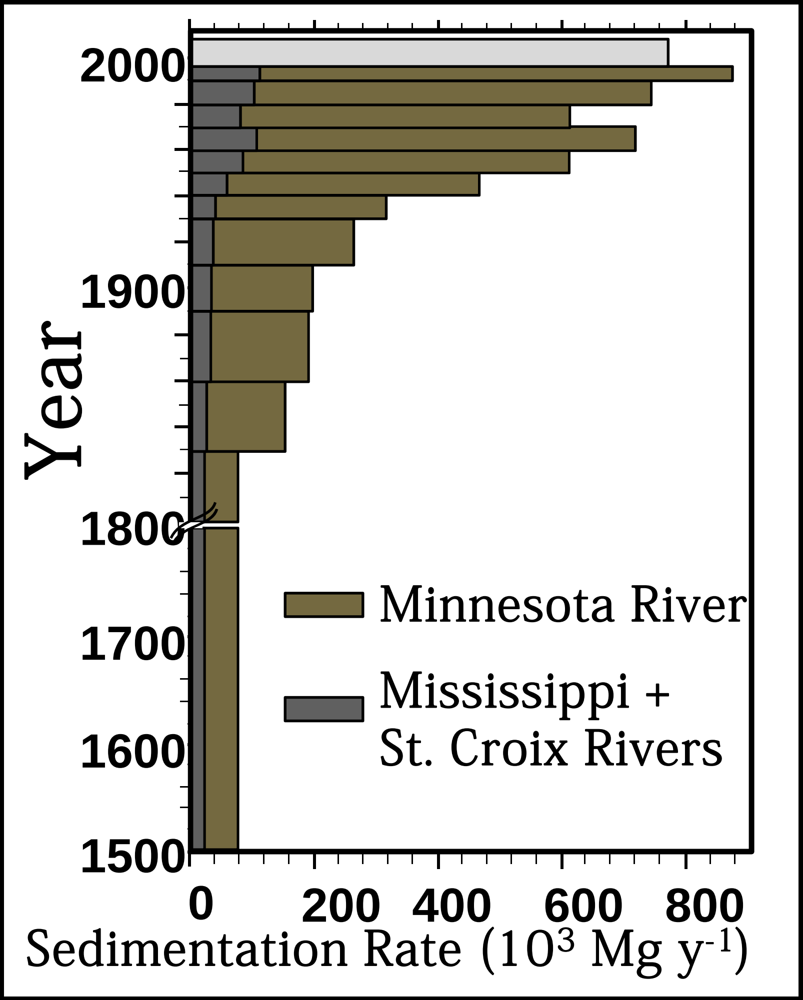
Collaborative for Sediment Source Reduction (CSSR) In the Greater Blue Earth River Basin: Summary of Findings

June 8, 2017

Karen Gran, University of Minnesota Duluth
Se Jong Cho and Ben Hobbs, Johns Hopkins University
Peter Wilcock and Patrick Belmont, Utah State University
Jeff Marr and Barbara Heitkamp, University of Minnesota

Lake Pepin Record



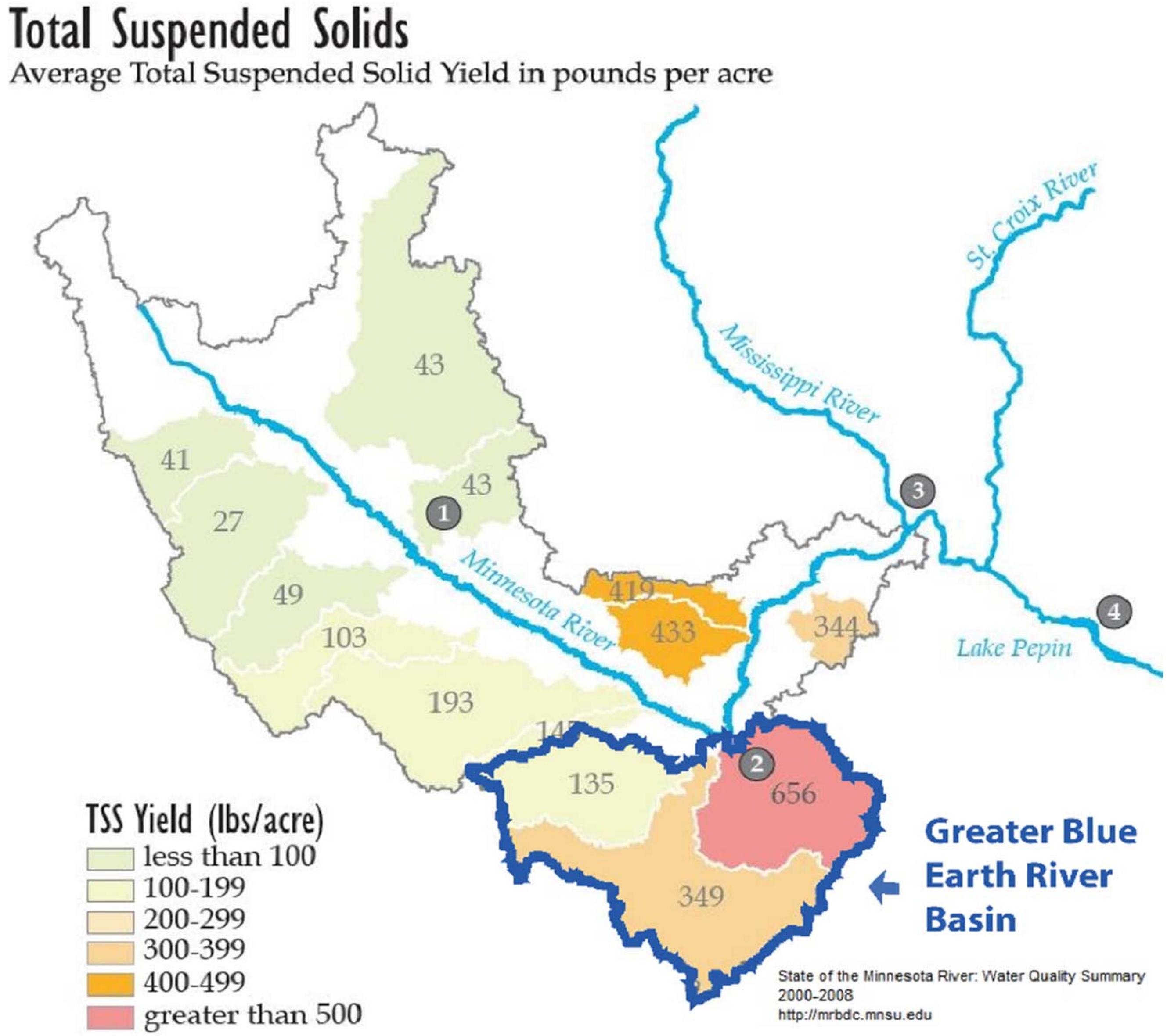
The load has increased following Western settlement

Minnesota River is primary source of sediment and nutrients for Upper Mississippi River

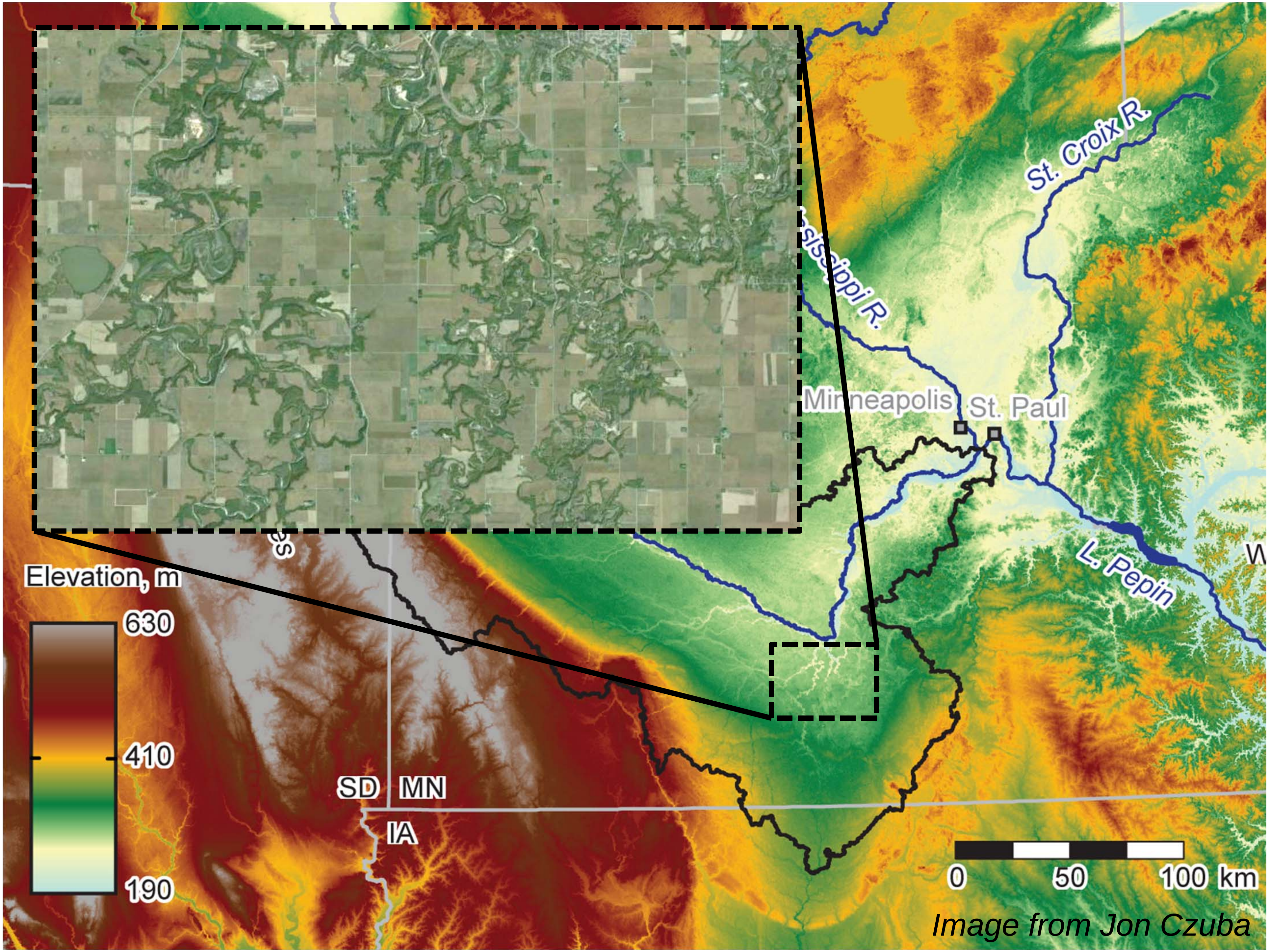
Engstrom et al. 2009; Kelley & Nater 2000; Blumentritt et al. 2013; Belmont et al., 2011

"Beating muddy heart" of the Minnesota River

-P. Wilcock

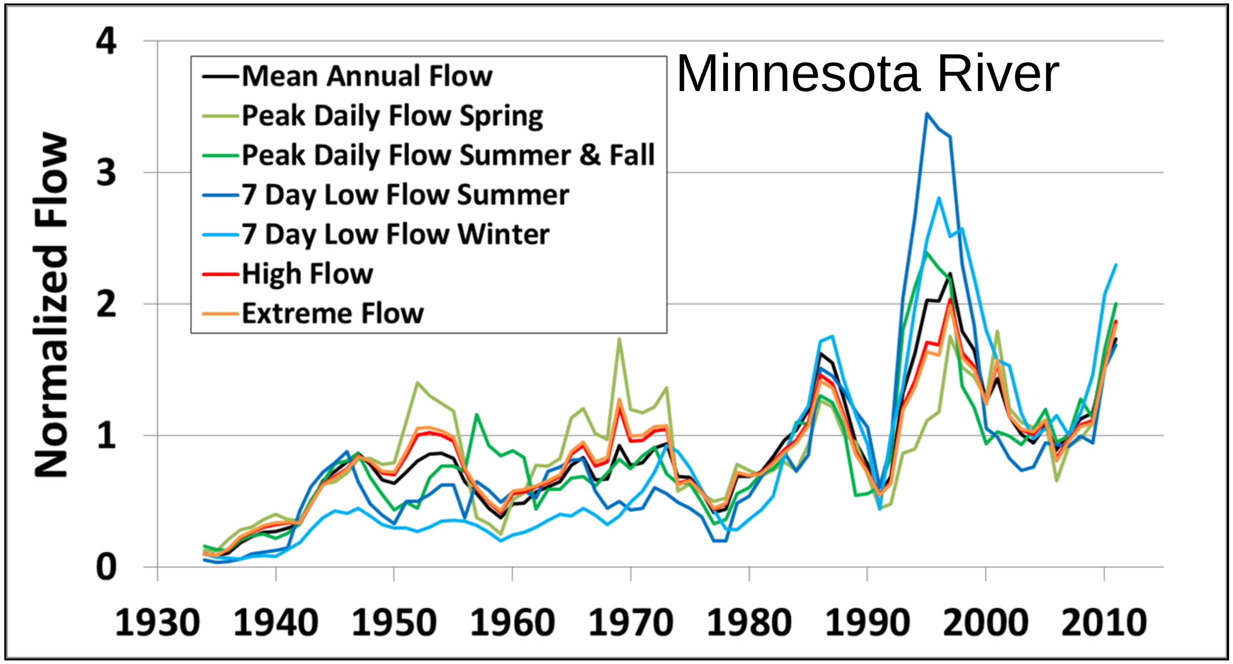


MPCA

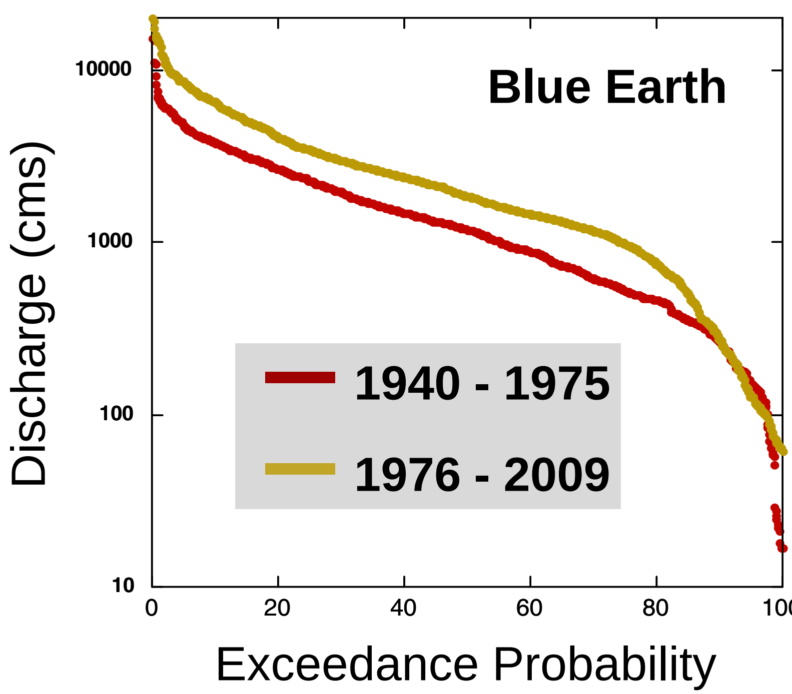


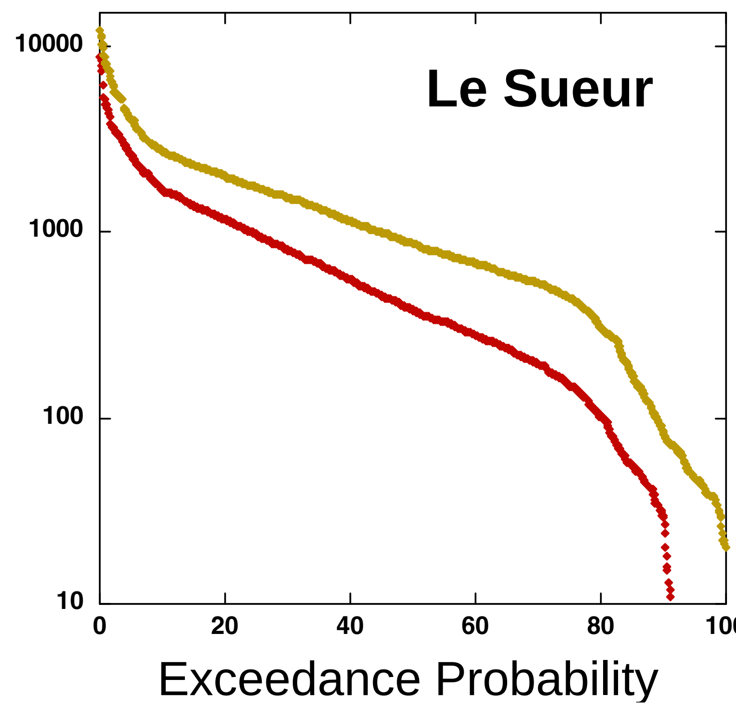
St. Croix R.
Mississippi R.
Minneapolis
St. Paul
L. Pepin
Elevation, m
630
410
190
SD
MN
IA
0
50
100 km
Image from Jon Czuba

Disconnected and poorly-drained landscape



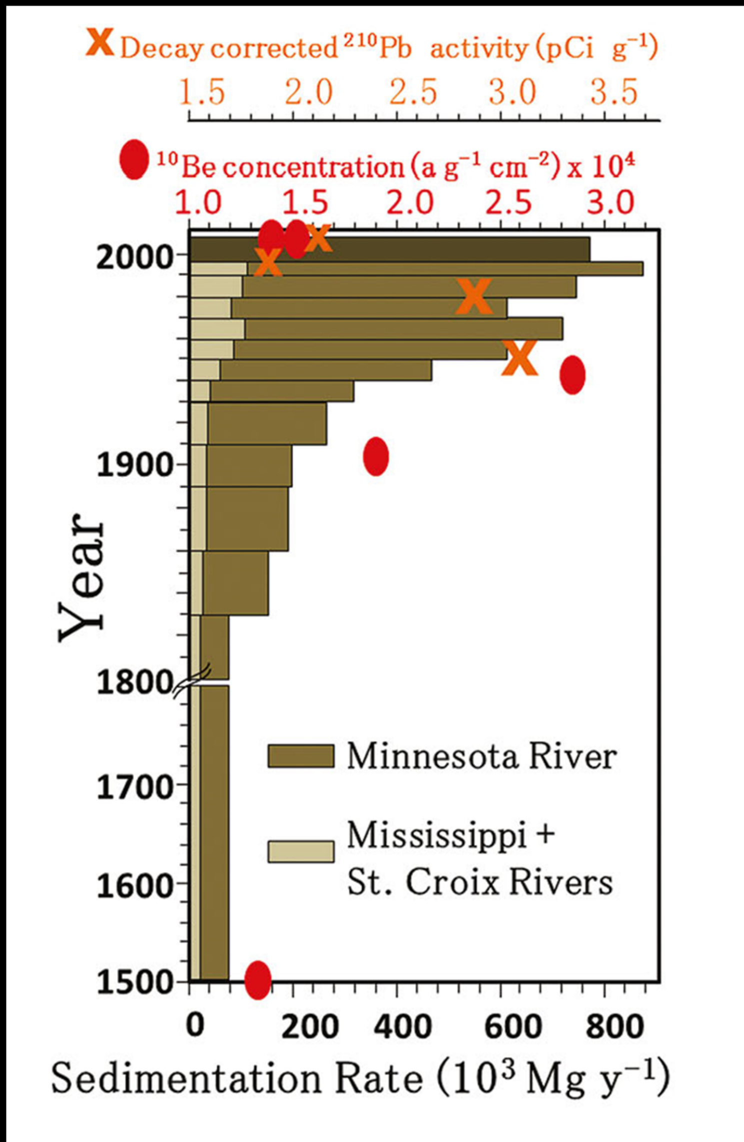
Novotny and Stefan (2007), Additional data from Sara Kelly





Modified from Schottler, 2011 WRC Conf

Changes in land use and hydrology have led to shifts in sediment sources in the past few centuries as seen through sediment fingerprinting.



Sediment loads stay high; Shift in sources back to non-field

Rise of agriculture; Increase in sedimentation; Shift in sources to predominantly field sediment

Presettlement conditions; Most sediment derived from non-field sources

Low **% Field** High

Belmont et al. (2011)

Photo: Star Tribune

CSSR
Collaborative for Sediment Source Reduction

***Goal**: To identify a **<u>consensus strategy</u>** for reducing sediment loading in the Greater Blue Earth watershed using a decision framework that incorporates the best available scientific information, accounts for uncertainty, and provides a model for decision making throughout the Minnesota River Basin.*

CSSR is about

Sediment

Blue Earth River Basin (esp. the Le Sueur)

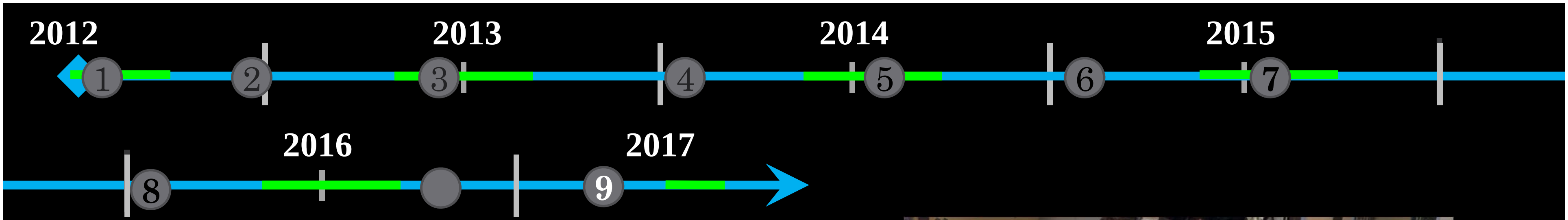
Finding a strategy at the watershed scale; not providing site specific design

Finding a strategy; not just about building a model.

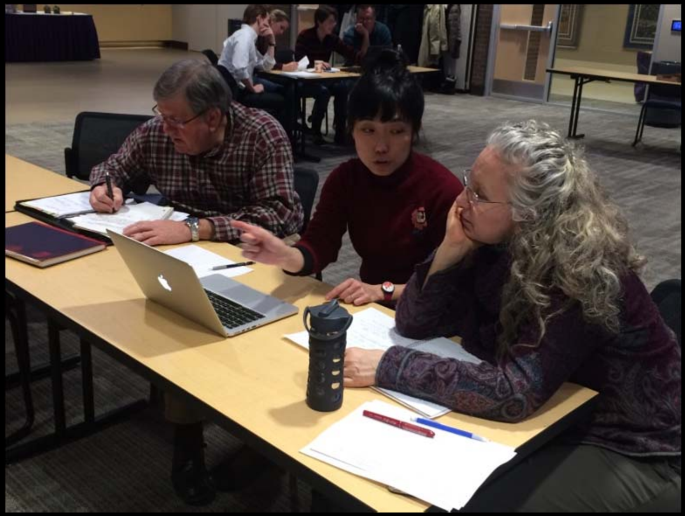
The Model is a means to an End: combine best available science with effective and accepted conservation practices to reduce sediment delivery

Finding a strategy – not solving a political problem.

If a clear strategy emerges – political solution might be easier to support!



Stakeholder Group

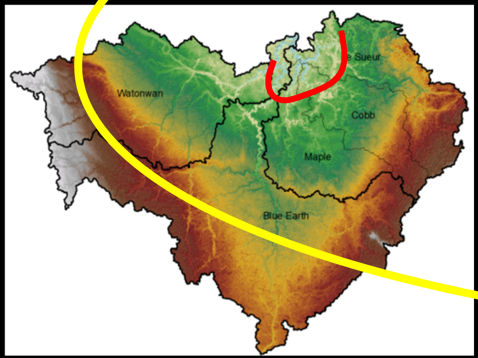


Thank-you!

Affiliations of stakeholders attending the final meeting

- Waseca County SWCD
- Cottonwood County SWCD
- Blue Earth County
- Greater Blue Earth River Basin Alliance (GBERBA)
- Lower Minnesota River watershed district
- Farmers
- MN Agricultural Water Resources Center
- MN Corn Growers Association
- MN Dept of Agriculture
- MN Dept of Natural Resources
- Board of Water and Soil Resources (BWSR)
- MN Pollution Control Agency
- Coalition for a Clean MN River
- Clean Up the River Environment
- Freshwater Society
- USACE
- Univ of Minnesota BBE
- Univ of Minnesota Water Resources Center
- MNSU Water Resources Center

Management Option Simulation Model (MOSM)



Greater Blue Earth River

Management Options

Extents

Rates

Costs

Processes

Hydrologic Modeling

Predict Erosion & Deposition

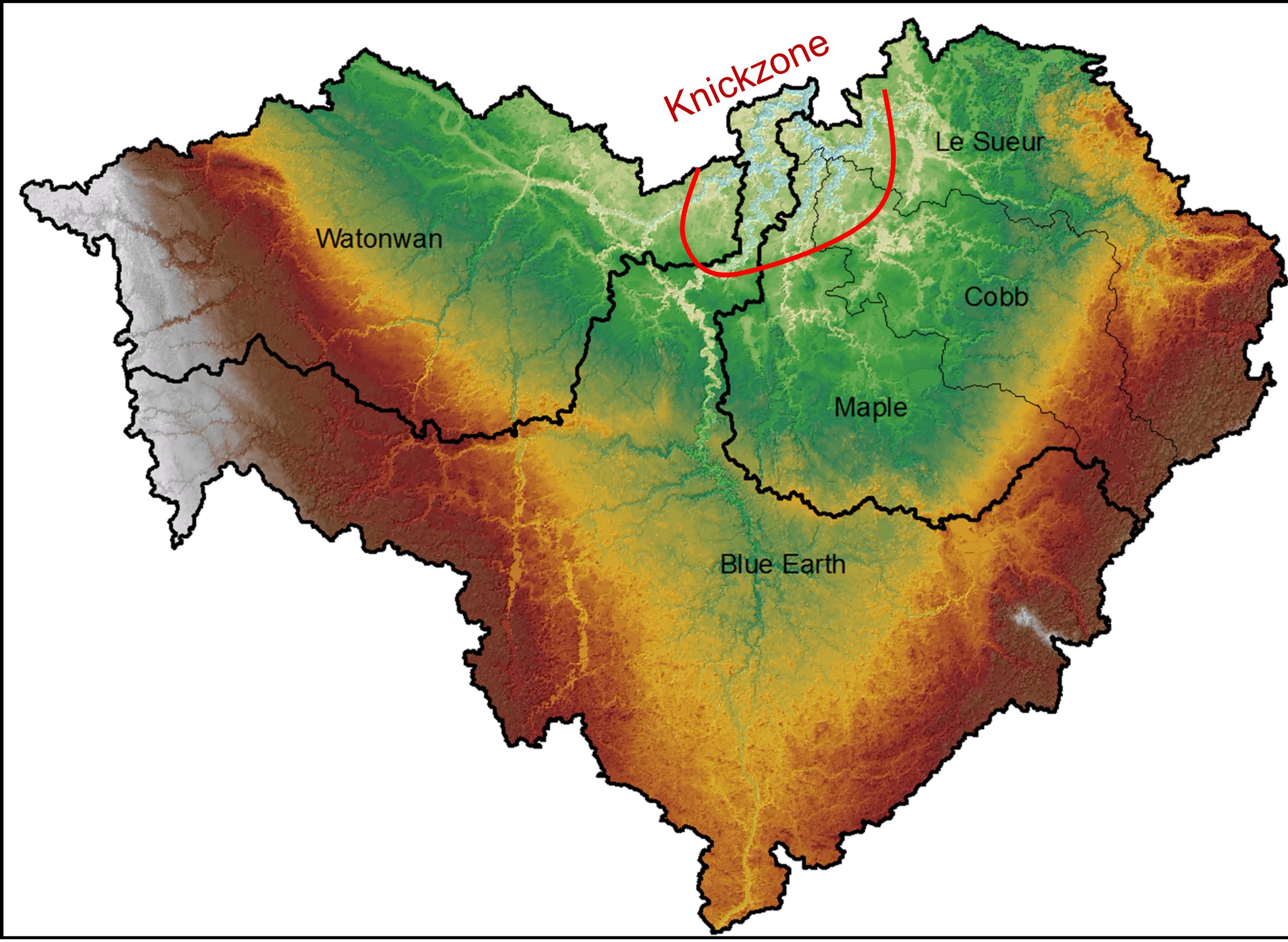
Via Sediment Budget

Water & Sediment Routing

Simulation Model

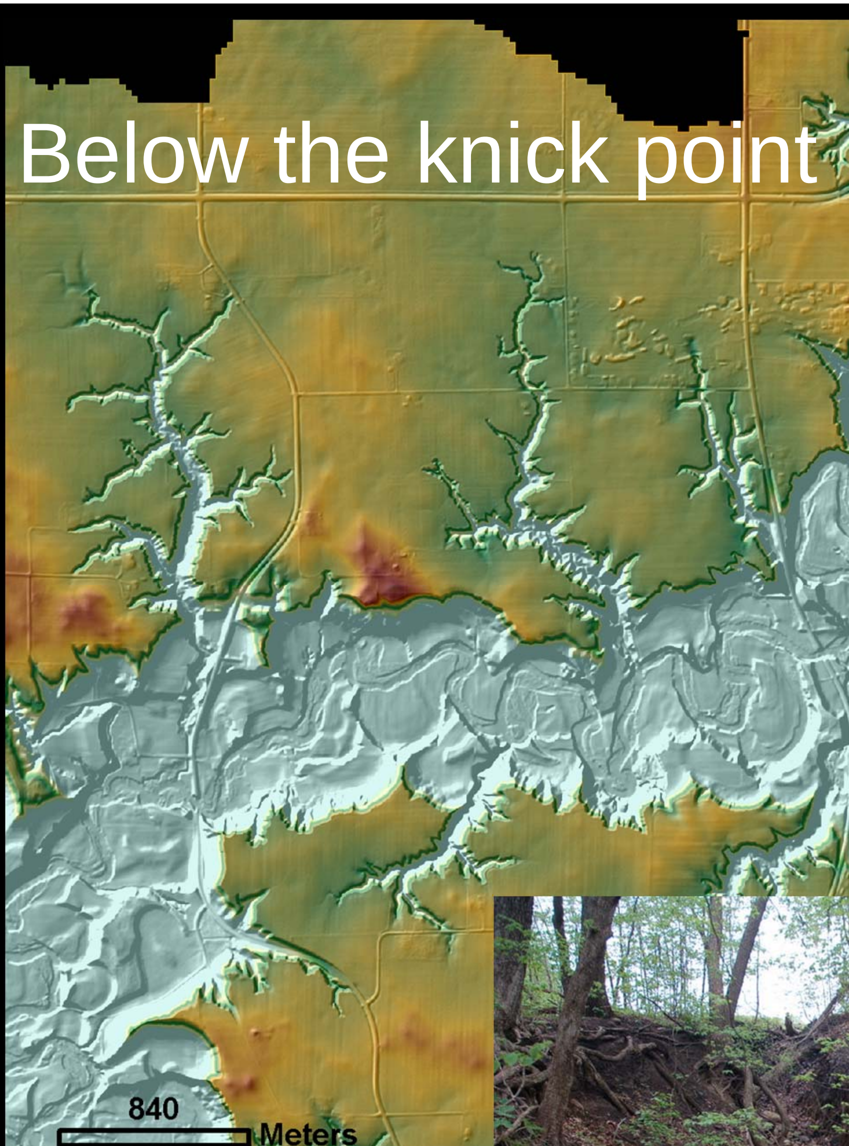
Consensus strategy!

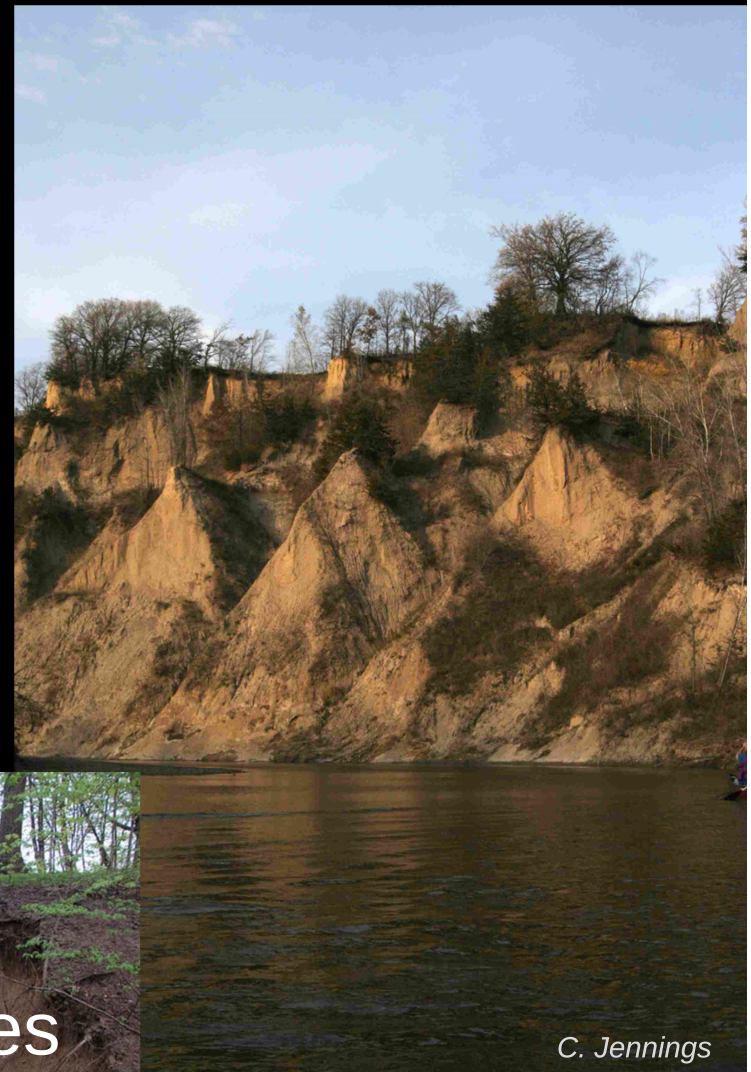
Sediment budget is structured accdg. to subwatershed and geomorphic environments within each watershed



Above the knick point

Bluffs

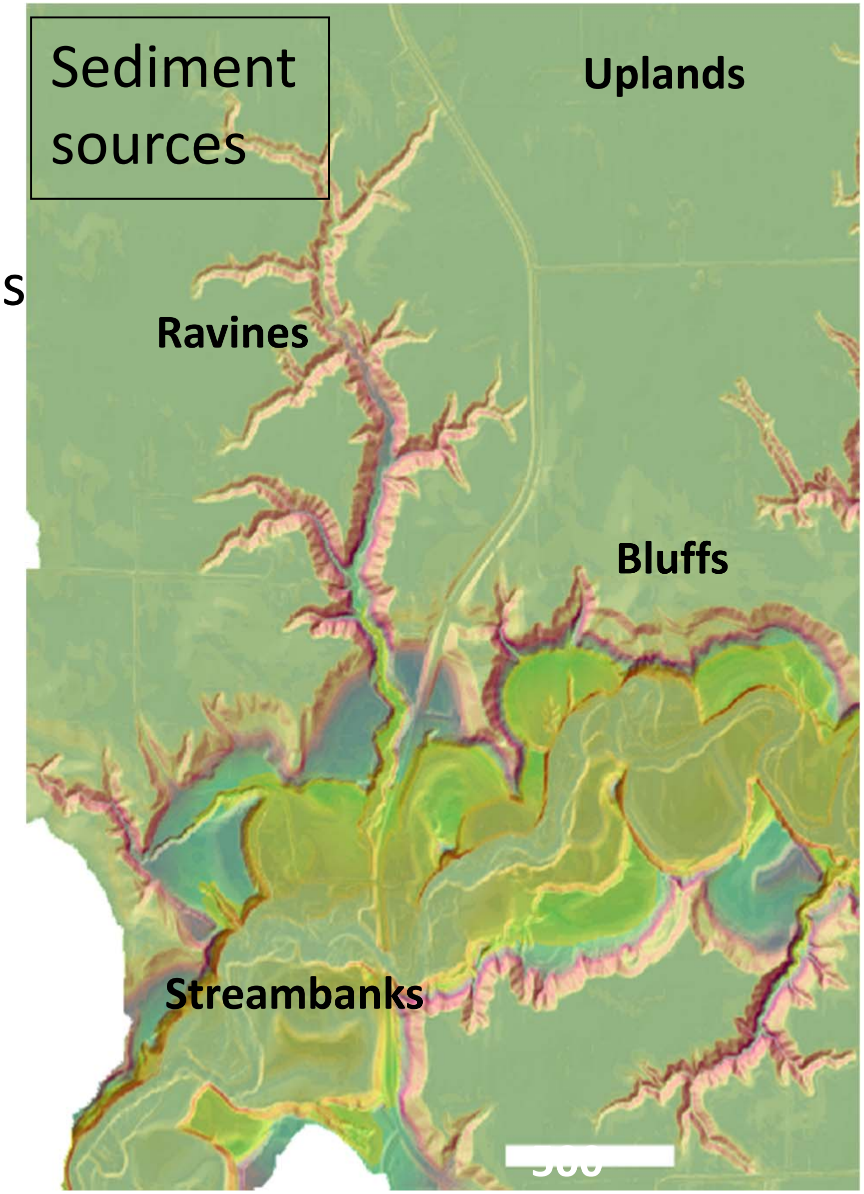

Below the knick point
840
Meters


C. Jennings


Ravines
C. Jennings

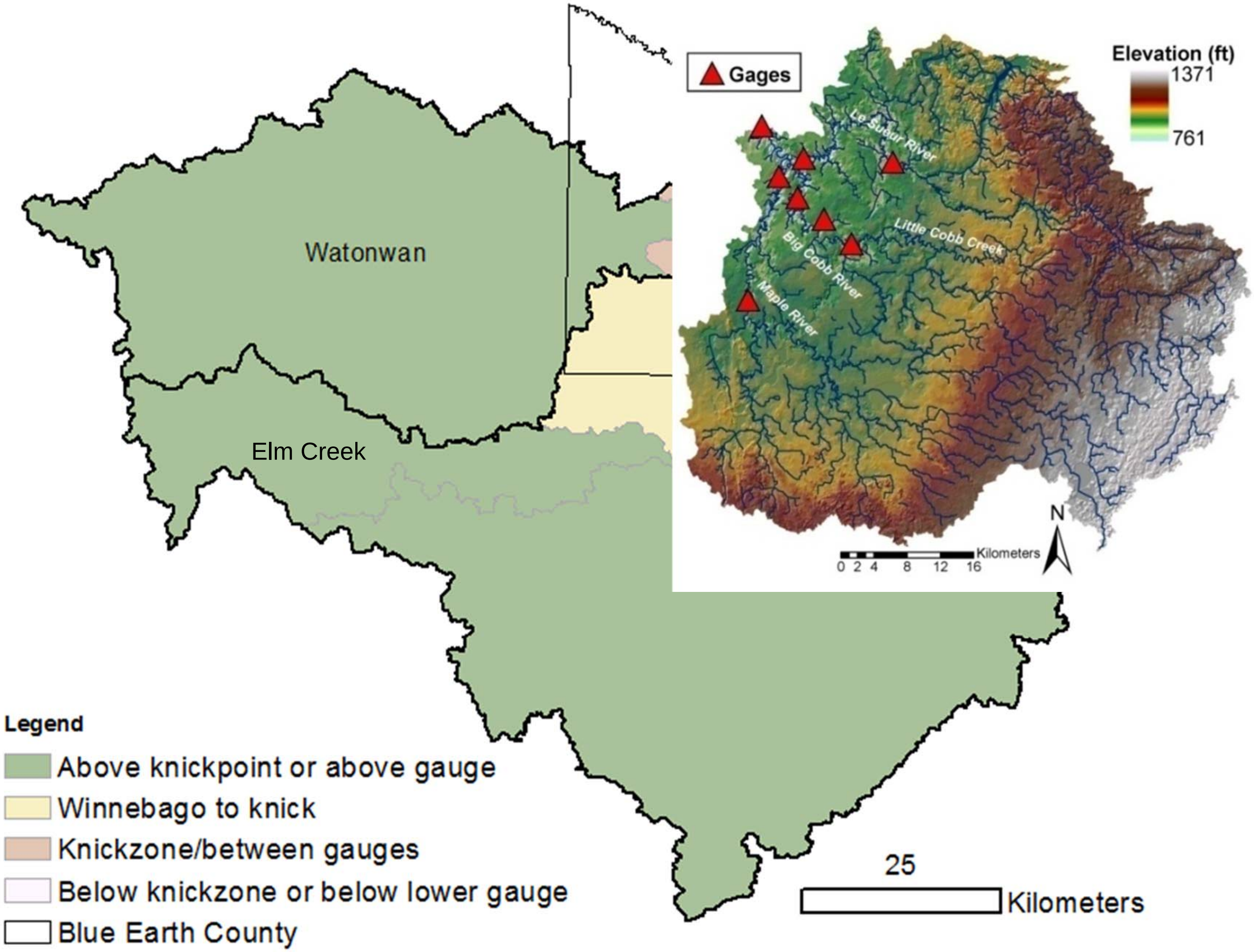
Sediment sources and sinks

- Load = erosion rate x extent
  - measuring erosion rates & source extents
  - erosion rate extrapolation methods
- Constrained by gaging records



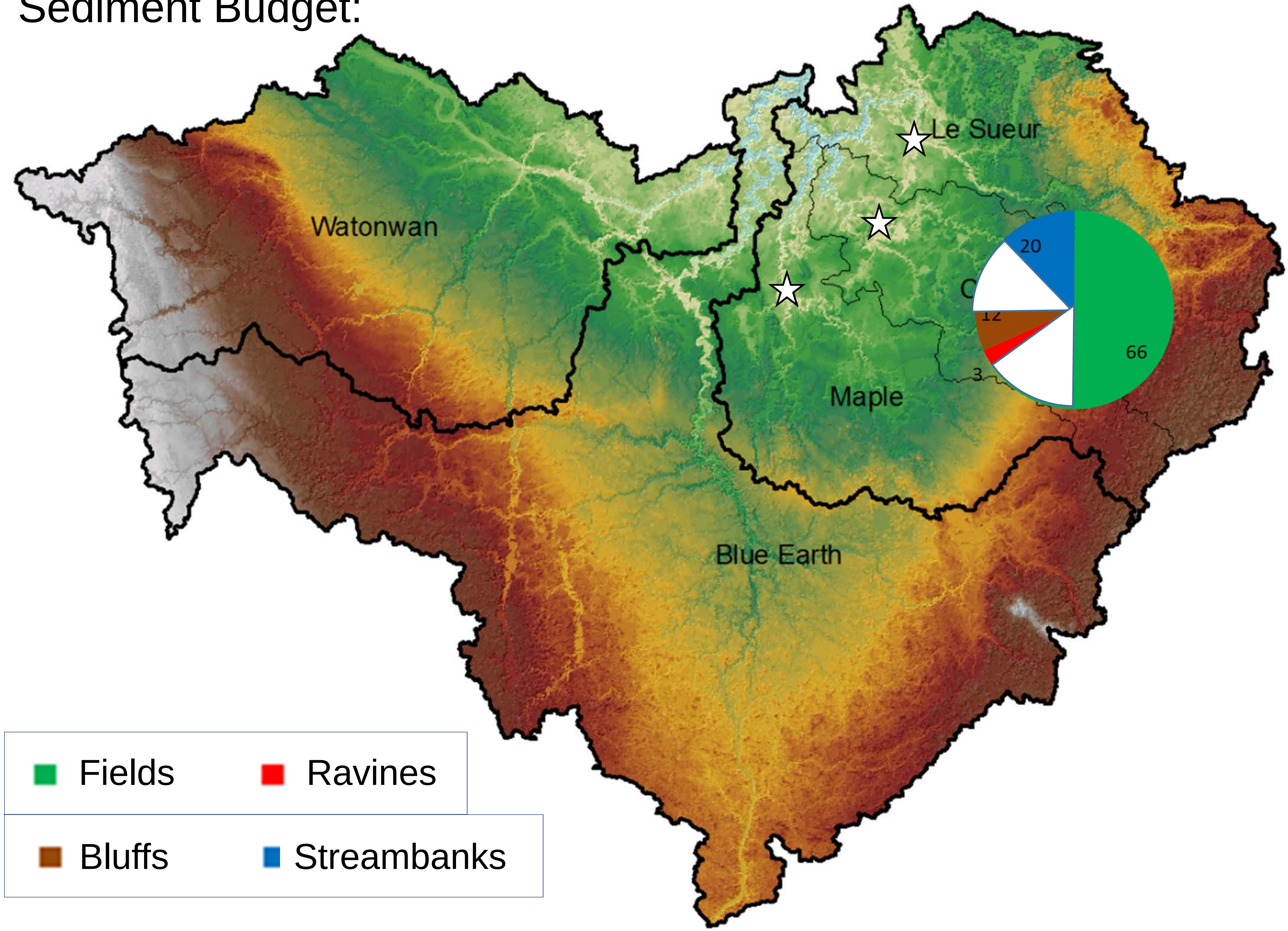
Sediment Sinks:
Floodplains
Lakes

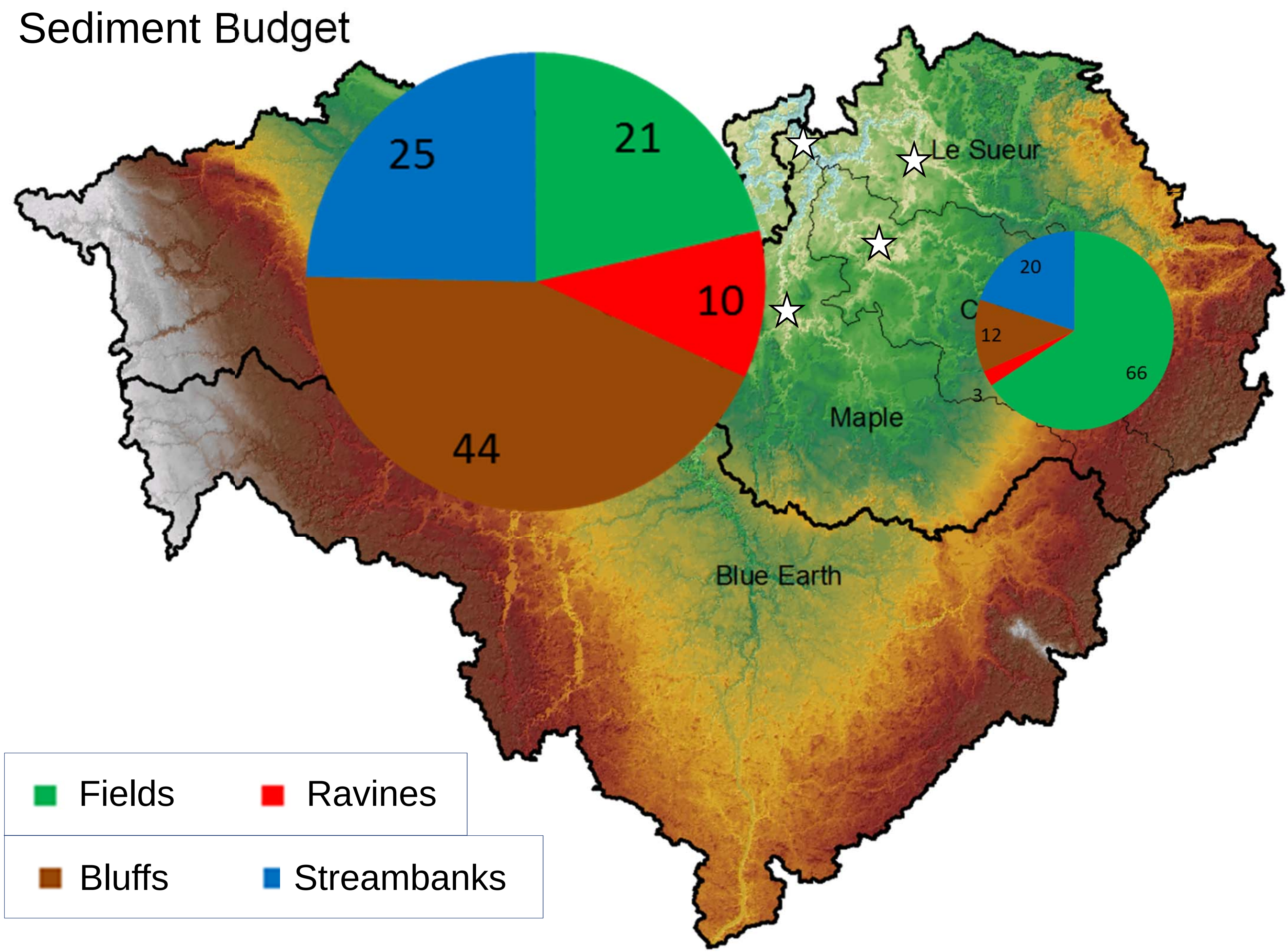
Excellent gaging network



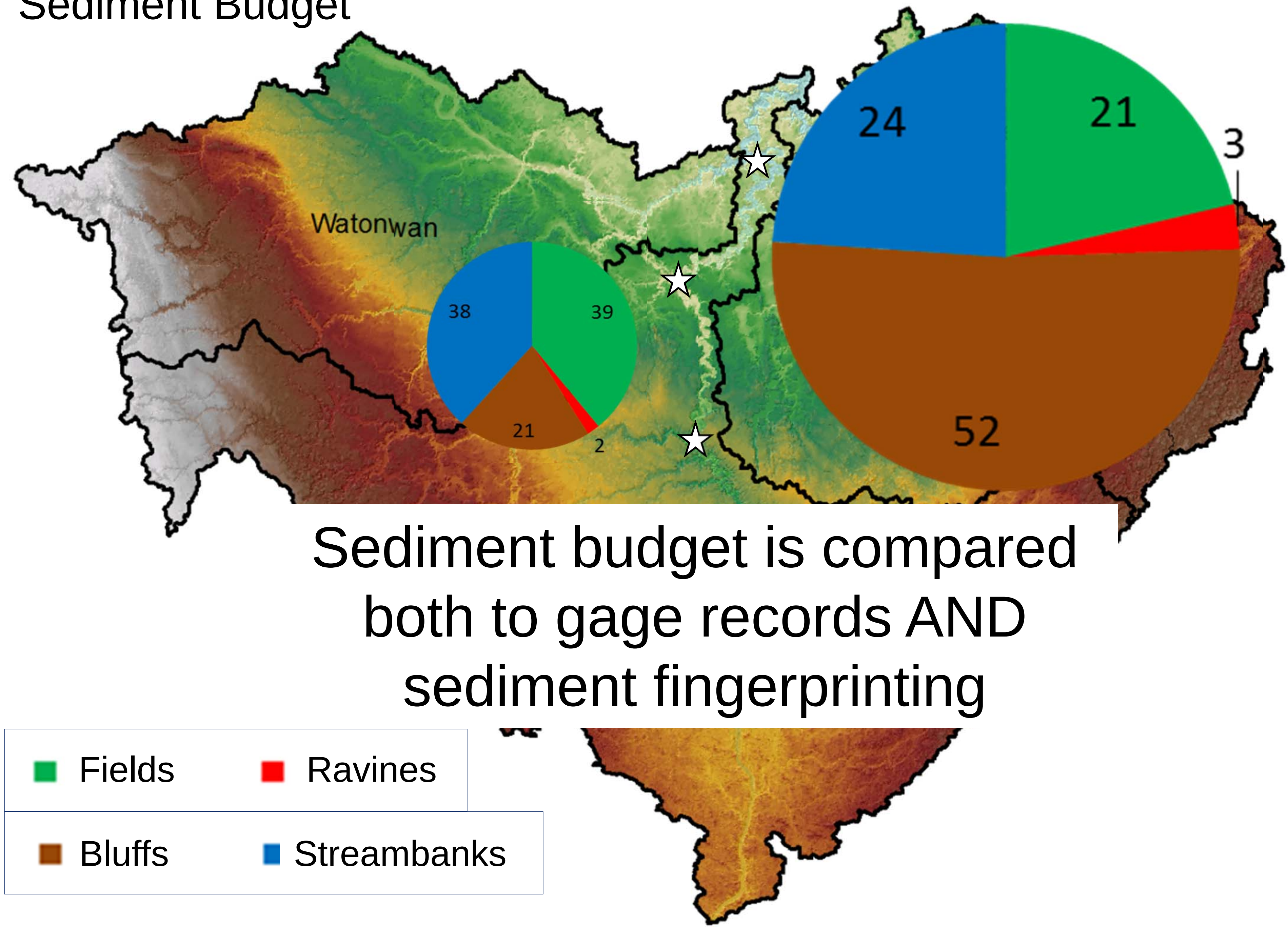
GC: Garden City; VC: Vernon City; RJP: Red Jacket Park

Sediment Budget:

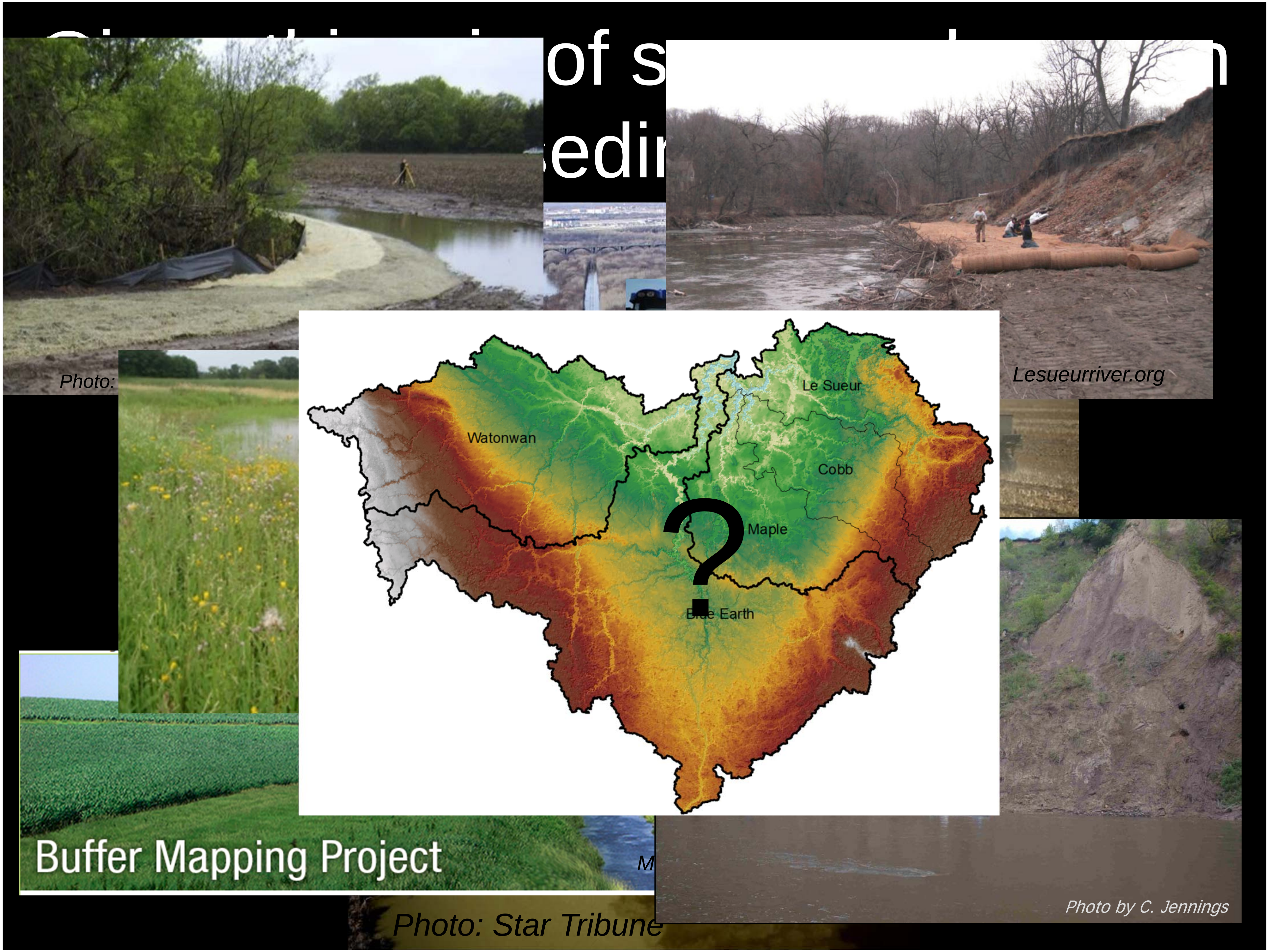



Sediment Budget
25
21
10
44
Le Sueur
20
C
12
66
3
Maple
Blue Earth
Fields
Ravines
Bluffs
Streambanks

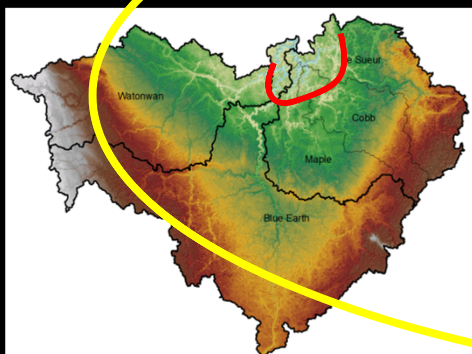
Sediment Budget



Sediment budget is compared both to gage records AND sediment fingerprinting


of s
sedi
Photo:
Lesueurriver.org
Watonwan
Le Sueur
Cobb
Maple
?
Earth
Buffer Mapping Project
Photo: Star Tribune
Photo by C. Jennings

Management Options Simulation Model (MOSM)



Greater Blue Earth River

Management Options
Extents
Rates
Costs

MOSM
Management
Option
Simulation
Model

Processes
Hydrologic Modeling

Predict Erosion & Deposition
Via Sediment Budget

Water & Sediment Routing

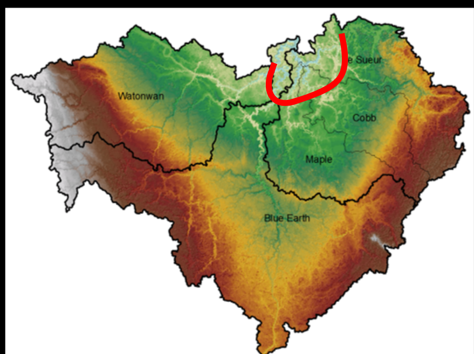
MOSM
(Management Option Simulation Model)

Reduced complexity model

- Erodes sediment off of the fields
- Transports (some) of it to streams
- Adds in discrete inputs from ravines & bluffs informed by sediment budget
- Routes water and sediment downstream using Muskingum-Cunge routing
- Deposition occurs along channel

Management Option Simulation Model (MOSM)

Management Options
Extents
Rates
Costs



a) Purpose built, using all available information

b) Fast

c) Allows comparison of many different portfolios of potential actions in real-time

d) Accounts for costs and benefits in transparent way to provide a foundation for watershed-scale decision-making

MOSM
Management
Option
Simulation
Model

Processes
Hydrologic Modeling

Predict Erosion & Deposition
Via Sediment Budget

Water & Sediment Routing

Tradeoffs to meet Sediment Reduction Targets
How much
of which actions,
at what cost,
in which areas,
can meet sediment reduction targets?

Challenges
(1) Sediment Delivery
(2) Near Channel Sources
(3) Management Options
(4) Interactions

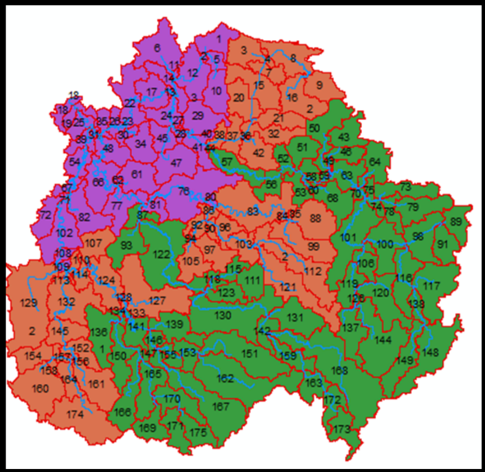
Challenges
(1) Sediment Delivery
(2) Near Channel Sources
(3) Management Options
(4) Interactions

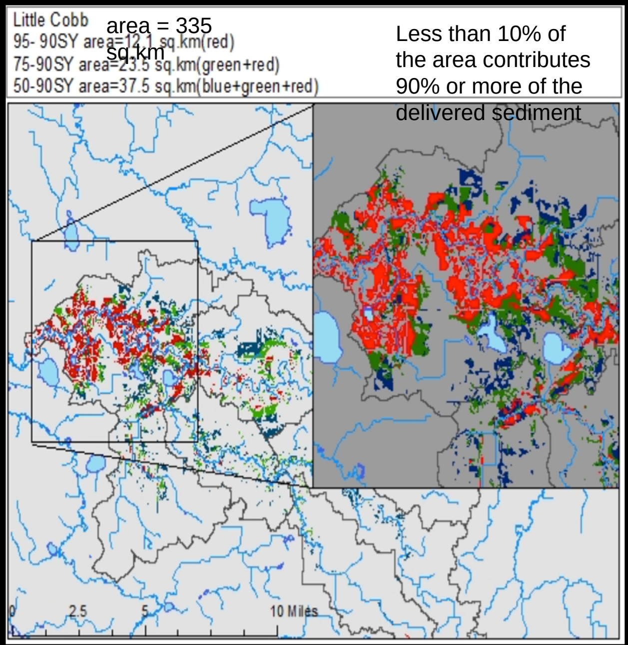
How much eroded sediment actually gets delivered to the Minnesota River?

Sediment Delivery Ratio: the fraction of eroded sediment delivered from the watershed

We developed a spatially distributed estimate of sediment delivery ratio
From field to stream and
Down the stream to the outlet

Using
High resolution topography
USLE / Sediment Budget to scale sources
Gage observations to constrain magnitude
Stochastic approach to incorporate uncertainty



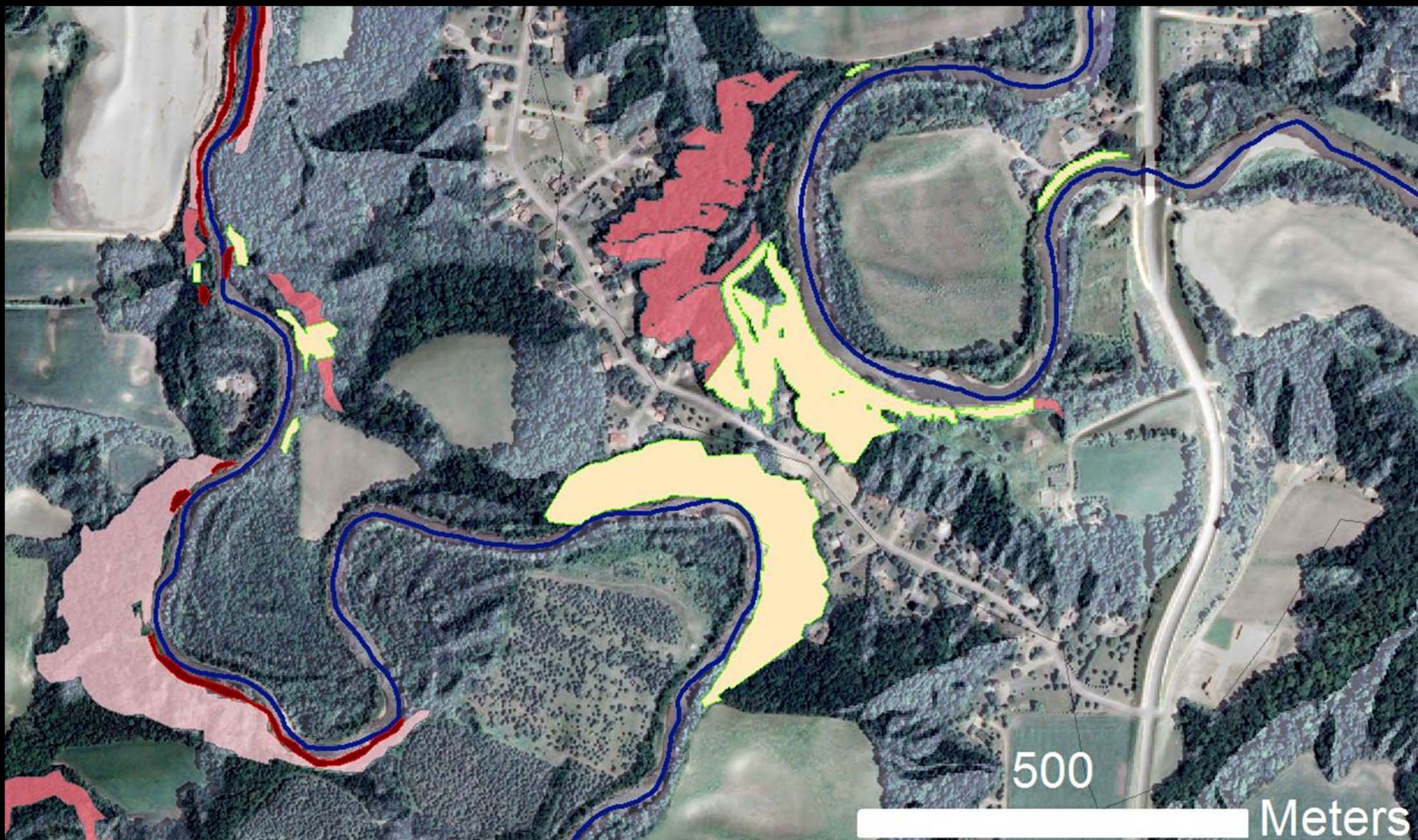


Challenges
(1) Sediment Delivery
(2) Near Channel Sources
(3) Management Options
(4) Interactions

How do we incorporate near-channel sources? And how are they affected by changes in hydrology?

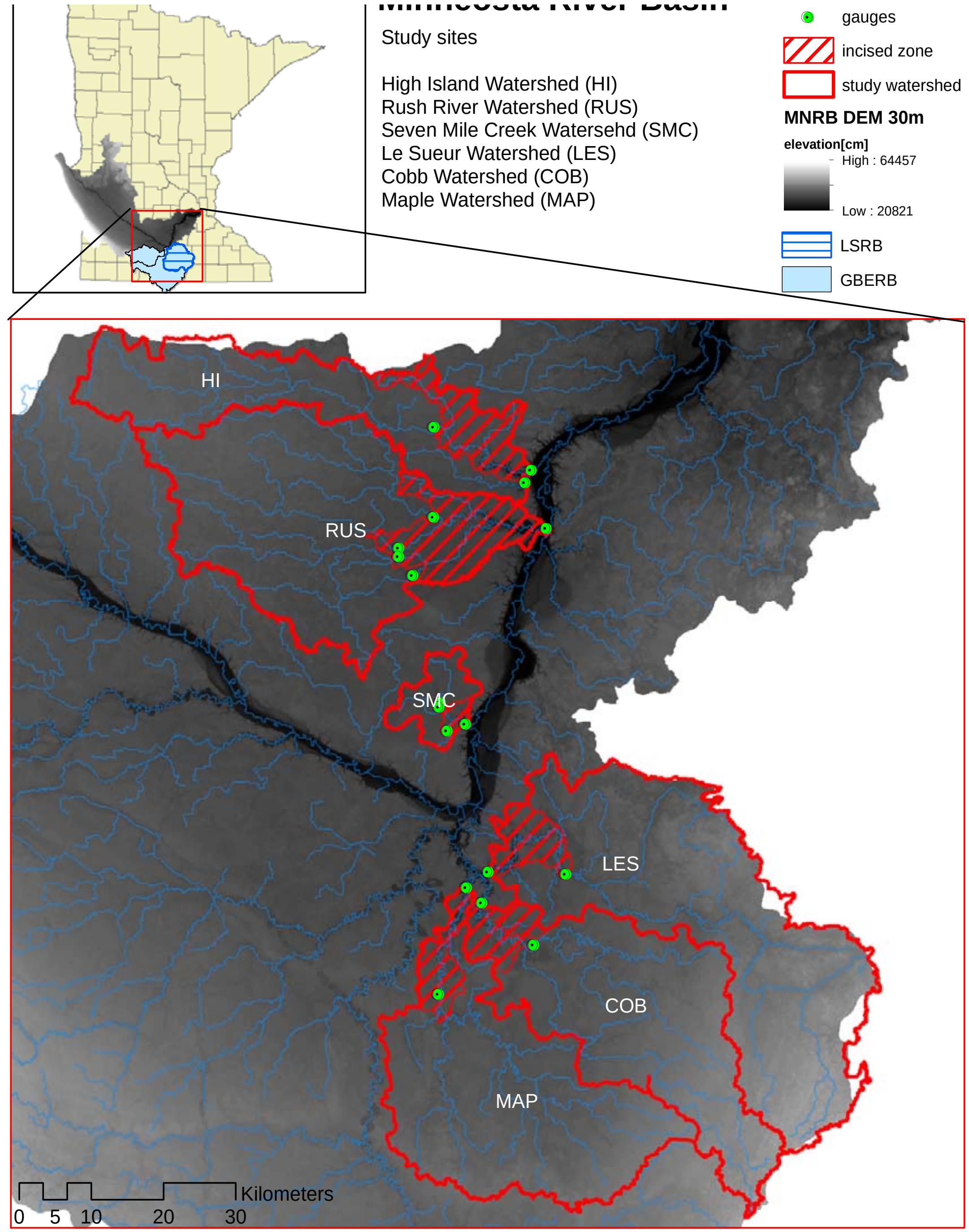
Challenges
(1) Sediment Delivery
(2) Near Channel Sources
(3) Management Options
(4) Interactions

How do we incorporate near-channel sources?

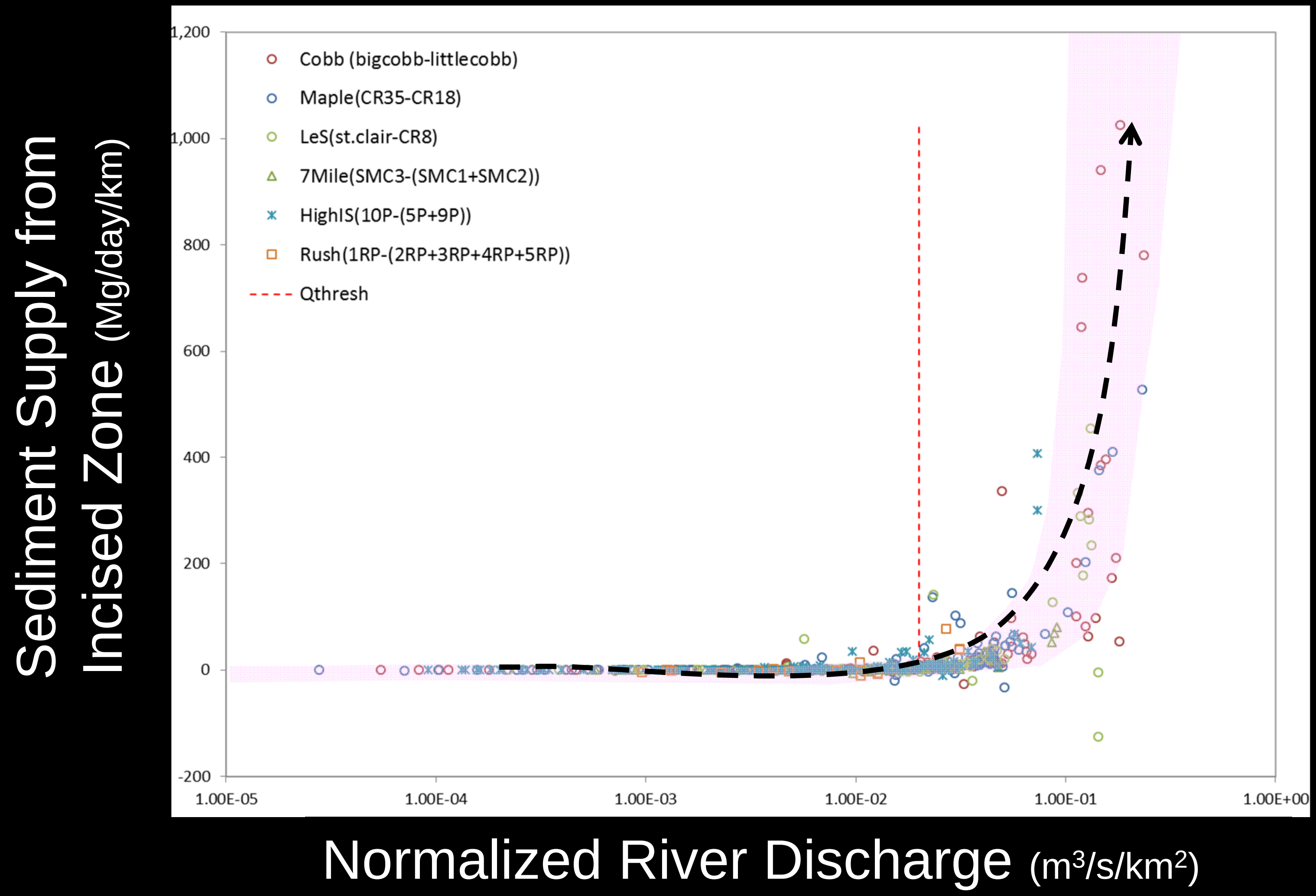


Challenges
(1) Sediment Delivery
(2) Near Channel Sources
(3) Management Options
(4) Interactions

And how are they affected by changes in hydrology?



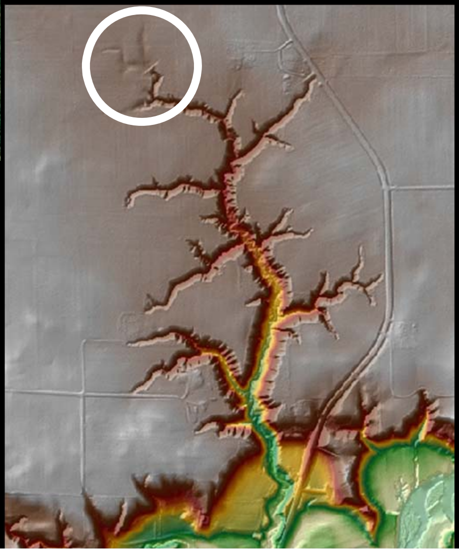
Bank and bluff erosion (near-channel erosion) is sensitive to hydrology. Erosion in the incised zone occurs primarily during peak flow events.



Cho, 2017

Challenges
(1) Sediment Delivery
(2) Near Channel Sources
(3) Management Options
(4) Interactions

Can we capture the many, many management options into a simpler set?



Management Options for Fields

1. Reduce erosion on field
2. Reduce sediment delivery ratio (SDR) from field to stream

Ravine management options

3. Reduce erosion on ravines through tip stabilization

Photo: StCroix360; Washington Conservation District

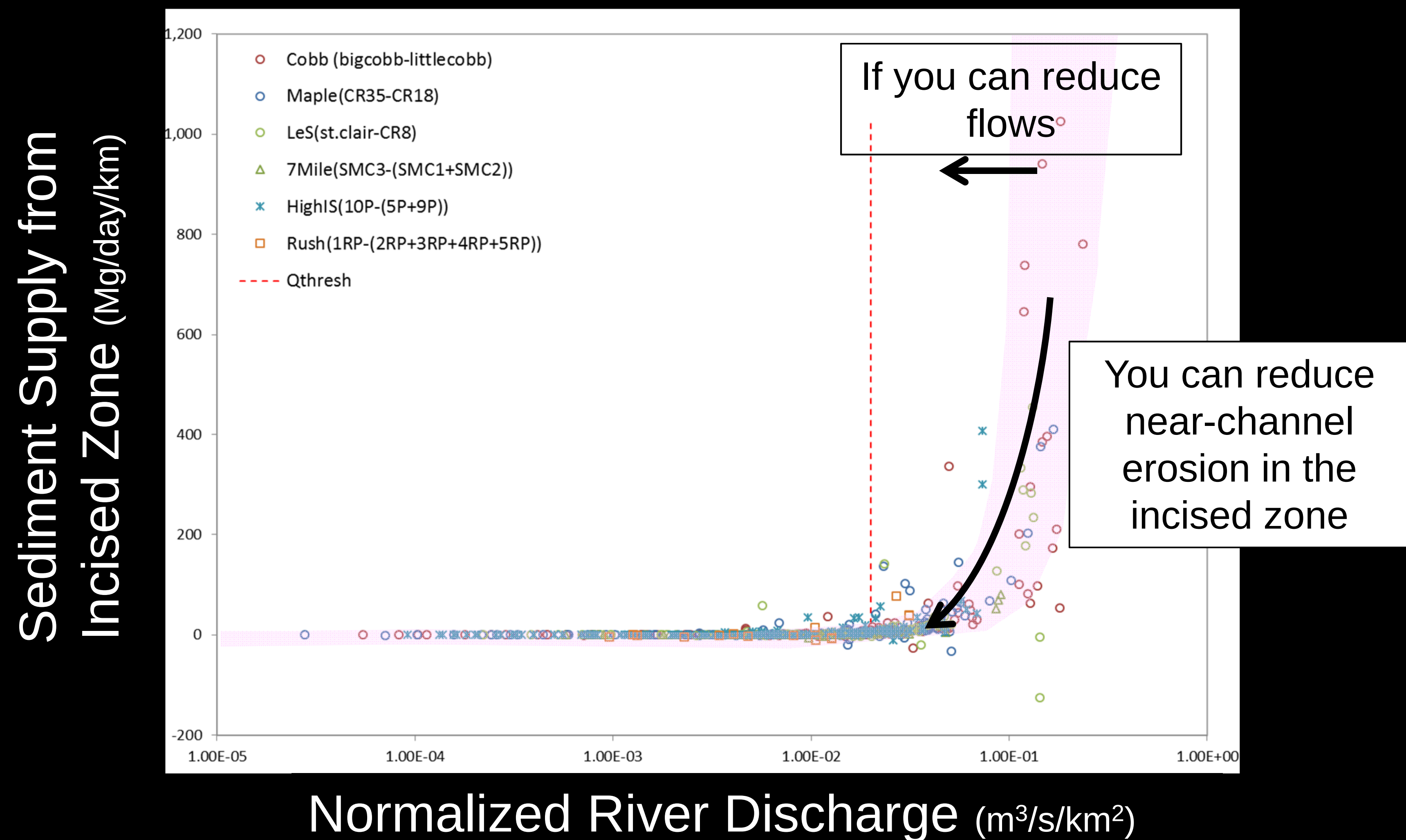
Bluff Management Options

4. Reduce erosion on bluffs via bluff stabilization

OR

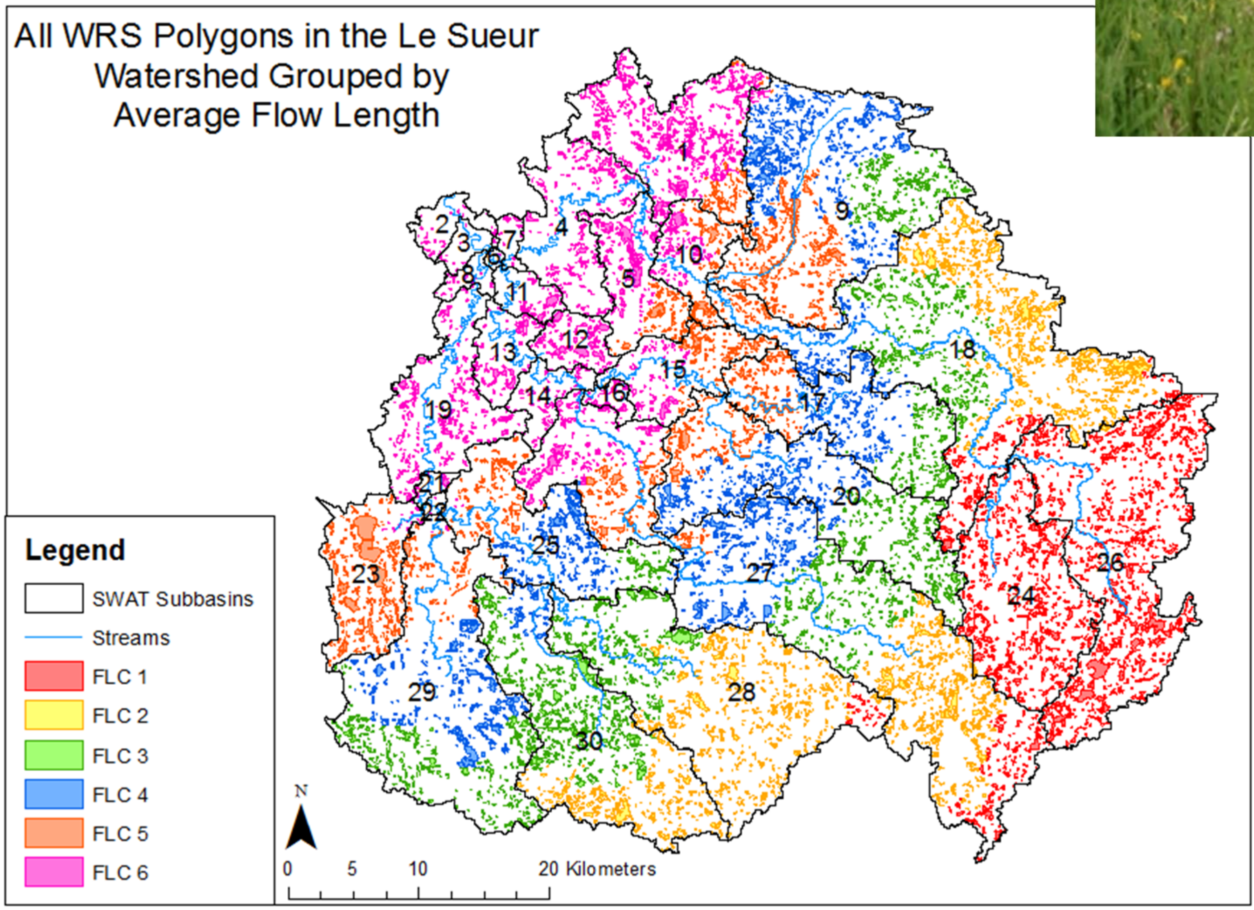
5. Reduce erosion on bluffs and banks via hydrology management

Reducing erosion via peak flow reduction



Cho, 2017

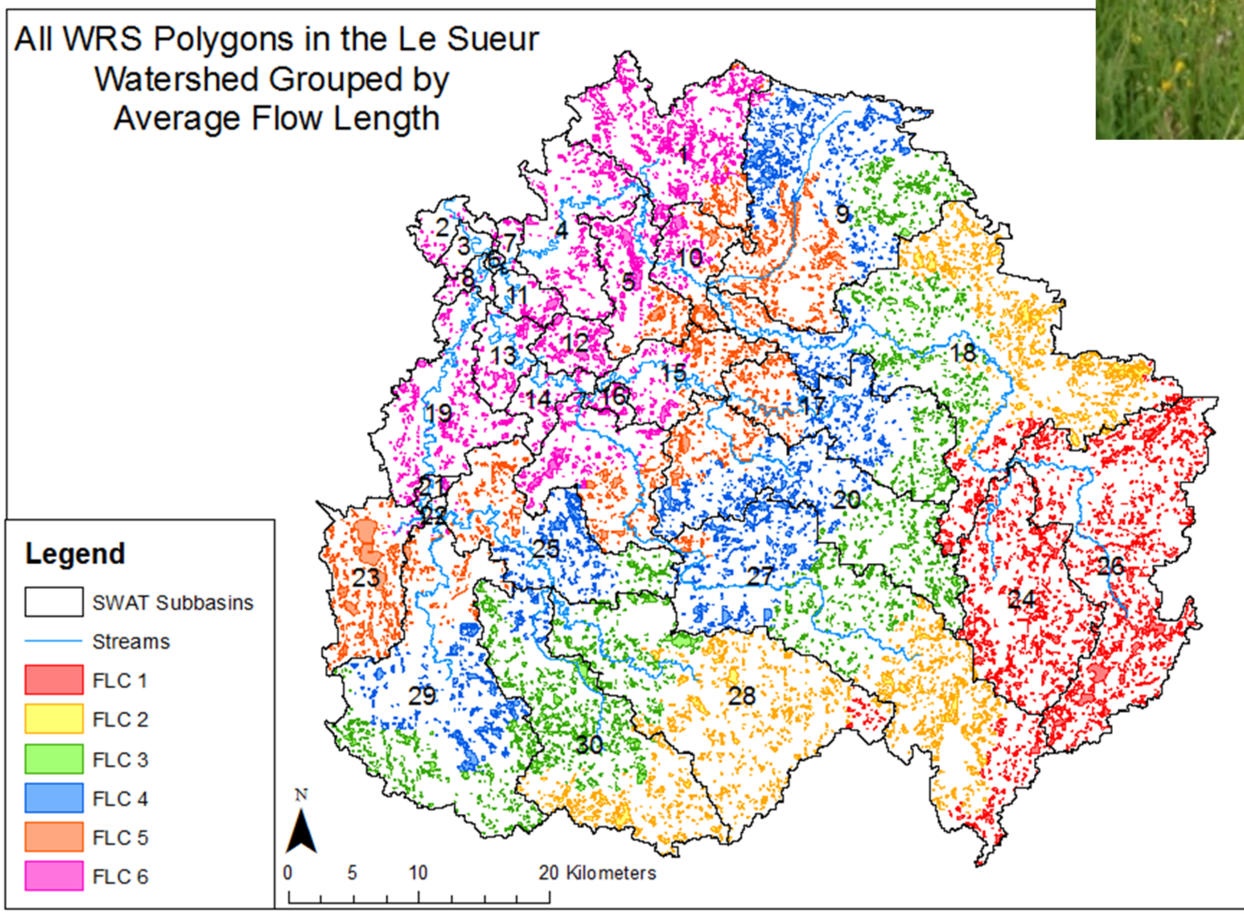
We mapped potential water storage sites in the watershed (closed depressions, hydric soils, CTI values)



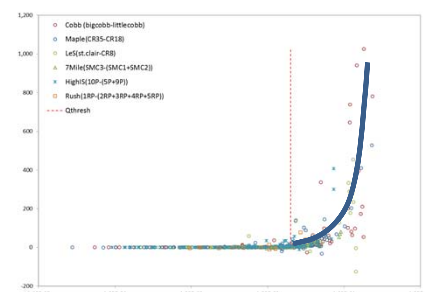
Mitchell et al., in prep

Add in water storage as a series of reservoirs that water flows through, with ET and seepage (WCMO).

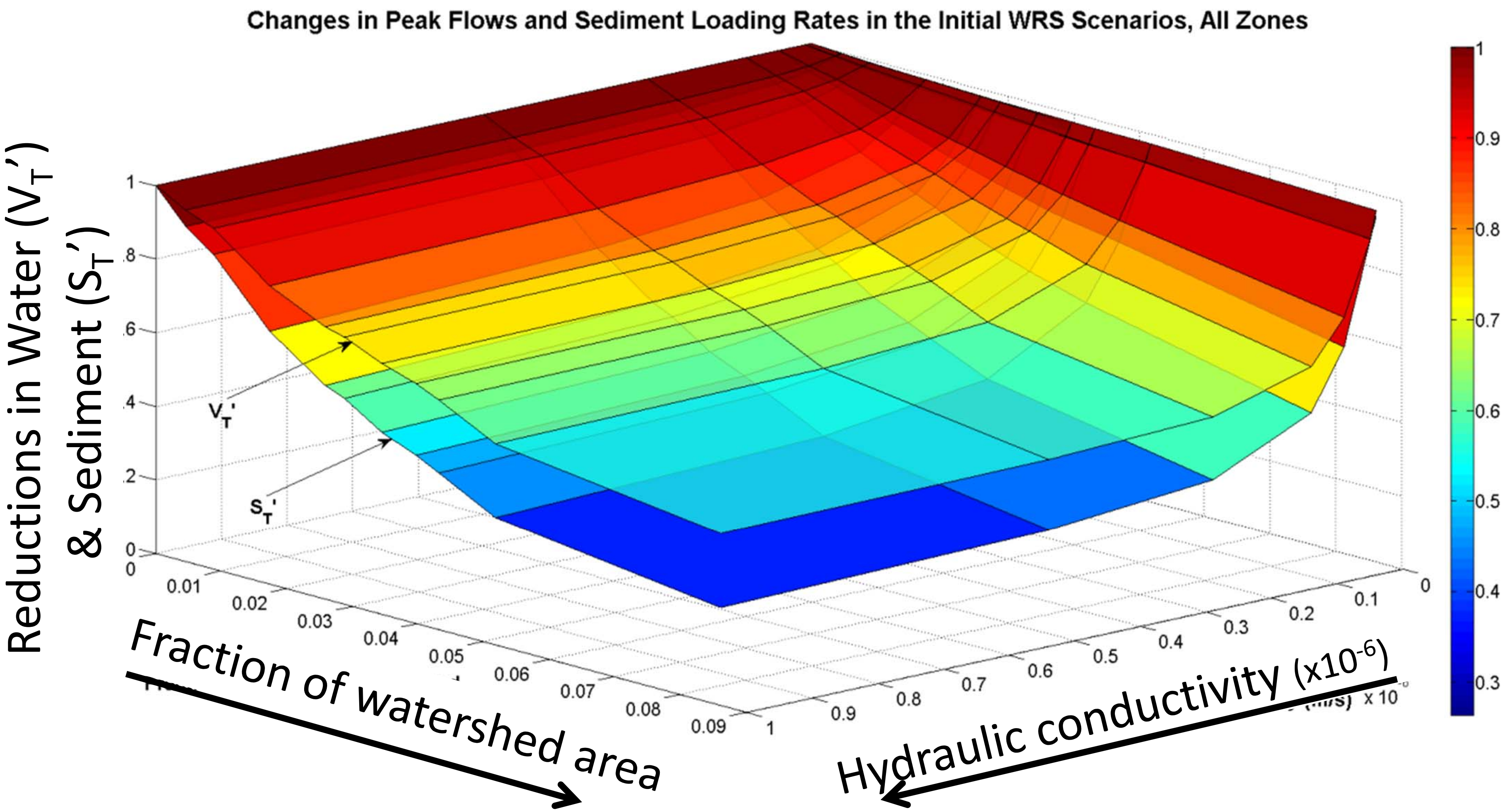
Also include in-ditch storage (ICMO)



Sediment reduction is determined from the “hockey stick” model



Mitchell et al., in prep

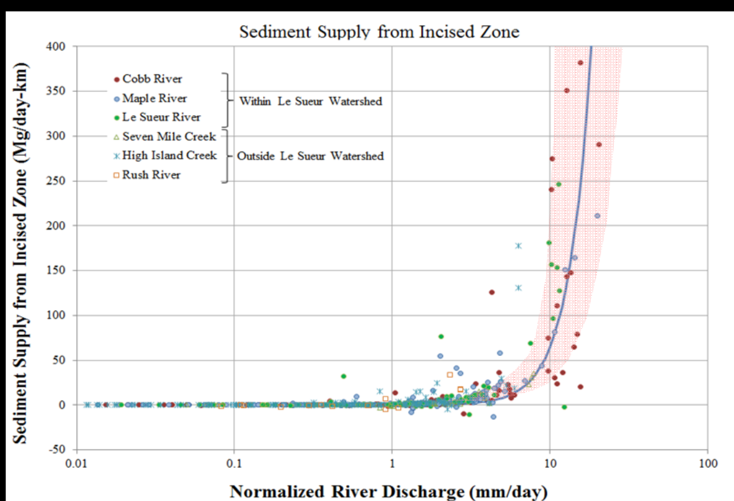


Compared favorably to results from SWAT model in Le Sueur. Water retention in the landscape can reduce peak flows and thus sediment loading. Dependent on area of water storage and K.

Mitchell et al., in prep

Challenges
(1) Sediment Delivery
(2) Near Channel Sources
(3) Management Options
(4) Interactions

We have to account for interactions among management options



River	LeSueur			Cobb			Maple			Extent	Extent	MO efficiency	Installation	Ann. Maintenance	Life Span	Total
Zone	Upland	Trans	Incised	Upland	Trans	Incised	Upland	Trans	Incised	inputed	selected	%	Cost	Cost	(yr)	Cost ($/yr)
Tillage Management Option (TLMO) ALLOCATION												**Tillage Management (TLMO) EFFECTIVENESS & COST**				
Extent of all farm land (	(i) 1,976	37,736	50,961	76,825	58,506	28,588	84,280	81,556	19,711	570,138	acre		Install. ($/ac)	Mntnc [$/(ac*yr)]	(yr)	Total ($/yr)
Conventional till (%)	33	33	33	33	33	33	33	33	33	190,046	142,534		26	8	1	4,846,171
Reduced till (%)	33	33	33	33	33	33	33	33	33	190,046	142,534		28	11	1	5,558,844
Conservation till (%)	33	33	33	33	33	33	33	33	33	190,046	285,069		14	6	1	5,701,378
Agricultural Field Management Option (AFMO) ALLOCATION												**Agricultural Field Management (AFMO) EFFECTIVENESS & COST**				
Extent of all MOs (ft)	(ii) ,638	153,344	163,291	259,759	192,325	94,596	254,013	230,363	44,849	1,882,178	AFMO*W [ac	Sed. Delivery	Install. ($/ac)	Mntnc [$/(ac*yr)]	Life Span	Cost ($/yr)
Input extent (ft)										-	2,167	75 %	3,200	64	10	3,211,682
Buffer Strip Management Option (BFMO) ALLOCATION												**Buffer Strip Management (BFMO) EFFECTIVENESS & COST**				
Extent of all MOs (ft)	(ii) ,389	332,417	600,050	615,745	475,117	379,555	647,512	647,400	175,287	4,943,473	BFMO*W [ac	Sed. Delivery	Install. ($/ac)	Mntnc [$/(ac*yr)]	Life Span	Cost ($/yr)
Input extent (ft)										-	9,964	100 %	1,000	45	10	11,873,978
Water Conservation Management Option (WCMO) ALLOCATION												**Water Conservation Management (WCMO) COST**				
Extent of all MOs (ac)	(iii) 424	4,676	6,637	7,791	5,142	3,324	7,871	8,158	1,553	60,577	WCMO [ac]	Sed. Delivery	Install. ($/ac)	Mntnc [$/(ac*yr)]	Life Span	Cost ($/yr)
Input extent (ac)										-	30,549	90 %	3,000	574	25	40,855,513
In-Channel Management Option (ICMO) ALLOCATION												**In-Channel Management (ICMO) COST**				
Extent of all MOs (ft)	(iii) 396	196,427	154,818	146,696	135,845	34,959	293,607	181,222	3,064	1,505,034	ICMO [ft]		Install. ($/ft)	Mntnc [$/(ft*yr)]	Life Span	Total ($/yr)
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-		250	1.4	10	0
Ravine Management Option (RAMO) ALLOCATION												**Ravine Management (RAMO) EFFECTIVENESS & COST**				
number of ravine tips	(v) -	-	275	-	-	132	-	14	196	617	RAMO [tips]	Sed. Erosion	Install. ($/TIP)	Mntnc [$/(tip*yr)]	Life Span	Total ($/yr)
Input number of tips	-	-	-	-	-	-	-	-	-	-	-	75 %	6,000	35	10	0
Near-Channel Source Management Option (NCMO) ALLOCATION												**Near-Channel Source Management (NCMO) EFFECTIVENESS & COST**				
Extent of all MOs (ft)	(iv) 774	3,061	60,676	8,222	4,091	44,997	3,520	11,175	46,831	252,346	NCMO [ft]	Sed. Erosion	Install. ($/ft)	Mntnc [$/(ft*yr)]	Life Span	Total ($/yr)
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-	70 %	200	0.7	5	0

(i) Reduce rate of soil erosion (TILMO)

(ii) Keep more eroded soil on fields and out of streams (AFMO; BFMO)

(iii) Store water, reducing peak flows in streams in order to reduce bluff and bank erosion (WCMO, ICMO)

(iv) Stabilize bluffs and banks to reduce erosion and inputs (NCMO)

(v) Reduce erosion from ravines (RAMO)

To review the Management Options…

River	LeSueur			Cobb			Maple			Extent	Extent	MO efficiency	Installation	Ann. Maintenance	Life Span	Total
Zone	Upland	Trans	Incised	Upland	Trans	Incised	Upland	Trans	Incised	inputed	selected	%	Cost	Cost	(yr)	Cost ($/yr)
Tillage Management Option (TLMO) ALLOCATION												**Tillage Management (TLMO) EFFECTIVENESS & COST**				
Extent of all farm land (	131,976	37,736	50,961	76,825	58,506	28,588	84,280	81,556	19,711	570,138	acre		Install. ($/ac)	Mntnc [$/(ac*yr)]	(yr)	Total ($/yr)
Conventional till (%)	33	33	33	33	33	33	33	33	33	190,046	142,534		26	8	1	4,846,171
Reduced till (%)	33	33	33	33	33	33	33	33	33	190,046	142,534		28	11	1	5,558,844
Conservation till (%)	33	33	33	33	33	33	33	33	33	190,046	285,069		14	6	1	5,701,378
Agricultural Field Management Option (AFMO) ALLOCATION												**Agricultural Field Management (AFMO) EFFECTIVENESS & COST**				
Extent of all MOs (ft)	489,638	153,344	163,291	259,759	192,325	94,596	254,013	230,363	44,849	1,882,178	AFMO*W [ac	Sed. Delivery	Install. ($/ac)	Mntnc [$/(ac*yr)]	Life Span	Cost ($/yr)
Input extent (ft)										-	2,167	75 %	3,200	64	10	3,211,682
Buffer Strip Management Option (BFMO) ALLOCATION												**Buffer Strip Management (BFMO) EFFECTIVENESS & COST**				
Extent of all MOs (ft)	1,070,389	332,417	600,050	615,745	475,117	379,555	647,512	647,400	175,287	4,943,473	BFMO*W [ac	Sed. Delivery	Install. ($/ac)	Mntnc [$/(ac*yr)]	Life Span	Cost ($/yr)
Input extent (ft)										-	9,964	100 %	1,000	45	10	11,873,978
Water Conservation Management Option (WCMO) ALLOCATION												**Water Conservation Management (WCMO) COST**				
Extent of all MOs (ac)	15,424	4,676	6,637	7,791	5,142	3,324	7,871	8,158	1,553	60,577	WCMO [ac]	Sed. Delivery	Install. ($/ac)	Mntnc [$/(ac*yr)]	Life Span	Cost ($/yr)
Input extent (ac)										-	30,549	90 %	3,000	574	25	40,855,513
In-Channel Management Option (ICMO) ALLOCATION												**In-Channel Management (ICMO) COST**				
Extent of all MOs (ft)	358,396	196,427	154,818	146,696	135,845	34,959	293,607	181,222	3,064	1,505,034	ICMO [ft]		Install. ($/ft)	Mntnc [$/(ft*yr)]	Life Span	Total ($/yr)
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-		250	1.4	10	0
Ravine Management Option (RAMO) ALLOCATION												**Ravine Management (RAMO) EFFECTIVENESS & COST**				
number of ravine tips	-	-	275	-	-	132	-	14	196	617	RAMO [tips]	Sed. Erosion	Install. ($/TIP)	Mntnc [$/(tip*yr)]	Life Span	Total ($/yr)
Input number of tips	-	-	-	-	-	-	-	-	-	-	-	75 %	6,000	35	10	0
Near-Channel Source Management Option (NCMO) ALLOCATION												**Near-Channel Source Management (NCMO) EFFECTIVENESS & COST**				
Extent of all MOs (ft)	69,774	3,061	60,676	8,222	4,091	44,997	3,520	11,175	46,831	252,346	NCMO [ft]	Sed. Erosion	Install. ($/ft)	Mntnc [$/(ft*yr)]	Life Span	Total ($/yr)
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-	70 %	200	0.7	5	0

(1) Determine extent over which Management Options can be implemented

(2) Specify efficiency and cost of Management Options

(3) Specify extent of the MO

Then,

(4) Allocate specified Management Option extents across zones and basins

(5) Reduce soil erosion rate (TLMO)

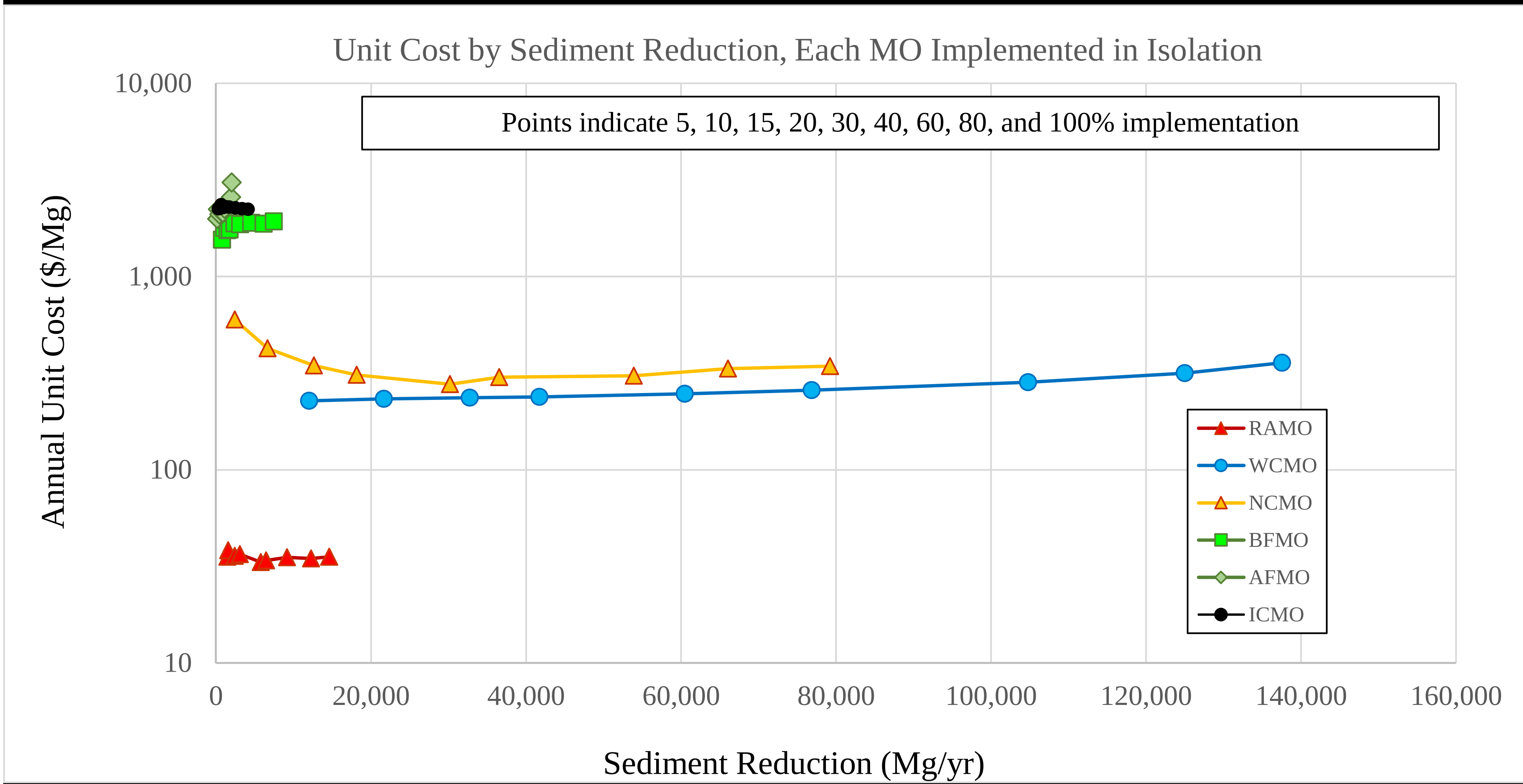
(6) Trap some eroded sediment on field (AFMO)
or in stream buffers (BFMO)

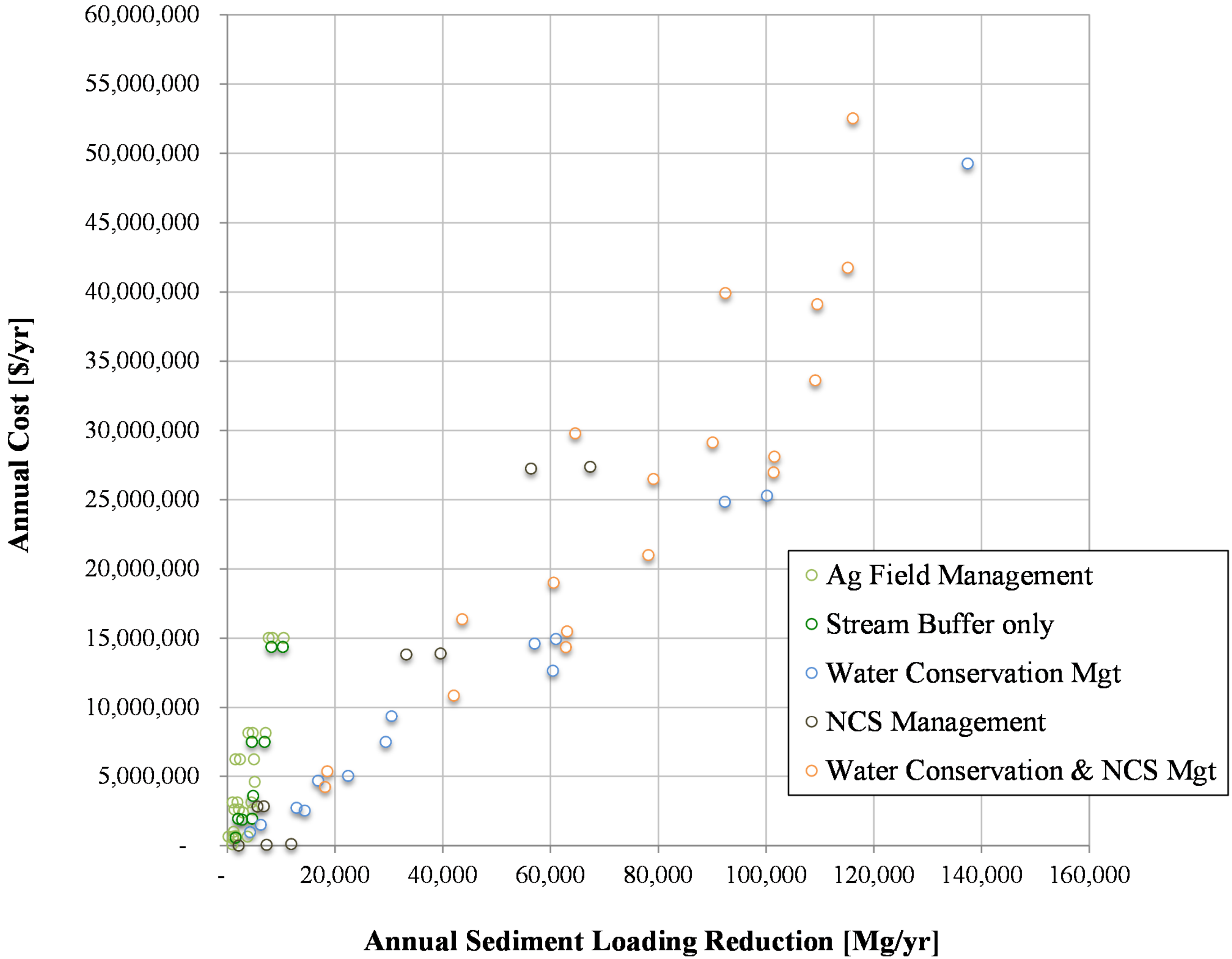
(7) Store water on field and in channels (WCMO, ICMO)

(8) Reduce bluff and bank erosion (reduced peak flows; NCMO)

(9) Reduce sediment erosion in ravines (RAMO)

All eroded sediment is reduced by sediment delivery ratio in streams


Unit Cost by Sediment Reduction, Each MO Implemented in Isolation
Points indicate 5, 10, 15, 20, 30, 40, 60, 80, and 100% implementation
Annual Unit Cost ($/Mg)
10,000
1,000
100
10
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Sediment Reduction (Mg/yr)
RAMO
WCMO
NCMO
BFMO
AFMO
ICMO



Annual Cost [$/yr]
60,000,000
55,000,000
50,000,000
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
-
-
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Annual Sediment Loading Reduction [Mg/yr]
Ag Field Management
Stream Buffer only
Water Conservation Mgt
NCS Management
Water Conservation & NCS Mgt

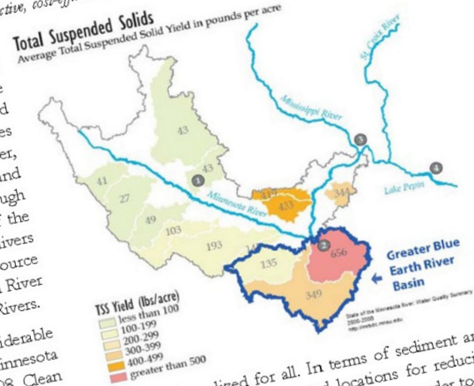
Consensus strategy

Collaborative for Sediment Source Reduction – Greater Blue Earth River Basin
Summary of Findings

The Collaborative for Sediment Source Reduction (CSSR) was a five-year effort to evaluate strategies for sediment source reduction in the Greater Blue Earth River Basin. With support from local, state, agribusiness, and environmental organizations, a diverse stakeholder group met nine times to evaluate watershed strategies for reducing sediment loading to the Minnesota River and beyond.

CSSR Goal: *To identify a strategy for reducing sediment loading in the Greater Blue Earth watershed using a decision framework that incorporates the best available scientific information, accounts for uncertainty, and provides a model for decision making throughout the Minnesota River Basin. We hope that the strategy developed will be effective, cost-efficient, fair, and supported by all stakeholders.*

There are numerous reasons to be concerned about sediment loading from the Blue Earth River Basin. The Minnesota River and many of its tributaries, including the Blue Earth, are known to be impaired for suspended solids. This causes problems downstream. Sediment causes deposition problems on the lower Minnesota River, degrades water quality in the Mississippi River, and increases the rate at which Lake Pepin is filling. Although the Minnesota River delivers only about one-third of the water to the Mississippi River and Lake Pepin, it delivers more than two-thirds of the sediment. The largest source of sediment to the Minnesota River is the Blue Earth River Basin, which includes the Watonwan and Le Sueur Rivers.



The citizens of Minnesota are committing considerable public funding to improve water quality in the Minnesota River, particularly with the passage of the 2008 Clean Water Land and Legacy Amendment. It is important that these funds are spent effectively, such that the benefit of cleaner water is realized for all. In terms of sediment and turbidity, that means we need to identify the most cost-effective conservation practices and locations for reducing excess soil and sediment erosion, along with associated phosphorus. We also need to think more broadly in order to set priorities for conservation investment throughout the watershed.

The Collaborative for Sediment Source Reduction (CSSR) was launched with the goal of developing an agreed-upon strategy for reducing sediment delivery from the Blue Earth River Basin. At the heart of CSSR was a group of local, state, and industry stakeholders with whom we developed a model to forecast changes in sediment loading in response to different combinations of conservation practices. Combined with information on the cost and effectiveness of different management options, the group used the model to evaluate watershed strategies for reducing sediment loading.

In addition to identifying the best methods and locations for reducing excess erosion and sediment delivery, solving the loading problem depends on a shared understanding of the issues among stakeholders, including farmers, producer groups, conservation groups, and regulatory agencies. CSSR provided a forum for different interests to work together to evaluate different conservation strategies. We focused on understanding how the landscape works, rather than assigning responsibility for its current condition or tackling the social challenges of funding and implementation. We hoped that a common understanding would lead to an agreed-upon strategy that would drive action to address this important problem. The watershed is large and there were many considerations. A key question concerned the best balance between directly reducing erosion of local sources (fields, ravines, streambanks, and bluffs) and indirectly reducing erosion by controlling runoff and reducing high river flows.

FRESHWATER SOCIETY
MAWRC Minnesota Agricultural Water Resource Center
NSF
St. Anthony Falls Laboratory
Minnesota Pollution Control Agency
Clean Water Land & Legacy Amendment
Minnesota Department of Agriculture

Summary of findings

1. *Ravines that are large local sources of sediment can be targeted. Investment in stabilizing these ravines is worthwhile, but not sufficient to reduce sediment loading to meet water quality standards.*

Summary of findings

2. *Eroding bluffs that threaten infrastructure and produce exceptionally large amounts of sediment can be targeted. Investment in stabilizing these bluffs is worthwhile, but bluff stabilization is not the most effective solution for long-term reduction in sediment loading across the watershed.*

Summary of findings

3. Achieving water quality standards will require priority investment in more temporary water storage to reduce high river flows and bluff erosion. This is a critical component of a strategy to reduce sediment in the Minnesota River.

There are some great examples to follow

nty JD 8 Restoration Project, Kriter, Magner and others

ner

1

BE County Ditch 57 Restoration Project, Duncanson, Brandel, BEC

Questions?

Karen Gran, *on behalf of many*
UMD Earth & Environmental Sciences
kgran@d.umn.edu

Thanks to our funding agencies!

Minnesota Pollution Control Agency

MAWRC
MINNESOTA AGRICULTURAL WATER RESOURCE CENTER

CLEAN WATER LAND & LEGACY AMENDMENT

MINNESOTA DEPARTMENT OF AGRICULTURE

CSSR
Collaborative for Sediment Source Reduction