Constructed Wetlands
an alternative to wastewater treatment

from Bluegrass
to Greengrass

a senior comprehensive project
by Matthew S. Vinten

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spring 1998
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I dedicate this project to the one that makes it all worth while, my fiance Aimee Gagel.
Abstract

This project is being done for Landscape Architecture 404 - Comprehensive project. It involves the entire design process to be initiated by the student. This involves developing and writing the projects design program and proposal, which is then implemented to a chosen site. This comprehensive project encompasses the investigation of using constructed wetlands as an alternative form of wastewater treatment for a small rural community. It addresses issues concerning the biological treatment of wastewater, biological diversity of constructed wetlands, and educational enrichment about wetlands.
**Introduction**

With the arrival of large industries and increasing populations, the need to dispose of increasing amounts of waste has become a major concern. Failing to deal with these wastes in the past led to contaminated surface and subsurface waters. Constructed wetlands is one method used to help purify wastewater. Constructed wetlands can be defined as a designed and man-made complex of saturated substrates, emergent and submergent vegetation, animal life, and water that simulates natural wetlands for human use and benefits. These benefits include the fact that constructed wetlands 1) are relatively inexpensive to construct and operate; 2) are easy to maintain; 3) provide effective and reliable wastewater treatment; 4) are relatively tolerant of fluctuating hydrologic and contaminant loading rates; and 5) may provide indirect benefits such as green space, wildlife habitats, and recreational and educational areas (Hammer and Bastian, 1989). Constructed wetlands are based on, but different than, natural wetlands. In constructed wetlands, a section of land is chosen near the source of wastewater that is to be purified. A shallow pond is built and plants found in natural wetlands such as cattails, reeds, and rushes are set out. The wastewater is then directed through the wetland. Microbial utilization and plant uptake of nutrients results in cleaner water leaving the constructed wetland than what entered. Wetlands also provide and promote ecologically diverse habitats for flora and fauna, giving rise to new and diverse biological communities.

With the increase of suburban sprawl, many families are moving out from the suburbs and into rural areas. This continuing trend has led to the creation of many small rural subdivisions detached from the city water and sewage lines. This constitutes a need for individual water supply and disposal. Many home owners have resorted to wells, septic tanks, and leach fields as their water and sewer treatment facilities. Over time this process will contaminate groundwater and surface water supplies which provide drinking water to those homes. The contamination of the water supply has caused environmental and health related problems which could have been easily avoided.

This project has taken a current and future problem and found an effective and safe solution, but in an unconventional way. This involves the integration of an existing rural community and uses the biological processes of a constructed wetland system to effectively and safely treat wastewater.
Problem

With growing populations and the need for waste disposal increasing, alternative methods for wastewater treatment will be needed. Current chemical practices are contaminating biologically sensitive ecosystems thereby decreasing the quality of water returned to the water supply and biological diversity of the surrounding ecological communities. The need to find alternatives for small communities is growing.

Sub-Problems

Many cities and their surrounding communities are growing at a rapid rate. This rapid growth has increased the amount of wastewater needed to be treated. The current treatment process for wastewater poses a threat to the diversity of flora and fauna within surrounding ecological communities. Excess wastewater often leads to overflow and leakage of raw sewage and chemicals into the surrounding community, and the appalling odor produced as a bi-product of chemical treatment processes.

The use of constructed wetlands for wastewater treatment can be an effective, environmentally productive, and safe alternative process for treating wastewater. Constructed wetlands will allow wastewater to be cleaned by natural biological processes which are beneficial to their surroundings and help increase the bio-diversity of surrounding flora and fauna ecosystems. Other benefits for constructing wetlands are their ability to replenish nutrient cycles to ecological communities, create a natural preserve for wildlife, and educational enrichment about environmental processes. Issues taken into consideration for this project were carrying capacity of constructed wetlands, the biological process for breaking down of wastewater, the impact of the surrounding land use, and the ecological systems with wetlands.
Assumptions

The complexity of this comprehensive design project warrants several assumptions to be made on the part of the designer. Assumptions allow the designer to focus on the problems to be solved through the design process.

* There is a need for alternative forms of wastewater treatment.
* Individuals of the community welcome the use of constructed wetlands for wastewater treatment.
* Funding for the project was raised through private money and research grants.
* The Constructed wetlands will be used as an educational and research site.
* The Maintenance will be through volunteer service groups.
* Water exiting the constructed wetlands meets all health standards, both state and federal.
* Any surrounding landuse problems are addressed and solved before the constructed wetlands are installed.
Goals and Objectives

The following goals and objectives were created to focus the projects topic and related areas.

Goal One: Provide an effective and safe alternative for treating community wastewater using constructed wetlands as an alternative for treating wastewater.
* Use a biological process for the breakdown of wastewater.
* Introduce plant and animal species that are beneficial to the treatment of wastewater.
* Create a treatment system that meets the waste disposal needs of the community.
* Involve researchers to regulate the constructed wetlands.

Goal Two: Integrate an existing community with a constructed wetland system.
* Connect all homes to the constructed wetlands.
* Use design aesthetics to provide a visual stimulus.

Goal Three: Facilitate learning about biological diversity through an interpretive trail system.
* Design a boardwalk trail system through the constructed wetlands.
* Users will use the constructed wetlands for research and education.
* Service organizations will help to maintain constructed wetlands through service projects.
Review of the Literature

The use of constructed wetlands is a relatively new frontier for wastewater treatment. The value that constructed wetlands provides is appreciated more than ever before. Constructed wetlands can introduce an important functional and aesthetic element into the landscape (Hammer, 1989). The benefits from using constructed wetlands range from having relatively inexpensive construction and maintenance costs, providing effective and reliable wastewater treatment, increasing wildlife habitats, and recreational and educational opportunities (Hammer and Bastian, 1989).

Constructed Wetland System

There are several types of constructed wetland systems which can be used for the treatment of wastewater. The two constructed wetland systems being considered for this comprehensive project are discussed herein in general terms. The two systems are soil-based and aquatic systems. Soil-based systems or Subsurface Flow Systems (SSF), Figure 1, allows water to flow laterally through the sand or gravel (De la Garza, 1996). For this process a trench or bed is constructed, underlain with an impermeable layer of clay or synthetic liner. The water flows through a porous large-grain material, usually rock but soil or sand can be used. The rock helps to support the plant material which treats the wastewater biologically and is then ready for reuse. The aquatic system or Free Water Surface Systems (SF), Figure 2, are usually basins or channels with natural or constructed clay or synthetic liners and soil along the bottom to support emergent plant material (Moos, 1993). Water is kept at a relatively low depth flowing over the surface of the soil. These systems can be designed to integrate islands for creating new wildlife habitats and enhancing vegetative species (De la Garza, 1996).

Biological Treatment Process

The biological treatment processes of wastewater are effective on many contaminants, including biochemical oxygen demand (BOD), suspended solids (SS), nitrogen, phosphorus, pathogens, and trace metals. This efficiency is due to a diversity of treatment mechanisms, including sedimentation, filtration, and chemical precipitation and adsorption, microbial interactions with contaminants, and uptake by vegetation (Hammer, 1989). This is illustrated in Figure 6.

Suspended and attached microbial growth is responsible for the removal of soluble
BOD. In surface flow systems, the major oxygen source for this process is reaeration at the water surface (Hammer, 1989). Wind-induced water mixing and algal production will be decreased by a dense stand of vegetation or ice cover. In subsurface flow systems, the major oxygen source is from diffusion from the atmosphere through the plants to the root zone, leading to plant selection being an important factor. Suspended solids are effectively removed by both types of systems. Most solids are filtered and settled within the first few meters beyond the inlet.

Nitrogen is removed in surface and subsurface flow systems by similar means. Although plant uptake of nitrogen occurs, only a small fraction can be removed by plants (Hammer, 1989). The majority of nitrogen is removed by the process of nitrification and denitrification processes performed by microorganisms. In this process ammonia is oxidized to nitrate by nitrifying bacteria in aerobic zones, and nitrates are converted to dinitrogen gas by denitrifying bacteria in anoxic zones.

Phosphorus removal in constructed wetlands occurs from adsorption, absorption, and precipitation (Hammer, 1989). Removal are highest in submerged bed designs when appropriate soils are selected as the media. Plants absorb phosphorus through their roots and transport it to growing tissues. As the above ground portion of the plant dies, partially decomposes, and releases part of its phosphorus content (Kent, 1994).

Pathogens are adsorbed by soil and organic litter and are based on the reduction of indicator species. Bacteria are removed by sedimentation, ultraviolet radiation, chemical reactions, natural die-off, and predation of zooplankton.

The mechanisms for trace metals are chemical oxidation or reduction, adsorption/absorption by soil or plants, and simple filtration or sedimentation (Kent, 1994).

Vegetation plays several roles in the constructed wetland scheme including wastewater treatment, habitat formation, and aesthetics. There are three categories in which vegetation can be classified (1) floating plants; (2) submerged plants, and (3) emergent plants. In general, vegetation provides surfaces for microbial growth on roots, rhizomes, leaves, and stems; filters solids; and transfers oxygen to provide an aerobic/oxidized environment for organic decomposition and desired microbial populations (Hammer, 1989). Floating plants, Figure 3, utilize atmospheric oxygen (O₂) and carbon dioxide (CO₂), all other nutrients must come from the waters in which the plant float (Dinges, 1982). Submerged plants, Figure 4, help to decrease CO₂, which causes an increase in the pH levels. This increase allows phosphorus (P) and other minerals to precipitate from solution while ammonia (NH₃) is lost to the atmosphere (Dinges, 1982). Emergent plants, Figure 5, help in supplying oxygen to microorganisms, stabilization of soil, and removal of nitrogen (N), phosphorus (P), heavy
metal, and the decomposition of organic matter (De la Garza, 1996). With these systems working together along with sediment settling and aquatic animals, keeping the vegetation in check, are the basics of the biological treatment of wastewater.

**Social Attitudes about Biological Treatment of Wastewater**

There is a wide spectrum of attitudes concerning constructed wetlands. Everyone agrees there is still much to be learned about the optimization of the process (Hammer, 1989). Some states are more willing to approve presently imperfect examples in an effort to further the knowledge of the system. Characteristic of wetlands that are beneficial to society are considered as wetlands values. Values are sociological, subjective terms, which are particularly flexible. The value establishes a worth, excellence, utility or importance of a given wetland function (Hammer, 1989).

A variety of individual, societal, and global functions of wetlands involve humans. Collectively termed cultural values, these less tangible wetlands values are culturally perceived attributes and include both consumptive and nonconsumptive uses (Kent, 1994). Consumptive uses are actual or potential uses of wetlands where consumable products are removed from the wetlands including aquaculture, peat harvesting, timber harvesting, etc. Aesthetics, educational, sociocultural, and recreational values of wetlands are important determinants associated with wetlands values (Kent, 1994).

**Interpretive Activity**

The educational and learning process is an important and enjoyable part of constructed wetlands. They have been described as living museums where the dynamics of ecological systems can be taught. No other type of ecosystem is more suitable for demonstration in such broad range of ecological principles within a small area (Hammer, 1989). Interpretive trails and station points, provide the educational frame work of the constructed wetlands. Stations, Figure 7, help visitor’s to increase their knowledge and understanding of their role in the natural environment, the biological systems of the constructed wetlands, the sensitivity and diversity of wetlands, and the diversity of flora and wildlife and their respective habitats. The design, year round use of the trail, and materials can give significance and respect to the constructive wetlands (Fogg, 1990).
Data and Methodology

The data needed for this research project will fall into a series of categories. They include the process for treating wastewater, flora used for treating wastewater, design and construction guidelines for constructed wetlands, visits to case study sites, social opinions and beliefs about constructed wetlands, and geographical information about the site. Information will also be needed for the planning and facilitating of the educational programs.

The location of the data will mostly come from Bracken Library at Ball State University. Within the library information will be collected from texts, periodicals, government publications, and other senior research studies. Information outside the library will be consumed from interviews, visits to case study sites, Internet exploration, questionnaires, polls or surveys, and public literature.

This information will be obtain by checking out books, photocopying periodicals, and interviewing personnel from case study sites. Data will also be accessed through written letters, phone calls, Internet computer system, results of returned surveys and visiting case study sites.

The data collected will be used throughout the design process. The information learned will promote a better understanding of current wastewater treatment processes, the different systems of treating wastewater biologically, and the physical structure of constructed wetlands. Data will be used to design the proper biological treatment of wastewater, choose an appropriate site for the constructed wetlands, plan and design the constructed wetlands, and select proper flora species for the constructed wetlands. The information will also be used in the implementation of educational programs about constructed wetlands.

Two research methods will be used for this research study, Historical Method and Descriptive or Normative Survey Method. The Historical Research Method, secondary data, will include reading texts and scientific data about wastewater treatment and constructed wetlands, government documents about guidelines and policies for constructed wetlands and wastewater treatment, and past research done using constructed wetlands for wastewater treatment. This method will produce the necessary information needed to understand, plan, and design a safe and effective system for treating community wastewater with constructed wetlands on a suitable site.
The Descriptive or Normative Survey Methods, primary data, involves questionnaires or surveys given to the local community on their views and values about wastewater and constructed wetlands, and observations of current wetlands being used for wastewater treatment. The information gained from this method provides the social attitudes and beliefs of a communities view points about wastewater and constructed wetlands. This data will focus on the community residents in which the constructed wetlands will serve and communities that are currently using wetlands for wastewater treatment.
Program and Elements

This comprehensive project involved the integration of an existing rural community and a constructed wetland to treat wastewater. The wastewater created by the homes will be filtered throughout the constructed wetlands, with some water being returned to the homes to be used as grey water. Constructed wetlands pose an outstanding opportunity for education. Interpretive signs will be placed at various spots in the wetlands to be used by the community and programs sponsored by PAWS, Inc. The following elements were needed to create this project.

* Constructed Wetlands - treating of wastewater from the homes.
* Wood Boardwalks - wetland and habitat access.
* Wetland Vegetation - wetland plant species for wastewater treatment.
* Native Vegetation - corridors around the constructed wetlands.
* Septic Tanks - primary treatment of wastewater.
* Pumping System - returning treated water to homes to use as grey water.
* Interpretive Signs - illustrating the various natural systems within the wetlands.
* Map/Brochure - describing the constructed wetlands and interpretive trail.
Site Selection

The site selected for this project is located in Delaware County within the state of Indiana. The chosen community is named Bluegrass Estates. It is located on the southside of State Highway 28 between County Road 300E and 400E. The area chosen for the constructed wetlands is adjacent to the community. This property is owned by James and Carolyn Davis and is a part of PAWS, Inc.

This community was selected because of its current septic system problem. Effluent from the single finger septic system is draining into backyards and surrounding farm fields and causing environmental damage to the lands.

Inventory

The site consists of 34 single family homes with an average of half acre lots. The proposed constructed wetland area consists of 100 acres of cropland, forest plot, and a fallowed agriculture field. See Appendix A.

Vegetation - The majority of the site consists of agriculture fields. In the northwest corner is a stand of oak/hickory trees and thorny shrubs undercover.

Soils - The site consists of Pewamo, Blount and Morley soils. The majority of the site is Pewamo soils.

Hydrology - The water on the site is running to the northeast of the site.

Topography - The site is relatively flat with some topography. The highest point of the site is to the east on two ridges.

Analysis

Vegetation - The stand of trees in the northwest corner are moderately marshy making them an ideal location for the final unloading of the water coming from the wetlands.

Soils - Pewamo soils are well suited for the use of wetlands. While Blount and Morley are suited and not suited respectively.

Hydrology - Water runoff on site will be the only major hydrology issue.

Topography - Ideal circumstances are created from the rolling topography of the site for elevation changes that must occur in the wetlands.
Conceptual Studies

concept one

The first concept is designed with a serpentine combination series. In this flow system cells are configured to move the wastewater back and forth through the cells in a serpentine motion. Water is pumped from the septic tanks and fed into the constructed wetlands and moves through the system by gravitational pull. The cell configuration for this concept, in which the wastewater moves through various types of cells is surface flow - subsurface flow - prairie - marsh. This system is illustrated in Figure 8.

concept two

The second concept is to use a parallel hydrologic flow to move the wastewater through the wetlands. For this flow wastewater flows through a series of parallel cells. Water is pumped from the septic tanks and fed into the constructed wetlands and moves through the system by gravitational pull. The configuration for cell type for this system is surface flow - pond - subsurface flow - prairie configuration. This is shown in Figure 9.

interpretive trail

The concept of the interpretive trail is to integrate people and nature in a living, hands-on ecological environment. This trail system incorporates interpretive signs providing information about the ecosystems they are presently standing in, flora, fauna, and its role in the treatment of wastewater. Each interpretive station gives opportunity for discovery and learning for each different ecological community they are in and will encounter along the trail. The trail will lead the visitor through the entire treatment process and the different ecological communities found in the constructed wetlands.
Master Plan

Constructed wetlands provide a biologically safe and effective means for treating wastewater. Wastewater created from homes is filtered through a series of constructed wetlands. These wetlands, utilizing both plants and animals working together to treat the wastewater by natural processes, which are beneficial to their surroundings and help to increase species diversity of ecologically communities within the system. It also provides opportunities for educational learning about environmental processes.

Constructed Wetlands

The master plan for the constructed wetlands involves several different systems working together. First, the hydrological flow of the wastewater is simple, but effective. Wastewater exists the homes and enters a septic tank for primary treatment. In this process solids are settled and anaerobic biological processes start to treat the wastewater. The wastewater is then pumped into the constructed wetland system. The system uses a series-combination series. Both series were combined from the two conceptual studies, serpentine and parallel. The configuration for the constructed wetland cells is surface flow - pond - subsurface flow - pond - wet prairie. The first cell is a surface flow cell consisting of cattails, rushes, sedges, and floating plants continuing to break down the wastewater. Within this cell suspended solids are removed and BOD and organic N and P are reduced. The water leaves the cell and enters a stream channel leading to a pond. The pond provides natural reaeration to enhance nitrification in the next cell. The pond also is home to a variety of emergent, submergent, and floating vegetation and aquatic animals. Each plays an important role of the treatment of the wastewater. After the water leaves the pond it enters two different stream channels and enters a parallel subsurface flow cells. Each cell is filled with cattails, rushes, reeds, sedges, and iris. Within these cells denitrification occurs and inorganic P is reduced. Water entering these cells is slowed down because of the horizontal movement through the cell. After being filtered in the subsurface cell, the water enters another pond. This pond again helps to provide natural reaeration and forms habitats for plants and animals. Once the water has traveled through half of the pond, it is clean enough to be returned to the homes to be used as grey water. The constructed wetland system is designed to have 60% of the water entering the wetlands be returned to the homes as grey water. The remaining 40% continues through the rest of the cell and enters a wet prairie for water polishing and return to the ground water.
The flow of the water is designed to be pulled through by gravity and only being pumped into the wetlands and returned as grey water. Based on the number of homes and bedrooms, the constructed wetlands has a loading rate of 12,500 gallons per day. As mentioned before, 60% will be returned as grey water and 40% will be returned to the groundwater supply. The retention time of the wastewater being in the wetlands is five to seven days.

**Ecological Communities**

Associated with constructed wetlands are four different types of ecological communities. These communities are a part of a larger ecological system and are important to the successfullness of the constructed wetlands. Each community is different in its own vegetation, wildlife, and habitats it creates, but they are the same in being a part of a larger system. Appendix A contains lists of various vegetation and wildlife species found within these communities. For this project each community is a part of the constructed wetland system and of the larger regional system.

- **forest** - the forest community serves several functions. First, it as habitat for deer, squirrel, snakes, etc. It also functions as a habitat corridor within the site of this project and to areas surrounding the site. These areas include wildlife sanctuaries, PAWS, Inc. research area, national birds preserves, and other corridors created by farm land.

- **prairie** - the prairie community is dominated by grasses and perennials. This prairie is the beginning of vast system that will eventually extend into the surrounding areas connecting different ecological communities. It will also uses maintenance practices as those used by PAWS, Inc.

- **wet prairie** - wet prairies are serve as the final treatment for wastewater. These species are most associated with those of the wetlands. This community is very divers in plant and animal species, because it is in between the prairie and wetland communities.

- **wetlands** - this community serves several function both physical and biological. First, it treats wastewater in a biologically safe and effective way. Second, it serves as a wildlife habitat. Many animal and plant species can be found in a wetland system including willows, cattails, ferns, dragonflies, frogs, birds, and fish. Also, it gives opportunities for outdoor educational laboratories.
Interpretive Trail

The interpretive trail system is one for educational and research purposes. The purpose of the trail is to integrate people and nature in a living, hands on ecological environment. An ecosystem being an area in which biotic (living) and abiotic (nonliving) organisms interact. This trail system, Figure 10, incorporates interpretive signs providing information about ecosystems in which they are presently standing in, flora, fauna, and its role in treating wastewater. Each interpretive station gives opportunity for discovery and learning for each different ecological community they are in and will encounter along the trail. Along with the stations, a workbook guide for students can be used for various learning activities along the trail. The guide will also include activities that can be done before and after visiting the constructed wetlands in classroom. A copy of this guide book is located in Appendix D.

Also available is a brochure that give the general function about the constructed wetlands and interpretive trail. A diagram shows the visitor a cross-section of a constructed wetland and its function. This brochure can be found in Appendix C.

Figure 10. Interpretive trail through the forest.
Conclusions

Constructed wetlands as alternative forms of wastewater gives a community many advantages. They are places of beauty, harmony, and serve a functional purpose. Constructed wetlands have the potential to enhance any landscape by introducing a water element, which is one of the most magnetizing and compelling of all design elements (Hammer, 1989). For both utilitarian and aesthetic reasons, wildlife and people are attracted to water. Opportunities for research and educational enrichment help to thrive a constructed wetland from a cultural view point. From a technical view point, constructed wetlands are a biologically safe and effective way for the treatment of wastewater, while enhancing and adding to the diversity and complexity of the surrounding flora and fauna. Constructed wetlands must strive to maximize the aesthetic design elements as much as possible without compromising treatment effectiveness.
Bibliography


Appendix A:

Presentation boards used for the final presentation. All boards were prepared on PageMaker and color rendered. They were used along with a PowerPoint presentation.
inventory analysis

Context Map

Inventory
Vegetation: The majority of the site consists of agriculture fields. In the lower corner of the site is a stand of oak-hickory trees and shagbark hickory. The site has two existing ponds.
Soil: The site consists of Fossum, Bloom, and Murray soils, with the majority being Fossum.
Hydrology: The site has a seasonally flooded area to the southwest. There are two standing pools located to the east.
Topography: The site is relatively flat with some rolling topography to the east.

Analysis
Vegetation: The stand of trees are moderately dense, making them an ideal location for the final polishing of the water from the wetlands.
Soils: Fossum soils are well suited for wetlands. Providing the current on-site wastewater treatment.
Hydrology: Water runs off the site is conveyed to a pond and then to the wetlands.
Topography: Rolling topography of the site provides needed elevation changes for the wetlands.

Constructed Wetlands
an alternative to wastewater treatment

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Comprehensive Project - 404
Spring 1998
Professor: Dr. Ron Spangler  Advisor: Martha Hunt
**System Diagrams**

**Biological Treatment Process**

The biological treatment process of wastewater is very interesting. Various systems are effective on many contaminates, including biological oxygen demand (BOD), suspended solids (SS), nitrogen, phosphorus, pathogens, and more. One efficiency factor is a diversity of treatment mechanisms, including collection, filtration, and chemical precipitation and absorption. Additional interactions with contaminants, and uptake by vegetation (Hamer, 1995).

Suspended and attached microbial growth are responsible for the removal of soluble BOD. In surface flow systems, the major oxygen source is from evaporation at the water surface (Hamer, 1995). Wind-induced water mixing and algal production will decrease by a factor equal to the area in a surface flow system. In subsurface flow systems, the major oxygen source is from diffusion from the atmosphere through the plant roots to the root zone, leading to plant photosynthesis being an important factor. Suspended solids are effectively removed by both types of systems. Microbes are filtered and settled while in the fine flow systems beyond the inlet.

Nitrogen is removed in surface and subsurface flow systems by similar means. Although plant uptake of nitrogen occurs, only a minor fraction can be removed by plants (Hamer, 1995). The majority of nitrogen is removed by the process of nitrification and denitrification processes performed by microorganisms. In the present systems, nitrification is induced in the roots by confining bacteria in a matrix. Nitrification is an effect of nitrogen uptake by plants, and other microorganisms and denitrification (Kiel, 1994).

Pathogens are adsorbed by soil and organic fiber and are not reduced by the reduction of microorganisms. Bacteria are removed by sedimentation, interception, and removal of organic material. Nitrates are absorbed by soil and organic fiber, but are not removed by denitrification or denitrification (Coff, 1994).

Vegetation plays several roles in the constructed wetland systems, including wastewater treatment, habitat formation, and rehabilitation. There are three categories in which vegetation can be classified: (1) soil surface, (2) submerged plants, and (3) emergent plants. In general, vegetation provides habitat for microorganisms, such as bacteria, clams, and crustaceans. Bacteria, algae, and bacteria transfer oxygen to provide an anoxic environment for septic decomposition and denitrification. Densities and densities of microorganisms (Hamer, 1995). Nitrification, denitrification, and anoxic bacteria are present in the airlow and with oxygen. Bacteria in the airlow and with oxygen are not removed by denitrification or denitrification (Coff, 1994).

**Optimal Biological Process**

- **Wastewater Components and Removal Mechanisms**
  - BOD: Microorganisms (aerobic and anaerobic)
  - Nitrogen: Amino-nitrogen followed by microbial assimilation and denitrification
  - Phosphorus: Soil uptake
  - Pathogens: Sedimentation, filtration
  - Toxic Metals: Sedimentation, filtration

**Constructed Wetlands**

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Aquatic System or Free Water Surface System (GFW)

Aerobic basins or channels with natural or constructed substrates of clay or synthetic material to promote treatment. Sediment or other types of suitable media are used to support the emergent or submersed plant species. Water is kept in a relatively shallow flow, moving over the surface of the soil. The shallow water depth, low flow velocity, and presence of plant roots and litter, regulates water flow and creates plug flow conditions.

Free water systems have the objective of creating new wildlife habitats or enhancing existing natural wetlands. Such systems include a combination of vegetation and open water areas and land blocks with appropriate vegetation to provide habitats (De la Garza, 1996).

Soil Based Systems or Subsurface Flow Systems (SSF)

This type of system allows water to flow laterally through the soil or gravel (De la Garza, 1996). For this process a trench or bed is constructed, underlain with an impermeable layer of clay or synthetic liner. The water flows through a porous, large-grain material, usually rock but soil or sand can be used. The water level is maintained just below the top surface of the medium. The roots of the plants grow within the spaces provided by the porous medium, creating a web through which the waste flows and diffuses. Wastewater moves horizontally through the plant root and medium, organic matter is decomposed microbiologically, nitrogen is denitrified, and phosphorus and metals fixed in the soil.

The system is built with a slope of 1:2% between the inlet and outlet. The wastewater moves from the inlet channel through the bed horizontally and is collected at the outlet channel ready for distribution. In general, the closer the source of wastewater, the faster the water flows and the larger the bed must be. The flow direction requires wide beds.

Emergent Plants

Emergent plants are anchored in the soil or substrate medium and extend through and above the water surface. They have adapted to growing in a waterlogged sediment by virtue of large internal air spaces for the transport of oxygen to the roots and rhizomes. These plants help in supplying oxygen to microorganisms, stabilization of soil, and removal of nutrients, metals, and decompensation of organic matter. Emergent plants effectively remove suspended solids and BOD, efficient rooted-seeded advanced secondary treatment quality (Sena, 1991). Emergent plants which grow on organic soils incorporate only a small percentage of added nutrients into biomass. Growth of emergent plants on gravel substrates significantly reduces substrate mineral nutrient concentrations.

Species of emergent plants include cattail, common reed, and bulrush.

Floating Plants

Floating plants float on the surface of the water and the roots extend into the body of water, but do not extend into the soil or sediments. Water depth is typically deep, ranging from 1.5 to 6.0 feet. Floating plants consume their carbon dioxide and oxygen requirements directly from the atmosphere and receive their nutrients from the water. The root system of floating plants provide the surface area for attached microorganisms. The plant also provides the needed conditions for the microbial decomposition process by transporting oxygen from the surface to the root zone. These plants can be used for nitrogen and phosphorus removal by incorporation into the plant biomass. Nitrogen can be removed as a consequence of phosphorus denitrification. The biomass is harvested frequently to sustain maximum productivity and to re-supplement inoculated nutrients.

Some floating plant species include water hyacinth and duckweed.

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Conceptual Studies

Concept One
Serpentine Combination Series

Cell Flow Pattern

Boardwalk Interpretive Trail

Concept Two
Parallel Cells Series

Boardwalk Perspective

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ecological communities

forest
Vegetation
Oak-Hickory
Beech-Maple
Paper
Redbud
Flowering dogwood
Jack-in-the-Pulpit
Sedge
Honeysuckle
Greenbrier
Violet
Lady's mantle
Elephant ears
Ferns
Lily of the Valley
Lungwort

Wildlife
Deer
Squirrel
Fox
Snakes
Birds
Hawks
Owls
Mice
Snakes
Insects

prairie
Vegetation
Big bluestem
Little bluestem
Aster spp.
Prairie coreopsis
Nedlegrass
Rough blazing star
Prairie sunflower
Prairie panic grass
Prairie phlox
Rose spp.
Yellow coneflower
Goldfield spp.
Pale purple coneflower
Wild strawberry
Milkweed
St.-John's Wort spp.
Prairie lily
Purple prairie clover
Black-eyed Susan
Indian grass
Evening primrose
Cardinal flower
Joe pye weed
Wild geranium

Wildlife
Snakes
Mice
Birds
Insects
Butterflies

wet prairie
Vegetation
Bluestem spp.
Common milkweed
Bluejoint grass
Prairie blazing star
Flowering spurge
Common horsetail
Prairie panic grass
Goldenrod spp.
Prairie willow
Purple meadow rue
Water hemlock
Aster spp.
Gland mallow
Sweet black-eyed Susan
Spiderwort
Western ironweed
Wild iris
Ironweed
Sedge spp.

Wildlife
Birds
Insects
Butterflies
Snakes
Salamanders
Frogs

wetlands
Vegetation
Willows
Swamp white oak
Sycamore
Cattails
Reed spp.
Rush spp.
Sedge spp.
Ivy spp.

Water hyacinth
Duckweed
Fairy moss
Water lettuce

Hornwort
Egeria
Elodea

Ferns
Day lilies
Bog sage
Marsh marigold
Arrowhead
Aristolochia

Wildlife
Dragonflies
Water striders
Frogs
Turtles
Snakes
Salamanders
Crayfish
Fish
Birds

Matthew S. Vinten
Comprehensive Project - 404
Spring 1998
Professor: Dr. Ron Spangler  Advisor: Martha Hunt
constructed wetlands
an alternative to wastewater treatment
Appendix B:

PowerPoint presentation slides used along side of the presentation boards, printed here in black and white. Also included is one slide printed in color.
Constructed Wetlands: an alternative to wastewater treatment

Matthew S. Vinten
Comprehensive Project - LA 404
Spring 1998
**Constructed Wetlands:**
an alternative to wastewater treatment

Constructed wetlands have the ability to enhance any landscape by introducing a water element, which is one of the most magnetizing and compelling of all design elements.
Project Introduction

Constructed wetlands can be defined as a designed and man-made complex of saturated substrates, emergent and submergent vegetation, animal life, and water that stimulates natural wetlands for human use and benefits. These benefits include the fact that constructed wetlands:

1) are relatively inexpensive to construct and operate
2) are easy to maintain
3) provide effective and reliable wastewater treatment
4) are relatively tolerant of fluctuating hydrologic and contaminant loading rates
5) may provide indirect benefits such as green space, wildlife habitats, and recreational and educational areas (Hammer and Bastian, 1989).
Site Selection

The community selected for this project is the Bluegrass Estates. The community consists of 34 single family homes. It is located on the south side of Indiana State Highway 28, between County Highways 200 and 300 East. The location of the constructed wetlands will be directly south on property own by James R. and Carolyn Davis.

This community was selected because of its current septic system problem. Effluent from the single finger septic systems is draining into back yards and surrounding farm fields and causing environmental damage to the land.
Site Inventory

- **Vegetation** - The majority of the site consists of agriculture fields. In the northwest corner is a stand of oak/hickory trees and thorny shrubs as understory.

- **Soils** - The site consists of Pewamo, Blount and Morley soils. The majority of the site is Pewamo soils.

- **Hydrology** - The water on the site is running to the northeast of the site.

- **Topography** - The site is relatively flat with a some topography. The highest point of the site is to the east on two ridges.
Site Analysis

- **Vegetation** - The stand of trees in the northwest corner are moderately marshy making them an ideal location for the possible final unloading of the water coming from the wetlands.

- **Soils** - Pewamo soils are well suited for the use of wetlands. While Blount and Morley are suited and not suited respectively.

- **Hydrology** - Water runoff on site will be the only major hydrology issue.

- **Topography** - Ideal circumstances are created from the flat and rolling topography of the site for elevation changes that must occur in the wetlands.

**Constructed Wetlands**
Project Goals and Objectives

Goal One: Provide an effective and safe alternative for treating community wastewater using constructed wetlands as an alternative for treating wastewater.
  - Use a biological process for the breakdown of wastewater.
  - Introduce plant and animal species that are beneficial to the treatment of wastewater.
  - Create a treatment system that meets the waste disposal needs of the community.
  - Involve researchers to regulate the constructed wetlands.

Goal Two: Integrate an existing community with a constructed wetland system.
  - Connect all homes to the constructed wetlands.
  - Use design aesthetics to provide a visual stimulus.

Goal Three: Facilitate learning about biological diversity through an interpretive trail system.
  - Design a boardwalk trail system through the constructed wetlands.
  - Users will use the constructed wetlands for research and educational purposes.
  - Service organizations will help to maintain constructed wetlands through service projects.
Program

- Constructed Wetlands - for the treating of wastewater from the existing homes.
- Wood Boardwalks - for wetland and habitat access.
- Wetland Vegetation - wetland plant species for wastewater treatment.
- Native Vegetation - used as corridors around constructed wetlands.
- Septic Tanks - for primary treatment of wastewater.
- Pumping System - used for returning treated water to homes to be used as gray water.
- Interpretive Signs - illustrating the various natural systems within the constructed wetlands.
- Maps/Brochure - describing the constructed wetlands and interpretive trail.
Assumptions

- There is a need for alternative forms of wastewater treatment.
- Individuals of the community welcome the use of constructed wetlands for wastewater treatment and its educational opportunities.
- Funding for the project was raised through private money and research grants.
- The constructed wetlands will be used as an outdoor educational and research site.
- Maintenance of the constructed wetlands will be through volunteer service groups and/or individuals.
- Water exiting the constructed wetlands meets all health standards, both state and federal.
- Any surrounding land use problems are addressed and solved before the constructed wetlands are installed.

Constructed Wetlands
Configuration Alternatives

- Single Cell
- Series Cell
- Parallel Cells
- Series Serpentine Cells
- Series-Combination Cells
- Series-Combination (common dikes)
- Combination Series-Parallel Cells
Optimal Biological Process

- **Primary Treatment**
  - Stage One - Suspended Solids.

- **Secondary Treatment**
  - Stage Two - Suspended Solids
    - BOD
    - Organic N and P
  - Stage Three - Nitrification
    - BOD
  - Stage Four - Denitrification
    - Inorganic P

- **Water Polishing**
  - Stage Five - Oxygenation
    - Inorganic N and P
Hydrologic Flow Diagram

- Wastewater exists the home to septic tanks for primary treatment.
- Wastewater exists the septic tanks and enters the constructed wetlands for secondary treatment and polishing.
- Wastewater travels through a series of ponds and cells, cleaning the wastewater biologically.
- The water is then clean enough to re-enter homes as gray water or be discharged back into the ground.
Components of Wastewater

- Suspended Solids - sedimentation
- BOD - microbial degradation
- Nitrogen - plant uptake
- Phosphorus - soil uptake
- Pathogens - UV radiation
- Trace Metals - soil and plant uptake
System Diagrams

Soil-Based Systems or Subsurface Flow Systems (SSF)

The Aquatic System or Free Water Surface Systems (SF)

Constructed Wetlands
Emergent Plants

Floating Plants

Submergent Plants
Conceptual Studies

**concept one**
Serpentine Combination Series
- serpentine hydrologic flow
- SF-SSF-prairie-marsh configuration

**concept two**
Parallel Cells Series
- parallel hydrologic flow
- SF-pond-SSF-prairie configuration

Cell Flow Pattern
Trail System

Constructed Wetlands
**Master Plan**

**final plan details**

- Series-Combination Hydrologic Flow.
- SF - pond - SSF - pond - wet prairie configuration.
- Loading rate 12,500 gallons per day.
  - 500 gallons during this presentation.
  - 60% returned as gray water.
  - 40% returned to the earth.
- Retention Time - 5 to 7 days.
- Width:Length ratio - 1:4.
- Interpretive trail system.

**Constructed Wetlands**
Ecological Communities

forest

prairie
Cross-Section Details

Constructed Wetlands
Master Plan

final plan details

• Series-Combination Hydrologic Flow.
• SF - pond - SSF - pond - wet prairie configuration.
• Loading rate 12,500 gallons per day.
  500 gallons during this presentation.
  60% returned as gray water.
  40% returned to the earth.
• Retention Time - 5 to 7 days.
• Width:Length ratio - 1:4.
• Interpretive trail system.
Appendix C:

Brochure developed to introduce the constructed wetlands to visitors or those interested in using it for an outdoor classroom laboratory.
from Bluegrass to Greengrass

...a natural treatment system
constructed wetlands for wastewater treatment:

Constructed wetlands provide a biological safe and effective means for treating wastewater. Wastewater created from homes is filtered through a series of constructed wetlands. These wetlands, utilize both plants and animals working together to treat the wastewater by natural processes, which are beneficial to their surroundings and help to increase species diversity of ecological communities within the system. It also provides opportunities for educational learning about environmental processes.

interpretive trail system:

The purpose of the trail is to integrate people and nature in a living, hands on ecological environment. An ecosystem being an area in which biotic (living) and abiotic (nonliving) organisms interact. This trail system incorporates interpretive signs provide information about the ecosystems in which they are presently standing in, flora, fauna, and its role in the treatment of wastewater. Each interpretive station gives opportunity for discovery and learning for each different ecological community they are in and will encounter along the trail.

constructed wetland diagram:

- open water
  - important for fish
  - oxygen supply
  - mosquito control
- evaporation
- wastewater
  - suspended solids
  - high nutrients
  - trace elements
  - beneficial bacteria
- sedimentation
  - nutrient uptake
  - reduce suspended solids
- shade
  - controls algae
- atmospheric gas exchange
- treated H₂O
- habitat islands
  - wildlife area
  - undisturbed area
Appendix D:

The student guide developed to help illustrate activities students could do while visiting the constructed wetlands and activities that could be done before and after their visit.
from Bluegrass
to Greengrass
...a natural treatment system

Constructed Wetland Systems:
Interpretive Trail

Student Guide
PRE-VISIT ACTIVITIES

Talk to the class about their upcoming visit to the Nature Center. Ask the class what they think a nature center is and what they expect to see there. Also, discuss some of the following terms with the class to improve their understanding of the Nature Center exhibits.

1. TERMS FOR DISCUSSION

HABITAT: the surroundings in which an organism lives. The habitat provides space, food, water and shelter to an organism. There are aquatic (water) and terrestrial (land) habitats. Examples of each are lakes and forests, respectively, but there are many different types of habitats in each of these categories as well. What other types of habitats can your class think of? (Don’t forget human habitats.) You may want to coordinate pre-visit activities 1 and 2 with this discussion.

PREDATOR: an animal which hunts another animal for food.

PREY: an animal which is hunted for food. Note that an animal can be both predator and prey. A mouse may hunt for an insect while an owl hunts for the mouse.

NATURAL: something that occurs without human intervention or help

COLD BLOODED: (heterotherm), an animal whose body temperature is determined by the temperature of its surroundings

WARM BLOODED: (homeotherm), an animal which can maintain a constant body temperature regardless of the temperature of its surroundings

FISH: cold blooded animals spending their entire lives in aquatic environments and possessing gills, scales and fins and breathing oxygen from the water.

AMPHIBIANS: cold blooded animals which live at least part of their lives in aquatic habitat. Many adults in this group have lungs, but not all, some having external gills instead. These animals usually have moist, smooth skin without scales or fins. They lay shell-less eggs in wet or aquatic environments. Frogs, toads, and salamanders are examples of amphibians.

REPTILES: cold blooded animals with lungs, dry, scaly skin and claws when feet are present. They lay eggs in leathery shells and do not take care of their young after hatching. Examples of this group include turtles, snakes and lizards.

BIRDS: warm blooded animals with lungs, feathers, wings and beaks. These animals lay eggs and provide care to their young. Ducks, hawks and songbirds are in this group.
MAMMALS: warm blooded animals with lungs and fur or hair, having young that are born alive and provide milk as nourishment to them. Humans are one example.

2. ACTIVITIES

Do an inventory of natural objects found on the playground or in your backyard. What plants or animals can you find? What benefits do you get from the living things you find? Do you benefit the plants and animals in any way?

Now do an inventory of the classroom. What things come from nature? Choose and object and draw it as it was in its natural habitat.

Go outdoors and find a comfortable place to sit. How many different colors can you see? Now close your eyes. What sounds do you hear? Is any one sound predominant? (This could be done once in an urban area and once again in the country for comparison.)
1. List characteristics that all turtles have in common. How are they different from each other?

**TURTLE SIMILARITIES**

1. ________________________________ 2. ________________________________
3. ________________________________ 4. ________________________________

**TURTLE DIFFERENCES**

1. ________________________________ 2. ________________________________
3. ________________________________ 4. ________________________________

2. List the different species (kinds) of turtles present in the pool.

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>3.</td>
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<td>5.</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
</tr>
</tbody>
</table>

3. If these turtles were in their natural habitat, where would you find them? What things do you see that you would observe in the turtles’ natural habitat? What things are missing?

_____________________________

5. List some characteristics that all birds have in common? How are birds different?

   **BIRD SIMILARITIES**

   1. 
   2. 
   3. 

   **BIRD DIFFERENCES**

   1. 
   2. 
   3. 

6. Describe what you imagine flying to be like.

   

   

7. Name the animals found in the display case across from the stained glass window. Which of these animals are predators, prey, or both? What do you think each of these animals may eat?

   1. 
   2. 
   3. 
   4. 
   5. 
   6. 
   7. 
   8.
8. Look at the small displays in front of the window overlooking the lake. Which one is
your favorite? Why do you like it best? Try to draw a picture of it.


9. The nature center has a very big bird feeder just outside the window over looking the
lake. Do you recognize any of the birds that might be there? List the names of birds you
see by looking them up in bird book present at the window.

1. ____________________________________

2. ____________________________________

3. ____________________________________

4. ____________________________________

10. The forest floor exhibit contains live reptiles and amphibians from this area. Can
you name an example of each in the exhibit?

Reptile ____________________________________

Amphibian ____________________________________

11. Caves are special habitats. Can you name animals that live in caves? How are they
specialized for this environment?

1. ____________________________________

2. ____________________________________

3. ____________________________________

12. List some of the game subjects in the downstairs display area.

________________________________________

________________________________________

________________________________________
AUTHOR: DeRoo, Sally A.

GRADE LEVEL: K-8

DESCRIPTIONS: When on a field trip to a pond, it is important to survey the total area. Each group of plants grow where there is enough water, soil and sunlight to meet their unique requirements.

Point out how the plants adapt to the niche in which they live. Animals found in and around the pond are unique in that they are always found among certain types of plants. The combination of plants and animals make up the unique niche within the plant and animal communities.

Woodland Trees

Bushes

Dogwood
Sumac
Berry

Cattails
Reeds
Sedges
Arrowheads

Water plankton
(floating vegetation)

Plants Near, Around, and In the Water Community
Strands Walk  An Ecological Observation

Carolyn Stevens, Fillmore Middle School, Fillmore, UT

Grade Level: Appropriate for grades 5-7.

Overview: Groups of living things interacting with each other and the environment compose an ecosystem. An ecosystem is one area in which all biotic (living) and abiotic (nonliving) things interact. The size of the ecosystem to be studied is determined by the student.

Objective(s): Students will be able to:
1. Determine, delineate, and observe an ecosystem.
2. Analyze the role of two abiotic factors in his ecosystem.
3. Analyze the role of three living things in his ecosystem.
4. Discuss the balance between producers and consumers.
5. Describe a possible food chain using organisms in his ecosystem.
6. Project the effect of the loss of a major factor of the ecosystem on the remaining factors.

Activities and Procedures:
1. Student should determine his or her area to delineate an ecosystem. This is best done in an area where there is a variety of plant and animal life. If possible, a wilderness area is a particularly good choice. I use this activity on a field trip to a local park in a national forest.
2. Students must separate and observe absolutely independently.
3. Student will observe his ecosystem using all senses for at least five minutes before listing observations.
4. Using the grid, student will list 5 observations
the pond.

5. Identify three changes in the two ecosystems over a span of months.

ACTIVITIES: These activities are only a few which can be used to involve children in nature in a real way. Instead of teaching an ecosystem unit, plant unit, or animal unit in isolation, the use of a local natural area ties all of these things together in a meaningful way for the children. It also gives the science curriculum continuity over time. Hopefully they will spark your imagination and you will come up with lots of other ideas for involving children with our natural world.

1. Take the children on many pond and woods walks to the same area to observe and identify plants and animals spanning the seasons. Do drawing and writing activities with the children both in the field and back in the classroom. Keep an ecosystem book.

2. After the children observe small pond creatures, bring back a few to the classroom for further observation. Be sure to bring back the pond water with them. Have the students observe some pond water under a microscope the first day, second day, and fourth day after bringing into a warm building. They make comparisons and note differences in both kind and number of organisms. Using prepared, colored slides of tiny pond creatures, have children look through the microscope and then on a four inch circle, draw what they observe through the microscope. Mounted all together, this is a very effective display.

3. On at least one woods walk, do hug-a-tree activities. In this activity children are blindfolded and led to a tree by another child and returned to a starting point after careful use of their sense of touch. Free of the blindfold, they are to find the tree they have hugged. Gather leaves and make leaf prints with the students after comparisons as to size, color, smell and feel. In a tall mature forest, ask the children to lie on the ground on their backs. With eyes
Lesson Plan #: AELP-BIO0031

A Habitat Made by ME!

Submitted by: Kelly Baeth
Endorsed by: Don Descy, Mankato State University
Date: May 14, 1997

Description:

This activity is designed to make each student more aware of the components involved in an aquatic environment. By creating a habitat in the classroom and observing it over a period of six weeks will involve the help and effort of each student providing them with hands on learning experiences.

Grade Level: Appropriate for 3rd and 4th grades.

Goal:

Students will develop an understanding and gain knowledge about aquatic ecosystems.

Objectives:

The students will create a journal consisting of observation notes concerning their aquatic creatures and plants.

Students will list necessary items to complete an aquatic ecosystem.

Students will create and present their ecosystems to the class.

Background Information:

This activity will make the students aware of how important habitats are for certain species. By using hands-on activities, such as creating an aquatic ecosystem, they will observe and monitor the processes as they occur. You may use many other bottle biology experiments that will also engage the students actively as in a Terrarium, Decomposition of biodegradable products, or the aquatic ecosystems.

Concepts:

The students will:

Learn what components are necessary for an aquatic ecosystem.

Work together using group communication and social skills while creating their habitat.

Materials:

5 or 6 two liter bottles of pop (empty), water, marker, scissors, tape, and a hole puncher.

Aquatic life (snails, guppies, plant life, and sand).

Fish food
Procedure:

****Group the students in groups of about three

2. Cut off the top of one bottle and the bottom of another.

3. Using the bottom piece, cut some holes in it for proper ventilation of air (this will be used as our lid).

4. Before adding the water, add about an inch or two of dirt or sand to give it a pond or lake environment (weed).

5. Add the plant life (elodea, and duckweed), but be sure to secure these plants in the sand and dirt so they won’t fall.

6. Add the rest of the aquatic life: *one male and one female guppy *two snails 25 pieces of elodea

7. Secure the lid and put a piece of tape on the bottle with the group members names and have them make a team name as well.

8. Store in a safe place and check it twice a week noting any changes or differences that occur.

Assessment:

I will look at their aquatic ecosystem and discuss each groups notes and any questions they have.

*I will ask each group the following questions:

1. What happened to the elodea in the bottle?

2. What other changes have occurred in your ecosystems?

3. What could we do to make it a better ecosystem?

*I will ask them to relate the aquatic ecosystem to our environment in which we live to see if they can identify some components of our everyday needs (air, water, food shelter, family, friends, etc...).

References:

*Kendall/Hunt publishing, Bottle Biology.

*http://www.rbs.org/mst/lesson2.w4.html

*http://www.wildlifehabitats.com/about.htm