A Framework for Addressing Altered Hydrology

Minnesota Water Resources Conference | October 18, 2017

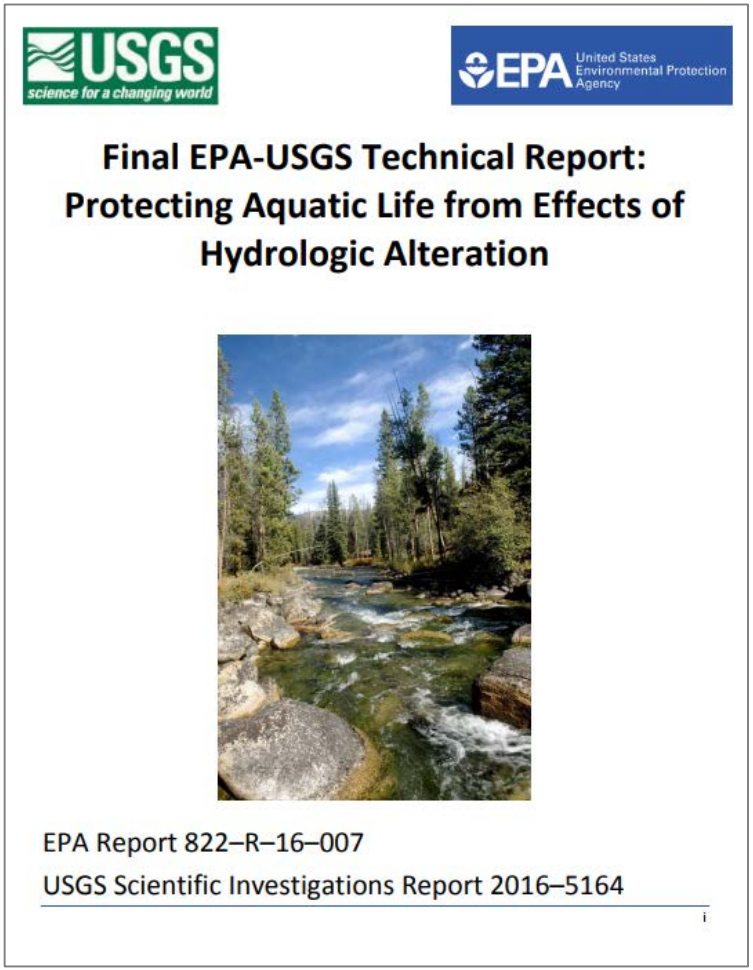
Timothy Erickson, PE,

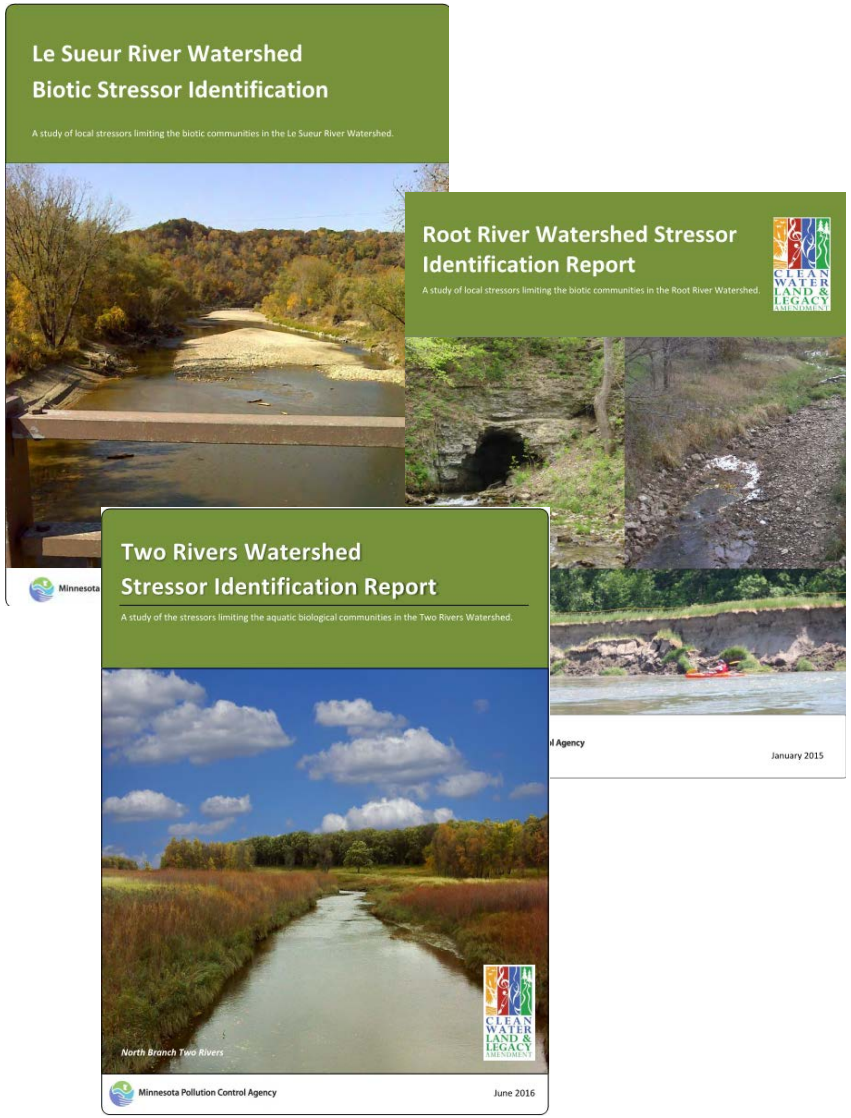
Houston Engineering Inc.

OUR DISCUSSION

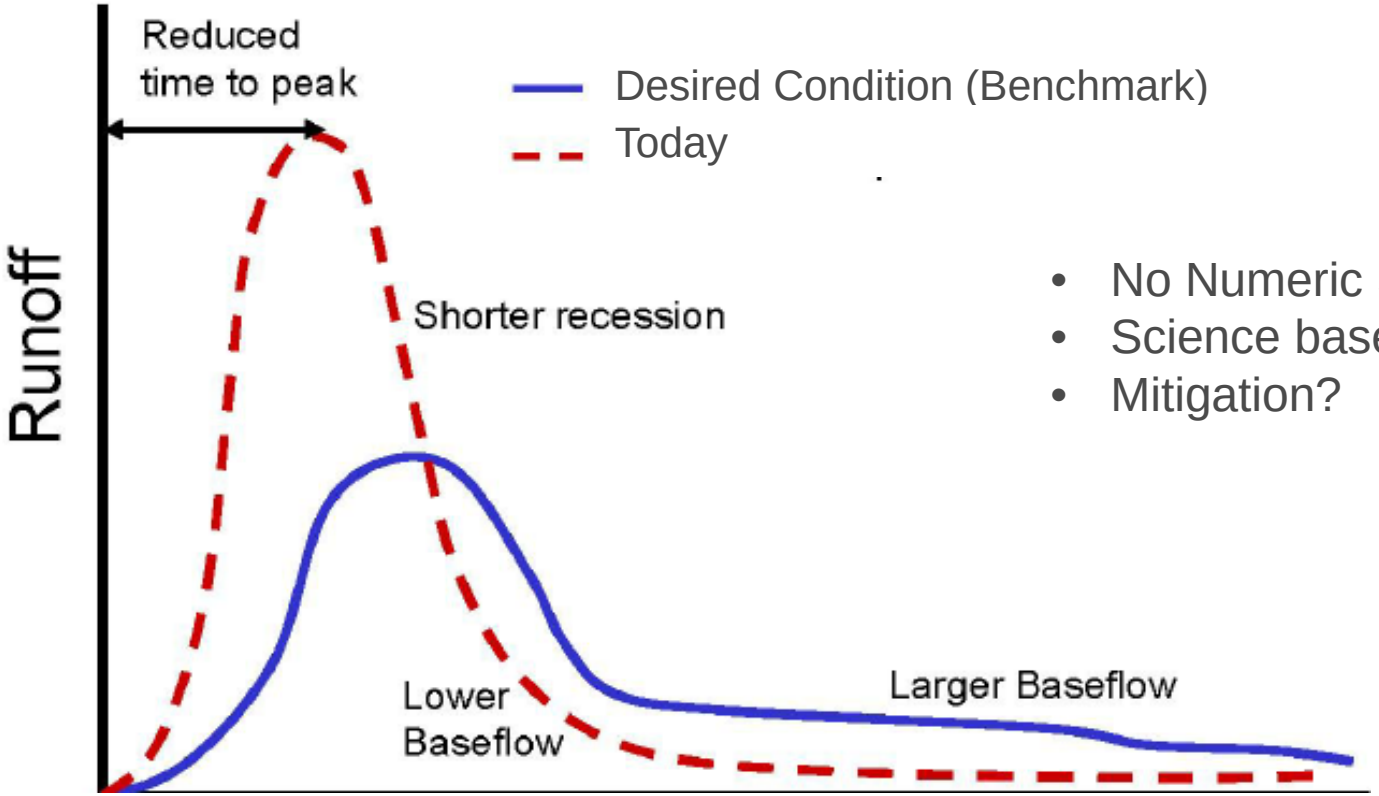
- **Hydrologic Alteration** as an emerging issue
- **Context** relative to the Clean Water Act
- Need for a **science based** framework
- Illustration of a **science based framework**
- **Vision** for success

EMERGENCE OF HYDROLOGIC ALTERATION (“ALTERED HYDROLOGY”)





ALTERED HYDROLOGY – THE CONCERN



- No Numeric Standard
- Science based method
- Mitigation?

Habitat

Sediment & Nutrients

Geomorphology

Impaired Aquatic Life

ANOTHER PERSPECTIVE

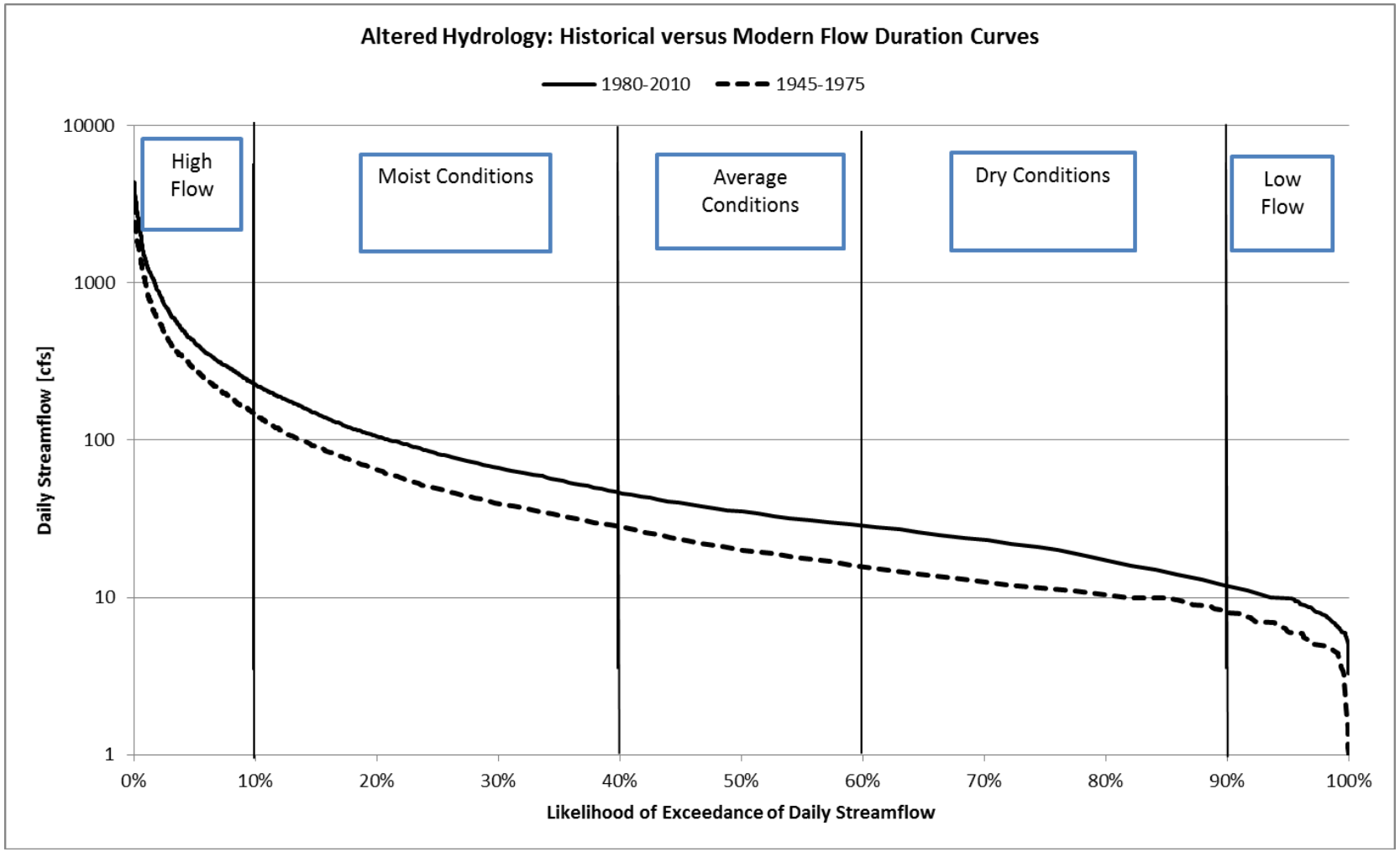
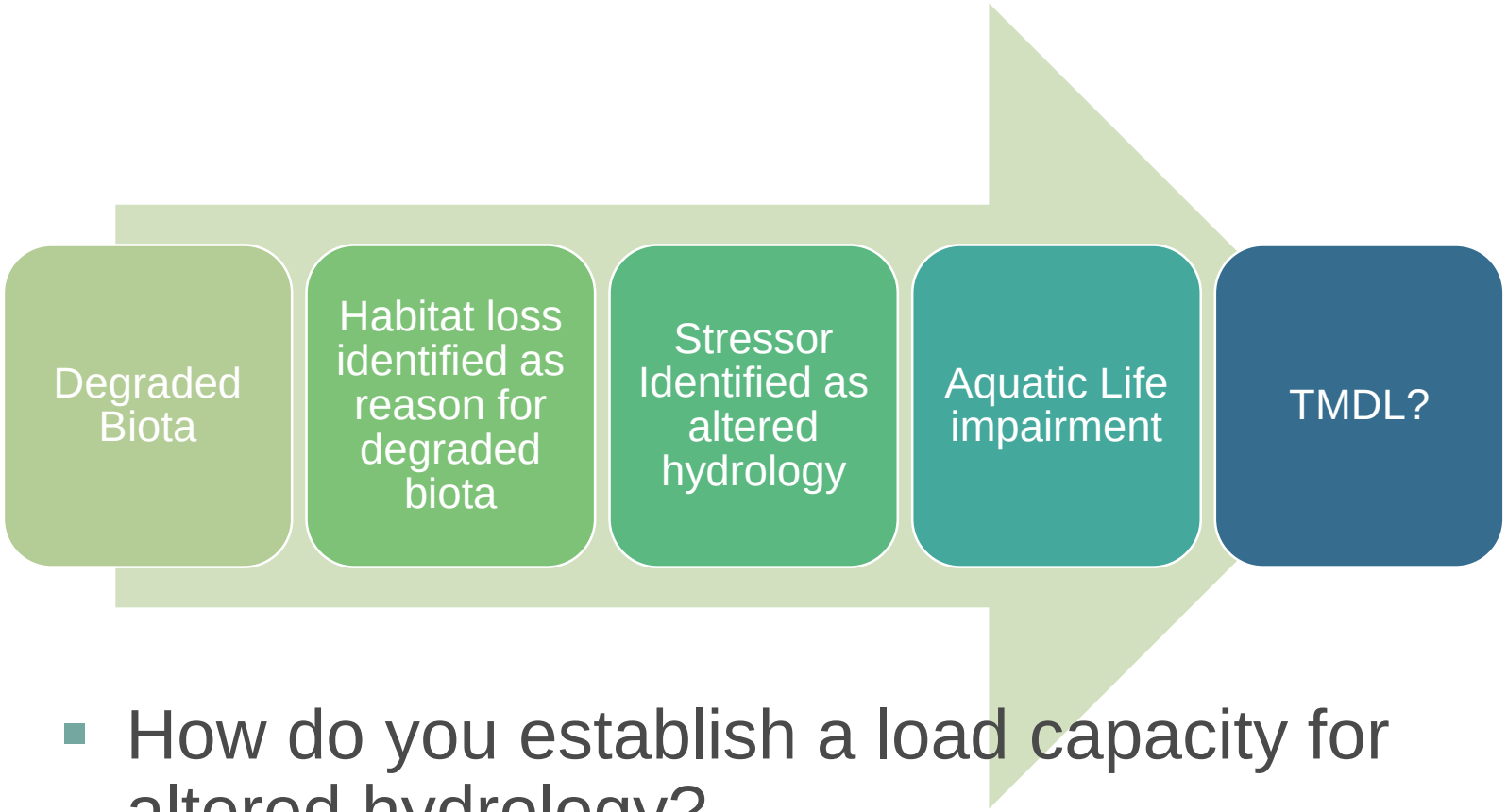


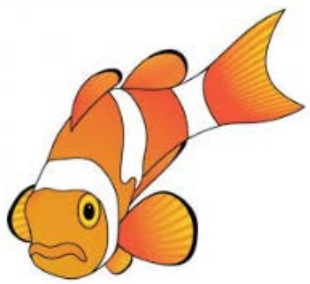
Figure 1. Flow duration curve for the Sand Hill River at Climax, Minnesota. The solid black line shows an increase in daily mean discharge for the 1980 – 2010 period, compared to the early 1945 – 1975 period.

RELEVANCE TO CLEAN WATER ACT



- How do you establish a load capacity for altered hydrology?
- How do you develop a solution?
- Some goal / target is needed.

NEED FOR SCIENCE BASED FRAMEWORK



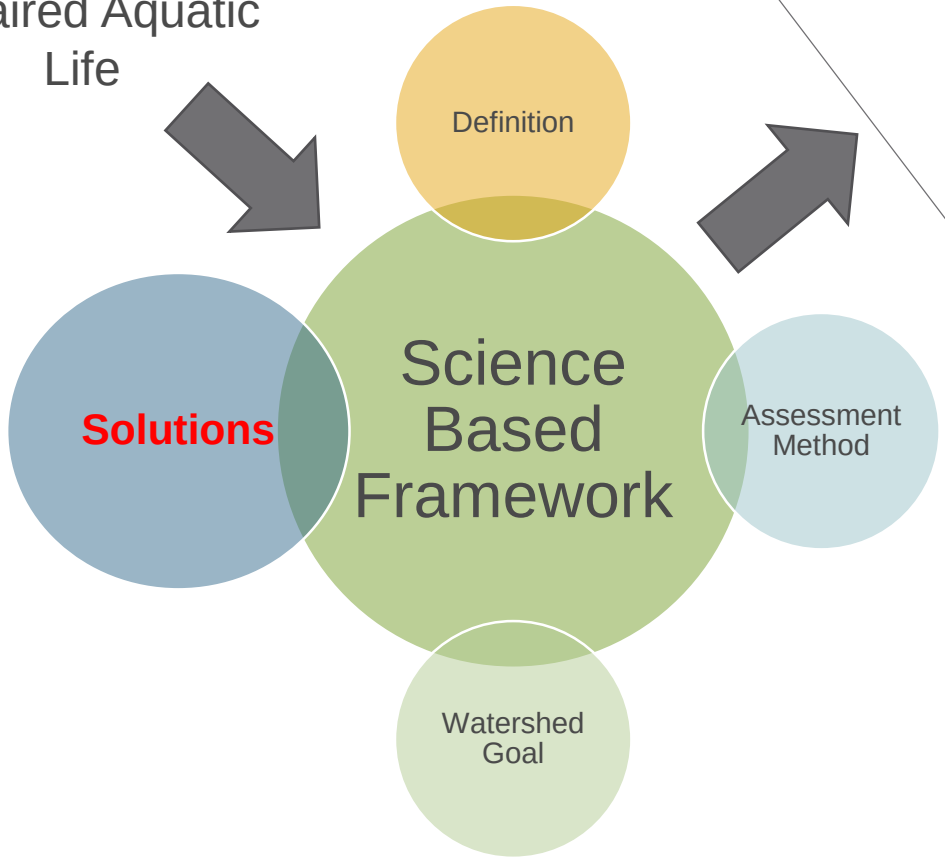
Impaired Aquatic Life

Regulatory

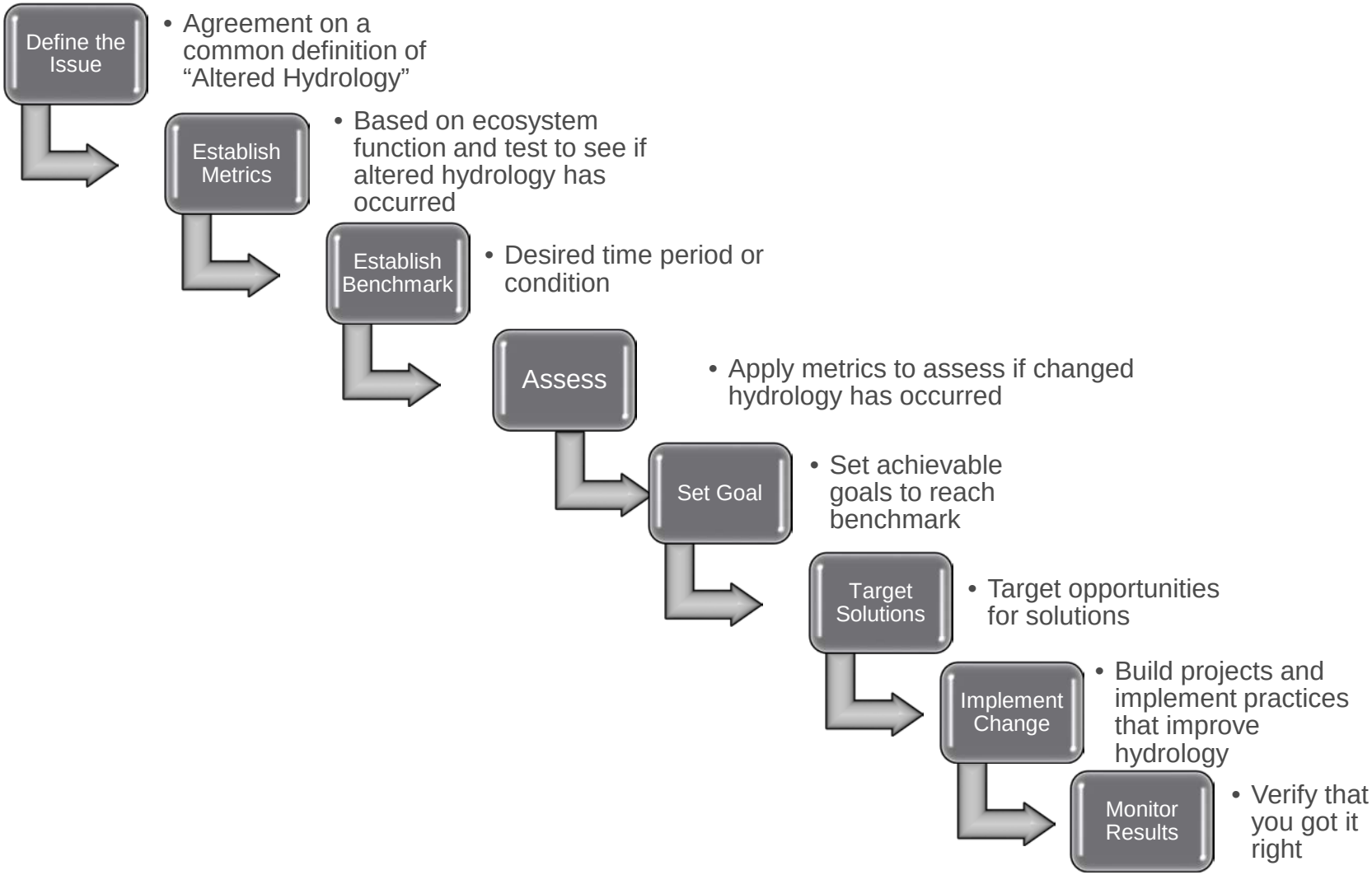
- Suspended solids standard
- Hydrologic standard?
- Land use controls?
- Ordinance?

Voluntary

Watershed based goal



A FRAMEWORK FOR PROGRESS



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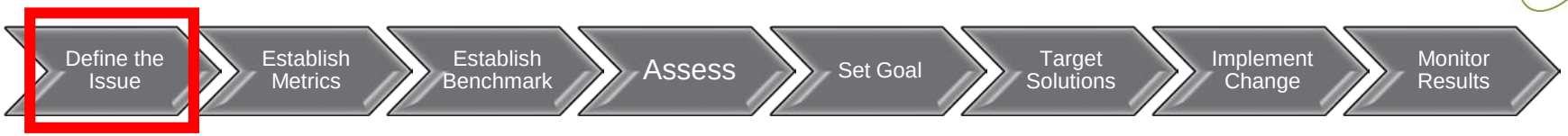
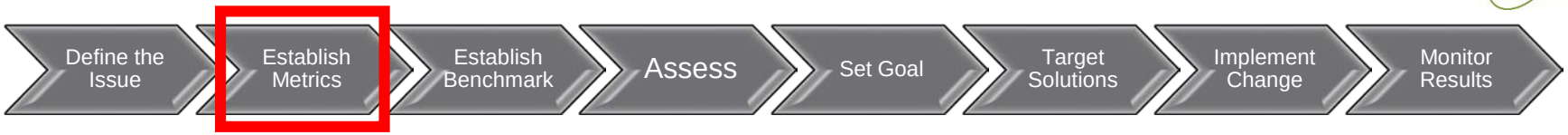


Establish a common/agreed definition:

- *Altered hydrology is defined as a discernable change in specific metrics derived from stream discharge, occurring through an entire annual hydrologic cycle compared to a benchmark condition, which exceed the measurement error.*

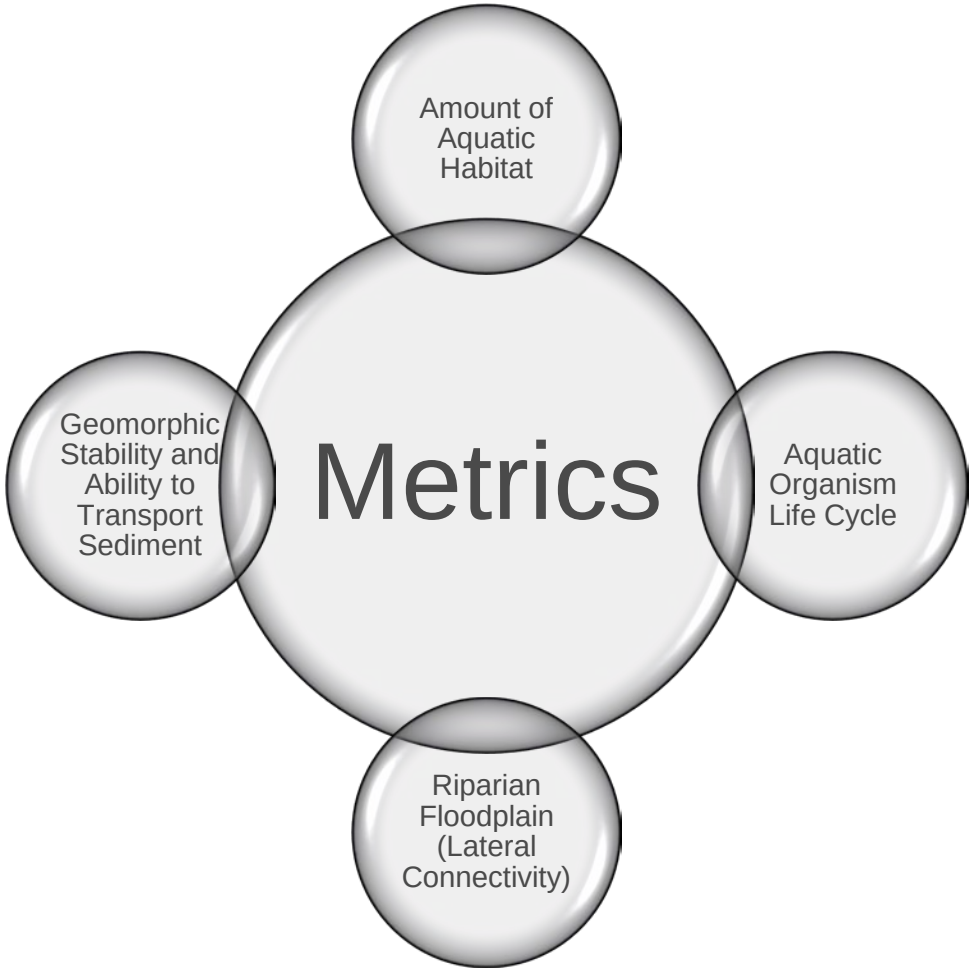
A FRAMEWORK FOR PROGRESS



Habitat

Sediment & Nutrients

Geomorphology



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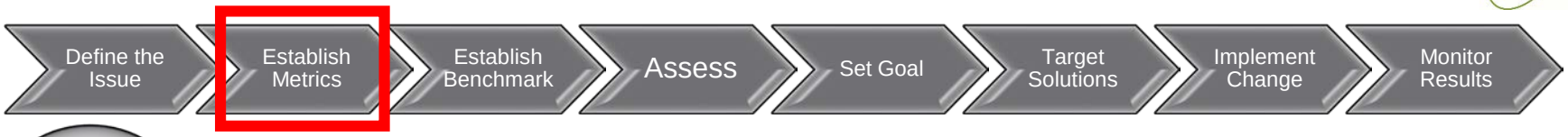


Amount of Aquatic Habitat

Low flows/Baseflows

- 10-yr, 30-day low flow; 10-yr, 7-day low flow; median November flow

Aquatic Organism Life Cycle

Shape and Timing

- Monthly flows; Julian day of maximum & minimum flows

Riparian Floodplain

Extreme flows and volumes

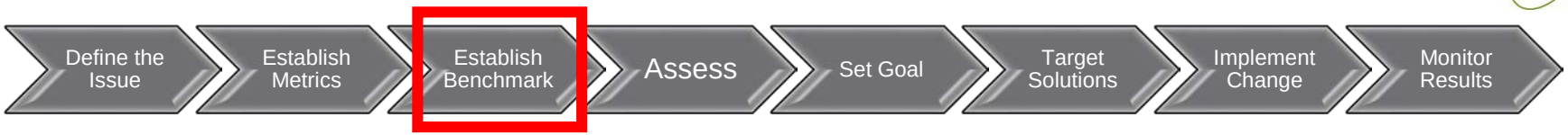
- Rate and Volume above 10-yr, 50-yr, 100-yr peak flow rates

Geomorphic Stability and Ability to Transport Sediment

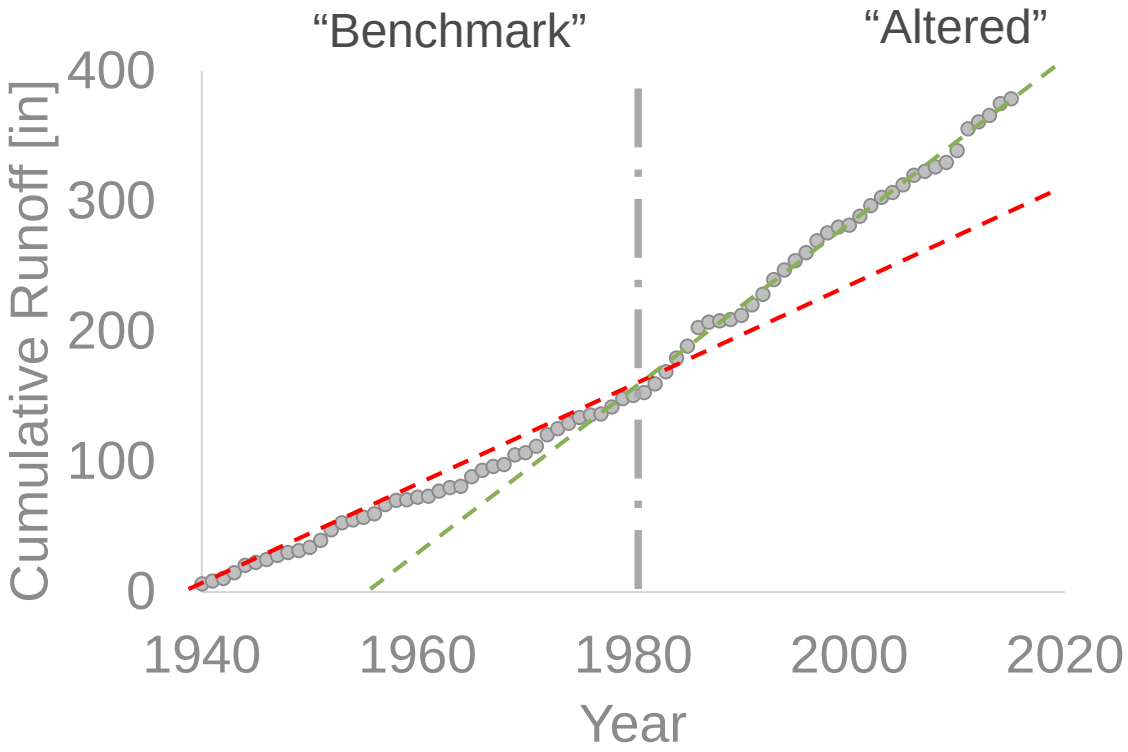
Channel forming flows and volumes

- Rate, Volume above, Duration above 1.5-yr, 2-yr peak flow rates
  Changes in flow duration curve

A FRAMEWORK FOR PROGRESS

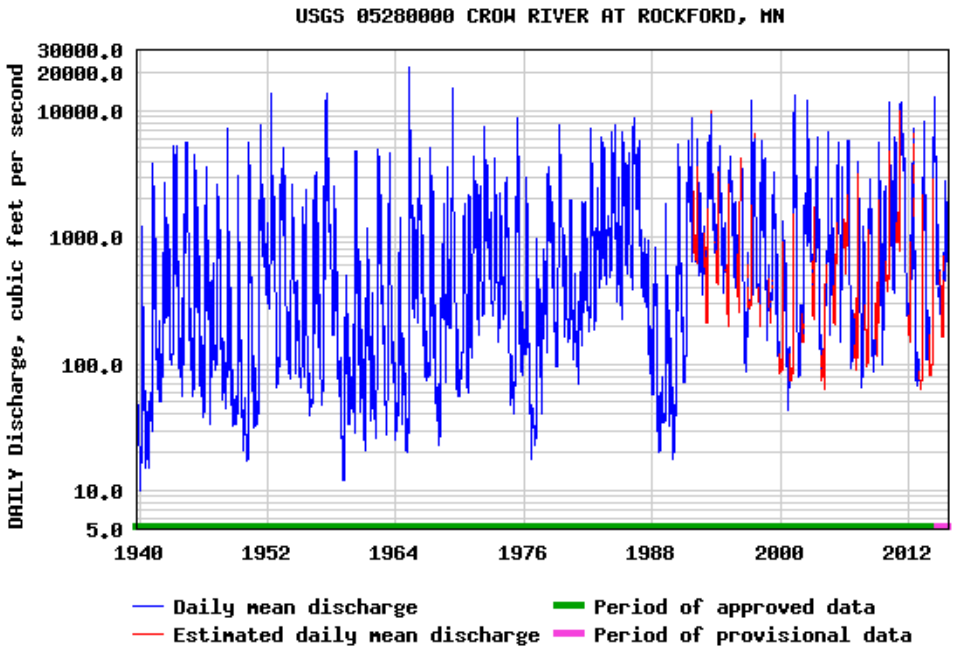


- *Benchmark = desired hydrologic condition*
- *Method – establish periods that represent "benchmark" and "altered" conditions*



GEOMORPHIC STABILITY ASSESSMENT

Define the Issue → Establish Metrics → Establish Benchmark → **Assess** → Set Goal → Target Solutions → Implement Change → Monitor Results



- Uses long-term continuous daily flows.
- Minimum 20 years of data in each period; 30+ years in preferred.
- USGS# 05280000-Crow River at Rockford, MN
- Benchmark Period: 1940 – 1975
- Altered Period: 1980 - 2015

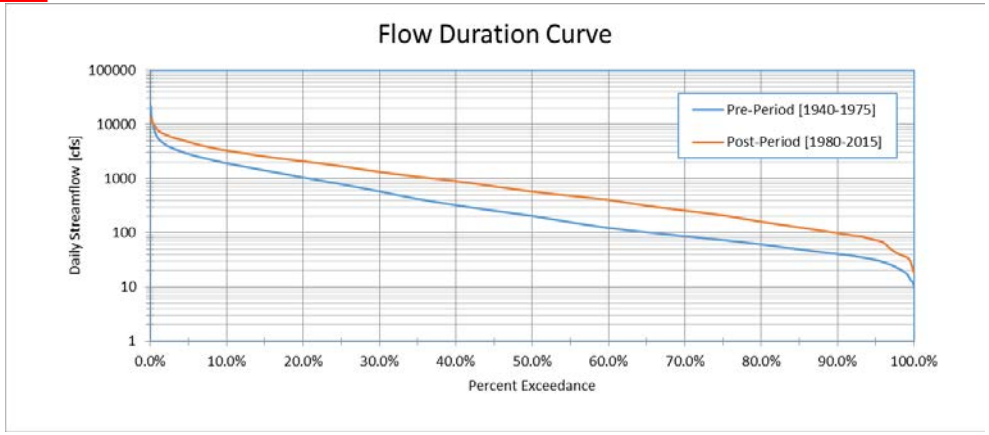
GEOMORPHIC STABILITY ASSESSMENT

Define the Issue → Establish Metrics → Establish Benchmark → **Assess** → Set Goal → Target Solutions → Implement Change → Monitor Results

Table 10. Geomorphic stability and capacity to transport sediment metrics for the Crow River at Rockford, MN

Flow Metric	Historic Period [1940-1975]	Modern Period [1980-2015]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	2,937	4,435	51.0%	+
Number of years with Discharge (Q) > Q_{pre} (1.5)	24	29	20.8%	+
Average number of days per year Q > Q_{pre}(1.5)	26	54	108.0%	+
Average annual cumulative volume > Q_{pre} (1.5) [ac-ft]	102,304	205,439	100.8%	+
2-Year Peak Discharge, Q(2) [cfs]	4,109	5,942	44.6%	+
Number of years with Discharge (Q) > Q_{pre} (2)	14	27	92.9%	+
Average number of days per year Q > Q_{pre} (2)	14	31	125.2%	+
Average annual cumulative volume > Q_{pre} (2) [ac-ft]	73,250	121,132	65.4%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period



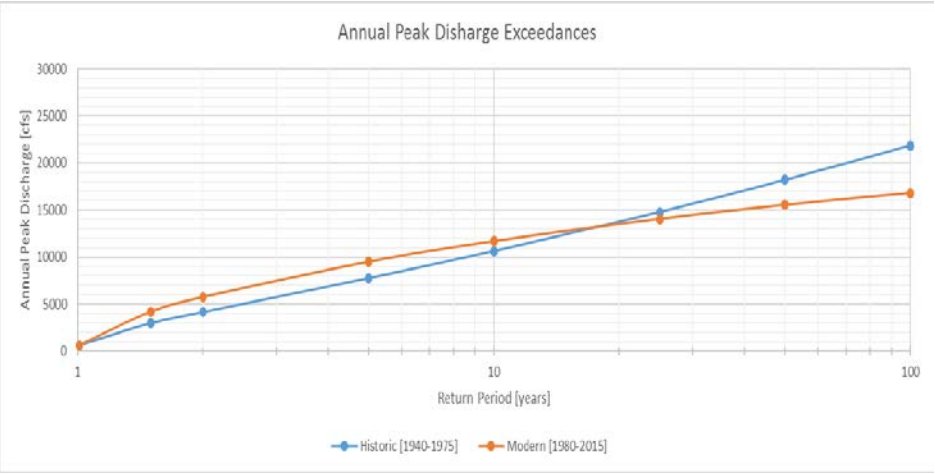


Table 9. Select summary of the flow duration curves for the Crow River at Rockford, MN

Percent Exceedance	Historic Period [1940-1975]	Modern Period [1980-2015]	% Diff.	Altered Hydrology
0.1%	13,785	11,700	-15.1%	-
1.0%	5,500	7,580	37.8%	+
10.0%	1,920	3,260	69.8%	+
25.0%	793	1,670	110.6%	+
50.0%	207	569	174.9%	+
75.0%	87	253	190.8%	+
90.0%	41	97	136.6%	+
99.0%	18	35	94.4%	+
99.9%	12	20	66.7%	+

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o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
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A FRAMEWORK FOR PROGRESS

Define the Issue → Establish Metrics → Establish Benchmark → **Assess** → Set Goal → Target Solutions → Implement Change → Monitor Results

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	118.40%	+	Yes - increase
	10-year, Annual Minimum 7-day Mean Daily Discharge	121.60%	+	
	Median November (Winter Base) Flow	329.80%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	77.2% - 207.8%	+	Maybe - increase
	Distribution of Monthly Runoff Volumes	-30.7% - 71.5%	O	
	Timing of Annual Peak Discharge	10.70%	+	
	Timing of Annual Minimum Discharge	4.50%	O	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	7.70%	O	Yes - decrease
	50-year Peak Discharge Rate	-18.4%	-	
	100-year Peak Discharge Rate	-27.1%	-	
	Average Cumulative Volume above the Historic 10-year Peak Discharge	-52.3%	-	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	-100%	-	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	-100%	-	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	51.0%	+	Yes - increase
	2-year Peak Discharge Rate	44.6%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	100.8%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	65.4%	+	
	Duration above the Historic 1.5-year Peak Discharge	108.0%	+	
	Duration above the Historic 2-year Peak Discharge	125.2%	+	
	Flow Duration Curve	-15.1% - 190.8%	+	

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A FRAMEWORK FOR PROGRESS

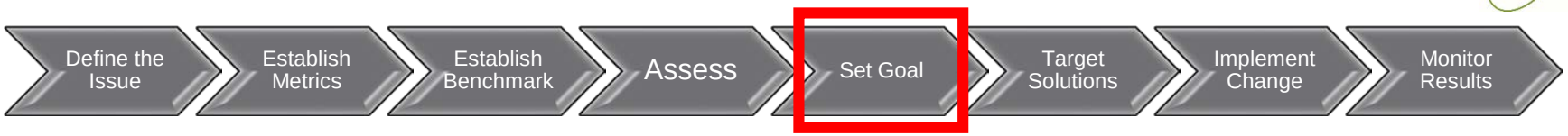
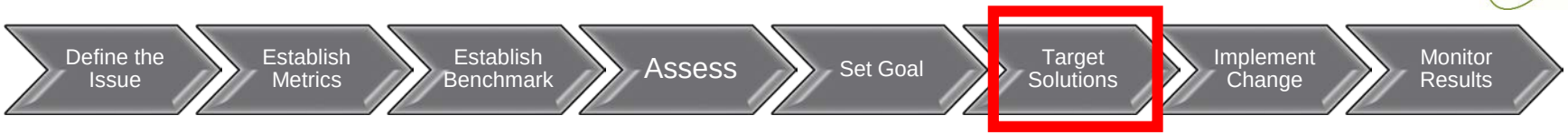


Table 14. Estimated storage goal for the Crow watershed upstream of Rockford, MN using method 3.

Return Period (Years)	Change in flow (Q_m-Q_h) (cfs)	Probability of Occurrence	Change in flow* Probability (cfs)	Probability weighted flow (AF/Day)	Change in the number of days above flow (days)	Storage Volume (AF)
1.5	1,498	0.67	1,004	1,991	28	55,757
2	1,834	0.5	917	1,819	17	30,928
5	1,722	0.2	344	683	0.2	137
10	819	0.1	82	162	0	0
					Total Volume Goal	**96,469 AF 0.69 inches**

A FRAMEWORK FOR PROGRESS



Water Retention for Water Quality Benefits: Targeting Practices that Improve Environmental Flows

Jun Yang, Drew Kessler, Mark Deutschman, and
Tim Erickson, Houston Engineering, Inc.

Wednesday, October 18th
3:00 Session-Track A

WHAT SOLUTIONS LOOK LIKE?

Management Practices

Soil Health & Productivity

Best Practices

Standards Operating Procedures / Processes

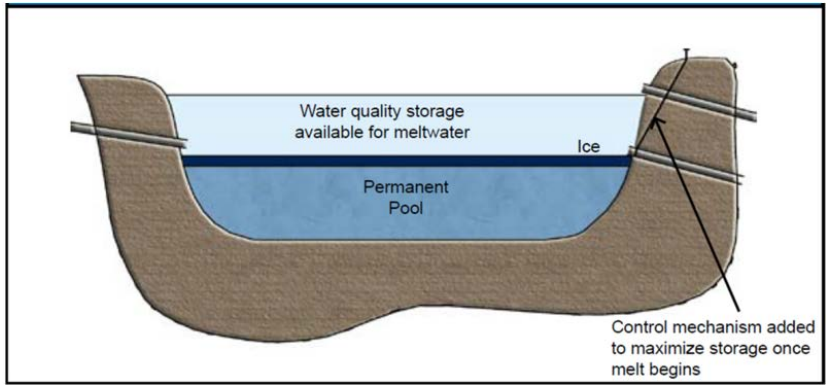
Structural Practices

Monitor

A FRAMEWORK FOR PROGRESS

Define the Issue → Establish Metrics → Establish Benchmark → Assess → Set Goal → Target Solutions → Implement Change → Monitor Results

- *Most important steps!!!!*



NEXT STEPS

- Using framework to establish storage goal in 1w1p's-in North Fork Crow 1w1p
- Using terrain analysis products to identify storage opportunities
- Evaluating methods to downscale approach to 12-digit HUC
- Developing approaches for assessing multiple benefits related to the metrics
- Need continued refinement of framework

THE END OF THE STORY

- Critical to have a science based framework or we all lack credibility
- Framework should be applicable statewide
- Focus on solutions rather than cause
- Need means to set goal
- Realize success won’t come from structural practices alone
- Be adaptable

THANK YOU!

Questions?

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Mark Deutschman Email: mdeutschman@houstoneng.com

Drew Kessler Email: dkessler@houstoneng.com

DISCLAIMER

No Assumption of Causality

Although it is important to water resource management to understand the mechanics behind the changes in hydrology, the focus of this methodology is developing a definition for altered hydrology, a method for assessing whether it has occurred within a watersheds, and establishing goals for addressing altered hydrology.

The Minnesota Public Drainage Manual—A Guide to Administering Minnesota Statutes, Chapter 103E Publically Administered Privately Owned Drainage Systems

Minnesota Water Resources Conference

Track A~10:00-11:30 AM

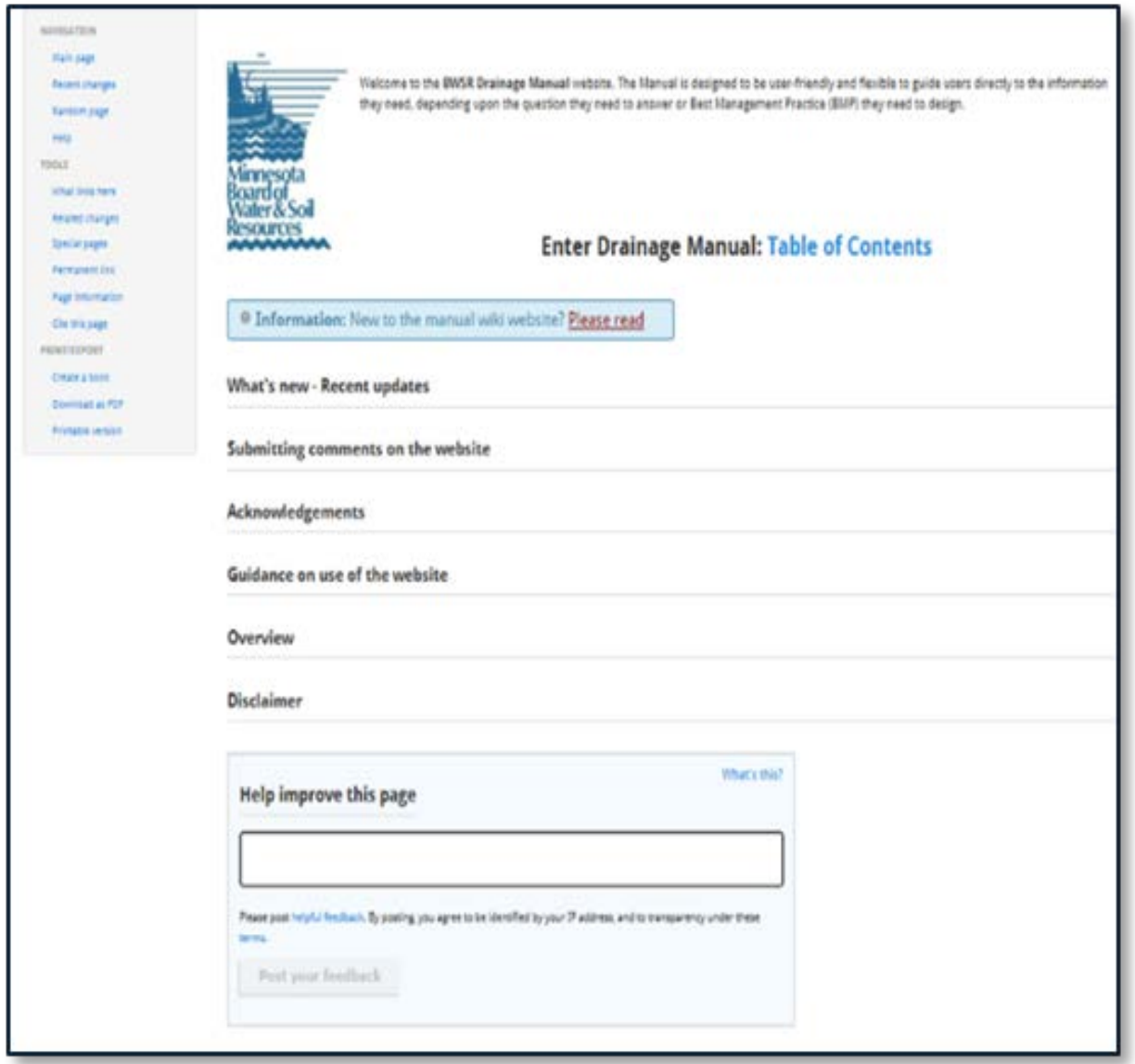
Saint Paul RiverCentre, St Paul, MN

October 18, 2017

Tim Gillette (BWSR), Conservation Drainage Engineer

Minnesota Public Drainage Manual (MPDM)

Updated 2016
Published in Wiki
Funded by a FY 2014
CWF Appropriation ($235,000)



Original MPDM Objectives:

- Promote uniformity in the interpretation of Minnesota drainage law, without speculating as to what drainage law ought to say;
- Suggest procedures for consistent implementation state drainage law;
- Provide standardized forms for use in drainage proceedings.
- Inform about the interaction between drainage law and other state and federal laws;

Additional MPDM Update Objectives:

- Reflect changes in drainage law and pertinent case law since 1991
- Create a web-based, user-friendly and easily updatable version of the manual;
- Provide enhanced guidance related to multipurpose water management considerations and authorities in drainage law;
- Provide guidance in a new chapter regarding implementation of BMPs for drainage projects and systems. (New Chapter 5);

MPDM Chapters

- **CHAPTER 1: Introduction and Definitions**
- **CHAPTER 2: Administration and Legal Issues**
- **CHAPTER 3: Engineering and Environmental Review**
- **CHAPTER 4: Viewing/Appraising**
- **CHAPTER 5: Drainage System Best Management Practices**
- **CHAPTER 6: Supporting Information/ Appendices**

The Minnesota Public Drainage Manual

- Published in a wiki format - still accessible by chapter.
- New ways to navigate coming on line in October 2017.
- Print with your browser.

https://drainage.pca.state.mn.us/index.php?title=Main_Page

BWSR

???????? Questions

Tim Gillette – Conservation Drainage Engineer, Board of Water and Soil Resources
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BOARD OF WATER AND SOIL RESOURCES

Thank You!

Tim Gillette

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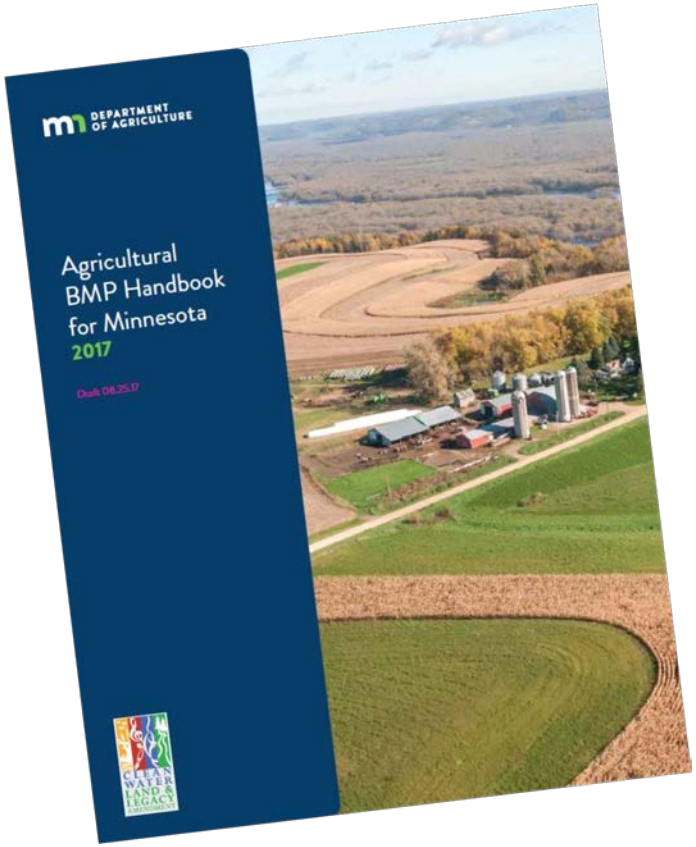
651-297-8287

Evolution of the Ag BMP Handbook

Water Resources Conference
October 18, 2017



Margaret Wagner
Clean Water Tech. Assistance Unit

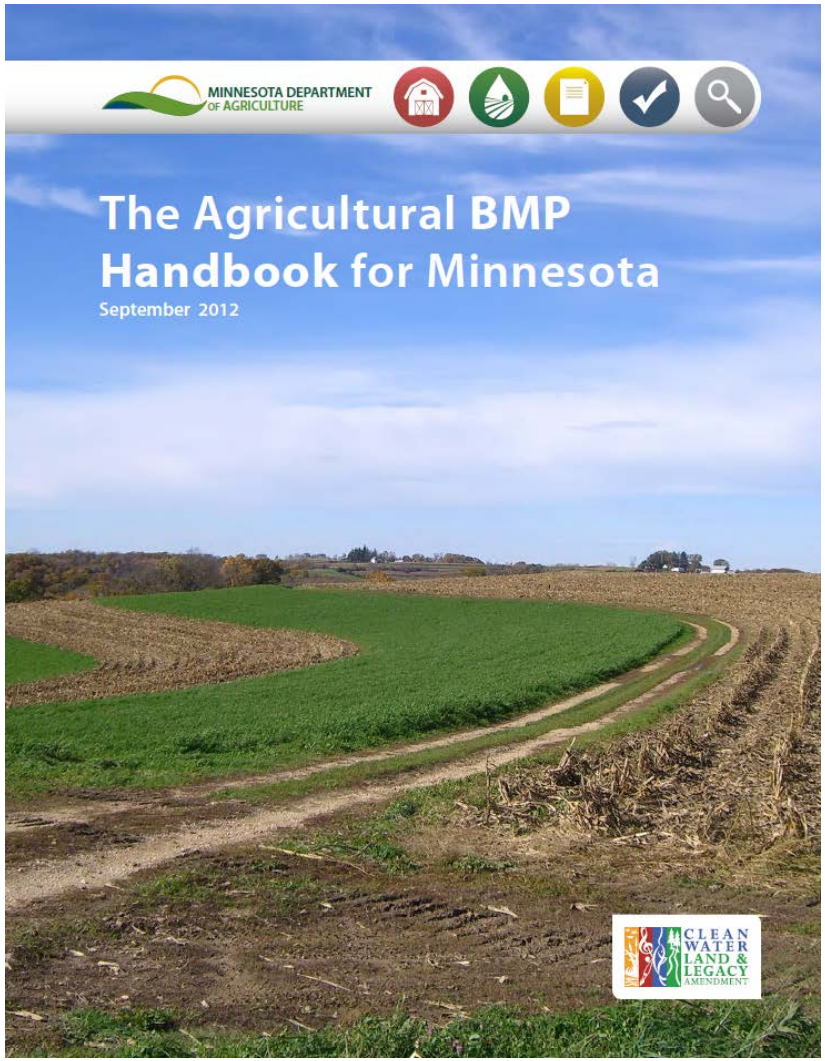
Christian Lenhart
Brad Gordon
Bioproducts & Biosystems Engineering

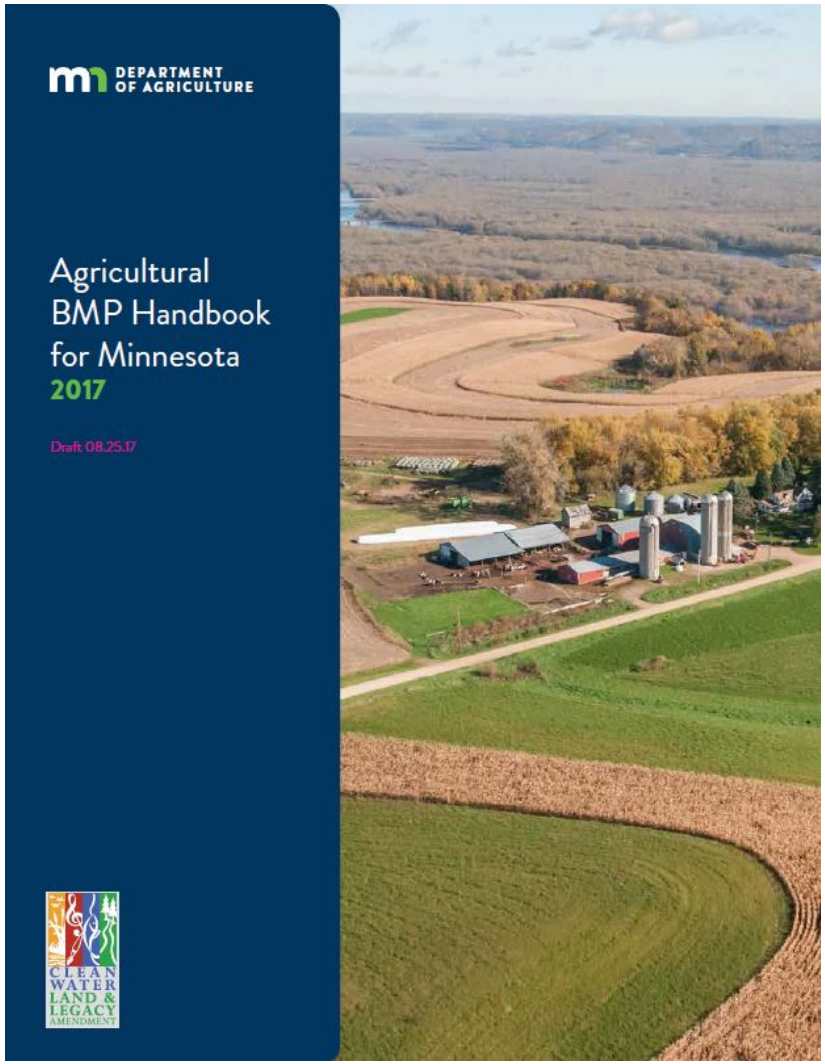
Walter Eshenaur
Leah Gifford

Outline

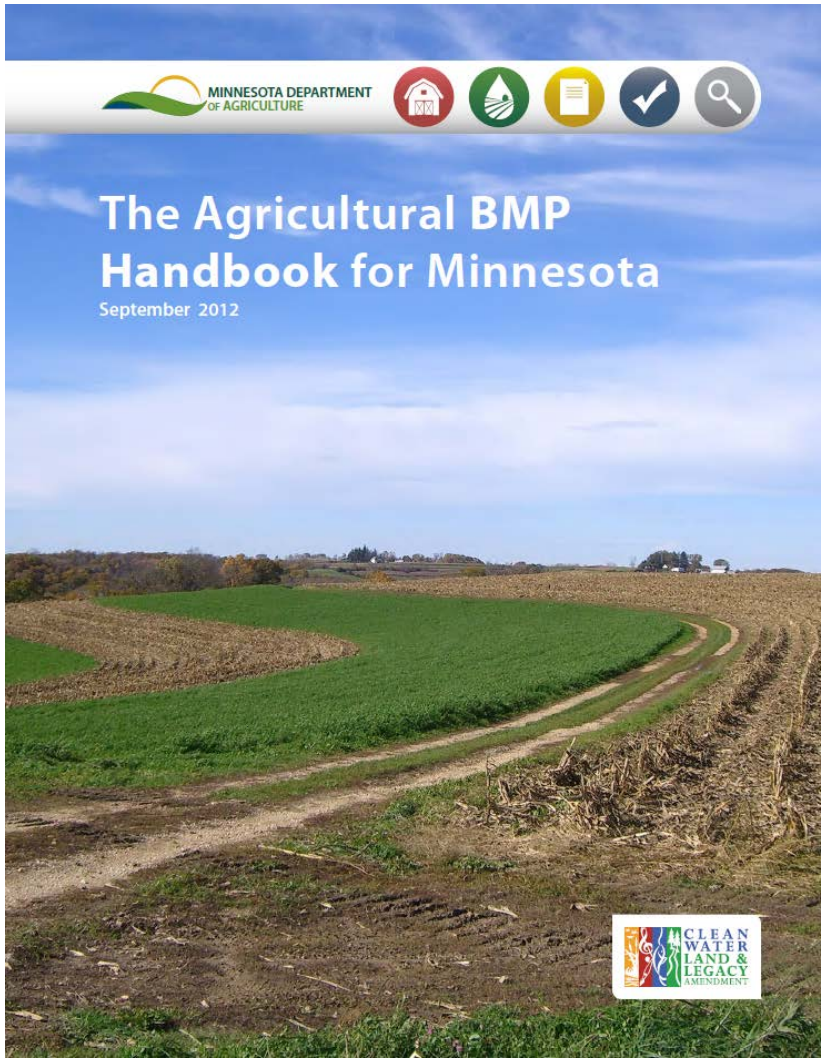
- History of the Ag BMP Handbook
- How has it been used
- Key features and updates
- Where is it available

Agricultural BMP Handbook





BMPS grouped by landscape position in Ag BMP Handbook



Timeline and Funding

- Original Ag BMP Handbook released in 2012
- Updated Handbook completed in November 2017
- Both supported through the Minnesota Department of Agriculture's Clean Water Fund Research Program

CLEAN WATER LAND & LEGACY AMENDMENT

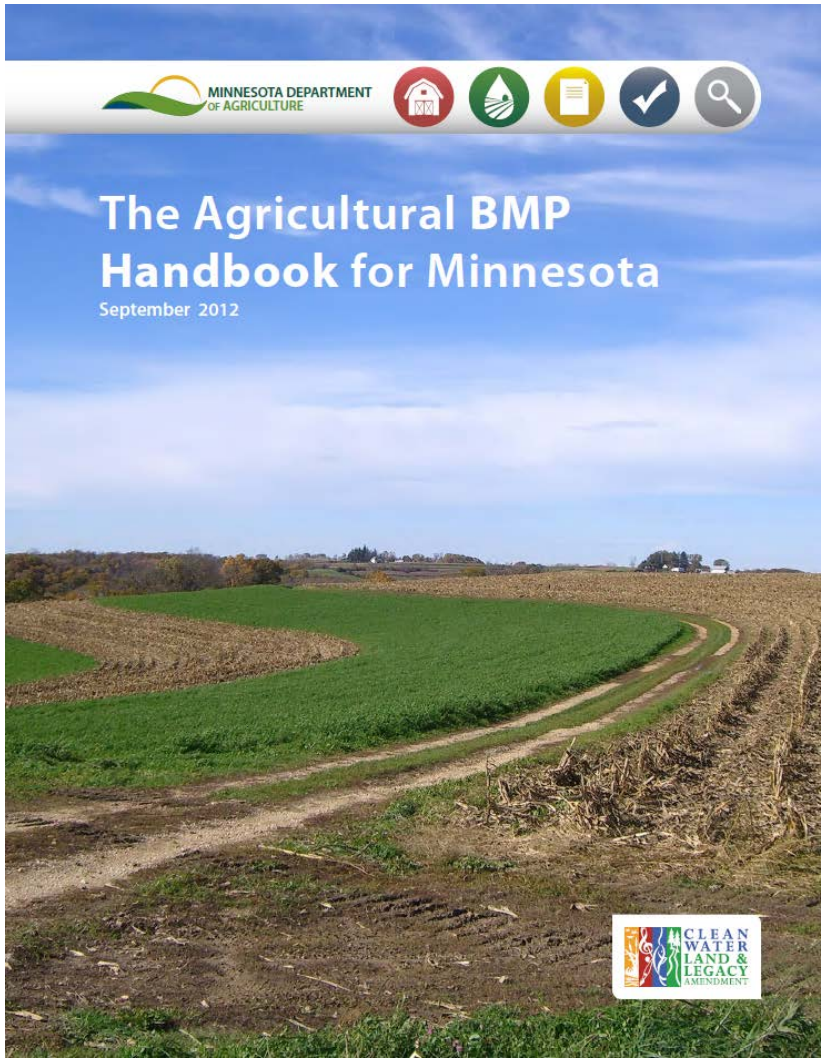
Intended Audience

- For landowners, agency staff, consultants
- Reading level - grade 12
- Focus on Minnesota, applies to upper Midwest
  - Some processes are similar across region
  - Others are very different, i.e. cover crops and drainage water management

How is it used?

- Used to support watershed planning, largest users are SWCD staff
- Pollutant load estimates used for TMDLs, WRAPS & computer modeling
  - PTMapp and alternative buffer tools
- State nutrient reduction strategies for N & P by the MPCA
- *Agricultural Conservation Planning Framework* M. Tomer, Iowa State and other GIS tools
- Cited in peer reviewed research articles

Handbook as a Critical Resource



"A handy resource when talking BMPs with landowners"

- SWCD staff

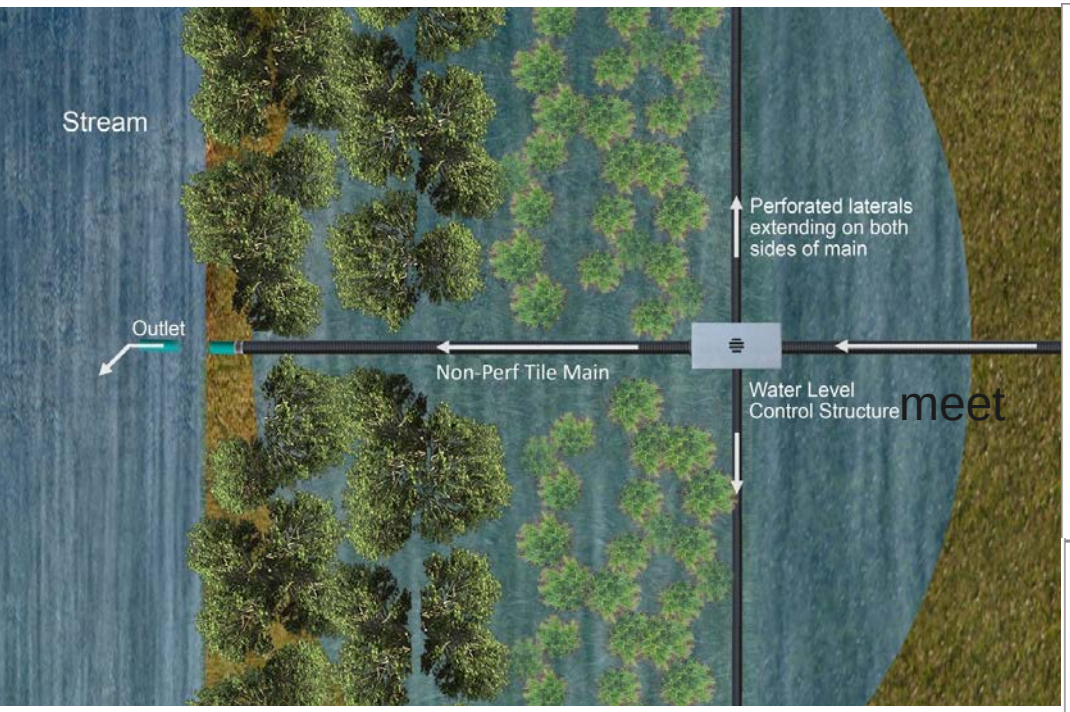
"The most comprehensive Ag BMP reference handbook available"

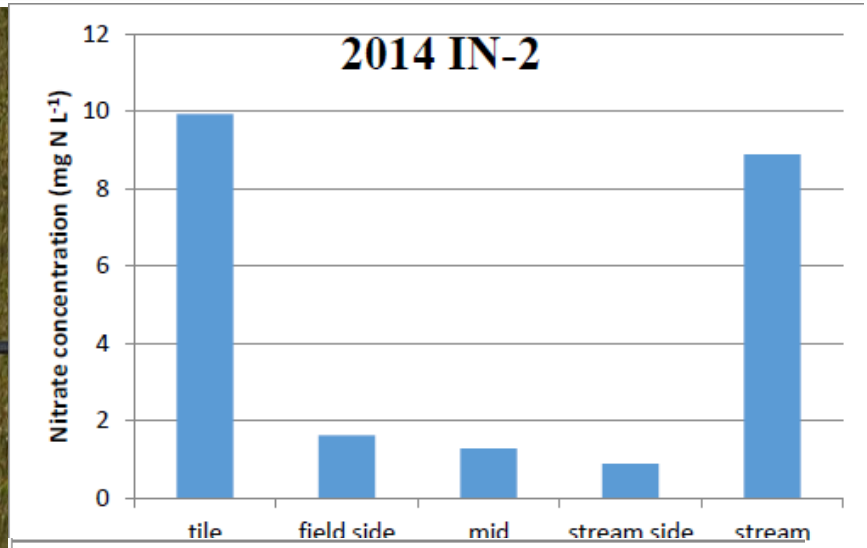
- Ag Professional

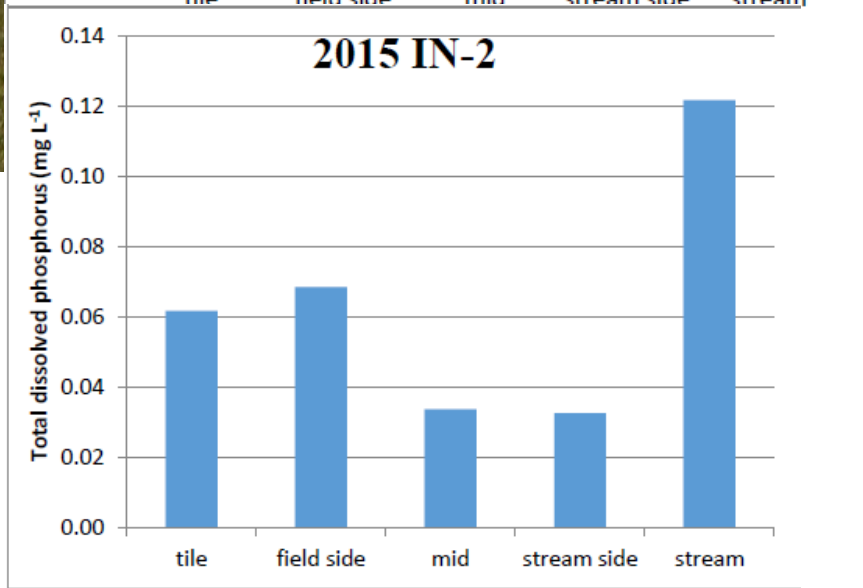
Updated Handbook- NEW!

- Interactive PDF
- New project website
- Updated references
- Expanded to include additional conservation practices
- Better define the variability of BMP effectiveness by season, geologic setting, soil characteristic, and rainfall regime
- Includes management and maintenance requirements
- More detailed costs and economic considerations

New: Saturated buffers







Utt, Jaynes and Albertsen 2015. Demonstrate and Evaluate Saturated Buffers at Field Scale to Reduce Nitrates and Phosphorus from Subsurface Field Drainage Systems.
Project report for USDA CIG

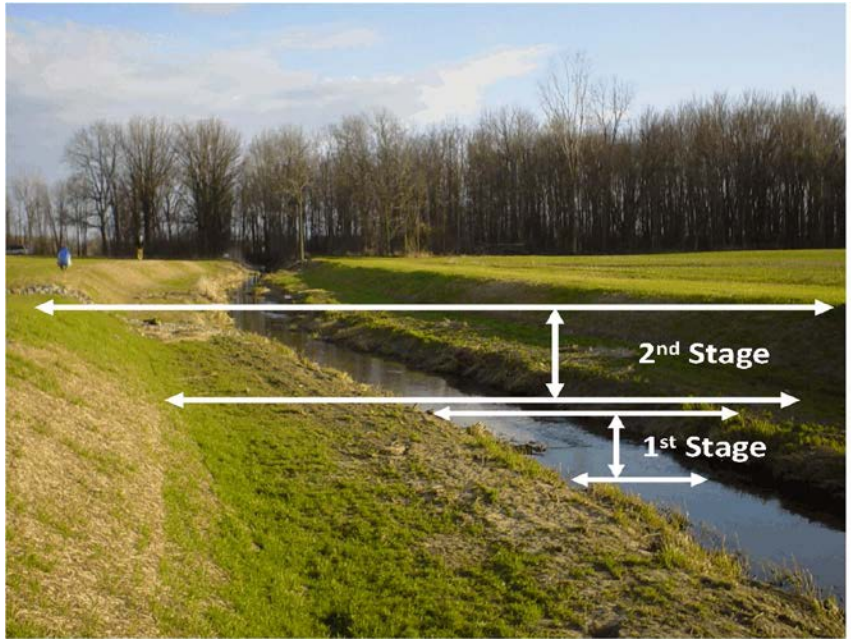
Bioreactors

- Numerous media assessed (biochar, woodchips, corncobs, other carbon sources)
- USDA-ARS (Feyereisen
- UMN- Magner, Krider, Wilson et al.
- Primarily for nitrate-nitrogen removal

Installation in Martin County

Two-stage ditches

- Many built in Ohio and Indiana
- Effective an Nitrogen removal but at a low level, ~ 10% of load
- Notre Dame research
- Mower County – U of M researchers Wilson , Magner, Krider



Treatment wetlands

- Constructed wetlands
- Primarily for nitrate-nitrogen removal
- New research: greater phosphorus removal via plant uptake

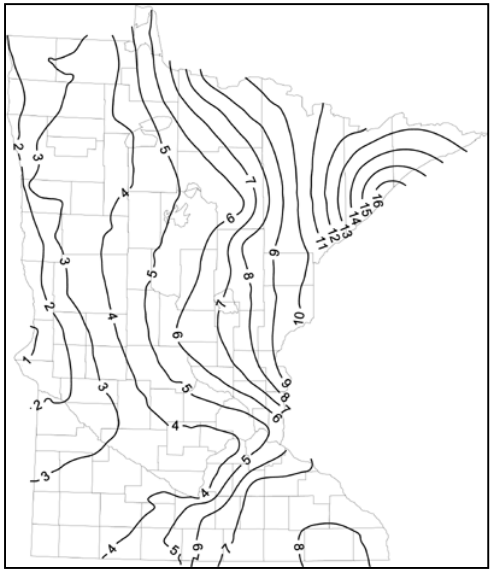
Lenhart, et al, 2016. Design and hydrologic performance of a tile drainage treatment wetland in Minnesota, USA, Water, 8: 549 - 568

Problem: BMP variability effectiveness

- Need to recognize BMP effectiveness is highly variable
- Problems: failure to meet water quality goals
- Some BMPs are well-studied; others not so much
  - Historical context: efforts to control sediment from the SCS etc.; relative success of TSS and TP measures
  - Recent focus on nitrate for hypoxia in coastal areas
  - Dissolved phosphorus we have the least knowledge about – Ohio example

Variability sources

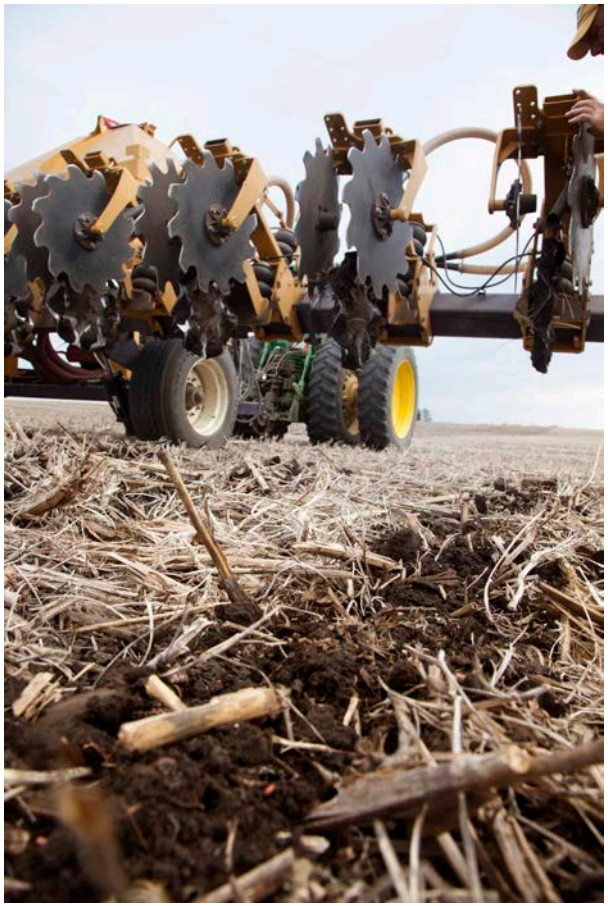
- **Design factors**
  - Reliability (guidelines, replicability)
- **Management and maintenance**
  - Lifespan, change in effectiveness over time?
- **Economic**
  - Implementation; management, easements or land purchase?
- **Social**
  - Adoption, fit with local systems, local landowner values
- **Climate & hydrology**
  - Inter-annual & seasonal
  - Tile drainage vs. Surface runoff



Annual streamflow in Minnesota

Most BMPs geared to sediment

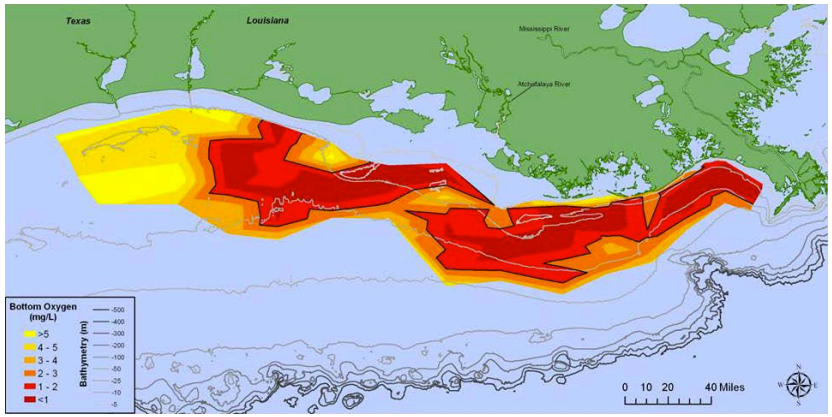
CONSERVATION COVER



CONTOUR STRIP-CROPPING

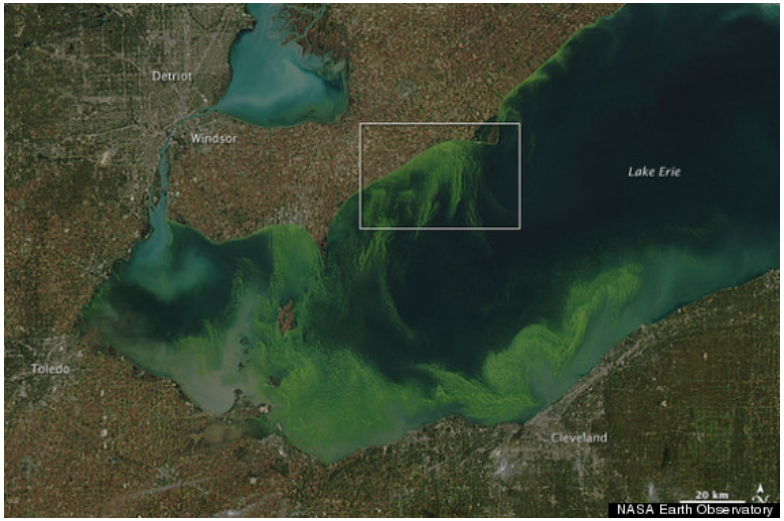
Problems with dissolved pollutants

Gulf Hypoxia: a nitrate issue



Source: NOAA

Lake Erie re-eutrophication: Dissolved phosphorus issue



Source: Huffington Post

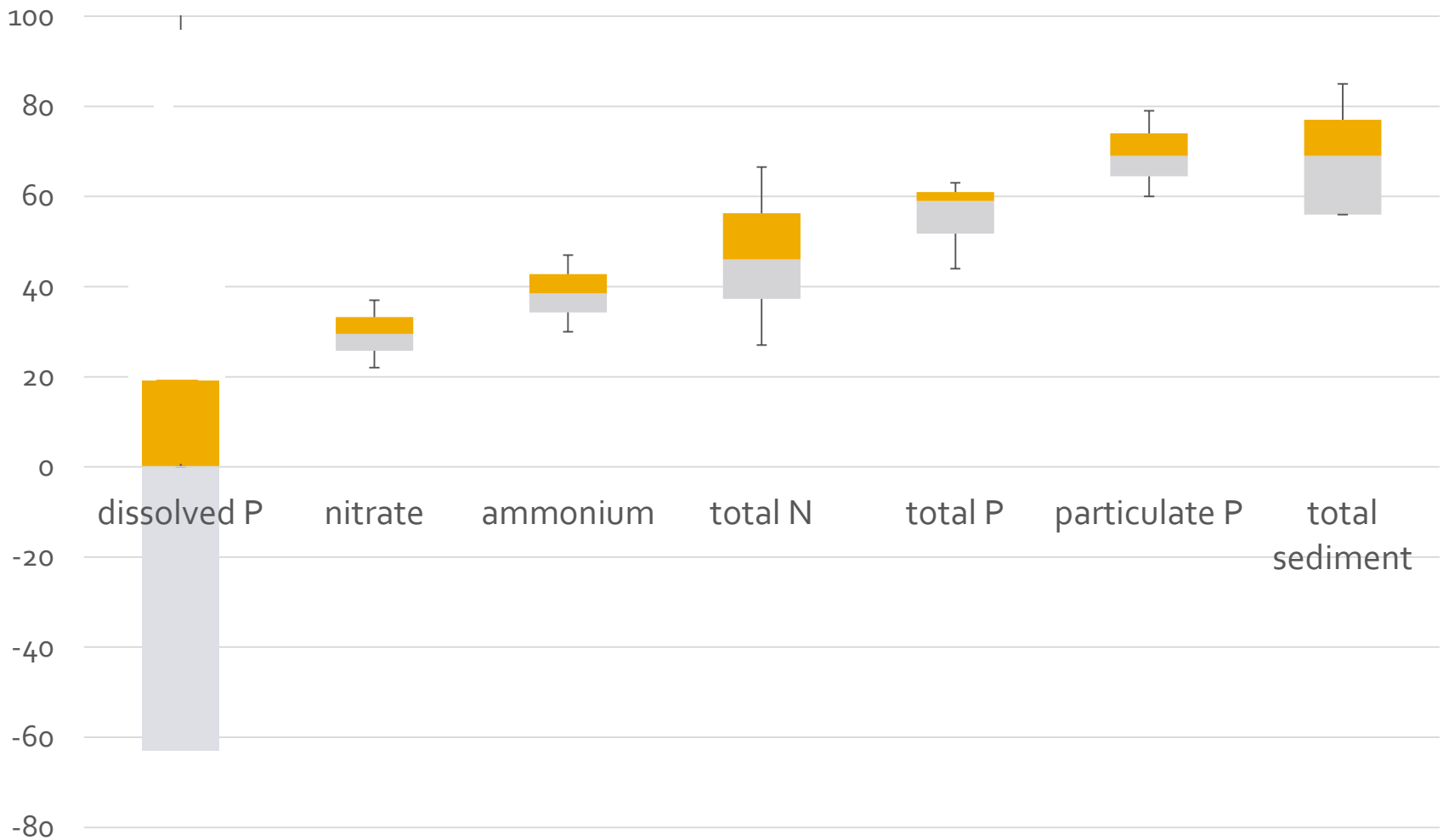
Meta-analysis of studies

- Values obtained from literature around the country (insufficient data from MN)
- Focus on field studies
- Group by flow path
- By landscape position Avoiding/controlling/trapping
- Pollutant type

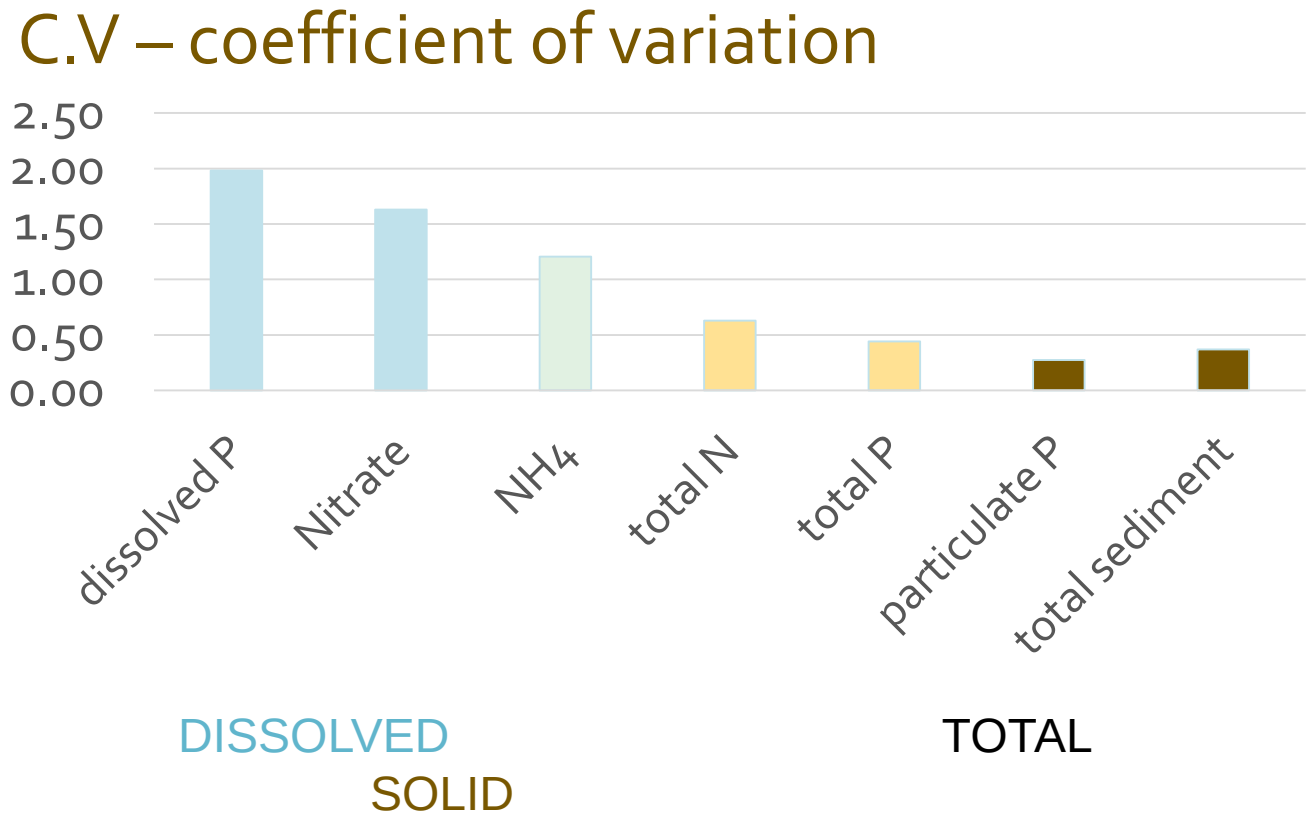
Results by pollutant form:

- Particulate
  - Process of removal are well–understood
  - Goal of the Soil Conservation Service and later NRCS programs since 1930s
- Dissolved
  - Dissolved P gets flushed (BMP may becomes a source, unlike sediment or nitrate)

Range of pollutant removal averages by type



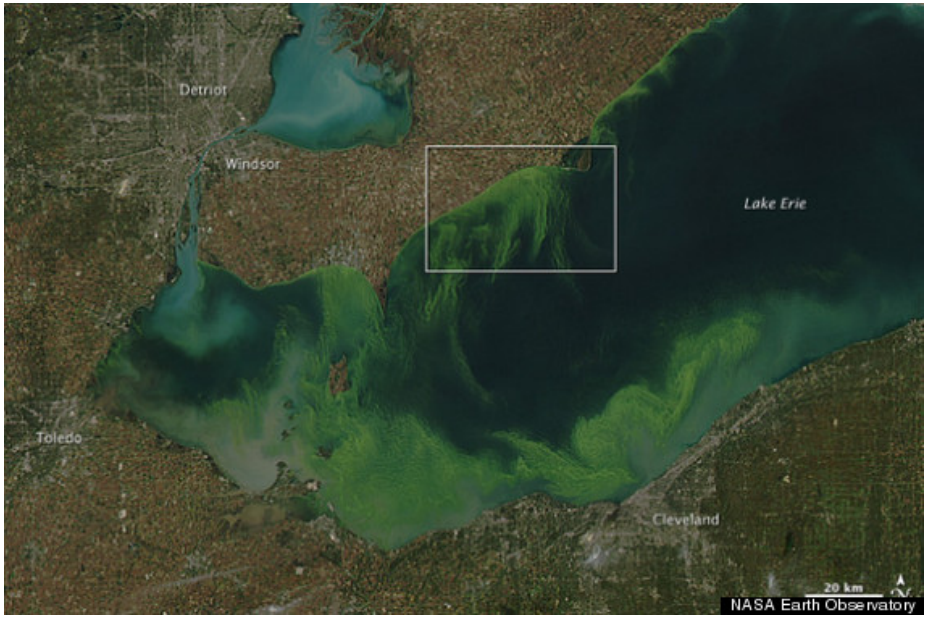
Variability of pollutant removal rates by type



Issues and research needs: dissolved P

- Legacy phosphorus
- Mobilization of phosphorus from topsoil; trapping BMPs
- Need for dissolved phosphorus retention and removal

- Lake Erie



Future research needs

- Combinations of BMPs or "treatment trains" lacking data
- Need for water storage and nutrient filtration
- Effectiveness of BMPs for less well understood pollutants
  - Pesticides
  - Emerging contaminants

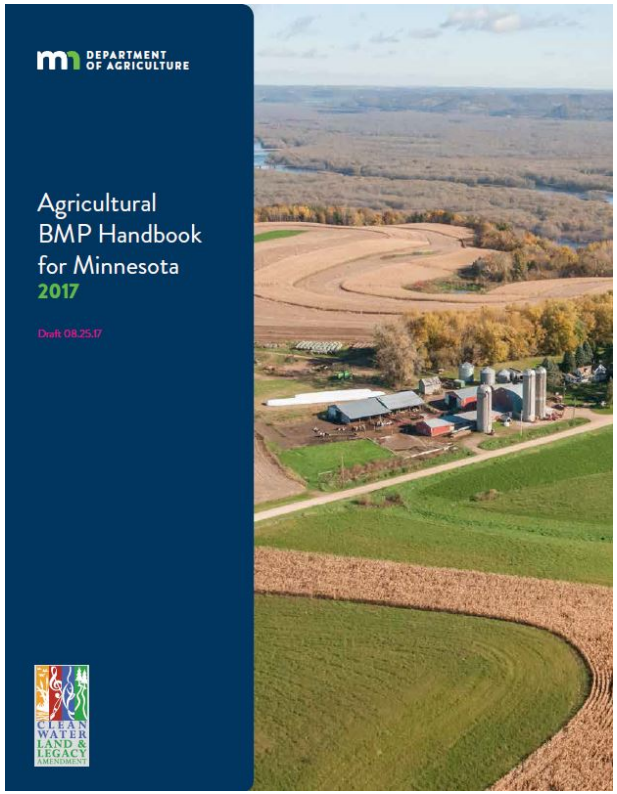
Where you will find it?

Minnesota Digital Water Research Library

www.mda.state.mn.us/mnwrl

BBE website: www.bbe.umn.edu

MDA website:
www.mda.state.mn.us/cleanwaterfund



Acknowledgements

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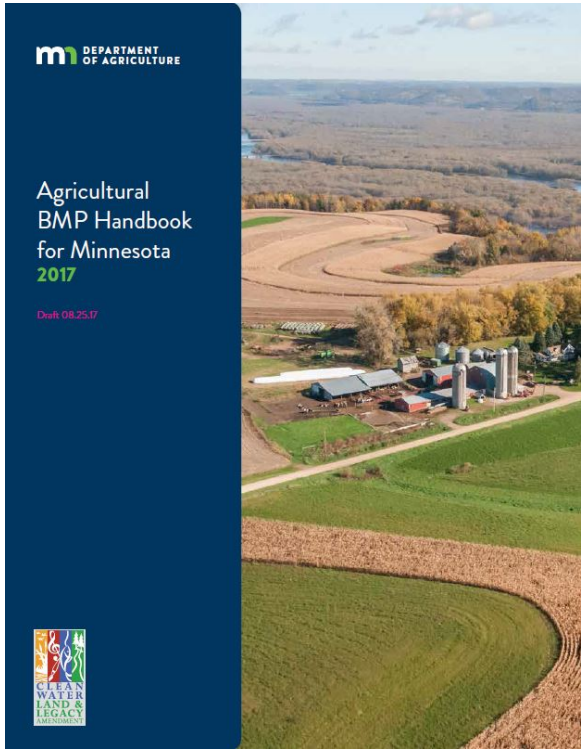
Thank you, questions?



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Improving the effectiveness of conservation in the Le Sueur River basin

Amy Hansen, Ph.D.

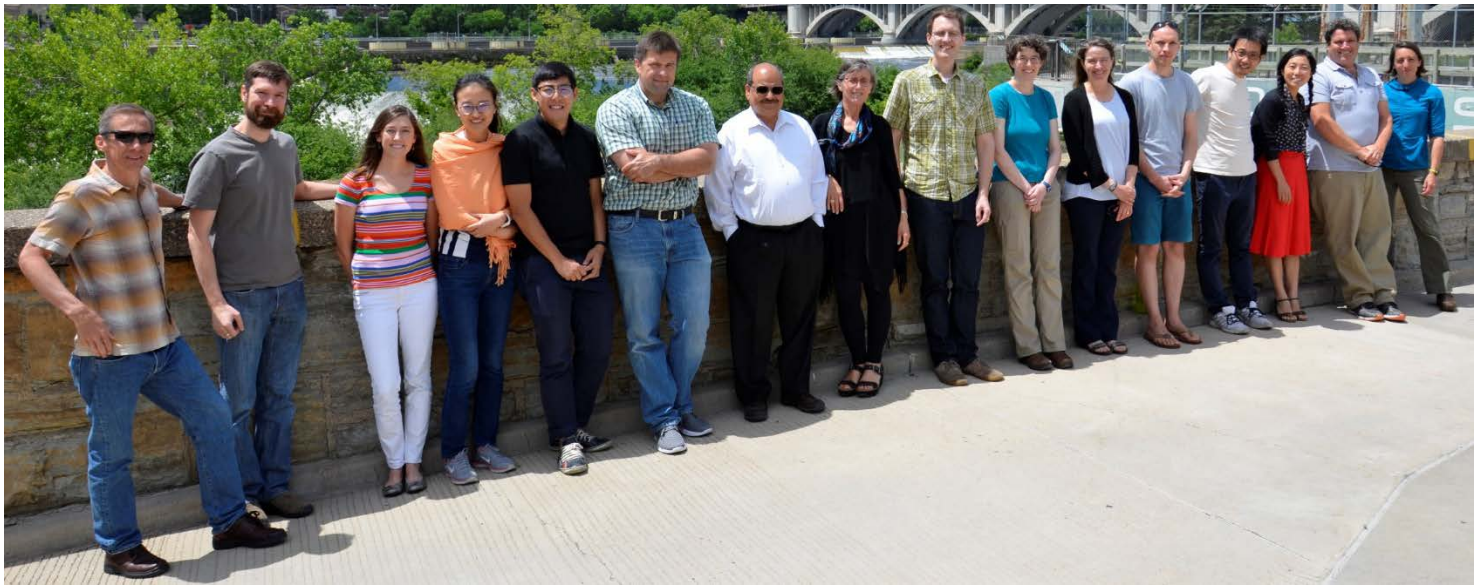
St. Anthony Falls Lab, University of Minnesota

Minnesota Water Resources Conference

October 18, 2017

REACH
Resilience under Accelerated Change

REACH Research Team:



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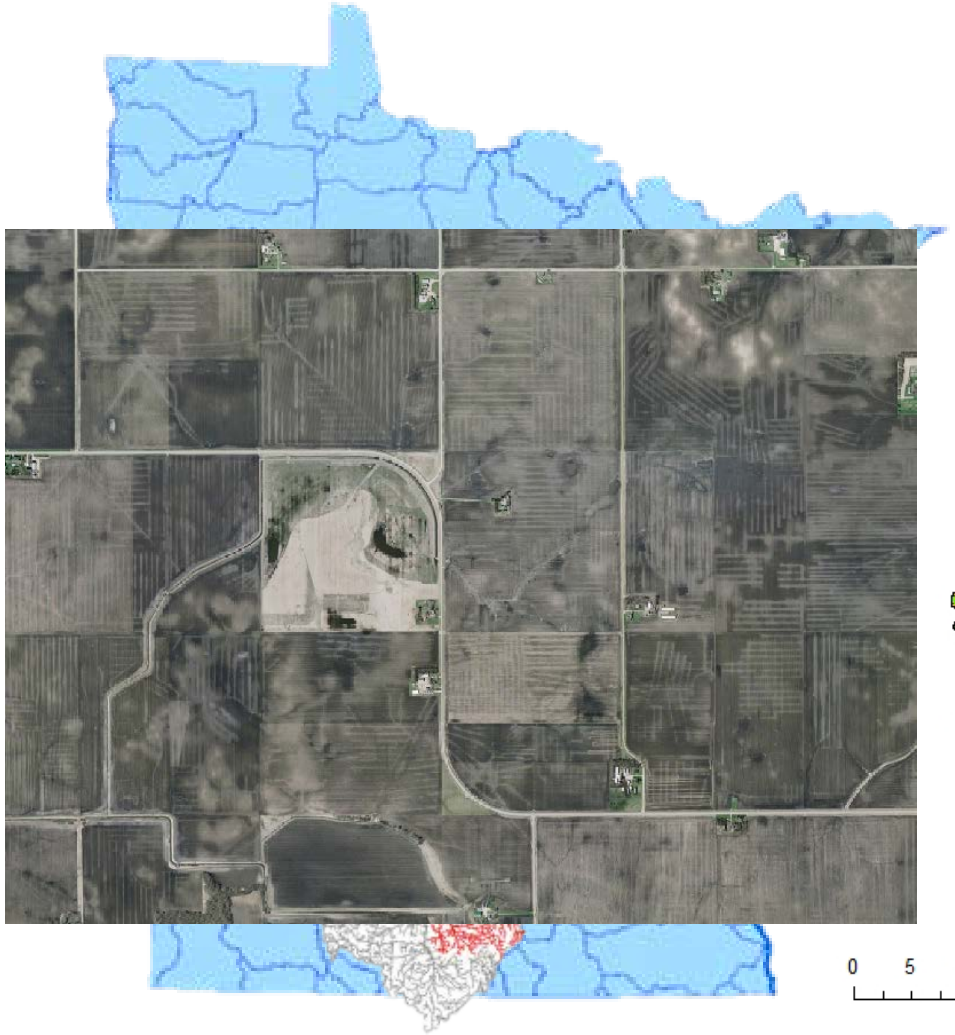
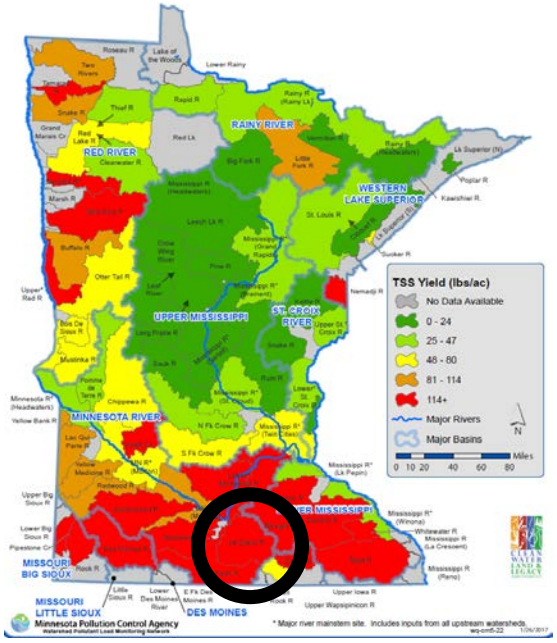
Le Sueur River Basin



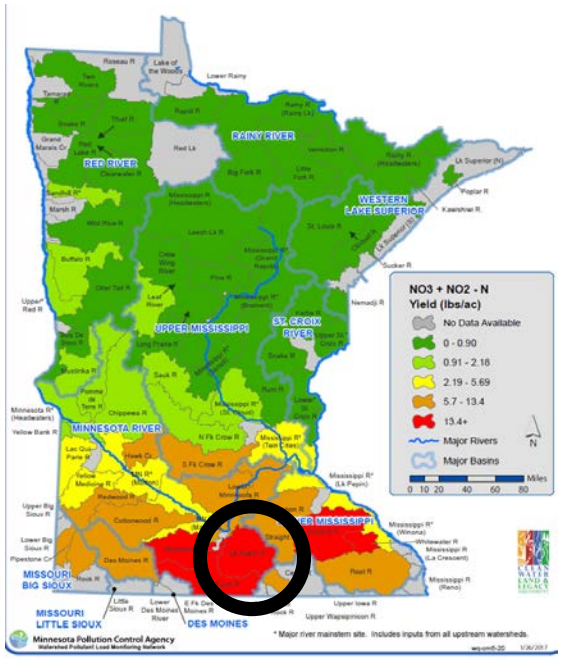
0 5 10 20 Kilometers

Le Sueur annual contaminant yields - compared to rest of MN

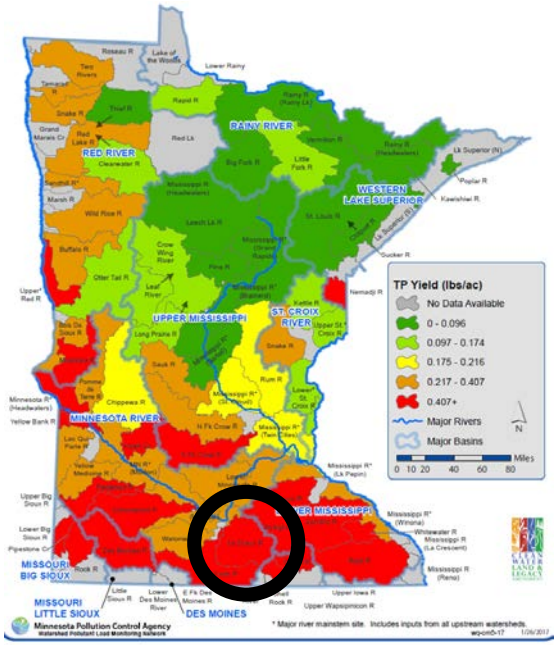
TSS



Nitrate

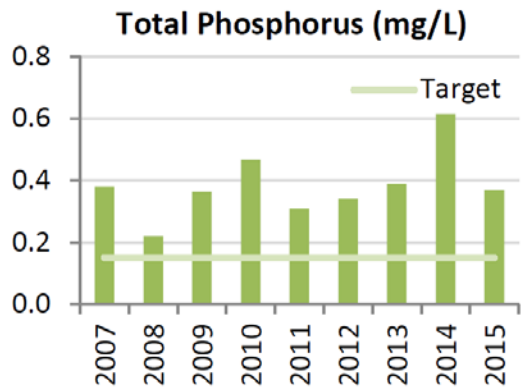


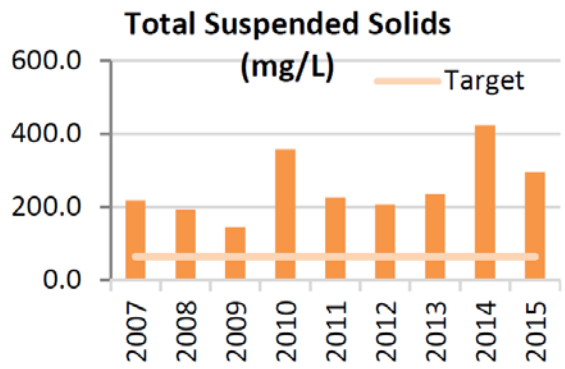
TP

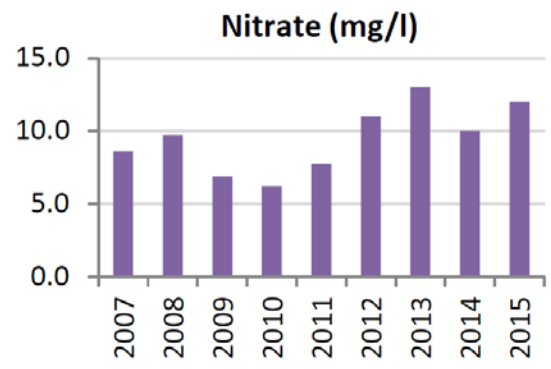


(MPCA 2017)

Le Sueur River water quality progress



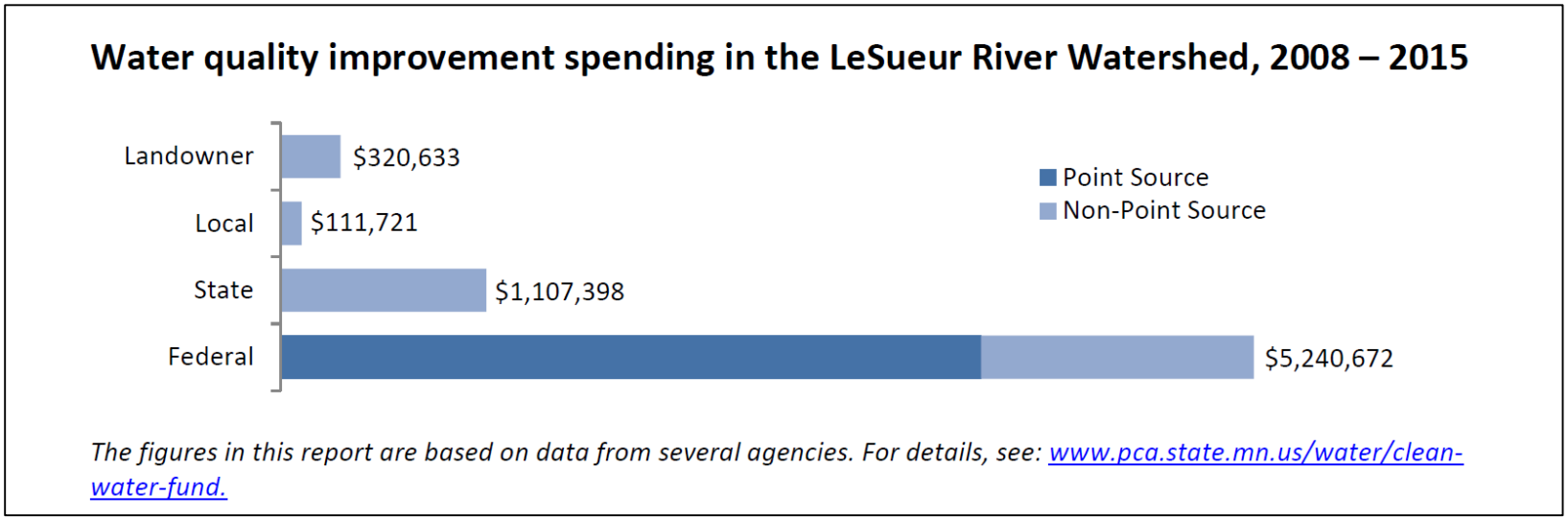




(MPCA: Le Sueur River Watershed Clean Water Accountability Progress Report 2016)

The Le Sueur River Watershed Restoration and Protection Strategy calls for a minimum **60% reduction in TP, a 65% reduction in sediment, and a 45% reduction in nitrogen**, in order to achieve water quality goals.

Improved edge of field water quality may not propagate towards improved water quality at the basin outlet.



Is the water quality problem intractable or could we do better if we shift from a field to a watershed perspective?

Hydrology, which is mediated by drainage systems and weather patterns, is the primary driver of pollutant export

(Foufoula-Georgiou et al. 2016, Kelly et al. 2017)

Near channel sediment sources (bluff and bank erosion) are significant and released during high streamflows

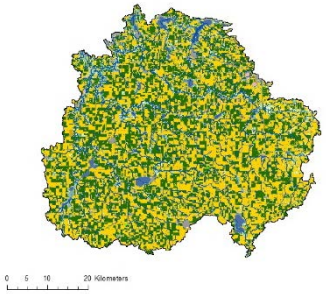
(Belmont et al. 2011, Cho et al. in prep)

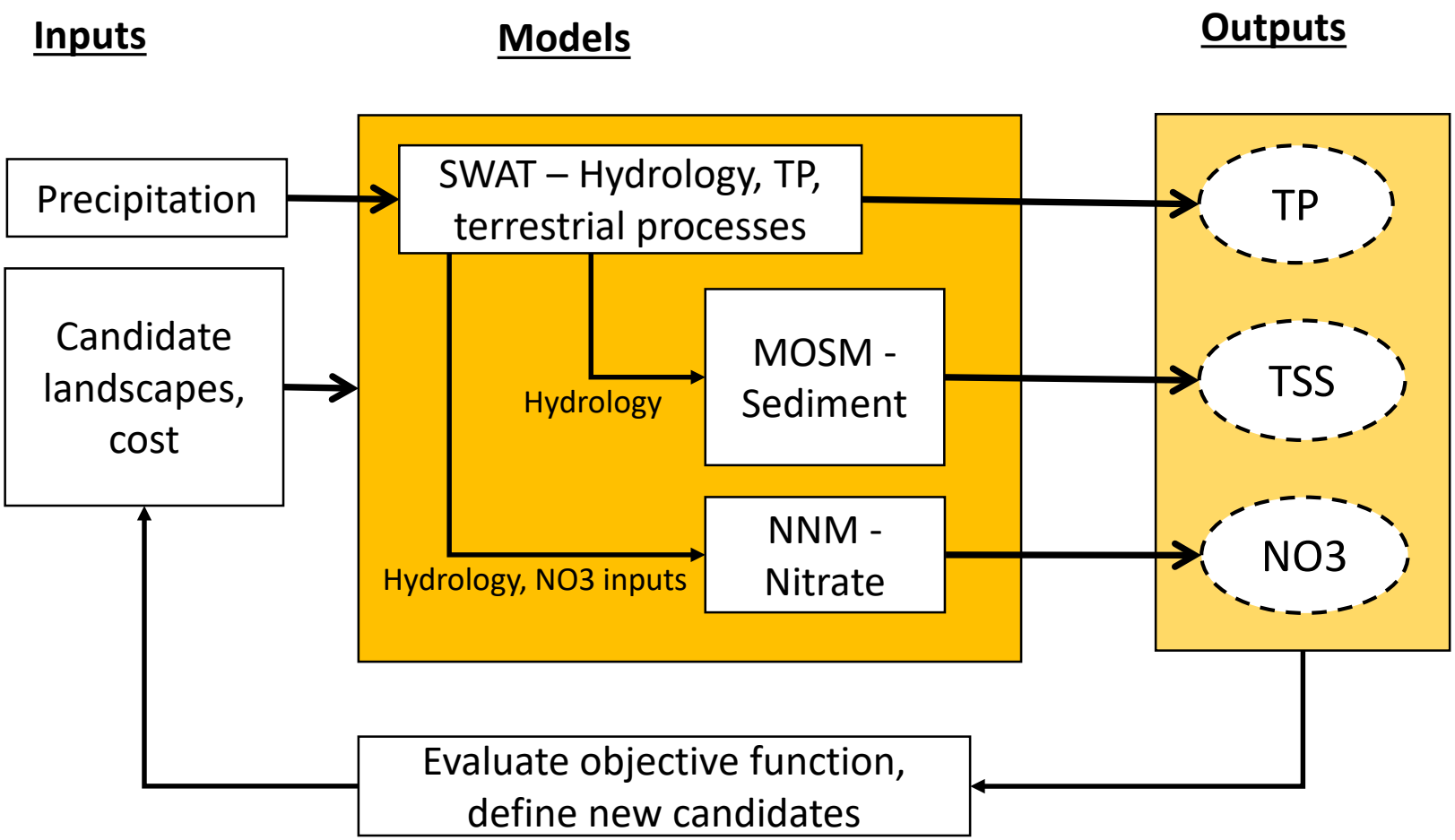
Wetlands and lakes are significant locations of nitrate removal, and reduce peak flows

(Hansen et al. 2016, Hansen et al. accepted, Czuba et al. in review)

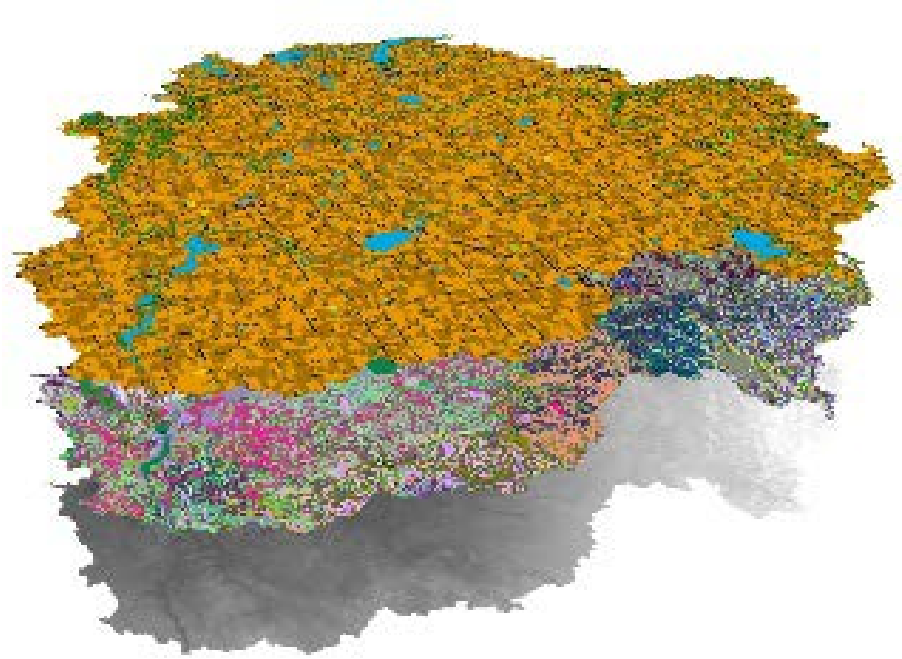
REACH modeling framework

- Daily time step
- Decadal run length





SWAT watershed model



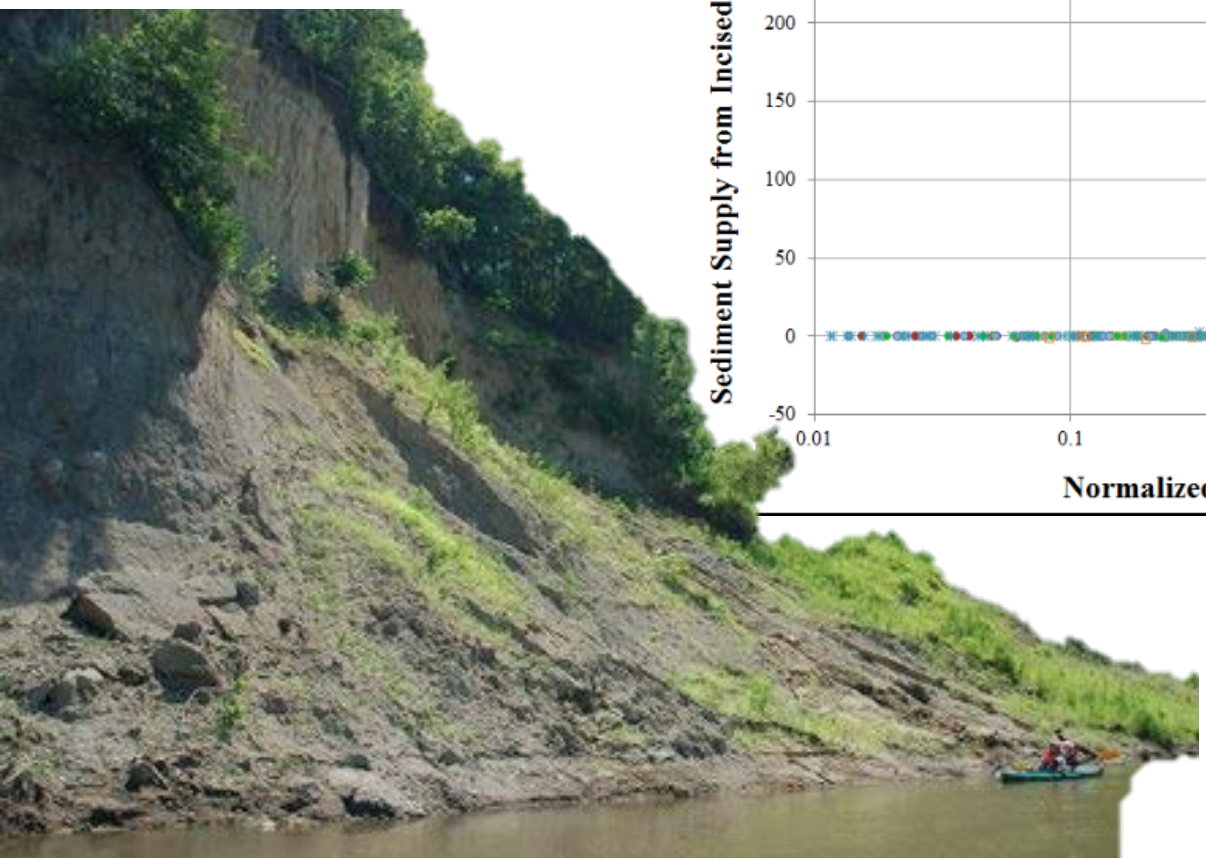
Land Cover and Management

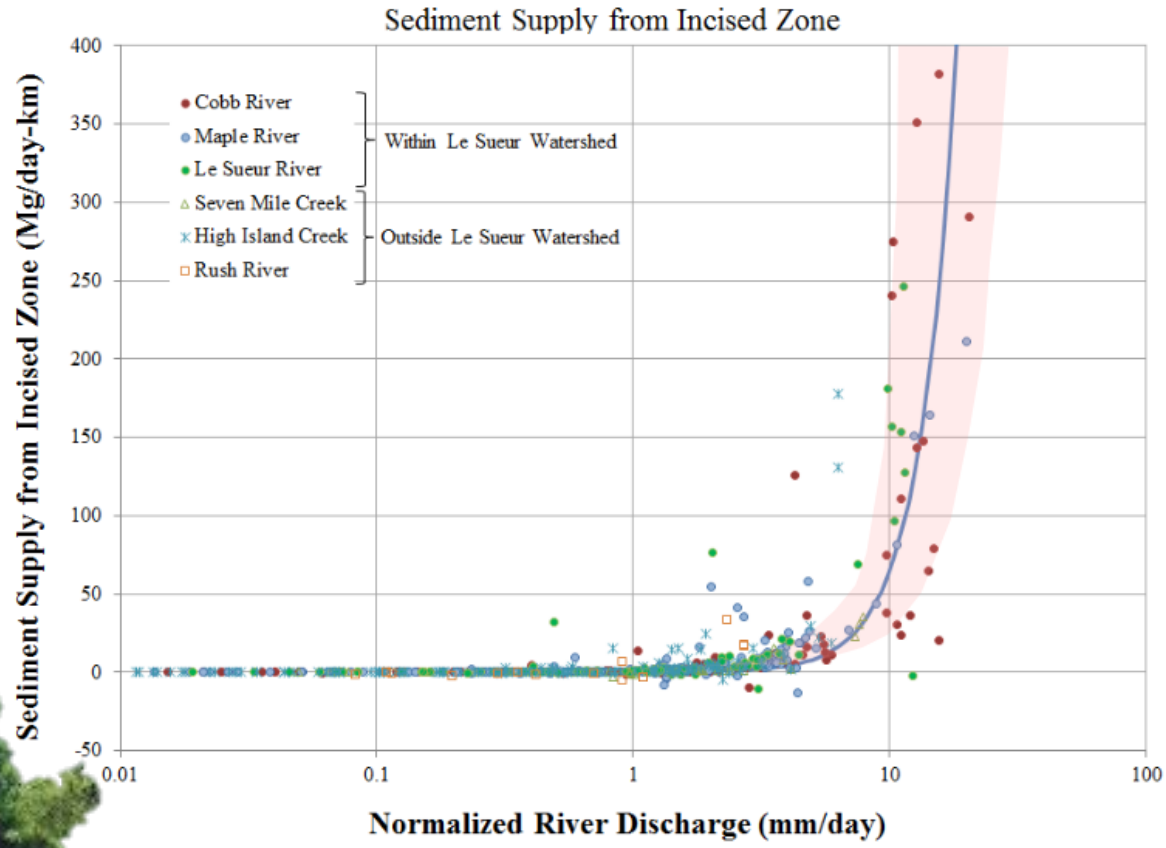
Soils

Topography

http://swat.tamu.edu

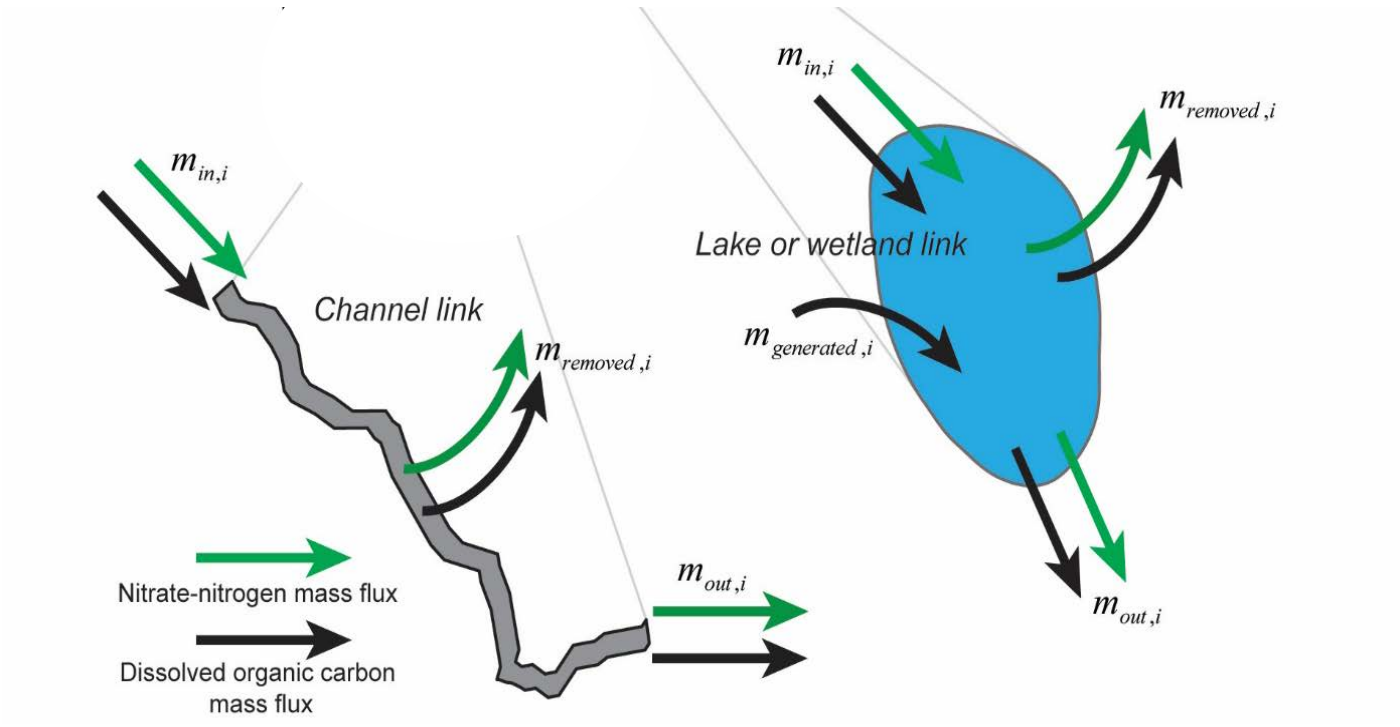
Near channel sediment – MOSM model



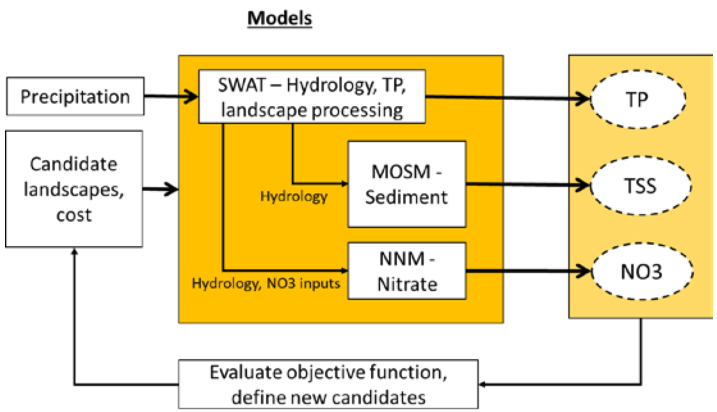


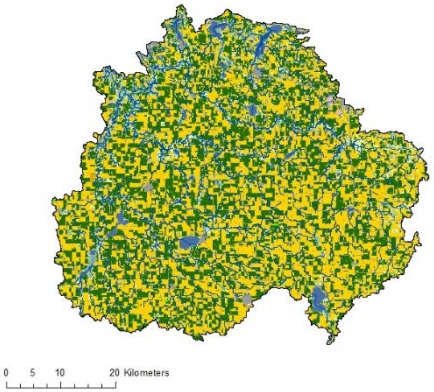
(Cho et al. in prep)

Aquatic nitrate removal – NNM model



(Czuba et al. in review)



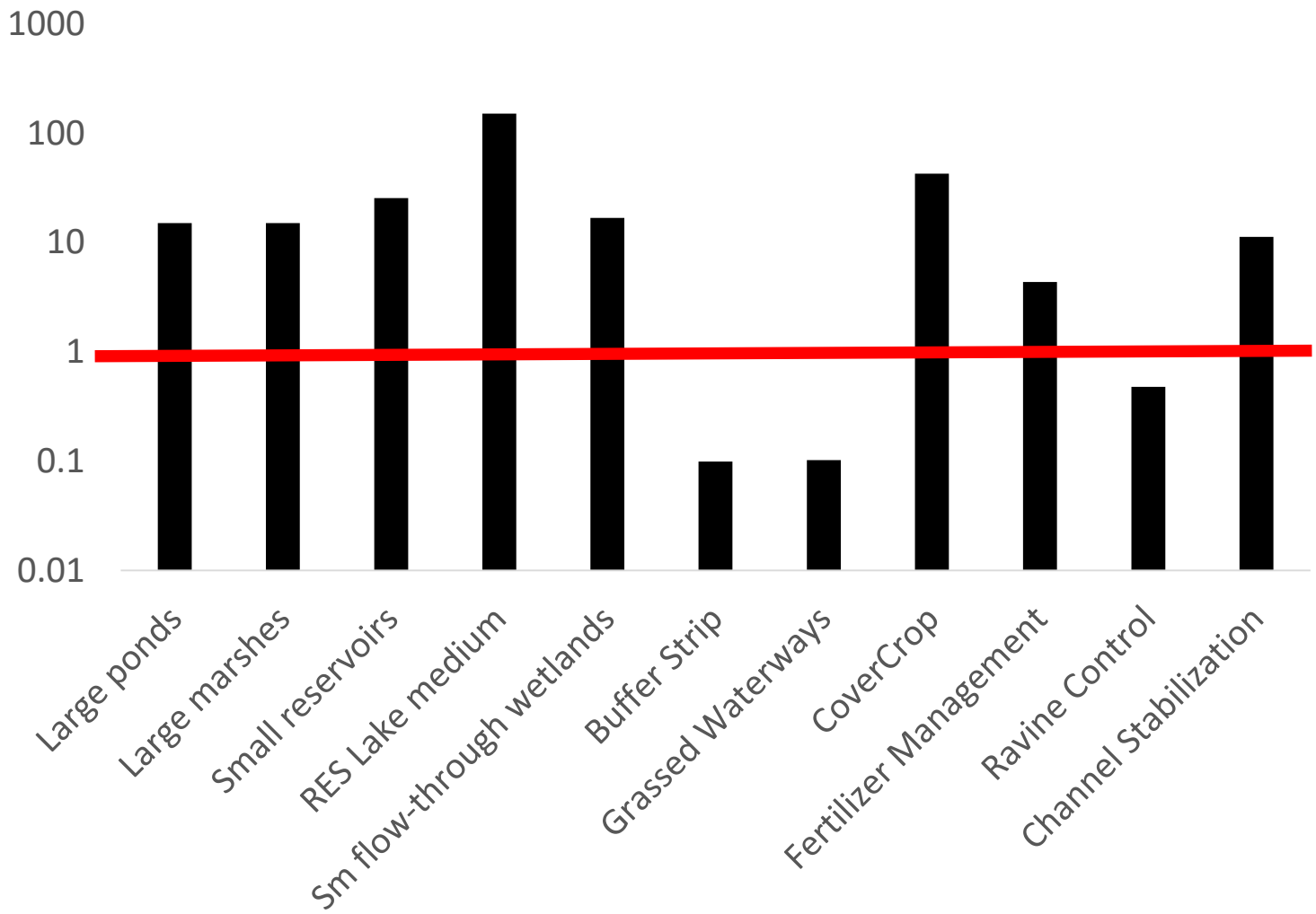


Can we meet water quality targets?

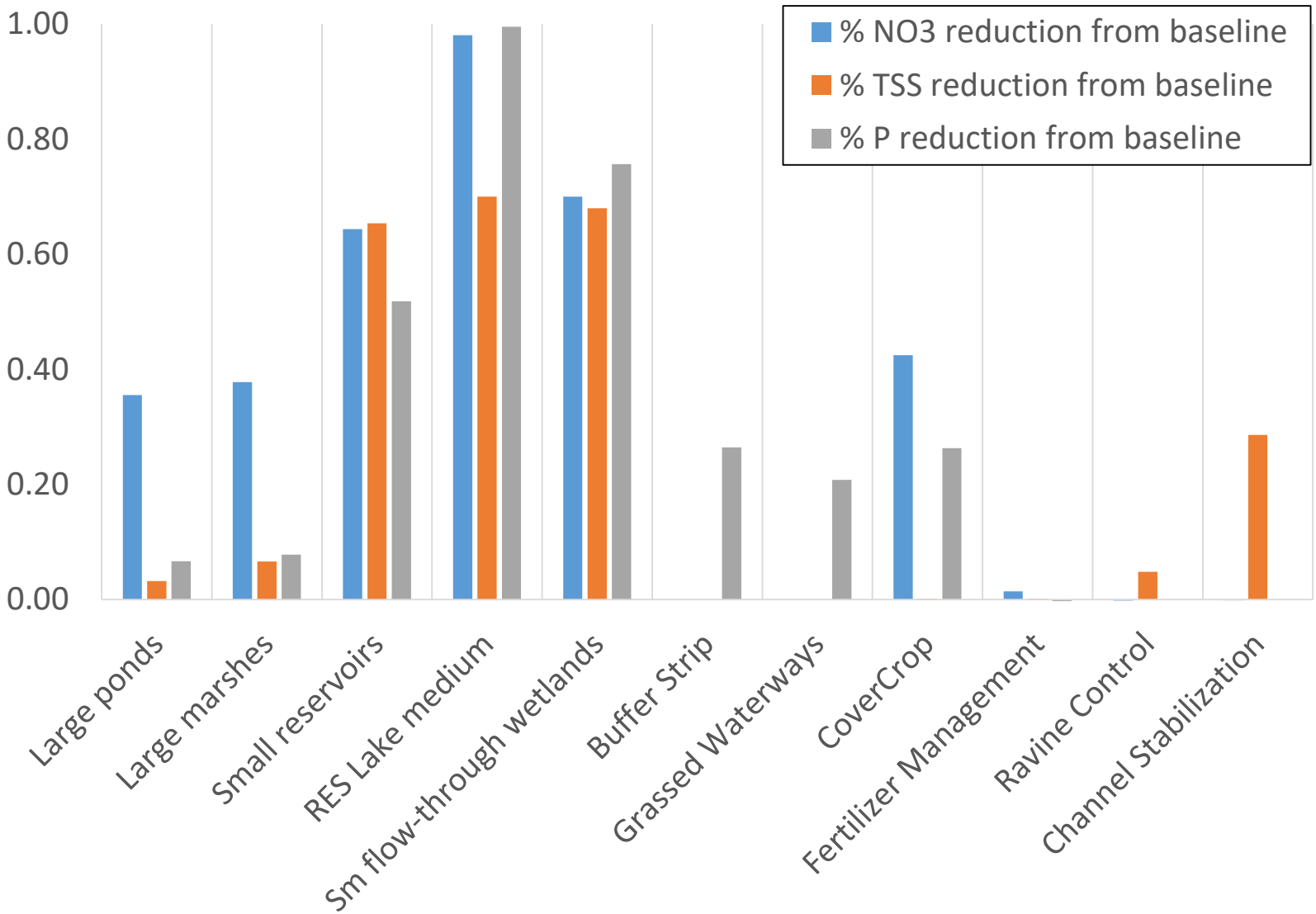
How much will it cost?

What management options will get us there?

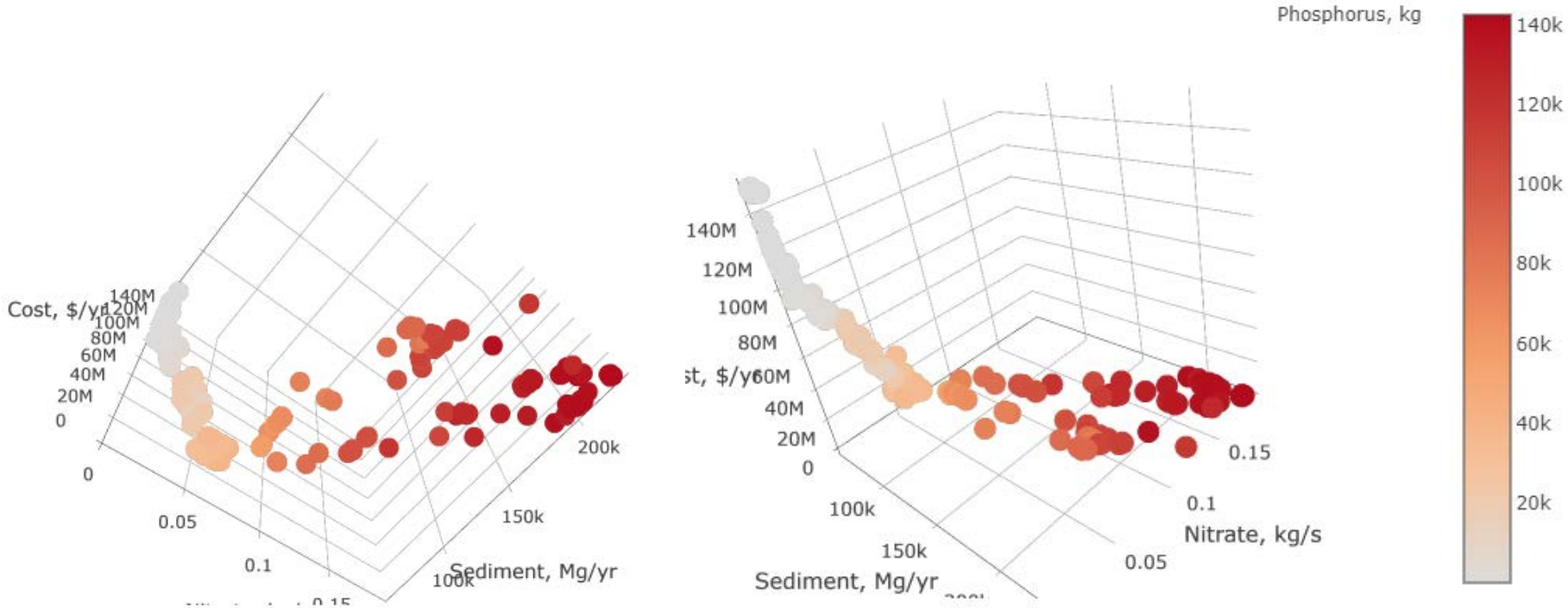
Cost (in millions of dollars)



Fraction of annual yield removed (compared to existing landscape)



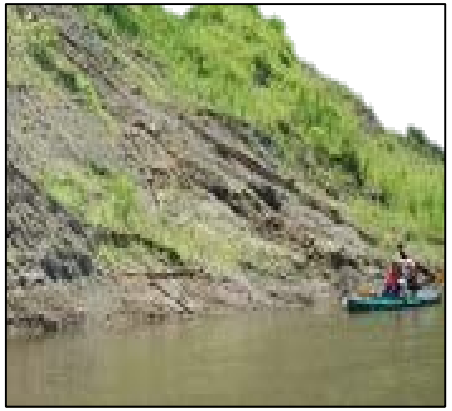
Cost-benefit tradeoff frontier



Management options selected in more optimal solutions:

+

+



(Fertilizer management, tillage options were rarely selected.
Low cost but not as effective.)

Optimal placement of management options TBD).

Can we meet our water quality targets? What will that look like?

- 25% reduction in nitrate
  - Cover crops

- 25 x 25 (25% reduction NO3, TP, TSS)
  - Cover crops, some flow-through marshes, near channel sediment stabilization.

- Le Sueur River Watershed Restoration and Protection Strategy
  - Many more small flow-through marshes, cover crops, near-channel sediment stabilization

 = $1 million/yr

Reported costs include recurring loss from taking land out of production

Questions?

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  - NSF grant SEES-1415206 under the Water Sustainability and Climate Program (WSC): *SEES Fellows: Leveraging the waterscape to increase agricultural landscape sustainability*