Coagulant Enhanced Stormwater Treatment for Use in the Chesapeake Bay Watershed

Chesapeake Bay Program

Urban Stormwater Workgroup Meeting, April 2023

Brown AND Caldwell

HAMPTON VA

Agenda

- Treatment Process Overview
  - Why select Coagulant Enhanced Treatment for Stormwater
  - Comparison of Treatment Efficiency with traditional practices
  - Treatment Chemistry

- Case Studies
  - Lake Ella, Tallahassee, Florida
  - Largo Central Park
  - Upper Lake Lafayette Nutrient Reduction Facility
  - Dixie Drain Nutrient Offset Project, City of Boise, Idaho
- Why Bring to Virginia and Bay States?
  - Pilot site in City of Hampton

What is Stormwater Enhanced Treatment?

Rapid coagulation/settling/removal of common pollutants in non-point source discharges:

- suspended solids
- phosphorus
- nitrogen
- pathogens
- turbidity
- BOD
- heavy metals
- other particulate pollutants

Treatment process, non-proprietary

Why Enhanced Treatment?

- Higher pollutant removal efficiencies
- Substantially less land
- Ability to treat large/entire watershed areas
- Typically lowest life cycle cost per mass TP, TN, and pathogens removed
- Improves surface water quality for habitat, aesthetics, and recreational use
- Accelerate and simplify NPDES MS4/TMDL requirements

Comparison of BMP Treatment Efficiencies for Primary Pollutants

Type of BMP	Estimated Removal Efficiencies (% Load Reduction)				
	TP	TN	TSS	BOD	Pathogens
INFILTRATION/REUSE 1.00" Volume Reduction 1.50" Volume Reduction	80 90	80 90	80 90	80 90	80 90
WET DET (14-21 day WSRT)	60-70	25-35	90	50-70	30-60
WET DET/FILTER	50	0-10	85	70	20-50
DRY DETENTION	20-40	10-20	20-60	20-50	10-30
DRY DET/FILTER	(-)-20	(-)-20	40-60	0-50	10-25
ENHANCED TREATMENT	**80-90**	**35-65**	**>90**	**30-60**	**90-99+**
WETLAND TREATMENT	(-)-90	(-)-60	50-90	(-)-50	(-)-50

BMP Life Cycle Cost Comparisons

Retrofit BMP	Life Cycle Cost per lb TP removed ($)	Life Cycle Cost per lb TN removed ($)
Second Generation Baffle Box	500 – 1,600	350 - 600
Wet Detention Pond	800 - 2,400	400 - 1,800
Dry Detention Basin	1,500 - 7,000	1,250 - 4,500
GI - Bioretention	3,000 - 50,000	2,000 - 30,000
Stream Restoration	1,500 - 6,000	700 – 4,000
Enhanced Treatment	200 - 600	100 - 400
Enhanced Wetland Treatment	250 - 1200	150 - 800

Larger regional systems tend to have significantly lower life cycle costs per mass removed than many smaller systems.

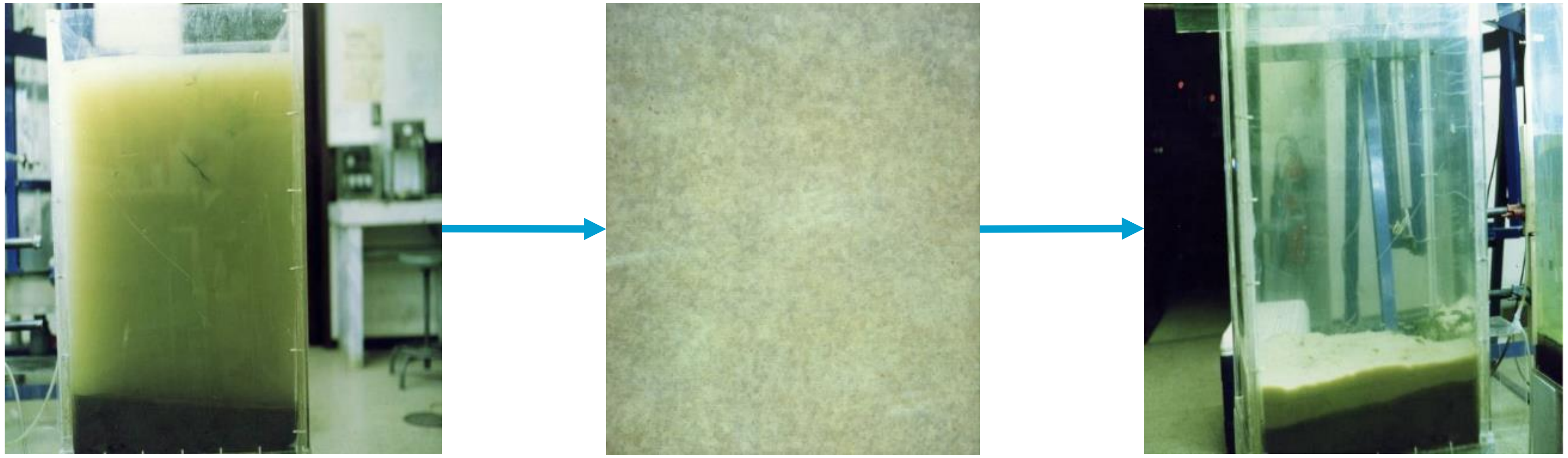
How Does the Process Work?

Removal of pathogens and particulate pollutants

$$Al^{+3} + 6H_2O \rightarrow Al(OH)_{3(s)} + 3H_3O^{+}$$

Removal of dissolved phosphorus

$$Al^{+3} + HnPO_4^{n-3} \rightarrow AlPO_{4(s)} + nH^{+}$$



History of Coagulant Treatment

- Aluminum salts used to treat drinking water in Roman times
- Drinking water to remove turbidity, color, organic carbon in early 1900s
- Wastewater to remove phosphorus later in 1900s
- 1970, First whole-lake surface treatment to improve water quality in WI
- 1987, First enhanced stormwater treatment constructed in FL
- 1990s, First off-line enhanced treatment systems constructed
- 2000s, First off-line enhanced system with constructed wetlands and coagulant treatment

Jar Testing is Essential

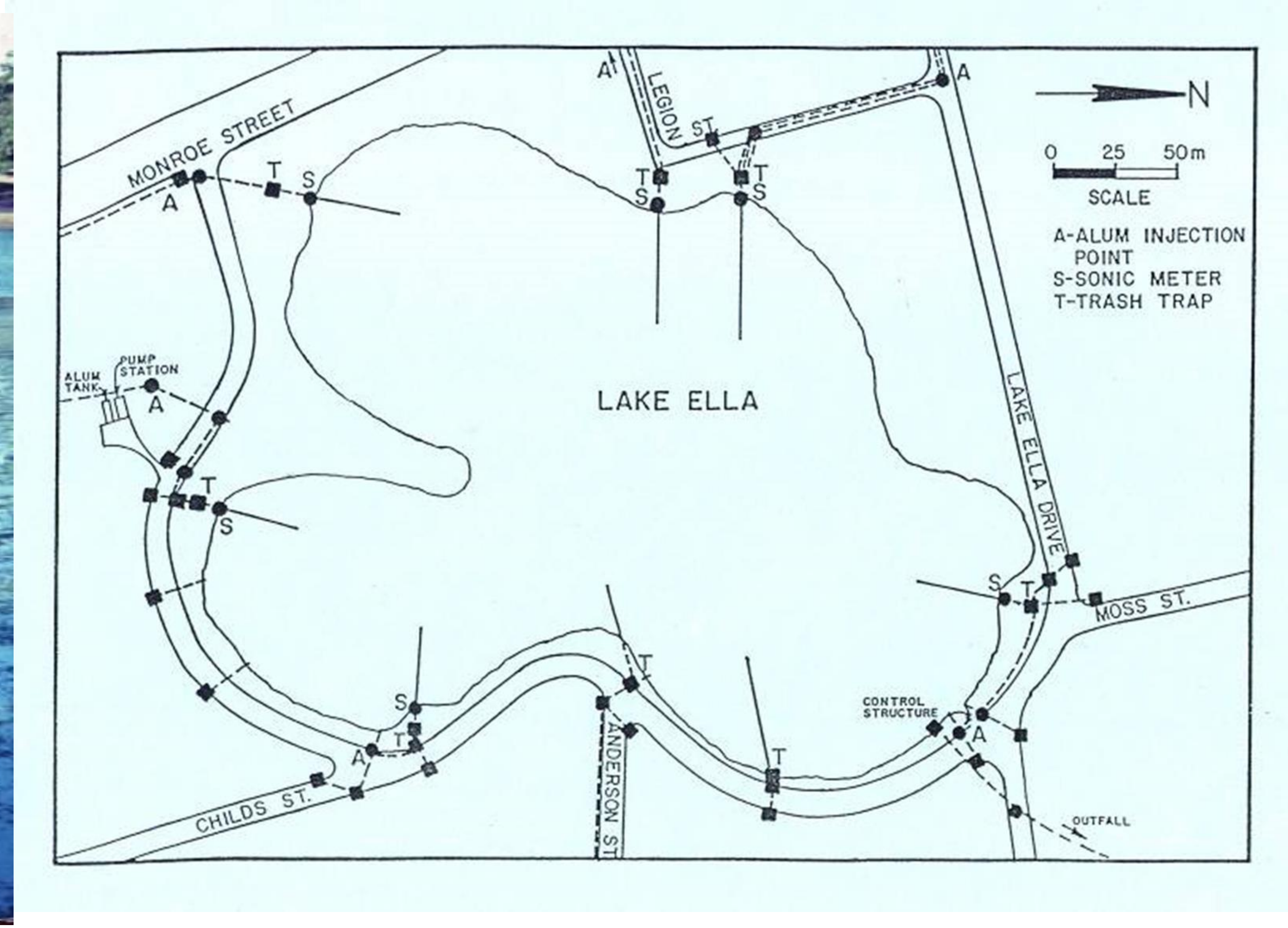
- Coagulant selection
- Coagulant dose
- Finished water chemistry
- Floc formation/settling/composition
- Floc quantity/consolidation

Parameter	Units	Composite Raw	Treated and Settled for 24 hours
pH (initial)	s.u.	6.95	6.48
pH (1 minute)	s.u.	6.99	6.50
pH (1 hour)	s.u.	6.97	6.74
pH (3 hour)	s.u.	7.00	6.84
pH (24 hours)	s.u.	7.01	6.95
Conductivity	umhos/cm	82	95
Alkalinity	mg/l	54	35
Nitrite-Nitrate	mg/l	0.014	0.026
Total Kjeldahl Nitrogen	mg/l	0.47	0.25
Total Nitrogen	mg/l	0.48	0.28
Total Phosphorus	mg/l	0.12	0.009
Turbidity	NTU	6.2	0.5
Total Suspended Solids	mg/l	26	<3
BOD	mg/l	<0.78	<0.78
Total Aluminum	mg/l	0.84	0.22
Dissolved Aluminum	mg/l	0.32	0.07
Fecal Coliform	No./100 ml	1700	<2

Treat Runoff from Common Rain Events

Rainfall Event Range (in)	Mean Rainfall Depth (in)	Mean Rainfall Duration (hours)	Number of Annual Events in Range
0.00-0.10	0.041	1.203	56.683
0.11-0.20	0.152	2.393	18.866
0.21-0.30	0.252	3.073	10.590
0.31-0.40	0.353	3.371	7.312
0.41-0.50	0.456	3.702	6.325
0.51-1.00	0.713	4.379	17.102 (117)
1.01-1.50	1.221	5.758	6.733
1.51-2.0	1.726	7.852	3.145
2.01-2.50	2.271	8.090	1.470
2.51-3.00	2.704	10.675	0.726
3.01-3.50	3.246	9.978	0.391
3.51-4.00	3.667	13.362	0.260
4.01-4.50	4.216	15.638	0.149
4.51-5.00	4.796	17.482	0.056
5.01-6.00	5.454	23.303	0.167
6.01-7.00	6.470	40.500	0.019
7.01-8.00	7.900	31.500	0.019

Initial In-Line Systems (1987 – 1996) Lake Ella



Lake Ella Complete

No land available in watershed for traditional treatment.

Largo Central Park

1,200-acre watershed treated using existing 3-acre pond, floc pumped to SS.
Construction cost = $1,000,000

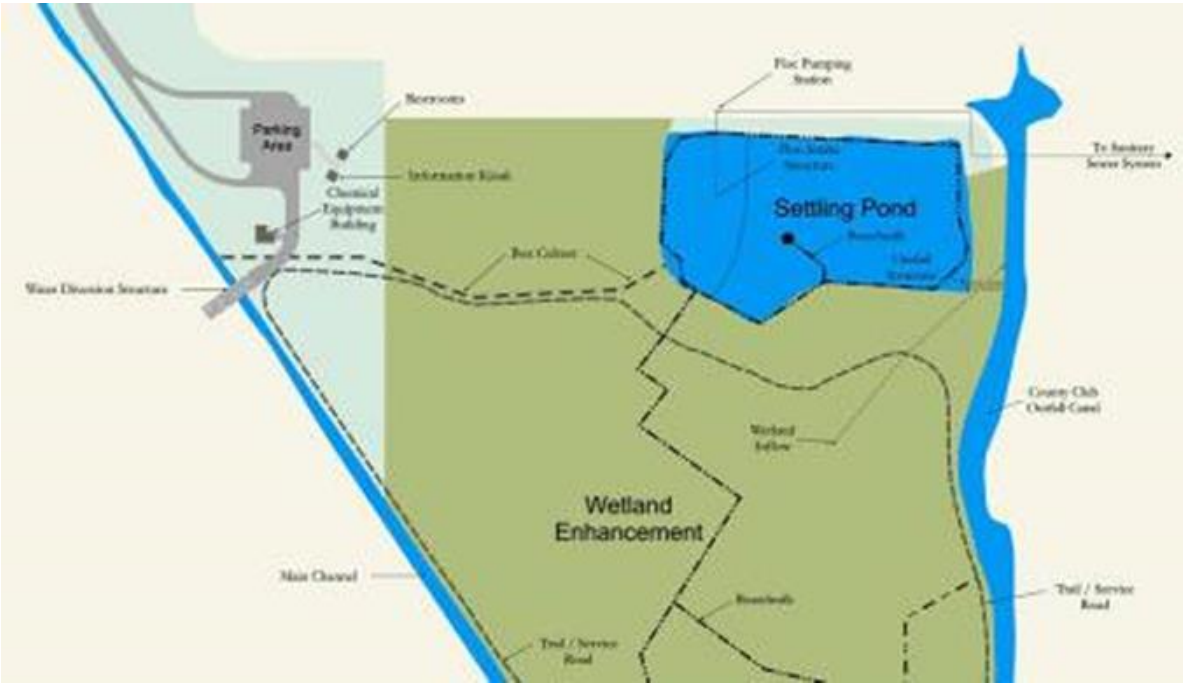

Stormwater
Treatment Process


Floc
Settling Pond

Monitored Efficiencies - Largo Central Park Treatment

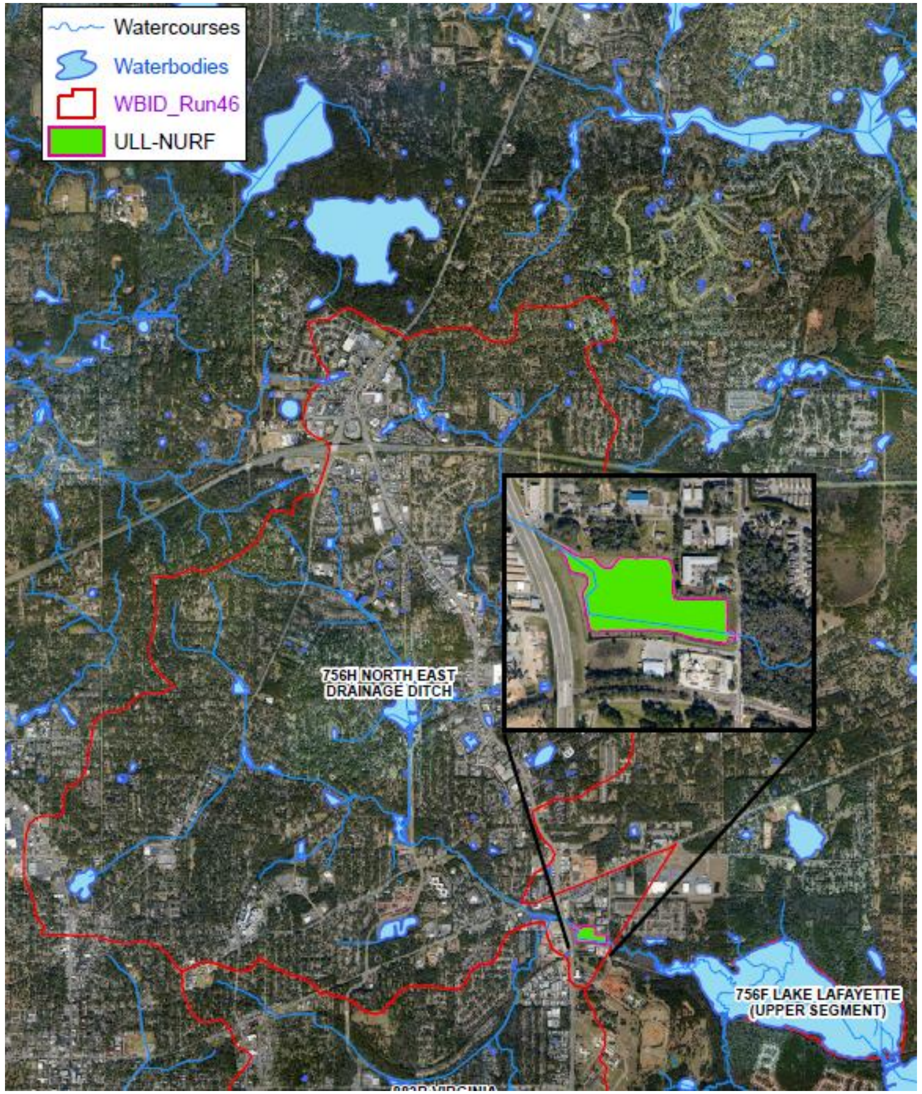
Parameter	9/11/02-12/15/02			
	Mass Input (kg)	Mass Outflow (kg)	Mass removal (kg)	Mass Removal (%)
Total N	2,606	1,637	969	37
Total P	257	38	219	85
TSS	22,339	2,734	19,605	88
BOD	2,924	2,150	774	26

Mean residence time = 3 days



Upper Lake Lafayette Nutrient Reduction Facility (NURF)

- 10,000 ac watershed
- Excessive pathogen and nutrient loads/TMDL
- Existing pond ineffective
- Treats up to 200 cfs of runoff, large storms bypass
- Highly effective



Historic Weems Pond Site

Construction – Costs & Grants

Total Project Cost
$6.5 million

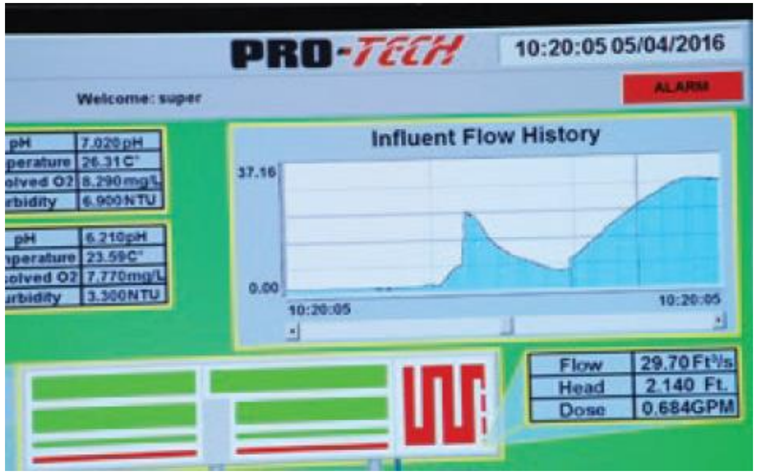
Construction Cost
$5.4 million

DEP Grant
$500,000

2nd Largest in FL

Operations

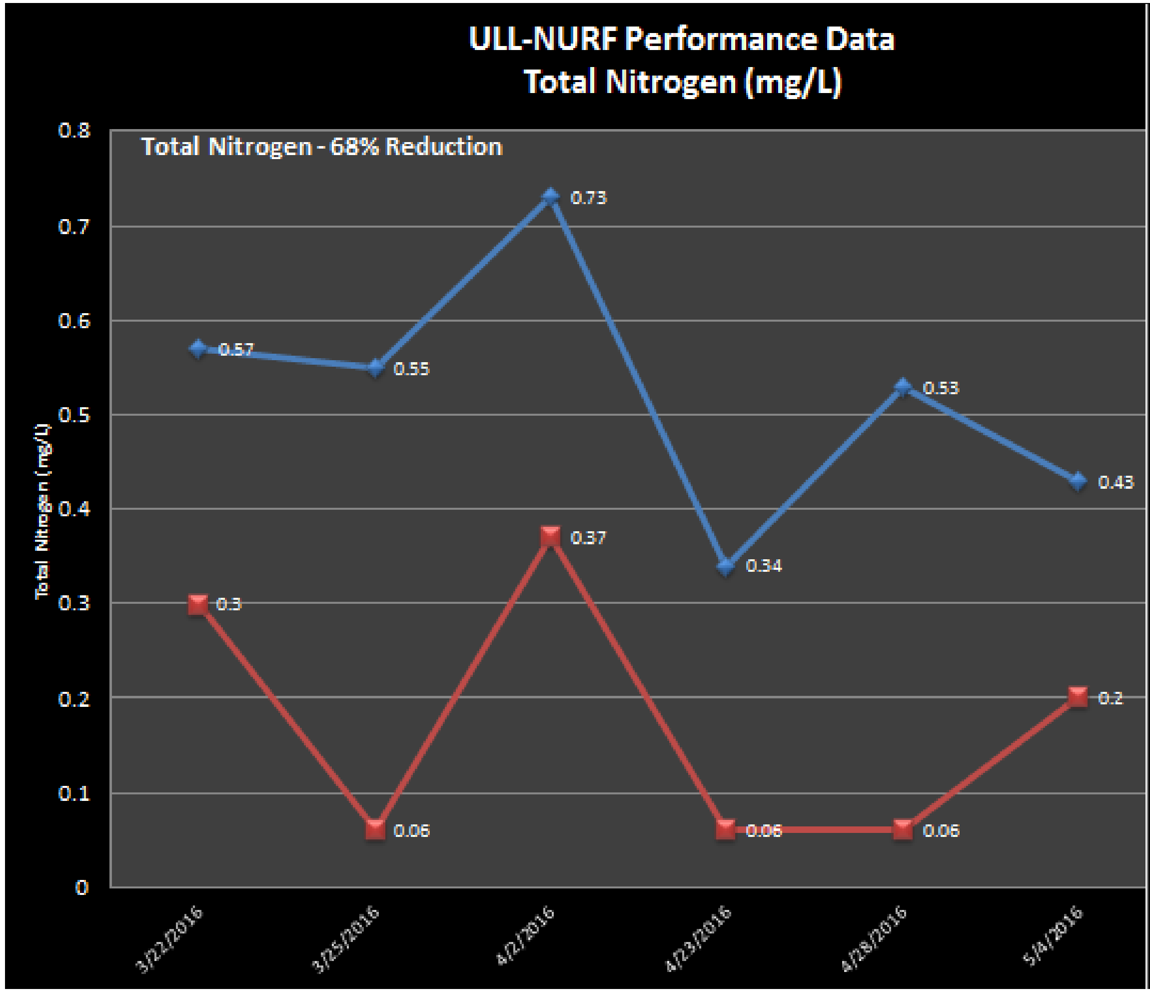
System can be monitored and controlled using an IPad

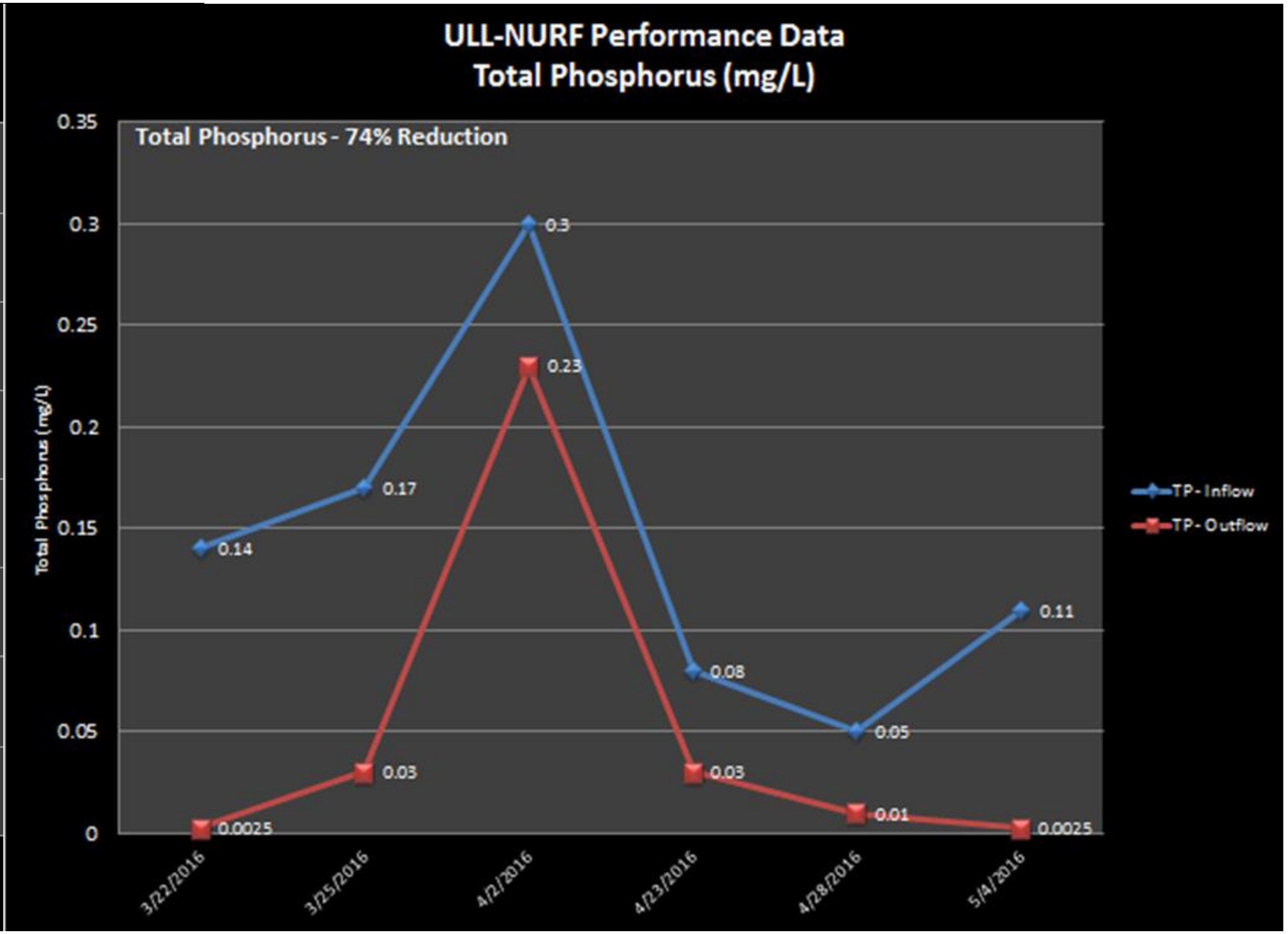


Pollutant Load Reductions (pounds/year)						
BMPs Installed		TSS lbs/yr	TP lbs/yr	TN lbs/yr	BOD lbs/yr	Fecal Coliform (total count)
Alum Injection						
Pollutant Loads	Pre-Project	143,318	3,175	11,506	48,155	9.07E+13
	Post-Project	31,964	838	8,681	32,389	1.73E+13
	Load Reduction	111,355	2,337	2,825	15,766	7.34E+13
	% Reduction	78%	74%	25%	33%	81%

Life cycle costs:
$200/lb TP
$166/lb TN
$4/lb TSS

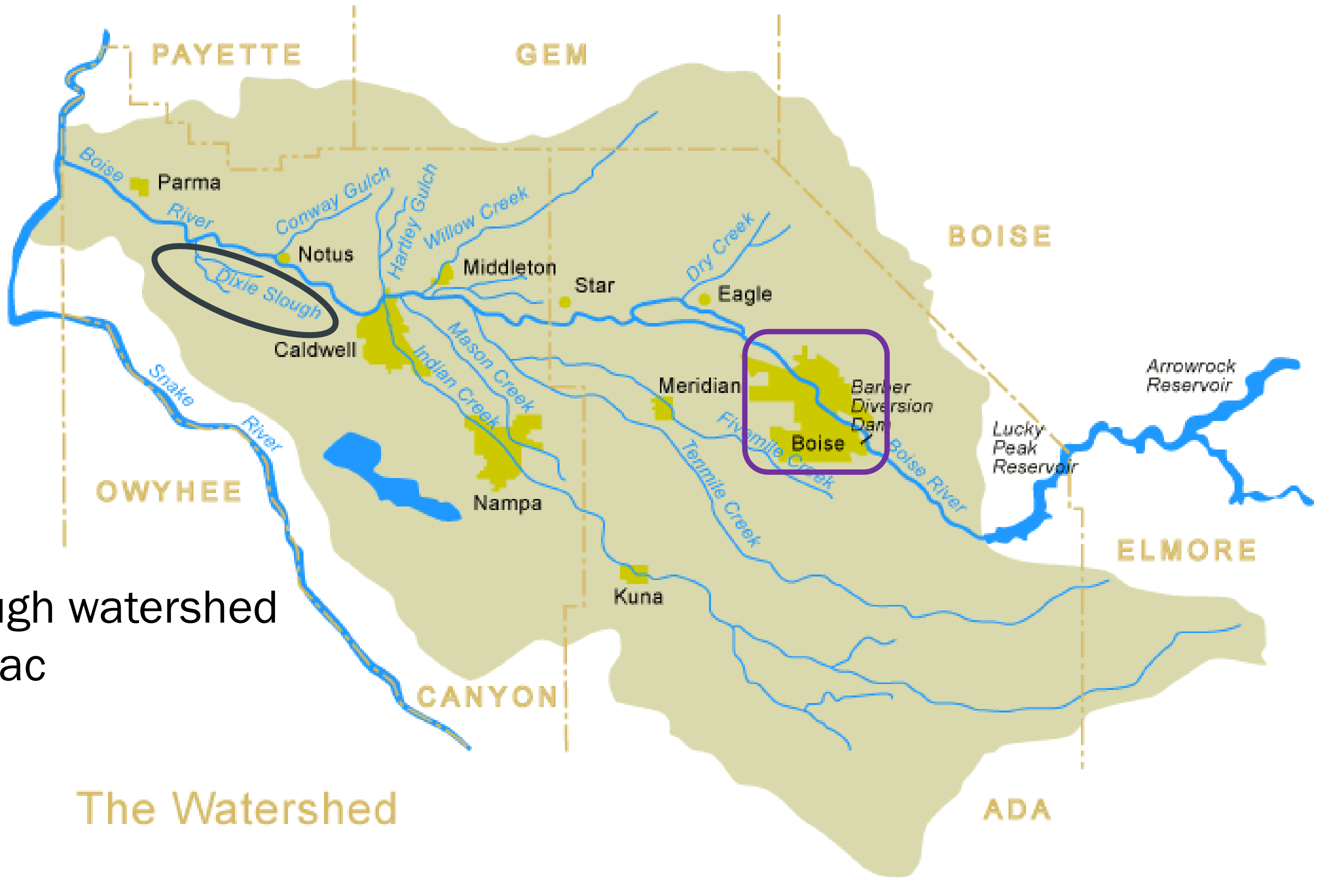
Nutrient Reduction Facility - Annual Mass Removal Efficiencies: TN (68%), TP (74%), FC (83%)





City of Boise (ID) Dixie Drain Nutrient Offset Project

Meet new Wastewater NPDES Permit TP requirements; reduce Phosphorus loads from the Boise River to the Snake River (TP TMDL)



Dixie Slough watershed
~40,000 ac

Dixie Drain Treatment System

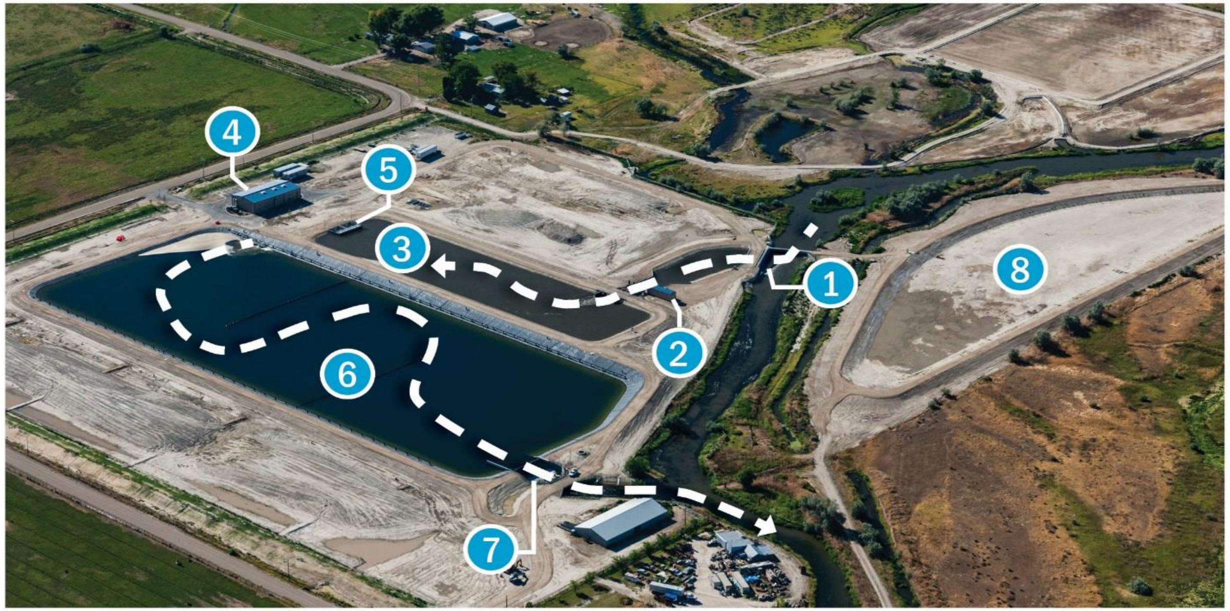
REMOVING
140 lbs
of phosphorus
PER DAY

1 **Inlet diversion and screening:** Located in the Dixie Drain channel, a set of gates control the water surface elevation in the channel and divert water into the screens, preventing vegetation from entering the process.

2 **Intake pump station:** The intake pump station controls the flow of water through the facility. Each of the four 150-horsepower pumps can convey 25 to 50 cubic feet per second (cfs) of water through the facility, for a maximum of 200 cfs.

3 **Sedimentation basin:** Up to 8,000 tons of sediment can settle out of the water in this 12-acre-foot basin.

4 **Operations building:** This structure houses storage for the water treatment chemical and serves as the control center for the facility.



5 **Flash mix facility:** Water is delivered to one of four pipe-mounted flash mixers where a water treatment chemical (polyaluminum chloride) is injected into the flow stream. This coagulation process removes dissolved phosphorus from the water, causing it to form a stable "floc" particle, making it easier to remove from the water.

6 **Settling pond:** The phosphorus-containing floc particles clump together and settle out in this low-velocity 97-acre-foot pond. Approximately 140 lbs of phosphorus per day is prevented from reaching the Boise River here.

7 **Outlet structure:** Treated water is returned to the Dixie Drain channel and subsequently the Boise River, removing 50 percent more phosphorus than would have been removed at a water renewal facility, and with significant solids reduction that would not have been otherwise realized.

8 **Floc management area:** Floc from the Settling Pond is dredged up and delivered to this basin to undergo a natural drying process.

Design Flow = 200 cfs
140 lbs/day TP reduction

Construction Cost = $14M

Life cycle cost = $300/lb TP

Untreated water

Treated water

Why Approve in Virginia and Bay States?

- Projects have been designed, permitted, and constructed in **USEPA Regions 4 and 10** and credited for pollutant load reduction and NPDES/TMDL compliance.
- Could accelerate achieving the Chesapeake Bay and other TMDL goals
- Existing ponds built as volume control facilities can be easily retrofitted for a cost effective treatment of large watershed areas.
- Traditional stormwater treatment not always feasible and require substantial land and costly
- Entire watershed areas can be treated reducing the effort and cost to operate and maintain.
- Local governments are reluctant to implement due to the lack of credit

Billy Woods Canal – Potential Enhanced Treatment Pilot

- SLAF Application submitted
- Retrofit of existing wet ponds (Lake 1 and Lake 2)
- Drainage area of 1,337 AC
- Estimated 1,058 lbs/year TP reduction, 1,621 lbs/year TN reduction

Thank you.

Questions?