**St. Louis District**

**Environmental Pool Management 2016 Summary Report**

**June 2017**

Funded by Sustainable Rivers Program

U.S. Army Corps of Engineers

Institute for Water Resources

Cover photo: Vegetation supported by environmental pool management (Ben McGuire, U.S. Fish and Wildlife Service - USFWS, formerly U.S. Army Corps of Engineers - USACE)

**SUSTAINABLE RIVER PROGRAM**

ENVIRONMENTAL POOL MANAGEMENT 2016 SUMMARY REPORT

ST. LOUIS DISTRICT

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# Chapter 1 Introduction

## 1.1 Project Area (Figure 1)

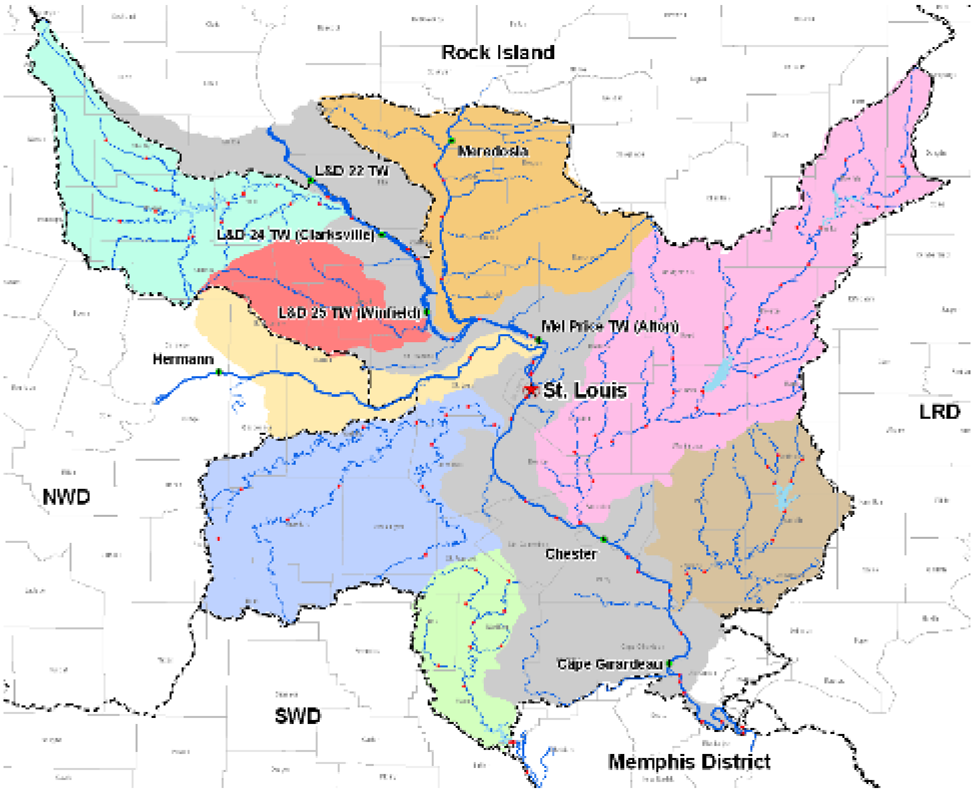


Figure 1. Watershed map of St. Louis District displaying HUC 4 units.

## 1.2 Introduction

Twenty years of managing Pools 24-26 below maximum regulated pool during the summer growing season for 30-40 days shows that ecological conditions could be significantly enhanced for annual emergent aquatic plants production (moist-soil plants). River shoreline, interior island wetlands and island fringe areas, which are exposed from the reduction are consistently revegetated with species such as smartweed (*Polygonum* spp.), millet (*Echinochloa* spp.), sedges (*Carex* spp.), Amazon sprangletop (*Leptochloa panicoides*), flatsedge (*Cyperus* spp.) etc. Seed production of these plants are valuable for resident and migratory waterbirds but also provide, bank stabilization, nutrient processing, sediment deposition, invertebrate habitat, egg-laying structure for fish and amphibians, food for aquatic reptiles, cover and nursery habitat for juvenile fish, etc. Long term fisheries monitoring indicate that native fish species are not negatively affected by this change. In fact, in Pool 25 it has been found that water level management for growing this type of plant community benefits riverine fish communities as a whole (Garvey *et al* 2003). Furthermore, nominal commercial and recreational issues have been reported as a result of the pool water level changes. Twenty years of demonstration indicates this is a beneficial practice to balance the needs of navigation with the needs of the ecosystem.

Prolonged high flow conditions upstream in 2014 necessitated an 86 day drawdown in lower Pool 26. River biologists observed this atypical condition produced not only annual aquatic vegetation but also perennial aquatic vegetation, such as arrowhead (*Sagittaria* spp.), American lotus (*Nelumbo lutea*), and spatterdock (*Nuphar lutea*). These observances demonstrated that it is still possible to grow perennial aquatic vegetation in this portion of the Upper Mississippi River (UMR). Prior to 1994, perennial aquatic vegetation was common in back waters of lower Pool 26. Currently however, perennial aquatic vegetation only exists within one backwater area in Pool 26. In the more northern pooled portion of the UMR, both annual and perennial plants have responded positively to reduced water level conditions when the reduction is targeted for 90 days of the growing season. Additionally, two consecutive years of water level reduction promotes perennial tubers, which can dramatically increase in size (up to 16 X first year growth) and persist for over six years after reflooding. The unique conditions of 2014 shows a restoration goal to regenerate a mix of annual and perennial aquatic vegetation is possible within the lower section of the UMR and would provide additional benefits to physical river function and biological resources.

In the fall 2014, river biologists again asked the Corps if the 30-40 day reduction could be extended to 90 or more days to improve conditions for annual and perennial aquatic plant response. The Corps said if hydrologic conditions provided an opportunity, they would attempt to manage pools 24-26 below full pool beginning as the spring flood waters receded. After coordinating with other state and federal natural resource managers it was decided to begin the reduction as the spring water levels receded in each of the three pools and depending on hydrologic conditions maintain that level for 90 or more days.

The St. Louis District of the Corps of Engineers attempted to maintain the water levels below maximum regulated pool in Pools 24-26 (Table 1, Figures 2 and 3) for most of the summer of 2015, beginning in April. An increase in flow around mid-June interrupted continuous reduction in all three pools but the Corps did return to reduced water levels after flood waters receded. Due to the height of the flood and duration, all the plants were lost during inundation. However, regrowth after the flood produced similar vegetative response and continued until water levels were raised to full pool by October 1, 2015.

In 2016 we attempted another extended water level reduction in Pools 24-26 (Figures 4, 5, and 6) with the following Goals and Objectives:

Goals:

1) Increase aquatic vegetation diversity in the Upper Mississippi River: Pools 24, 25, and 26.
2) Increase emergent aquatic vegetation production by extending Environmental Pool Management (EPM) operations.
3) Quantify the response of aquatic vegetation to extended EPM operations.

Objectives:

1) Increase EPM operations to 90+ days for Pools 24, 25, and 26.
2) Quantify aquatic vegetation seed production using Integrated Waterbird Management and Monitoring's (IWMM) *Seed Head Assessment Guide* 2015.
3) Use established aquatic vegetation monitoring protocols (*Long Term Resource Monitoring Program Procedures: Aquatic Vegetation Monitoring* and *IWMM's Vegetation Survey* 2015*)* to quantify aquatic vegetation response to 90+ day EPM operations.

## 1.3 EPM Operations

Table 2. Lock and dam operation limits in terms of pool elevations for L&D 26, 25, and 24.

| Location | Upper Limit (ft) | Lower Limit (ft) | Hinge Point Limits (ft) |
|---|---|---|---|
| Lock & Dam 24 | 449.0 | 445.5 | 11.5-12.2 |
| Lock & Dam 25 | 434.0 | 429.7 | 434.0-437.0 |
| Lock & Dam 26 (Melvin Price) | 419.0 | 412.5 | 14.2-16.2 |

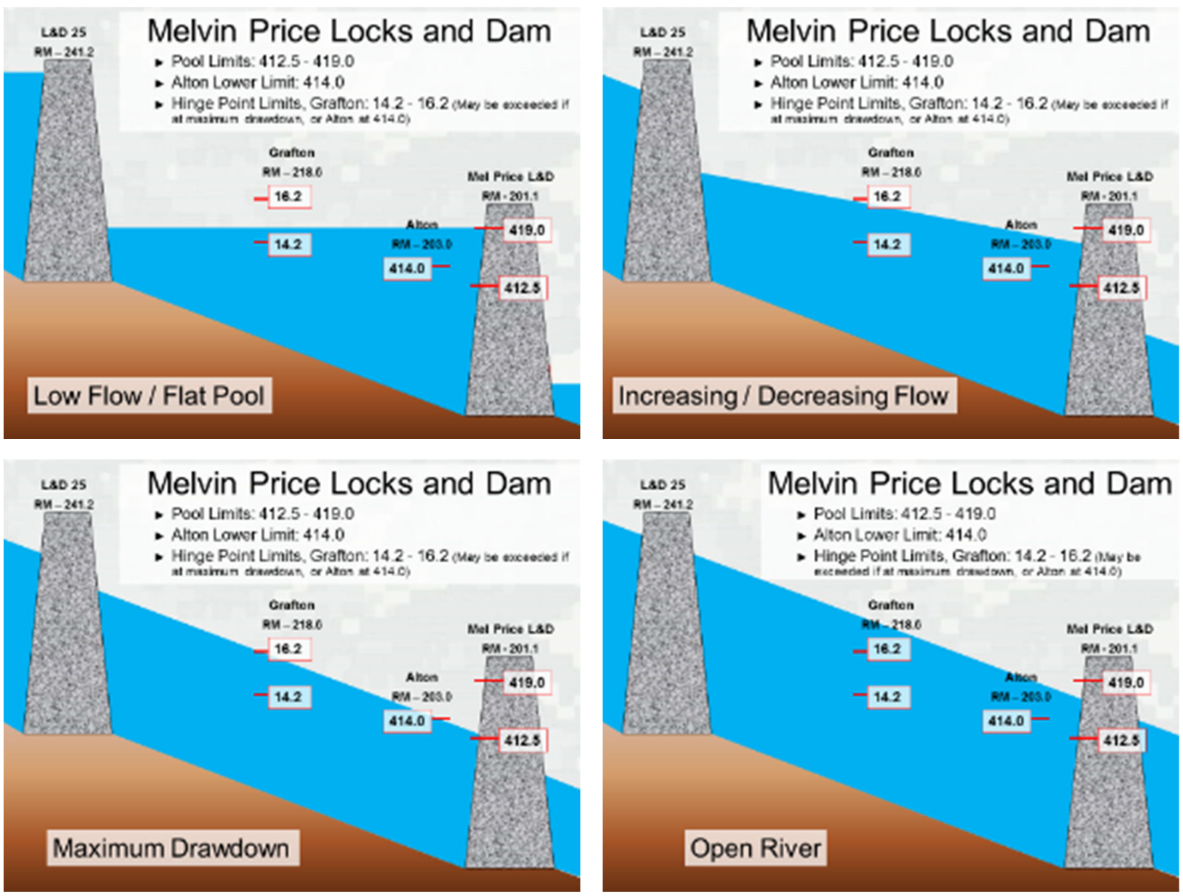


Figure 2. Schematics depicting water levels with upper and lower dam point and upper and lower hinge point elevations at Mel Price Locks and Dam during low flow/flat pool (upper left), increasing/decreasing flow (upper right), maximum drawdown (lower left), and open river (lower right).

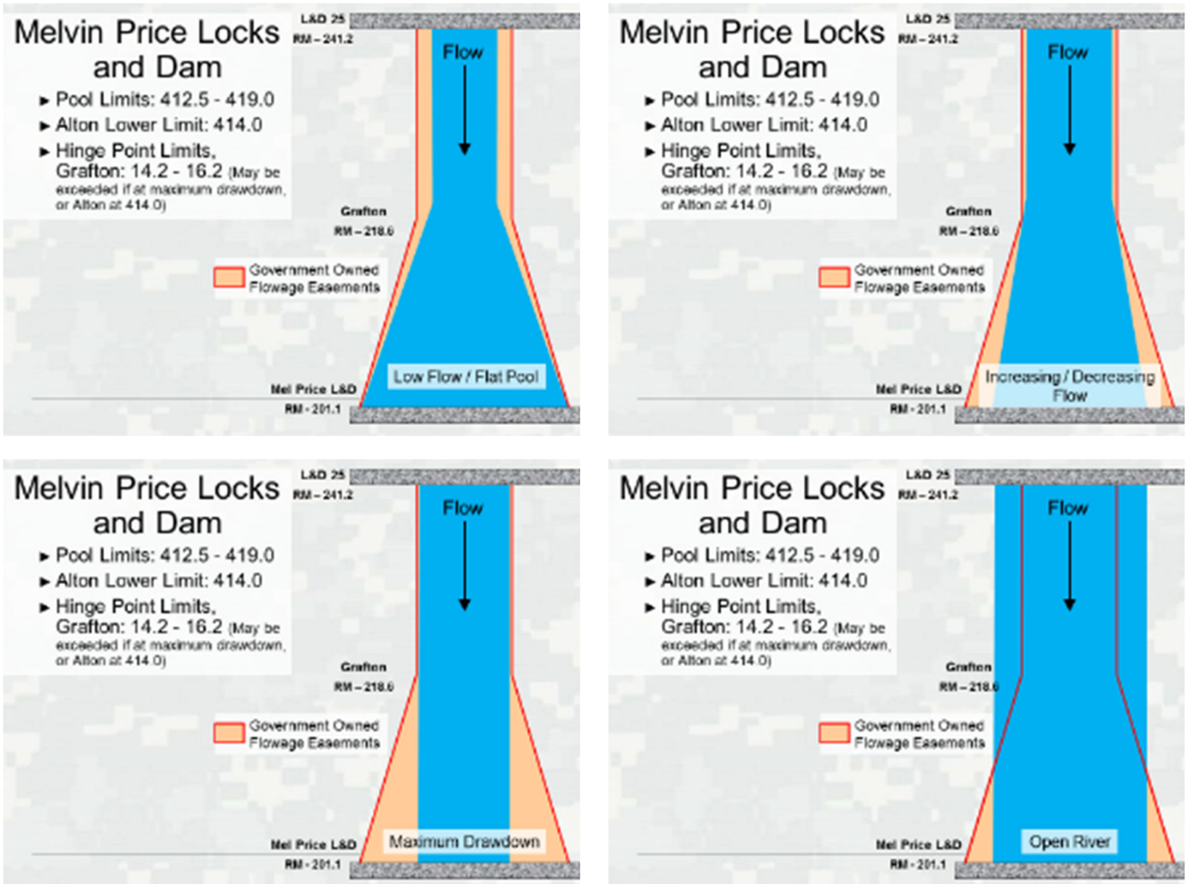


Figure 3. Schematic depicting water conveyance and USACE owned flowage easements during low flow/flat pool (upper left), increasing/decreasing flow (upper right), maximum drawdown (lower left), and open river (lower right).

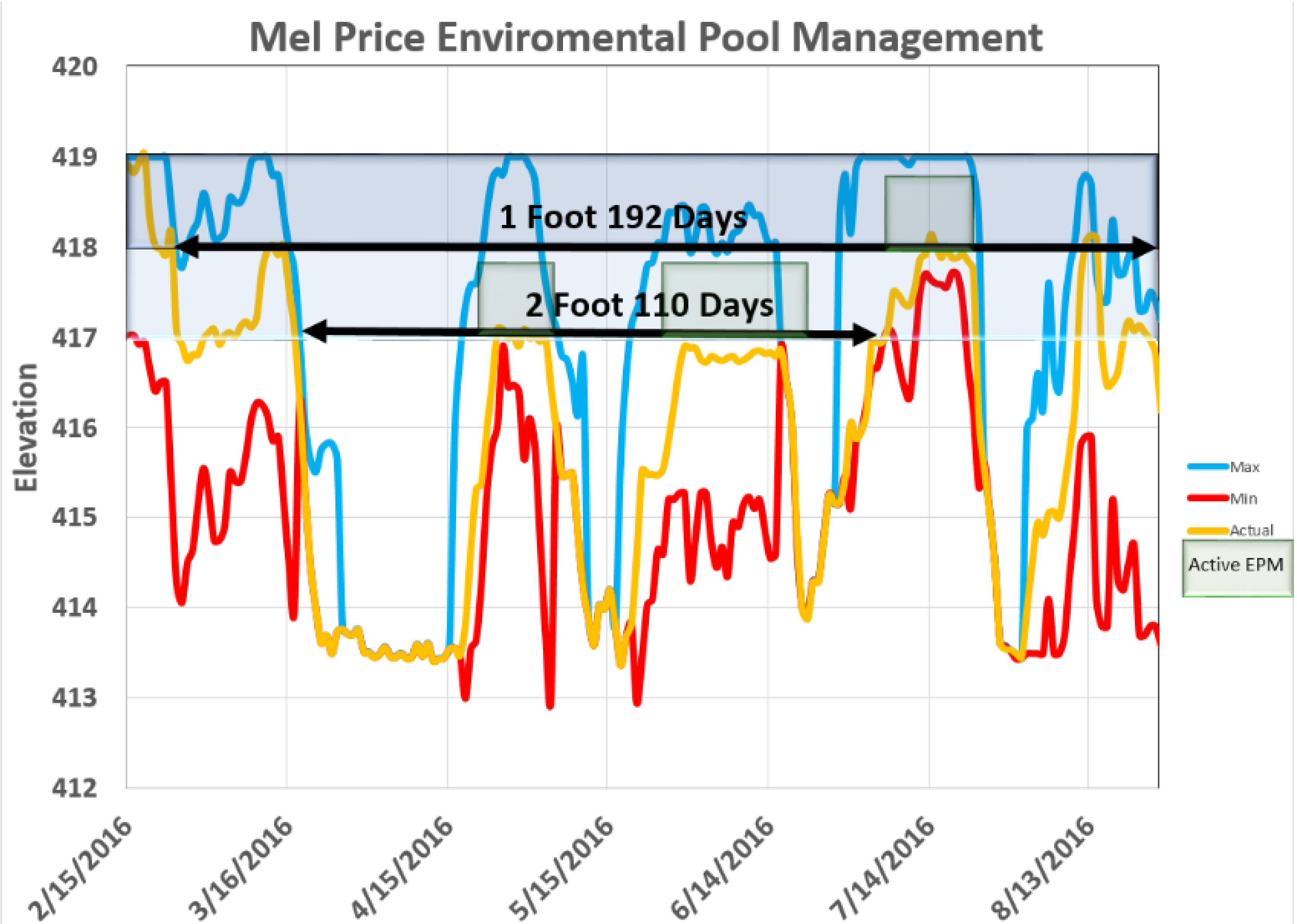


Figure 4. Hydrograph of Pool 26 showing maximum (blue), minimum (red), and actual (yellow) operational bounds. The green boxes show areas in which Environmental Pool Management was implemented to keep water elevations lower.

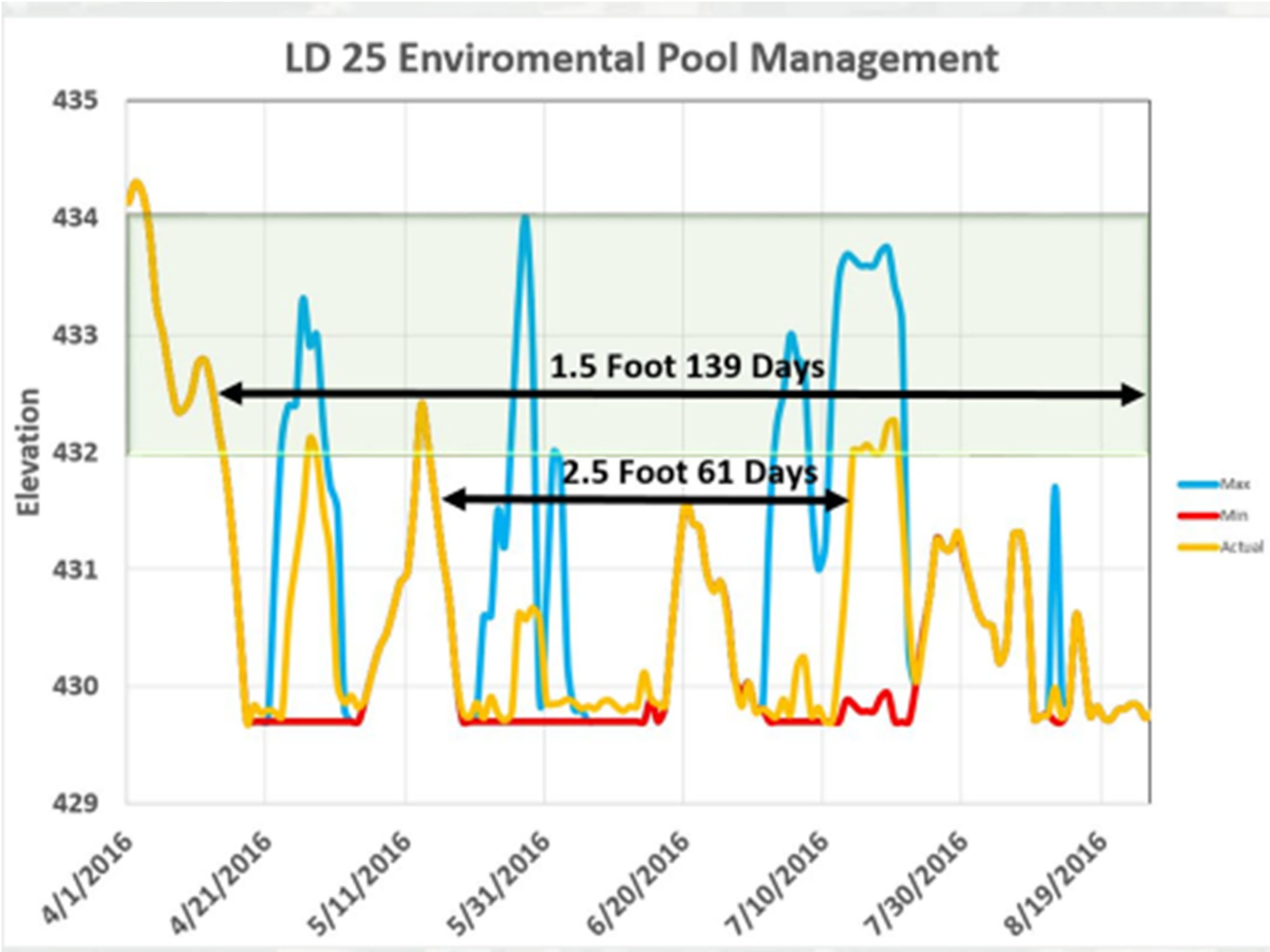

Figure 5. Hydrograph of Pool 25 showing maximum (blue), minimum (red), and actual (yellow) operational bounds. The green box shows areas in which Environmental Pool Management was implemented to keep water elevations lower.

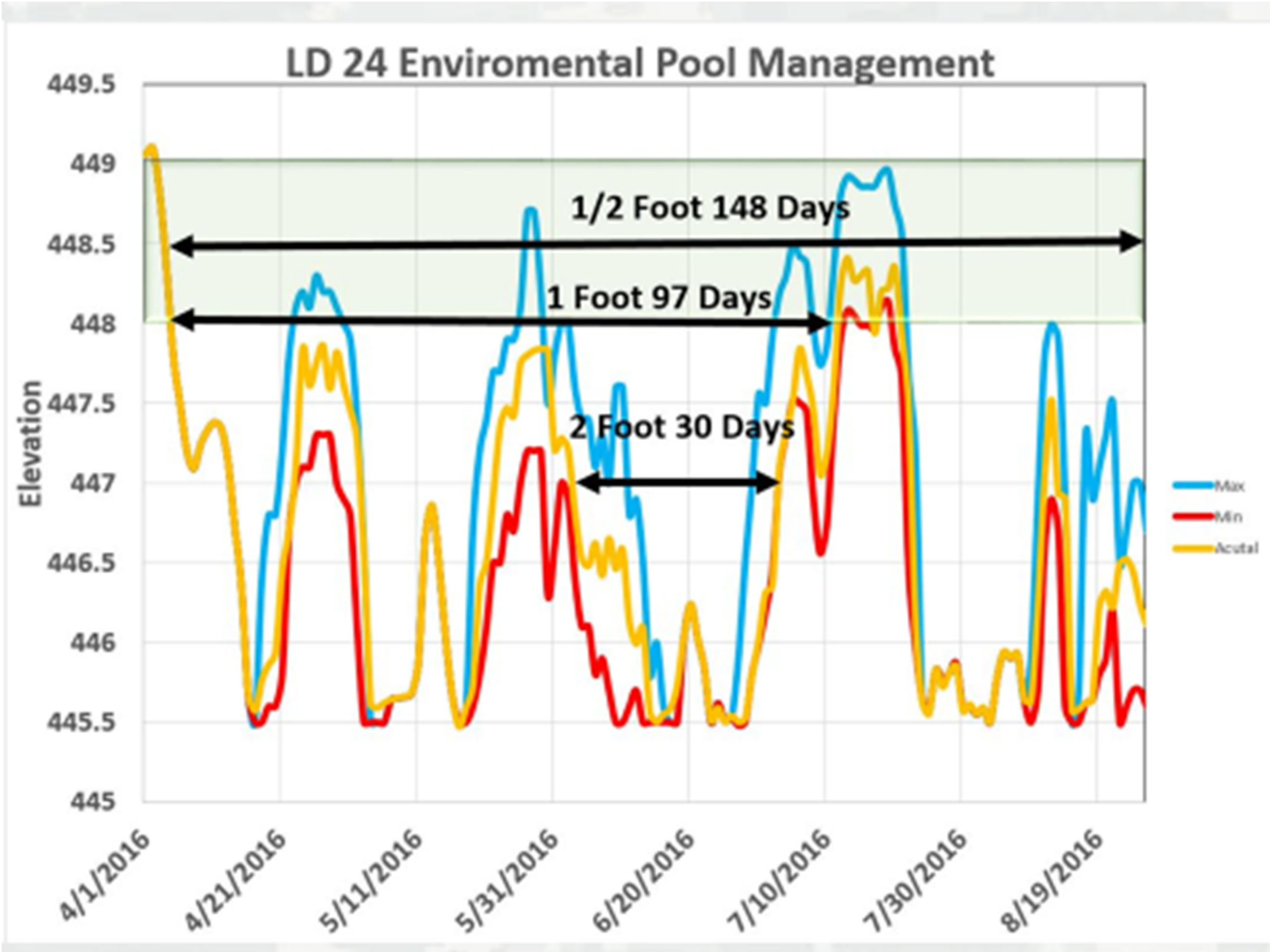


Figure 6. Hydrograph of Pool 26 showing maximum (blue), minimum (red), and actual (yellow) operational bounds. The green box shows areas in which Environmental Pool Management was implemented to keep water elevations lower.

# Chapter 2 Vegetation Surveys

## 2.1. Site Selection

An aerial imagery analysis was conducted to locate areas with exposed mudflat during the growing season in previous EPM implemented years. Potential sites were identified and a target of six sites per pool was set to have a large enough data set and attain measurable results. Site selection preference was given to sites with larger overall area as well as connection with the river. Sites disconnected from the river or that contained a water control structure of some sort were not included due to a difference in hydrology compared to the river. In addition, professional judgement and knowledge from field personnel was taken into account for known locations where emergent vegetation occurred in previous years. However, due to the structure and variance of geomorphology between pools, average site sizes and locations varied between pools. For example, Pool 26 contains more connected backwater locations with larger overall areas compared to Pools 25 and 24 (Table 2 and Figure 7). Site selection was as follows for each pool: Pool 26 Dresser Island Conservation Area, Alton Lake, Ellis Bay, Mile 210, Eagles Nest Island, Piasa Island (Figure 8); Pool 25, Batchtown (exterior), Turner Island 1, Turner Island 2, Jim Crow Island, Hausgen Island, Stag Island (Figure 9); Pool 24, Middleton Island, Pharrs Island, Crider Island, Gosline Island, Ducher Island, Willow Island (Figure 10).

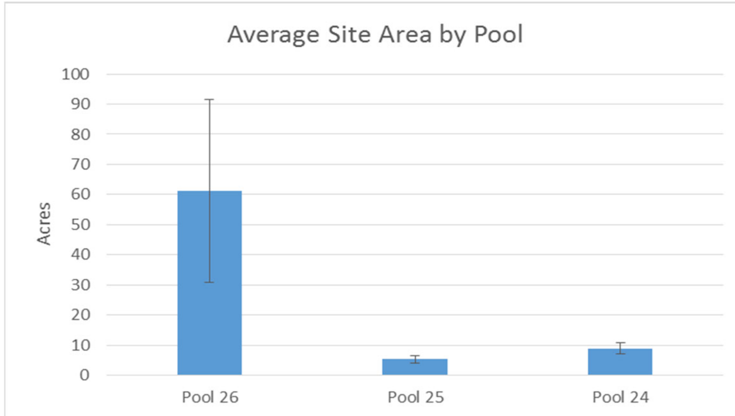

Figure 7. Average size of vegetation survey sites (in acres) by Pool with standard error bars.

Table 3. Size of vegetation survey sites in acres.

| Pool 26 | | Pool 25 | | Pool 24 | |
|---|---|---|---|---|---|
| **Site** | **Acres** | **Site** | **Acres** | **Site** | **Acres** |
| Dresser | 45.4 | Batchtown (Exterior) | 3.0 | Middleton Island | 9.2 |
| Alton Lake | 210.0 | Turner Island 1 | 10.5 | Pharrs Island | 12.7 |
| Ellis Bay | 39.1 | Turner Island 2 | 3.2 | Crider Island | 14.0 |
| Mile 210 | 28.3 | Jim Crow Island | 5.8 | Gosline Island | 10.4 |
| Eagles Nest Island | 4.1 | Hausgen Island | 6.3 | Ducher Island | 6.2 |
| Piasa Island | 40.7 | Stag Island | 3.2 | Willow Island | 1.0 |

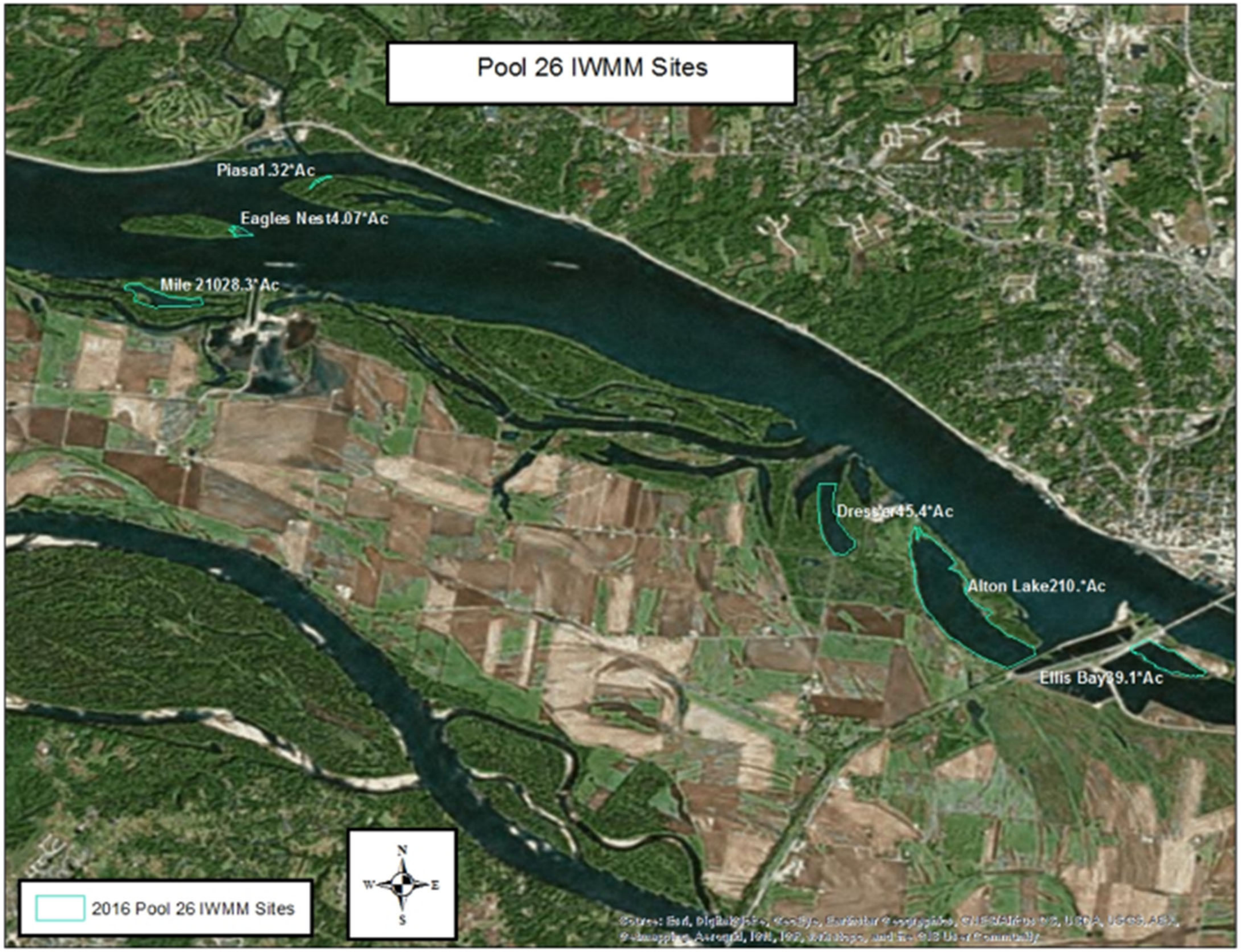


Figure 8. Pool 26 selected sites with acreages. Sites include: Dresser Island Conservation Area, Alton Lake, Ellis Bay, Mile 210, Eagles Nest Island, and Piasa Island.

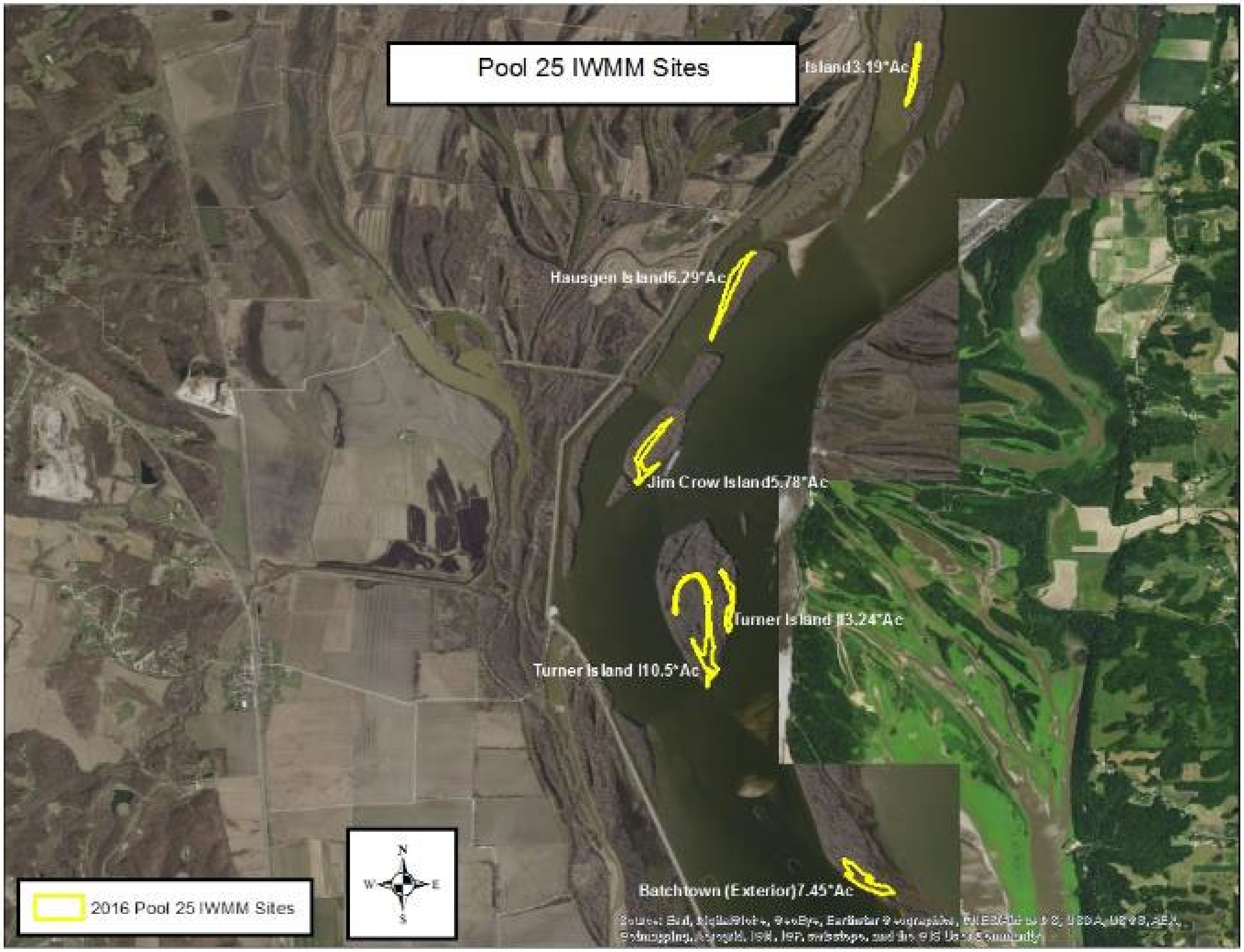


Figure 9. Pool 25 selected sites with acreages. Sites include: Batchtown (exterior), Turner Island 1, Turner Island 2, Jim Crow Island, Hausgen Island, Stag Island.

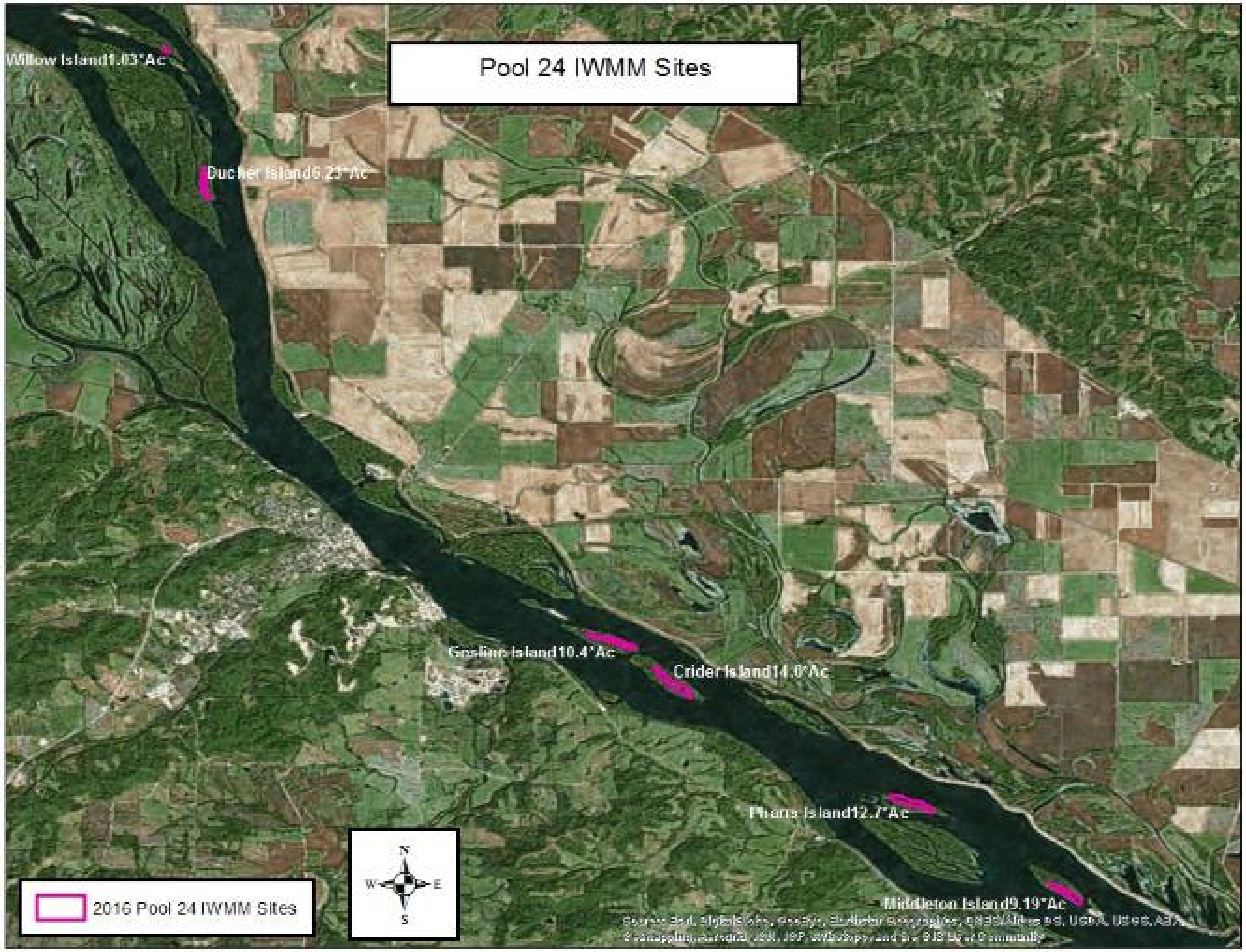


Figure 10. Pool 24 selected sites with acreages. Sites include: Middleton Island, Pharrs Island, Crider Island, Gosline Island, Ducher Island, Willow Island.

## 2.2 Integrated Waterbird Management and Monitoring Vegetation Surveys

### 2.2.1 Methods

A total of 18 sites as described in Section 2.1 were surveyed to assess individual emergent plant species cover in Pools 26, 25, and 24 (Table 2). The Integrated Waterbird Management and Monitoring protocol was utilized to assess species abundance and percent cover (USFWS 2015). Only emergent vegetation from the current growing season was assessed. To complete the vegetation surveys while adhering to the protocol, two major steps were completed: 1) an assessment of percent cover of emergent vegetation within the survey unit was completed and 2) a species inventory and species-specific percent cover assessment within the areas of emergent vegetation were completed.

To complete the first step, the location of all emergent vegetation areas within each survey unit were determined. This was done by a visual assessment throughout each survey unit. Once all areas of emergent vegetation were identified, an estimate of the percent cover of the survey unit by emergent vegetation was completed. Percent cover is defined as the percentage of the survey unit covered by vertical projections from the outermost perimeter of the plants' foliage (Anderson 1986).

To complete the second step, a list of all common emergent vegetation species was compiled and an estimate of each species' percent cover was completed. For this estimate, percent cover is defined as above except that it is estimated as a percentage of emergent vegetation area, not as a percentage of the total survey unit area. For example, a survey unit could only contain a single species, Species X across 50% of the total survey unit area, but as an individual plant species it could cover 100% of the emergent vegetation area within the survey unit. So, 100% would be recorded for this measurement. Total cover across species can exceed 100% due to the stratification of plant species with varying heights and growth forms.

In addition to the two above measurements taken at each site, a qualitative estimate of seed head size and density was completed for each common emergent plant species. Seed head sizes were assigned a size of average, smaller, or larger than the average size for each species as compared to diagrams provided by this protocol. For seed head densities, the density of stems for a species and proportion of as species' stems with seed heads were assessed. Densities were assigned as low, moderate, or high. Low densities were characterized by large areas of bare ground and low proportion of seed heads to plant stems. High seed head densities were characterized by areas with little bare ground and a high proportion of seed heads to stems. Moderate seed head densities fall between the two aforementioned categories.

Mean percent cover was calculated by pool to compare species composition and densities between the June surveys and August surveys. Mean percent cover during IWMM surveys in June and August was calculated by site. Mean percent cover was analyzed using a standard t-test to compare June and August for each pool. Species percent frequency of occurrence for was calculated by pool for June and August. Species richness was calculated by pool for June and August. An additional t-test was performed with the three pools combined. P-values less than 0.05 were considered statistically significant for the four t-tests. Simpson's diversity indices were calculated for Pools 26, 25, and 24 for June and August.

Simpson's evenness was calculated for Pools 26, 25, and 24 for June and August. Frequency of seed head size during June and August was calculated for Pools 26, 25, and 24. All species encountered throughout the IWMM and LTRM surveys were recorded and are displayed in Table 3.

2.2.2 Results

Table 4. Table of all species encountered during vegetation surveys.

| **Species Code** | **Latin Name** | **Common Name** |
|---|---|---|
| AMCO | *Ammonia coccinea* | Valley redstem |
| AMSP | *Amaranthus spp.* | Pigweed spp. |
| ASSP | *Aster spp.* | Daisy spp. |
| ARAN | *Artemisia annua* | Annual wormwood |
| BISP | *Bidens spp.* | Beggarticks |
| BOFL | *Bolboschoenus fluviatilis* | River bulrush |
| CASP | *Carex spp.* | Sedge spp. |
| CYES | *Cyperus esculenta* | Yellow nutsedge |
| CYSP | *Cyperus spp.* | Flatsedge spp. |
| ECCR | *Echinochloa crusgalli* | Barnyard grass |
| ECES | *Echinochloa esculenta* | Japanese millet |
| ECPR | *Eclipta prostrata* | False daisy |
| ECWA | *Echinochloa walteri* | Walter's millet |
| ELSP | *Eleocharis spp.* | Spikerush spp. |
| ERHY | *Eragrostis hypnoides* | Teal lovegrass |
| EUPE | *Eupatorium spp.* | Thoroughwort spp. |
| HUJA | *Humulus japonicus* | Japanese hops |
| LEOR | *Leersia oryzoides* | Rice cutgrass |
| LEPA | *Leptochloa panicoides* | Amazon sprangletop |
| LIDU | *Lindernia dubia* | Yellowseed false pimpernel |
| LIMI | *Limna minor* | Duckweed |
| LUSP | *Ludwigia spp.* | Water primrose spp. |
| LYER | *Lycopus americana* | American bugleweed |
| MIRI | *Mimulus ringens* | Monkeyflower |
| NELU | *Nelumbo lutea* | American lotus |
| PADI | *Panicum dichotomiflorum* | Fall panicum |
| PASP | *Panicum spp.* | Panicum spp. |
| PEDI | *Pentharum sedoites* | Ditch stonecrop |
| PHLA | *Phyla lanceolata* | Lanceleaf frogfruit |
| POLA | *Polygonum lapathifolium* | Curlytop smartweed |
| POPE | *Polygonum pensylvanicum* | Pennsylvania smartweed |
| RUSP | *Rumex spp.* | Dock spp. |
| SALA | *Sagittaria latifolia* | Broadleaf arrowhead |
| SANI | *Salix nigra* | Black willow |
| SASP | *Sagittaria spp.* | Arrowhead spp. |
| SYLA | *Symphyotrichum lanceolatum* | White panicle aster |
| SYPR | *Symphyotrichum praealtum* | Willowleaf aster |
| VEHA | *Verbena hastata* | Swamp verbena |

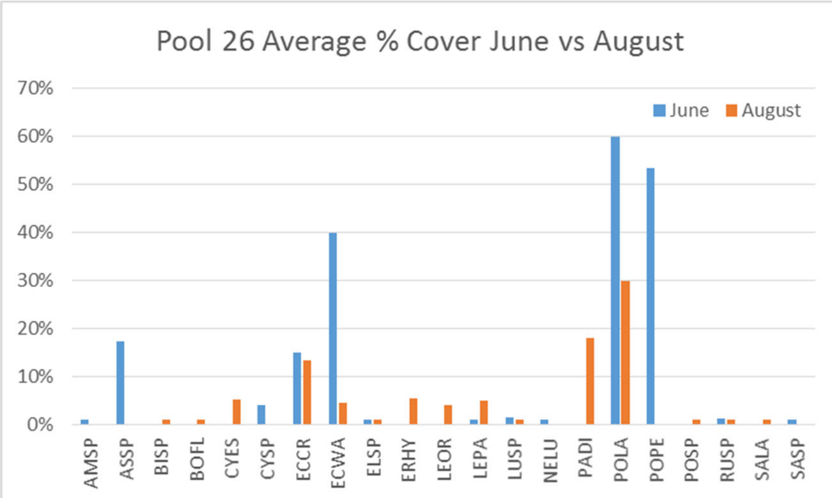


Figure 11. Pool 26 average percent cover during IWMM surveys in June and August

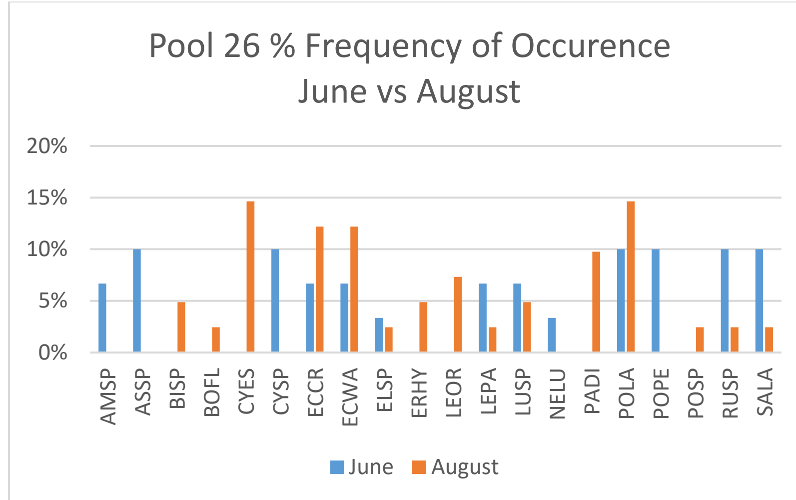


Figure 12. Pool 26 species percent frequency of occurrence for IWMM surveys, June vs August.

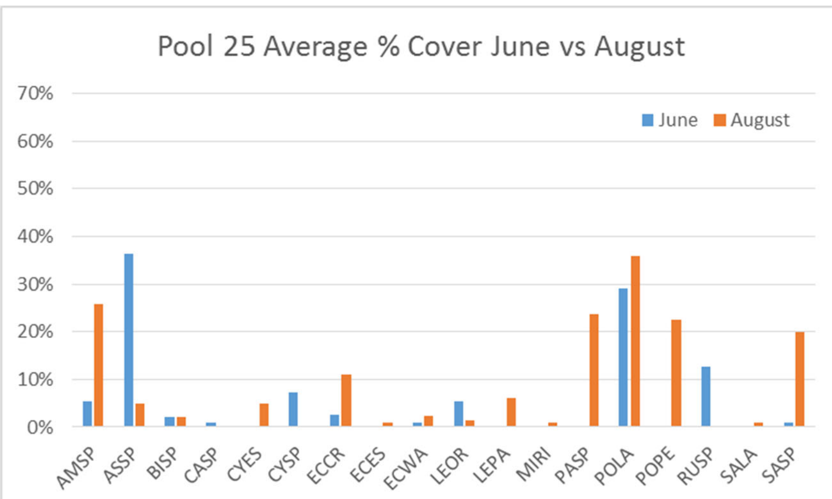


Figure 13. Pool 25 average percent cover during IWMM surveys in June and August

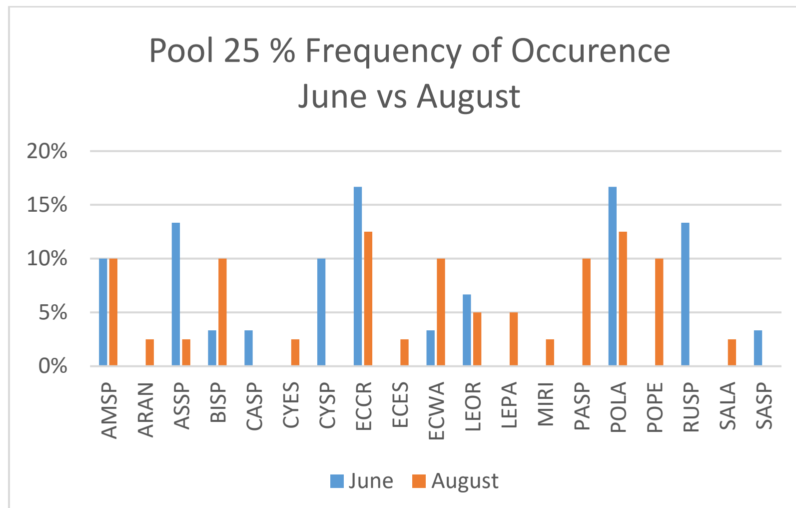


Figure 14. Pool 25 species percent frequency of occurrence for IWMM surveys, June vs August.

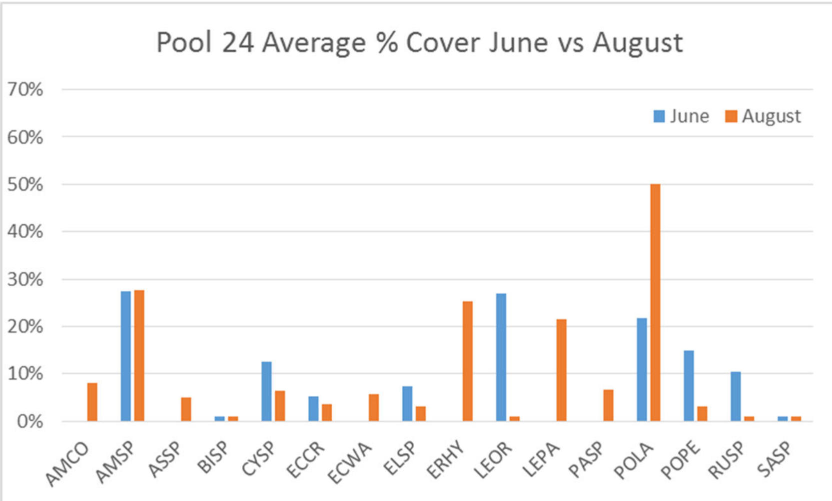


Figure 15. Pool 24 average percent cover during IWMM surveys in June and August

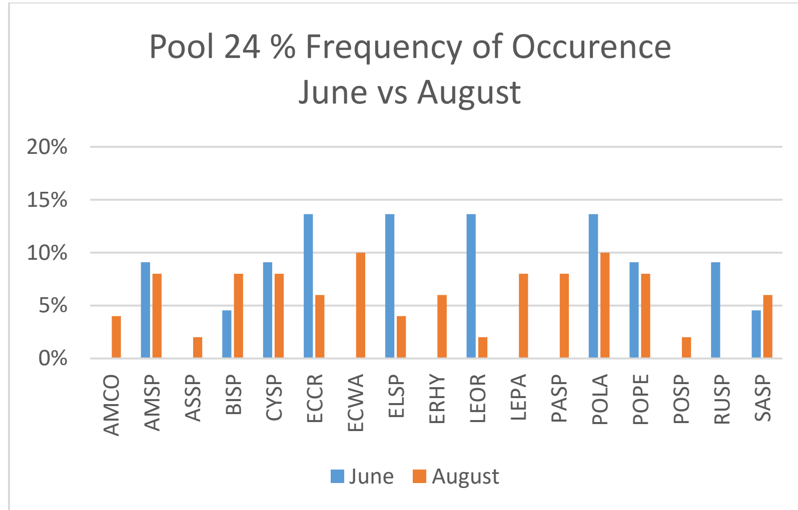


Figure 16. Pool 24 species percent frequency of occurrence for IWMM surveys, June vs August.

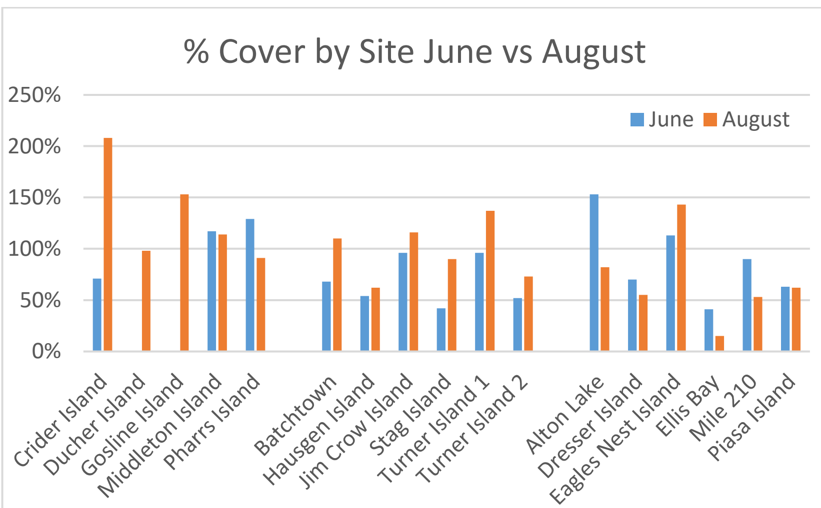


Figure 17. Average percent cover during IWMM surveys in June and August by site. Left group: Pool 24 sites; Middle group: Pool 25 sites; and Right group: Pool 26 sites.

| *Pool 26* | *June* | *August* |
| --- | --- | --- |
| Mean | 0.754 | 0.656 |
| Variance | 0.07483 | 0.22088 |
| Observations | 5 | 5 |
| Pearson Correlation | 0.8884359 | |
| Hypothesized Mean Difference | 0 | |
| df | 4 | |
| t Stat | 0.8448904 | |
| P(T<=t) one-tail | 0.2228728 | |
| t Critical one-tail | 2.1318468 | |
| P(T<=t) two-tail | 0.4457456 | |
| t Critical two-tail | 2.7764451 | |

Table 5. T-test test for total percent cover in Pool 26 IWMM surveys, June vs August. P-values < 0.05 are statistically significant.

| *Pool 25* | *June* | *August* |
| --- | --- | --- |
| Mean | 0.68 | 0.956 |
| Variance | 0.0674 | 0.09503 |
| Observations | 5 | 5 |
| Pearson Correlation | 0.845918174 | |
| Hypothesized Mean Difference | 0 | |
| df | 4 | |
| t Stat | -3.753799407 | |
| P(T<=t) one-tail | 0.009940723 | |
| t Critical one-tail | 2.131846786 | |
| P(T<=t) two-tail | 0.019881446 | |
| t Critical two-tail | 2.776445105 | |

Table 6. T-test test for total percent cover in Pool 25 IWMM surveys, June vs August. P-values < 0.05 are statistically significant.

| *Pool 24* | *June* | *August* |
| --- | --- | --- |
| Mean | 0.615 | 1.14 |
| Variance | 0.5067 | 0.076867 |
| Observations | 4 | 4 |
| Pearson Correlation | -0.5011316 | |
| Hypothesized Mean Difference | 0 | |
| df | 3 | |
| t Stat | -1.1878507 | |
| P(T<=t) one-tail | 0.16018316 | |
| t Critical one-tail | 2.35336343 | |
| P(T<=t) two-tail | 0.32036632 | |
| t Critical two-tail | 3.18244631 | |

Table 7. T-test test for total percent cover in Pool 24 IWMM surveys, June vs August. P-values < 0.05 are statistically significant.

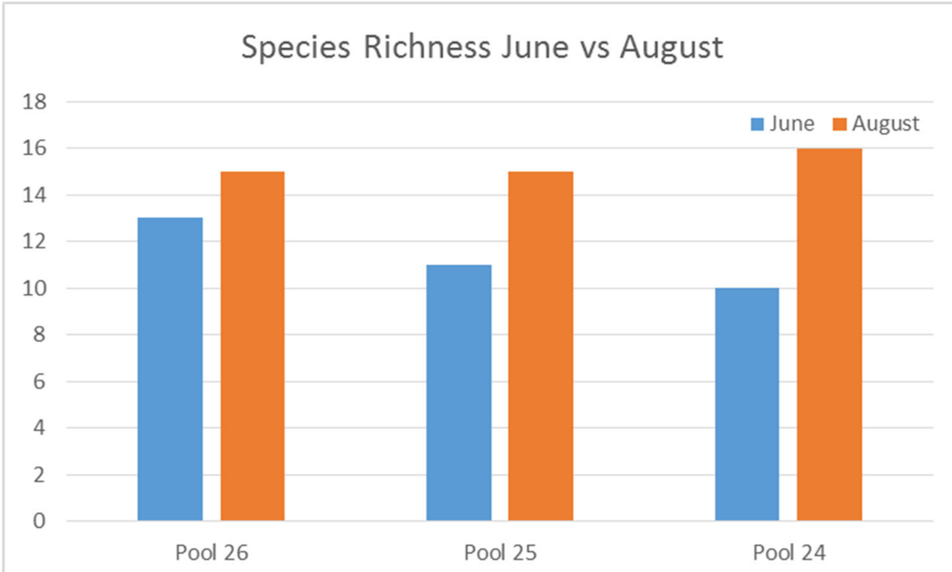

Figure 18. Species richness for Pools 26, 25, and 24 from IWMM surveys in June

| *Combined Pools (26, 25, & 24)* | *June* | *August* |
|---|---|---|
| Mean | 11.333 | 15.333 |
| Variance | 2.333 | 0.333 |
| Observations | 3 | 3 |
| Pearson Correlation | -0.756 | |
| Hypothesized Mean Difference | 0 | |
| df | 2 | |
| t Stat | -3.464 | |
| P(T<=t) one-tail | 0.03709 | |
| t Critical one-tail | 2.9199856 | |
| P(T<=t) two-tail | 0.0741799 | |
| t Critical two-tail | 4.3026527 | |

Table 8. T-test test for combined species richness for Pool 26, Pool 25, and Pool 24 IWMM surveys, June vs August. P-values < 0.05 are statistically significant.

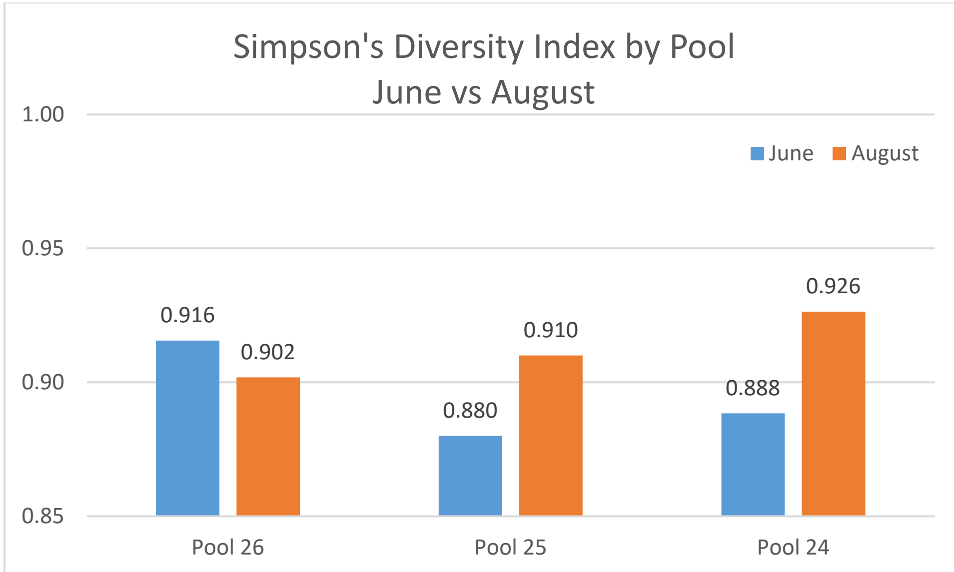


Figure 19. Simpson's diversity index for Pools 26, 25, and 24 from IWMM surveys in June and August.

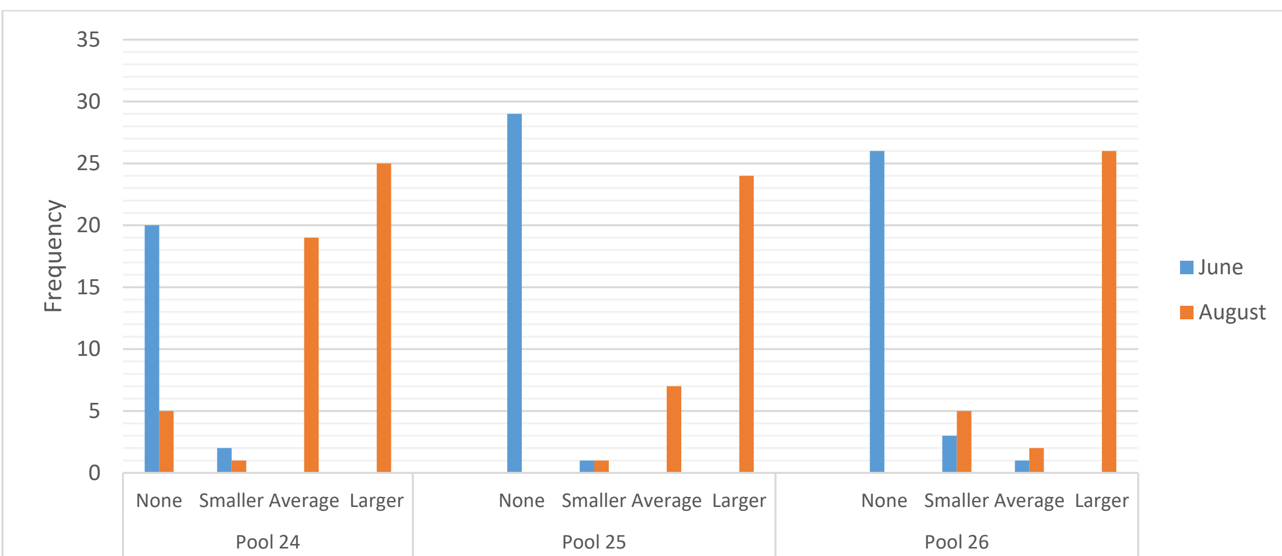


Figure 20. Frequency of occurrence of seed head size (all species) by pool from IWMM surveys during June and August.

2.2.3 Discussion

Average percent species cover varied by timing of surveys. In Pool 26, average percent cover was primarily dominated by *Polygonum* and *Echinochloa* spp in June (Figure 11). However, by July, species were more evenly distributed and diversity was also higher. Mean percent cover for Pool 26 was lower in August (66%) than in June (75%) (Table 4). Pool 26 had higher combined species frequency of occurrence in June compared to August (Figure 12). However, there were more species documented in August. This demonstrates that although there was lower percent frequency of occurrence for most species in August, these values were likely lower than June because additional species likely lowered the overall proportion of each species that occurred in June.

In Pool 25, in June, average percent cover was dominated by *Polygonum* and *Aster* species (Figure 13). Whereas, in August, average percent cover was more evenly distributed across species with increased diversity. Mean percent cover for Pool 25 was higher in August (96%) than in June (68%) (Table 5). Pool 25 had higher species frequency of occurrence in June compared to August (Figure 14). However, there were more species documented in August. This demonstrates that although there was lower percent frequency of occurrence for most species in August, these values were likely lower than June because additional species likely lowered the overall proportion of each species that occurred in June.

Results for average percent cover in Pool 24 were not as clear, percent cover was observed in both June and August and *Polygonum* spp. dominated later (Figure 15). Mean percent cover for Pool 24 was higher in August (114%) than in June (61%) (Table 6). Pool 24 had higher combined species frequency of occurrence in June compared to August (Figure 16). However, there were more species documented in August. This demonstrates that although there was lower percent frequency of occurrence for most species in August, these values were likely lower than June because additional species likely lowered the overall proportion of each species that occurred in June.

When comparing total percent cover, regardless of species, nearly all sites in Pool 26, 25, and 24 appeared to show an increase between June and August (Figure 17). Although generalities can be extracted from the percent cover of occurring at each site, a larger and more robust dataset was needed to assess mean percent cover occurring in June and August. The t-tests performed on mean percent cover by pool are an accurate way to determine whether or not there was a statistically higher probability of higher percent cover in August versus June. The t-tests mostly yielded statistically non-significant results. Pool 26 (Table 4) and 24 (Table 6) did not have a statistically higher mean percent cover when comparing the survey results between June and August. However, Pool 25 (Table 5) showed a statistically higher mean percent cover in August than in June, $P = 0.01$. This shows that although we would have expected a higher mean percent cover in August than June due to the longer growing season, there was in fact not higher percent cover observed in Pools 26 and 24.

August surveys had a higher species richness than June for all three pools (Figure 18). When combining Pools 26, 25, and 24 for species richness using a t-test, results showed a statistically different mean species richness for June versus August, $P = 0.04$ (Table 7). August had a higher mean species richness of 11.33 than June 15.33. This demonstrates that the longer the pools can sustain lower water elevations, the higher the species richness. This is further shown when using Simpson's diversity indices for each pool and comparing June to August (Figure 19). The Simpson's diversity index measured the probability that the two randomly sampled individuals belong to different species, occurring between 1 and 0, i.e., the higher the number, the more diverse the community measure. Both Pool 25 and 24 demonstrated a higher diversity index in August (0.910 and 0.926, resp.) compared to June (0.880 and 0.888, resp.). Pool 26 on the other hand had a lower diversity index in August (0.902) than it did in June (0.916).

Seed producing emergent plant species seed head sizes increased from mid-season to end of season. Figure 20 compares frequency of occurrence of June vs August seed head sizes and densities by pool. All three pools had a higher frequency of emergent plant species that produce seed heads in August as compared to June. Both Pool 25 and 26 had high frequencies of occurrence of no seed heads present in June but shifted to categories smaller, average or larger by August. Larger seed heads became more frequent in all three pools in August compared to June. Fewer frequencies of occurrence of small seed head sizes occurred compared to medium and large in August. This demonstrates that the longer period of time in which the seed producing emergent plants can grow, the larger the seed head size, which means the more seed produced for wildlife such as waterfowl.

The above results not only show that the sites sampled had high diversity, percent cover, and potential for seed production, but that these values increased improved over time as well. This is particularly important when considering the length in which Environmental Pool Management is implemented. Past practices had an average of 30 to 45 days in which Pools 26, 25, and 24 attempted to maintain lower water elevations when flows allowed. The higher flow conditions in 2016, which resulted in periods of at least one foot of water elevation reduction of nearly 100 days or more for all three pools, produced large amounts of vegetation coverage and higher species diversity as the growing season continued. This is particularly important for the resiliency of the aquatic ecosystem, in that the longer growing season created favorable conditions for perennial species that have been lacking compared to historic conditions. Although not high compared to other documented species, *Sagittaria* species increased in frequency of occurrence in August as well as percent cover. It would be expected that as these species continue to have favorable growing conditions, their abundance and coverage would increase over time as individuals develop larger below-ground resources.

## 2.3 Long Term Resource Monitoring Vegetation Surveys

### 2.3.1 Methods

Sites as described in Section 2.2 were sampled utilizing the Long Term Resource Monitoring Vegetation Survey Protocol, Yin *et al* 2000. Within each site, plot locations were determined using the LTRM Stratified Random Sampling design, where a 50 x 50 meter grid is generated and overlaid into a GIS map. Nodes of the grid are geo-spatially registered with coordinates generated. Nodes that fall within the sites were selected as vegetation survey plot locations. A total of 30 plots were generated per pool. At each plot location, sampling is normally done via a boat and a total of six subplots are located off each corner of the boat and off the port and starboard sides of the boat. Each subplot is assigned a percent cover estimate using a rating of 0 to 5. The cover rating relating to species percent cover is as follows: 0 = None; 1 = 1-20%; 2 = 21-40%; 3 = 41-60%; 4 = 61-80%; 5 = 81-100%. A cover rating was assigned to each species within each subplot.

Although this vegetation survey protocol is primarily designed for sampling submersed aquatic vegetation via a boat, in Section 1.4.3 of the LTRM vegetation sampling protocol, *Unusual Situations* describes circumstances in which emergent aquatic vegetation sampling can be done on the ground. When utilizing this approach, the subplots are estimated visually as to their approximate location as if sampling was done from a boat.

Species richness was calculated by pool (Figure 21). Average species percent cover was calculated for Pools 26, 25, and 24 (Figures 22, 24, and 26). Species percent frequency of occurrence was calculated for Pools 26, 25, and 24 (Figures 23, 25, and 27). Simpson's diversity indices were calculated for Pools 26, 25, and 24 (Figure 28).

### 2.3.2 Results

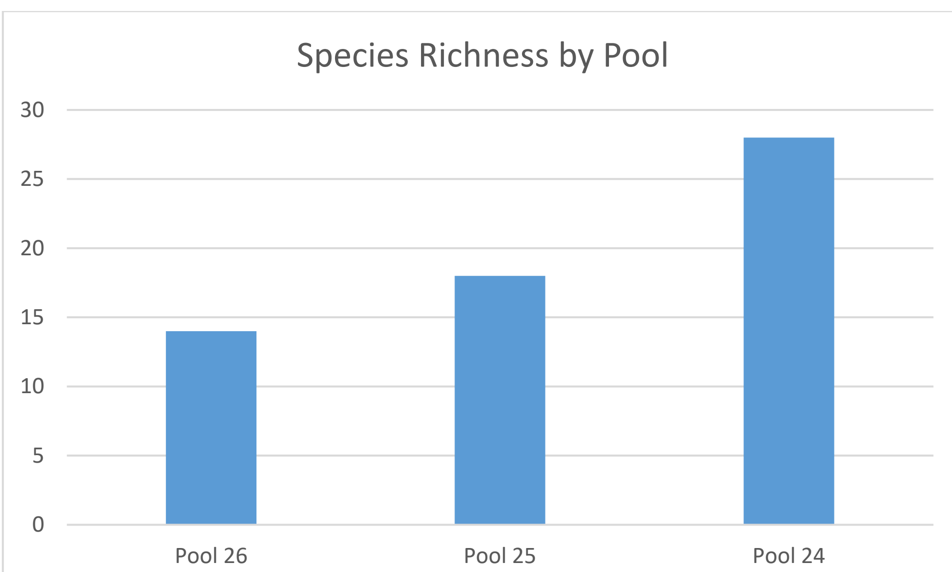


Figure 21. Species richness for Pools 26, 25, and 24 from LTRM vegetation survey.

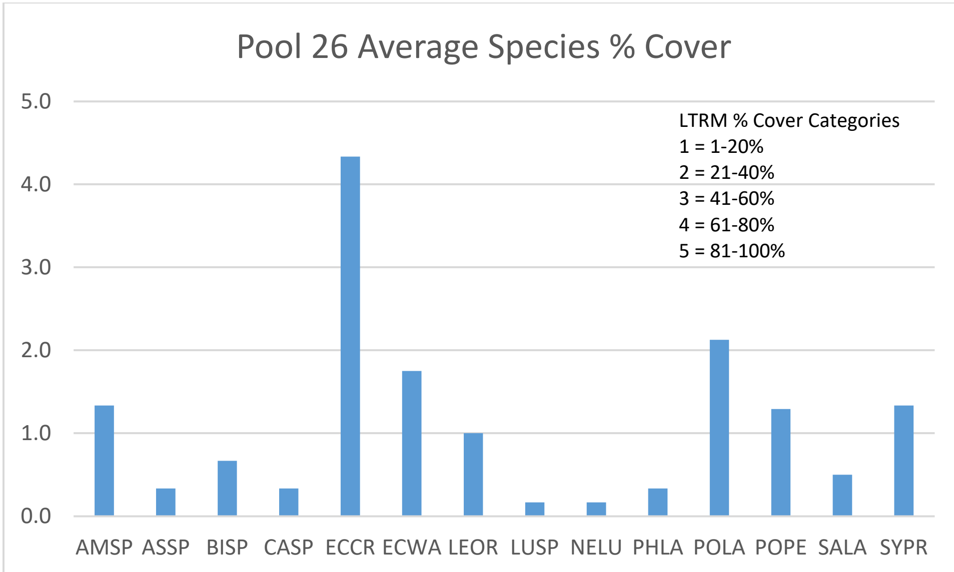

Figure 22. Pool 26 average percent cover from LTRM vegetation survey.

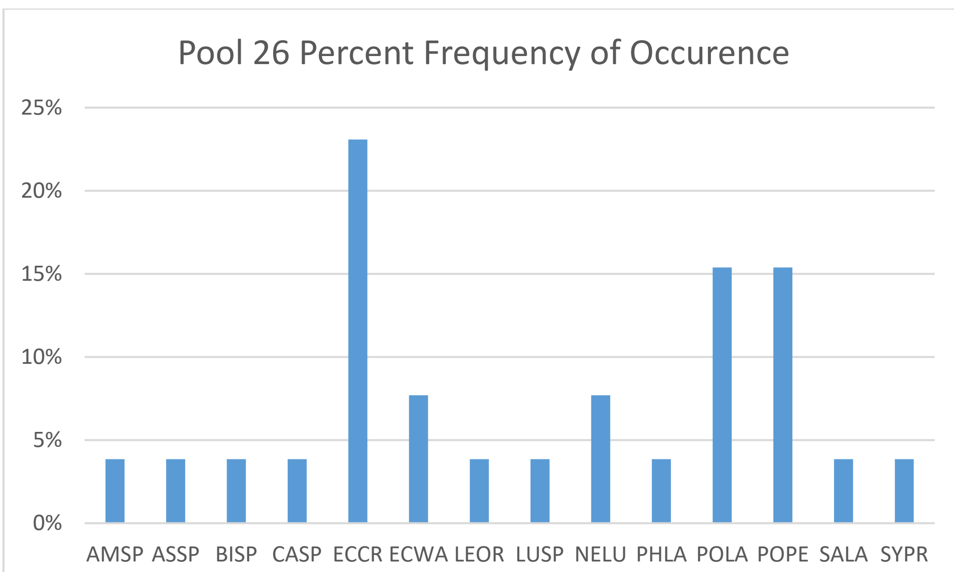

Figure 23. Pool 26 species percent frequency of occurrence for LTRM surveys.

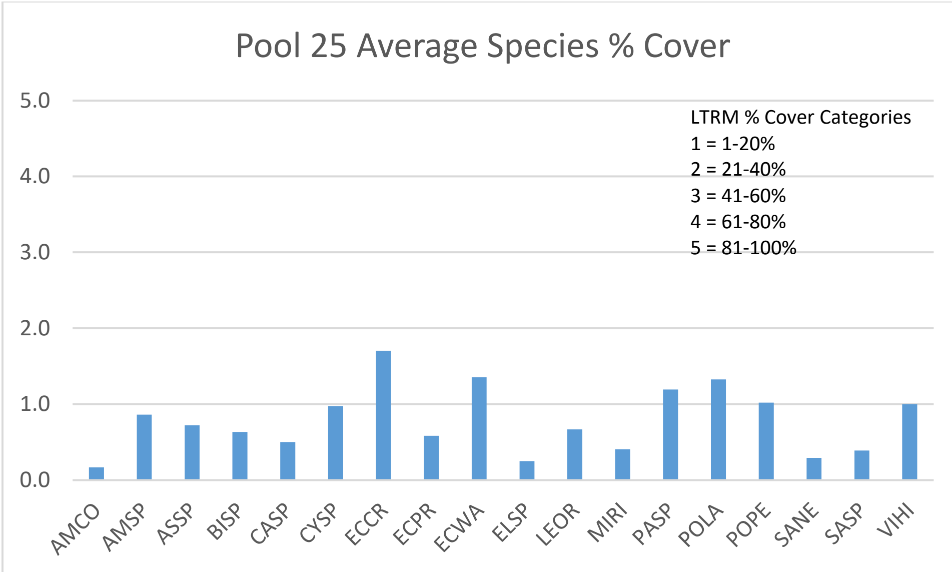

Figure 24. Pool 25 average percent cover from LTRM vegetation survey.

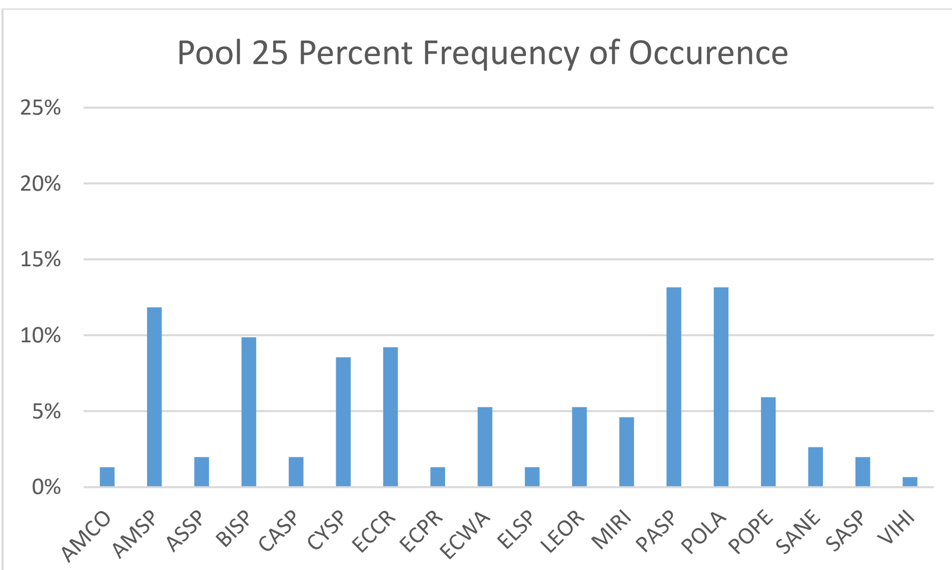

Figure 25. Pool 25 species percent frequency of occurrence for LTRM surveys.

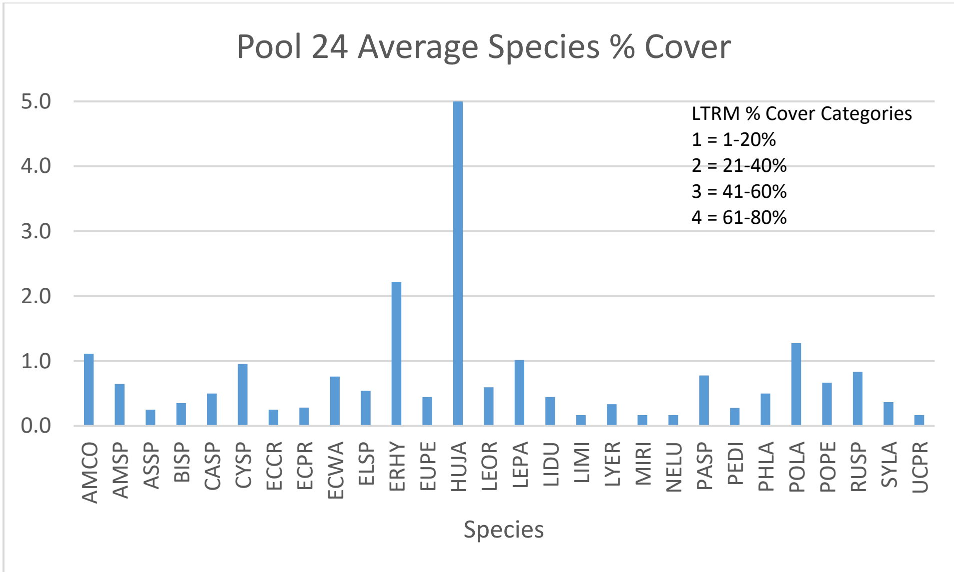

Figure 26. Pool 24 average percent cover from LTRM vegetation survey.

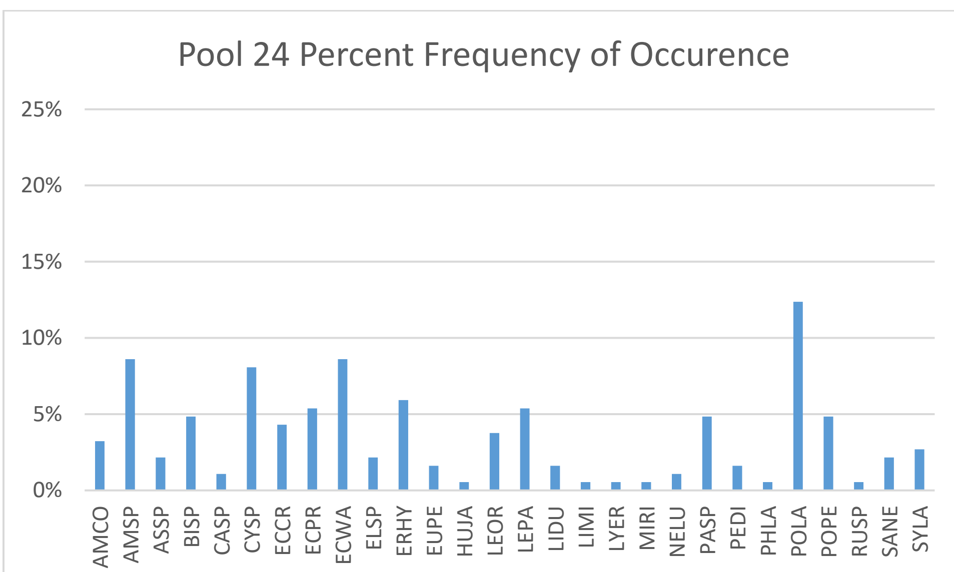

Figure 27. Pool 24 species percent frequency of occurrence for LTRM surveys.

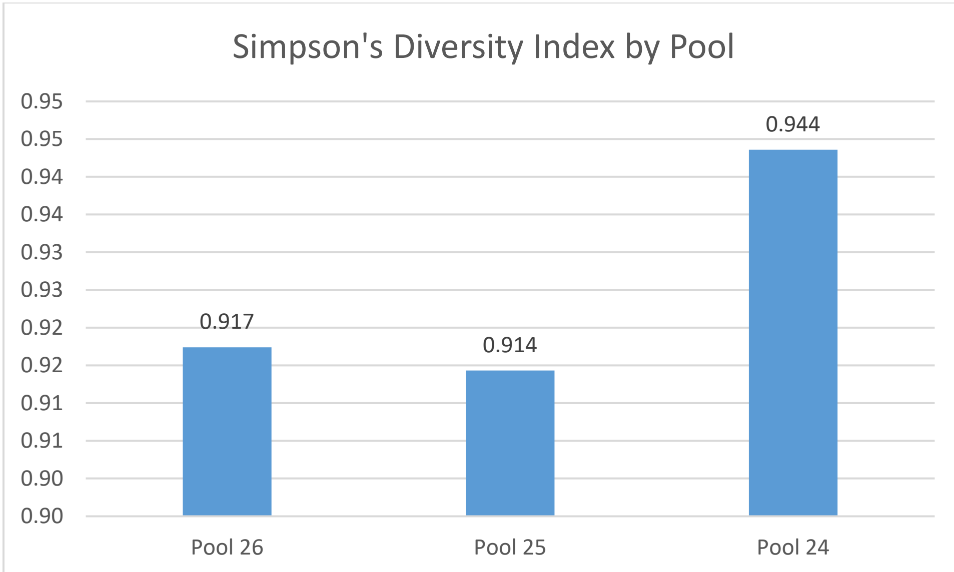


Figure 28. Simpson's diversity index for Pools 26, 25, and 24 from LTRM vegetation surveys.

### 2.3.3 Discussion

In total, 33 species were documented during the surveys. Species richness increased from Pool 26 to Pool 24. A total of 14 species were documented in Pool 26, 18 species in Pool 25, and 28 species in Pool 24. Acreages capable of growing emergent vegetation decreases from Pool 26 upstream to Pool 24. This means that there are more transitional areas in Pool 24, which had smaller sites compared to Pool 26, with larger, more expansive sites (Table 2).

Species were relatively evenly distributed for average percent cover by Pool, except for Pool 24, which had a high average percent cover of Japanese hops (*Humulus japonicas*) and Pool 26, which had a high average percent cover of millet (*Echinochloa crusgalli*). This was due to a low number of occurrences of Japanese hops but a high percent coverage (Figure 27 and 24). This species, which is a non-native invasive species was only documented at one site in Pool 24. On the other hand, millet occurred frequently and at high densities throughout the sites in Pool 26 (Figure 25 and 22). This species produces seed which is beneficial to migratory waterfowl.

Pool 26 had higher percent frequency of occurrence for three main species: *Echinochloa crusgalli, Polygonum lapathifolium,* and *Polygonum pensylvanicum*. While Pool 25 had a relatively even distribution of frequency of occurrence between species, Pool 24 had a higher frequency of *Polygonum lapathifolium.* Although occurrences of *Sagittaria* species were relatively low for each of the pools, at least one species from the genus occurred in each of the pools. As stated in 2.2.3, as conditions in which these species can grow are increased, frequency and density would be expected to increase. Reese and Lubinski 1986, documented large continuous areas of *Sagittaria* previously occurring in Pool 26. However, this species presently does not often occur unless conditions are appropriate as they were during the 2016 EPM season. The trial period of four years of an extended water elevation reduction within Pools 26, 25, and 24 will likely create conditions favorable to these perennial species.

## 2.4 Seed Head Analysis

### 2.4.1 Methods

In order to quantify the amount of seed produced from emergent aquatic plant species, a seed analysis was conducted. Two sites were chosen, Middleton Island in Pool 24 and Dresser Island Conservation Area in Pool 26, with high emergent vegetation plant growth and qualitatively observed high rates of seed production. Sampling occurred when the majority of the plants had produced seed heads and before shattering. To accomplish the seed head analysis, six randomly placed 1 $m^2$ plots were established at each site. Within each plot, the number of seed-producing plant stems were counted. Only the seven species that currently have a model built for seed production were counted, following Gray *et al* 2009. These species include: flatsedge (*Cyperus erythrorhizos*), barnyard grass (*Echinochloa crusgalli*), Walter's millet (*E. walteri*), Amazon sprangletop (*Leptochloa panicoides*), rice cutgrass (*Leersia oryzoides*), fall panicum (*Panicum dichotomiflorum*), and curlytop smartweed (*Polygonum lapathifolium*). One randomly selected plant stem specimen from each species was collected from each plant. In cases with multiple seed heads per stem, all seed heads were collected. Once seed heads were collected, they were placed into plastic bags while in the field. Upon returning from the field, the bags were opened and a fan was placed on them for drying. Drying was necessary to prevent mold from growing on the collected seed heads between sampling and during shipping of the specimens. Samples were sent to University of Tennessee, Knoxville for analysis utilizing Gray *et al* 2009 approach to quantify kilograms of dry seed produced per hectare, duck-energy-days (Kaminski *et al* 2003), total kilograms of seed produced per site, and total duck energy days (DEDs) per site.

Figure 29. Photo of vegetation survey plot (1$m^2$) used for seed head surveys. Photo taken at Middleton Island in Pool 24. Vegetation shown is predominantly Amazon sprangletop (*Leptochloa panicoides*). Photo by Ben McGuire, USFWS, formerly USACE.

2.4.2 Results

Duck energy-day estimates are provided in Appendix A. Total estimated DEDs for the Dresser site (18.4 ha, 45.4 ac) was 113,762 DEDs, which is equivalent to having the energetic potential to support 1,034 ducks per day for 110 days. Total estimated DEDs for the Middleton site (3.7 ha, 9.2 ac) was 26,548 DEDs, which is equivalent to having the energetic potential to support 241 ducks per day for 110 days. Moist-soil vegetation managers attempt to provide overwintering forage for migratory waterfowl. The overwintering time period for waterfowl in this geographic area is typically 110 days.

2.4.3 Discussion

The results in section 2.4.2 show a high seed production yield as compared to other wetlands which used the same quantification approach (Dugger & Fedderssen 2009). The mean seed production rates of 757.9 lbs/acre and 656.6 lbs/acre for Pool 24 and Pool 26 respectively are higher than average sampled moist-soil unit sites (Dugger & Fedderssen 2009). Since the plots shown in Figure 29 were randomly placed within each of the sampled sites, areas which did not have vegetation, i.e., bare earth were sampled. Therefore, these calculations are conservative and do not represent the seed per acre produced within vegetated areas. Further, since the sites sampled contained were at random, these results can be extrapolated and from each of the sites sampled and applied to the entire pool in which each of the sites were located. The results from Middleton Island can be applied to all of Pool 24 for areas that can support vegetation during the 2016 EPM season (315.61 acres), resulting in 239,200.82 pounds of seed produced in 2016 during the growing season. Similarly, the results from Dresser Island can be applied to Pool 26 for areas that can support vegetation during the 2016 EPM season (753.57 acres), resulting in 885,149.33 pounds of seed produced. The calculated DEDs for Middleton Island and Dresser Island can also be applied throughout Pool 24 and 26, respectively. Middleton Island produced 2,885.7 DEDs/acre, which translates to supporting the metabolic requirements of 910,740 ducks for one day or 8,280 ducks for 110 days in Pool 24. Dresser Island produced 2,505.8 DEDs/acre, which translates to supporting the metabolic requirements of 3,377,978 ducks for one day or 30,708 ducks for 110 days in Pool 26.

# Chapter 3 Aerial Imagery Analysis

## 4.1 Methods

In order to quantify the acres within each Pool exposed during EPM and thus approximate acres of vegetation grown, satellite photography was acquired and downloaded from DigitalGlobe (https://evwhs.digitalglobe.com). This website displays satellite images of areas more frequently than other applications such as GoogleEarth. In 2016, satellite photos were taken of the Mississippi River area within the St. Louis District during the EPM growing season on April 16 within the Pool 26 area and June 29 in the Pool 25 area. An aerial image from a previous, year, April 23, 2015 was used for Pool 24. During February 2017, additional satellite aerial images were acquired specifically for Pools 26, 25, and 24. Areas with water were delineated and polygons were drawn around all water bodies, both connected to the pool and isolated during the drawdown. All of these areas were connected to the pool, i.e., no areas that had water control structures or levees obstructing the water were included. Once polygons were drawn around all areas with water, acreage was calculated and subtracted from already known delineated acreages at full-pool.

## 4.2 Results

Acreages from the aerial image delineations vary by water elevation when the images were acquired. For instance, the Pool 26 image from April 26, 2016 (Figure 34) yielded a total of 1,348 acres. The elevation for the pool at that time was at 413.35 feet, which is near maximum drawdown (413.5 feet). Therefore, 1,348 acres of exposed mudflat is the highest potential area that could be achieved only if Pool 26 sustained enough flow to be at maximum drawdown for the entire growing season. In the past, EPM operations have sustained approximately 418.0 feet water elevation in Pool 26 during the growing season. During the 2016 EPM season, due to sustained higher flows, approximately 416.7 feet and above was likely the water elevation in which the vegetation sustained growth throughout the growing season. This is based on timing of fluctuations, approximate vegetation heights within the pool, and field observations. See Figure 31 for the hydrograph with this elevation applied. Satellite images acquired on February 3, 2017 for Pool 26 (Figure 30) will likely yield more accurate acreages of the actual area of vegetation grown during the 2016 EPM season. When the images were taken, the L&D 26 headwater elevation was at 416.90 feet, which is within 0.2 feet elevation difference of the elevation likely driving vegetation growth during the 2016 growing season. There was a 594.51 acre difference between April 26, 2016 image (Figure 34) and February 3, 2017 image (Figure 35). The headwater elevation difference between these two dates was 3.34 feet. This difference on average is approximately 178.0 acres exposed per 1.0 feet of elevation reduction, assuming a linear relationship between acres exposed and elevation.

The same application was completed for Pool 25. A satellite image from June 29, 2016 was used to delineate areas which were exposed and had the capability of growing vegetation (Figure 36). On the date in which this image was take, the headwater at Pool 25 was 430.03 feet and yielded a total acreage capable of growing vegetation of 448.33 acres. In addition, a satellite image from February 3, 2017 was delineated in the same way (Figure 37) when the headwater elevation at L&D 25 was 429.80 and yielded a total of 518.97 acres. The image from June 29, 2016 likely was more representative of the vegetation actually grown this year since the elevation likely driving vegetation growth was 430.51 (Figure 32). The headwater elevation difference between these two dates was 0.23 feet. This difference is approximately 307.13 acres exposed per 1.0 feet of elevation reduction, assuming a linear relationship between acres exposed and elevation. This higher exposed acreage per foot of elevation reduction compared to Pool 26 is likely due to the limited acreage that is connected to the river within Pool 25 and included in this analysis. Areas that remain unimpounded for this analysis are main channel border areas, which have a higher elevation relief that the larger unimpounded backwater areas of Pool 26.

The acreages for Pool 24 were determined in the same way as Pools 26 and 25. The satellite image from April 23, 2015 in which the L&D 24 headwater elevation was 447.71, yielded 315.61 acres of exposed area in which vegetation could be grown (Figure 38). The satellite image from February 3, 2017 (Figure 39), in which the L&D 24 headwater elevation was 446.95, yielded 338.77 acres in which vegetation could be grown. The image from April 23, 2015 is likely a more accurate representation of the acres of vegetation grown during the 2016 EPM season, given that the elevation driving vegetation growth was likely 447.80 (Figure 33). The headwater elevation difference between these two dates was 0.76 feet. This difference on average is approximately 30.47 acres exposed per 1.0 feet of elevation reduction, assuming a linear relationship between acres exposed and elevation.

See Table 8 for summary of acres exposed when the satellite images were taken with water elevations, and total acreage of area exposed. The image delineation gives approximate acres exposed at various elevations. More accurate acreages at any headwater elevation could be calculated if LiDAR was acquired for each of the pools while they are at or near maximum drawdown.

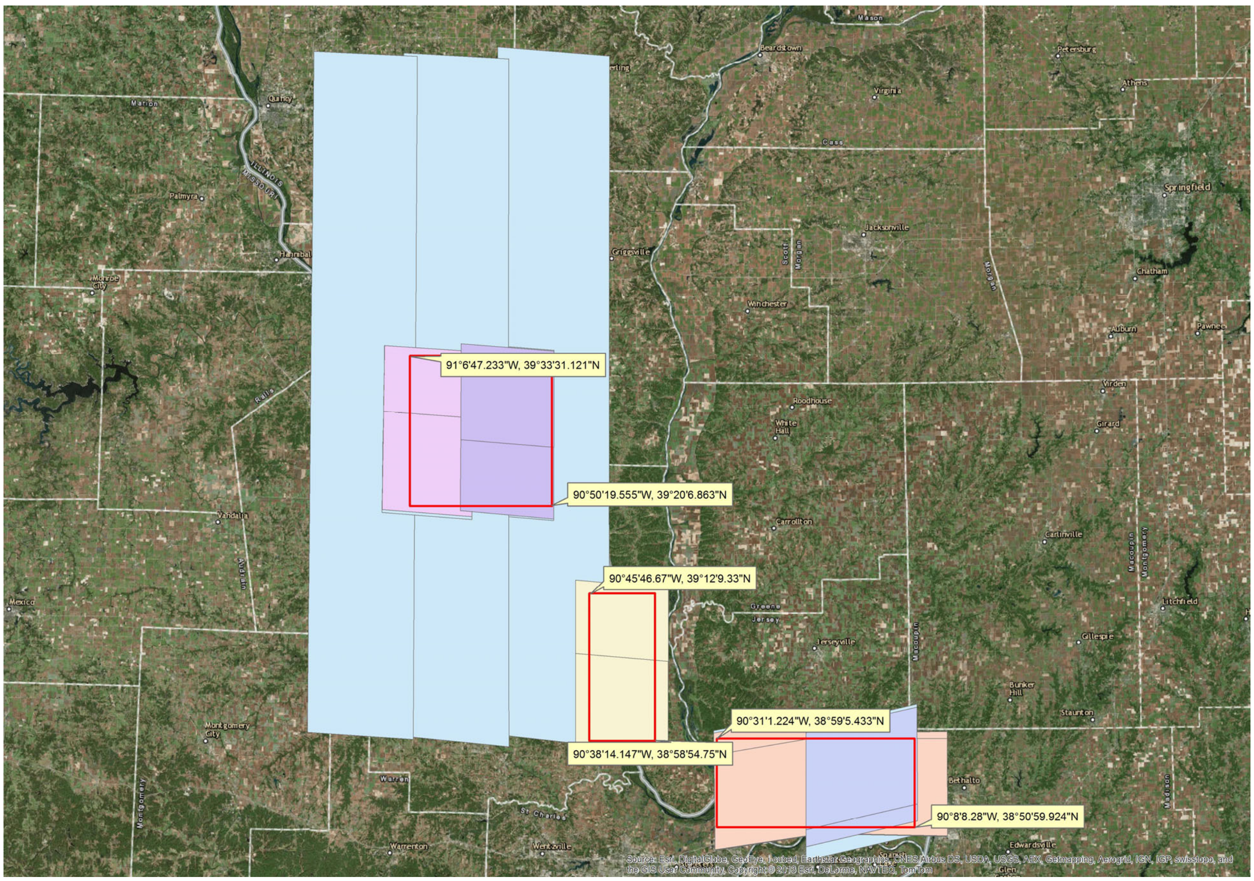

Figure 30. Aerial image showing satellite image acquisition via DigitalGlobe on February 3, 2017.

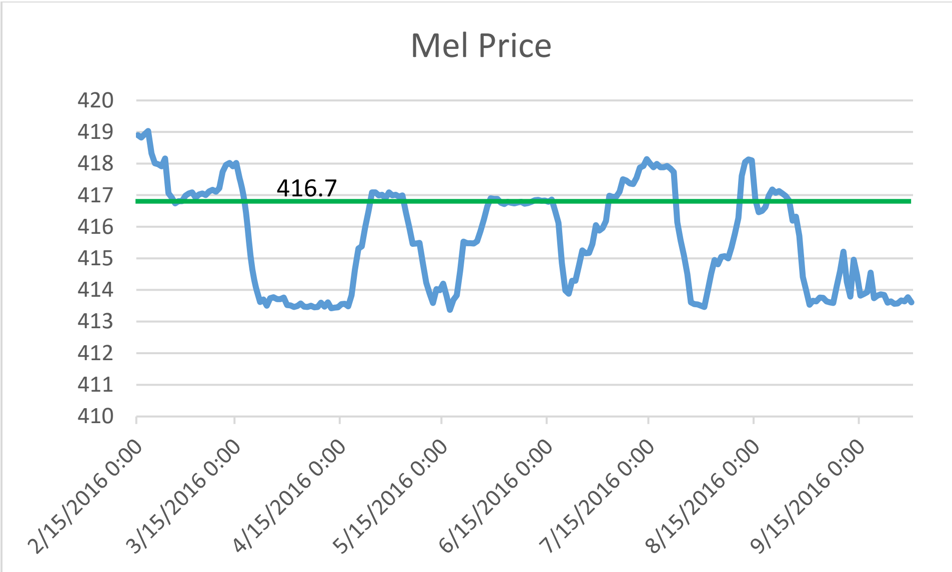


Figure 31. Hydrograph of Pool 26 (blue) with line denoting likely lower elevation (green) in which vegetation was grown for the season.

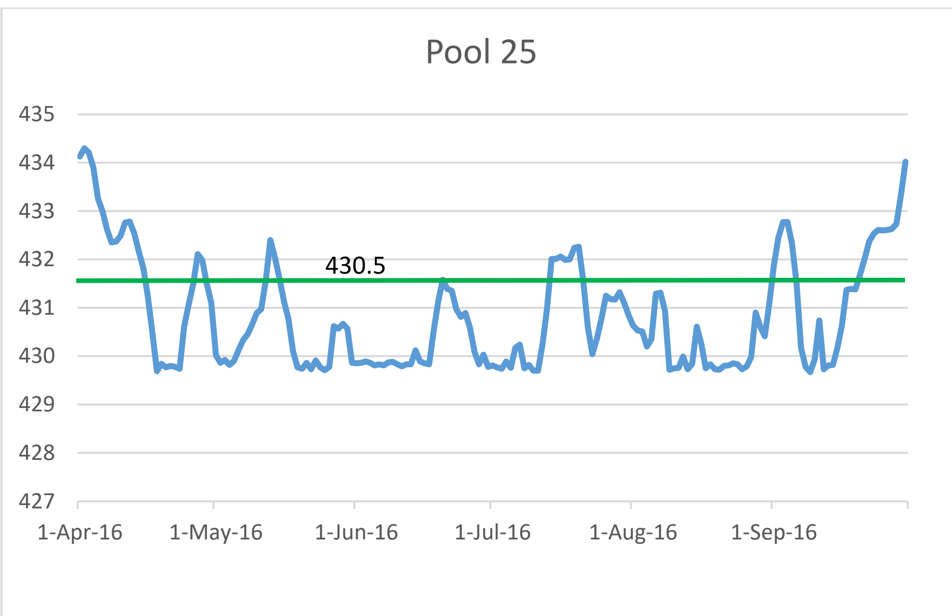


Figure 32. Hydrograph of Pool 25 (blue) with line denoting likely lower elevation (green) in which vegetation was grown for the season.

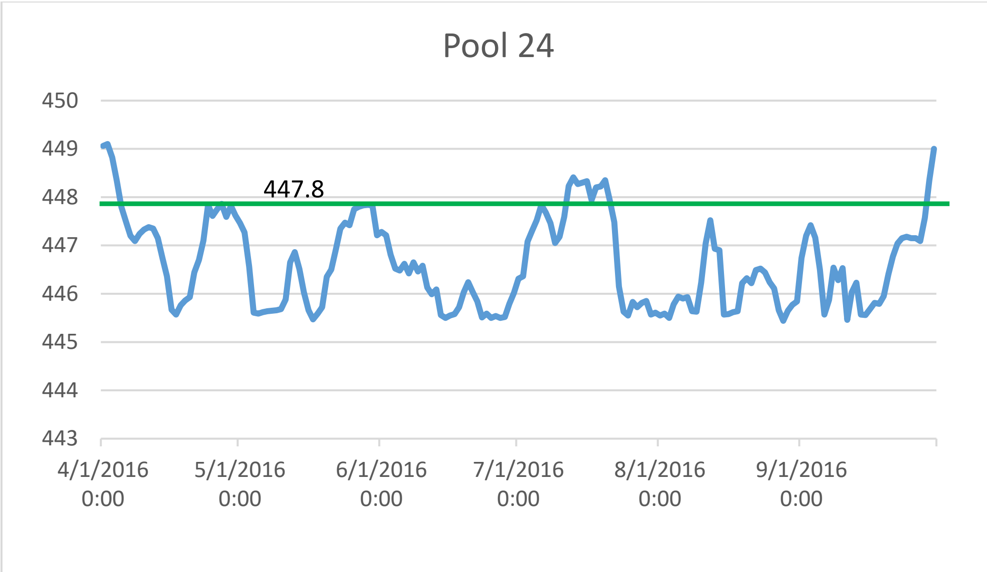


Figure 33. Hydrograph of Pool 24 (blue) with line denoting likely lower elevation (green) in which vegetation was grown for the season.

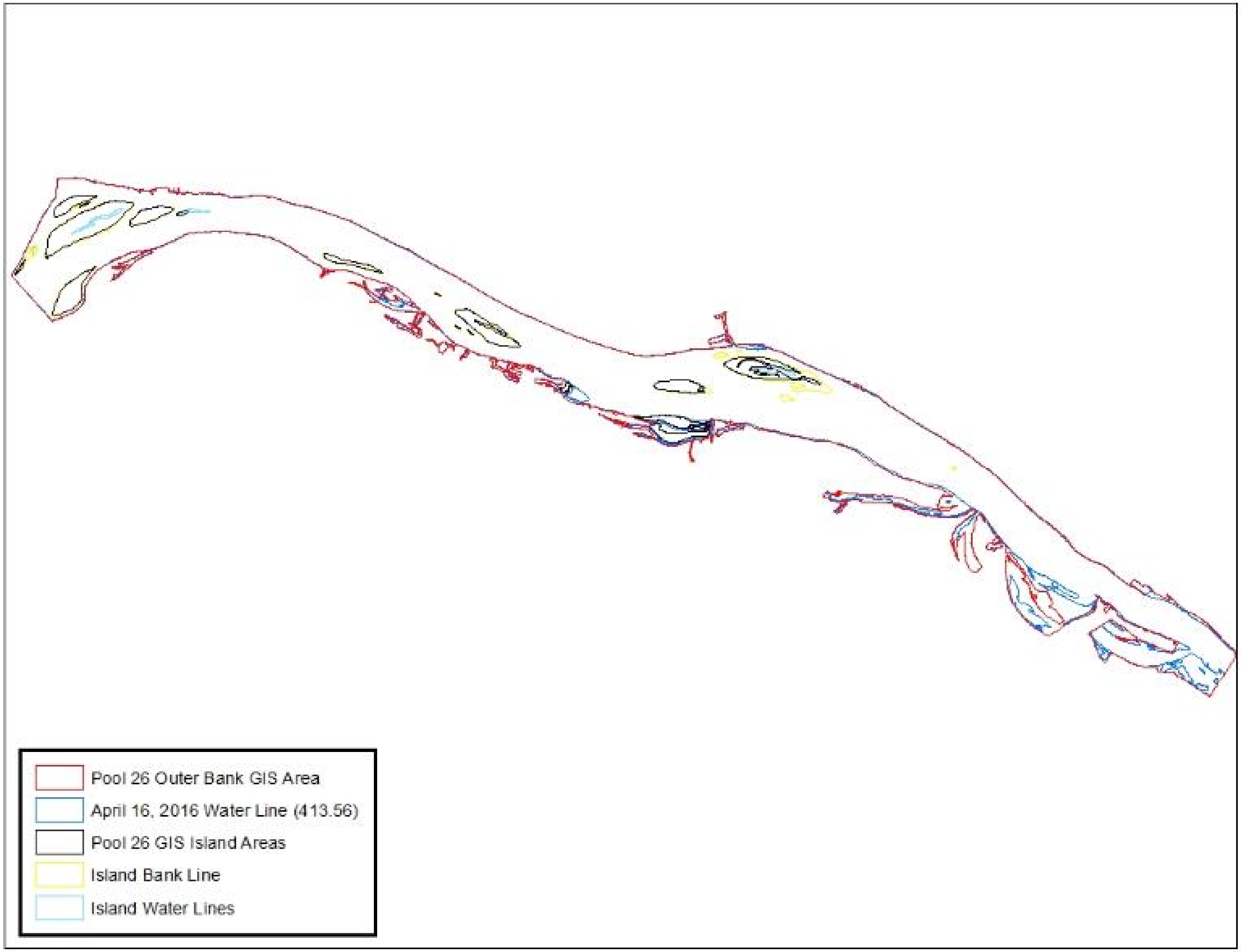


Figure 34. Satellite image delineation for Pool 26. Satellite image taken April 16, 2016. Mel Price L&D headwater elevation 413.56.


Figure 35. Satellite image delineation for Pool 26. Satellite image taken February 3, 2017. Mel Price L&D headwater elevation 416.9.

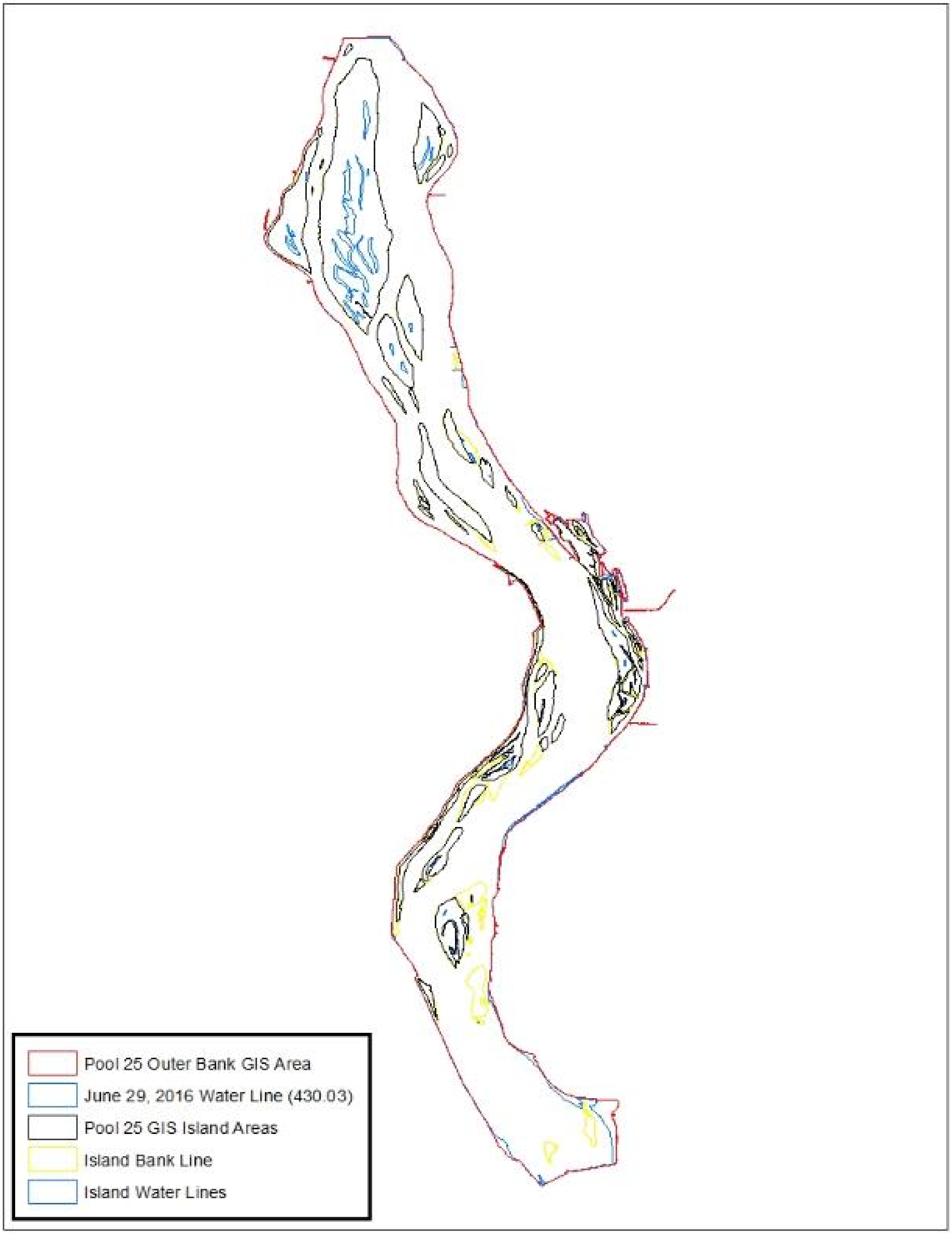


Figure 36. Satellite image delineation for Pool 25. Satellite image taken June 29, 2016. L&D 25 headwater elevation 430.03.

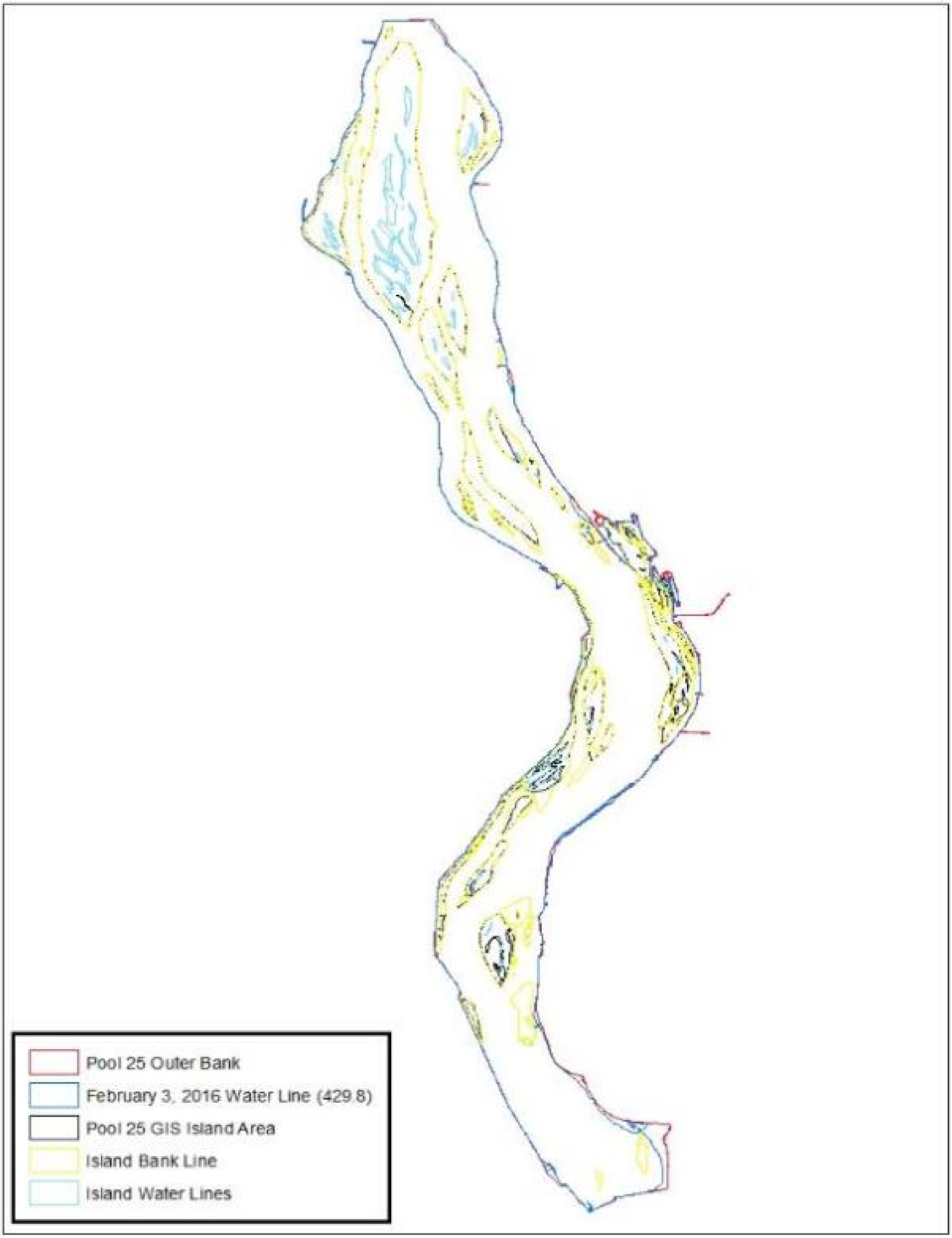

Figure 37. Satellite image delineation for Pool 25. Satellite image taken February 3, 2017. L&D 25 headwater elevation 429.8.

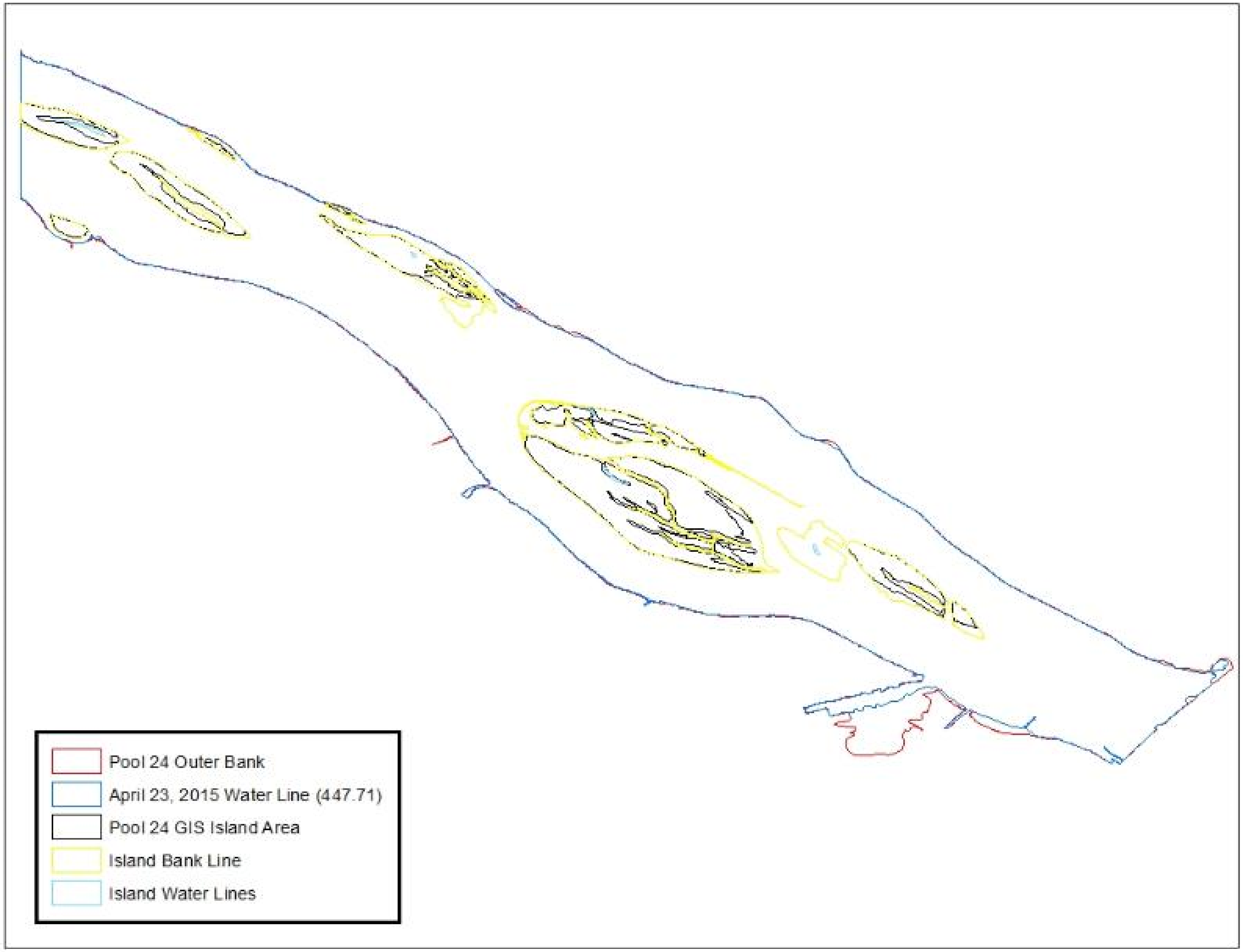

Figure 38. Satellite image delineation for Pool 24. Satellite image taken April 23, 2015. L&D 24 headwater elevation 447.71.

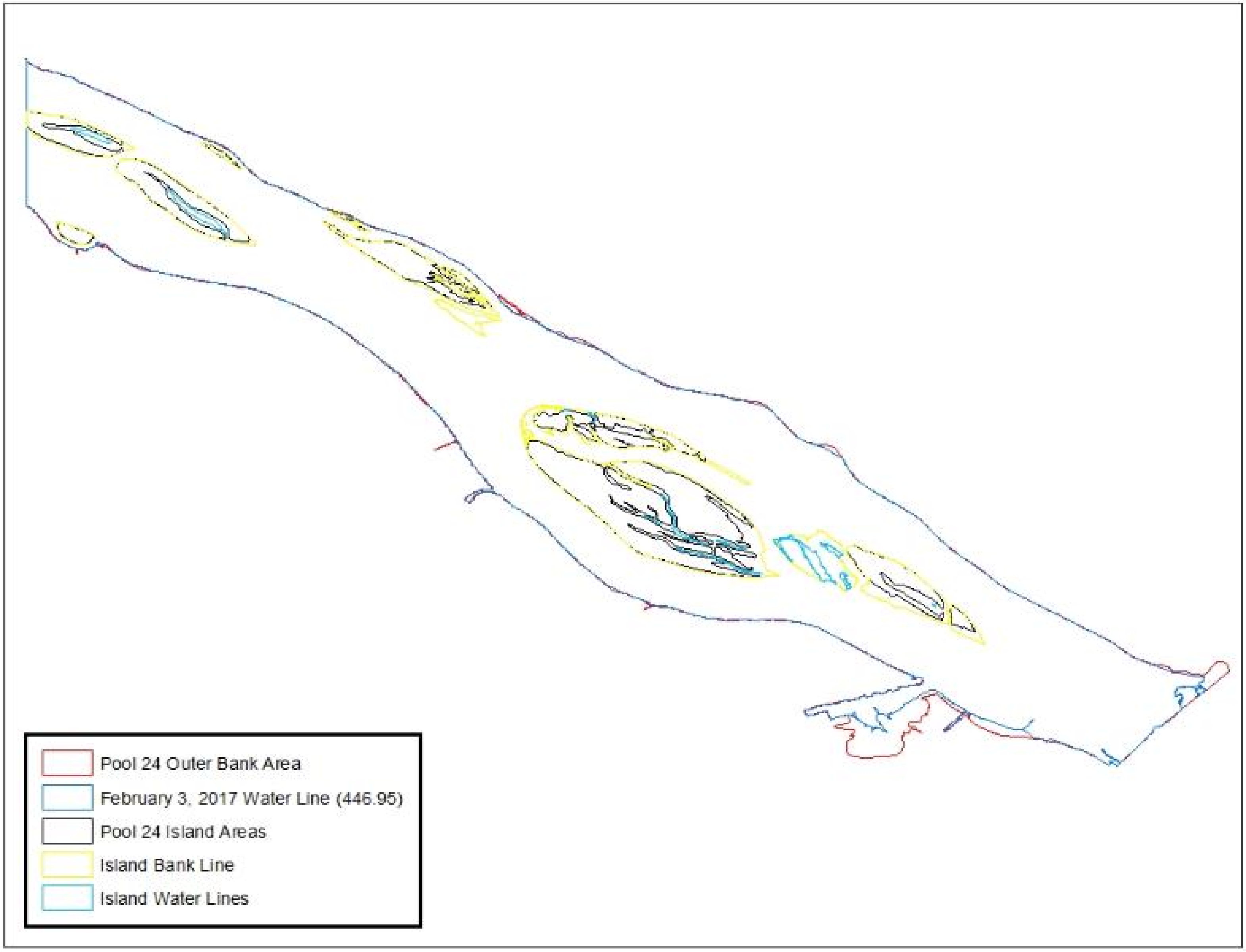

Figure 39. Satellite image delineation for Pool 24. Satellite image taken February 3, 2017. L&D 24 headwater elevation 446.95.

| Pool | Image Date | Pool Elevation | Typical EPM Elevations | 2016 Elevation Driving Vegetation Growth | Acreage |
|---|---|---|---|---|---|
| Pool 24 | 23-Apr-15 | 447.71 | 448.0-448.5 | 447.80 | 315.61 |
| Pool 24 | 3-Feb-17 | 446.95 | 448.0-448.5 | 447.80 | 338.77 |
| Pool 25 | 3-Feb-17 | 429.80 | 432.00 | 430.51 | 518.97 |
| Pool 25 | 29-Jun-16 | 430.03 | 432.00 | 430.51 | 448.33 |
| Pool 26 | 26-Apr-16 | 413.56 | 418.00 | 416.70 | 1348.08 |
| Pool 26 | 3-Feb-17 | 416.90 | 418.00 | 416.70 | 753.57 |

Table 9. Summary of satellite image acreage delineations with image dates, elevations of the pools with headwater elevations, typical Environmental Pool Management elevations, and estimated elevation driving vegetation growth as shown in Figures 32, 33, and 34.

# Chapter 4 Outreach

## 4.1 Meetings

| Meeting Attended | Approximate USACE dollar expenditure |
|---|---|
| RRAT Tech Meeting | 1k |
| EPM End of Season Meeting | 3k |
| RRAT Boat Trip | 2k |
| Water Control Open House Meetings | 10k |
| Misc. MVS Meetings and Coordination | 5k |
| MVD Environmental Community of Practice | 1k |
| Upper Mississippi River Conservation Committee presentation | 2k |
| Upper Mississippi River Basin Association presentation | 5k |
| **Total** | **34k** |

Table 11. Summary of approximate fund expenditures by MVS during the 2016 EPM season.

| Task Completed | Approximate Partner dollar expenditure |
|---|---|
| TNC Participation | 20k |
| IDNR Participation | 5k |
| FWS Participation | 5k |
| MDC Participation | 5k |
| | |
| **Total** | **30k** |

Table 10. Summary of approximate fund expenditures by partners during the 2016 EPM season.

Throughout 2016, MVS provided additional support with in-house funds, totaling approximately 30-40k. Personnel from the Rivers Project Office assisted with internal coordination, vegetation surveys, and public outreach. Open houses were hosted by MVS Water Control in Pools 26, 25, and 24 to inform the public of operations and current conditions. In addition, multiple presentations were given internally as well as externally to promote the water level management success in MVS throughout the Upper Mississippi River. This intense outreach has resulted in a multi-agency and partner workshop scheduled in spring of 2017 to discuss water level management and implementing EPM in locations within MVR and MVP.

During the post-season meeting, new guidelines were established to reflect the longer duration EPM operations as follows:

1) Provide safe and dependable navigation channel
2) Begin pool drawdowns around 1$^{st}$ of April before majority of *Centrachid* fish spawn begins
3) Continue drawdowns from the 1$^{st}$ of May to the 30$^{th}$ of July for most suitable period of vegetation growth and seed production
4) Minimum of 0.5 feet drawdown for 30 days

5) After initial drawdowns, allow the pools to rise at a rate of < 0.3 ft/day, which allows some vegetation to survive and continue to grow

## 4.2 Articles

The success of the 2016 growing season generated much public interest, which results in multiple articles. Published articles are below:

St. Louis Post Dispatch:

http://www.stltoday.com/business/local/corps-conservationists-bringing-back-river-wetlands/article_70d156f1-8094-5b24-9266-ea60cbb763e6.html

E&E News:

http://www.eenews.net/stories/1060041871

NPR:

http://news.stlpublicradio.org/post/federal-water-spending-bill-could-improve-missouri-water-quality-and-flood-protection#stream/0

# Chapter 5 Qualitative Results

## 5.1 Vegetation

In Pool 26 at Alton Lake, seeds of American lotus (*Nelumbo lutea*) were observed throughout the site in the substrate (Figure 40). The same species was also observed growing in numerous locations (Figures 41, 42, and 43). This species was documented at this site during past LTRM surveys but has more recently not been observed. The longer water level reduction time during 2016 likely restored conditions in which American lotus could germinate. This species has seeds that are viable for long periods of time. With continued longer duration water level reductions, this species would likely continue to germinate, build below-ground resources, and possibly persist if given multiple seasons to do so.  In addition, the consolidated sediment observed in this site and others would improve establishment conditions for this rooted floating leaf aquatic plant as well as submersed aquatic plants. These species are often not able to root into the flocculent sediment that exists throughout man areas where they occurred historically.

Figure 40. Photo of American Lotus (*Nelumbo lutea*) seeds at Alton Lake in Pool 26 (photo by Ben McGuire, USFWS, formerly USACE).

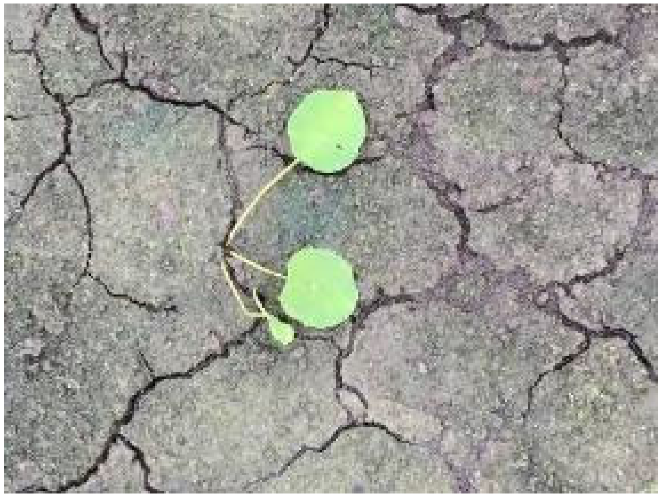

Figure 41. Photo of American Lotus (*Nelumbo lutea*) growing at Alton Lake in Pool 26 (photo by Ben McGuire, USFWS, formerly USACE).

Figure 42. Photo of American Lotus (*Nelumbo lutea*) and root system at Alton Lake in Pool 26 (photo by Ben McGuire, USFWS, formerly USACE).

Figure 43. Photo of American Lotus (*Nelumbo lutea*) growing at Mile 210 area in Pool 26 (photo by Ben McGuire, USFWS, formerly USACE).

## 5.2. Least Tern

Figure 43. Image of adult least terns displaying courtship behavior on 08 JUN 2016, on a sandbar just south of Pharr's Island, Calumet Township, MO. Photo by Shane Simmons, USACE.

In addition to the tremendous vegetative response during the 2016 EPM season, additional benefits of low water levels with a long duration were observed this year. A successful nesting attempt by the federally endangered interior least tern in Pool 24 was documented. On 08 JUN 2016, two adult least terns were spotted on an exposed mudflat downstream of Pharr's Island (39.39768º lat., -90.93781º long.) demonstrating courtship behavior (Figure 44). This consisted of the female standing on an exposed sandbar with the male fishing and returning his catch to the female. Before giving the female the catch, he exhibited the typical parading display as described in Hardy (1957, Whitman 1988). This behavior was observed at least three times, and it appeared that the female accepted the fish each time. In the same vicinity one additional adult least tern was also observed fishing in the shallows near the sandbar. This area was noted and then subsequently monitored for continued least tern use.

On 22 JUN 2016, four adult least terns were observed, flying around the exposed sandbar that is located in between Pharr's and Middleton Islands. Successful fishing attempts were noted, which allowed for the tracking of one of the terns delivering fish to an adult that was located on the sandbar. The adult was resting on the sandbar, as if it were sitting on a nest. Upon closer investigation, a nest was identified, and photographic evidence (Figure 44. Image of the nest discovered on 22 JUN 2016, on a sandbar just south of Pharr's Island, Calumet Township, MO. Photo by Lane Richter and Justin Garrett, USACE.of a nest containing three eggs confirmed the successful nesting attempt by a minimum of at least one breeding pair of interior least terns. Mobbing behavior was observed while photos were taken. GPS coordinates of the nest location were recorded (39.3943º lat., -90.93648º long.).

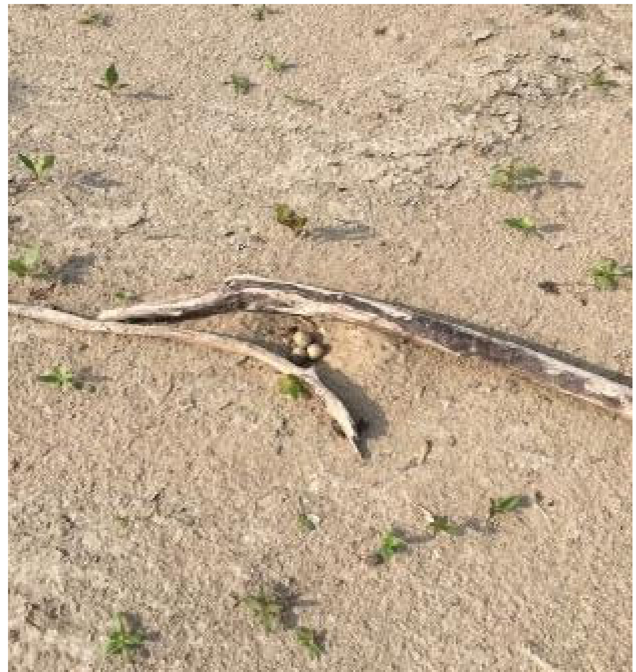

Figure 44. Image of the nest discovered on 22 JUN 2016, on a sandbar just south of Pharr's Island, Calumet Township, MO. Photo by Lane Richter and Justin Garrett, USACE.

In order to document the success or failure of the only nest discovered near Pharr's Island, observations were made again on 14 JUL 2016. By this time, the water level had risen to 448.2 ft. (NVGD29) on the Lock & Dam 24 gauge and covered nearly the entire sandbar where the nest had been located. However, adult least terns were observed foraging approximately 0.32 miles downstream, on a sandbar near the western edge of Middleton Island. A visual search of the sandbar was performed, at which time mobbing behavior was exhibited by the adult terns. This prompted a more extensive search until a fledgling tern was spotted on the ground near the river's edge (Figure 45. Fledgling least tern along river's edge south of Pharr's Island, Calumet Township, MO on 14 JUL 2016. Photo by Lane Richter and Justin Garrett, USACE.). The GPS coordinates of the fledgling's approximate location when first spotted was recorded (39.39215º lat., -90.93140º long.). A short time later, the fledgling took flight, staying near the sandbar. It was noted that mobbing behavior exhibited by the adults only occurred while the fledgling was on the ground. While in flight, at least one of the adults stayed near the fledgling at all times. Photographic evidence was also documented of the fledgling in flight (Figure 46. Fledgling in flight on the western edge of sandbar located below Pharr's Island on 14 JUL 2016. Photo by Lane Richter and Justin Garrett, USACE.). The observation of a fledgling at this early life-stage is evidence of a successful nesting at this location, as it would be highly unlikely for such a young fledgling to have been hatched elsewhere. This

Figure 45. Fledgling least tern along river's edge south of Pharr's Island, Calumet Township, MO on 14 JUL 2016. Photo by Lane Richter and Justin Garrett, USACE.

Figure 46. Fledgling in flight on the western edge of sandbar located below Pharr's Island on 14 JUL 2016. Photo by Lane Richter and Justin Garrett, USACE.

documentation is the northern-most documented confirmation of successful nesting in the impounded reaches of the upper Mississippi River, post-dam construction.

A successful nesting attempt does not always lead to a successful reproductive event. For least terns, a successful nest has been described as the probability that a nest will hatch at least one egg (Smith & Renken 1993). Subsequently, nest success also does not necessarily result in reproductive success. For the entire reproductive event to be considered a success, at least one egg needs to survive until fledging (Smith & Renken 1993). The behavior and activity observed this season near Pharr's island prompted USACE personnel to continue monitoring efforts of the site throughout the 2016 breeding season; as no known described tern recruitment had been documented since anthropogenic river modification had come to the Upper Mississippi basin.

Interior least tern populations have increased in the Lower Mississippi Alluvial Valley and along the Missouri River since their listing (Lott 2006); however, populations within the Upper Mississippi River (UMR) are likely still below historical levels based on latest population studies (Lott et al 2013, USFWS 2013). As discussed in (USFWS 1985), available nesting habitat along the UMR continues to limit the restoration of the breeding and nesting range of the interior least tern. As seen in 2016, available habitat during the breeding season was a direct result of high flows throughout the Upper Mississippi River (UMR) for much of the breeding and nesting season. This resulted in the reduction of water elevations in the lower portion of Pool 24 during water conveyance downstream, exposing additional nesting habitat. In addition, high flows within the Missouri River likely displaced breeding individuals earlier in the season, which led to individuals searching for suitable nesting habitat elsewhere, ultimately leading to the use of available habitat approximately 80 river miles above the confluence of the Missouri and Mississippi River.

A considerable amount of data shows that interior least terns can readily recolonize newly available habitat that emerge from fluctuating water levels (Leslie et al. 2000, USACE 2011). This ability to quickly respond to changing conditions should also promote exploitation of newly available habitat, regardless of causation; whether it be from water level fluctuation, or anthropogenic habitat restoration events (Busby et al. 1997, USACE 2011, 2012). Further evidence for this is the largest known (by an order of magnitude) ILT colony within their range, which utilizes man-made sandbar island that appeared downstream of dike field construction (Lott 2006, Killgore et al. 2014).

Water level management should be further evaluated to maximize water level reductions throughout the UMR to coincide with the breeding and nesting season. Low water levels that are temporally synced with the breeding season have shown to produce high levels of reproductive success

(Dugger et al. 2002); also, as observed in 2016, there is an association between spring water level decreases and habitat availability, which was also described conceptually in Tibbs and Galat (1998, Dugger et al. 2002).

Although EPM operations are currently utilized in Pools 26, 25, and 24, operations do not normally occur upstream in the Rock Island and St. Paul Districts. Regularly implementing water level reductions throughout the entire UMR would likely benefit the range restoration of the interior least tern.

## 5.3 Forest Component

Figure 47. Photo of willow growth on periphery of Middleton Island, Pool 24 on June 8, 2016 (photo by Ben McGuire, USFWS, formerly USACE).

Throughout Pools 24, 25, and 26, seedlings of black willows (*Salix nigra*) were observed at vegetation survey sites along the peripheries. Many of these willow seedlings appeared to have germinated the previous year (2015) and were approximately 6 ft tall on June 8, 2016 (Figure 47. Photo of willow growth on periphery of Middleton Island, Pool 24 on June 8, 2016 (photo by Ben McGuire, USFWS, formerly USACE).). Like emergent aquatic plant species, willows require bare soil that is not under water to germinate, meaning that this area was exposed during EPM operations in 2015.Willows are considered early successional species assist in bank stabilization. They are a limited forest component in the Upper Mississippi River and provide valuable habitat to neotropical migrant bird species. Although likely not all of the willows pictured will survive, there will likely be enough survival to add to sediment capturing capabilities, nutrient uptake, and potentially reducing bank erosion. As noted above, this type of growth was observed throughout each of the three pools. When taking into account this total acreage, the benefits will likely be multiplied in continuing years.

## 5.4 Sediment Consolidation

Sediment consolidation and drying was observed to some degree at every site during 2016. However, the instance at Alton Lake was extraordinary. Figure 49 shows in the lower left corner bare earth in which ATVs and eventually pickup trucks drove on to get to the duck blinds located in this site. In previous years, flocculent sediment was observed to be approximately 1.5 feet deep in that same area. The prolonged water level reduction created conditions where the sediment was exposed and able to dry (Figure 50 and 51). Further sediment consolidation would benefit rooted floating leaf and submersed aquatic plants as discussed in section 5.1.

Figure 48. Photo with vehicle road occurring in bottom left corner at Alton Lake in Pool 26 (photo by Ben McGuire, USFWS, formerly USACE).

Figure 49. Photo showing sediment consolidation occurring at Alton Lake in Pool 26 (photo by Ben McGuire, USFWS, formerly USACE).

Figure 50. Photo showing sediment consolidation occurring at Alton Lake in Pool 26 (Photo by Ben McGuire, USFWS, formerly USACE).

## 5.5 Nutrient Uptake

Large growth heights of vegetation were observed in many locations. Pharrs Island in Pool 24 had particularly tall smartweed (*Polygonaum* spp.) that reached heights of over eight feet tall by late August (Figure 52-55). As in other plants, increased macro-nutrient availability yields higher biomass, i.e., larger and taller plants. In this case, high amounts of Nitrogen availability likely contributed to the high amounts of biomass relative to this species. This instance documents the ability of these wetland sites, when exposed during EPM operations, to uptake large amounts of Nitrogen and Phosphorus, which are the leading cause of the Gulf Hypoxia.

Figure 52. Photo showing vegetation growth at Pharrs Island in Pool 24 on June 8, 2016 (photo by Ben McGuire, USFWS, formerly USACE).

Figure 53. Photo showing vegetation growth at Pharrs Island in Pool 24 on July 15, 2016 (photo by Ben McGuire, USFWS, formerly USACE).

Figure 54. Photo showing vegetation growth at Pharrs Island in Pool 24 on August 15, 2016 (photo by Ben McGuire, USFWS, formerly USACE).

Figure 55. Photo showing vegetation growth at Pharrs Island in Pool 24 on August 29, 2016 (photo by Ben McGuire, USFWS, formerly USACE).

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## Appendix A – Seed Head Analysis Report

USACE submitted un-pressed seed heads to the University of Tennessee Wetlands Program for seed production and duck energy-day (DED) estimates that were collected randomly from 12 1-$m^2$ plots in moist-soil wetlands at two sites located along the Mississippi River in Missouri. Seed heads were pressed for one week, seed-head area for each plant was scanned, and seed-head area ($cm^2$) estimates used to predict dry seed mass (g) per plant using models in Gray et al. (2009). Plant species that were collected included redroot flatsedge (*Cyperus erythrorhizos*), sprangeltop (*Leptochloa panicoides*), fall panicum (*Panicum dichotomiflorum*), wild millet (*Echinochloa crus-galli*), Walter's millet (*E. walterii*), and nodding smartweed (*P. lapathifolium*). Seed production/plant was multiplied by plant density/$m^2$ for each species, seed production was summed across species within a plot, and estimates were converted to kg/ha and lbs/ac. Duck energy-day estimates were calculated using seed production, true metabolizable energy of seed, and the daily energy requirement of mallards (Gray et al. 2013). Details on methods are available at http://fwf.ag.utk.edu/mgray/DED/DED.htm. Seed production and DED estimates were averaged among plots, and the standard deviation and 95% confidence intervals were calculated.

At the Dresser site, seed production among plots ranged from 0 – 1743 kg/ha (0 – 1555 lbs/ac, Table a). Average seed production among wetlands was 736 kg/ha (657 lbs/ac; Table b), and could be classified as high seed yield (see reference values below). Plots with highest seed production were #1 and #5, and the lowest seed production was in plot #3 (Table a).

At the Middleton site, seed production among plots ranged from 315 – 2231 kg/ha (281 – 1991 lbs/ac, Table a). Average seed production among wetlands was 850 kg/ha (758 lbs/ac; Table b), and could be classified as high seed yield (see reference values below). Plots with highest seed production were #1 and #2, and the lowest seed production was in plot #6 (Table a).

<u>Seed Production Reference Values</u>[1]

- <200 kg/ha = low production
- 200-600 kg/ha = moderate production
- >600 kg/ha = high production

[1]Based on moist-soil production estimates provided in Gray et al. (1999) and Kross et al. (2008).

Based on the plant species present and high seed production, the moist-soil wetlands surveyed in this study could be classified as early successional, and disturbance to set back succession (e.g., disking) probably isn't currently necessary. It should be noted that seed production was variable among plots, resulting in large standard deviations, especially at the Dresser site (Table b). Thus, spot treatment of mechanical manipulations or herbicides, or supplemental planting of an agricultural variety of a moist-soil plant species (e.g., Japanese millet, *E. esculenta*) might improve seed production in those areas. Moderate application of fertilizer also can improve seed production in moist-soil wetlands (Gray et al. 2013).

Duck energy-day estimates are provided (Tables a – b). Total estimated DEDs for the Dresser site (18.4 ha, 45.4 ac) was 113,762 DEDs, which is equivalent to having the energetic potential to support **1,034 ducks per day for 110 days**. Total estimated DEDs for the Middleton site (3.7 ha, 9.2 ac) was 26,548 DEDs, which is equivalent to having the energetic potential to support **241 ducks per day for 110 days**.

Table a. Seed production and duck energy-days (DED) estimated from 12 plots in moist-soil wetlands located at two sites (Dresser and Middleton) along the Mississippi River, Missouri, USA, October 2016.

| Site | Acreage | Plot | Kg/ha | DED/ha | Lbs/ac | DED/ac |
|---|---|---|---|---|---|---|
| Dresser | 18.4 ha | 1 | 1315.1 | 11049.0 | 1173.3 | 27290.9 |
| | (45.4 ac) | 2 | 283.6 | 2382.6 | 253.0 | 5884.9 |
| | | 3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | 4 | 7.3 | 61.1 | 6.5 | 150.9 |
| | | 5 | 1742.8 | 14641.9 | 1554.9 | 36165.5 |
| | | 6 | 1066.7 | 8961.7 | 951.7 | 22135.5 |
| Middleton | 3.72 ha | 1 | 2231.3 | 18746.1 | 1990.7 | 46302.8 |
| | (9.19 ac) | 2 | 660.6 | 5550.0 | 589.4 | 13708.6 |
| | | 3 | 645.3 | 5421.5 | 575.7 | 13391.2 |
| | | 4 | 616.9 | 5182.8 | 550.4 | 12801.5 |
| | | 5 | 628.0 | 5276.0 | 560.3 | 13031.6 |
| | | 6 | 314.7 | 2643.5 | 280.7 | 6529.5 |

Table b. Descriptive statistics for seed production and duck energy-days (DED) at two sites (Dresser and Middleton) along the Mississippi River, Missouri, USA, October 2016.

| Site | Statistic | Kg/ha | DED/ha | Lbs/ac | DED/ac |
|---|---|---|---|---|---|
| Dresser | Mean | 735.9 | 6182.7 | 656.6 | 15271.3 |
| | Median | 675.1 | 5672.1 | 602.4 | 14010.2 |
| | STD | 739.7 | 6214.5 | 660.0 | 15349.9 |
| | Confidence | 591.9 | 4972.6 | 528.1 | 12282.3 |
| | Lower 95% CI | 144.0 | 1210.1 | 128.5 | 2989.0 |
| | Upper 95% CI | 1327.8 | 11155.3 | 1184.6 | 27553.5 |
| Middleton | Mean | 849.5 | 7136.7 | 757.9 | 17627.5 |
| | Median | 636.7 | 5348.8 | 568.0 | 13211.4 |
| | STD | 689.3 | 5791.5 | 615.0 | 14304.9 |
| | Confidence | 551.6 | 4634.1 | 492.1 | 11446.1 |
| | Lower 95% CI | 297.9 | 2502.6 | 265.8 | 6181.4 |
| | Upper 95% CI | 1401.0 | 11770.7 | 1250.0 | 29073.7 |

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