# Trust Fund 2009 Work Program

**Date of Report:** May 8, 2009
**Date of Next Progress Report:** February 1, 2010
**Date of Work Program Approval:** *to be determined*
**Project Completion Date:** July 1, 2012

## I. PROJECT TITLE: Intensified Tile Drainage Evaluation


| | |
|---|---|
| **Project Manager**: | Shawn Schottler |
| **Affiliation:** | Science Museum of Minnesota-<br>St. Croix Watershed Research Station |
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**Location:** Study will evaluate 24 watersheds throughout Minnesota contributing to Lake Pepin. See map in appended research addendum.

| | | |
|---|---|---|
| **Total Trust Fund Project Budget:** | **Trust Fund Appropriation** | **$ 300,000** |
| | **Minus Amount Spent:** | **$ 0** |
| | **Equal Balance:** | **$ 300,000** |

**Legal Citation: M.L. 2009, Chp. 143, Sec. 2, Subd. 5d**

**Appropriation Language:**
$300,000 is from the trust fund to the Science Museum of Minnesota for the St. Croix watershed research station to conduct a comparative assessment of hydrologic changes in watersheds with and without intensive tile drainage to determine the effects of climate and tile drainage on river erosion. This appropriation is available until June 30, 2012, at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

## II. PROJECT SUMMARY AND RESULTS:

Vast areas of Minnesota have been extensively altered with artificial drainage, including sub-surface tile, ditches, wetland drainage, and surface inlets. The effect of these manipulations in altering hydrology and sediment erosion is not well understood. Sediment cores from Lake Pepin provide an integrated historical record of erosion rates in Minnesota. Sediment accumulation rates have increased by nearly ten fold since European settlement and are currently dominated by erosion of non-field sources such as streambanks, bluffs and ravines. The increase in non-field sources coincides with the intensification of artificial drainage and with periods of increased precipitation. The impacts of artificial drainage networks on destabilizing near channel sediment sources, and increasing riverine sediment loads cannot be examined until the installation history and density is inventoried. Equipped with the knowledge of how tile density varies among watersheds, it will be possible to do comparative assessments of long-term changes in hydrology in watersheds with and without artificial drainage, and relate these effects and temporal trends to the observed sedimentation rates in Lake Pepin. Specifically this project will:

- Quantify artificial drainage density and extent in ~23 watersheds contributing to Lake Pepin and estimate the time trends of installation.
- Provide a comparative assessment of changes in 14 hydrologic parameters in watersheds with and without intensive artificial drainage to determine the effect of drainage and precipitation in changing river hydrology/erosive potential.
- Estimate the role of drainage in accelerating non-field sediment erosion by correlating time trends of artificial drainage and precipitation/climate to the historical sediment loading trends in Lake Pepin.

## III. PROGRESS SUMMARY AS OF

(note: when submit in future, 250 word limit)

## IV. OUTLINE OF PROJECT RESULTS*:*

### Result 1: Quantification of temporal and spatial extent of artificial drainage

**Description:**

Currently, no systematic inventory of the amount or location of artificial drainage in the Lake Pepin watershed is available. Correlating changes in hydrology and sediment loading to the expansion of artificial drainage networks is dependent on knowing the chronology and extent of the installation history. Present-day artificial drainage density in 23 watersheds contributing to Lake Pepin will be estimated from GIS mapping of judicial ditches, a statistical inventory of surface inlets, aerial photography, mapping of ditch outlets, and color infrared photographing showing density of pattern tiling. Temporal trends in installation of drainage networks will be estimated from historical aerial photos starting in the 1930's, farm records, and production records of drain tile. Details of the methodology are presented in the appended Research Addendum.

| Deliverable | Completion Date |
|---|---|
| 1. Estimation of present day artificial drainage. | July 2011 |
| 2. Historical trends of installation of artificial drainage | July 2012 |

**Summary Budget Information for Result 1:**

| | |
|---|---|
| **Trust Fund Budget:** | **$ 150,000** |
| **Amount Spent:** | **$ 0** |
| **Balance:** | **$ 150,000** |

| Deliverable | Completion Date | Budget | Status |
|---|---|---|---|
| **1.** Estimation of present day artificial drainage. | July 2011 | $ 75,000 | 0% |
| **2.** Historical trends of installation of drainage | July 2012 | $ 75,000 | 0% |

**Result Status as of** *February 2010*:

**Result Status as of** *August 2010***:**

**Result Status as of** *February 2011*:

**Result Status as of** *August 201:*

**Result Status as of** *February 2012:*

**Final Report Summary:**

**Result 2: Comparative assessment of hydrologic changes due to tile drainage**

Changes in erosion rates and sources are linked to changes in watershed scale hydrology. The importance of artificial drainage can be quantified by comparing a suite of long-term hydrologic parameters in watersheds with different degrees of drainage intensity. The working hypothesis to be tested in this study can be stated as follows: When normalized to climate (e.g., precipitation or drought indices), watersheds with extensive artificial drainage networks will show changes in hydrologic parameters such as the flow to precipitation ratio, peak flows, and base flow duration that are distinctly different from those watersheds with minimal artificial drainage. There are 23 agricultural watersheds in Minnesota that have nearly continuous flow records from 1940 to present. The density of artificial drainage varies from minimal to intense in these 23 watersheds. A suite of 14 hydrologic parameters will be normalize to changes in precipitation/climate and examined to see if a temporal trend exists in each watershed. Trends and magnitude of changes in hydrology will be correlated to changes in artificial drainage for each watershed, and the impact of artificial drainage on changing hydrology will be estimated. Superimposing the findings of Result 1 and 2 onto the sediment accumulation record in Lake Pepin will allow a semi-quantitative assessment of the importance of artificial drainage in increasing erosion of non-field sediments. Details of the method are presented in the appended Research Addendum.

**Description:**

| Deliverable | Completion Date |
|---|---|
| 1. Quantification of changes in 14 hydrologic parameters in 23 watersheds. | July 2010 |
| 2. Comparative assessment of watersheds to determine the effect of artificial drainage and climate on changes in hydrology. | July 2012 |
| 3. Correlation between trends in artificial drainage and acceleration of sediment accumulation rates in Lake Pepin. | July 2012 |

**Summary Budget Information for Result 1:**

**Trust Fund Budget: $ 150,000**
**Amount Spent: $ 0**
**Balance: $ 150,000**

| **Deliverable** | **Completion Date** | **Budget** | **Status** |
|---|---|---|---|
| **1.** Quantification of changes in 14 hydrologic parameters in 23 watersheds. | July 2010 | $ 50,000 | 0% |
| **2.** Comparative assessment of watersheds to | July 2012 | $ 75,000 | 0% |

| | | | |
|---|---|---|---|
| determine effect of drainage and climate on hydrology | | | |
| **3.** Correlation between trends in drainage and sediment accumulation rates in Lake Pepin | July 2012 | $ 25,000 | 0% |

**Result Status as of** *February 2010)*:

**Result Status as of** *August 2010)***:**

**Result Status as of** *February 2011*

**Result Status as of** *August 2011*

**Result Status as of** *February 2012*

**Final Report Summary:**

**V. TOTAL TRUST FUND PROJECT BUDGET:**

| | |
|---|---|
| **Personnel**: | $ 112,200 |
| **Contracts:** | $ 150,000 |
| **Equipment/Tools/Supplies**: | $ 2,800 |
| **Other (Graduate Student stipend):** | $ 35,000 |

**TOTAL TRUST FUND PROJECT BUDGET: $ $ 300,000**

**Explanation of Capital Expenditures Greater Than $3,500:** None

**VI. PROJECT STRATEGY:**

**A. Project Partners:**

Result 1 will be contracted to Minnesota State University-Mankato, Water Resources Center. Staff in the MSU-Water Resources center have extensive experience in delineating and mapping artificial drainage systems. The Water Resources Center (WRC) at Minnesota State Mankato was created in 1987 to serve as a regional center for environmental research and information exchange. The WRC staff has completed drainage inventory projects for the Blue Earth River Basin and a drainage ditch buffer study for the Board of Water and Soil Resources. The WRC has also been coordinating numerous TMDL projects and have several ongoing research studies involving the hydrologic, nutrient, and bacterial influences of tile on water quality.

**B. Project Impact and Long-term Strategy:**

Findings from this project will be paramount in guiding statewide decision making on water quality issues statewide and will directly affect implementation strategies for turbidity TMDLs. Results will provide some of the first watershed scale quantification on the effect of tile drainage on hydrology.

**C. Other Funds Proposed to be spent during the Project Period:**

The Minnesota Pollution Control Agency (MPCA) will provide $300,000 in matching funds secured from EPA sponsored section 319 funds. This matching money will be distributed between the SCWRS and MSU-WRC, with 60% of the funds going to the SCWRS.

**D. Spending History:**

Funding from MPCA ($297,000) Lake Pepin TMDL to fingerprint sediment sources. Original funding to develop sediment fingerprinting method provided by LCMR, 1999, $350,000.

## VII. DISSEMINATION:

The final product of this project will be an interpretive report describing (a) the extent and distribution of artificial drainage in 23 agricultural watersheds, and (b) the relation between artificial drainage and changes in the hydrologic conditions in these 23 watersheds. The report will include a quantitative analysis of the relationship between artificial drainage and climate/precipitation as drivers of increased sediment erosion as recorded in Lake Pepin. Findings and results from this study will be presented in one or more manuscripts to be submitted for publication in peer-reviewed journals. Results will be presented at state technical advisory meetings and at state and national water quality related conferences. All reports from this project will be made available via the Museum's web site. Any exhibits or programming developed for the general public will depend on external funding procured by the Science Museum of Minnesota.

## VIII. REPORTING REQUIREMENTS:

Periodic work program progress reports will be submitted not later than February and August of 2010 and 2011 and February 2012. A final work program report and associated products will be submitted between June 30 and August 1, 2012 as requested by the LCCMR**.**

## IX. RESEARCH PROJECTS: Research addendum is appended.

**Attachment A: Budget Detail for 2009 Projects**

**Project Title:** Does Intensified Tile Drainage Create More Erosive Rivers

**Project Manager Name: Shawn Schottler**

**Trust Fund Appropriation: $** 300,000

| 2009 Trust Fund Budget | Result 1 Budget: | Amount Spent 5-8-09 | Balance 5-8-09 | Result 2 Budget: | Amount Spent 5-8-09 | Balance 5-8-09 | TOTAL BUDGET | TOTAL BALANCE |
|---|---|---|---|---|---|---|---|---|
| | Quantification of extent of artificial drainage | | | assessment of hydrologic changes due to drainage | | | | |
| **BUDGET ITEM** | | | | | | | | |
| **PERSONNEL: wages and benefits**<br>Shawn Schottler (30% time, 3 yrs = $74,400)<br>Jim Almendinger (25% time, 2 yrs= $37,800) | | | | 112,200 | 0 | 112,200 | 112,200 | 112,200 |
| ***Explanation of Benefits:*** FTE's only = 28%<br>Medical: Single ~$200/month, Family ~720/month<br>Retirement- Employer Contribution = 4% of salary | | | | | | | | |
| **Contracts** | | | | | | | | |
| **Professional/technical** (Minnesota State University-Mankato; Water Resource Center. Responsible for completing Result 1) | 150,000 | 0 | 150,000 | | | | 150,000 | 150,000 |
| **Supplies**<br>lab supplies | | | | 2,800 | 0 | 2,800 | 2,800 | 2,800 |
| **Other**<br>**Graduate Student stipend** | | | | 35,000 | 0 | 35,000 | 35,000 | 35,000 |
| **COLUMN TOTAL** | **$150,000** | **$0** | **$150,000** | **$150,000** | **$0** | **$150,000** | **$300,000** | **$300,000** |

## Project ID B1-038:

# Does Intensified Tile Drainage Create More Erosive Rivers?

Shawn Schottler[1.] (project manager), Jim Almendinger[1.],
Daniel R. Engstrom[1.], and Richard Moore[2.] and Shannon Fisher[2.]

1. *St. Croix Watershed Research Station, Science Museum of Minnesota, Marine on St. Croix, MN 55047*
2. *Minnesota State University-Mankato, Water Resources Center, Mankato, MN 56001*

**Abstract**

Based on multiple sediment cores from Lake Pepin, which integrate watershed scale processes in the Minnesota River basin, sediment erosion rates have increased ten fold since European settlement and loads are dominated by non-field sources. Increases in non-field sediment loading coincide with intensification of artificial drainage and periods of increased precipitation. Artificial drainage networks have proliferated in the Lake Pepin watershed, but the spatial extent, density and installation trends have not been inventoried. The effect of these artificial drainage networks on river hydrology is unknown and must be examined in the context of changing patterns in precipitation. This project seeks to quantify the impact of drainage and precipitation on altering riverine hydrology and determine if these changes have increased the erosive potential of these rivers.

**Background**

Lake Pepin, a natural impoundment on the Mississippi River, provides a temporally and spatially integrated archive of the erosion history of the agricultural watersheds of Minnesota. With the loss of wetlands, the conversion of prairies to annual row crops, and other land-use changes an increase in erosion rates is expected. Consequently sediment accumulation rates in Lake Pepin have increased by tenfold since the advent of European settlement and the introduction of row crop agriculture (Engstrom 2009). The Minnesota River basin contributes 85% of the sediment loading to Lake Pepin and currently 92% of the watershed is utilized for row crop agriculture. Between ~1850 and 1950 more than 95% of all prairie and a significant percentage of wetlands in the Minnesota River basin were converted to agriculture. As a result, sediment delivery to Lake Pepin increased by a factor of 4 during this period. Despite the fact that nearly all the loss in prairie/perennial cover was completed by ~1950, sediment accumulation rates continued to increase by an additional 6 fold from 1950 to present, reaching 10 times the natural rate. Decadal increases in precipitation trends, the continued loss of wetlands and the associated intensification of artificial drainage are possible causes of the continuing increases in erosion rates and sediment loading to Lake Pepin.

New research is showing that the sources of sediment to Lake Pepin have been changing over the last half-century and are increasingly dominated by non-field sources. Preliminary results from this new research indicate that the load of sediment (kg/yr) eroded from fields and entering Lake Pepin has remained nearly constant since about 1940. Thus, non-field sources, such as streambanks and ravines, must be responsible for a majority of the continued increases in sediment loading to the lake.

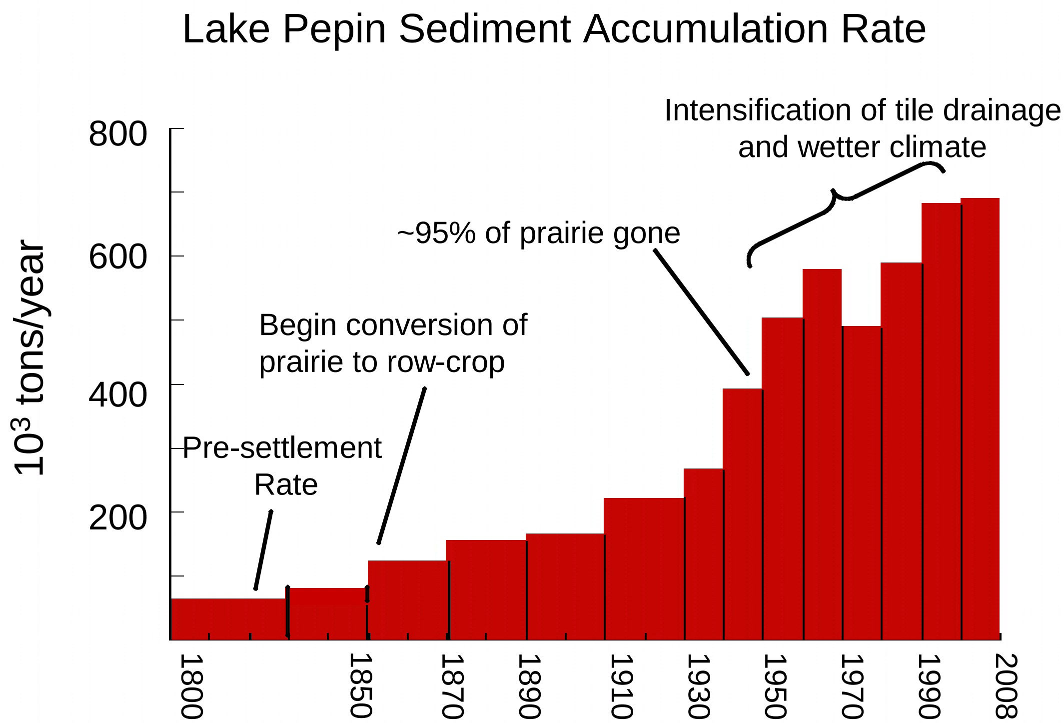


**Figure 1.** Lake Pepin integrates and archives the sediment erosion history of the Minnesota, Mississippi and St. Croix rivers. Sediment erosion rates increases with the conversion of prairie to row-crop agriculture starting the mid-1800's. By 1950 ~ 95% of all prairie had been converted yet sediment rates continued to increase, and currently greater than 60% of all sediment is coming from non-field sources. Tile drainage or increased precipitation could change hydrologic conditions such as peak flow, which could make rivers more erosive. Are the increases in sedimentation rates linked to the intensification of artificial drainage, greater precipitation or both? Efficient allocation of management dollars is dependent on knowing where the sediment is coming from and the causes of changes in erosion rates

Directly linking trends in precipitation or the intensification of artificial drainage to changes in erosion rates or sources is difficult and not easily quantified. A first step in examining the effects of climate or land use on erosion is to determine if these forces cause a change in hydrology, specifically hydrologic responses such as riverine peak flow or runoff ratio, that increase the erosive potential of runoff.

This proposal seeks to use a comparative assessment of long-term flow records in ~23 sub-watersheds of the upper Mississippi river above Lake Pepin with similar changes in precipitation trends but with different intensities of artificial drainage to determine if the effect of these variables can be separated and independently linked to changes in watershed hydrology and temporal trends in Lake Pepin sediment accumulation rates. Novotny and Stefan (2007) and Mallawantantir et al. (*http://www.soils.umn.edu/research/mn-river/doc/trends.html*) have shown that increased flow of upper Mississippi river tributaries can be correlated with increases in average precipitation or the Palmer Hydrologic Drought Index (PHDI) over the last few decades. However, increases in precipitation trends and intensification of artificial drainage are temporally coincident, and each could have the effect of increasing flow. Thus a comparative analysis of geographically and climatically similar watersheds with varying densities of artificial drainage may be the best approach to separate the influences of precipitation from artificial drainage on long-term trends in flow.

**Hypotheses and Questions**

Regarding the relations among landscape erosion, changes in river hydrology and the link of both to tile drainage and precipitation, we put forth the following hypotheses and questions:

- Changes in erosion rates and sources are linked to changes in watershed-scale hydrology.
- Changes in hydrology over the last ~60 years in the agricultural sub-watersheds of Lake Pepin are controlled principally by changes in precipitation and/or increases in agricultural artificial drainage.
- Changes in precipitation trends over the past 60 years will have minimal effects on monthly trends in flow and other riverine hydrologic parameters relative to effects caused by artificial drainage.
- The importance of artificial drainage can be quantified by comparing a suite of long-term hydrologic parameters in watersheds with varying degrees of artificial drainage intensity. Climatic effects on hydrologic parameters such as the ratio of flow to precipitation (Q/P ratio) can be determined from watersheds with minimal artificial drainage. Watersheds with extensive artificial drainage networks can be used to examine the combined effects of climate and drainage on trends in flow parameters. Comparing trends in each of the watershed types will permit the effect of increasing artificial drainage to be separated from precipitation trends and to determine the magnitude of the impact of artificial drainage on altering hydrology. An example of the type of comparative assessment that will be done is shown in Figure 1.
- The working hypothesis to be tested in this study can be stated as follows: When normalized to climate (e.g., precipitation or PHDI), watersheds with extensive artificial drainage networks will show changes in hydrologic parameters such as Q/P ratio, peak flows, and base flow duration that are distinctly different from those watersheds with minimal artificial drainage.

## Methodology

### Result 1. Quantification of temporal and spatial extent of artificial drainage

Currently, no systematic inventory of the amount or location of artificial drainage in the Lake Pepin basin is available. Correlating changes in hydrology and sediment loading to the expansion of artificial drainage networks is dependent on knowing the chronology and extent of the installation history. Present-day artificial drainage density in 23 watersheds contributing to Lake Pepin (Figure 2) will be estimated from GIS mapping of judicial ditches, a statistical inventory of surface inlets, aerial photography and mapping of ditch outlets, and color infrared photographing showing density of pattern tiling. Temporal trends in installation of drainage networks will estimated from historical aerial photos starting in the 1930's, farm records, and production records of drain tile.

### A. Estimation of Present Day Artificial Drainage Density.

i. Judicial ditch density.

Total length of judicial ditches and statistically-based roadside surveys of tile-surface risers will be used as surrogates to estimate the extent of artificial drainage in each of the 23 watersheds. Judicial ditch density (kilometers of ditch per unit watershed area) will be calculated from existing hydrographic GIS coverage's for each of the watersheds. While this metric is an imperfect representation of artificial drainage intensity, we assume that watersheds with extensive sub-surface tile networks will also be watersheds with more judicial ditches. In addition, judicial ditching was often accomplished early in the 20$^{th}$ century and represents a relatively static measurement. Nevertheless, judicial ditch density should provide a quantifiable comparison among watersheds.

ii. Surface riser density.

Many tile networks incorporate surface inlets to drain depressions of standing water. These surface inlets are usually marked by flags or stakes and are readily visible in the spring and fall. Twenty 1-mile segments of rural township roads will be randomly selected for each watershed. These roads will be driven in the spring or fall and surface inlets will be inventoried along each segment. Based on these roadside surveys, the density (number/mile) of surface inlets will be calculated for each watershed. Again, this is an imperfect estimation of artificial drainage density, connectivity, and extent, but it does provide a quantifiable comparison among watersheds.

iii.Drainage Ditch Tile Outlets

Using a combination of aerial photography, drainage ditch records, and field survey, the locations and size of tile outlets into the main surface ditch system will be surveyed. A set number of random sections from each townships will be selected for analysis and the density of tile outlets will be calculated and used as a comparative analysis for the 23 watersheds. Sections

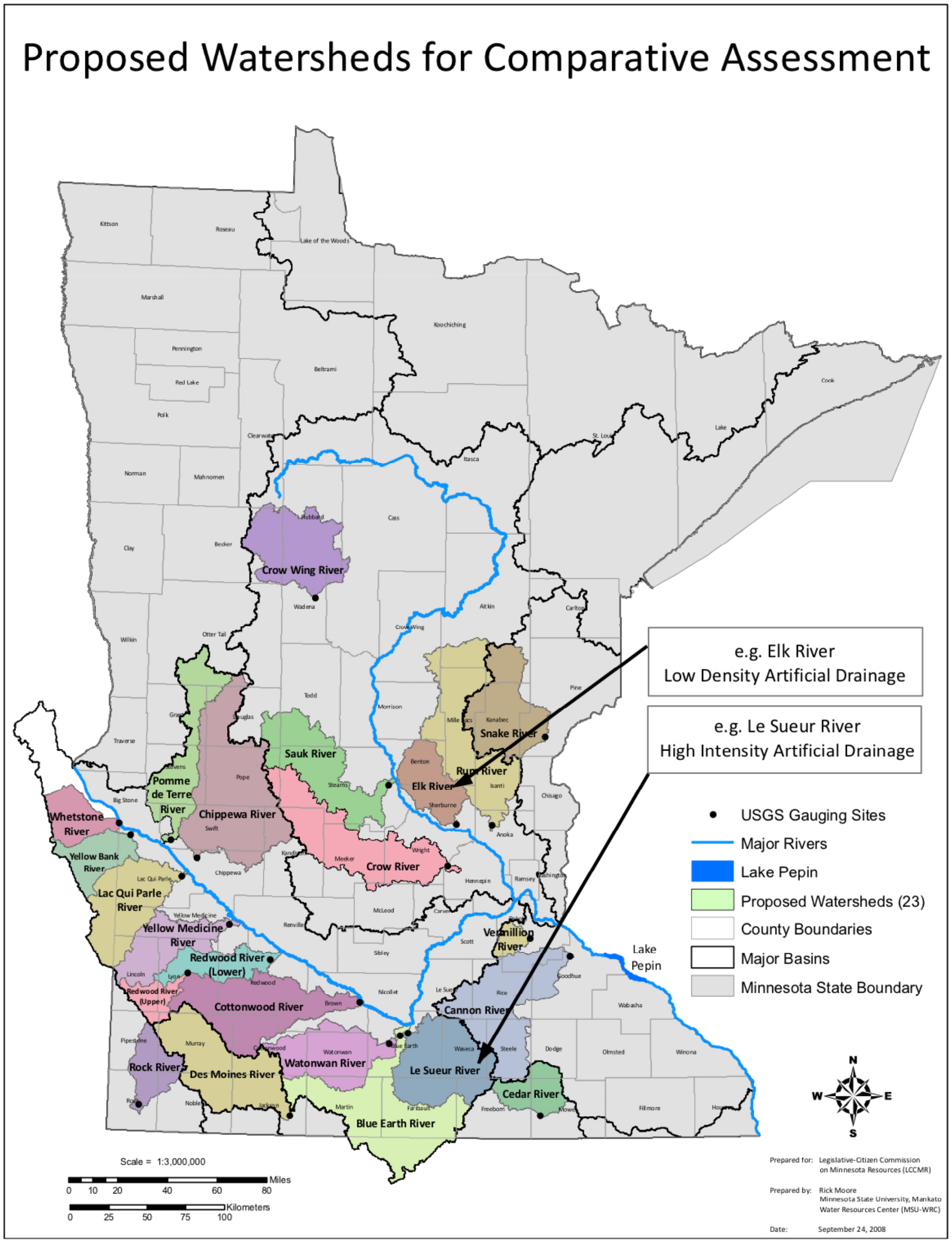


**Figure 2.** Installation density and historical trends of tile drainage will be quantified in 23 watersheds. Changes in 14 hydrologic conditions from 1940 to present will be quantified in these same 23 watersheds. Comparing climate normalized changes in watersheds with varying levels of artificial drainage and correlating to the sediment record in Lake Pepin will help determine the link between drainage and increasing sediment inputs.

that have a majority of its area that is wooded or in CRP will be screened from the random sample.

iv. Density of Pattern Tiling

The use of color infrared (CIR) aerial photographs and GIS analysis for mapping tile line is documented in a paper by Verma and Cook titled "*Mapping Subsurface Drainage Systems with Color Infrared Aerial Photographs*". The drain (tile) mapping procedure is based on the fact that the soil over efficiently draining tile line dries faster than the soil at other locations in the field and has higher reflectance in the infrared region of the radiation spectrum. CIR aerial photographs for the study area were taken in spring, a few days after a heavy rain storm, converted to digital format, and subjected to edge enhancement to heighten the sharpness of the images. A GIS package (IDRISI) was used to overlay soil data, hydrological parameters, topography, and vegetation cover. The combination of these map layers made it possible to identify the layout of functional tile drainage systems. The accuracy of the method was evaluated by comparing the locations of some of the systems thus identified with ground-truth data.

Where available, aerial photography will be acquired for this analysis. Certain conditions need to be in place for tile lines to be visualized and extracted from the aerial photography. Where conditions of the aerial photography make the extraction of tile features from photo possible, the use of feature analysis will be completed. Where available and applicable, the identification of subsurface drainage will be determined using the procedures outlined in this paper. Aerial photography of pre-vegetation or post vegetation works the best for feature extraction. An example of this is the Blue Earth County Lidar data flown in early spring showing the soil contrast between wet and dry soils over tile lines. Aerial photography of this nature will be pursued and utilized in this project.

## B. Temporal trends in tile drainage density

Correlating the changes in hydrology determined in Result 2 to the installation and expansion of artificial drainage networks is dependent on knowing the chronology of artificial drainage history. The estimates generated in Phase 1 provide only present-day values and use surrogate measures of tile density. Estimating density of tile networks over time is difficult but may be possible by using the following proposed methods.

i. Historic aerial photography.

Sub-surface drainage networks, including patterning tiling, are often visible in spring and fall air photos. Air photos for most parts of Minnesota are available on regular intervals beginning about 1936. By examining photos of the same parcel on a decadal basis from the 1930s to present it is possible to estimate the time trends of artificial drainage installation and spatial density. This type of information is currently unavailable for sub-basins in the Lake Pepin watershed. Based on the information learned during Phase 1, six watersheds with varying levels of artificial drainage will be selected for further analysis. A stratified, random selection of air photos covering at least 25 sections of each watershed will be interpreted for drainage density at selected time intervals. Interpretation will quantify pattern-tile density, connectivity, and surface area of drained wetlands. Using spatial analysis with aerial photographs, the locations of pattern tiling will be determined as described in the article by Verma and Cook. Certain areas of the study area have aerial photography that was flown at certain times of the year and can yield the patterns of subsurface drainage (tile) due to color variations in the soil. Those areas in the study area will be looked at for their ability to yield pattern tile structures.

ii. Farm records.

To a limited degree maps of tile networks are on file at farm service agencies, and some landowners have personal records of tile networks. In the six watersheds selected for detailed drainage history, FSA and NRCS offices will be contacted for available tile maps. Landowners in the 25 sections selected for air photo interpretation will be contacted and interviewed to determine what personal record are available to validate the photo interpretation findings. All information from landowners will be requested on a voluntary basis. Utilizing those areas that have been involved in the Minnesota River Assessment Project, a detailed analysis of the information gathered for those areas will yield comparative data necessary to show tiling over time.

iii. Production records and other historical information.

Quantifying historical trends in tile installation history is critical to relating its effect on changes in hydrology, and yet essentially no estimation of these trends is available. An effort will be made to search out efficient and accurate ways to quantify tile installation history. It is possible that production or sales records for perforated tile or tile company purchasing records exist. It is uncertain how to obtain this information or what is even available. As part of Result 1, a thorough examination of alternative methods to garner artificial drainage history will be undertaken.

**Result2- Comparative assessment of changes in hydrologic parameters in agricultural watersheds with and without extensive artificial drainage.**

A. Hydrologic assessment.

There are 23 watersheds in the agricultural regions of Minnesota that have nearly continuous flow records from 1940 to present. (Note: All 23 watersheds will be examined, and those that have intact and reliable records will be used. It is possible that some watershed will have incomplete or compromised data.) A suite of hydrologic parameters will be examined in each of these watersheds to see if temporal trends exist (see Figure 3 for an example). There are few watersheds with reliable records prior to 1940. Given that the increases in both artificial drainage and precipitation have occurred over the past 70 years, examining flow records from 1940 to present should be sufficient. Long-term precipitation and PHDI records also exist for each of these watersheds and will be utilized to normalize for climatic conditions. When appropriate, flow and climate variables will be stratified on a cumulative monthly or seasonal basis. Richter et al. (1996) identified 32 hydrologic parameters within 5 groups to assess hydrologic alteration at a watershed scale. We will use a subset of these parameters and, when possible, normalize them to climate variables such as PDHI and precipitation, to quantify time trends in our 23 watersheds. A commercially available program such as *RiverMorph*, will be applied to the flow data to compute several of the hydrologic parameters such as flow frequency.

**Table 1.** Summary of hydrologic parameters used to assess changes in flow in watersheds with varying intensities of artificial drainage. Modified from Richter et al. 1996.

| **Hydrologic Group** | *Parameter* |
|---|---|
| Group 1. Magnitude of monthly water conditions | Q/P ratio (Q= discharge m3/month)<br>(P = precipitation m/month)<br><br>Yield/P ratio (Yield = Q/watershed area)<br><br>Q/PHDI<br><br>Yield/PHDI |
| Group 2. Magnitude and duration of extreme water conditions | Monthly 1 day maxima<br><br>Monthly 1 day minima |
| Group 3. Timing of annual extreme conditions | Julian date of monthly maxima<br><br>Julian date of seasonal maxima |
| Group 4. Frequency and duration of high and low pulses | Frequency of high pulses each month<br><br>Mean Duration of high pulses<br><br>Mean Duration of base flow period |
| Group 5. Rate and frequency of water condition changes | Means of all positive differences between consecutive daily means normalized to cumulative monthly precip and PHDI<br><br>Means of all negative difference between consecutive daily means normalized to P and PHDI<br><br>Number of rises and number of falls |

B. Quantify the relationship between artificial drainage and changes in hydrology.

The 23 watersheds selected for this study are all agricultural basins and will likely have a continuum of artificial drainage densities. To compare and quantify the effect of artificial drainage on river flow, trends (unit change per year) for each of the hydrologic parameters listed in Table 1 will be regressed against the two estimations of artificial drainage density. For example, the mean annual change in Q/P from 1940 to present for each watershed will be plotted against corresponding estimation of tile density and a regression will be fit to the 23 data points. When doing regression analyses, hydrologic parameters will be scaled to landscape characteristics such as basin area, slope, soil type and eco-region. Some hydrologic parameters, even when normalized to landscape characteristics, precipitation or PHDI, may have time trends related to climate. This should be most apparent in watersheds with minimal artificial drainage. For these watersheds the temporal trends in monthly precipitation or PHDI will be determined and applied to all watersheds as the amount of change in a given hydrologic parameter that can be attributed climate alone. By combining ("subtracting") these two relationships, an estimation of the statistical strength and magnitude of the effect of artificial drainage on hydrology can be calculated.

C. Watershed model to examine sensitivity of hydrograph to changes in precipitation and tiling

While statistical correlations are useful for inferring potential cause and effect, a more mechanistic approach using watershed modeling could provide stronger evidence of causal links. In theory watershed computer models take into account the complicated linkages between climate, land use, and runoff-generating mechanisms. In practice model results must be carefully winnowed to avoid over-interpretation. Still, one strength of modeling is in determining relative differences due to changing conditions in the watershed, including climate and land-use changes.

Here we propose to model one watershed from the set of six mentioned above using the USDA/ARS Soil and Water Assessment Tool (SWAT). Ideally this watershed will have (a) a complete flow and climate record for the full 60-year study period, and (b) a reasonably well-known tiling history, with little to no tiling in the early record and a high density of tiling in the later record. The model will be calibrated to the early flow record (the first 10-20 years), which will require some assumptions about cropping patterns and extent of wetland drainage at that time. Tiling will not be explicitly added to the model, under the assumptions that the amount of tiling was minimal during the period of model calibration, and that that which existed can be accommodated by adjustment of more conventional model parameters.

To test the effect of tiling, the model will be run for the latter part of the record (with some adjustments for cropping pattern changes), with the known climate record as input. If changes in tiling have an impact, then model output (which ignores tiling) should diverge from the actual hydrograph (which is under the influence of tiling). In particular, the hydrologic statistics examined under Phase 1 will be evaluated for the model and compared against those for the actual hydrograph. The change in the model hydrograph (and its selected statistics) over the last 40 years will be the effect of climate alone; the divergence between the model and actual hydrograph will be the effect due to tiling during any selected time slice.

Several other complimentary scenarios could be run as well. First, the model sensitivity to different climatic inputs could be examined. For example, even in the absence of tiling, the Q/P ratio may increase as P increases, because once runoff-generating thresholds are exceeded in a watershed, runoff would be expected to increase directly with P. How much would P have to increase to generate the increased Q/P ratios such as that shown in Figure 1b, in the absence of tiling? Is the required increase in P so great that some other cause, such as tiling, must be invoked? Second and more obviously, tiling could be added to the model, with direct before-and-after comparisons. However, we are skeptical of the ability of current models to realistically simulate the effect of tiling, both subsurface and surface-riser tiling.

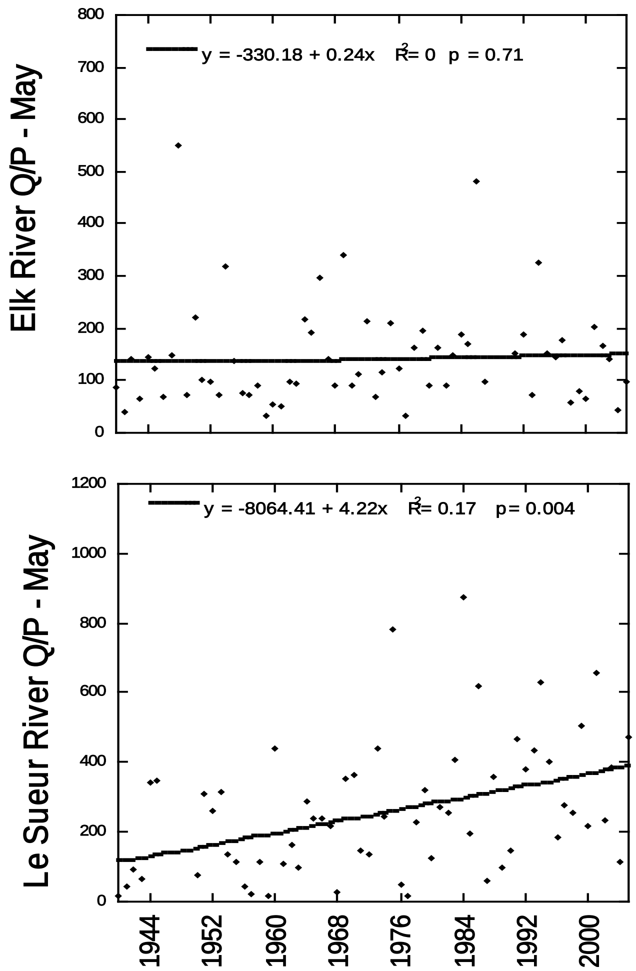


**Figure 2.** Example of comparative analysis of hydrologic parameters in watersheds with high and low densities of artificial drainage. Q/P is the ratio of cumulative flow volume to precipitation ($m^3/m$) for the month of May from 1940 to 2005. The Elk watershed is presumed to have low artificial drainage density as compared to the intense drainage installed in the LeSueur watershed. Because the Q/P ratio in the Elk watershed shows no significant increase over time, it suggests that trends in precipitation have had minimal effect on cumulative flow volume. However, the heavily drained LeSueur watershed shows a statistically significant increase in precipitation-normalized flows since 1940. Because climate trends are not large enough to affect the Q/P ratio in the Elk watershed, it could be inferred that artificial drainage is the driving variable effecting flow in the LeSueur watershed. Q/P ratio is one of 14 hydrologic

parameters that will be examined on a monthly and seasonal basis and compared among 23 watersheds with long-term flow records. This example serves to illustrate the type of comparisons that can be made. A more rigorous statistical separation of the effects related to precipitation and drainage will be performed in the study.

D. Relating temporal trends in artificial drainage density to temporal trends in hydrologic parameters and Lake Pepin sediment accumulation rates.

Ultimately, relating artificial drainage density to changes in hydrology, and the consequent increases in erosion, is the objective of this study. Superimposing the historical changes in artificial drainage on other known land-use and climate changes (either natural or human induced) in the Lake Pepin watershed will help provide a more robust interpretation of the causes of the continuing increases in sediment accumulation. Long-term historical sediment loading data are not available for the 23 rivers in this study, thus it is not possible to directly correlate changes in hydrologic conditions to potential changes in streambank or other near channel erosion sources. However, the installation history of artificial drainage, decadal trends in climate and changes in hydrologic parameters can be correlated to changes in sediment accumulation rates in Lake Pepin. Results 2: A - C generates an understanding of the magnitude of artificial drainage and its effects on changing hydrology. Coupling this with the historical trends in installation history or drainage and climate variations and comparing these trends to the sediment record in Lake Pepin allows for a semi-quantitative assessment to be made of the link between drainage and non-field sediment erosion. A more quantitative approach will be attempted using a multiple regression models relating sediment accumulation rates in Lake Pepin and suspended sediment record for the Minnesota River at Mankato to installation trends of drainage, decadal changes in precipitation or PDSI and decadal trends in hydrologic parameters that were found to be related to changes in flow.

**Deliverables**

1. Assessment of hydrologic changes from 1940 to present in 23 agricultural watersheds based on 14 hydrologic parameters.

2. Estimation of present day artificial drainage density in the same 23 agricultural watersheds using surveys of two surrogate metrics.

3. Quantitative comparison of the effect of artificial drainage and precipitation on hydrology.

4. Detailed quantification of trends in installation of artificial drainage using multiple assessment tools for six watersheds

5. Analysis of relationship between temporal trends in artificial drainage density and changes in hydrology.

6. Analysis of SWAT model results to seek causal relations between climate, tiling, and runoff in a selected watershed.

7. Statistical comparison of trends in artificial drainage and precipitation with suspended sediment loads in the Minnesota River at Mankato and sediment accumulation rates in Lake Pepin.

## Dissemination and Use

The final product of this project will be an interpretive report describing (a) the extent and distribution of artificial drainage in 23 agricultural watersheds, and (b) the relation between artificial drainage and changes in the hydrologic conditions in these 23 watershed. The report will include a semi-quantitative analysis of the relationship between artificial drainage and climate/precipitation as drivers of increased sediment erosion as recorded in Lake Pepin. This report will be written as one or more manuscripts to be submitted for publication in peer-reviewed journals. A fact sheet summarizing the principal findings of this project will be distributed to LCCMR members and other selected legislators at the state and federal level. Results will be present and state technical advisory meetings and at state and national water quality related conferences. All reports from this project will be made available via the Museum's web site. Any exhibits or programming developed for the general public will depend on external funding procured by the Science Museum of Minnesota.

**References:**

Engstrom, D.R., J.E. Almendinger, and J.A. Wolin. 2009. Historical changes in sediment and phosphorus loading to the upper Mississippi River: mass-balance reconstructions from the sediments of Lake Pepin. J. Paleolimnol. doi: 10.1007/s10933-008-9292-5.

Mallawantantri A., Mulla D. J., and Seeley M. Sediment and phosphorus in the Minnesota River and it tributaries, http://www.soils.umn.edu/research/mn-river/doc/trends.html

Novotny, E. V. and Stefan H. G. Stream flow in Minnesota: Indicator of climate change, Journal of Hydrology, 334, p. 319-333 2007

Richter, B. D., J.V. Baumgartner, J. Powell, and D. P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems, Conservation Biology, v 10, p. 1163-1174.

Verma, A., Cooke, R., and Wendte, L. Mapping Subsurface Drainage Systems with Color Infrared Aerial Photographs. Remote Sensing Core Curriculum-Volume 4: Applications in Remote Sensing. (1996) http://www.r-s-c-c.org/rscc/Volume4/verma/verma.html

## Timetable

| Task | 2009 | | 2010 | | | | 2011 | | | | 2012 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | July –Sept. | Oct-Dec | Jan- Mar | Apr-Jun | July-Sept | Oct-Dec | Jan- Mar | Apr-Jun | July-Sept | Oct-Dec | Jan- Mar | Apr-Jun |
| **Result 1. Quantification of Tile Drainage** | | | | | | | | | | | | |
| A. Estimation of Present day drainage | x | x | x | x | x | | | | | | | |
| i. Judicial ditch density inventory | | x | x | x | x | x | | | | | | |
| ii. Surface riser density inventory | | | | x | x | x | x | x | | | | |
| iii. Tile outlet inventory | | | | x | x | x | x | x | | | | |
| iv. Pattern tiling density | | | | | | x | x | x | x | | | |
| B. Temporal trends in drainage installation | | | | | | | | | | | | |
| i. aerial photography interpretation | | | | x | x | x | x | x | x | x | | |
| ii. Farm records survey | | | | x | x | x | | | | | | |
| iii. Production records and other methods | | | | | | | x | x | x | x | x | |
| **Result 2. Comparative Assessment of hydrology** | | | | | | | | | | | | |
| A. Hydologic assessment of 23 watersheds | x | x | x | x | x | x | x | | | | | |
| B. Quantify relationship between hydrologic changes and drainage | | | | | | | x | x | | | | |
| C. Watershed model, sensitivity | | | | | x | x | x | x | x | | | |
| D. Relating trends to L. Pepin sed accumulation | | | | | | x | x | x | x | x | x | |
| Project Final Report | | | | | | | | | | | | x |

## Budget and Invoicing

| Item | LCCMR Amount | EPA-319 Matching Funds |
|---|---|---|
| ***Result 1 Quantification of Tile Drainage*** | | |
| **Contracts - MN State University Mankato** | $150,000 | $123,933 |
| ***Result 2 Comparative Assessment of Hydrology*** | | |
| **Personnel (salary + benefits)** | | |
| Shawn Schottler (60% time 3 years) | $74,400 | $78,664 |
| Jim Almendinger ( 25% time 2 years) | $37,800 | $6,040 |
| Daniel Engstrom (5% time 2 years) | | $10,800 |
| **Equipment/Supplies** | $2,800 | $2,473 |
| **Indirect Costs** | | $43,090 |
| **Other** | | |
| Graduate Student Stipends (24 months, 50% time) | $35,000 | $35,000 |
| **Total** | **$300,000** | **$300,000** |

## Credentials

### Organization Description

The Science Museum of Minnesota (SMM) is a private, non-profit 501(c)3 institution dedicated to encouraging public understanding of science through research and education. Its mission is to invite learners of all ages to experience their changing world through science. The St. Croix Watershed Research Station is a program of the SMM with the mission to foster, through research and outreach, a better understanding of rivers and lakes at the watershed scale and to provide information to help sustain similar ecological systems.

The Water Resources Center (WRC) at Minnesota State Mankato was created in 1987 to serve as a regional center for environmental research and information exchange. The WRC has participated in more than 100 research, educational, and resource planning projects involving partnerships with dozens of public and private organizations. Project management and collaboration has involved studies in groundwater and lake assessment, water quality monitoring, and watershed management. The WRC staff has completed drainage inventory projects for the Blue Earth River Basin and a drainage ditch buffer study for the Board of Water and Soil Resources. The WRC has also been coordinating numerous TMDL projects and have several ongoing research studies involving the hydrologic, nutrient, and bacterial influences of tile on water quality.

### Curriculum Vitae Summary

One page summaries of principal investigators are attached on the following pages.

**Shawn Schottler, Ph.D.-- Associate Scientist,**
**St. Croix Watershed Research Station, Marine, MN**
**Curriculum Vitae Summary**

**Education**

**Ph.D. University of Minnesota, Minneapolis, Minnesota**
Environmental Engineering, 1996
**B.S. University of Minnesota, Minneapolis, Minnesota**
Geotechnical Engineering, 1989

**Research**

**Associate Scientist: St. Croix Watershed Research Station, 1997-**
Radioisotopic tracers of sediment sources in agricultural watersheds
New techniques for sampling of suspended sediment, and field erosion
Refine analytical methodology of using radioisotopes as sediment tracers
Quantify the effects of land use-BMP on water quality and hydrology
Coordination and supervision of upland restoration projects
**Post-Doctoral Research: University of Minnesota, 1996- 1997**
Dept. of Health Sciences: Fate and transport of airborne toxins to the Great Lakes
**Research Associate: Gray Freshwater Institute, Navarre MN, 1989-1995**
Sources and transport of pesticides in the Minnesota River, and Great Lakes
Correlation between land use and non-point source inputs to agri-watersheds

Selected Publications

**Schottler S. P**. and Engstrom, D. R. 2006. A chronological assessment of Lake Okeechobee (Florida) sediments using multiple dating markers. Journal of Paleolimnology, v. 36, 19-36.

Engstrom, D. R., **Schottler, S. P**., Leavitt, P. R., and Havens K. E. 2006. A Re-evaluation of the cultural eutrophication of Lake Okeechobee using multiproxy sediment records, Ecological Applications, v.16(3), 1194-1206.

**Schottler, S.P**., Identification of Sediment Sources in an Agricultural Watershed, Final Report to the Legislative Commission on Minnesota's Resources, December 30, 2002

Swackhamer, D.S., **Schottler, S.P**., and Pearson, R.F. Air-Water Exchange and Mass balance of Toxaphene in the Great Lakes, *Environmental Science and Technology*, v.33, pp. 3864-3872, 1999

**Schottler S.P**., Heinz N., and Eisenreich S.J., Temporal and Spatial Trends of Atrazine, DEA and DIA in the Great Lakes, In *Triazine Herbicides: A Risk Assessment,* (Cpt. 18) Ballantine, L.; McFarland, J. Hackett, D., (Eds.); ACS Books: Washington D.C., Symp. Series no. 683, 1998

**Schottler S.P**. and Eisenreich S.J., A Mass Balance Model for Quantifying Atrazine Sources and Transformation Rates in the Great Lakes, *Environmental Science and Technology*, v. 31, p. 2616-2625, 1997.

**Schottler S. P**., Port J. and DeGolier, T., 2008, Influence of floristic diversity on songbird nesting preferences in a suite of adjacent reconstructed grasslands, Ecological Restoration, v. 26 (3), 195-197.

**Schottler S. P**., Port J. and DeGolier, T., 2008, An efficient method for quickly surveying pheasant nesting site preferences, Ecological Restoration, v. 26 (3), 198-199

**JAMES EDWARD ALMENDINGER**

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**Education**

1978. B.A., Botany. Ohio Wesleyan University, Delaware, OH 43015
(Valedictorian; Summa Cum Laude; Phi Beta Kappa)

1988. Ph.D., Ecology. University of Minnesota, Minneapolis, MN 55455
(Dissertation: "Lake and groundwater paleohydrology: a groundwater model to explain past lake levels in west-central Minnesota")

1988-89. Postdoctoral research, University of Minnesota, Minneapolis MN 55455
(Landscape evolution and lake ontogeny, Glacier Bay, Alaska)

1989-90. Postdoctoral research, University of Lund, Lund, Sweden
(Lake and groundwater paleohydrology of the Vomb Plain, Sweden)

**Appointments**

| | |
|---|---|
| 1995- | Associate Scientist, St. Croix Watershed Research Station, Science Museum of Minnesota |
| 2001- | Adjunct Professor, Dept. of Geology and Geophysics, Univ. of Minn. |
| 2000- | Adjunct Professor, Water Resources Science Program, Univ. of Minn. |
| 1990-95. | Hydrologist, U.S. Geological Survey, Mounds View, MN. |
| 1989-90. | Fellow, American-Scandinavian Foundation, Univ. of Lund, Sweden. |
| 1981-89. | Research Assistant/Associate, Univ. of Minnesota. |
| 1978-81. | NSF Predoctoral Fellow, Univ. of Minnesota. |

**Selected Publications**

Clark, J.S., E.C. Grimm, J.J. Donovan, S.C. Fritz, D.R. Engstrom, and **J.E. Almendinger**. 2002. Drought cycles and landscape responses to past aridity on prairies of the northern Great Plains, USA. Ecology 83(3): 595-601.

Engstrom, D.R., S.C. Fritz, **J.E. Almendinger**, and S. Juggins. 2000. Chemical and biological trends during lake evolution in recently deglaciated terrain. Nature 408:161-166.

**Almendinger, J.E.** 1999. A method to prioritize and monitor wetland restoration for water-quality improvement. Wetlands Ecology and Management 6:241-251.

Balogh, S.J., D.R. Engstrom, **J.E. Almendinger**, M.L. Meyer, and D.K. Johnston. 1999. A history of mercury loading in the upper Mississippi River reconstructed from the sediments of Lake Pepin. Environmental Science and Technology 33: 3297-3302.

**Almendinger, J.E.**, and J.H. Leete. 1998. Peat characteristics and ground-water geochemistry of calcareous fens in the Minnesota River Basin, U.S.A. Biogeochemistry 43: 17-41.

**Almendinger, J.E.**, and J.H. Leete. 1998. Regional and local hydrogeology of calcareous fens in the Minnesota River Basin, U.S.A. Wetlands 18: 184-202.

**Almendinger, J.E.** 1993. A groundwater model to explain past lake levels at Parkers Prairie, Minnesota, USA. The Holocene 3: 105-115.

Almquist-Jacobson, H., **J.E. Almendinger**, and S. Hobbie. 1992. Influence of terrestrial vegetation on sediment-forming processes in kettle lakes of west-central Minnesota. Quaternary Research 38: 103-116.

**Almendinger, J.E.** 1990. Groundwater control of closed-basin lake levels under steady-state conditions. Journal of Hydrology 112: 293-318.

# Daniel R. Engstrom


| | | |
|---|---|---|
| St. Croix Watershed Research Station | Tel: | 651-433-5953 |
| Science Museum of Minnesota | E-mail: | dre@smm.org |
| Marine on St. Croix, MN 55047 | Web page: | www.smm.org/scwrs/ |


## 1. Education

| | | |
|---|---|---|
| Ph.D. | 1983 | University of Minnesota, Minneapolis (Ecology) |
| M.S. | 1975 | University of Minnesota, Duluth (Zoology, minor: Botany) |
| | 1971-73 | University of Wisconsin, Madison (Zoology: Limnology) |
| B.A. | 1971 | University of Minn., Duluth (Zoology, minor: chemistry) Magna cum Laude |

## 2. Positions

| | |
|---|---|
| 1999- | Director, St. Croix Watershed Research Station, Science Museum of Minn. |
| 1995-99 | Sr. Scientist, St. Croix Watershed Research Station, Science Museum of Minn. |
| 1990- | Adjunct Professor, Dept. of Geology and Geophysics, University of Minnesota |
| 2004- | Adjunct Professor, Water Resources Science, Univ. of Minnesota |
| 1983-95 | Research Associate, Limnological Research Center, Univ. of Minnesota |

## 3. Research Expertise

General research interests in geological and chemical limnology. Current research projects include: (1) atmospheric mercury deposition and cycling in temperate and Arctic regions; (2) historic nutrient and contaminant loading to the upper Mississippi and St. Croix Rivers; (3) the paleohydrology and paleochemistry of saline lakes in the northern Great Plains; and (4) fingerprinting suspended sediment sources in agricultural watersheds.

## 4. Selected Publications (of more than 80)


Lindberg, S.E., O.R. Bullock, R. Ebinghaus, D.R. Engstrom, X. Feng, W.F. Fitzgerald, N. Pirrone, E.M. Prestbo, and C. Seigneur. 2007. A synthesis of progress and uncertainties in attributing the sources of mercury in deposition. *Ambio* (in press).

Wiener, J.G., B.C. Knights, M.B. Sandheinrich, J.D. Jeremiason, M.E Brigham, D.R. Engstrom, L.G. Woodruff, W.F. Cannon, and S.J. Balogh. 2006. Mercury in soils, lakes, an fish in Voyageurs National Park (Minnesota): importance of atmospheric deposition and ecosystem factors. *Environmental Science and Technology* DOI: 10.1021/es060822h.

Engstrom, D.R., Schottler, S.P., Leavitt, P.R., and Havens, K.E. 2006. A re-evaluation of the cultural eutrophication of Lake Okeechobee, Florida, using multiproxy sediment records. *Ecological Applications* 16: 1194-1206.

Engstrom, D.R. and Fritz, S.C. 2006. Coupling between primary terrestrial succession and the trophic development of lakes at Glacier Bay, Alaska. *Journal of Paleolimnology* 35: 873-880.

Jeremiason, J.D., D.R. Engstrom, E.B. Swain, E.A. Nater, B.M. Johnson, J.E. Almendinger, B.A. Monson, and R.K. Kolka. 2006. Sulfate addition increases methylmercury production in an experimental wetland. *Environmental Science and Technology* 40: 3800-3806.

Engstrom, D.R. 2005. Long-term changes in iron and phosphorus sedimentation in Vadnais Lake, Minnesota, resulting from ferric chloride addition and hypolimnetic aeration. *Lake and Reservoir Management* 21:96-106.

Fitzgerald, W.F., D.R. Engstrom, C H. Lamborg, C.-M. Tseng, P. Balcom, and C.R. Hammerschmidt. 2005. Modern and historic atmospheric mercury fluxes in northern Alaska: global Sources and Arctic depletion. *Environmental Science and Technology* 39: 557-568.

Shapley, M.D., W.C. Johnson, D.R. Engstrom, and W.R. Osterkamp. 2005. Late Holocene flooding and drought in the Northern Great Plains, reconstructed from tree rings, lake sediments and ancient shorelines. *The Holocene* 15: 29-41.

Ramstack, J.M., S.C. Fritz, and D.R. Engstrom. 2004. Twentieth-century water-quality trends in Minnesota lakes compared with pre-settlement variability. *Canadian Journal of Fisheries and Aquatic Sciences* 61: 561-576.

# Richard J. Moore

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**Education**

2004. M.S., Geography/GIS. Minnesota State University-Mankato, Mankato, MN 56001
(Thesis: "Location, Location, Location and It's Use in a Real Estate Decision Making System")

1994. B.S., Geography. University of Minnesota, Minneapolis, MN 55455
1993 Flooding in the Mississippi River Basin

**Appointments**

| | |
|---|---|
| 2007- | GIS Research Analyst, Water Resources Center, Minnesota State University, Mankato |
| 2008-2009 | Adjunct Professor, Dept. of Geography, Minnesota State University, Mankato |
| 2004-2007 | GIS Planner, Mid-Minnesota Regional Development Commission, Willmar, MN. |
| 2004 | Adjunct Professor, Dept. of Geography, Minnesota State University, Mankato |

**Selected Publications**


Fisher, S.J., and R.J. Moore. 2008. Application of the Wisconsin Tillage Erosion Model to Minnesota, Final Report to the Minnesota Board of Water and Soil Resources, December, 2008

Fisher, S.J., and R.J. Moore. 2008. 2007 Tillage Transect Survey, Final Report to the Minnesota Board of Water and Soil Resources, December, 2008

R.J. Moore. 2008. Drainage Records Modernization Guidelines, Final Report to the Minnesota Board of Water and Soil Resources, September, 2008

**Shannon James Fisher**
Minnesota River Board and Water Resources Center
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Mankato, MN 56001
(507) 389-5690; shannon.fisher@mnsu.edu

## Education

- 1999, Ph.D., Biological Sciences - South Dakota State University
- 1996, M.S., Wildlife and Fisheries Sciences – South Dakota State University
- 1994, B.S., Biology (Chemistry minor) - Northland College (Ashland, WI)

## Appointments

- Executive Director, Minnesota River Board (2005-present)
- Director, Water Resources Center (2005-present)
- Associate Professor of Biology, MN State University, Mankato (2005-present)
- Environmental Review Ecologist, MN Dept. Natural Resources (2003-2005)
- Adjunct Assistant Professor of Biology, Gustavus Adolphus College (1998-2003)
- Fisheries Specialist, MN Dept. Natural Resources (2000-2003)
- Assistant Professor of Conservation, South Dakota State University (1999-2000)

## Selected Publications and Agency Reports

- Fisher, S.J. and G. Larson. 2007. Procedures for the 2007 Minnesota Tillage Transect Survey. Minnesota State University, Water Resources Center.
- Matteson, S. and S. Fisher. 2007. Fecal Coliform TMDL Assessment for 21 Impaired Streams in the Blue Earth River Basin. Minnesota State University, Water Resources Center Publication 07-01.
- Ward, M., Fisher, S.J., and D.W. Willis. 2007. Environmental influences on walleye fingerling production in southwestern Minnesota shallow lakes. North American Journal of Aquaculture 69:297-304.
- Musser, K., S. Matteson, P. Baskfield, and S.J. Fisher. 2006. State of the Minnesota River: Water Quality Summary 2000-2005. Minnesota State University, Water Resources Center Publication.
- Matteson, S. S. Kudelka, and S. Fisher. 2006. Fecal Coliform TMDL Assessment for the High Island Creek and Rush River. Minnesota State University, Water Resources Center, Publication 06-02.
- Kean, A., S. Moe, and S.J. Fisher. 2006. Public Drainage Ditch Buffer Study. MN Board of Water and Soil Resources Report. Minnesota State University, Water Resources Center Publication 06-02.
- Fisher, S.J., S. Sparlin, L. Nelson, and L. Gunderson. 2005. Resident Perceptions of the Minnesota River Basin. Water Resources Center Publication 05-04.
- Berg, C., and S.J. Fisher. 2005. Minnesota River Aggregate and Ecological Resource Evaluation. MN Department of Natural Resources, Ecological Services Report. Minnesota State University, Water Resources Center Publication 05-01.
- Conroy, T., J. Schneider, N. Hansel-Welch, and S. Fisher. 2005. Shallow Lakes: Hope for Minnesota’s Troubled Waters. Minnesota Department of Natural Resources.