Effluent polishing in constructed wetlands in the United States

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Type of Wetlands Used for Polishing

Free water surface wetlands are usually used for effluent polishing in the United States

Some application of subsurface wetlands are used for denitrification

Hybrid system-wetland/soil/other

Examples of Tertiary Goals

Less than 5 mg/l BOD / TSS/TN

Groundwater recharge/critical stream

Marine discharge-nitrogen limitation

Fecal coliform less than 200 cfu/100 ml

Irrigation reuse

Total ammonia levels less than 1 mg/l

Receiving streams with sensitive fish species

Total phosphorus less than 0.5 mg/l

Receiving streams/eutrophication potential

Examples of some of the over 150 applications of polishing constructed wetlands in the USA

Great Swamp Effluent Management System Beaufort-Jasper Water & Sewer Authority Beaufort, South Carolina (400 Acres-3 MGD)

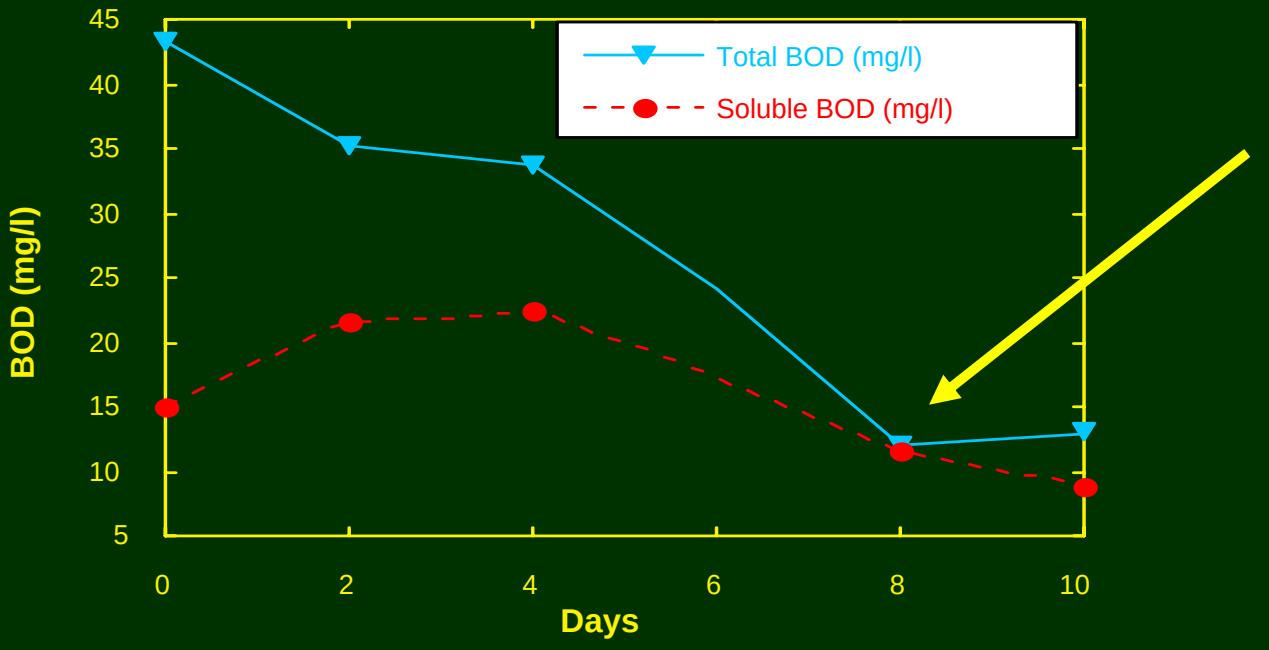
Arcata Marsh and Wildlife Sanctuary, Arcata, California, (40 acres 2.7 MGD)

National Wildlife Visitor Center (U.S. Fish and Wildlife Service), Laurel, Maryland. (6 acres-13,000 gpd)

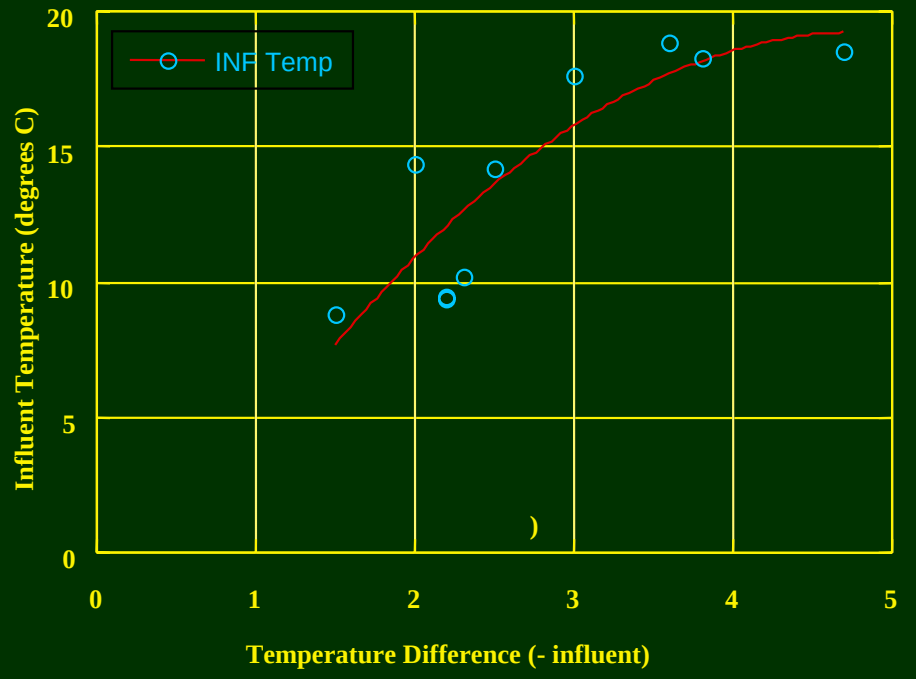
Tres Rios, Phoenix, Arizona (60 acres demonstration, 1MGD))

Orange County Water District -Prado Wetlands, Orange County California (425 acres 2 MGD)

Soluble BOD is released from the Particulate BOD (Settled Solids)
By day 8 all BOD is soluble -only internal BOD load is present

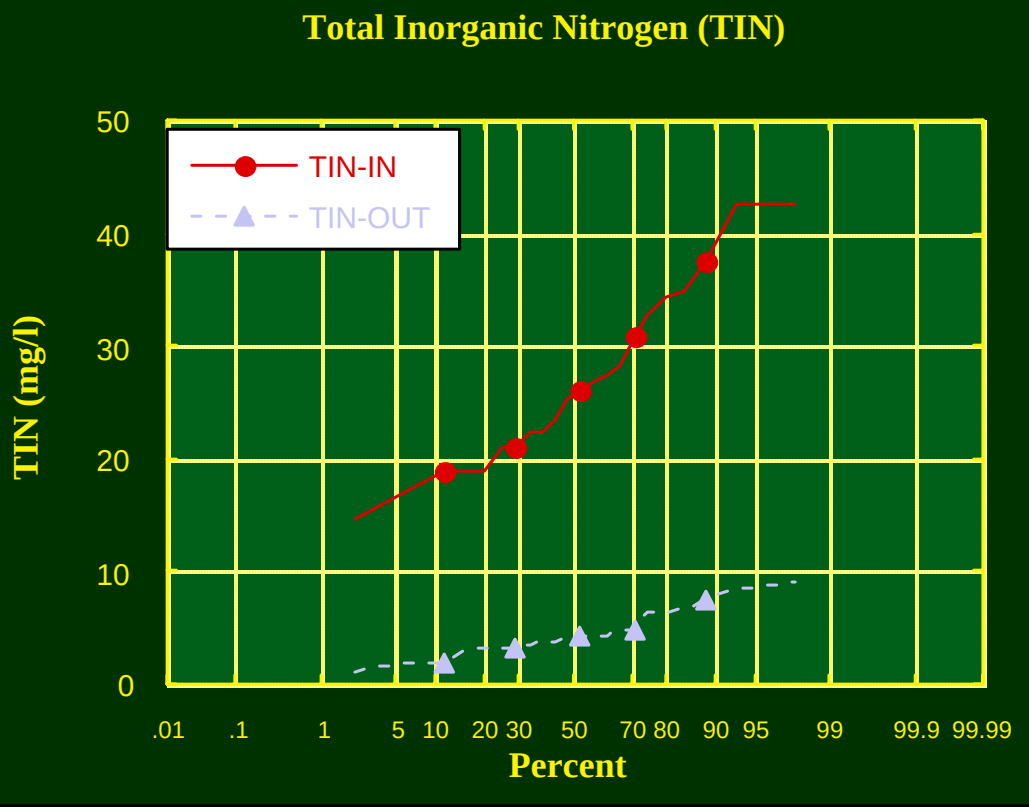


Temperature attenuation to meet instream thermal standards for anadromous fish in California-delta 5 centigrade above 20 degrees C

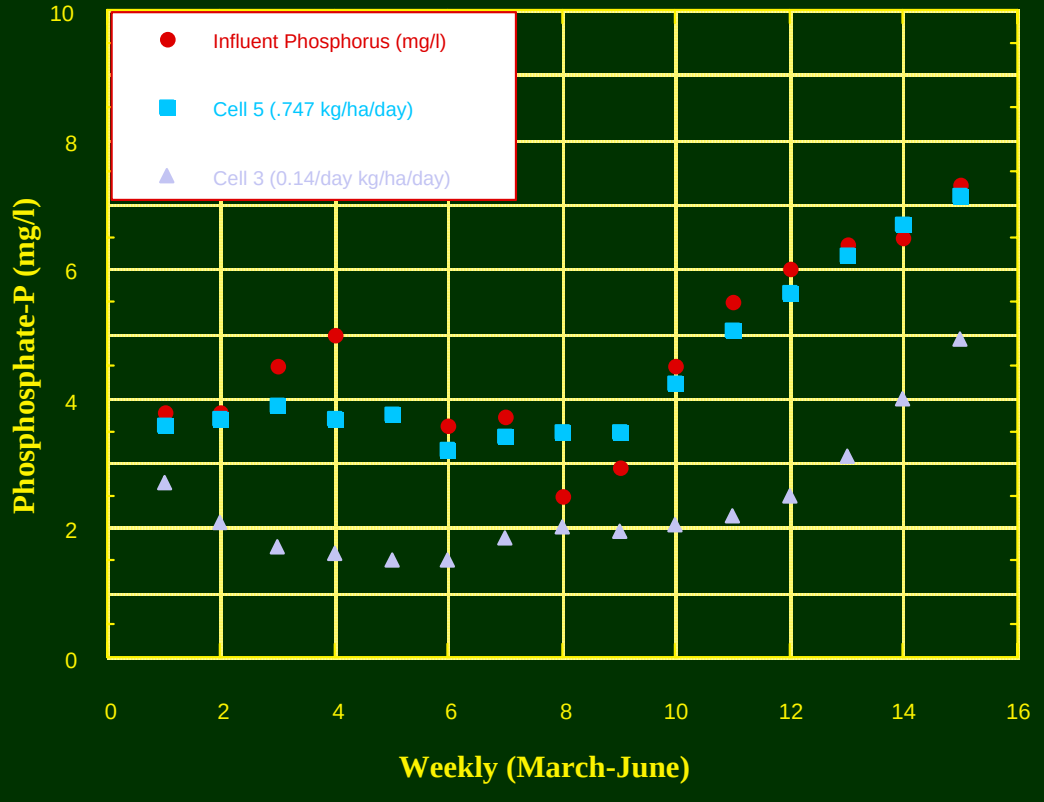


$Y = M0 + M1*x + \ldots M8*x^{8} + M9*x^{9}$	
M0	-5.1033
M1	10.107
M2	-1.0486
R	0.87086

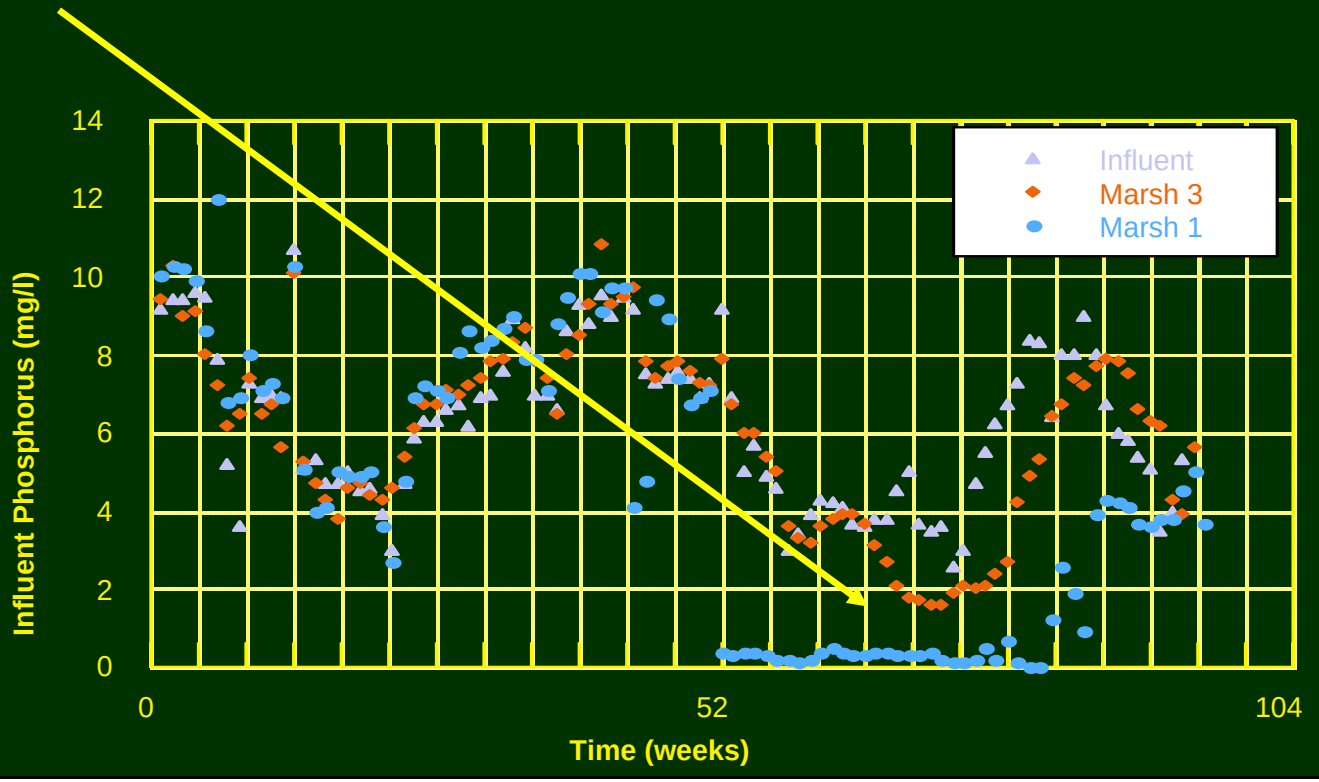
Probability Plot of Removal of TIN (ammonia, nitrite, and nitrate) after 10 days HRT 99% of weekly values less than 10 mg/l median value of 4 mg/l-Arcata



Phosphorus removal showing a net uptake of approximately 2 mg/l at a loading of 0.14 kg P/ha/day during the growing season



Seasonal Phosphorus absorption and release-blue dots represent tap water in wetland that received secondary effluent-orange dots represent a lower P load-phase shift but phosphorus returns to about 90% of influent in non-growing season



Phosphorus Removal

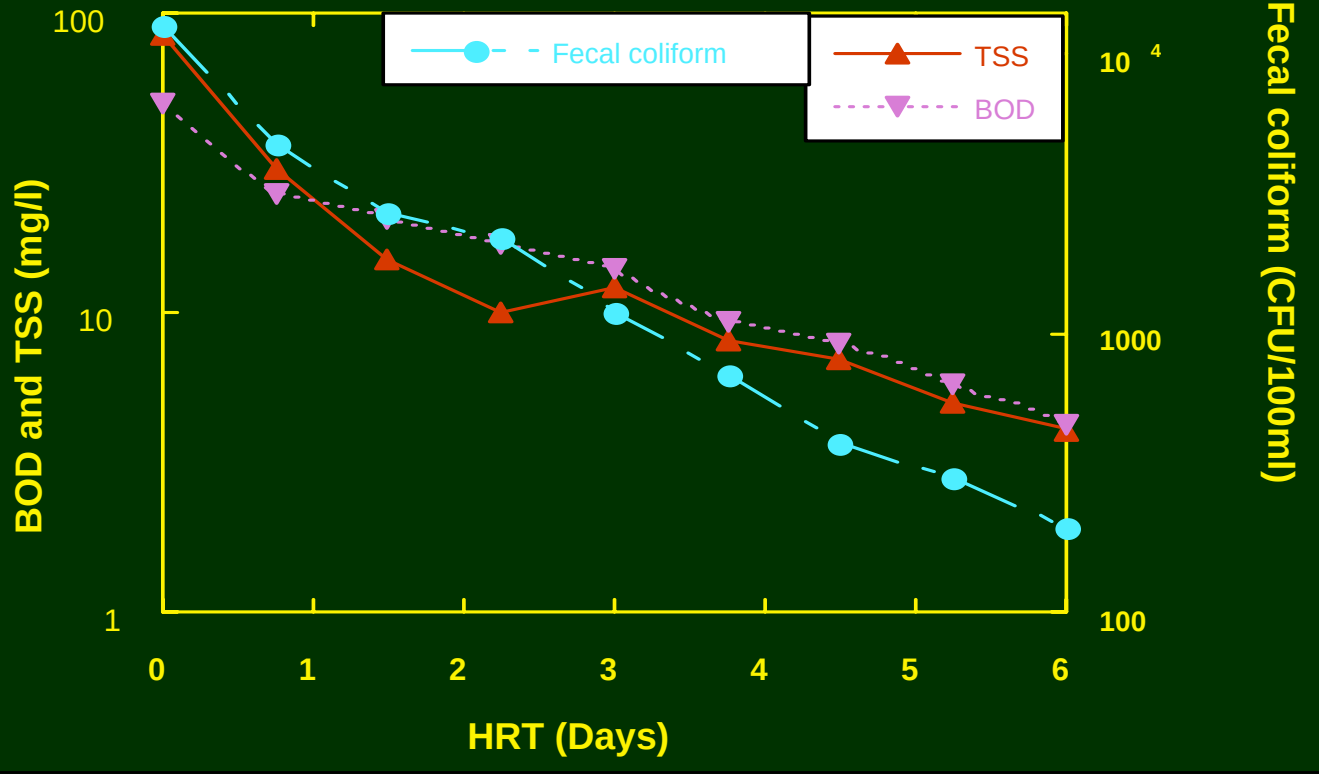
Difficult to meet eutrophication limits of 0.01 mg/l with a wetland system

Wetland can significantly take up phosphorous in growing season -which is period of eutrophication expression

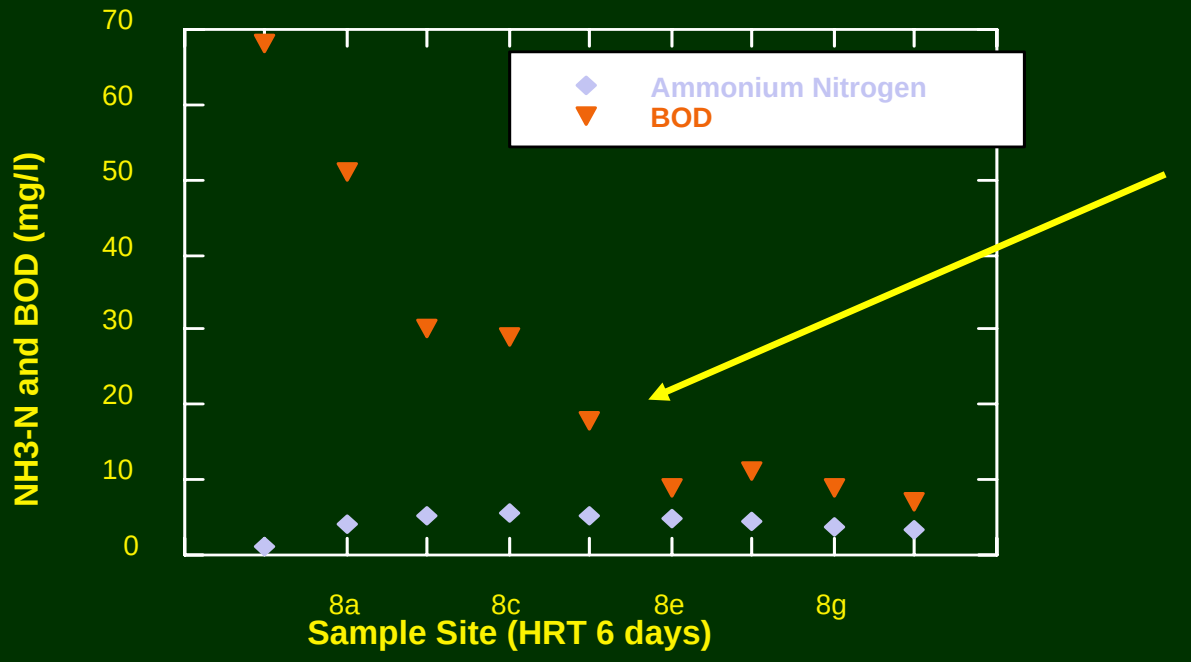
The internal phosphorus release will be a factor in meeting monthly standards (not seasonally adjusted)

Soil/phosphorus interaction becomes less a factor as the detrital layer builds up on the bottom of the wetland

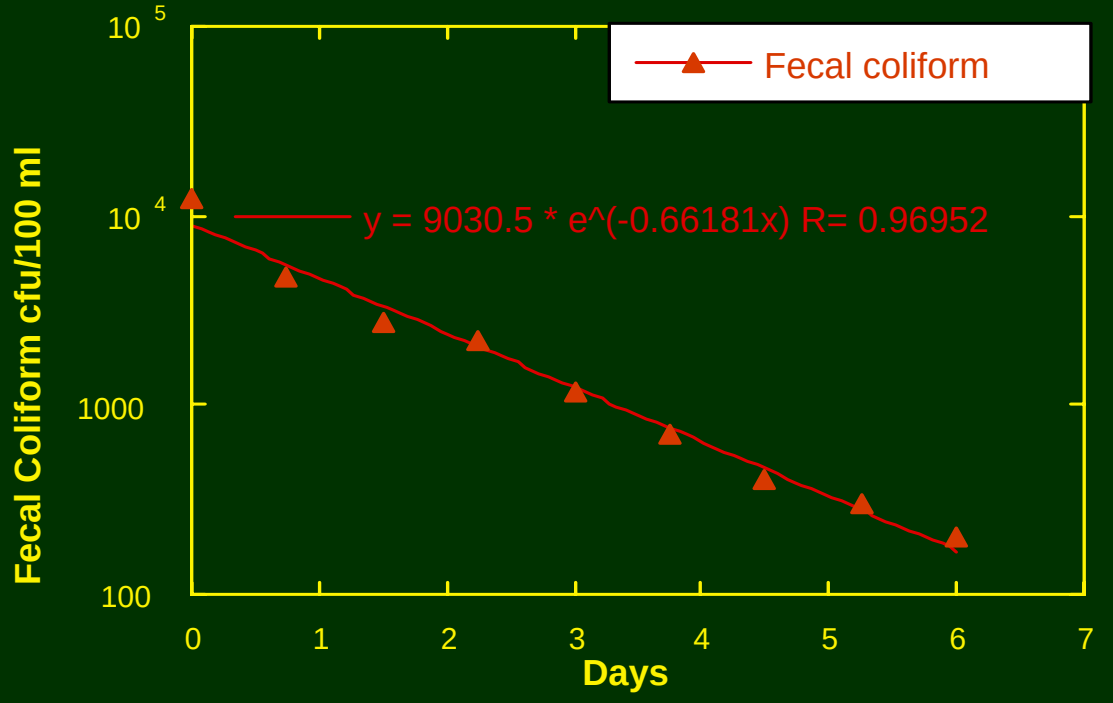
Synchronous Removal of TSS, BOD, and Fecal coliform suggesting a common mechanisms-settling process ?



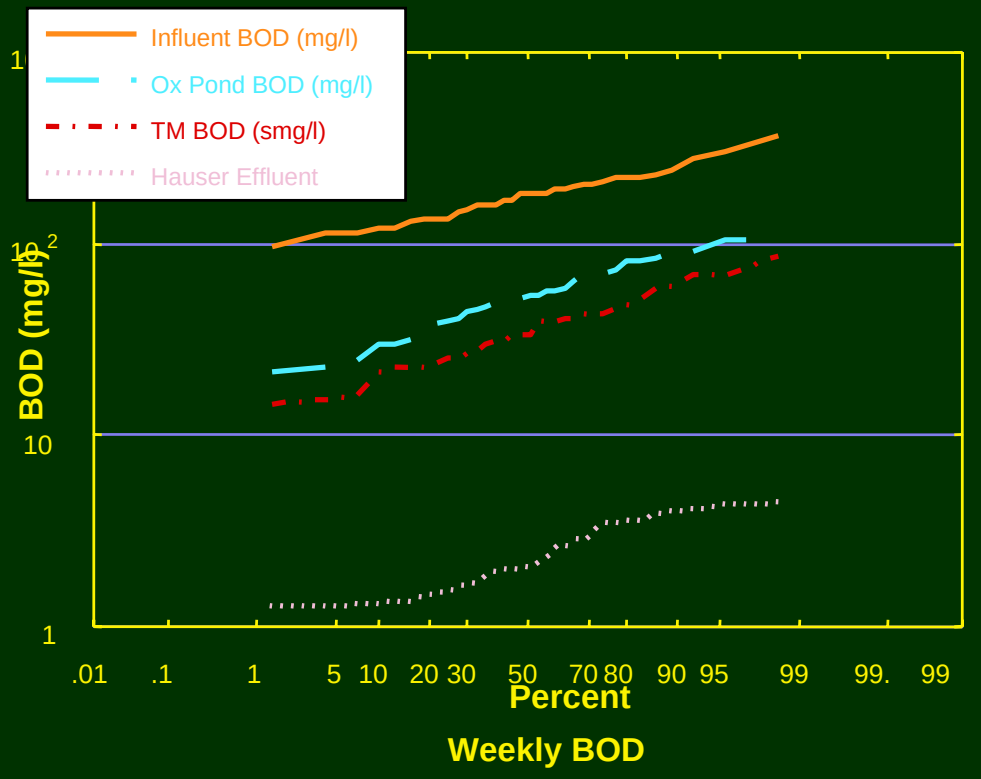
Ammonia nitrogen release from TSS decomposition-increases at 8c (3days HRT



Fecal coliform removal through FWS constructed wetland-two log order in 6 days human pathogens (*Salmonella spp.)* found to follow similar rate



Example of BOD Probability Removal from a natural system to meet tertiary goal (Arcata, CA)



Trace metal concentrations and removal rates, Sacramento Regional Wastewater Treatment Plant (SCRSD, 1998)

	Influent (mg/L)			Effluent (mg/L)			Removal Rate
Metal	Min	Mean	Max	Min	Mean	Max	(%)
Silver	0.25	0.29	0.32	0.02	0.03	0.03	90
Arsenic	2.00	2.23	2.60	1.50	2.20	3.10	1.3
Cadmium	0.040	0.077	0.140	0.005	0.009	0.019	88
Chromium	0.50	1.05	1.40	0.50	0.77	3.10	27
Copper	4.60	8.62	17.00	1.60	4.04	7.00	19
Mercury	0.0084	0.0105	0.0144	0.0021	0.0031	0.0041	71
Nickel	4.30	8.23	23.00	4.10	8.96	20.00	---
Lead	0.25	0.58	1.20	0.05	0.14	0.26	55
Antimony	0.40	0.41	0.42	0.12	0.15	0.20	63
Selenium	0.50	0.50	0.50	0.50	0.50	0.50	---
Zinc	6.4	26.2	34.0	1.30	3.53	8.70	70

Settling Processes-dominant mechanism

Discrete settling

Flocculant Settling

Little to no resuspension in a wetland

Internal surface in a wetland important - detrital layers, etc

Predation concentration-settling

Construction

- Barriers to infiltration-liners
- Planting techniques
- Berm size/structure and specifications
- Inlet and outlet types

Issues that need to be resolved to further the application of the use of constructed wetland to polish domestic effluents

Operation and Maintenance

- Vector control-mosquitoes
- Vegetation harvesting-planting
- Odor problems
- Burrowing mammals

Wetland Processes

- Removal and internal load mechanisms for BOD, ammonia, and phosphorus
- Role of different function types of vegetation- floating, submergents, and emergents-oxygen transfer, uptake, etc.
- Role of settling, autoflocculation and anaerobic breakdown of solids
- Evapotranspiration processes-plant types/coverage, size of system, climate, etc.
- Porosity, short circuiting, resistance (head loss), etc.

Design Considerations

- Design approach-design equations-assumptions North American Database-evaluation – Background constituents
- Aspect ratio, number of cells, shape, etc.
- Long term operation-performance, life cycle, etc.
- Open water (floating/submergent) vs closed water (emergent)
- Inlet/outlet type-location

Permitting/Policy

- Waters of the United States vs treatment area
- Once a wetland always a wetland-wetland policy
- Attractive nuisance-Endangered Species Act
- Natural system effluent variation-discharge requirements
- Conversion of degraded wetlands-enhancement
- Leaky (infiltration) wetlands groundwater

Water Quality

- Dissolved organic carbon compounds-DOC
  THM precursors
- Refractory organics
- Low level virus titers
- Perchlorates

Conclusions

- A wide range of applications and treatment levels
  - Habitat enhancement
  - Groundwater recharge
  - Fisheries protection
  - High public use passive recreation
  - Aquaculture
- Limitation of treatment level dependent on internal factors related to the wetland plants, soils, biological activity, etc.
- The fusing of polished effluent with background water quality is a goal-
- Psychological effect of using natural systems (constructed wetlands) as a barrier between effluent processing and water quality benefits is significant in reuse i.e., drinking water, Native American fisheries, etc.