



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Streambank and Lake Restoration

**Christopher C. Obropta, Ph.D., P.E.**

**Assistant Professor, Dept. of Environmental Sciences**

**Assistant Extension Specialist in Water Resources, RCRE**

**obropta@envsci.rutgers.edu**

**732-932-4917**

**[www.water.rutgers.edu](http://www.water.rutgers.edu)**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Lake Restoration

**Lakes and ponds are valuable resources that provide ecological, aesthetic, and recreational services**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Lake Restoration

**Lakes can be stressed by anthropogenic or natural influences**

- **Shoreline erosion**
- **Sediment buildup**
- **Eutrophication**
- **Algal blooms**
- **Invasive species**





# Lake Restoration

- **Lake Ecology**
- **Eutrophication Issues**
- **Algae Control**
- **Biomanipulation**
- **Lake Dredging**
- **Stream bank and Shoreline Restoration**



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
**COOPERATIVE**  
RESEARCH & EXTENSION

# Lake Ecology

NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**

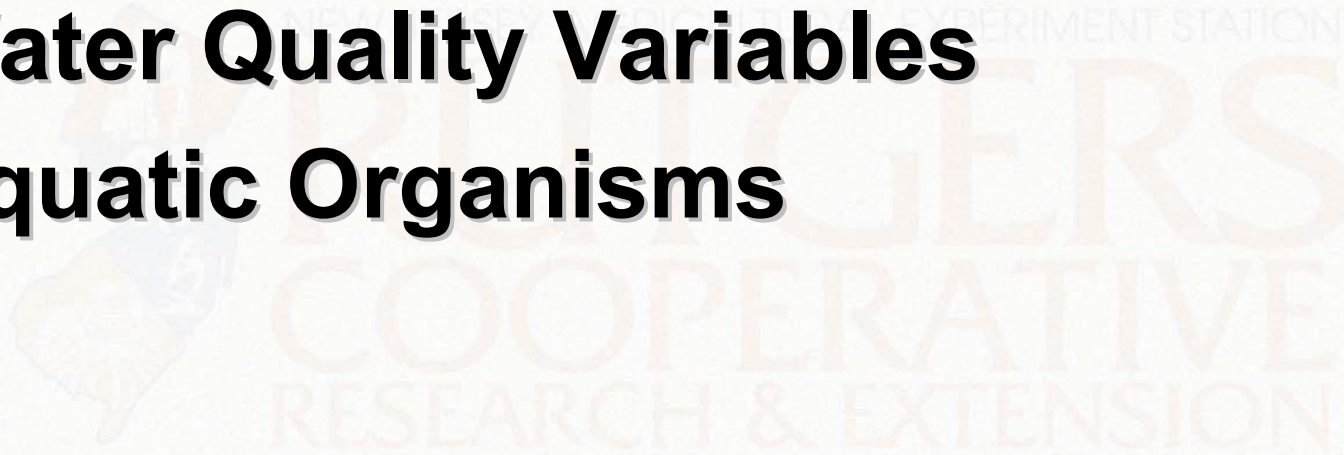


NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Lake Ecology

- **Lake Morphology**
- **Water Quality Variables**
- **Aquatic Organisms**



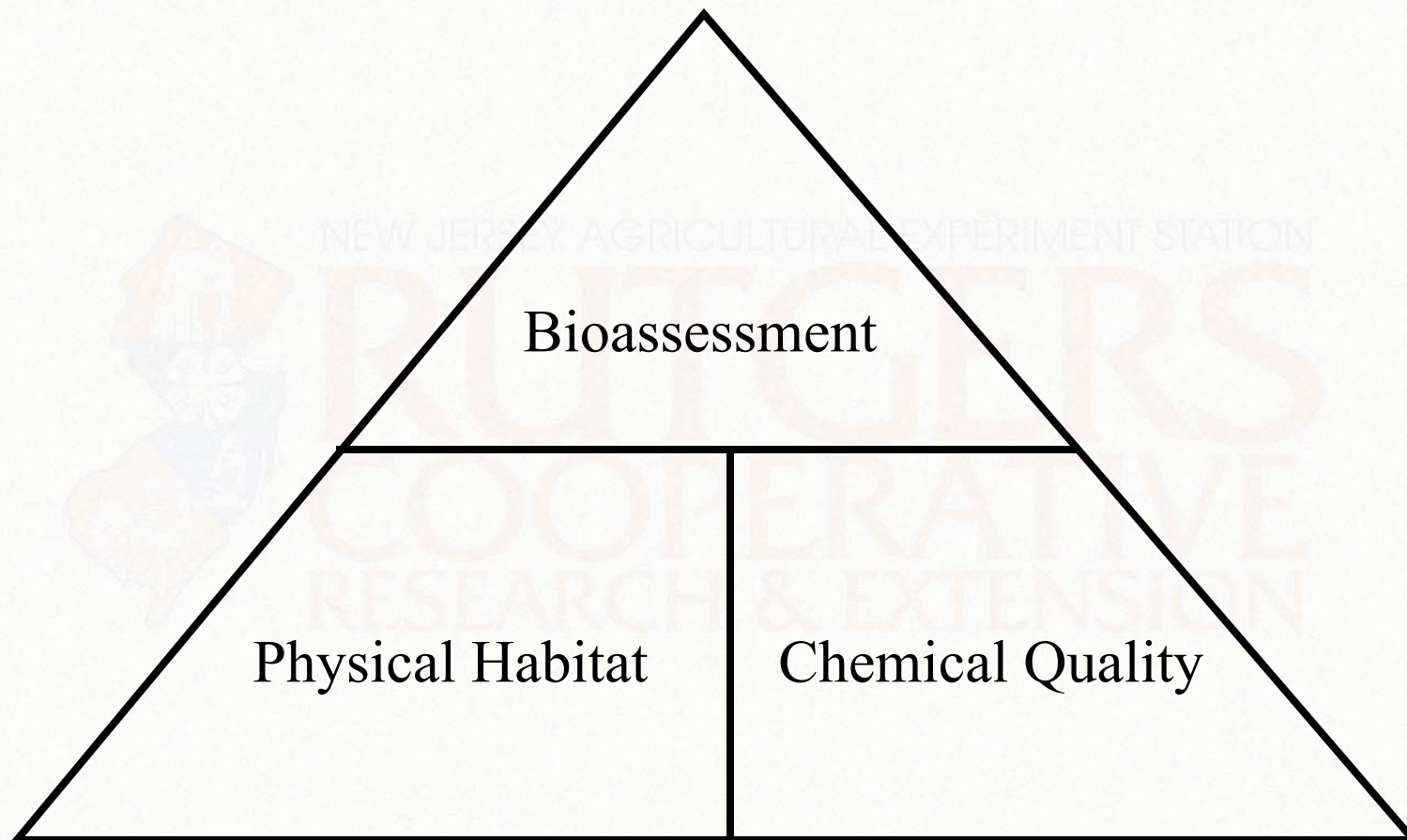
THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Lake System





# Lake Morphology

## Shape and Size

- Depth
- Surface area
- Volume
- Length of shoreline

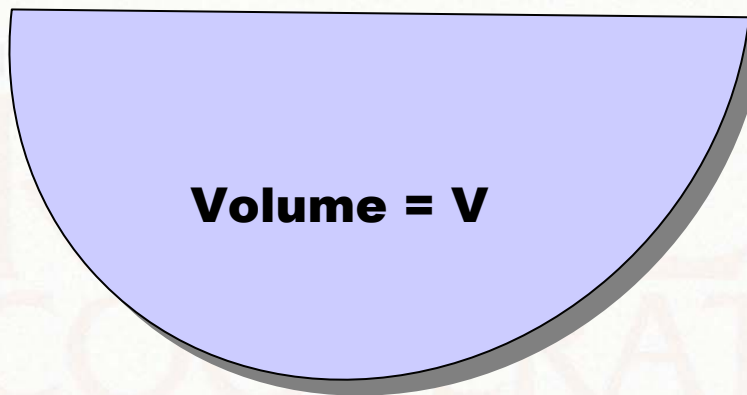
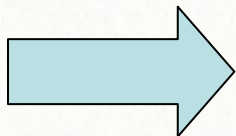
## Hydraulic residence time

- Determines flushing rate
- Usually a slow resupply of water



# Lake Morphology

**Inflow = Q**



**Volume = V**

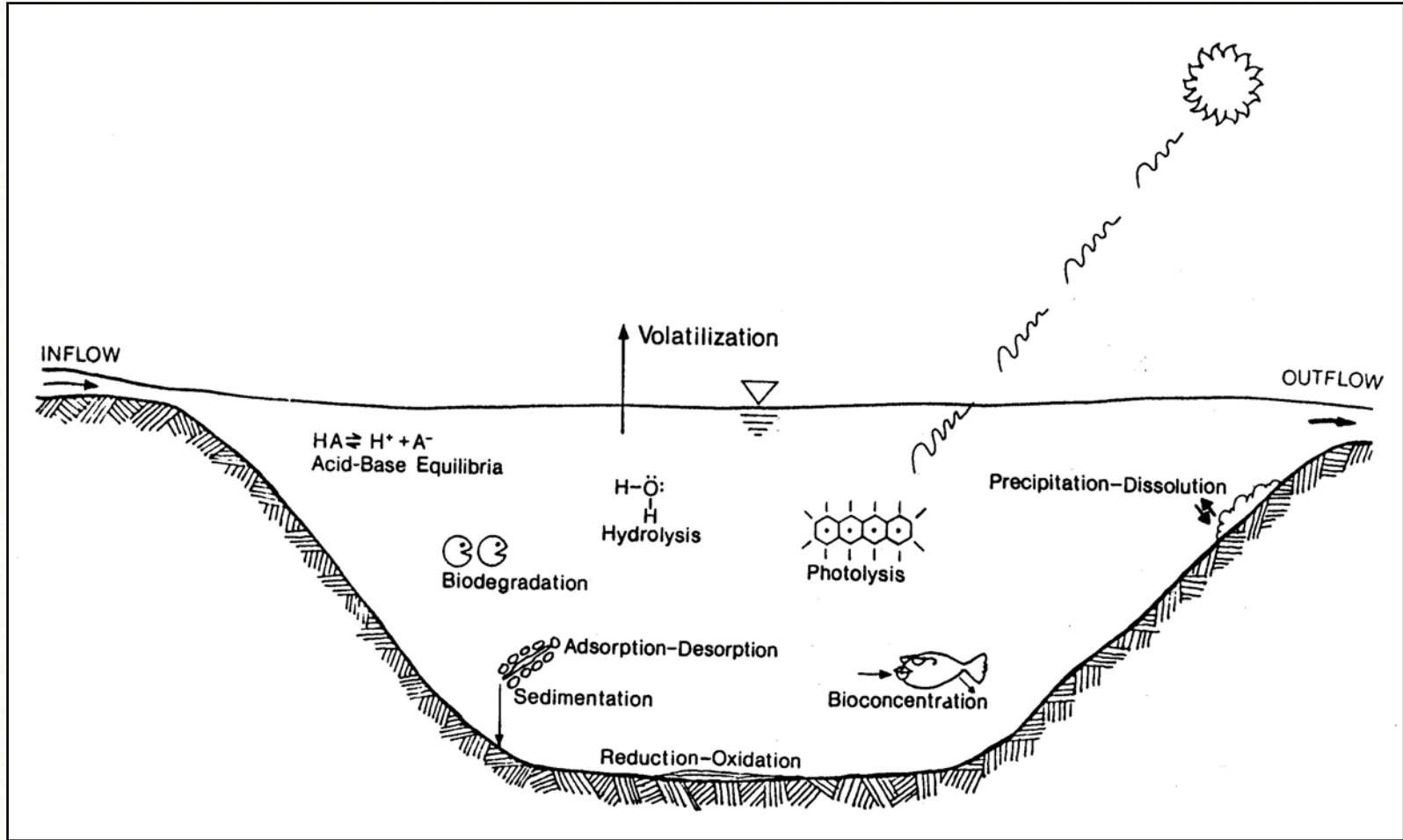


**Residence Time =  $T_R$**

$$T_R = \frac{V}{Q}$$



# Water Quality Process





# Water Quality

- **Tends to vary with depth and season**
  - Pollutant loading determined by land use
  - Sediments can be a factor
- **Minimal reaeration from surface**
- **Riparian buffers very important**
  - Protection of shoreline
  - Filtration
  - Nutrient uptake





# Water Quality

## Water Quality Variables

- **Acidity**
- **Alkalinity**
- **Hardness**
- **Color**
- **Turbidity**
- **Transparency**
- **Nutrients**
- **Dissolved Oxygen**
- **Toxic substances**
  - **Metals**
  - **Pesticides**
  - **Petroleum products**
- **Microorganisms**
  - **Bacteria**
  - **Viruses**
  - **Protozoa**

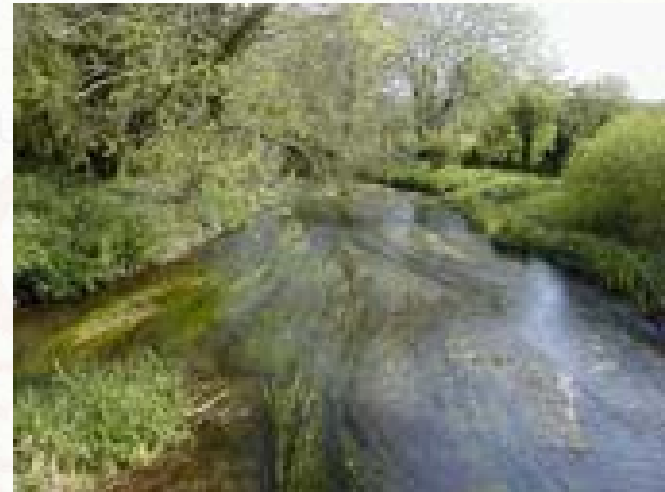


NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Aquatic Organisms

- Plankton
- Macrophytes
- Invertebrates
- Vertebrates
- Microorganisms



THE STATE UNIVERSITY OF NEW JERSEY

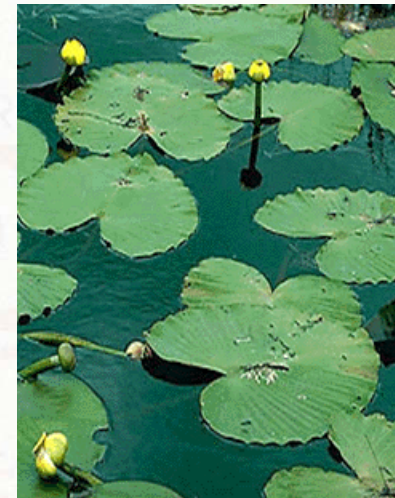
**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Lake Biota

- **Less streamlined than in streams**
  - Fish wider bodies
  - Plants wider leaves
- **Entire water column**
  - Invertebrates swim
  - Planktonic organisms
- **Large predators**
  - Often hunt
  - Food will swim by



LARGEMOUTH BASS



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
**COOPERATIVE**  
RESEARCH & EXTENSION

# Eutrophication

NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Eutrophication

## Eutrophication - definition

Excess **nutrient** and **sediment** load into lakes at a rate sufficient to increase the potential for high biological production and a decrease in basin volume



# Eutrophication

## Causes

- **Excess nutrients and silt entering lake system from runoff**
- **Nutrients can be sorbed on silt which can later become available to algae and plants**
- **Excess plants deplete oxygen and release more nutrients as they decay**
- **Nutrients can be released from sediments**



# Eutrophication

## Common Symptoms

- **Reduced clarity**
- **Large daily oscillations in dissolved oxygen**
- **pH shifts**
- **Algae blooms**
- **Excessive weed growth**
- **Fish kills**
- **Odor, aesthetic, and taste problems**



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
**COOPERATIVE**  
RESEARCH & EXTENSION

# Algae Control



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Algae Control

**Algae blooms are a tell tale sign of a nutrient enriched system**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Algae Control

## 1<sup>st</sup> defense: source control of nutrients

- Limit fertilizer use
- Landscaping to limit lawn area
- Native plant buffer to intercept nutrients in runoff - biofilters
- Manage leaf litter
- Maintenance of on-site septic systems
- Restrict boat traffic to prevent resuspension of phosphorous in sediments



# Algae Control

## Other algae control techniques

- Precipitate phosphorus with chemical addition (buffered alum)
- Dyes
- Aeration
- Barley straw
- Aquascaping
- Algaecides
- Physical removal – nets or booms



# Buffered Alum

- **Binds with inorganic phosphorus**
- **Phosphorus precipitates out of the water**
- **Best for deep lakes**
- **Use in lakes that flush infrequently**



# Buffered Alum

## Application techniques

- **Low dose whole lake application from a boat as a solid or a slurry**
- **Sediment blanket**
- **Flow metered dosing**
- **Integration with sediments**
- **Apply with an aerator**



# Buffered Alum

## Potential problems

- Alum toxicity
- Stimulated growth
- Elevated bacteria counts (temporary)
- Temporary reduction in benthic assemblage

## Cost

- \$25 per bag or \$0.50 per gallon



# Dyes

- **Block sunlight**
- **Reduce algae growth**
- **Best in shallow lakes with severe benthic or filamentous algae problems**
- **Can enhance blue color**





# Dyes

- **Liquid or powder form**
- **Inert dye similar to blue food colorant #5**
- **Use the dye in lakes or ponds that have limited outlets and a long detention time**
- **Usually lasts 6 to 8 weeks**



# Aeration

## Artificial circulation brings oxygen-poor water up to the surface

- **Surface Spray**
- **Paddlewheel**
- **Air Diffusers**





# Aeration

## Benefits

- Provides oxygen for aerobic decomposition of organic matter
- Controls blue-green algae
- Prevents fish kills
- Liberates dissolved gases into the air instead of allowing them to build to harmful levels in the pond ( $\text{NH}_3$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{S}$ , and methane)



# Aeration

## Surface agitators create turbulence

- **Oxygen circulation**
- **Nutrient consumption**
- **Temperature control**





# Aeration

## Selecting an aerator

- **Oxygen Transfer Rates (OTR) in excess of 1lb/5kg per horse power per hour**
- **Pumps in excess of 300 GPM or 1200 LP per horsepower**
- **Recommend 1 to 3HP aerating units per surface acre**



# Aeration

## Surface Spray

- **Best vertical circulation in lakes less than 15 ft deep**
- **Create convection currents**
- **Break up algae mats**





# Aeration

## Paddlewheel

- **Shallow lakes**
- **Low above surface spraying**
- **Creates a strong current**





# Aeration

## Air Diffusion

- **Best mixing for deep lakes**
- **Diffuser on lake bottom**
- **Supplied by an air compressor**





# Aeration

## Considerations

- **Keep units off the sediments**
- **Place aerator to create a positive current**
- **Align to prevent shore erosion**
- **Cost \$500 to \$7000 plus power**



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Barley Straw

**Decomposition  
produces  
compounds that  
inhibit or reduce  
algal growth**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Barley Straw

## Application

- **Contained in wire mesh and staked to the bottom**
- **Deployed in spring**
- **Approximately 225 pounds of straw per acre**
- **EPA considers barley straw an algicide**



# Aquascaping

## “Water Gardening”

- The use of aquatic plants to create a desirable plant community
- Plants compete with algae for nutrients
- Serve as habitat for zooplankton to compete with algae for nutrients
- Deter geese
- Stabilize shoreline
- Improve aesthetics and habitat

## Planting

- Match species to depth
- Use diverse native species
- Be aware of invasive intrusion
- Includes vegetative buffers





# Algaecides

## Is it an algae or a plant?

- **ID the algae**
- **Establish a nutrient control plan**
- **Select an appropriate algaecide**





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Algaecides

## Problematic algae

- **Filamentous**
- **Planktonic**
- **Stalked**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Algaecides

## Filamentous

- stringy
- grows on bottom
- breaks off and accumulates on surface



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Algaecides

## Planktonic

- exist throughout water column
- can form surface scums
- includes blue-green algae





# Algaecides

## Stalked

- *Chara* and *Nitella*
- can look like plants
- no roots
- usually beneficial for habitat
- can be a nuisance in shallow ponds





# Algaecides

## Active ingredients

- copper
- coppersulfate
- endothol
- percarbonate



**AlgaePro from SePro – copper**

**AquaCure from Gordons – copper**



# Algaecides

## Application

- Like herbicides, must be applied by licensed applicator in New Jersey
- EPA registered algaecides
- Apply according to label
- Water temperature requirements
- Usually apply once start growing, but not so late in the summer that decaying biomass is a problem



# Algae Removal

- Removal with nets and booms**
- Works best with filamentous algae**
- A lot of biomass to dispose of**
- Does not control source of problem**





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Bio-manipulation

NEW JERSEY AGRICULTURAL EXPERIMENT STATION

RUTGERS  
COOPERATIVE  
RESEARCH & EXTENSION



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Biomanipulation

- **Ecosystem control**
- **Manage aquatic plants**
  - Introduce grass carp
- **Manage algal blooms**
  - Add predatory fish to eat the small minnows that feed on the zooplankton that feed on the algae



# Biomanipulation

## Grass Carp (White Amur)

- **Biological tool for weed control**
- **Not native to US**
- **Triploid strain (sterile)**





# Bio-manipulation

## Grass carp considerations

- Can the problem plant be controlled by grass carp?
- Use only triploid certified fish
- Obtain appropriate permits
- Stock at least 8" fish in spring
- Stocking density 5-15/acre
- Monitoring



# Biomanipulation

## Palatable plant species

- **Milfoil**
- **Naiad**
- **Elodea**
- **Coontail**
- **Curley leaf pond weed**
- **Duckweed**
- **Bladderwort**
- **Musk Grass**
- **Water star grass**
- **Cabomba**



# Biomanipulation

## Regulation of grass carp in New Jersey

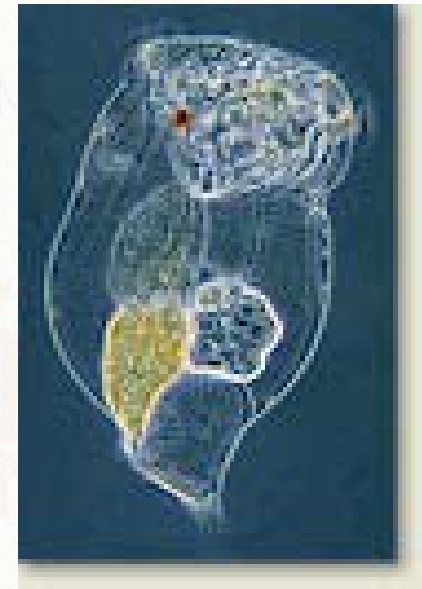
- Restricted to ponds less than 10 acres
- Fish certified triploid strain
- Only use if have more than 40% coverage of weeds, palatable to grass carp
- Restrict fish from downstream outlet



# Biomanipulation

## Algae control

- Limit the population of fish that graze on zooplankton by introducing other predator fish
- Bottom line is to increase zooplankton population





# Bio-manipulation

## Lake Hopatcong

- Considering bio-manipulation with a nutrient management plan
- Need to conduct holistic fish survey
- Hybrid striped bass and brown trout considered
- Alewife the dominant zooplankton-eating fish

## Oradell Reservoir

- Introduced hybrid striped bass to control perch and gizzard shad



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
**COOPERATIVE**  
RESEARCH & EXTENSION

# Lake Dredging

NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Lake Dredging

## Why dredge?

- **Deepening**
- **Limit nutrient cycling**
- **Reduction of macrophyte nuisances**
- **Removal of toxic sediments**



# Lake Dredging

## Dredging Concerns

- Release of nutrients
- Resuspension of contaminants
- Destruction of benthic fish-food organisms
- Adequate disposal facility
- Cost



# Lake Dredging

## **Sediment source control (root cause analyses)**

- ID source of sediments**
- Control the source to reduce the need to dredge again in the near future**



# Lake Dredging

## Sediment Sources

**Stormwater outfalls, ditches**

**Bank erosion**

**Impervious surfaces**

**Agriculture**

**Construction sites**



# Lake Dredging

## Sediment Testing

- **Sampling**
  - Sediment cores to project depth
  - Core composition
- **Physical Analyses**
  - Water content
  - Organic content
  - Particle size distribution



# Lake Dredging

## Chemical Analyses for upland disposal

**total phenols**  
**oil and grease**  
**reactivity**  
**nitrogen**  
**phosphorus**  
**minerals (Ca, Mg, K)**  
**base neutral priority**  
**pollutant organics**

**heavy metals**  
**TCLP**  
**PCB's, DDT, and metabolites**  
**pH**  
**sulfur**  
**chlorides**  
**chlordanane**



# Lake Dredging

## Standards to compare the results

- **If testing of dredge sediments is required, it is compared to the soil cleanup criteria for site remediation (e.g., residential or nonresidential)**



# Lake Dredging

## Permits to dredge

### County –

**Soil Conservation District S&E Permit, may also need approvals to transport over county roads**

### State –

**NJDEP Freshwater Wetlands**

**GP 1 Maintenance of existing structure**

**GP 13 Lake and pond dredging**



# Lake Dredging

## State permits (cont'd)

**NJDEP Stream Encroachment**

**NJDEP Bureau of Solid Waste (if landfilling)**

**Water Quality Certificate**

**NJDEP Lake Lowering, NJDEP Fish & Wildlife**

**NJPDES may be required as part of a hydraulic dredging project**



# Lake Dredging

## Public Notice

**Adjacent property owners**

**County planning board**

**Local planning board**

**Environmental Commission**



# General Permit 13

- May request permit no more than once every 5 years**
- DEP may require testing of the sediment if it is suspected to be contaminated**



# General Permit 13

## Required Documentation

- **Aerial photography**
- **Original construction plans**
- **Core borings**
- **Show that dredging will go no deeper than the original configuration and bottom contours of the lake**
- **Show will not enlarge the lake beyond the original configuration**



# General Permit 13

## Lakes larger than five acres

- A USGS quad map showing all of the upstream land and water surface areas draining to the lake
- Land use in the upstream drainage area
- List and locations of sediment sources that discharge directly into the lake or into a tributary within 1,000 feet of the lake
- An estimate of the percent impervious surface cover of upstream drainage area



# Lake Dredging

## Dredging Process

**Mechanical – best for small projects & shorelines**

- **Grab buckets**
- **Clam shell**
- **Excavation**
- **Dragline**

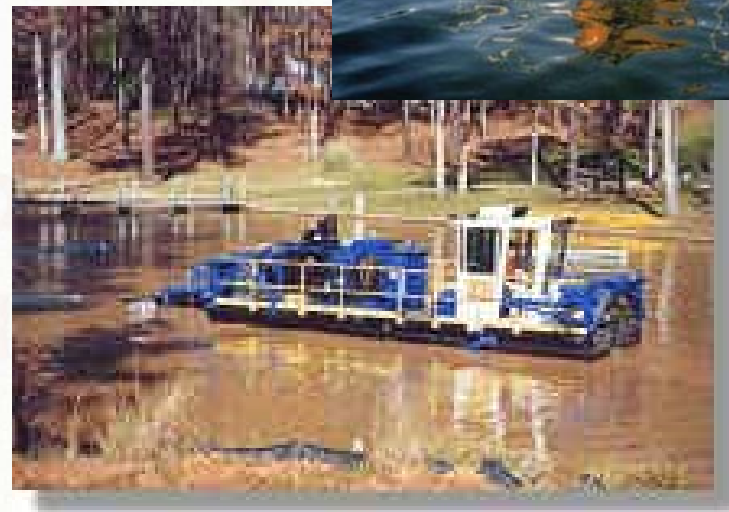




# Lake Dredging

## Hydraulic

- Pumps as a slurry
- Best for large scale projects
- Softer sediments
- Produces a high water content to be disposed





# Lake Dredging

## Disposal of dredge material

### Beneficial reuse vs. disposal at landfill

- Engineered uses
- Agricultural and product uses
- Environmental Enhancement
- Roadway embankments
- Beach nourishment
- Use options depend on material type



# Lake Dredging

## Cost of dredging

### Mechanical

- \$8 – \$25/ yd<sup>3</sup>
- Plus containment

### Hydraulic

- \$6-\$12/ yd<sup>3</sup>
- Plus travel



# Disposal

## Site Preparation

- **Engineering  
(for hydraulic must  
size sedimentation  
basin)**
- **Clearing**
- **Dikes and berms**
- **Drainage**
- **Access**
- **Security**





# Disposal

## Environmental Protection

- Liners
- Monitoring Wells
- Chemical Testing



## Site Closure

- Time for dewatering
- Grading and seeding
- Landscaping





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
**COOPERATIVE**  
**RESEARCH & EXTENSION**

# Shoreline Restoration

NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
**COOPERATIVE**  
**RESEARCH & EXTENSION**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
**COOK COLLEGE**

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Shoreline Restoration

## Predominant shoreline issue is erosion

### Causes of erosion

- **Runoff**
- **Wave action**
- **Ice**
- **Access points**





# Shoreline Restoration

**Bioengineering and hard structure**

**Vegetative buffer enhancements**

- Native plants
- Water tolerant, sturdy vegetation

**Revetments – riprap, rootrap, gabions**

**Outfall retrofitting with BMPs**

- Stormwater treatment wetlands
- Bioretention systems
- Premanufactured treatment systems.



# Shoreline Restoration

## Bioengineering solutions

**Plants and other natural materials used to stabilize and restore existing or potential erosion problems**





# Shoreline Restoration

## Benefits of Bioengineering

- Improve aesthetics
- Long term, low maintenance
- Cost
- Environmental quality



# Shoreline Restoration

## Basic components of bioengineering

- **Grading**
- **Live cuttings**
- **Erosion blanket**
- **Biologs**
- **Seeding**





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Shoreline Restoration

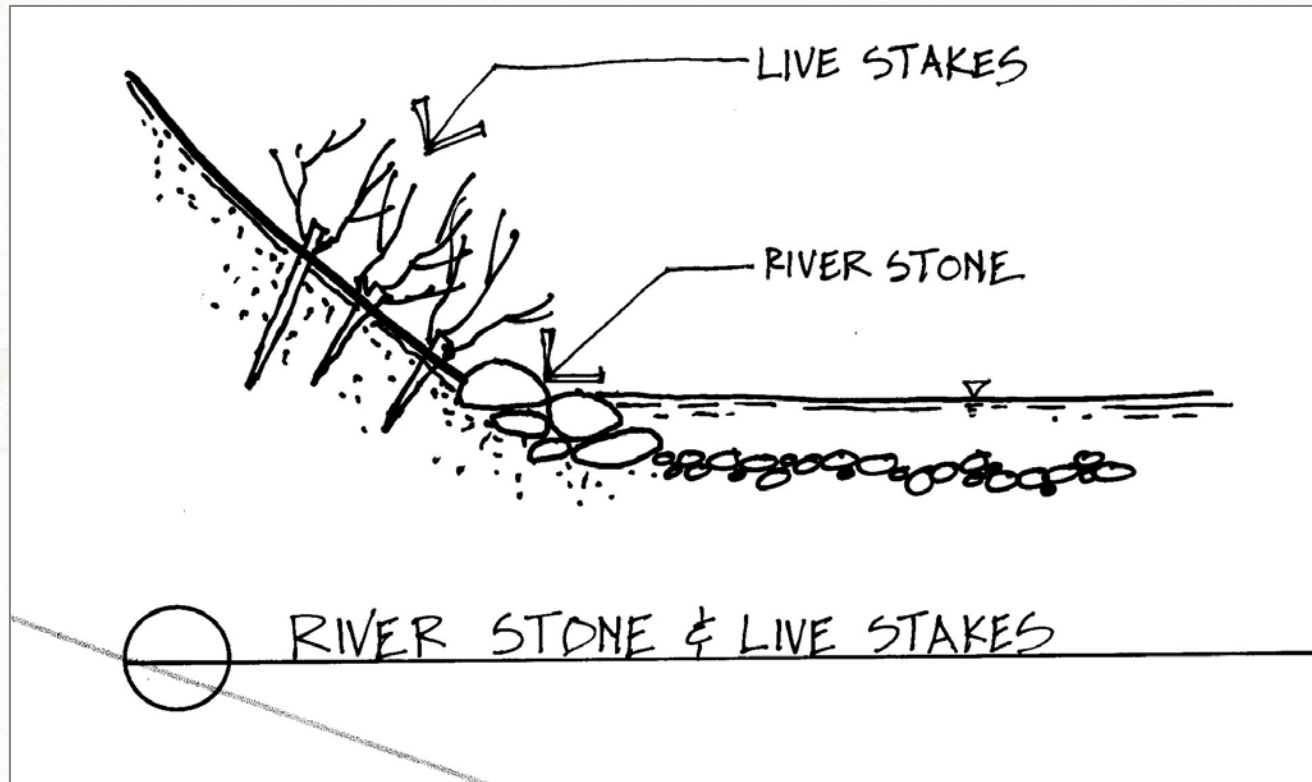
## Vegetative systems





# Shoreline Restoration

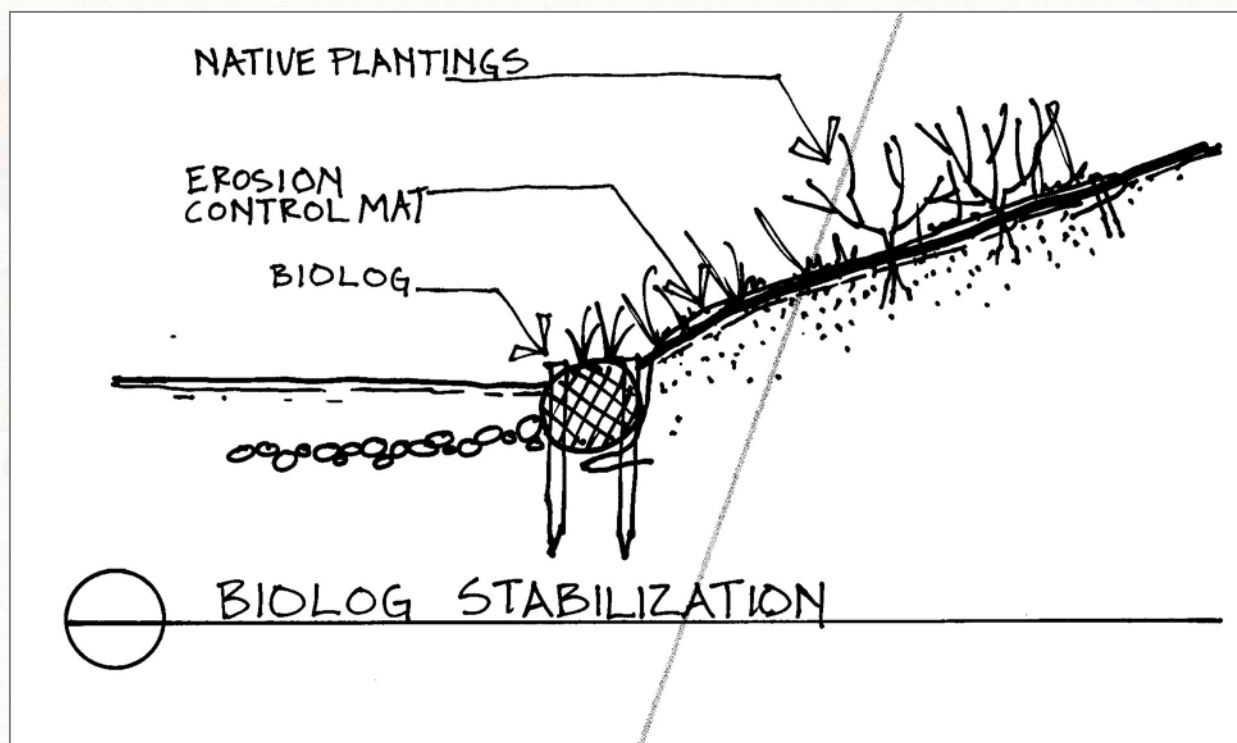
## Structural Design





# Shoreline Restoration

## Stabilization with biologs





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Shoreline Restoration

## Biologs





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Shoreline Restoration

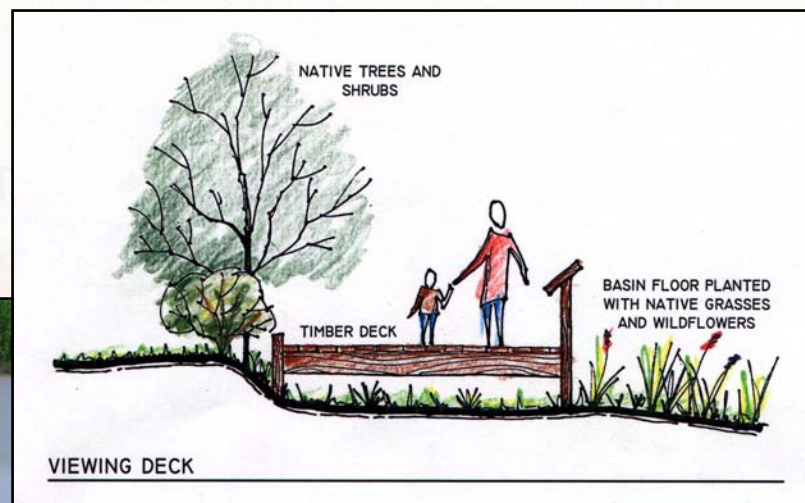
## Logs for bank stabilization





# Shoreline Restoration

## Provide human access points to the lake



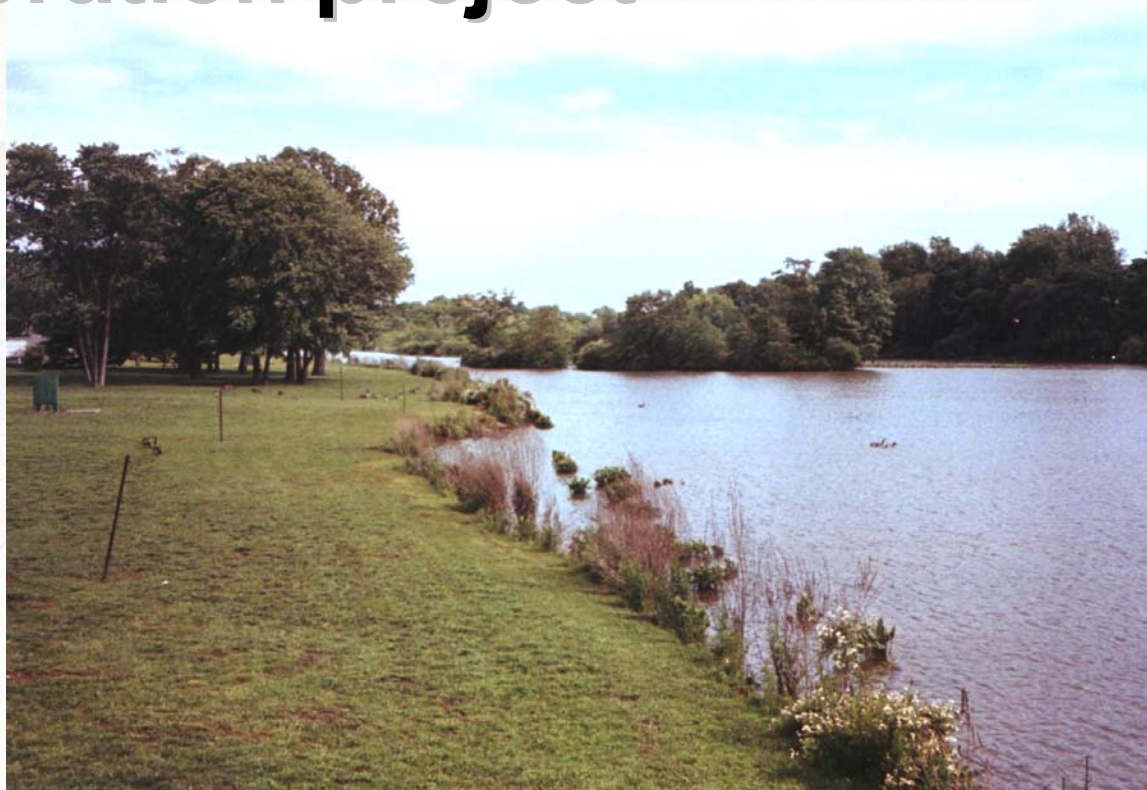


NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Shoreline Restoration

## Restoration project



**Original Condition**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Shoreline Restoration



**Restoration in progress**





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Shoreline Restoration



**Restored shoreline**



THE STATE UNIVERSITY OF NEW JERSEY

**RUTGERS**  
COOK COLLEGE

THE STATE UNIVERSITY OF NEW JERSEY  
**RUTGERS**



# Shoreline Restoration

## Outfall retrofitting with BMPs

- Stormwater treatment wetlands
- Bioretention systems
- Pre-manufactured treatment systems





# Shoreline Restoration

## Stormwater treatment wetlands





NEW JERSEY AGRICULTURAL EXPERIMENT STATION

**RUTGERS**  
COOPERATIVE  
RESEARCH & EXTENSION

# Shoreline Restoration

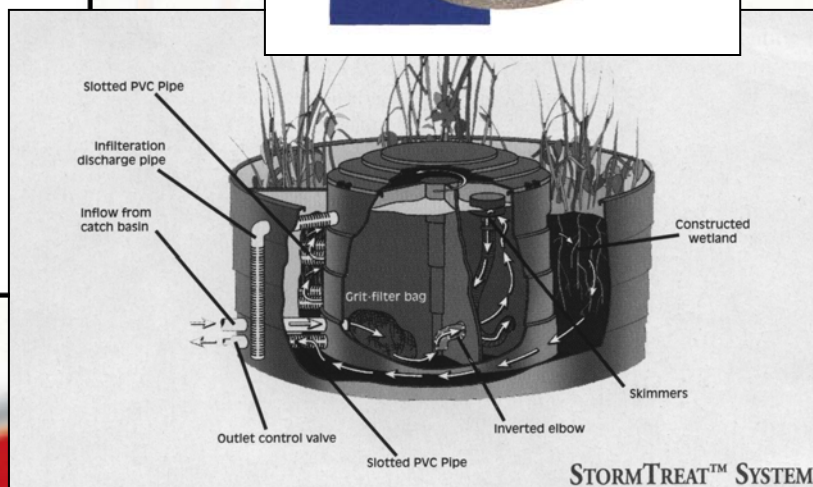
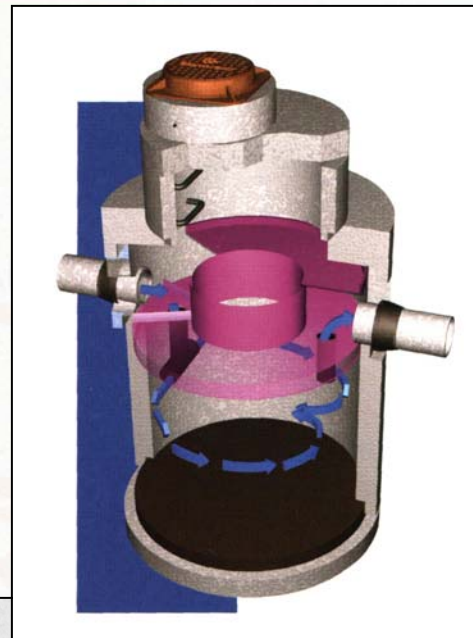
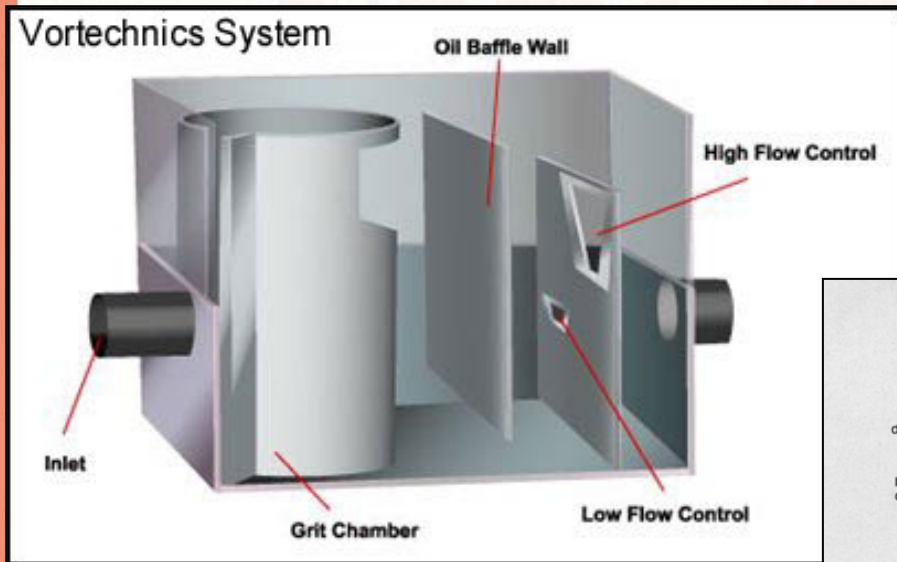
## Bioretention Systems





# Shoreline Restoration

## Pre-manufactured treatment systems





# References

Cooke, G.D, Welch, E.B., Peterson, S.A., and Newroth, P.R., 1993. Restoration and Management of Lakes and Reservoirs, Second Edition, Lewis Publishing, CRC Press, Inc.

McComas, S., 1993. LakeSmarts, The First Lake Maintenance Handbook, Terrene Institute.

USEPA, 1990. The Lake and Reservoir Restoration Guidance Manual, Second Edition, EPA 440/4-90-006.

Terrene Institute and North American Lake Management Society, 2001. Managing Lakes and Reservoirs, Third Edition.

FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US gov't). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3. [http://www.nrcs.usda.gov/technical/stream\\_restoration](http://www.nrcs.usda.gov/technical/stream_restoration)