Assessing the Impact of Alternative Management Strategies in a Dairy-dominated Agricultural Watershed Vulnerable to High Sediment and P Runoff

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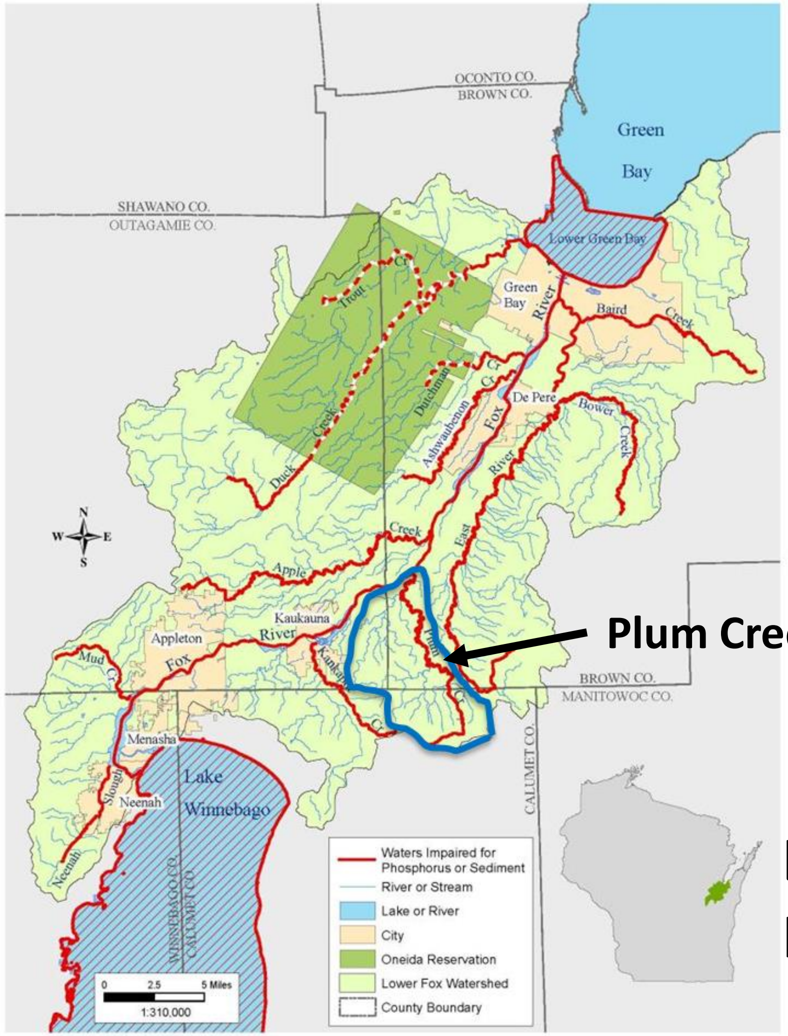
Outline

Project overview

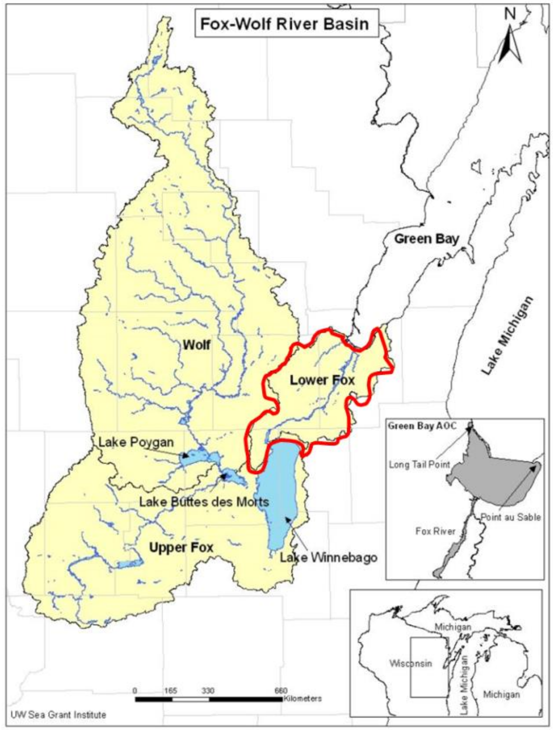
Calibration and Validation

BMP Applications

Summary

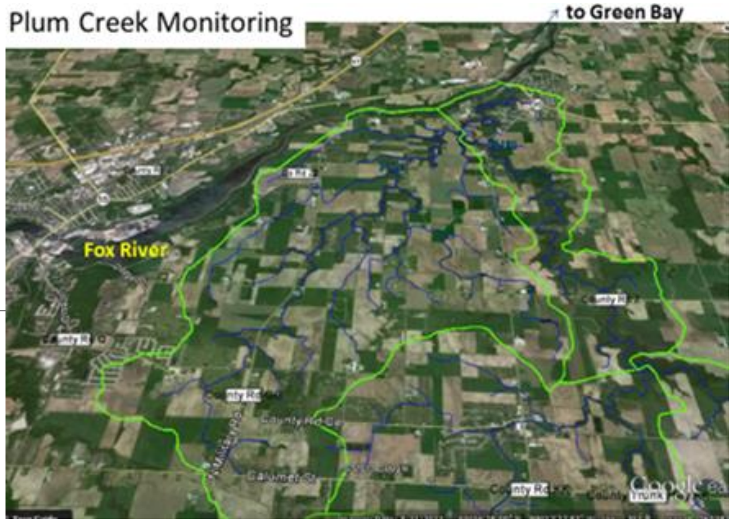


Plum Creek

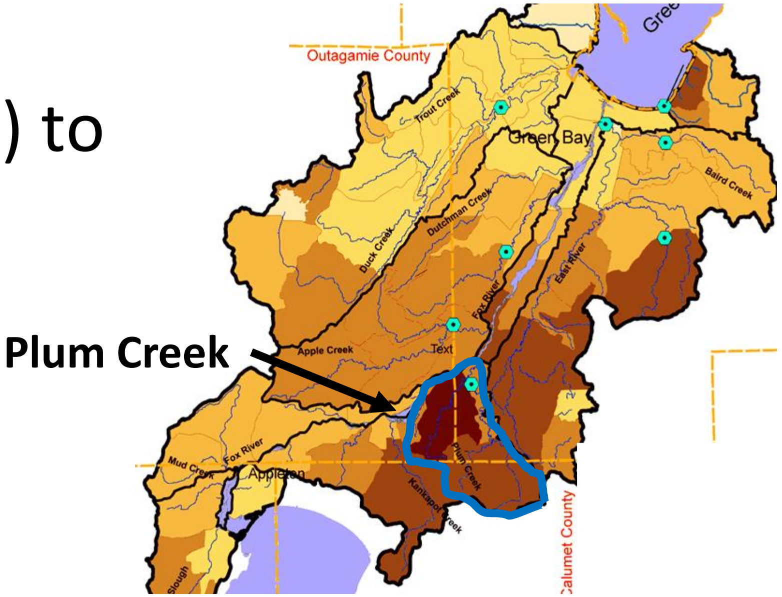


Lower Fox River
Impaired waters (red)

Study Site: Plum Creek Watershed



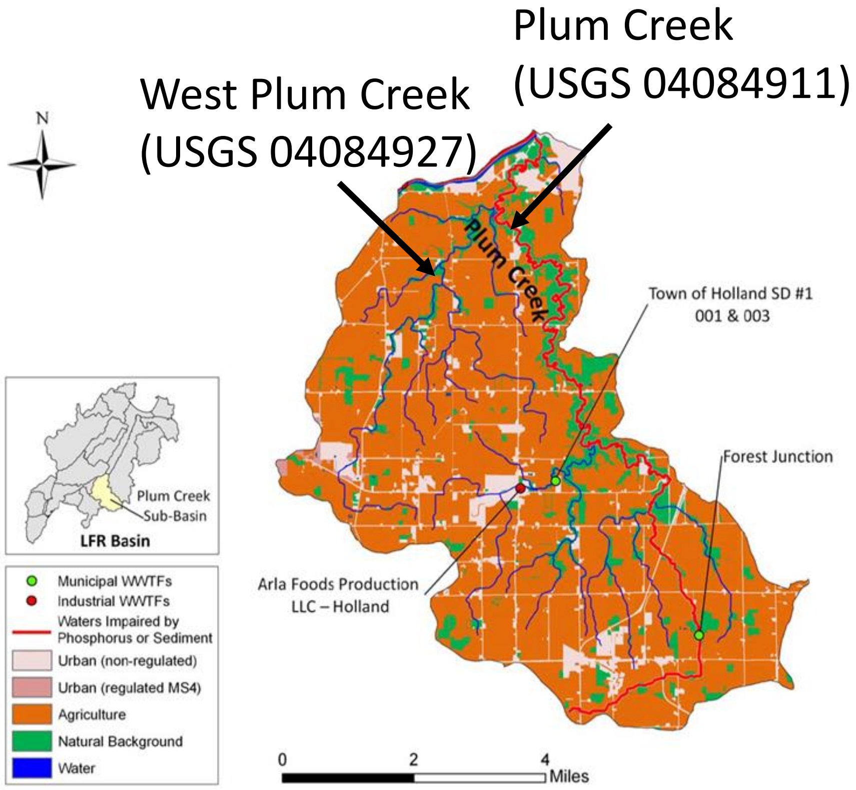
- 9,010 ha (90.1 km^2)
- High density of intensive farming (76% ag.)
- Part of the Lower Fox River TMDL
- Highest contributor of sediment and phosphorus (P) to the Lower Fox River & the Bay of Green Bay
- WY 2011 – 2013 average yields (measured)
  - TSS: 1.04 tons/ha
  - Total P: 2.00 kg/ha



TP Yields to Green Bay (2012 TMDL)

Project Overview

- Simulate impacts of alternative management (BMPs) and climate projections on water quality
- Alternative management practices modeled at various implementation levels across watershed
  - reduced soil P (nutrient management)
  - increased conservation tillage
  - cover cropping
  - managed grazing



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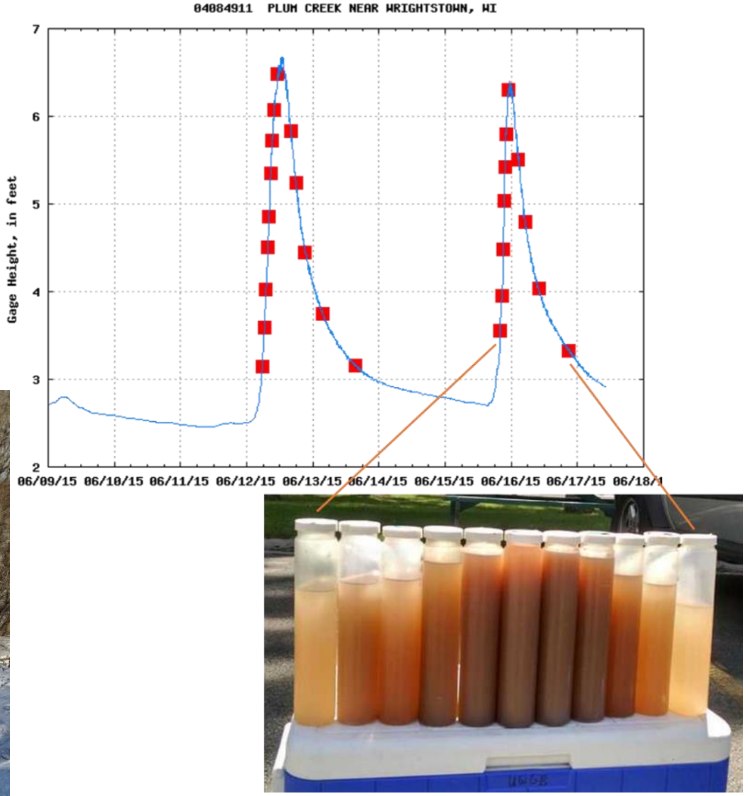
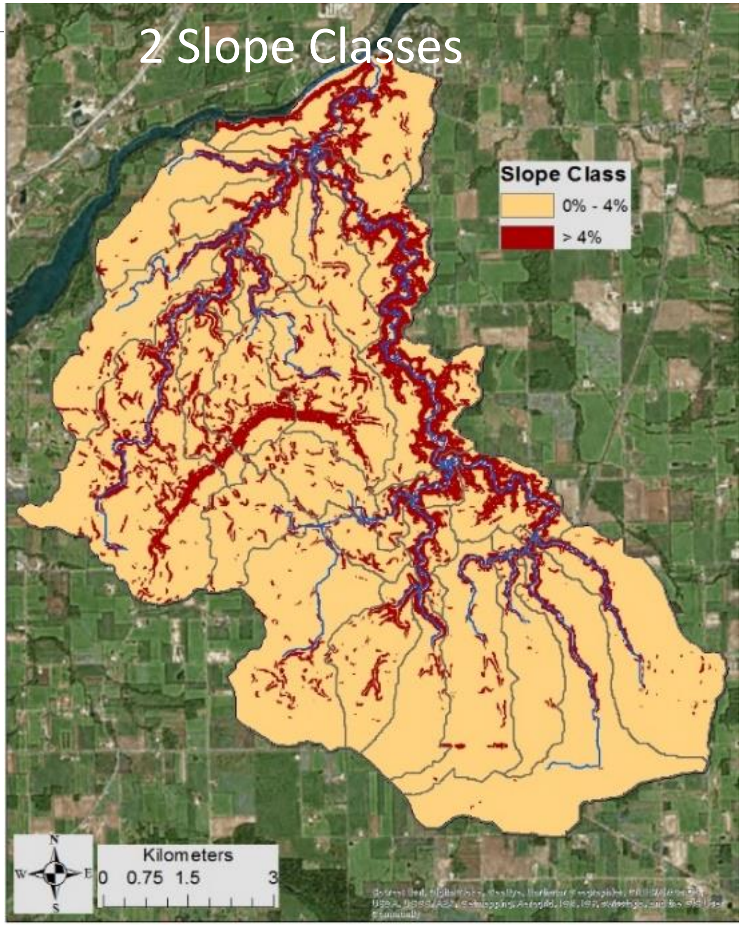


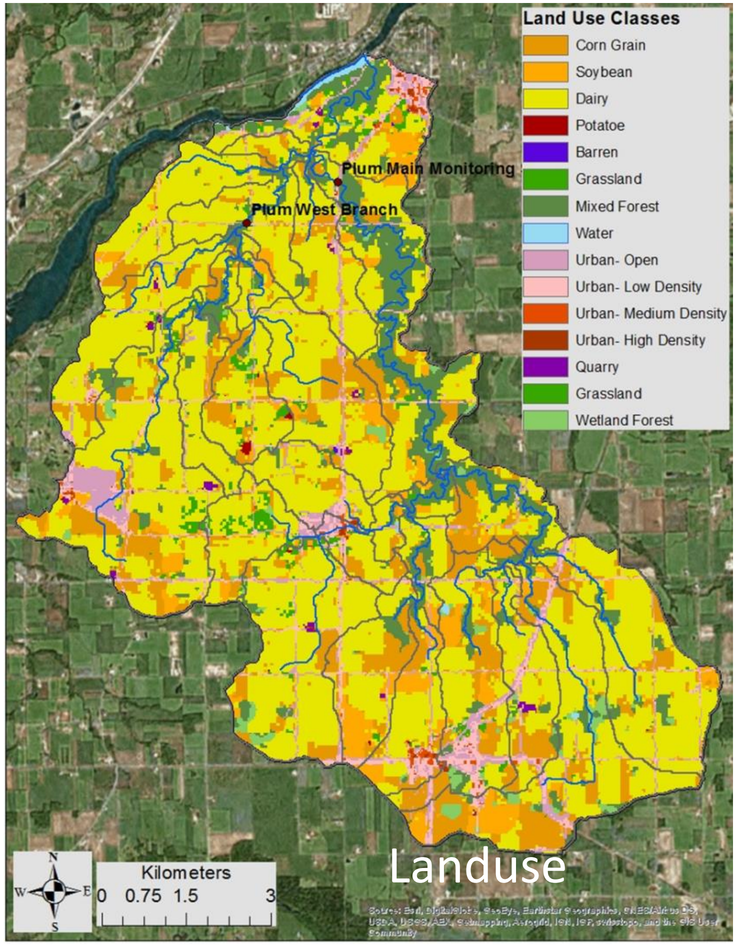
Modeling Methods – Data Inputs

- **10 m x 10 m Digital Elevation Model**
  - Two Slope classes were defined: 0 – 4% and >4%
- Soils input from **SSURGO database**
  - Most soil types were C class or poorly drained
- Land use was derived from **NASS Cropland Data Layers**
  - 2006 – 2011 (dairy = any area with Alfalfa in 1 of 6 years)
  - Initial Soil Test P = 40 ppm



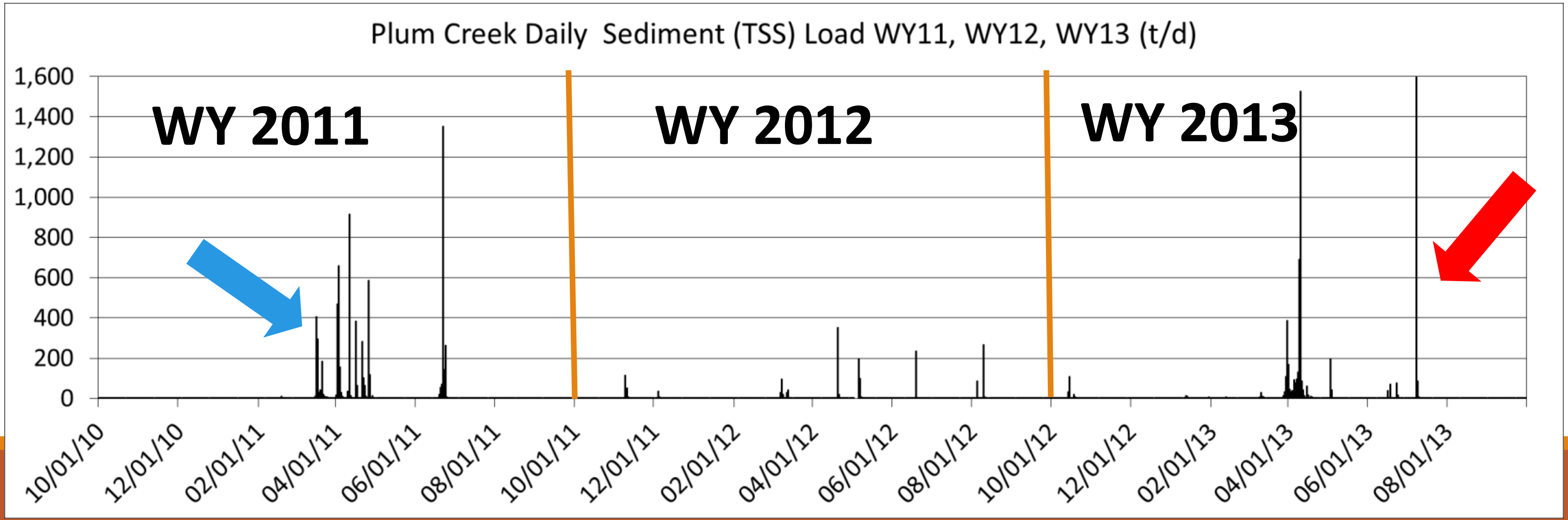
Modeling Methods – Land Management

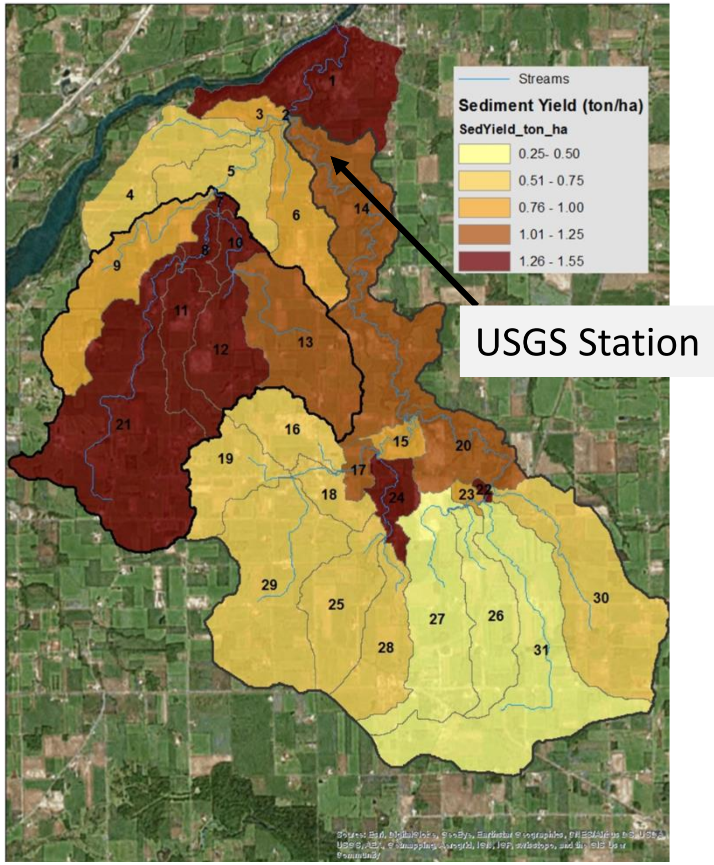
- **Three tillage options:** Conventional till (moldboard), reduced till (chisel) and no-till
- **Dairy rotation**: 6 year rotation (55% of area) (18 HRUs)
  - Corn grain/silage mixed crop, Silage, Winter Wheat, Alfalfa (x3)
  - Manure applied before corn and winter wheat and topdressings on Alfalfa
- **Cash grain rotation:** 3 year rotation (21% of area) (9 HRUs)
  - Two years corn grain, one year soybean
  - Manure applications in fall of each year



Modeling Methods – Calibration & Validation

- Measured Daily Discharge, Sediment, and Phosphorus loads for 3 years at main branch with USGS cooperation
- Monthly loads used to calibrate and validate SWAT model
- **2 year calibration, 1 year validation**





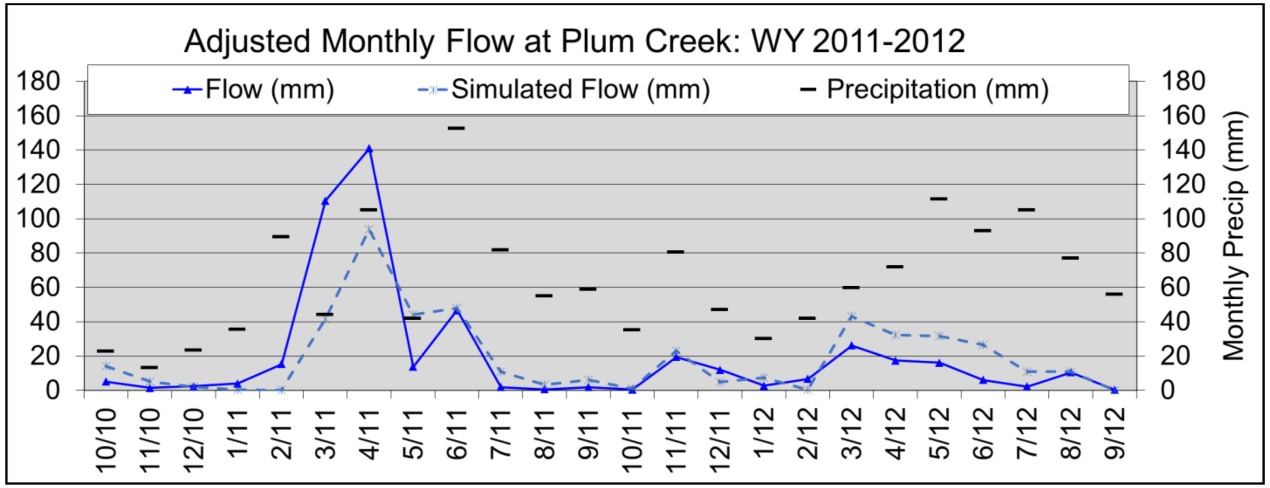
Modeled yields by subbasin

Modeling Methods – Parameterization

- Crop.dat values calibrated (CMIN, BE, Harvest efficiencies) to meet yield goals
- Till.dat inputs altered to match local tilling operations
- .mgt inputs mirrored previous modeling work and discussions w/ LCD

SWAT Input Parameter	Description	Default	Calibrated Value
CN_Froz	Parameter for frozen soil adjustment on infiltration/runoff	0.000862	0.00001
SFTMP	Snowfall temperature [ºC]	1	1.5
SMTMP	Snow melt base temperature [ºC]	0.5	2.02
SMFMX	Melt factor for snow on June 21 [mm H2O/ºC-day]	4.5	2
SMFMN	Melt factor for snow on December 21 [mm H2O/ºC-day]	4.5	0.1
TIMP	Snow pack temperature lag factor	1	0.8
SNOCOVMX	Minimum snow water content that corresponds to 100% snow cover [mm]	1	10
SURLAG	Surface runoff lag time [days]	4	0.5
CN2	Initial SCS CN II value	70 - 91	72 - 90
USLE_C	Minimum value of USLE C factor for water erosion applicable to the land cover/plant.	0.001 - 0.5	0.003-0.2
SPCON	Linear parameter for calculating the maximum amount of sediment that can be re-entrained during channel routing	0.0001	0.0008
PRF	Peak rate adjustment factor for sediment routing in the main channel	1	1.25
USLE_P	USLE support practice factor	0 - 1	0.25
PSP	Phosphorus sorption coefficient	0.4	0.7

Modeling Methods – Calibration WY 2011 - 2012

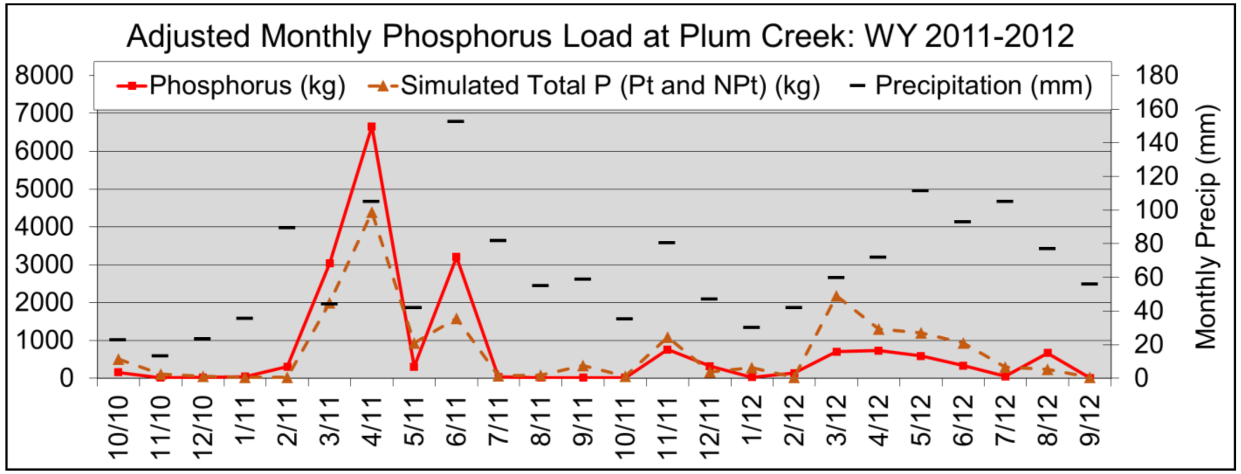


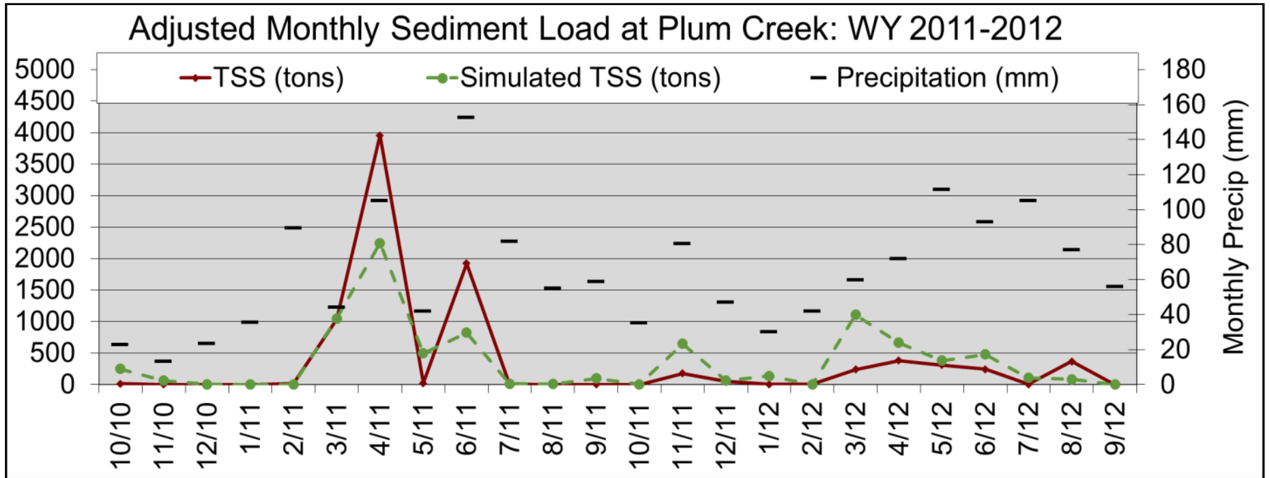
Model Efficiency Statistics

* Yearly comparison

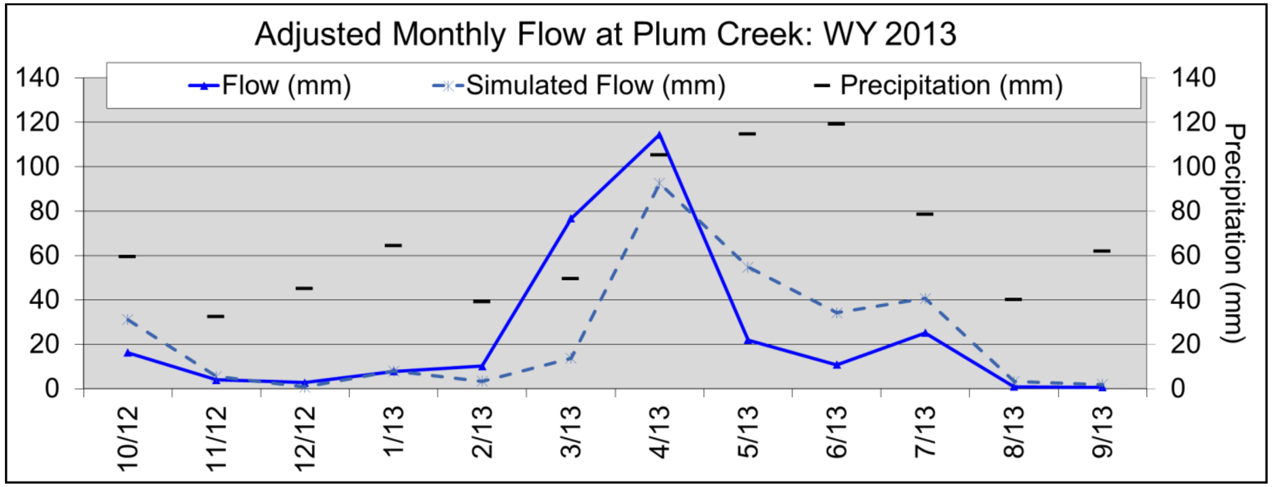
	R^2	NSE	PBias*
Flow	.68	.65	-0.7
Sediment	.75	.68	-0.3
Phosphorus	.80	.75	-1.2

NSE: Nash Sutcliff Efficiency Coefficient >0 and close to 1; R^2 close to 1 better; %Err closer to 0 is better





Modeling Methods – Validation WY 2013



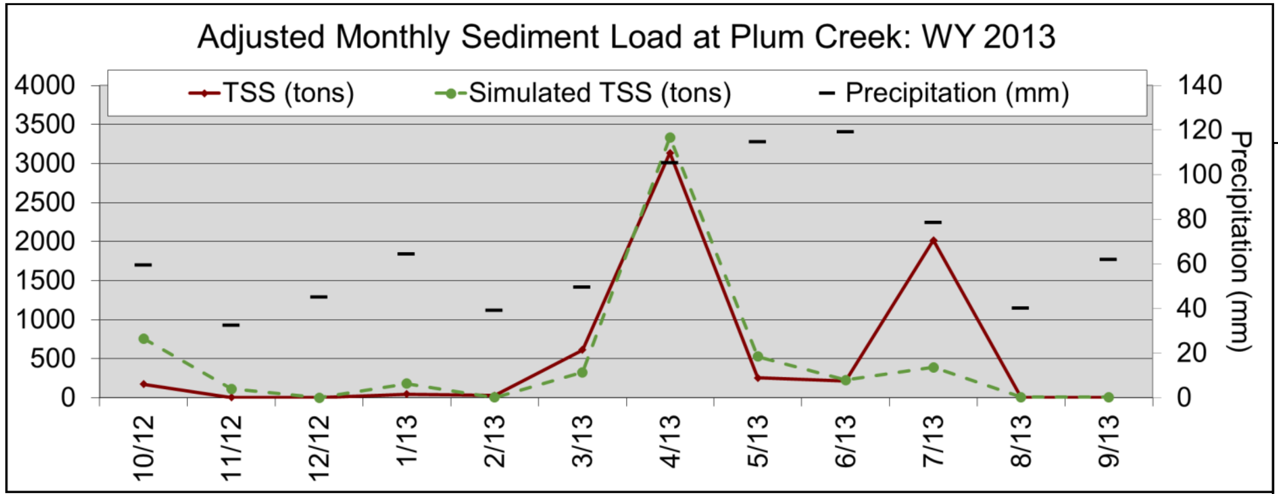
Model Efficiency Statistics

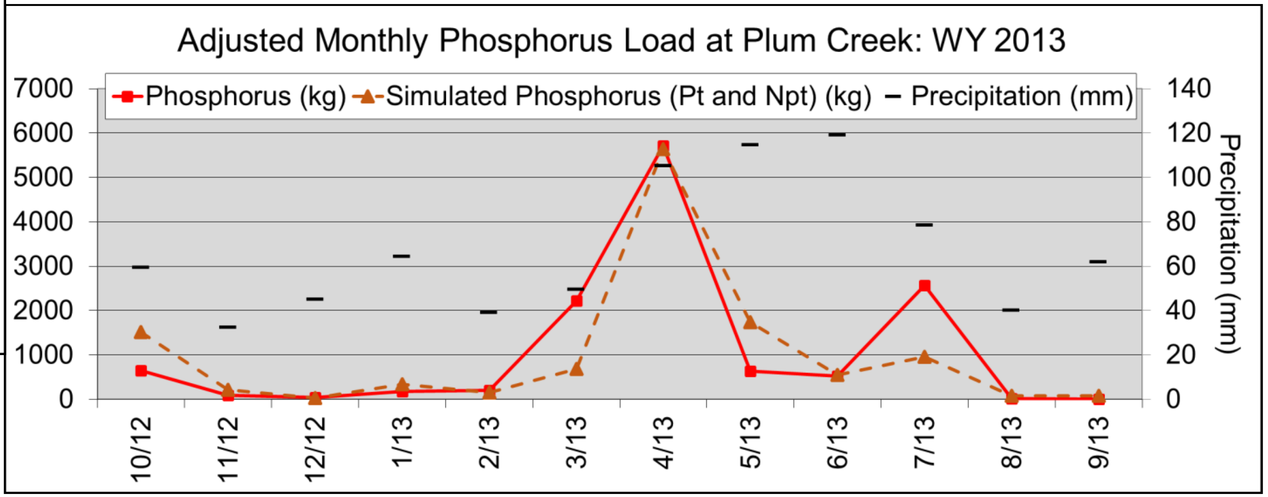
* Yearly comparison

	R^2	NSE	PBias*
Flow	.52	.51	-0.6
Sediment	.72	.71	-9.4
Phosphorus	.78	.78	-6.9

July 2013

- 4 day event July 8-11
- Contributed 23.6 mm of 25.1 mm monthly total
- Simulated Flow was OK, but Sed and P was understated





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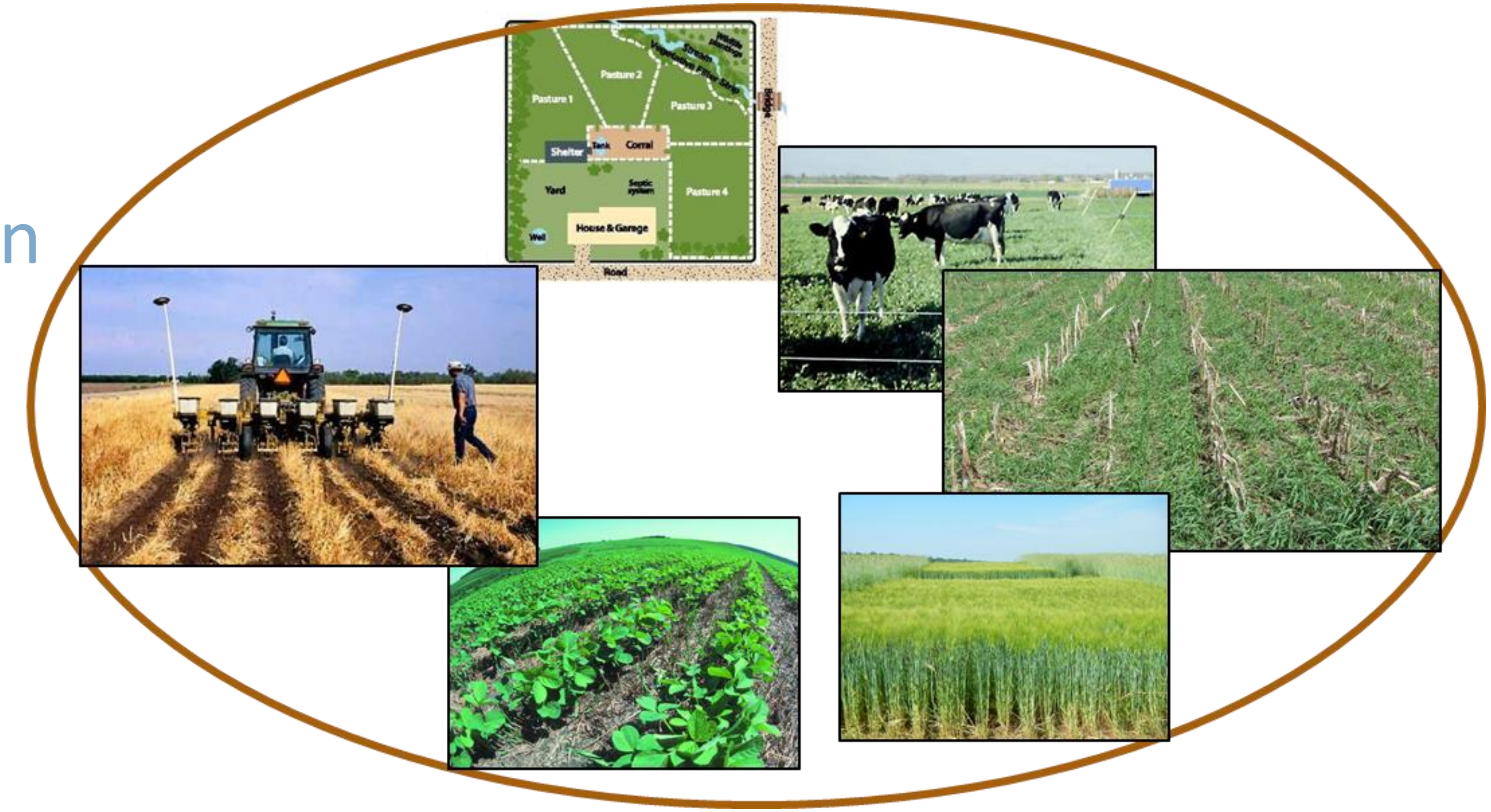
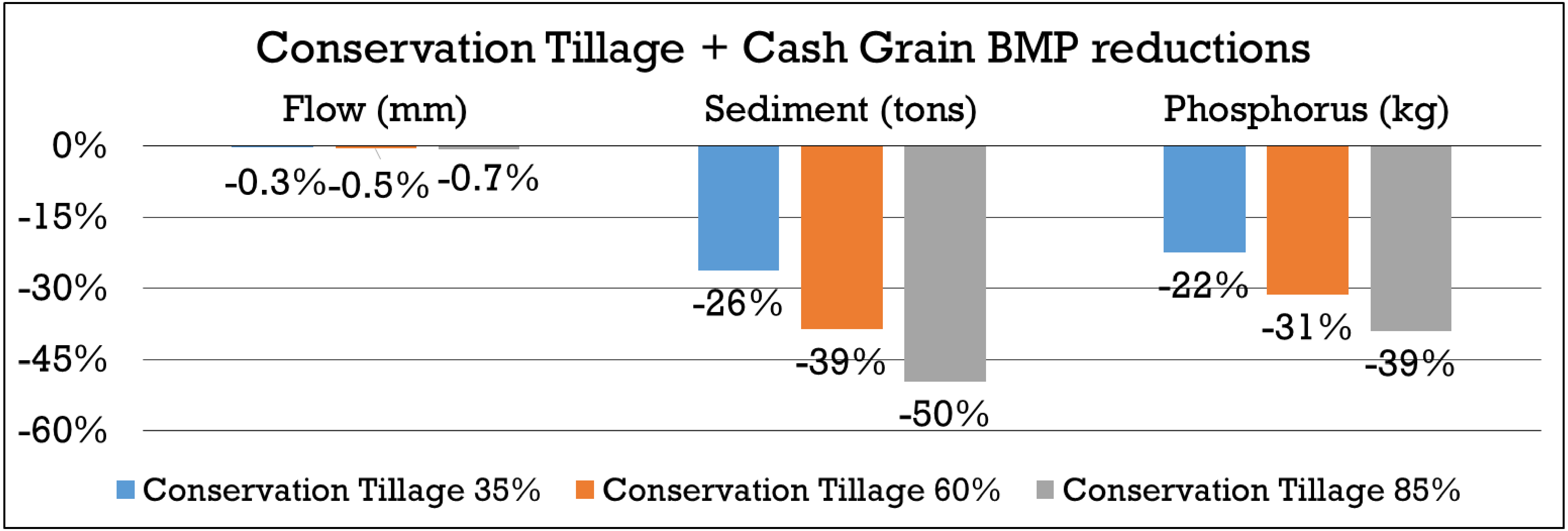


Alternative Management Practice Implementation- **Conservation Tillage**

- Baseline scenario:
  - Conventional tillage at 90%, Reduced tillage at 10%, No-till tillage at 0%
- Increasing conservation tillage:
  - Curve number decreased, BIOMIX increased for no till, CMIN in crop.dat lowered for crops in reduced and no till
  - Areas multiplied by different fractions to return desired % area changes
  - E.g. 60% conservation tillage scenario of dairy acres:
    - Conventional tillage at 40%, Reduced tillage at 35%, No-till tillage at 25%

Alternative Management Practice Implementation- Conservation Tillage



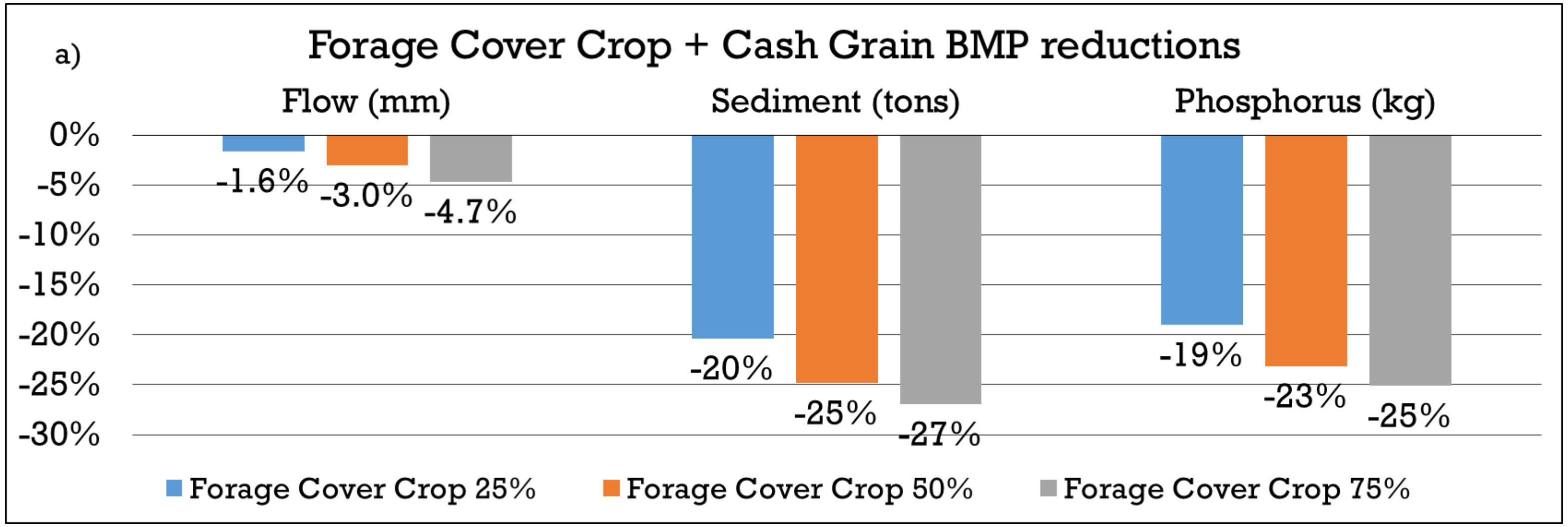
* All results include Cash Grain BMPs (reduced STP, cover crops, conservation tillage)

Alternative Management Practice Implementation- Cover Cropping

	Practice Changed								
	Harvest date		Manure application		CC Planting	Harvest of Cover Crop	Planting of following crop	
Crop – Cover Crop	Base	BMP	Base	BMP	BMP	BMP	Base	BMP
Soybeans -Nonforage Barley	Oct. 22nd	Oct. 8th	Full rate Fall	1/2 rate fall & spring	mid Oct.	Kill/ Leave residue	May 24th	May 24th
Silage - Nonforage Barley	Oct. 8th	Sept. 1st	Full rate Fall	1/2 rate fall & spring	mid Sept.	Kill/ Leave residue	May 24th	May 24th
Silage - Forage Rye	Oct. 8th	Sept. 1st	Full rate Fall	1/2 rate fall & spring	mid Sept.	Harvest in spring	May 24th	June 20th

Alternative Management Practice Implementation-

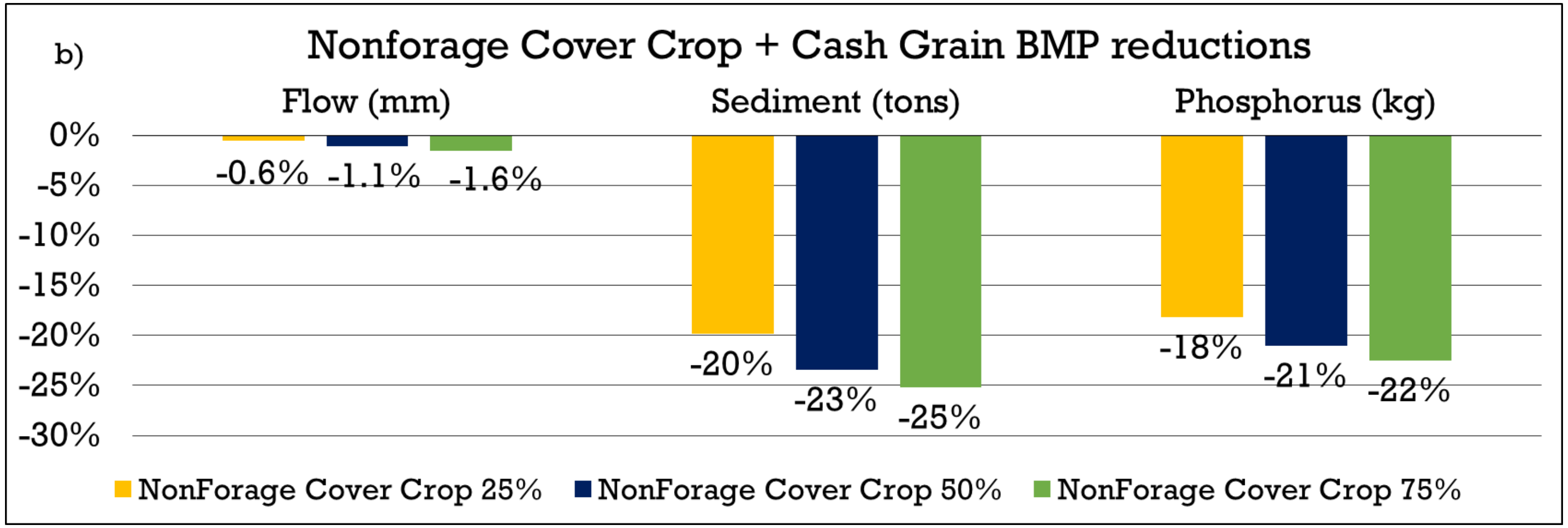
Cover Cropping



Three implementation levels on dairy acres:

25%, 50%, 75%

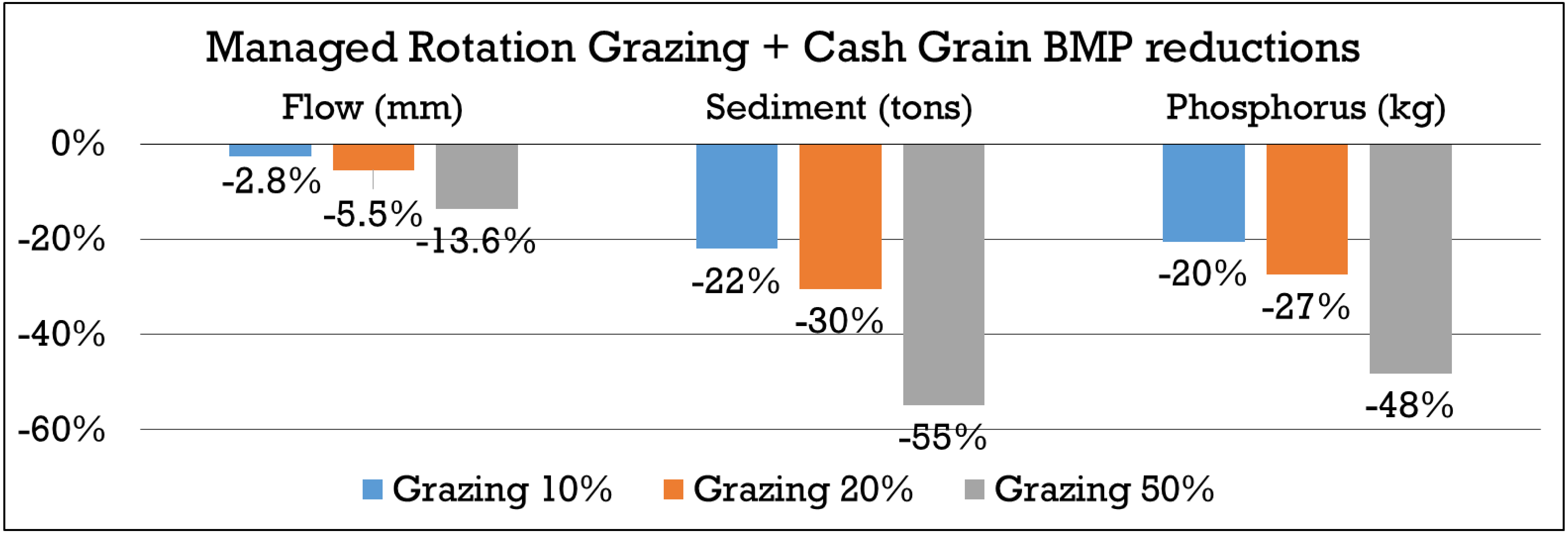
- 65%, 40%, & 15% stayed in conventional management.



Alternative Management Practice Implementation- **Managed/Rotational Grazing**

- Paddocks rotated every 30 days and each dairy phase (6) grazed for 5 days
- Average consumption rate calculated as 4.5% of body weight for a 550 lb cow
- Stocking rates from Adamski operations in Northeast Wisconsin
- Manure applied during grazing was equivalent to dairy crop rotation
  - Ratio of 2.2:1 consumption to manure deposition
  - Other grazing literature applied about a 2.1:1 or 2.9:1 ratio of consumption to manure deposition (Pai, 2011 and Almendinger, 2010)

Alternative Management Practice Implementation- Managed/Rotational Grazing



Alternative Management Practice Implementation

Reduce Soil Test P – net result was a ~14% reduction in P export

- Previous Soil Test P work shows watershed average about 42 ppm

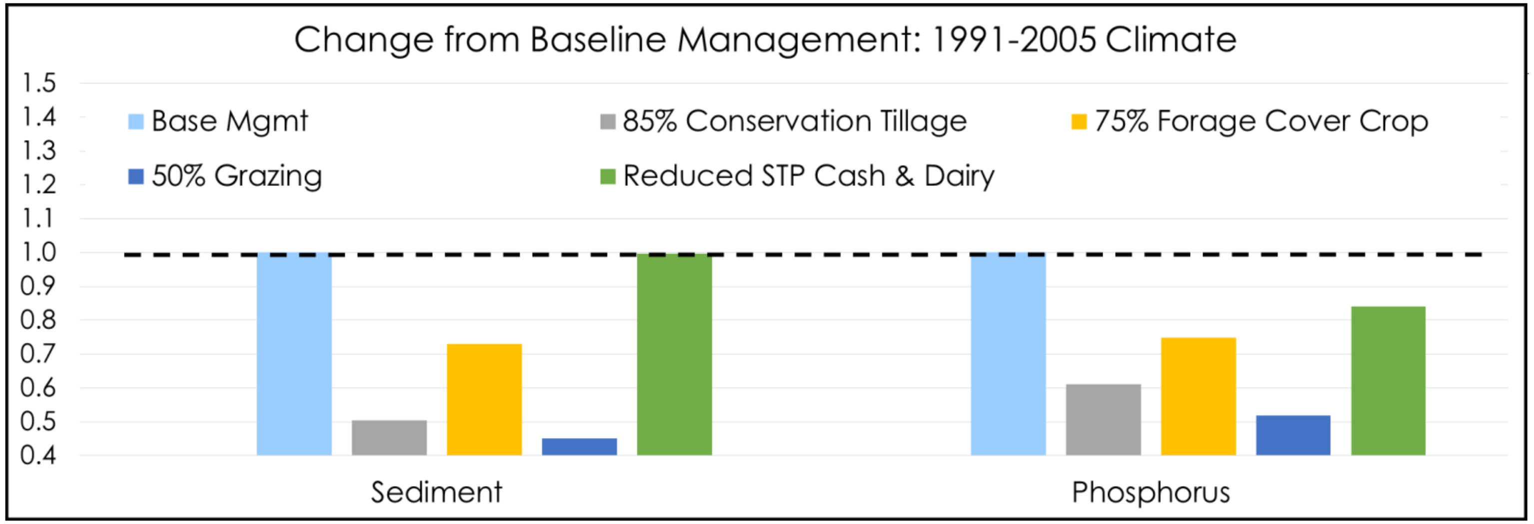
  Jacobson, 2012; 9 Key Elements Plan by Outagamie County LCD for Plum/Kankapot

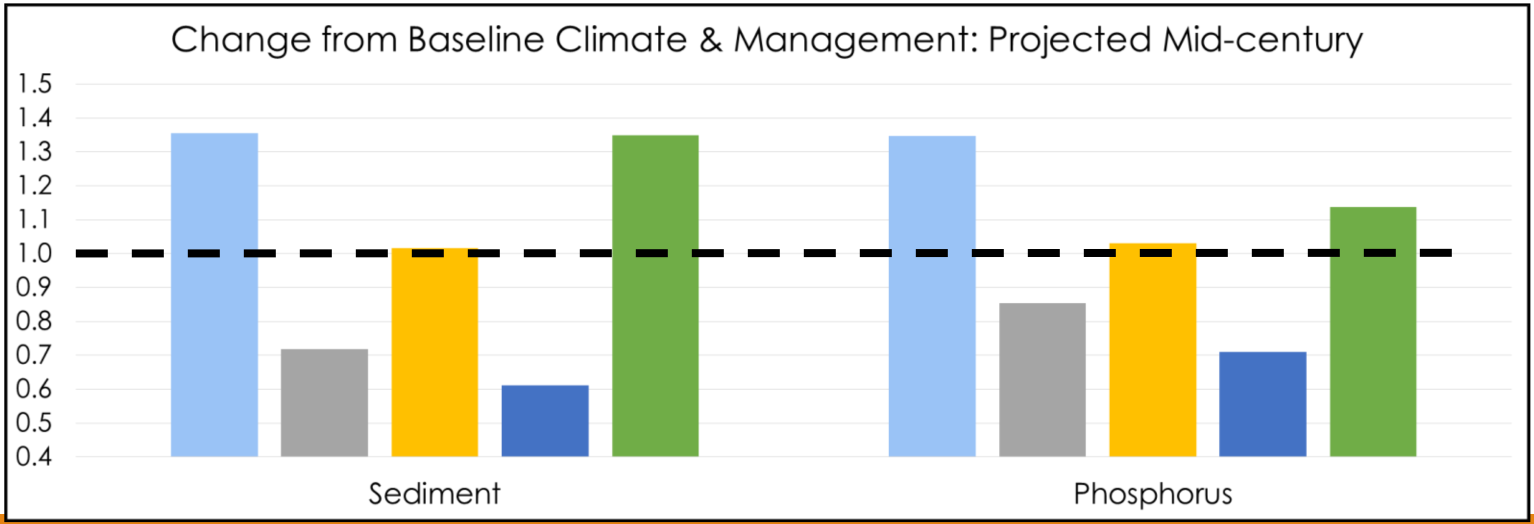
- Labile P (in .chm files) was parameterized at 40 ppm, 30 ppm, 20 ppm for top 3 layers
- BMP: Reduced to 25 ppm, 20 ppm, and 15 ppm to reflect 1970's STP levels

Combination scenarios incorporated various single BMPs

- Various levels of implementation
- **Results**: 32 – 75% reductions of TSS & 29 – 64% reductions of TP

How will alternative management perform under projected climate?





Downscaled, projected climate 2046-65. A1B emission scenario. **M**eteorological **R**esearch **I**nstitute Coupled Atmosphere–Ocean General Circulation Model, version 2.3.2 (D. Lorenz, Ctr Climate Research/WICCI, U. Wis.)

- CO_2 changed to 550 ppm

% Precip change from baseline

Seasons	Warmer/Wetter climate model
Winter	28%
Spring	10%
Summer	5%
Autumn	10%

Seasons	Change Max ° C	Change Min ° C
Winter (Dec-Feb)	+3.9	+4.8
Spring (Mar-May)	+2.2	+2.5
Summer (Jun-Aug)	+1.9	+2.5
Autumn (Sep-Nov)	+2.3	+2.2

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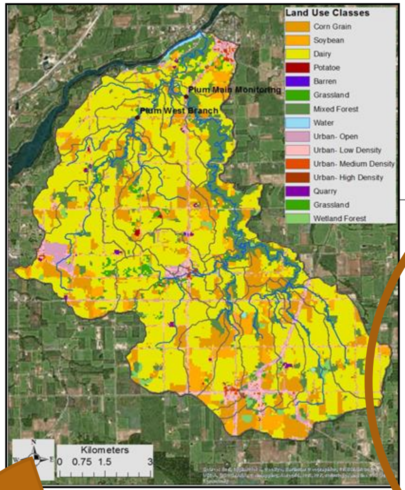
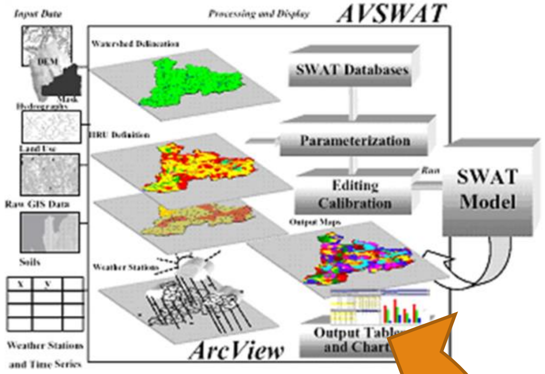
A dairy dominated watershed . . .

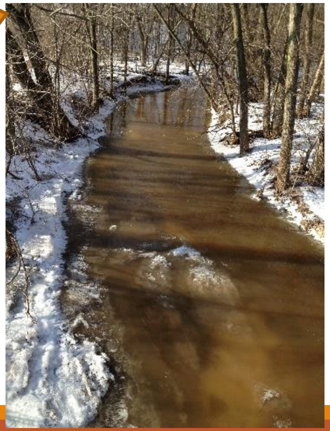


. . . To predict impact on water quality and loading from BMP implementation.

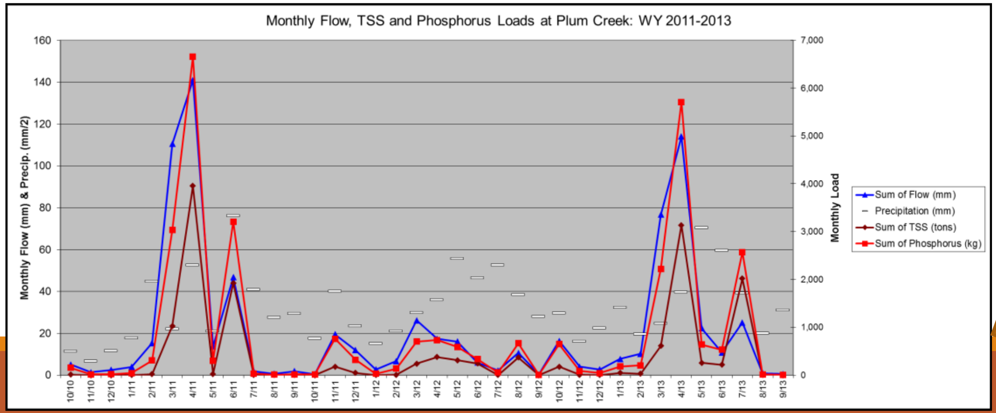
. . . To build a model based on land use/management, soil, and slopes . . .



. . . With water quality issues . . .



. . . And three years of data for 60% of the basin . . .



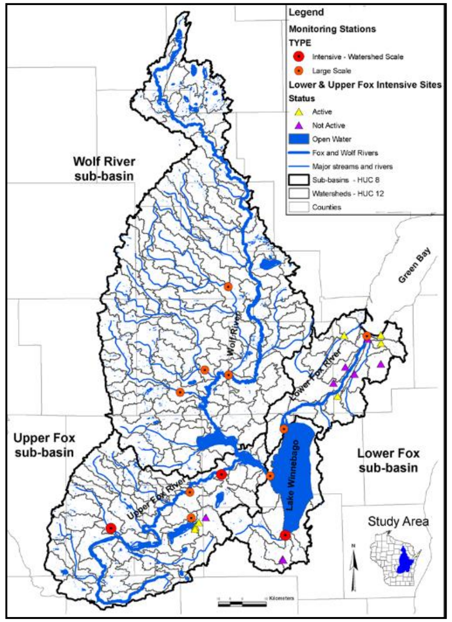
And we found….

- The SWAT model was effectively applied to the Ag. dominant watershed
- To meet TMDL goals, ag system changes will be required
- Alternative practices have potentially significant impacts on Water Quality

		% Difference from Base Case		
BMP Combination	HRU management changes with %HRU of dairy management	Flow (mm)	Sediment (tons)	Phosphorus (kg)
Forage + Conservation Till Low Implementation	Conv/Reduced/No-till w. cover 80/15/5	**-6.6%**	**-32.0%**	**-29.2%**
Forage + Conservation Till High Implementation	Conv/Reduced/No-till w. cover 40/35/25	**-7.6%**	**-49.7%**	**-41.0%**
Forage + Graze Low Implementation	Graze/Reduced/No-till w. cover 20/55/25	**-12.8%**	**-64.1%**	**-52.8%**
Forage + Graze High Implementation	Graze/Reduced/No-till w. cover 50/25/25	**-19.1%**	**-74.8%**	**-63.7%**
Grazing + Forage Cover + Conservation Tillage + Baseline STP	Graze/Reduced/No-till w. cover 33/33/34	**-15.6%**	**-70.0%**	**-58.2%**
Grazing + Forage Cover + Conservation Tillage + Reduced STP	Graze/Reduced/No-till w. cover 33/33/34	**-15.5%**	**-70.1%**	**-61.8%**
Grazing + Reduced Till Low Implementation	Graze/Reduced till/ No-till at 10/65/25	**-3.7%**	**-53.7%**	**-43.1%**
Grazing + Reduced Till Moderate Implementation	Graze/Reduced till/ No-till at 20/55/25	**-6.6%**	**-58.4%**	**-47.7%**
NonForage + Conservation Till Low Implementation	Tillages w. cover 80/15/5	**-2.1%**	**-29.4%**	**-25.6%**
NonForage + Conservation Till High Implementation	Tillages w. cover 40/35/25	**-2.6%**	**-47.3%**	**-37.6%**
NonForage + Graze Low Implementation	Graze/Reduced/No-till w. cover 20/55/25	**-8.4%**	**-61.3%**	**-49.6%**
NonForage + Graze High Implementation	Graze/Reduced/No-till w. cover 50/25/25	**-16.3%**	**-73.3%**	**-62.0%**
Grazing +NonForage Cover + Conservation Tillage + Baseline STP	Graze/Reduced/No-till w. cover 33/33/34	**-11.9%**	**-68.0%**	**-56.0%**
Grazing + NonForage Cover + Conservation Tillage + Reduced STP	Graze/Reduced/No-till w. cover 33/33/34	**-11.8%**	**-68.2%**	**-60.5%**

Future work....

- Knowledge gained about alternative management strategies in the Plum Creek model will be applied to other regions of the Green Bay watershed.



Thank you!

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