1

Welcome to ITRC's Internet-Based Training: "Constructed Treatment Wetlands"

Thank you for joining us. Today's training focuses on the ITRC Technical and Regulatory Guidance Document entitled:

" Technical & Regulatory Guidance for Constructed Treatment Wetlands "

The training is sponsored by: ITRC & EPA Office of Superfund Remediation and Technology Innovation

Creating Tools & Strategies to Reduce Technical & Regulatory Barriers for the Deployment of Innovative Environmental Technologies

Presentation Overview:

Natural wetlands have been called 'nature's kidneys' because of their ability to remove contaminants from the water flowing through them. Wetlands are perhaps second only to tropical rain forests in biological productivity; plants grow densely and there is a rich microbial community in the sediment and soil in part supported by the plant roots.

Constructed treatment wetlands are manmade wetlands developed specifically to treat contaminants typically in water that flows through them. They are constructed to recreate, to the extent possible, the structure and function of natural wetlands. Like other phytoremediation approaches, treatment wetlands are self-sustaining (though sometimes optimized with minimal energy input), making them a very attractive option for water treatment compared to conventional treatment systems, especially when lifetime costs are compared.

Based on *Technical and Regulatory Guidance Document for Constructed Treatment Wetlands* (WTLND-1, 2003), this course describes the physical, chemical, and biological mechanisms operating in wetlands treatment systems; the contaminants to which they apply; the characteristics of sites suitable to treatment in this fashion; and relevant regulatory issues. Download Guidance Document at: www.itrcweb.org click on "Guidance Documents."

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org

Training Co-Sponsored by: EPA Office of Superfund Remediation and Technology Innovation (www.clu-in.org)

ITRC Course Moderator: Mary Yelken (myelken@earthlink.net)

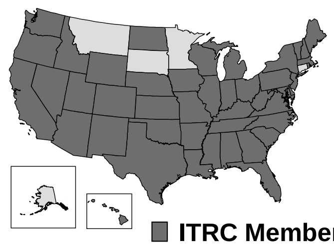
ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Network
  - State regulators
  - Federal government
  - Industry
  - Consultants
  - Academia
  - Community stakeholders
- Documents
  - Technical and regulatory guidance documents
  - Technology overviews
  - Case studies
- Training
  - Internet-based
  - Classroom

Host Organization

ECOS

ITRC State Members



Federal Partners

DOE DOD EPA

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of 45 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network approaching 7,500 people from all aspects of the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

ITRC – Course Topics Planned for 2006

Popular from 2005

- Alternative Landfill Covers
- Constructed Treatment Wetlands
- Environmental Management at Operational Outdoor Small Arms Ranges
- DNAPL Performance Assessment
- Mitigation Wetlands
- Perchlorate Overview
- Permeable Reactive Barriers: Lessons Learn and New Direction
- Radiation Risk Assessment
- Radiation Site Cleanup
- Remediation Process Optimization
- Site Investigation and Remediation for Munitions Response Projects
- Triad Approach
- What's New With In Situ Chemical Oxidation

New in 2006

- Characterization, Design, Construction and Monitoring of Bioreactor Landfills
- Direct-Push Wells for Long-term Monitoring
- Ending Post Closure Care at Landfills
- Planning and Promoting of Ecological Re-use of Remediated Sites
- Rads Real-time Data Collection
- Remediation Process Optimization Advanced Training
- More in development…….

Training dates/details at: www.itrcweb.org
Training archives at: http://cluin.org/live/archive.cfm

More details and schedules are available from www.itrcweb.org under "Internet-based Training."

Constructed Treatment Wetlands

4

Logistical Reminders

- Phone Audience
  - Keep phone on mute
  - * 6 to mute your phone and * 7 to un-mute
  - Do NOT put call on hold
- Simulcast Audience
  - Use ? at top of each slide to submit questions
- Course Time = 2 ¼ hours
- 2 Question & Answer Periods
- Links to Additional Resources
- Your Feedback

Presentation Overview

- What are Constructed Wetlands
- Mechanisms of treatment when using constructed wetlands
- Various applications for treating surface water using Constructed Wetlands
- Contaminants most commonly treated using constructed wetlands
- Important design consideration when considering using Constructed wetlands
- Limitations
- Regulatory Issues
- Key questions you should ask

Presentation Overview:

Natural wetlands have been called 'nature's kidneys' because of their ability to remove contaminants from the water flowing through them. Wetlands are perhaps second only to tropical rain forests in biological productivity; plants grow densely and there is a rich microbial community in the sediment and soil in part supported by the plant roots.

Constructed treatment wetlands are manmade wetlands developed specifically to treat contaminants typically in water that flows through them. They are constructed to recreate, to the extent possible, the structure and function of natural wetlands. Like other phytoremediation approaches, treatment wetlands are self-sustaining (though sometimes optimized with minimal energy input), making them a very attractive option for water treatment compared to conventional treatment systems, especially when lifetime costs are compared.

Based on *Technical and Regulatory Guidance Document for Constructed Treatment Wetlands* (WTLND-1, 2003), this course describes the physical, chemical, and biological mechanisms operating in wetlands treatment systems; the contaminants to which they apply; the characteristics of sites suitable to treatment in this fashion; and relevant regulatory issues. Download Guidance Document at: www.itrcweb.org click on “Guidance Documents”

Meet the ITRC Instructors

Paul Eger
Minnesota Department of Natural Resources
500 Lafayette Road, Box 45
St Paul, MN 55155
Phone: 651-296-9549
Fax: 651-296-5939
paul.eger@dnr.state.mn.us

Arati Kolhatkar
Atlantic Richfield Company
(a BP affiliate)
501 Westlake Blvd, Suite 20.104B,
Houston, TX 77079
Phone: 281-366-5596
Fax: 281-366-7094
arati.kolhatkar@bp.com

Charles Harman
AMEC Earth & Environmental, Inc
285 Davidson Ave, Suite 100
Somerset, NJ 08873
Phone: 732-302-9500 ext. 127
Fax: 732-302-9504
charles.harman@amec.com

Paul Eger, Minnesota Department of Natural Resources, 651-296-9549, paul.eger@dnr.state.mn.us

Paul Eger is a principal engineer for the Minnesota Department of Natural Resources, Division of Lands and Minerals, where for over 25 years he has worked with environmental issues related to mining. He was a pioneer in the use of wetlands to remove trace metals from mine drainage, and much of his work has focused on the development of successful passive treatment systems to control mine drainage problems. He has also been a leader in the development of cost-effective and environmentally safe reclamation using waste products, such as municipal solid waste compost, paper processing waste, and dredge material from Lake Superior. He has served as an expert witness on water quality issues and at reclamation rules hearings and serves on the Department's hazardous waste team, where he has been responsible for the clean up of abandoned dump sites. In his spare time he tries to control and regulate his three daughters and to enjoy the outdoors by hiking, biking, canoeing and skiing.

Arati Kolhatkar, Environmental Technology, 281-366-5596, arati.Kolhatkar@bp.com

Arati Kolhatkar is an Environmental Engineer at Atlantic Richfield Co. (a BP affiliate). She is a chemical engineering graduate (B. Chem. Eng. from University of Bombay, India, M.S. in Chemical Engineering from University of Tulsa, OK). Her areas of research included biotreatment of wastewaters, biodesulfurization, microbially enhanced oil recovery, development of hydraulic fracturing fluids, and soil bioremediation. As a team member of the Environmental Technology group, she is responsible for developing and advocating the use of constructed treatment wetlands to meet various goals. In addition, she is very involved in the phytoremediation efforts carried out for clean-up and/or prevention. Arati also actively participates in development and demonstration efforts focused on finding natural technologies as well as establishment of regulatory guidance on the use of these innovations through the US EPA's Remediation Technologies Development Forum, and the Interstate Technology and Regulatory Council.

Charles R. Harman, P.W.S., AMEC, 732-302-9500, Charles.harman@amec.com

Charles Harman is a Senior Associate Ecologist with AMEC Earth & Environmental located in Somerset, New Jersey. A terrestrial ecologist, Mr. Harman has over 18 years of experience in the environmental consulting field. Mr. Harman specializes in natural resource related assessment and management activities, including wetlands management and ecological restorations, ecological risk assessments, and natural resource damage assessments. He is responsible for the completion of ecological risk assessment projects and wetlands evaluations at hazardous waste sites and industrial facilities around the country. Mr. Harman has delineated wetlands using both the 1987 and 1989 methods manuals and has designed and managed wetland restoration projects as part of remediation activities. He has designed and conducted detailed evaluations of the potential for ecological impacts to wetlands from the implementation of remedial actions, including pump and treat systems. He has evaluated wetlands and other ecological receptors at sites located in sensitive habitats, including the New Jersey Pinelands, the New Jersey Hackensack Meadowlands, coastal estuaries, and freshwater swamps and marshes. In a cooperative research venture with an industrial client, Mr. Harman has been evaluating the efficacy of constructed wetlands to remove arsenic, chromium and copper in stormwater. Mr. Harman is certified as a Professional Wetland Scientist. He has a Bachelor of Science Degree in Wildlife Ecology from Texas A&M University and a Master of Arts in Biology from Southwest Texas State University.

6

What are Constructed Treatment Wetlands?

- Man made
- Built specifically to remove contaminants in waters that flow through them
- Wide variety of removal processes
- Generally not designed to fully recreate the structure & function of natural wetlands
  - See ITRC Guidance Document: Characterization, Design, Construction, and Monitoring of Mitigation Wetlands (WTLND-2, 2005)

Habitat may be good or bad, depending on site and type of species

For example, beaver can change water levels

Need to consider the possibility of habitat in design stage

In arid areas the use of constructed treatment wetlands for habitat may be desirable, particularly if the wetland is used as a polishing step.

Reference **Constructed Wetlands for Wastewater Treatment and Wildlife Habitat 17 Case Studies**

United States Environmental Protection Agency EPA832-R-93-005 September 1993

ITRC Guidance Document: Characterization, Design, Construction, and Monitoring of Mitigation Wetlands (WTLND-2, 2005) available at www.itrcweb.org under “Guidance Documents” then “Mitigation Wetlands.”

Background

- Wetlands have been used to treat wastewater in US for several decades
  - Primarily municipal and stormwater
- Application of technology expanding to new areas
- Newer designs based on a more thorough understanding of science and underlying mechanisms

Some natural wetlands used as convenient wastewater discharge sites for 80- 90 years, no monitoring until the 60s and 70s

According to EPA there were about 324 “swamp” discharges in the 14 states in Region 4 and 5 in the mid 1980s, it wasn’t until water quality data began to be collected that the ability of wetlands to treat water was realized, in the 1980’s began to construct wetlands for municipal treatment rather than simply using existing wetlands

Why Wetlands?

- Wetlands may offer a lower cost, lower maintenance alternative to standard chemical treatment
- Classic example of passive treatment
  - Passive treatment systems use natural processes to remove contaminants
  - Designed to be low maintenance
- A “perfect” passive system would operate indefinitely with no maintenance

A wetland treating mine drainage in Minnesota appears to have reached a point where the treatment could be self sustaining.

Paul Eger Jon Wagner THE USE OF WETLANDS TO REMOVE NICKEL FROM MINE DRAINAGE - IS PERPETUALTREATMENT REALLY POSSIBLE? Paper presented at the 2002 National Meeting of the American Society of Mining and Reclamation, Lexington, KY, June 9-13, 2002. Published by ASMR, 3134 Montavesta Rd., Lexington, KY, 40502.

9

Key questions to ask

- Is a wetland appropriate for this situation?
- Is this the right design?
- Is the wetland big enough to handle changes over time?
- How long will it continue to provide treatment?
  - Will it be necessary to dispose of the substrate in the wetland?
- Will it produce consistent compliance?
- Are there any potential ecological impacts?

The guidance document will help you address these questions.

Applications

- ✓ **Stormwater Runoff**
- ✓ **Municipal Waste Treatment**
- ✓ **Mine Drainage**
- ✓ **Industrial Waste Treatment**
- ✓ **Remedial Wastewater Treatment**
- ✓ **Effluent from Landfills**
- ✓ **Agricultural**
- ✓ **On-site Wastewater**

This is order discussed in document

What We Need to Know Before Constructing Treatment Wetlands

- Fundamental mechanisms of wetlands function
- Characteristics of the water being treated
  - Chemistry
  - Flow
- Site characteristics (Climate and Topography)
- Removal rates
- Regulatory Limits

Arati will address mechanisms

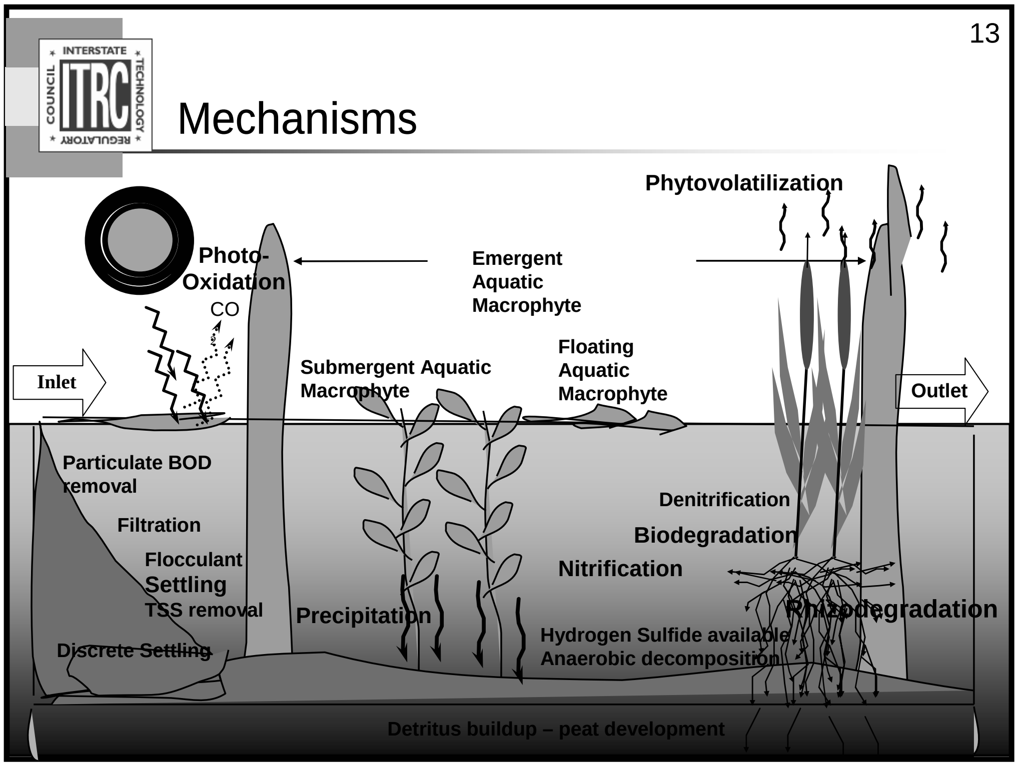
Chuck will address the characteristics and how they relate to design.

Mechanisms

- **Abiotic**
  - Settling & sedimentation
  - Sorption
  - Chemical Oxidation & Reduction-precipitation
  - Photo oxidation
  - Volatilization
- **Biotic**
  - Aerobic or anaerobic Biodegradation/ Biotransformation
  - Phytoaccumulation
  - Phytostabilization
  - Rhizodegradation
  - Phytodegradation
  - Phytovolatilization

Constructed Treatment Wetlands are specifically engineered with water quality improvement as the primary goal. Wetland design hence necessitates an understanding of the fundamental mechanisms of pollutant removal.

Wetlands are complex ecosystems with a multitude of processes taking place simultaneously, and/or sequentially. These processes can be either Abiotic (physical or chemical processes) or Biotic (those that occur due to the presence/aid of microorganisms, plants or other higher animals).



Improvement in water quality is achieved through the interaction of the wastewater with the wetland's vegetation, microorganisms and soils. This slide is a schematic representation of processes that may occur in a constructed wetland.

The primary Abiotic processes taking place in a wetland include:

Settling & sedimentation: particulate and suspended matter by gravitational settling

Sorption: Wetland soils have a high trapping efficiency for a variety of chemical constituents by the combined processes of adsorption and absorption.

Precipitation: Conversion of metals in the influent to its insoluble form

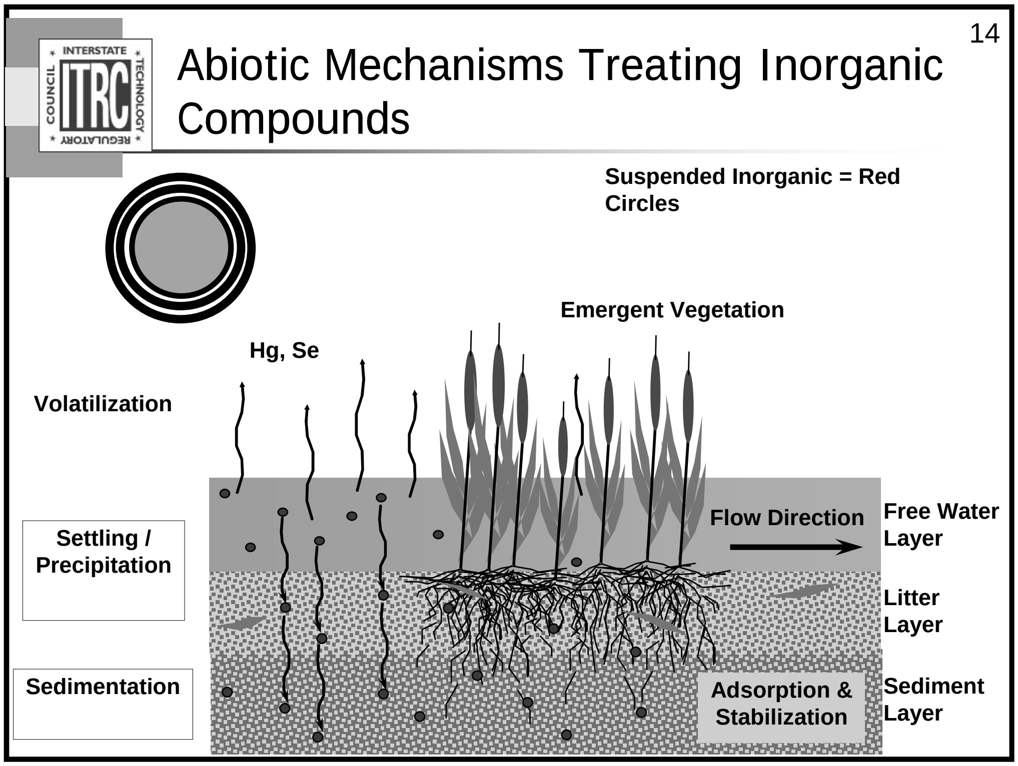
Photo oxidation is the break down/oxidation of compounds in the presence of sunlight.

Volatilization: is partitioning of the compounds into the gaseous state.

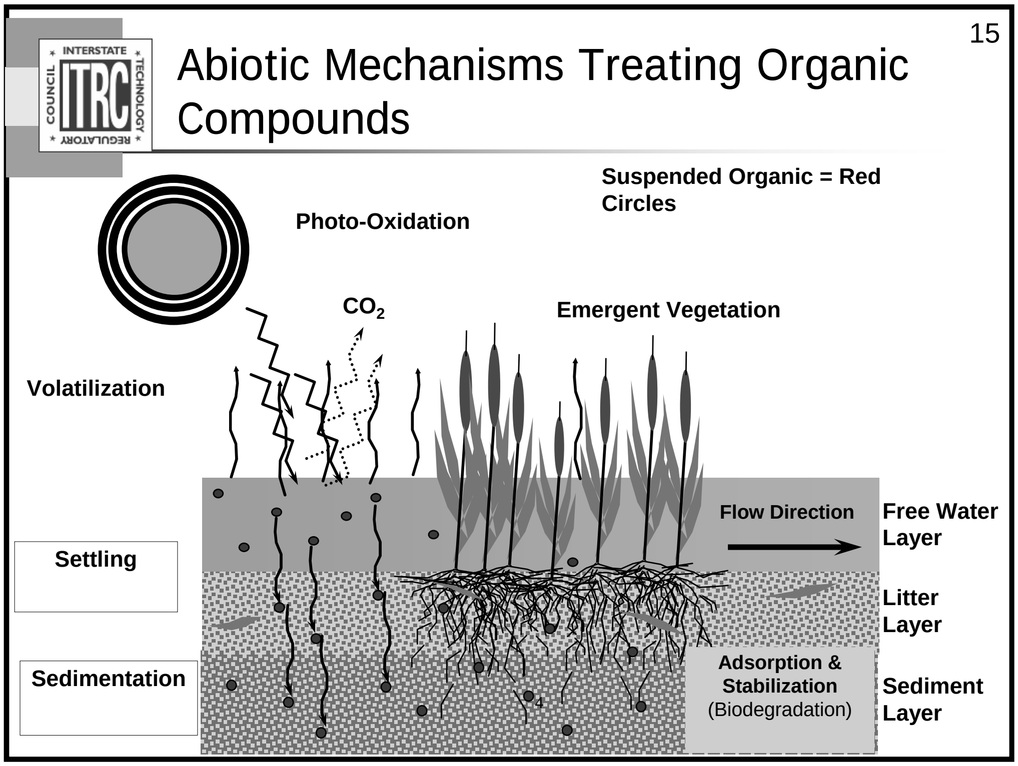
Biotic mechanisms:

Plants are either responsible for direct uptake of contaminants or provide exudates that enhance microbial degradation – this is rhizodegradation. The compounds of concern taken up by the plants are either enzymatically broken down by phytodegradation or are subsequently transpired through the leaves by phytovolatilization. The uptake and accumulation of contaminants is phytoaccumulation and the sequestration of contaminants is phytostabilization.

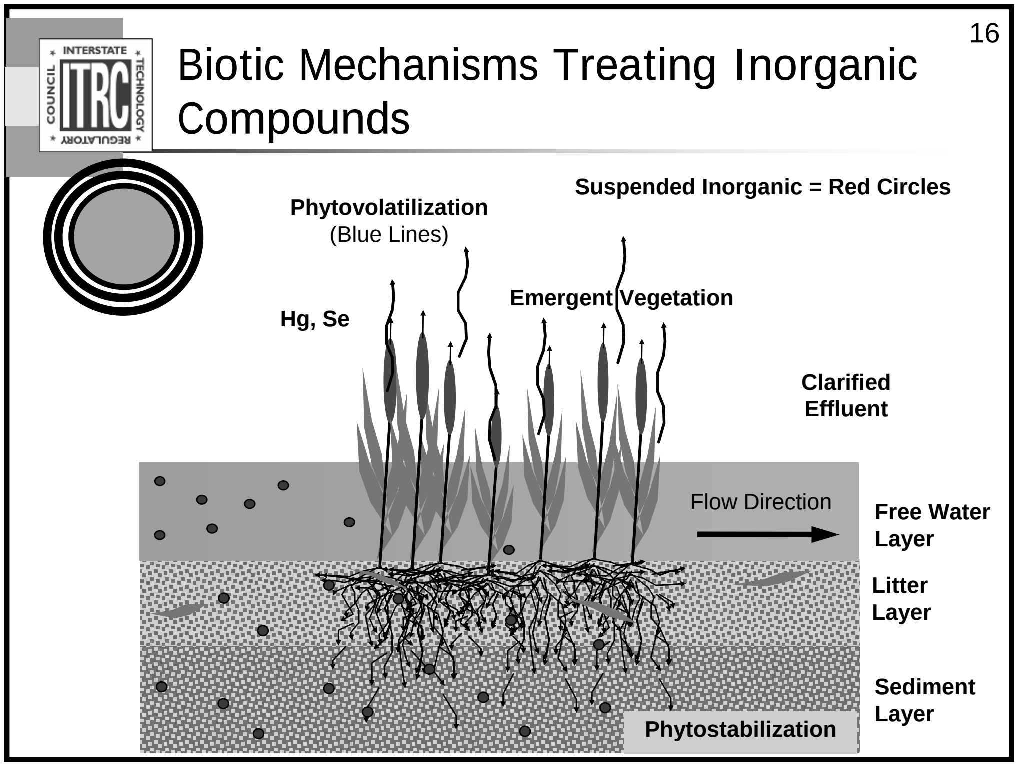
Wetland systems can be designed to contain emergent, submergent and/or floating plants that create an environment that supports a wide range of physical, chemical, and microbial processes.



Wetland systems support a variety of of sequential and often complementary processes. The predominant abiotic processes for removal of inorganic contaminants is summarized in this slide.

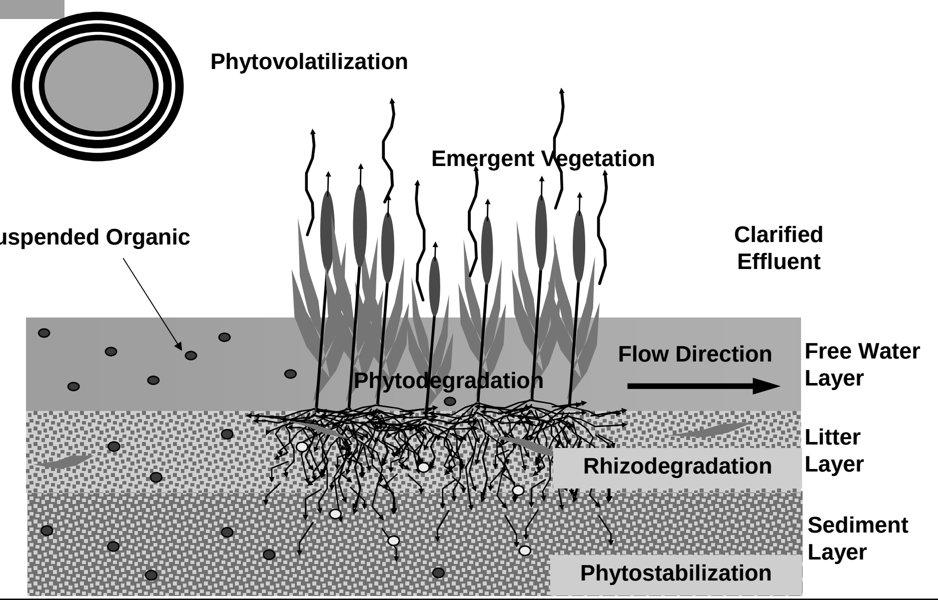


Similar to abiotic mechanisms involved in treating inorganic compounds, the organic contaminants are removed from the influent stream by settling/sedimentation, sorption, volatilization. In addition, photo-oxidation – oxidation in the presence of light may oxidize the organics to gaseous carbon dioxide (CO2) which escapes from the wetland.



This slide describes some biotic mechanisms that can result in removal of these inorganic compounds.

Biotic Mechanisms Treating Organic Compounds



In addition to phytovolatilization, phytoaccumulation, phytostabilization, removal of organic contaminants also involves microbial degradation under aerobic/anaerobic conditions, rhizodegradation and phytodegradation.

Primary Contaminant Removal Mechanisms (See Table 2-1)

Contaminant Group or Water Quality Parameter	Physical	Chemical	Biological
Total Suspended Solids	Settling,		Biodegradation
Organics • Biochemical Oxygen Demand (BOD)	Settling	Oxidation/	Biodegradation
Hydrocarbons • Fuels, oil and grease, alcohols, BTEX, TPH • PAHs, chlorinated and non-chlorinated Solvents, pesticides, herbicides, insecticides	Diffusion/ Volatilization, Settling	Photochemical Oxidation	Biodegradation Phytodegradation Phytovolatilization Evapotranspiration
Nitrogenous Compounds • Organic N, NH_3, NH_4, NO_3^{-2}, NO_2^-	Settling		Bio-denitrification Nitrification & Plant uptake
Phosphoric Compounds • Organic P, PO_4^{-3}	Settling	Precipitation Adsorption	Microbes Plant uptake
Metals • Al, As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se, Ag, Zn	Settling	Precipitation Adsorption Ion exchange	Phytoaccumulation Phyto-volatilization
Pathogens		UV radiation	Die-off Microbes

This table summarizes the abiotic (physical and chemical) and biotic processes responsible for contaminant removal as the wastewater flows through a wetland. Specific mechanism for various metals is discussed in the next slide

Removal Mechanisms for Metals

(See Table 2-2)

Aluminum (AL)	•Oxidation and hydrolysis
Arsenic (As)	•Formation of insoluble sulfides; Binding to iron and manganese oxides
Cadmium (Cd)	•Formation of insoluble sulfides; Filtration of solids and colloids
Chromium (Cr)	•Reduction to non-mobile form by bacterial activity
Copper (Cu)	•Sorption onto organic matter; Formation of insoluble sulfides; Binding to iron and manganese oxides; Reduction to non-mobile form by bacterial activity
Iron (Fe)	•Oxidation/hydrolysis; Formation of carbonates or sulfides; Binding to iron/manganese oxides
Lead (Pb)	•Formation of insoluble sulfides; Filtration of solids and colloids; Binding to iron and manganese oxides
Manganese (Mn)	•Oxidation and hydrolysis; Formation of carbonates; Binding to iron and manganese oxides;
Nickel (Ni)	•Sorption onto organic matter; Formation of carbonates; Binding to iron and manganese oxides
Selenium (Se)	•Reduction to non-mobile form by bacterial activity
Silver (Ag)	•Form insoluble sulfides; Filtration of solids and colloids
Zinc (Zn)	•Formation of insoluble sulfides; Filtration of solids and colloids; Binding to iron and manganese oxides

This slide tabulates the probable mechanisms for removal of various metals present in wastewater.

Although not listed on this slide, metals are also incorporated into biomass by the uptake via roots and distributed and accumulated within the plant (also known as phytoaccumulation). The extent of uptake and distribution within the plant depends on the metal and plant species.

Types of Systems

- Surface Flow (SF)
- Subsurface Flow (SSF)
- Riparian Buffer

Wetland systems are classified into SF, SSF, RB based on the flow pattern, matrix used as substrate.

Surface Flow Wetlands (SF)

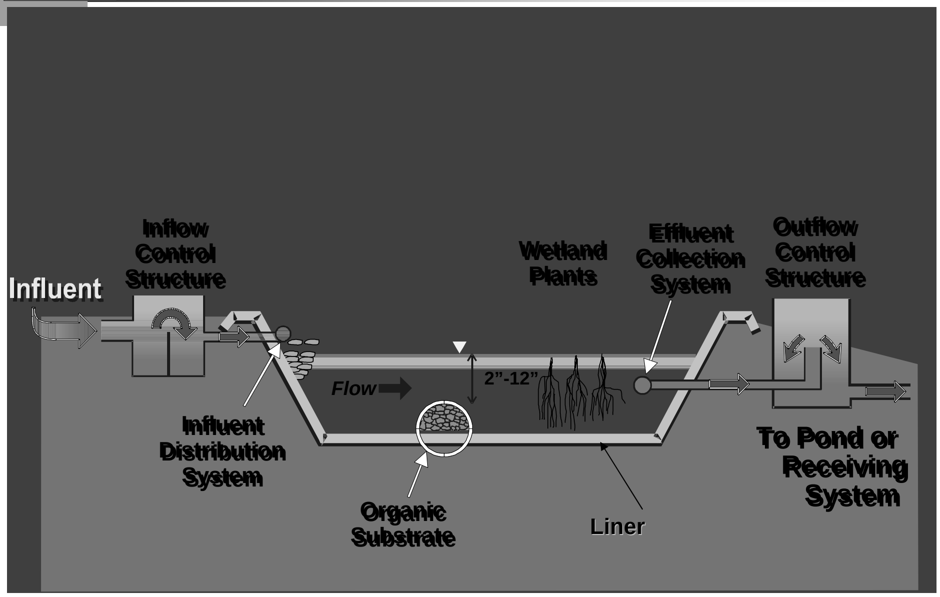
- Water flow occurs above the substrate
- Preferred choice for treatment of contaminants that are predominantly removed by aerobic processes

Advantages

- Simple design
- Less costly as compared to Subsurface systems

Surface Flow systems simulate a type of natural wetlands in which contaminated water flows over the soil at shallow depths. These are designed and constructed to exploit the biotic and abiotic processes naturally occurring in wetlands. The water surface is exposed to the atmosphere and hence aerobic processes predominate.

Surface Flow Wetland



This is a schematic representation of a Surface Flow Wetland.

To minimize short circuiting in a surface flow wetland: use of control structures at inlet and outlet

Depending on the final treatment goal, different types of vegetation can be chosen.

To prevent impact to groundwater: An impervious barrier is installed at the bottom of the wetland to prevent infiltration to groundwater.

Subsurface Flow

- Water flows below ground surface through the substrate
- Two types of systems based on hydraulics:
  - Horizontal
  - Vertical
- Also known as
  - Rock Reed filters , Reed beds, Gravel beds, Vegetated submerged beds, or Root zone method

Subsurface flow systems use the flow of contaminated water through a permeable medium, such as sand or gravel, to keep water below the surface.

Based on the configuration and hydraulics, SSF systems are classified into: Horizontal and Vertical.

Horizontal: the water flows under/through the substrate.

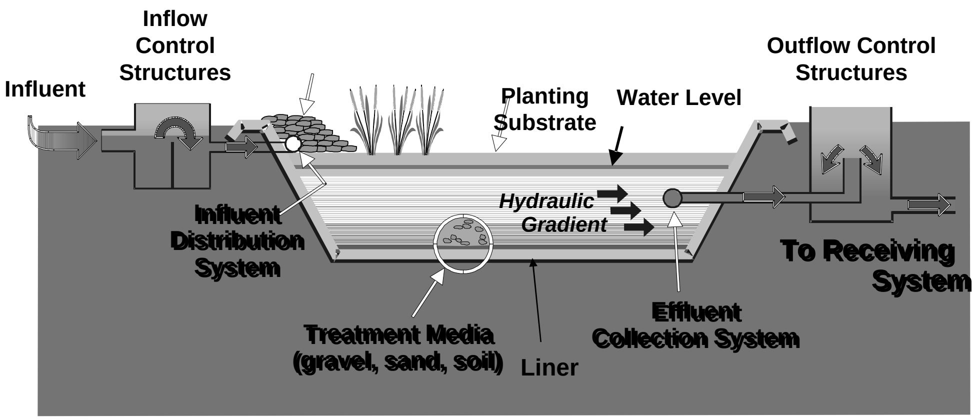
Vertical flow wetlands : are subsurface wetlands in which the configuration of the matrix forces the water to flow perpendicular to the length of the wetland.

Subsurface Flow Wetland Advantages

- Higher treatment efficiencies as compared to surface flow systems
  - More surface area for biofilm development
- Reduced risk of public exposure, odors, or insect vectors
- Greater thermal protection due to subsurface flow of water
- Increased accessibility for maintenance

No Associated Notes

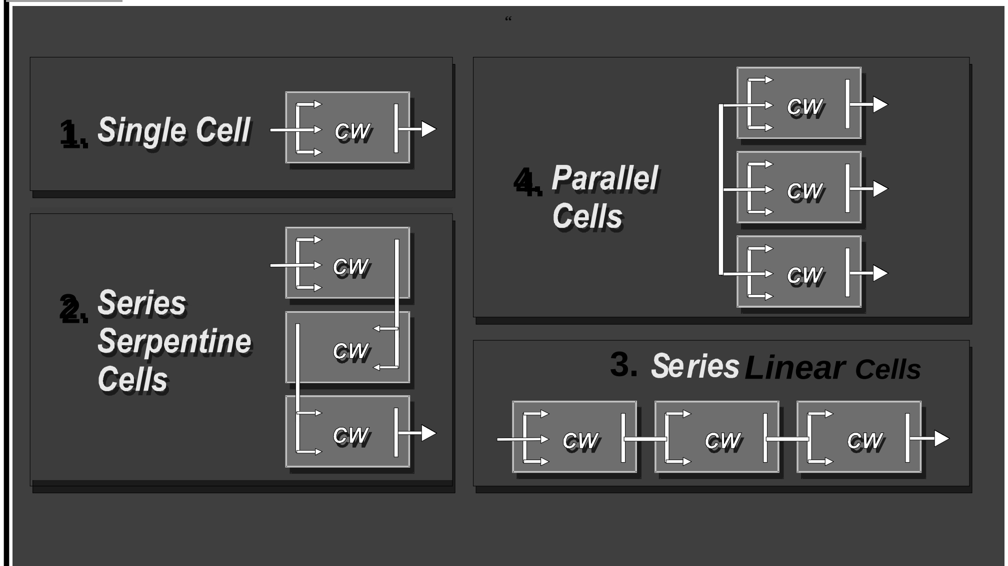
Subsurface Flow Wetland



In a subsurface flow wetland system, water flow through the substrate. This substrate matrix could be gravel, sand, or soil. As in the surface flow systems, the inlet and outlet control structure and the influent/effluent distribution/collection system are used to prevent short circuiting and ensure uniform distribution along the width.

26

Typical Configurations of Constructed Wetlands



The treatment goals and the available area decides the type of configuration chosen for a constructed wetland.

Figure 1 is a single cell in which influent wastewater enters at one end, is treated as it moves to the other end.

Figures 2 and 3 show a series configuration in which constituent mass is gathered at the outlet end of one cell and redistributed to the inlet of the next cell.

Figure 4 depicts a multiple cell configurations operated in parallel. Advantage: operational flexibility

Choice of Wetland Type

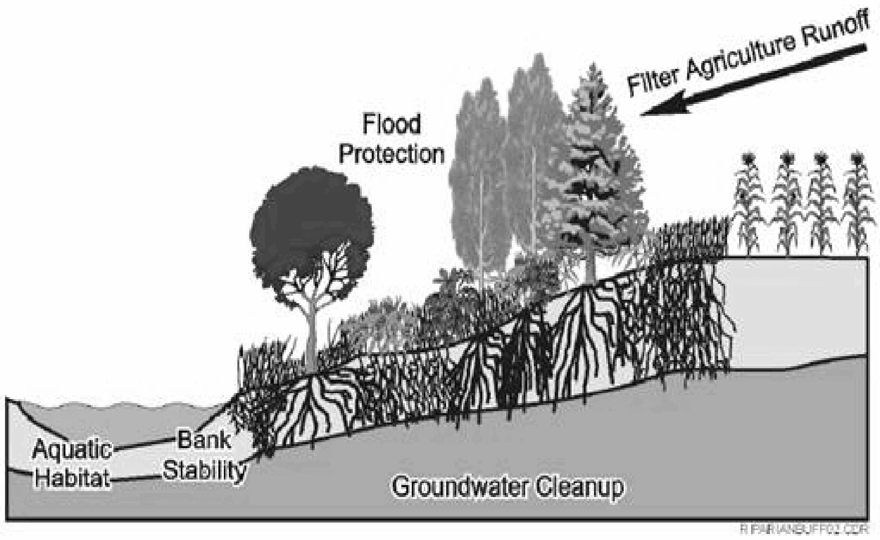
- Treatment goals
- Mechanisms involved
- Maintenance Issues
- Air Emissions/Ecotoxicity Concerns
- Area availability
- Cost

Each wetland type has its own advantages that we have seen in the previous slides and all the factors listed on this slide have to be weighed to make any decision of choice of wetland.

Selection of the type of wetland will depend on treatment goals, which mechanisms can be optimized most efficiently in the different types, in some cases maintenance issues and cost.

Application-specific criteria for choosing between SF and SSF are discussed in detail in the guidance document.

Riparian Buffer



Riparian buffers are vegetated areas that protect the water resources from non-point source pollution, provide bank stabilization and habitats for aquatic for aquatic and other wildlife.

Groundwater impacts can eventually find their way to the surface water body as well. In order to protect these waters, riparian buffers can be established along the boundaries.

The plant species used in a riparian buffer can include obligates (upland and wetland) and all facultatives...basically any plant.

Applications

- **Stormwater Runoff**
- **Municipal Waste Treatment**
- **Mine Drainage**
- **Industrial Waste Treatment**
- **Remedial Wastewater Treatment**
- **Effluent from Landfills**
- **Agricultural**
- **On-site Wastewater**

Introductory slide to application section

Document is arranged by application rather than parameter

Team felt that since the primary audience was regulators that it was best to organize by application

Removal efficiency for parameters that are not generally associated with a particular application can be found in other applications

For example, mine drainage sometimes contains elevated nitrate due to residue from blasting compounds, information on nitrate can be found in the municipal and agricultural sections

Stormwater Control

- Primary function: reduce suspended solids

  Generally contains low levels of contaminants

  Reduce peak discharge of infrequent large storm events

Greenwood Park, Orlando, Florida

Wetlands are considered a best management practice for the control of stormwater.

High flow main concern is suspended solids, many of contaminants are attached to particles
Low flow, dissolved nutrients can be an issue

Orlando, population 160,000, receives over 50 inches of rain annually. To improve water quality and protect groundwater/drinking water supplies, Orlando built a series of artificial wetland treatment ponds. The city also enlarged the lake from 4 to 13 acres, installed weirs to maximize stormwater detention, and added a sediment trap to increase pollutant removal at the upstream end of the system. A shallow shelf around the lake provides increased water storage and creates an area for marshes to establish, which further aid in the treatment of stormwater. After construction, monitoring showed that water quality improved above standards. The system, which the city found to be cost-effective, provides flood protection, pretreatment of stormwater, aquifer protection, and irrigation water. Orlando built a natural park with paths and wildlife viewing as part of the project. Economic benefits include an increase in property values and revenues from selling the excavated fill.

Stormwater
"Typical Constituents and Concentrations"

Constituent	Undeveloped	Urban Runoff (mg/L)	Industrial Runoff (mg/L)	Residential Runoff (mg/L)	Highway Runoff (mg/L)
BOD	1.5	20	9.6	3.6 – 20	--
Oil & Grease		2.6	--	--	30
TSS	11	150	94	18 – 140	220
TN	1.2	2.0	1.8	1.1 – 2.8	up to 3.4
TP	0.05	0.36	0.31	0.05 – 0.40	up to 0.7
Cadmium		0.0015	--	--	--
Chromium		0.034	--	--	--
Lead		0.140	0.20	0.07 – 0.21	0.55
Nickel		0.022	--	--	--
Zinc		0.20	0.12	0.046 - 0.170	0.38

Blank values not reported.

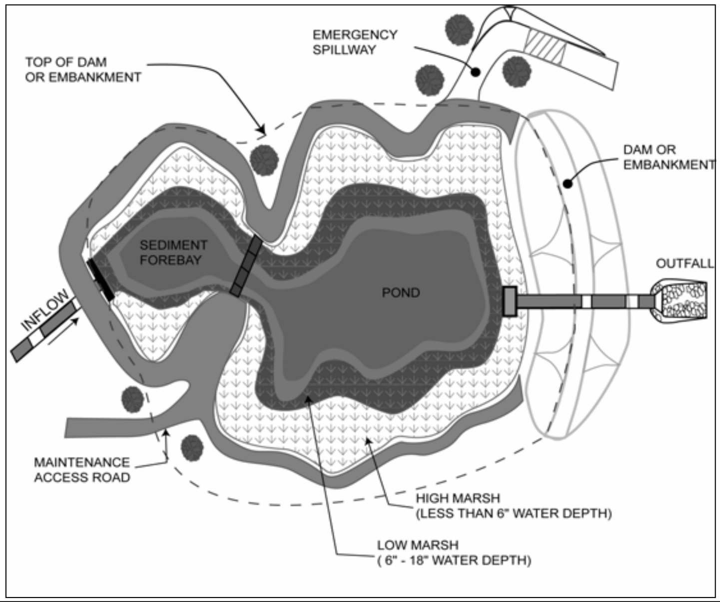
Chemistry of stormwater is a function of source, time, and the amount and intensity of rainfall.

This table provides general values but can see from the table that TSS is a particular problem at all sites. Values in table represent flow weighted average. Instantaneous values can be much higher than the averages in the table

32

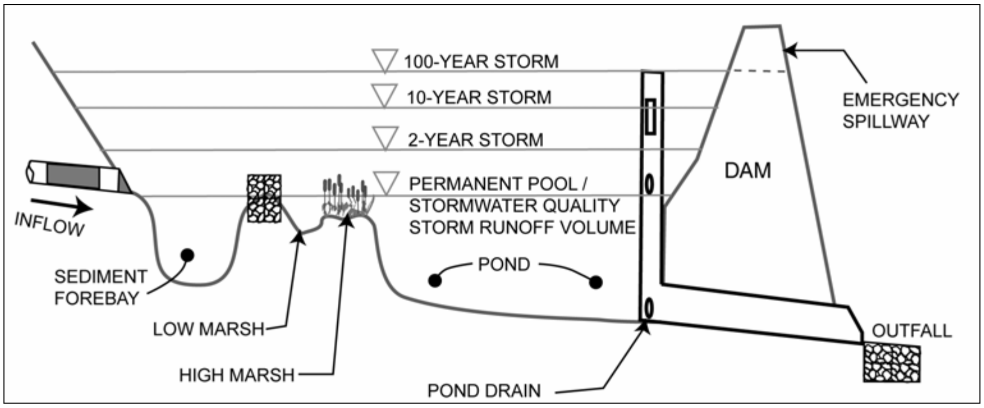
Constructed Stormwater Wetland

- **Generally surface flow**
- **Low levels of contaminants**



Typical design for a surface flow storm water wetland. In general, most stormwater wetlands are surface flow.

Typical Surface Flow Wetland Design



This is a representative cross section of the wetland on the previous slide. It shows the change in water level as a function of storm return interval. The longer the return interval the greater the rainfall and as a result the greater the volume of storm water.

Stormwater Wetland Removal Efficiencies %

Parameter	**Removal %**
TSS	77-89
NH_4-N	15-79
Total Phosphorus	7-77
Lead	54-96

General summary;
Removal very good for TSS, but other parameters have much more variability

Summaries are from Knight, R. L., Kadlec, R. H., (1998) Creating and Using Wetlands for Wastewater and Stormwater Treatment and Water Quality Improvement. University of Wisconsin, Madison. Engineering Professional Development Course, Madison WI.

35

Municipal Wastewater Wetland Treatment

- Used in 34 states to treat municipal wastewater
  - Typically as a polishing step
- Now considered effective as a secondary treatment

Tres Rios constructed wetlands, Arizona

polishing means tertiary treatment

Additional design information specific to municipal wastewater provided in the document.

Typical Characteristics of Municipal Wastewater

Constituent, mg/l	Septic Tank Effluent	Primary Effluent (Settling Pond)	Secondary Effluent (Oxidation Pond)
BOD	129-147	40-200	11-35
Soluble BOD	100-118	35-160	7-17
COD	310-344	90-400	60-100
TSS	44-54	55-230	20-80
VSS	32-39	45-180	25-65
TN	41-49	20-85	8-22
NH_3	28-34	15-40	0.6-16
NO_3	0-0.9	0	0.1-0.8
TP	12-14	4-15	3-4
Ortho-Phosphate	10-12	3-10	2-3
Fecal Coliform (log/100ml)	5.4-6.0	5.0-7.0	0.8-5.6

(EPA 2000)

primary treatment is settling

Secondary, microbiological reactions reduce overall load

EPA document discusses wetlands for secondary treatment, can also be used for tertiary

oxidation pond effluent would be a secondary effluent going into a wetland for polishing or tertiary treatment

Municipal Wastewater Characteristics and Removal Efficiencies, Tertiary Treatment

Constituent	Influent Concentration	Removal Efficiency
BOD	20 - 100 mg/L	67-80 %
Suspended Solids	30 mg/L	67-80 %
Ammonia Nitrogen	15 mg/L	62-84 %
Total Nitrogen	20 mg/L	69-76 %
Total Phosphorus	4 mg/L	48 %
Cd Cu Pb Zn	10 ug/L 50 ug/L 50 ug/L 300 ug/L	50-60 % 50-60 % 50-60 % 50-60 %

(Data is from Kadlec and Knight 1996)

Typical minimum requirements for secondary treatment is 30/30 rule, mean monthly BOD and TSS standards are 30 mg/L

Summary of contaminant removal efficiency in treatment wetlands, based on the North American Wetland Treatment System Database (Knight et al., 1994). Average values of combined performance data for surface- and subsurface-flow wetlands are presented. (Table adapted from Kadlec and Knight [1996])

Mine Drainage

- Water in contact with rock containing reactive minerals
- Primarily iron sulfides
- Nearly 12,000 miles of rivers and streams & 180,000 acres of lakes and reservoirs affected in the US

Mine waste stockpiles

No Associated Notes

Mine Drainage

- Net Acid: Acidity> Alkalinity
  - Generally pH < 6 (Excess acidity)
  - Net acidic water require subsurface wetlands
- Net Alkaline:Acidity< Alkalinity
  - pH > 6 (Excess Alkalinity)
  - Net Alkaline waters can be treated using Surface or Subsurface wetlands
- Design information in guidance document

Mine drainage wetland, northern Minnesota

Additional design information specific to mine drainage applications is presented in the document

Use of wetlands has increased in last decade.

Characteristics of Mine Drainage

Parameter	Coal Mine Drainage		Metal Mine Drainage	
	Net Acid	**Net Alkaline**	**Net Acid**	**Net Alkaline**
pH	3-4	6.5-7.5	3-4	6.5-7.5
Acidity	100 – 10,000	0	100-10,000	0
Sulfate	1,000 – 10,000	100 – 3,000	1,000-10,000	100 - 3000
Iron	100 – 1,000	< 10 – 100	100-1,000	<10
Aluminum	10 – 1,000	< 1	1-100	< 1
Manganese	5 - 100	< 5	2 – 25	< 2
Copper	ND – 1	ND	1-100	0.1 –1
Zinc	ND – 5	ND	10-1,000	1-10
Cadmium	ND	ND	0.05-1	0.01-0.1
Lead	ND	ND	0.5-10	0.01-0.1

Except for pH all concentrations are in mg/L

The main difference between coal mine drainage and metal mine drainage is the level of trace metals present in the drainage. The specific trace metals are a function of the ore that is being mined.

Typical Range of Removal in Wetlands Constructed to Treat Mine Drainage

Parameter	Coal Mine Drainage	Metal Mine Drainage
	Typical removal efficiencies	Typical removal efficiencies
pH	>6	>6
Acidity	75-90%	75-90%
Sulfate	10-30%	10-30%
Iron	80- 90+%	80- 90+%
Aluminum	90+%	90+%
Copper	NM	80- 90+%
Zinc	NM	75-90+%
Cadmium	NM	75-90+%
Lead	NM	80- 90+%

NM not measured, in general most coal mine drainage contains only low levels of these metals so they are not routinely monitored.

Manganese removal very variable, in general don't see much in wetland

Industrial Waste Water Wetlands Treatment

- Petrochemical Facilities
  - Refineries
- Pulp and paper processing
- Tanneries
- Food Processing
- Department of Defense Facilities
  - Deicing
  - Explosive residue

Chevron Wetland

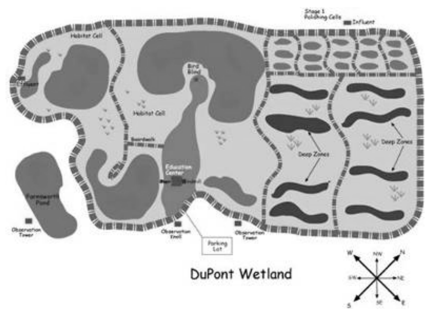
No Associated Notes

43

Industrial Wastewater

- Highly variable between sites
  - Function of type of industry process
- Relatively constant at given site
  - Function of specific industrial
  - Flow
  - Water quality
- May require pretreatment

Dupont Victoria wetland, Texas



Flow is typically not storm related, so do not have the large peak flows that must design for in storm water and certain mine drainage situations

Some industrial waste may contain constituents that are toxic, so would need to pretreat prior to wetlands treatment

44

Treatment Efficiency, Industrial Wastewaters (Petrochemical)

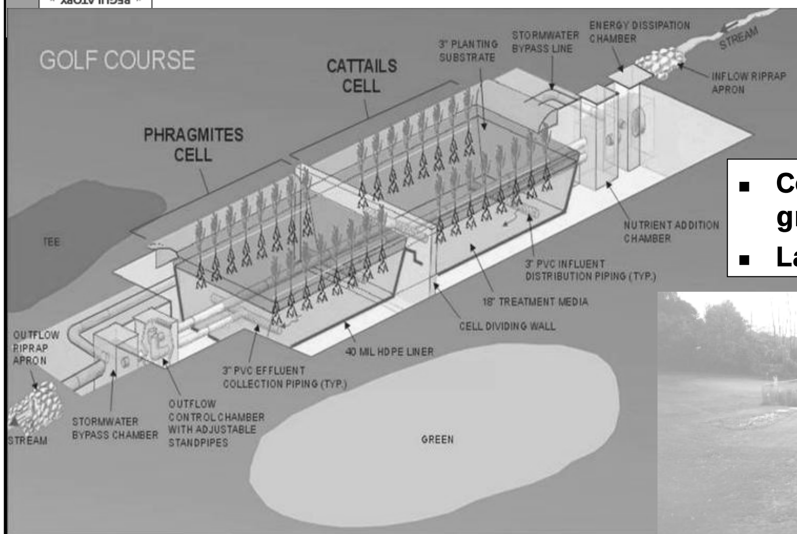
Parameter	Influent Range (mg/l)	Percent Removal
Oil & Grease	0.84-2.10	65-94%
Total suspended solids	20-181	45-86%
Phenols	0.027-0.08	63-79%
Phenanthrene	0.385	99.9%

Data from petrochemical industries
Detailed data , summary info taken from this table, in text

Wetland Type and System **Contaminant**
Influent (mg/L) **Percent Removal**
SF wetland-pond, oily water, Mandan, ND Oil & Grease
2.10 94
SF wetland-pond, oily water, China Oil & Grease
0.84 65
SSF, oily water, Houston TX. Oil & Grease

90
SSF, vehicle wash water, Surprise, AZ. Oil & Grease
------- 54 – 92
SF wetland-pond, oily water Mandan ND TSS
35.0
86
SF oily water, Richmond, CA. TSS
20.0
45
SF wetland-pond, oily water, China TSS
181
77
SSF, refinery effluent pilot-scale, Germany Phenanthrene
0.385 99.9
SF wetland-pond, oily water, Mandan ND Phenol
0.08 79
SF, floating aquatic plants (water hyacinth) Phenol
------- 81
SF wetland-pond, oily water, China Phenol
0.027
63
SF, floating aquatic plants (water hyacinth) Benzene, Toluene
------- > 99
SF, floating aquatic plants (water hyacinth) Napthalene
------- 86
SF, floating aquatic plants (water hyacinth) Diethyl Phthalate
------- 75
SSF, microcosm, UNM, Albuquerque, NM Benzoic acid
40.0 99

Remedial Activities



- **Contaminated groundwater**
- **Landfills**

SUBSURFACE CONSTRUCTED WETLANDS TREATMENT SYSTEM
Exxon Mobil Corporation, East Providence Terminal

No Associated Notes

Remedial Wastewater

- Site specific
- Typical contaminants
  - VOC's
  - BOD, COD
  - PAH's
  - metals

No Associated Notes

Hazardous Waste Landfill, Concentrations and Removal Efficiency

Constituent	Input (mg/L)	Removal Efficiency %
BOD	70	95
Ammonia Nitrogen	230	91
Phosphorus	1.9	99
Benzene	0.0055	94
Xylene	0.045	98
Iron, total	51	98
Copper, total	0.030	89
Lead, total	0.013	100
Nickel, total	0.065	82

Data from New York, see document

Municipal and Sanitary Landfill Leachate

- Leachate composition is related to
  - type of waste
  - landfill age
- Other factors affecting leachate quality
  - variability in landfill design
  - annual precipitation
  - evapotranspiration
  - groundwater flow

No Associated Notes

Landfill Leachate Characteristics

Note: Data from NCEL, 1991

Pollutant	< 2 years Old (mg/l)	> 10 Years Old (mg/l)
pH	5.0 – 6.5	6.5 – 7.5
BOD	4,000 – 30,000	< 100
COD	10,000 – 60,000	50 – 500
TOC	1,000 – 20,000	< 100
Total Solids	8,000 – 50,000	1,000 – 3,000
TSS	200- 2,000	100 – 500
Total N	100 – 1,000	< 100

Naval Civil Engineering Laboratory (NCEL), 1991, Contract Report, CR91.013

Municipal and Sanitary Landfill Leachate

Fort Edward, NY landfill

Wetland treatment system

No Associated Notes

51

Wetland Treatment of Municipal Landfill Leachate, Fort Edward, New York.

Appendix A Case Study 12

Constituent	Input Concentration mg/l	Output Concentration mg/l
Fe	20-97	1-39
As	<0.005-0.1	<0.005-0.011
Vinyl Chloride	<0.01-300	<0.01
1,2-Dichloroethene	<0.001-0.3	0.002-0.010

4 acres subsurface wetland planted with phragmites

3 cells in parallel

Input is combination of seepage and groundwater, wetland started in September 1998

An air stripper pretreatment was used initially to eliminate the VOC's, but when concentrations decreased in the leachate the air stripper was discontinued (only ran for 1 month)

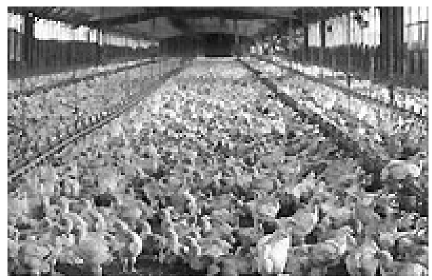
the original concern at the site was PCB's since they were disposed at this site with other chlorinated solvents

Now the major concern is iron and other parameters similar to municipal landfills

Data in table is ranges from 2002 data, almost all, 99% of dichloroethene is in cis form

Agricultural Waste Water

- Wastewater includes runoff and water associated with
  - Cultivated fields
  - Animal areas
- CAFO (Confined Animal Feeding Operations), special case
  - Concentration of pollutants are generally high and require pretreatment
  - Anaerobic Digesters and primary and secondary treatment lagoons are typical pretreatment



CAFO's are like small (or depending on size large) communities, so more like municipal waste water

TVA using a reciprocating system, switching between an aerobic an anaerobic wetland

What is an animal unit?

Animal units are based on the amount of manure that a certain animal produces. 1,000 animal units is equivalent to:

•1,000 head of feeder cattle

•100,000 laying hens

•2,500 swine (each weighing 55 lbs. or more)

•500 horses

•700 dairy cattle

•10,000 sheep

•55,000 turkeys

Therefore, the amount of waste from 2,500 swine is approximately the same amount produced by 100,000 laying hens. The waste from 1 hog is equivalent to the amount produced by 2.5 people.

So a 10,000 hog operation produces about the same amount of waste load as a community of 25,000 people

Common Constituents Found in Agricultural Wastewaters & Removal Efficiencies

Parameter	Input concentrations (mg/l)	Removal (%)
TSS	100-1000	60-90
BOD	100-1000	50-90
Total Nitrogen	30-250	50-90
NH_4-N	10-200	50-90
Total Phosphorus	10-30	40-80

Summary of table in guidance document

On-Site Waste Water

- Single Family Dwellings, Public Facilities, Parks, Apartment & Commercial Developments
- Several hundred square feet in area
- Can provide better than Secondary levels of treatment for BOD, TSS, and fecal coliform w/ variable performance for removal of ammonium nitrogen
- Normally discharges to subsurface soils rather than surface water

Usually used when on site soils are not suitable for standard drain field or water table is too close to surface

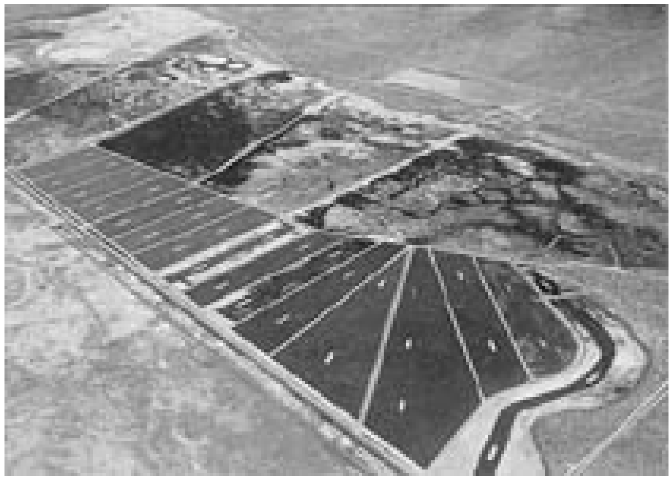
septic tank feeds to wetland

Can be surface or subsurface, in cold climates subsurface is preferred to minimize freezing problems

Subsurface also minimizes mosquito problems

Used in many states, for example, Nebraska, Texas, Minnesota, Tennessee, Rhode Island

In Summary



Incline Village, Nevada

No Associated Notes

Question & Answer

??

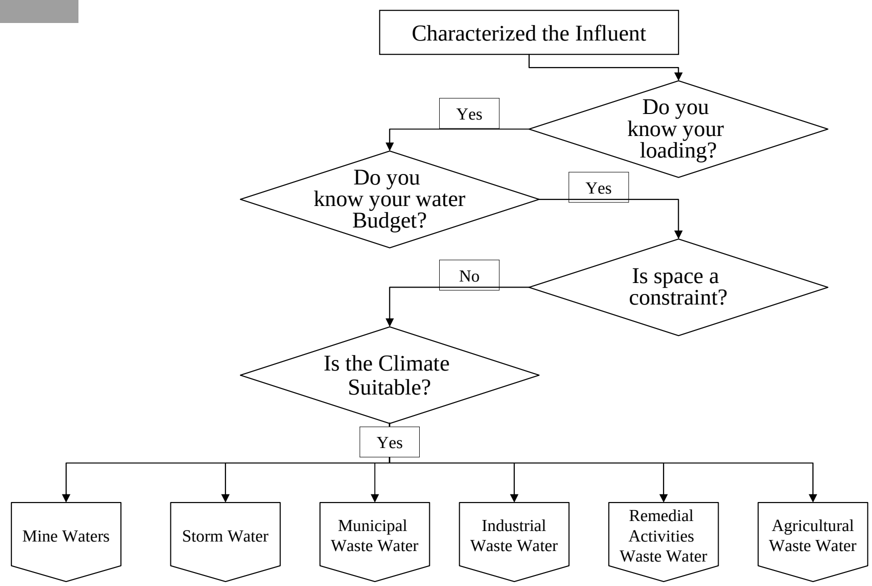
??

??

No Associated Notes

57

Decision matrix for determining the applicability of constructed wetlands for a site



See figure 1-1 in the guidance document for the full page diagram

Design of a constructed wetland is an iterative process involving site-specific data. Prior to design and construction, however, information must be evaluated regarding the conditions of the site to assess the efficacy of the proposed constructed wetlands. The design of the constructed wetland will need to be based on the best available wetland science in order to develop preliminary treatment removal rates and hydraulic loading rates. This decision tree should be followed as a means of determining whether a constructed wetland is an appropriate treatment system for the circumstances of a specific site.

Influent Characterization

- Most critical step in determining whether a treatment wetlands will work

- What is the chemistry?
- Net alkaline or net acid?
- What is the flow?
- Average/expected maximum?
- What future changes are expected?
- What are the water quality limits?
- Are constituents treatable through a constructed wetlands?

No Associated Notes

Water Budget Calculation

- All water in and out of a wetland cell
  - natural flows, process flows, stormwater runoff, precipitation, ice thaws, and groundwater

P + SWI + GWI = ET + SWO + GWO + S

Where

P = Precipitation

SWI = Surface water input

GWI = Groundwater input

ET = Evapotranspiration

SWO = Surface water outflow

GWO = Groundwater outflow

S = Change in storage

Water movement into, through and out of a wetland must be understood for proper design of a treatment wetland. Catastrophic failures of constructed wetlands (i.e., wetlands that are dry or frequently flooded) are most often due to inattention of these water fluxes during design. Water budgets are used to create inflow and outflow quantities needed for design parameters such as depth or flow. Preferential internal flow paths (short circuits) should be considered because of their ability to compromise treatment efficiency. Hydraulic loading rate (HLR) and residence time are used to compare and predict wetland performance

60

Determination of Site Suitability

- Available land area
- Climate
- Soil
- Groundwater
- Topographic conditions
- Biological conditions
- Potential risk issues
- Stormwater

Wetlands are ideally suited to sites which have a relatively large available area, have a source of year-round water, an appreciable growing season, and a relatively large volume of water requiring treatment with low to moderate contaminant concentrations. Since there are many considerations in treatment wetland implementation, it is advisable to conduct a feasibility study and alternative analysis for treatment technology selection. This involves the site-specific collection and analysis of selected information and evaluating this information versus other treatment technologies. This should answer fundamental but important questions such as whether the influent is excessively toxic or if the land area required makes a wetland treatment option impractical.

Climate

- Precipitation
  - Daily & Seasonal
  - Design Storm Events
- Daily and seasonal air temperatures
  - Evapotranspiration
  - Freezing
- Available Sunlight

Several climatic factors affect the design of a constructed wetland. Daily and seasonal precipitation patterns determine the amount and timing of runoff events to stormwater treatment wetlands. Daily and seasonal air temperatures affect biological and chemical processes. Humidity affects temperature and precipitation where both are controlling factors in biological and physical processes. Climatic factors that are important in treatment wetland design include typical and extreme patterns of sunlight, rainfall, temperature, evapotranspiration, and freezing. The amount of sunlight impinging on the wetland is important since this energy input is the primary driving force for most physical and biological processes. Plant productivity is affected by the amount of sunlight, both directly through photosynthesis and indirectly through the effect of sunlight on air and water temperature. Evapotranspiration from wetlands is highly correlated with the amount of incident sunlight. Microbial processes affecting nitrogen concentrations (e.g., mineralization, nitrification, and denitrification) are all significantly reduced at lower temperatures. While organic matter decomposition is also slowed at low temperatures, the global affect of cold climates on BOD treatment in wetlands is negligible.

62

Site Soils

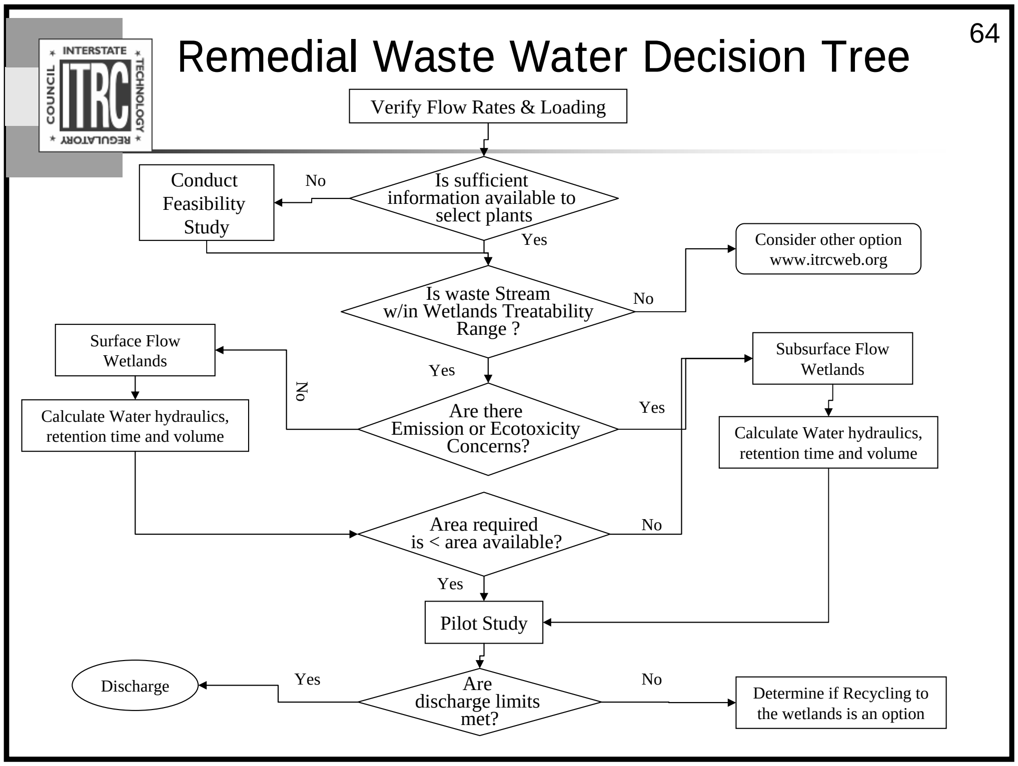
- Unified soil classification
- % sand, silt, clay organics
- Permeability
- Field Capacity
- Cation Exchange Capacity

Site soils need to be understood in order to predict hydrology, prepare for excavation, and determine suitability for wetland plants. Several soil samples from more than one location beneath the proposed wetland site should be collected and classified.

Design/Construction Process

- Pre-design investigations
  - Treatability assessment/feasibility study
- Conceptual design
- Detailed design
- Construction
- Operations and Maintenance
- Monitoring

No Associated Notes



While there is a general approach to the design and construction of treatment wetlands, individual applications will require specific considerations unique to that application.

Design Checklist

- ✓ Role and responsibilities of the project team
- ✓ Treatment goals
- ✓ Baseline site characterization
- ✓ Treatability assessment/feasibility study
- ✓ Proposed design
- ✓ Work plan for implementing final design
- ✓ Detailed study to eliminate safety hazards
- ✓ Evaluation of hazards to public health/environment
- ✓ Operations/maintenance and monitoring plans
- ✓ Plan to deal with secondary wastes
- ✓ Contingency plan if wetlands do not achieve goals
- ✓ Site security

A design checklist, in conjunction with the aforementioned decision trees, can be effectively used to plan, review, and study the constructed wetland system performance. This checklist will highlight the data requirements, site needs, and action plans to the site owners, system operators, regulators, and stakeholders.

Engineering Issues Considered as Part of the Design

- Site-specific water budget
- Sizing the wetland
- Liners
- Berms
- Inlet/Outlet structures
- Treatment Media
- Plant selection

No Associated Notes

Site-Specific Water Budget

- Water budget
  - All water in and out of a wetland cell
- Depth and velocity
  - Laminar to promote settling (Less than 6 inches/second)
  - Depth of water in SF systems is generally 4.0 inches to 24.0 inches
  - Subsurface systems have flow depths varying from 1.6 to 2.6 ft
  - Vertical flow component may be critical in some wetlands
- Internal flow path
  - Internal flow patterns can promote mixing and better treatment or they can also promote "short-circuiting" and reduced removal efficiency.

Water movement into, through and out of a wetland must be understood for proper design of a treatment wetland. Catastrophic failures of constructed wetlands (i.e., wetlands that are dry or frequently flooded) are most often due to inattention of these water fluxes during design. Water budgets are used to create inflow and outflow quantities needed for design parameters such as depth or flow. Preferential internal flow paths (short circuits) should be considered because of their ability to compromise treatment efficiency. Hydraulic loading rate (HLR) and residence time are used to compare and predict wetland performance

Sizing the Wetland

Determine the time and area needed to reduce the input concentrations to an acceptable outflow

- Sizing/performance
  - Removal Rates
    - Kinetic Expression
    - Areal loading
    - Empirical-Field or Laboratory
  - Residence time
  - Hydraulic loading rate
- Rules-of-Thumb:
  - Stormwater treatment wetland:
    - Wetland size ~ 1 to 5 % of the contributing watershed
    - Design storm
  - Municipal wastewater wetland treatment
    - Surface flow wetlands - ~ 50 Acres/MGD
    - Subsurface flow wetlands - ~ 20 acres/MGD

No Associated Notes

Sizing Calculations

- Mass balance or input/output models to estimate area requirement
  - $A = -Q/k \times \ln[(C_{outlet} – C^*)/(C_{inlet} – C^*)]$
    - Above equation assumes 1st order rate of reaction
    - design relationships are available
- Residence time (T) days
  - $T = V / Q$
- Hydraulic Loading Rate (HLR) or (q)
  - $q = Q / A$
    - V = Wetlands volume (m^3)
    - A=wetland area (m^2)
    - Q = Average flow Rate (m^3/day)
    - k = first order rate constant (m/yr)
    - C*=irreducible background concentration (g/ m^3)
    - C_{outlet} /C_{inlet} = outlet/inlet concentration of contaminant (g/ m^3)

1 meter = 3.28 feet

Arati's notes: Reference for design equation: Kadlec & Knight; various design equations are available for wetland sizing – rate constant could be area/volume based; concept of irreducible background concentration (computed based on inlet concentration e.g. for BOD removal, C*=3.5 + 0.035Cinlet)

Chuck's notes: Both residence time (or hydraulic residence time – HRT) and hydraulic loading rate (HLR) are gross wetland parameters used to predict and make generalizations about overall wetland performance. Increasing residence time and lowering the HLR generally improves treatment efficiencies. Residence time refers to the nominal or theoretical amount of time discrete mass (i.e. a water molecule) will remain in the wetland. Hydraulic loading rate (q) refers to the flow rate per unit area. This is also a gross parameter and generalizes wetland characteristics, but is an easy calculation for basic comparisons of systems.

Liners & Berms

- Liners (synthetic or clay, see section 5.2.2 of the text)
- Berms provide the basic containment structure for the constructed wetlands, and ensure that the basic hydrologic foundation of the wetlands is met.

Geotextile Liners

In all rocks are less than 3/8 inches in diameter no geotextile is required.

If the visible rocks are less than 3/4inches , 4 oz. non-woven polyester or polypropylene geotextile fabric should be placed on the subgrade to protect the liner from punctures

If the rocks are larger than 3/4inches and smaller than 1-1/4inches, then an 8 oz geotextile should be used.

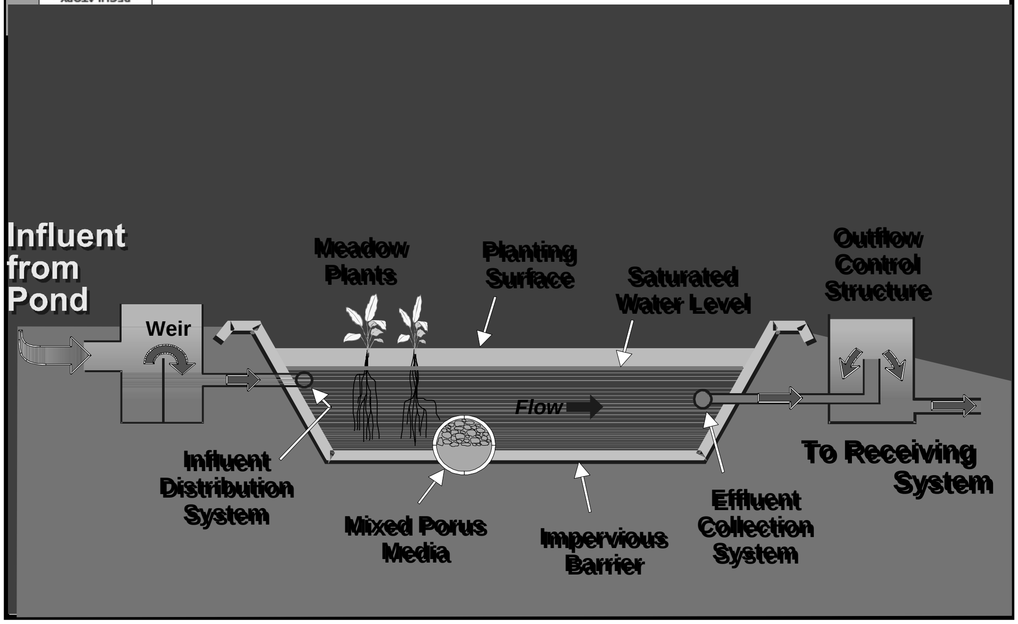
Rocks larger than 1-1/4inches should be removed, or a 6 – 12inches underlayment of sand should be placed on the subgrade that will prevent the bridging of the liner material over the rocks

Inlet & Outlet

- Flow distribution Structure
  - V-notch or horizontal weirs
  - flow splitters for small flows (10,000 gpd or less).
- Flow distribution piping
  - wastewater must be uniformly distributed in the front end of the wetlands
- Flow Collection Piping
  - reverse of flow distribution
- Level Adjust Structures
  - 100-foot long wetland with a 1% slope will have water standing 24 inches at one end and 12 inches at the other end.

Constructed wetlands require structures that can uniformly distribute wastewater into the wetlands, control the depth of water in the wetlands, and collect the treated effluent leaving the wetlands. In designing these structures, ease of construction, ease of maintenance, operator safety and visibility should be the primary considerations for the designer.

Wetland Inlet/Outlet Structures



No Associated Notes

Treatment Media

- More typical to subsurface flow wetlands
- Average treatment media depth is 12 to 30 inches
- Standard media
  - Sand
  - Gravel
  - Rock
- Surface flow media generally soil
- Organic material
  - Peat/hay bales
  - Compost

The general principle is to select treatment media materials that are within a few sieve sizes. For example, specify gravel between 1/2 to 1inches, or pea gravel from the #8 to 3/8inches sieve. This will produce the material with the greatest void ratios and testing will routinely show void ratios greater than 40%. Examining the gravel pits standard sieving operations can be used to develop other combinations.

Plant Selection

- Native
- Noxious and invasive
  - Phragmites, purple loosestrife
  - Check your state's list of invasive plant species
- Vegetative form
  - Submerged
  - floating
  - Emergent
- Select plants based on the type and objectives of your treatment wetland

http://plants.usda.gov/

Design Implementation

- Soil erosion and sediment control
- Grading and sub-grading preparation/construction
- Plant installation
  - Grid spacing
  - Soil / stratum type
  - Fill wetland gradually, establishment period
- Post-construction activities
  - As-Built Reports
  - O&M
  - Monitoring

No Associated Notes

Operation & Maintenance

- O & M
  - Water level
  - Control of nuisance pests
    - Mosquitoes
    - Beavers
    - Muskrats
  - Longevity
  - Substrate Disposal
  - Invasive species

Whether the need for a maintenance activity is identified during the periodic vegetative monitoring, or through casual routine observations of the site, certain actions will be necessary to ensure the efficacy of the constructed wetlands. Potential maintenance activities include maintenance of water flow uniformity (inlet and outlet structures), management of vegetation, odor control, control of nuisance pests and insects, and maintenance of berms and dikes and other constructed water control structures.

Possible Monitoring Requirements

Parameters	Sampling Locations	Minimum Sampling Frequency
Inflow and Outflow Water Quality ▪BOD5, COD , TSS, pH, DO, Conductivity, Temperature, oils and grease, nitrate-nitrogen , ammonia nitrogen, Total phosphorous, Chlorides, Sulfate ▪Metals, organics, toxicity	Inflow and outflow Inflow and outflow	Monthly to weekly Semiannually
Flow rate	Inflow and outflow	Daily
Rainfall	Adjacent to Wetland	Daily
Water levels	Within Wetland	Daily
Biological indicators (microorganisms, plant cover, macrovertebrates fish and invasive species)	Inflow, Center, Outlflow	Quarterly to annually [weekly to daily visual observations are recommended]

Monitoring is needed to measure system performance and discharge compliance; maintain wetland operational control; allows the identification of performance trends that might develop into problems early on, when intervention is most effective. A written monitoring plan is essential if continuity is to be maintained throughout the life of the project, which may span decades. Regulators will probably insist on an agreed upon monitoring plan prior to permit submittal or they will add permit conditions requiring specific monitoring activities. Additional regulatory monitoring may be required depending on the nature of the project (i.e., research or compliance).

Costs

- Variables
  - Detention time
  - Treatment goals.
  - Depth of media
  - Type of Pretreatment.
  - Number of Cells
  - Source and Availability of Treatment Media.
  - Terrain.

No Associated Notes

Cost Comparison

- Average construction costs for surface flow wetlands
  - $22,000 per acre ($0.78/1000 gallon treated)
- Average construction costs for subsurface flow wetlands
  - $87,000 per acre ($0.62/1000 gallon treated)
- Technology comparison (from Section 7.4 in the document)
  - Sequencing batch reactor
    - $596,700 in capital costs, $1,657,902 in O&M (20 years)
  - Wetland and sand filter
    - $365,300 in capital costs, $206,902 in O&M (20 years)

Reed and Brown,

No Associated Notes

Regulations

- Federal
- State
- Local

Your friendly regulator

No Associated Notes

Federal Regulations

Federal law	Purpose	Responsible Agency
• Clean Water Act (CWA)	• Elimination or management of Point and Non Point Sources of Pollution.	• EPA Administers Section 402 (NPDES)
• National Environmental Policy Act (NEPA)	• Requires Federal agencies or anyone conducting an action on federal lands to consider the environmental impacts of that action	• Council of Environmental Quality (CEQ)
• Endangered Species Act (ESA)	• Protects all endangered or threatened species	• U.S. Fish and Wildlife Service

No Associated Notes

Permitting, the process may be ugly…

City of Renton	Washington State	Federal
1. Shoreline Development Permit.	1. Shoreline Management Act	1. Individual Fill Permit (CWA Section 404)
2. Grade and Fill Permit	2. Hydraulic Project Approval	
3. Environmental Review	3. Water Quality Certification (CWA Section 401)	
	4. Management	

Project at Renton Sewage treatment plant

Urban wetlands, treated stormwater and provided water to the sewage treatment plant

Wetland enhancement project designed to improve wetland functions (including improving water quality) as well as providing recreational opportunities (trails), add info on Renton water park which was incorporated into the project

Large number of agencies at all levels involved

But the result can be beautiful....

Renton Wetland

Combining stormwater treatment and art

PHOTO: NED AHRENS, KING COUNTY, WA

PHOTO: NED AHRENS, KING COUNTY, WA

PHOTO: NED AHRENS, KING COUNTY, WA

King County, WA, makes the public aware of stormwater infrastructure in an unexpected place.

By Donna Gordon Blankinship

Seven years after it opened to public and industry accolades, Waterworks Gardens in south King County, WA, still attracts international attention for the way it turned stormwater treatment into a beautiful thing.

A common goal at water treatment plants has always been to avoid being seen, heard, and most especially smelled, relates Richard Butler, process control supervisor for King County's South Treatment Plant in Renton. So when an artist hired to "dress up" an addition to the plant suggested replacing stormwater ponds with a pond-filled public park, her idea was not even close to what the planners had in mind. The artist, Lorna Jordan, was quite persuasive, however, and now those associated with the project speak proudly of the successful collaboration.

"It turned out really well. Some of us were surprised that it was accepted so quickly and given so much praise," Butler says. "There are a lot of art projects involved in so many government projects. They tend not to get this kind of praise on a communitywide basis."

What really amazes Butler and others is how much the park is used every day; they also have been astounded by some unusual requests from the public. "We've had calls from people interested in having weddings in the Grotto!" which is the stonework focal point of the garden. A wedding at a water treatment plant? Butler still laughs at the idea.

Treating Stormwater Runoff

Waterworks Gardens is an 8-ac. facility that naturally filters stormwater collected from more than 40 ac. of impervious surface at the South Treatment Plant through the use of 11 ponds and enhanced existing wetlands. The ponds are connected by a series of pipes that allow for up to a 4.5-cfs flow rate as delivered by the stormwater pump station, which adds up to about 2.2 million gal. a day. The ponds are fed by both a variable speed pump and a constant speed pump, which can serve as a backup. Valves at the plant can be set to divert flow to the wastewater treatment plant rather than to the wet ponds to allow for inspection, draining, and servicing. Before the waterworks were built, all of the stormwater runoff from the plant went into the wastewater treatment system.

Waterworks Gardens was built as part of the third phase of the South Treatment Plant. The plant opened in 1965 and now serves a population of more than 600,000 people in south and east King County.

The ponds are designed to hold a total of 642,327 gal., including room for 15.9% sediment storage. Sediment is removed from the ponds, however, when it exceeds 10% of the total volume. Some of the ponds have emergency drains to catch overflow water. The paths around the ponds also were built in a way to create a flood drainage system. The park is designed to handle a peak 24-hour, two-year storm.

All of the wet ponds are constructed with a layer of indicator rock on the final, exposed bottom surface. This protects the underlying impermeable layer of polyvinyl chloride sheeting.

A recirculation pump draws water from the last wet pond and returns it to the first pond, resulting in a continuously flowing loop of about 250 gal./min. cascading through all the wet ponds. This helps avoid stagnation, prevent ice formation, enhance pollutant removal, distribute makeup water, and provide a water supply for the water features. The process also seems to keep the mosquito population under control.

Before releasing the water into neighboring Springbrook Creek, King County concerns itself with ridding the water of sediment, oil, and grease from vehicles on the plant roadways; suspended metals; and fecal coliform from the bird population in the wetlands. The principal sources of silt-laden runoff on the site are construction vehicles associated with onsite earthwork

ISSUES!

No Associated Notes

85

Issues

- Treatment vs. Compliance
  - May not be able to meet extremely low limits
    - Background concentrations may exceed limits
  - Abandoned sites
    - Water quality improvement without meeting strict numeric standards
- Maintenance
  - During operation
  - Long term
- Winter operation
  - Flow problems due to ice build up
  - Slower reaction rates

Abandoned sites, particularly true with applications to mining.

Background concentrations in wetlands may be higher than very low limits required by TMDL allocations

Constituent	Background Wetland Concentrations
TSS	3
BOD	5-10
Total Nitrogen	2
NH_4-N	1
Total Phosphorus	
Fecal coliform	
Cfu/100 ml	200

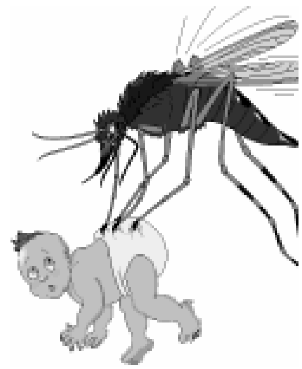
This can be a particular problem if the wetland is used by wildlife, can get elevated levels of fecal coliform

Winter operation

Subsurface generally preferred in cold climates, since less problems with freezing, need to design so that incorporate slower winter reaction rates

Issues (cont’d)

- Longevity
  - Function of parameter and removal process
- Substrate Disposal
- Ecological Impacts
  - Nuisance organisms
  - Food chain impacts



Nuisance organisms, will require monitoring and maintenance

Invasive species – early identification, removal

Mosquitoes usually stay close to breeding area, (female typically travels < 1 mile) so if remote or in area with other wetlands, limits the impact

subsurface systems minimize breeding area

In warmer climates, mosquito fish, successful in controlling population, some areas may consider Gambusia as a nuisance species

There are also chemical treatments available which have been shown to have minimal environmental impacts

These products include:

¨ Bti, which is a fermentation product of the

bacteria *Bacillus thuringiensis* var*israelensis*

¨ s-Methoprene. Bti, a growth regulator.

Bti does not contain live bacteria – its active elements are crystalline spores which are suspended in water at treatment and destroy the gut lining after being filtered from water by feeding larvae. Methoprene is a mimic of the natural “hormone” which controls the moulting process when mosquito larvae become pupae. It produces high mortality in the pupal stage and is effective against some mosquito species at concentrations as low as 12 ppb. Bti is generally applied as a liquid formulation, while methoprene is usually presented coated onto sand granules or in a slow release charcoal matrix. A second bacterial product based on *Bacillus sphaericus* is likely to be commercially available in the near future and is expected to be particularly suited to control of mosquito larvae in organically polluted water.

Problems in surface systems can occur if BOD loading is too high, this reduces oxygen concentration in water and restricts predators, e.g. mosquito fish and dragonfly and damselfly larvae

Food chain impacts

Function of constituent and type of wetland, for trace metals, little metals into plant, most into sediment

Some metals more concern than others, e.g. lead

Can limit organisms exposure by using a subsurface flow

Why Do Wetlands Fail?

- Too small
- Improper design
- Lack of construction supervision
- Changing conditions
  - Input
  - Wetland

Ongoing observations of the wetland are critical to insure that the wetland continues to function as designed

Why Do Wetlands Fail?

Prior

Proper Planning

Prevents Poor Performance

No Associated Notes

Wetland Failure

Pilot wetland, northern Minnesota, summer 2001

Goal was to remove sulfate through anaerobic sulfate reduction reactions, the majority of flow in this design was across the surface of the wetland resulting in ineffective treatment

Wetland, Take 2

Pilot wetland, northern Minnesota, summer 2002

Redesigned system as subsurface, problems, too many fine sized particles restricted flow, overworking substrate may have caused compaction which also restricted flow

If at first you don't succeed.....

Pilot wetland, northern Minnesota, summer 2003

Redesigned, much more detail given to hydraulics, coarser substrate, much more successful

Limitations

- Appropriate land must be available
- Wetland establishment can be relatively slow
- Dependent on local climatic conditions

One of classic reasons for wetland failure is inadequate size

Plants take several years to establish. Transplants establish more quickly but are more expensive to buy and require more labor to plant.

Wetlands have been built and operated successfully in all climates. Problems with winter operation, slower reaction rates, ice buildup, must be incorporated into the design. Some increased operational costs may be required to insure proper operation during winter. The slower reaction rates in winter will require a larger wetland area than is needed during the summer

93

Advantages

- Low maintenance
  - passive
  - solar-driven system
- Applicable in remote locations without utility access.
- Decreased emissions and sludge production compared to conventional treatment plants
- Able to remediate sites with multiple or mixed contaminants.

The lower maintenance and as a result lower operating cost is the key advantage. The lack of power requirements makes these systems ideal for remote locations and abandoned sites.

Depending on the particular contaminant and the wetland design, there may be no solid disposal issues as there is with chemical treatment facilities. Also handling of chemicals is eliminated.

Advantages (continued)

- Habitat creation or restoration provides land reclamation upon completion.
- Favorable public perception, increased aesthetics, and lower noise than mechanical systems.
- Increasing regulatory acceptance and standardization.
- Carbon dioxide (greenhouse gas) sequestration.

Again if creating habitat either during operation or at the end is a goal, it must be incorporated into the design.

95

Thank you for your participation

Links
To
Resources

Links to additional resources: http://www.clu-in.org/conf/itrc/wetlands/resource.cfm

Your feedback is important – please fill out the form at: at http://www.clu-in.org/conf/itrc/wetlands/

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

•helping regulators build their knowledge base and raise their confidence about new environmental technologies

•helping regulators save time and money when evaluating environmental technologies

•guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

•helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

•providing a reliable network among members of the environmental community to focus on innovative environmental technologies

•**How you can get involved in ITRC:**

•Join a team – with just 10% of your time you can have a positive impact on the regulatory process

•Sponsor ITRC's technical teams and other activities

•Be an official state member by appointing a POC (Point of Contact) to the State Engagement Team

•Use our products and attend our training courses

•Submit proposals for new technical teams and projects

•Be part of our annual conference where you can learn the most up-to-date information about regulatory issues surrounding innovative technologies