Novel Ecotechnologies Employed in an Urban Context: The Application of Floating Wetlands, Regenerative Stream Conveyance and Algal Turf Farms in Support of Chesapeake Bay Restoration Goals

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Chesapeake Water Environment Association
Using Alternative BMPs to Achieve Chesapeake Bay TMDL Requirements
Maritime Institute of Technology
December 14, 2016

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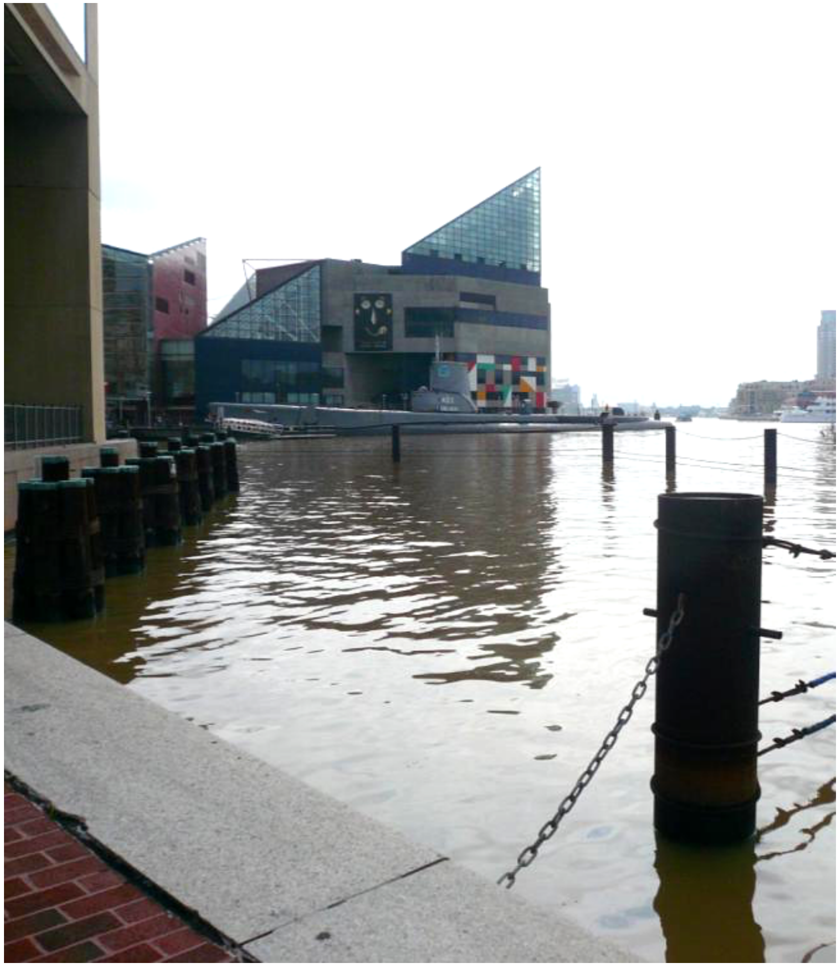
Overview

- Location
- Problem Summary
- Vision
- Floating Wetland Design
- Regenerative Stream Design
- Algal Turf Scrubber Design
- Comparisons of Performance



Biohabitats

Baltimore St
Lombard St
Historic Jonestown
Pratt St
Fells Point
Gough St
Bank St
Little Italy
Eastern Ave
Inner Harbor
Harbor East
Fleet St
Aliceanna St
Conway St
Lee St
West Shore Park
Light St
Rash Field
Key Hwy
Hughes St
Montgomery St
Churchill St
Henrietta St
Warren Ave
Federal Hill Park
Federal Hill
South Baltimore
Cross St
West St
Ostend St
E Clement St
Fort Ave
E Randall St
Riverside
Riverside Park
Heath St
Barney St
Locust Point
Fort McHenry
Thames St
Lancaster St
Exeter St
Central Ave
Caroline St
Ann St
Wolfe St
Washington St
Chester St
Hanover St
Charles St
Gay St
Market Pl
Calvert St
Water St
1
2
3
4
5
6
7
8
9

Water Quality Impairments (Patapsco)

- Eutrophication
  - Sediment - 24,650 tons/year
  - TP – 146,000 lb/year
  - TN – 2,475,000 lb/year
- Annual Fish Kills
  - Hypoxia And Anoxia
- Sediment Contamination
  - Chlordane and PCBs
  - Toxic Metals

Total Maximum Daily Loads of Nitrogen and Phosphorus for the Baltimore Harbor in Anne Arundel, Baltimore, Carroll and Howard Counties and Baltimore City, Maryland

FINAL

MARYLAND
DEPARTMENT OF THE ENVIRONMENT

1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

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Problem

Eutrophication of harbor water has spurred harmful algal blooms causing low dissolved oxygen events and fish kills

The city and local organizations want to do something about it and show progress

Source: www.watergarden.com

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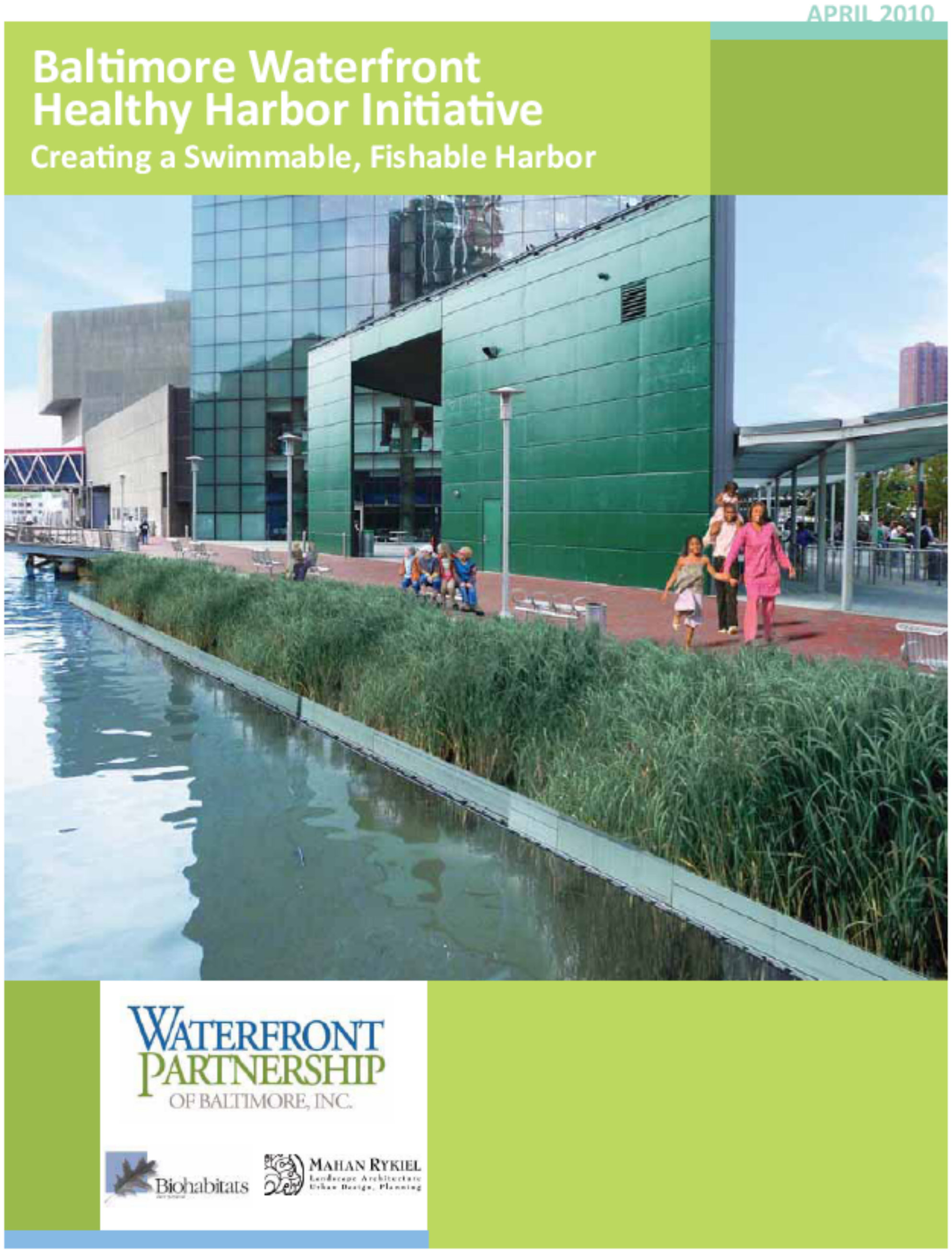

APRIL 2010

Baltimore Waterfront Healthy Harbor Initiative

Creating a Swimmable, Fishable Harbor

WATERFRONT PARTNERSHIP OF BALTIMORE, INC.

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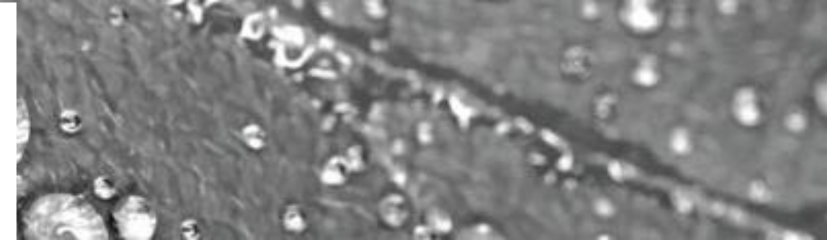
MAHAN RYKIEL Landscape Architecture Urban Design, Planning



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Waterfront is 125 acres of a 135,000 acre watershed

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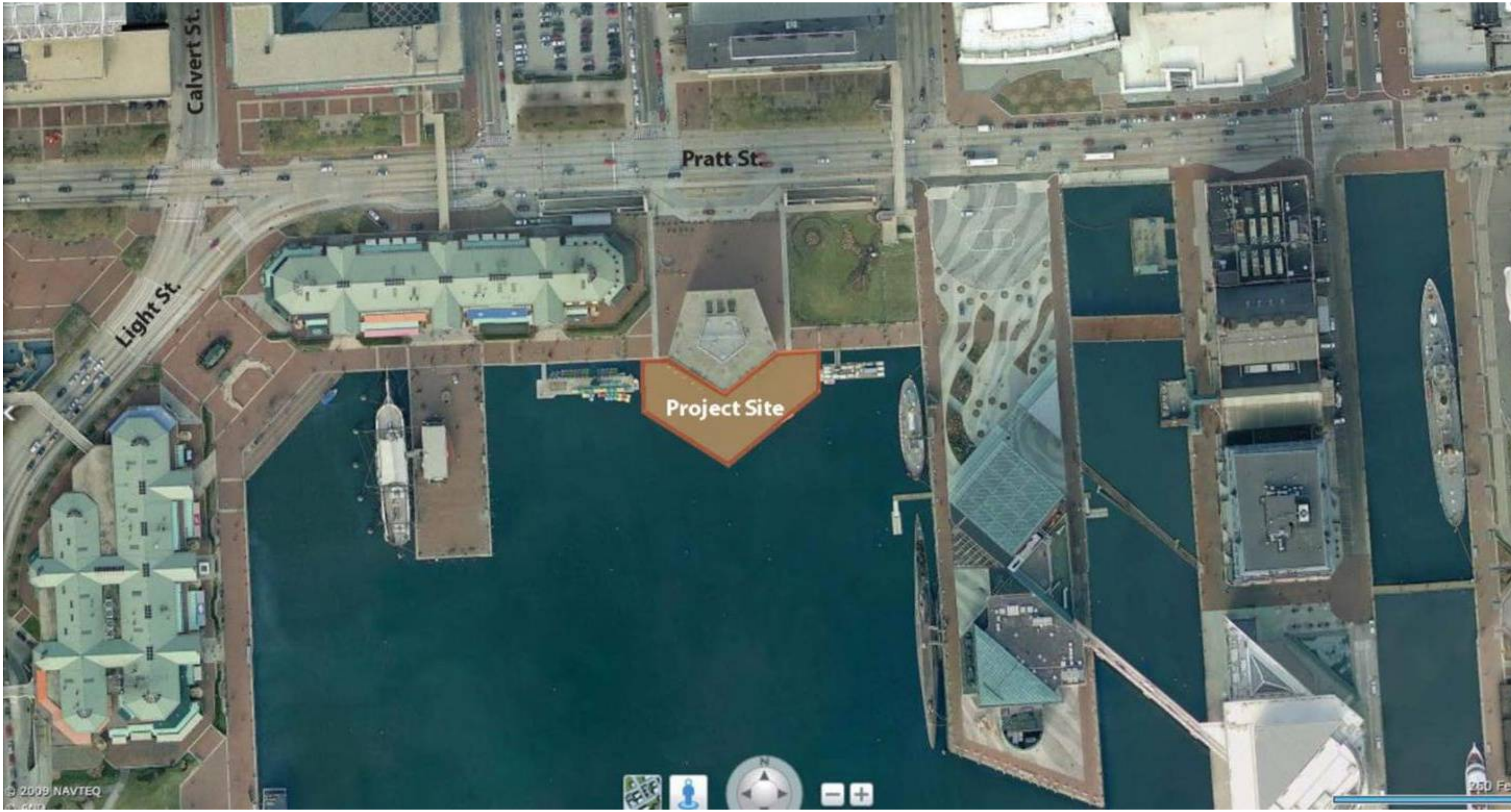
Leverage the exposure of over 6.5 million visitors per year to build civic awareness

Project Location



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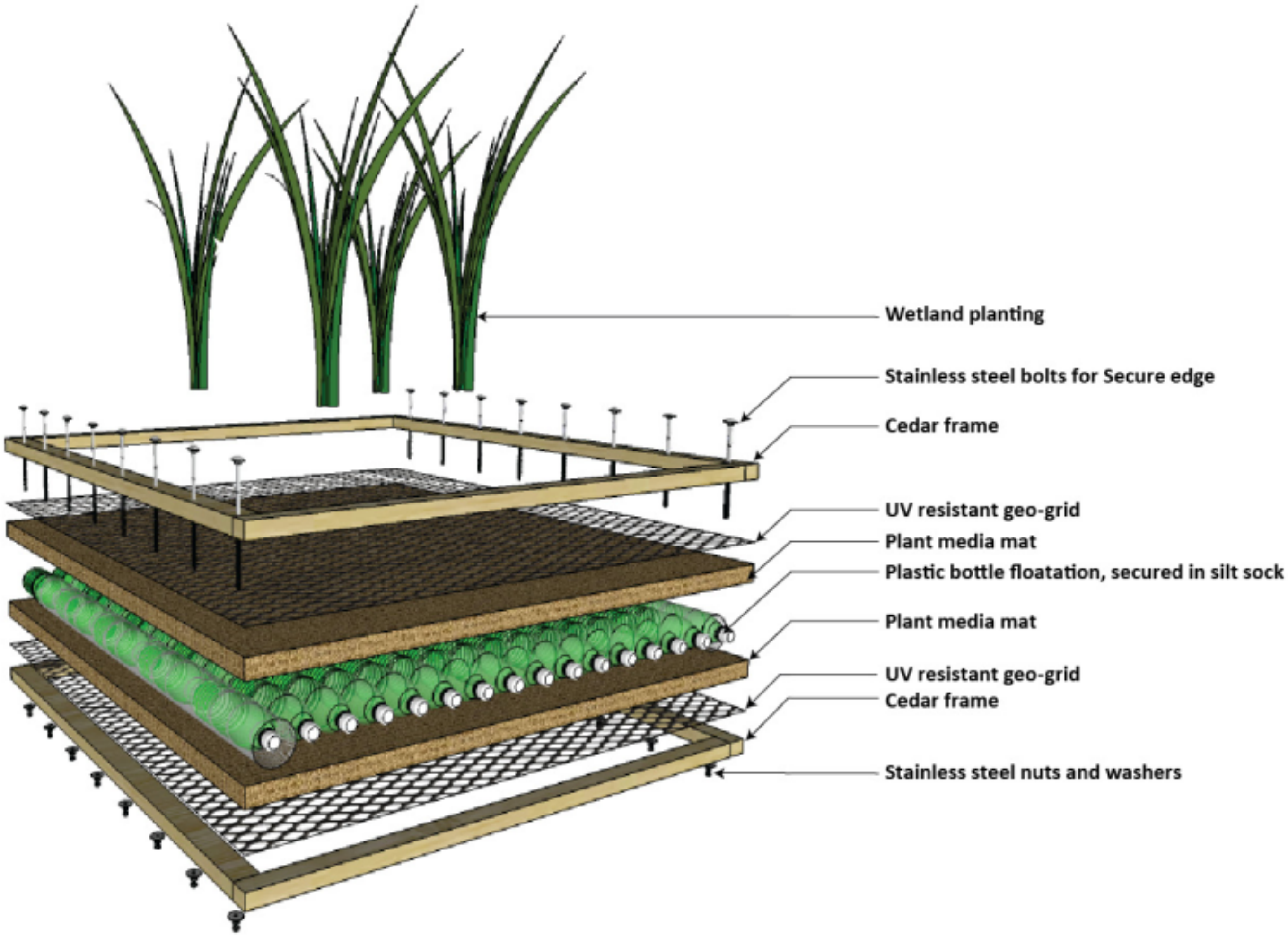
423

Floating Wetland Design



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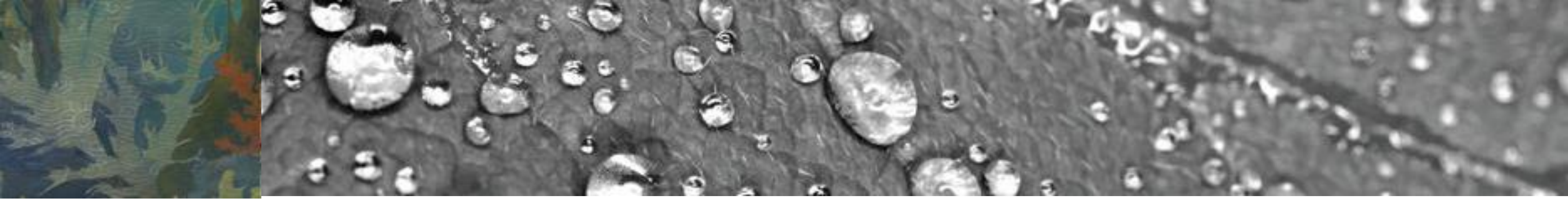

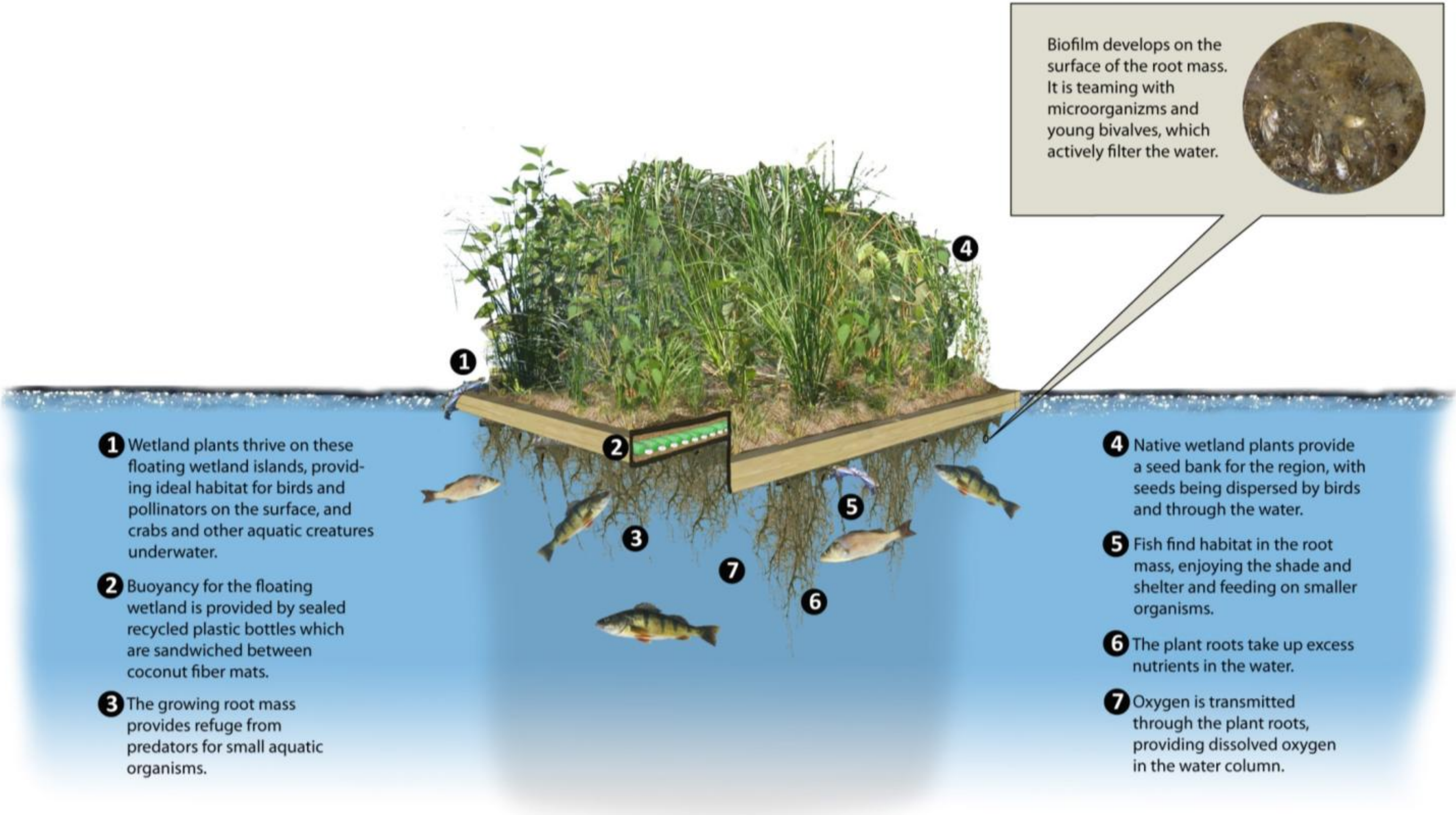

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Biohabitats

Biohabitats

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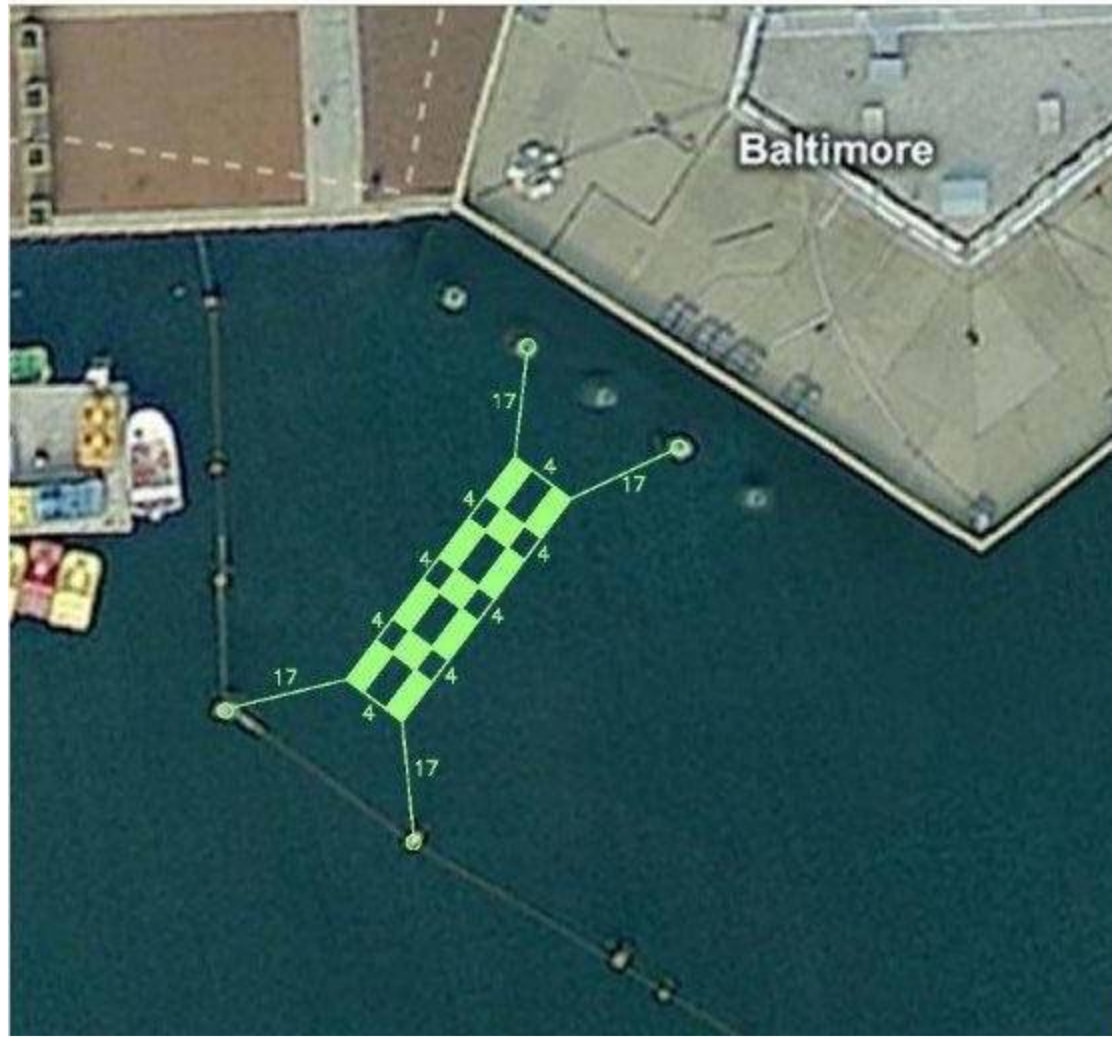
- Wetland Plan Area ≤ 200 Sq. Ft.
- Wetland Moored to and between Existing WTC Security Pylons
- Plans to scale up to 2,000 Sq. Ft.



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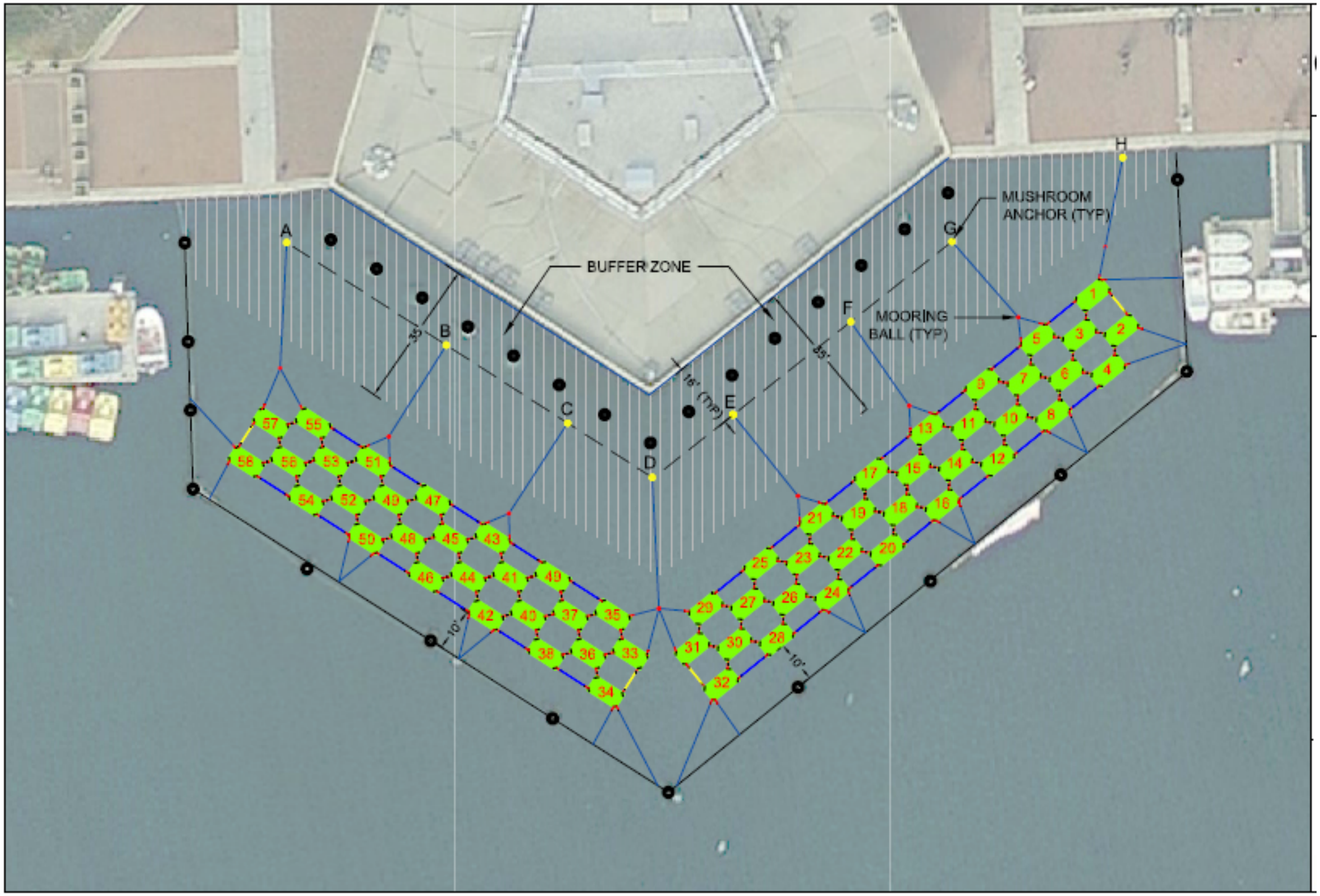
Design – 2000 square feet



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BALTIMORE


U.S.S. CONSTE N MUSEUM
CURY

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Floating Wetland Design - Flora

Flora Species	Common Name	Reason for Selection
Acorus americanus	Sweet flag	Tolerant of 0.5 – 10 ppm salinity (Harbor) and inundation, availability
Scirpus pungens	Common three-square	
Spartina patens	Saltmeadow cordgrass	
Spartina alterniflora	Smooth cordgrass	
Scirpus robustus	Saltmarsh bulrush	
Juncus roemarianus	Black needlerush	
Hibiscus moscheutos	Marsh hibiscus	“ “, flowering

Acorus americanus

Source:www.northcreeknurseries.com/_ccLib/image/plants/DETA-490.jpg

Scirpus robustus

Source:http://ccrm.vims.edu/wetlands/teaching_marsh/Photos%20&%20Posters/Salt%20marsh%20plants/scirpus-robcomm_web.jpg

Spartina alterniflora

Source:www.wetland.org/plant%20of%20the%20month/nursery_POTM_Cordgrass.htm

Spartina patens

Source:http://blackwaternurseriesllc.com/images/spartina_paten.jpg

Hibiscus moscheutos

Source:www.wetland.org/plant%20of%20the%20month/nursery_POTM_Marsh_hibiscus.htm

Biohabitats

Estimated number of organisms per 200 sf of floating wetland

	July 15		July 22		July 29		August 5	
Barnacle	143	200,200	286	400,400	-	-	-	-
Bryozoan	6,864	9,609,600	45,760	64,064,000	76,648	107,307,200	129,558	181,381,200
Ciliate	5,291	7,407,400	18,161	25,425,400	64,779	90,690,600	46,189	64,664,600
Hydra	2,288	3,203,200	18,018	25,225,200	8,294	11,611,600	-	-
Mudworm	5,434	7,607,600	2,860	4,004,000	14,729	20,620,600	7,007	9,809,800
Mussel	-		3,003	4,204,200	572	800,800	5,863	8,208,200
Polychaete	-		-	-	-	-	1,287	1,801,800
Protozoan	4,290	6,006,000	2,288	3,203,200	1,430	2,002,000	-	-
Stentor	30,888	43,243,200	25,740	36,036,000	8,294	11,611,600	-	-

Biohabitats

Performance - Influences on Local Fauna

Fauna Species	Common Name	Effect
Anas platyrhynchos	Mallard	Possible source of invertebrates and plant material as food
Fulica americana	American Coot	Possible source of invertebrates and plant material as food
Ardea herodias	Great Blue Heron	Possible perching area for resting or fish foraging
Butorides striatus	Green-backed Heron	Possible perching area for resting or fish foraging
Phalacrocorax auritus	Double-crested Cormorant	Possible perching area for resting or fish foraging
Agelaius phoeniceus	Red-winged Blackbird	Possible perching area for resting or invertebrate foraging

Biohabitats

Performance - Influences on Local Fauna

Fauna Species	Common Name	Effect
Morone americana	White perch	Possible source of invertebrates and small fish as food, low level oxygen production
Morone saxatilis	Striped bass	Possible source of fish as food, low level oxygen production
Fundulus sp.	Killifish	Possible habitat in root mat and source of invertebrates as food, low level oxygen production
Brevoortia tyrannus	Atlantic menhaden	Low level oxygen production in harbor
Callinectes sapidus	Blue crab	Possible resting site and source of invertebrates and fish as food, low level oxygen production

Biohabitats

Performance - Influences on Local Fauna

Fauna Species	Common Name	Effect
Hydrobia sp.	Seaweed snail	Possible habiatat in root mat, source of algae, fungi and bacteria as food, low level oxygen production
Palaemonetes pugio	Common grass shrimp	Possible habiatat in root mat, source of algae, fungi and bacteria as food, low level oxygen production
Balanus improvisus	Bay barnacle	Possible attachment site for filter feeding
Acartia sp.	Copepods	Possible source of algae and decaying plant material
Nerodia sipedon	Northern water snake	Possible sunning and forage area for fish

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Regenerative Stream Conveyance as an Approach to the Design of High Value Functional Streams

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Sand Seepage Bed

Riffle Weir Grade Control Structure

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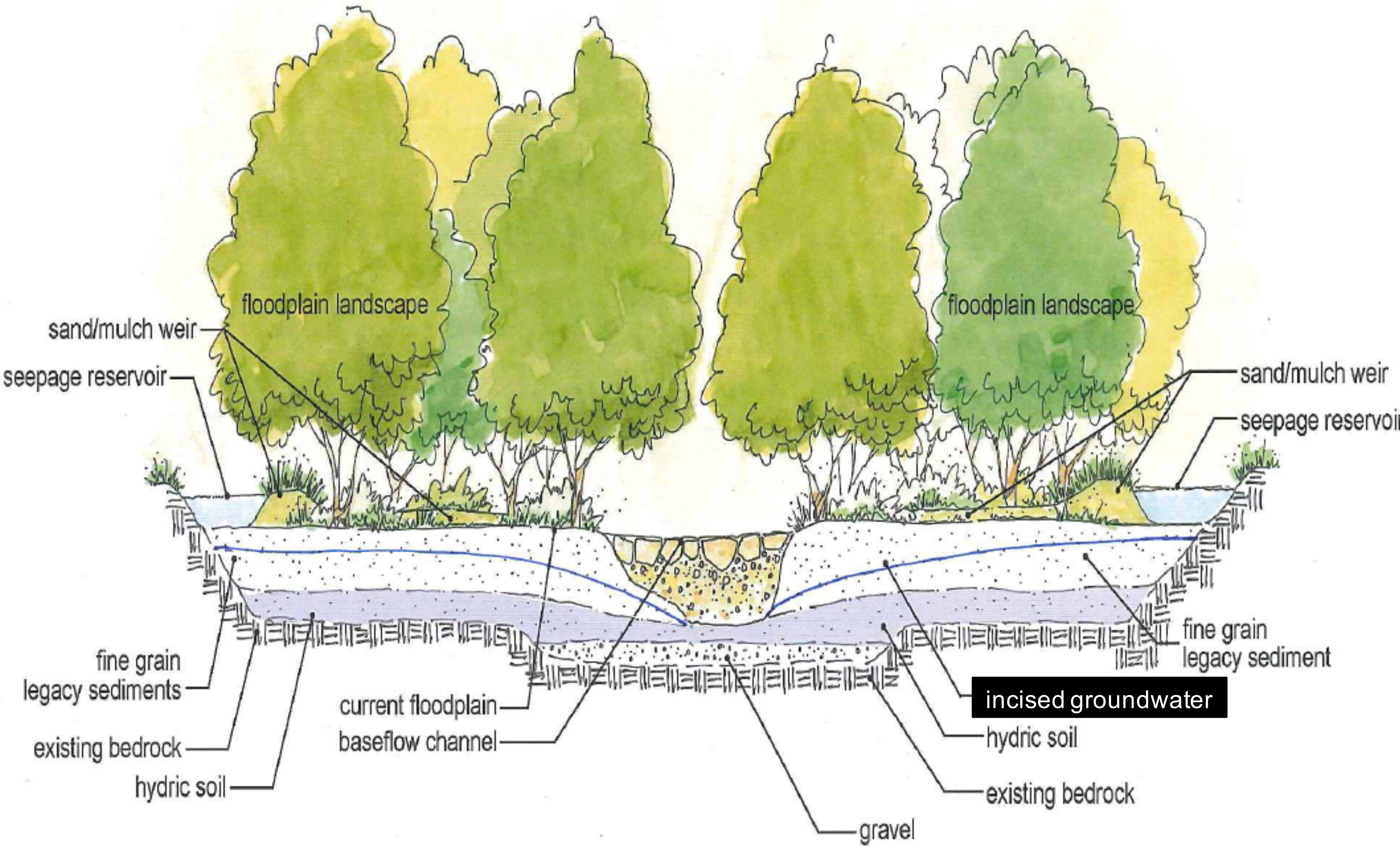
Source of Photos: Underwood & Associates

Groundwater Restoration




60
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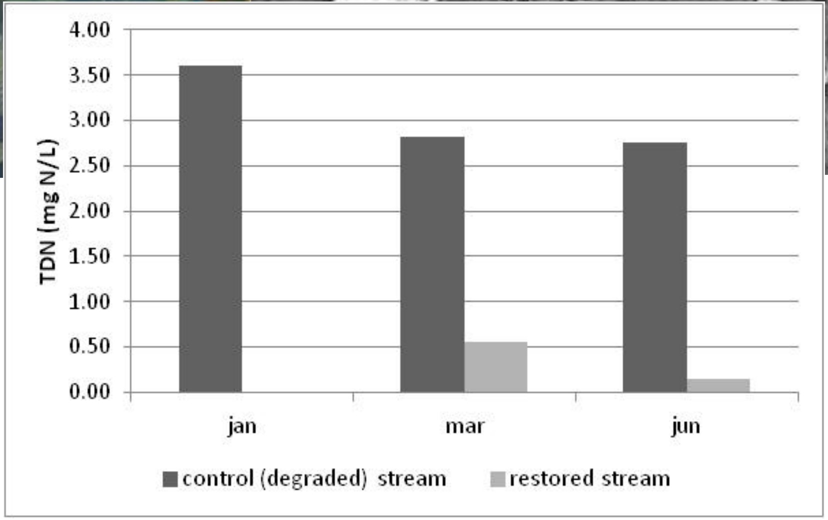
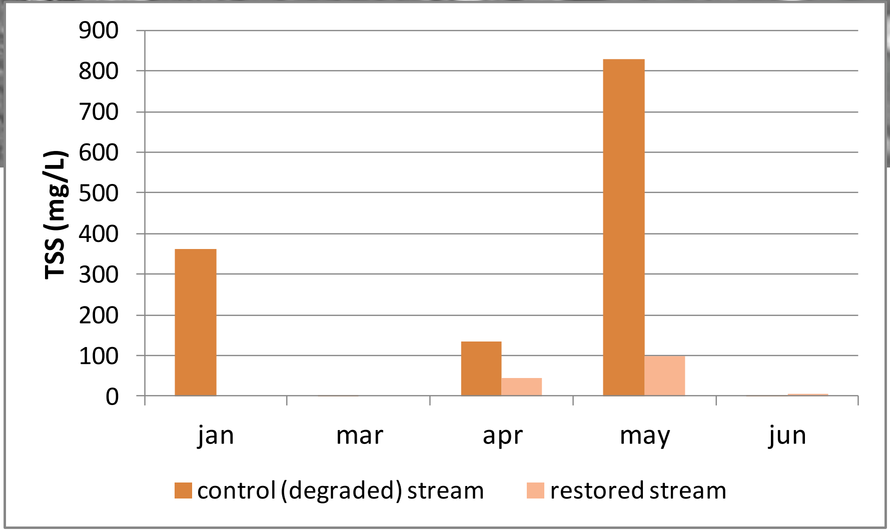
Regenerative Stream Channel Design

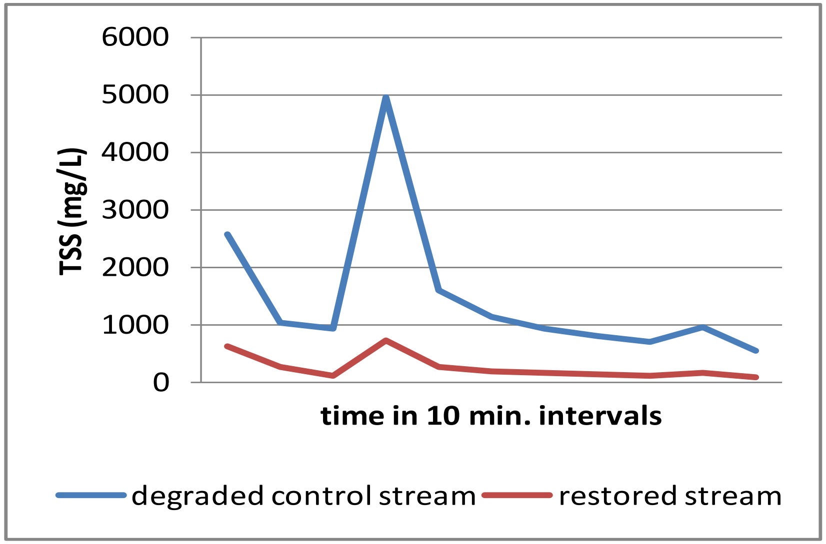
Tributary to Rock Creek
Washington, DC

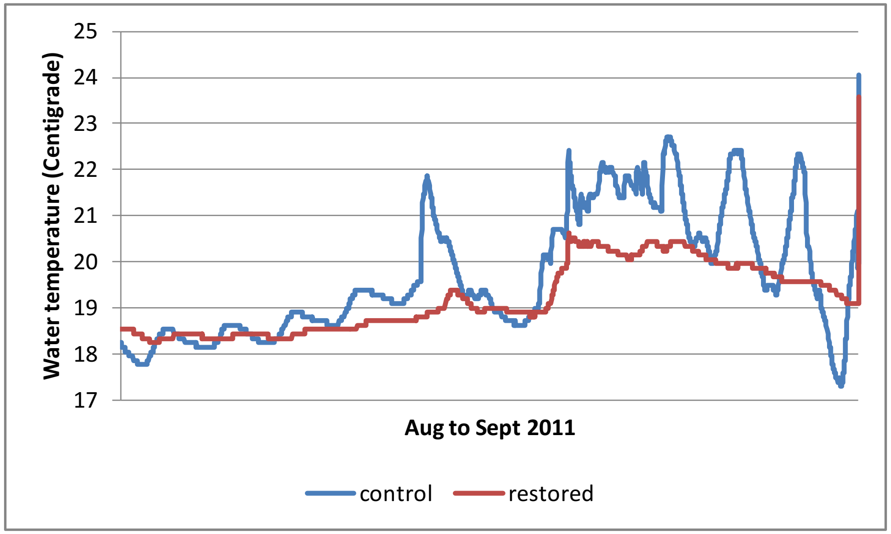
What is the Stream Design Solution?


Tributary to Rock Creek
Washington, DC
October 2011
Connected to Riparian Zone









Carriage Hills,
Source: Solange Filoso, University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory

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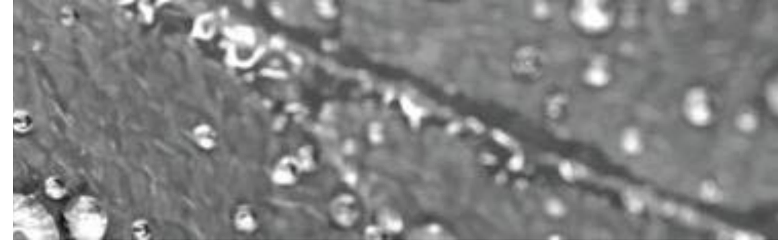

Accounting for Stormwater Wasteload Allocat And Impervious Acres Tr

Guidance for
National Pollutant Discharge Eliminat
Stormwater Permits

June (Draft) 2011

Maryland
Department of the Environment

1800 Washington Boulevard | Baltimore, MD 21230-1718 | www.mde
410-537-3000 | 800-633-6101 | TTY Users: 800-735-2258
Martin O'Malley, Governor | Anthony G. Brown, Lt. Governor | Robert M.

Table 4. Structural BMP Retrofit Matrix

BMP Practice	TN	TP	TSS
CBP Structural BMPs			
Dry Detention Ponds	5%	10%	10%
Hydrodynamic Structures	5%	10%	10%
Dry Extended Detention Ponds	20%	20%	60%
Wet Ponds and Wetlands	20%	45%	60%
Infiltration Practices	80%	85%	95%
Filtering Practices	40%	60%	80%
Vegetated Open Channels	45%	45%	70%
Erosion and Sediment Control	25%	40%	40%
Stormwater Management by Era			
Development Between 1985 - 2002	17%	30%	40%
Urban BMP Retrofit	25%	35%	65%
Development Between 2002 and 2010	30%	40%	80%
Development After 2010	50%	60%	90%
ESD to the MEP from the *Manual*			
Green Roofs	50%	60%	90%
Permeable Pavements	50%	60%	90%
Reinforced Turf	50%	60%	90%
Disconnection of Rooftop Runoff	50%	60%	90%
Disconnection of Non-Rooftop Runoff	50%	60%	90%
Sheetflow to Conservation Areas	50%	60%	90%
Rainwater Harvesting	50%	60%	90%
Submerged Gravel Wetlands	50%	60%	90%
Landscape Infiltration	50%	60%	90%
Infiltration Berms	50%	60%	90%
Dry Wells	50%	60%	90%
Micro-Bioretention	50%	60%	90%
Rain Gardens	50%	60%	90%
Grass, Wet, or Bio-Swale	50%	60%	90%
Enhanced Filters	50%	60%	90%
Additional Structural BMP Guidance			
Redevelopment (MDE)	50%	60%	90%
Existing Roadway Disconnect (MDE)	50%	60%	90%
Step Pool Storm Conveyance (MDE)	50%	60%	90%

Baltimore Harbor Algal Turf Scrubber® Pilot Floway

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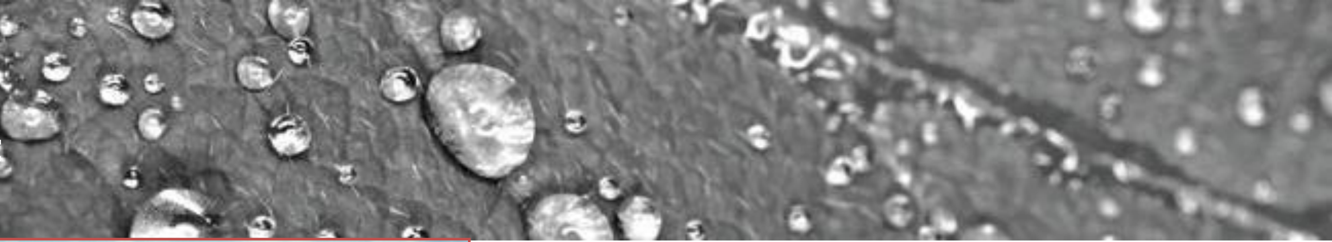
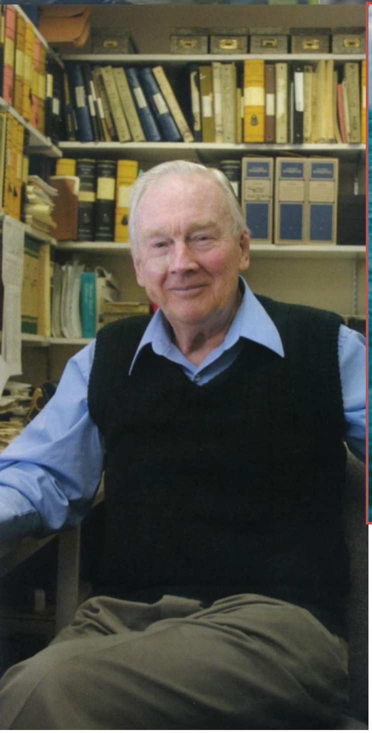
Algal Turf Scrubber®
Early Stage Development
1970s – 1980s





United States Patent [19] — [11] **4,333,263**

Adey — [45] **Jun. 8, 1982**

[54] ALGAL TURF SCRUBBER

[75] Inventor: Walter H. Adey, McLean, Va.

[73] Assignee: The Smithsonian Institution, Washington, D.C.

[21] Appl. No.: 194,726

[22] Filed: Oct. 7, 1980

[51] Int. Cl.³ A01G 7/00

[52] U.S. Cl. 47/1.4; 56/9; 210/620

[58] Field of Search 47/1.4, 59; 210/601-632; 56/9

[56] **References Cited**

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4,236,349	12/1980	Ramus	47/1.4
4,259,828	4/1981	Pace	56/9

FOREIGN PATENT DOCUMENTS

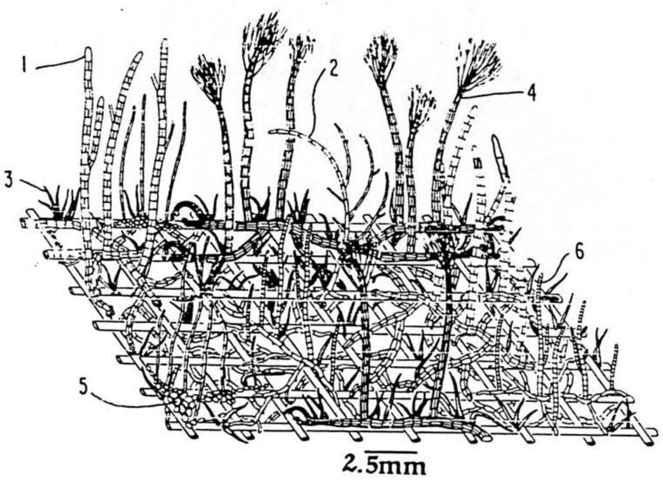
743644	6/1980	U.S.S.R.	47/1.4

Primary Examiner—Robert E. Bagwill
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas

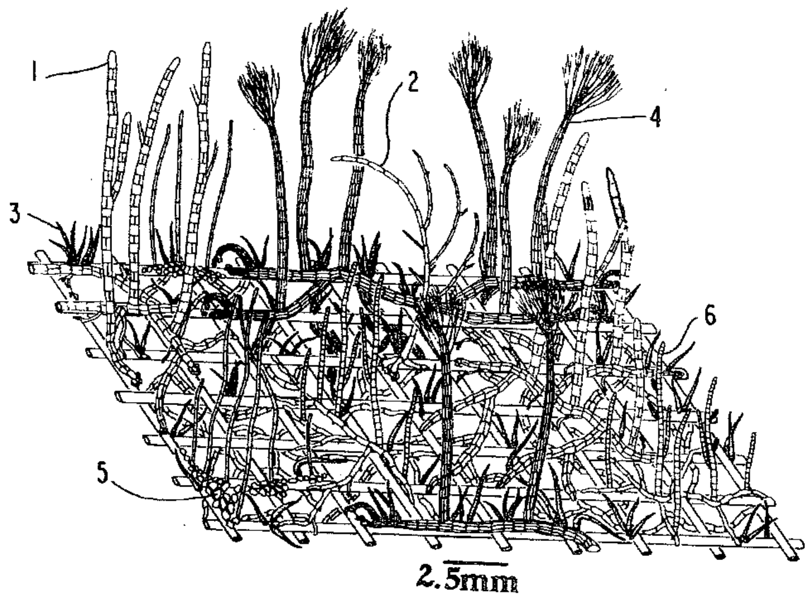
[57] **ABSTRACT**

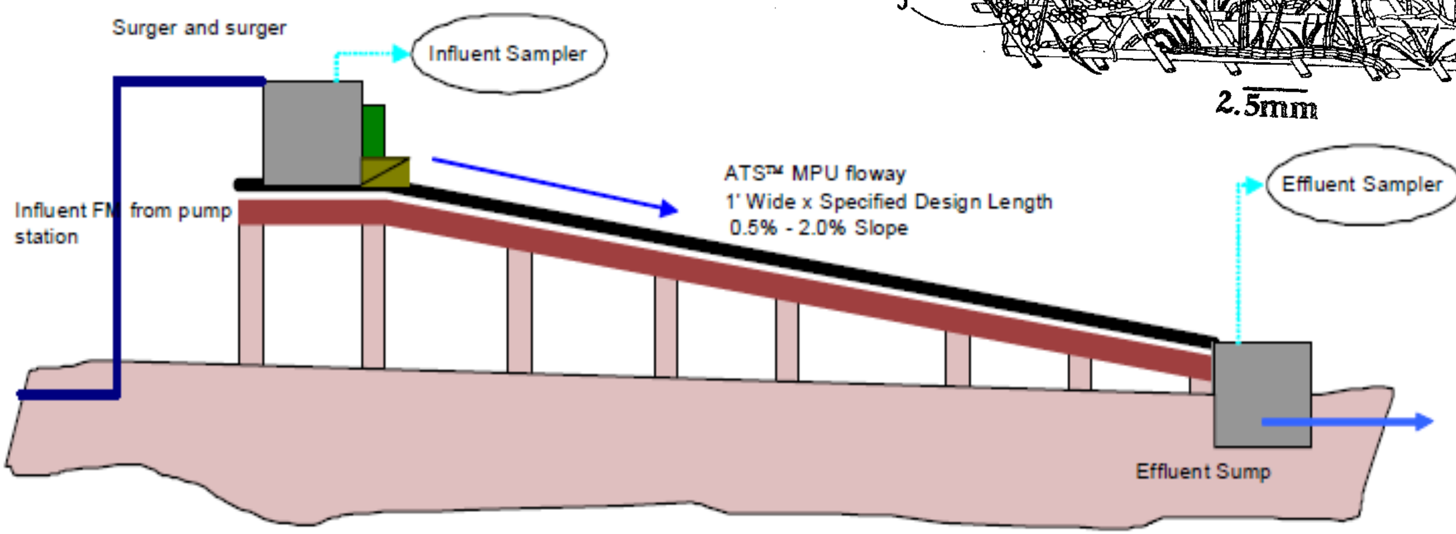
A method of producing an algal turf for use as a scrubber of carbon dioxide, nutrients and pollutants as well as biomass production is disclosed. A growing surface for spores or benthic microalgae is provided on a water surface. The growing surface is subjected to periodic water surge action to promote metabolite cellular-ambient water exchange and light is provided, natural or artificial to promote growth. The growing turf is harvested before being overgrown by larger macroalgae.

9 Claims, 6 Drawing Figures



Basic ATS™ Pilot Floway Design Components





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ATS™ – Algal Floway Community

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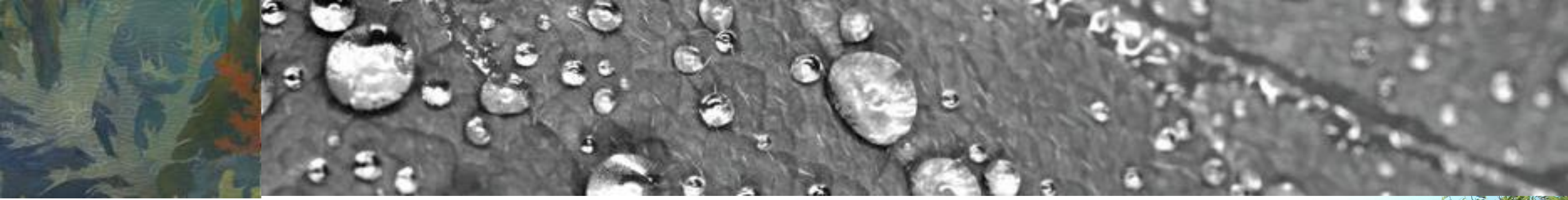

Pilot Scale ATS™

Biohabitats

Patterson ATS™ (1995-1996) Stanislaus County, CA
0.2 MGD x 500'

Medium Scale ATS™

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Large Scale ATS™

The ATS technology has been implemented at the very large scale in Florida and Texas by a commercial company named Hydromentia, headquartered in Ocala, Florida. Biohabitats is partnered with Hydromentia on scaling up further systems.

HydroMentia

Biohabitats

Algal Turf Scrubber® Design

HydroMentia

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Algal Turf Scrubber® Design

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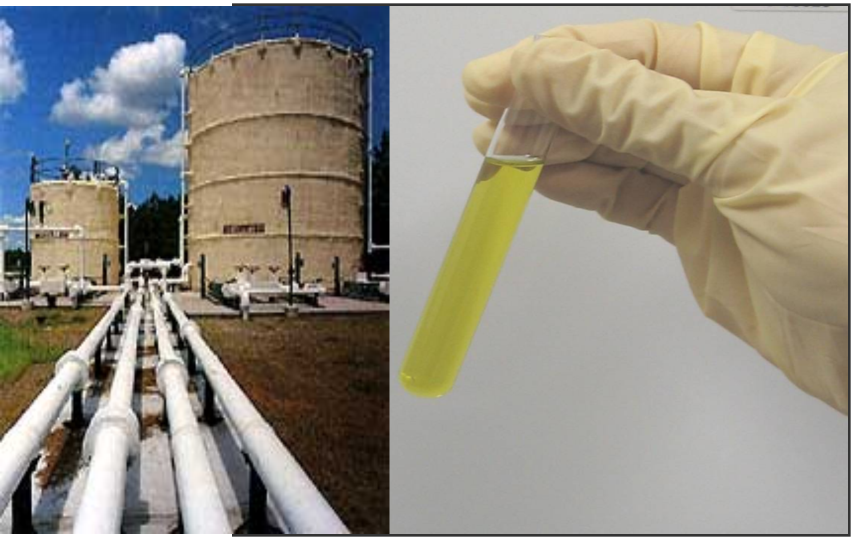
Potential Algal Biomass Products



HydroMentia

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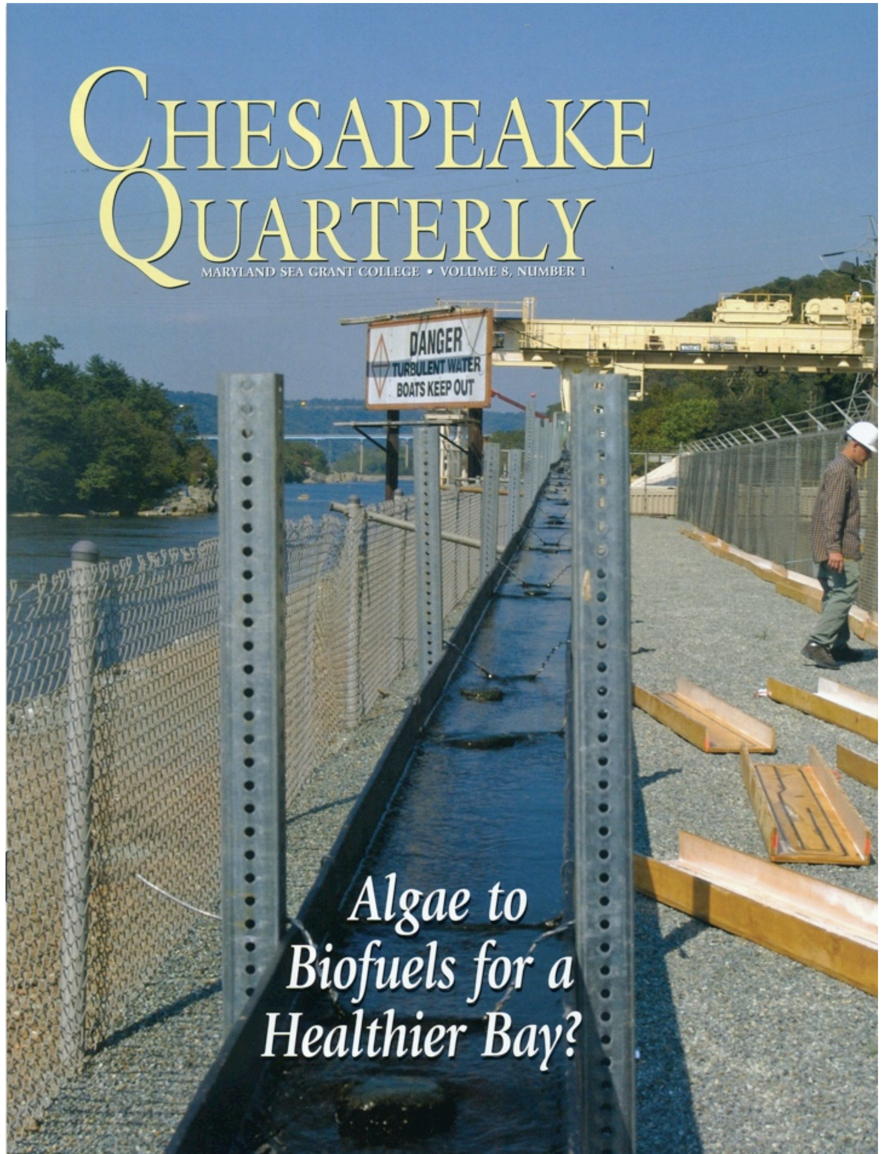

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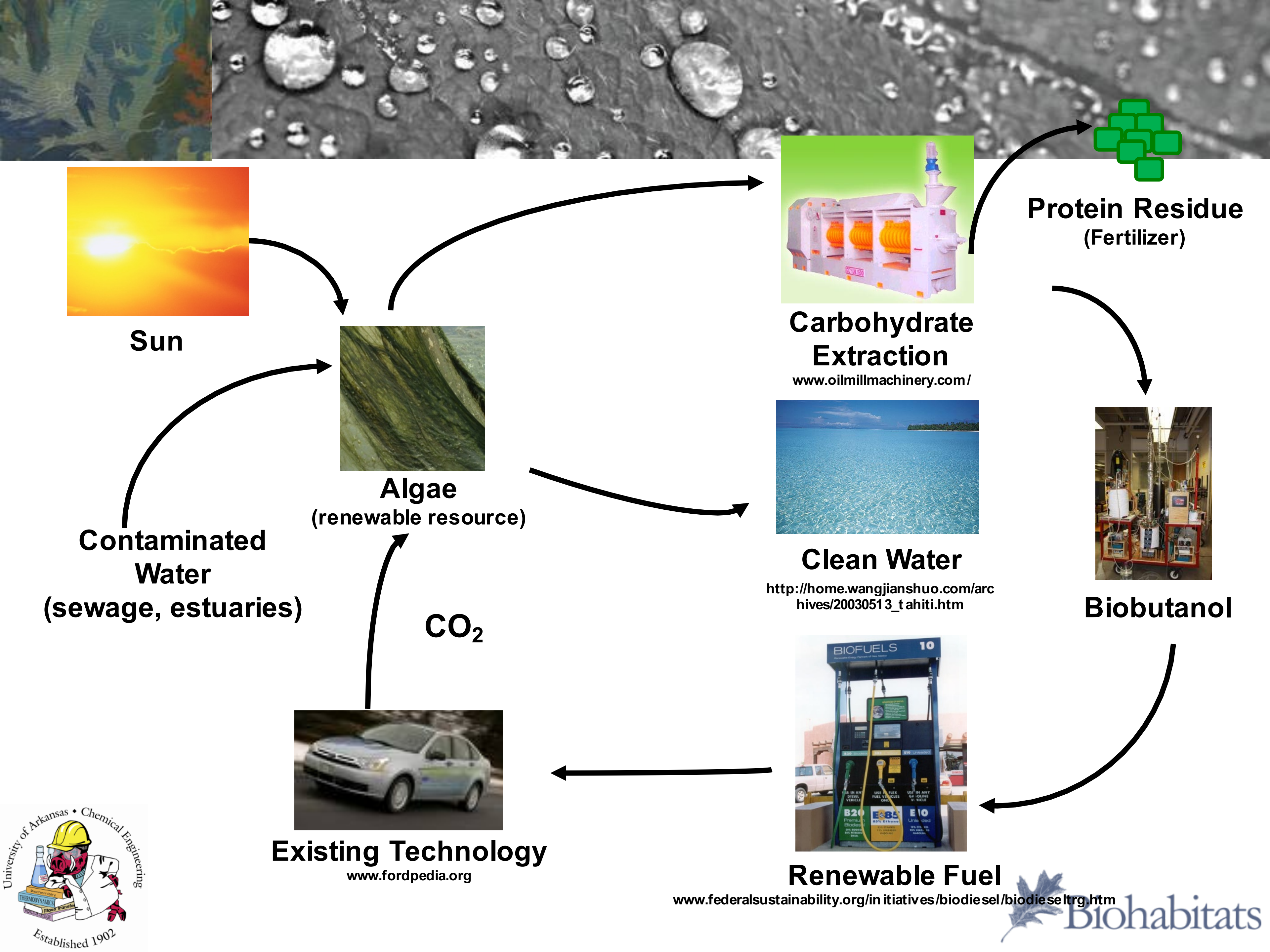

Sun
Algae
(renewable resource)
Carbohydrate Extraction
www.oilmillmachinery.com/
Protein Residue
(Fertilizer)
Clean Water
http://home.wangjianshuo.com/archives/20030513_tahiti.htm
Biobutanol
Contaminated Water
(sewage, estuaries)
CO_2
Existing Technology
www.fordpedia.org
Renewable Fuel
www.federalsustainability.org/initiatives/biodiesel/biodieseltrg.htm
BIOFUELS
B20
E85
E10
University of Arkansas • Chemical Engineering
Established 1902
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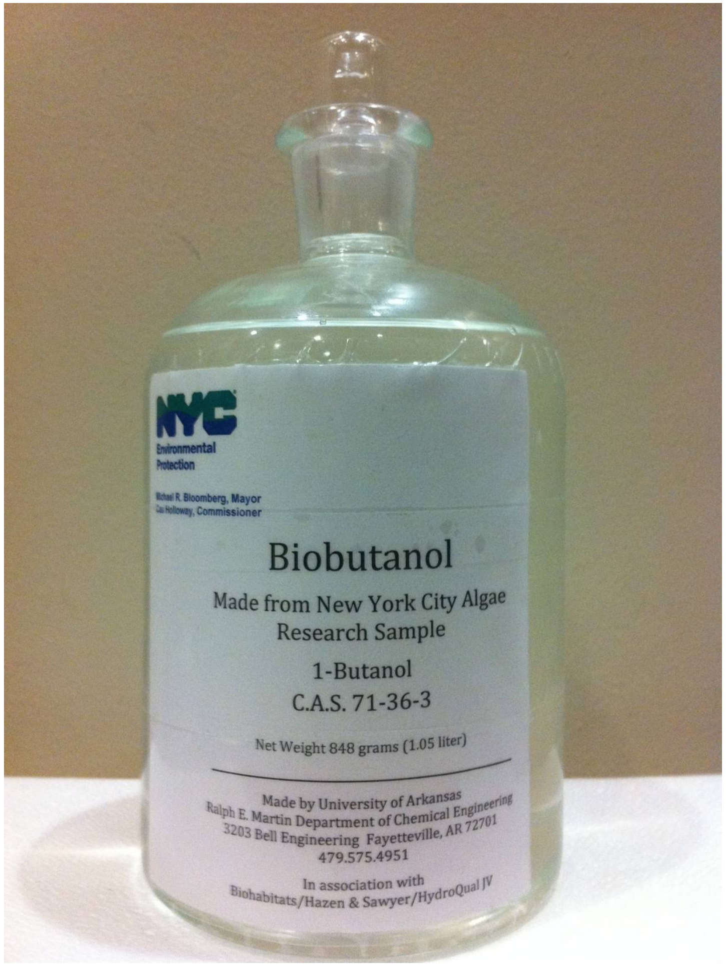
NYC Algae to Biofuel-(Butanol)



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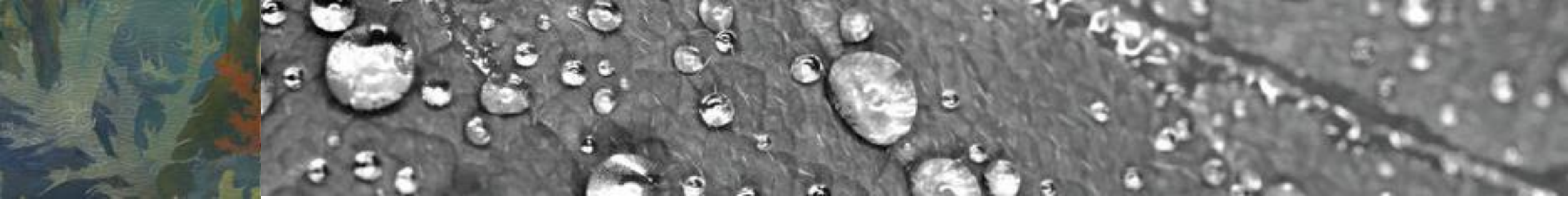

With the ATS technology we take advantage of the power of microalgae to take up nutrients and grow fast!

Pioneering modern ecologist H. T. Odum called this approach "ecological jujitsu"…

Attached filamentous algal "turf" pulls nutrients and traps sediment from the inflowing water while pumping dissolved oxygen into the outflowing water.

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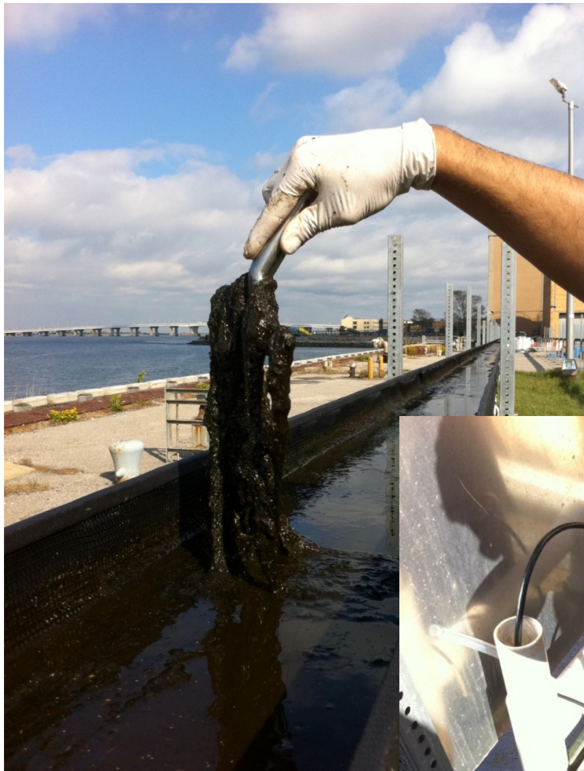
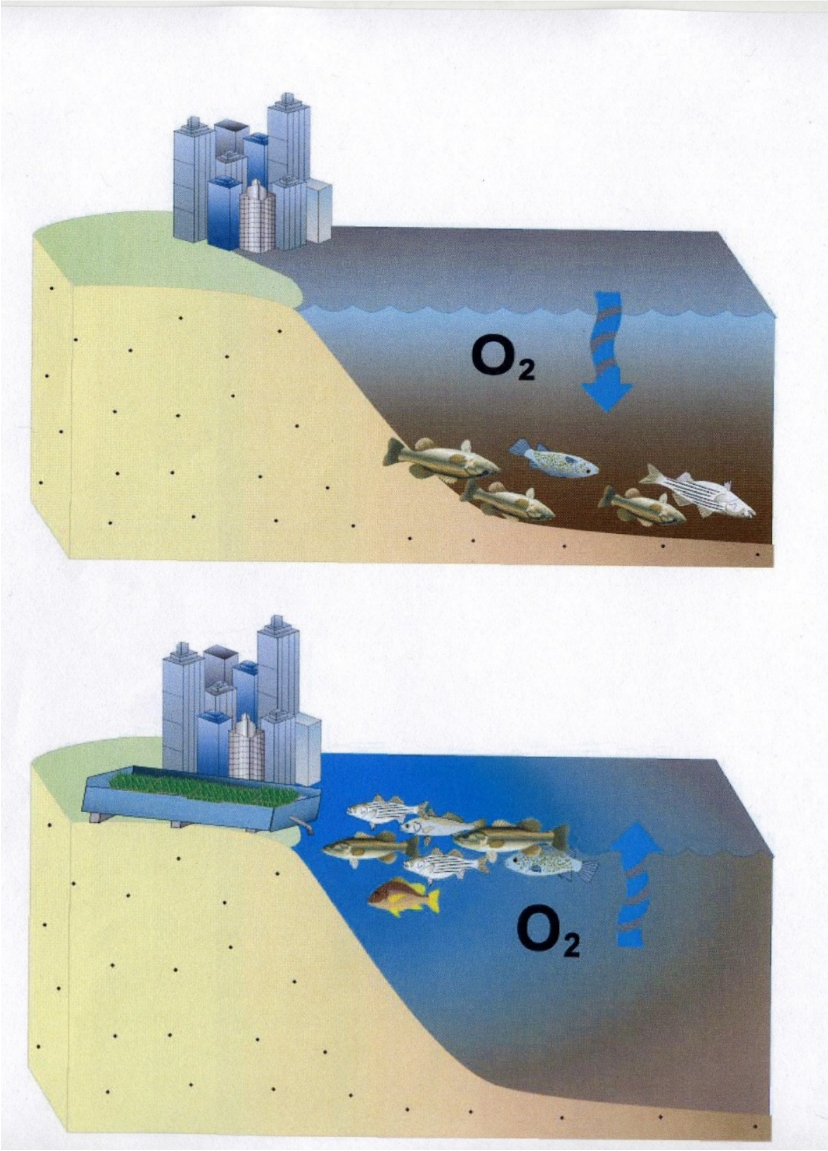
ATS Harvested Algal Biomass





We won't discuss the oxygen production by the ATS today but it is significant!

Today we want to focus on water quality improvement through nutrient removal.

Fish kills extend into Inner Harbor and Fort McHenry

Testing reveals areas of oxygen-depleted water

By Timothy B. Wheeler
The Baltimore Sun

The algae blooms fouling Maryland waters have claimed more victims, as more dead fish have been spotted floating in the Inner Harbor and washing ashore at Fort McHenry just south of downtown.

Investigators with the Maryland Department of the Environment, who saw upward of 100,000 dead fish in creeks south of the city Wednesday and hundreds more in Dundalk, confirmed the Inner Harbor die-off Thursday. Department spokesman Jay Apperson said mahogany-colored water in the harbor fits the recipe for an algae bloom-related fish kill.

Charles Poukish, the MDE's chief fish-kill investigator, counted about 165 dead fish in the Inner Harbor and estimated there were 1,000 in all, according to Apperson.

Laurie Schwartz, executive director of the Waterfront Partnership, a nonprofit group campaigning to make the harbor fishable and swimmable by 2020, said Wednesday night that dead fish were popping up in Fells Point and elsewhere in the Inner Harbor, with the water giving off a strong smell.

Hundreds of dead fish could be seen Thursday washing up on a small sandy beach by Fort McHenry.

John Hasener, a retired state employee, said he walks around the national monument every day and until recently the water was clear.

"A month and a half ago, you could see 4½ feet down," he said. It's a murky brown now.

He said he doubts that algae are responsible for the fish kill, suggesting that dredging going on around the harbor may be responsible.

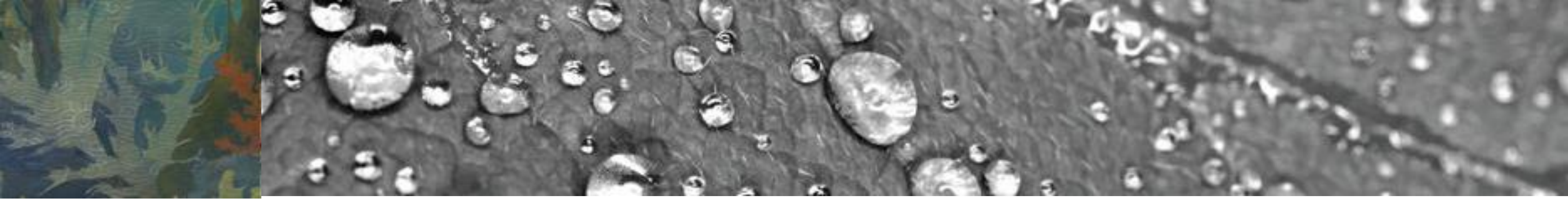
Experts, though, say the fish kills are following the classic pattern from algae blooms of this type, which cloud the water, then generate a foul odor and kill off fish as the tiny aquatic plants die and decay. The decomposing algae consume the oxygen in the water that fish need to breathe, which is why they're often seen thrashing about on the surface during such episodes, trying to escape suffocation.

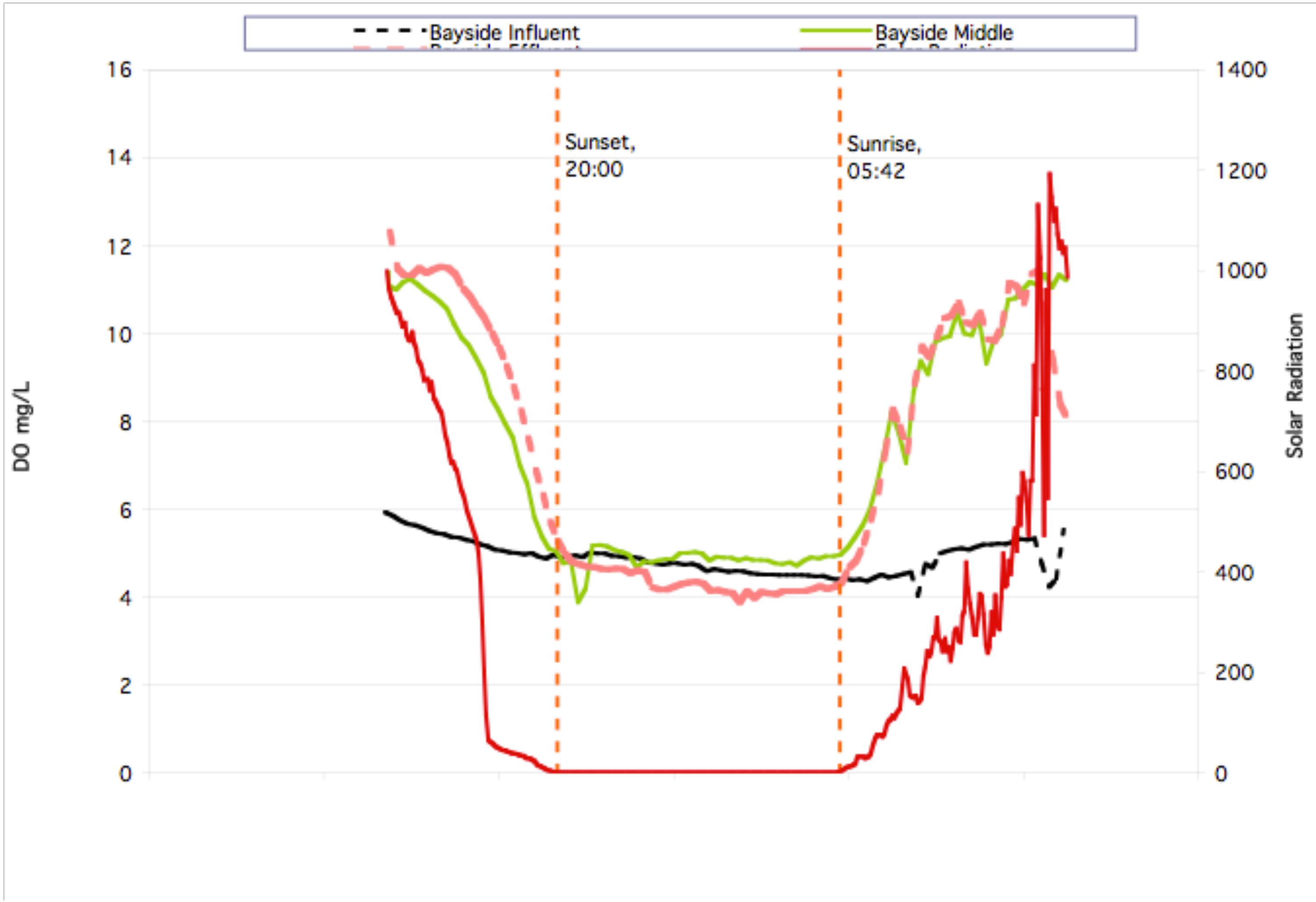
Water-quality sampling by the state Department of Natural Resources shows dissolved oxygen levels crashing in the water at Masonville Cove, not far from Fort McHenry.

The mahogany tide stretches from north of Baltimore in the upper Chesapeake Bay to south of the Bay Bridge, according to Catherine Wazniak, who tracks algae blooms for the DNR. This type of algae commonly appears in the bay, but usually later in the summer and not as thickly as it is now, she said.

tim.wheeler@baltsun.com

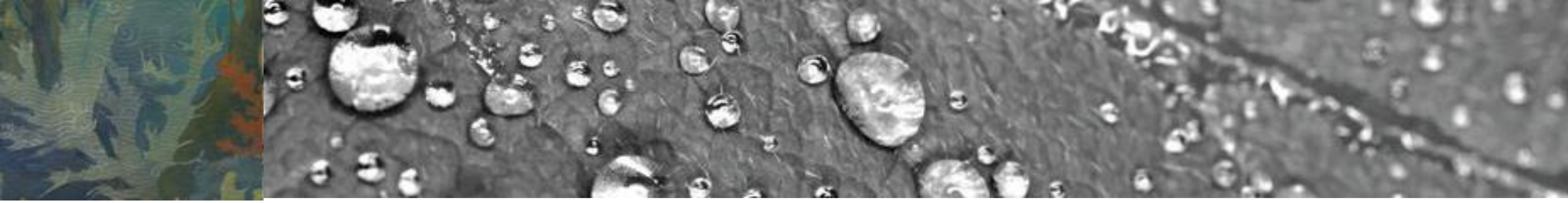
Biohabitats

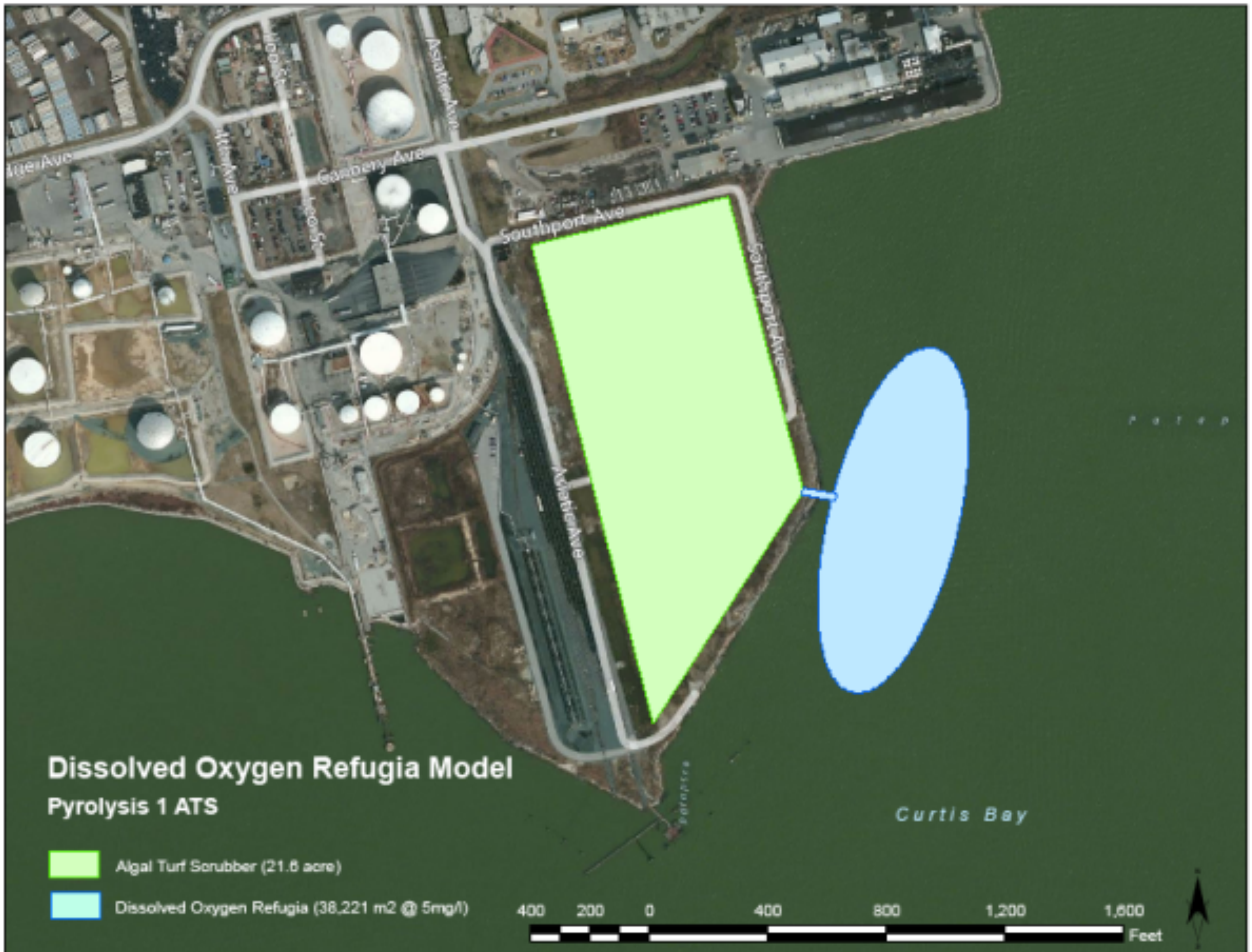




NYC ATS Diurnal O_2 Curve

Biohabitats





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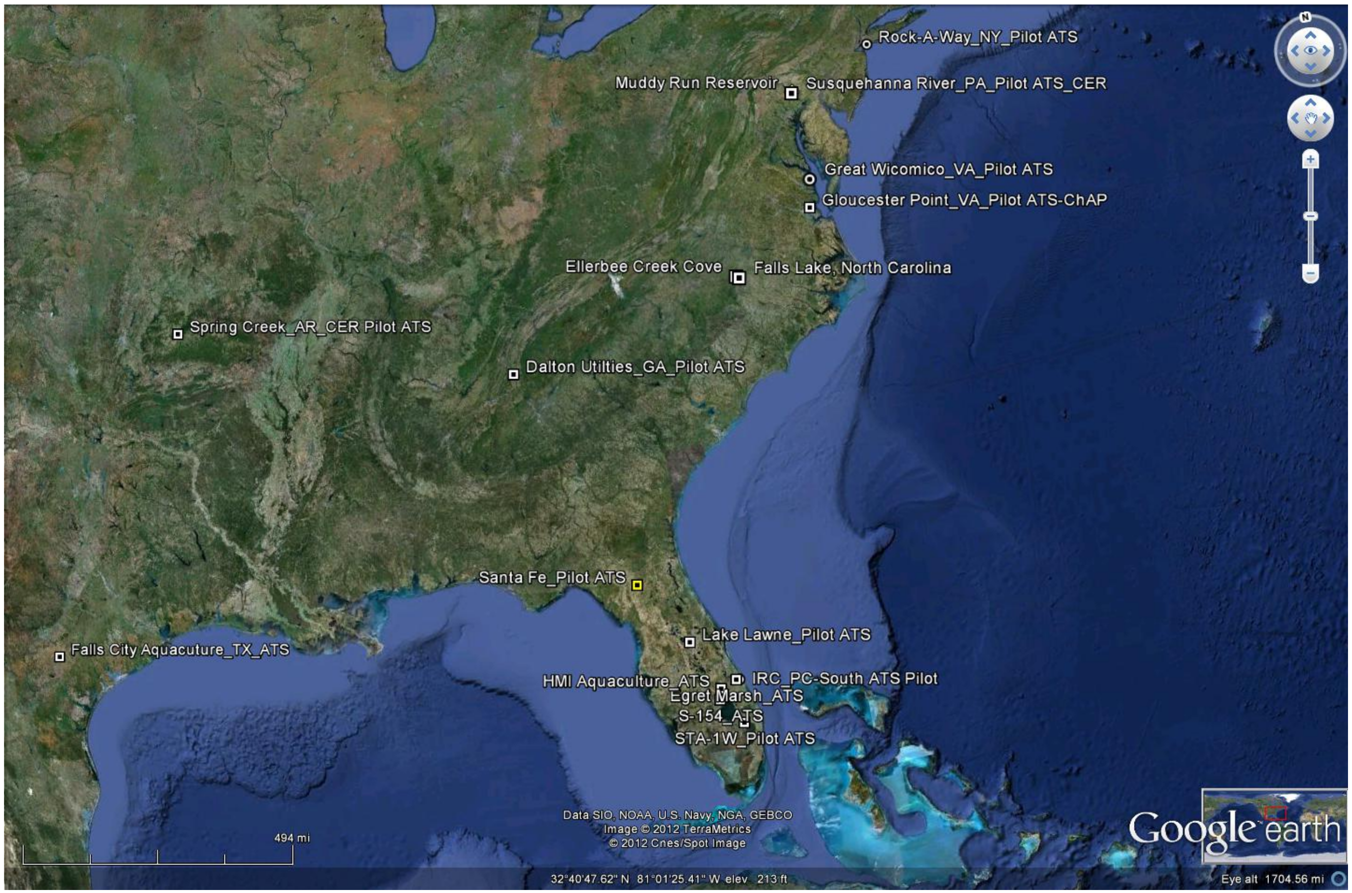
Warm Vs. Cold Weather Performance



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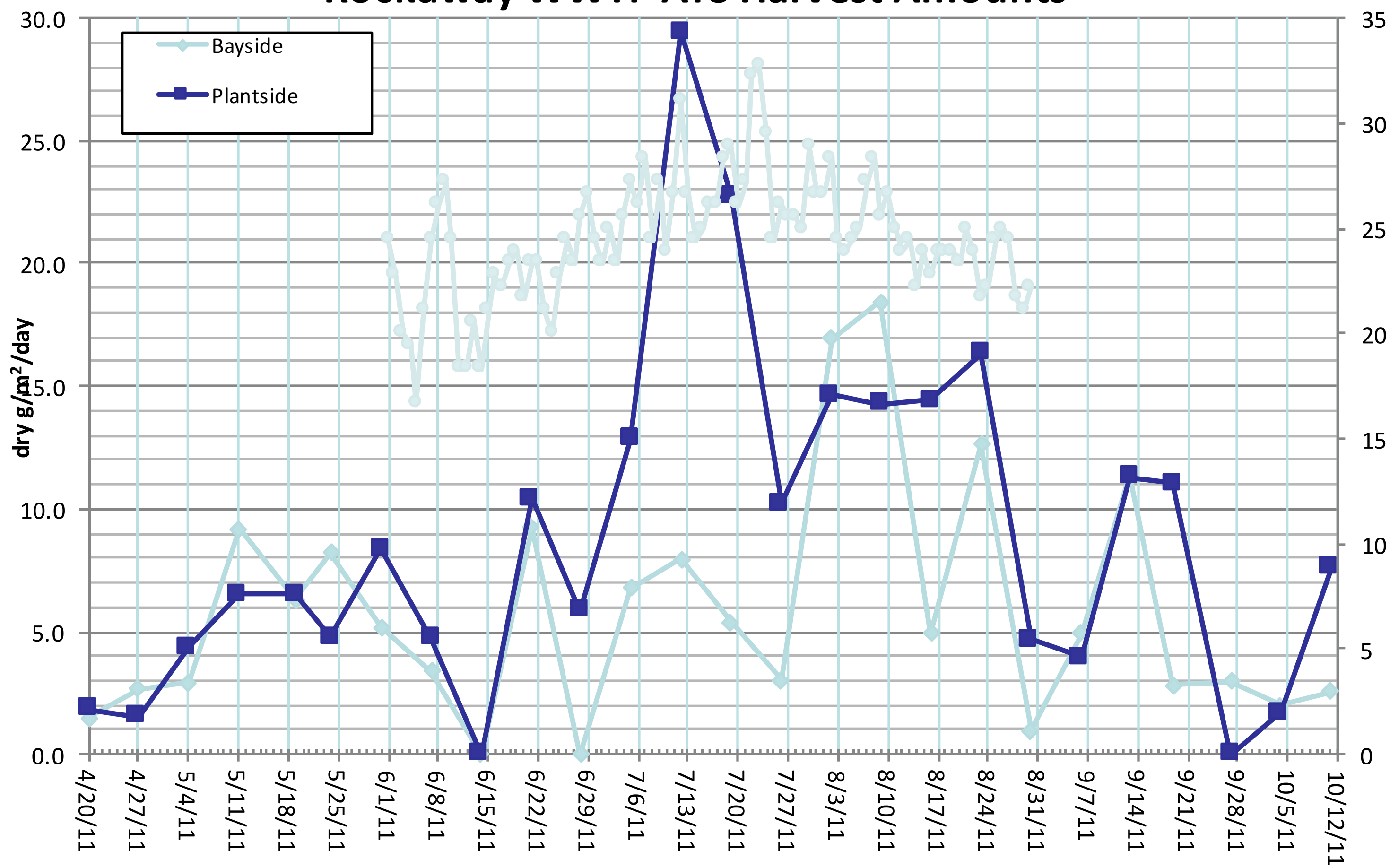
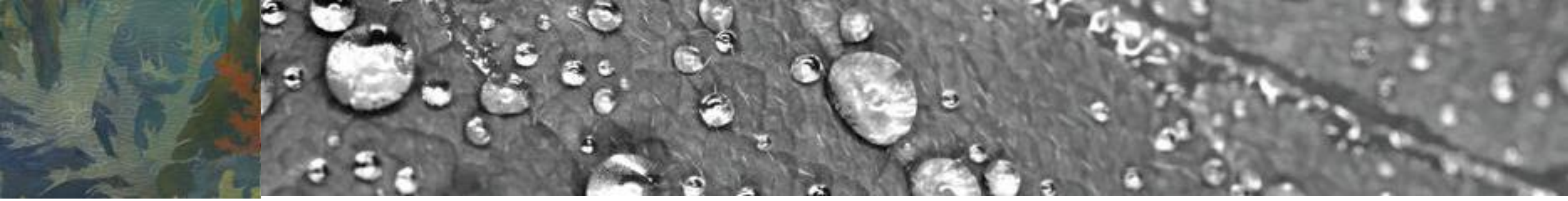
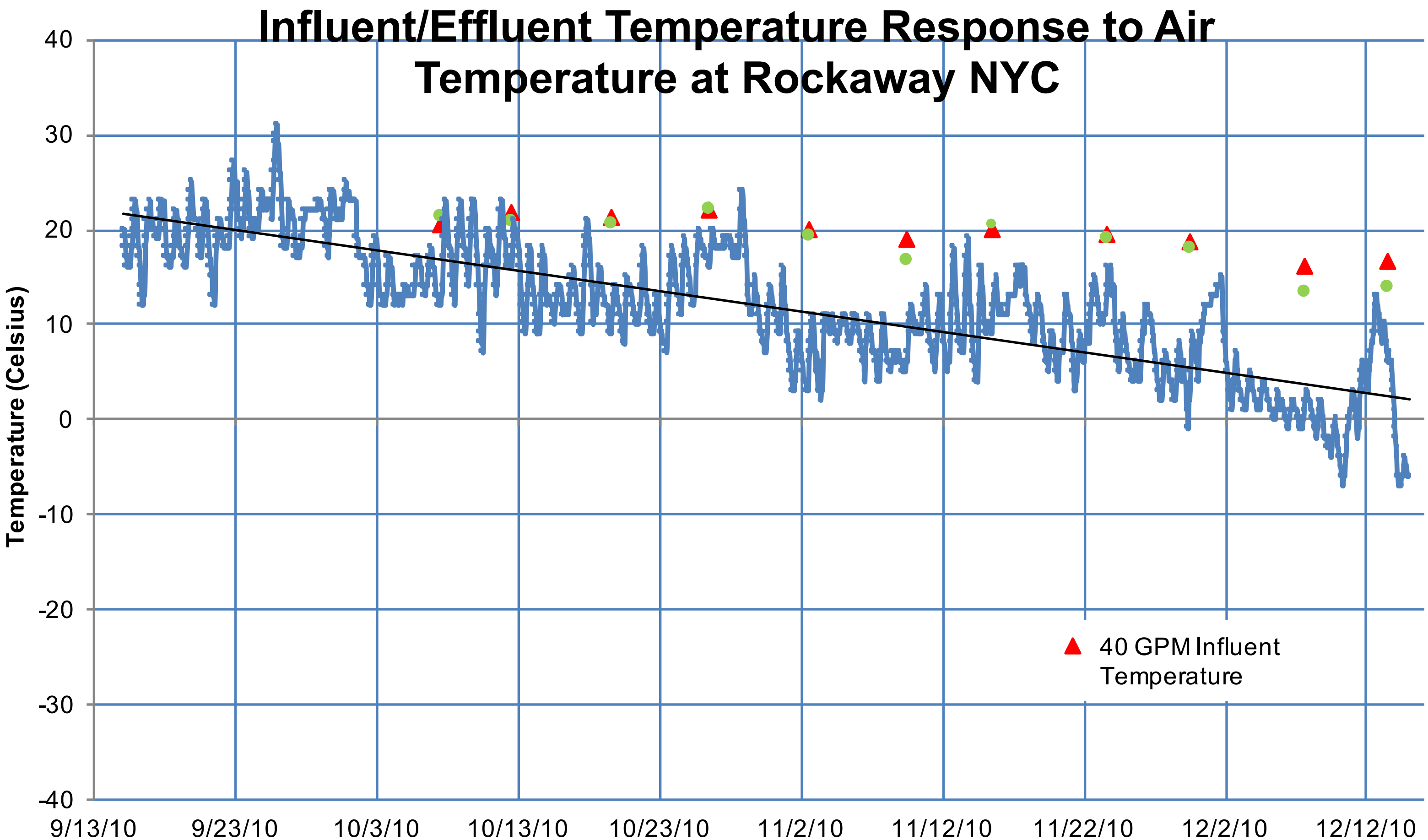
Rockaway WWTP ATS Harvest Amounts



Biohabitats





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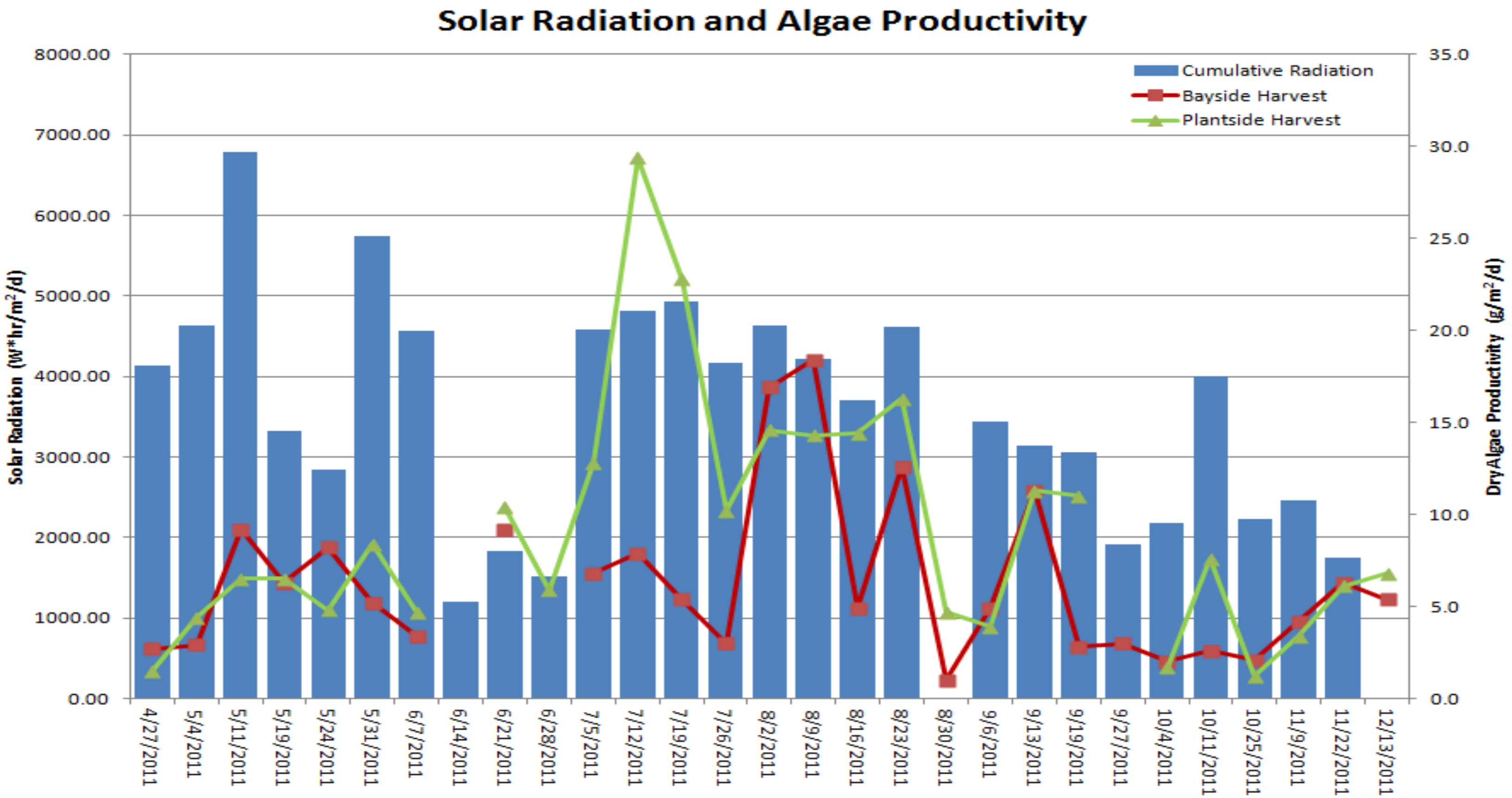
Rockaway New York City



Note: Solar radiation logger was removed to prevent damage prior to Hurricane Irene from August 26th to September 1st. Solar radiation data was not available prior to April 21st or after December 6th.

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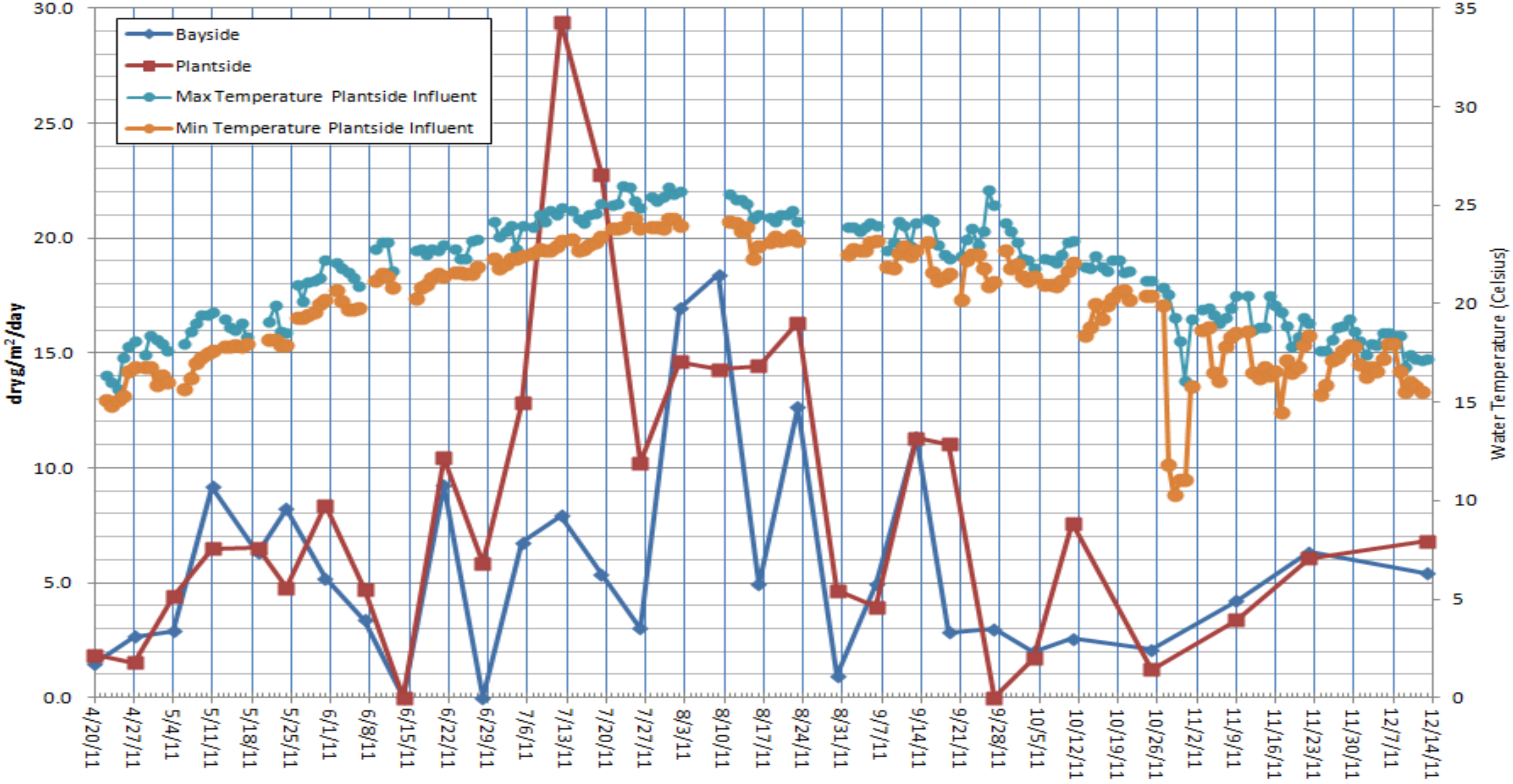
Rockaway WWTP ATS Harvest Amounts and Water Temperatures



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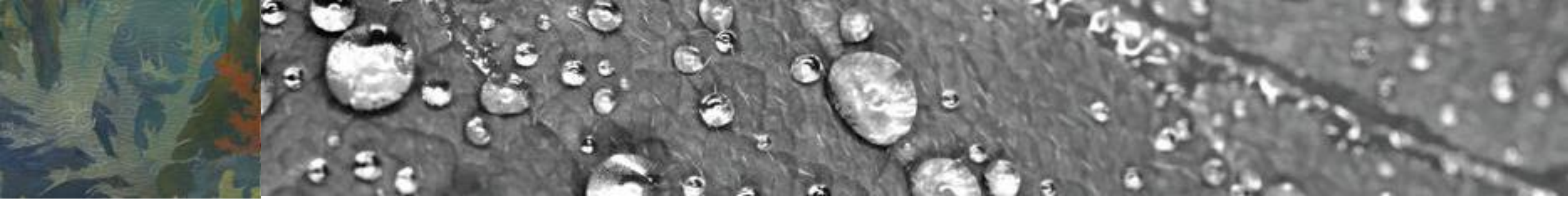
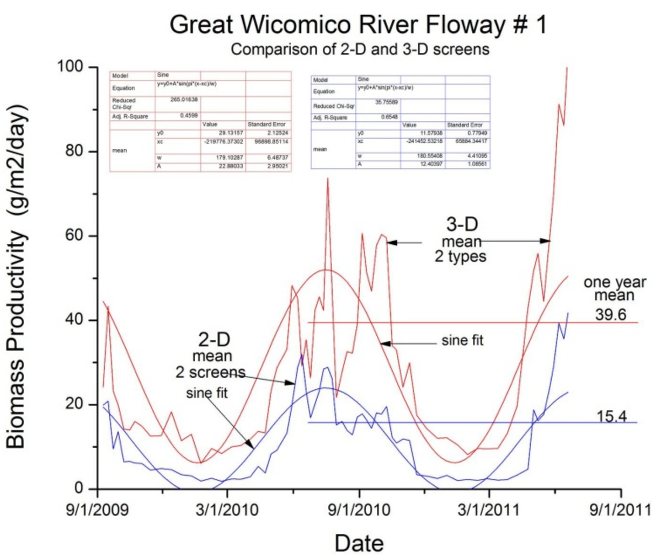
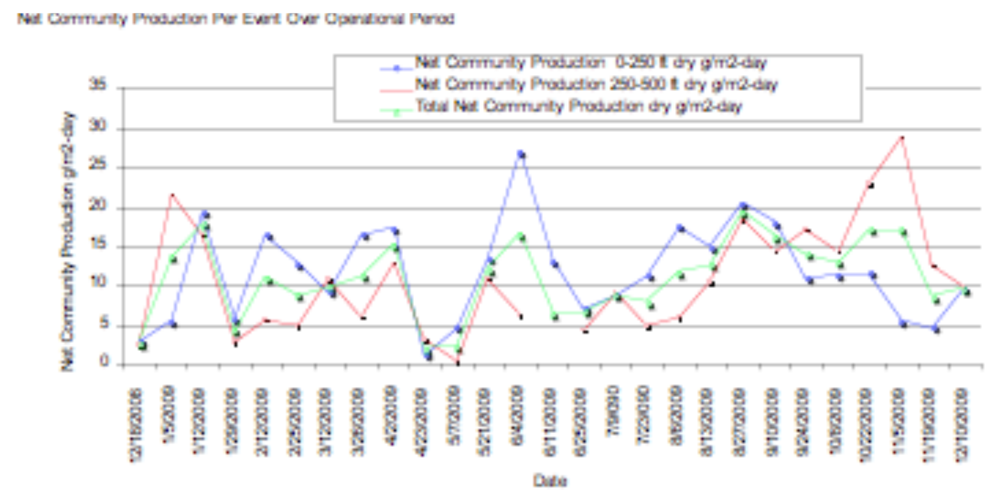


Warm Vs. Cold Weather Performance





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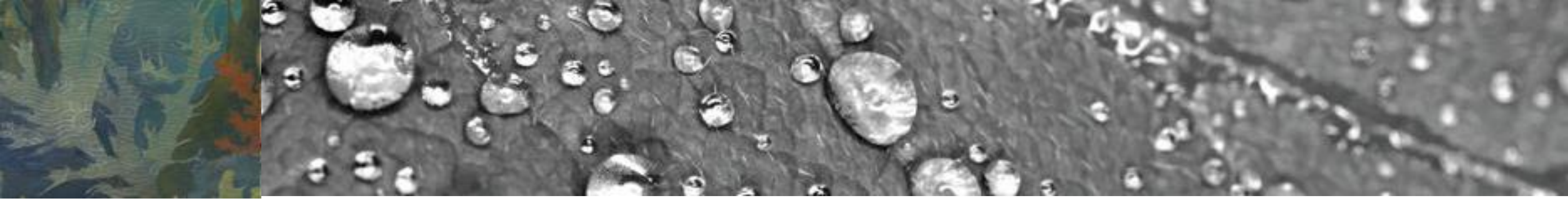
Egret Marsh ATS™ Case Study

CHALLENGE

The Egret Marsh Regional Stormwater Facility was designed to treat fertilizer-laden urban and agricultural runoff currently discharging to the Indian River Lagoon.

RESULTS

An initial feasibility study indicated that construction of a wetland on the site would provide removal of 18-48 pounds of phosphorus per year. Through implementation of an Algal Turf Scrubber® based process train designed by HydroMentia, significant nutrient load reductions have been achieved. For the 12-month monitoring period in 2010-2011, with influent total nitrogen and phosphorus concentrations averaging 0.95 mg/L and 0.101 mg/L, respectively; total load reduction achieved was 1,477 pounds (49.4%) of phosphorus and 5,278 pounds (18.3%) of nitrogen.



PC-South ATS™ Case Study

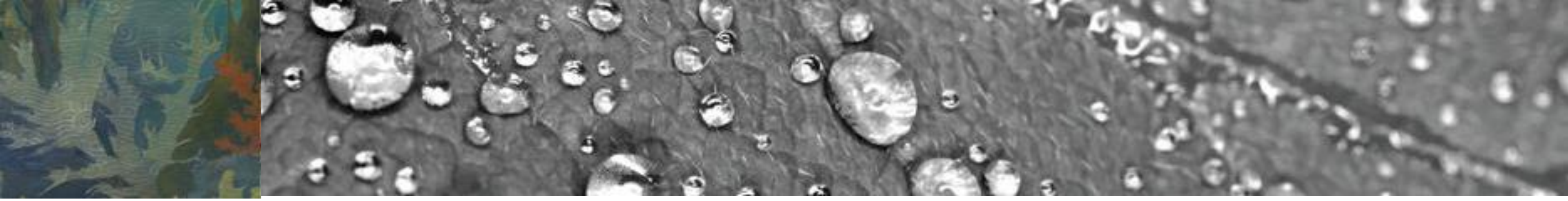
CHALLENGE

Indian River County, FL is required to provide additional treatment to reduce toxicity in reject water released from the South County Reverse Osmosis (RO) plant into the South Relief Canal. The process water blends with stormwater runoff in the canal, ultimately discharging into the Indian River Lagoon. This project had three goals:

- Render the Reverse Osmosis concentrate nontoxic to targeted bioassay organisms.
- Establish an effluent suitable for discharge into the South Canal in accordance with the facility's Industrial Wastewater Permit.
- Reduce nutrient loads in the South Relief Canal in accordance with the County's program for reduction on nutrient discharge into the Indian River Lagoon.

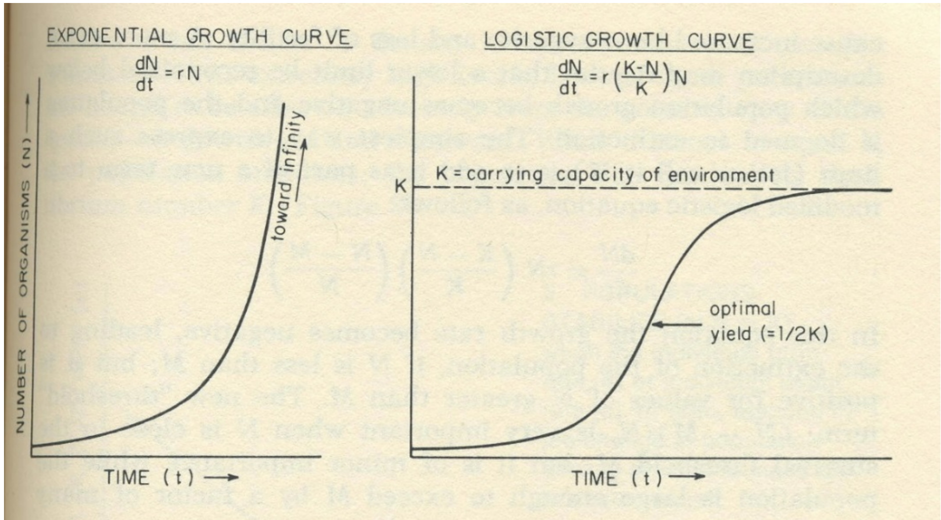
RESULTS

Based on the 6-month pilot, test results showed an absence of toxicity, and the Florida Department of Environmental Protection approved use of the ATS™ technology for treatment of the combined process flow. In addition to elimination of toxicity, the pilot system achieved a total phosphorus removal rate of 59%, and an annual areal removal rate of 574 pounds per acre of ATS™ at an inflow total phosphorus concentration of 139 parts per billion (ppb), while achieving a total nitrogen removal rate of 38%, and an annual areal removal rate of 2361 pounds per acre of ATS™ at an inflow total nitrogen concentration of 0.89 mg/L.



A key function in the ATS technology is harvesting the algae.

We can optimize productivity, and therefore nutrient uptake, by harvesting at the inflection point in the growth curve of the attached algae…and then the algae grows right back exponentially…



1 TWO ELEMENTARY FORMS of population increase: Exponential growth (*curve on left*) and logistic growth (*curve on right*).

Thus, harvesting the ATS is like lawn mowing…

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Baltimore Inner Harbor ATS Pilot Project Location

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Our most recent project is located at the Port of Baltimore which won an Innovation Award as a BMP…

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The most important thing here is the Port staff (MES) adapted their storm drain cleaning approach for harvesting and processing the algae…

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VAC-TRON
EQUIPMENT
DO NOT
RUN DRY
Vermeer

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ATS™ and Chesapeake Bay

Draft material prepared for consideration by the Federal Leadership Committee for the Chesapeake Bay — 9 September 2009

DRAFT REPORT

Focusing Resources to Restore and Protect the Chesapeake Bay and its Tributary Waters

Executive Order 13508, Section 202b Report

Draft material prepared for consideration by the Federal Leadership Committee for the Chesapeake Bay — 9 September 2009

Algal Turf Scrubber

Dr. Walter Adey's 1980s algal turf scrubber (ATS) process, which is being used increasingly in Everglades clean up work, has not yet been applied to tackle the Chesapeake Bay nutrient problems. Dr. Kangas, University of Maryland professor, and Dr. Adey would like to see that change. ATS uses pretty simple technology – nutrient-laden water is diverted into raceways containing screens with algae. The algae absorb the nutrients and oxygenate the water, which is returned to its source. The two scientists are conducting a pilot in Lancaster County, PA to test the ATS technology in a temperate climate. Partnering with Exelon Power Company, which owns and operates Muddy Run Storage and the Conowingo Dam, the project is generating encouraging results. On-site researchers have measured a near doubling of oxygen concentration in waters after their journey through the raceways, while water samples analyzed at USDA's Beltsville facility showed nitrogen reductions of over 30 percent. The hardworking algae are harvested periodically to keep them at peak performance and the residue offers another opportunity according to the researchers – conversion to biofuels. The partners in this pilot are already talking about scaling up. Adey and Kangas have a vision of ATS systems on small strips of farmland along the rivers and creeks of the Chesapeake Bay Watershed (Chesapeake Quarterly, 2009). And they may not be alone in that vision, the Caroline County Conservation District is doing just that – testing a field-scale application of the ATS technology to achieve nutrient load reductions from agricultural drainage systems in the Upper Choptank River watershed. The project was funded in 2008 through the Chesapeake Bay Conservation Innovation Grants program, supported by USDA and the National Fish and Wildlife Foundation. The project team will be evaluating the feasibility of this innovative approach to nutrient reduction, including the overall maintenance costs and barriers to acceptance.

The Perdue AgriRecycle litter recycling plant on the Delmarva peninsula is an example of industry led solutions to a significant environmental issue. The plant has handled more than 500,000 tons of poultry litter in its first seven years of operation; reducing

ATS ™ Pilot locations around Chesapeake Bay and the draft technical report supporting Executive Order 13508 directing Chesapeake Bay cleanup which includes ATS ™ as an emerging technology in the effort.

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Types of ATS studies in the Chesapeake Bay Region:

Site	Special Feature
Muddy Run	hydroelectric dam
Peach Bottom	thermal discharge from nuclear power plant
Baltimore Inner Harbor	urban setting with low dissolved oxygen
Bush River	oligohaline bay waters
Patapsco River	high density residential waterfront setting
USDA BARC	dairy wastewaters
Patuxent River	turbid, freshwater tidal river
Caroline County	agricultural drainage water
Choptank River	oyster farm
Fruitland	domestic sewage
Great Wicomico River	three dimensional screen experiment
VIMS	turbid, mid salinity river

Nutrient Removal Calculation

- **Nutrient removal by the algal production systems is calculated as follows:**
- Nutrient removal rate = biomass production rate x nutrient content of biomass
- *grams nutrient/m2/day= grams dry weight/m2/day x grams nutrient/grams dry weight*
- Typical biomass production rates for ATS ™ in the Chesapeake Bay region range from 10 – 35 grams dry weight/m2/day and typical nutrient contents are 3-5% nitrogen and 0.3-0.5% phosphorus.
- ***A unique quality of the ATS ™, relative to other BMPs, is that nutrient removal is quantifiable and easily verifiable.***
- ***ATS ™ will also can inject significant quantities of dissolved oxygen to the water.***

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Nitrogen Uptake

Table ___. Nitrogen uptake calculations for an ATS in the Chesapeake Bay region.

Lower boundary estimate: productivity of 10 g DW/m2/day; growing season of 8 months; nitrogen content of 1 % of biomass

(10 g DW/m2/day)(240 days/year)(0.01 N) (4047 m2/acre)(1 kg/1000 g)(2.2 pounds/1 kg) = **214 pounds N/acre/year**

Upper boundary estimate: productivity of 30 g DW/m2/day; growing season of 12 months; nitrogen content of 3 % of biomass

(40 g DW/m2/day)(365 days/year)(0.03 N)(4047 m2/acre)(1 kg/1000 g)(2.2 pounds/1 kg) = **3900 pounds N/acre/year**

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Phosphorus Uptake

Table ___. Phosphorus uptake calculations for an ATS in the Chesapeake Bay region.

Lower boundary estimate: productivity of 10 g DW/m2/day; growing season of 8 months; phosphorus content of 0.2 % of biomass

(10 g DW/m2/day)(240 days/year)(0.002 P)(4047 m2/acre)(1 kg/1000 g)(2.2 pounds/1 kg) = **43 pounds P/acre/year**

Upper boundary estimate: productivity of 30 g DW/m2/day; growing season of 12 months; phosphorus content of 0.3 % of biomass

(40 g DW/m2/day)(365 days/year)(0.003 P)(4047 m2/acre)(1 kg/1000 g)(2.2 pounds/1 kg) = **390 pounds P/acre/year**

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Areal Nutrient Uptake Rates for an ATS in the Chesapeake Bay Region

	Lower Boundary Estimate lbs / acre / year	Upper Boundary Estimate lbs / acre / year
Nitrogen	214	3900
Phosphorus	43	390

Averages from data collected from ATS studies on outdoor raceways operated for at least one annual cycle.

System Location	Water Treated	%N	%P
Lancaster, PA	Susquehanna River	2.5	0.3
Beltsville, MD	Dairy Manure	5.9	0.8
Bridgetown, MD	Ag Drainage Ditch	2.0	0.3
Gloucester, VA	York River	1.3	0.2
Reedville, VA	Great Wicomico River	2.5	0.2

For example, using median values from the previous slides, total removal rates for 1 acre of ATS in the Chesapeake Bay watershed would be on the order of:

1 ton of TN/acre/year

0.1 ton of TP/acre/year

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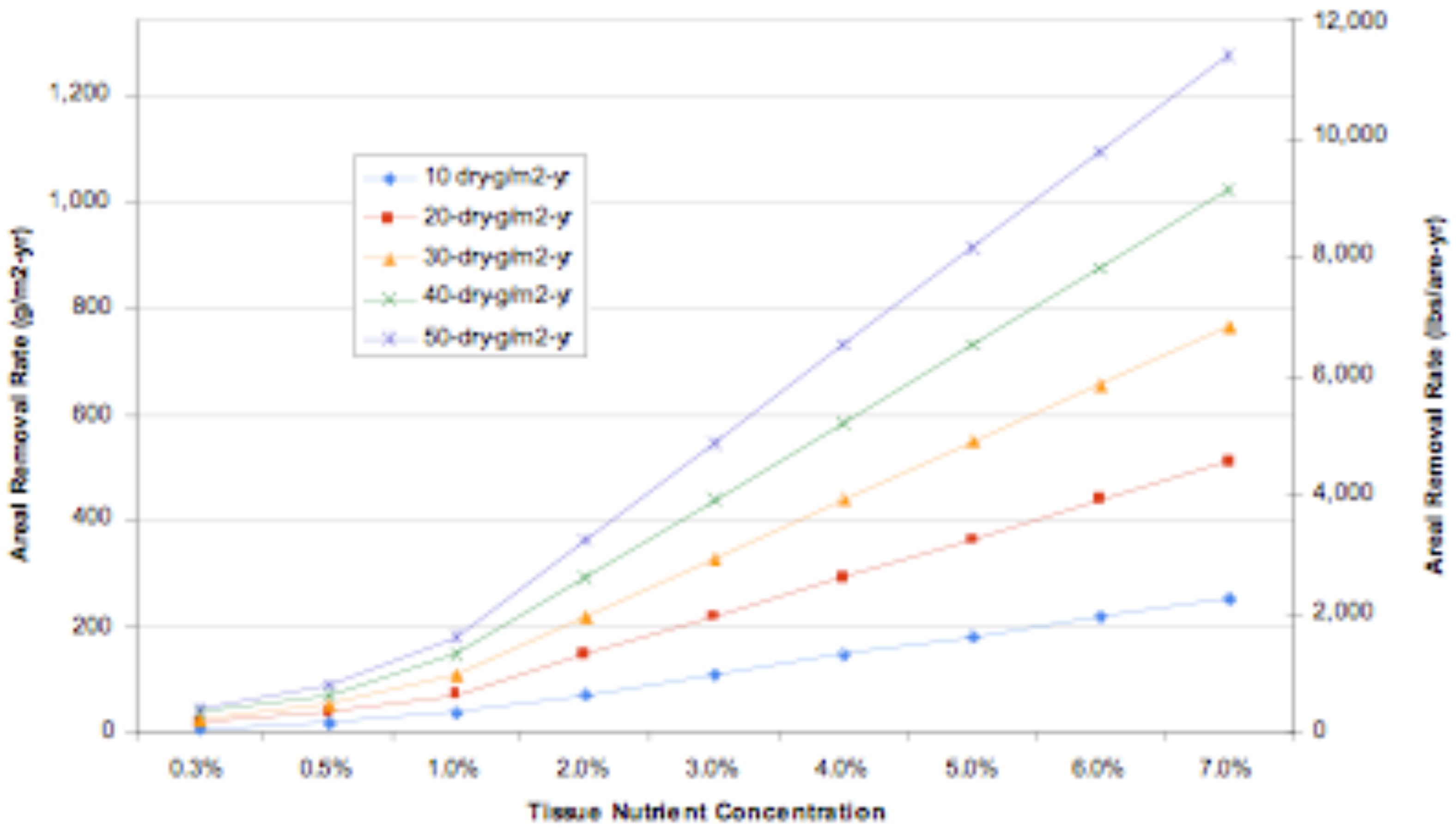
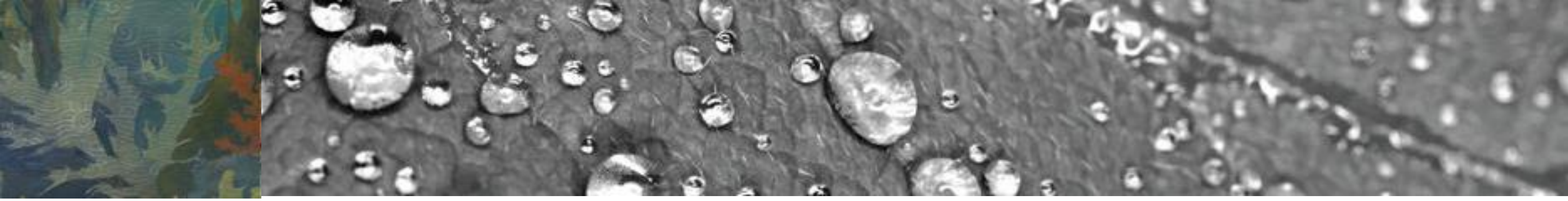
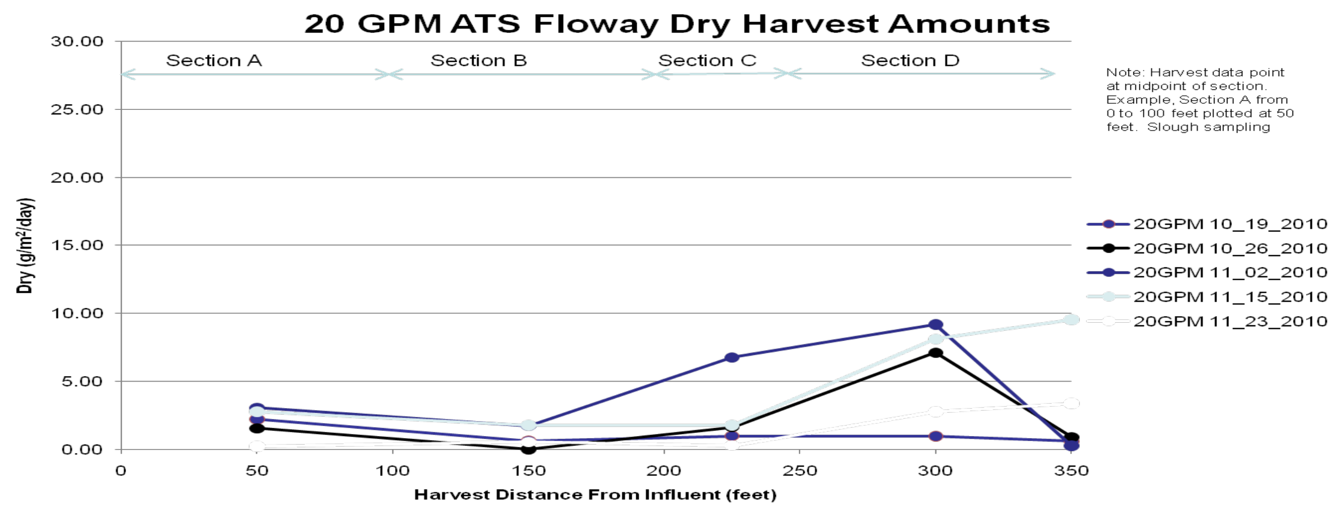
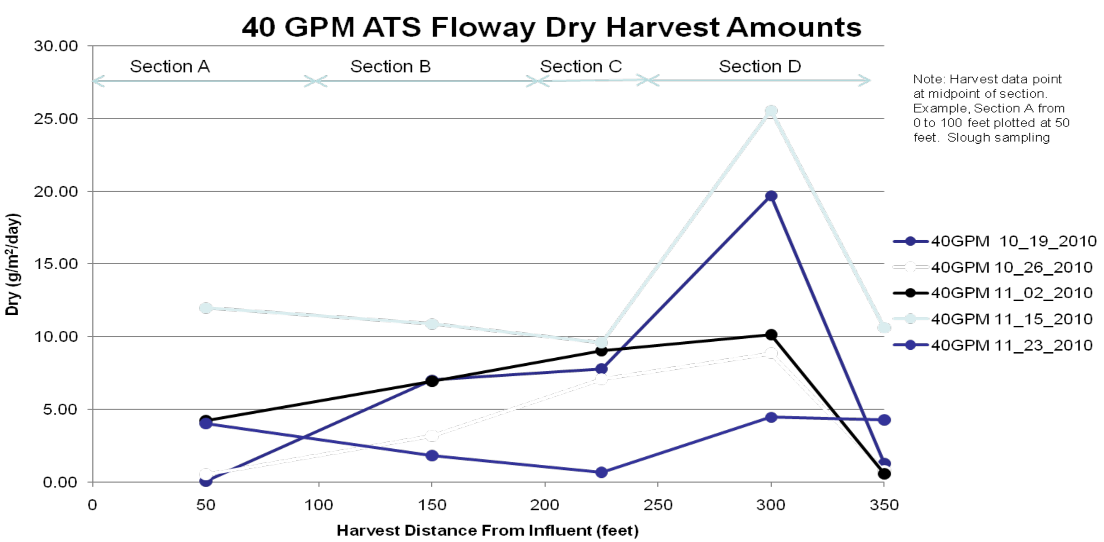
Treatment Performance and Design Objectives

Areal Removal Rate and Inflow Concentrations









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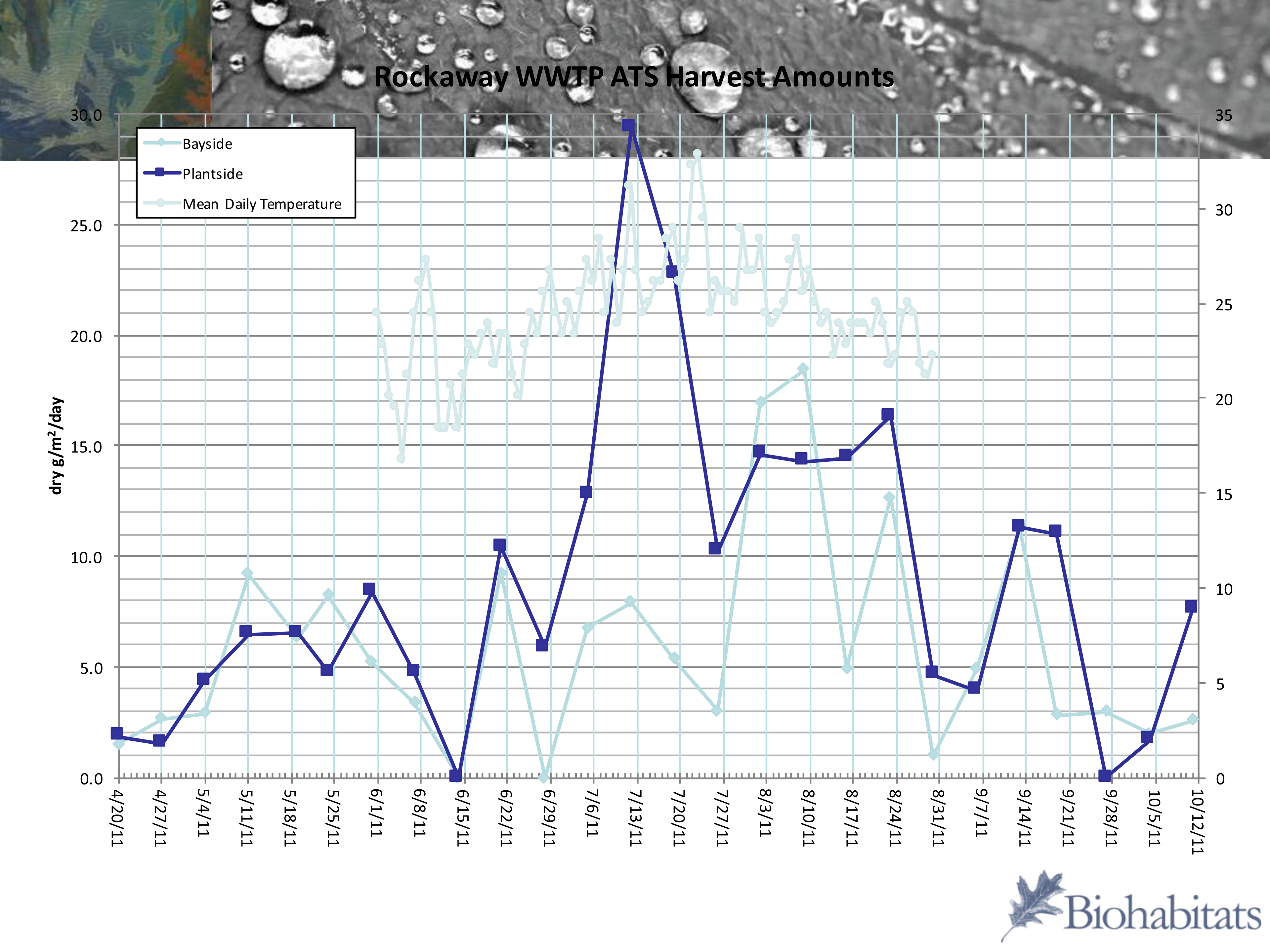

Rockaway WWTP ATS Harvest Amounts
Bayside
Plantside
Mean Daily Temperature
dry g/m²/day
30.0
25.0
20.0
15.0
10.0
5.0
0.0
35
30
25
20
15
10
5
0
4/20/11
4/27/11
5/4/11
5/11/11
5/18/11
5/25/11
6/1/11
6/8/11
6/15/11
6/22/11
6/29/11
7/6/11
7/13/11
7/20/11
7/27/11
8/3/11
8/10/11
8/17/11
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10/12/11
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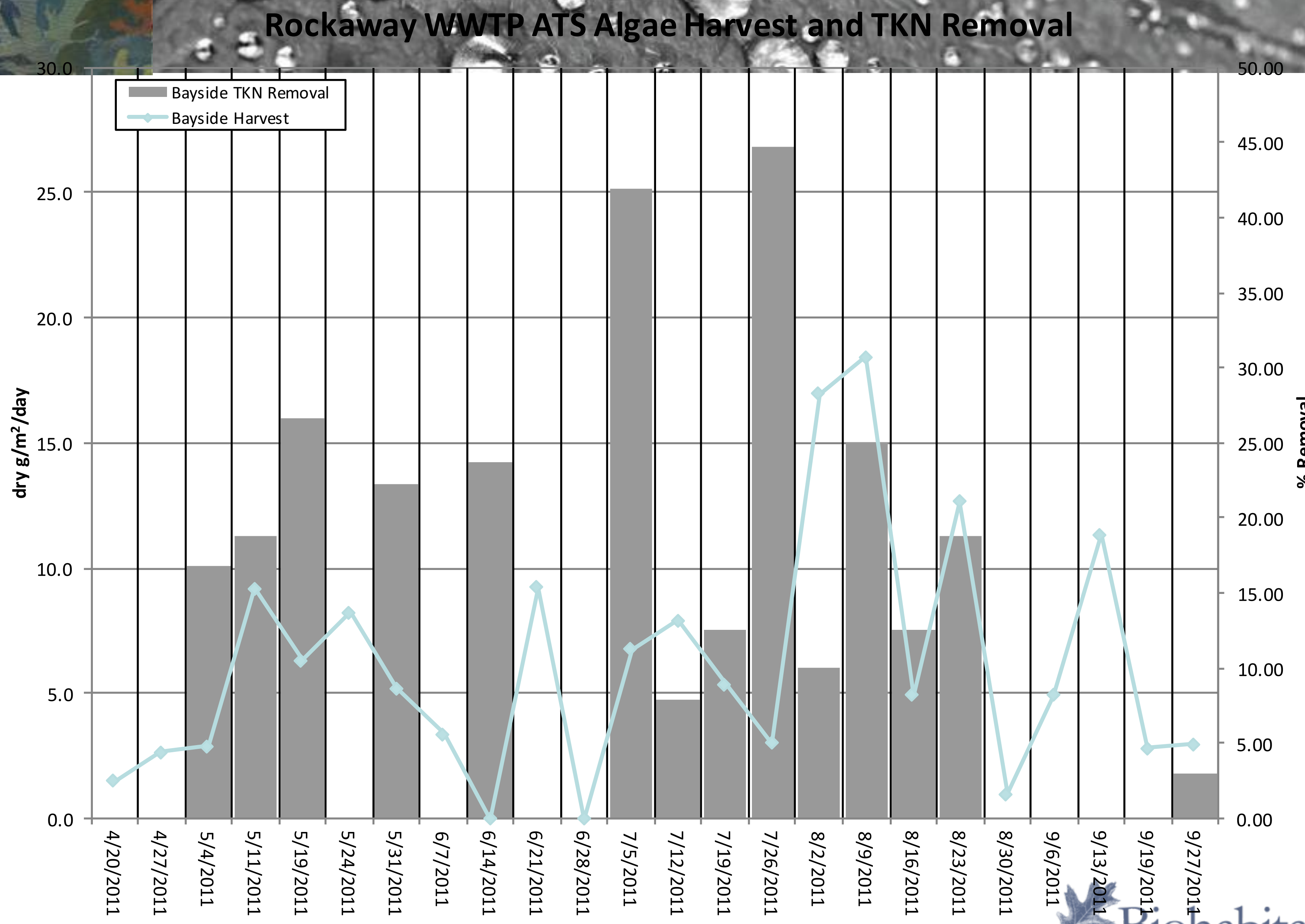

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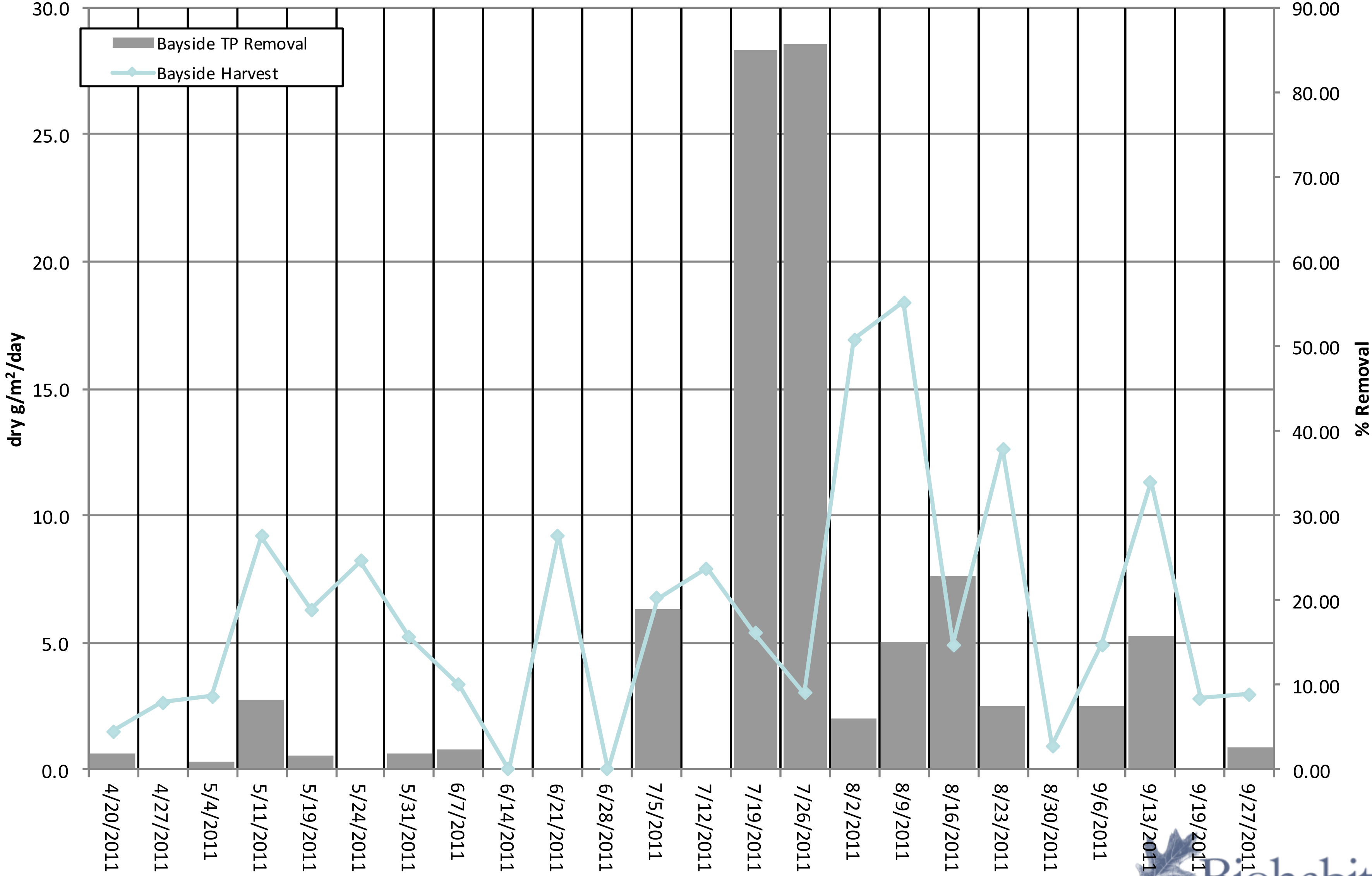
Rockaway WWTP ATS Harvest and Total Phosphorus Removal



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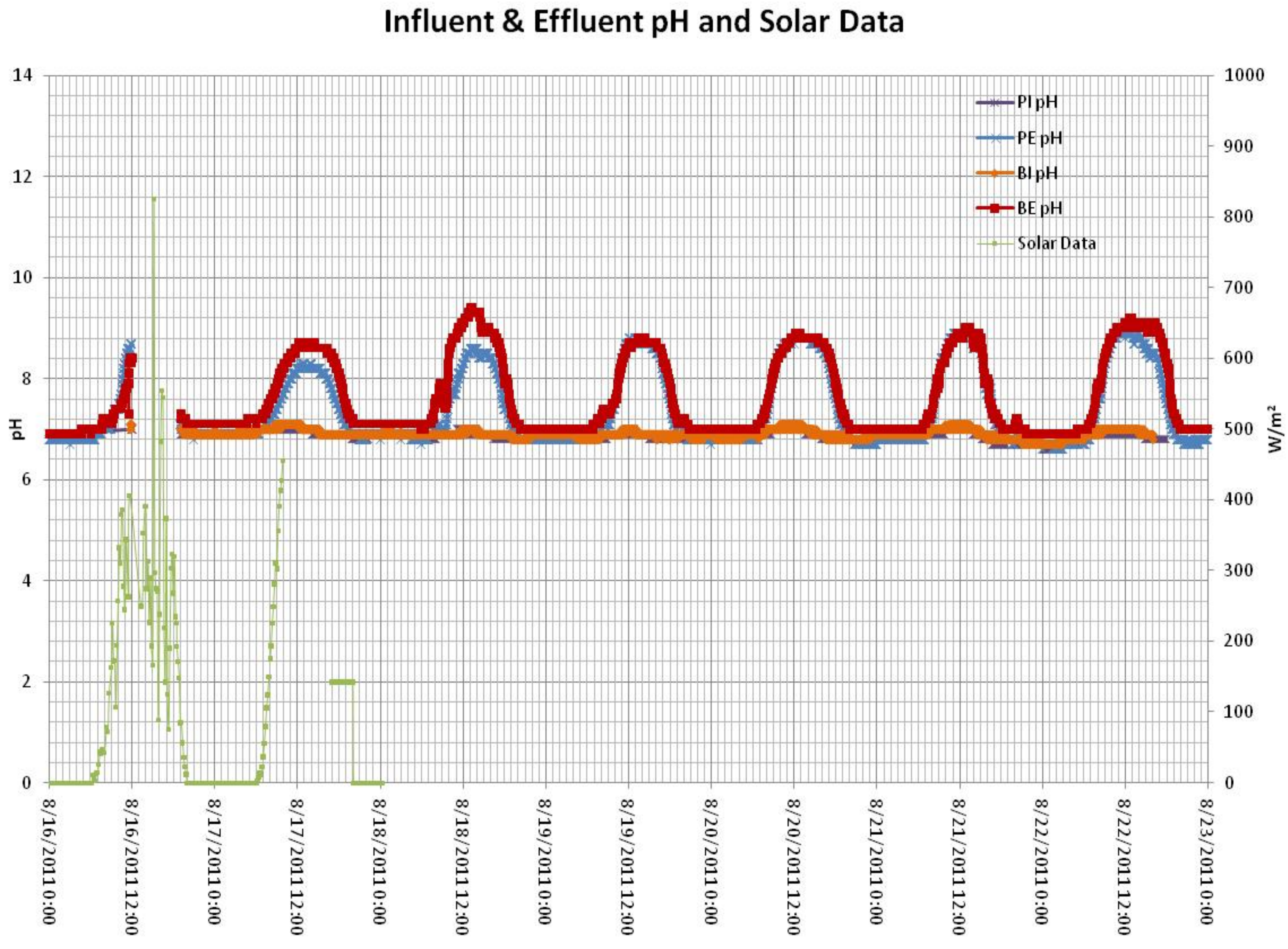
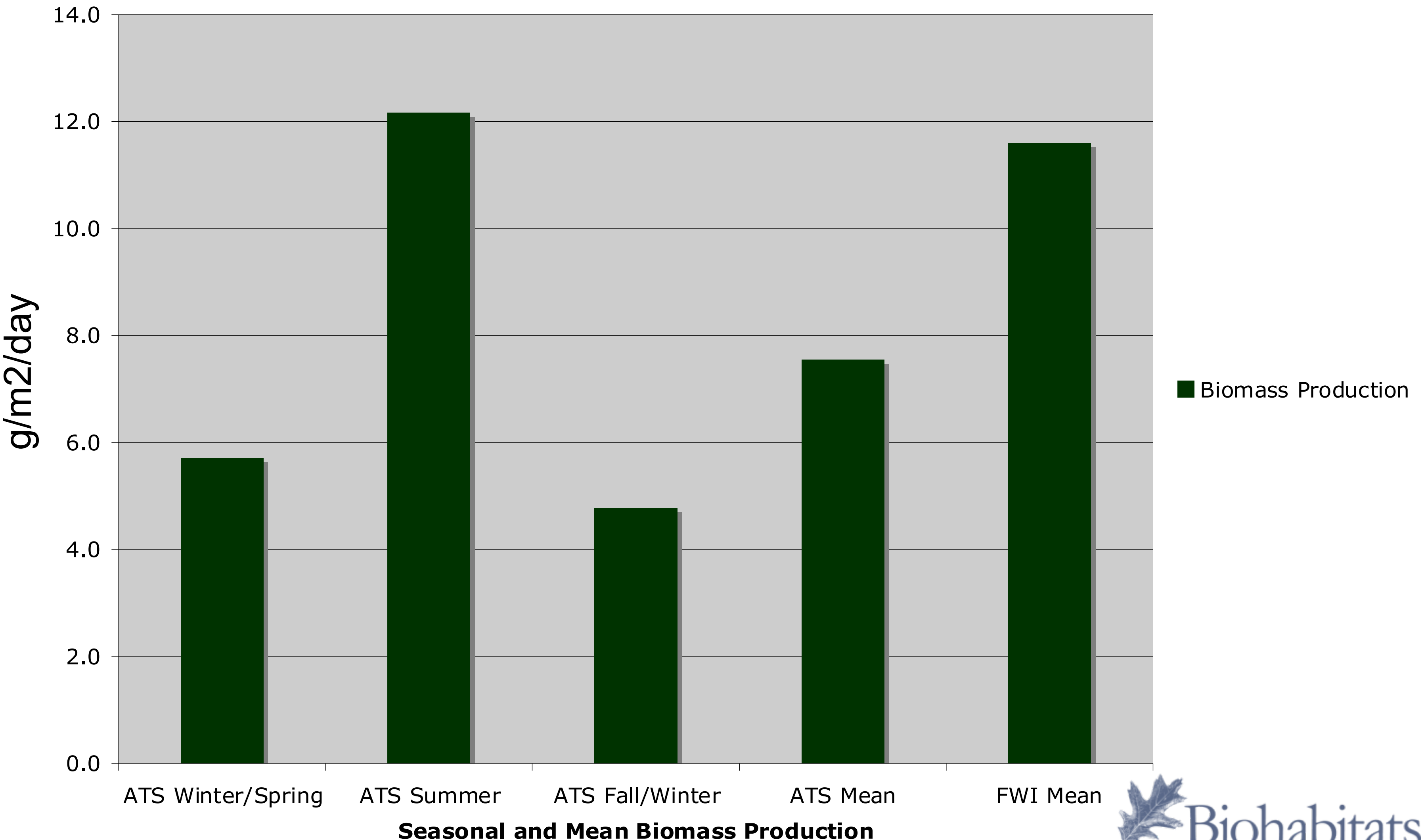


Influent & Effluent pH and Solar Data
pH
W/m²
PI pH
PE pH
BI pH
BE pH
Solar Data
0
2
4
6
8
10
12
14
0
100
200
300
400
500
600
700
800
900
1000
8/16/2011 0:00
8/16/2011 12:00
8/17/2011 0:00
8/17/2011 12:00
8/18/2011 0:00
8/18/2011 12:00
8/19/2011 0:00
8/19/2011 12:00
8/20/2011 0:00
8/20/2011 12:00
8/21/2011 0:00
8/21/2011 12:00
8/22/2011 0:00
8/22/2011 12:00
8/23/2011 0:00

Biomass Production for ATS and FWI in 2012



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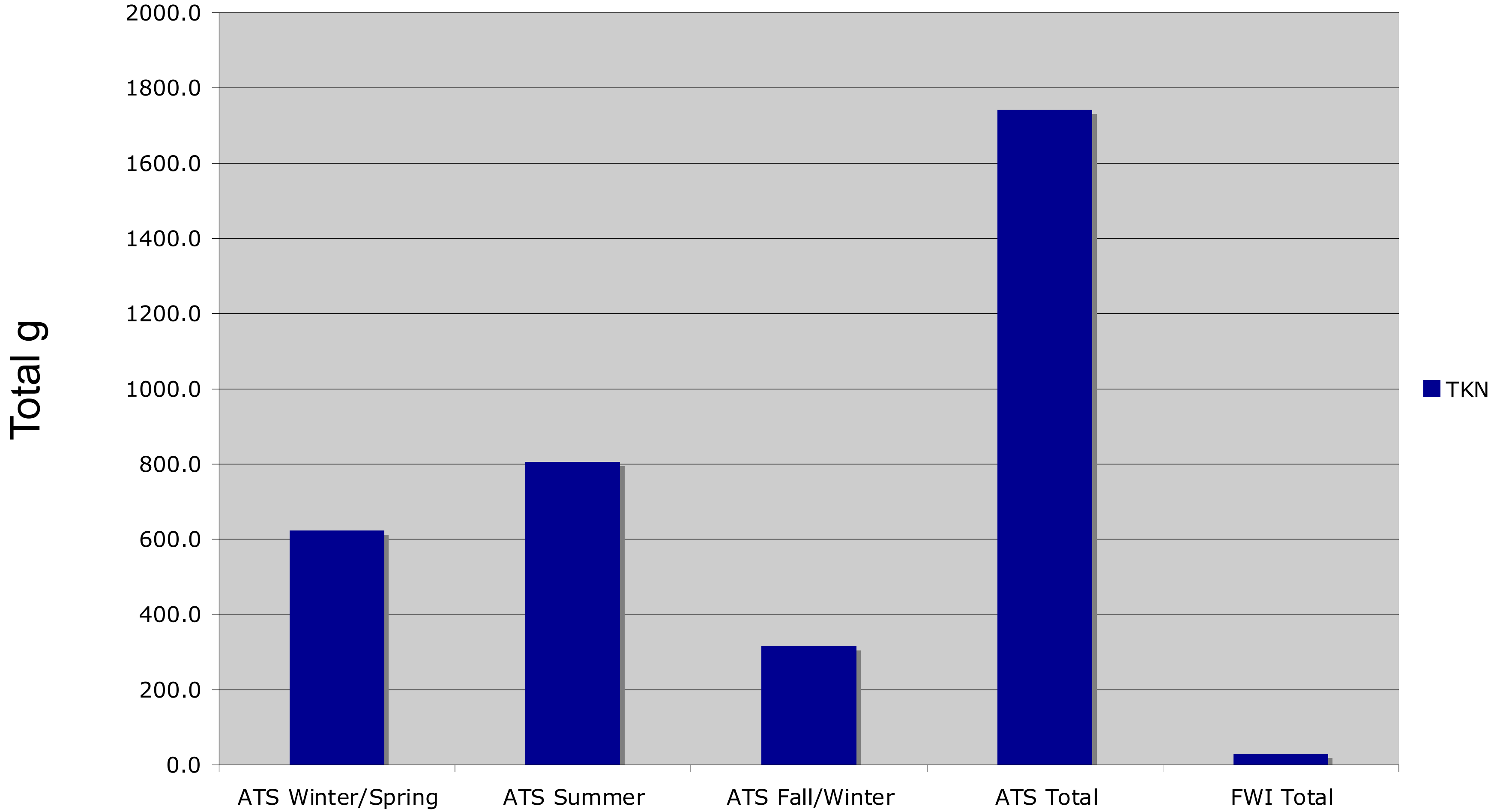
Total TKN Removed by ATS and FWI in 2012



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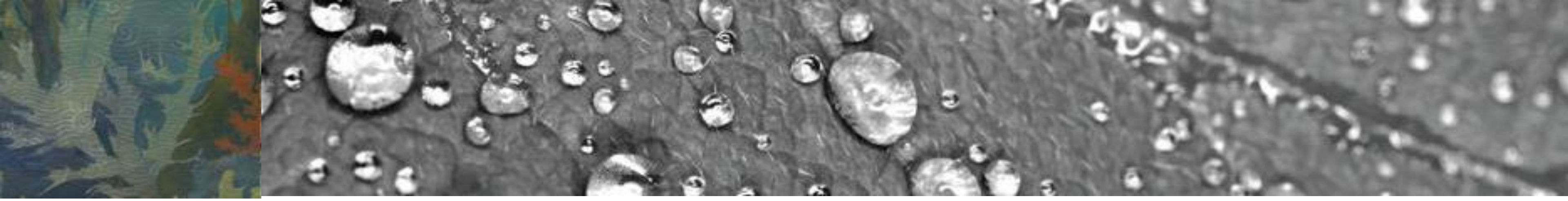
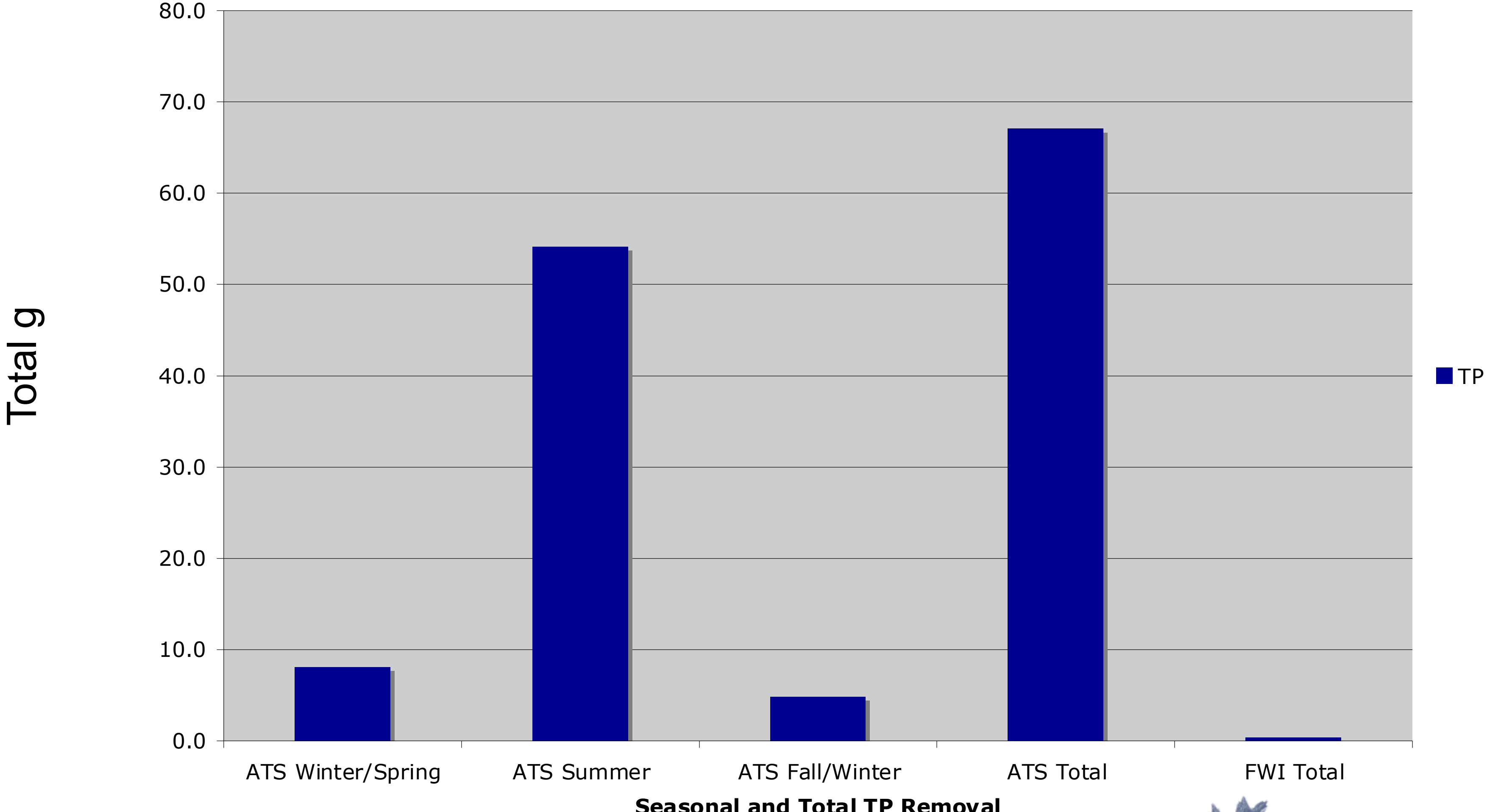


ATS and FWI Total Phosphorous Removed in 2012



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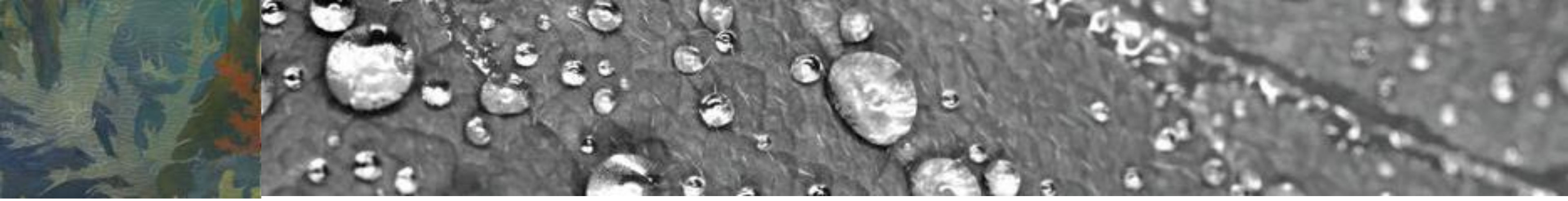

Pilot Data on Biomass Production, Nutrient Uptake, Harvest and Scale Up

	ATS	FWI
Pilot unit area sampled m2	27.87	20.81
Total g biomass harvested	54,065	31,915
Days operational / deployed	298	264
Biomass production g/m2/day	7.55	11.60

	ATS	FWI
Average TKN content by dry wt	3.20%	0.92%
Average TP content by dry wt	0.10%	0.01%
2012 TKN removed g	1,741.95	28.72
2012 Total P removed g	67.09	0.36
TKN g/m2/day removed	5.85	0.23
TP g/m2/day removed	0.11	0.0001

	ATS	FWI
Persons required to harvest	two	three
Harvest visits per year	twenty four	once
Person hours removal/m2/yr	3.44	0.46
Hectare area TKN removal kg/yr	820.1	362.2
Hectare area TP removal kg/yr	13.0	3.9

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LOWER TREATMENT COSTS - Nitrogen

Typical Nitrogen Reduction Unit Costs to Comply with TMDLs in the Lower St Johns River Watershed

Project Type	Average ($/lb N/yr)	Typical Range ($/lb N/yr)	Comments
Wastewater Treatment	26	23–28	Size of facility and ultimate level of treatment effect unit cost.
Residential Reclaimed Water (Reuse)	78	27–190	Does not include household hookups or irrigation systems. Quality of effluent and service territory specific characteristics affect unit cost (better effluent, high unit costs).
Stormwater Treatment Systems	475	150–500	Land availability is a major implementation constraint in older urban settings. Mean is for retrofitting older urban areas, and low range is for relatively easy projects. These projects may not completely meet nutrient reduction requirements for MS4 permit holders.
Regional Land Application (Recharge)	60	25–250	Very high initial capital costs for a regional project.

Source: CH2MHill, 2007. LSJR Main Stream Nutrient TMDL

Algal Turf Scrubber®	25	15-60	Assumes direct treatment of impaired surface water or Ultra-AWT treatment of wastewater

Source: HydroMentia, Inc.

HydroMentia

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Operations and Maintenance

HydroMentia

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CONCLUSIONS

Strengths

The ATS is a relatively simple system that is easy to apply to variety of settings.

The ATS has high rates of biomass production and nutrient removal.

ATS performance is transparent and verifiable (e.g., mass of nutrients removed is known with certainty).

Numerous empirical studies have demonstrated the performance of the ATS in the Chesapeake Bay region and elsewhere.

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Issues

The ATS requires electricity and labor to operate.

The ATS requires relatively large areas of land in order to have a significant impact on nutrient pollution.

Port Estimate ½ acre=50acres Impervious

Although algal biomass is potentially useful, market development is needed.

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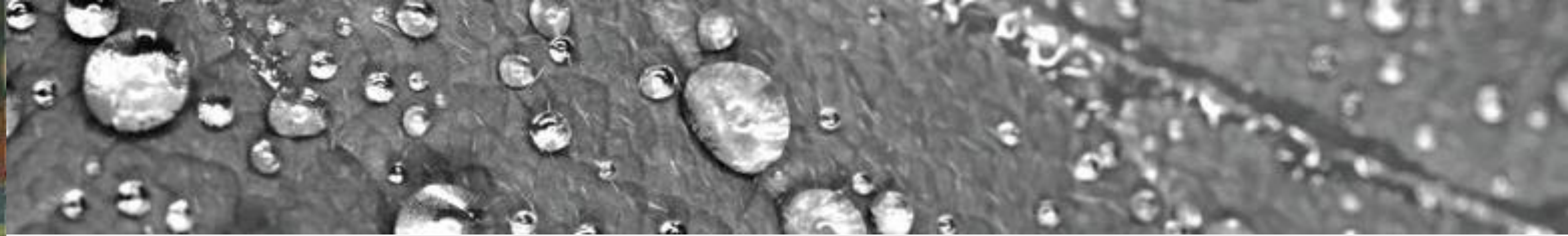

The Future of ATS in Urban Areas?

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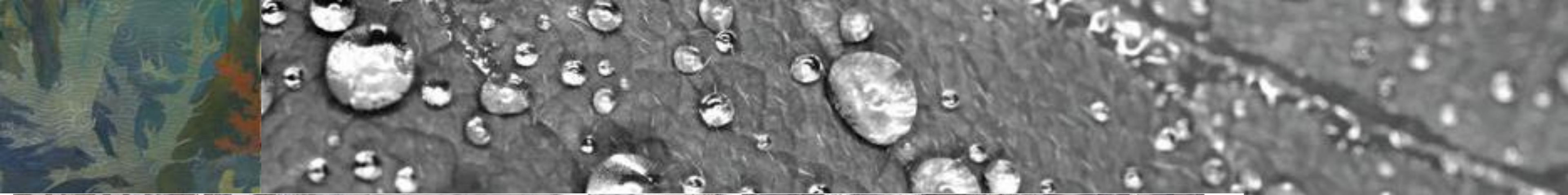

The Future In Baltimore?

Westport ATS

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- Questions and Discussion

Contact Peter May pmay@biohabitats.com
pimay@umd.edu

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