Recommended Measures to Improve Water Quality at Lake Thunderbird

Environmental Engineering Capstone

May 6, 2021

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PRESENTATION ROAD MAP

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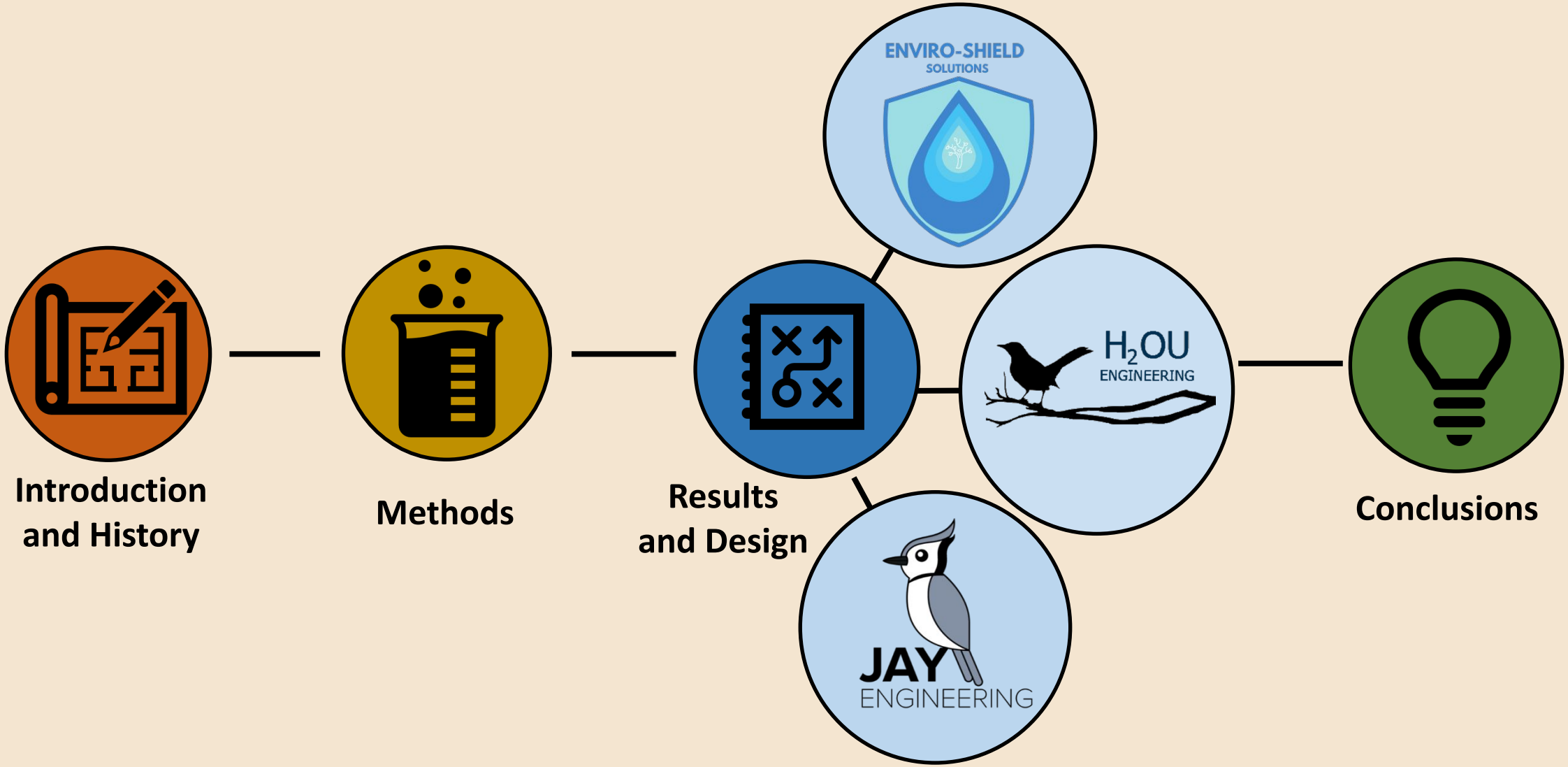

INTRODUCTION & HISTORY

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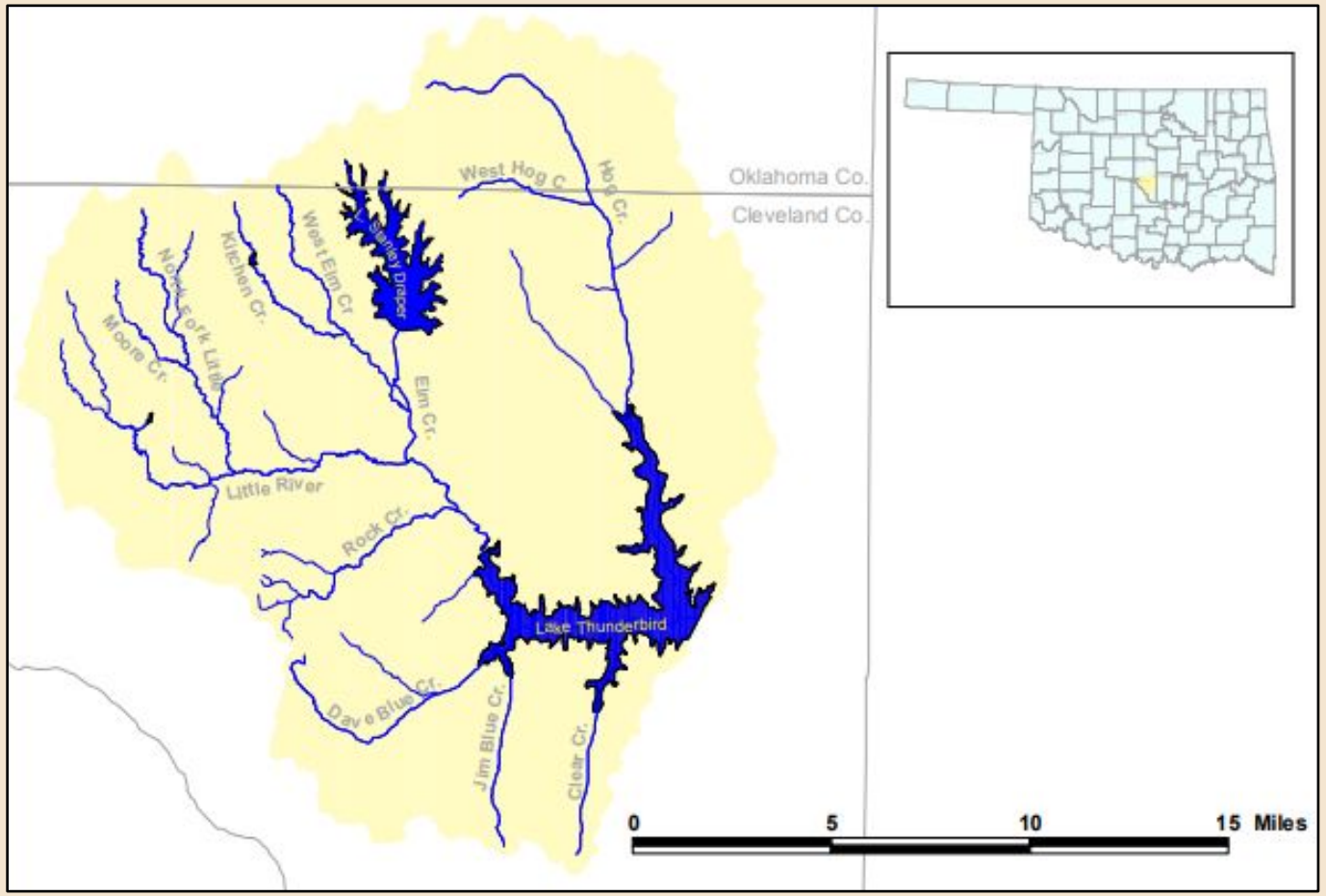
- **666 km^2 (256 mi^2) in Cleveland and Oklahoma counties**
- **Principal tributaries Little River and Hog Creek**
- **Primary drainage from Norman, Moore, and OKC**
- **Drinking water to Norman, Del City, and Midwest City**



Lake Thunderbird Watershed (OCC 2008)

INTRODUCTION & HISTORY

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- Sensitive Water Supply (SWS)
- DEQ 303(d) list
- Total Maximum Daily Load (TMDL)
  - Chlorophyll-a (Chl-a)
  - Dissolved Oxygen (DO)
  - Turbidity

Photo taken at Lake Thunderbird

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Methods

METHODS

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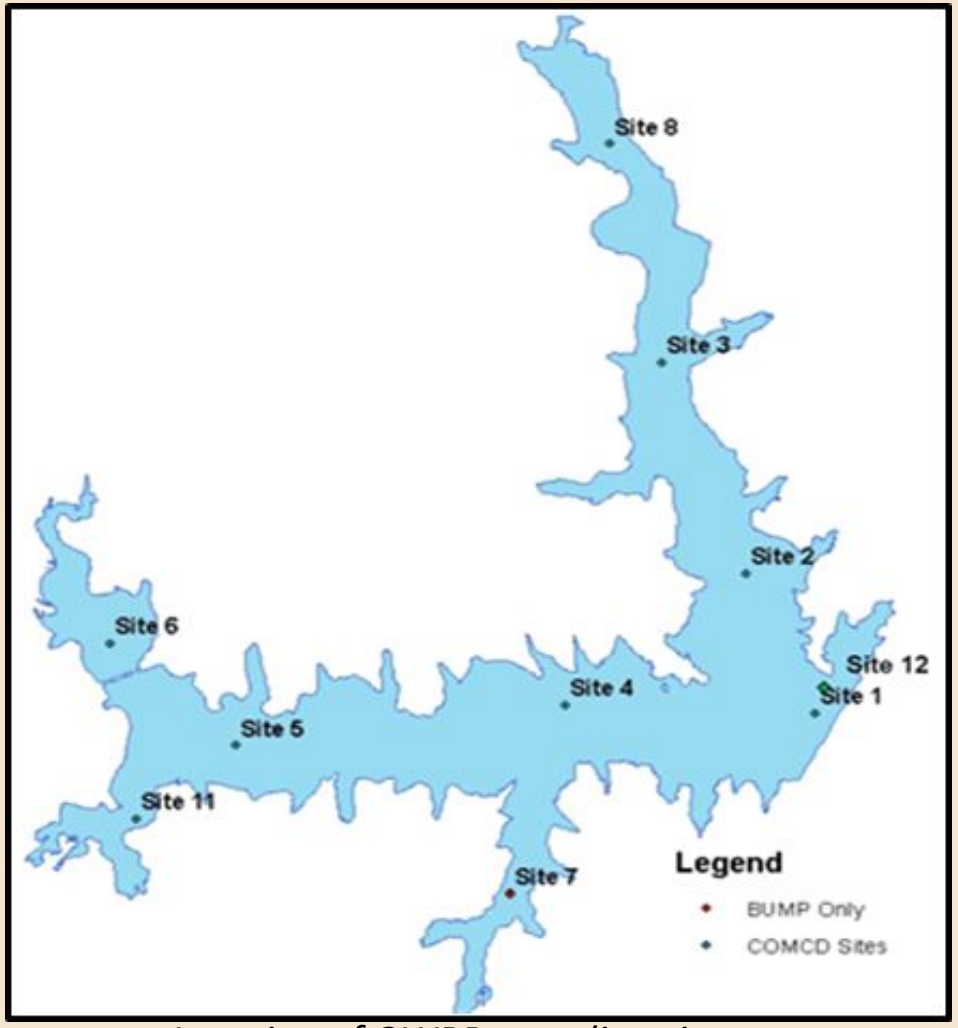
- **OWRB data over last 20 years**
  - **30 Parameters**
  - **Correlations**
  - **Seasonal Variations**
  - **Hydrologic Effects**



Location of OWRB sampling sites on Lake Thunderbird sampled from 2000-2020 (OWRB 2020)

SAMPLING TRIP

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- March 20, 2021
- Sampled sites 1, 2, 4, 5, 6, and 11
  - Field Tests
    - Alkalinity
    - Hardness
    - Chl-a
    - DO
    - Turbidity
    - Secchi Disk Depth
  - Laboratory Tests
    - Total Nitrogen (TN)
    - Total Phosphorous (TP)
    - Total Suspended Solids (TSS)

OBJECTIVE

Identify measures to improve Lake Thunderbird's water quality…

ENVIRO-SHIELD SOLUTIONS

H_2OU ENGINEERING

JAY ENGINEERING

ENVIRO-SHIELD

SOLUTIONS

MEET OUR TEAM

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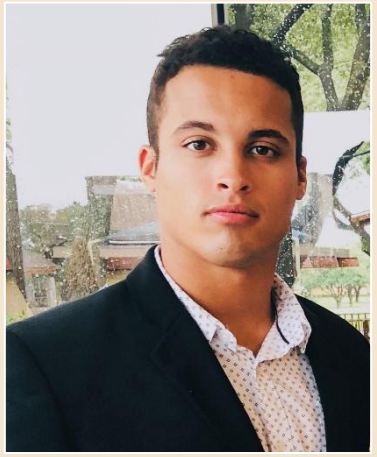
Heath Orcutt



Oscar Tavarez

ENVIRO-SHIELD
SOLUTIONS

Cameo Holland

Peter Wolbach

DATA ANALYSIS

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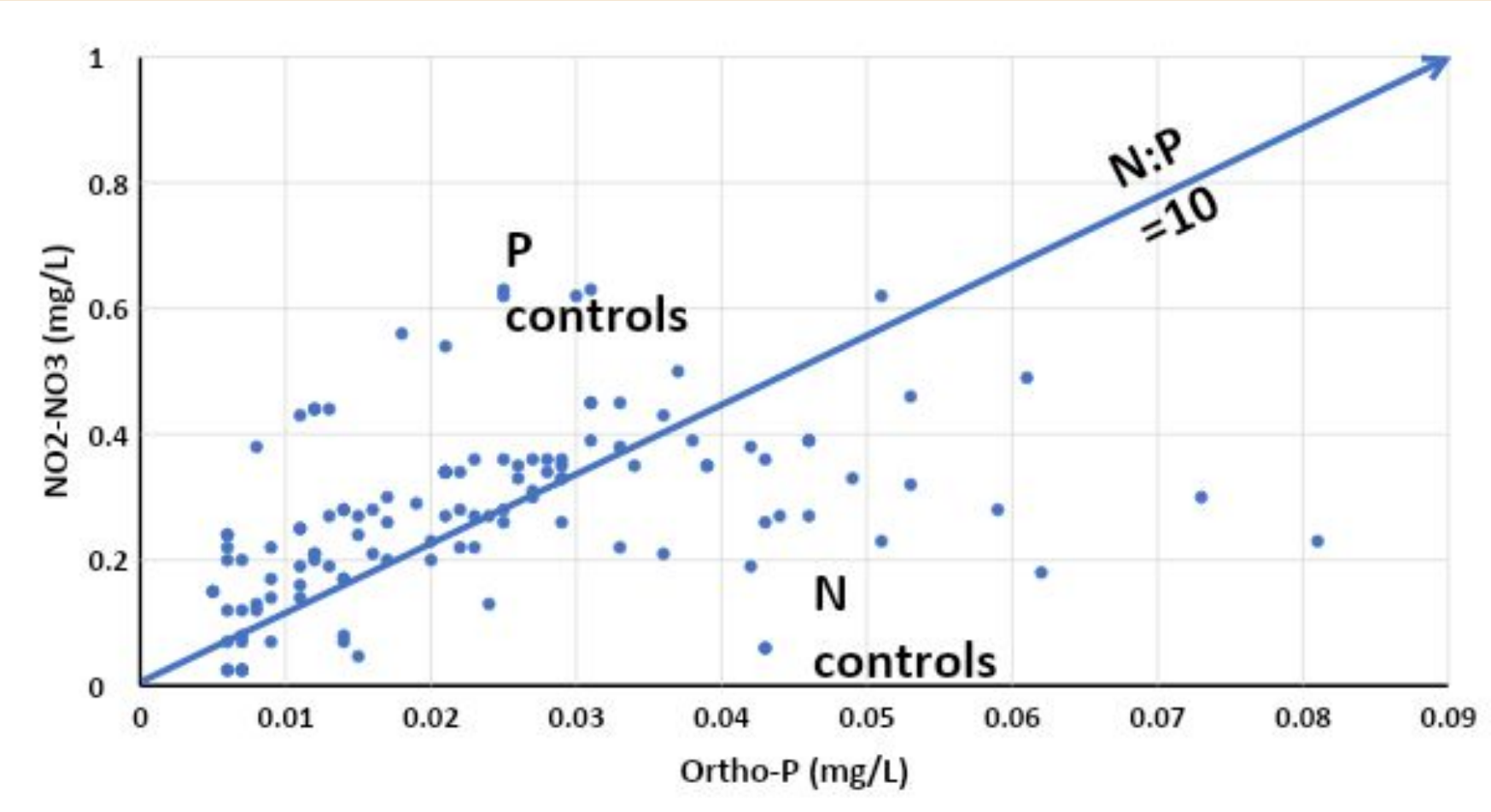
Need to determine the limiting nutrient: Phosphorus!



N:P Ratios from 2000-2015 OWRB data set (Nitrate vs. Ortho-P)

ENVIRO-SHIELD SOLUTIONS

DATA ANALYSIS

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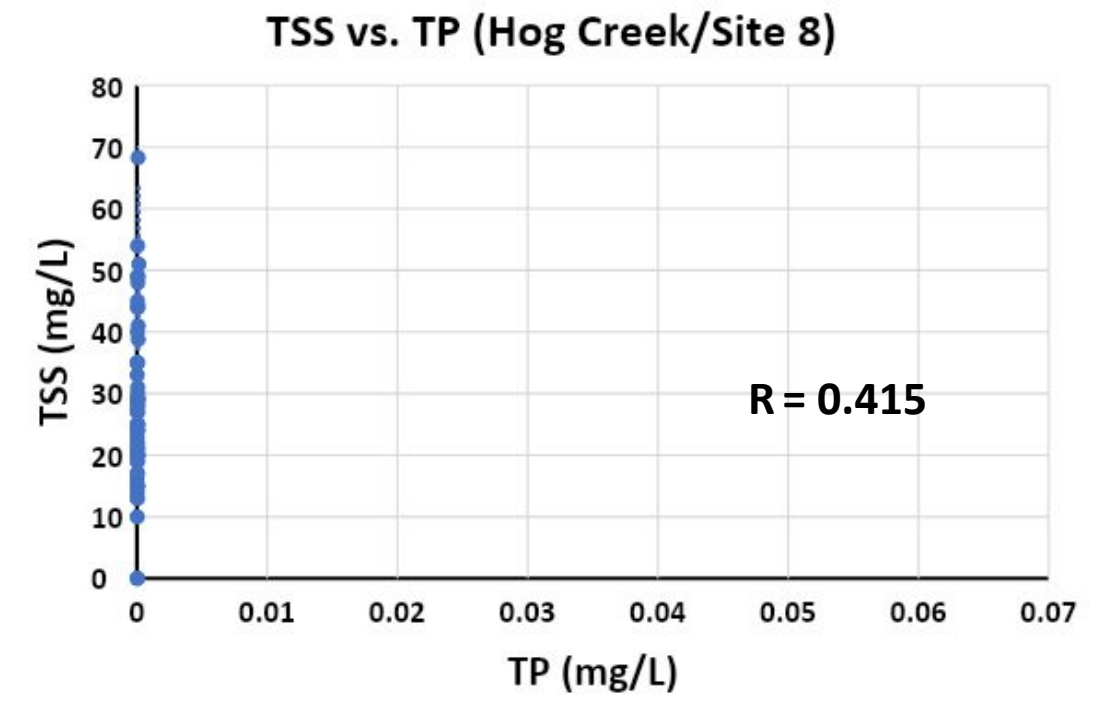
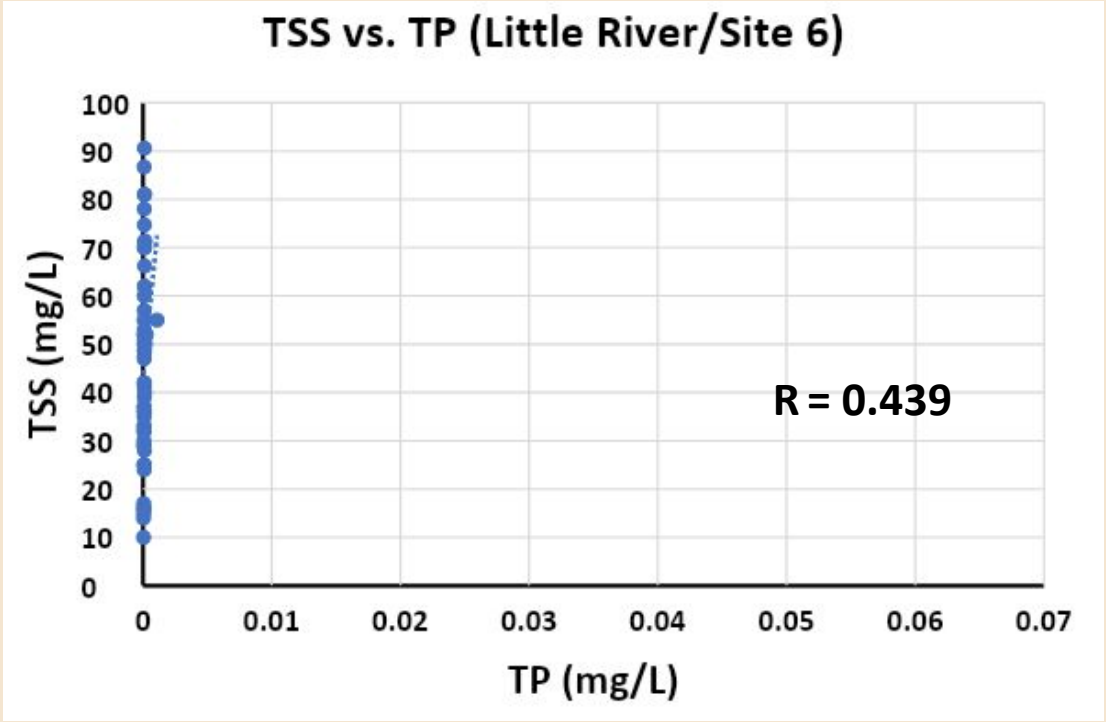
Does an increase in TP indicate an increase in sediment loading?





(2005-2016 OWRB Dataset)

✔ **Positive correlation**

ENVIRO-SHIELD SOLUTIONS

DATA ANALYSIS

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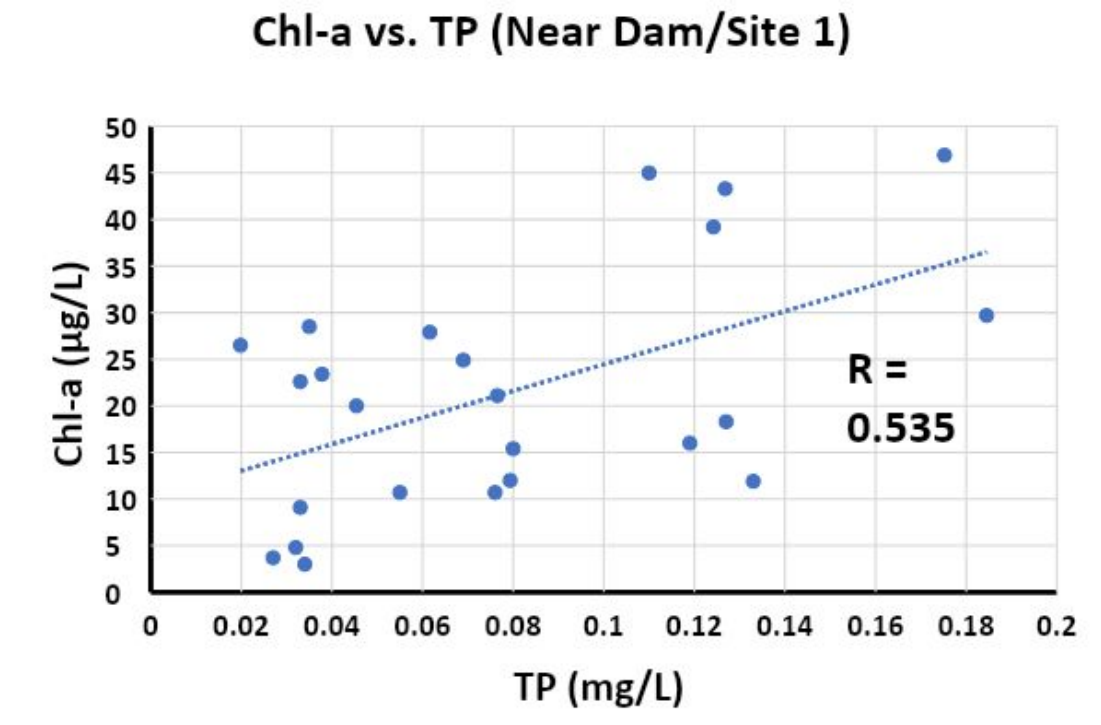
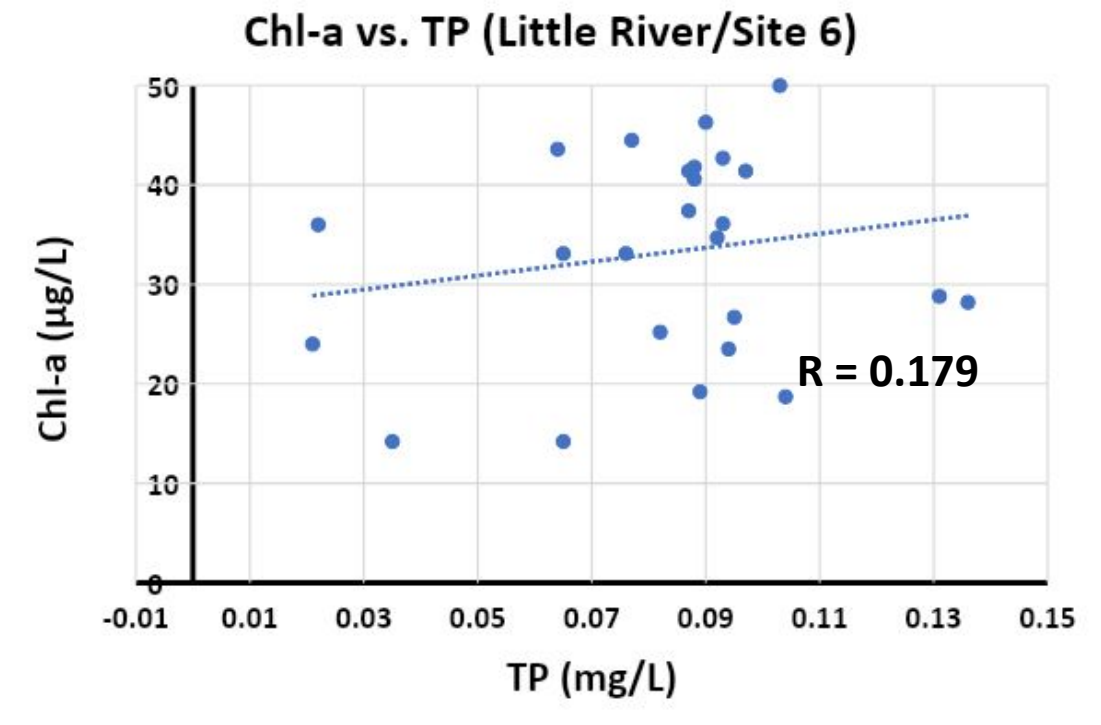
Does an increase in TP lead to an increase in Chl-a?





(2016-2019 OWRB Dataset)

✔ **Positive correlation**

↓ sediment loading + ↓ phosphorus loading = ↓ Chl-a

Limit eutrophication!

ENVIRO-SHIELD SOLUTIONS

EVALUATION CRITERIA

- **Adapted from 2016 City of Norman "Strategic Water Supply Plan"**
- **Weighted percentages from COMCD**
- **Technologies ranked on 1 to 5 scale (1 = lowest, 5 = highest)**

ENVIRO-SHIELD SOLUTIONS

RESULTS

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Objective	Sub-objective	BB	CGRs	LV	IB	H_2O_2	SC	P	UI	SRv	CW	FW
Affordability	Minimize capital cost	4	5	5	4	1	2	1	2	3	3	5
	Minimize life-cycle cost											
Efficacy	Reduction in volume runoff	5	1	1	5	1	1	1	1	2	1	1
	Reductio		1	1	4	4	5	1				
	Reductio		1	1	4	1	3	5				
	Reductio		5	1	5	4	1	1				
Environmental Stewardship	Minimize temporary construction impacts and environmental mitigation needs	3	5	5	4	5	2	5	5	4	4	3
	Minimize permanent ecosystem impacts	5	5	5	4	1	4	4	3	3	4	3
	Public/political acceptability	3	5	5	3	2	5	2	3	5	5	3
Lifetime Assessment	Temporal reliability	5	4	2	4	3	3	3	4	2	5	5
Community Values	Impact on non-water supply benefits	5	4	4	3	1	4	4	3	5	3	5
	Reliance on natural infrastructure	4	3	4	4	1	1	1	1	5	5	4
	Protection of property rights	2	3	3	2	5	4					5
	Environmental Equity	5	1	1	3	1	1					2
	Access to Nature	5	2	2	3	5	5					4
Water Quality Aesthetics	Minimize taste and odor potential	3	1	1	1	4	5					3
	Address DO levels	4	1	1	1	4	5	1	3	1	3	3
Raw Scores		**3.71**	3.00	2.59	3.29	2.59	3.06	2.65	3.12	3.18	3.29	3.24
Weighted Scores		**3.77**	3.32	2.73	3.33	2.54	3.08	2.55	3.24	2.87	3.46	3.45

Watershed BMP: Bioretention Basins

In-Lake Technology: Constructed Wetlands

Technologies/BMPs	BB	CGRs	LV	IB	H_2O_2	SC	P	UI	SRv	CW	FW
Weighted Scores	**3.77**	3.32	2.73	3.33	2.54	3.08	2.55	3.24	2.87	**3.46**	3.45

Floating Wetlands (attempted before)

ENVIRO-SHIELD SOLUTIONS

BIORETENTION BASINS

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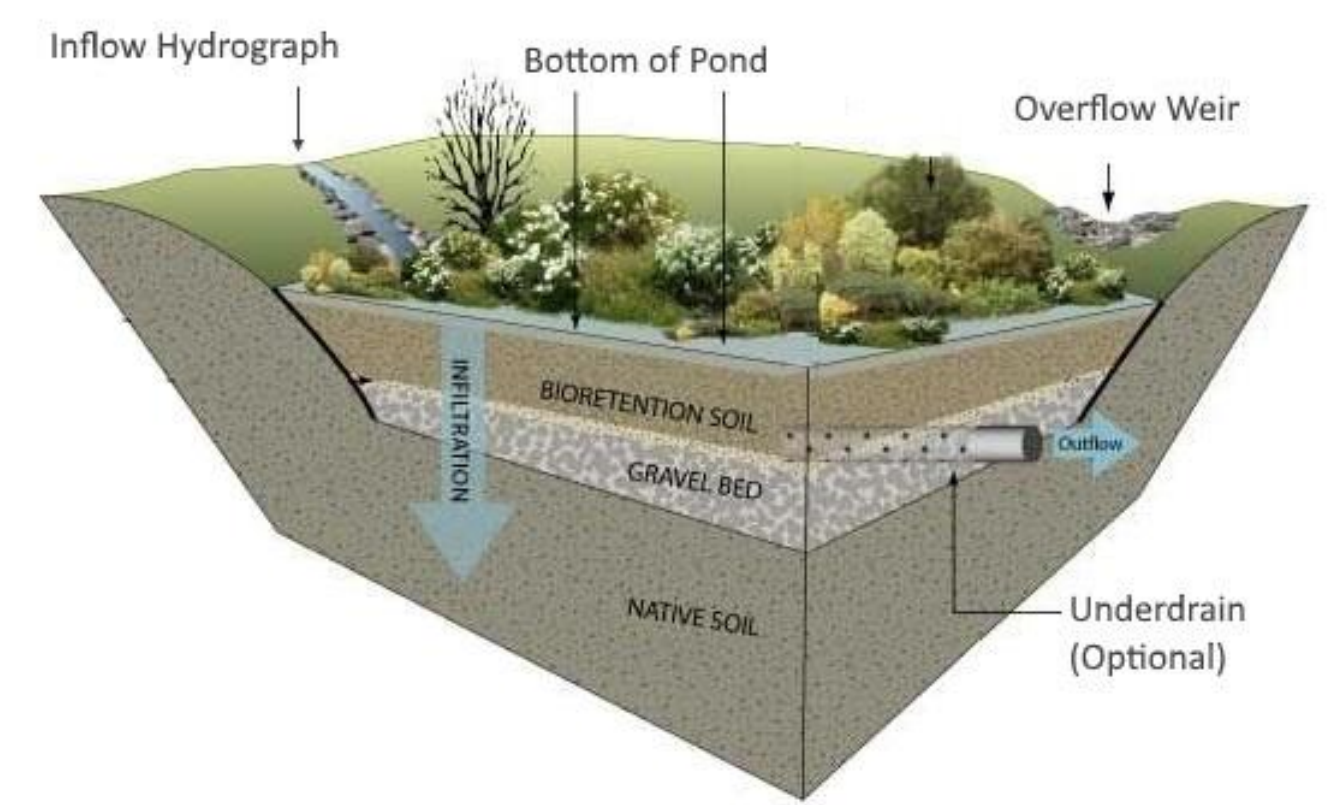

Bioretention basin schematic (Hydrology Studio, n.d.)

Bioretention basin during storm event (USEPA, 2013)

- **5% of impervious areas**
- **Distribute in hydrologically sensitive areas**

(Martin-Mikle et al., 2015)

ENVIRO-SHIELD SOLUTIONS

NUTRIENT LOADING

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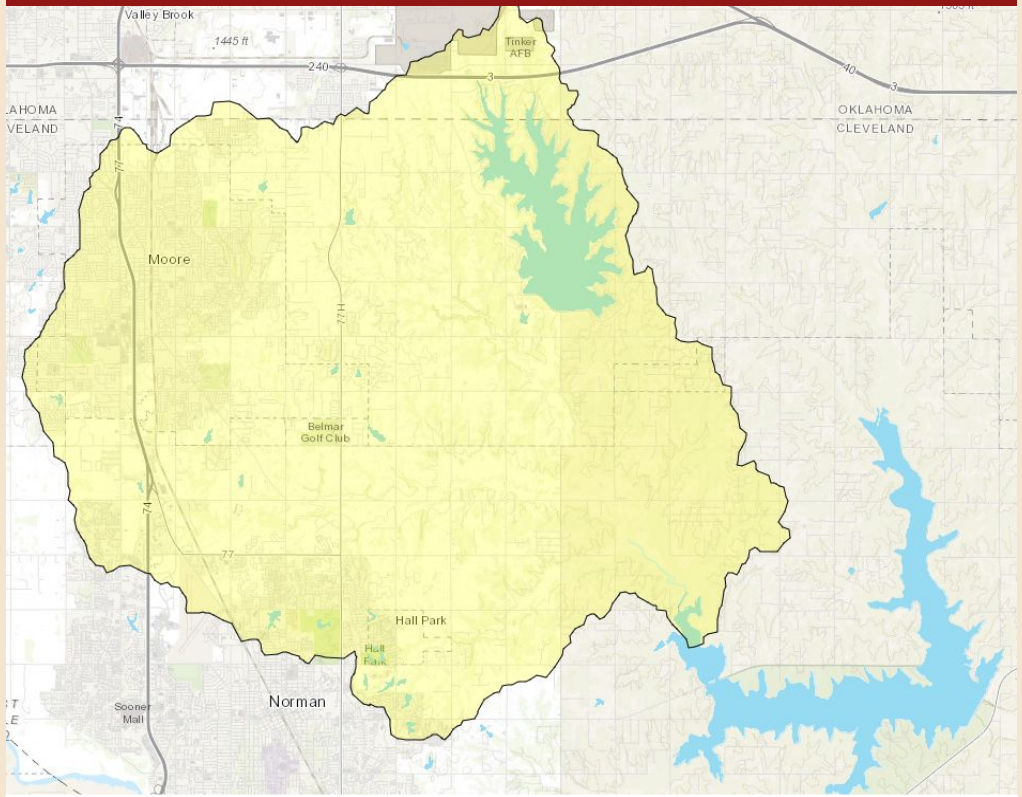
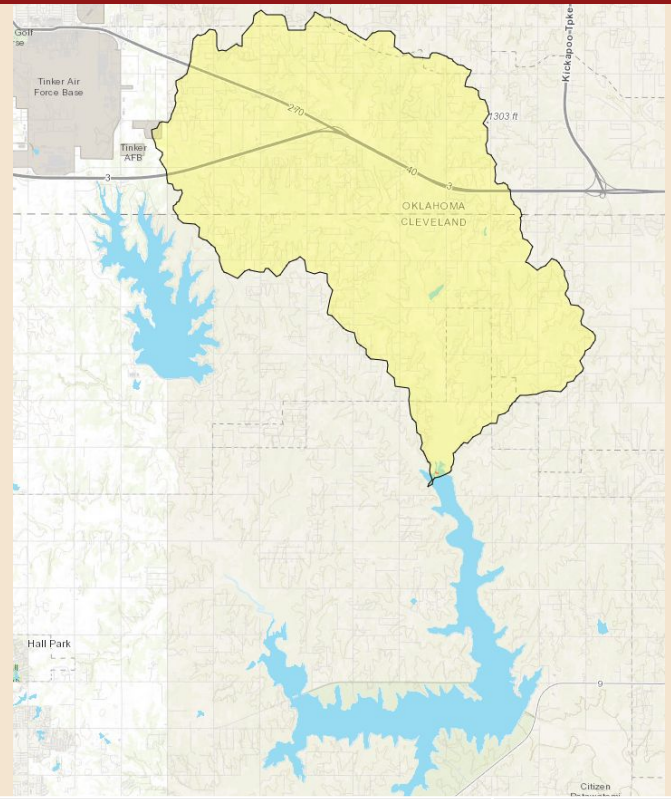
Little River Drainage Basin



Peak TP Loading	6235	kg/d
Average TP Loading	8.5	kg/d

Hog Creek Drainage Basin



Peak TP Loading	2320	kg/d
Average TP Loading	2.3	kg/d

ENVIRO-SHIELD SOLUTIONS

CONSTRUCTED WETLAND

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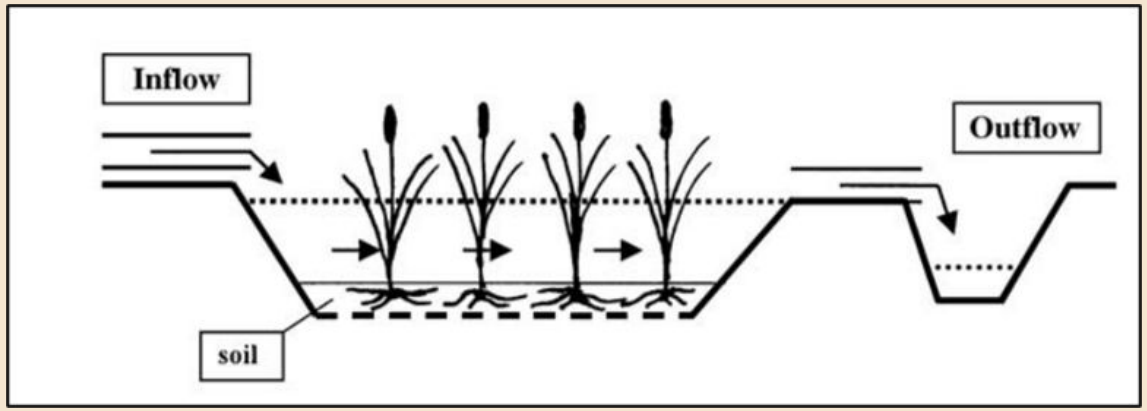

Free water surface and emergent macrophytes schematic (Vymazal, 2017)

East Fork Wetland in North Texas (NTMWD, n.d.)

Recommended Location for Constructed Wetland N of Alameda Bridge (StreamStats, 2021)

ENVIRO-SHIELD SOLUTIONS

CONCEPTUAL DESIGN

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Bioretention Basins					
TP Reduction	TN Reduction	TSS Reduction	Total Area (acres)	Lifetime	Total Cost
31%	32%	60%	240	20 yrs	$2.6 Million

Constructed Wetland Design (Max TP Loadings)					
TP Reduction	TN Reduction	TSS Reduction	Total Area (acres)	Lifetime	Total Cost
50%	80%	95%	831	40 yrs	$18.2 Million

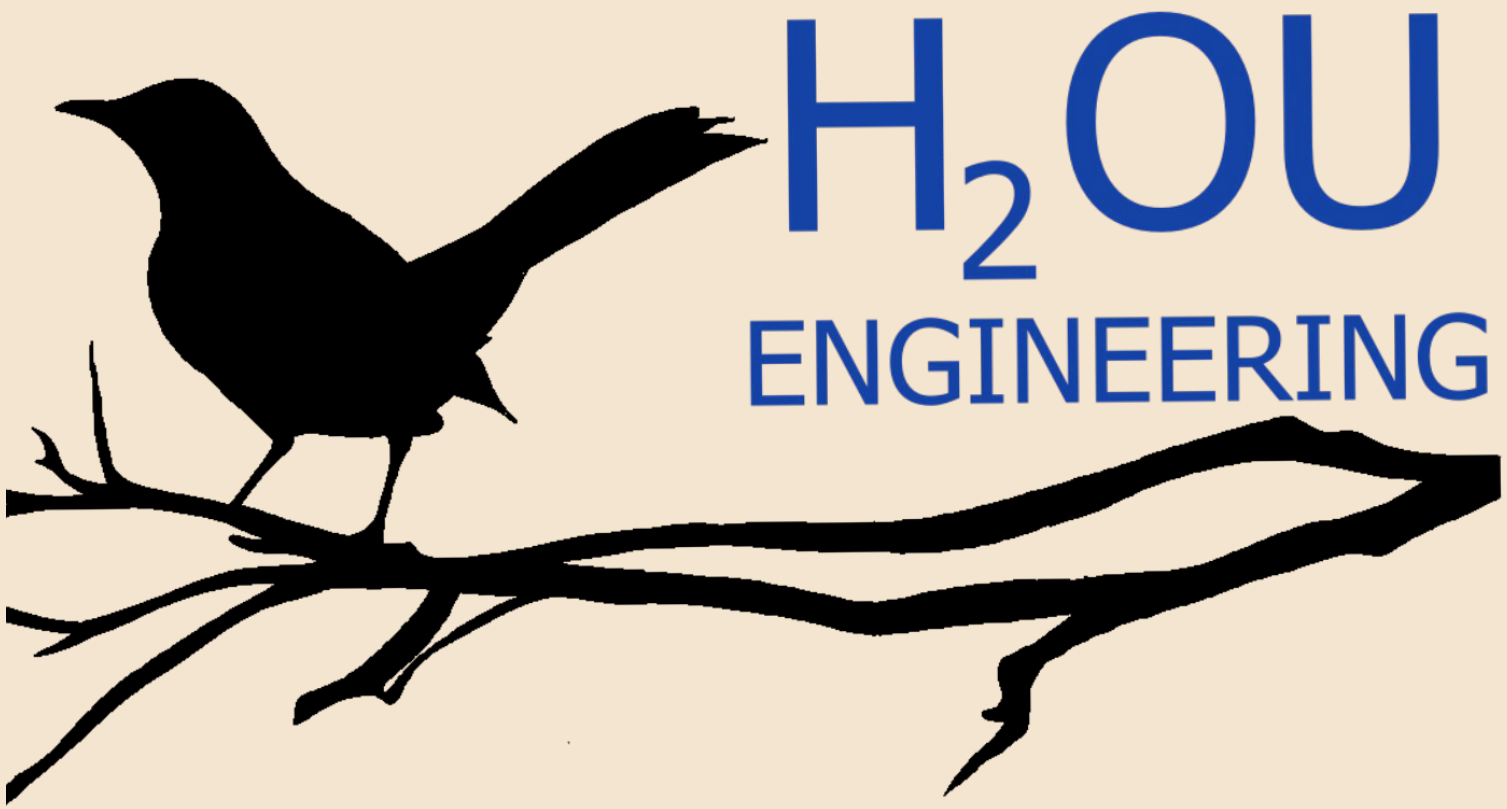
ENVIRO-SHIELD
SOLUTIONS

OPPORTUNITIES

- **March 29, 2021 – EPA Sewer Overflow and Stormwater Reuse Municipal Grants Program**
  - **20% of funding to "green infrastructure"**
  - **Application open**
- **March 31, 2021 – American Jobs Plan**
  - **$56 billion proposed for "upgrading and modernizing America's wastewater, stormwater, and drinking water systems"**

Clean Water State Revolving Fund (CWSRF) Loan Program Bioretention roundabout in Bixby, OK (OWRB, n.d.)

ENVIRO-SHIELD SOLUTIONS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Sarah Hobson

Rachel Bandy

Monica Ha

Paige Hardman

Kaleb Schwab

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DATA ANALYSIS OBJECTIVES

Turbidity, Chlorophyll-a, Dissolved Oxygen

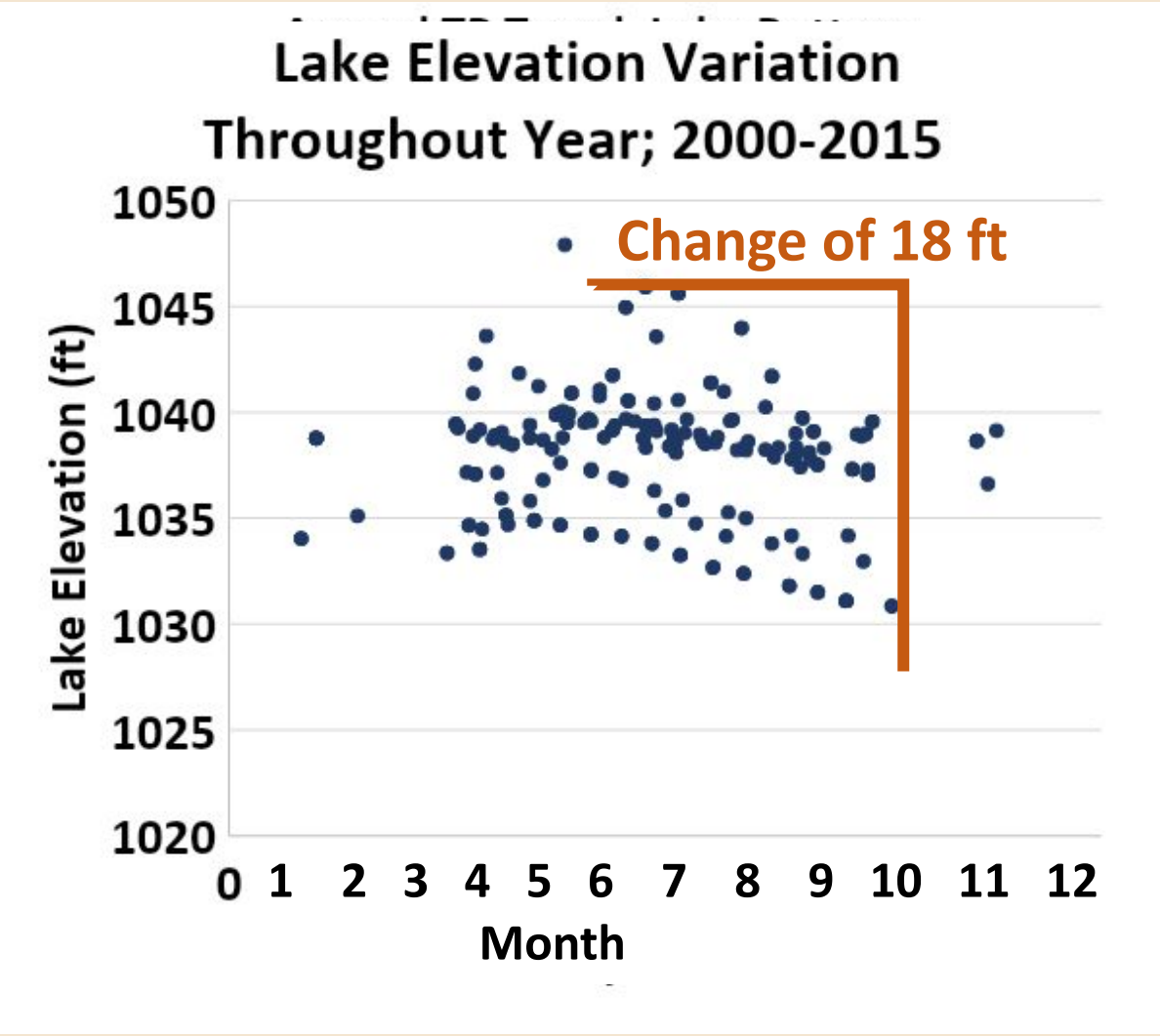
Measure Variation by

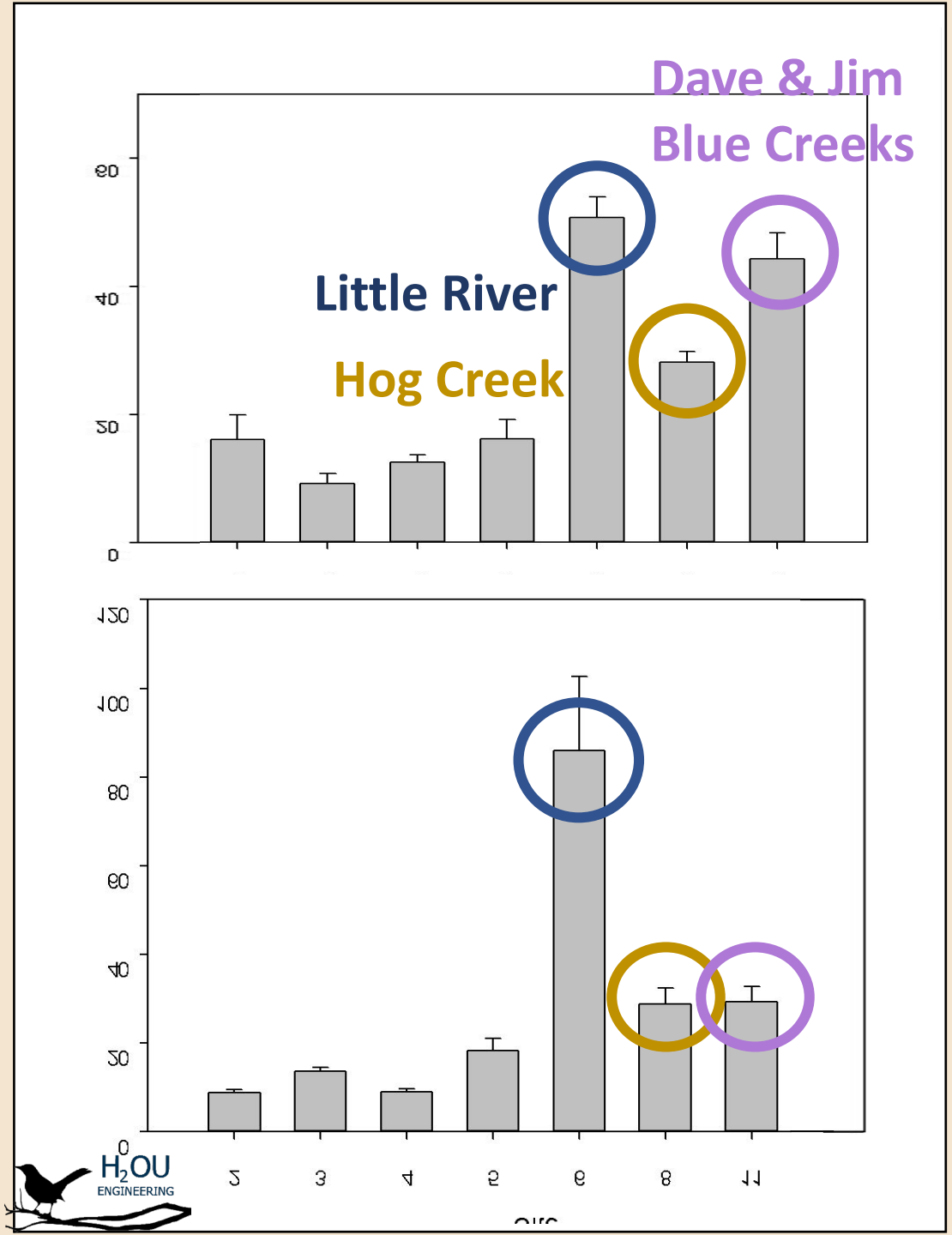
Location	Depth	Day of Year	Relationship to Parameters

Relate to Treatment Methods

DATA ANALYSIS FINDINGS

- Increase in TP with TSS and lake depth
- Nutrient concentrations increase with lake turnover
- Lag correlation between TP and Chl-a
- Elevated Chl-a in summer
- Horizontal mixing
- 18 ft elevation change over 15 years




Dave & Jim
Blue Creeks
Little River
Hog Creek


Hog Creek
Site 8
Site 3
Site 2
Little River
Site 6
Site 12
Site 1
Site 4
Site 5
Site 11
Site 7
Dave & Jim
Blue Creeks

DATA ANALYSIS FINDINGS

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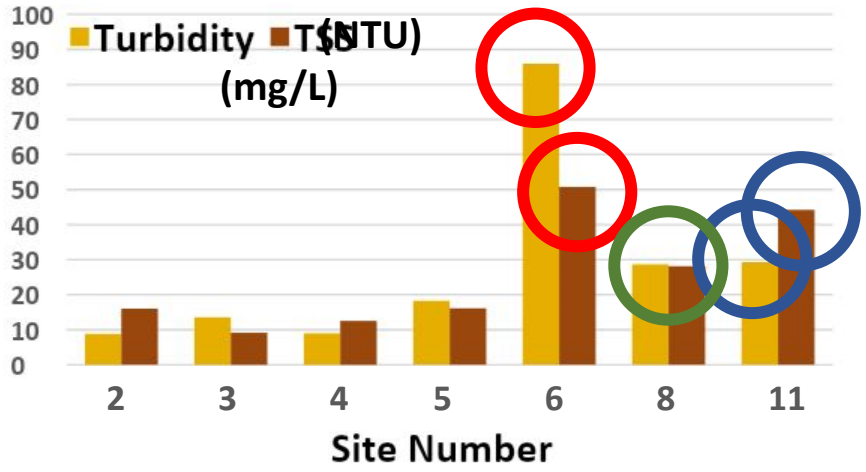
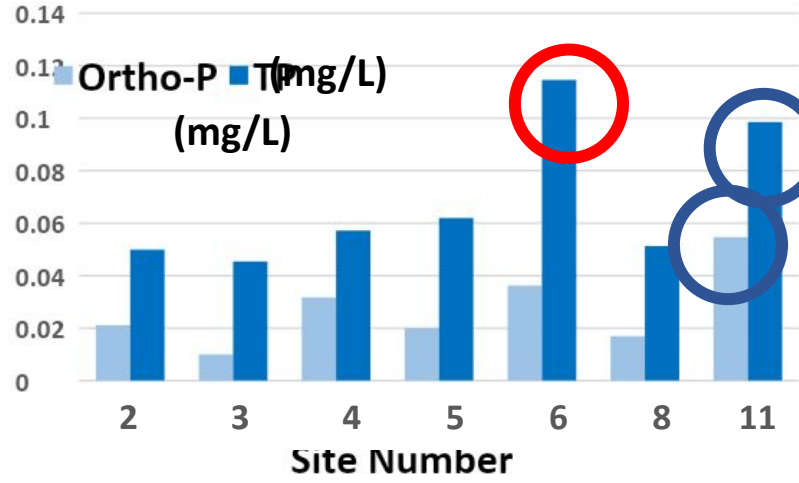
Loadings From

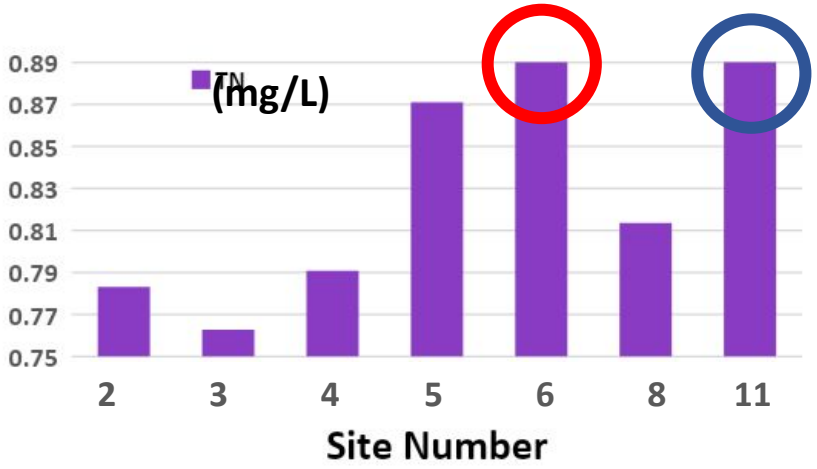
Little River

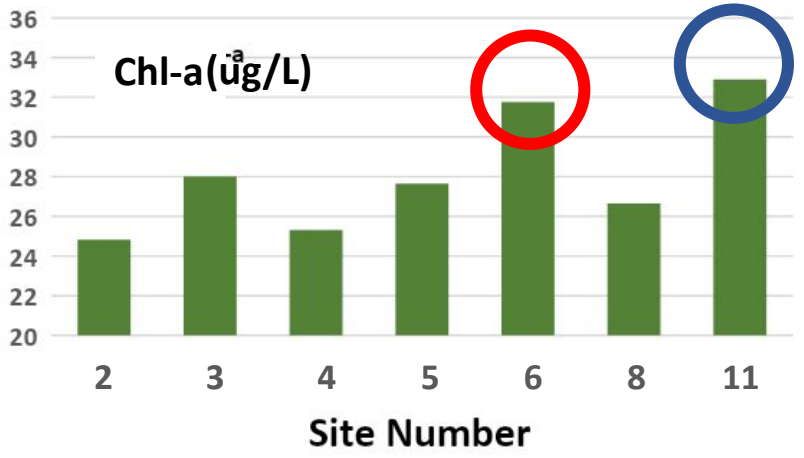
Dave & Jim Blue Creeks

Hog Creek









EVALUATION PROCESS

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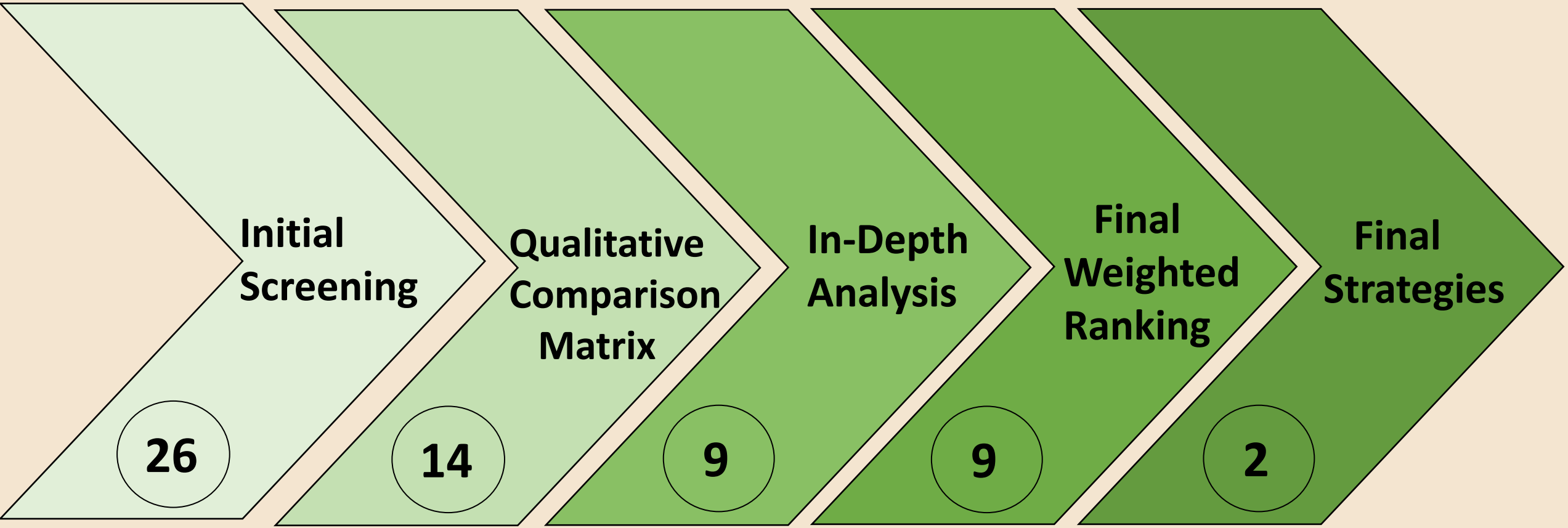

DECISION CRITERIA WEIGHTS

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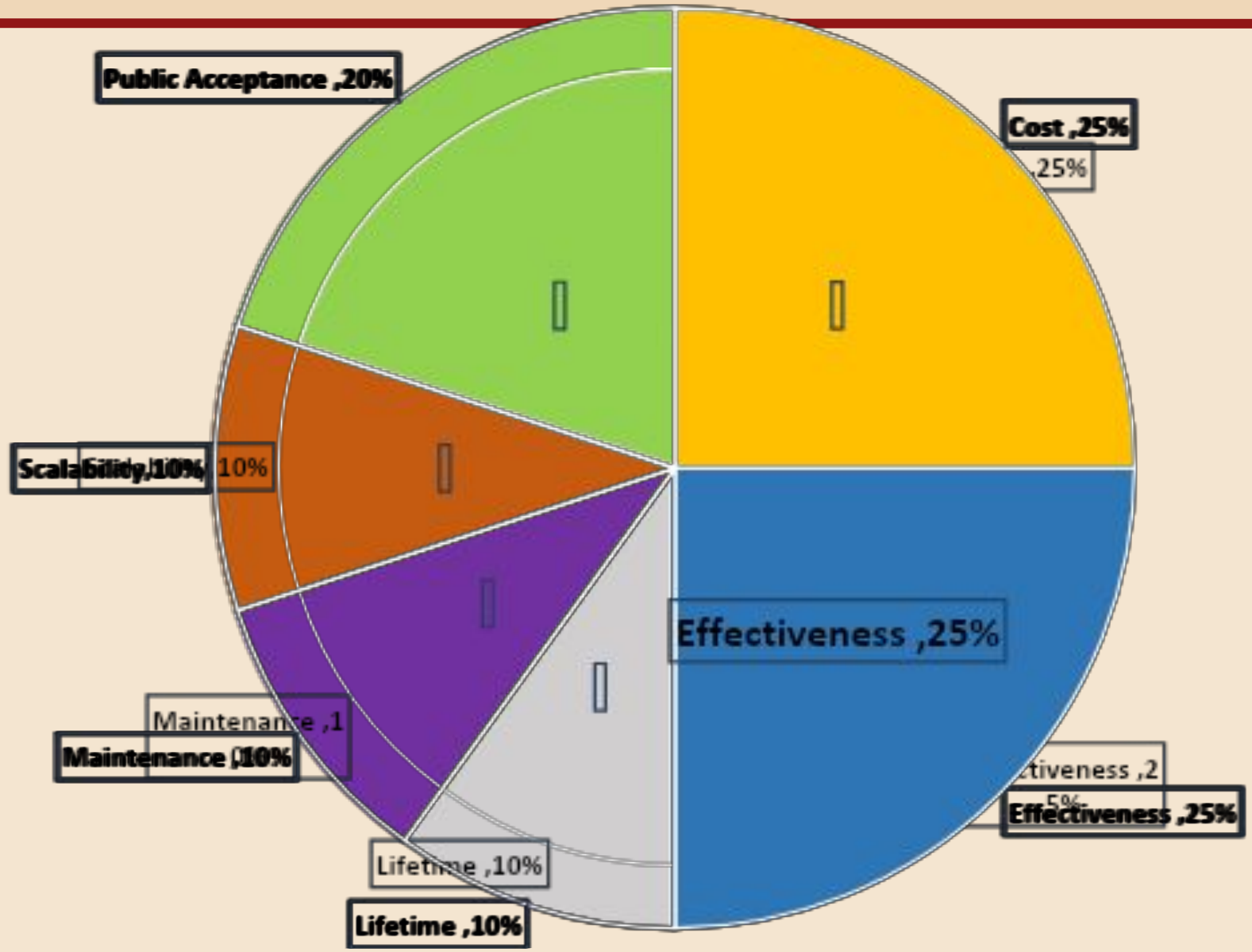

WEIGHTED RANKING RESULTS

Lake Level Strategy	Cost	Effectiveness	Lifetime	O&M	Scale	Public Acceptance	Total
Multiplier	**0.25**	**0.25**	**0.10**	**0.10**	**0.10**	**0.20**	
Constructed Wetlands	3.00	4.00	3.00	4.00	3.00	3.00	**3.35**
Biomanipulation	4.00	2.00	3.00	3.00	4.00	4.00	3.30
P Inactivation	4.00	4.00	3.00	2.00	2.00	3.00	3.25
Shoreline Revegetation	4.00	2.00	4.00	3.00	3.00	4.00	3.20
Breakwater Systems	4.00	2.00	3.00	3.00	3.00	4.00	3.10
Down Flow Bubble Contact System	2.00	3.50	3.00	2.00	4.00	4.00	3.00
Coagulation Magnetic Separation	4.00	3.00	3.00	2.00	1.00	3.00	2.90
Sediment Dredging	1.00	4.00	3.00	3.00	4.00	1.00	2.40
Sediment Oxidation	2.00	2.50	3.00	2.00	1.00	2.00	2.13

CONCEPTUAL DESIGN

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Wetland Design

- Horizontal Free Surface Flow

Suggested Areas and Locations

- Hog Creek: 400 acres
- Little River: 800 acres
- Dave & Jim Blue Creeks: 200 acres

Total: 1400 acres

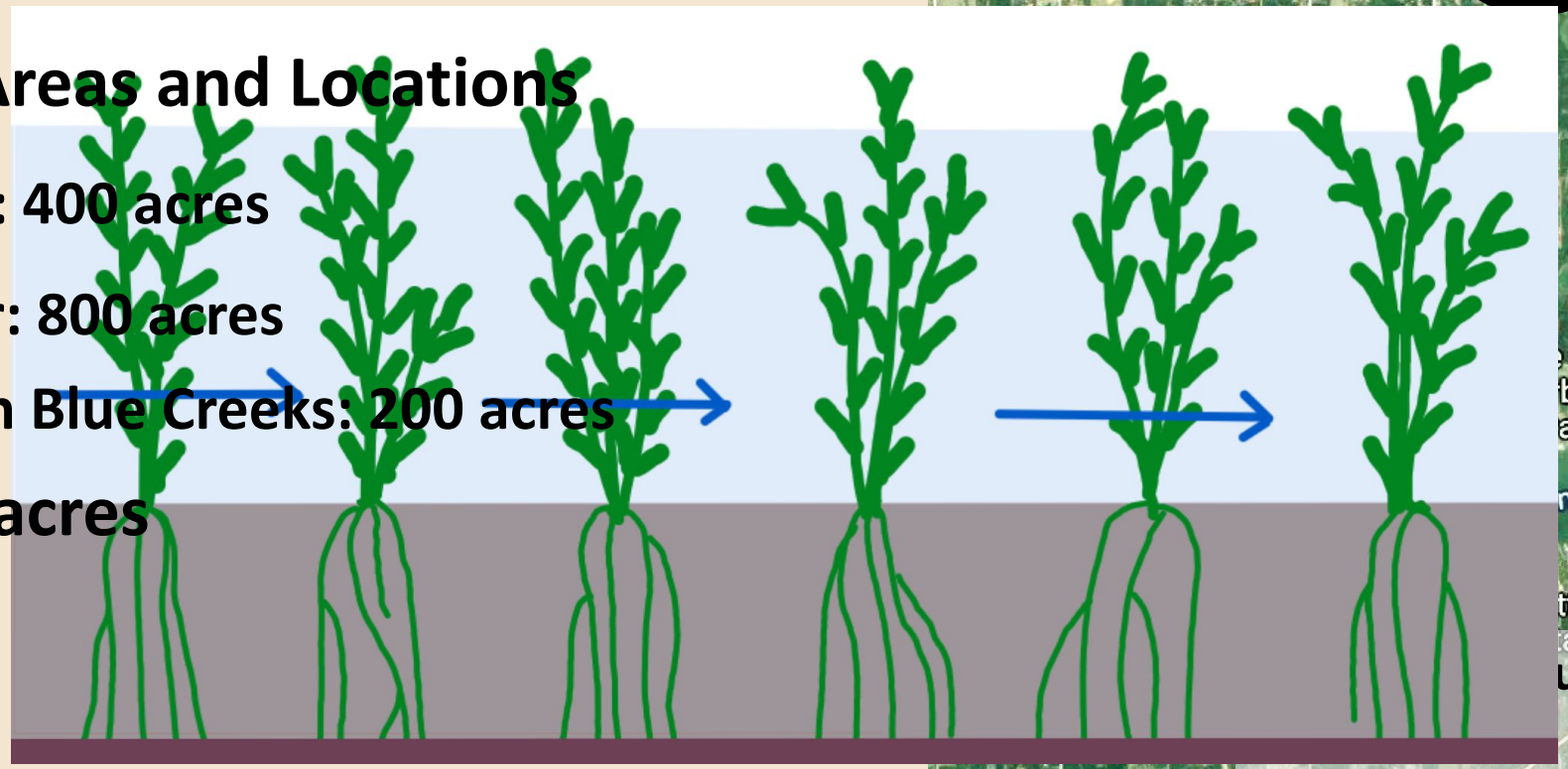

Diagram for Free Surface Horizontal Flow Wetland

H_2OU constructed Wetland Design Locations

CONSTRUCTED WETLANDS

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Effectiveness

- 79% TN
- 50% TP
- 91% TSS

Lifetime

- 20+ years

Cost

- Capital - $4.8 million
- Annual O&M - $790,000
- Total - $28.3 million

Constructed wetland, Pagosa Springs, Colorado

PERVIOUS PAVEMENT

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Pavement Type

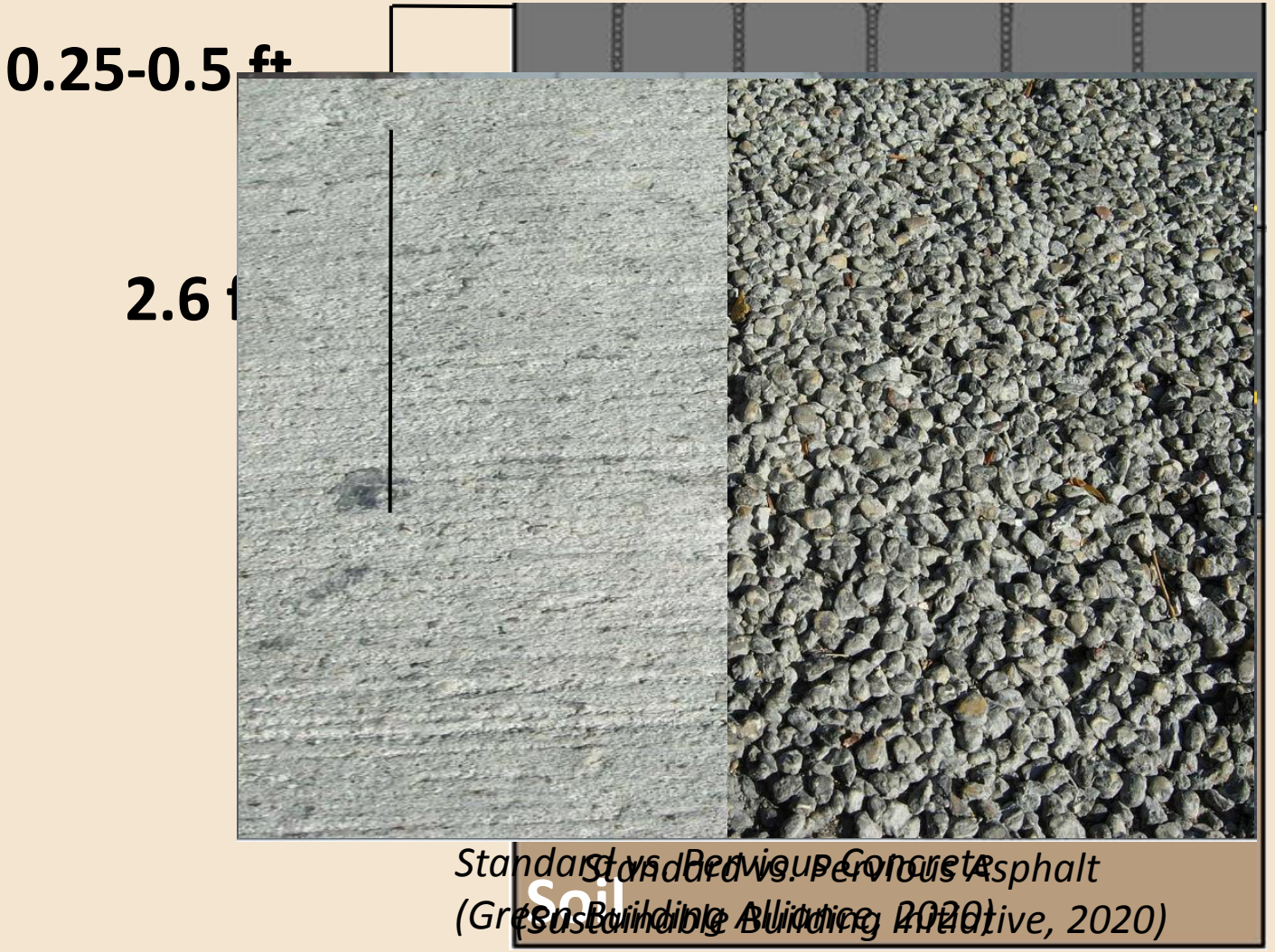
- Pervious Concrete
- Pervious Asphalt

Locations

- Sidewalks
- Parking Lots
- New Road Construction

Effectiveness

- 85% TP
- 30% NO_3^-
- 85% TSS



Standard vs. Pervious Concrete
Standard vs. Pervious Asphalt
(Green Building Alliance, 2020)
(Sustainable Building Initiative, 2020)

CONCEPTUAL DESIGN

Lifetime

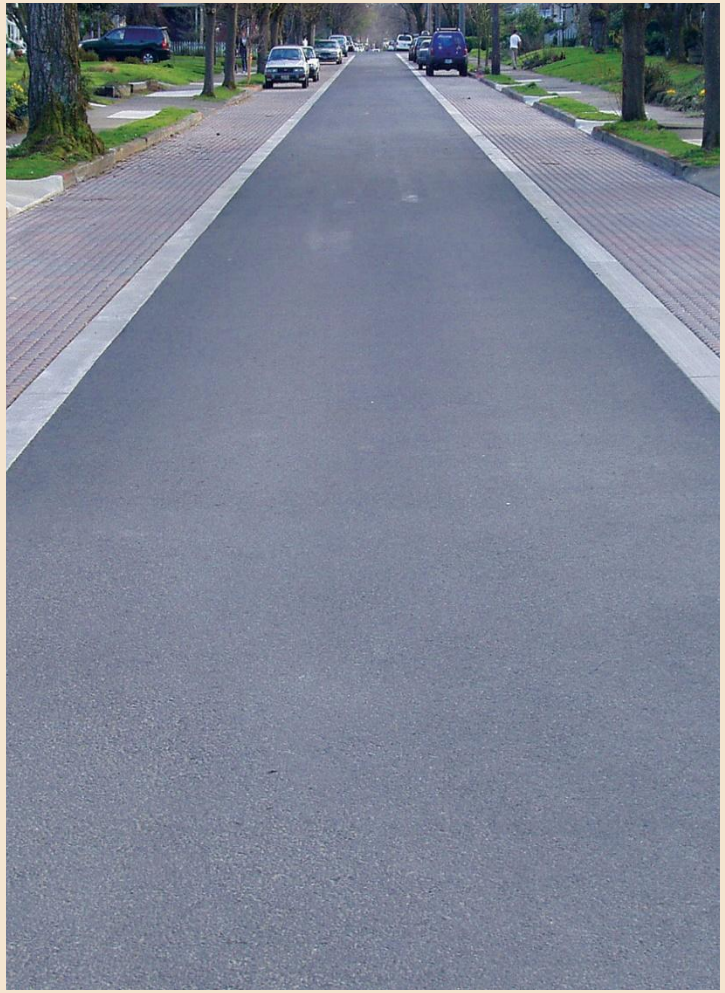
- 20+ years

Suggested Area

- 230 Acres

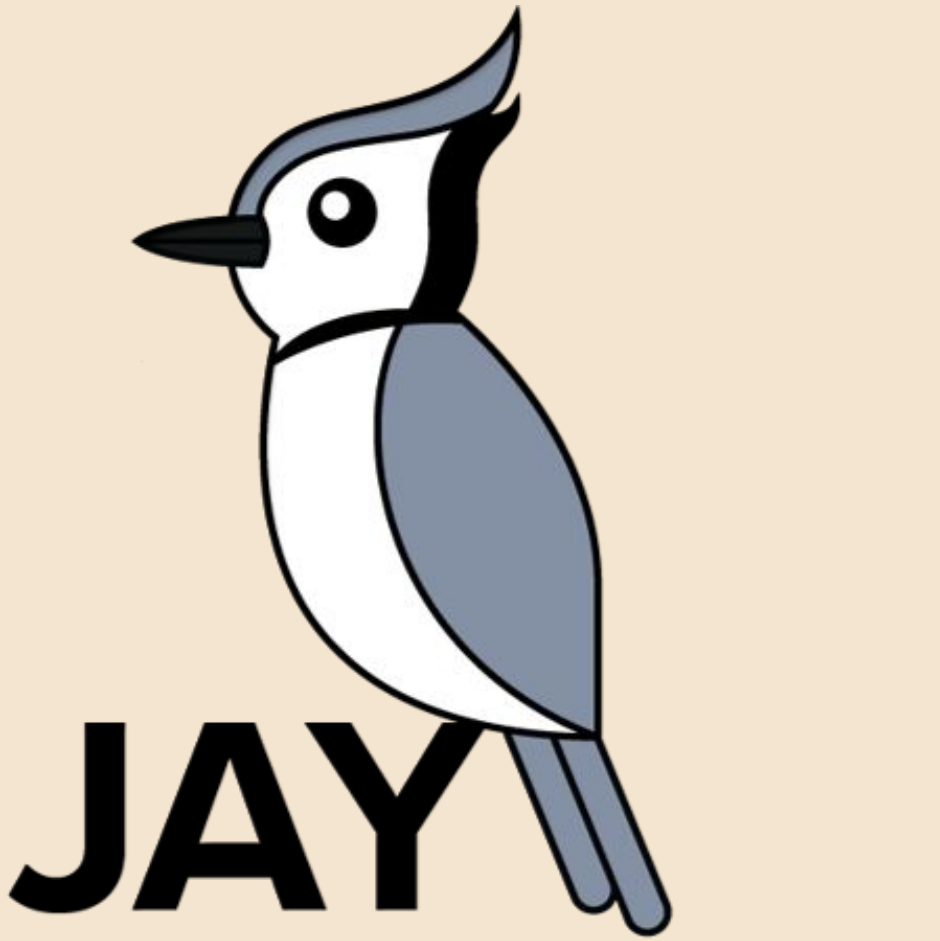
Cost

- Capital - $17 million
- Annual O&M - $184,000
- Total - $22.7 million



Example pervious road

Example pervious sidewalk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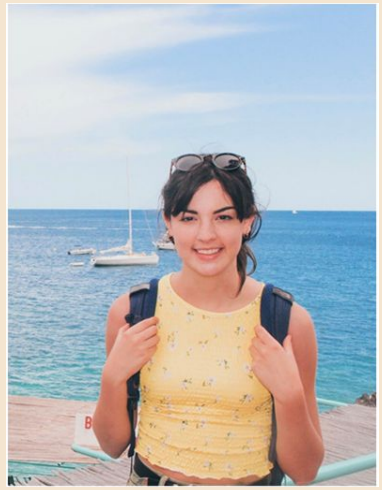
Kristen Soucheck

Addisyn Clagg

Hannah Curtis



John Puzz

Rodrigo Peralta

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DATA ANALYSIS RESULTS

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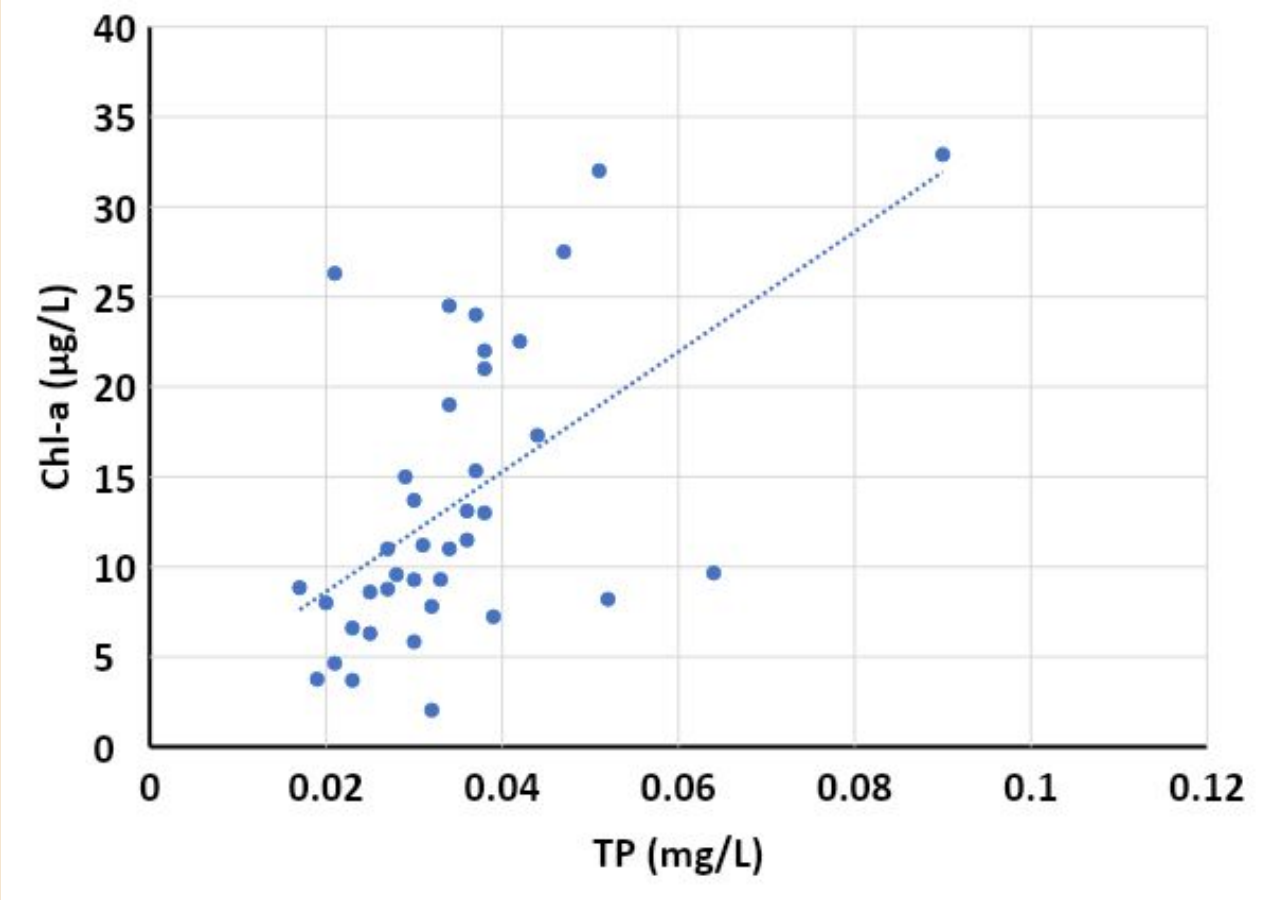
- 58% of samples >10 µg/L Chl-a
  - Ten-year average: 19.15 µg/L
- 29% of samples >25 NTU turbidity
- Relationship between TSS and TP
  - Stormwater runoff
- Positive relationship between Chl-a and TP
  - Reducing P loading may control algal growth



Relationship between TP and Chl-a concentrations at Lake Thunderbird from 2010 to 2019, Site 1

Relationship between TP and Chl-a concentrations at Lake Thunderbird from 2010 to 2019, Site 1

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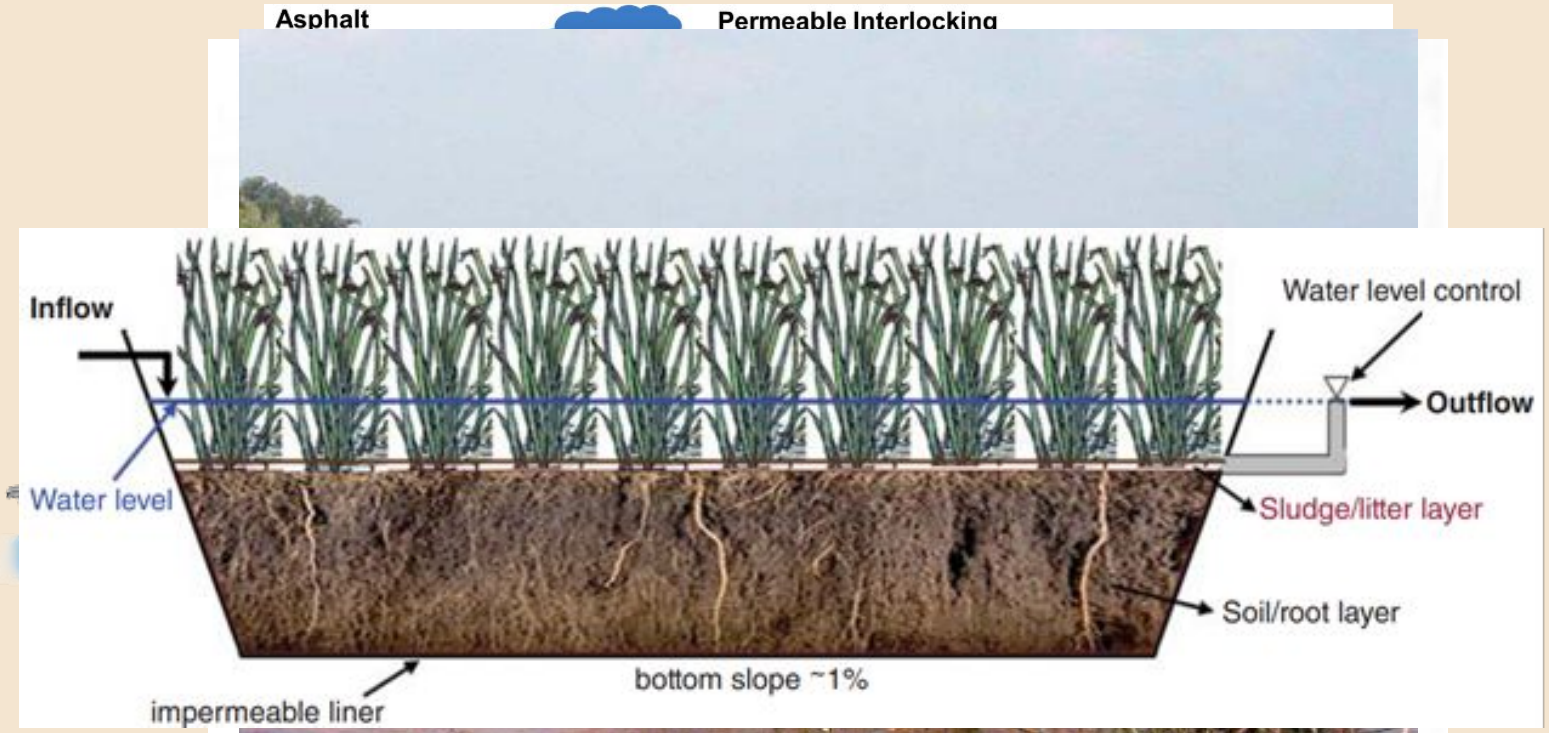
POTENTIAL SOLUTIONS

- **Bioretention Cells**
- **Sand Filters**
- **Pervious Pavement with Cisterns**
- **Shoreline Revegetation**
- **Constructed Wetlands**



Schematic of a typical free water surface constructed wetland (Stefanakis 2018)

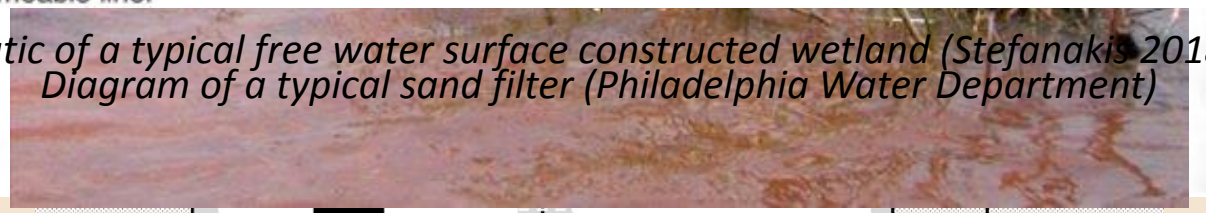


Diagram of a typical sand filter (Philadelphia Water Department)

Cross-section of a bioretention cell incorporating an underdrain, with typical media depths (DER 2007)

Softstem bulrush planted shoreward of branchbox at Lake Thunderbird (OWRB 2005)

Cross-section of a pervious pavement and cistern stormwater treatment train (Winston et al. 2020)

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EVALUATION CRITERIA

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Cost (25%)

Ease of Implementation (20%)

Effectiveness (25%)

Sustainability (10%)

Public Acceptance (20%)

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ALTERNATIVES EVALUATION

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	Cost	Ease of Implementation	Effectiveness	Sustainability	Public Acceptance	Weighted Total
Bioretention Cells	3	3	5	4	5	4.00
Sand Filters	2	3	4	3	3	3.25
Pervious Pavement	3	2	4	2	4	2.90
Shoreline Revegetation	4	4	3	5	5	4.05
Constructed Wetlands	5	4	5	4	4	4.50

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WETLANDS DESIGN

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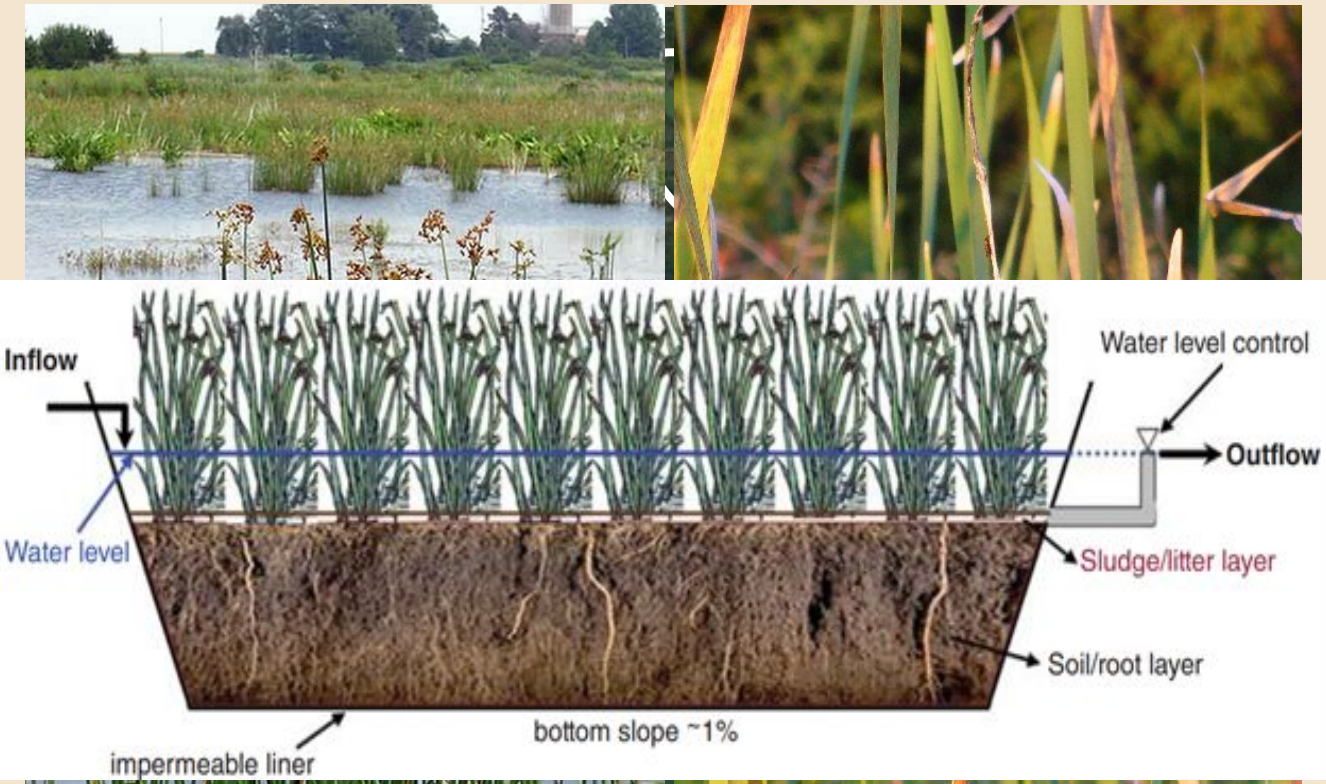
- Free water surface wetlands
- 500 acres on Little River
- 400 acres on Hog Creek
- Recommended plant species
  - Softstem bulrush
  - Broadleaf cattail



Schematic of a typical free water surface constructed wetland (Stefanakis 2018)

A stand of softstem bulrush (Tennessee Wholesale Nursery, 2021)

Broadleaf cattail (NRCS n.d.)

Areas identified for constructed wetlands on Little River (left) and Hog Creek (right) arms of Lake Thunderbird (adapted from Nairn 2014)

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WETLANDS DESIGN

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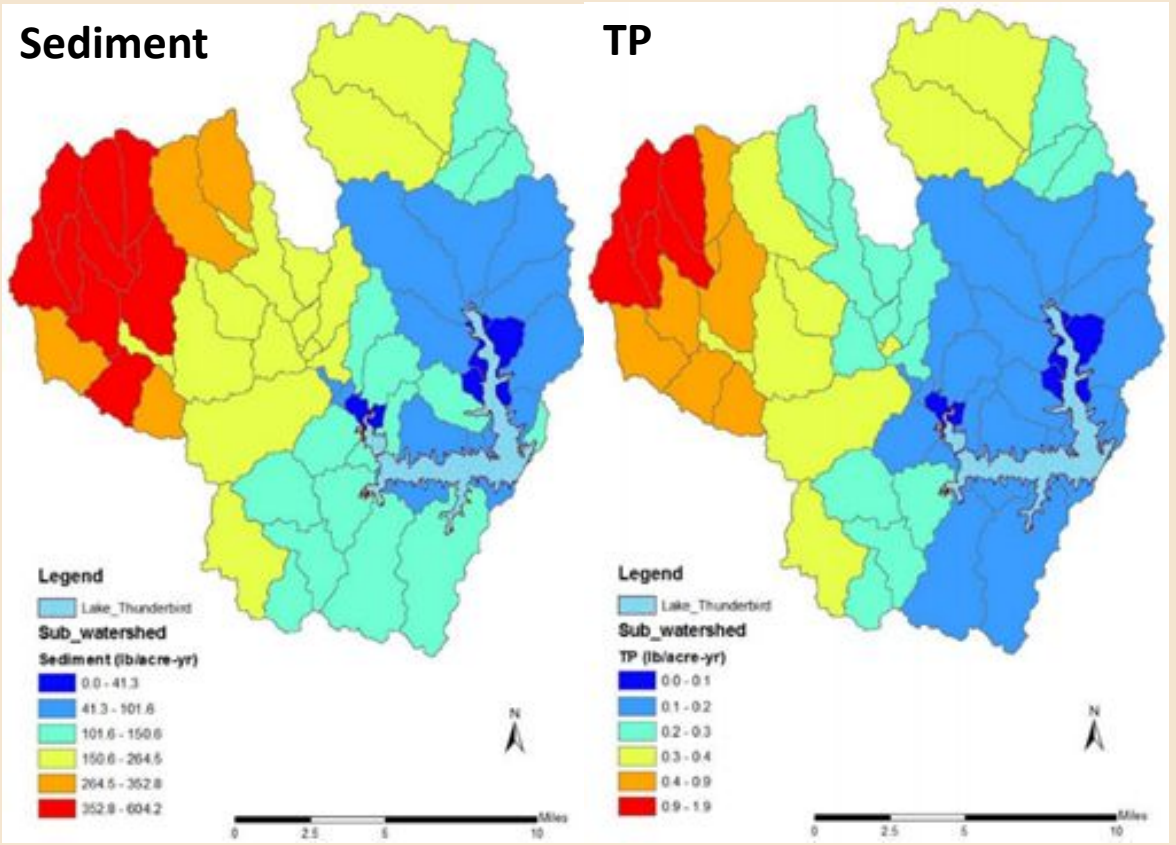
- **Removal efficiencies**
  - **TSS: >80%**
  - **TN: 50%**
  - **TP:**
    - **43% at Little River**
    - **62% at Hog Creek**
- **20 year design life**
- **Total capital cost: $13.1 million**
- **Total present worth: $25.9 million**



Sediment and TP loadings into Lake Thunderbird by catchment (Dynamic Solutions 2013)

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REVEGETATION DESIGN

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- 5% of shoreline (22,700 ft)
- Erosion categories 4 and 5
- Branchbox and Coir Geotextile Roll (CGR) breakwater systems
- Recommended plant species
  - Softstem bulrush
  - Prairie cordgrass
  - Black willow

A stand of prairie cordgrass (NRCS n.d.)

A black willow tree (Bruce Marlin 2007)

Example of Category 5 erosion at Lake Thunderbird (Allen 2001)

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REVEGETATION DESIGN

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- 21,800 ft^3 soil retained
- Nutrient uptake
  - 720 kg N/year
  - 180 kg P/year
- 20 year design life
- Total capital cost: $716,200
- Total present worth: $950,400

Sediment accumulation behind branchbox between April 2003 (top) and April 2004 (bottom) at Lake Thunderbird (OWRB 2005)

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Conclusions

CONCLUSIONS

Recommended Measures…

ENVIRO-SHIELD SOLUTIONS

Constructed Wetland

50% ↓ TP, 80% ↓ TN, 95% ↓ TSS

$18.2 Million

Bioretention Basins

31% ↓ TP, 32% ↓ TN, 60% ↓ TSS

$2.6 Million

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Constructed Wetlands

50% ↓ TP, 79% ↓ TN, 91% ↓ TSS

$28.3 Million

Pervious Pavement

85% ↓ TP, 30% ↓ NO_3^-, 85% ↓ TSS

$22.7 Million

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Constructed Wetlands

52% ↓ TP, 50% ↓ TN, >80% ↓ TSS

$ 25.9 Million

Shoreline Revegetation

↓ 720 kg N/year, ↓ 180 kg P/year

$950,400

Acknowledgments

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Thank You!
Any Questions?