

US EPA ARCHIVE DOCUMENT



Two-Stage Ditch

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Nature, gives us a lot of information.

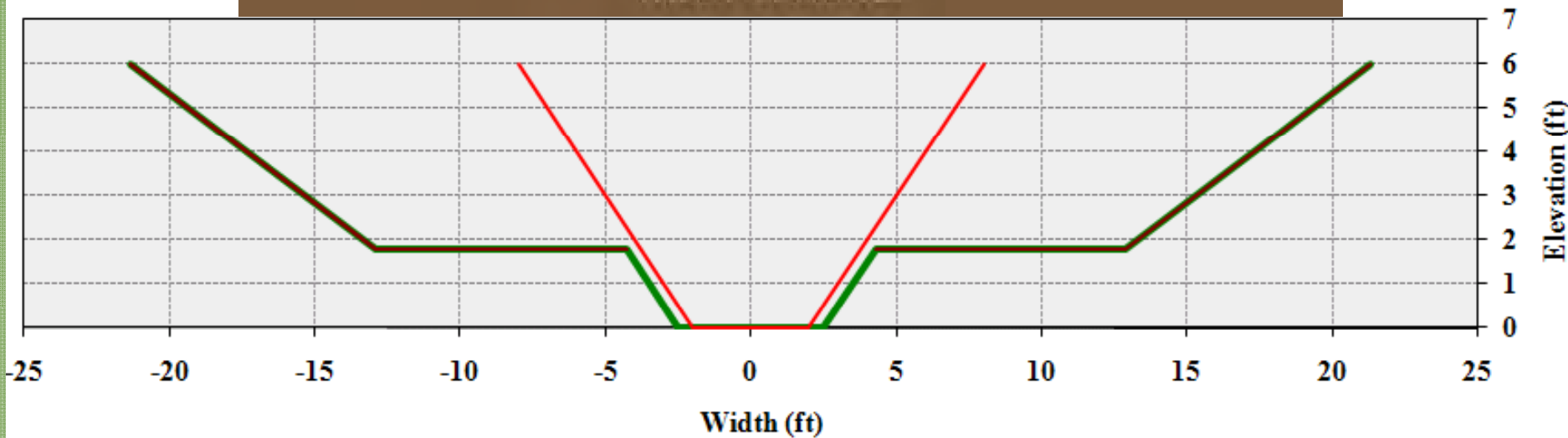
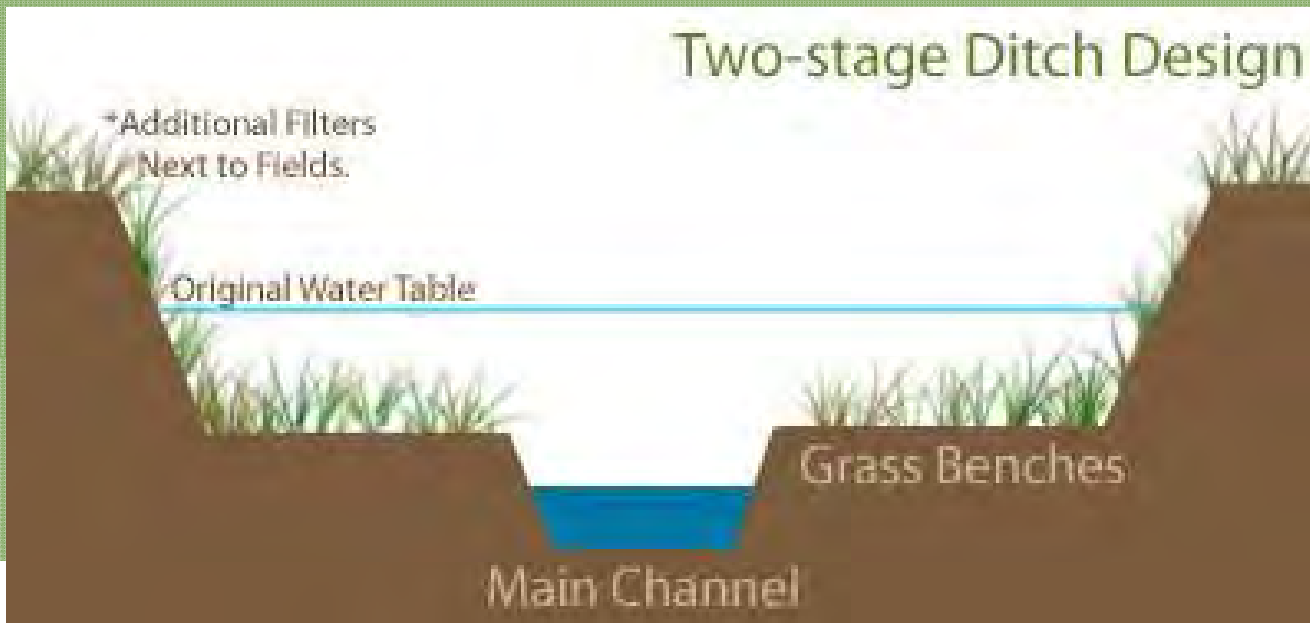
Why did we get interested?

Targets:

- Aquatic System
- Freshwater



Two-Stage Ditch Design





Benefits of a Two-Stage Ditch

Nutrient and sediment removal





Increased capacity of the ditch system and floodwater retention





Helps to mitigate downstream flooding





Improves ditch bank stability and reduces bank sloughing



Improved in-stream habitat



Two Stage Site Selection Criteria

1. Is the 2-stage ditch installation accompanied by a conservation buffer? (20 Points)
2. Is the project's drainage area less than 7,500 acres? (20 Points)
3. Is the depth of the ditch (top of bank to water) less than 10 feet? (20 Points)
4. Is there significant woody vegetation that must be removed? (Significant means more than just a few scrubby trees and shrubs) (30 Points)
5. Is there adequate area for spreading the spoil on-site? (20 Points)
6. Is the channel to be constructed a contiguous channel of 0.4 miles long or greater? (20 Points)

Two Stage Site Selection Criteria

7. Is this application part of a larger multi-landowner application which will result in construction of a larger 2-stage project? (10 Points)
8. Are the soils in the proposed bench area stable and suitable for bench construction? (15 Points)
9. Is this project being considered in a legally-maintained drain, and if so are the local drainage officials on-board with the project? (15 Points)
10. Is the project located within one mile of the ditch /stream's outlet into a lake or river? (15 Points)

Total Points Available 185

2-Stage Ditch Costs

- Typical cost of 2-stage Construction
 - \$8 - \$ 12 per linear foot
- Factors that affect your cost of installation
 1. Depth of the ditch (top of bank to waterline)
 2. Width of ditch channel (and benches)
 3. Amount of natural benches already starting to form
 4. Absence of adequate area to spread spoil
 5. Number of tile outlets to be addressed
 6. Greater velocities requiring erosion control blanket

Two-Stage Construction



\$6 per linear foot



\$10 per linear foot



\$12 per linear foot



\$13 per linear foot



Design and Engineering Using Simple Tools

CALCULATED EARTHWORK FOR TWO-STAGE

188,707	Earthwork Volume (cubic ft)
6,989	Earthwork Volume (cubic yds)
3.5	Earthwork Volume (cubic yds/linear ft)

EARTHWORK COSTS FOR TWO-STAGE CONSTRUCTION

\$2.00	Excavation Cost (\$ per cubic yd)
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17

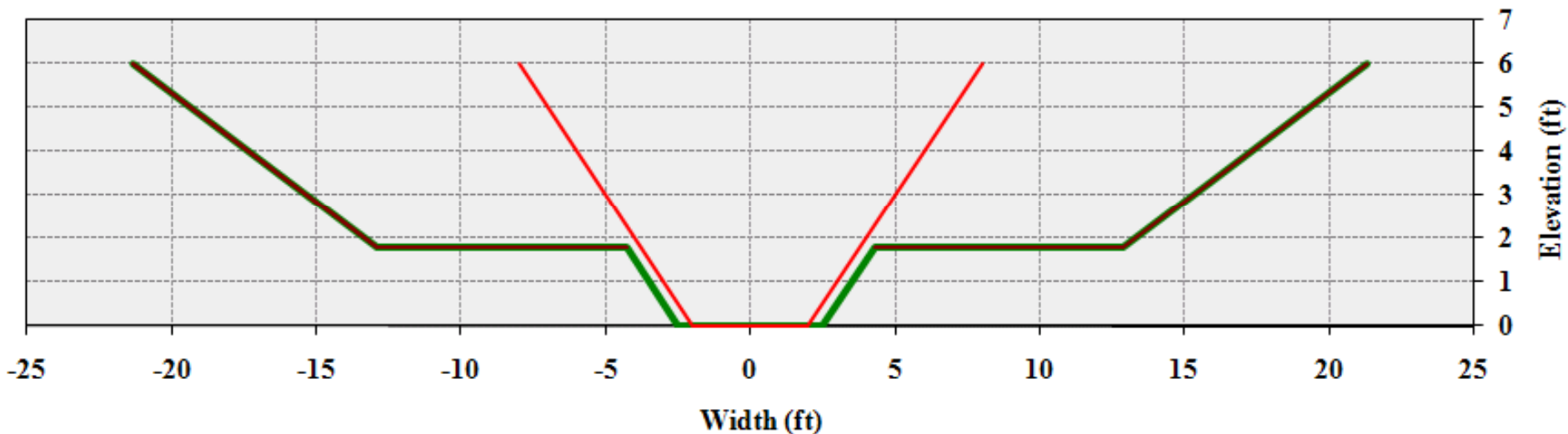
CALCULATED COSTS FOR TWO-STAGE CONSTRUCTION

\$13,978	Total Earthwork Costs (\$)
\$6.99	Cost per Linear Foot (\$)

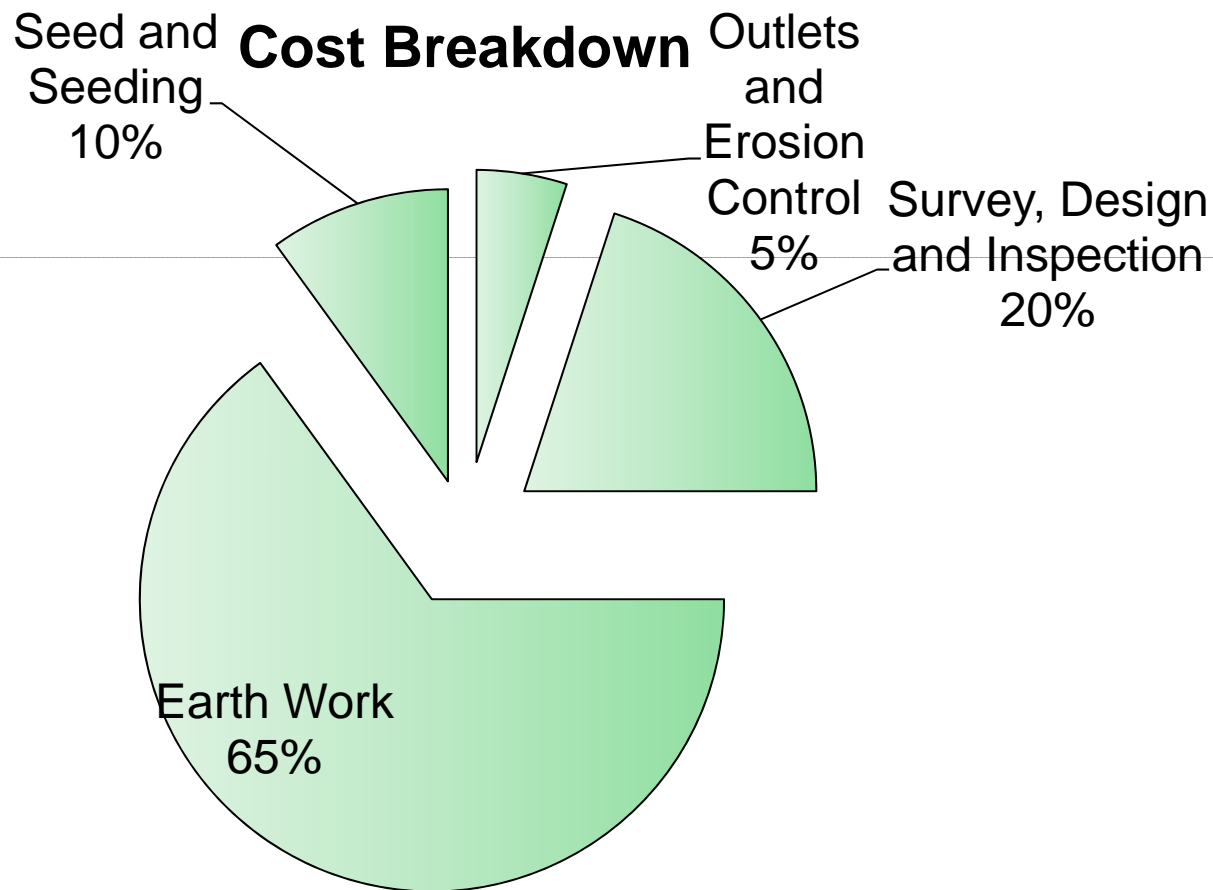
Cross Section View

Earthwork Balance: cut 94 sq.ft.

Bench Elevation: 1.8 ft



Breakdown of Project costs



Technology Transfer





Two-Stage Ditch Locations

2 Stage Ditch - Indiana



Red Dots - interested in finding sites
Green Dots - implemented projects
White Dots - potential projects in planning

Sources of Funding

- Grant funds
- County Assessments
- NRCS – EQIP cost-share
- State Revolving Fund
- Nutrient Trading



Two-Stage Ditch Resources

- www.nature.org/2stageditch
- www.dnr.state.oh.us/soilandwater/water/stream_morphology/default/tabid/9188/Default.aspx
- www.vimeo.com/7901535



Effect of the two-stage ditch on sediments and nutrients in Midwestern agricultural streams

Jennifer L. Tank,
Robert T. Davis, Sarah S. Roley, and Ursula H. Mahl
University of Notre Dame



Two-Stage Ditch Monitoring Goals

1. Does the two-stage ditch reduce water turbidity, sediments, and phosphorus export?
2. Does the two-stage ditch improve stream-bottom habitat?
3. Does the two-stage ditch increase N removal?

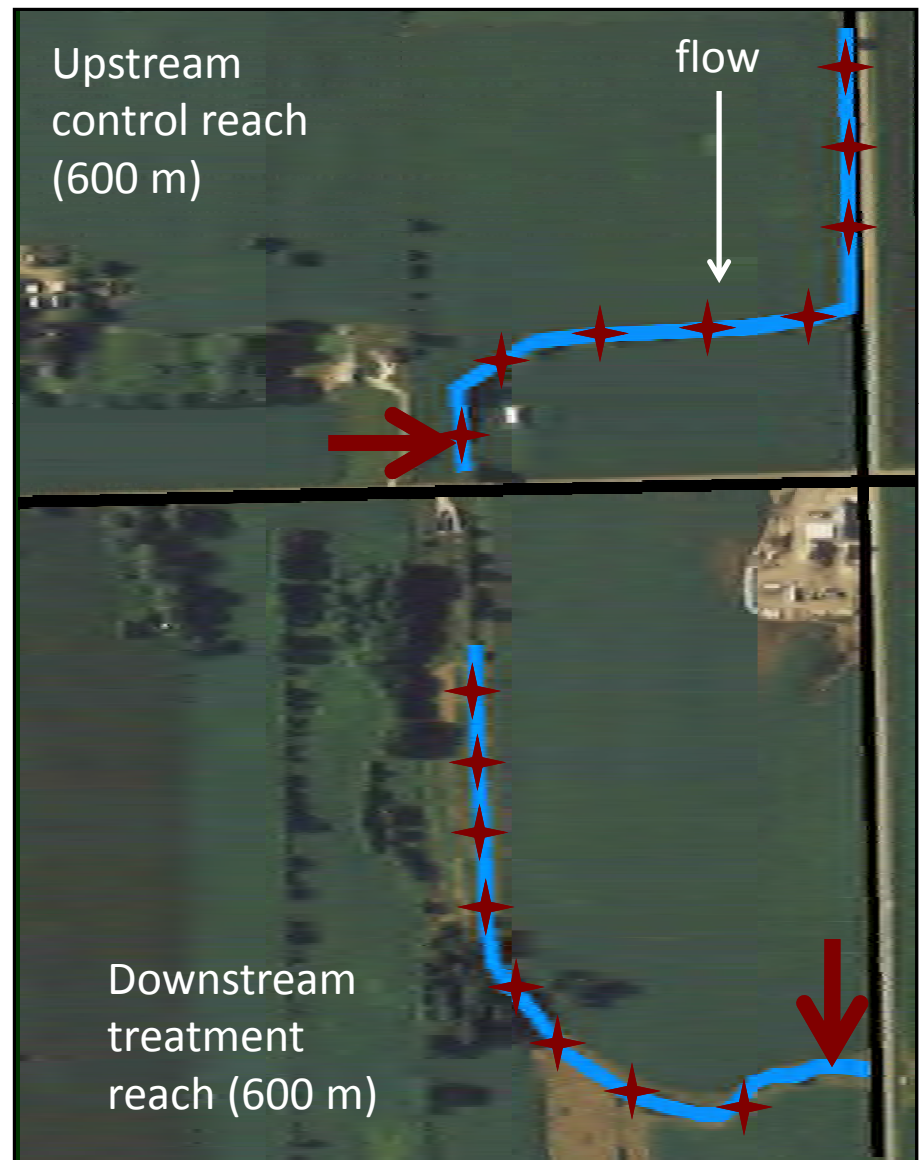


Two-stage sites to capture a range of ditch characteristics, particularly age and N load



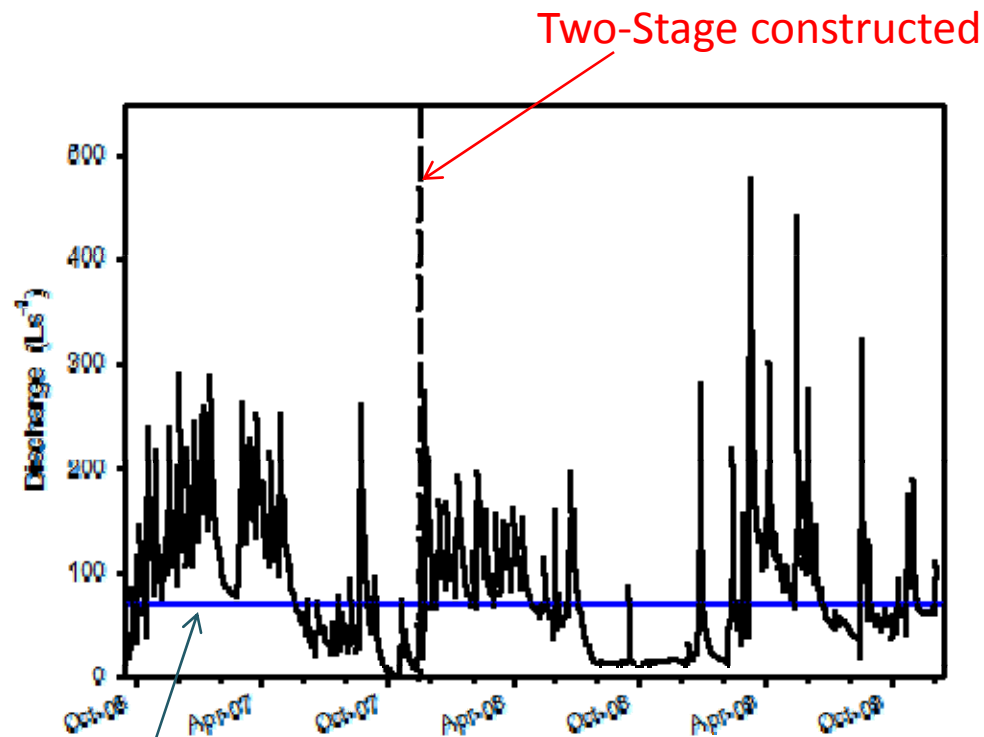
Demonstration Project in Shatto Ditch, Indiana: Experimental Design

- Upstream control reach:
 - Trapezoid design
- Downstream treatment:
 - Two-stage design
- Before-After-Control-Impact (BACI)
 - 1 year of pre-restoration data (2007)
 - Up to 4 years post-restoration data (2008-2012)
- Sampling:
 - Continuous turbidity & depth measurements (every 30 min)
 - Periodic surface water sampling
 - Seasonal denitrification transects



What is the flow regime in Shatto Ditch?

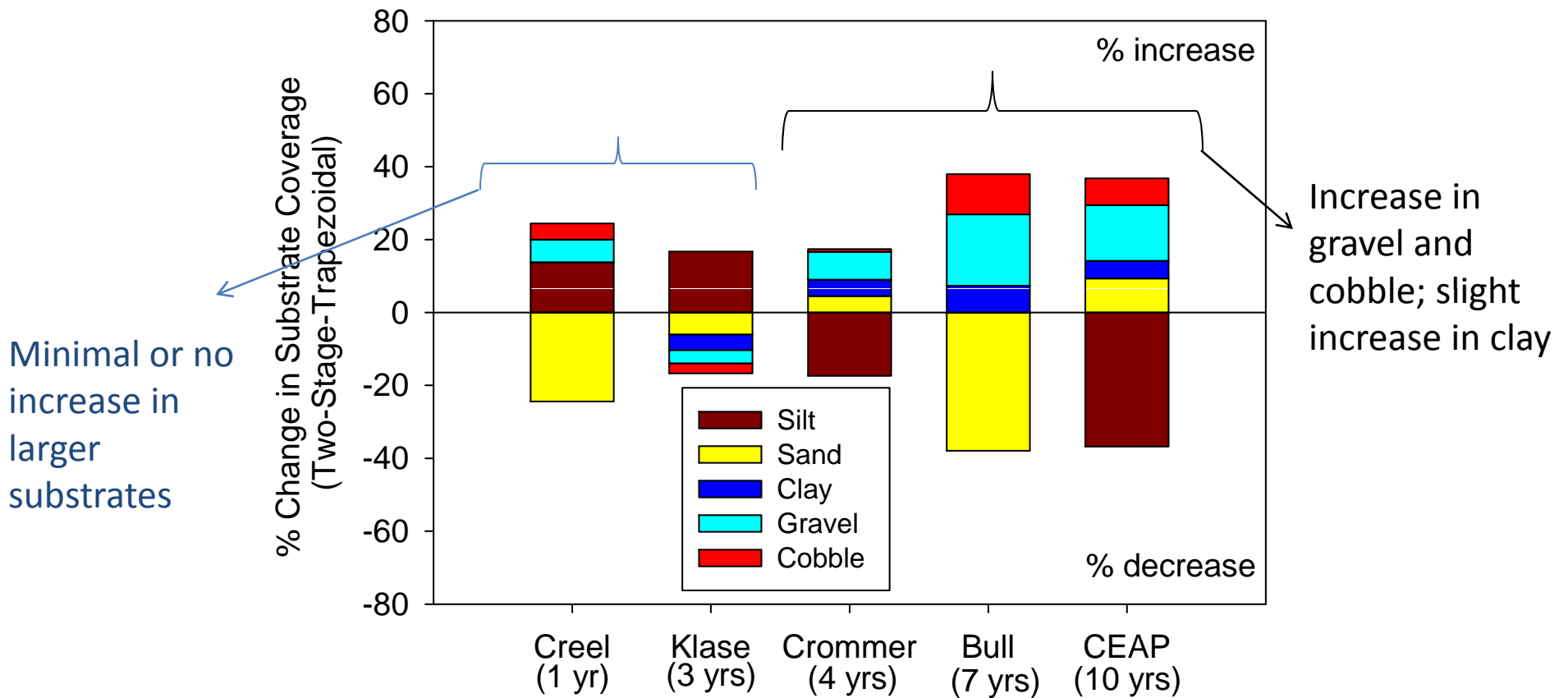
- Flashy discharge
- Typically, low flows in late summer, high flows in spring
- Benches inundated 8 times in year 1, and 16 times in year 2
- Most inundation events lasted < 2 days, but total inundation ranges from 29-132 days.



Benches Inundated

Year	Reach	Days Inundated	Inundation Events
2008	Benches (top 5 cm)	29	8
	Benches (top 15 cm)		
	Stream CTL		
	Stream TRT		
2009	Benches (top 5 cm)	132	16
	Benches (top 15 cm)		
	Stream CTL		
	Stream TRT		

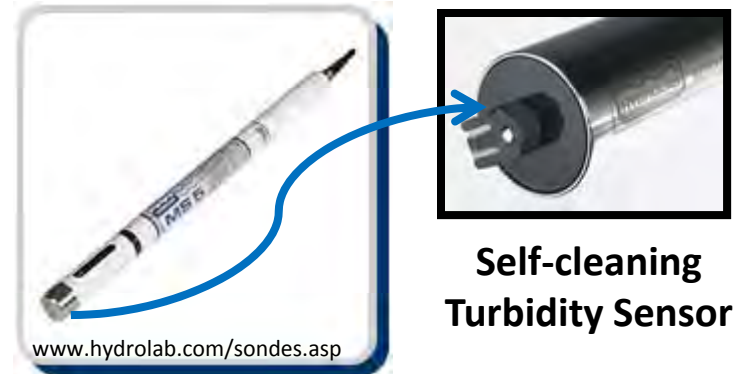
Benthic sediment size on stream bottoms increased in older two-stage ditches



Take Home: Two-stage effect on substrate is delayed; starts to appear in ditches ≥ 4 years old

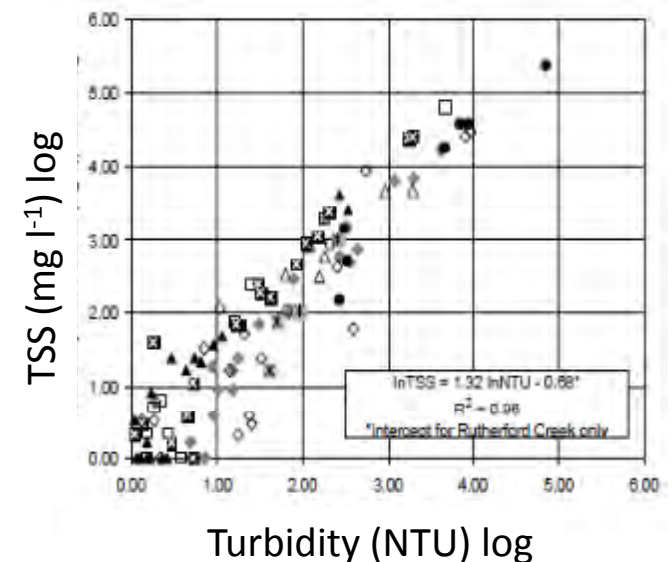
Prediction 1: Two-stage will ↓ turbidity, ↓ total suspended solids and ↓ total phosphorus

- Equipment
 - HACH Hydrolab MiniSondes:
Turbidity = water clarity
 - Capacitance Meters:
Depth to estimate continuous flow as well as frequency & duration of floodplain inundation



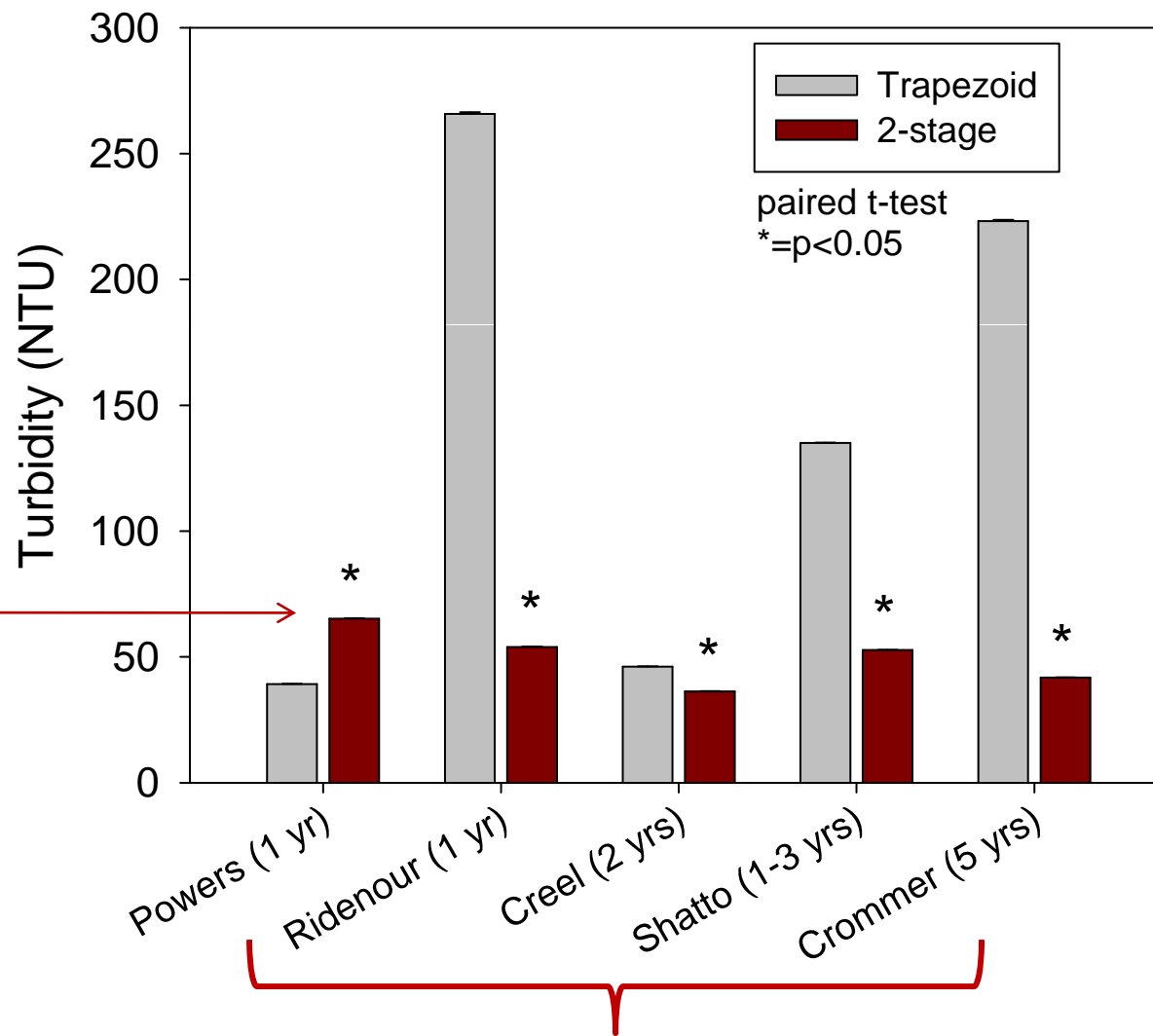
- Linking continuous measurements with sediment & nutrient export:

Goal: use turbidity as a proxy for TSS, which has been shown to correlate with TP



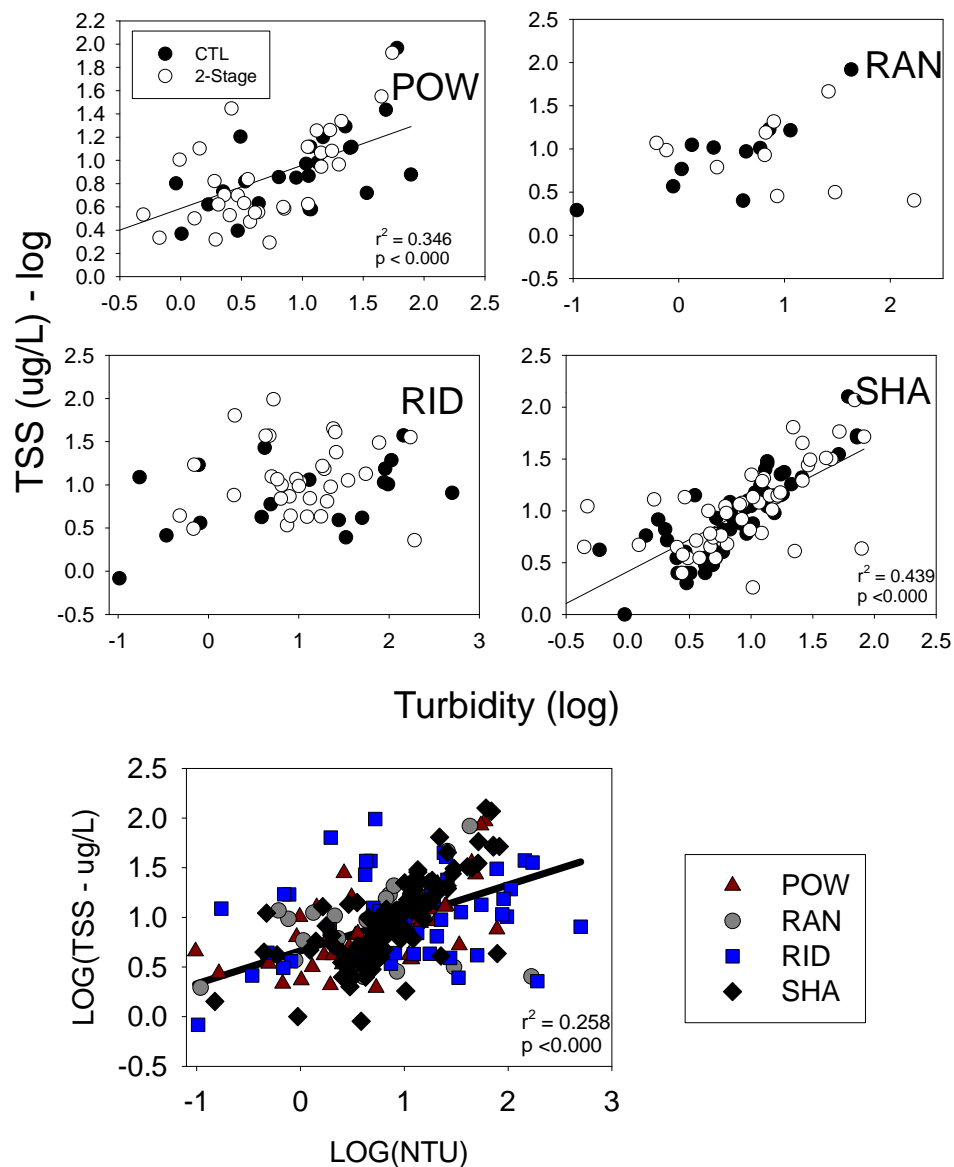
Two-stage reduced water column turbidity in 4 of 5 streams, which correlates with reduced sediment

Powers:
turbidity
increased due
to improper
construction,
bank
slumping



Tank, Davis et al. unpublished data

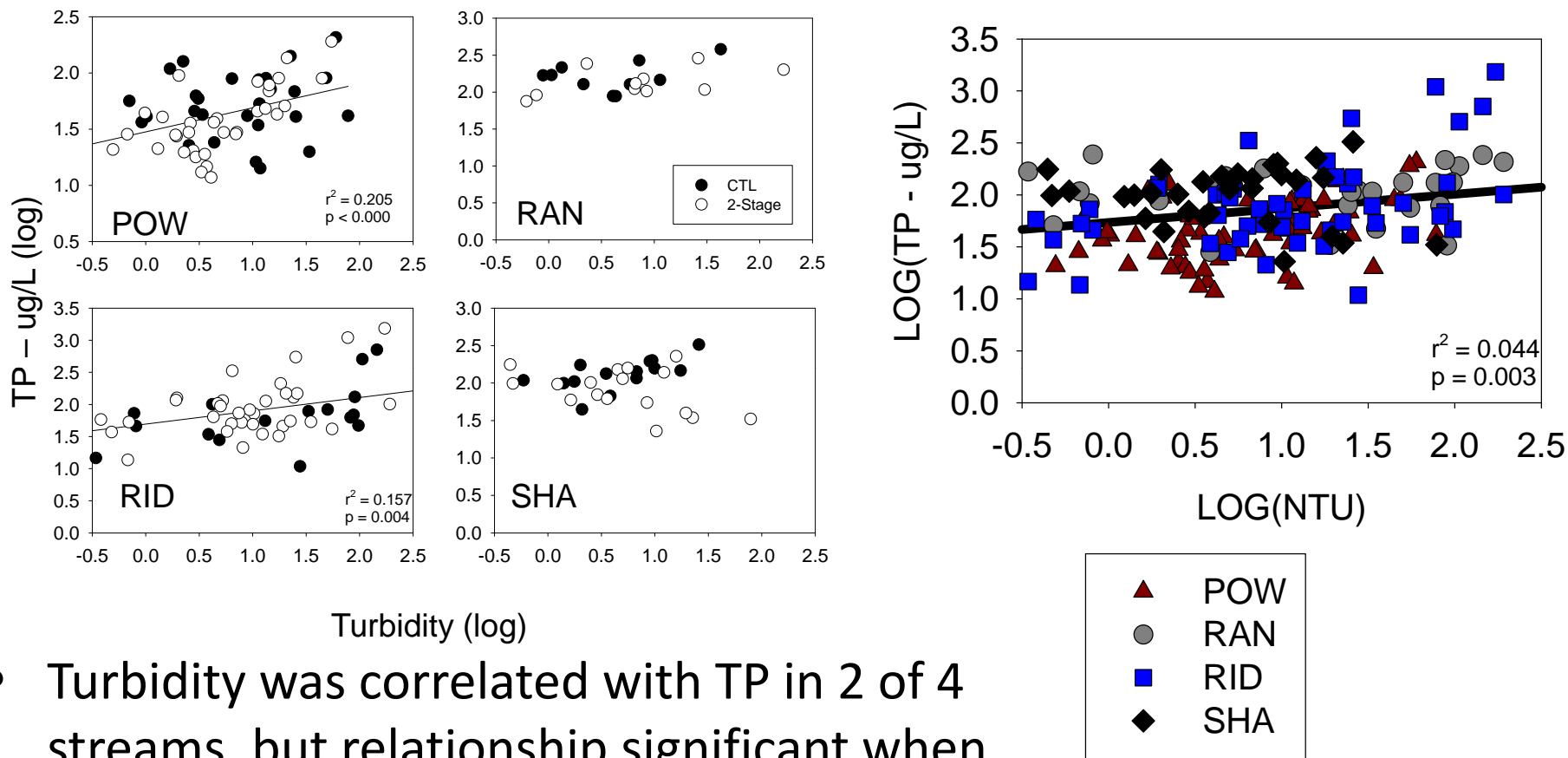
Turbidity correlated with water column TSS in 2 of 4 streams



- Turbidity correlates strongly with TSS over range of discharge
- Relationship between streams not significantly different (ANCOVA, $p = 0.670$)

Take home: With no additional maintenance, the two-stage ditch slowed water velocity during storms and allowed sediments to deposit onto benches.

Turbidity predicts TP across multiple agricultural streams



- Turbidity was correlated with TP in 2 of 4 streams, but relationship significant when data pooled from all 4 streams.

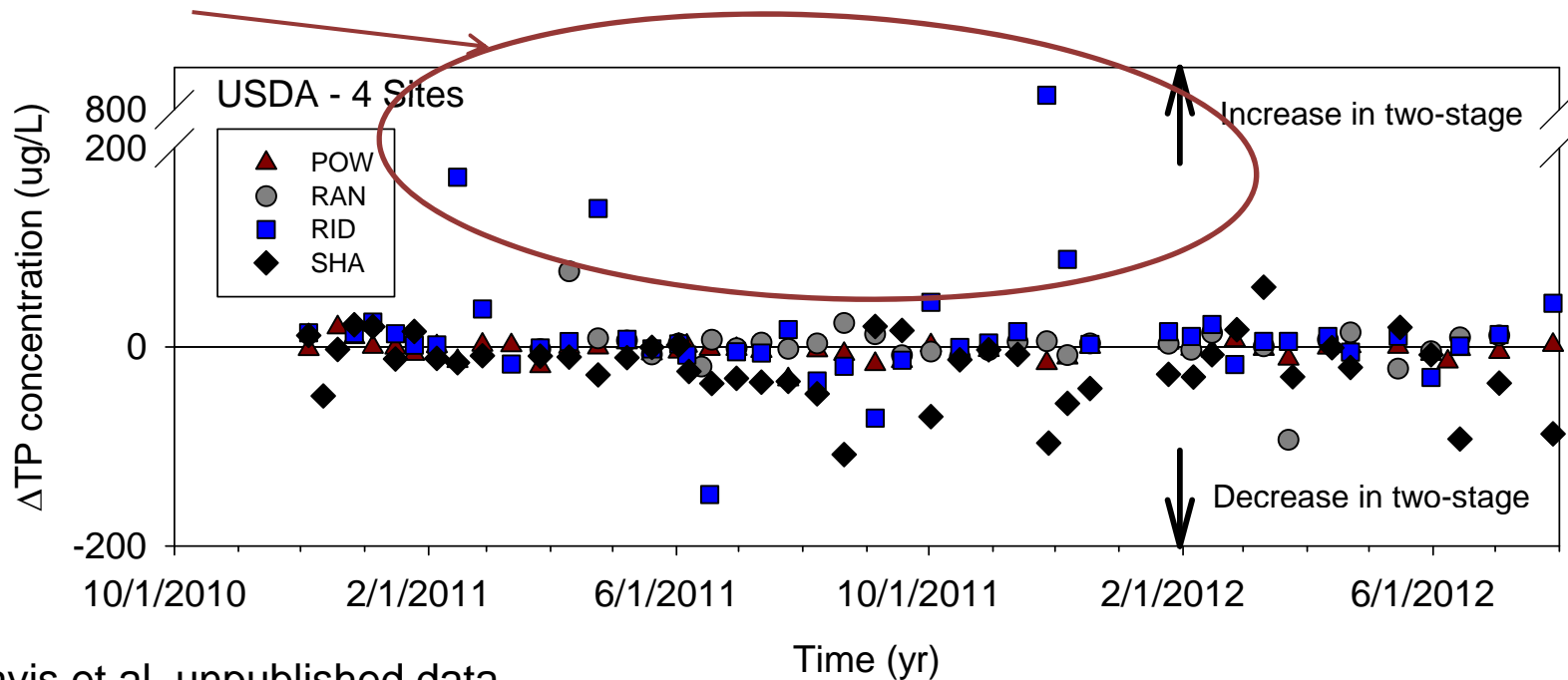
Take-home: real-time turbidity may be useful in predicting TP export from agricultural streams

Two-stage reduced TP in 2 of 4 streams, but is site dependent

- Two-stage decreased TP at 2 of 4 sites; TP varied among sites. Farming practices do matter.
- Using paired data (TRT-CTL) from 4 streams, two-stage had significantly lower TP concentrations (paired t-test, $p=0.04$)
- Paired samples suggest two-stage could reduce TP export; influences SRP

Site	TP ($\mu\text{g l}^{-1}$) mean (SE)	
	Trapezoid	2-stage
Shatto	96 (5)	80 (4)
Ransbottom	146 (14)	134 (21)
Ridenour	163 (3)	201 (20)
Powers	48 (3)	47 (3)

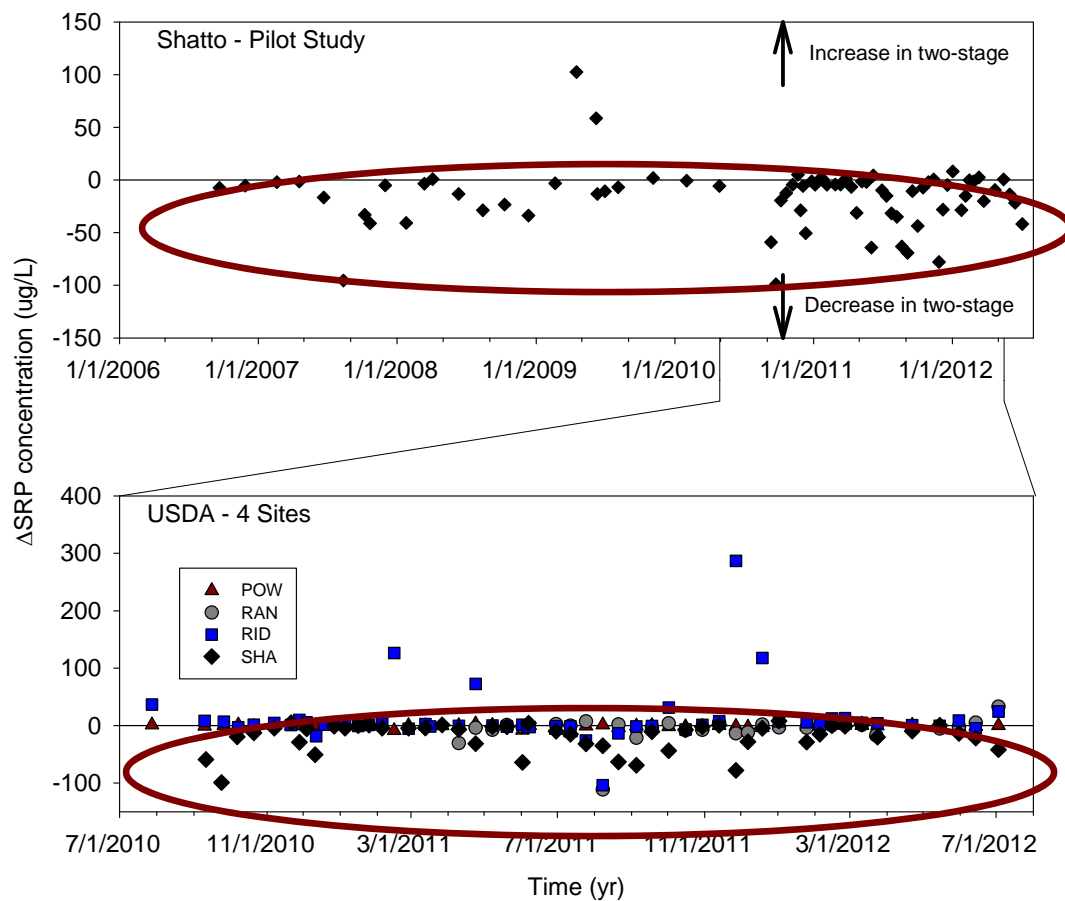
Manure applied to two-stage reach.



Tank, Davis et al. unpublished data

Two-stage reduced SRP concentrations, but site dependent

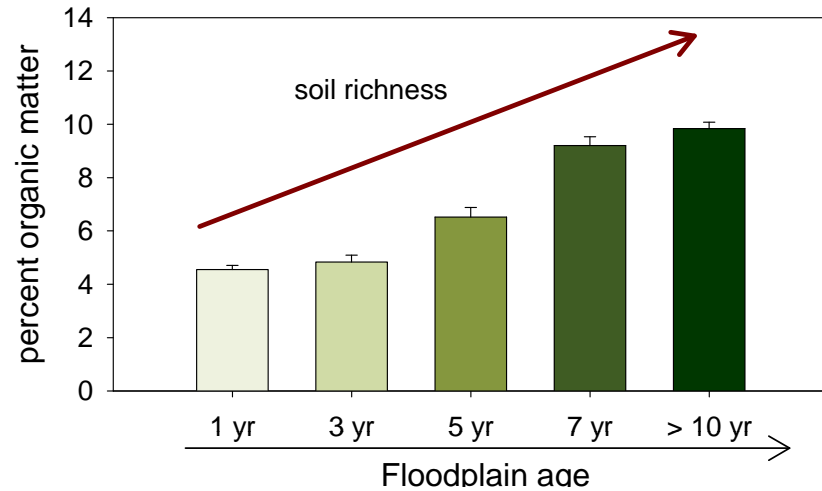
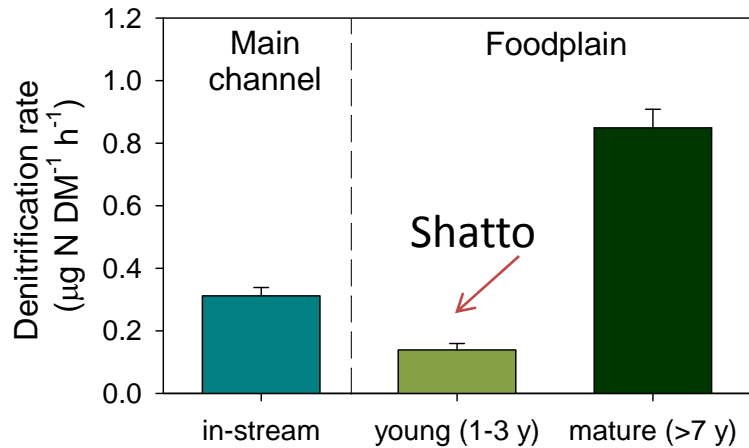
- SRP not as variable; reduced in 3 streams
- Using paired data: two-stage reduced SRP concentrations (paired t-test, $p=0.04$)



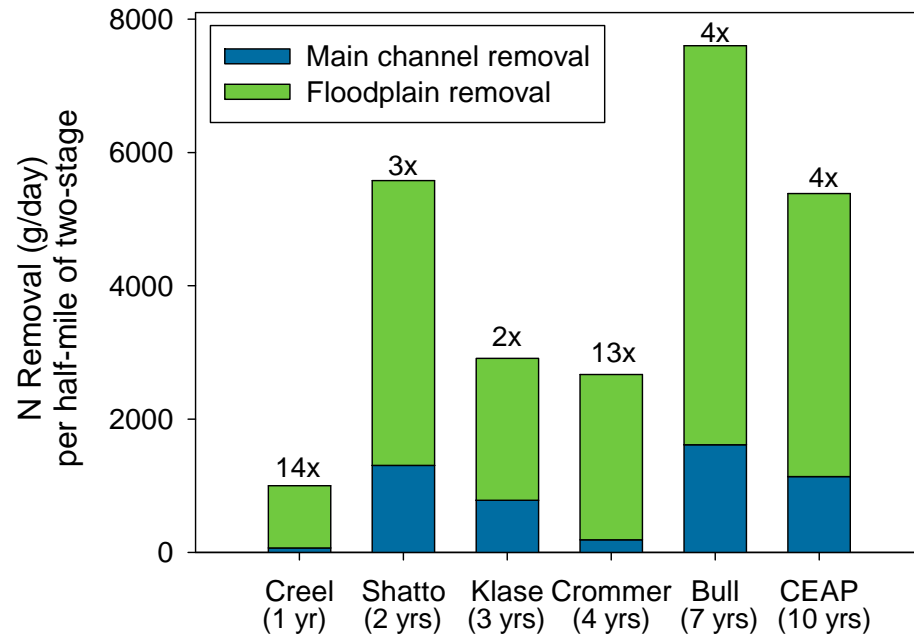
Site	SRP ($\mu\text{g l}^{-1}$) mean (SE)	
	Trapezoid	2-stage
Shatto	39 (0.6)	25 (0.4)
Ransbottom	67 (2.1)	59 (1.7)
Creel	25 (2.7)	9 (0.3)
Crommer	19 (1.3)	22 (1.2)
Ridenour	43 (2.0)	50 (2.0)
Powers	15 (0.3)	14 (0.3)

Take Home: Effects of two-stage on TP & SRP depend on land management & quality of two-stage construction

Take home: Benches “mature” through time. Two-stage denitrification improves as it ages without additional stream management

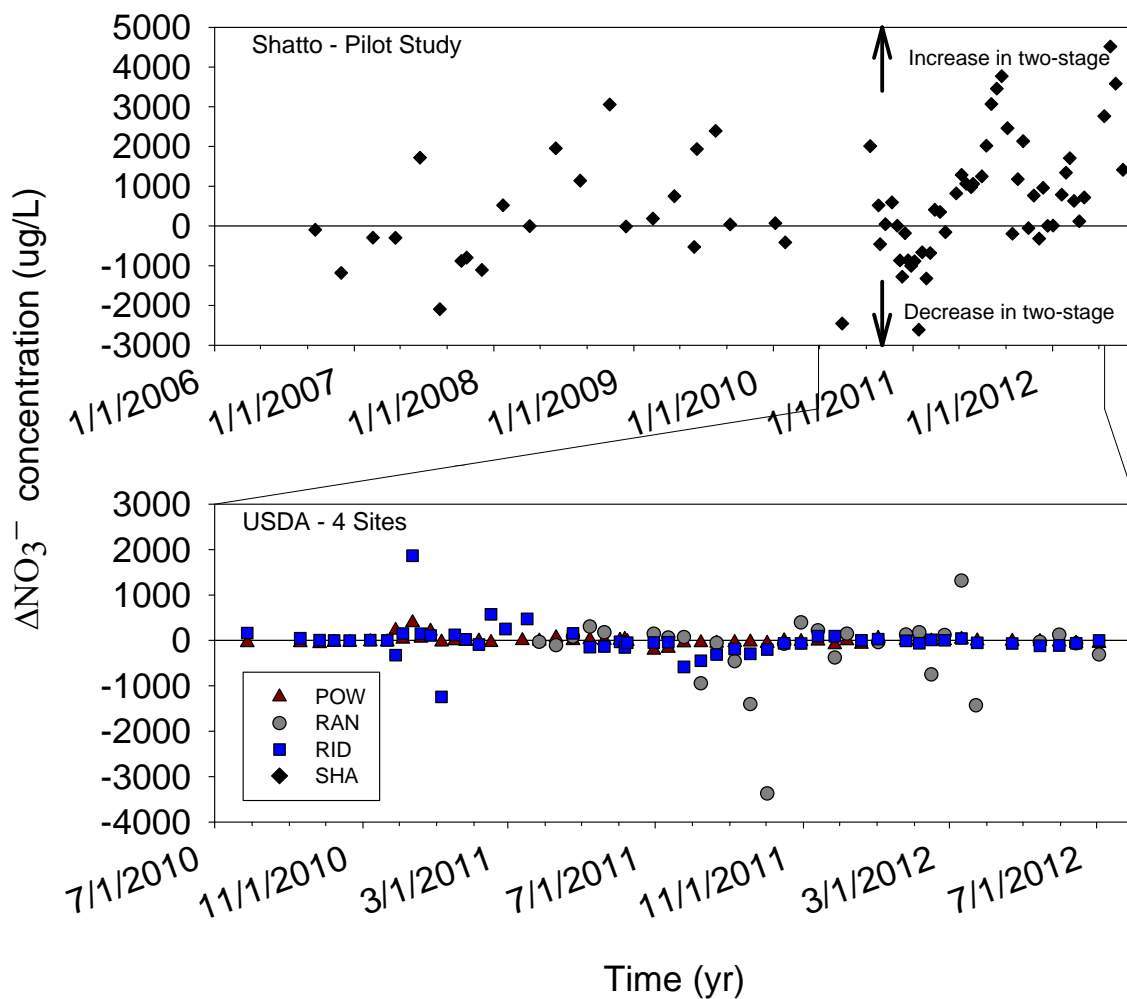


- Our initial estimates of N removal were made on young benches (i.e. Shatto Ditch)
- Denitrification rates generally higher on older floodplains
- Older floodplains have richer soils, which can support higher denitrification rates
- During flood events, two-stage increases reach scale N-removal 2-14x relative to trapezoidal reach



Tank, Davis et al. unpublished data

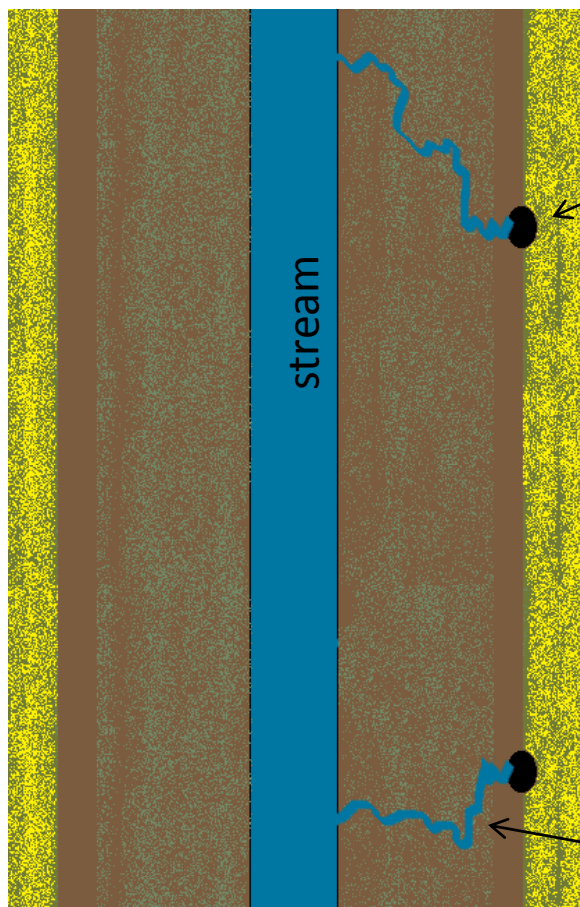
Did two-stage decrease NO_3^- concentration?



- No decrease in NO_3^- at Shatto over 5 years, very high and variable
- Also no change across 4 additional sites over 2 years with more frequent sampling

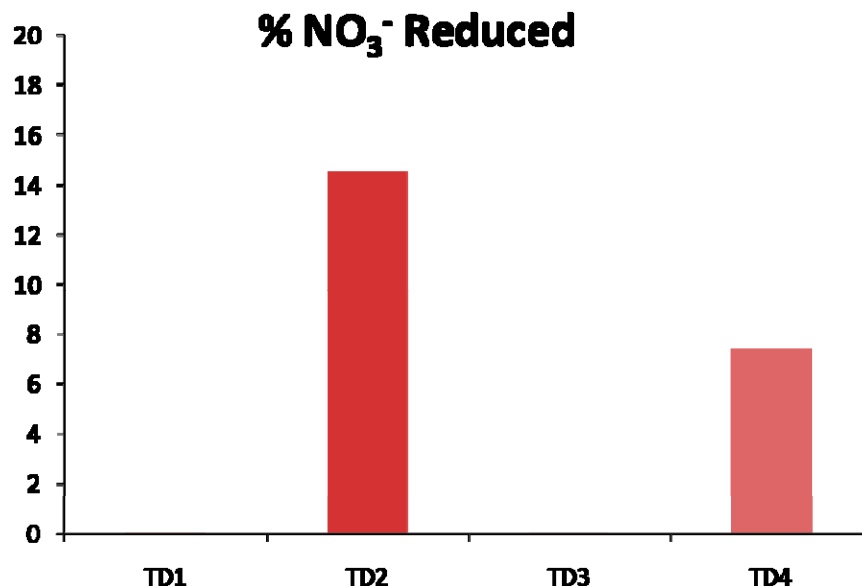
Take-home: NO_3^- is currently too high in these streams to be reduced solely by 600m of two-stage. Efficacy would be improved if length extended and practice combined with other land management practices to reduce NO_3^- inputs.

Two-stage floodplains can reduce NO_3^- in tile outflows



aerial schematic

tile drains are a source of highly-concentrated NO_3^-



pilot study: NO_3^- concentrations reduced by **6-19%** as water flows along floodplain

Take-home: Retaining tile drain flow on benches during base flow may improve N removal efficacy; trials planned.

Returning to our predictions on effects of two-stage :

1. **Reduce water column turbidity, sediment and P export**

Yes. Turbidity was lower in properly-constructed two-stage ditches; TSS, TP, and SRP were also lower in two-stage.

2. **Increase particle size of benthic sediments**

Yes. But substrate effect takes time to appear, evident in two-stage ditches ≥ 4 years old.

3. **Increase reach-scale N removal**

Yes. Two-stage denitrification was 2-14x higher; but nitrate was not lower due to very high N loading.

Roley, S. S., J.L. Tank, M.L. Stephen, L.T. Johnson, J.J. Beaulieu and J.D, Witter. 2012. Floodplain restoration enhances denitrification and reach-scale nitrogen removal in an agricultural stream. *Ecological Applications*. 22: 281–297.

Roley, S. S., J.L. Tank, and M.A. Williams. 2012. Hydrologic connectivity increases denitrification in the hyporheic zone and restored floodplains of an agricultural stream. *J. Geophys. Res- Biogeosciences*.. doi:10.1029/2012JG001950

Implementation best practices – two-stage ditch efficacy improves when:

- Floodplain benches are inundated regularly.
 - Shatto Ditch averaged 12 inundation events per year.
- Tile water flows across floodplains for as long as possible.
 - Construct so that tile outlets are not rip-rapped.
- Floodplain benches “age” better when vegetated.
 - Species identity secondary, does not affect N removal.

Take-home: The two-stage is a self-sustaining practice that potentially reduce nutrients and sediment in agricultural streams and can coexist with productive agriculture.

Two-stage Information:

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