Nitrogen and Wastewater Systems:

Fate of Nitrogen in Wastewater, Control Technology Options, Managing Wetlands and other Natural Systems to Control Nitrogen, etc.

briefing for

SAB's Integrated Nitrogen Committee

Wednesday, 31January 2007

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Office of Wastewater Management

2003-2008 EPA Strategic Plan: Direction for the Future

- **Goal 2**: Clean and Safe Water
- **Objective 2.2**- Protect water quality… of rivers, lakes, streams on watershed basis and protect oceans and coastal waters
  - Sub-Objective 2.2.1- Improve water quality on a watershed basis
  - Sub-Objective 2.2.2- Improve coastal and ocean waters

Improving Water Quality on a Watershed Basis

- Strengthen WQ standards program
- Improve WQ monitoring and assessment programs
- Develop effective watershed plans/TMDLs
- Implement effective NPS control program
- Strengthen NPDES permit program
- Effective management of infrastructure assistance programs

CWA Classes of Pollutants

- Conventional pollutants
  - BOD, TSS, oil and grease, fecal coliform bacteria, and pH
- Toxic pollutants
  - 126 “Priority Pollutants”
  - Heavy metals (e.g., Cu, Pb, Hg)
  - Organic compounds (e.g., PCBs, dioxin)
- Non-Conventionals
  - Everything else…
  - E.g., chlorine, ammonia, nitrogen, phosphorus

Nutrient Loading Paradigm

Urban Run off

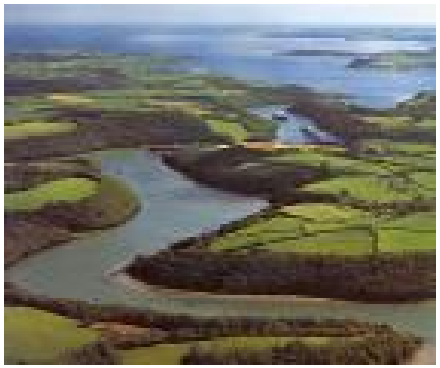
Agriculture

Sewage/Septic

Atmospheric Deposition

Forest

Ocean



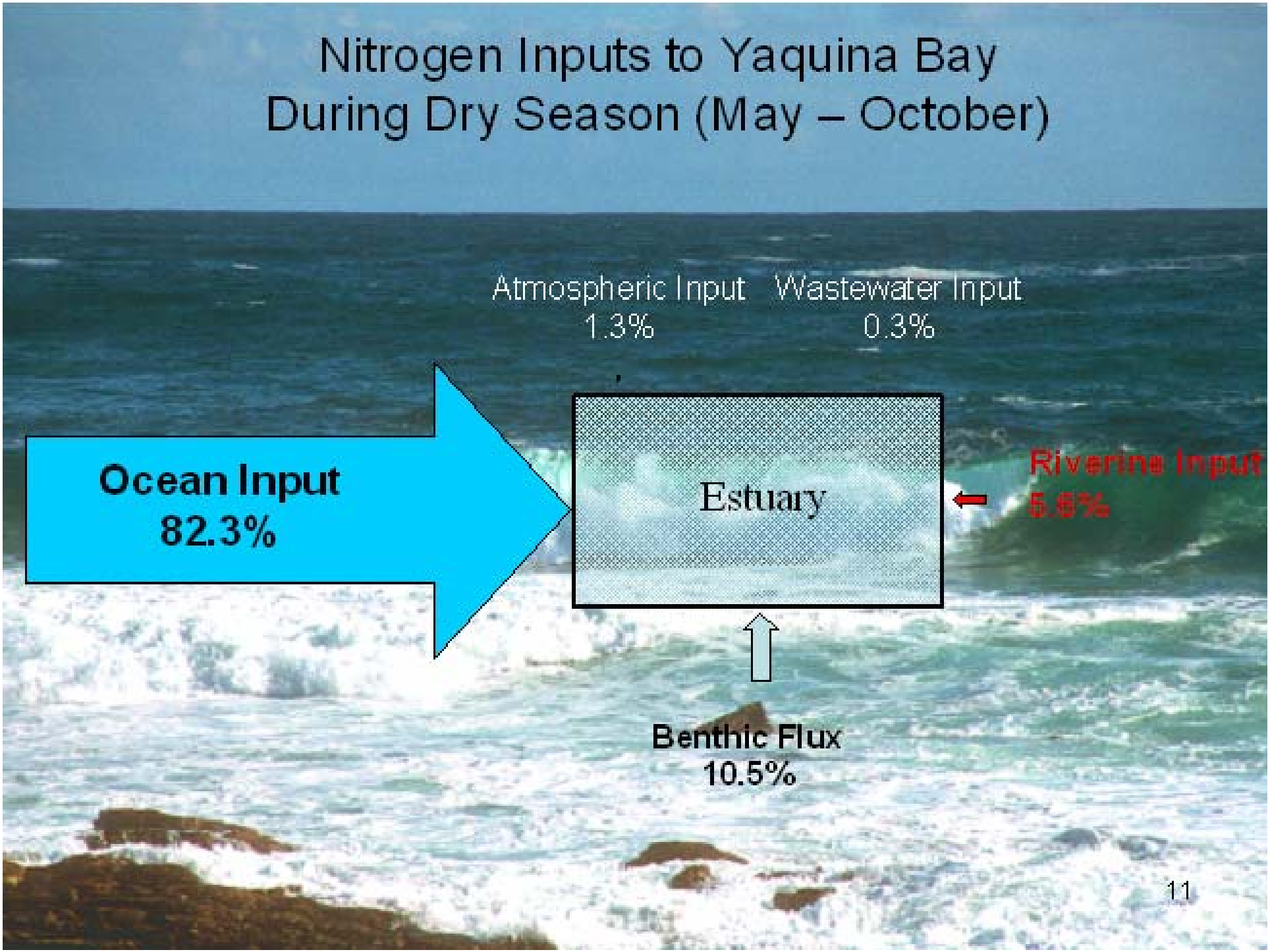
Fish Kills

HABs

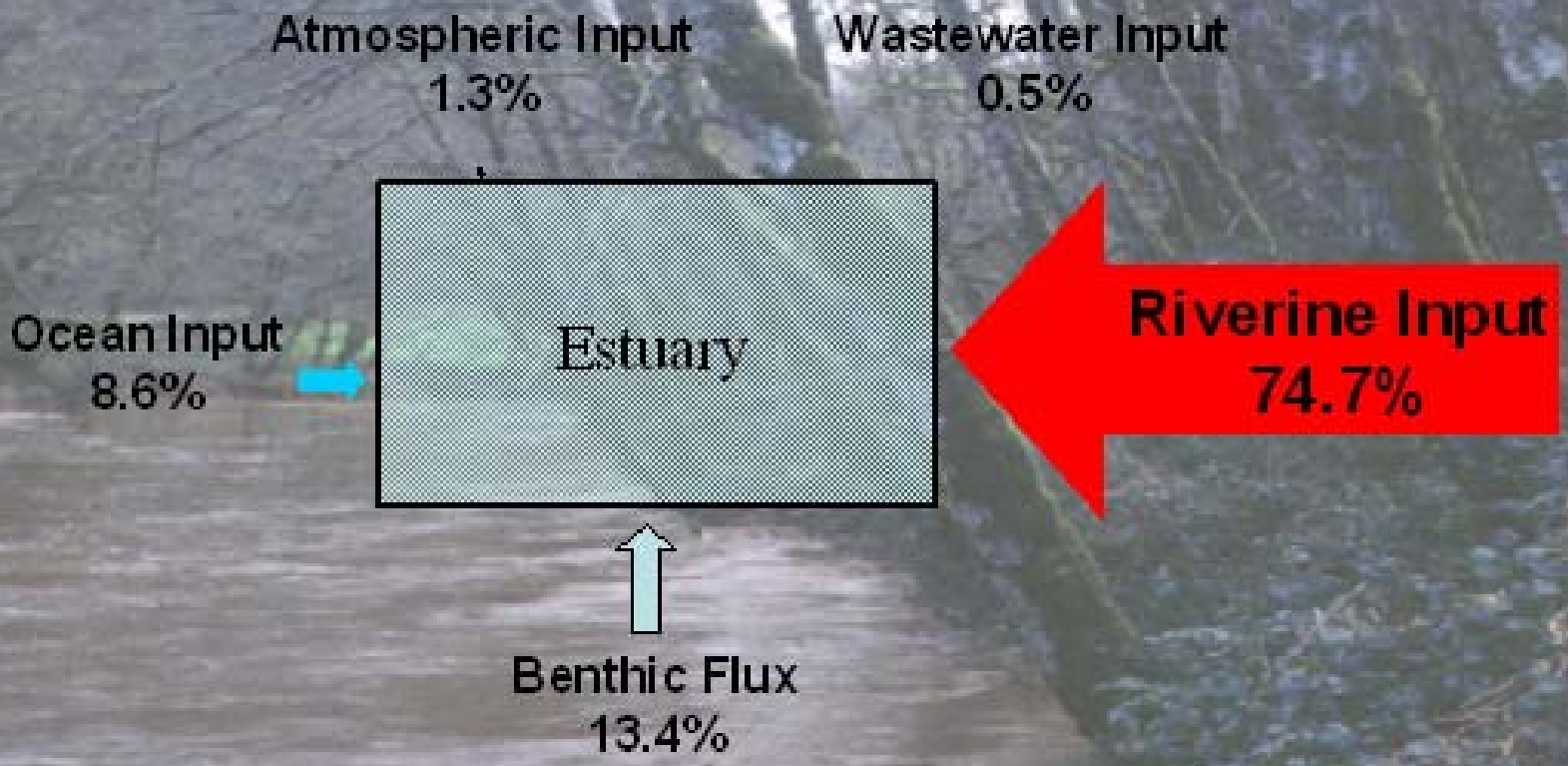
Macroalgal Blooms

Seagrass Loss

Nitrogen Inputs to Yaquina Bay During Dry Season (May – October)



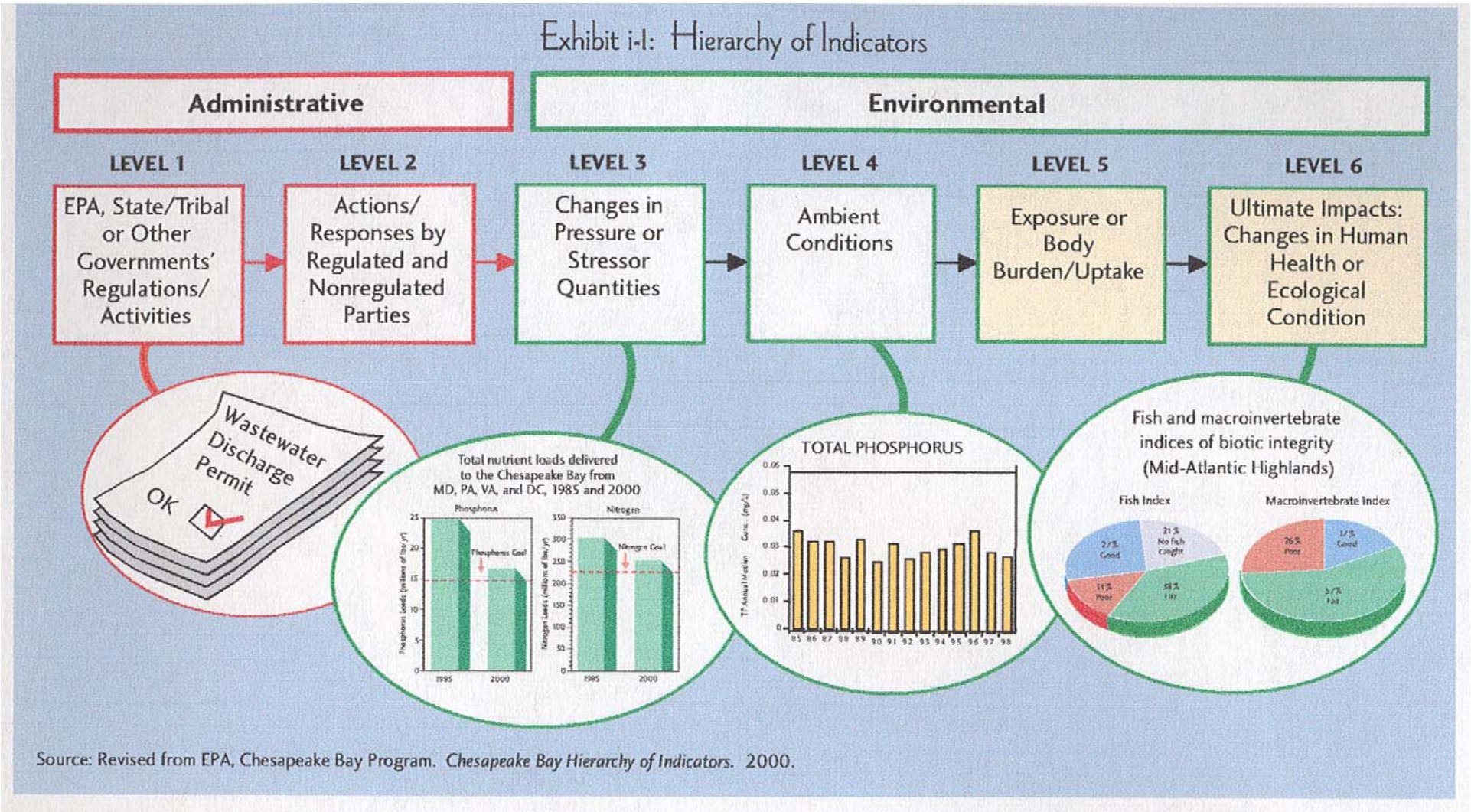
Nitrogen Inputs to Yaquina Bay During Wet Season (Nov – Apr)



Chemical & Physical Indicators

- Water clarity (secchi depth; chlorophyll; suspended solids)
- Dissolved oxygen
- Chemical contaminants (pesticides/metals)
- Nutrients (N,P) & Organic carbon/BOD ambient levels and loads in surface waters
  - Farmland; forest; urban; coastal; large rivers; lakes & reservoirs

Hierarchy of Indicators



Source: Revised from EPA, Chesapeake Bay Program. *Chesapeake Bay Hierarchy of Indicators.* 2000.

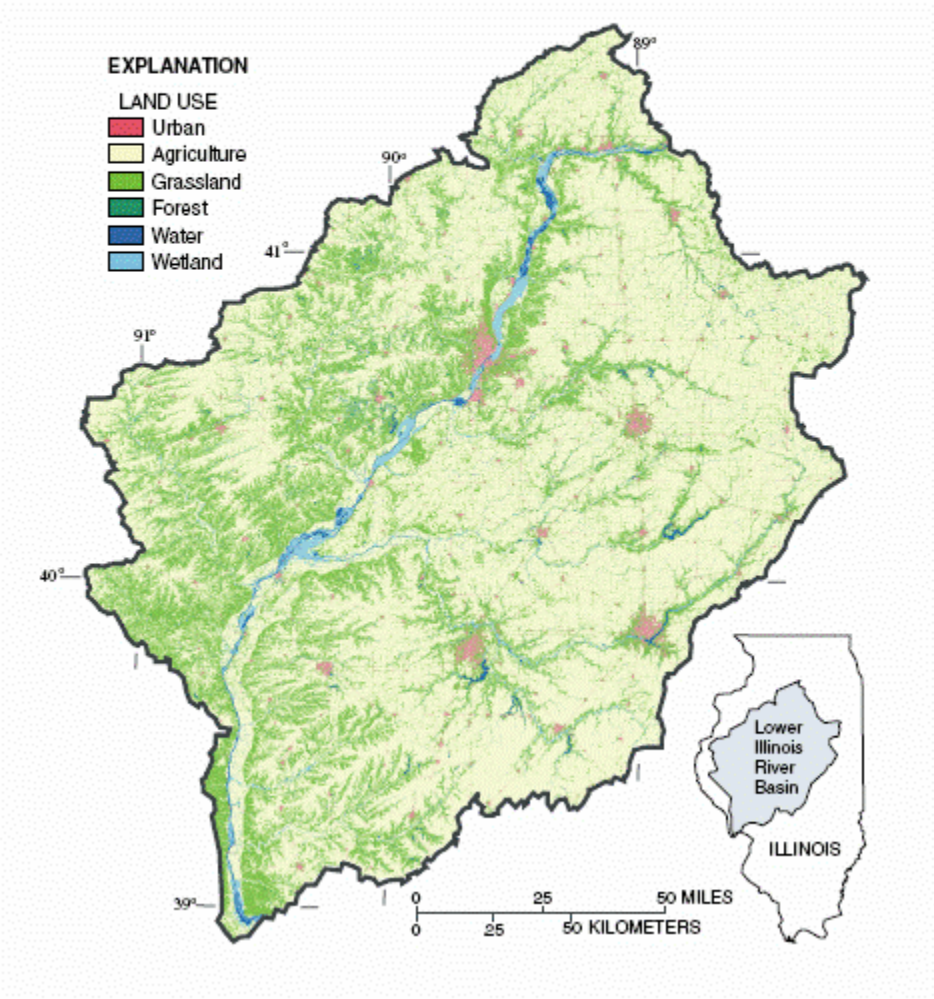
Layers of *Cladophora* algae along
a Lake Erie rocky shoreline.

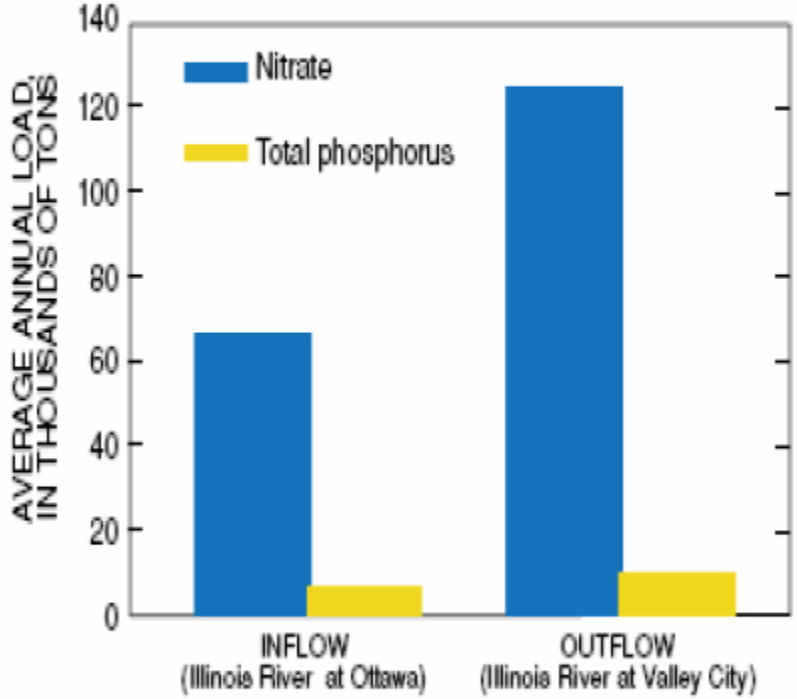
Retrospective Questions
Clean Water Act (CWA)

- What are PS & NPS loading trends since CWA ?
- What are water quality trends since CWA ?
- What are aquatic resource trends since CWA ?
- How do you evaluate effectiveness of PS & NPS control policies, programs & regulations ?

Availability of models, monitoring data & accurate assessment methods is essential to provide answers to Congress & stakeholders

Looking at Diffused Sources of Nitrogen

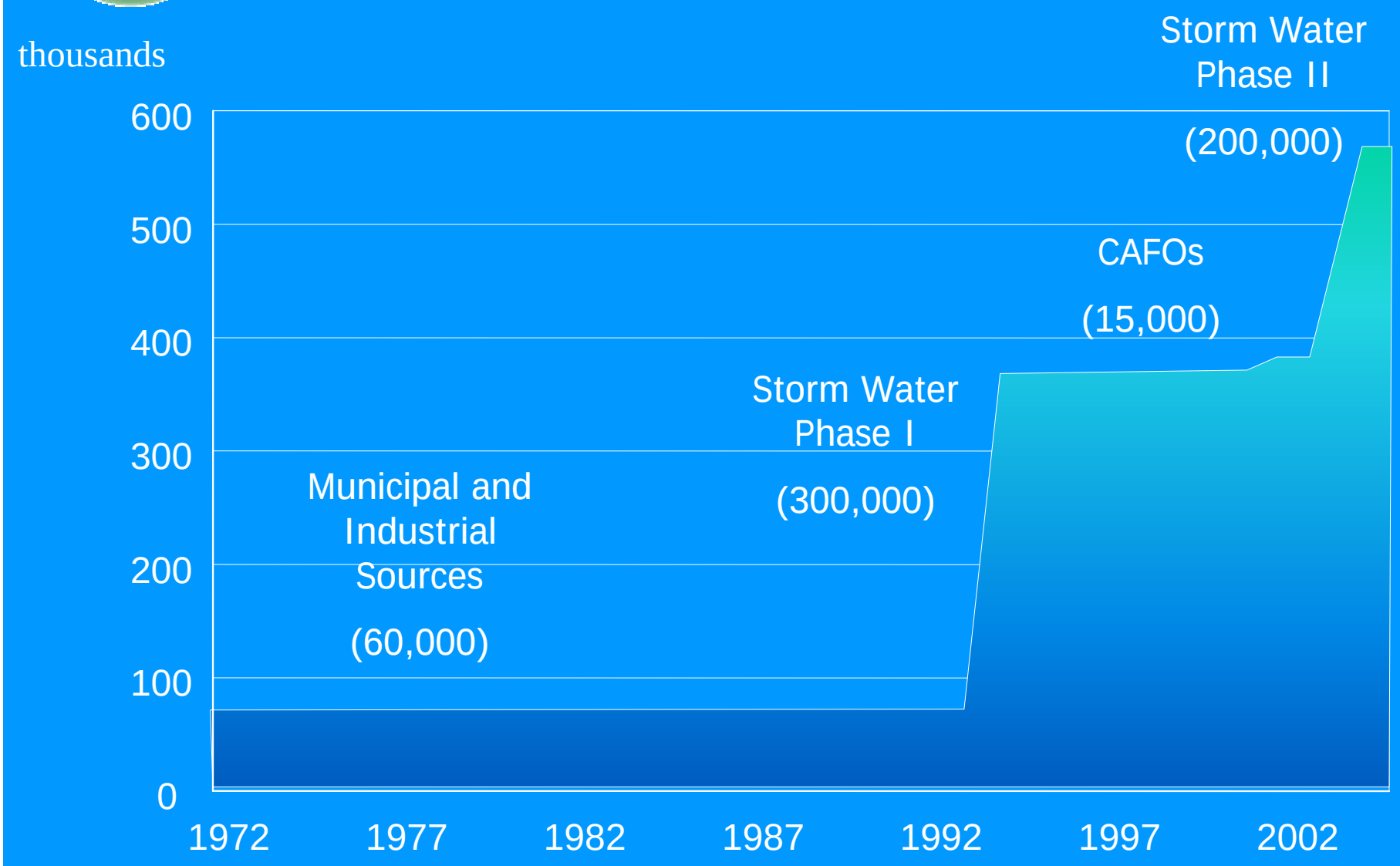




Performance Measures of Water Quality

- PS & NPS control policies are designed to reduce ‘peak’ levels of key water quality constituents to meet designated uses and comply with water quality criteria/standards
- Assessments based on key water quality chemical & physical constituents at ‘worst case’ conditions of streamflow, season, location on reach, presence/absence of PS discharges

NPDES Universe

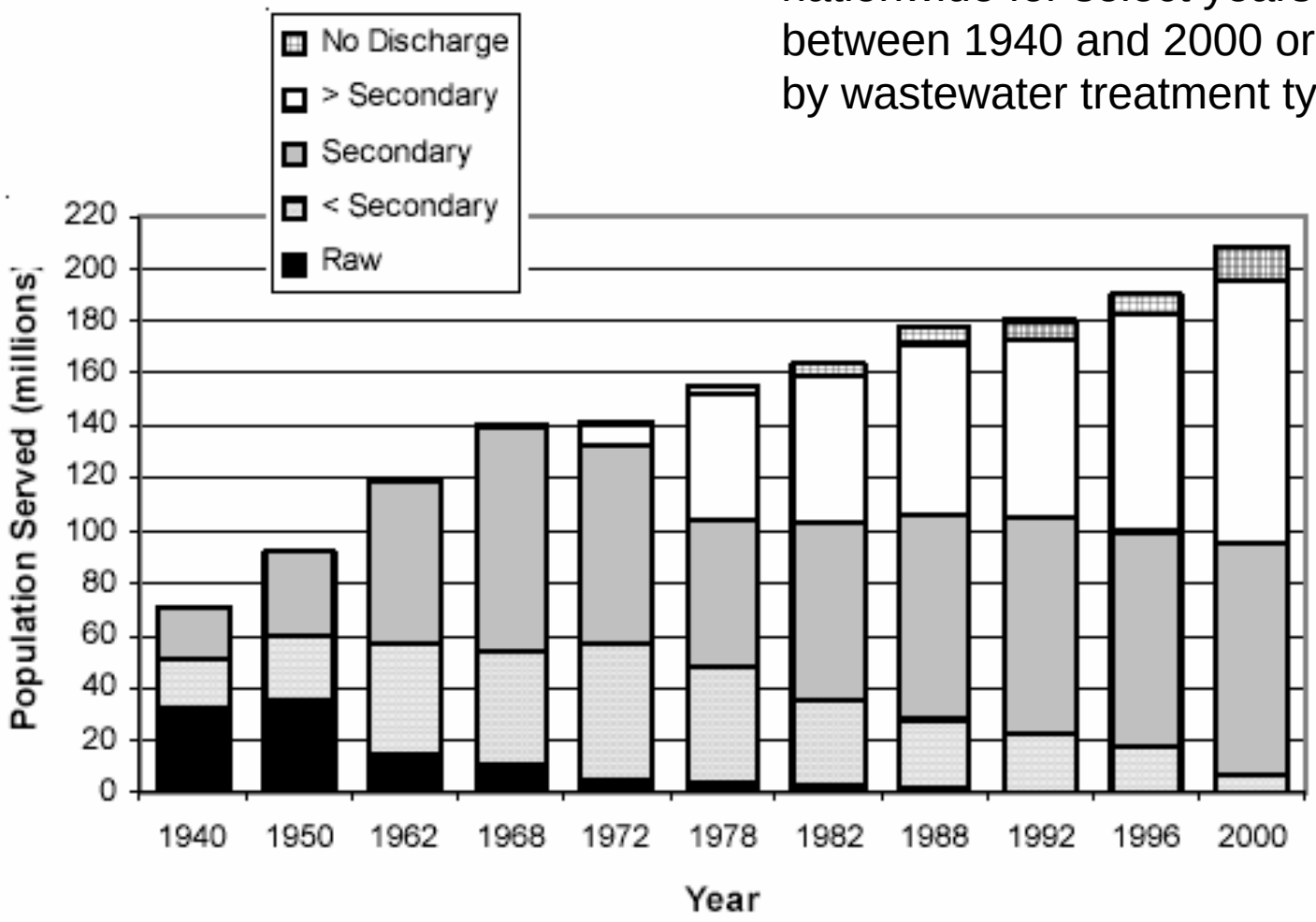


Number of POTWs by flow range

	POTWs in Operation in 2000	
Existing Flow Range in mgd	Number of POTWs	Total Existing Flow (mgd)
0.001 to 0.100	6,583 (40%)	290 (.8%)
0.101 to 1.000	6,462 (40%)	2,339 (7%)
1.001 to 10.000	2,665 (16%)	8,328 (24%)
10.001 to 100.000	487 (3%)	12,741 (37%)
100.001 and greater	46 (.3%)	11,201 (32%)
Other*	12 (.07%)	--
Total	**16,255**	34,899

*flow data for these facilities were unavailable

Population served by POTWs nationwide for select years between 1940 and 2000 organized by wastewater treatment type.



The findings of a nationwide analysis comparing POTW discharges in 1968 and 1996 revealed that …

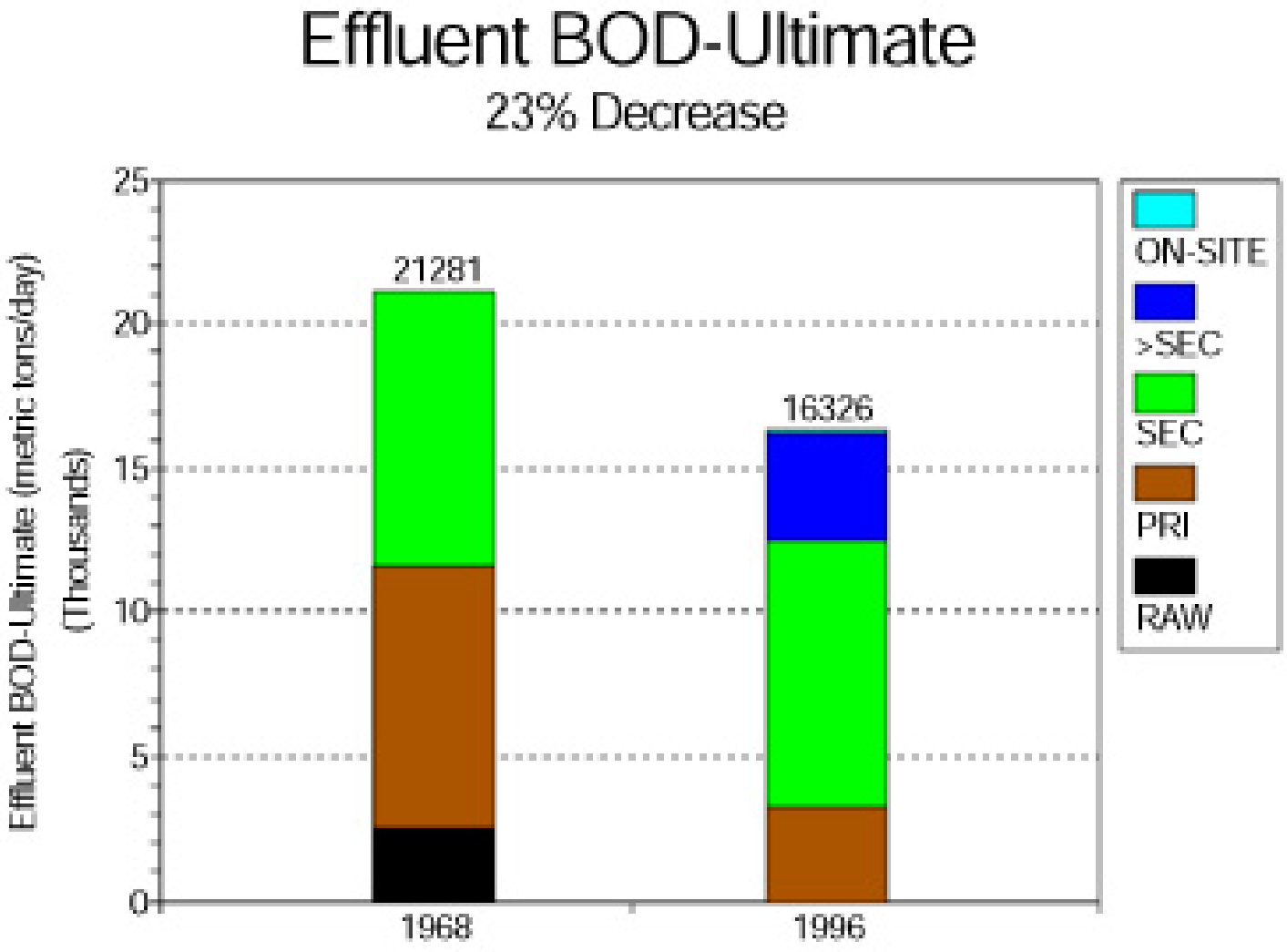
- Effluent BOD_5 releases from POTWs were reduced by 45%
- While influent loadings to POTWs increased by 35%
- The number of people served by POTWs with secondary or greater levels of treatment almost doubled (from 85.9 million to 164.8 million)
- Nationwide aggregate removal efficiencies for BOD_5 and BOD_U in 1968 were about 63% and 39% respectively, while by 1996, these removal efficiencies rose to nearly 85% and 65% respectively

The findings of a nationwide analysis comparing POTW discharges in 1968 and 1996 revealed that …

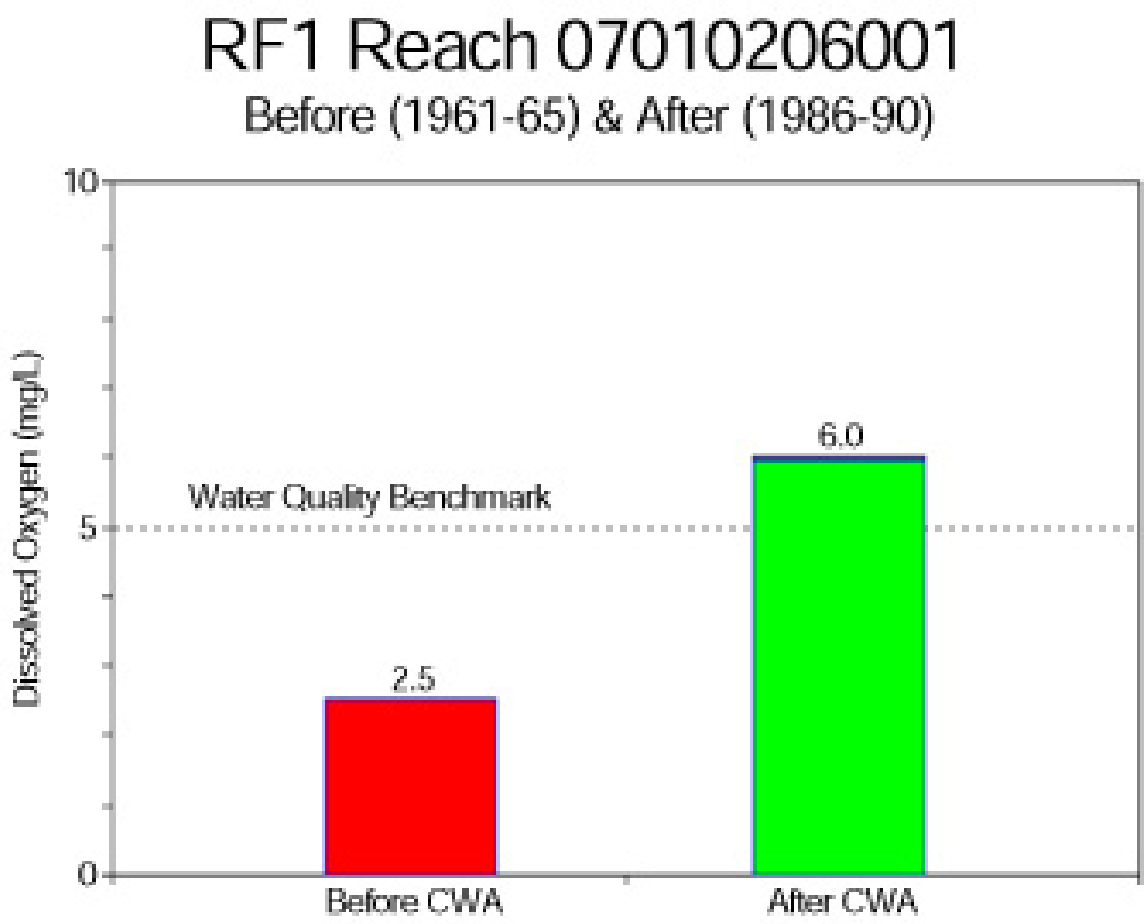
- The study also projects that without continued improvements in wastewater treatment infrastructure resulting in increased removals of pollutants, future population growth will erode away many of the CWA achievements in effluent loading reduction to the point that by the year 2016, BOD loadings rates could be similar to those experienced in the mid-1970s.

- These findings and projections underscore the importance of the need to continually invest in improvements to wastewater infrastructure in order to maintain and improve pollutant removal efficiencies and avoid reversing the environmental gains of the last three decades.

Municipal Wastewater:1968-96

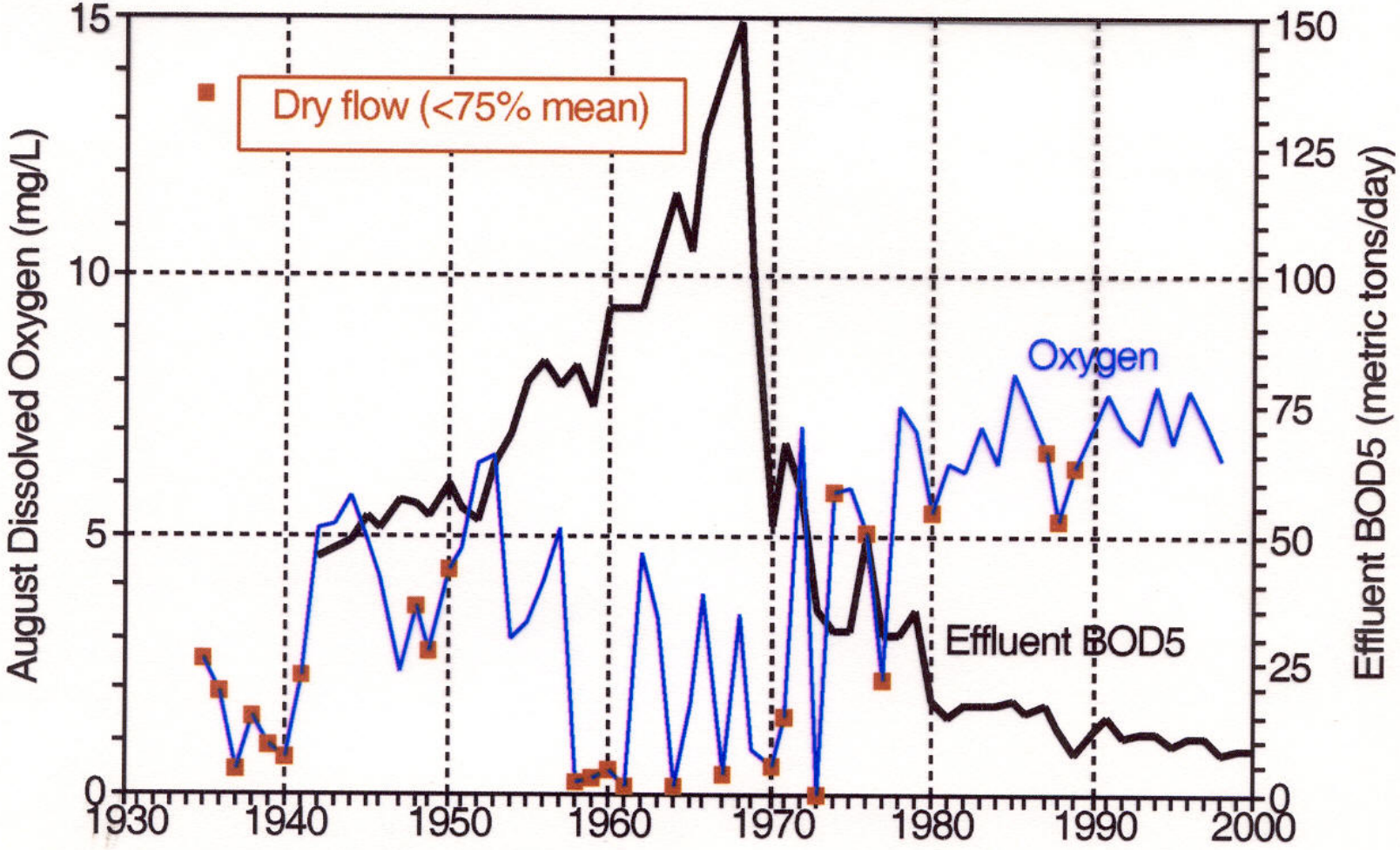


Upper Mississippi River Dissolved Oxygen “Signal”



Upper Mississippi River

Grey Cloud (UM 826.7)



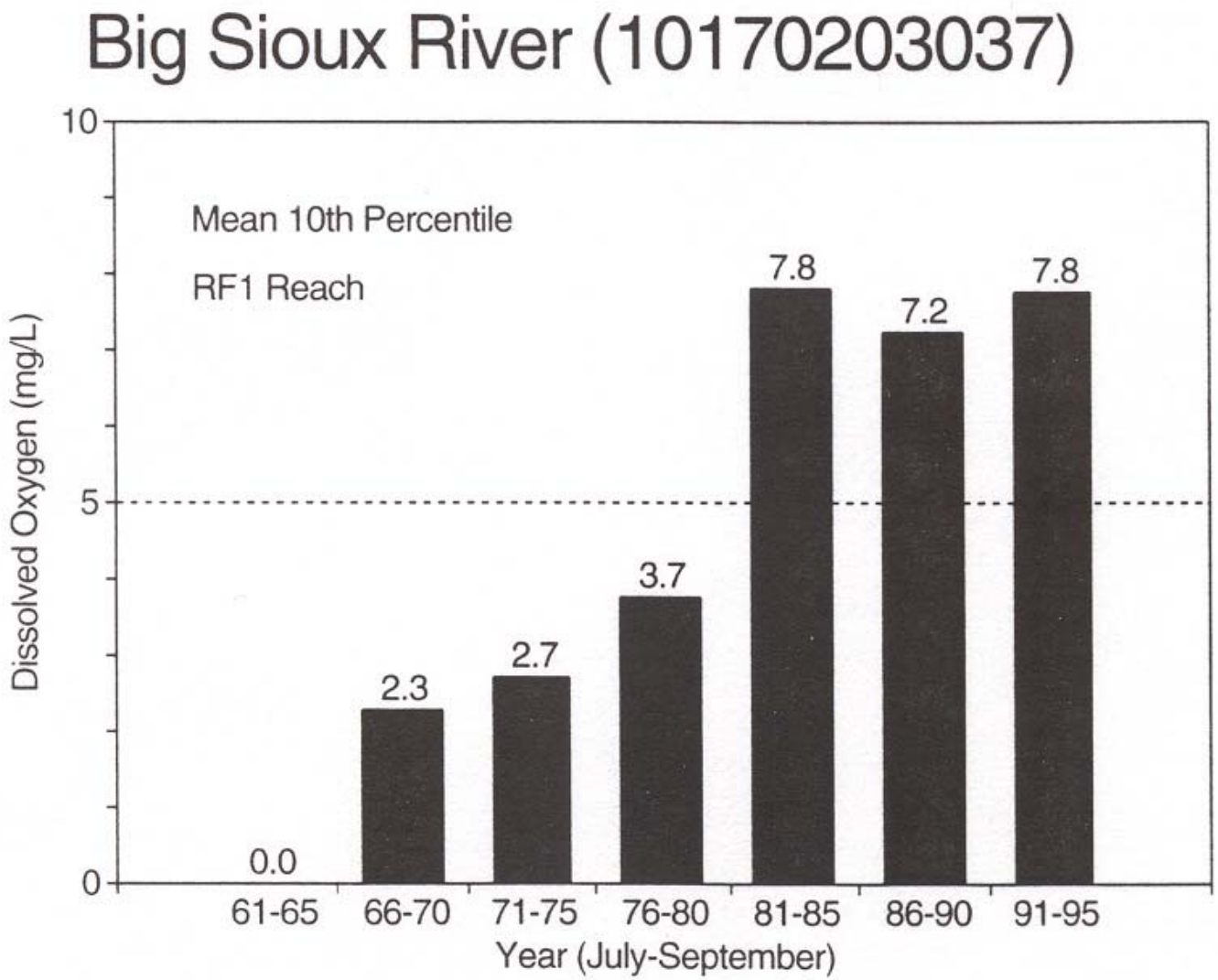
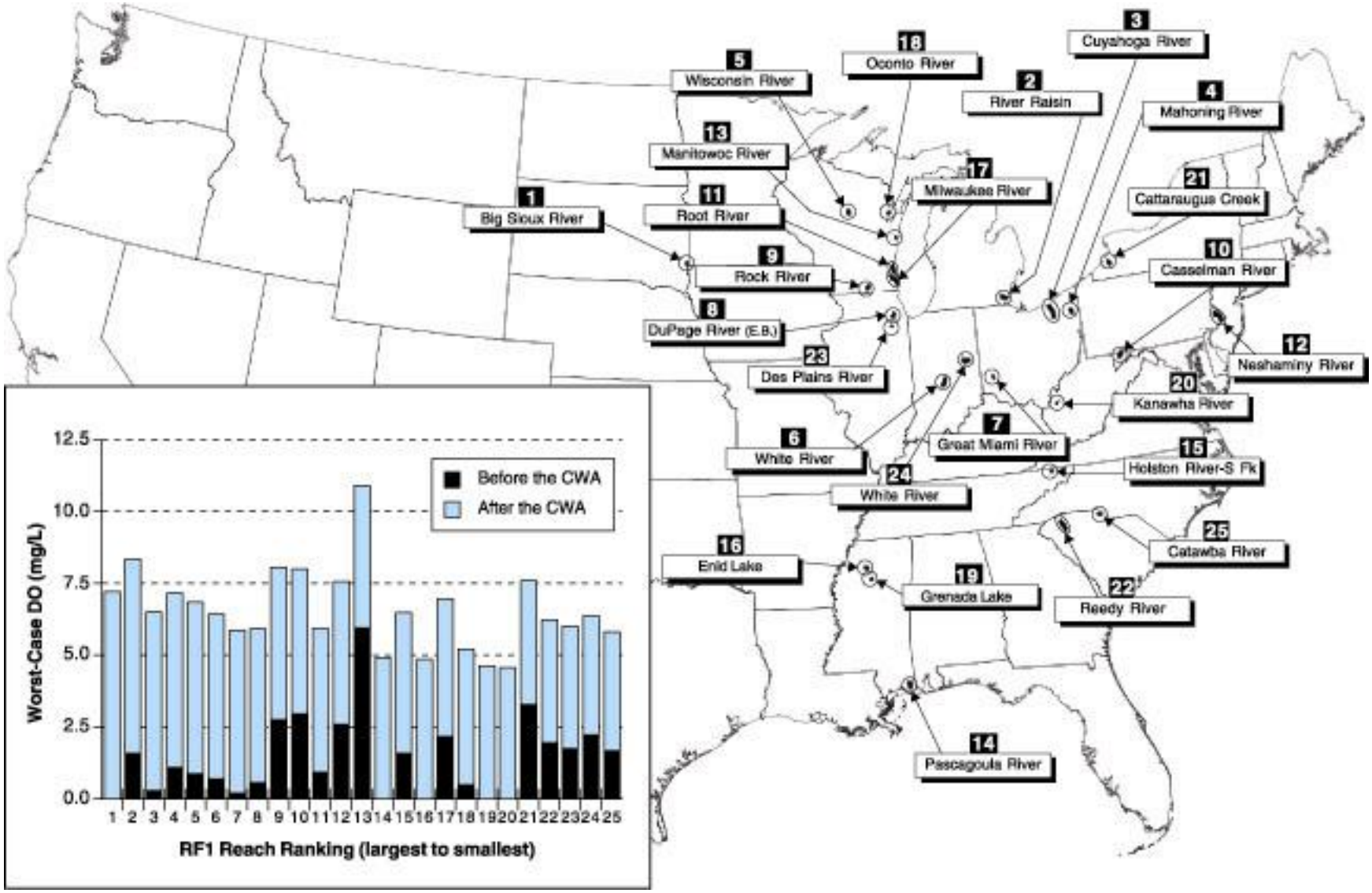
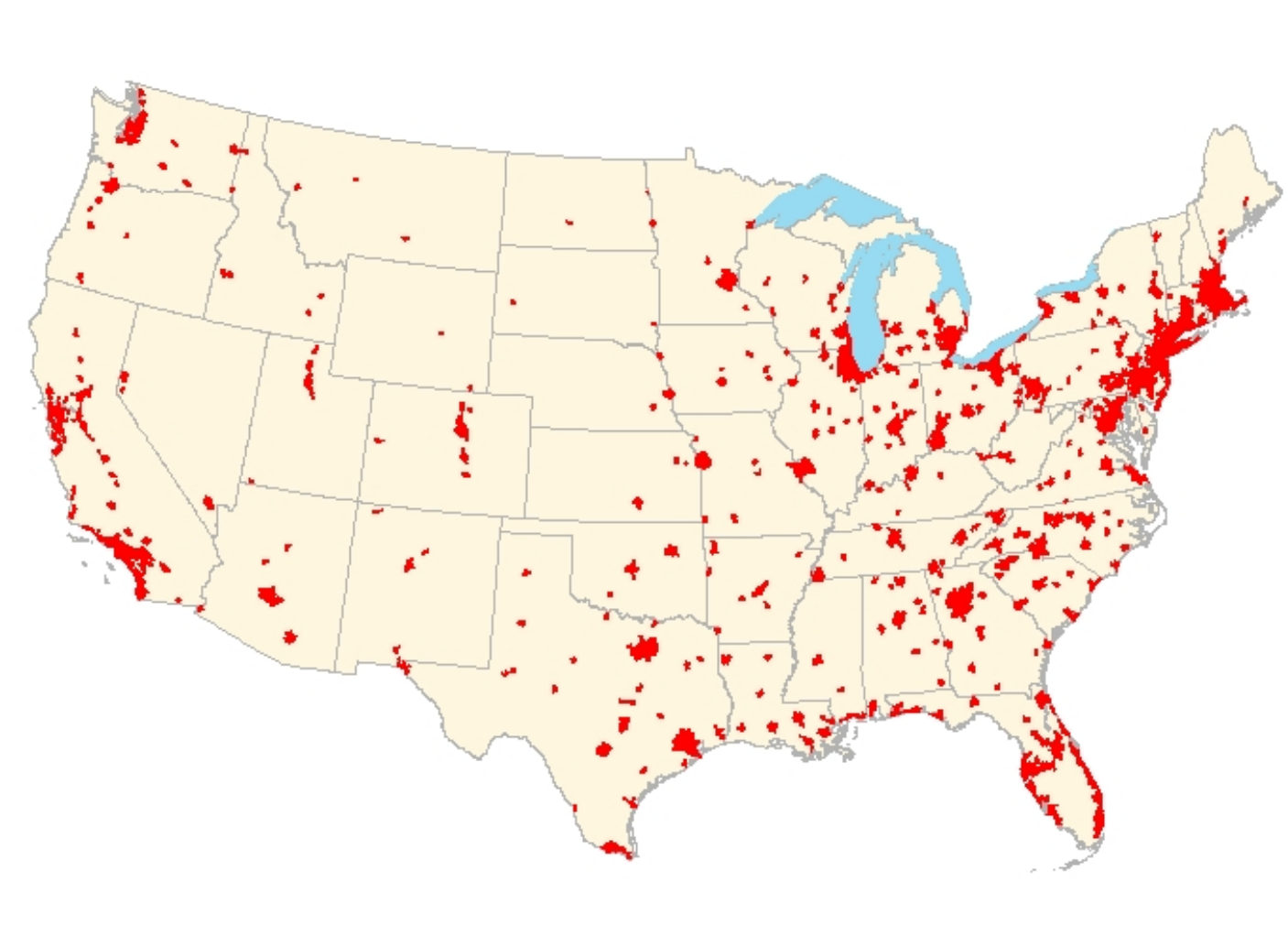


Figure 3-36 Time series from 1961–1995 of tenth percentile dissolved oxygen: (*a*) for Lower Big Sioux catalog unit (10170203), and (*b*) for Big Sioux River RF1 reach (10170203037). *Source:* USEPA STORET.

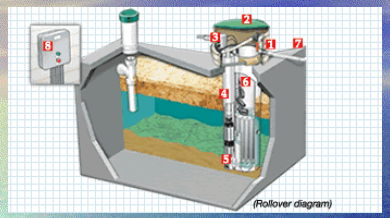
Distribution of 25 RF1 Reaches with greatest DO Improvements



Urbanized Areas, 2000 Census



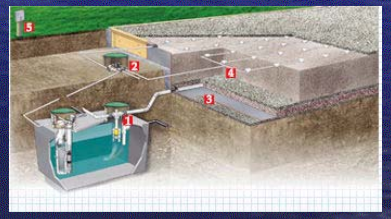
Examples of Advanced Treatment Technologies



Effluent Pumping

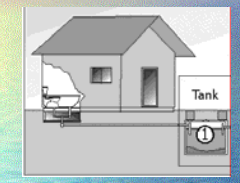
Textile Filter

Intermittent Sand Filter



Recirculating Sand Filter

Technology Capabilities



WASTEWATER FROM HOME

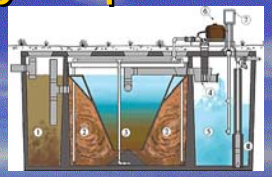
BOD: 110 - 400 mg/L
TSS: 100 - 350 mg/L
TN: 40 - 100 mg/L
TP: 5 - 15 mg/L
Fecal: 10^6 - 10^9 col/100 ML

SEPTIC TANK EFFLUENT

BOD: 110 - 200 mg/L
TSS: 50 - 100 mg/L
TN: 40 - 100 mg/L
TP: 5 - 15 mg/L
Fecal: 10^6 - 10^8 col/100 ML

SEPTIC TANK EFFLUENT, WITH RECYCLE

BOD: 80 - 120 mg/L
TSS: 50 - 80 mg/L
TN: 10 - 30 mg/L
TP: 5 - 15 mg/L
Fecal: 10^6 - 10^9 col/100 ML



AEROBIC UNIT EFFLUENT

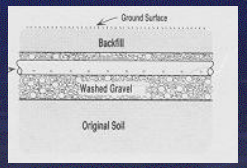
BOD: 5 - 50 mg/L
TSS: 5 - 100 mg/L
TN: 25 - 60 mg/L
TP: 4 - 10 mg/L
Fecal: 10^3 - 10^4 col/100 ML

SAND FILTER EFFLUENT

BOD: 2 - 15 mg/L
TSS: 5 - 20 mg/L
TN: 10 - 50 mg/L
TP: <1 - 10 mg/L
Fecal: 10^1 - 10^3 col/100 ML

FOAM/TEXTILE FILTER EFFLUENT

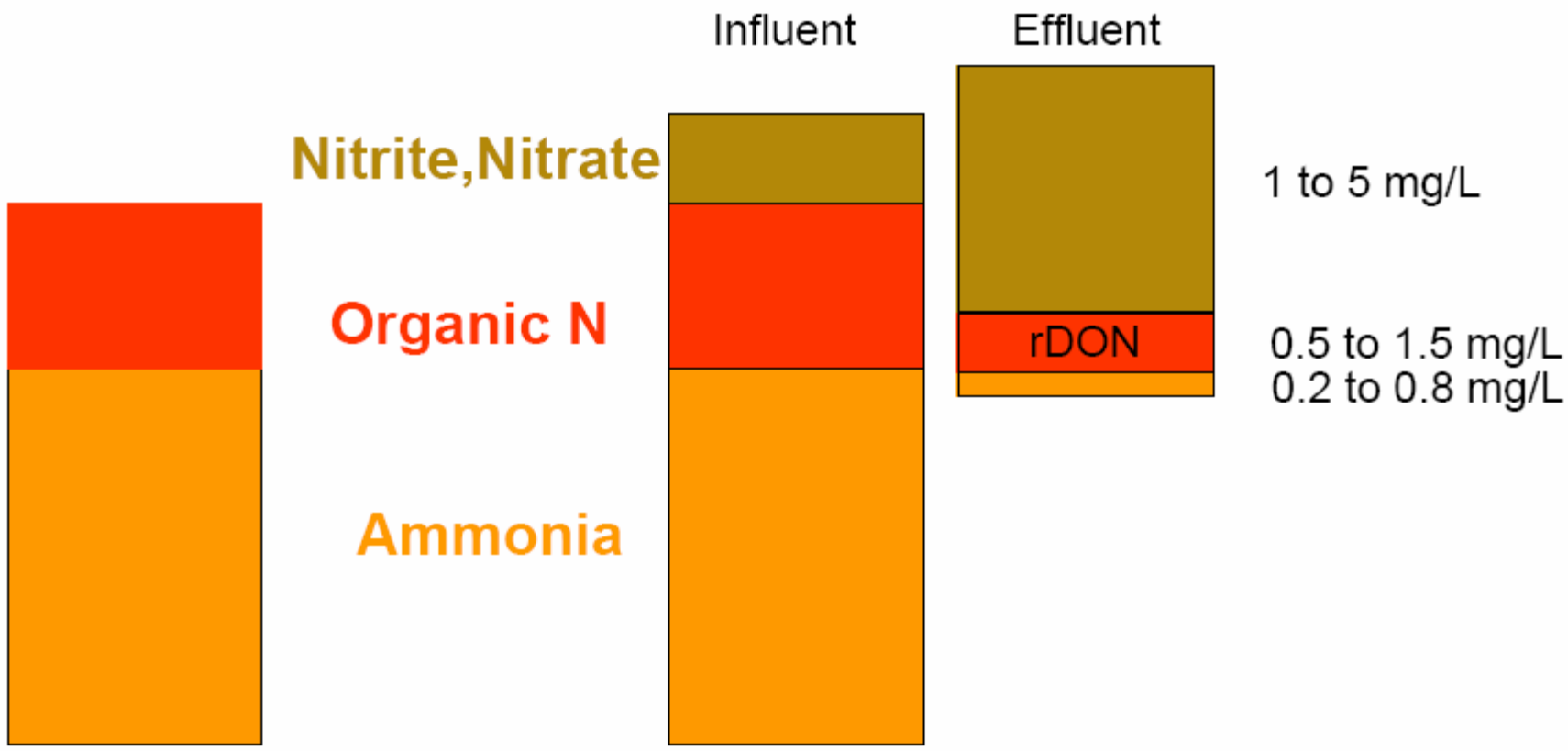
BOD: 5 - 15 mg/L
TSS: 5 - 10 mg/L
TN: 3 - 60 mg/L
TP: 5 - 15 mg/L
Fecal: 10^1 - 10^3 col/100 ML



FURTHER ATTENUATION BY SOIL

BOD: >90%
TSS: >90%
TN: 10 TO 20%
TP: 0 - 100%
Fecal: >99.99%

Classification of Nitrogen Compounds



Total Kjeldahl Nitrogen (TKN)

Total Nitrogen (TN)

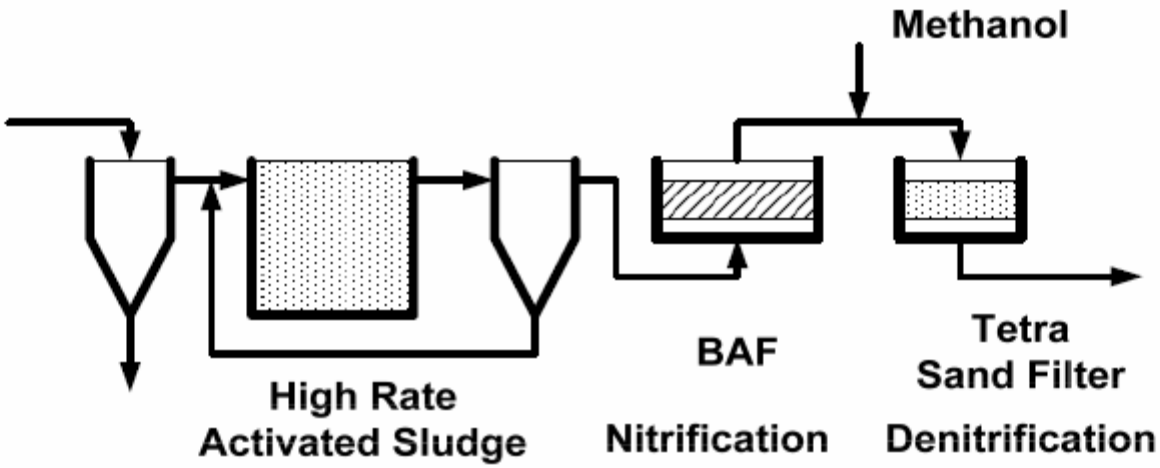
Influent Total Nitrogen

- Mostly Organic N and Free and Saline Ammonia
- Most Organic N quickly hydrolyze to Ammonia
- Nitrates and Nitrates seldom present in raw waste
- Typical influent TKN range: 30 - 40 mg/L (Ammonia ~ 70% of TKN)

Treatment Methods

- Mostly Biological - Nitrification/Denitrification
  - Suspended growth
  - Fixed Film growth
- Physical/Chemical methods for return streams with high concentration

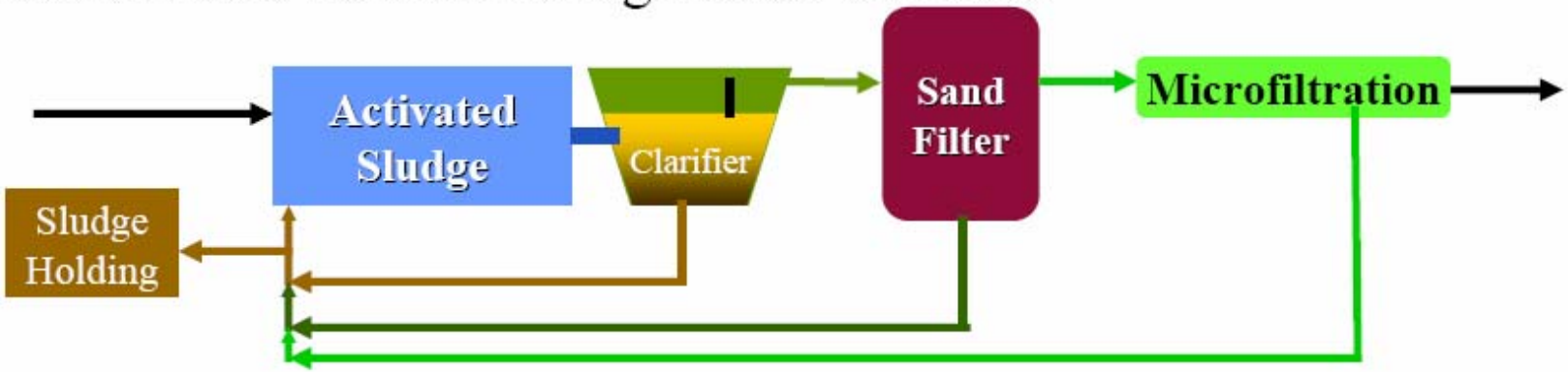
Retro-fitting High Rate Non Nitrifying plants for TN Removal



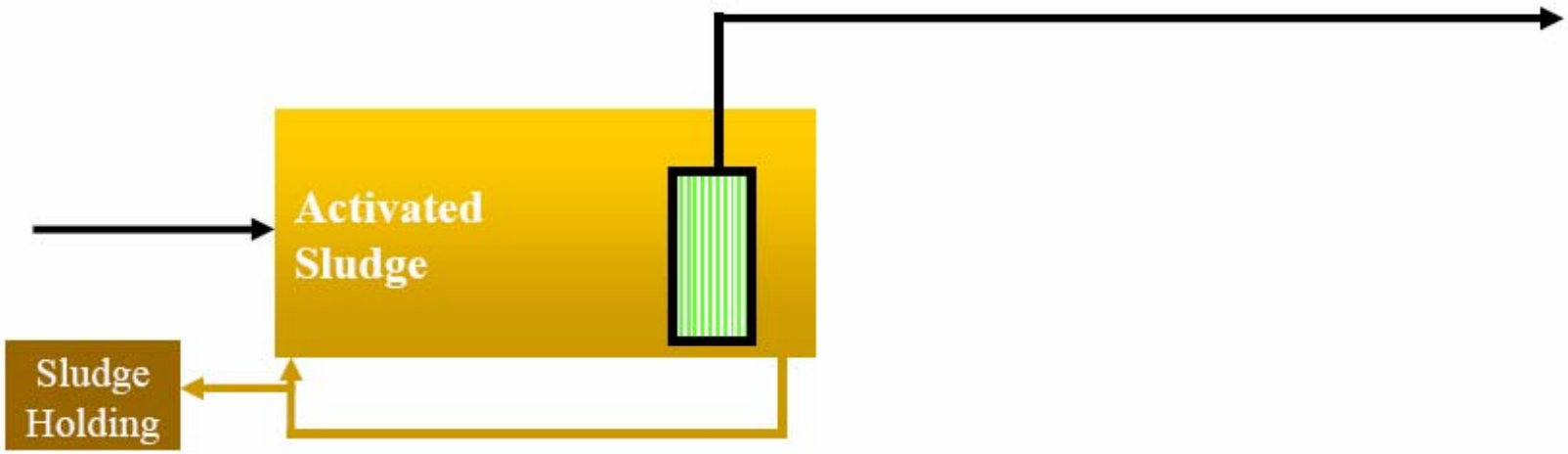
High Rate systems	Nitrification	Denitrification
Hi-rate activated sludge	Activated sludge	Denitrification Filters
Trickling filters	Trickling filters	BAF
BAF	BAF	MBBR
MBBR	MBBR	Fluidized Bed
	SAF	

Integrating Membranes with Activated Sludge Process

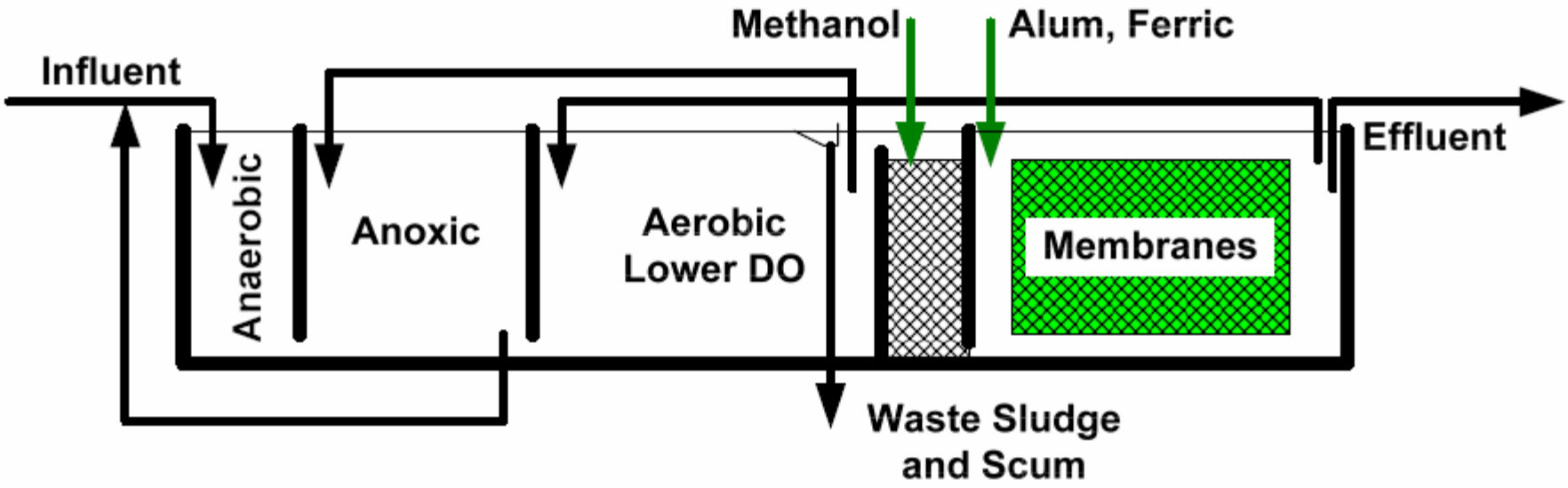
Conventional Process Using Micro-filtration



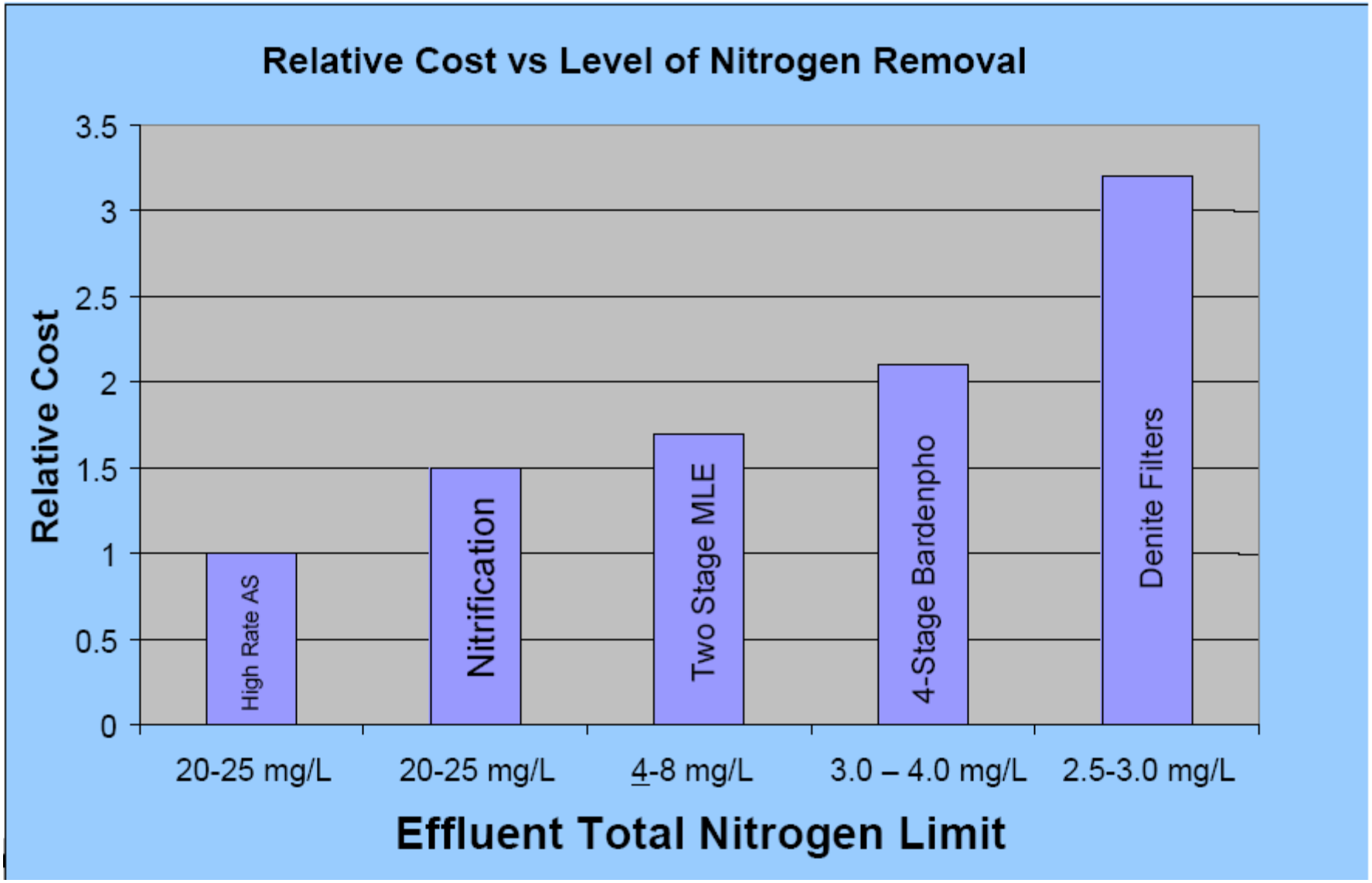
Integrated Membrane Bioreactor



Futuristic MBR BNR for low Total Nitrogen and Phosphorus



Relative Costs – Site Specific



Assessment of Nutrient Control Technologies

- Full Scale Facilities – w/one-year of performance data or more.
- Permit Limit-based groups
  - Added P removal to 1 ppm, 0.5 ppm, and 0.1 ppm and less (~0.01 ppm min.)
  - Added Nitrogen removal down to 8 ppm, 5 ppm, and 3 ppm and less (~0.05 ppm min.)
  - Combined Nitrogen and Phosphorus Removal (TN ~0.84 ppm; TN ~0.06 ppm min.)

(min. = reported minimums)

Case Study Selection Criteria

- Technologies for enhancing nutrient removal
  - Chemical Addition
  - Filtration
- Emerging Technologies
  - Moving Bed Biofilm Reactor (MBBR)
  - Integrated Fixed-Film Activated Sludge (IFAS)
  - Membrane Bio-Reactors (MBR)
- Design and Operational Issues
- Technologies for treatment of recycle flows

Developing effective controls to protect public health and the environment

- Address multiple legislative mandates
  - Clean Water Act (CWA)
  - Resources Conservation and Recovery Act (RCRA)
  - National Environmental Policy Act (NEPA)
- Establish effective policies, regs and guidance
  - Use of sound science in decision-making
  - Consider implementation costs, technical feasibility, social and political considerations, etc.
- Use of voluntary programs and partnerships in lieu of traditional regulatory requirements
- Provide funding and effective management tools to assist project design and implementation

Voluntary programs and partnerships in lieu of traditional regulatory requirements

- Environmental Management Systems (EMSs), ISO 9,000/4,001 Standards, and other coalitions
- Use of effluents as an alternative water supply
- Use of residuals in alternative products (e.g., high quality fertilizer and soil amendment products)
- Use of residuals in restoration efforts (e.g., land reclamation, SUPERFUND and Brownfield sites)

Address conflicting legislative mandates

… Protect public health & the environment while:

- Encouraging recycling/reuse
- Encouraging use of new technology
- Minimizing costs, reporting burdens, etc.
- Assuring implementability
- Using sound science
- Providing flexibility
- Facilitate public involvement thru an open, transparent process

Suggested Water Recycling Treatment and Uses*

Increasing level of treatment

Water Collection System

Primary Treatment: Sedimentation

- No uses Recommended at this level

Secondary Treatment: Biological Oxidation, Disinfection

- Surface irrigation of orchards and vineyards
- Non-food crop irrigation
- Restricted landscape impoundments
- Groundwater recharge of nonpotable aquifer**
- Wetlands, wildlife habitat, stream augmentation**
- Industrial cooling processes**

Tertiary/Advanced Treatment: 1. Chemical Coagulation, Filtration, Disinfection

- Landscape and golf course irrigation
- Toilet flushing
- Vehicle washing
- Food crop irrigation
- Unrestricted recreational impoundment
- Indirect potable reuse: Groundwater recharge of potable aquifer and surface water reservoir augmentation**

Increasing level of human exposure

*Suggested uses are based on Guidelines for Water Reuse, developed by U. S. EPA.
**Recommended level of treatment is site-specific.

Sustainable Land Application **Practices**

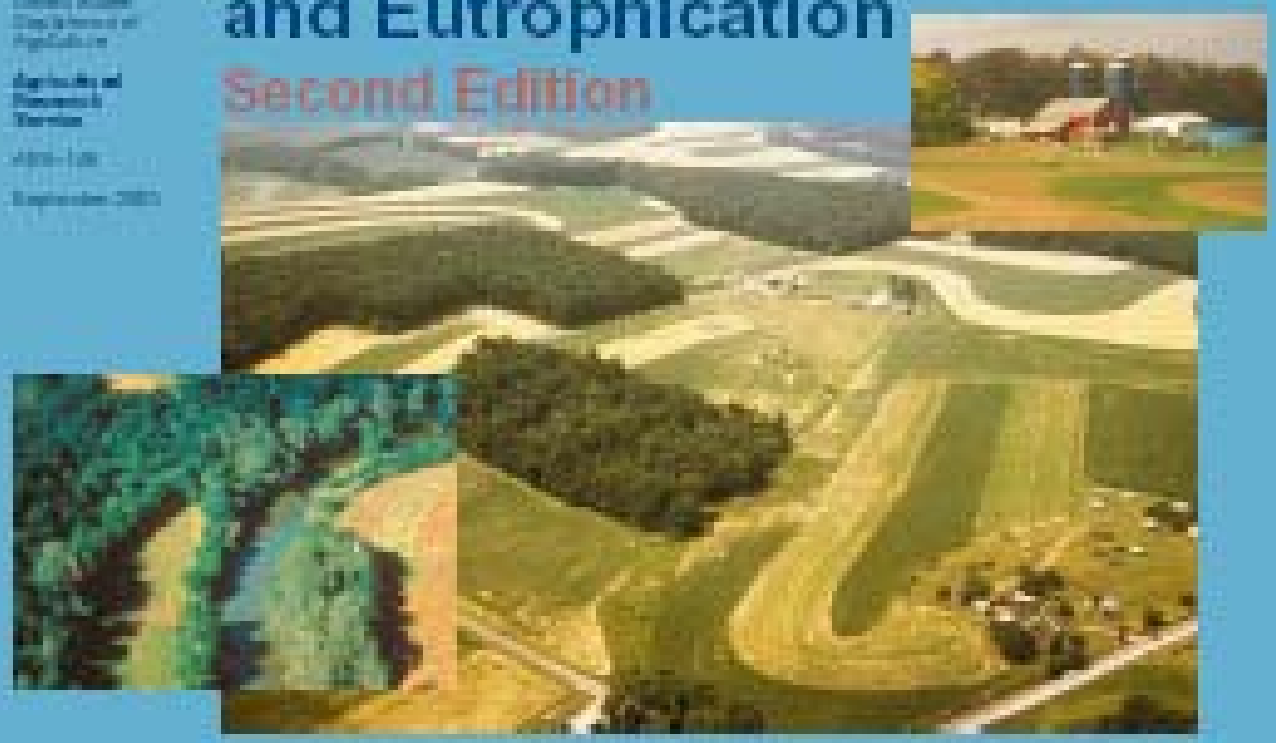
- The extensive available information developed over the years on soil and crop benefits, fate and effect of pollutants present in land applied effluents, sludges, manure, etc. under a wide range of conditions suggests that sustainable land application systems can be established and managed to achieve optimal yields while controlling excess levels of contaminants and pathogens

Sustainable Land Application Practices

- Soil reactions, some of which are temporary and others permanent, play an important role in developing controls and management practices for sustainable systems
  - Direct oxidation/reduction reactions
  - Adsorption/desorption
  - Biodegradation
  - Plant uptake
  - etc.

Agricultural Phosphorus and Eutrophication

Second Edition



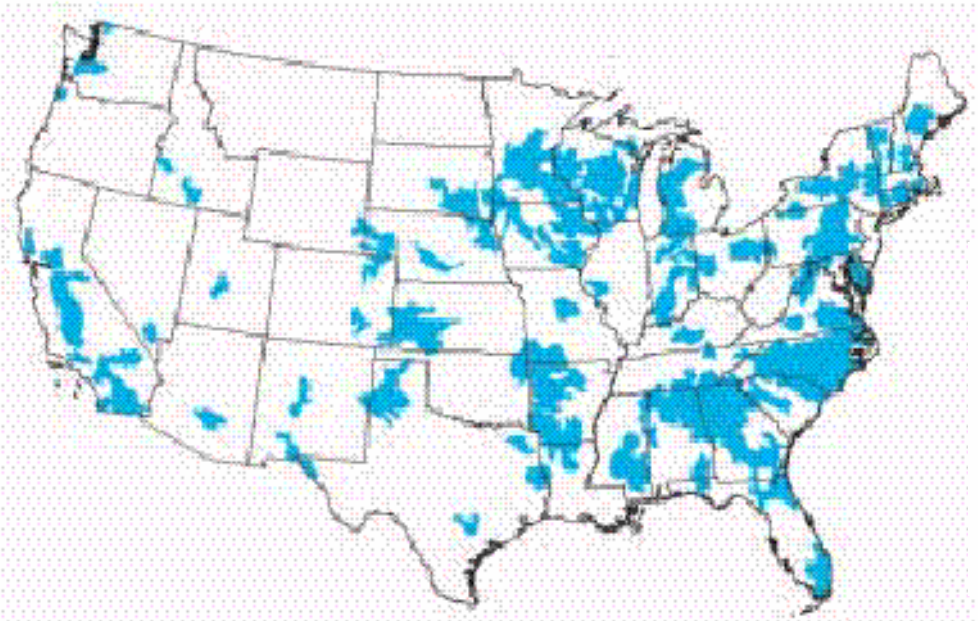


Figure 1. Watersheds with a high potential for soil and water degradation from manure P (Adapted from Kellogg and Lander 1999).

Table 1. Farming system and P balance

P	Farming system: Crop*	Dairy†	Poultry‡	Hogs§
Input	lb P/acre/yr			
Fertilizer	20	10	0	0
Feed	0	20	1,375	95
Output	–18	–13	– 365	-60
Balance	+2	+17	+1,010	+35

SOURCE: Lanyon and Thompson (1996) and Bacon et al. (1990).

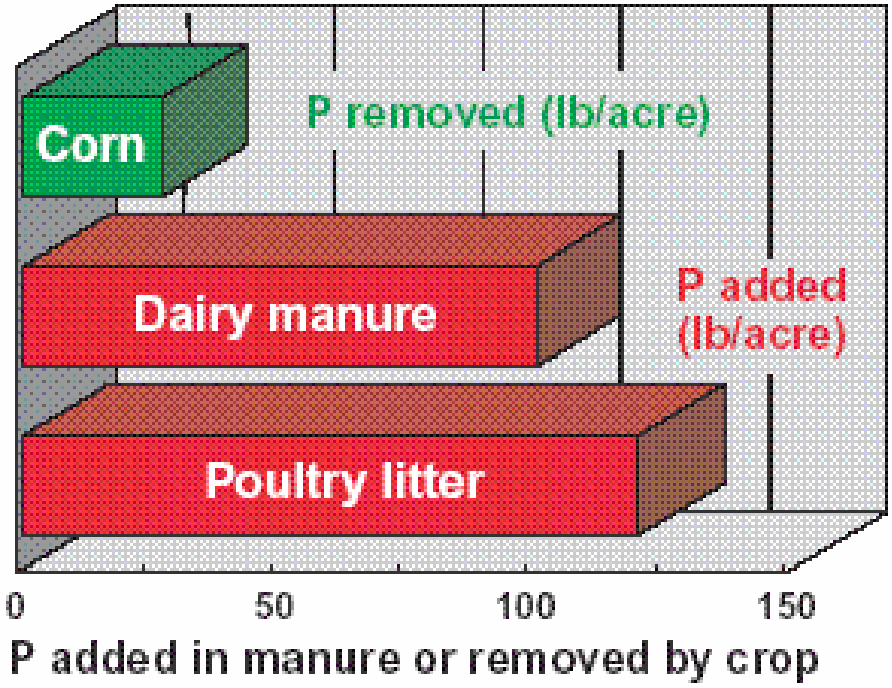
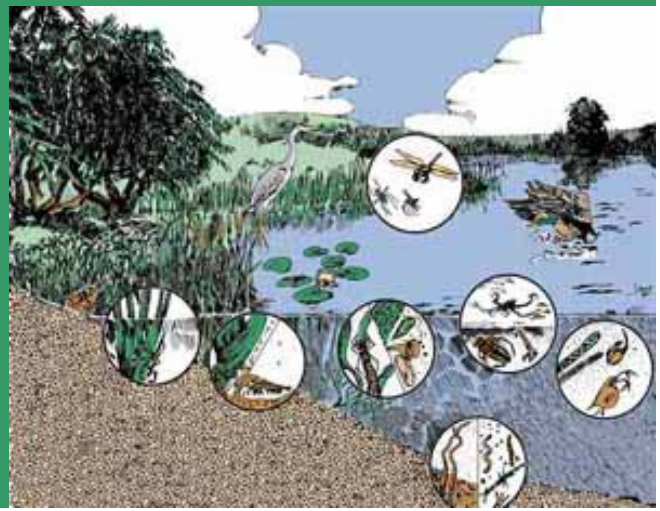
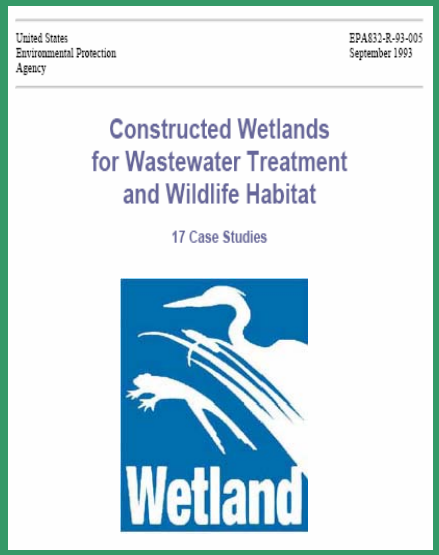
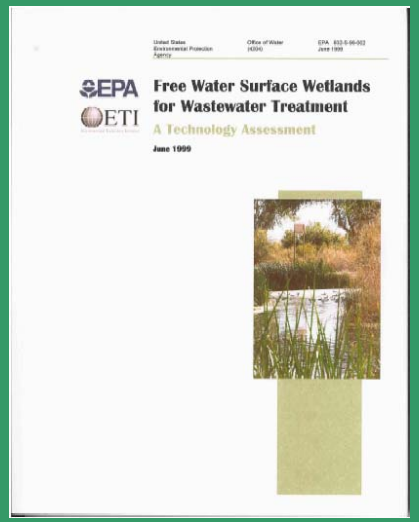


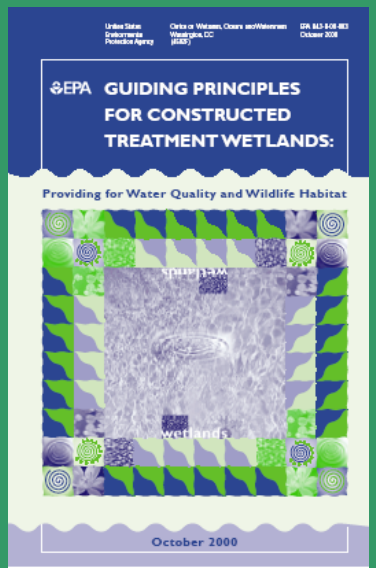
Figure 5. Applying manure to meet crop N needs (about 200 lb available N/acre) adds much more P than corn crop needs.

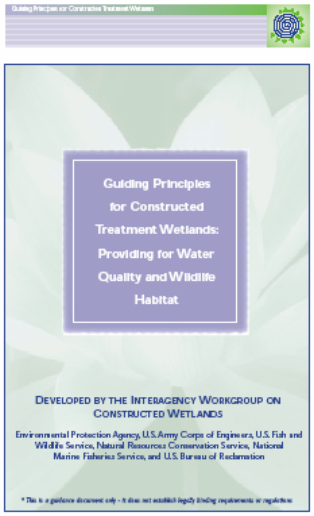


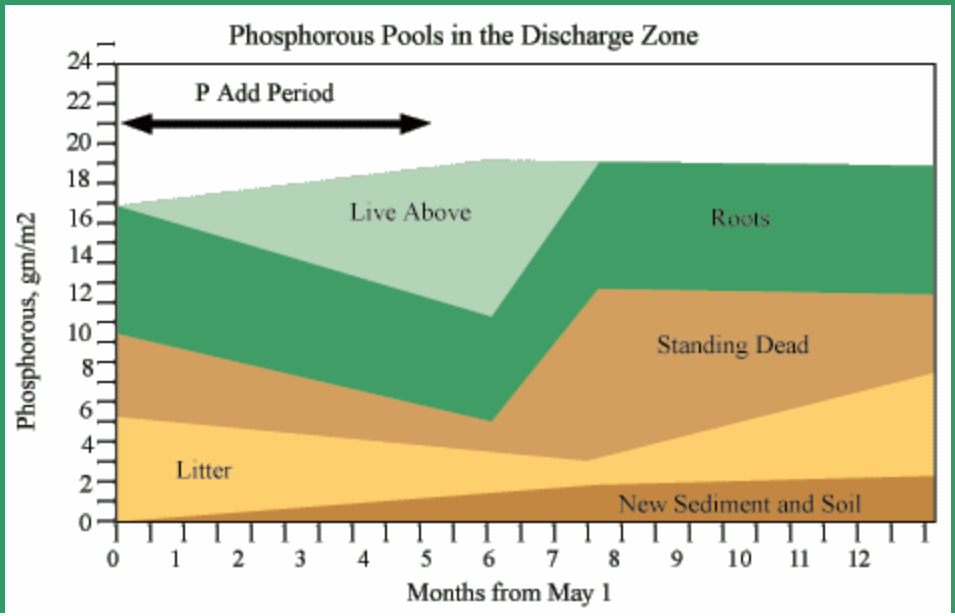




Constructed Treatment Wetland
System Description and Performance Database






Phosphorous Pools in the Discharge Zone
P Add Period
Live Above
Roots
Standing Dead
Litter
New Sediment and Soil
Phosphorous, gm/m2
Months from May 1
0
2
4
6
8
10
12
14
16
18
20
22
24
0
1
2
3
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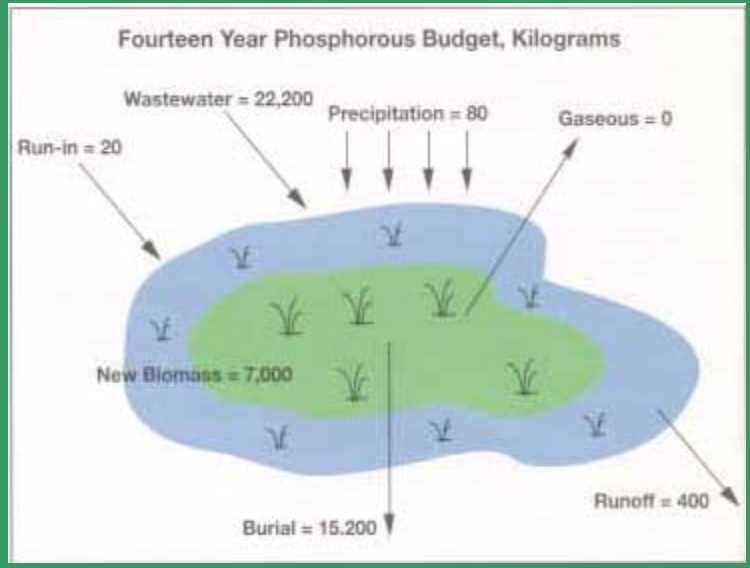
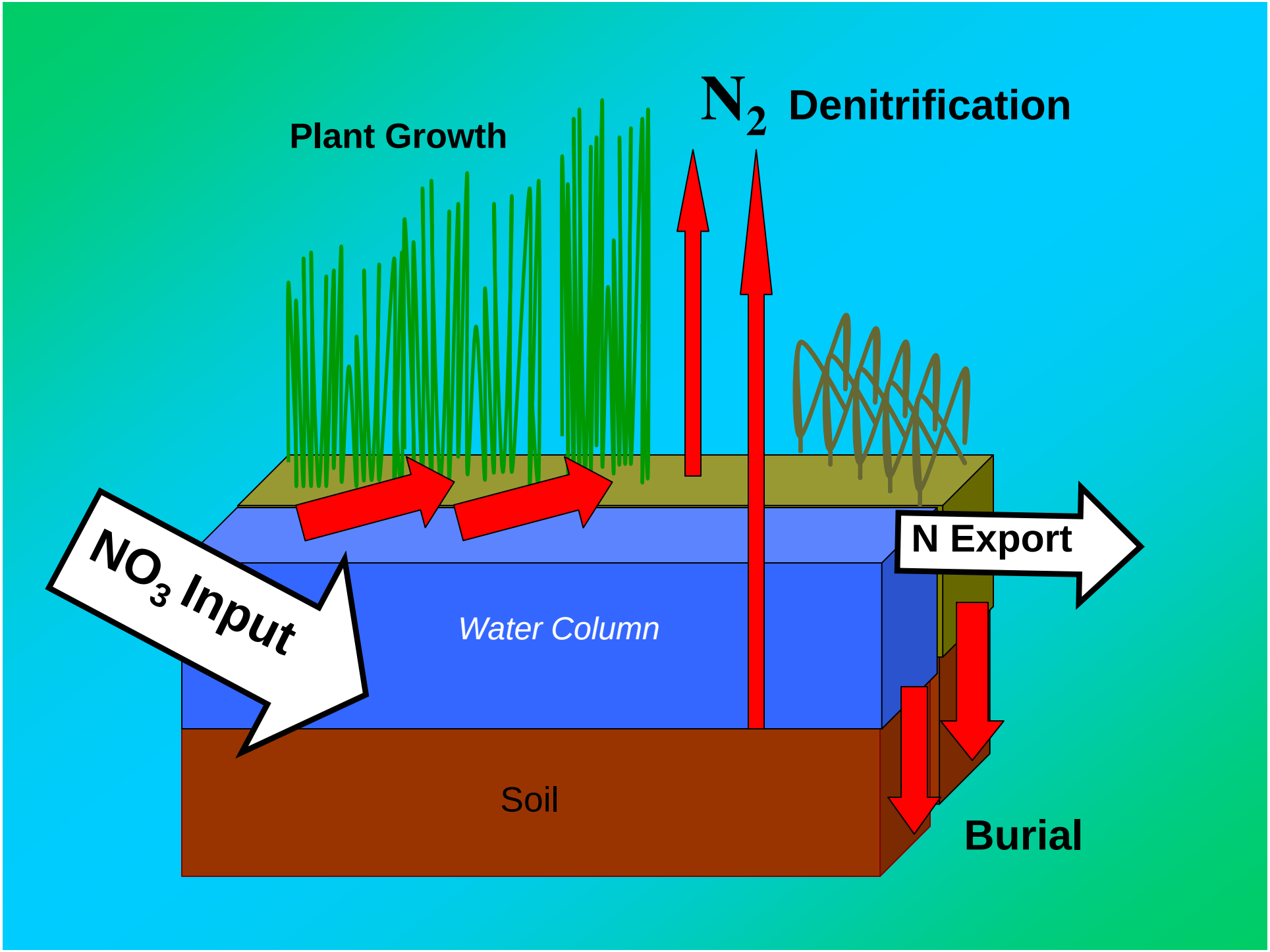

Fourteen Year Phosphorous Budget, Kilograms
Wastewater = 22,200
Precipitation = 80
Gaseous = 0
Run-in = 20
New Biomass = 7,000
Burial = 15.200
Runoff = 400


Plant Growth
N_2 Denitrification
NO_3 Input
N Export
Water Column
Soil
Burial

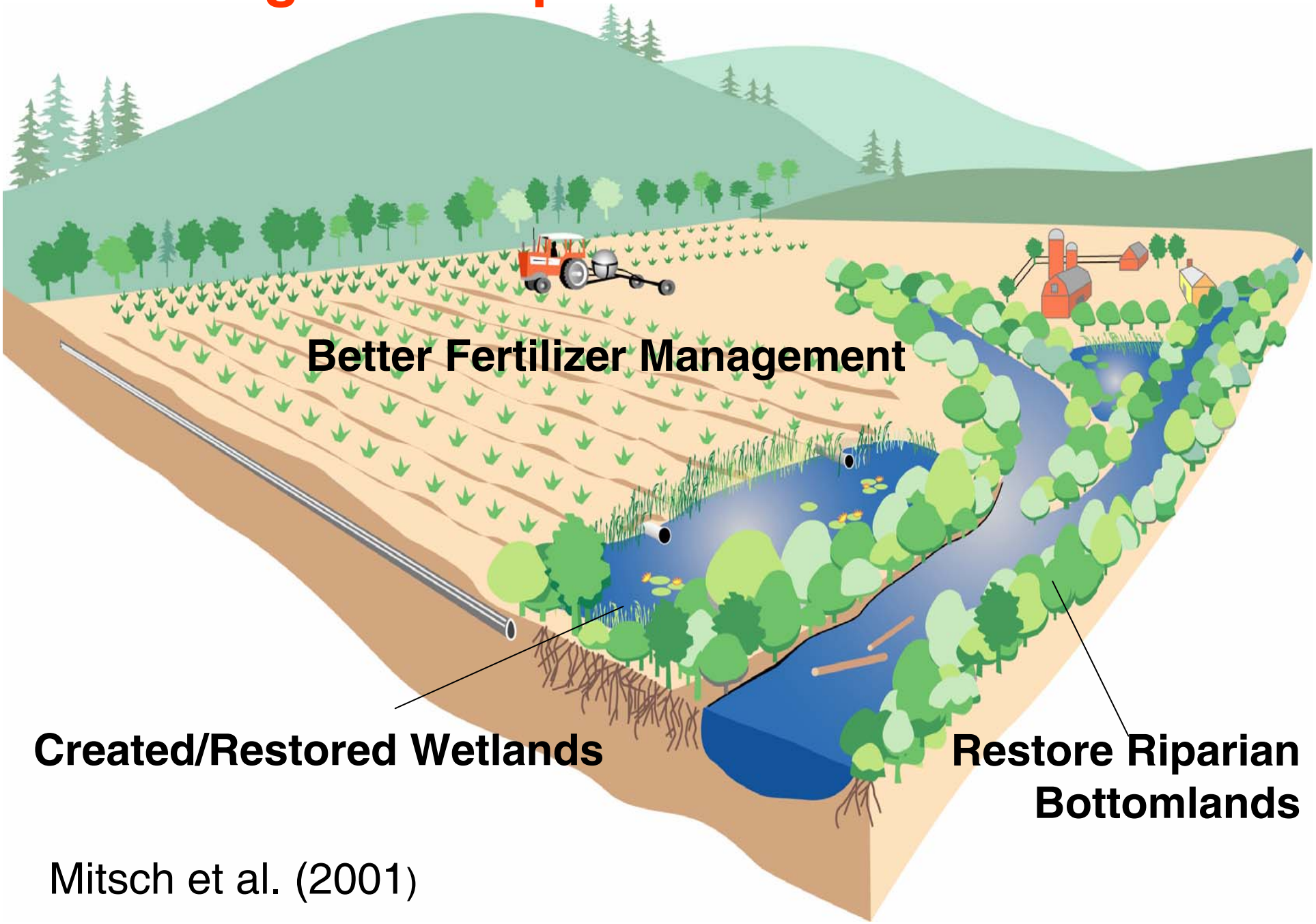
The Wetlands Initiative

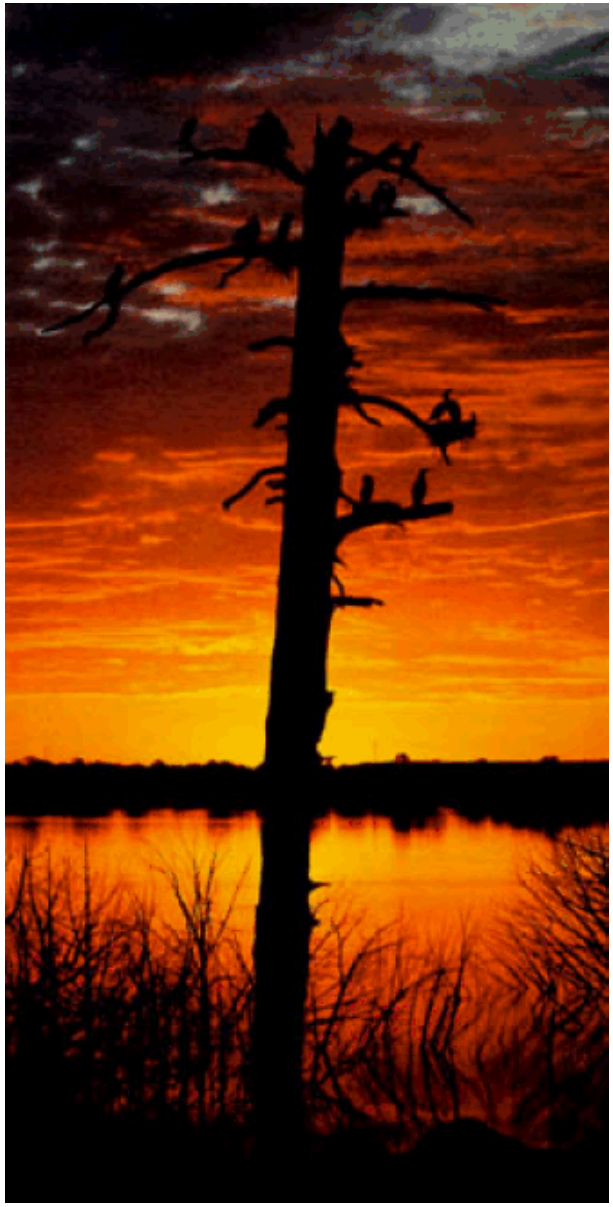
Agriculture Template

Conventional

Conservation

Resulting landscape scale recommendations



Mitsch et al. (2001)

- Provide funding and effective management tools to assist in project design and implementation
  - Clean Water SRF Program
  - CWA §319 Non Point Source Grants
  - USDA funding programs – CSREES, NRCS, RUS
  - Soil testing programs
  - Soil conservation programs
  - Whole farm nutrient management plans
  - Design manuals,
  - Onsite storage guidance
  - Odor management guidance
  - National Demonstration Projects