Slowing the Flow: Setting Priorities and Defining Success in Lake Superior's South Shore Watersheds

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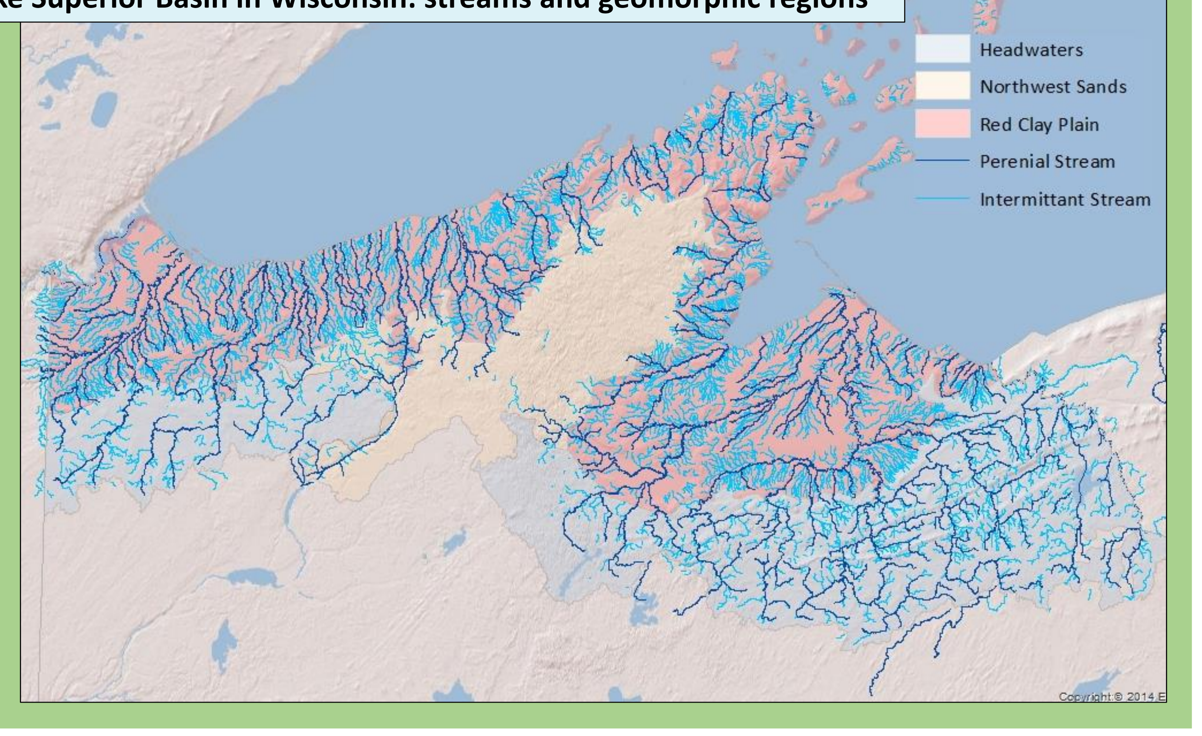
Introduction

- Many efforts to improve water quality in Wisconsin's Lake Superior basin have focused on the "slow the flow" approach, which seeks to reduce peak flows using landscape-scale watershed restoration to increase in-channel roughness, upland roughness, upland retention and infiltration. As the frequency of high intensity storms increases, improved methods to prioritize slow the flow efforts and measure success are needed.
- Through extensive literature review, we identified metrics and associated thresholds for landscape scale watershed restoration, and compiled the best available datasets to evaluate those metrics. Recommendations based on that review provide a framework for prioritizing and evaluating slow the flow efforts on the south shore of Lake Superior in Wisconsin.
- Newly available spatial data layers, for example the updated Wisconsin Wetland Inventory, Potentially Restorable Wetlands and others, now allow us to implement recommendations by identifying and prioritizing specific restoration and protection opportunities across all of Wisconsin's south shore watersheds.

Landscape Setting

- Lake Superior's south shore watersheds are situated in clay-rich glacial and lacustrine soils deposited during the most recent ice age.
- Heavy clay soils line the coast and transition to sandy soils further inland. Since the last ice age, lower reaches of streams incised through glacial sediments, creating a transition zone in the middle portion of the watersheds. This area is characterized by steep stream slopes, narrowing valley walls, and a transition from clay-rich soils to sandy soils.
- Transition zone areas can be more prone to erosion and gully formation due to concentrated runoff flow and/or shallow groundwater seeping at the clay soil/sand soil boundary.
- The central portion of the Bayfield Peninsula is characterized by deep glacial outwash sand with gravel deposits. This area drains rapidly and provides substantial groundwater recharge for surrounding streams.

Lake Superior Basin in Wisconsin: streams and geomorphic regions



Stream Flow: Peak Discharge

An understanding of peak flows in south shore streams is integral to efforts to improve and evaluate slow the flow efforts. Increases in peak flows attributed to the intensity and duration of large storm events has substantial effects on in-channel and bluff erosion processes and sediment movement, with corresponding effects on water quality.

The National Stream Statistics (NSS) is an easy to use program which provides regression equations for every state in the US to estimate streamflow statistics including peak discharge at ungauged sites (Walker and Krug, 2003). Using this program, we first calculated peak discharges for 1,600 pour point south shore sub-watersheds.

NSS Regression Equation Parameters for Northern Wisconsin Peak Streamflow
Watershed Size
Annual Snowfall
Soil Permeability
Storage
Stream Slope

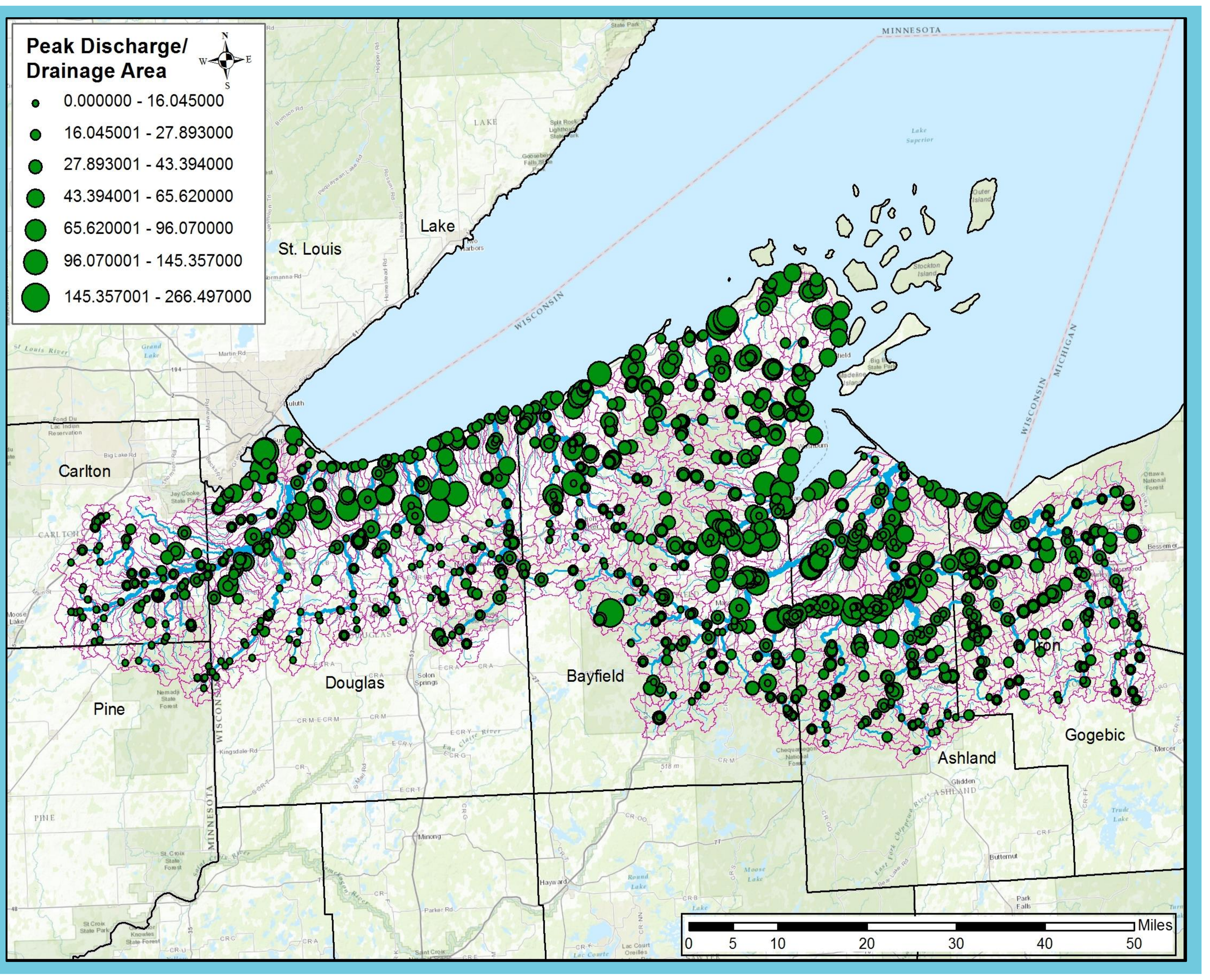
Then, we calculated the 2 year peak discharge to drainage area ratio (map at right).

- Identifies "flashiest" watersheds in region
- Provides indication of parameters driving accelerated runoff, which can be used to focus restoration efforts.

Recommendation:

- Prioritize watersheds with high peak discharge to drainage area ratios for wetland restoration, reforestation, agricultural BMPs, and increasing in-channel and upland roughness.

Metrics & Datasets: NHD+ watersheds and catchments, 2 year peak discharge/drainage area, amount of Potentially Restorable Wetlands, % open lands, % forest, and % agricultural land use.



Watershed Storage

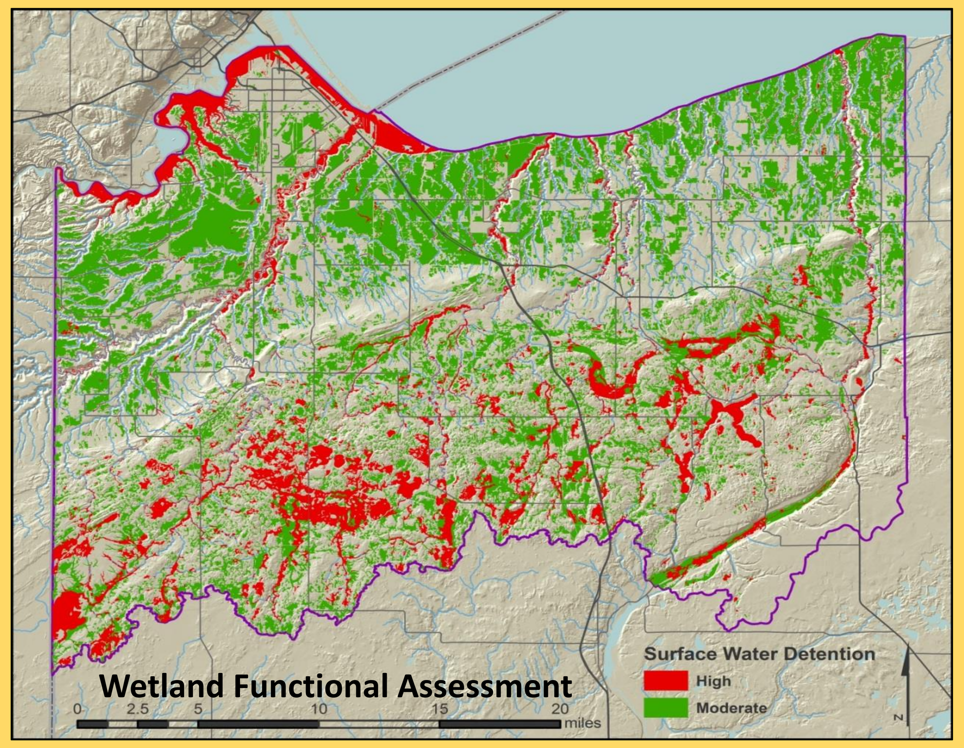
Increased watershed storage increases flow duration, reduces peak flows, and is therefore a high priority in the Lake Superior basin. Below watershed storage thresholds of 5 % - 24%, increases in peak flows can be observed.

Recommendation: Reestablish wetlands where they can maximize storage and desynchronize flows in both agricultural and forested settings.

Far Left: Drainage ditch in agricultural field pre-restoration. Left: Wetland restoration provides water storage benefits post restoration. Photos courtesy of Ted Koehler.

Recommendations for increasing wetland storage	Datasets & Metrics
• Target watersheds with less than 15% storage • Target watersheds with open lands greater than 50%	*Wisconsin Wetland Inventory* (WWI) - Available for Lake Superior basin. • Existing distribution and extent of wetlands digitized from aerial photos.
• Target watersheds with wetland losses greater than 30%	*Potentially Restorable Wetlands* (PRW) – Available for Lake Superior basin, with further refinements available for Douglas County and Marengo watershed. • Identifies likely historic wetlands using soils, flow pathways, and slopes.
• Investigate potential for installing wetlands in agricultural ditches • Design wetland restoration sites to drawn down when possible • Promote multiple small projects in headwaters for cumulative increase, preferably in parallel	*Functional Wetland Assessment* (NWI+) - Available for Douglas County, in progress for Marengo and Nemadji watersheds. • Wetlands/waterbodies are characterized by Landscape Position, Landform, Waterbody type and Water flow path.

Below: Map of potentially restorable wetlands for the Bad River.



Above: Distribution of PRWs that can provide flood attenuation functions in Douglas Co. Analysis and image provided by St. Mary's Geospatial Services .

Turning Science into Action

A **multi-metric decision matrix** is a quantitative technique used to rank the multi-dimensional factors influencing a set of options.

- Frequently used in engineering for making design decisions but can also be used to rank investments options, vendor options, product options or any other set of multidimensional entities.
- A basic decision matrix consists of establishing a set of weighted criteria upon which the potential options can be decomposed, scored, and summed to gain a total score which can then be ranked.

Slow The Flow Decision Support

Our literature review compiles the existing understanding of landscape scale conditions and hydrologic effects. Our peak discharge analysis identifies watersheds with accelerated flow. A multi-metric decision support matrix (such as the example below) will incorporate the watersheds with accelerated flow along with the additional factors discussed here to identify priority locations and priority practices to reduce peak flows. This work (currently in development) will help support decision making for slow the flow on the south shore of Lake Superior in Wisconsin.

Watershed ID	*Peak discharge/ drainage area ratio*	*Amount of storage (lakes and wetlands)*	*Amount of potentially restorable wetlands*	*Wetland functional assessment*	*Proportion of Open Lands*	*Proportion of forest*	*Amount of inactive farmland*	*Transition Area/Soils – Soil Permeability*	Totals
1									
2									
3									
4									
5									
6									
Weights									

In-channel and Upland Roughness

Upland and in-channel roughness controls boundary shear stress and the ability of water to erode sediment. Roughness can be influenced by all types of vegetation and the soil duff layer for upland areas, and by woody debris and vegetation in channels.

Recommendations for Upland Roughness

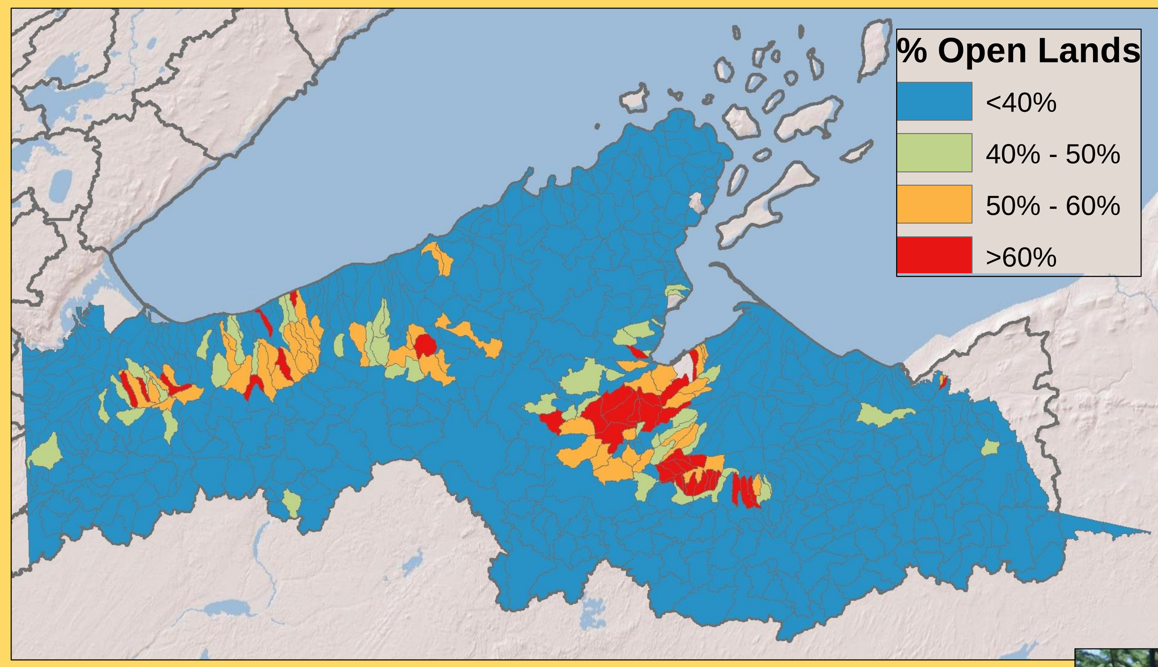
- For groundwater-flow driven gullies, increase interception with coniferous tree plantings.
- For surface-flow driven gullies, increase roughness to promote infiltration. Use vegetative filter strips and detention basins at the heads of gullies.

Recommendations for In-channel Roughness

- Focus efforts in upper reaches of the Basin.
- Address stability of upper bluffs including bluff slope and seeps.

Metrics & Datasets: Opportunities to increase roughness can be evaluated at the landscape- to project-scale using a range of datasets including remote sensing data (LiDAR, aerial photos, etc); and project-based field data collection.

Left: Roughness elements installed in upland gullies of the Bark River. Photo courtesy of Faith Fitzpatrick.



Map left: 2009 Open Lands. Existing management plans recommend increasing forest cover and watershed storage in subwatersheds with more than 40 - 60% open lands.

Below: Riparian tree planting provides many benefits.

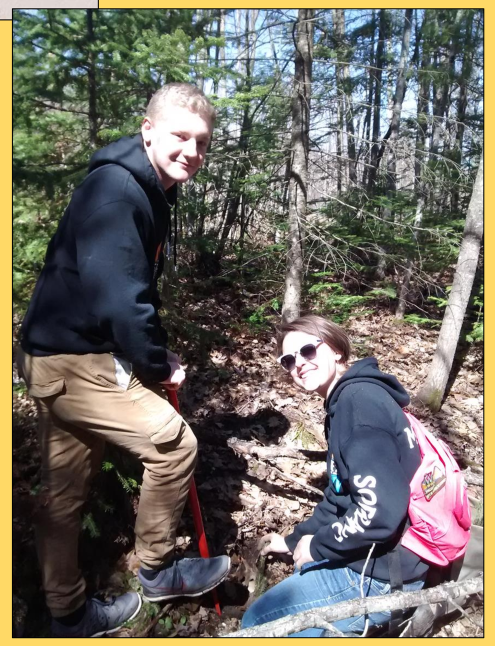
- Shading/temperature regulation
- Wildlife habitat & corridors
- Increased roughness
- Increased floodplain infiltration
- Wood recruitment to stream
- Reduced bank/floodplain erosion

Forestry Land Use

Forests influence stream hydrology through snowpack accumulation, snow melt, interception of rain events, and evapotranspiration. The age, composition, and structure of forests impact the volume and timing of runoff received in the waterway. Past and present land use practices have converted pre-settlement boreal forest-dominated communities to aspen-dominated communities, and shifted age structures to be dominated by younger trees.

Recommendations:

- Establish a target for percent open lands and given scale. For example, reduce or maintain less than 50 – 60% open land by subwatershed of 1-2km scale.
- Maintain forest composition mimicking pre-settlement conditions with an emphasis on mature, shade-tolerant species.
- Look to establish and expand riparian management zones on public and private lands.
- Prohibit harvest of live/dead trees within 30 meters of channel to promote wood recruitment to streams to increase roughness.



Metrics & Datasets: Establish a regular means to obtain and evaluate open lands by subwatershed to assess open lands targets.

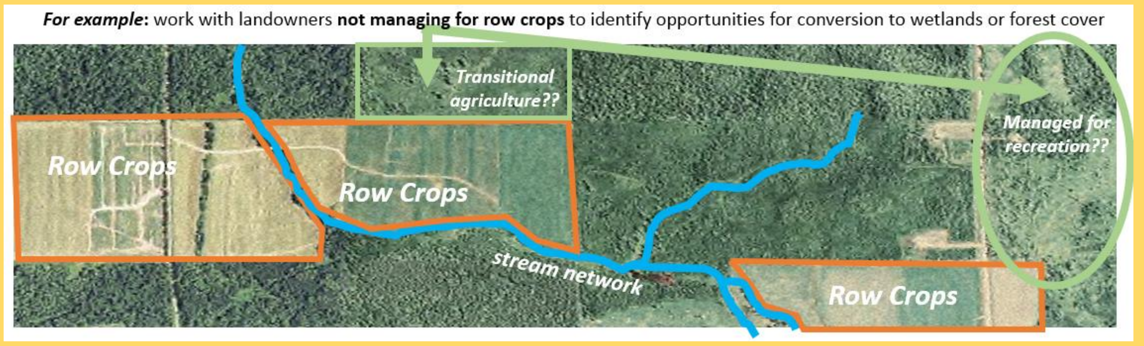
Agricultural Land Use

Watersheds with more open lands, especially high-intensity agricultural lands, have increased peak flows. Clay-rich soils limit infiltration, and frequent compaction due to equipment use during wet periods may further limit infiltration.

Recommendations: The extent to which agricultural BMPs effect hydrology is difficult to quantify and currently debated. To increase effectiveness of slow the flow efforts in agriculture-dominated watersheds, we recommend the following:

- Non-point Source Trading: The largest reductions in peak flows will be from land use conversion. Explore within-watershed opportunities to offset agriculture-related increases in runoff by increasing wetland storage and forest cover.
- Explore opportunities to diversify crops and promote short rotation woody crops which may increase infiltration compared to traditional crops, while meeting biomass energy demands.
- In areas of high-intensity agriculture, BMPs like those shown at the right should continue to be promoted to increase infiltration and limit runoff. For full table, see Lewandowski et al., 2015.

For example: work with landowners **not managing for row crops** to identify opportunities for conversion to wetlands or forest cover



Left: A coppiced hybrid poplar stand (background) with more spring snow retention than a mature hybrid poplar stand (foreground)

Right: a willow snow fence with spring snow retention

Example of on-farm BMP's and their effect on hydrology. Modified from Lewandowski et al., 2015	Increase spring transpiration	Increase filtration	Increase soil water holding capacity	Reduce peak flows
1. IN-FIELD: CROP AND SOIL MANAGEMENT				
Perennial crops, and crop rotations with winter annuals	•	•	•	•
Cover crops	•	•	•	•
Reduced tillage, contour cropping & residue management		•	•	
2. INFIELD: DRAINAGE WATER MANAGEMENT				
Alternative drainage design (depth, spacing, capacity)		•		

Metrics and Datasets: NASS Cropland Data Layer is reproduced annually and can be used to evaluate changes in land cover including high-intensity agriculture, low-intensity agriculture, and forested land use (Boryan, et al., 2011).

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