Types, Effectiveness, and Cost of BMPs, LID/GI, and Treatment Trains

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Brown AND Caldwell

Hydrology: Most rainfall events are 1-inch or less

Manage common rain events for WQ improvement

Rainfall Event Range (inches)	Mean Rainfall Depth (inches)	Mean Rainfall Duration (hours)	Fraction of Annual Rain Events	Number of Annual Events in Range
0.00-0.10	0.041	1.203	0.427	56.683
0.11-0.20	0.152	2.393	0.142	18.866
0.21-0.30	0.252	3.073	0.080	10.590
0.31-0.40	0.353	3.371	0.055	7.312
0.41-0.50	0.456	3.702	0.048	6.325
0.51-1.00	**0.713**	**4.379**	**0.129**	**17.102 (117)**
1.01-1.50	1.221	5.758	0.051	6.733
1.51-2.0	1.726	7.852	0.024	3.145
2.01-2.50	2.271	8.090	0.011	1.470
2.51-3.00	**2.704**	**10.675**	**0.006**	**0.726**
3.01-3.50	3.246	9.978	0.003	0.391
3.51-4.00	3.667	13.362	0.002	0.260
4.01-4.50	4.216	15.638	0.001	0.149
4.51-5.00	4.796	17.482	0.000	0.056
5.01-6.00	5.454	23.303	0.001	0.167
6.01-7.00	6.470	40.500	0.000	0.019
7.01-8.00	7.900	31.500	0.000	0.019
8.01-9.00	8.190	3.500	0.000	0.019
>9.00	10.675	46.250	0.001	0.075

Which Pollutants? Which Forms?

- Sediment
- Biochemical oxygen demand
- Pathogens
- Phosphorus: **SRP, OP**, TP
- Nitrogen: TKN = Org N + **NH_3**; **$NO_X = NO_2 + NO_3$**

  TN = TKN + NO_X

  (Only some forms of nutrients are bioavailable)
- Metals
- Toxic compounds

Organic or inorganic, dissolved or particulate; it matters

BMP Selection Criteria

- Land area availability/ownership/access
- Site characteristics
- Regulatory requirements and constraints
- Mass pollutant load reduction/environmental benefits
- Construction/Annual O&M/Life cycle cost
- Maintenance staff availability/sophistication
- Decreased maintenance of problem areas
- Social Factors/Public acceptance
- Funding partners/Grant potential
- **Piggyback on other planned capital improvements**
- Regional vs. many smaller systems

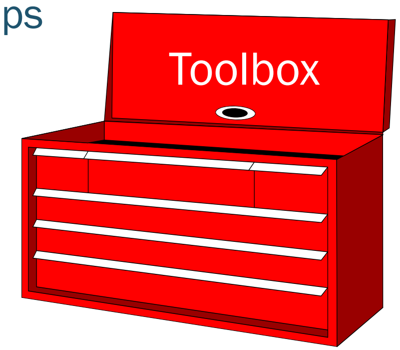
Evaluation and Selection of Projects

- Identify primary and secondary pollutants
- Determine min and max influent pollutant concentrations and stormwater flow rates
- Determine desired removal efficiencies
- Identify available land area
- Identify effective treatment train components
- Evaluate potential treatment trains based on BMP Selection Criteria Factors
- Implement best solution – keep pushing forward, you will have obstacles!

Treatment Train - Implementing Cost Effective BMPs For Non-Point Source Management

MAXIMIZE → MINIMIZE

Runoff & Load Generation	Conveyance and Pretreatment	Additional Treatment & Attenuation	Final Treatment and Attenuation
Regulations	Swales	Detention	Retention
Public education	Catch Basins	Wetland	Detention
Erosion control	Inlets filters	Storage	Wetland
Roof runoff	Oil/water separators	Sediment sump	Chemical
Disconnect IA	Trash/sediment traps		Ozone
Landscaping			UV
Pervious paving			Reuse
Pavement cleaning			End of pipe
GI			



Maximize Implementation of Non-Structural BMPs

Nutrient Management
Street Sweeping
Catch Basin Cleanout
Material Storage

Typically cost effective pollutant load reduction

Relative Comparison of Structural BMP Pollutant Removal Effectiveness

POLLUTANT	INFILTRATION/ VOLUME REDUCTION	DETENTION	WETLAND[1]	CHEMICAL COAGULATION	FILTRATION/ UV	FILTRATION/ OZONE	LIQUID/SOLIDS SEPARATION STUCTURE
Nitrogen	H - VH	L - M	L – H	L - M	L - M	L - M	L
Phosphorus	H - VH	L - M	L – H	H - VH	L - M	L - M	L
TSS	H - VH	H	H	H - VH	H - VH	H -VH	L – M
BOD	H - VH	L - M	M	M	M – H	M – H	L – M
Heavy Metals	H - VH	L - M	M - H	M - H	L - M	L – M	L – M
Pathogens	H - VH	L	L	H - VH	VH	VH	L
Gross Solids	H - VH	H	H	L - H	VH	VH	H-VH

1. Highly dependent on influent pollutant concentration and hydraulic loading rate

VH – Very High H – High M – Medium L- Low

End of Pipe Stormwater Treatment

- Typically for gross solids and sediment removal but new medias effective for removing other pollutants
- Used extensively for removal of primary pollutants
- Minimal land required
- Relatively inexpensive
- Can be implemented relatively quickly

BC Design for CalTrans

Baffle Box
CDS Unit
Vortechnics
Stormceptor
Many others
$50k to $500k

Comparison of BMP Treatment Efficiencies for Primary Pollutants

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

Volume Reduction

No volume = no load
Also reduces conveyance requirements and cost.

Disconnect Impervious Areas

Rainwater Harvesting and Reuse

Stormwater Storage and Reuse

Low Impact Development
and Infiltration Practices

Permeable Pavers and Porous Pavement

Soils, groundwater, and proper material installation critical to success. Maintenance required.

Rainwater Harvesting and Reuse
(relatively clean water)

1-inch of runoff over 3,000 sf = 1,870 gallons.

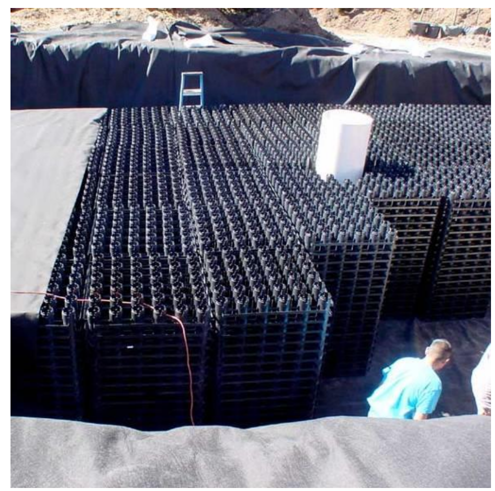
55 gallon rain barrels provide minimal storage for a typical single family home.

HDPE Tanks ~ $1/gallon storage

Stormwater Reuse

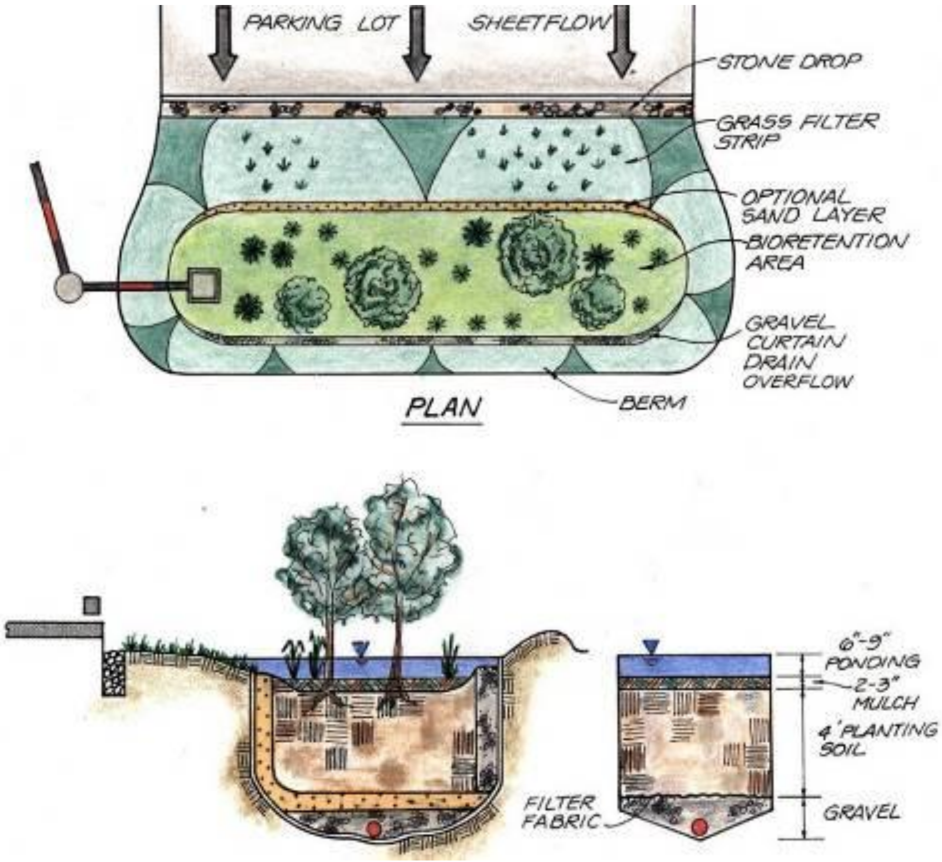
Reduces runoff volume and pollutant load and reduces potable water demand.

Higher concentrations of pollutants than rainwater but can be used for irrigation and gray water.



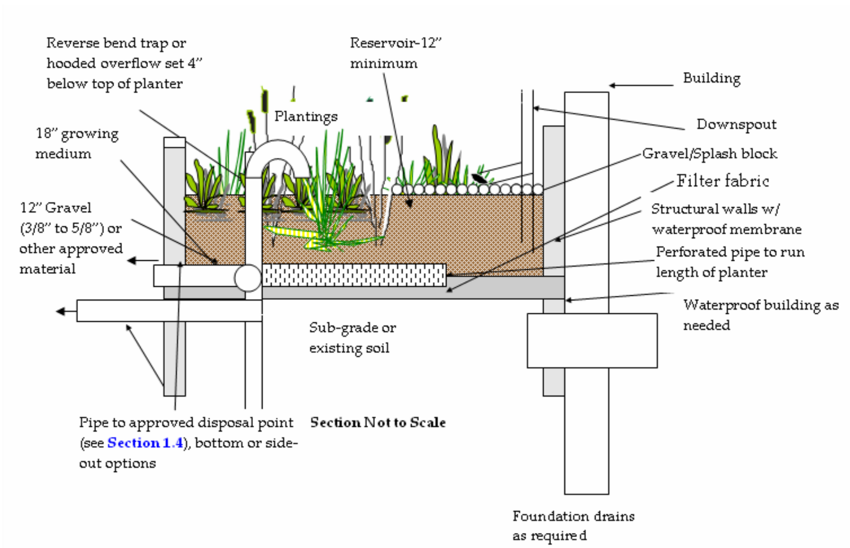
Must have sediment removal element prior to any underground storage with ability to remove sediment.

Bioretention Area (different than biofiltration)



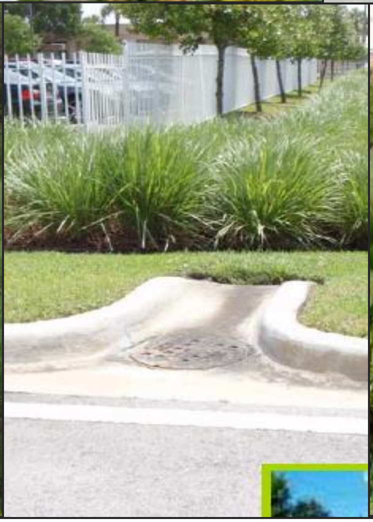
Research to improve TP and TN removal.
Aluminum precipitates for TP (4-5x).
Anaerobic zone for denitrification.

Biofiltration/Biodetention

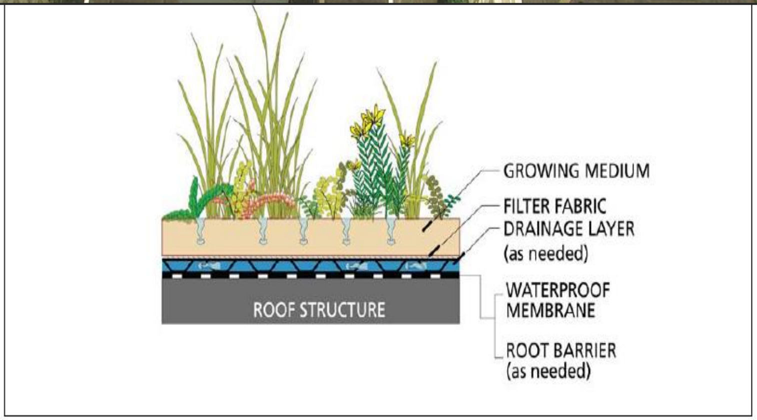


Lower volume reduction than bioretention
but can achieve substantial pollutant concentration reduction.
Dense vegetation/engineered soil key.

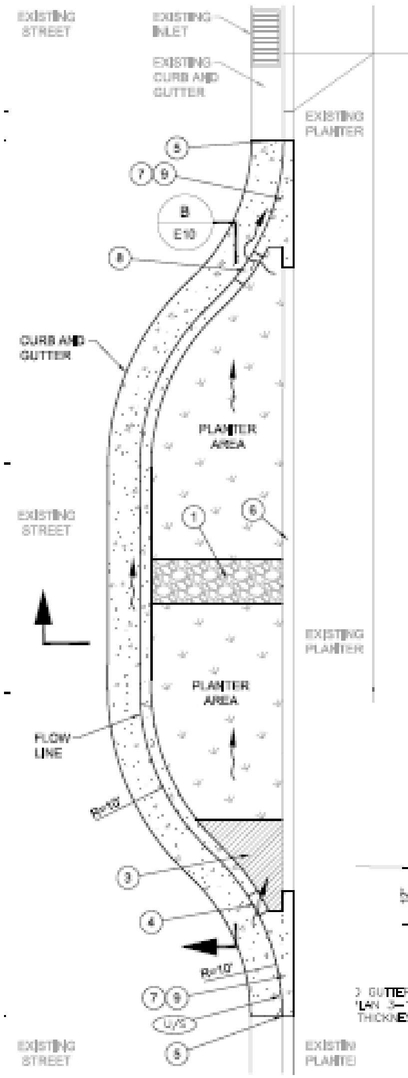
Bioswales



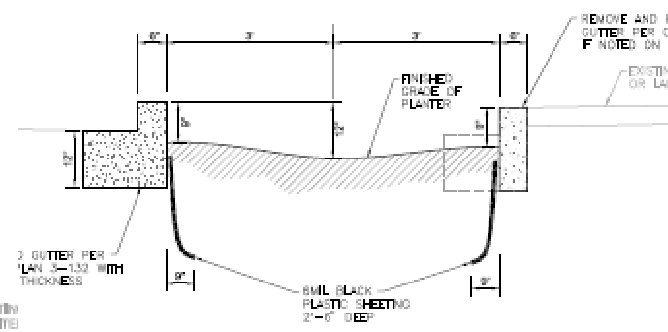
Blue/Green Roof



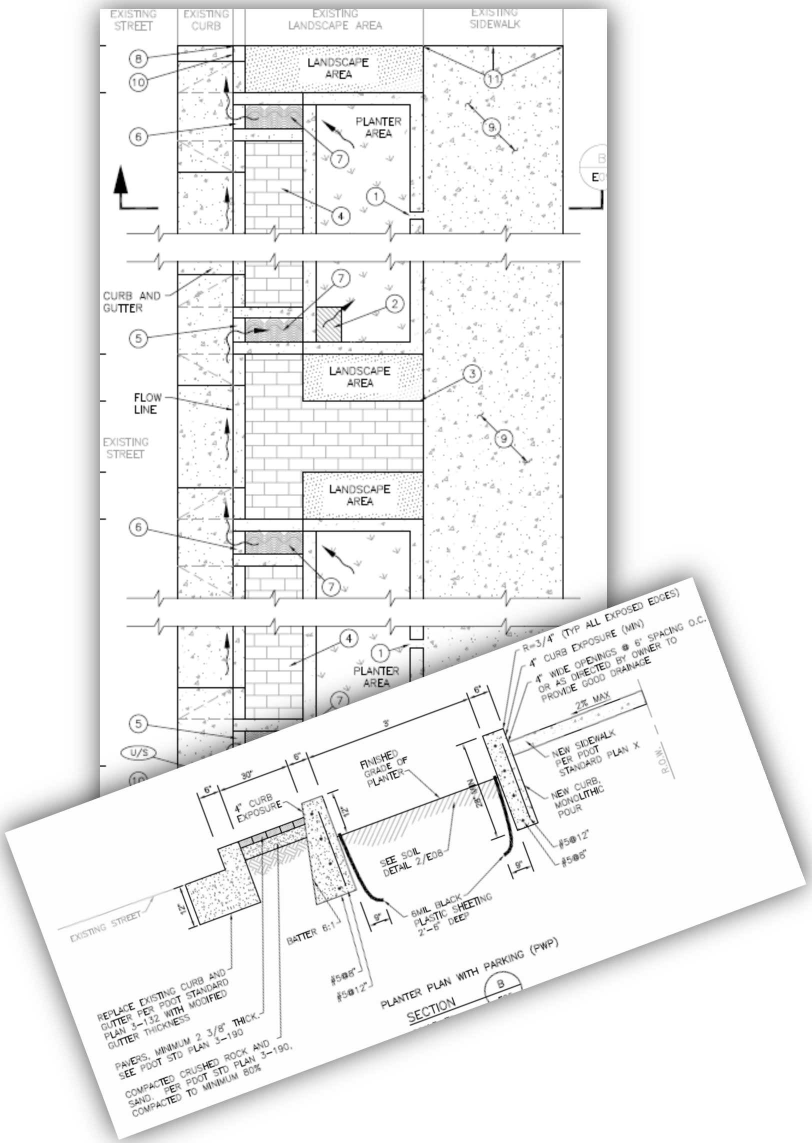
Curb Extension



CURB EXTENSION PLAN



Sidewalk Planter



Wet Detention and Wetland Treatment

PPV and residence time key factor for wet detention effectiveness (21+ days)

Significant land area required for wetlands, efficiencies highly dependent on influent concentrations and hydraulic loading rate, plan for future maintenance.

- emergent marsh w/ open water pools
- submerged aquatic vegetation (SAV)
- hardwood elements
- design to minimize short circuiting

Lake Claiborne Restoration

- Removed 442,043 lbs/yr TSS/restored PPV
- Completed in 6 months
- $1.2M Construction Cost
- $3.68/lb TSS
- County average cost per pound is $10/lb TSS
- Homeowners happy
- Monitor for WQ and habitat improvements


15 Acre SAV/Wet Detention System treats 600 acres
Construction cost $1M
Annual O&M cost $20,000
Property owned by FDOT

Enhanced Treatment Using Coagulants

- Achieves significantly higher removal efficiencies than traditional treatment methods for many pollutants; **80-90% TP, 99.9% pathogen removal**
- Requires significantly less land than traditional methods
- Typically has the lowest life cycle cost per mass TP and pathogen removed
- Improves receiving surface water quality for aesthetics, recreational use or public health
- Provides source water protection and controls growth of algae and bacteria (including blue-green algae)

How Does the Process Work?

Removal of particulate pollutants

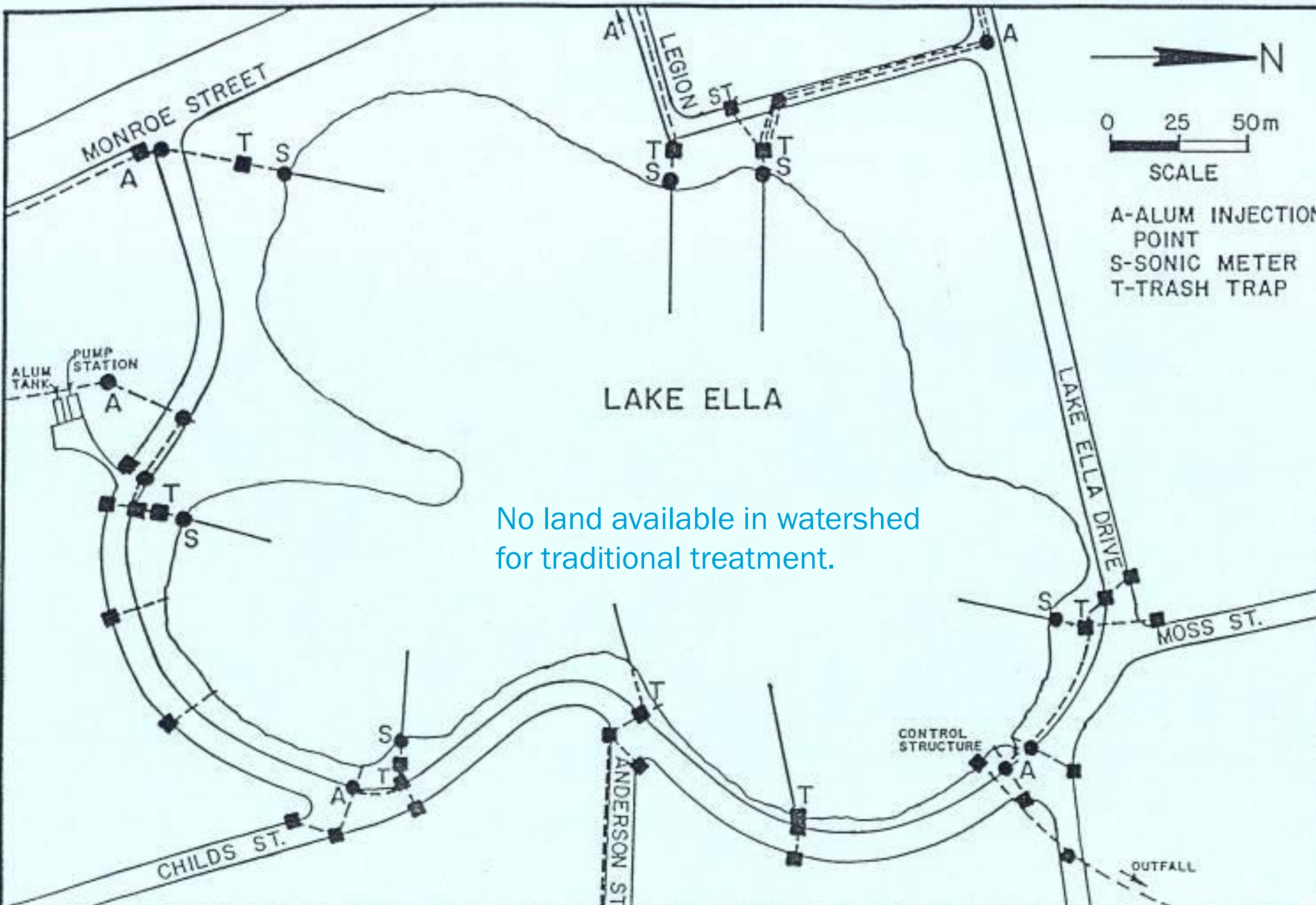
$$Al_2(SO_4)_3 \ + \ 6HCO_3^- \ \text{----->} \ 2Al(OH)_3 \ (ppt) \ + \ 3SO_4^{-2} \ + \ 6CO_2$$

Removal of dissolved phosphorus

$$Al_2(SO_4)_3 \ + \ 2PO_4^{-3} \ \text{----->} \ 2AlPO_4 \ (ppt) \ + \ 3SO_4^{-2}$$

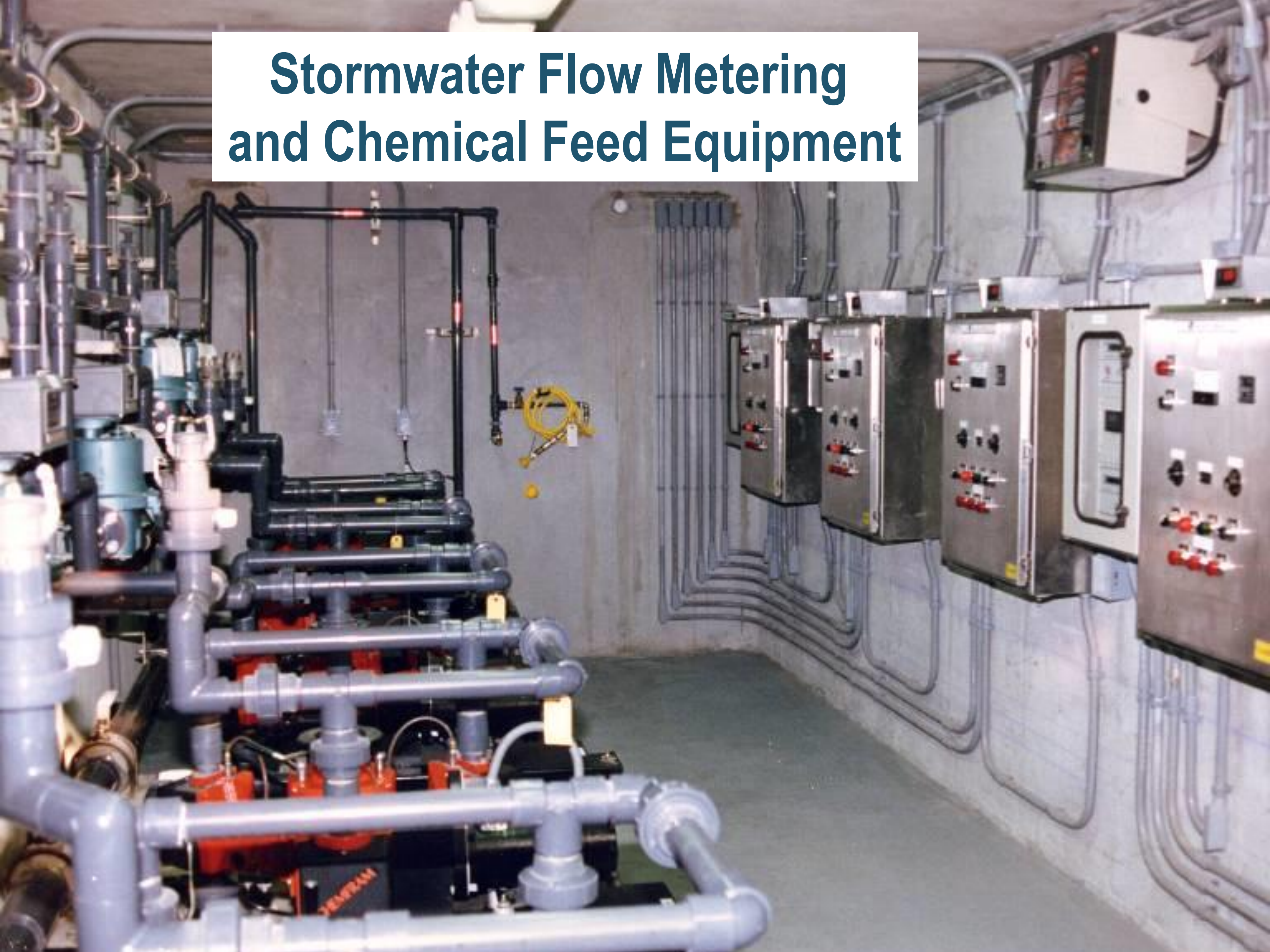
The addition of acid salts consumes alkalinity and reduces water pH, however, a pH buffer is rarely required.


Before Stormwater Chemical Treatment



No land available in watershed for traditional treatment.

Stormwater Flow Metering and Chemical Feed Equipment




After Stormwater Chemical Treatment

Largo Central Park

1200 acre watershed treated using 3 acre pond, floc pumped to SS
Construction cost = $1,000,000
Annual O&M cost = $50,000


Stormwater
Treatment Process

Existing Weems Pond Site Conditions

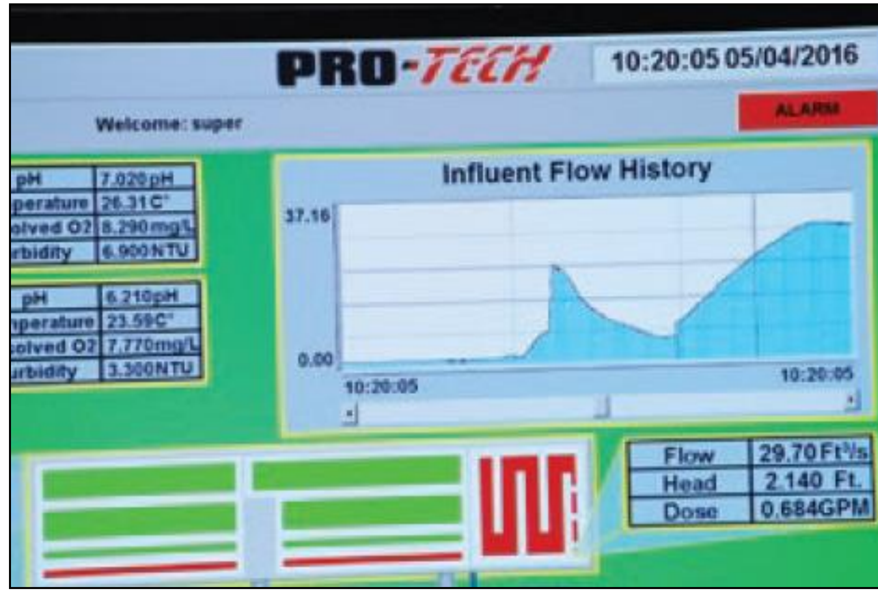
Design – 10,000 acre watershed

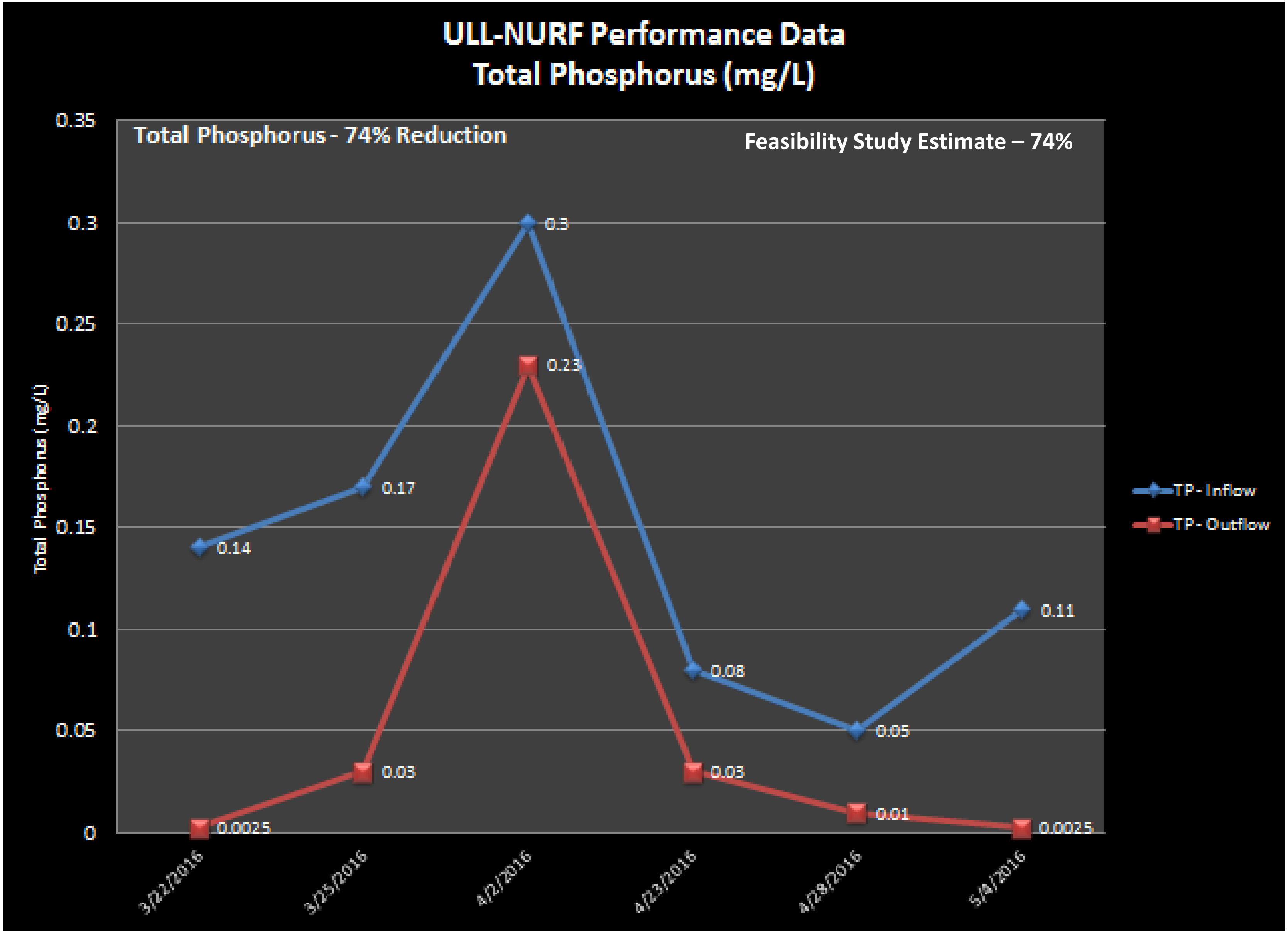
Pollutant Load Reductions (pounds/year)						
BMPs Installed		TSS lbs/yr	TP lbs/yr	TN lbs/yr	BOD lbs/yr	Fecal Coliform
Alum Injection						(total count)
Pollutant Loads	Pre-Project	143,318	3,175	11,506	48,155	9.07E+13
	Post-Project	31,964	838	8,681	32,389	1.73E+13
	Load Reduction	111,355	2,337	2,825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

Construction - Cost & Grants

- Total Project Cost = ~$6.5 million
- Construction Cost = ~$5.4 million
- FDEP Grant = $500,000
- 2nd Largest in FL

Operations


PRO-TECH
10:20:05 05/04/2016
ALARM
Welcome: super
pH 7.020pH
perature 26.31C°
olved O2 8.290mg/L
rbidity 6.900NTU
pH 6.210pH
perature 23.59C°
olved O2 7.770mg/L
urbidity 3.300NTU
Influent Flow History
37.16
0.00
10:20:05
10:20:05
Flow 29.70 Ft³/s
Head 2.140 Ft.
Dose 0.684GPM


ULL-NURF Performance Data
Total Phosphorus (mg/L)
Total Phosphorus - 74% Reduction
Feasibility Study Estimate – 74%
Total Phosphorus (mg/L)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.14
0.17
0.3
0.08
0.05
0.11
0.0025
0.03
0.23
0.03
0.01
0.0025
3/22/2016
3/25/2016
4/2/2016
4/23/2016
4/28/2016
5/4/2016
TP- Inflow
TP- Outflow

Floc Removal and Dewatering

Capital Trail Cascade Park

Aero Photo
727.520.8181
www.aerophoto.com

Capital Cascades Park

Image # 1406020094
Date 06.02.14

Enhanced Wetland Treatment System to Meet TMDL

6500 acre watershed treated
Flows up to 100 cfs diverted

Construction cost = $2,000,000
Annual O&M cost = $75,000

Reduces chemical requirements; wetland alone achieves desired TP reduction during lower flows.

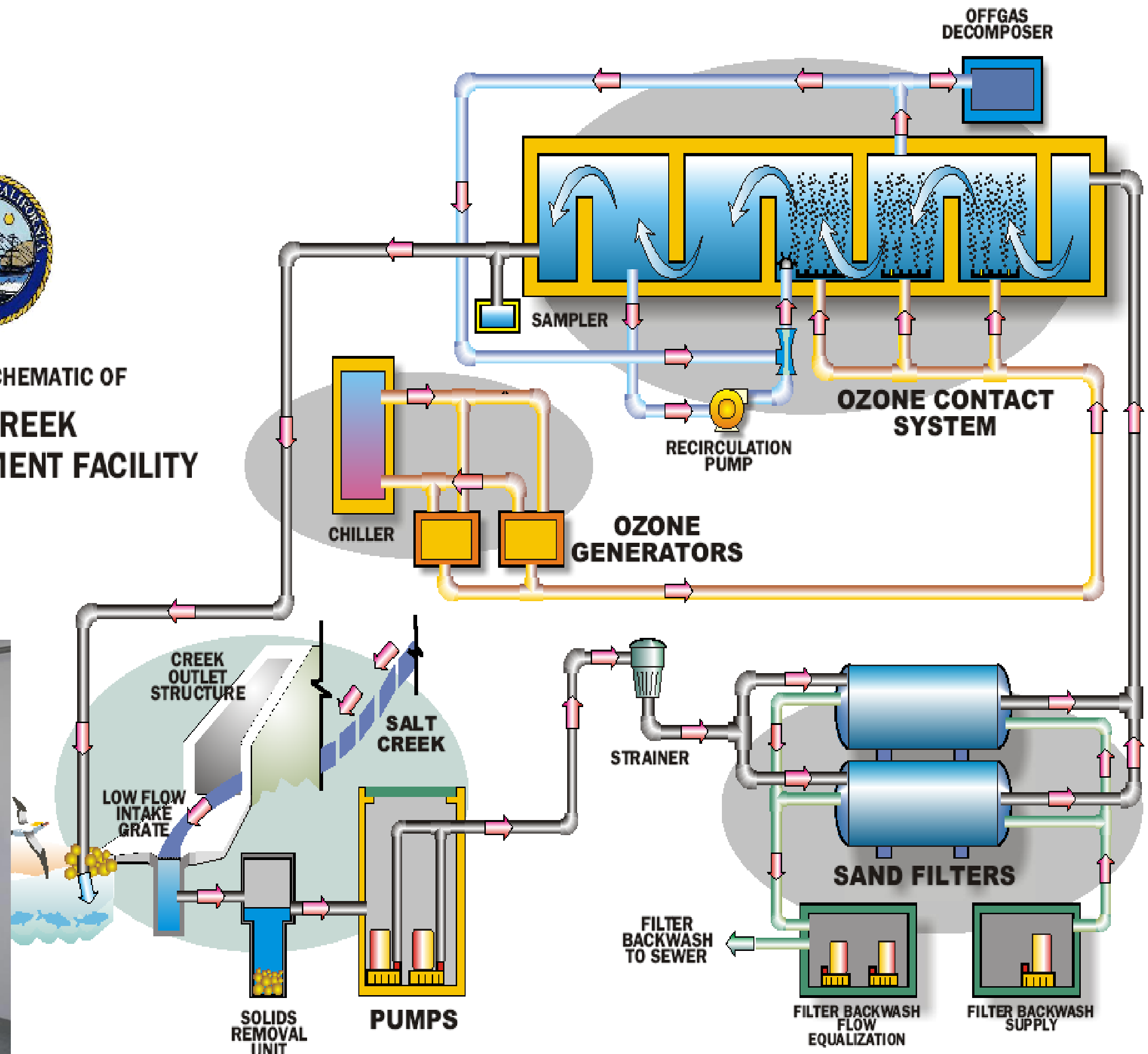
Dewatered floc used to amend constructed wetland treatment soils to bind P

Annual load reductions = 2,000 kg TP, 1,300 kg TN, 18,000 kg TSS

Ozone Disinfection

SIMPLIFIED SCHEMATIC OF

SALT CREEK
WATER TREATMENT FACILITY



Influent and Treated Water Monitoring Results

Summary of Representative Data (through July - 06)			
Location	**Minimum**	**Maximum**	**Mean**
Influent			
Total Coliform (MPN/100mL)	1,400	160,000	33,539
Fecal (E. Coli) (MPN/100mL)	170	30,000	4,266
Enterococcus (MPN/100mL)	15	37,000	5,859
Treated Water			
Total Coliform	2	30	6
Fecal (E. Coli)	2	30	2
Enterococcus	1	140	13

Treats 1 cfs Baseflow; Construction Cost $3M,
Annual O&M Cost $40,000

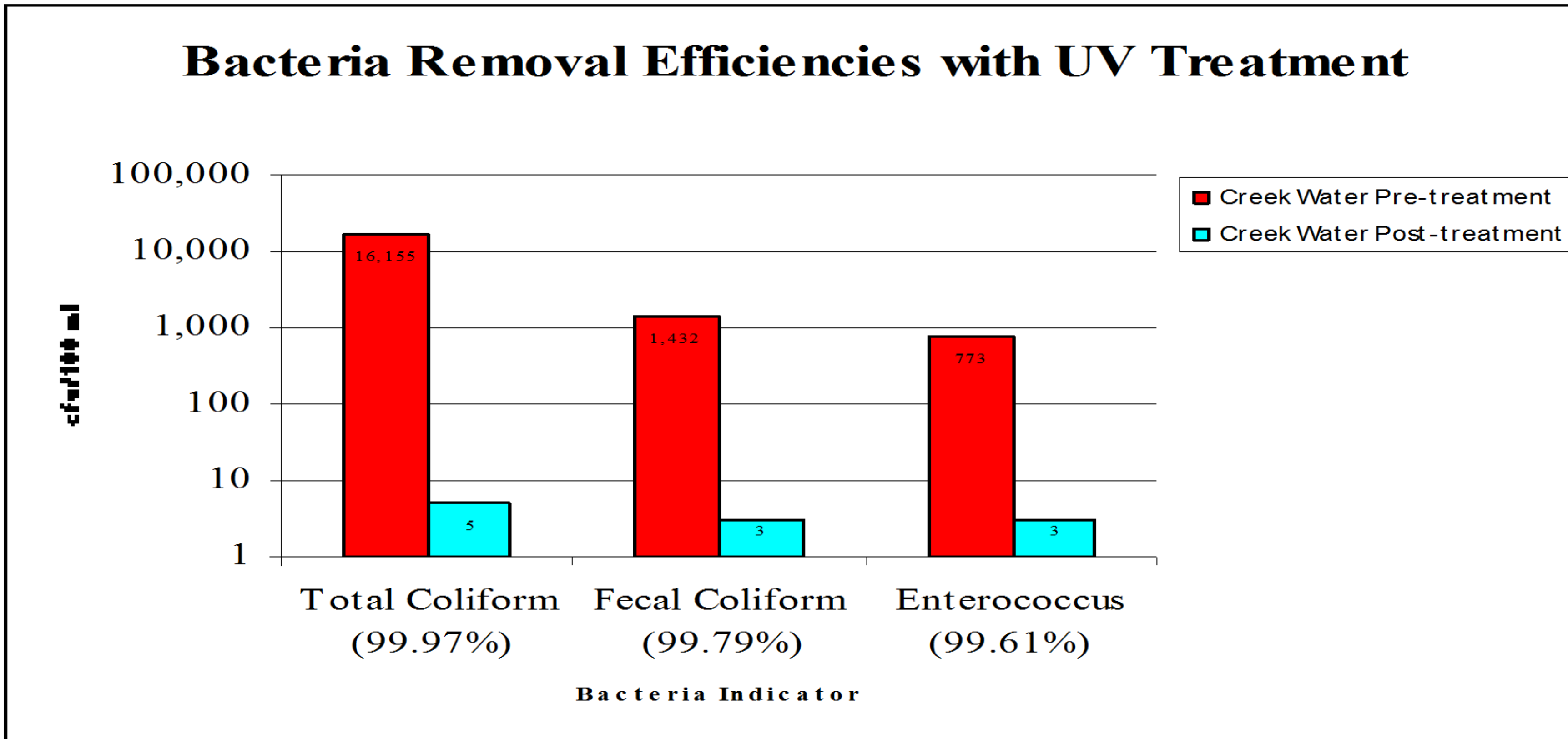
UV Disinfection

- Intake line from creek inside of existing box culvert
- Wet well with alternating pumps
- Basket filters
- Multimedia filters
- UV light bulbs
- Discharge from facility re-introduced to creek inside existing box culvert

3 Year Monitoring Results

- >99% Bacteria Kill in Treated Water from the Plant

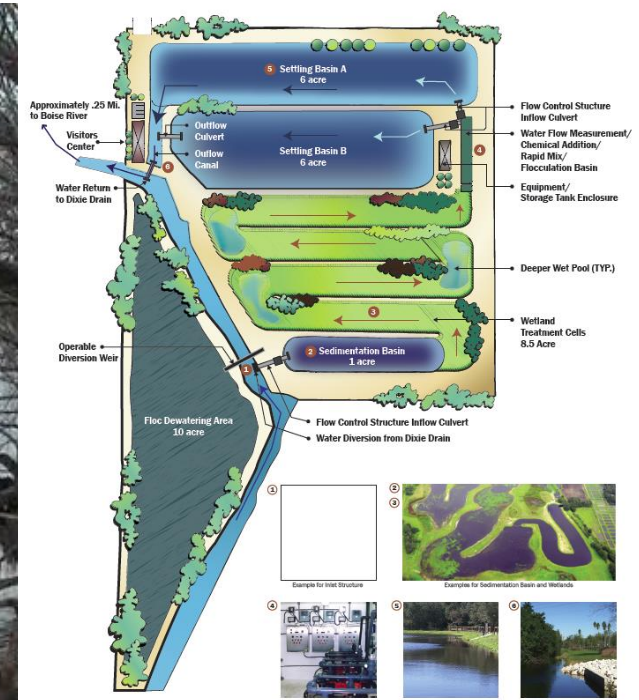
Treats 0.33 cfs Baseflow, Construction Cost $400,000; Annual O&M Cost $20,000



City of Boise, Idaho

Dixie Drain Enhanced Water Quality Treatment Phosphorus Offset Project

- Nutrient removal
- Integrated watershed approach



- First nonpoint source project used to offset total phosphorus requirements in a wastewater NPDES permit
- Includes coagulant addition facility to precipitate TP from the diverted agricultural flows

Recreational and Educational Elements

Include recreational elements to allow a stormwater treatment system to be useful to the public and a benefit to community

BMP Life Cycle Cost Comparisons are highly variable

Retrofit BMP	Life Cycle Cost per kg TP removed ($)	Life Cycle Cost per kg TN removed ($)
Pet Waste Education	**150 - 300**	**20 - 40**
Second Generation Baffle Box	**400 – 1,600**	**250 - 500**
Wet Detention Pond	200 - 2,400	100 - 1,000
Dry Detention Basin	1,500 - 7,000	1,250 - 2,500
Bioretention	1,000- 40,000	500 - 5,000
Stream Restoration	1,000 - 4,000	300 - 600
Chemical Treatment	90 - 180	50 - 100
Enhanced Wetland Treatment	100 - 200	100 - 200

Larger - regional systems tend to have significantly lower life cycle costs per mass pollutant removed than many smaller systems. LID for new construction is more cost effective.

Questions

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