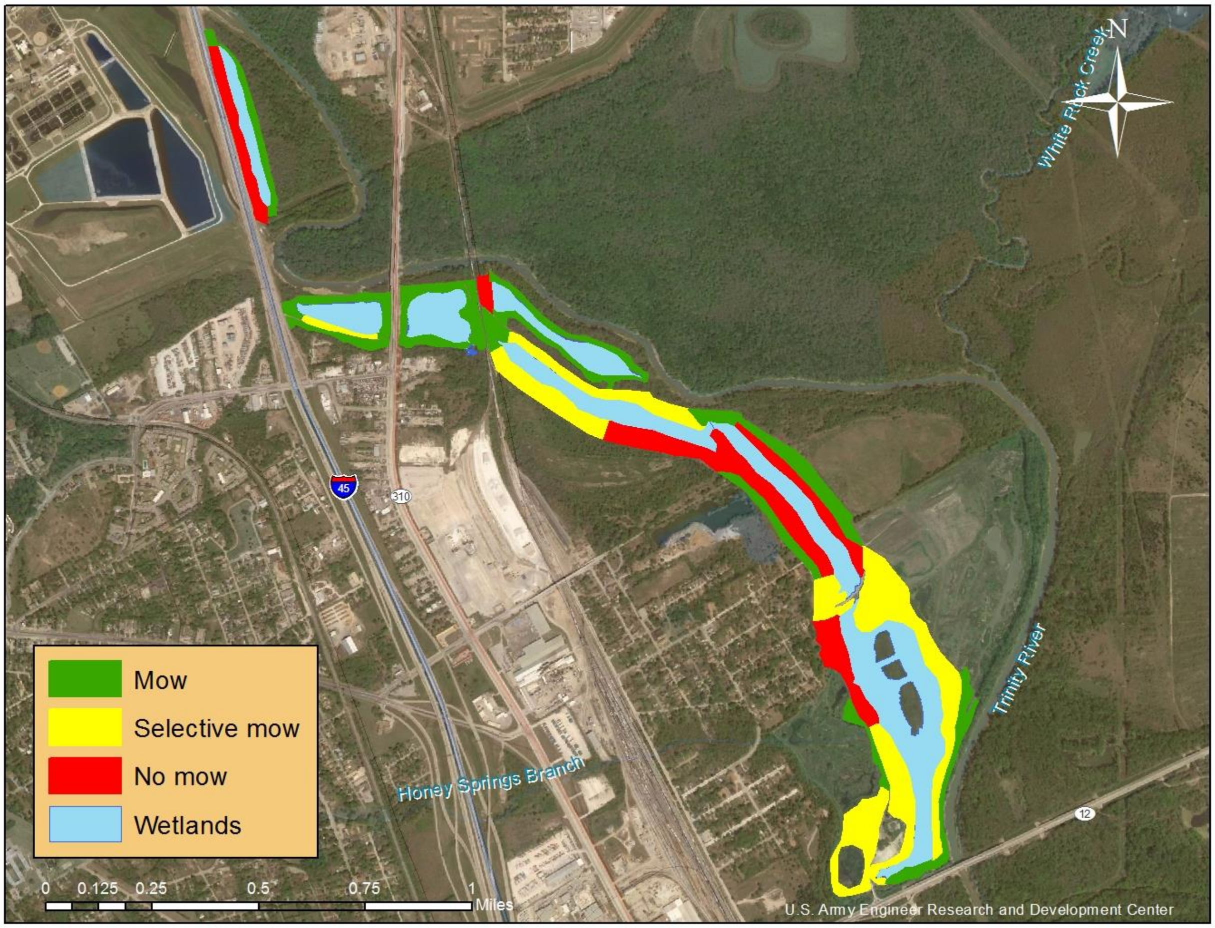


Figure 29. ERDC provided a map for selective mowing around the adjacent grasslands to contractors to improve efforts.

Plant community response to this mowing schedule has been evident in transect data recorded during the spring of each year (Appendix G). In all, 70 species were identified along transects in 2014, 82 in 2013, 64 in 2012, 94 in 2011, and 70 in 2010. Variations in numbers observed include year-to-year environmental differences (e.g., spring 2012 was very dry, possibly reducing or delaying annual species sprouting) and the amount of cover crop in an area (e.g., dense stands of cool season grasses, such as ryegrass, reduced or "masked" early stage annuals in 2014) at the time transects surveys were conducted. However, diversity remains high in the LCOW even under mowed conditions.

Five years of transect data have begun to show interesting results, even though longer-term grassland vegetation community responses to management (mowing, but also plantings and other management such as hand-pulling and selective herbicides) are not yet conclusive. For instance, when categorized as desirable (non-problematic native), acceptable (non-problematic non-native), or undesirable (problematic native or non-native) grassland plants, the frequency of occurrence of desirable versus native has shown a slow, but steady increase in favor of desirable and acceptable species: desirable and acceptable species have become relatively more common in the grasslands, and undesirable species less common (Table 14). Desirable and acceptable species, for instance, have had frequency increases since 2010 (from 44.8% to 58.0%; and from 26.0% to 30.3%, respectively) while undesirable species frequency has declined from 24.0% to 9.8%. We believe this is directly due to targeted management of several of the more prominent undesirable species occurring, including giant ragweed and Johnsongrass. Selective mowing implemented in 2013 and 2014 should hasten this trend, with managed areas opened to establishment and spread by desirable and acceptable species, particularly with inclusion of planted grasslands plots throughout the LCOW, which will serve as seed sources for natural spread to weed-managed areas.

Table 14. Frequency estimates for the grassland surveys conducted annually 2010 - 2014 in the LCOW (includes I-45 grasslands).

	2010	2011	2012	2013	2014
Desirable	44.8	53.1	47.1	54.2	58.0
Acceptable	26.0	28.5	37.4	23.5	30.3
Undesirable	24.0	18.3	16.1	18.0	9.8
Unknown	5.1	0.1	0.0	3.7	2.4

Percent coverage of desirable, acceptable, and undesirable vegetation can be more revealing in terms of ecological condition of the grasslands, reflecting dominance of the vegetation community by beneficial or harmful plants (Table 15). Changes in percent coverage of these three categories have occurred between 2010 and 2014, with increases in desirable species (25% in 2010 to 41% in 2014) and acceptable species (21.5% in 2010 to 24.1% in 2014), and a substantial decrease in undesirable species (34.3% in 2010 to 15.7% in 2014). This shift reflects the goals of ERDC work in the grasslands: to replace a vegetation community dominated (by coverage) by undesirable species to one dominated by desirable and/or acceptable species. Much of the shift has come about by controlling giant ragweed, which was at one time the most commonly encountered species and was found to cover over 25% of the grassland vegetation community at the LCOW.

Table 15. Estimated percent coverage by grassland species category for surveys conducted annually 2010 – 2014 in the LCOW (includes I-45 grasslands).

	2010	2011	2012	2013	2014
Desirable	25.0	43.2	35.7	44.8	41.0
Acceptable	21.5	22.8	30.1	23.6	24.1
Undesirable	34.3	24.1	15.6	21.7	17.3
Bare	17.6	10.9	18.3	7.84	15.7
Unknown	1.5	>0.1	0.0	2.0	1.4

Meander surveys have been conducted to verify transect results and evaluate the overall grassland community condition at the LCOW since 2010. Appendix G (Figures G-1 through G-3) provides results from 2014 meander surveys. These surveys have corroborated results reported from transects: since 2010 the grasslands have shown a large decline in giant ragweed accompanied by surges in several desirable grassland species in the spring and early summer, which persist throughout the summer. Meander surveys further support transect data suggesting that several undesirable species, including Johnsongrass and Bermudagrass, are not spreading at rapid rates due to management of giant ragweed, but rather that desirable plants such as switchgrass, white tridens, pink evening primrose, and others are filling in those areas more rapidly (Figure 30). Meander surveys also help identify and categorize plants at the LCOW: for instance, two species of potential concern that increased somewhat in 2011 after 2010 mowing---common morning-glory and balloonvine---were no longer as widespread in 2012, 2013, or 2014, and continued to be categorized as acceptable.

Figure 30. Pink evening primrose flowering along the south side of F (East) spring 2013.

Two undesirable species that were first identified in late winter 2012 that have the potential to become problematic and are currently characterized as undesirable at the LCOW, although both currently infest only a small percentage of the grasslands, are annual bastardcabbage (*Rapistrum rugosum*) and nodding plumeless thistle (*Carduus nutans*). ERDC initiated management of species in the grasslands surrounding the LCOW (but primarily in Cell G and Cell F), using a combination of hand-pulling, digging, and herbicides. Both triclopyr and glyphosate have been used to control the weeds with success. However, additional treatments were needed to ensure the infestations did not get out of hand and that re-infestations from nearby colonies (Loop 12 right-of-ways and Linfield Landfill) were held in check. Management efforts against both species intensified during 2013 and 2014, and will continue in 2015, and have included seed broadcasting and planting containerized grasses in areas where either has been removed.

Grasslands Summary

The LCOW grasslands are on the right track to meet project goals of establishing a plant community dominated by desirable and acceptable species that are tolerant of conditions that occur at the LCOW---excessive dry periods occasionally interrupted by overbanking events. After four years of management, the grasslands have been transformed from one dominated by undesirable plants (mostly giant ragweed) to one in transition between cover crop/acceptable species and desirable plants (Figure 31). As management continues to target undesirable species, their occurrence should continue to decline as they are replaced by beneficial grassland species. In taking charge of the LCOW, the City of Dallas will be responsible for continuing management of the grasslands. This will require consistent monitoring of responses by the grasslands to management for making necessary adjustments that will ensure ecosystem stability and services.

Figure 31. Giant ragweed dominated most of the LCOW grasslands in 2009 and 2010 (left). Mowing was initiated in late 2010, primarily targeting giant ragweed: by late 2012, the species was no longer dominant, providing the opportunity for establishment and spread of desirable grassland species such as switchgrass, Eastern gamagrass, and others (right). This condition has persisted and improved through 2014.

Operations and Maintenance Manual

An O&M manual is critical to ensure that the local sponsor, the City of Dallas, is capable of engaging in interactive management of the wetlands cells in a manner necessary to provide sustainable aquatic and migratory bird species diversity and stability once the Corps completes its project obligations. ERDC developed a draft O&M manual for Cell D during 2009, with iterations since that time incorporating the remaining cells in the LCOW as their proper management has been developed. Additional modifications to the O&M were incorporated in 2012 and 2013 for SWF and the City of Dallas review, and it is anticipated that the manual will be completed during 2015 with inclusion of grassland management strategies developed by ERDC.

For more information, please contact:

Dr. Gary Owen Dick
garydick@laerf.org

Lynde L. Dodd
lyndedodd@laerf.org

Aaron N. Schad
anschad@gmail.com

Lewisville Aquatic Ecosystem Research Facility
Lewisville, Texas

972-436-2215

Additional Contacts:

Mandy Mcguire **Amanda.Mcguire@usace.army.mil** **817-886-1864**	**USACE Fort Worth District** **Environmental Resources**
Jon Loxley **Jon.K.Loxley@usace.army.mil** **214-671-9384**	**USACE Fort Worth District** **Project Manager** **Trinity River Corridor Project**
Andy Johnston **Andrew.I.Johnston@usace.army.mil** **817-304-7500**	**USACE Fort Worth District** **Project Coordinator** **North Texas Resident Office**
Clayton Church **Clayton.A.Church@usace.army.mil** **817-886-1310**	**USACE Fort Worth District** **Public Affairs Specialist**
Jim Frisinger **James.C.Frisinger@usace.army.mil** **817-901-9644**	**USACE Fort Worth District** **Public Affairs Specialist**
Sarah Standifer **Sarah.standifer@dallascityhall.com** **214-671-9581**	**City of Dallas** **Assistant Director** **Trinity River Corridor Project**

Appendix A

Dallas Floodway Extension

Establishment, monitoring, and adaptive management of native aquatic vegetation and adjacent native grasslands; and monitoring aquatic organism utilization of project aquatic features:

2014 Task Status Report Summary

US Army Engineer Research and Development Center
Lewisville Aquatic Ecosystem Research Facility

Planning and Materials

Materials were purchased to complete tasks through August 2014
Additional materials were purchased to complete tasks through December 2014

Plant Production

All aquatic and grassland plants were produced for plantings through August 2014
Additional grassland plants were produced for plantings through December 2014
Additional plants are being produced and maintained for plantings beyond December 2014

Plantings

<u>All Cells</u>

No plantings were required during 2014.

<u>Wood Duck Pond</u>

Additional plantings were made in this water feature in 2014.

<u>Riverine Armoring - Trinity River @ IH-45</u>

No plantings were required during 2014.

<u>Cell F / G armoring</u>

No plantings were required during 2014.

<u>Cell G Outfall</u>

No plantings were required during 2014.

<u>Cell E West Outfall / Cut</u>

No plantings were required during 2014.

<u>Cell F-North Outfall / Cut</u>

No plantings were required during 2014.

Plant and Water Quality Monitoring

Several wetland cell meander surveys were conducted throughout the LCOW during 2014.

Water quality was measured periodically between 2006 and 2013, but was not measured during 2014.

Sediment Monitoring

Because no overbank events occurred, wetland cell elevation measurements were not made during 2014.

Biological Monitoring

Fisheries

Sampling was not undertaken in 2014.

Macroinvertebrates

Sampling was not undertaken in 2014.

Birds, mammals, and other vertebrates

Informal surveys were conducted throughout the LCOW on a monthly basis through December 2014.

Grassland Planting and Monitoring

Test Plots

Evaluations of grassland species establishment test plots continued in 2014.

Large-scale grassland plantings continued in winters 2013/2014 and 2014-2015.

Plant Production

Plants needed for grassland planting were acquired and put under nursery production in spring and summer 2014. Those needed for additional plantings are being produced for 2015 plantings.

Mowing

ERDC oversaw LCOW-wide contractor mowing during summer 2014.

Grassland Vegetation Surveys

Grassland areas were surveyed for vegetation presence and coverage in spring (transect surveys) and fall (meander surveys) 2014.

Site Management

Plant Communities

Submersed plant exclosures were repaired, as needed, spring – summer 2014

Herbivory

Turtle removal and relocation was made seasonally during summer 2014---this effort was conducted in Cells D, and F (West), and G.

Nuisance plant management

Spot treatments were required to control willows and cattails in the wetland cells during 2014.

Hand-removal, triclopyr and glyphosate treatments were required to control annual bastardcabbage and nodding plumeless thistle during spring and summer 2014.

Biocontrol treatments

Re-introduction of alligatorweed flea beetles were made to all LCOW wetland cells and the CWWTP supply channel on four occasions during 2014: mid-spring, late spring, early summer, and mid-summer.

Reports

The FY2013 status report was completed and submitted in March 2014.

A draft O&M manual for the LCOW was produced and submitted in early winter 2014; discussions with the COD regarding comments were initiated.

Appendix B

Dallas Floodway Extension

Establishment, monitoring, and adaptive management of native aquatic vegetation and adjacent native grasslands; and monitoring aquatic organism utilization of project aquatic features:

Wetland Vegetation

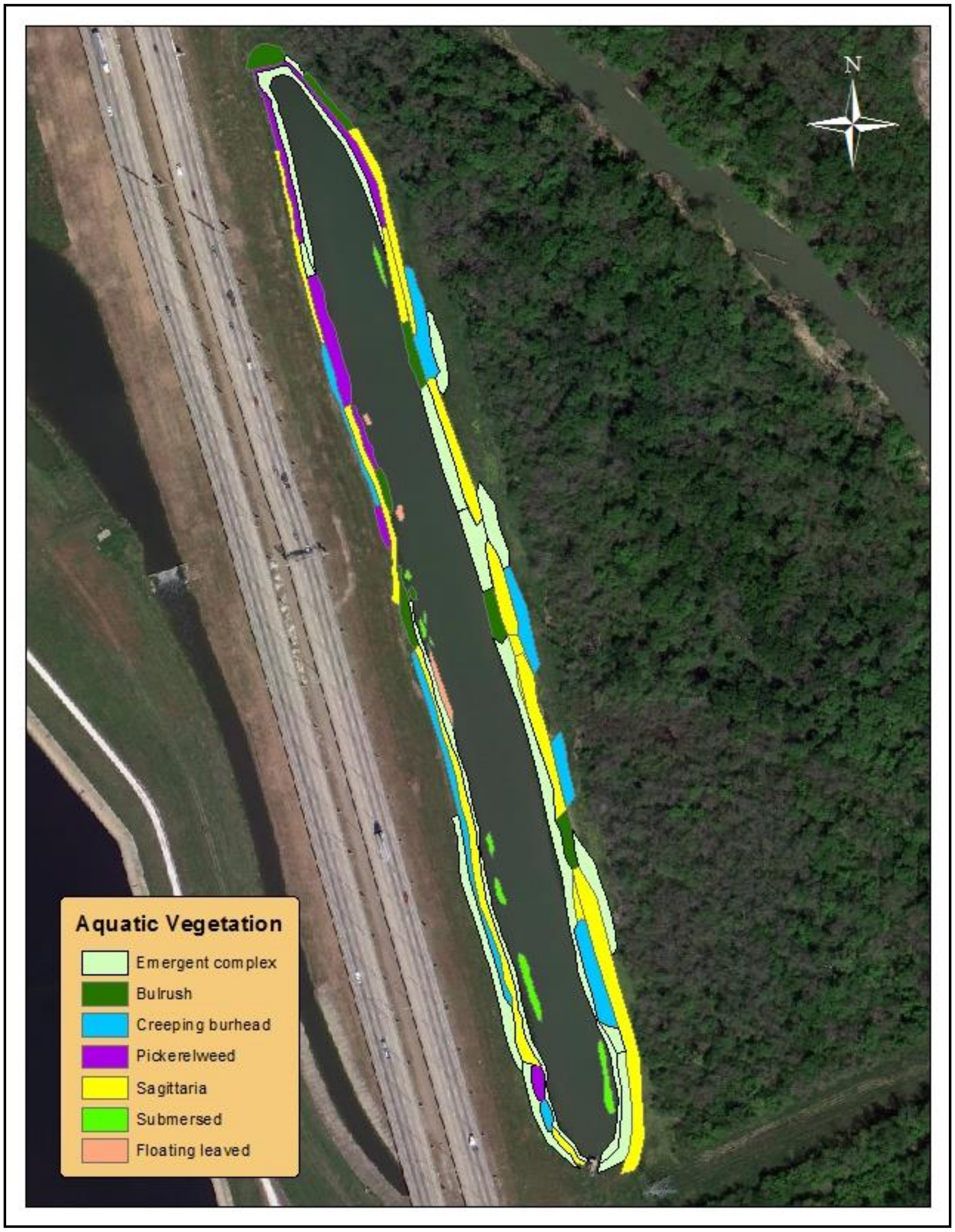


Figure B-1. Native wetland plants persisted around Cell D as of 2014. Emergent complexes were dominated by spikerushes, smartweeds, and water primrose, but included American water-willow, bulrushes, sedges, spotflower, and others.

Figure B-2. Native wetland plants were established around Cell E-as of 2014. Emergent complexes were dominated by spikerushes and smartweeds, but included water primrose, American water-willow, bulrushes, sedges, spotflower, and others.

Figure B-3. Native wetland plants were established around Cell E as of 2014. Emergent complexes were dominated by spikerushes, smartweeds, and water primrose, but included bulrushes, sedges, sesbania, spotflower, and others.

Figure B-4. Native wetland plants were established around Cell F-North as of 2014. Emergent complexes were dominated by water primrose, smartweeds, and spikerushes, but included water willow, bulrushes, and sedges.

Figure B-5. Native aquatic plants were established around the perimeter of Cell F (West) as of 2014. Emergent complexes were dominated by spikerushes, smartweeds, and water primrose, but included sedges, sesbania, bulrushes, spotflower, and others.

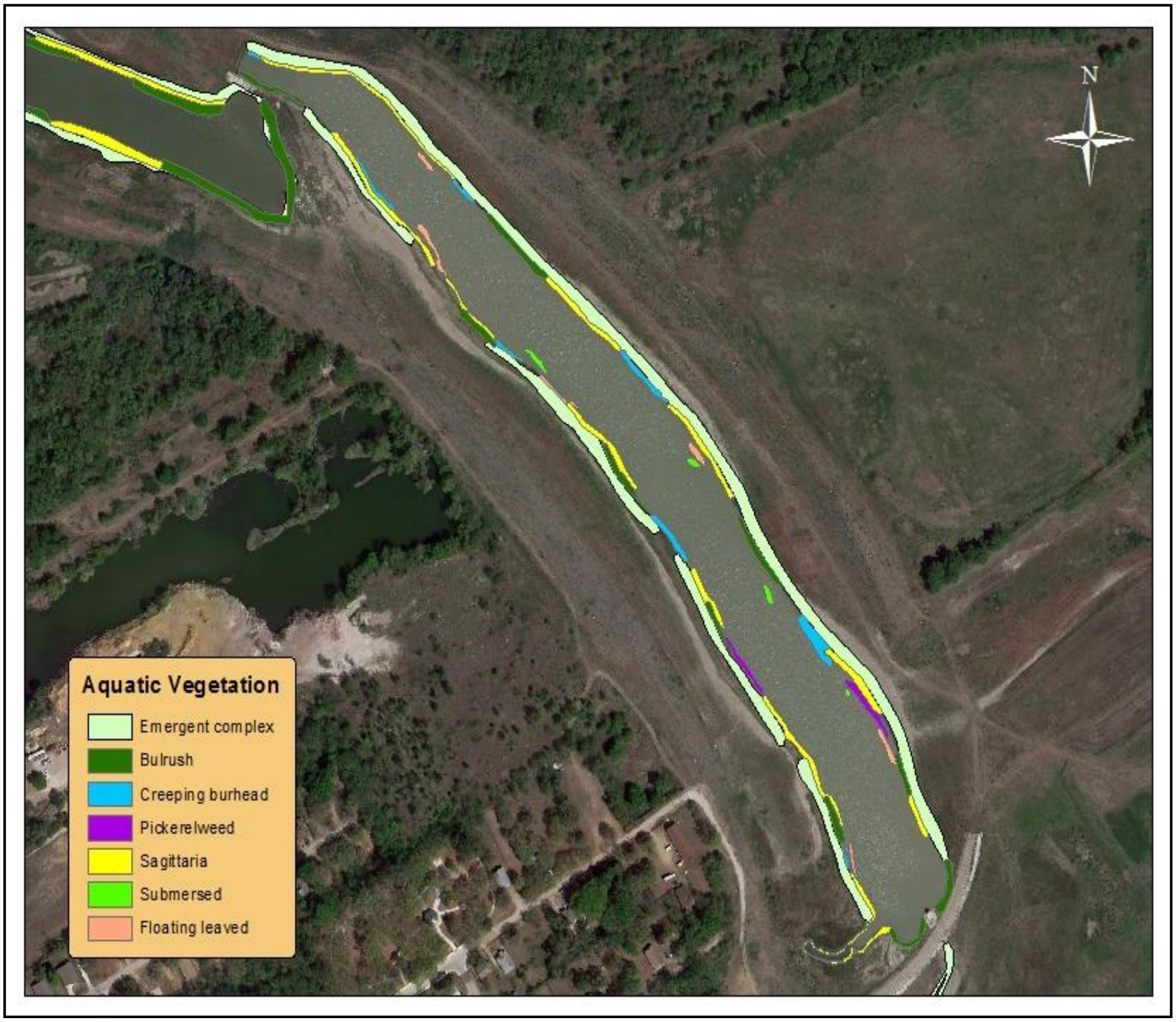


Figure B-6. Native aquatic plants were established around the perimeter of Cell F (East) as of 2014. Emergent complexes were dominated by spikerushes, smartweeds, and water primrose, but included sedges, burheads, pickerelweed, sesbania, spotflower, and others.

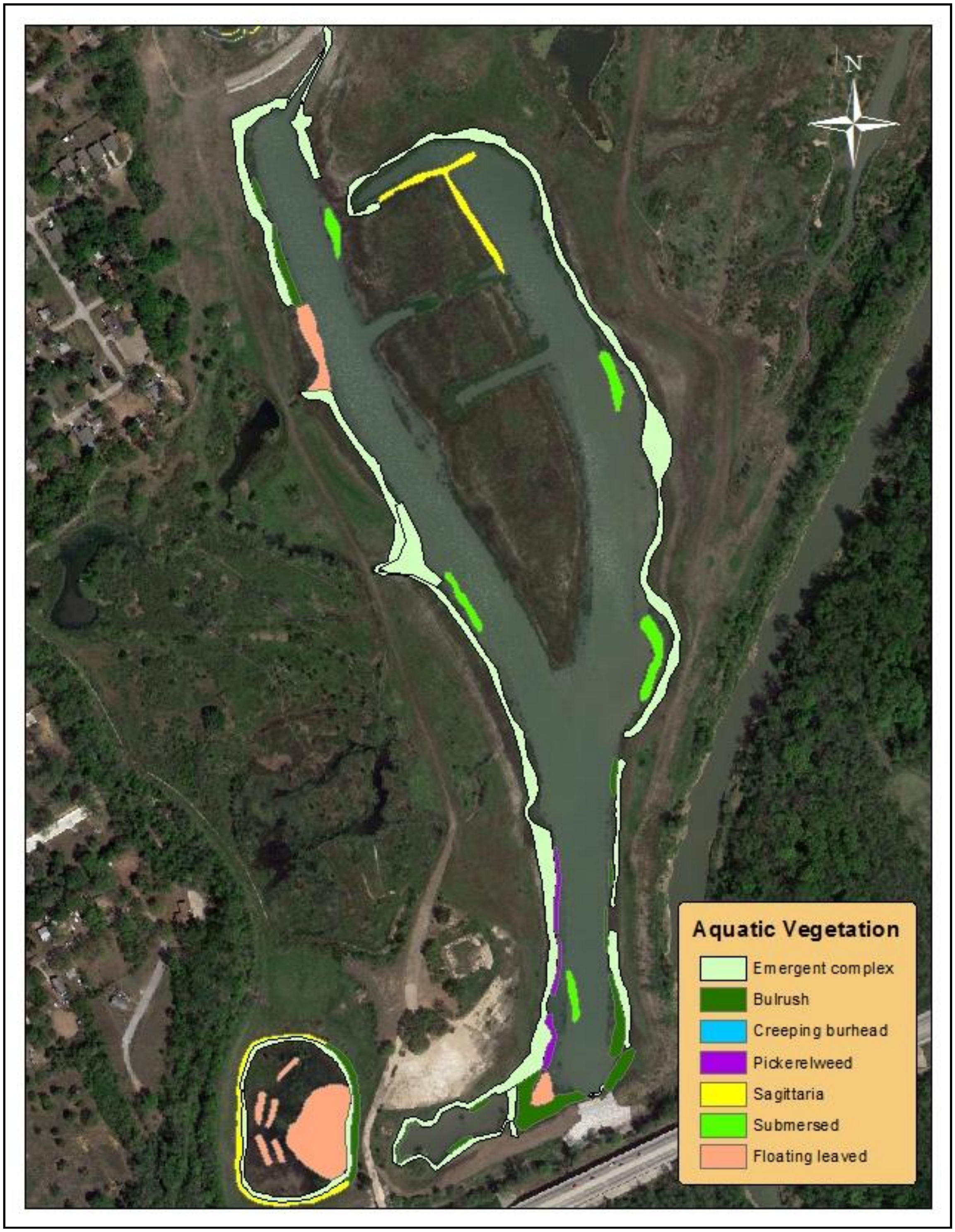


Figure B-7. Native aquatic plants were around Cell G and the Wood Duck Pond (southwest side of Cell G) as of 2014. Emergent complexes were dominated by spikerushes, smartweeds, and water primrose, but frequently included water willow, bulrushes, sedges, sesbania, spotflower, and others.

Appendix C

Dallas Floodway Extension

Establishment, monitoring, and adaptive management of native aquatic vegetation and adjacent native grasslands; and monitoring aquatic organism utilization of project aquatic features:

Water Quality

The LCOW receives water from several different sources: direct precipitation, overland runoff, overbanking of the Trinity River, and most importantly, effluent from CWWTP. Effluent is pumped into Cells D, E-West and E. Cells D and E-West are isolated waterbodies that drain directly into the Trinity River. Cell E functions as the head of a chain of four wetlands and water released from Cell E flows into Cell F (East and West, which are separated by a narrow band of riprap) which flows into Cell G then drains into Honey Branch Creek, which merges with the Trinity River. Cell F (West) can also drain into F-North when at maximum pool; however, F-North becomes isolated from the chain during lower water periods.

Initially, water levels in Cell D were maintained (to counter evaporation and wicking by grassland areas) by pumping effluent 6 hours or more per day. This resulted in substantial input of nutrients, with total nitrogen sometimes exceeding 8 mg/L and total phosphorus exceeding 5 mg/L (as reported by the City of Dallas in 2006). These nutrient loads were responsible for significant algal blooms that occurred during spring 2006, and were first dominated by filamentous species (Figure C-1). We were able to reduce filamentous algal blooms by dropping the water level by six inches below summer pool, exposing the shallow shelf where the majority of the algae occurred, eliminating it through desiccation. After bringing water levels back to summer pool, however, a planktonic algae bloom occurred, resulting in water quality problems due to high rates of photosynthesis. On several occasions, ERDC recorded pH in excess of 10 units (hand-held meter, spot checks), a level that is harmful to fish and possibly to some aquatic vegetation. Whereas an established community of aquatic vegetation can serve to reduce algal blooms, the vegetation community was not mature enough for that to occur. Therefore, we opted to implement measures in an effort to limit algal growth. First, we reduced pumping to 1 or 2 hours per day to lower input of new nutrients. We also raised the water level by six inches above summer pool to inundate some of the emergent and terrestrial species that had established on the shallow shelf. We reasoned that these plants, which were better established than submersed species, had better potential to compete with algae for nutrients and would help reduce the overall nutrient loading in the water column. Subsequent to these actions, planktonic algae became less and less problematic, and plant growth increased. While pH remained moderately high, it fell to acceptable levels for fish and other aquatic wildlife (9.5 and below). An overbanking event

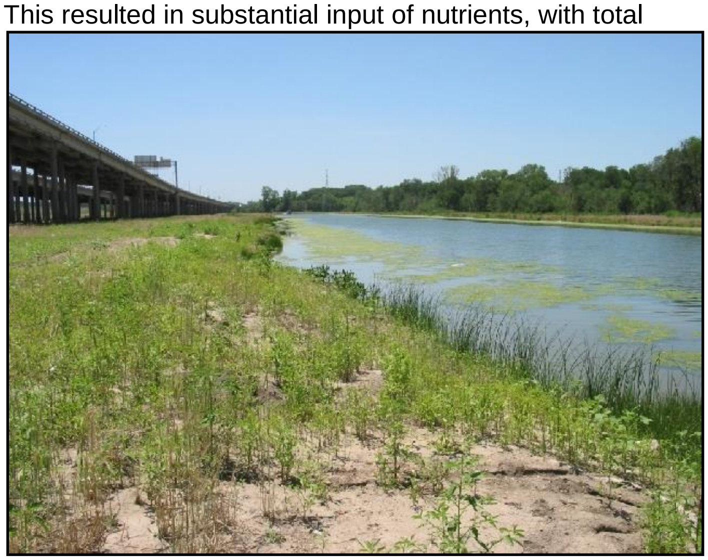


Figure C-1. Algal blooms were once common in the LCOW, but modification of water supply management and maturity of wetland cells has kept blooms in check since 2006.

near the end of the 2006 growing season additionally benefited the system by flushing nutrients (and moderate algal bloom) out of the water column. The system has since matured further due to plant growth, adding organic materials to substrates and binding nutrients, with decomposition contributing to water quality (ecosystem nutrient recycling). Problematic algae blooms have not occurred in Cell D since 2006.

As learned from Cell D, monitoring water quality in the wetland chain is critical for optimal adaptive management strategy development needed to establish and manage submersed species and the ecosystem as a whole. Because water from the treatment plant first enters Cell E (and separately Cell E-West) and then flows into other cells, we initially planted these cells more densely to hasten plant community establishment. This approach facilitated removal of some nutrients, thereby reducing the likelihood of algal blooms in downstream cells. We have additionally reduced pumping to a minimum (thereby reducing nutrient inputs during the establishment phase) for maintaining water levels, even permitting drops of several inches below target elevations at times. This combined effort has thus far resulted in only short-lived and mostly insignificant algal blooms in any of the cells.

We measured several water quality parameters periodically in each of the wetland cells between 2009 and 2013, coinciding with sampling of macroinvertebrates and fish conducted during the spring, summer, and fall (discussed later in this report), as a means of providing information to clue us in to developing water quality issues. Field readings of temperature, pH, dissolved oxygen, and conductivity using a Hydrolab Quanta, (Loveland, CO) were made in all cells near each's inlet and outlet to provide guidance for when algae management or other water quality actions are necessary. Although variations occur within and between cells, water quality remained within ranges conducive to growing aquatic plants and supporting fish and other aquatic wildlife between 2009 and 2013 (Table C-1). Occasional periods of high pH (usually in summer or fall) have occurred in Cell E-West and E, where water enters the cells directly from the wastewater treatment plant, reflecting increased algal photosynthesis responding to nutrient loading. However, as water flows through the system, nutrients are sequestered by plants, reducing algal photosynthesis (expressed as lower pH). Spikes or dips in some parameters may reflect influences of water source changes such as overbanking events or disruption of pump service. For instance, increased conductivity in 2011 and 2013 emphasized the relative lack of overbanking events coupled with pump issues occurring during part of those years.

Table C-1. Average LCOW-wide water quality (temperature, pH, dissolved oxygen, and conductivity) measured in spring, summer, and fall, was stable and generally fell within acceptable parameters for aquatic wildlife between 2009 and 2013.

Year	Temp (°C)	pH units	DO mg/L	Conductivity uS/cm
2009	20.8	8.4	11.2	451
2010	23.8	7.6	8.5	530
2011	22.9	**7.7**	10.0	641
2012	20.7	7.9	9.3	580
2013	23.5	8.6	10.8	603
Mean of means	**22.34**	**7.9**	**9.96**	**561**

In addition to our regular water quality monitoring, three more intensive water quality assessments were conducted during between March and August 2013 to evaluate potential changes occurring between LCOW input from CWWTP and LCOW output to the Trinity River. Although not designed to polish effluent, the parameters we were measuring appeared to indicate that water quality further down the chain might be better than that entering in terms of nutrient loading.

Macroinvertebrate and fish sampling sites (near inlets and outlets of each cell) were used to collect *in situ* measurements and subsurface water samples for analyses in the LAERF analytical lab. Data reported herein are the mean of the two sites for each cell. CWWTP effluent data was collected during the last two sampling dates for comparison with water quality in the cells. Parameters measured in the field include water temperature, dissolved oxygen, pH, and conductivity; analyses of turbidity, pH, alkalinity, and conductivity, and nutrient concentration analyses of soluble reactive phosphorus, total phosphorus, nitrogen (as ammonia), potassium, calcium, magnesium, sodium and iron were made in the lab. Additionally, chlorophyll *a* content was analyzed as an indication of phytoplankton. Analyses followed APHA Standard Methods for the Examination of Water and Wastewater (22nd edition). Water quality data are given in Figures 19 through 21.

As seen with yearly seasonal (spring, summer, and fall) measurements made starting in 2009, 2013 water temperatures in the wetland cells varied seasonally (Figure C-2). Surface water temperature averaged 13 C in late winter, which warmed to 31 C by late summer, temperatures typical of North Texas shallow water bodies. Interestingly, as water traversed the main chain of wetlands (E to G) in early March, water temperatures declined slightly, influenced by low air temperatures occurring at that time. This trend reversed in May and August, when temperatures increased slightly as water passed through the chain.

Effluent pH was measured at below 7 on the two dates sampled, but pH in cells was regularly measured at 9 or higher in 2013 (Figure C-2). While pH was occasionally measured at levels potentially harmful to fish and other wildlife, no stressed organisms were observed, and it is more than likely that pH refugia were available in deeper waters and shaded areas occurring in the cells. Several variables contributed to these differences, most notably planktonic algal populations that occurred in the cells. Changes in phytoplankton (as seen in chlorophyll *a* measurements given in Figure C-2) are reflected by changes in pH, where higher densities of algae result in higher pH. Differences in pH between cells, particularly where water sources and fates are different, were also evident. In Cell D, which is the most mature of all cells, pH was generally lower due to competition for nutrients between vegetation and algae. In Cell E and E-West, pH was higher than in other cells due to the fact that both directly receive nutrient rich effluent, but are not as mature as Cell D and therefore more nutrients are available to algae. A steady decline in pH (and chlorophyll *a*) occurred from Cell E to Cell G, indicating that nutrients were being removed as the water passed through the chain. Low pH (and chlorophyll *a*) in Cell F-North were due to absence of water (and nutrient) input from Cell F (West) in 2013.

Dissolved oxygen readings were consistent of wetland cells fed with nutrient rich source water and elevated levels of greater than 10 mg/L in May and August were consistent with increased phytoplankton populations, especially in directly effluent-fed Cell E and Cell E-West (Figure C-3). Declines in dissolved oxygen as water passed from Cell E to Cell G reflected lower photosynthesis rates due to fewer algae.

Alkalinity of the effluent was typical of wastewater, in May reported at 50 mg ($CaCO_3$)/L and in August, 27 mg ($CaCO_3$)/L (Figure C-3). Wetland cells demonstrated higher buffering capacity averaging 110 to 113 mg ($CaCO_3$)/L in March and May, but decreased to 83 mg ($CaCO_3$)/L by August, possibly due to lower alkalinity in effluent at that time. A general increase in alkalinity occurred as water passed through the chain, reflecting continued water/sediment interaction in the wetland cells.

Conductivity readings of 770 and 720 µS/cm for May and August, respectively, reflect the amount of dissolve inorganic solids entering the system via effluent (Figure C-3). Conductivity declined within the wetlands, reflecting utilization of ions by processes of photosynthesis and decomposition, particularly as water passed through the Cell E-Cell G chain.

Effluent entering the wetland system was relatively clear as its turbidity level was below 3.3 NTUs regardless of date. Turbidity was higher within cells, ranging from 11 to 37 NTUs over the course of assessments (Figure C-4). Higher turbidity in cells was due to resuspension of fine sediments caused by wave action and disturbance by fish, turtles, and waterfowl, as well as by phytoplankton. No distinct trends were noted in terms of turbidity changes in relation to water sources or fate. For instance, it appeared that turbidity declined as water passed from Cell E to Cell G in May, but increased in August.

Nitrogen (N) as ammonia (NH_3-N) was analyzed to characterize the amount of N in the system as well as determine the amount of N readily available for aquatic plant growth within the wetland cells (Figure C-4).

For the most part, as water passed through the chain of wetlands, N concentrations declined considerably (from 0.04 mg/L effluent to 0.01 mg/L at outflow of Cell G in August). However, several cells sometimes exhibited higher N concentrations than was present in effluent, indicating one of several possibilities: concentration of N related to effluent flow rates/evaporative rates, stormwater runoff from surrounding residential areas (to the north of the cells, west of the river), etc. N concentrations were consistently lowest in Cell F-North, which did not receive effluent, stormwater runoff, or overbanking water from the Trinity River during the sampling period.

Wetlands are known to function as nutrient sinks and reduction of phosphorus (P) was evident in the LCOW. Substantial declines in effluent total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations occurred in all cells receiving effluent (Figure C-4). For instance, of approximately 2.5 mg/L TP measured in effluent entering Cell E, only 0.12 mg/L remained by the time water returned to the Trinity River at the outlet of Cell G in August. A closer look at the fate of P within each wetland cell is given in Table C-2. The greatest reduction of TP occurred in Cell D and Cell E-West, both of which receive lower flow of effluent than does the Cell E to Cell G chain. However, cumulative reduction of TP was greatest in the chain, with a reduction of over 95% of effluent content occurring by the time water exited Cell G.

Table C-2. Total phosphorus (TP) declined as water flowed through the wetland cells, likely a result of uptake by plants, algae, and substrates. Cell F-North is excluded from these results because no water (other than precipitation) was added to the cell in 2013.

Cell	**Cell TP (mg/L)**			**Water source**	**% Reduction TP from water source**
	Inlet	Outlet	Mean		
D	0.446	0.350	0.398	Effluent	84
E-West	0.298	0.291	0.294	Effluent	88
E	1.026	0.932	0.979	Effluent	40
F (West & East)	0.585	0.355	0.470	Cell E outlet	50
G	0.177	0.118	0.146	Cell F outlet	41

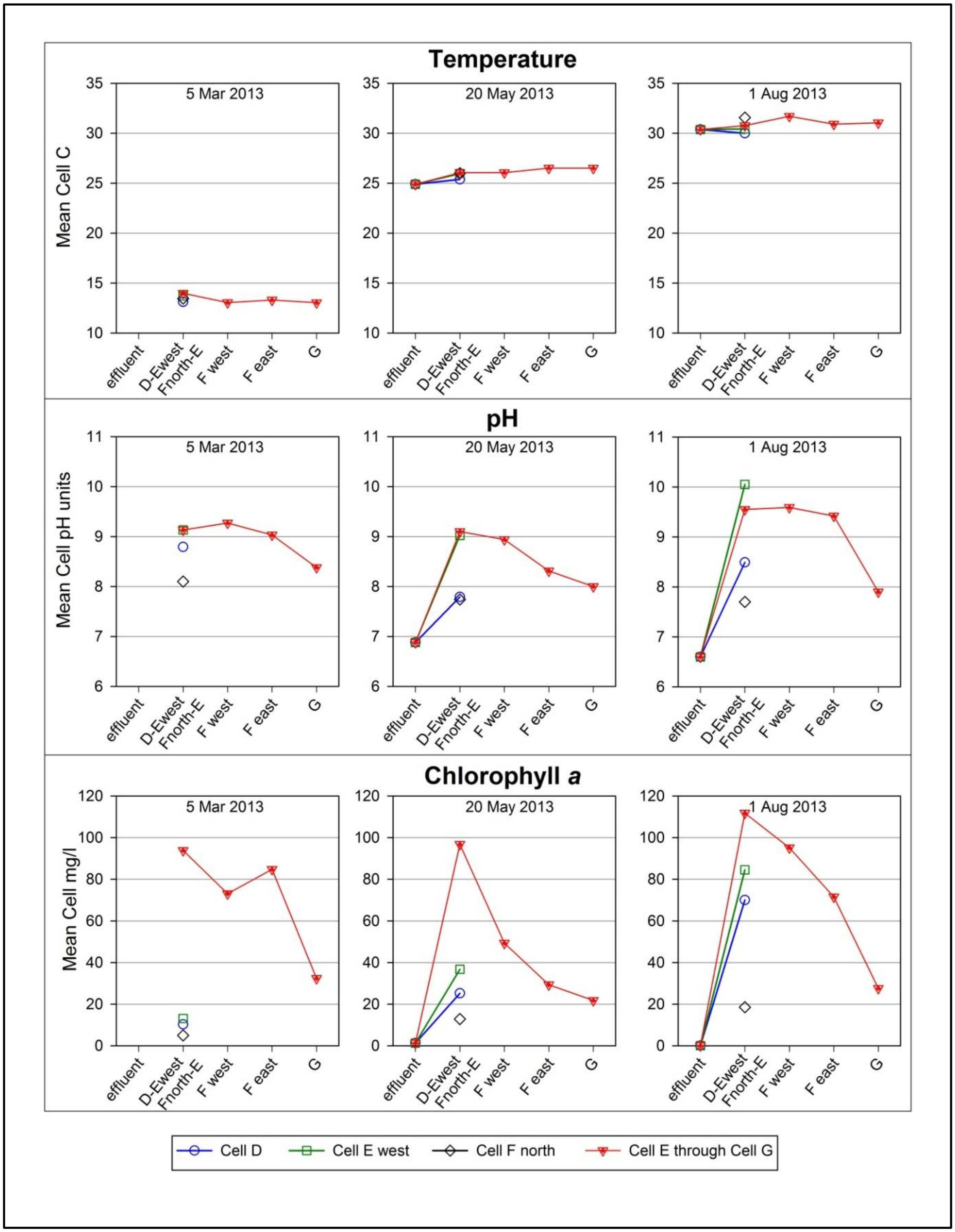


Figure C-2. Mean water temperature, pH and chlorophyll *a* at the three 2013 assessment dates. Note the similarities between pH and chlorophyll *a*, both driven by the presence of algae, and partly, plants.

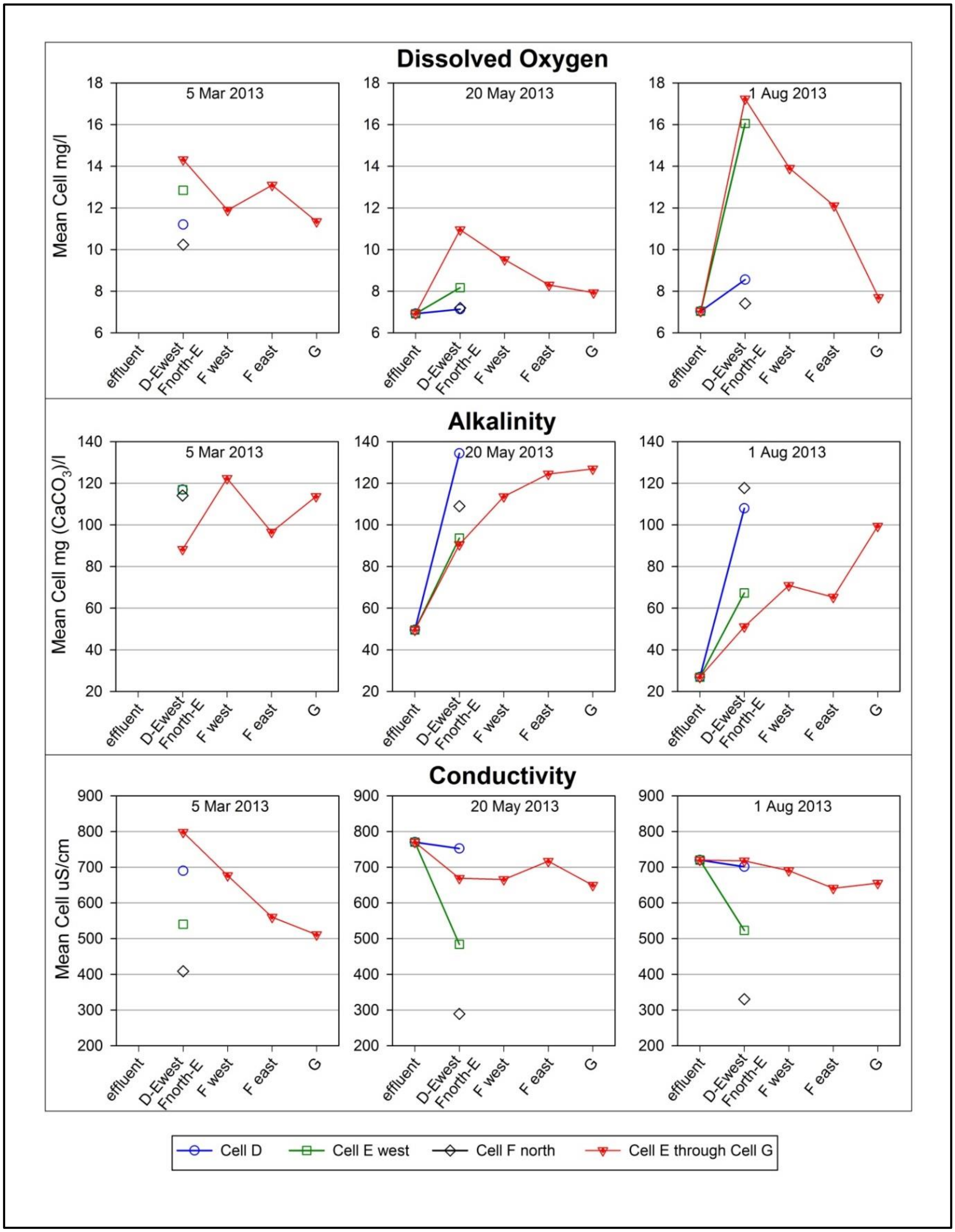


Figure C-3. Mean dissolved oxygen, alkalinity and conductivity at the three 2013 assessment dates. Dissolved oxygen and conductivity were influenced heavily by photosynthetic activity (plants and algae); increasing alkalinity was due to interactions of water with substrates.

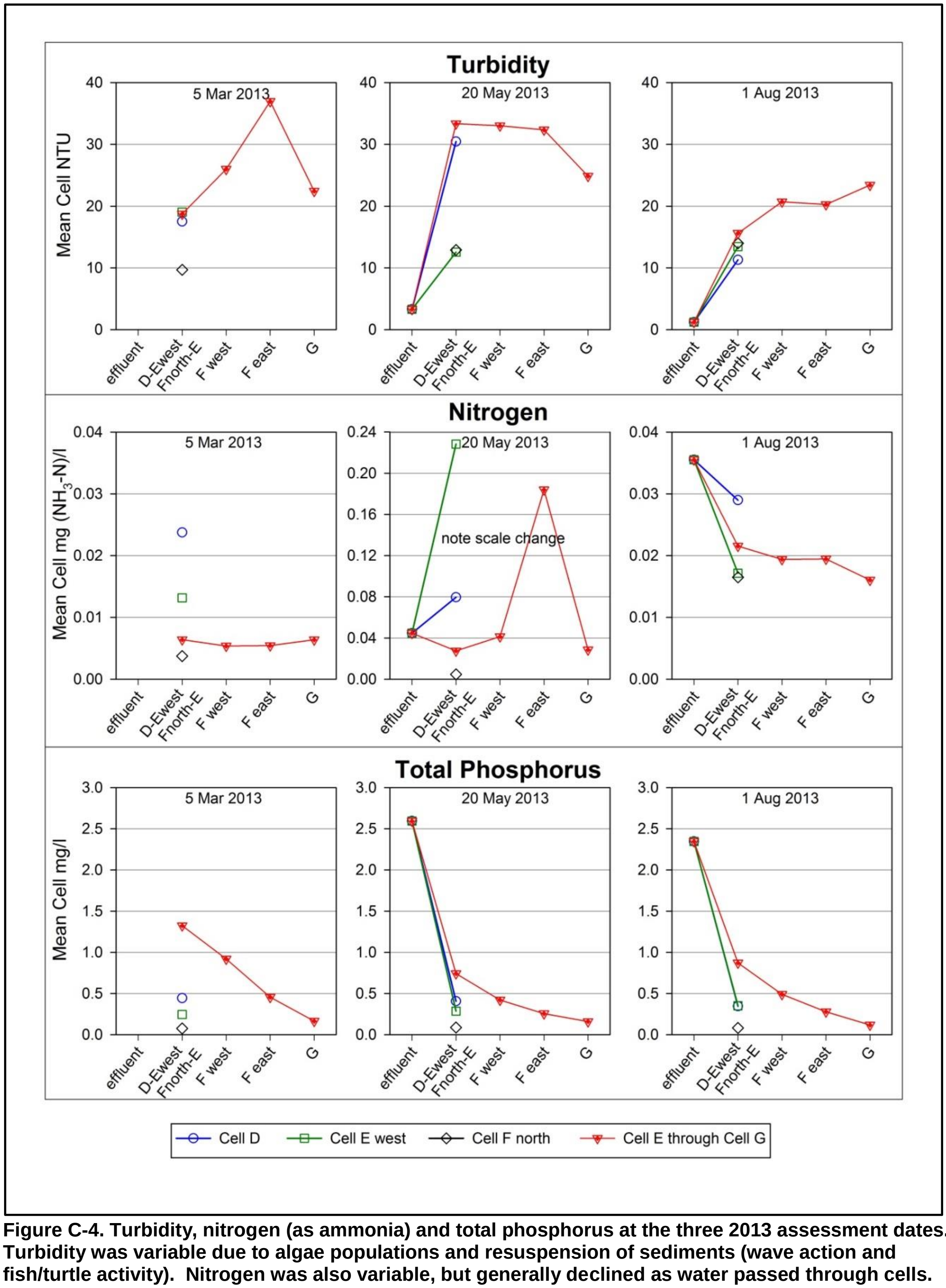


Figure C-4. Turbidity, nitrogen (as ammonia) and total phosphorus at the three 2013 assessment dates. Turbidity was variable due to algae populations and resuspension of sediments (wave action and fish/turtle activity). Nitrogen was also variable, but generally declined as water passed through cells. Total phosphorus showed distinct declines, averaging reductions of over 80 percent before entering the Trinity River.

Other nutrients important to plant and algal growth were measured, including potassium, calcium, magnesium, sodium and iron. All varied seasonally but declined slightly as they were taken up by plants, algae and other processes in the LCOW. Water quality data collected between 2009 and 2013 are given in Tables C-3 and C-4.

Table C-3. Water quality parameters of temperature, pH, dissolved oxygen (DO), and conductivity collected from the LCOW between 2009 and 2013.

Sample site	Season	Temperature C					pH					Dissolve Oxygen (mg/L)					Conductivity (µS/cm)				
		2009	2010	2011	2012	**2013**	2009	2010	2011	2012	**2013**	2009	2010	2011	2012	**2013**	2009	2010	2011	2012	**2013**
Effluent	Spring																				
	Summer					24.9					6.9					6.9					770
	Fall					30.4					6.6					7.0					720
Effluent Mean						**27.6**					**6.7**					**7.0**					**745**
D inlet	Spring	28.6	33.3	30.4	30.7	13.8	8.4	8.4	9.2	8.3	9.1	6.6	8.3	12.3	7.9	11.0	485	485	402	579	676
	Summer	24.2	28.4	26.0	24.0	25.5	8.4	6.7	8.2	7.9	8.2	8.7	7.0	6.0	8.4	7.7	379	467	888	669	754
	Fall	6.1	12.6	14.1	9.7	30.3	8.2	8.1	7.4	6.8	8.7	11.6	11.5	8.4	15.1	8.5	432	760	808	732	701
D outlet	Spring	28.6	32.1	30.1	30.2	12.4	8.7	8.1	9.3	9.3	9.1	8.9	6.7	11.9	10.2	11.4	520	494	707	507	704
	Summer	24.5	28.2	27.9	25.1	25.3	8.8	6.8	8.9	8.4	8.0	10.1	6.1	8.1	10.3	6.6	352	418	887	664	751
	Fall	6.3	10.5	12.9	8.3	29.7	7.5	8.4	7.6	7.8	8.9	10.7	11.4	9.2	16.4	8.6	440	759	806	714	702
E-West inlet	Spring	31.0	33.7	30.0	30.7	13.5	8.8	10.1	9.3	8.9	9.4	7.6	12.7	12.5	8.2	13.3	375	480	730	390	542
	Summer	24.7	28.4	28.0	24.5	25.9	9.2	6.8	8.5	8.8	9.3	12.3	6.4	10.1	9.9	8.3	435	350	756	619	484
	Fall	7.6	9.9	12.2	8.3	30.7	8.4	8.2	7.7	7.9	10.4	13.0	10.3	12.9	9.2	15.6	482	610	754	706	523
E-West outlet	Spring	29.9	32.8	29.9	31.8	13.9	8.7	9.9	8.9	8.9	9.1	7.3	13.5	10.5	8.6	12.4	387	499	740	391	539
	Summer	25.3	28.8	27.4	24.3	26.0	8.9	7.1	9.2	9.1	9.3	11.4	6.4	13.3	11.3	8.0	442	340	751	591	484
	Fall	8.3	10.7	13.0	8.6	30.2	8.8	8.1	8.0	7.9	10.3	12.8	9.3	13.1	9.2	16.5	478	815	748	702	523
E inlet	Spring	30.7	31.8	31.4	32.2	14.3	9.8	8.7	9.4	8.9	9.4	15.8	11.9	10.7	8.9	14.2	535	710	366	549	791
	Summer	25.4	29.3	28.8	23.9	26.1	7.6	7.8	9.7	7.3	9.6	10.7	7.9	10.9	6.1	12.0	727	541	570	665	671
	Fall	8.0	11.0	13.0	9.8	30.3	9.3	7.7	8.0	7.9	9.7	15.5	10.4	11.5	15.5	13.8	457	808	560	736	714
E outlet	Spring	31.0	32.7	32.1	29.6	13.7	9.6	8.9	9.6	8.9	9.5	14.2	11.5	12.0	8.0	14.5	516	706	316	547	805
	Summer	25.2	29.4	28.7	23.7	26.1	7.5	8.3	9.8	7.6	9.3	7.8	6.9	8.8	8.4	9.9	724	535	568	663	667
	Fall	5.7	11.2	13.2	9.4	31.2	9.5	7.6	7.6	7.9	10.1	16.1	8.0	9.8	12.5	20.7	466	812	589	741	722
F-North inlet	Spring	32.2	31.7	30.0	30.4	13.6	8.7	8.5	8.1	7.7	8.5	7.1	9.2	7.0	7.4	10.3	385	349	344	307	402
	Summer	24.9	28.4		24.8	25.4	8.2	6.9		7.9	8.2	7.4	6.5		6.4	7.7	378	350	0	161	233
	Fall	8.7	10.6	12.4	8.1	31.5	8.8	8.2	7.8	8.0	8.0	13.3	9.6	10.4	10.2	7.5	393	385	317	255	309
F-North outlet	Spring	31.3	33.8	31.3	31.4	13.3	8.7	8.7	8.3	8.0	8.3	7.5	6.9	7.7	5.4	10.2	410	340	356	344	415
	Summer	25.6	28.9		24.1	26.7	8.7	7.5		7. 9	7.9	9.4	7.2		7.9	6.7	353	332	0	374	345
	Fall	6.5	9.8	10.9	7.8	31.6	8.7	8.1	8.1	7.9	8.0	10.9	9.6	10.8	7.9	7.4	403	390	334	374	351
F (West) inlet	Spring	26.6	32.7	31.1	30.5	13.2	9.3	9.4	8.6	8.9	9.6	9.6	8.7	8.6	8.7	11.4	350	652	524	454	677
	Summer	26.4	28.4	26.2	23.1	25.9	9.1	7.7	8.9	8.5	9.4	10.6	5.9	8.6	6.8	9.9	594	346	791	685	654
	Fall	7.8	10.5	11.6	8.1	31.6	8.7	7.9	7.6	7.9	9.8	12.8	8.7	9.7	10.3	13.1	499	769	732	751	702
F (West) outlet	Spring	30.5	32.1	28.6	29.5	12.9	9.6	9.3	8.2	8.7	9.6	13.3	6.9	6.9	8.0	12.3	380	631	512	482	677
	Summer	27.7	28.3	26.0	23.8	26.2	9.1	7.7	8.9	8.8	9.2	12.2	6.2	10.4	8.8	9.2	570	357	726	687	677
	Fall	8.9	10.1	11.2	7.7	31.8	8.6	8.3	7.3	7.9	10.0	13.9	12.0	9.5	10.9	14.7	528	757	725	757	679
F (East) inlet	Spring	26.6	32.7	30.3	28.7	13.3	9.5	9.2	9.2	8.7	9.5	15.5	7.9	10.5	7.9	13.1	440	575	616	526	627
	Summer	26.9	29.0	25.9	23.8	27.0	9.2	7.7	8.9	8.8	8.8	12.5	6.5	9.7	9.7	9.1	496	337	785	690	711
	Fall	8.7	9.9	11.7	7.8	31.6	8.2	8.0	8.1	7.9	9.9	12.3	9.7	11.9	10.4	13.9	539	679	739	747	664
F (East) outlet	Spring	29.7	31.2	30.6	28.1	13.3	9.7	8.5	9.3	8.6	9.2	13.2	8.3	12.4	7.6	13.1	322	501	607	527	493
	Summer	24.9	28.2	27.7	23.1	26.1	9.1	7.8	9.1	8.1	8.5	13.4	4.9	11.0	10.0	7.5	364	330	790	647	723
	Fall	6.5	9.9	12.7	7.5	30.2	8.7	8.1	7.6	7.9	9.6	12.3	11.1	10.7	8.6	10.3	509	645	750	748	619
G inlet	Spring	29.4	31.1	30.2	28.4	13.2	9.6	8.3	8.6	8.7	8.9	9.5	7.6	10.5	8.8	12.0	324	477	520	417	505
	Summer	25.6	29.2	25.0	22.6	26.4	8.9	7.5	8.2	8.6	8.4	11.8	5.2	8.1	7.7	8.5	361	386	762	650	665
	Fall	5.9	9.4	9.3	7.8	31.8	8.4	8.4	6.8	7.9	8.6	11.4	10.7	8.9	10.1	9.0	488	642	729	745	650
G outlet	Spring	28.9	31.2	30.3	29.7	12.8	8.8	7.2	8.2	8.4	8.5	7.6	4.7	8.3	6.4	10.7	369	495	528	420	517
	Summer	24.4	28.9	26.0	22.4	26.6	8.5	7.5	7.0	8.1	8.2	8.8	3.8	7.0	8.1	7.4	361	385	787	660	634
	Fall	8.3	9.6	10.5	7.5	30.3	8.8	7.4	6.8	7.9	8.0	14.2	11.1	9.2	12.3	6.4	475	556	731	745	661
Wetlands Mean		20.8	23.8	22.9	20.7	**23.5**	8.4	7.6	7.7	7.9	**8.6**	11.2	8.5	10.0	9.3	**10.8**	451	530	611	579	**603**

Table C-4. Alkalinity, turbidity, soluble reactive phosphorus (SRP), total phosphorus (TP), nitrogen, potassium (K), calcium (Ca), chlorophyll *a*, magnesium (Mg), sodium (Na) and iron (Fe) collected from the LCOW in 2013.

Sample site	Season	Alkalinity ($mgCaCO_3/L$)	Turbidity (NTU)	SRP (mg/L)	TP (mg/L)	Nitrogen (NH3-N mg/L)	K (mg/L)	Ca (mg/L)	Chlorophyll *a* (mg/L)	Mg (mg/L)	Na (mg/L)	Fe (mg/L)
		2013	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**
Effluent	Spring											
	Summer	49.5	3.29	2.375	2.594	0.04	16.86	67.37	1.31	5.44	71.42	0.66
	Fall	26.9	1.22	1.647	2.346	0.04	21.00	50.66	0.1			
Effluent Mean		**38.2**	**2.26**	**2.011**	**2.470**	**0.04**	**18.93**	**59.01**	**0.71**	**5.44**	**71.42**	**0.66**
D inlet	Spring	112.6	19.0	0.301	0.485	0.03	13.47	66.35	8.58	5.21	72.68	0.03
	Summer	131.0	25.0	0.240	0.455	0.05	14.38	76.71	24.19	6.16	74.40	0.66
	Fall	106.6	11.5	0.221	0.399	0.03	18.77	50.72	57.49			
D outlet	Spring	121.2	16.0	0.173	0.401	0.02	13.43	65.91	11.99	5.15	73.12	0.02
	Summer	137.6	35.9	0.179	0.358	0.11	14.65	78.17	26.20	6.00	73.73	0.66
	Fall	109.2	11.1	0.103	0.290	0.03	18.97	51.56	82.47			
E-West inlet	Spring	118.6	21.9	0.636	0.290	0.01	9.68	57.15	15.33	4.95	45.96	0.02
	Summer	92.8	12.4	0.161	0.276	0.19	10.22	45.48	35.43	4.58	60.25	0.66
	Fall	69.9	14.6	0.097	0.327	0.02	20.60	34.62	79.48			
E-West outlet	Spring	115.2	16.1	0.150	0.199	0.02	9.67	54.33	10.87	4.78	50.92	0.02
	Summer	94.5	12.7	0.167	0.297	0.27	10.81	46.31	38.05	4.69	50.34	0.67
	Fall	64.6	12.3	0.095	0.376	0.02	20.80	34.85	89.56			
E inlet	Spring	86.2	17.6	0.876	1.385	0.01	15.72	70.40	102.76	5.27	85.62	0.02
	Summer	87.0	33.8	0.235	0.706	0.02	15.39	65.54	130.20	4.63	67.73	0.66
	Fall	47.7	17.5	0.296	0.988	0.03	14.91	54.25	90.63			
E outlet	Spring	90.2	19.9	0.777	1.261	0.00	15.39	69.12	84.91	5.25	80.37	0.02
	Summer	94.1	32.9	0.478	0.779	0.04	14.76	63.83	63.33	4.72	65.61	0.67
	Fall	54.4	13.7	0.123	0.756	0.02	14.98	54.71	132.94			
F-North inlet	Spring	112.1	10.8	0.030	0.093	0.00	6.05	45.69	7.33	3.62	30.00	0.03
	Summer	89.8	14.0	0.065	0.131	0.01	4.21	32.76	20.30	2.02	14.98	0.68
	Fall	96.9	19.4	0.004	0.105	0.02	19.19	42.44	29.24			
F-North outlet	Spring	116.0	8.6	0.041	0.057	0.00	6.40	48.20	2.59	4.05	30.86	0.03
	Summer	128.1	11.8	0.000	0.043	0.00	5.11	43.06	5.30	3.51	24.20	0.65
	Fall	138.5	8.6	0.002	0.059	0.02	19.23	49.55	7.81			
F (West) inlet	Spring	125.4	30.5	0.252	1.164	0.00	12.51	66.85	72.99	5.12	58.23	0.02
	Summer	110.3	36.7	0.260	0.404	0.00	14.53	65.29	31.16	4.89	66.85	0.67
	Fall	66.0	21.6	0.121	0.632	0.02	18.72	46.03	106.87			
F (West) outlet	Spring	119.3	21.5	0.232	0.675	0.01	13.12	68.15	73.06	5.13	62.88	0.03
	Summer	116.9	29.3	0.302	0.437	0.08	14.43	63.85	67.48	5.30	67.45	0.66

	Fall	75.8	19.8	0.089	0.347	0.02	17.97	50.72	83.42			
F (East) inlet	Spring	108.8	28.6	0.157	0.670	0.00	12.17	59.90	78.92	4.96	58.61	0.01
	Summer	122.3	34.9	0.152	0.285	0.04	14.80	65.07	34.17	5.89	69.30	0.63
	Fall	73.0	24.4	0.082	0.353	0.02	8.64	46.53	79.23			
F (East) outlet	Spring	84.2	45.3	0.049	0.242	0.01	10.54	40.43	90.62	4.66	46.36	0.03
	Summer	126.5	29.8	0.147	0.226	0.33	14.26	67.40	24.40	6.15	71.19	0.67
	Fall	57.6	16.1	0.013	0.203	0.02	7.85	37.70	63.75			
G inlet	Spring	101.8	29.0	0.035	0.186	0.01	10.12	44.43	51.48	4.56	46.23	0.02
	Summer	127.1	25.7	0.007	0.217	0.05	12.72	66.04	17.79	6.09	57.35	0.65
	Fall	93.6	33.2	0.005	0.128	0.02	16.86	46.94	25.76			
G outlet	Spring	125.4	15.8	0.022	0.143	0.00	9.81	50.95	13.24	4.62	47.34	0.02
	Summer	126.6	24.0	0.001	0.103	0.01	13.27	61.18	25.81	5.76	60.83	0.63
	Fall	105.2	13.6	0.003	0.107	0.02	16.71	51.66	29.39			
Wetlands Mean		**101.9**	**21.4**	**0.176**	**0.406**	**0.04**	**13.47**	**54.78**	**50.63**	**4.92**	**57.62**	**0.34**
Sample site	**Season**	**Alkalinity ($mgCaCO_3/L$)**	**Turbidity (NTU)**	**SRP (mg/L)**	**TP (mg/L)**	**Nitrogen (NH3-N mg/L)**	**K (mg/L)**	**Ca (mg/L)**	**Chlorophyll *a* (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**	**Fe (mg/L)**
		2013	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**	**2013**

Scheduled water quality monitoring was discontinued in 2014 in anticipation of turning the project over to the local sponsor, the City of Dallas. However, our SOW called for water quality evaluations in the event of noticeable changes in the ecosystem, such as fish kills, excessive greening of water, etc. No water quality-related events were observed during that year, circumventing data collection. Delays in management turnover (now to occur sometime in 2015) will enable us to conduct several spot-checks of water quality to verify acceptable conditions continue to occur in the LCOW.

Appendix D

Dallas Floodway Extension

Establishment, monitoring, and adaptive management of native aquatic vegetation and adjacent native grasslands; and monitoring aquatic organism utilization of project aquatic features:

Overbanking and sedimentation

The Trinity River generally overbanks an average of three to four times per year at the LCOW, with the most notable events occurring in June 2007 (6 week duration) and September 2010 since construction began (Table D-1 and Figure D-1). During those events, silt is deposited in the wetland cells and surrounding areas, particularly when overbanking lasts for an extended period of time. In addition to overbanking that occurs during Major (40-ft crest), Moderate (38-ft crest), and Minor (30-ft crest) Flood Stages of the Trinity River (overbanking begins when the river crests at about 33-ft), periods of high flow before and after flood stages causes backflows into the outlet at Cell D, the outlet and cut at Cell F (West), and the outlet and cut at Cell F-North. Our observations suggest that this begins as soon as the river crests at near 30-ft (Minor Flood Stage), several feet lower than crests needed for full overbanking to occur. While all flood stages have the potential to deposit sediments in the LCOW, Cell D, E-West, and F-North are perhaps the most vulnerable due to longer periods of time at which the river exceeds Minor Flood Stage. For instance, during the September 2010 overbanking event, full overbanking occurred over an approximate three-day period, but Cells D, E-West, and F-North received river water over almost four days (Figure D-2). No overbanks occurred during 2014.

Table D-1. Historical crests for Trinity River, Dallas, TX since January 2007 through January 2014.

Date	Historical crests (ft)	Flood stage	Effect on LCOW
Jan-07	34.29	Minor	Full overbank
Apr-07	35.71	Minor	Full overbank
Jun-07	40.25	Major	Full overbank
Jul-07	32.06	Minor	Flow into D, E-West, and F-North
Sep-07	34.21	Minor	Full overbank
Oct-07	31.63	Minor	Flow into D, E-West, and F-North
Mar-08	37.52	Moderate	Full overbank
Apr-08	33.02	Minor	Partial overbank
Nov-08	31.96	Minor	Flow into D, E-West, and F-North
Mar-09	31.87	Minor	Flow into D, E-West, and F-North
May-09	33.29	Minor	Partial overbank
Jun-09	38.19	Moderate	Full overbank
Sep-09	38.55	Moderate	Full overbank
Oct-09	37.14	Minor	Full overbank
Jan-10	35.92	Minor	Full overbank
Feb-10	34.28	Minor	Full overbank
Mar-10	30.41	Minor	Flow into D, E-West, and F-North
Sep-10	41.39	Major	Full overbank
May-11	31.99	Minor	Flow into D, E-West, and F-North
Jan-12	38.30	Moderate	Full overbank
Feb-12	31.34	Minor	Flow into D, E-West, and F-North
Mar-12	38.25	Moderate	Full overbank
Jan-13	33.35	Minor	Partial overbank
Dec-13	30.04	Minor	Flow into D, E-West, and F-North

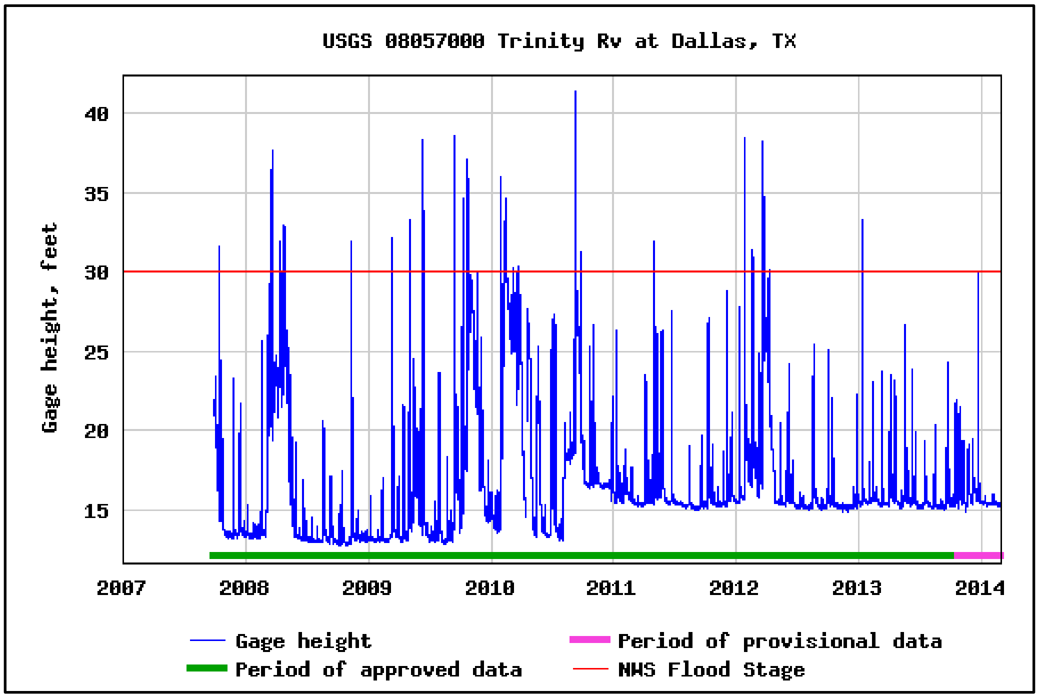


Figure D-1. USGS Trinity River gage data from January 2009 through February 2014. The red line (30 ft) indicates when backflow of the Trinity River begins in the LCOW. Overbanking has not occurred since December 2013.

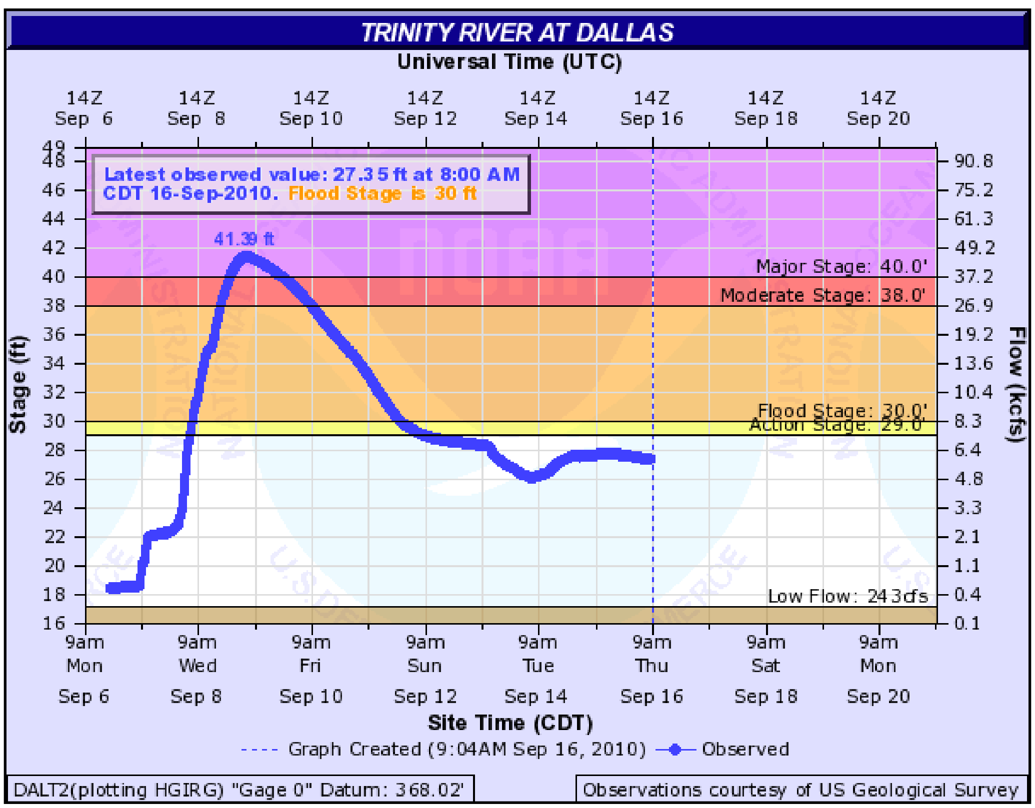


Figure D-2. USGS Trinity River gage data for the mid-September, 2010 overbanking event at the LCOW.

SWF requested that ERDC periodically measure sedimentation rates in the LCOW cells beginning in 2008. Since that time, water depth measurements have been recorded along permanent, GPS-marked transects (three to seven per cell evenly distributed along each cell's length) (Figure D-3). Water surface elevation is recorded for each cell using weir box elevation data, with depths subtracted to calculate cell bottom elevations at each measured point. Depth measurements are made twice-yearly, in spring and fall, unless conditions (e.g., overbanking) precluded safe access to the cells or overbanking did not occur between monitoring periods. Because no overbanking events occurred during 2014, no measurements were made in that year.

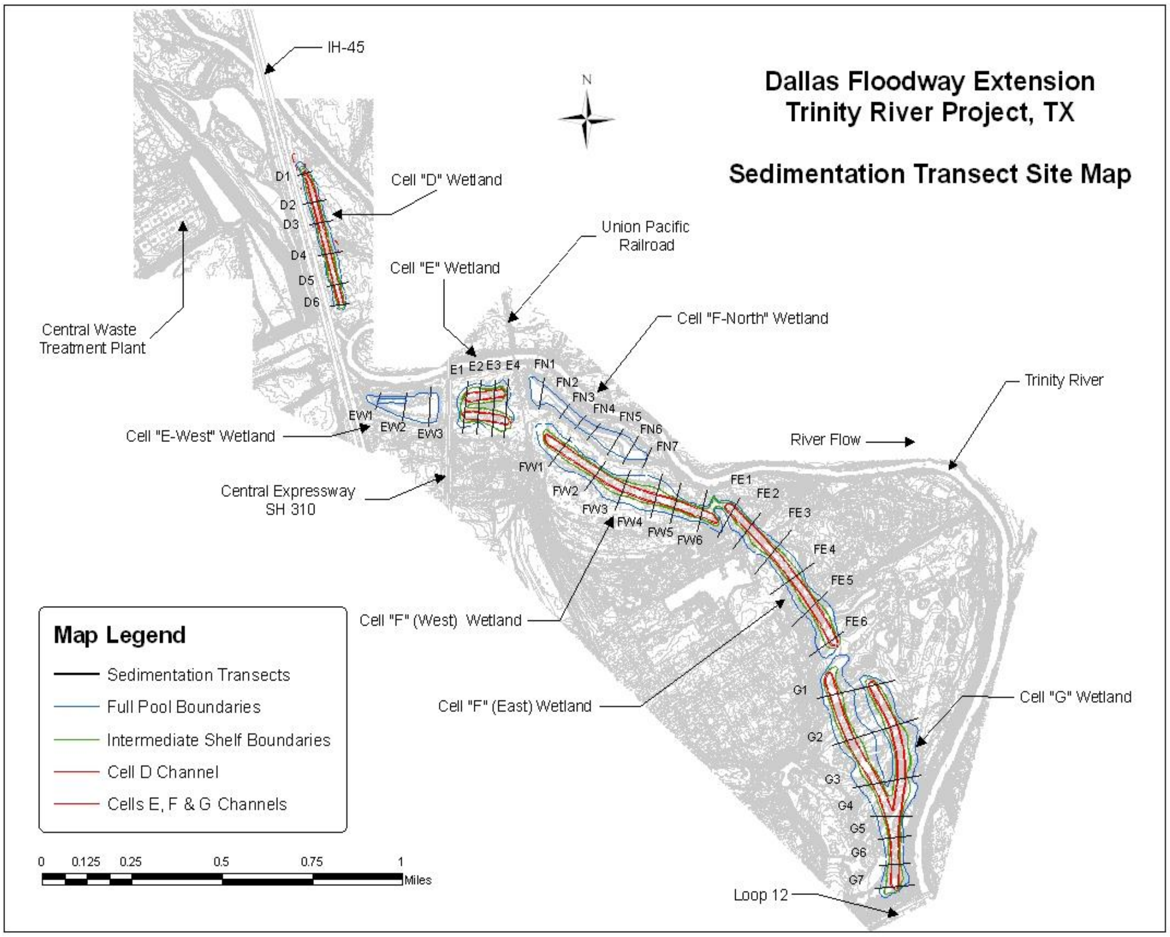


Figure D-3. LCOW sedimentation transect site map. Transects are symbolized by the wetland cell letter and transect number north-to-south or west-to-east (i.e., the northernmost transect in Cell D is designated as D1).

Depth readings were taken beginning in 2008 (Cell D) or 2009 (remaining LCOW cells) and were continued through 2013. Data presented here reflect initial measurements taken in 2008 (Cell D) and 2009 (all other cells) and our most recent measurements made at the end of summer 2013 (Tables D-2 through D-8). Other measurements made during the project are given in Tables D-10 through D-23.

Table D-2. Elevation (ASL in feet) calculated from depths taken along six transects in Cell D in 2008 (baseline) and 2013.

Transect D1		Transect D2		Transect D3	
2008	**2013**	**2008**	**2013**	**2008**	**2013**
388.05	389.33	387.89	389.36	388.05	389.03
385.36	386.93	384.77	386.08	384.61	385.75
384.77	386.34	384.11	385.75	384.11	385.49
385.59	386.41	384.77	386.08	384.77	386.01
387.79	389.03	387.89	389.20	387.79	389.36
Transect D4		**Transect D5**		**Transect D6**	
2008	**2013**	**2008**	**2013**	**2008**	**2013**
387.89	389.03	388.05	389.85	388.05	389.20
384.61	387.72	384.77	385.42	386.25	386.74
384.11	385.42	384.11	385.49	385.92	386.08
384.77	385.72	384.41	385.65	386.41	386.05
387.79	389.36	387.72	388.87	388.22	388.70

Table D-3. Elevation (ASL in feet) calculated from depths taken along three transects in Cell E-West in 2009 (baseline) and 2013.

Transect EW1		Transect EW2		Transect EW3	
2009	**2013**	**2009**	**2013**	**2009**	**2013**
383.75	383.52	382.43	379.25	383.35	383.02
380.96	380.89	382.83	379.25	380.43	378.60
381.22	380.96	377.15	376.63	376.3	377.28
382.14	380.96	377.94	378.60	375.71	377.61
383.35	382.89	383.35	382.86	375.81	378.66
				376.37	378.76
				379.12	379.88
				382.17	382.86

Table D-4. Elevation (ASL in feet) was calculated from depths taken along four transects in Cell E in 2009 (baseline) and 2013.

Transect E1		Transect E2		Transect E3		Transect E4	
2009	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**
387.54	386.03	387.67	386.85	387.57	386.85	387.54	386.52
386.03	385.38	386.23	383.90	385.93	382.49	382.82	383.08
382.36	381.77	382.65	382.39	382.59	382.69	381.96	382.42
382.33	382.10	382.59	382.26	382.49	382.75	386.36	386.33
382.29	382.10	382.49	382.36	382.42	382.69	386.59	386.69
386.10	382.42	386.23	386.85	382.75	382.62	381.77	382.26
387.57	386.69	387.67	386.69	387.54	386.39	382.71	382.75
387.21	385.38	387.51	386.03	387.57	386.03	387.34	387.02
386.43	385.38	386.29	384.72	386.20	386.00		
382.03	382.39	382.42	381.60	382.16	382.06		
381.44	382.42	382.26	381.60	381.77	382.26		
382.00	381.93	382.16	381.67	381.77	382.10		
382.42	383.08	382.42	381.83	382.10	381.44		
387.67	386.36	382.03	381.60	387.54	386.36		
		387.67	386.69				

Table D-5. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell F (West) in 2009 (baseline) and 2013.

Transect FW1		Transect FW2		Transect FW3		Transect FW4		Transect FW5		Transect FW6	
2009	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**
386.34	385.36	386.67	385.03	386.41	385.36	386.31	385.03	386.51	384.70	386.61	384.97
384.97	384.80	384.90	384.97	385.52	385.03	385.23	384.70	385.36	383.23	385.43	384.21
381.1	380.77	380.28	381.10	380.67	380.80	384.70	382.08	380.51	380.60	380.47	381.56
381.03	380.70	380.60	380.80	380.87	380.60	381.33	380.60	380.77	380.44	381.36	380.44
381.03	381.16	380.93	380.77	380.83	381.10	380.64	380.60	380.93	380.60	380.87	380.93
381.85	383.72	380.55	380.77	385.36	382.74	380.64	380.77	382.57	380.77	380.90	380.93
385.56	384.93	386.08	383.72	385.2	384.87	385.10	384.77	385.03	384.38	384.74	383.98
386.7	385.33	386.51	385.03	386.34	385.26	386.57	385.03	386.51	385.00	386.57	384.87

Table D-6. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell F (East) in 2009 (baseline) and 2013.

Transect FE1		Transect FE2		Transect FE3		Transect FE4		Transect FE5		Transect FE6	
2009	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**
386.02	384.87	386.21	385.62	386.02	385.10	386.51	384.70	386.05	385.06	386.34	384.21
385.26	384.80	384.74	384.70	385.26	384.87	384.70	381.13	385.16	384.70	384.77	383.72
385.29	384.70	380.47	383.39	380.50	380.60	380.93	380.44	381.36	380.77	381.10	383.00
385.13	384.64	380.93	380.64	380.77	380.44	380.18	380.18	382.74	380.47	380.34	381.03
385.13	384.61	381.1	380.77	380.77	380.77	382.67	380.11	380.77	380.44	379.46	380.11
384.44	384.70	382.74	380.83	381.10	382.90	380.22	382.57	381.10	381.23	379.50	381.75
384.97	384.93	384.02	380.77	385.52	384.70	385.10	384.87	384.97	384.41	385.03	384.70
386.34	385.85	386.21	383.79	386.31	385.52	386.18	384.97	386.51	386.02	385.26	385.39

Table D-7. Elevation (ASL in feet) was calculated from depths taken along seven transects in Cell F-North in 2009 (baseline) and 2013.

Transect FN1		Transect FN2		Transect FN3		Transect FN4		Transect FN5		Transect FN6		Transect FN7	
2009	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**
382.51	382.20	382.51	383.19	382.74	383.35	382.31	382.86	382.61	383.19	382.48	382.20	382.34	382.86
380.61	377.61	382.18	381.88	382.15	382.53	381.46	381.22	381.29	381.88	381.52	382.20	379.06	380.24
378.05	377.55	382.18	381.71	382.48	383.29	382.57	382.86	382.41	381.55	382.61	383.52	376.28	378.43
377.00	377.58	381.95	381.38	382.54	383.19	382.61	383.52	382.67	383.19	382.48	383.52	376.28	377.45
377.88	377.78	381.59	381.22	380.77	380.66	381.43	379.58	380.70	379.25	379.85	377.94	376.60	377.45
378.74	378.10	382.54	382.20	382.57	383.19	378.74	376.63	376.18	376.79	376.77	377.19	381.20	381.22
379.72	377.68					377.88	376.30	376.11	376.46	376.44	376.79	382.51	382.20
381.36	378.43					379.82	380.20	375.85	377.12	376.44	376.79		
382.67	382.86					381.66	381.22	378.08	377.94	379.85	378.92		
						382.74	381.88	377.91	376.96	382.67	382.53		
						383.29	383.35	380.61	378.60				
								383.59	382.20				

Table D-8. Elevation (ASL in feet) was calculated from depths taken along seven transects in Cell G in 2009 (baseline) and 2013.

Transect G1		Transect G2		Transect G3		Transect G4		Transect G5		Transect G6		Transect G7	
2009	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**	**2009**	**2013**
382.69	384.26	382.62	384.52	382.62	384.13	382.75	385.02	382.03	384.85	382.03	384.36	383.70	384.06
380.20	381.47	380.20	380.10	380.33	382.39	380.06	379.87	380.06	380.92	379.97	380.42	379.67	380.42
380.06	380.13	380.16	379.77	380.10	380.19	380.13	379.96	378.10	380.19	379.80	379.80	379.60	379.77
382.52	379.60	382.69	384.36	382.56	383.80	379.77	379.77	379.93	382.72	380.10	379.74	377.77	380.00
382.03	384.06	382.56	383.87	382.52	383.67	382.82	384.69	382.82	384.16	382.69	384.69	379.41	384.20
381.05	379.77	380.06	380.92	380.03	380.78								
380.42	380.52	378.88	380.10	380.25	379.93								
380.89	383.28	382.52	384.36	383.38	384.43								
381.89	384.49												

As of the end of 2013, despite several overbanking events per year, and notably the long-term overbanking that occurred during the summer of 2007 and extensive overbanking in 2010, few of the LCOW cells appear to be filling with sediments at significant rates (Table D-9). On the contrary, most cells appear to have deepened slightly on average, likely the result of scouring occurring during overbanking events. Cell D, the oldest cell in 2013 (10 years), and Cell G, 6 years old in 2013, showed the greatest sediment build up, averaging less than 2 inches of sedimentation per year at that time, with buildup occurring throughout the cells. In addition to its greater age (and therefore exposure to more overbanking events), one explanation for greater sedimentation rates in Cell D may be its position relative to flow: when the Trinity River overbanks, water flow is perpendicular to the length of this cell, whereas flow over other cells is generally parallel to their lengths. While portions of all cells can serve as sediment traps, it apparently occurs most regularly where elevations change significantly and alter flow rates. Cell D's orientation results in a larger portion of the cell (its entire length) subject to this occurrence compared with other cells (upstream and downstream widths, or "ends"). Buildup of sediments that has occurred in Cell G may be related to its position in the LCOW: it is the furthest downstream cell and is nearest to water backup due to the flow constriction where Loop 12 crosses the river, an area prone to slowing flow and deposition of sediments.

Table D-9. Mean changes in elevation (in feet) between baseline observations and 2013 observations in the LCOW.

Wetland cell	Change in elevation per transect (ft)							Total cell	Annual sedimentation rate
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Mean (ft)**	**Mean (ft)**
D	1.56	1.85	1.58	1.91	1.56	0.76		1.54	+0.15
E- West	-0.44	-2.47	0.93					-0.66	-0.11
E	-1.02	-1.04	-1.4	0.21				-0.81	-0.14
F -North	-0.97	-0.23	0.49	-0.44	-0.24	0.05	0.80	-0.08	-0.01
F (West)	-0.64	-0.86	-0.68	-0.87	-1.60	-1.07		-0.95	-0.16
F (East)	-0.43	-0.74	-0.71	-1.49	-1.13	-0.26		-0.79	-0.13
G	0.15	0.54	0.44	0.25	1.48	0.38	1.16	0.63	+0.10

The primary source of sediment deposition in the cells appears to be from overbanking events, although movement of soil during erosion of grassland areas may play a role in areas where some sediment deposits have been observed. Washing out of unvegetated shorelines has occurred during windy days, and grassland soils are carried into the cells during most heavy rain events and in some areas during overbanking events. In 2005, this was highly evident along portions of Cell D prior to establishment of grassland cover crops (winter rye) and wetland vegetation along the shoreline, and was similarly evident in the remaining LCOW in 2009 following construction. However, once grassland plants were established, this type of erosion became less significant, with cover crops holding topsoils in place. Additionally, soil that did wash towards the cell was caught by plants established along the shoreline; at the same time, shoreline plants have minimized shoreline erosion due to wave action.

Cells that are filling in with sediments at highest rates include Cell D and Cell G. Based upon sedimentation rates calculated over 10 years (Cell D) and 6 years (Cell G), preliminary predictions are that, at current rates of sedimentation, the Cell D channel will be filled in approximately 16 years, and the Cell G channel in approximately 33 years, at which times decisions will have to be made regarding any need to dredge materials to recover some functions of each cell. While flood conveyance will not be affected, ecosystem function will change in response to sedimentation. It remains to be seen whether or not those changes will be positive or negative, and whether or not they can be incorporated into the overall LCOW ecosystem management strategies.

We did not recalculate sediment buildup following 2014 for two reasons: 1) no measurements were taken due to absence of overbanking events and 2) even though substrate elevations did not likely change that year, calculations would extend the life-expectancy of deep channels, but might not accurately reflect then-current conditions. To provide the sponsor with longer-term data for evaluating sediment buildup trends, ERDC will conduct an additional assessment of the LCOW cells in late spring 2015. This information will be used to update fill-in estimates and will be valuable in predicting actions and formulating management plans for the LCOW.

Elevation Transect Data from 2008-2011

Table D-10. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell D in 2008, 2009, and 2010.

Transect D1					Transect D2					Transect D3				
Mar-08	**Oct-08**	**May-09**	**Jun-10**	**Oct-10**	**Mar-08**	**Oct-08**	**May-09**	**Jun-10**	**Oct-10**	**Mar-08**	**Oct-08**	**May-09**	**Jun-10**	**Oct-10**
388.05	387.52	388.20	389.41	388.87	387.89	387.33	387.90	389.08	388.70	388.05	387.65	387.90	389.38	388.70
385.36	385.16	385.80	387.31	386.74	384.77	384.37	384.49	386.13	385.72	384.61	384.70	384.19	385.90	385.36
384.77	384.87	385.83	386.98	386.24	384.11	384.04	384.26	385.97	385.36	384.11	383.78	384.03	385.77	385.10
385.59	385.09	385.97	387.11	386.51	384.77	384.11	384.49	385.93	385.46	384.77	384.24	384.29	385.90	385.65
387.79	387.62	388.23	389.31	388.54	387.89	387.39	388.03	389.08	388.38	387.79	387.39	388.10	389.08	388.93
Transect D4					**Transect D5**					**Transect D6**				
Mar-08	**Oct-08**	**May-09**	**Jun-10**	**Oct-10**	**Mar-08**	**Oct-08**	**May-09**	**Jun-10**	**Oct-10**	**Mar-08**	**Oct-08**	**May-09**	**Jun-10**	**Oct-10**
387.89	387.65	387.97	389.08	388.34	388.05	387.33	387.80	388.69	387.69	388.05	387.82	387.93	388.03	388.05
384.61	384.27	384.13	385.80	385.03	384.77	384.50	384.72	385.47	385.03	386.25	385.98	385.38	387.21	387.06
384.11	383.95	384.10	385.67	384.93	384.11	383.91	384.42	385.47	385.00	385.92	385.52	385.15	386.88	386.44
384.77	384.34	384.46	385.57	385.10	384.41	384.24	384.69	385.47	385.06	386.41	386.01	385.11	386.85	386.41
387.79	387.49	388.39	388.95	389.10	387.72	387.49	387.87	388.85	388.61	388.22	387.65	388.00	387.70	388.08

Table D-11. Elevation (ASL in feet) was calculated from depths taken along three transects in Cell E-West in 2009 and 2010.

Transect EW1			Transect EW2			Transect EW3		
May-09	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**
383.75	383.22	383.02	382.43	383.22	383.35	383.35	383.35	383.52
380.96	381.22	381.22	382.83	381.55	380.56	380.43	381.55	378.83
381.22	382.27	382.53	377.15	380.56	376.33	376.30	376.79	376.99
382.14	382.20	381.55	377.94	376.30	376.99	375.71	376.30	376.86
383.35	383.02	383.52	383.35	383.35	383.19	375.81	376.00	376.63
						376.37	376.46	376.46
						379.12	378.76	377.19
						382.17	382.56	383.52

Table D-12. Elevation (ASL in feet) was calculated from depths taken along four transects in Cell E in 2009 and 2010.

Transect E1			Transect E2			Transect E3			Transect E4		
May-09	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**
387.54	386.20	386.36	387.67	387.44	386.46	387.57	387.02	387.05	387.54	386.52	386.69
386.03	386.10	384.06	386.23	385.97	385.97	385.93	383.74	383.74	382.82	382.82	382.46
382.36	382.42	382.00	382.65	383.08	382.42	382.59	382.59	382.46	381.96	382.39	382.39
382.33	382.26	381.74	382.59	382.46	382.46	382.49	382.42	382.36	386.36	386.36	387.02
382.29	382.10	381.70	382.49	382.26	382.59	382.42	382.26	382.33	386.59	386.59	386.43
386.10	386.10	386.10	386.23	386.03	386.03	382.75	382.75	382.59	381.77	382.16	382.16
387.57	385.70	385.87	387.67	385.70	387.02	387.54	386.20	386.69	382.71	382.23	382.78
387.21	387.08	386.03	387.51	386.20	386.36	387.57	387.41	387.28	387.34	386.85	386.95
386.43	386.16	386.10	386.29	386.36	386.03	386.20	386.03	385.87			
382.03	382.36	384.72	382.42	381.90	381.90	382.16	382.26	381.83			
381.44	382.03	381.74	382.26	382.10	381.83	381.77	382.03	381.74			
382.00	381.77	382.10	382.16	382.10	381.60	381.77	381.77	381.60			
382.42	382.42	381.93	382.42	381.70	381.83	382.10	382.10	382.10			
387.67	386.69	386.75	382.03	382.03	381.83	387.54	386.36	386.36			
			387.67	386.20	386.36						

Table D-13. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell F (West) in 2009 and 2010.

Transect FW1			Transect FW2			Transect FW3			Transect FW4			Transect FW5			Transect FW6		
May-09	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**
386.34	385.69	385.52	386.67	385.66	385.75	386.41	386.05	385.85	386.31	386.18	385.79	386.51	385.69	385.75	386.61	386.02	386.08
384.97	383.06	384.77	384.90	384.11	384.11	385.52	385.03	385.20	385.23	384.54	384.54	385.36	382.90	384.05	385.43	384.05	384.21
381.10	380.11	380.83	380.28	380.83	380.70	380.67	380.44	380.70	384.70	384.38	384.38	380.51	380.51	380.60	380.47	380.47	380.37
381.03	380.77	380.44	380.60	380.83	380.77	380.87	380.60	380.60	381.33	380.08	380.47	380.77	380.47	380.51	381.36	380.44	380.60
381.03	380.70	380.77	380.93	380.70	380.90	380.83	380.60	380.83	380.64	380.37	380.51	380.93	380.60	380.80	380.87	380.51	380.60
381.85	381.85	381.13	380.55	380.77	380.93	385.36	384.87	384.87	380.64	380.44	380.51	382.57	380.77	380.57	380.90	380.64	380.67
385.56	384.97	384.97	386.08	383.88	385.20	385.20	384.74	385.03	385.10	384.21	384.93	385.03	384.31	384.38	384.74	383.79	384.41
386.70	386.02	385.88	386.51	385.52	385.75	386.34	385.82	386.34	386.57	385.88	386.02	386.51	386.08	386.05	386.57	386.08	386.18

Table D-14. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell F (East) in 2009 and 2010.

Transect FE1			Transect FE2			Transect FE3			Transect FE4			Transect FE5			Transect FE6		
May-09	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**	**May-09**	**Jun-10**	**Oct-10**
386.02	385.79	386.02	386.21	386.11	386.28	386.02	385.85	386.08	386.51	385.85	385.36	386.05	386.02	386.05	386.34	385.98	385.43
385.26	384.77	384.97	384.74	384.87	384.87	385.26	385.03	385.00	384.70	383.56	383.75	385.16	384.70	384.70	384.77	384.64	385.00
385.29	384.87	384.70	380.47	380.77	380.67	380.50	380.60	380.41	380.93	380.70	380.70	381.36	381.10	380.60	381.10	381.10	381.36
385.13	384.87	384.20	380.93	380.64	380.51	380.77	380.37	380.34	380.18	379.95	380.37	382.74	380.14	380.37	380.34	380.11	380.51
385.13	385.13	384.87	381.10	380.83	380.83	380.77	380.57	380.31	382.67	379.95	380.11	380.77	380.44	380.34	379.46	380.01	380.34
384.44	384.70	384.90	382.74	380.70	380.77	381.10	380.83	380.57	380.22	380.44	379.78	381.10	380.44	380.74	379.50	379.78	379.95
384.97	384.44	384.70	384.02	384.05	382.74	385.52	383.98	384.31	385.10	383.39	384.61	384.97	384.38	384.61	385.03	384.61	384.54
386.34	385.85	386.02	386.21	385.85	386.08	386.31	385.62	385.62	386.18	385.85	386.34	386.51	386.18	386.34	385.26	386.08	385.52

Table D-15. Elevation (ASL in feet) was calculated from depths taken along seven transects in Cell F-North in 2009 and 2010.

Transect FN1			Transect FN2			Transect FN3			Transect FN4			Transect FN5			Transect FN6			Transect FN7		
May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10
382.51	383.25	383.52	382.51	382.96	383.16	382.74	383.35	383.52	382.31	383.19	383.25	382.61	383.52	383.22	382.48	383.68	383.35	382.34	383.02	383.06
380.61	380.47	376.96	382.18	382.53	381.94	382.15	382.89	382.34	381.46	382.04	381.84	381.29	382.20	381.88	381.52	382.04	381.19	379.06	380.20	380.53
378.05	377.45	376.96	382.18	382.86	381.91	382.48	383.78	383.52	382.57	383.52	383.35	382.41	383.19	381.58	382.61	383.68	382.76	376.28	378.27	379.15
377.00	377.45	377.55	381.95	382.60	381.58	382.54	383.35	383.02	382.61	383.35	383.52	382.67	383.52	381.74	382.48	382.89	381.84	376.28	376.79	377.94
377.88	377.19	376.96	381.59	381.71	381.25	380.77	381.29	380.73	381.43	382.86	381.32	380.70	380.56	380.60	379.85	379.81	376.56	376.60	377.12	378.53
378.74	377.12	377.22	382.54	383.02	383.25	382.57	383.81	383.52	378.74	381.58	379.09	376.18	376.89	377.25	376.77	377.22	376.69	381.20	380.24	379.48
379.72	377.28	378.89							377.88	379.51	377.28	376.11	376.79	376.53	376.44	376.92	376.76	382.51	383.45	383.16
381.36	379.74	381.45							379.82	378.50	378.50	375.85	376.63	376.14	376.44	376.96	378.43			
382.67	383.25	383.19							381.66	379.22	380.17	378.08	376.76	376.00	379.85	379.91	381.15			
									382.74	381.38	381.94	377.91	377.91	376.27	382.67	382.70	383.68			
									383.29	383.29	383.35	380.61	380.89	379.55						
												383.59	383.52	383.45						

Table D-16. Elevation (ASL in feet) was calculated from depths taken along seven transects in Cell G in 2009 and 2010.

Transect G1			Transect G2			Transect G3			Transect G4			Transect G5			Transect G6			Transect G7		
May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10	May-09	Jun-10	Oct-10
382.69	382.35	382.12	382.62	382.25	382.93	382.62	382.35	382.35	382.75	382.35	382.02	382.03	382.48	382.16	382.03	382.19	382.84	383.70	383.25	383.25
380.20	379.92	379.66	380.20	379.92	379.66	380.33	380.12	379.53	380.06	380.09	379.60	380.06	381.83	380.74	379.97	380.51	380.51	379.67	384.45	383.17
380.06	379.60	379.56	380.16	379.92	379.73	380.10	380.09	379.76	380.13	379.92	379.66	378.10	380.12	379.76	379.80	380.09	379.76	379.60	379.76	379.24
382.52	382.53	383.79	382.69	382.35	382.25	382.56	382.22	382.25	379.77	379.76	379.60	379.93	379.86	379.33	380.10	379.76	378.78	377.77	379.10	380.15
382.03	382.35	384.58	382.56	382.35	382.70	382.52	382.52	383.93	382.82	382.55	382.66	382.82	382.17	382.09	382.69	381.24	383.04	379.41	381.17	380.09
381.05	381.89	379.83	380.06	379.89	381.56	380.03	380.74	380.74												
380.42	380.42	379.76	378.88	379.99	379.86	380.25	380.25	379.76												
380.89	381.56	381.56	382.52	382.35	382.53	383.38	384.02	383.19												
381.89	382.19	384.02																		

Table D-17. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell D in 2008 (baseline) and 2011.

Transect D1			Transect D2			Transect D3		
Mar-08	Jun-11	Nov-11	Mar-08	Jun-11	Nov-11	Mar-08	Jun-11	Nov-11
388.05	390.02	389.59	387.89	389.75	389.36	388.05	389.85	388.67
385.36	387.00	386.57	384.77	386.57	387.06	384.61	386.47	386.15
384.77	386.57	386.44	384.11	386.74	386.41	384.11	386.15	386.08
385.59	387.06	387.33	384.77	387.00	386.38	384.77	386.31	386.34
387.79	389.85	389.20	387.89	389.69	388.54	387.79	389.85	389.03
Transect D4			Transect D5			Transect D6		
Mar-08	Jun-11	Nov-11	Mar-08	Jun-11	Nov-11	Mar-08	Jun-11	Nov-11
387.89	390.02	388.38	388.05	389.52	389.52	388.05	390.44	388.70
384.61	386.11	385.82	384.77	386.15	385.95	386.25	388.38	386.11
384.11	386.05	386.01	384.11	386.34	385.85	385.92	387.88	386.01
384.77	386.77	386.05	384.41	386.41	385.92	386.41	387.33	386.24
387.79	389.52	389.20	387.72	389.69	389.03	388.22	389.52	388.70

Table D-18. Elevation (ASL in feet) was calculated from depths taken along three transects in Cell E-West in 2009 (baseline) and 2011.

Transect EW1			Transect EW2			Transect EW3		
May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11
383.75	383.29	382.86	382.43	382.70	382.53	383.35	382.20	383.19
380.96	380.89	380.70	382.83	380.07	380.24	380.43	376.79	379.58
381.22	381.22	380.73	377.15	378.10	376.46	376.30	376.63	377.94
382.14	381.55	381.38	377.94	376.46	376.79	375.71	377.19	377.12
383.35	382.53	382.53	383.35	383.19	383.19	375.81	377.78	377.58
						376.37	378.43	378.60
						379.12	379.91	379.91
						382.17	384.01	383.02

Table D-19. Elevation (ASL in feet) was calculated from depths taken along four transects in Cell E in 2009 (baseline) and 2011.

Transect E1			Transect E2			Transect E3			Transect E4		
May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11
387.54	385.70	387.03	387.67	386.03	386.70	387.57	385.87	386.74	387.54	385.97	386.31
386.03	384.06	382.51	386.23	382.42	383.33	385.93	383.90	383.92	382.82	382.36	382.60
382.36	382.42	382.77	382.65	382.39	382.60	382.59	382.42	383.10	381.96	382.39	382.67
382.33	382.10	382.41	382.59	382.59	383.33	382.49	382.33	382.41	386.36	385.87	386.57
382.29	382.10	382.41	382.49	382.59	383.23	382.42	382.46	382.90	386.59	386.36	386.34
386.10	381.93	382.77	386.23	385.70	386.54	382.75	382.39	382.47	381.77	382.10	382.44
387.57	385.87	385.75	387.67	386.52	387.69	387.54	386.52	387.39	382.71	383.08	385.10
387.21	386.03	386.05	387.51	386.03	386.21	387.57	386.69	387.52	387.34	386.46	386.38
386.43	386.10	386.87	386.29	385.67	386.05	386.20	385.61	386.44			
382.03	384.72	383.78	382.42	381.90	382.44	382.16	381.87	382.47			
381.44	381.90	382.47	382.26	381.87	382.41	381.77	381.93	382.67			
382.00	382.10	382.18	382.16	381.44	382.08	381.77	382.10	382.96			
382.42	382.39	381.95	382.42	381.77	382.11	382.10	381.60	382.05			
387.67	385.38	387.03	382.03	381.77	381.75	387.54	386.20	386.21			
			387.67	385.87	386.21						

Table D-20. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell F (West) in 2009 (baseline) and 2011.

Transect FW1			Transect FW2			Transect FW3			Transect FW4			Transect FW5			Transect FW6		
May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11
386.34	385.66	385.53	386.67	385.92	385.20	386.41	386.08	385.37	386.31	386.05	385.20	386.51	386.28	385.20	386.61	386.02	385.79
384.97	384.97	383.89	384.90	385.10	382.58	385.52	385.10	384.06	385.23	385.13	384.38	385.36	384.31	383.89	385.43	384.34	384.15
381.10	380.64	380.94	380.28	381.03	380.94	380.67	380.70	380.78	384.70	380.77	381.66	380.51	380.51	380.78	380.47	380.54	380.78
381.03	380.87	380.91	380.60	380.96	380.94	380.87	380.80	380.74	381.33	380.64	380.61	380.77	380.60	380.64	381.36	380.47	380.78
381.03	380.74	380.94	380.93	381.03	380.91	380.83	380.90	380.94	380.64	380.87	380.55	380.93	380.67	380.78	380.87	380.57	380.64
381.85	381.10	380.91	380.55	380.80	380.94	385.36	381.06	382.91	380.64	380.80	380.78	382.57	380.64	380.91	380.90	380.80	380.91
385.56	384.70	384.38	386.08	385.10	383.24	385.20	385.13	384.88	385.10	384.97	384.38	385.03	384.05	383.56	384.74	384.31	382.91
386.70	386.21	385.53	386.51	386.05	385.20	386.34	386.18	385.37	386.57	386.05	385.27	386.51	385.52	385.50	386.57	385.98	384.84

Table D-21. Elevation (ASL in feet) was calculated from depths taken along six transects in Cell F (East) in 2009 (baseline) and 2011.

Transect FE1			Transect FE2			Transect FE3			Transect FE4			Transect FE5			Transect FE6		
May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11
386.02	385.88	385.37	386.21	385.69	385.86	386.02	386.25	385.53	386.51	386.41	384.94	386.05	385.98	385.37	386.34	386.25	385.37
385.26	385.20	384.88	384.74	384.97	384.55	385.26	385.06	383.86	384.70	384.87	384.22	385.16	384.97	383.40	384.77	384.84	384.84
385.29	384.93	384.81	380.47	380.44	381.96	380.50	384.97	380.78	380.93	381.42	380.19	381.36	384.80	380.28	381.10	381.13	380.35
385.13	385.00	384.68	380.93	380.74	380.78	380.77	381.29	380.68	380.18	380.70	380.25	382.74	382.93	380.28	380.34	380.51	380.32
385.13	384.87	384.81	381.10	381.10	380.78	380.77	380.70	380.58	382.67	382.41	380.45	380.77	380.87	380.35	379.46	380.11	380.58
384.44	384.74	384.55	382.74	382.87	380.78	381.10	381.03	380.51	380.22	384.54	380.58	381.10	381.06	381.10	379.50	383.82	382.09
384.97	384.87	384.71	384.02	383.88	383.24	385.52	385.69	384.88	385.10	384.97	384.38	384.97	384.70	384.55	385.03	384.70	384.61
386.34	386.21	385.86	386.21	386.31	385.37	386.31	386.25	385.56	386.18	386.05	385.20	386.51	386.28	385.70	385.26	385.69	386.02

Table D-22. Elevation (ASL in feet) was calculated from depths taken along seven transects in Cell F-North in 2009 (baseline) and 2011.

Transect FN1			Transect FN2			Transect FN3			Transect FN4			Transect FN5			Transect FN6			Transect FN7		
May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11
382.51	383.52	383.69	382.51	382.53	383.52	382.74	383.52	384.02	382.31	383.52	383.52	382.61	383.02	383.20	382.48	383.19	383.52	382.34	383.52	384.02
380.61	377.61	378.18	382.18	382.20	382.64	382.15	382.04	383.00	381.46	383.19	383.29	381.29	382.04	382.64	381.52	381.88	382.77	379.06	380.24	379.06
378.05	377.28	378.05	382.18	382.20	382.64	382.48	383.19	383.69	382.57	383.02	383.62	382.41	381.88	382.38	382.61	382.86	383.20	376.28	377.61	378.05
377.00	377.61	378.11	381.95	382.04	382.54	382.54	381.55	383.20	382.61	383.02	383.52	382.67	381.71	382.41	382.48	382.04	383.20	376.28	376.96	378.37
377.88	378.10	378.28	381.59	381.71	381.88	380.77	381.06	381.56	381.43	381.22	381.00	380.70	380.73	381.13	379.85	377.12	378.41	376.60	378.27	378.77
378.74	377.78	378.83	382.54	382.70	383.52	382.57	383.02	383.52	378.74	379.58	379.72	376.18	377.28	378.18	376.77	377.12	377.78	381.20	379.09	380.90
379.72	378.86	379.92							377.88	376.96	379.26	376.11	376.86	377.72	376.44	376.79	377.29	382.51	383.02	383.52
381.36	381.29	381.03							379.82	378.76	379.92	375.85	376.63	377.42	376.44	378.76	377.62			
382.67	382.70	383.69							381.66	379.74	381.56	378.08	376.66	377.46	379.85	380.40	377.75			
									382.74	382.14	382.34	377.91	376.46	377.42	382.67	383.52	384.18			
									383.29	383.19	383.43	380.61	379.25	379.26						
												383.59	383.19	383.69						

Table D-23. Elevation (ASL in feet) was calculated from depths taken along seven transects in Cell G in 2009 (baseline) and 2011.

Transect G1			Transect G2			Transect G3			Transect G4			Transect G5			Transect G6			Transect G7		
May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11	May-09	Jun-11	Nov-11
382.69	382.42	382.25	382.62	383.53	382.19	382.62	382.76	382.42	382.75	382.22	382.88	382.03	382.09	382.70	382.03	382.16	382.55	383.70	383.86	384.19
380.20	379.76	380.09	380.20	379.60	380.22	380.33	379.92	380.32	380.06	379.53	380.09	380.06	380.71	379.99	379.97	382.94	379.96	379.67	383.17	380.42
380.06	379.83	379.53	380.16	379.76	380.09	380.10	380.06	380.51	380.13	379.53	380.09	378.10	379.73	381.50	379.80	380.12	380.15	379.60	379.17	380.28
382.52	383.53	383.22	382.69	382.02	382.52	382.56	383.79	383.86	379.77	379.60	379.99	379.93	379.40	380.32	380.10	378.84	380.15	377.77	380.55	379.92
382.03	384.68	383.86	382.56	383.96	384.19	382.52	382.75	383.22	382.82	382.69	383.01	382.82	382.88	382.10	382.69	382.74	380.19	379.41	380.58	380.25
381.05	381.02	380.35	380.06	380.06	380.58	380.03	380.09	380.32												
380.42	380.58	380.91	378.88	379.27	380.51	380.25	379.60	380.38												
380.89	380.09	380.61	382.52	382.97	381.40	383.38	383.22	384.19												
381.89	382.79	382.42																		

Appendix E

Dallas Floodway Extension

Establishment, monitoring, and adaptive management of native aquatic vegetation and adjacent native grasslands; and monitoring aquatic organism utilization of project aquatic features:

Biological Monitoring: Fish

Collection sites were selected and marked (GPS) as permanent monitoring stations for development of a baseline for existing populations of fish. In the river, one station was within an area in which erosion control rip-rap and additional bank armoring has since been installed (under IH–45), one station was 200-ft upstream, and one station was 200-ft downstream of the rip-rap area. Additionally, two sampling stations were established in each of the wetland cells, one near the inflow (Site 1) and one near the outflow (Site 2). Cell F was treated as two cells for fish sampling: F (West) and F (East). Fish were collected with backpack electrofishing equipment, identified to the species level, counted in the field, and then released. Species richness (the number of different species identified) was calculated for fish surveys. All fishery sample data collected from the LCOW are given in later in this appendix.

Figure E-1. Mosquitofish were the most common fish species encountered in the Trinity River in 2008.

Riverine Fish: Five species of fish were collected from the river prior to installation of bank armoring in fall 2008, including mosquitofish (*Gambusia affinis*), bluegills (*Lepomis macrochirus*), brook silversides (*Labidesthes sicculus*), blacktail shiners (*Cyprinella venusta*), and a single tadpole madtom (*Noturus gyrinus*) (Table E-1). Mosquitofish were the dominant species collected, representing over 90% of individuals collected from all three sites (Figure ED-1). The upstream sample site (1) included riffles from a remnant bridge/culvert and supported the greatest species richness, including blacktail shiners, which represented 24% of the fish collected at that site. Sites under the bridge (2, now armored) and downstream from the bridge (3) had hardpan substrates with little structure and supported fewer fish species and numbers of individuals.

Table E-1. Five fish species were collected from the Trinity River near and under the IH-45 overpass during fall 2008 sampling, prior to river bottom and bank armoring. Site 1 is upstream from the bridge; Site 2 is the rip-rap area under the bridge; Site 3 is downstream from the bridge.

Sample site	Mosquitofish	Bluegill	Brook silverside	Blacktail shiner	Tadpole madtom	Species richness
1	400	2	0	125	1	3
2	100	0	0	0	0	1
3	200	0	2	0	0	2

Fish sampling in the river was conducted again in spring 2009, with summer and fall sampling not conducted due to hazards using the backpack electrofisher in the rip-rap areas during moderately high flow conditions. While the same areas were sampled when flow permitted, actual sampling technique was altered due to addition of rip-rap at the base of the interlocking armoring along the bank of sampled areas. Instead of wading through shallows adjacent to the shoreline, observations of fish were made by walking along the armored shoreline and holding sampler electrodes out into the water. Fish collected in 2009 using these methods are given in Table E-2. The fish assemblage had shifted from one dominated by mosquitofish, which prior to armoring had occupied quieter waters along the shorelines, to blacktail shiners, which occupied turbulent areas generated by flow over and between rip-rap below the bridge. Prior to armoring, highest species richness was observed at the upstream sample site, which was adjacent to riffles and a large, fallen tree. However, following armoring below the bridge, highest species richness shifted to Site 2, indicating that riffles and other habitat (e.g., gaps between rip-rap) created by the armoring benefitted more species in this section of the Trinity River.

Table E-2. Four fish species were collected from the Trinity River near and under the IH-45 overpass during spring 2009 sampling. Site 1 is upstream from the bridge; Site 2 is the rip-rap area under the bridge; Site 3 is downstream from the bridge.

Sample site	Mosquitofis h	Bluegil l	Redfin shiner	Blacktail shiner	Species richness
1	0	0	1	23	2
2	2	1	3	53	4
3	1	0	0	57	2

Fish were sampled along the river during fall 2010; spring and summer samplings were not conducted during that year due to high flow conditions (Table E-3). No fish were collected upstream (Site 1) or downstream (Site 3) from the bridge along the river's edge. Five species were collected from Site 2 below the bridge. Riffles, interstitial spaces between rip-rap, and overall structure provided by this area appeared to continue supporting fish relative to the bare upstream and downstream channel. While total numbers of fish collected during this sampling period were low, attributable to cool water temperatures (10° C) occurring at that time, species richness had increased from the previous year.

Table E-3. Five fish species were collected from the Trinity River near and under the IH-45 overpass during a fall 2010 sampling. Site 1 is upstream from the bridge; Site 2 is the rip-rap area under the bridge; Site 3 is downstream from the bridge.

Sample site	Largemo uth bass	Blu egill	Warmo uth	Blackta il shiner	Tadpole madtom	Species richness
1	0	0	0	0	0	0
2	1	2	1	2	1	5
3	0	0	0	0	0	0

Because conditions during spring, summer, and fall sampling periods in 2011 were deemed unsuitable, a fish sampling was performed in winter 2011 (Table E-4). While not directly comparable to other samplings, we conducted this sampling to verify earlier findings. This sampling resulted in the highest species richness collected during the project in the rip-rap areas below the bridge and included two species not previously collected from the river, log perch (*Percina caprodes*) and green sunfish (*Lepomis cyanellus*). Only a single species, the blacktail shiner, was collected from the other sites. This appears to confirm that the rip-rap area below the bridge is serving as suitable habitat for riffle-dependent and structure-dependent fisheries.

Table E-4. Six fish species were collected from the Trinity River near and under the IH-45 overpass during a winter 2011 sampling. Site 1 is upstream from the bridge; Site 2 is the rip-rap area under the bridge; Site 3 is downstream from the bridge.

Sample site	Log perch	Blu egill	Gree n sunfi sh	Mosqui to-fish	Blackt ail shiner	Redfi n shin er	Speci es richne ss
1	0	0	0	0	0	0	0
2	2	4	1	1	29	1	6
3	0	0	0	0	4	0	1

No fish sampling was conducted in 2012 or 2013 due to flow conditions and safety concerns.

Wetland Cells Fish: Electrofishing sampling has been conducted fifteen times in Cell D (2008-2013) and fourteen times in all other wetland cells (2009-2013). Sampling was not conducted in 2014, but a single spring sampling event is planned for 2015. For the purposes of fish sampling, Cell F was treated as two cells: F (West) and F (East). Data collected during wetland cell fishery sampling is given later in this appendix. The first sampling in Cell D occurred several years after fish had been introduced through overbanking events and fishery development had already occurred. Sampling in other cells commenced soon after they filled, enabling us to better track development of those fisheries from their onset. This is reflected by low numbers collected in spring 2009, but higher numbers collected later that year, when many of the fish in the latter samplings were young-of-the-year. Numbers collected have also been influenced by environmental conditions: for instance, low numbers and species collected in fall 2009 and 2011 in most cells reflect cold temperatures (below 8°C) that occurred during those sample periods---fish had moved to deeper waters and were not as harvestable using shallow water electrofishing equipment. While five years of data is now available, long-term sampling should be continued to provide information on whether or not the LCOW is supporting substantial, quality fisheries and to evaluate whether or not those fisheries are sustainable under LCOW conditions.

Twenty-one fish species have been collected from LCOW cells between 2008 and 2013 (Table E-5). Sunfishes, shad, and minnows have made up the majority of fish collected during most sampling periods, with bluegill and shad appearing to dominate the forage-predator base, and large-mouth bass serving as major predators. Other forage species include redear sunfish, orange-spotted sunfish, blacktail shiners, and redfin shiners. Predators include warmouth, white crappie, several catfish species, and spotted gar.

Table E-5. Twenty-one fish species have been collected in the LCOW between 2008 and 2013.

Common name	Scientific name	Cell(s)	Reproductive recruitment	Comments
Warmouth	*Lepomis gulosus*	All except F-North	Yes	Common centrarchid in the LCOW; desirable predator
Bluegill	*Lepomis macrochirus*	All	Yes	Abundant centrarchid in the LCOW; desirable forage/predator
Redear sunfish	*Lepomis microlophus*	D	Unknown	Uncommon centrarchid in the LCOW; desirable forage/predator
Orange-spotted sunfish	*Lepomis humilis*	All except E and F-North	Yes	Common to abundant centrarchid in the LCOW; desirable forage/predator
Longear sunfish	*Lepomis megalotis*	All except F (West)	Yes	Uncommon to common centrarchid in the LCOW; desirable forage/predator
Green sunfish	*Lepomis cyanellus*	All except D and F-North	Yes	Uncommon to common centrarchid in the LCOW; desirable forage/predator, but can become problematic
Largemouth bass	*Micropterus salmoides*	All	Yes	Common centrarchid in the LCOW; desirable predator
White crappie	*Poxomis annularis*	All except F-North	Yes	Common centrarchid in the LCOW; desirable predator
Blacktail shiner	*Cyprinella venusta*	All	Yes	Common cyprinid in the LCOW; desirable forage
Redfin shiner	*Lythrurus umbratilis*	E-West, F (East), and G	Unknown	Uncommon cyprinid in the LCOW; desirable forage
Common carp	*Cyprinus carpio*	All except F-North	Unknown	Uncommon to common cyprinid in the LCOW; undesirable benthic feeder
Blackspotted topminnow	*Fundulus notatus*	F-North and G	Yes	Uncommon cyprinodontid in the LCOW; desirable forage
Brook silverside	*Labidesthes sicculus*	D, F-North, and G	Yes	Uncommon to common atherinid in the LCOW
River redhorse	*Moxostoma carinatum*	E-West and E	Unknown	Rare stream cyprinid in the LCOW; desirable benthic feeder
Channel catfish	*Ictalurus punctatus*	E	Unknown	Uncommon ictalurid in the LCOW; desirable predator; numbers likely higher
Bullhead	*Ictalurus sp.*	F (East)	Unknown	Uncommon ictalurid in the LCOW desirable predator; numbers likely higher
Flathead catfish	*Pylodictis olivaris*	G	Unknown	Uncommon ictalurid in the LCOW; desirable predator; numbers likely higher
Mosquitofish	*Gambusia affinis*	All	Yes	Common to abundant poeciliid in the LCOW; desirable forage/mosquito larvae predator
Spotted gar	*Lepisosteus oculatus*	All except E and F (West)	Unknown	Uncommon to common lepisosteid in the LCOW; somewhat desirable predator
Log perch	*Percina caprodes*	D, E, F-North, F (East) and G	Yes	Uncommon to common percid in the LCOW; desirable
Gizzard shad	*Dorosoma cepedianum*	All	Yes	Abundant clupeid in the LCOW; desirable filter feeding forage

The greatest numbers of species have been collected from Cell G (18), followed by Cell F (East) (16), Cells D and E-West (15), Cell E (12), and Cells F-North and F (West) (11). Table E-6 provides a summary of species richness (spring, summer, and fall averaged for each year) for each cell. A general trend of increasing species richness has occurred in the LCOW as a whole, with greater numbers of species collected from most cells in subsequent years. This is indicative of wetland cell maturity and stability, and has occurred despite periodic overbanking events.

Table E-6. Mean fish species richness (spring, summer, and fall) for each of the LCOW cells.

Cell	Species richness *mean* 2009	Species richness *mean* 2010	Species richness *mean* 2011	Species richness *mean* 2012	Species richness *mean* 2013	5-year *mean*
D	6.0	5.3	6.7	5.3	**6.0**	**5.8**
E-West	6.3	5.3	4.0	4.3	**6.0**	**5.2**
E	5.3	5.3	5.3	5.3	**7.0**	**5.6**
F-North	3.7	4.3	3.0	4.0	**5.0**	**4.0**
F (West)	4.0	4.3	5.3	5.7	**6.5**	**5.2**
F (East)	3.7	5.3	6.3	6.0	**6.5**	**5.6**
G	3.3	6.3	7.3	7.3	**7.5**	**6.3**
LCOW *mean*	**4.6**	**5.2**	**5.4**	**5.4**	**6.4**	**5.4**

Fifteen species of fish have been collected from Cell D since 2008 (Table E-7). Introduction of fish into the cell probably began in late 2004 during overbank events or possibly through the inflow pump. Species richness has been moderately stable since sampling began, with average annual richness of 5.8 (range: 5.3-6.7, Table E-6). Since sampling began, the fishery has typically been dominated by several forage species (bluegill, shad, and mosquitofish, mostly), but includes significant numbers of predators such as largemouth bass (*Micropterus salmoides*) and warmouth (*Lepomis gulosus*). The cell also supports small numbers of undesirable fish, most notably common carp. Mixed size classes of many species, particularly the sunfishes, indicates reproduction of those species has been occurring in the cell since sampling began in 2008. Overall, it appears a moderately stable largemouth bass-bluegill fishery has developed in Cell D. One species was collected from Cell D for the first time in 2013: blackspotted topminnows (*Fundulus notatus*).

Figure E-2. Mixed size classes of shad have been commonly collected from Cell E-West and other cells since 2009.

Fifteen species have been collected during samplings conducted in Cell E-West from 2009 to 2013 (Table E-8). Overall, species occurring in the cell were similar to those seen in Cell D, not surprising considering the two cells share their source of introduction (Trinity River overbanking). Richness has been somewhat variable since sampling began, with the fewest numbers of species collected in 2011, on average (Table E-6). Bluegill and mosquitofish commonly dominate samples, with largemouth bass, warmouth, and green sunfish (*Lepomis cyanellus*) comprising the predator species. Orange-spotted sunfish (*Lepomis humilis*) are more commonly encountered in this cell than in others. The consistent presence of shad indicates that in addition to the centrarchid fishery, a sustained open-water fishery has developed in the cell (Figure E-2). The fishery appears to be stable, but may be influenced by the limited littoral zone (no shallow water planting shelves). However, sunfish and shad have reproduced readily in this cell. Log perch (*Percina caprodes*) were collected from Cell E-West for the first time in 2013.

Twelve species have been collected from Cell E since 2009 (Table E-9), with species richness remaining stable since sampling began, although a richness spike occurred in 2013 sampling (Table E-6). Bluegill and mosquitofish regularly dominate the samples, although shad are periodically caught in greater numbers. Predators include largemouth bass, warmouth, and green sunfish. Reproductive recruitment is occurring by many of the species inhabiting the cell. No previously uncollected species were found in Cell E during 2013.

Eleven species have been collected from Cell F-North between 2009 and 2013 (Table E-10). Species richness has been consistently lower in this cell than others in the LCOW (Table E-6). This cell is the shallowest of the LCOW, and vegetation had only just begun to establish significantly in 2011, likely contributing to fewer species of fish established. Additionally, the cell is maintained as a near-ephemeral system, with water levels permitted to drop naturally (to a point---complete drying is avoided). Bluegill and mosquitofish have been the dominant forage species; largemouth bass are the dominant predators. Relatively low numbers of open-water species (shad) are also present in the cell. Although initially this cell appeared to be the only one supporting a breeding population of blackspotted topminnows, mixed size classes of the species has since been found in several other cells. No previously uncollected species were found in Cell F-North during 2013.

Eleven species have been collected from Cell F (West) between 2009 and 2013 (Table E-11). Species richness has increased gradually over time in this cell, indicating that the fishery is continuing to develop (Table E-6). Bluegill and mosquitofish have dominated the forage population, with largemouth bass comprising most of the predator population since 2009. Shad were collected for the first time in 2011 and have subsequently been collected yearly, indicating that an open-water fishery has developed. No new fish species were collected from this cell in 2013.

Sixteen species have been collected from Cell F (East) between 2009 and 2013 (Table E-12), and species richness has increased gradually over time, similarly to Cell F (West), to which F (East) is directly connected (Table E-6). Bluegill and mosquitofish typically dominate collections; largemouth bass, warmouth, and green sunfish are the predators. Shad have been collected in a number of samples, indicating open-water fishery development. No new species were collected from this cell in 2013.

Eighteen species have been collected from Cell G between 2009 and 2013 (Table E-13). Only mosquitofish were initially collected, indicating that fishery development was in its early stages in the cell in 2009. Since that time, species richness has increased and represents the highest of all cells (Table E-6), with bluegill and mosquitofish dominating; predators have been dominated by largemouth bass. Shad have been collected periodically, indicating that the cell supports an open-water fishery. Heavy usage of Cell G by cormorants and white pelicans in 2009, 2010, 2012, and 2013 were indicative of shad serving as a significant food source for migratory birds in those years. No previously uncollected species were collected in 2013.

Assessments conducted over five years have provided some insight into trends that are occurring in the fishery populations in the LCOW wetland cells. Cells that support more vegetation appear to support greater numbers of fish species. In Cell E-West and Cell F-North, where littoral zones (and thus vegetation) and water levels are limited, respectively, fish communities are represented by fewer species, and it appears that some of those present (orange-spotted sunfish in Cell E-West and blackspotted topminnows in Cell F-North) may be suited best to conditions provided by those cells (but limited in other cells). Five years, however, may not be adequate to draw conclusions about sustainability of fish populations in the cells. For instance, early data suggested that the fisheries in each cell were being reset following each overbanking event. Under those conditions, and considering the unpredictability of overbanking, it was possible that stable fisheries could not establish in the cells, lowering the overall value of the habitat. However, longer-term monitoring is showing that fish are likely taking refuge in vegetation or other structures, or in the deeper channels, during overbanking, and significant numbers of individuals remain (combined with new individuals from the river) in the cells to sustain their populations. Longer-term monitoring will provide enough information to confirm this supposition, and alert managers to any need to intervene in fishery population management outside of water level manipulations currently used for managing wetland vegetation.

Fishery Data

Table E-7. Number of fish collected per species per season. Fourteen species of fish were collected from two sites in Cell D from 2008-2013.

Common name	Scientific name	Fall 2008	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011	Spring 2012	Summer 2012	Fall 2012	**Spring 2013**	**Summer 2013**
Warmouth	*Lepomis gulosus*	8	1	6	2				1		1	2	1			
Bluegill	*Lepomis macrochirus*	75	19	96	64	14	30	14	29	50	16	37	43	10	**22**	**26**
Redear sunfish	*Lepomis microlophus*		1											1		
Common carp	*Cyprinus carpio*	1			1		1	1	1	1			1		**1**	
Blacktail shiner	*Cyprinella venusta*	1				1			1	3			1			**2**
Brook silverside	*Labidesthes sicculus*	1							2							
Blackspotted topminnow	*Fundulus notatus*															**2**
Longear sunfish	*Lepomis megalotis*	1					1	1								
Orange-spotted sunfish	*Lepomis humilis*								1		1				**1**	
Largemouth bass	*Micropterus salmoides*	2	6	4	3	1	2	4	11	5	1	6	6	1	**2**	**5**
Mosquitofish	*Gambusia affinis*	90	54	120	3	10	3	50	100	10	1	4			**90**	**65**
Spotted gar	*Lepisosteus oculatus*			1	1			1	1				1	1		
Log perch	*Percina caprodes*			1										1		
White crappie	*Poxomis annularis*							1						4		**1**
Gizzard shad	*Dorosoma cepedianum*									8		8			**3**	
	Totals	179	81	221	76	26	37	72	147	77	20	57	53	18	**119**	**101**
	Richness	8	5	6	7	4	5	7	9	6	5	4	5	7	**6**	**6**
	Mean Richness	**8.0**	**6.0**			**5.3**			**6.7**			**5.3**			**6.0**	

Table E-8. Number of fish collected per species per season. Fourteen species of fish were collected from two sites in Cell E-West from 2009-2013.

Common name	Scientific name	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011	Spring 2012	Summer 2012	Fall 2012	**Spring 2013**	**Summer 2013**
Warmouth	*Lepomis gulosus*		1			1	2								
Bluegill	*Lepomis macrochirus*	1	45	11	3	46	23	16	15	9	14	24	26	**4**	**24**
Green sunfish	*Lepomis cyanellus*		4			1	1			1					
Blacktail shiner	*Cyprinella venusta*	3	23			4								**1**	
Redfin shiner	*Lythrurus umbratilis*	1	1									5			
River redhorse	*Moxostoma carinatum*		1												
Longear sunfish	*Lepomis megalotis*		1				1		10						
Orange-spotted sunfish	*Lepomis humilis*							3		1		2	1	**1**	**3**
Largemouth bass	*Micropterus salmoides*		2			1	3				2	4	2	**2**	**2**
Gizzard shad	*Dorosoma cepedianum*	2	1	15		3			3			1		**2**	**3**
Mosquitofish	*Gambusia affinis*	3	174	49	58	21	124	151	146	250	31			**249**	**140**
Spotted gar	*Lepisosteus oculatus*		1												
Log perch	*Percina caprodes*														**1**
Common carp	*Cyprinus carpio*						6	2			1				
White crappie	*Poxomis annularis*												1		
Totals		10	254	75	61	77	237	172	175	261	48	36	29	**259**	**173**
Richness		5	11	3	2	7	7	4	4	4	4	5	4	**6**	**6**
Mean Richness		**6.3**			**5.3**			**4.0**			**4.3**			**6.0**	

Table E-9. Number of fish collected per species per season. Thirteen species of fish were collected from two sites in Cell E from 2009-2013. Sampling was not conducted in Summer 2013 due to high water conditions caused by flow restrictions at the weir box.

Common name	**Scientific name**	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011	Spring 2012	Summer 2012	Fall 2012	**Spring 2013**	**Summer 2013**
Warmouth	*Lepomis gulosus*	1				2	1		1				1	**1**	**-**
Bluegill	*Lepomis macrochirus*	6	23	27	10	35	30	19	45	6	30	24	11	**42**	**-**
Green sunfish	*Lepomis cyanellus*	1	2	1		5	3				4		1	**1**	**-**
Common carp	*Cyprinus carpio*	1						1				1		**1**	**-**
Blacktail shiner	*Cyprinella venusta*		7			4			1			1			**-**
River redhorse	*Moxostoma carinatum*			6											**-**
Largemouth bass	*Micropterus salmoides*	1	1	2	1	2	1	2	5	1	4	2	3	**18**	**-**
Gizzard shad	*Dorosoma cepedianum*		76			11		23	55			29	8		**-**
Mosquitofish	*Gambusia affinis*	89		1	4	16		500	93	250	64	35	22	**68**	**-**
Longear sunfish	*Lepomis megalotis*					1									**-**
Log perch	*Percina caprodes*								1						**-**
White crappie	*Poxomis annularis*								1				3		**-**
Channel catfish	*Ictalurus punctatus*					1								**1**	**-**
	Totals	99	109	37	15	77	35	545	202	257	102	92	49	**132**	**-**
	Richness	6	5	5	3	9	4	5	8	3	4	6	6	**7**	**-**
	Mean Richness	**5.3**			**5.3**			**5.3**			**5.3**			**7.0**	

Table E-10. Number of fish collected per species per season. Eleven species of fish were collected from two sites in Cell F-North from 2009-2013. Samples were not collected during summer 2011 because of low water conditions, nor in Spring 2013 due to high water conditions.

Common name	**Scientific name**	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011	Spring 2012	Summer 2012	Fall 2012	**Spring 2013**	**Summer 2013**
Bluegill	*Lepomis macrochirus*		26	8	3	18	15	6	-	2	5	13	4	**-**	**6**
Blacktail shiner	*Cyprinella venusta*		8			3	5		-					**-**	**8**
Brook silverside	*Labidesthes sicculus*		3			1			-		2	2	1	**-**	
Blackspotted topminnow	*Fundulus notatus*								-	1	11	2	6	**-**	**18**
Longear sunfish	*Lepomis megalotis*		1						-					**-**	
Largemouth bass	*Micropterus salmoides*		4				1	1	-			2		**-**	**1**
Gizzard shad	*Dorosoma cepedianum*	2	2			2		1	-				1	**-**	**2**
Mosquitofish	*Gambusia affinis*	2	17	1	520	265		420	-					**-**	
White crappie	*Poxomis annularis*						1		-					**-**	
Log perch	*Percina caprodes*						1		-				1	**-**	
Spotted gar	*Lepisosteus oculatus*								-	3				**-**	
	Totals	4	61	9	524	289	23	428	-		18	19	13	**-**	**35**
	Richness	2	7	2	3	5	5	4	-	2	3	4	5	**-**	**5**
	Mean Richness		**3.7**			**4.3**			**3.0**			**4.0**		**5.0**	

Table E-11. Number of fish collected per species per season. Eleven species of fish were collected from two sites in Cell F (West) from 2009-2013.

Common name	Scientific name	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011	Spring 2012	Summer 2012	Fall 2012	**Spring 2013**	**Summer 2013**
Warmouth	*Lepomis gulosus*		3						2			1		**1**	**1**
Bluegill	*Lepomis macrochirus*	3	48	2	6	15	47	7	46	12	43	43	15	**12**	**16**
Green sunfish	*Lepomis cyanellus*		3								6	6			
Common carp	*Cyprinus carpio*		1						2						
Blacktail shiner	*Cyprinella venusta*		47			3	2		2		1		1		
Orange-spotted sunfish	*Lepomis humilis*							4						**2**	**1**
Largemouth bass	*Micropterus salmoides*	1	1		1	2	2	2	3	2	10	10	1	**4**	**2**
Gizzard shad	*Dorosoma cepedianum*								3	1					**6**
Mosquitofish	*Gambusia affinis*	59	226	3	80	150	45	12	1400	260	7	7	150	**44**	**15**
Brook silverside	*Labidesthes sicculus*					1									
White crappie	*Poxomis annularis*						1		1		2	2	2	**2**	**1**
	Totals	63	326	5	87	171	97	25	1459	275	69	69	169	**65**	**42**
	Richness	3	7	2	3	5	5	4	8	4	6	6	5	**6**	**7**
	Mean Richness	**4.0**			**4.3**			**5.3**			**5.7**			**6.5**	

Table E-12. Number of fish collected per species per season. Sixteen species of fish were collected from two sites in Cell F (East) from 2009-2013.

Common name	**Scientific name**	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011	Spring 2012	Summer 2012	Fall 2012	**Spring 2013**	**Summer 2013**
Warmouth	*Lepomis gulosus*		1						2						**1**
Bluegill	*Lepomis macrochirus*	1	28	31	4	37	18	28	63	7	15	35	6	**14**	**29**
Green sunfish	*Lepomis cyanellus*		4	3								1		**1**	
Common carp	*Cyprinus carpio*								1	1		1			
Blacktail shiner	*Cyprinella venusta*		11			25	3	31	26		12	2	14		
Orange-spotted sunfish	*Lepomis humilis*							1	1			1			**1**
Largemouth bass	*Micropterus salmoides*		1			1	1	6	3		10	2	1	**5**	**7**
Gizzard shad	*Dorosoma cepedianum*		2					1	4		4	25	15		**14**
Mosquitofish	*Gambusia affinis*	4	30		44	26	13	2	200				1	**21**	**20**
Redfin shiner	*Lythrurus umbratilis*				3										
Brook silverside	*Labidesthes sicculus*					2		8							
Longear sunfish	*Lepomis megalotis*					1									
Bullhead	*Ictalurus sp.*						1								
White crappie	*Poxomis annularis*						1						2	**1**	**1**
Log perch	*Percina caprodes*						1	1	2			1			**2**
Spotted gar	*Lepisosteus oculatus*								1						
	Totals	5	77	34	51	92	38	78	302	8	41	68	39	**42**	**75**
	Richness	2	7	2	3	6	7	8	9	2	4	8	6	**5**	**8**
	Mean Richness		**3.7**			**5.3**			**6.3**			**6.0**		**6.5**	

Table E-13. Number of fish collected per species per season. Eighteen species of fish were collected from two sites in Cell G from 2009-2013.

Common name	Scientific name	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011	Spring 2012	Summer 2012	Fall 2012	**Spring 2013**	**Summer 2013**
Warmouth	*Lepomis gulosus*						1	1		11		1			
Bluegill	*Lepomis macrochirus*		28	2	22	41	25	25	29	4	18	27	16	**22**	**24**
Green sunfish	*Lepomis cyanellus*										1				
Blacktail shiner	*Cyprinella venusta*		7			8		101	1	2	13	7	8	**2**	**4**
Redfin shiner	*Lythrurus umbratilis*								1		1				
Brook silverside	*Labidesthes sicculus*		4		3	20			1						
Blackspotted topminnow	*Fundulus notatus*								1			3			**9**
Orange-spotted sunfish	*Lepomis humilis*		1			1	3	10	10					**2**	**1**
Largemouth bass	*Micropterus salmoides*		12				1		16		5	1	3	**3**	**3**
Gizzard shad	*Dorosoma cepedianum*	4	14	4	186	19	20	465	21			8	13	**4**	
Mosquitofish	*Gambusia affinis*		1								100	20	8	**320**	**92**
Flathead catfish	*Pylodictis olivaris*					1		1		1		1			
Common carp	*Cyprinus carpio*					2									**1**
Longear sunfish	*Lepomis megalotis*				1	1	3	1							
Green sunfish	*Lepomis cyanellus*							1					1	**1**	
White crappie	*Poxomis annularis*								3	1	2			**1**	
Log perch	*Percina caprodes*						1								
Spotted gar	*Lepisosteus oculatus*										1				
Totals		4	67	6	212	93	54	605	83	19	141	67	49	**355**	**134**
Richness		1	7	2	4	8	7	8	9	5	8	8	6	**8**	**7**
Mean Richness		**3.3**			**6.3**			**7.3**			**7.3**			**7.5**	

Appendix F

Dallas Floodway Extension

Establishment, monitoring, and adaptive management of native aquatic vegetation and adjacent native grasslands; and monitoring aquatic organism utilization of project aquatic features:

Biological Monitoring: Macro-invertebrates

Macro-invertebrates were collected with a sweep net (three samples per site), preserved in the field, and returned to the lab for identification (to Family or Genus) and enumerated. After addition of rip-rap to the river, macro-invertebrates were sampled by brushing them off rocks into a downstream collection net. In addition, three rip-rap samples were taken back to the lab and macro-invertebrates were rinsed off, collected and sorted. Simpson Diversity Indices (SDI) were calculated for macro-invertebrates, where lower numbers tend to indicate fewer species and individuals, and higher numbers indicate greater numbers of species and/or greater equitability between numbers of species present. Species evenness was calculated to evaluate relative abundance of species, which can be used as an indicator of ecosystem stability. Sampling was initiated in fall 2008, with only the river, Cell D, and Cell E sampled---other cells were still under construction at that time and not sampled. Fourteen additional samplings have been conducted since that time (spring, summer, and fall 2009-2013, excluding fall 2013) and results are given in this report. All macro-invertebrate sample data collected from the LCOW are given in this Appendix (F).

Riverine Macro-invertebrates: Macro-invertebrates collected from the Trinity River and IH-45 between 2008 and 2012 are given in Appendix E. Two families of macro-invertebrates, both insects, were collected from this location in fall 2008, including water striders (Hemiptera: Gerridae) and whirligig beetles (Coleoptera: Gyrinidae). Both families primarily use the water surface for habitat. No benthic macro-invertebrates were collected from any site. Only water striders were collected from all sample sites. Macro-invertebrate numbers and diversity were low (richness of R = 2, evenness E = 0.772, and Simpson's diversity (SDI) = 0.353) at all river sample sites, likely due to hard, relatively smooth substrates associated with each site. The upstream sample site that is adjacent to the riffles showed the highest diversity of fish, but that "close by" effect was not noted for macro-invertebrates. Overall, habitats (hard, smooth substrates in varying water flow velocities) in areas sampled were not suitable for colonization by many macro-invertebrates otherwise likely to be found in the river in the fall of 2008.

Six families of macro-invertebrates, all insects, were collected from the river in spring 2009 after the addition of rip-rap below the IH-45 bridge (R = 6, E = 0.296, D = 0.436). All macro-invertebrates collected were from rip-rap samples taken under the bridge (Site 2) while no macro-invertebrates were collected from upstream and downstream sites (1 and 3 respectively). Common netspinner caddisflies (Trichoptera: Hydropsychidae) (71.5%) and common midges (Diptera: Chironomidae) (22.3%) dominated the rip-rap samples, while three mayfly families (Ephemeroptera: Baetidae, Caenidae, Heptageniidae) (5.3%) as well as narrow-winged damselflies (Odonata: Coenagrionidae) (0.8%) were collected. Species collected in fall 2008 were not present at any of the sample sites in spring of 2009 after the rip-rap addition. This was attributed to seasonal changes or a transformation in stream ecology due to addition of rip-rap making a more lotic system with a lack of depositional environments more complimentary to species such as water striders and whirligig beetles. Both taxa richness and diversity improved from 2008 to 2009, while evenness declined due to the dominance of highly productive taxa such as Chironomidae and Hydropsychidae.

2010 macro-invertebrate sampling demonstrated the continuance of this colonization dynamic due to hard-armoring and rip-rap additions. Taxa richness, evenness, and diversity increased from 2009 (R = 12, E = 0.384, D = 0.783). New taxa, including riffle beetles (Coleoptera: Elmidae), burrower mayflies, brushlegged mayflies (Ephemeroptera: Ephemeridae, Isonychiidae), dobsonflies (Megaloptera: Corydalidae), and longhorned caddisflies (Tricoptera:

Leptoceridae) were all sampled for the first time. Sample site 2 remained similar to that of 2009, although increased in diversity and evenness as well as the riffle beetle population. Interestingly, Site 3, in which no individuals were detected in 2009, had the highest richness (R = 9) in 2010. This could be due to how the additions under IH-45 have changed the flow regime as well as added habitat structure, which is in turn developing suitable lotic and lentic macro-invertebrate habitat for colonization downstream.

Similar trends were observed in 2011 as in previous sampling periods, in that the primary location of taxa richness is from Site 2 or under the IH-45 overpass. This, as previously stated, is most likely because this sample site contains added rip-rap and has increased the macro-invertebrate refuge due to the enormity of interstitial spaces. New taxa collected during this sampling period included bladder snails (Physidae), leaf beetles (Chrysomelidae), and black flies (Simulidae). Diversity improved throughout each sample set and ranged from 0.754-0.849 compared to the 0.353-0.783 previously observed.

In 2012/2013 Site 2 (IH-45 rip-rap) remained the richest sampling site in terms of taxa. New taxa collected in 2012 include longhorned caddisflies (Trichoptera: Leptoceridae), freshwater snails (Gastropoda: Pomatiopsidae), broad-shouldered water striders (Hemiptera: Veliidae), and basket clams (Bivalvia: *Corbicula sp.*). 2013 macro-invertebrate sampling of the Trinity River is given in Table F-1. No new taxa were collected during this sampling period indicating community stabilization from the hard-armoring, which continues to appear to have improved colonization for a greater number of macro-invertebrates with the increased diversity of habitat types it created.

Table F-1. Macroinvertebrates collected from the Trinity River near and under the IH-45 overpass during a winter 2013 sampling. Site 1 is upstream from the bridge; Site 2 is the rip-rap area under the bridge; Site 3 is downstream from the bridge. M = mean and Mf = mean frequency.

Trinity River & IH - 45		Spring 2013					Summer 2013				
Taxa	**Common name**	**1**	**2**	**3**	**M**	**Mf**	**1**	**2**	**3**	**M**	**Mf**
Insecta											
Baetidae	Small Minnow mayflies		1		0.33	0.01		1		0.33	0.01
Caenidae	Small squaregill mayflies		2		0.67	0.02		6		2	0.06
Chironomidae	Common midges	12	25	17	18	0.64	18	52	5	25	0.74
Corixidae	Water boatmen	3		9	4	0.14		2	4		
Corydalidae	Dobsonflies		1								
Gerridae	Water Striders	5		1	2	0.07	6		1	2.33	0.07
Gyrinidae	Whirligig Beetles								1		
Heptageniidae	Flatheaded mayflies		2					4		1.33	0.04
Hydropsychidae	Common netspinners		8					1		0.33	0.01
Leptoceridae	Longhorned caddisflies		6		2	0.07					
Simulidae	Black flies		2		0.67	0.02					
Veliidae	Broad-shouldered water striders			1							
Mollusca											
Corbicula	Basket clams		1		0.33	0.01		8		2.67	0.08
Summary											
Totals		20	48	28	28	1.00	24	74	11	34	1.00
Taxa Richness						12.00					10.00
Evenness						0.19					0.18
Simpson's Diversity						0.55					0.44

Wetland Cells Macro-invertebrates: Macro-invertebrate sampling has been conducted sixteen times in Cell D and fifteen times in all other wetland cells. Similarly to electrofishing, sampling in Cell D began in late 2008, several years after its construction, with vegetation establishment well under way. Sampling in other cells started soon after they were filled, enabling ERDC to track colonization from their onset. In addition to macro-invertebrates collected during sampling (see below), large benthic mollusks common to the Trinity River drainage were occasionally encountered, including the paper pondshell mussel (*Utterbackia imbecillis*), giant floater (*Pyganodon grandis*), and introduced Asiatic clam (*Corbicula* sp.), all of which are considered biological indicators of fair to good water quality.

Community structure metrics, taxa (family) richness or R, evenness (E), and Simpson's diversity index (SDI, scale from 0 to 1, with 1 being the best diversity), are given in Table F-2 for all wetland cells during the FY2013 sampling period. In 2012, R ranged from 16-13 and Cells D and G were among the highest in taxa richness. This was due to the significant successes of establishing submersed aquatic vegetation in these cells, in some cases in close proximity to the macro-invertebrate sampling sites (Figure F-1). For example, taxa were collected and identified in these cells that correlate with the establishment of the submersed aquatic vegetation American pondweed and water stargrass, such as microcaddisflies (Tricoptera: Hydroptilidae), whom create their final instar purse-shape cases from submersed leaves, as well as water-lily leafcutter moths (Lepidoptera: *Synclita),* which larvae cut leaf matter for casing and eventual pupation. In 2013, mean R across the LCOW ranged from 16 to 10. This similarity illustrates that, although with slightly lower taxa richness, these wetland cells have ecologically progressed in taxonomically similar ways in terms of the macro-invertebrate communities and have become stable. Flora-dependent macro-invertebrates remained entrenched in all cells.

Similar to 2012 mean Simpson's diversity indices (SDI) ranged from 0.6 to 0.8 in the LCOW during 2013 sampling indicating that the macro-invertebrate community colonization across all wetlands continues to stabilize and improve with wetland development and establishment. It also suggests that the faunal community dynamics appear to be sustainable regardless of overbanking events or other significant hydrological issues, although minimal overbanking events occurred in FY2013. Mean diversity across all wetlands and sampling dates in FY2013 was SDI = 0.7 suggesting a healthy macro-invertebrate community across the entirety of the LCOW.

Table F-2. Population characteristics of macro-invertebrates collected from the LCOW from fall 2012 to summer 2013.

Wetland	Season	D	E	E-West	F-North	F (West)	F (East)	G	Mean
Taxa Richness	Fall 2012	7	9	9	14	8	10	5	8.9
	Spring 2013	15	12	9	24	11	14	14	14.1
	Summer 2013	13	11	12	11	10	6	13	10.9
Evenness	Fall 2012	0.27	0.33	0.40	0.27	0.42	0.29	0.38	0.3
	Spring 2013	0.25	0.35	0.30	0.19	0.29	0.21	0.16	0.3
	Summer 2013	0.40	0.39	0.39	0.52	0.45	0.46	0.59	0.5
Diversity	Fall 2012	0.51	0.66	0.73	0.72	0.70	0.65	0.47	0.6
	Spring 2013	0.74	0.76	0.63	0.78	0.63	0.66	0.47	0.7
	Summer 2013	0.80	0.77	0.79	0.83	0.79	0.64	0.87	0.8
	Mean Taxa Richness	11.7	10.7	10.0	16.3	9.7	10.0	10.7	11.3
	Mean Evenness	0.3	0.4	0.4	0.3	0.4	0.3	0.4	0.3
	Mean Diversity	0.7	0.7	0.7	0.8	0.7	0.7	0.6	0.7

Figure F-1. American pondweed (*Potamogeton nodosus*) establishment in Cell G has contributed to high numbers and diversity of macro-invertebrates.

ERDC has identified 56 total families of macroinvertebrates from the LCOW including aquatic springtails, insects, worms, spiders, crustaceans, and mollusks (Figure F-2). All freshwater functional feeding groups are represented by the fauna collected in each wetland cell including filtering collectors (Brachycentridae), scrapers (Gastropoda), engulfing (Coenagrionidae) and piercing predators (Belostomatidae), piercing herbivores (Corixidae), collector gatherers (Chironomidae), shredders (Amphipoda), and scavenger/omnivores (Physidae). Total taxa richness for each cell over the duration of macro-invertebrate sampling in 2013 is given in Table F-3 along with the individual taxa observed in each wetland cell. All cells increased in taxa richness from 2012 to 2013 with four new aquatic insect families to the LCOW (Cordulidae, Nepidae, Naucoridae, and Notonectidae). Cell D continues to support the highest richness at 41 total taxa, while the remaining LCOW cells range from 29 to 37 taxa. This verifies the ecological maturity of Cell D versus the remaining cells, but also indicates a positive trend with the remaining LCOW.

Figure F-2. A diversity of aquatic macro-invertebrates have been collected and identified from the LCOW wetland cells since 2008, including aquatic insects, mollusks, and crustaceans.

Table F-3. Macro-invertebrates collected from the LCOW from 2008–2013.

Taxa	Common name	D	E	EW	FN	FW	FE	G
Entognatha								
Isotomidae	Springtails				X			
Sminthuridae	Springtails	X						
Insecta								
Acrididae	Semi-aquatic grasshoppers						X	X
Aeshnidae	Hawker dragonflies				X			X
Baetidae	Small minnow mayflies	X	X	X	X	X	X	X
Belostomatidae	Giant water bugs	X	X	X	X	X	X	X
Brachycentridae	Humpless case makers		X	X	X	X	X	X
Caenidae	Small squaregill mayflies	X	X	X	X	X	X	X
Ceratopogonidae	Biting midges	X	X	X	X	X	X	X
Chaoboridae	Phantom midges			X	X			X
Chironomidae	Midges	X	X	X	X	X	X	X
Chrysomelidae	Leaf beetles	X						
Coenagrionidae	Narrow-winged damselflies	X	X	X	X	X	X	X
Cordulidae	Emerald dragonflies				X			X
Corixidae	Water boatmen	X	X	X	X	X	X	X
Culicidae	Mosquitoes	X		X				
Curculionidae	Weevils	X	X					
Dytiscidae	Predaceous diving beetles	X		X	X	X	X	X
Elmidae	Riffle beetles					X		
Ephydridae	Shore flies	X			X		X	X
Gerridae	Water striders	X		X	X	X		X
Gomphidae	Clubtail dragonflies	X		X	X		X	
Gyrinidae	Whirligig beetles						X	
Haliplidae	Crawling water beetles	X	X	X	X	X	X	X
Hebridae	Velvet water bugs	X				X	X	
Hydrometridae	Marsh treaders	X						X
Hydrophilidae	Water scavenger beetles	X	X	X	X	X	X	X
Hydropsychidae	Net-spinning caddisflies							
Hydroptilidae	Microcaddisflies	X	X	X	X	X		X
Libelullidae	Skimmers (dragonflies)	X	X	X	X	X	X	X
Limnephilidae	Northern case makers			X	X	X	X	
Mesoveliidae	Water treaders		X	X	X	X	X	X
Naucoridae	Creeping water bugs				X			
Nepidae	Water scorpions					X		
Noteridae	Burrowing water beetles	X						
Notonectidae	Backswimmers				X			
Pleidae	Pygmy backswimmers	X	X		X			X
Pyralidae	Grass moths	X						
Sciomyzidae	Marsh flies	X	X					
Stratiomyidae	Soldier flies	X	X	X	X	X	X	X
Synclita	Water-lily leafcutter moth	X	X	X	X	X		X
Veliidae	Broad-shouldered water striders	X	X	X	X	X	X	
Annelida								
Hirudinea	Freshwater leeches	X		X		X		
Oligochaeta	Aquatic worm	X	X	X	X	X	X	X
Arachnida								
Hydracarina	Water mites	X	X	X	X		X	X
Crustacea								
Cambaridae	Freshwater crayfish	X						
Hyalellidae	Amphipods	X	X	X	X	X	X	X
Palaemonidae	Grass shrimp	X	X	X	X		X	X
Mollusca								
Ancylidae	Freshwater limpets	X	X	X	X		X	X
Corbicula	Basket clams	X					X	X
Lymnacidae	Pond snails	X	X	X	X	X	X	X
Physidae	Bladder snails	X	X	X	X	X	X	X
Planorbidae	Ram's horn snails	X	X		X	X	X	X
Pomatiopsidae	Freshwater snails	X		X	X	X		
Unionidae	Freshwater mussels		X					X
Valvatidae	Valve snails	X	X	X	X			
Totals		**41**	**29**	**33**	**37**	**29**	**29**	**32**

ERDC has identified certain dynamics about the development of the macroinvertebrate community structure as a whole in a floodway passage. First, macro-invertebrate taxa richness, evenness, and diversity improved with time and appear to coincide with development of native aquatic vegetation communities. Second, macro-invertebrate colonies may be “reset” by overbanking events to some extent, but not detrimentally. Third, as wetland development and aquatic vegetation community establishment continues to progress in the LCOW, the wetlands are becoming more taxonomically similar to each other and specifically to the more mature Cell D with increased taxa richness and diversity. This suggests that the remaining LCOW continues to be on the proper path ecologically to community stabilization.

Macro-invertebrate data collected over the course of the project are given below (Tables F-4 through F-30).

Riverine Macro-invertebrates
Field collection data

Table F-4. Macro-invertebrates were collected periodically from 3 sites under the IH-45 Trinity River Bridge in 2008-2010. 1 = upstream site, 2 = IH-45 bridge site, 3 = downstream site, M = mean, M*f* = frequency.

		Fall 2008					Spring 2009					Summer 2010				
Taxa	**Common name**	**1**	**2**	**3**	***M***	***Mf***	**1**	**2**	**3**	***M***	***Mf***	**1**	**2**	**3**	***M***	***Mf***
								Insecta								
Baetidae	Small minnow mayflies							2		0.67	0.01	1	10	4	5	0.04
Caenidae	Small squaregill mayflies							3		1	0.01		6	12	6	0.05
Chironomidae	Common midges							54		18	0.22	22	36	68	42	0.36
Coenagrionidae	Narrow-winged damselflies							2		0.67	0.01					
Corydalidae	Dobsonflies												1		0.33	0.01
Elmidae	Riffle beetles												27	1	9.33	0.08
Ephemeridae	Common burrower mayflies											1		3	1.33	0.01
Gerridae	Water striders	2	5	1	2.67	0.22										0.01
Gyrinidae	Whirligig beetles	4		23	9	0.77										0.01
Heptageniidae	Flatheaded mayflies							8		2.67	0.03		25	1	8.67	0.07
Hydropsychidae	Common netspinners							173		57.7	0.71		35	7	14	0.12
Isonychiidae	Brushlegged mayflies													1	0.33	0.01
Leptoceridae	Longhorned caddisflies													1	0.33	0.01
								Mollusca								
Bivalvia	Freshwater bivalves												74	7	27	0.23
Valvatidae	Valve snails													5	1.67	0.01
Totals		**6**	**5**	**24**	**11.7**	**1.0**		**242**		**80.7**	**1.00**	**24**	**214**	**110**	**116**	**1.00**
Taxa Richness						**2**					**6**					**12**
Evenness						**0.77**					**0.29**					**0.38**
Simpson's Diversity						**0.35**					**0.43**					**0.78**

Table F-5. Numbers of macro-invertebrates collected from 3 sites under the IH-45 Trinity River Bridge in 2010 and 2011. 1 = upstream site, 2 = IH-45 bridge site, 3 = downstream site, M = mean, M*f* = frequency.

Trinity River & IH - 45		**Fall 2010**					**Spring 2011**					**Summer 2011**				
Taxa	**Common name**	**1**	**2**	**3**	***M***	***Mf***	**1**	**2**	**3**	***M***	***Mf***	**1**	**2**	**3**	***M***	***Mf***
									Insecta							
Baetidae	Small minnow mayflies		28		9.33	0.17							16	1	5.66	0.09
Caenidae	Small squaregill mayflies	3	5		2.66	0.05	2	2		1.333	0.05		7	5	4	0.06
Chironomidae	Common midges	11	17	1	9.66	0.18	2	5	6	4.333	0.18	1	17		6	0.10
Chrysomelidae	Leaf beetles													1	0.33	0.01
Coenagrionidae	Narrow-winged damselflies		7		2.33	0.04		1		0.333	0.01		28	2	10	0.16
Corixidae	Water boatmen						5			1.667	0.07	1			0.33	0.01
Corydalidae	Dobsonflies												7		2.333	0.03
Elmidae	Riffle beetles															
Ephemeridae	Common burrower mayflies	1			0.33	0.01										
Gerridae	Water Striders															
Gyrinidae	Whirligig Beetles								1	0.333	0.01					
Heptageniidae	Flatheaded mayflies		31		10.33	0.19		13		4.333	0.18		5		1.66	0.02
Hydrophilidae	Water scavenger beetles							2		0.667	0.02		2		0.66	0.01
Hydropsychidae	Common netspinners		21	1	7.33	0.14		12		4	0.17		78		26	0.43
Isonychiidae	Brushlegged mayflies															
Leptoceridae	Longhorned caddisflies															
Simulidae	Black flies		11		3.667	0.07										
									Mollusca							
Bivalvia	Freshwater bivalves		19		6.333	0.12		17		5.667	0.24					
Physidae	Pond snails								2	0.667	0.02		6	2	2.66	0.045
Valvatidae	Valve snails															
Totals		**15**	**139**	**2**	**52**	**1.00**	**9**	**52**	**9**	**23.33**	**1.00**	**2**	**166**	**11**	**59.6**	**1.00**
Taxa Richness						**9**					**8**					**11**
Evenness						**0.73**					**0.74**					**0.36**
Simpson's Diversity						**0.84**					**0.83**					**0.75**

Table F-6. Numbers of macro-invertebrates collected from 3 sites under the IH-45 Trinity River Bridge in 2012. 1 = upstream site, 2 = IH-45 bridge site, 3 = downstream site, M = mean, M*f* = frequency.

Trinity River & IH - 45		**Spring 2012**					**Summer 2012**				
Taxa	**Common name**	**1**	**2**	**3**	**M**	**Mf**	**1**	**2**	**3**	**M**	**Mf**
Insecta											
Baetidae	Small minnow mayflies							2		0.67	0.024
Caenidae	Small squaregill mayflies							1		0.33	0.012
Chironomidae	Common midges	37	62	40	46.3	0.908	24	21	10	18.3	0.671
Corixidae	Water boatmen			1	0.33	0.007					
Corydalidae	Dobsonflies							2		0.67	0.024
Gerridae	Water striders			2	0.67	0.013			2	0.67	0.024
Gyrinidae	Whirligig beetles			1	0.33	0.007					
Heptageniidae	Flatheaded mayflies							8		2.67	0.098
Hydropsychidae	Common netspinners							10		3.33	0.122
Leptoceridae	Longhorned caddisflies		5		1.67	0.033					
Veliidae	Broad-shouldered water striders		1		0.33	0.007					
Mollusca											
Bivalvia	Freshwater bivalves										
Corbicula	Basket clams		2	1	1	0.020		2		0.67	0.024
Pomatiopsidae	Freshwater snails		1		0.33	0.007					
Totals		**37**	**71**	**45**	**51**	**1.000**	**24**	**46**	**12**	**27.3**	**1.000**
Taxa Richness						**8.000**					**8.000**
Evenness						**0.151**					**0.262**
Simpson's Diversity						**0.173**					**0.523**

Wetland Cell Macro-invertebrates
Richness, Evenness, and Diversity (2008 through 2012)

Table F-7. Population characteristics of macro-invertebrates collected from two sample sites in Cell D from 2008 – 2010.

Cell D	Fall 2008	Spring 2009	Summer 2009	Fall 2009	Spring 2010	Summer 2010
Taxa Richness	18	17	16	8	21	12
Evenness	0.224	0.104	0.180	0.557	0.274	0.149
Simpson's Index of Diversity	0.752	0.435	0.653	0.775	0.826	0.442

Table F-8. Population characteristics of macro-invertebrates collected from Cells E, E-West, F-North, F (West), F (East), and G in spring 2009.

Season	Site	E	EW	FN	FW	FE	G	Mean
Spring 2009	**Taxa Richness**	9	7	10	11	5	6	8.000
	Evenness	0.142	0.197	0.220	0.125	0.208	0.361	0.209
	Simpson's Index of Diversity	0.215	0.276	0.546	0.271	0.038	0.539	0.314

Table F-9. Population characteristics of macro-invertebrates collected from Cells E, E-West, F-North, F (West), F (East), and G in summer 2009.

Season	Site	E	EW	FN	FW	FE	G	Mean
Summer 2009	**Taxa Richness**	5	5	10	10	7	10	7.833
	Evenness	0.590	0.280	0.466	0.267	0.285	0.435	0.387
	Simpson's Index of Diversity	0.661	0.286	0.785	0.625	0.499	0.770	0.604

Table F-10. Population characteristics of macro-invertebrates collected from Cells E, E-West, F-North, F (West), F (East), and G in fall 2009.

Season	Site	E	EW	FN	FW	FE	G	Mean
Fall 2009	**Taxa Richness**	9	9	13	8	6	6	8.500
	Evenness	0.189	0.460	0.308	0.323	0.459	0.522	0.377
	Simpson's Index of Diversity	0.413	0.759	0.750	0.613	0.637	0.681	0.642

Table F-11. Population characteristics of macro-invertebrates collected from Cells E, E-West, F-North, F (West), F (East), and G in spring 2010.

Season	Site	E	EW	FN	FW	FE	G	Mean
Spring 2010	**Taxa Richness**	12	13	10	10	12	14	11.833
	Evenness	0.353	0.270	0.590	0.226	0.101	0.179	0.287
	Simpson's Index of Diversity	0.764	0.715	0.831	0.557	0.177	0.600	0.607

Table F-12. Population characteristics of macro-invertebrates collected from Cells E, E-West, F-North, F (West), F (East), and G in summer 2010.

Season	Site	E	EW	FN	FW	FE	G	Mean
Summer 2010	**Taxa Richness**	10	10	9	6	4	10	8.167
	Evenness	0.119	0.171	0.181	0.315	0.535	0.135	0.243
	Simpson's Index of Diversity	0.162	0.416	0.387	0.471	0.533	0.259	0.371

Table F-13. Population characteristics of macro-invertebrates collected from the LCOW in fall 2010.

Season	Site	D	E	E-West	F-North	F (West)	F (East)	G	Mean
Fall 2010	**Taxa Richness**	11	15	7	7	8	10	15	10.429
	Evenness	0.412	0.219	0.335	0.310	0.382	0.563	0.494	0.388
	Simpson's Index of Diversity	0.779	0.696	0.573	0.539	0.673	0.823	0.865	0.707

Table F-14. Population characteristics of macro-invertebrates collected from the LCOW in spring 2011.

Season	Site	D	E	E-West	F-North	F (West)	F (East)	G	Mean
Spring 2011	**Taxa Richness**	13	16	9	6	6	9	14	10.429
	Evenness	0.371	0.262	0.437	0.768	0.269	0.164	0.130	0.343
	Simpson's Index of Diversity	0.793	0.761	0.745	0.783	0.381	0.322	0.451	0.605

Table F-15. Population characteristics of macro-invertebrates collected from the LCOW in summer 2011.

Season	Site	D	E	E-West	F-North	F (West)	F (East)	G	Mean
Summer 2011	**Taxa Richness**	12	13	6	11	4	11	10	9.571
	Evenness	0.327	0.117	0.421	0.346	0.327	0.426	0.156	0.303
	Simpson's Index of Diversity	0.745	0.340	0.605	0.737	0.236	0.787	0.359	0.544

Table F-16. Population characteristics of macro-invertebrates collected from the LCOW from fall 2011 to summer 2012.

Wetland	Season	D	E	EW	FN	FW	FE	G	Mean
Taxa Richness	Fall 2011	25	15	14	8	11	10	10	13.3
	Spring 2012	18	14	8	8	12	16	14	12.9
	Summer 2012	23	10	17	23	18	14	25.00	18.6
Evenness	Fall 2011	0.12	0.10	0.31	0.34	0.21	0.26	0.18	0.22
	Spring 2012	0.20	0.41	0.38	0.30	0.33	0.29	0.50	0.34
	Summer 2012	0.17	0.28	0.34	0.23	0.24	0.26	0.21	0.25
Diversity	Fall 2011	0.67	0.36	0.77	0.64	0.56	0.62	0.45	0.58
	Spring 2012	0.72	0.83	0.67	0.59	0.74	0.78	0.45	0.68
	Summer 2012	0.74	0.65	0.83	0.81	0.77	0.73	0.81	0.76
	Mean Taxa Richness	**22.0**	**13.0**	**13.0**	**13.0**	**13.7**	**13.3**	**16.3**	**14.9**
	Mean Evenness	**0.16**	**0.27**	**0.34**	**0.29**	**0.26**	**0.27**	**0.30**	**0.27**
	Mean Diversity	**0.71**	**0.61**	**0.75**	**0.68**	**0.69**	**0.71**	**0.57**	**0.67**

Macro-invertebrate data collected from all LCOW cells in fall 2011, spring 2012, and summer 2012; and Trinity River 2008-2011

Table F-17. Numbers of macro-invertebrates collected from Cell D between fall 2011 and summer 2012.

		Fall 2011				Spring 2012				Summer 2012			
Taxa	**Common name**	**I**	**O**	***M***	***Mf***	**I**	**O**	***M***	***Mf***	**I**	**O**	***M***	***Mf***
						Entognatha							
Sminthuridae	Springtails	1		0.5	0.001								
						Insecta							
Belostomatidae	Giant water bugs		1	0.5	0.001						1	0.5	0.006
Caenidae	Small squaregill mayflies	12	2	7	0.015	6	2	4	0.051	7	12	9.5	0.109
Ceratopogonidae	Biting midges	5	4	4.5	0.010		4	2	0.026				
Chironomidae	Midges	117	376	247	0.541	15	15	15	0.192	6	17	11.5	0.132
Coenagrionidae	Narrow-winged damselflies	64	12	38	0.083		1	0.5	0.006				
Corixidae	Water boatmen					8	3	5.5	0.071				
Ephydridae	Shore flies	5	1	3	0.007								
Gerridae	Water striders					75		37.5	0.481		20	10	0.115
Gomphidae	Clubtail dragonflies									1		0.5	0.006
Haliplidae	Crawling water beetles										3	1.5	0.017
Hebridae	Velvet water bugs	1	1	1	0.002								
Hydrophilidae	Water scavenger beetles					1		0.5	0.006	2	5	3.5	0.040
Hydroptilidae	Microcaddisflies	8	102	55	0.121								
Libelullidae	Skimmers (dragonflies)									1		0.5	0.006
Pleidae	Pygmy backswimmers		2	1	0.002								
Strayiomyidae	Soldier flies									1		0.5	0.006
Synclita	Water-lily leafcutter moth	44	16	30	0.066								
Veliidae	Broad-shouldered water striders	8	5	6.5	0.014								
						Annelida							
Oligochaeta	Aquatic worms	2		1	0.002	5	2	3.5	0.045		5	2.5	0.029
Hirudinea	Freshwater leeches										1	0.5	0.006
						Arachnida							
Hydracarnia	Water mites	16	20	18	0.040								
						Crustacea							
Hyalellidae	Amphipods						2	1	0.013	4	1	2.5	0.029
Palaemonidae	Grass shrimp						1	0.5	0.006				
						Mollusca							
Ancylidae	Freshwater limpets					3		1.5	0.019				
Corbicula	Basket clams										2	1	0.011
Lymnacidae	Pond snails					1	1	1	0.013				
Physidae	Bladder snails	57	27	42	0.092	10	1	5.5	0.071	31	49	40	0.460
Planorbidae	Ram's horn snails	2	1	1.5	0.003					1	3	2	0.023
Pomatiopsidae	Freshwater snails										1	0.5	0.006
Totals		**341**	**570**	**456**	**1.000**	**124**	**32**	**78**	**1.000**	**54**	**120**	**87**	**1.000**

Table F-18. Numbers of macro-invertebrates collected from Cell E between fall 2011 and summer 2012.

		Fall 2011				Spring 2012				Summer 2012			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Caenidae	Small squaregill mayflies	1		0.5	0.004	2	22	12	0.185	3	12	7.5	0.153
Ceratopogonidae	Biting midges	1		0.5	0.004		1	0.5	0.008				
Chironomidae	Midges	66	150	108	0.794	15	14	14.5	0.223	6	8	7	0.143
Coenagrionidae	Narrow-winged damselflies	2		1	0.007		1	0.5	0.008	1		0.5	0.010
Corixidae	Water boatmen					25	3	14	0.215				
Hydrophilidae	Water scavenger beetles						1	0.5	0.008				
Hydroptilidae	Microcaddisflies		25	12.5	0.092								
Sciomyzidae	Marsh flies		1	0.5	0.004								
Stratiomyidae	Soldier flies										2	1	0.020
Synclita	Water-lily leafcutter moth		1	0.5	0.004								
Veliidae	Broad-shouldered water striders	1	1	1	0.007								
Annelida													
Oligochaeta	Aquatic worms	1	7	4	0.029						5	2.5	0.051
Arachnida													
Hydracarnia	Water Mites	2	2	2	0.015								
Crustacea													
Palaemonidae	Grass shrimp										2	1	0.020
Hyalellidae	Amphipods						20	10	0.154		2	1	0.020
Mollusca													
Ancylidae	Freshwater limpets					2		1	0.015	2		1	0.020
Lymnacidae	Pond snails	1		0.5	0.004								
Physidae	Bladder snails	2	5	3.5	0.026	7	10	8.5	0.131	25	29	27	0.551
Planorbidae	Ram's horn snails	1		0.5	0.004	2		1	0.015				
Unionidae	Freshwater mussels						1	0.5	0.008				
Valvatidae	Valve snails	2		1	0.007	4		2	0.031	1		0.5	0.010
Totals		**80**	**192**	**136**	**1.000**	**57**	**73**	**65**	**1.000**	**38**	**60**	**49**	**1.000**

Table F-19. Numbers of macro-invertebrates collected from Cell E-West between fall 2011 and summer 2012.

		Fall 2011				Spring 2012				Summer 2012			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Baetidae	Small minnow mayflies		1	0.5	0.006								
Belostomatidae	Giant water bugs										4	2	0.016
Brachycentridae	Humpless case makers					1		0.5	0.026				
Caenidae	Small squaregill mayflies										17	8.5	0.067
Chaoboridae	Phantom midges												
Chironomidae	Midges	15	17	16	0.184	12	8	10	0.513	12	41	26.5	0.208
Coenagrionidae	Narrow-winged damselflies	4	5	4.5	0.052					5	56	30.5	0.239
Corixidae	Water boatmen	3		1.5	0.017	1		0.5	0.026	3	2	2.5	0.020
Culicidae	Mosquitoes										1	0.5	0.004
Dytiscidae	Predaceous diving beetles	1		0.5	0.006								
Gerridae	Water striders									7		3.5	0.027
Gomphidae	Clubtail dragonflies												
Haliplidae	Crawling water beetles												
Hydrophilidae	Water scavenger beetles		1	0.5	0.006						1	0.5	0.004
Hydropsychidae	Net-spinning caddisflies	1		0.5	0.006								
Libelullidae	Skimmers (dragonflies)						1	0.5	0.026		1	0.5	0.004
Limnephilidae	Northern case makers												
Mesoveliidae	Water treaders										3	1.5	0.012
Stratiomyidae	Soldier flies		1	0.5	0.006					1	2	1.5	0.012
Synclita	Water-lily leafcutter moth										3	1.5	0.012
Annelida													
Hirudinea	Freshwater leeches					1		0.5	0.026				
Oligochaeta	Aquatic worms										25	12.5	0.098
Crustacea													
Hyalellidae	Amphipods	9	35	22	0.253								
Palaemonidae	Grass shrimp	7		3.5	0.040					1		0.5	0.004
Mollusca													
Ancylidae	Freshwater limpets	10		5	0.057	8		4	0.205				
Lymnacidae	Pond snails						1	0.5	0.026				
Physidae	Bladder snails	22	40	31	0.356	5	1	3	0.154	21	40	30.5	0.239
Pomatiopsidae	Freshwater snails		1	0.5	0.006								
Valvatidae	Valve snails		1	0.5	0.006								
Totals		**72**	**102**	**87**	**1.000**	**28**	**11**	**19.5**	**1.000**	**50**	**205**	**128**	**1.000**

Table F-20. Numbers of macro-invertebrates collected from Cell F-North between fall 2011 and summer 2012.

		Fall 2011				Spring 2012				Summer 2012			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Baetidae	Small minnow mayflies	1		0.5	0.005								
Belostomatidae	Giant water bugs									2		1	0.016
Caenidae	Small squaregill mayflies						3	1.5	0.103		3	1.5	0.024
Ceratopogonidae	Biting midges									1	2	1.5	0.024
Chironomidae	Midges	12	15	13.5	0.126	5	12	8.5	0.586	9	10	9.5	0.150
Coenagrionidae	Narrow-winged damselflies		23	11.5	0.107					1	1	1	0.016
Corixidae	Water boatmen	69	47	58	0.540								
Dytiscidae	Predaceous diving beetles									1		0.5	0.008
Ephydridae	Shore flies									1	2	1.5	0.024
Gerridae	Water striders						1	0.5	0.034				
Haliplidae	Crawling water beetles									1		0.5	0.008
Hydrophilidae	Water scavenger beetles									2		1	0.016
Libelullidae	Skimming dragonflies										2	1	0.016
Stratiomyidae	Soldier flies									1	1	1	0.016
Crustacea													
Hyalellidae	Amphipods										4	2	0.031
Palaemonidae	Grass shrimp									1		0.5	0.008
Mollusca													
Lymnacidae	Pond snails									25	5	15	0.236
Physidae	Bladder snails	15	30	22.5	0.209	2	5	3.5	0.241	12	29	20.5	0.323
Planorbidae	Ram's horn snails		3	1.5	0.014		1	0.5	0.034	3		1.5	0.024
Valvatidae	Valve snails									8		4	0.063
Totals		**97**	**118**	**108**	**1.000**	**7**	**22**	**14.5**	**1.000**	**68**	**59**	**63.5**	**1.000**

Table F-21. Numbers of macro-invertebrates collected from Cell F (West) between fall 2011 and summer 2012.

		Fall 2011				Spring 2012				Summer 2012			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
						Insecta							
Belostomatidae	Giant water bugs										1	0.5	0.009
Brachycentridae	Humpless case makers					1		0.5	0.009	2	2	2	0.037
Caenidae	Small squaregill mayflies		1	0.5	0.033	10	39	24.5	0.450	7	10	8.5	0.159
Ceratopogonidae	Biting midges					17		8.5	0.156				
Chironomidae	Midges		3	1.5	0.100	11	3	7	0.128	16	8	12	0.224
Coenagrionidae	Narrow-winged damselflies												
Corixidae	Water boatmen	7	12	9.5	0.633					5		2.5	0.047
Gerridae	Water striders										6	3	0.056
Gomphidae	Clubtails					8		4	0.073				
Haliplidae	Crawling water beetles									1		0.5	0.009
Hydroptilidae	Microcaddisflies									1		0.5	0.009
Libelullidae	Skimming dragonflies										1	0.5	0.009
Synclita	Water-lily leafcutter moth	1		0.5	0.033								
						Annelida							
Hirudinea	Freshwater leeches					1		0.5	0.009				
Oligochaeta	Aquatic worms					3		1.5	0.028	4		2	0.037
						Crustacea							
Hyalellidae	Amphipods						3	1.5	0.028				
						Mollusca							
Physidae	Bladder snails	5		2.5	0.167		5	2.5	0.046	19	22	20.5	0.383
Lymnacidae	Pond snails	1		0.5	0.033		7	3.5	0.064	2		1	0.019
Pomatiopsidae	Freshwater snails						1	0.5	0.009				
Totals		**14**	**16**	**15**	**1.000**	**51**	**58**	**54.5**	**1.000**	**57**	**50**	**53.5**	**1.000**

Table F-22. Numbers of macro-invertebrates collected from Cell F (East) between fall 2011 and summer 2012.

		Fall 2011				Spring 2012				Summer 2012			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
				Insecta									
Acrididae	Semi-aquatic grasshoppers						1	0.5	0.007				
Baetidae	Small minnow mayflies					1		0.5	0.007				
Belostomatidae	Giant water bugs									1	2	1.5	0.028
Brachycentridae	Humpless case makers					1		0.5	0.007	2		1	0.019
Caenidae	Small squaregill mayflies					25	5	15	0.197	19		9.5	0.179
Ceratopogonidae	Biting midges					2		1	0.013	2		1	0.019
Chironomidae	Midges		5	2.5	0.068	51	5	28	0.368	12		6	0.113
Coenagrionidae	Narrow-winged damselflies					1		0.5	0.007				
Corixidae	Water boatmen	15	25	20	0.548	15	7	11	0.145		7	3.5	0.066
Ephydridae	Shore flies		1	0.5	0.014								
Haliplidae	Crawling water beetles	1		0.5	0.014								
Hebridae	Velvet water bugs		1	0.5	0.014								
Hydrophilidae	Water scavenger beetles		2	1	0.027	2		1	0.013	1		0.5	0.009
Libelullidae	Skimmers (dragonflies)									1		0.5	0.009
				Annelida									
Oligochaeta	Aquatic worms						3	1.5	0.020				
				Crustacea									
Hyalellidae	Amphipods	3	17	10	0.274					3	7	5	0.094
Palaemonidae	Grass shrimp	3		1.5	0.041								
				Mollusca									
Ancylidae	Freshwater limpets					2		1	0.013				
Corbicula	Basket clams					12		6	0.079				
Physidae	Bladder snails					18		9	0.118	28	21	24.5	0.462
Planorbidae	Ram's horn snails					1		0.5	0.007				
Totals		**22**	**51**	**36.5**	**1.000**	**131**	**21**	**76**	**1.000**	**69**	**37**	**53**	**1.000**

Table F-23. Numbers of macro-invertebrates collected from Cell G between fall 2011 and summer 2012.

		Fall 2011				Spring 2012				Summer 2012			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Acrididae	Semi-aquatic grasshoppers									1	1	1	0.007
Aeshnidae	Hawker dragonflies		1	0.5	0.002						1	0.5	0.004
Baetidae	Small minnow mayflies	1	1	1	0.005								
Belostomatidae	Giant water bugs									15		7.5	0.056
Brachycentridae	Humpless case makers						1	0.5	0.007				
Caenidae	Small squaregill mayflies		3	1.5	0.007	4	21	12.5	0.163	2	12	7	0.052
Ceratopogonidae	Biting midges	2		1	0.005					2	1	1.5	0.011
Chironomidae	Midges	204	95	150	0.724	9	20	14.5	0.190	10	19	14.5	0.109
Coenagrionidae	Narrow-winged damselflies	2	18	10	0.048		7	3.5	0.046	7	1	4	0.030
Corixidae	Water boatmen						29	14.5	0.190		14	7	0.052
Dytiscidae	Predaceous diving beetles									3		1.5	0.011
Ephydridae	Shore flies									2		1	0.007
Gomphidae	Clubtails					1	1	1	0.013				
Haliplidae	Crawling water beetles										2	1	0.007
Hydrometridae	Marsh treaders									3	1	2	0.015
Hydrophilidae	Water scavenger beetles	1		0.5	0.002		10	5	0.065	6	2	4	0.030
Hydroptilidae	Microcaddisflies	9	6	7.5	0.036								
Libelullidae	Skimming dragonflies									5		2.5	0.019
Mesoveliidae	Water treaders										1	0.5	0.004
Pleidae	Pygmy backswimmer										1	0.5	0.004
Stratiomyidae	Soldier flies										1	0.5	0.004
Synclita	Water-lily leafcutter moth	4	6	5	0.024						1	0.5	0.004
Annelida													
Oligochaeta	Aquatic worms						3	1.5	0.020	17		8.5	0.064
Crustacea													
Hyalellidae	Amphipods						5	2.5	0.033	21	5	13	0.097
Palaemonidae	Grass shrimp										1	0.5	0.004
Mollusca													
Ancylidae	Freshwater Limpets										1	0.5	0.004
Corbicula	Basket clams						1	0.5	0.007		3	1.5	0.011
Lymnacidae	Pond snails					3		1.5	0.020				
Physidae	Bladder snails	26	34	30	0.145	5	21	13	0.170	69	36	52.5	0.393
Unionidae	Freshwater mussels					6	6	6	0.078				
Totals		**249**	**164**	**207**	**1.000**	**28**	**125**	**76.5**	**1.000**	**163**	**104**	**134**	**1.000**

Table F-24. Numbers of macro-invertebrates collected from Cell D between fall 2012 and summer 2013.

		Fall 2012				Spring 2013				Summer 2013			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
						Insecta							
Baetidae		1		0.5	0.020						1	0.5	0.012
Belostomatidae	Giant water bugs												
Caenidae	Small squaregill mayflies	1		0.5	0.020	5	11	8	0.084	2	3	2.5	0.059
Ceratopogonidae	Biting midges						5	2.5	0.026				
Chironomidae	Midges	20	14	17	0.667	32	40	36	0.379	10	15	12.5	0.294
Coenagrionidae	Narrow-winged damselflies	3	1	2	0.078	3		1.5	0.016	1	5	3	0.071
Corixidae	Water boatmen		1	0.5	0.020						1	0.5	0.012
Culicidae						1		0.5	0.005				
Gomphidae	Clubtail dragonflies					5	1	3	0.032				
Hydrometridae										2		1	0.024
Hydrophilidae	Water scavenger beetles						2	1	0.011				
Hydroptilidae	Microcaddisflies					2		1	0.011		2	1	0.024
Hymenoptera						1		0.5	0.005				
Libelullidae	Skimmers (dragonflies)					2		1	0.011				
Mesoveliidae							6	3	0.032		1	0.5	0.012
Synclita	Water-lily leafcutter moth					3		1.5	0.016	22		11	0.259
Veliidae	Broad-shouldered water striders					5		2.5	0.026	1		0.5	0.012
						Annelida							
Oligochaeta	Aquatic worms					13	50	31.5	0.332	3	2	2.5	0.059
						Mollusca							
Lymnacidae	Pond snails	1		0.5	0.020					1		0.5	0.012
Physidae	Bladder snails	3	6	4.5	0.176		3	1.5	0.016	8	5	6.5	0.153
Totals		**29**	**22**	**25.5**	**1**	**72**	**118**	**95**	**1**	**50**	**35**	**42.5**	**1**

Table F-25. Numbers of macro-invertebrates collected from Cell E between fall 2012 and summer 2013.

		Fall 2012				Spring 2013				Summer 2013			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Belostomatidae										1		0.5	0.017
Brachycentridae			1	0.5	0.005								
Caenidae	Small squaregill mayflies	2	19	10.5	0.100	2		1	0.021	2	2	2	0.067
Ceratopogonidae	Biting midges						1	0.5	0.010			0	0.000
Chironomidae	Midges	15	62	38.5	0.365	16	18	17	0.351	1	4	2.5	0.083
Coenagrionidae	Narrow-winged damselflies	5	5	5	0.047	1		0.5	0.010	1	2	1.5	0.050
Corixidae	Water boatmen	1		0.5	0.005	1		0.5	0.010	1		0.5	0.017
Haliplidae			2	1	0.009								
Hydrophilidae	Water scavenger beetles		1	0.5	0.005								
Hydroptilidae	Microcaddisflies		6	3	0.028						2	1	0.033
Hymenoptera	Parasitic wasps						4	2	0.041				
Mesoveliidae						1		0.5	0.010	1		0.5	0.017
Pleidae						1		0.5	0.010				
Stratiomyidae	Soldier flies									1		0.5	0.017
Annelida													
Oligochaeta		32	60	46	0.436	14	8	11	0.227		21	10.5	0.350
Mollusca													
Ancylidae	Freshwater limpets					3		1.5	0.031				
Lymnacidae	Pond snails									1	2	1.5	0.050
Physidae	Bladder snails					22	1	11.5	0.237	4	14	9	0.300
Planorbidae	Ram's horn snails					1	3	2	0.041				
Totals		**55**	**156**	**106**	**1**	**62**	**35**	**48.5**	**1**	**13**	**47**	**30**	**1**

Table F-26. Numbers of macro-invertebrates collected from Cell E-West between fall 2012 and summer 2013.

		Fall 2012				Spring 2013				Summer 2013			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
						Insecta							
Baetidae	Small Minnow Mayflies	1	1	1	0.024								
Caenidae	Small squaregill mayflies	6	14	10	0.238	3	3	3	0.062				
Chaoboridae	Phantom Midges		2	1	0.024								
Chironomidae	Midges	16	21	18.5	0.440	26	27	26.5	0.546	6	1	3.5	0.121
Coenagrionidae	Narrow-winged damselflies		4	2	0.048	4		2	0.041	1	4	2.5	0.086
Corixidae	Water boatmen	6	3	4.5	0.107	1		0.5	0.010				
Gerridae	Water Striders									2		1	0.034
Haliplidae	Crawling water beetles										1	0.5	0.017
Hydrophilidae	Water scavenger beetles		1	0.5	0.012		1	0.5	0.010				
Hydroptilidae			1	0.5	0.012		2	1	0.021				
Hymenoptera	Parasitic wasps										1	0.5	0.017
Libelullidae	Skimmers (dragonflies)										3	1.5	0.052
Mesoveliidae	Water Treaders										15	7.5	0.259
Naucoridae											1	0.5	0.017
Veliidae											1	0.5	0.017
						Annelida							
Oligochaeta	Aquatic worm	4	4	4	0.095	17	8	12.5	0.258		1	0.5	0.017
						Mollusca							
Lymnacidae	Pond snails									1		0.5	0.017
Physidae	Bladder snails						4	2	0.041	5	15	10	0.345
Valvatidae	Valve snails					1		0.5	0.010				
Totals		**33**	**51**	**42**	**1**	**52**	**45**	**48.5**	**1.000**	**15**	**43**	**29**	**1**

Table F-27. Numbers of macro-invertebrates collected from Cell F-North between fall 2012 and summer 2013.

		Fall 2012				Spring 2013				Summer 2013			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Aeshnidae	Darters						1	0.5	0.002				
Baetidae	Small Minnow Mayflies	2		1	0.012		4	2	0.010				
Belostomatidae	Giant water bugs					8		4	0.019				
Brachycentridae			1	0.5	0.006	6		3	0.014				
Caenidae	Small squaregill mayflies	23	53	38	0.458	1	11	6	0.029	2	1	1.5	0.031
Ceratopogonidae	Biting midges	1		0.5	0.006		6	3	0.014	1	10	5.5	0.115
Chaoboridae	Phantom midges						3	1.5	0.007				
Chironomidae	Midges	19	19	19	0.229	12	58	35	0.169	11	13	12	0.250
Coenagrionidae	Narrow-winged damselflies	2	8	5	0.060	24	7	15.5	0.075				
Cordulidae			2	1	0.012						1	0.5	0.010
Corixidae	Water boatmen	1	1	1	0.012								
Culicidae						1	1	1	0.005				
Dolichopodidae											5	2.5	0.052
Gerridae	Water Striders					1		0.5	0.002				
Haliplidae	Crawling water beetles		1	0.5	0.006								
Hydrophilidae	Water scavenger beetles					3		1.5	0.007	2	5	3.5	0.073
Hydroptilidae		3	2	2.5	0.030		2	1	0.005				
Hymenoptera	Parasitic wasps					4		2	0.010				
Libelullidae	Skimming dragonflies		5	2.5	0.030		5	2.5	0.012				
Mesoveliidae						3		1.5	0.007				
Notonectidae	Backswimmer					3		1.5	0.007				
Pleidae							1	0.5	0.002				
Stratiomyidae	Soldier flies						4	2	0.010		4	2	0.042
Synclita		2		1	0.012	13	1	7	0.034				
Veliidae	Water skimmers					2	2	2	0.010		1	0.5	0.010
Annelida													
Oligochaeta		8	9	8.5	0.102	57	113	85	0.410	1	23	12	0.250
Mollusca													
Ancylidae						2		1	0.005				
Lymnacidae	Pond snails										1	0.5	0.010
Physidae	Bladder snails		4	2	0.024	23	33	28	0.135	5	10	7.5	0.156
Totals		**61**	**105**	**83**	**1**	**163**	**252**	**208**	**1**	**22**	**74**	**48**	**1**

Table F-28. Numbers of macro-invertebrates collected from Cell F (West) between fall 2012 and summer 2013.

		Fall 2012				Spring 2013				Summer 2013			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Caenidae	Small squaregill mayflies	34	22	28	0.263	7	11	9	0.124				
Ceratopogonidae	Biting midges					2		1	0.014		1	0.5	0.018
Chironomidae	Midges	8	37	22.5	0.211	14	9	11.5	0.159	11	1	6	0.211
Coenagrionidae	Narrow-winged damselflies	1	7	4	0.038		1	0.5	0.007		1	0.5	0.018
Corixidae	Water boatmen	1	5	3	0.028								
Hydrophilidae		1	1	1	0.009	1		0.5	0.007				
Haliplidae	Crawling water beetles						2	1	0.014				
Hydroptilidae	Microcaddisflies	1		0.5	0.005		2	1	0.014	1	1	1	0.035
Mesoveliidae										1		0.5	0.018
Nepidae						1		0.5	0.007				
Stratiomyidae						2		1	0.014				
Synclita	Water-lily leafcutter moth										1	0.5	0.018
Veliidae											1	0.5	0.018
Annelida													
Oligochaeta	Aquatic worms	73	17	45	0.423	47	35	41	0.566	11		5.5	0.193
Mollusca													
Physidae	Bladder snails					5	6	5.5	0.076	8	12	10	0.351
Lymnacidae	Pond snails	5		2.5	0.023					7		3.5	0.123
Totals		**124**	**89**	**107**	**1**	**79**	**66**	**72.5**	**1**	**39**	**18**	**28.5**	**1**

Table F-29. Numbers of macro-invertebrates collected from Cell F (East) between fall 2012 and summer 2013.

		Fall 2012				Spring 2013				Summer 2013			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
						Insecta							
Baetidae	Small minnow mayflies	2		1	0.007	2	1	1.5	0.013				
Belostomatidae	Giant water bugs					1		0.5	0.004				
Caenidae	Small squaregill mayflies		28	14	0.104	22	12	17	0.150		2	1	0.020
Chironomidae	Midges	42	29	35.5	0.264	3	5	4	0.035	3	4	3.5	0.071
Coenagrionidae	Narrow-winged damselflies	5	7	6	0.045	2		1	0.009				
Corixidae	Water boatmen	1	11	6	0.045	5	1	3	0.026				
Gomphidae						4	1	2.5	0.022				
Haliplidae	Crawling water beetles		2	1	0.007								
Hydracarina	Water Mite					4		2	0.018				
Hydrophilidae	Water scavenger beetles	1		0.5	0.004	1	3	2	0.018				
Hymenoptera	Parasitic wasps					1		0.5	0.004				
Libelullidae	Skimmers (dragonflies)					2		1	0.009		1	0.5	0.010
Mesoveliidae						9		4.5	0.040				
Stratiomyidae		1		0.5	0.004								
Veliidae										1	50	25.5	0.515
						Annelida							
Oligochaeta	Aquatic worms	43	95	69	0.513	116	8	62	0.546		10	5	0.101
						Mollusca							
Physidae		2		1	0.007	24		12	0.106	8	20	14	0.283
Totals		**97**	**172**	**135**	**1**	**196**	**31**	**114**	**1**	**12**	**87**	**49.5**	**1.000**

Table F-30. Numbers of macro-invertebrates collected from Cell G between fall 2012 and summer 2013.

		Fall 2012				Spring 2013				Summer 2013			
Taxa	**Common name**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**	**I**	**O**	**M**	**Mf**
Insecta													
Baetidae	Small minnow mayflies	1		0.5	0.014								
Brachycentridae	Humpless case makers						1	0.5	0.004				
Caenidae	Small squaregill mayflies	1		0.5	0.014	1	12	6.5	0.047	1	8	4.5	0.167
Chaoboridae										1		0.5	0.019
Ceratopogonidae	Biting Midges					1	1	1	0.007	1		0.5	0.019
Chironomidae	Midges	39	9	24	0.676	5	13	9	0.066	1	9	5	0.185
Coenagrionidae	Narrow-winged damselflies					3		1.5	0.011	3		1.5	0.056
Cordulidae											1	0.5	0.019
Corixidae	Water boatmen		2	1	0.028								
Haliplidae	Crawling water beetles					3		1.5	0.011		2	1	0.037
Hydrometridae	Marsh Treaders					1		0.5	0.004			0	0.000
Hydrophilidae	Water scavenger beetles					2		1	0.007	8	1	4.5	0.167
Hydroptilidae	Microcaddisflies					1	1	1	0.007				
Libelullidae	Skimming dragonflies					1		0.5	0.004				
Mesoveliidae	Water Treaders					1		0.5	0.004		1	0.5	0.019
Stratiomyidae	Soldier flies									1	1	1	0.037
Annelida													
Oligochaeta	Aquatic worms					87	109	98	0.715	3	4	3.5	0.130
Mollusca													
Lymnacidae	Pond snails	19		9.5	0.268		27	13.5	0.099	3	4	3.5	0.130
Physidae	Bladder snails					4		2	0.015				
Planorbidae											1	0.5	0.019
Totals		**60**	**11**	**35.5**	**1**	**110**	**164**	**137**	**1**	**22**	**32**	**27**	**1.000**

Appendix G

Dallas Floodway Extension

Establishment, monitoring, and adaptive management of native aquatic vegetation and adjacent native grasslands; and monitoring aquatic organism utilization of project aquatic features:

Grasslands

Table G-1. Percent cover of grassland plants identified at the LCOW in 2010 – 2014; excludes Linfield Landfill. Status: I = Introduced, N = native, NS = native seeded, P = planted, D = desirable, A = acceptable, and U = undesirable.

Scientific Name	Common name	Status	*Percent cover* 2010			*Percent cover* 2011			*Percent cover* 2012			*Percent cover* 2013			*Percent cover* 2014		
			D	A	U	D	A	U	D	A	U	D	A	U	D	A	U
Acer negundo	Box elder	N						0.03									
Acmella decumbens	Creeping spotflower	N				0.04											
Agalinis sp.	Foxglove	N	0.35														
Allium drummondii	Drummond's onion	N	0.10			0.01			0.04						0.01		
Alternanthera philoxeroides	Alligatorweed	I			0.06			0.97			1.36			0.38			0.26
Amaranthus sp.	Amaranth	N	0.85			0.09			0.57			0.32			0.35		
Ambrosia artemisiifolia	Common ragweed	N					0.04										
Ambrosia trifida	Giant ragweed	N			25.30			11.60			3.19			4.03			2.12
Amphiachyris dracunculoides	Prairie broomweed	N				0.01											
Andropogon gerardii	**Big bluestem**	**NS/P**				**0.01**											
Argemone polyanthemos	Prickly poppy	N										0.02					
Aster sp.	Aster	N				0.24											
Avena fatua	Wild oat	I					0.13			0.03			0.03			0.52	
Baccharis halimifolia	Eastern baccharis	N						0.12									
Bifora americana	Prairie bishop	N				0.02			<0.01						0.02		
Bouteloua curtipendula	**Sideoats grama**	**NS**	**0.11**			**0.88**			**0.07**			**<0.01**					
Bouteloua dactyloides	Buffalograss	N				0.96			0.19			0.95					
Bromus catharticus	Rescuegrass	I					0.03			0.33			0.04			0.16	
Bromus japonicus	Japanese brome	I					0.06						0.73			1.26	
Bromus sp.	Brome	I						0.14									
Bromus tectorum	Cheat grass	I									1.20			0.30			0.41
Calyptocarpus vialis	Straggler daisy	I											0.08				
Cardiospermum halicacabum	Balloonvine	I		0.42			0.06			0.07			0.45			0.06	
Carduus nutans	Nodding thistle	I									0.06			0.25			
Carex cherokeensis	Cherokee sedge	N	0.59			0.77									0.24		
Carex crus-corvi	Crow's food sedge	N				0.49			0.93			0.20			1.54		
Carex festucacea	Fescue sedge	N	0.02			0.01						0.01					
Carex sp.	Sedge	N				0.30			1.61			2.83			0.01		

Scientific Name	Common name	Status	*Percent cover*			*Percent cover*			*Percent cover*			*Percent cover*			*Percent cover*		
			2010			**2011**			**2012**			**2013**			**2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Celtis laevigata	Sugarberry	N			0.10			0.01									
Centaurea americana	**Basketflower**	**NS**										**0.42**			**0.01**		
Chamaecrista fasciculata	**Partridge pea**	**NS**	**0.07**									**0.06**					
Chamaesyce serpens	Matted sandmat	N										**<0.01**					
Chasmanthium latifolium	Inland seaoats	N				0.01											
Chenopodium album	Lambsquarters	I					<0.01										
Cirsium texanum	Texas thistle	N	0.01														
Cirsium vulgare	Common thistle														0.07		
Conyza canadensis	Canadian horseweed	N	0.54			0.19						0.03			2.54		
Coreopsis tinctoria	**Plains coreopsis**	**NS**	**0.68**			**2.21**			**1.52**			**2.72**			**0.28**		
Croton texensis	Texas croton	N							0.15						0.03		
Cyclachaena xanthifolia	Giant sumpweed	N				0.01											
Cynodon dactylon	Bermudagrass	I			5.23			5.55			2.12			8.90			7.26
Cyperus erythrorhizos	Umbrella sedge	N										0.01			0.14		
Cyperus esculentus	Yellow nutsedge	N				0.26			0.04			1.47			6.57		
Cyperus sp.	Cyperus	N	1.40									0.20					
Daucus carota	Queen Anne's lace	I					0.17										
Desmanthus illinoensis	**Illinois bundle flower**	**NS**	**0.93**			**0.94**			**2.36**			**4.27**			**4.83**		
Dichondra carolinensis	Carolina ponysfoot	N										0.13					
Digitaria ischaemum	Smooth crabgrass	I		0.67			<0.01										
Dracopis amplexicaulis	**Clasping coneflower**	**NS**	**3.09**			**4.96**			**5.40**			**4.51**			**4.31**		
Echinochloa colona	Junglerice	I		2.76													
Echinochloa crus-galli	Barnyardgrass	I		0.19			0.18									0.57	
Eleocharis acicularis	Needle spikerush	N	0.16														
Eleocharis palustris	Flatstem spikerush	N	0.08									0.14					
Eleocharis quadrangulata	Squarestem spikerush	N										0.33					
Eleocharis sp.	Spikerush	N				0.76			0.61			0.85			1.90		
Eleusine indica	Goosegrass	I					0.05			0.33							
Elymus canadensis	**Canada wildrye**	**NS**	**0.41**			**0.05**											

Scientific Name	Common name	Status	*Percent cover* 2010			*Percent cover* 2011			*Percent cover* 2012			*Percent cover* 2013			*Percent cover* 2014		
			D	A	U	D	A	U	D	A	U	D	A	U	D	A	U
Elymus virginicus	Virginia wildrye	N	1.53			3.81						5.26			2.26		
Engelmannia pinnatifida	**Cutleaf daisy**	**NS**				**0.02**						**0.04**					
Erodium cicutarium	Redstem stork's bill	I					1.37			0.43			0.02			0.02	
Euphorbia sp.	Spurge	N	0.05						0.04			0.03			0.09		
Fraxinus pennsylvanica	Green ash	N						0.61									
Gaillardia pulchella	**Firewheel**	**NS**	**0.01**			**0.07**			**<0.01**						**0.17**		
Galium sp.	Bedstraw	N				0.01											
Gaura parviflora	Velvetweed	N										0.06					
Gaura sp.	Beeblossom	N				0.30											
Geranium carolinianum	Wild geranium	N										0.19					
Glandularia bipinnatifida	Dakota mock vervain	N	0.02														
Grindelia papposa	Wax goldenweed	N	0.01			0.02			0.02			0.00			0.01		
Helenium microcephalum	Smallheaded sneezeweed	N										0.01			0.01		
Helianthus annuus	Common sunflower	N	0.01			0.04			0.07						0.03		
Helianthus maximiliani	**Maximilian sunflower**	**NS/P**				**0.24**			**<0.01**								
Heterotheca subaxillaris	Camphorweed	N							0.45								
Hordeum pusillum	Little barley	N				0.23			0.32						1.32		
Hydrocotyle umbellata	Manyflower marshpennywort	N										0.10					
Ipomoea lacunosa	Whitestar	N										0.47			1.31		
Ipomoea purpurea	Tall morning glory	I		0.02			0.15			0.17			0.12			0.61	
Ipomoea sp.	Morning glory	I											0.84				
Ipomoea wrightii	Wright's morning-glory	I					0.05						0.52			0.12	
Iva annua	Marsh-elder	N	1.02			2.75			1.13			2.48			1.77		
Juncus sp.	Rush	N	0.15			0.44			0.23								
Koeleria macrantha	Prairie Junegrass	N				0.04											
Lactuca serriola	Prickly lettuce	I			0.77												
Lathyrus hirsutus	Caley pea	I					1.71			0.45			0.20			4.66	
Lepidium austrinum	Pepperwort	N				0.05			0.16						0.76		
Lepidium virginicum	Virginia pepper-grass	N				1.06			0.04			1.17					

Scientific Name	Common name	Status	*Percent cover*			*Percent cover*			*Percent cover*			*Percent cover*			*Percent cover*		
			2010			2011			2012			2013			2014		
			D	A	U	D	A	U	D	A	U	D	A	U	D	A	U
Limnodea arkansana	Ozarkgrass	N							0.28								
Lippia nodiflora	Turkey tangle frogfruit	N	1.67			0.92			2.74			2.45			2.92		
Lolium perenne	Ryegrass	I		3.12			10.40			20.20			11.92			8.81	
Ludwigia peploides	Creeping water primrose	N	0.06			5.55											
Ludwigia sp.	Water primrose	N				0.02			0.04			0.20			0.03		
Lycopus americanus	American water-horehound	N				0.21											
Medicago orbicularis	Button medic	I		0.17			0.77						0.01			0.47	
Medicago polymorpha	Burclover	I					2.46									0.13	
Melilotus officinalis	Yellow sweetclover	I		2.26			0.19			0.06			0.02				
Monarda citriodora	**Lemon beebalm**	**NS**	**0.04**									**0.01**					
Morus sp.	Mulberry	N			0.04												
Neptunia lutea	Yellowpuff	N							0.01								
Oenothera speciosa	**Pink evening primrose**	**NS**				**3.29**			**8.82**			**6.10**			**3.41**		
Oxalis stricta	Common yellow oxalis	N										0.39			0.07		
Panicum capillare	Witchgrass	N										0.10					
Panicum coloratum	Kleingrass	I			0.19												
Panicum virgatum	**Switchgrass**	**NS/P**	**0.06**			**0.74**			**0.90**			**0.55**			**1.24**		
Parthenocissus quinquefolia	Virginia creeper	N		0.04													
Paspalum dilatatum	Dallisgrass	I											0.80				
Paspalum distichum	Knotgrass	N	1.34						0.53						0.31		
Phalaris canariensis	Annual canarygrass	I						1.90			2.68			1.29			
Phyllanthus polygonoides	Knotweed leaf-flower	N	1.05			0.36											
Physalis angulata	Ground cherry	N							<0.01								
Physostegia intermedia	**Obedient plant**	**NS**	**0.07**						**0.10**								
Pluchea sp.	Camphor weed														0.01		
Polygonum hydropiperoides	Swamp smartweed	N	0.12														
Polygonum lapathifolium	Willow smartweed	N	0.70														
Polygonum pennsylvanica	Pink smartweed	N	0.85														

Scientific Name	Common name	Status	Percent cover 2010			Percent cover 2011			Percent cover 2012			Percent cover 2013			Percent cover 2014		
			D	A	U	D	A	U	D	A	U	D	A	U	D	A	U
Polygonum sp.	Smartweed	N	0.23			1.31			0.18			2.54			0.35		
Populus deltoides	Cottonwood	N			0.20			0.04									
Pyrrhopappus pauciflorus	Texas dandelion	N				0.61			1.23			0.34			0.08		
Ranunculus macounii	Buttercup	N				1.01			0.26								
Rapistrum rugosum	Annual bastardcabbage	I												0.07			
Ritibida columnifera	Mexican hat														0.04		
Rosa sp.	Rose	N									0.06						
Rubus sp.	Dewberry	N				0.01						0.39			0.36		
Rudbeckia hirta	**Blackeyed Susan**	**NS**	**0.02**														
Rumex crispus	Curly dock	I		1.01			1.26			1.84			2.41			1.74	
Salix nigra	Black willow	N			0.31			0.17						0.01			0.76
Salvia azurea	**Azure blue sage**	**NS**				**0.06**			**0.01**								
Schizachyrium scoparium	Little bluestem														0.02		
Schoenoplectus pungens	American bulrush	N	0.05														
Secale cereale	Rye	I		9.47			0.01			2.04			0.10				
Sesbania herbacea	Coffee-bean sesbania	N	0.14			0.01			0.30						0.08		
Setaria parviflora	Knotroot bristlegrass	N	0.30									0.21					
Setaria viridis	Green bristle grass	I		0.21												0.30	
Sium suave	Water parsnip														0.21		
Smilax sp.	Green briar	N	0.16			0.20						0.10			0.21		
Solanum elaeagnifolium	Silver-leaf nightshade	N	0.02			0.02						0.08			0.14		
Solidago sp.	Goldenrod	N				0.04											
Sonchus sp.	Sowthistle	I					0.61			1.03			0.61			1.20	
Sorghum halepense	Johnsongrass	I			2.09			2.97			4.69			5.51			5.67
Symphyotrichum subulatum	Slim aster	N	5.16			6.35			3.71			0.67			0.10		
Tetragonotheca ludoviciana	Louisiana nerveray	N	0.10														
Torilis arvensis	Spreading hedgeparsley	I		1.10			2.67			3.13			4.57			3.42	
Toxicodendron radicans	Poison Ivy	N		0.06												0.03	

Tragia sp.	Noseburn	N				0.01			<0.01								
Scientific Name	**Common name**	**Status**	***Percent cover***			***Percent cover***			***Percent cover***			***Percent cover***			***Percent cover***		
			2010			**2011**			**2012**			**2013**			**2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Tridens albescens	White tridens	N										0.01			0.20		
Tridens sp.	Fluffgrass	N				0.09			0.07								
Tridens texanus	Texas fluffgrass	N	0.41														
Trifolium sp.	Clover	N										<0.01					
Triodanis sp.	Venus' looking-glass	N				0.04											
Tripsacum dactyloides	**Eastern gamagrass**	**NS/P**				**0.02**			**0.59**			**1.30**			**0.66**		
Typha latifolia	Cattail	N					0.01										
Ulmus spp.	Elm										0.24			0.91			0.77
Verbena halei	Texas vervain	N										0.08					
Vicia sp.	Vetch	I					0.43										
Viola missouriensis	Missouri violet	N	0.04														
Vitis mustangensis	Mustang grape	N											0.08				
Xanthium strumarium	Cocklebur	N	0.23			0.01						0.01			0.07		
Total			**25.0**	**21.5**	**34.3**	**43.2**	**22.8**	**24.1**	**35.7**	**30.1**	**15.6**	**44.8**	**23.6**	**21.7**	**41.0**	**24.1**	**17.3**
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Bare			**17.6**			**10.9**			**18.3**			**7.84**			**15.7**		
Unknown			**1.54**			**0.01**						**1.98**			**1.37**		
Total number of species			**70**			**94**			**64**			**82**			**70**		

Table G-2. Frequencies of grassland plants identified at the LCOW in 2010 – 2014; excludes Linfield Landfill. Status: I = Introduced, N = native, NS = native seeded, P = planted, D = desirable, A = acceptable and U = undesirable.

Species	**Common name**	**Status**	**Frequency**			**Frequency**			**Frequency**			**Frequency**			**Frequency**		
			2010			**2011**			**2012**			**2013**			**2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Acer negundo	Box elder	N						0.43									
Acmella decumbens	Creeping spotflower	N				0.29											
Agalinis sp.	Foxglove	N	0.73														
Allium drummondii	Drummond’s onion	N	0.15			0.18			0.53						0.14		
Alternanthera philoxeroides	Alligatorweed	I			0.31			0.58			2.08			0.78			0.28
Amaranthus sp.	Amaranth	N	1.23			0.48			0.91			1.53			0.57		
Ambrosia artemisiifolia	Common ragweed	N					0.13										
Ambrosia trifida	Giant ragweed	N			13.47			6.52			2.80			3.08			1.71
Amphiachyris dracunculoides	Prairie broomweed	N				0.18											
Andropogon gerardii	**Big bluestem**	**NS/P**				**0.18**											
Argemone polyanthemos	Prickly poppy	N										0.13					
Aster sp.	Aster	N				0.32											
Avena fatua	Wild oat	I					0.04			0.26			0.33			0.85	
Baccharis halimifolia	Eastern baccharis	N						0.42									
Bifora americana	Prairie bishop	N				0.26			0.08						0.28		
Bouteloua curtipendula	**Sideoats grama**	**NS**	**0.28**			**0.13**			**0.34**			**0.05**					
Bouteloua dactyloides	Buffalograss	N				0.73			0.35			0.49					
Bromus catharticus	Rescuegrass	I					0.57			1.24			0.23			0.28	
Bromus japonicus	Japanese brome	I					0.23						0.79			1.14	
Bromus sp.	Brome	I						0.30									
Bromus tectorum	Cheat grass	I									0.41			0.14			0.28
Calyptocarpus vialis	Straggler daisy	I											0.13				
Cardiospermum halicacabum	Balloonvine	I		1.96			0.60			0.99			1.00			0.57	

Species	**Common name**	**Status**	**Frequency 2010**			**Frequency 2011**			**Frequency 2012**			**Frequency 2013**			**Frequency 2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Carduus nutans	Nodding thistle	I									0.34			0.33			
Carex cherokeensis	Cherokee sedge	N	0.24			0.84									0.43		
Carex crus-corvi	Crow's food sedge	N				0.69			1.14			0.54			2.42		
Carex festucacea	Fescue sedge	N	0.23			0.18						0.13					
Carex sp.	Sedge	N				1.74			4.19			3.65			0.14		
Celtis laevigata	Sugarberry	N			0.41			0.05									
Centaurea americana	**Basketflower**	**NS**										**0.13**			**0.14**		
Chamaecrista fasciculate	**Partridge pea**	**NS**	**0.19**									**0.56**					
Chamaesyce serpens	Matted sandmat	N										0.05					
Chasmanthium latifolium	Inland seaoats	N				0.23											
Chenopodium album	Lambsquarters	I					0.04										
Cirsium texanum	Texas thistle	N	0.20														
Cirsium vulgare	Common thistle	N													0.14		
Conyza canadensis	Canadian horseweed	N	1.28			0.95						0.33			4.13		
Coreopsis tinctoria	**Plains coreopsis**	**NS**	**1.86**			**2.20**			**2.21**			**2.24**			**0.14**		
Croton texensis	Texas croton	N							0.49						0.14		
Cyclachaena xanthifolia	Giant sumpweed	N				0.13											
Cynodon dactylon	Bermudagrass	I			3.38			2.82			2.53			4.43			2.42
Cyperus erythrorhizos	Umbrella sedge	N										0.15			0.14		
Cyperus esculentus	Yellow nutsedge	N				0.40			1.06			4.26			8.40		
Cyperus sp.	Cyperus	N	2.52									0.48					
Daucus carota	Queen Anne's lace	I					0.13										
Desmanthus illinoensis	**Illinois bundle flower**	**NS**	**2.52**			**1.98**			**4.43**			**4.44**			**5.56**		
Dichondra carolinensis	Carolina ponysfoot	N										0.06					
Digitaria ischaemum	Smooth crabgrass	I		0.50			0.04										
Dracopis amplexicaulis	**Clasping coneflower**	**NS**	**5.34**			**7.29**			**4.53**			**3.91**			**5.56**		

Species	**Common name**	**Status**	**Frequency**			**Frequency**			**Frequency**			**Frequency**			**Frequency**		
			2010			**2011**			**2012**			**2013**			**2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Echinochloa colona	Junglerice	I		3.19													
Echinochloa crus-galli	Barnyardgrass	I		0.39			0.62									1.42	
Eleocharis acicularis	Needle spikerush	N	0.34														
Eleocharis palustris	Flatstem spikerush	N	0.24									0.16					
Eleocharis quadrangulata	Squarestem spikerush	N										0.29					
Eleocharis sp.	Spikerush	N				0.59			0.41			0.28			0.85		
Eleusine indica	Goosegrass	I					0.04			0.30							
Elymus canadensis	**Canada wildrye**	**NS**	**0.48**			**0.23**											
Elymus virginicus	Virginia wildrye	N	4.12			5.25						7.08			5.98		
Engelmannia pinnatifida	**Cutleaf daisy**	**NS**				**0.04**						**0.05**					
Erodium cicutarium	Redstem stork's bill	I					3.06			1.04			0.05			0.28	
Euphorbia sp.	Spurge	N	0.21						0.23			0.21			1.14		
Fraxinus pennsylvanica	Green ash	N						0.22									
Gaillardia pulchella	**Firewheel**	**NS**	**0.07**			**0.09**			**0.11**						**0.14**		
Galium sp.	Bedstraw	N				0.13											
Gaura parviflora	Velvetweed	N										0.14					
Gaura sp.	Beeblossom	N				0.40											
Geranium carolinianum	Wild geranium	N										0.58					
Glandularia bipinnatifida	Dakota mock vervain	N	0.07														
Grindelia papposa	Wax goldenweed	N	0.18			0.04			0.11			0.05			0.14		
Helenium microcephalum	Smallheaded sneezeweed	N										0.11			0.14		
Helianthus annuus	Common sunflower	N	0.07			0.04			0.36						0.14		
Helianthus maximiliani	**Maximilian sunflower**	**NS/P**				**0.04**			**0.11**								
Heterotheca subaxillaris	Camphorweed	**N**							0.25								
Hordeum pusillum	Little barley	N				1.61			1.59						2.85		
Hydrocotyle umbellata	Manyflower marshpennywort	N										0.13					

Species	**Common name**	**Status**	**Frequency 2010**			**Frequency 2011**			**Frequency 2012**			**Frequency 2013**			**Frequency 2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Ipomoea lacunosa	Whitestar	N										0.84			1.42		
Ipomoea purpurea	Tall morning glory	I		0.21			0.79			0.91			0.05			0.85	
Ipomoea sp.	Morning glory	I											1.49				
Ipomoea wrightii	Wright's morning-glory	I					0.59						0.64			0.71	
Iva annua	Marsh-elder	N	0.45			2.93			1.18			2.40			2.85		
Juncus sp.	Rush	N	1.04			0.74			0.55								
Koeleria macrantha	Prairie Junegrass	N				0.36											
Lactuca serriola	Prickly lettuce	I			1.61												
Lathyrus hirsutus	Caley pea	I					1.29			0.59			0.97			2.99	
Lepidium austrinum	Pepperwort	N				0.19			0.43						1.42		
Lepidium virginicum	Virginia pepper-grass	N				1.04			0.16			1.76					
Limnodea arkansana	Ozarkgrass	N							0.76								
Lippia nodiflora	Turkey tangle frogfruit	N	2.05			1.18			2.06			2.57			1.99		
Lolium perenne	Ryegrass	I		4.17			9.94			15.24			8.35			6.84	
Ludwigia peploides	Creeping water primrose	N	0.13			2.21											
Ludwigia sp.	Water primrose	N				0.10			0.25			0.11			0.14		
Lycopus americanus	American water-horehound	N				0.35											
Medicago orbicularis	Button medic	I		0.21			0.66						0.11			1.00	
Medicago polymorpha	Burclover	I					0.52									0.71	
Melilotus officinalis	Yellow sweetclover	I		2.02			0.35			1.09			0.43				
Monarda citriodora	**Lemon beebalm**	**NS**	**0.13**									**0.06**					
Morus sp.	Mulberry	N			0.13												
Neptunia lutea	Yellowpuff	N							0.15								
Oenothera speciosa	**Pink evening primrose**	**NS**				**3.02**			**5.89**			**5.56**			**4.27**		
Oxalis stricta	Common yellow oxalis	N										0.81			0.71		

Species	**Common name**	**Status**	**Frequency 2010**			**Frequency 2011**			**Frequency 2012**			**Frequency 2013**			**Frequency 2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Panicum capillare	Witchgrass	N										0.15					
Panicum coloratum	Kleingrass	I			0.75												
Panicum virgatum	**Switchgrass**	**NS/P**	**0.31**			**0.66**			**1.53**			**0.54**			**0.71**		
Parthenocissus quinquefolia	Virginia creeper	N		0.13													
Paspalum dilatatum	Dallisgrass	I											0.44				
Paspalum distichum	Knotgrass	N	0.75						1.13						0.14		
Phalaris canariensis	Canarygrass	I						3.34			4.21			3.51			
Phyllanthus polygonoides	Knotweed leaf-flower	N	2.24			0.74											
Physalis angulata	Ground cherry	N							0.08								
Physostegia intermedia	**Obedient plant**	**NS**	**0.14**						**0.25**								
Pluchea sp.	Camphor weed	N													0.13		
Polygonum hydropiperoides	Swamp smartweed	N	0.07														
Polygonum lapathifolium	Willow smartweed	N	1.40														
Polygonum pennsylvanica	Pink smartweed	N	2.31														
Polygonum sp.	Smartweed	N	0.38			2.03			1.28			2.46			0.57		
Populus deltoides	Cottonwood	N			0.57			0.10									
Pyrrhopappus pauciflorus	Texas dandelion	N				1.90			2.84			0.83			0.39		
Ranunculus macounii	Buttercup	N				0.92			0.49								
Rapistrum rugosum	Annual bastardcabbage	I												0.11			
Ritibida columnifera	Mexican hat	N													0.28		
Rosa sp.	Rose	N									0.16						
Rubus sp.	Dewberry	N				0.18						0.15			0.28		
Rudbeckia hirta	**Blackeyed Susan**	**NS**	**0.07**														
Rumex crispus	Curly dock	I		4.30			2.97			4.92			3.05			3.99	
Salix nigra	Black willow	N			0.78			0.49						0.15			0.28

Species	**Common name**	**Status**	**Frequency 2010**			**Frequency 2011**			**Frequency 2012**			**Frequency 2013**			**Frequency 2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Salvia azurea	**Azure blue sage**	**NS**				**0.22**			**0.11**								
Schizachyrium scoparium	Little bluestem	N													0.14		
Schoenoplectus pungens	American bulrush	N	**0.10**														
Secale cereale	Rye	I		6.42			0.13			4.76			0.26				
Sesbania herbacea	Coffee-bean sesbania	N	0.53			0.25			0.25						0.43		
Setaria parviflora	Knotroot bristlegrass	N	1.92									0.20					
Setaria viridis	Green bristle grass	I		0.49												0.71	
Sium suave	Water parsnip	N													0.14		
Smilax sp.	Green briar	N	0.13			0.10						0.15			0.14		
Solanum elaeagnifolium	Silver-leaf nightshade	N	0.07			0.04						0.10			0.43		
Solidago sp.	Goldenrod	N				0.10											
Sonchus sp.	Sowthistle	I					2.11			2.66			1.99			3.99	
Sorghum halepense	Johnsongrass	I			2.63			3.07			3.34			4.49			4.13
Symphyotrichum subulatum	Slim aster	N	5.68			4.69			3.33			2.56			0.28		
Tetragonotheca ludoviciana	Louisiana nerveray	N	0.35														
Torilis arvensis	Spreading hedgeparsley	I		1.62			3.12			3.36			3.14			3.85	
Toxicodendron radicans	Poison Ivy	N		0.41												0.14	
Tragia sp.	Noseburn	N				0.18			0.11								
Tridens albescens	White tridens	N										0.14			0.71		
Tridens sp.	Fluffgrass	N				0.25			0.33								
Tridens texanus	Texas fluffgrass	N	1.12														
Trifolium sp.	Clover	N										0.05					
Triodanis sp.	Venus' looking-glass	N				0.54											
Tripsacum dactyloides	**Eastern gamagrass**	**NS/P**				**0.25**			**0.49**			**0.39**			**0.57**		
Typha latifolia	Cattail	N					0.22										
Ulmus spp.	Elm	N									0.25			1.00			0.71

Verbena halei	Texas vervain	N										0.13					
Species	**Common name**	**Status**	**Frequency**			**Frequency**			**Frequency**			**Frequency**			**Frequency**		
			2010			**2011**			**2012**			**2013**			**2014**		
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Vicia sp.	Vetch	I					0.26										
Viola missouriensis	Missouri violet	N	0.21														
Vitis mustangensis	Mustang grape	N											0.05				
Xanthium strumarium	Cocklebur	N	0.70			0.10						0.06			0.14		
Total			**44.8**	**26.0**	**24.0**	**53.1**	**28.5**	**18.3**	**47.1**	**37.4**	**16.1**	**54.2**	**23.5**	**18.0**	**58.0**	**30.3**	**9.8**
			D	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**	**D**	**A**	**U**
Unknown			**5.08**			**0.08**			**0.0**			**3.75**			**2.40**		
Total number of species			**70**			**94**			**64**			**82**			**70**		

Table G-3. Grassland species observed during meander surveys conducted fall 2012, 2013 and 2014. Status: N = native; NS = native seeded, P = planted; I = introduced. Category: U = undesirable; A = Acceptable; D = desirable.

Scientific Name	Common name	Status	Category	2012	2013	2014
Amaranthus sp.	Amaranth	N	D	x	x	x
Allium drummondii	Drummond's onion	N	D	x		x
Ambrosia artemisiifolia	Common ragweed	N	A	x	x	x
Ambrosia trifida	Giant ragweed	N	U	x	x	x
Andropogon gerardii	Big bluestem	NS/P	D	x	x	x
Andropogon glomeratus	Bushy bluestem	N/P	D		x	
Aristida sp.	Three awn grasses	N	D	x		
Bothriochloa ischaemum	Yellow bluestem	I	A	x	x	x
Bouteloua curtipendula	Sideoats grama	NS	D	x	x	x
Bouteloua dactyloides	Buffalograss	NS/P	D	x	x	x
Callirhoe involucrata	Winecup	NP	D		x	x
Cardiospermum halicacabum	Balloon vine	I	A	x	x	x
Carex sp.	Sedge	N	D	x	x	x
Croton texensis	Texas croton	N	D	x	x	
Cynodon dactylon	Bermudagrass	I	U	x	x	x
Cyperus esculentus	Yellow nutsedge	N	D	x	x	
Desmanthus illinoensis	Illinois bundle flower	NS/P	D	x	x	
Echinochloa colona	Junglerice	I	A	x	x	
Echinochloa crus-galli	Barnyardgrass	I	A	x	x	
Eleocharis sp.	Spikerush	N	D	x		
Elymus virginicus	Virginia wildrye	N	D	x	x	x
Eragrostis secundiflora	Red lovegrass	N	D			x
Eriochloa sericea	Texas cupgrass	NS	D	x	x	x
Erigeron sp.	Fleabane	N	D	x		
Euphorbia sp.	Spurge	N	D	x	x	x
Helianthus annuus	Common sunflower	N	D	x	x	
Helianthus maximiliani	Maximillian sunflower	NS/P	D	x	x	
Hibiscus sp.	Rosemallow	N	D	x		x
Ipomoea purpurea	Common morning glory	I	A	x		
Iva annua	Annual marsh elder	N	D	x	x	x
Lactuca serriola	Prickly lettuce	I	U	x		x
Leptochloa dubia	Green sprangletop	NS	D	x	x	
Leptochloa mucronata	Red sprangletop	N	D	x	x	
Lippia nodiflora	Turkey tangle frogfruit	N	D	x	x	x
Lolium perenne	Annual ryegrass	I	A		x	
Oenothera speciosa	Pink evening primrose	NS	D	x	x	x
Oxalis stricta	Common yellow oxalis	N	D	x	x	x
Panicum capillare	Witchgrass	N	D	x	x	x
Panicum coloratum	Kleingrass	I	U	x	x	
Panicum virgatum	Switchgrass	NS/P	D	x	x	x
Paspalum dilatatum	Dallisgrass	I	A	x	x	
Paspalum distichum	Knotgrass	N	D	x	x	
Polygonum pennsylvanica	Smartweed	N	D	x	x	
Pyrrhopappus pauciflorus	Dandelion	N	D	x	x	
Ratibida columnifera	Mexican hat	NS	D	x		
Rapistrum rugosum	Annual annual bastardcabbage	I	U	x		x
Rumex crispus	Curly dock	I	A	x	x	x
Salvia azurea	Pitcher sage	NS	D	x		x
Schizachyrium scoparium	Little bluestem	NP	D	x	x	
Setaria macrostachya	Large-spike bristlegrass	NS	D	x		x
Setaria parviflora	Knotroot bristlegrass	N	D	x	x	x
Solidago sp.	Goldenrod	N	D	x		x
Sorgastrum nutans	Indiangrass	NS/P	D	x	x	x
Sorghum halepense	Johnsongrass	I	U	x	x	x
Symphyotrichum ericoides	White heath aster	N	D	x	x	x
Symphyotrichum subulatum	Slim aster	N	D	x	x	x
Tridens albescens	White tridens	N/P	D	x	x	x
Tripsacum dactyloides	Eastern gamagrass	NS/P	D	x	x	x
Vicia sp.	Vetch	I	A		x	
Xanthium strumarium	Cocklebur	N	D	x	x	

Figure G-1. Dominant vegetation observed around Cells D, E-West, and E during 2014 meander surveys.

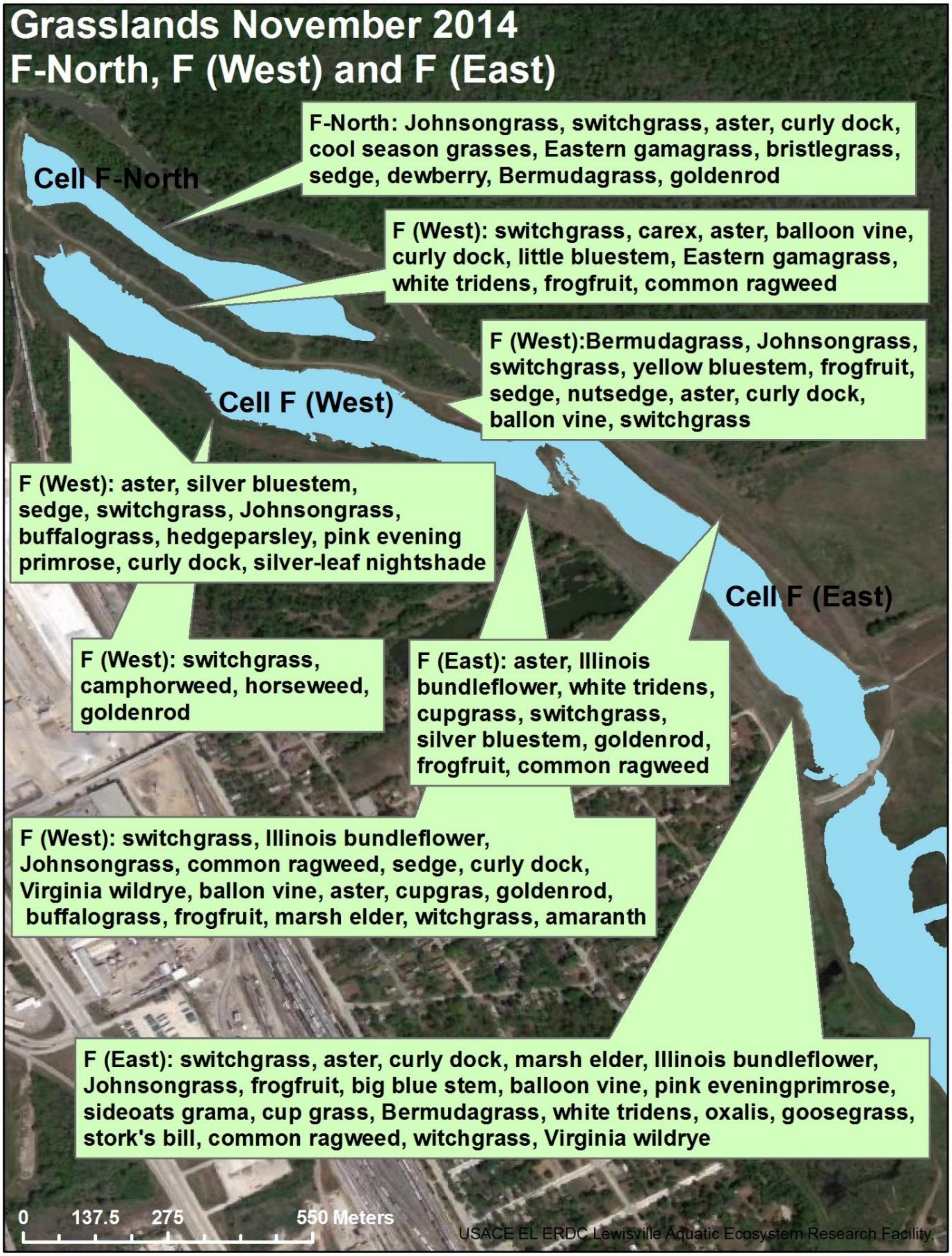


Figure G-2. Dominant vegetation observed around Cells F-North, F (West) and F (East) during 2014 meander surveys.

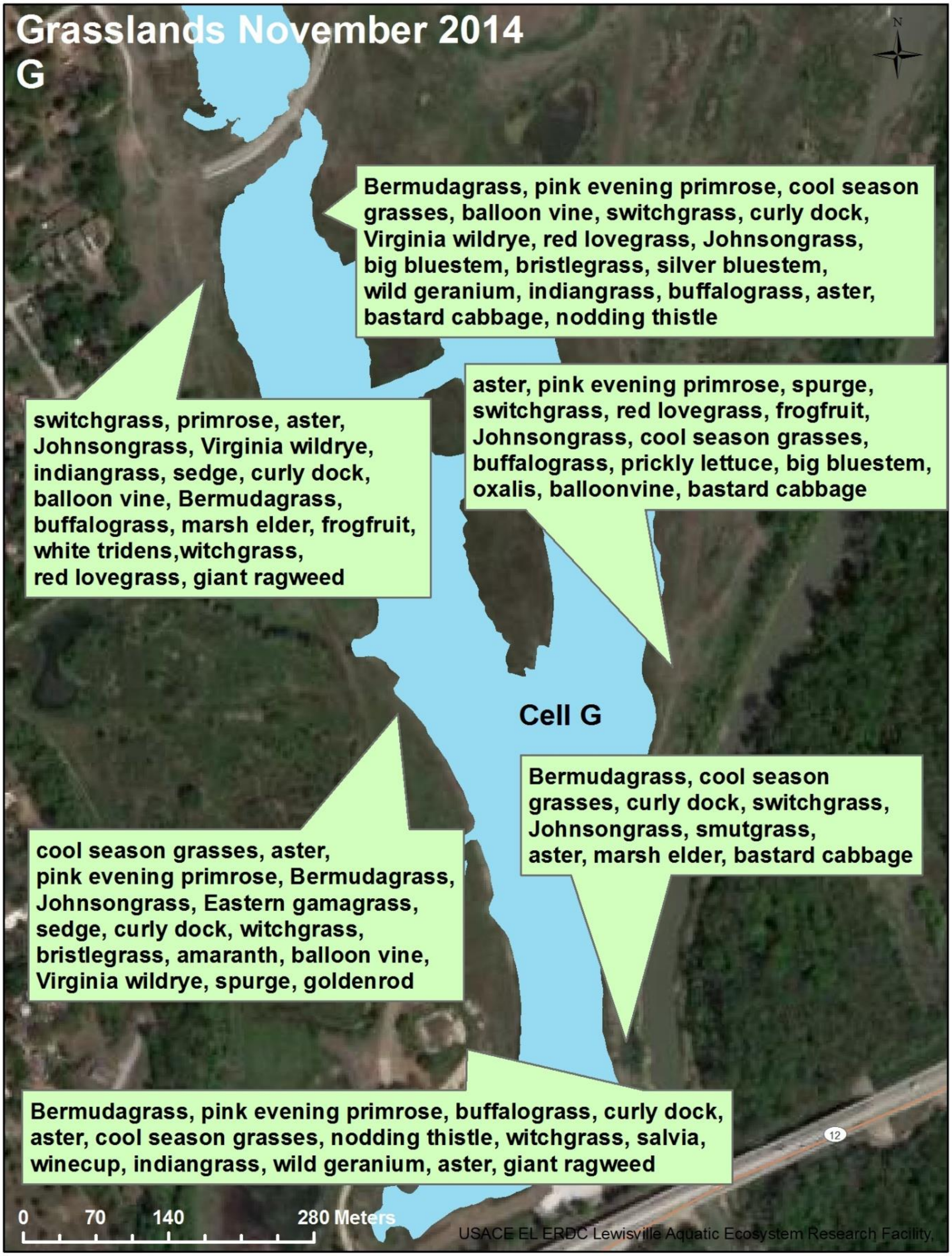


Figure G-3. Dominant vegetation observed around Cell G during 2014 meander surveys.

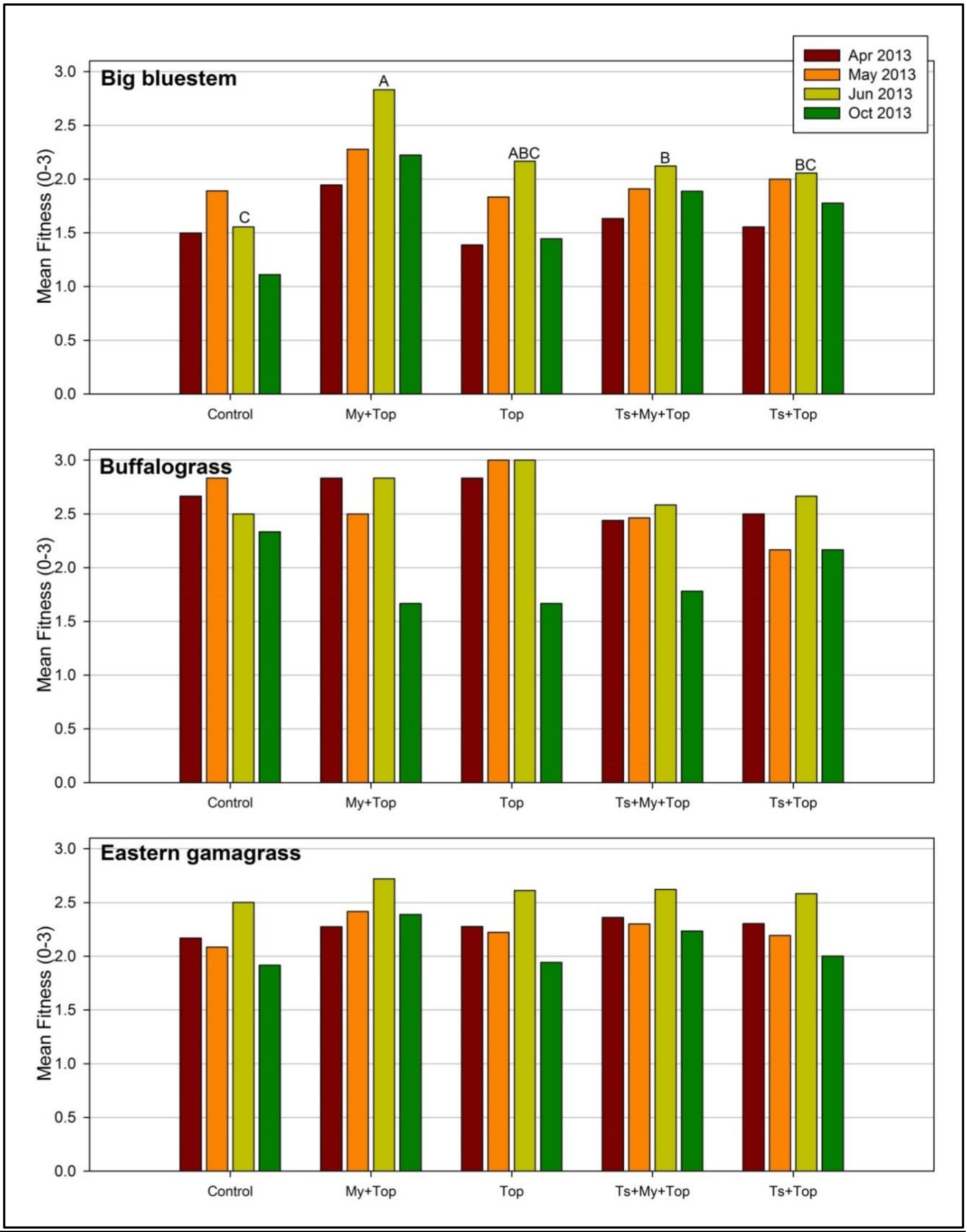


Figure G-4. Mean fitness scores for big bluestem, buffalograss, and Eastern gamagrass for all plot treatments. Soil amendments of top soil (Top), mycorrhizal fungi and top soil (My+Top), Terra-sorb and top soil (Ts+Top), and Terra-sorb and mycorrhizal fungi and top soil (Ts+My+Top) mean fitness was compared at four assessment dates to unamended soil (Control).

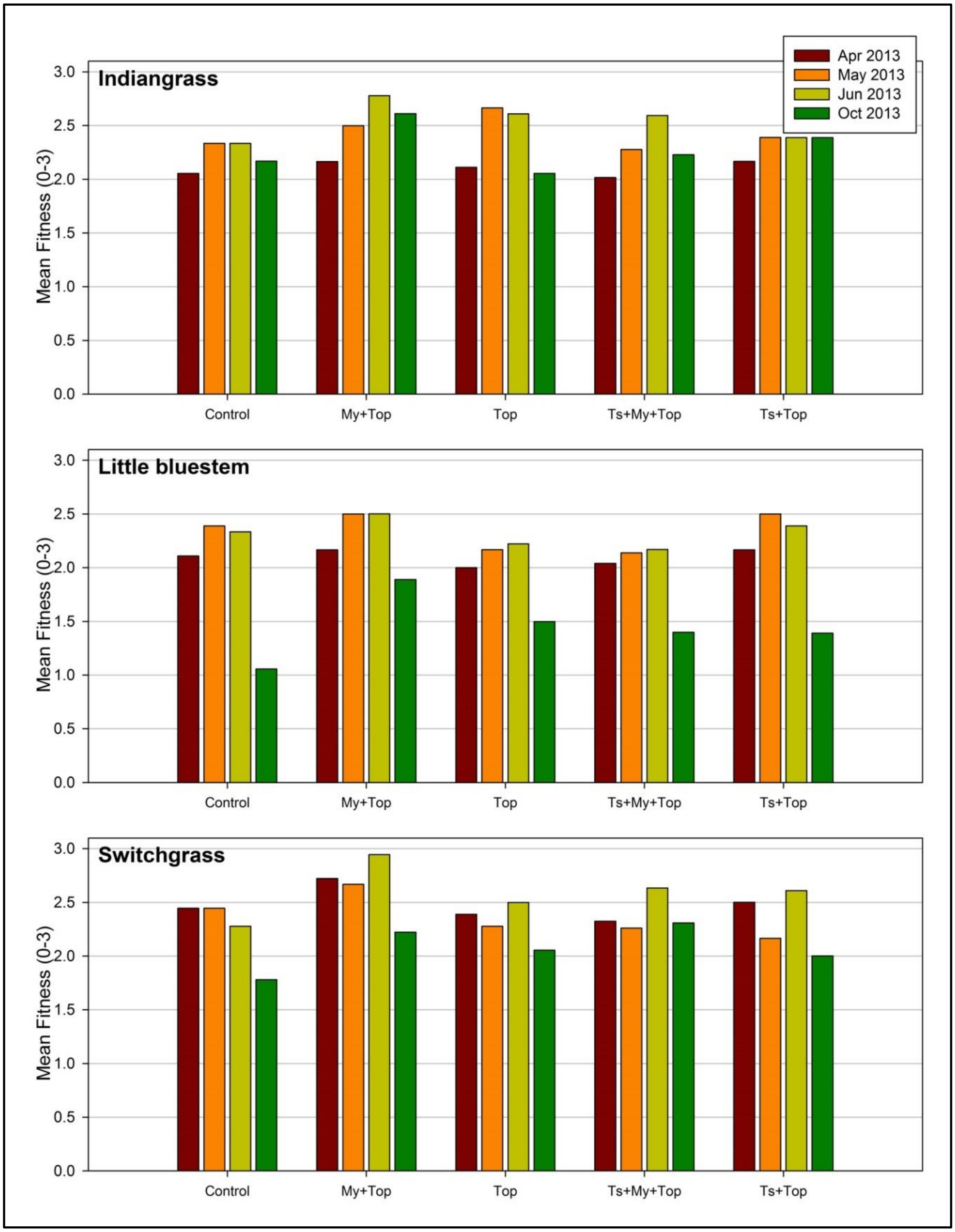


Figure G-5. Mean fitness scores for Indiangrass, little bluestem, and switchgrass for all plot treatments. Soil amendments of top soil (Top), mycorrhizal fungi and top soil (My+Top), Terra-sorb and top soil (Ts+Top), and Terra-sorb and mycorrhizal fungi and top soil (Ts+My+Top) mean fitness was compared at four assessment dates to unamended soil (Control).

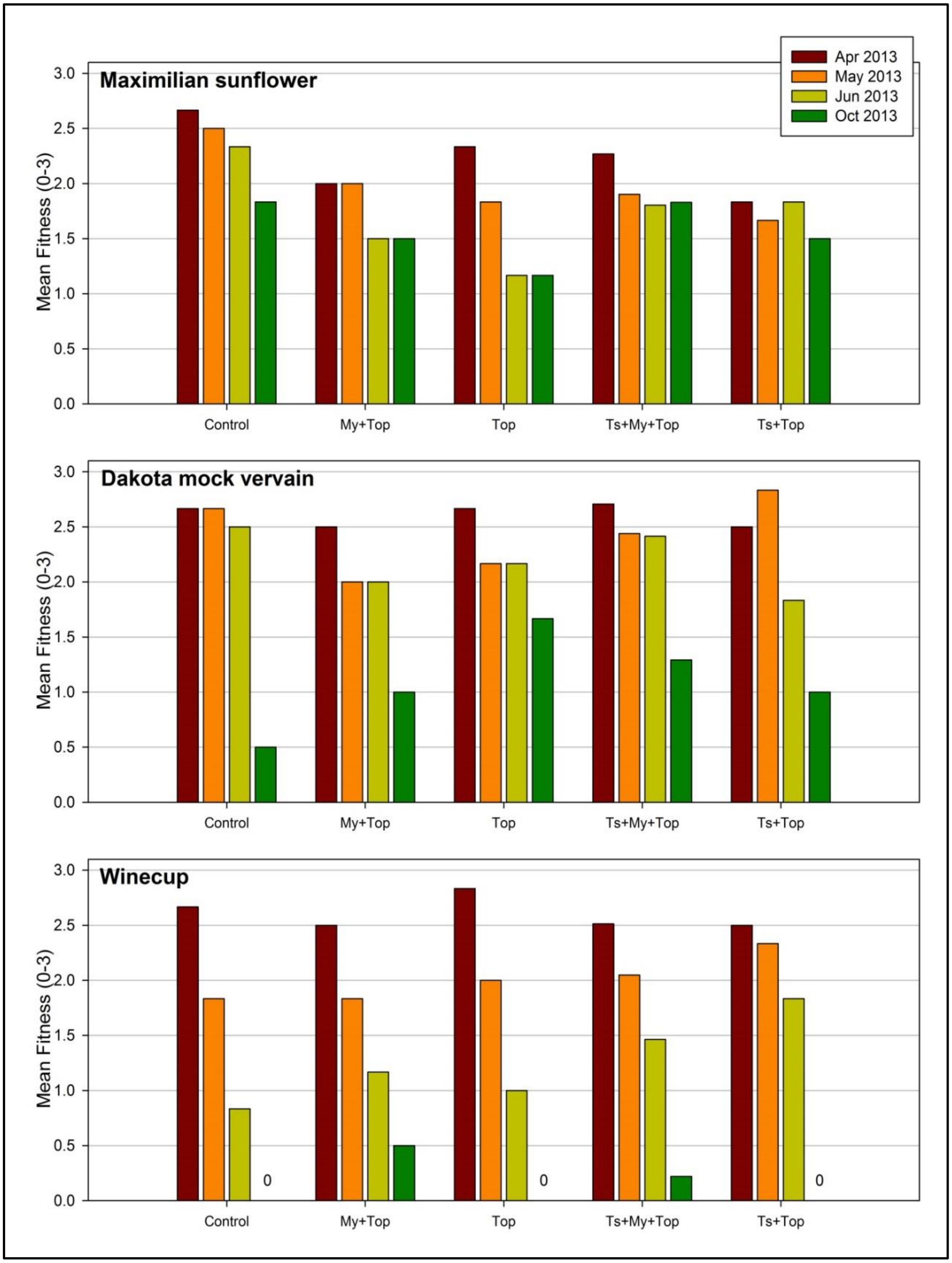


Figure G-6. Mean fitness scores for Maximillian sunflower, Dakota mock vervain, and winecup for all plot treatments. Soil amendments of top soil (Top), mycorrhizal fungi and top soil (My+Top), Terra-sorb and top soil (Ts+Top), and Terra-sorb and mycorrhizal fungi and top soil (Ts+My+Top) mean fitness was compared at four assessment dates to unamended soil (Control).

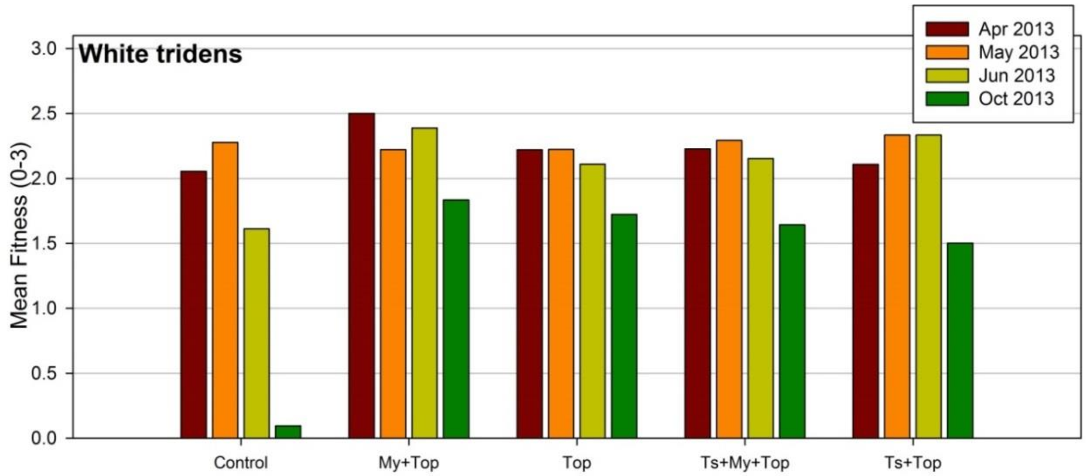


Figure G-7. Mean fitness scores for white tridens for all plot treatments. Soil amendments of top soil (Top), mycorrhizal fungi and top soil (My+Top), Terra-sorb and top soil (Ts+Top), and Terra-sorb and mycorrhizal fungi and top soil (Ts+My+Top) mean fitness was compared at four assessment dates to unamended soil (Control).

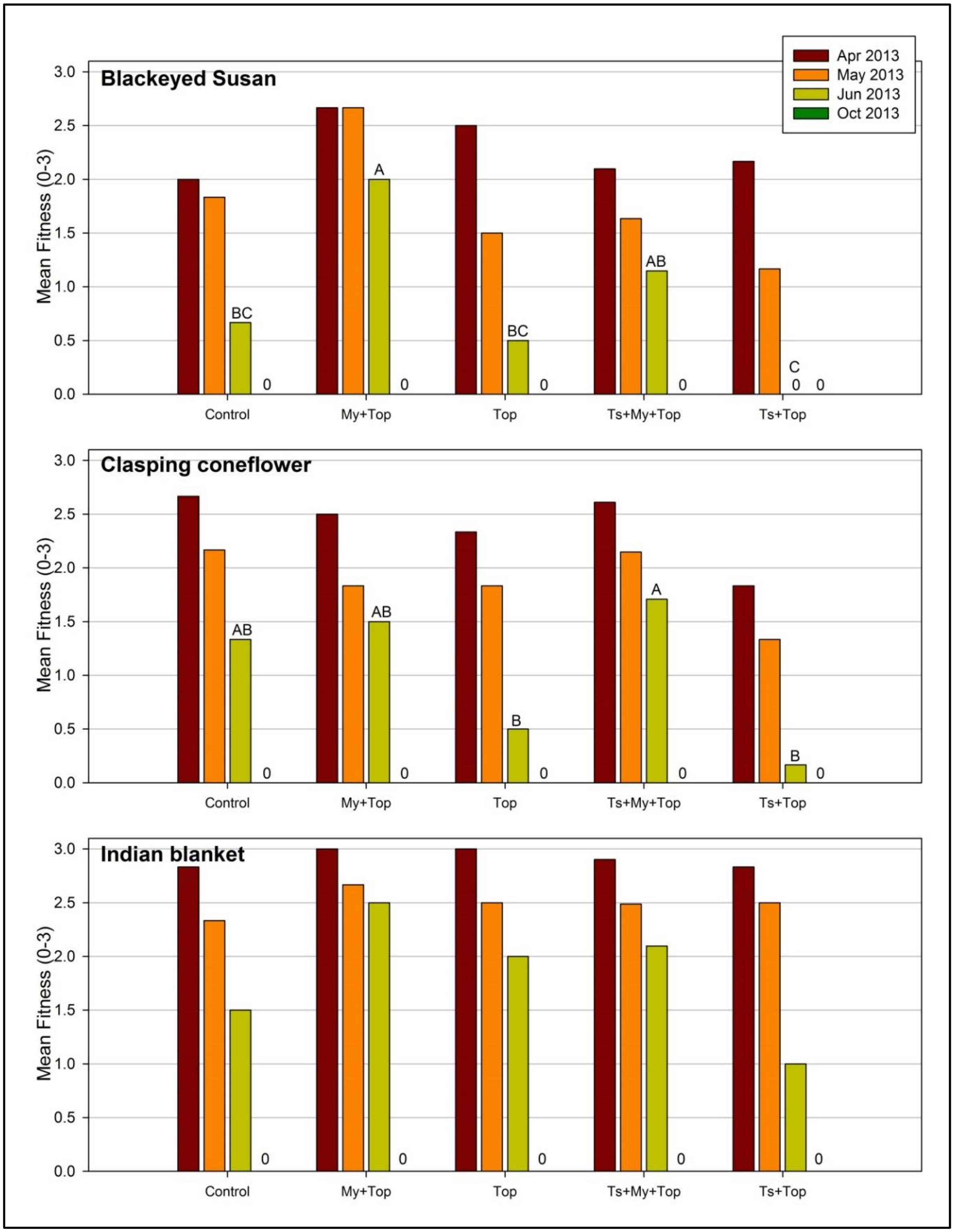


Figure G-8. Mean fitness scores for blackeyed Susan, clasping coneflower, and Indian blanket for all plot treatments. Soil amendments of top soil (Top), mycorrhizal fungi and top soil (My+Top), Terra-sorb and top soil (Ts+Top), and Terra-sorb and mycorrhizal fungi and top soil (Ts+My+Top) mean fitness was compared at four assessment dates to unamended soil (Control).

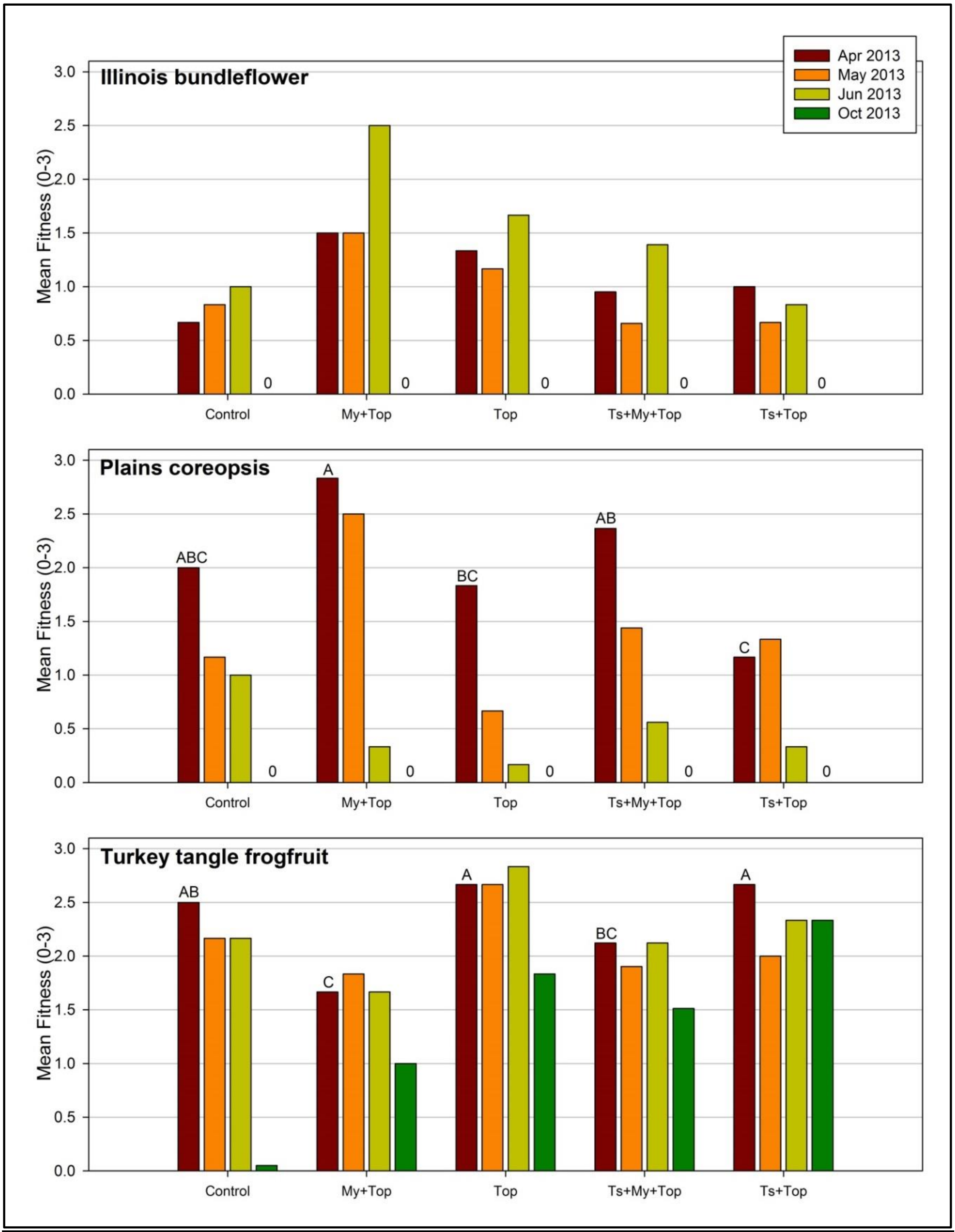


Figure G-9. Mean fitness scores for Illinois bundleflower, plains coreopsis, and turkey tangle frogfruit for all plot treatments. Soil amendments of top soil (Top), mycorrhizal fungi and top soil (My+Top), Terra-sorb and top soil (Ts+Top), and Terra-sorb and mycorrhizal fungi and top soil (Ts+My+Top) mean fitness was compared at four assessment dates to unamended soil (Control).

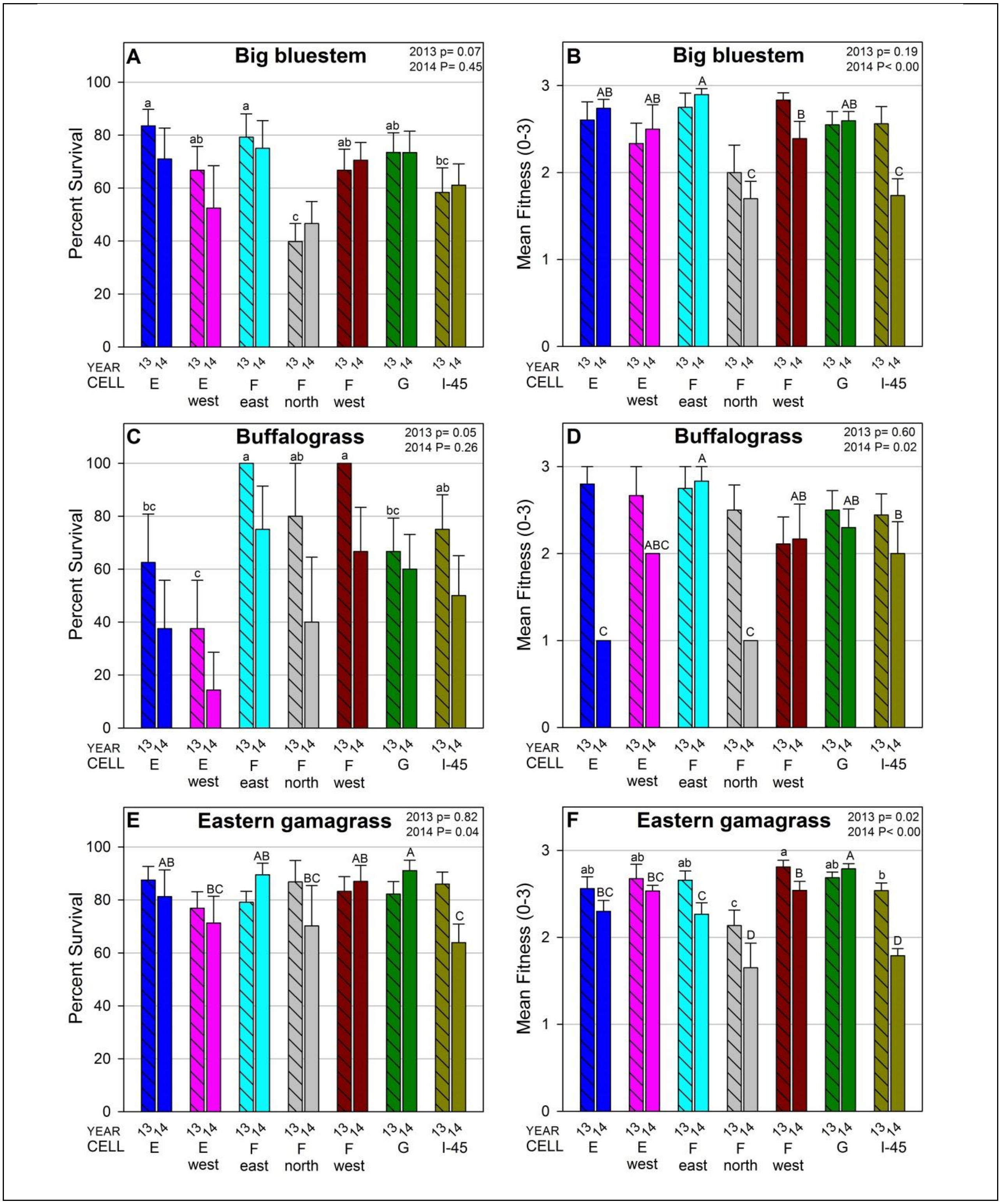


Figure G-10. Differences in percent survival dependent upon wetland cell occurred for big bluestem and buffalograss in 2013 whereas the 2014 assessment percent survival differed for Eastern gamagrass. Fitness of surviving plants was wetland cell related for gamagrass in 2013 whereas big bluestem, buffalograss and eastern gamagrass all demonstrated wetland cell related differences in 2014.

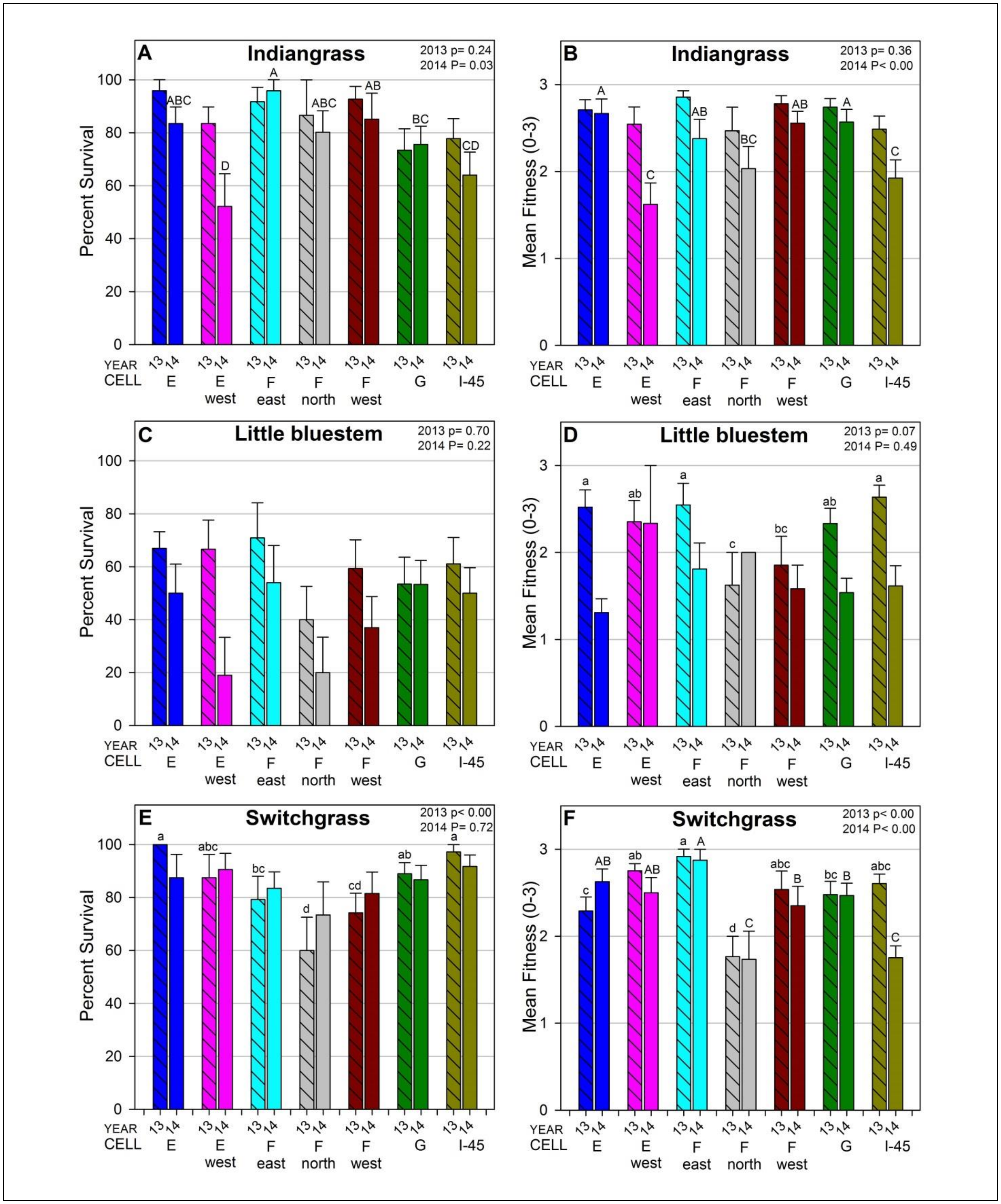


Figure G-11. Differences in percent survival dependent upon wetland cell occurred for switchgrass in 2013 whereas the 2014 assessment percent survival differed for Indiangrass. Fitness of surviving plants was site wetland cell-related for little bluestem in 2013 whereas Indiangrass and switchgrass demonstrated wetland cell-related differences in 2014.

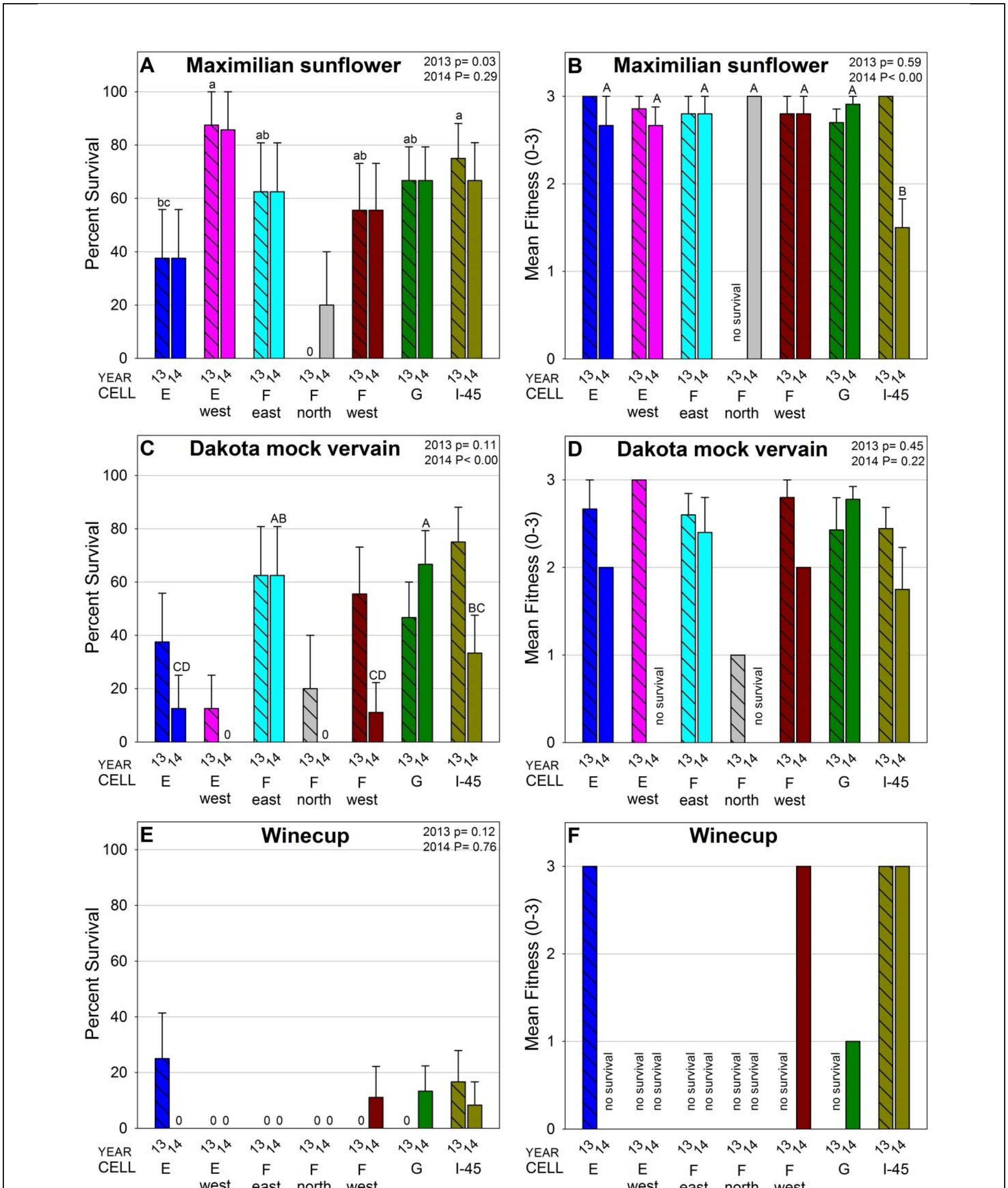


Figure G-12. Differences in percent survival dependent upon wetland cell occurred for Maximillian sunflower in 2013 and 2014. Whereas no wetland cell-related fitness of surviving Maximilian sunflower occurred in 2013, differences were detected in 2014.

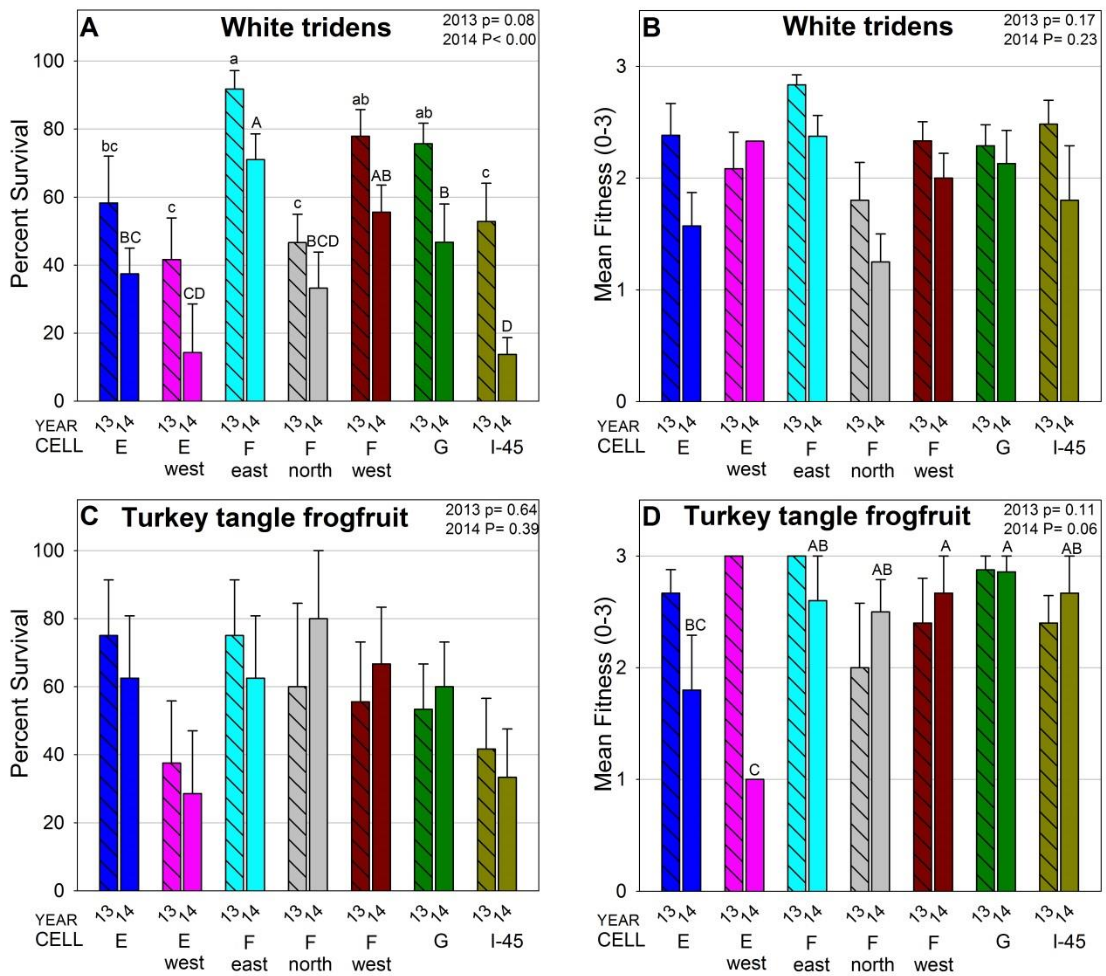


Figure G-13. Differences in percent survival dependent upon wetland cell occurred for white tridens in 2013 and 2014. Whereas no wetland cell-related fitness of surviving turkey tangle frog fruit occurred in 2013, differences were detected in 2014.

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