Plan for research on aquatic vegetation in the Upper Mississippi River System

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Aquatic vegetation plays a critical role in the Upper Mississippi River System (UMRS) ecosystem. Plants are an important food source for migratory waterfowl (Korschgen *et al.* 1988, Stafford *et al.* 2007) and provide habitat and food for invertebrates, fish, and wildlife (Anderson and Day 1986, Chilton 1990, Dewey *et al.* 1997, Flinn *et al.* 2005, Darrah and Krementz 2009). Fish use plant beds for various stages of their life cycle including spawning and cover for larval and young-of-the year fish (Holland and Huston 1984, Holland and Huston 1985, Dewey and Jennings 1992). Plants influence dissolved oxygen concentrations, improve water clarity by stabilizing sediments, and are key drivers in nutrient cycling in the river (Barko *et al.* 1991, Cavanaugh *et al.* 2006, James *et al.* 2008, Kreiling *et al.* 2011). Because of the importance of plants in the UMRS, they have been one of the main components of the Environmental Management Program Long Term Resource Monitoring Program (EMP-LTRMP) since its inception and a wealth of information has been collected pertaining to plant distribution and relative abundance (EMP-LTRMP online-component update).

Historically, aquatic vegetation was found throughout the UMRS (Green 1947, Green 1960, Sohmer 1975, Eckblad *et al.* 1977, Clark and Clay 1985, Donnermeyer and Smart 1985, Steffeck *et al.* 1985, McConville *et al.* 1986, Peck and Smart 1986, Bhowmik and Adams 1989, Tazik *et al.* 1993). In the early 1900s, aquatic vegetation thrived in the Illinois River, until the diversion of water from Lake Michigan to the Illinois River when plants began to disappear in the main channel and backwater lakes (Richardson 1921, Cook *et al.* 2007). From 1958 to 1961, increases in turbidity and sediment resuspension led to a further decline in aquatic vegetation in the Illinois River (Sparks *et al*. 1990). Following lock and dam construction on the Upper Mississippi River, plants were abundant in the newly-formed impoundments (Moore *et al.* 2010). During the late 1980s and early 1990s, drought, sedimentation, and low light transparency caused a system-wide decline in submersed plants in most of the Upper Mississippi River (Rogers 1994, Fischer and Claflin 1995). However, these same drought conditions increased SAV occurrence in Pool 26 through increased light transparency (Theiling *et al.* 1996). In the Open River Reach, below the confluence of the sediment-laden Missouri River, submersed aquatic vegetation (SAV) did not occur because light availability was naturally limiting. Aquatic vegetation did occur in other waters in the floodplain such as oxbows and floodplain lakes. In recent years, vegetation was able to rebound in some areas of the UMRS (Tyser *et al.* 2001, Blackburn and Kirby 2003, EMP-LTRMP online-component update and graphical browser); however, abundant SAV has only been found regularly in Pools 4 through 15, Pool 19 and in the upper pools of the Illinois River (Yin *et al.* 2002, Cook *et al.* 2007, MACTEC Engineering and Consulting 2006, Sass *et al.* 2010). Moist-soil and emergent plants do occur in the lower pools and Open River Reach of the Upper Mississippi River and in all pools of the Illinois Rivers.

Although not fully known, many abiotic and biotic factors, acting alone, in various combinations or synergistically, may limit the growth of submersed plants below Pool 15 (with the exception of Pool 19), in Pools 1 through 3, in the lower pools of the Illinois River and in the Open River (Yin and Langrehr 2005). Abiotic factors include variability in water level (Theiling *et al.* 1996), high overall discharge (Spink and Rogers 1996), high velocity, low light transparency (Kimber *et al.* 1995b, Best *et al.* 2001, Kreiling *et al.* 2007), nutrient levels (Rogers *et al.* 1995), agricultural herbicides (USEPA 2003), wind- and wave-induced sediment resuspension (Cook and Pegg 2011) and sediment composition (Roseboom *et al.* 1992). Biotic factors limiting aquatic vegetation may include seed bank viability (Kimber *et al.* 1995a, McFarland and Rogers 1998, Kenow and Lyon 2009, Sass *et al.* 2010), sediment resuspension caused by fish (Korschgen 1990, Bellrichard 1994) and herbivory by turtles, geese, and carp (Janecek 1988, Sass *et al.* 2009). Focused studies, such as those completed by Sass *et al.* 2009, Sass *et al.* 2010, and J. Chick, unpublished data, need to be done to determine the main factors limiting growth so river managers can implement management strategies to encourage plant development.

Efforts have been made to reestablish plants in the UMRS. For example, management tools such as drawdowns have been successful in renewing plant growth (WLMTF 2007, Kenow and Lyon 2009). Drawdowns mimic the natural hydrograph, allowing for lower water levels during the growing season. Small-scale drawdowns in Pools 24, 25, and 26 and in the Illinois River have resulted in the establishment of moist-soil and emergent plants in dewatered areas (Wlosinski *et al.* 2000). Pool-wide drawdowns in Pools 5 and 8 have increased the level of emergent and submersed plants (WLMTF 2007); however, the effects may have been aided by a system-wide trend in increased growth of submersed vegetation (EMP-LTRMP online-component update). The positive effects of drawdowns are typically only seen for a limited number of years after the drawdown (Harris and Marshall 1963, van der Valk and Davis 1978, Seabloom *et al.* 2001). In 2004 and 2005, drawdowns in Middle Swan Lake lead to the growth of emergent vegetation; however, no plants grew the following year when a drawdown was not conducted (Garvey *et al.* 2007). Thus, drawdowns may need to occur multiple times to sustain plant growth and abundance.

Habitat Rehabilitation and Enhancement Projects (HREPs), which include constructing islands and creating moist-soil units through the use of dikes and levees, have also been used to promote plant growth. Islands reduce wind fetch and water velocity, allowing for the stabilization of fine particles and for the establishment of aquatic vegetation. The construction of islands in many pools has led to the increased growth of plants in the influence area of the islands (Langrehr *et al.* 2007), but the species composition and long-term effects of many of these islands are unknown. Age and island-structure may shape the plants that occur in the area of influence and studies need to be done to determine how these factors influence life-form and species composition and abundance. In the lower pools, on the Illinois River and in the Open River Reach, water-control structures are used to produce isolated moist-soil impoundments where water levels can be regulated to produce areas sufficient to moist-soil and emergent plant growth (Heitmeyer and Westphall 2007)

Species composition and life form (*i.e.* emergent, rooted-floating, and submersed) may play a critical role in the habitat requirements of some animal species. Migrating waterfowl feed on tubers of *Vallisneria americana* and *Sagittaria latifolia* (Korschgen *et al.* 1988). Fish species tend to occur in backwater areas that are typically composed of *Ceratophyllum demersum* and *Elodea canadensis* (Janecek 1988). It is not certain whether plant species composition and life form or overall plant density and biomass play more of an important role in habitat selection for fish. Ferreiro *et al.* (2011) determined that SAV that have a greater surface area (*e.g. Ceratophyllum demersum*) support more macroinvertebrates (an important fish food), suggesting that species composition is important. Also, too much plant growth may have a detrimental effect on fish and wildlife. During the winter, decomposing plant matter in areas with dense macrophyte growth can lead to localized hypoxia (Mathias and Barica 1980, Meding and Jackson 2003), resulting in fish mortality. Rehabilitation projects are often designed to promote plant growth to provide habitat for fish and wildlife, however, further research needs to be done to determine whether plant biomass and density or species composition and life form are more important for the development of optimal habitat.

Overall, the research framework laid out in this document is developed based on the following basic views of the planning committee.

1. A wealth of data on spatial patterns and temporal dynamics of SAV in the UMRS has already been collected under the EMP-LTRMP over the past two decades.
2. These data, including aerial photos, satellite images, and ground sampling data, reveal distinct SAV distributional patterns. For example, SAV can be expected to occur with high prevalence in most years in the reach below Lake Pepin (Lake City, Minnesota) to Lock and Dam 13 (Bellevue, Iowa). Within these pools, SAV is prevalent in shallow, slow-flowing channel areas and isolated and contiguous backwaters. Occurrence of SAV above or below this reach is scarce and/or opportunistic, usually in small patches and/or during steady and low-flow months or years.
3. These patterns are in a stable state, capable of recovering after perturbation.
4. The rapid habitat deterioration post-impoundment of the system appears to have slowed down.
5. Aquatic vegetation is deemed desirable by river managers and is actively promoted through management actions such as drawdowns and habitat construction projects that address one or more factors limiting aquatic vegetation (*e.g.* wind fetch, waves, altered hydrology and turbidity).

Based on these observations and assumptions, the goal of this research framework is to identify questions that still exist and to outline potential approaches to answer those questions. Questions are written in the priority that they should be given in addressing these issues. Along with answering these questions, members of this planning committee also encourage EMP-LTRMP management to establish a river partnership with researchers working on other river systems. Information can be gathered to compare the impacts of locks and dams, eutrophication, climate change, and invasive species on vegetation (along with other key river components) in different river systems and to look for global similarities to further our understanding of river processes and functions.

Question 1. What are the primary drivers behind the spatial and temporal patterns of aquatic vegetation in the UMRS?

Approach: Extensive data have been collected on the upper pools, especially in Pools 3 through 13, while limited data have been collected on the lower pools and in the Illinois River (Table 1). Current data can be used to develop ecological models that predict vegetation distribution, species composition, and biomass for SAV and possibly emergent plants. For SAV models, key drivers would likely include water quality, wind fetch/wave action, and water level fluctuations. Once developed, these models can be applied to the pools where vegetation is lacking to determine what management steps are needed to promote vegetation and also if vegetation is even possible in these areas given extraneous factors (*e.g.* navigation requirements, contributions of sediment and nutrients from tributaries, and agricultural run-off events). Some models have already been developed (see Best *et al.* 2001, Best *et al.* 2008 and Yin *et al.* online model).

Baseline data may need to be collected in areas where data holes exist (*i.e.* Pools 14-26, the Illinois River, and major tributaries) and to provide more detailed information about emergent and moist soil plants. Large-scale, reach-wide surveys can be conducted using existing or modified EMP-LTRMP methods, EMAP methods or rapid reconnaissance surveys (Yin *et al.* 2002) to fill in data gaps. If possible, sampling in each area should occur over a range of environmental conditions to avoid any biases from extreme events (*e.g.* flooding or drought). Once collected, the new data can be used to calibrate and validate the ecological models.

Question 2. What are the long-term effects of different management tools (*i.e.* drawdowns and HREPs) on aquatic plants?

Question 2a. What are the long-term effects of drawdowns on specific life forms and species?

Approach: Pre- and post-drawdown monitoring needs to occur in pools that have been drawn down and are being considered for drawdown. Monitor the drawdown area for multiple years post-drawdown to determine how long the renewed plant growth can be sustained. Include monitoring of emergent and moist-soil plants in the sampling regime.

To fully realize the potential benefits on submersed species, a drawdown should be performed on a pool with low occurrence of submersed species (*e.g.* Pools 3 or 18) where other management tools are not being employed. In these pools, a drawdown would likely increase water clarity and stabilize water levels enough to allow submersed plants to grow.

Question 2b. What are the long-term effects of HREPs on aquatic plants and how do we measure HREP success?

Approach: Research is needed to determine the effect of design and age of HREPs on plant communities. Detailed analyses of plant zonation in the area of influence would allow managers to determine the optimal HREP for targeted life forms. Rohweder *et al.* (2008) have developed models to determine how different HREP configurations reduce wind fetch in the area of influence. The same types of models can be developed for aquatic plants. Pre- and post-monitoring of HREPs would provide vital information in assessing HREP success. Some analysis by Gray *et al.* (2010) has shown that existing EMP-LTRMP data can be used to determine the cumulative effects of multiple HREPs, thus EMP-LTRMP vegetation data may be sufficient to measure HREP effects in key pools.

Question 3. What are the main drivers limiting vegetative colonization and recolonization on the Illinois River and in Pools 1-3 and 16-26? What are the thresholds for vegetative colonization? Can sections of these Pools be managed to promote growth of aquatic plants, especially species of interest such as *Sagittaria latifolia* and *Vallisneria americana*?

Question 3a. What limits the growth of aquatic plants on the Illinois River and in Pools 1-3 and 16-26?

Approach: Design mesocosm and seed bank studies to specifically determine what factors may be limiting plant growth, especially the growth of life forms of interest, in these areas. Look at specific sediment and soil characteristics such as shear strength, nutrient composition, texture, and presence of agricultural chemicals and toxic elements that may affect seed germination. Determine the individual and synergistic effects of factors such as water nutrients, low light penetration, high velocity, herbivory, variable discharge, sediment resuspension by carp and waves, and plant DNA composition on the establishment of seedlings and long-term survival of plant beds. Compare the stress tolerance of seedlings and mature plants to the present conditions. Perform water analyses for agricultural chemicals such as herbicides which may be contaminating the water and killing any plant species that may occur.

Question 3b. What are the thresholds for vegetative colonization?

Approach: Once specific growth-limiting variables are determined for a location, use these variables to input into models developed under question 1. Determine what the critical threshold for colonization is for that variable. These thresholds could be similar to the UMRCC thresholds developed for water quality (UMRCC 2003).

Question 3c. Can sections of the Pools be managed or HREPs be designed to promote the growth of certain life forms and species?

Approach: Design mesocosm and seed bank studies to determine which aquatic plants, if any, are able to grow and reproduce in the existing environmental conditions. Determine the viability of the seed bank in these areas using methods similar to Kenow and Lyon (2009) and Andress and Romano (2011). Use information obtained from answering questions 2 and 3a to model the growth and reproduction of certain life forms and species of interest under different management scenarios. Specific examples include the response to the construction of moist-soil units, response to the establishment of areas with decreased turbidity and stable water levels, and response to the reduction of sediment input from tributaries. Use model output to determine the best management strategy to promote plant growth and reproduction under varying environmental conditions.

Question 4. With our current understanding of the UMRS, how can we maximize the information gathered by EMP-LTRMP to address the fundamental questions about plant distribution and relative abundance? What information is lacking?

Question 4a. Are the vegetation procedures outlined in the minimum sustainable program (MSP) enough to determine plant distribution?

Approach: In addition to sampling the same three key pools, sample other pools either with existing or modified EMP-LTRMP methods, EMAP methods or rapid reconnaissance surveys. Include Pools 26 and La Grange in the MSP. Collect more information on emergent and moist-soil plants by analyzing historic (*e.g.* 1989, 2000) and current (2010) aerial photos and augmenting them with on-the-ground sampling. Run a power analysis to test whether the present rake procedure is effective in determining certain trends.

Question 4b. What additional information can EMP-LTRMP produce that would benefit our understanding of UMRS vegetation?

Approach: Develop two-dimensional hydraulic models that are calibrated and verified so they simulate measured water surface elevations at existing gages, and measured flow distributions within the pool for a range of total river discharges between low flow conditions and bankfull conditions. Simulations should be done for total river discharges exceeded 75%, 25%, and 5% of the time. The discharge exceeded 75% of the time corresponds to low flow conditions, while the discharges exceeded 25% and 5% of the time correspond to moderate flow and near bankfull flow conditions. Additional simulations may be added as needed (*e.g.* the total river discharge exceeded 95% of the time represents drought conditions). Model results will be used to determine the annual (or growing season) variation in flow velocities and nutrient or sediment fluxes in the areas of interest. Combining these with sediment transport or bioenergetics-based models and principles, may provide insights on the optimal range of hydraulic conditions for plant growth or nutrient cycling and the effects of SAV on sediment transport and depositions.

Collect biomass in Pools 4 and 13 to get a more quantitative measurement of plant abundance, for species both individually and collectively, and to calibrate the EMP-LTRMP rake method for those pools (Kenow *et al.* 2007).

Question 4c. What additional cross-component information can the individual MSP sampling components collect to produce more useful datasets without adding additional cost to the program?

Approach: Collect simple water quality measurements such as secchi depth and velocity during vegetation stratified random sampling. Collect more in-depth vegetation data during fish sampling and analyze fisheries and vegetation data simultaneously to better understand optimal habitat for fish species. Collect more in-depth vegetation data during water quality sampling and analyze vegetation and water quality data simultaneously to better understand water quality requirements for plants. This information can then be incorporated into HREP planning. This information would also be useful for the five individual states and the Upper Mississippi River Basin Association's Water Quality Task Force as they try to comply with the Clean Water Act.

Question 5. What are the potential effects of climate change and the establishment of aquatic invasive species on aquatic vegetation?

Question 5a. What are the potential effects of climate change on aquatic vegetation?

Approach: Model plant distribution and abundance at different precipitation levels, water temperatures and hydrological regimes. Determine the northward migration of exotic species such as *Eichhornia crassipes* and *Hydrilla verticillata*. Determine the effects of an increase and northward migration in herbivores such as red-eared sliders (Tucker *et al.* 2008) on aquatic plants.

Question 5b. What are the potential effects of the establishment of aquatic invasive species on aquatic vegetation?

Approach: Because juvenile silver carp mature in backwaters, perform exclosure experiments to determine the effect of a large number of silver carp on water quality in plant beds (Bellrichard 1994). Use this information to model potential system-wide effects of the northward movement of silver carp.

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Table 1. List of available datasets for work done on the UMRS.

Pool	Investigator/Group	Years	Sampling Method	Data Format
1	Moore/EMAP	2006-2008	Rake Random	Dataset
1	UMESC/EMP-LTRMP	1890, 1989, 2000	Aerial Photo	GIS Coverage
1	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
2	Moore/EMAP	2006-2009	Rake Random	Dataset
2	UMESC/EMP-LTRMP	1890, 1989, 2000	Aerial Photo	GIS Coverage
2	UMESC/EMP-LTRMP	1977, 1994	Aerial Photo	Aerial Photo
3	Moore/EMAP	2006-2009	Rake Random	Dataset
3	Reid/UMRCC	2008	Rake SRS	Dataset
3	Dieterman/MN DNR	1993-2009	Visual Survey	Report
3	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
3	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
4	MN DNR/EMP-LTRMP	1991-2000	Rake Transect	Dataset
4	MN DNR/EMP-LTRMP	1998-present	Rake SRS	Dataset
4	Moore/EMAP	2006-2009	Rake Random	Dataset
4	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
4	UMESC/EMP-LTRMP	1981, 1982, 1987, 1991, 1992, 1993, 1994	Aerial Photo	Aerial Photo
4	UMESC/EMP-LTRMP	1995, 1998, 1999, 2001, 2003	Aerial Photo	Aerial Photo
5	Moore/EMP-LTRMP	2002	Rake SRS	Dataset
5	Moore/EMAP	2006-2008	Rake Random	Dataset
5	Nelsen/Moore/USFWS/MNDR	1999-2007	Rake SRS	Dataset
5	Rogers/UMESC	1991-1993	Rake Transect	Report
5	Olson/U of Minnesota	1939, 1973	Aerial Photo	Thesis
5	Orr/USACOE	2006	Visual/Rake	Report
5	Dieterman/MN DNR	1993-2009	Visual Survey	Report
5	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
5	UMESC/EMP-LTRMP	1977, 1981, 1982, 1983, 1985, 1986, 1987	Aerial Photo	Aerial Photo
5	UMESC/EMP-LTRMP	1991, 1992, 1993, 1996, 2001, 2004, 2005	Aerial Photo	Aerial Photo
5a	Moore/EMAP	2006-2008	Rake Random	Dataset
5a	McConville/St. Mary’s College	1980, 1983	Visual Survey	Manuscript
5a	Seibel/St. Mary’s College	1982	Visual Survey	Thesis
5a	Olson/U of Minnesota	1939, 1973	Aerial Photo	Thesis
5a	Dieterman/MN DNR	1993-2009	Visual Survey	Report
5a	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage

Pool	Investigator/Group	Years	Sampling Method	Data Format
5a	UMESC/EMP-LTRMP	1977, 1992, 1993, 1994, 1996, 2002	Aerial Photo	Aerial Photo
6	Moore/EMAP	2006-2008	Rake Random	Dataset
6	Reid/UMRCC	2007	Rake SRS	Dataset
6	Olson/U of Minnesota	1939, 1973	Aerial Photo	Thesis
6	Dieterman/MN DNR	1993-2009	Visual Survey	Report
6	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
6	UMESC/EMP-LTRMP	1977, 1980, 1981, 1982, 1983, 1986, 1987	Aerial Photo	Aerial Photo
6	UMESC/EMP-LTRMP	1991, 1992, 1993, 1994, 1995, 1996, 1999	Aerial Photo	Aerial Photo
7	Langrehr/EMP-LTRMP	2002	Rake SRS	Dataset
7	Langrehr/EMAP	2006-2008	Rake Random	Dataset
7	Korschgen/USFWS	199 -Present	*Vallisneria* Quadrat	Dataset
7	McFarland/USCOE	1996	Seed Bank Study	Manuscript
7	Nichols/UMESC	1993	Quadrat Biomass	Manuscript
7	Sohmer/UW-La Crosse	1973	Transect Biomass	Manuscript
7	Olson/U of Minnesota	1939, 1973	Aerial Photo	Thesis
7	Dieterman/MN DNR	1996-2009	Visual Survey	Report
7	UMESC/EMP-LTRMP	1890, 1975, 1989, 1994, 2000	Aerial Photo	GIS Coverage
7	UMESC/EMP-LTRMP	1977, 1979, 1980, 1982, 1983, 1984, 1987	Aerial Photo	Aerial Photo
7	UMESC/EMP-LTRMP	1991, 1992, 1993, 1995, 1996, 1997, 1998	Aerial Photo	Aerial Photo
7	UMESC/EMP-LTRMP	2001	Aerial Photo	Aerial Photo
8	Langrehr/EMP-LTRMP	1991-2000	Rake Transect	Dataset
8	Langrehr/EMP-LTRMP	1998-present	Rake SRS	Dataset
8	Langrehr/EMAP	2006-2008	Rake Random	Dataset
8	Kreiling/ EMP-LTRMP	2001-2002	Quadrat Biomass	Dataset
8	Kenow/UMESC	1999-2001	Quadrat Biomass	Manuscript
8	Kenow/UMESC	2000	Seed Bank Study	Manuscript
8	Sefton/UW-La Crosse	1975	Quadrat Biomass	Thesis
8	Fischer/UW-La Crosse	1991	Quadrat Biomass	Thesis
8	Korschgen/USFWS		*Vallisneria* Quadrat	Dataset
8	Sohmer/UW-La Crosse	1973	Transect Biomass	Manuscript
8	Swanson/UW-La Crosse	1975, 1976	Floristic Survey	Manuscript
8	Olson/U of Minnesota	1939, 1973	Aerial Photo	Thesis
8	UMESC/EMP-LTRMP	1890, 1975, 1989, 1991	Aerial Photo	GIS Coverage
8	UMESC/EMP-LTRMP	1994, 1998, 2000, 2002	Aerial Photo	GIS Coverage
8	UMESC/EMP-LTRMP	1977, 1979, 1980, 1981, 1982, 1983, 1984	Aerial Photo	Aerial Photo

Pool	Investigator/Group	Years	Sampling Method	Data Format
8	UMESC/EMP-LTRMP	1985, 1987, 1992, 1993, 1995, 1996, 1997	Aerial Photo	Aerial Photo
8	UMESC/EMP-LTRMP	1999, 2001, 2003	Aerial Photo	Aerial Photo
9	Langrehr/EMAP	2006-2008	Rake Random	Dataset
9	Griffin/UMRCC	2005, 2006	Rake SRS	Dataset
9	Clark/Iowa State University	1985	*Sagittaria* Quadrat	Manuscript
9	Donnermeyer/UW-La Crosse	1985	*Vallisneria* Biomass	Manuscript
9	Olson/U of Minnesota	1939, 1973	Aerial Photo	Thesis
9	Orr/USACOE	2006	Rake Survey	Report
9	Dieterman/MN DNR	1994-2009	Visual Survey	Report
9	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
9	UMESC/EMP-LTRMP	1977, 1980, 1981, 1982, 1983, 1987, 1991	Aerial Photo	Aerial Photo
9	UMESC/EMP-LTRMP	1992, 1993, 1994, 1996	Aerial Photo	Aerial Photo
10	Langrehr/EMAP	2006-2008	Rake Random	Dataset
10	Olson/U of Minnesota	1939, 1973	Aerial Photo	Thesis
10	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
10	UMESC/EMP-LTRMP	1977, 1983, 1992, 1994, 1996	Aerial Photo	Aerial Photo
11	Langrehr/EMAP	2006-2008	Rake Random	Dataset
11	Yin/EMP-LTRMP	2001	Rake SRS	Dataset
11	Griffin/UMRCC	2009	Rake SRS	Dataset
11	Orr/USACOE	2006	Visual/Rake	Report
11	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
11	UMESC/EMP-LTRMP	1982, 1983, 1992, 1994	Aerial Photo	Aerial Photo
12	Blackburn/EMP-LTRMP	2002	Rake SRS	Dataset
12	Petersen/EMAP	2009	Rake Random	Dataset
12	Griffin/UMRCC	2009	Rake SRS	Dataset
12	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
12	UMESC/EMP-LTRMP	1983, 1992, 1994	Aerial Photo	Aerial Photo
13	IDNR/LTMRP	1991-2000	Rake Transect	Dataset
13	IDNR/EMP-LTRMP	1998-present	Rake SRS	Dataset
13	Petersen/EMAP	2009	Rake Random	Dataset
13	Orr/USACOE	2006	Visual/Rake	Report
13	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
13	UMESC/EMP-LTRMP	1981, 1983, 1987, 1990, 1991, 1992, 1993	Aerial Photo	Aerial Photo
13	UMESC/EMP-LTRMP	1994, 1995, 1996, 1997, 1998, 1999, 2003	Aerial Photo	Aerial Photo
14	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage

Pool	Investigator/Group	Years	Sampling Method	Data Format
14	UMESC/EMP-LTRMP	1983, 1992, 1994	Aerial Photo	Aerial Photo
14	UMESC/EMP-LTRMP	2002	Rapid Reconnaissance/Rake	Report
15	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
15	UMESC/EMP-LTRMP	1983, 1994	Aerial Photo	Aerial Photo
15	UMESC/EMP-LTRMP	2002	Rapid Reconnaissance/Rake	Report
16	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
16	UMESC/EMP-LTRMP	1983, 1994	Aerial Photo	Aerial Photo
16	UMESC/EMP-LTRMP	2002	Rapid Reconnaissance/Rake	Report
17	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
17	UMESC/EMP-LTRMP	1983, 1994, 1995, 1996	Aerial Photo	Aerial Photo
17	UMESC/EMP-LTRMP	2002	Rapid Reconnaissance/Rake	Report
18	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
18	UMESC/EMP-LTRMP	1983, 1994	Aerial Photo	Aerial Photo
18	UMESC/EMP-LTRMP	2002	Rapid Reconnaissance/Rake	Report
18	UMRCC	2007	Rake SRS	Dataset
18	Andress/USFWS	2009	Seed Bank Study	Report
19	Steffeck/USFWS	1977	Visual Transect	Manuscript
19	Tazik/INHS	1956, 1962, 1975	Aerial Photo	Manuscript
19	Tazik/INHS	1978, 1985, 1987	Aerial Photo	Manuscript
19	Thompson/Ich. Assoc.	1967	Aerial Photo	Report
19	Orr/USACOE	2006	Visual/Rake	Report
19	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
19	UMESC/EMP-LTRMP	1983, 1992, 1993, 1994	Aerial Photo	Aerial Photo
19	UMESC/EMP-LTRMP	2002	Rapid Reconnaissance/Rake	Report
19	UMRCC	2005, 2006	Rake SRS	Dataset
20	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
20	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
21	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
21	UMESC/EMP-LTRMP	1993, 1994, 1995, 1996	Aerial Photo	Aerial Photo
22	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
22	UMESC/EMP-LTRMP	1994, 1995, 1996	Aerial Photo	Aerial Photo
24	Dalrymple/MDOC	1995, 1996		Report
24	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
24	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
25	Dalrymple/MDOC	1995, 1996		Report

Pool	Investigator/Group	Years	Sampling Method	Data Format
25	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
25	UMESC/EMP-LTRMP	1994, 1995	Aerial Photo	Aerial Photo
25	SIU	1999-2001	Quadrat	Report
26	INHS/EMP-LTRMP	1991-2000	Rake Transect	Dataset
26	INHS/EMP-LTRMP	1998-2004	Rake SRS	Dataset
26	Dalrymple/MDOC	1995, 1996		Report
26	UMESC/EMP-LTRMP	1890, 1975, 1989, 1994, 2000	Aerial Photo	GIS Coverage
26	UMESC/EMP-LTRMP	1991, 1992, 1995	Aerial Photo	Aerial Photo
Open River	UMESC/EMP-LTRMP	1890, 1975, 1989, 2000	Aerial Photo	GIS Coverage
Open River	UMESC/EMP-LTRMP	1990, 1991, 1994, 1995	Aerial Photo	Aerial Photo
Alton	INHS/EMP-LTRMP	2002	SRS Rake	Dataset
Alton	Dalrymple/USFWS	2009	Enclosure	Dataset
Alton	UMESC/EMP-LTRMP	1989, 2000	Aerial Photo	GIS Coverage
Alton	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
Alton	INHS/SIU	2004-2006	Rake/Quadrat	Report
Alton	INHS/EMP-LTRMP	2008	Rake SRS	Report
La Grange	INHS/EMP-LTRMP	1991-2000	Rake Transect	Dataset
La Grange	INHS/EMP-LTRMP	1984-2004	Rake SRS	Dataset
La Grange	UMESC/EMP-LTRMP	1989, 1991, 2000	Aerial Photo	GIS Coverage
La Grange	UMESC/EMP-LTRMP	1992	Aerial Photo	Aerial Photo
La Grange	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
La Grange	INHS	1999-2001	Transect/Seed Bank Study	Manuscript
La Grange	INHS/EMP-LTRMP	2008	Rake SRS	Report
Peoria	UMESC/EMP-LTRMP	1989, 2000	Aerial Photo	GIS Coverage
Peoria	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
Peoria	INHS/EMP-LTRMP	2008	Rake SRS	Report
Starved Rock	UMESC/EMP-LTRMP	1989, 2000	Aerial Photo	GIS Coverage
Starved Rock	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
Starved Rock	INHS/EMP-LTRMP	2005	Rake SRS	Report
Starved Rock	MACTEC	2005	Rapid Reconnaissance/Rake	Report
Starved Rock	INHS/EMP-LTRMP	2008	Rake SRS	Report
Marseilles	UMESC/EMP-LTRMP	1989, 2000	Aerial Photo	GIS Coverage
Marseilles	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
Marseilles	INHS/EMP-LTRMP	2005	Rake SRS	Report
Marseilles	MACTEC	2005	Rapid Reconnaissance/Rake	Report

Pool	Investigator/Group	Years	Sampling Method	Data Format
Marseilles	INHS/EMP-LTRMP	2008	Rake SRS	Report
Dresden	UMESC/EMP-LTRMP	1989, 2000	Aerial Photo	GIS Coverage
Dresden	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
Dresden	INHS/EMP-LTRMP	2005	Rake SRS	Report
Dresden	MACTEC	2005	Rapid Reconnaissance/Rake	Report
Dresden	INHS/EMP-LTRMP	2008	Rake SRS	Report
Brandon	UMESC/EMP-LTRMP	1989, 2000	Aerial Photo	GIS Coverage
Brandon	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo
Lockport	UMESC/EMP-LTRMP	1989, 2000	Aerial Photo	GIS Coverage
Lockport	UMESC/EMP-LTRMP	1994	Aerial Photo	Aerial Photo