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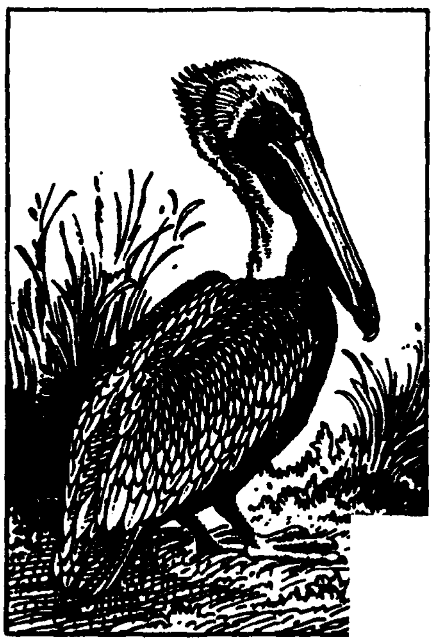
Wetlands Research Program Technical Report WRP-CP-2

Summary of Literature Describing the Functional Ability of Wetlands to Enhance Wastewater Quality

by R. C. Phillips, H. E. Westerdahl, A. L. Mize, S. A. Robinson



August 1993 – Final Report

The following two letters used as part of the number designating technical reports of research published under the Wetlands Research Program identify the area under which the report was prepared:

	Task		Task
CP	Critical Processes	RE	Restoration & Establishment
DE	Delineation & Evaluation	SM	Stewardship & Management

Wetlands Research Program

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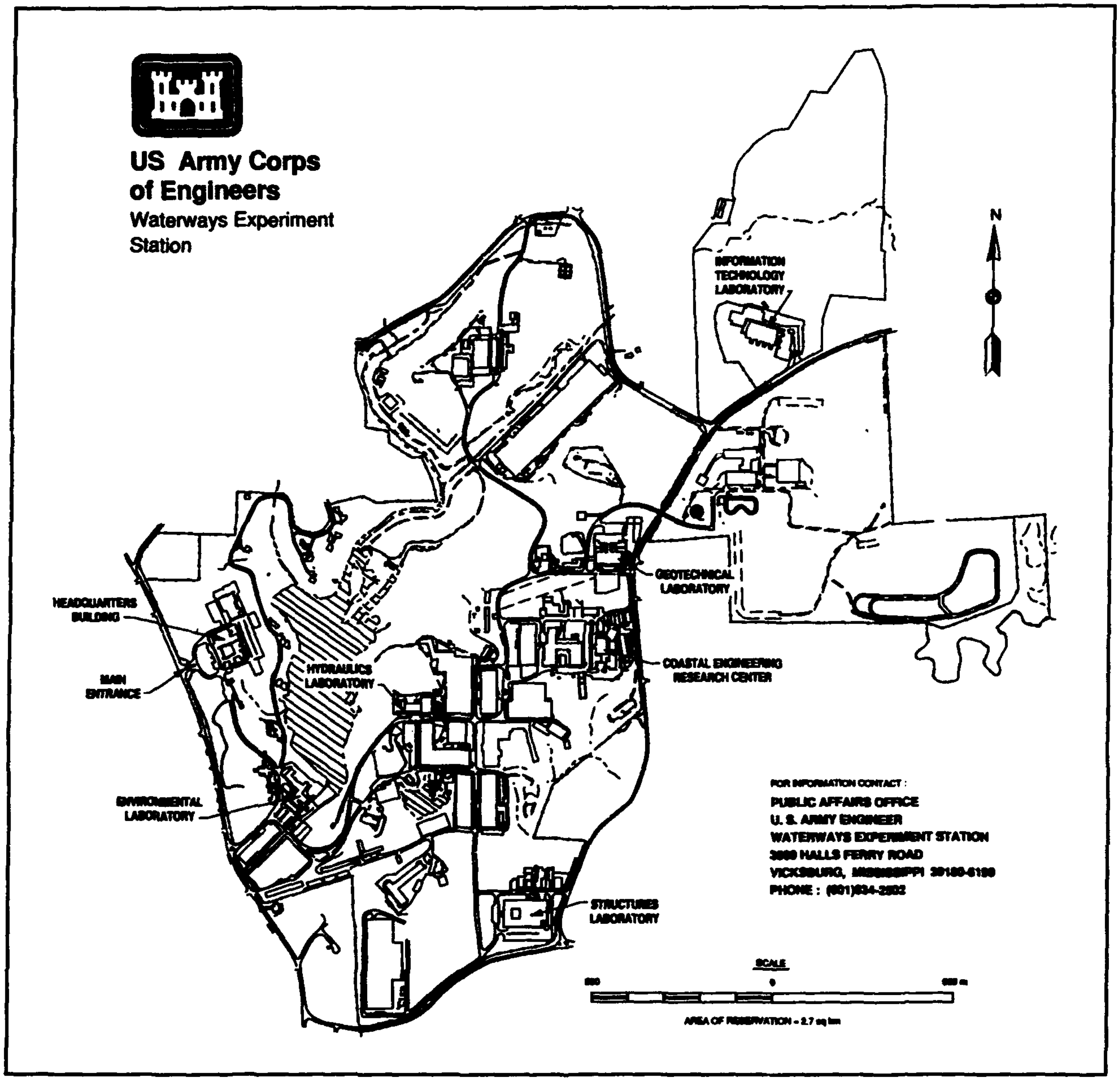

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Wetlands and Water Quality

Summary of Literature Describing the Functional Ability of Wetlands to Enhance Wastewater Quality (TR WRP-CP-2)

ISSUE:

Wetlands can effectively remove pollutants from wastewaters and runoff and improve water quality. There is a need for methods to estimate the amount of water quality improvement provided by wetlands. Some insight can be gained through review of past wetland water quality studies.

RESEARCH:

The literature review summarizes the effectiveness of wetlands for enhancing wastewater quality. Results are categorized by the type of wastewater (i.e., municipal domestic, stormwater, industrial, agricultural, and mining) and wetland (i.e., natural and constructed). For each type of wastewater and wetland, the following constituents are addressed: suspended solids, nutrients, heavy metals, toxic organic materials, and other constituents (e.g., bacteria and pathogens). The results are presented in terms of removal efficiency (i.e., percent decrease in pollutant concentration) where possible. The report also contains a bibliography of the most pertinent literature categorized by wastewater type. Each literature citation includes an abstract.

SUMMARY:

Literature clearly revealed that wetlands effectively improve wastewater quality. This report provides examples of removal efficiencies for various types of wastewaters, wetlands, and water quality constituents. The review aids in identifying information that will be used to develop methods for estimating removal efficiency for various wetland characteristics.

AVAILABILITY OF REPORT:

The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, telephone (601) 634-2355.

To purchase a copy, call the National Technical Information Service (NTIS) at (703) 487-4650. For help in identifying a title for sale, call (703) 487-4780.

NTIS report numbers may also be requested from the WES librarians.

About the Authors:

The literature review was performed by R. C. Phillips, H. E. Westerdahl, A. L. Mize, and S. A. Robinson of Battelle Pacific Northwest Laboratory, Richland, WA. Point of contact at WES is Mark S. Dortch, USAE Waterways Experiment Station, ATTN: CEWES-ES-Q, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, Phone (601) 634-3517.

Contents

Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Critical Processes Task Area of the Wetlands Research Program (WRP). The work was performed under Work Unit 32753, "Water Quality," for which Dr. Mark Dortch was Principal Investigator. Mr. Pete Juhle (CECW-EH-W) was the WRP Technical Monitor for this work.

Mr. Jesse A. Pfeiffer, Jr. (CERD-C), was the WRP Coordinator at the Directorate of Research and Development, HQUSACE; Dr. William L. Klesch (CECW-PO) served as the WRP Technical Monitors' Representative; Dr. Russell F. Theriot, U.S. Army Engineer Waterways Experiment Station (WES), was the Wetlands Program Manager. Mr. Gregory L. Williams (CEWES-CD-SE) was the Task Area Manager.

The work was performed at Battelle Pacific Northwest Laboratories (PNL). This report was prepared by Drs. R. C. Phillips, H. E. Westerdahl, A. L. Mize, and Mr. S. A. Robinson of PNL, under a Related Services Agreement with the U.S. Department of Energy, Contract DE-AC06-76RLO 1830. The work was performed under the direct supervision of Dr. Dortch, Chief, Water Quality and Contaminant Modeling Branch, Environmental Processes and Effects Division (EPED), Environmental Laboratory (EL), WES, and the general supervision of Mr. Donald L. Robey, Chief, EPED, Dr. John Keeley, Assistant Director, EL, and Dr. John Harrison, Director, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
feet	0.3048	meters
gallons (U.S. liquid)	3.78541?	liters

1 Introduction

The responsibility for water quality protection has undergone major changes. The Federal Water Pollution Control Act (FWPCA) of 1948 was one of the first national legislative efforts to deal with water quality problems. This Act gave the states primary jurisdiction for controlling water pollution. The FWPCA Amendments passed in 1972 were the basis for the Clean Water Act (CWA), which shifted primary responsibility for water pollution away from the states and local jurisdictions to the Federal Government. In 1987, the Water Quality Act Amendments to the CWA returned the focus of water pollution control back to the states (Smith 1989).

The Federal grants program for municipal wastewater treatment was eliminated, and a State Revolving Loan Program was funded. As a result, funds declined from the Federal Government for municipal pollution control, but construction needs to protect water quality remained great. Both the reduction in available Federal dollars and the increasing focus on water quality underscore the need for a continual effort to identify and encourage technologies that provide effective, low-cost treatment (Smith 1989).

Only recently have wetlands been recognized as a potentially cost-efficient treatment system for wastewater discharges. Studies have shown that both natural and constructed wetlands provide high quality wastewater treatment at relatively low cost. In the natural setting of the wetland, the desired processes consume less energy, are more reliable, require less operation and maintenance, and cost less. In addition, use of natural and created wetlands for wastewater treatment is preferred as they become wildlife habitats and can even serve as nature centers (Smith 1989). A number of mechanisms have been found to account for high pollutant removal efficiencies observed at the high loading rates characteristic of many treatment situations. These include bacterial transformations and physico-chemical processing including adsorption, precipitation, and sedimentation (Gersberg et al. 1986).

This report summarizes literature describing the functional ability of wetlands to enhance wastewater quality and is based on recent literature (1985 through May 1991). In rare cases, a reference was retained from 1983 or 1984 if it were the only one found for a particular category or topic. Approximately 1,400 references were marshaled for review. This number was reduced to approximately 500 references for further evaluation and potential inclusion in this report. Eleven databases were searched: Waternet, Water Resources Abstracts, Environmental Bibliography, Biosis Previews, Pollution Abstracts, Enviroline, Dissertation Abstracts, Oceanic Abstracts, Agricola, Compendex Plus, and NTIS. A series of key words and combinations of these key words were used to find the needed abstracts. The principal key words used were as follows: wetland, swamps, bogs, marshes, treatment, restoration, disposal, wastewater, sewage, waste, pollute, contamination, fishery, fisheries, man-made, artificial, constructed, municipal, urban, industrial, agriculture, natural wetlands, marine, saline, salt water, tidal, tidewater, coastal, note other artificial wetlands, note other marine wetlands, note freshwater wetlands, and note other natural wetlands.

As the literature was reviewed, one aspect emerged. The literature on wastewater treatment by wetlands is very uneven in regard to the reporting of loading and flow rates of the pollutants into the wetlands, the retention times, and the most effective seasons of treatment. Standards do not seem to be set for reporting work accomplished. Undoubtedly, this could be done by the various investigators, but at present, they have not presented their work in such a fashion. The main concern to date appears to be to report what type of wasteload is being treated, the design of the wetland system, and the final results (i.e., effectiveness of the wetland in removing the various pollutants).

In Chapter 2, the discussion will distinguish between natural and constructed wetlands. Discussion will be further organized around wasteload types (i.e., wastewater and domestic *municipal* sewage, stormwater, industrial wastewater, agriculture, and mining activity). These types will each be treated according to constituent types (i.e., suspended solids, nutrients, heavy metals, toxic organic materials, and other water quality constituents, such as bacteria and pathogens). Because the literature for coastal wetlands is meager, the report focuses on freshwater wetlands and is organized by northern and southern latitudes. Chapter 3 summarizes literature on wetland design for water quality treatment.

Each chapter presents conclusions or overviews of the literature found. Data tabulations, charts, and diagrams are not included. Readers interested in a specific report or topic are encouraged to read the original documents. A bibliography of the most pertinent literature is provided in Appendix A, categorized by wastewater type. The references and the bibliography include an abstract for each citation.

2 Effectiveness of Wetlands for Removing and Storing Wastewater Contaminants

The use of wetlands and the importance of aquatic plants in wastewater treatment is a relatively recent activity. Early research conducted in these areas commenced in the 1960s. Only during the past 15 years has the ecology of natural wetlands been studied extensively. An international conference held at the University of Pennsylvania in 1976 produced only six papers in the area of aquatic plants and wastewater treatment. Since then the research on this topic has expanded greatly and includes the use of natural and constructed wetlands in fresh (inland) and coastal waters. One symposium volume (Reddy and Smith 1987) contained 87 papers, most of which concerned wastewater and wetlands. Another volume (Hammer 1989) contained 82 papers and summarized the knowledge and literature for constructed wetlands and wastewater treatment.

This chapter will be organized into the following topics:

- Wastewater and Domestic Municipal Sewage.
- Stormwater.
- Industrial Wastewater.
- Agriculture.
- Mining Activity.

For each of the above wasteload types, the following subtopics will be treated:

- Suspended Solids.
- Nutrients (Nitrogen, Phosphorus, and Total Carbon).
- Heavy Metals.
- Toxic Organic Materials.
- Other Water Quality Constituents (e.g., bacteria and pathogens).

For both natural and constructed wetlands, the two large symposium volumes mentioned above should be consulted for an exhaustive background on the use of wetlands for urban wastewater/stormwater, industrial wastewater, agriculture, and mining activity treatment. This chapter summarizes the more pertinent papers.

For each wasteload type and constituent category (e.g., suspended solids), the removal efficiencies of the wetland are related to the plant species involved, the loading rate, the retention time in the wetland, and other factors. Table 1 presents the removal efficiencies (percentages) reported for each wetland type and constituent category. Removal efficiency is defined as the inflowing concentration minus the outflowing concentration with the difference divided by the inflowing concentration, times 100.

Wastewater and Domestic Municipal Sewage

Natural wetlands

One general reference was released--a bibliography containing citations concerning the ability of wetland areas to degrade, absorb, filter, consume, and mitigate natural and human-related pollution and wastes, while maintaining their ability to provide refuge and breeding grounds for wildlife (Wetland Areas: Natural Water Treatment System 1990).

Suspended solids. The McCarrons Treatment System, a surface water management facility consisting of a detention pond followed by six "chambered" wetlands, was designed to improve the water quality of Lake McCarrons in Roseville, Minnesota. The system is located at the bottom of a 243-ha urban watershed. Most of the reduction in pollutants occurs in the detention pond. The postdetention wetland system was introduced to "polish" outflows from the detention pond before the water discharged to the lake. The wetland continued the process of settling solids that began in the pond, but was less effective in removing soluble nutrients. This latter aspect is related to additional inputs from a separate tributary, overland runoff, and atmospheric deposition. Because the wetland system augments a net reduction in solids and nutrients, the wetland system is performing as expected (Wotzka and Oberts 1988).

The Central Slough on the Waccamaw River in Horry County, South Carolina, a 32-ha forested wetland system made up of cypress-gum. provided a 70-percent reduction in total suspended solids. The loading capacity of treated wastewater on this wetland was 400,000 gpd.[1] After 2 years, changes did not occur in the canopy, subcanopy, and shrub importance values. Water quality downstream of the wetland and groundwater in the area indicated no impacts from this discharge of wastewater to the wetland (Baughman et al. 1989).

[1] A table of factors for converting non-SI units of measurement to SI units is presented on page viii.

Table 1
Summary of Removal Efficiencies for Various Contaminants

Wasteload Type	Wetland Type	Contaminant[1]	Removal Efficiency, percent	Author
Wastewater and domestic municipal sewage	Natural	TSS UOD TN,TP,NH_3-N	70 90-1st year 70-2nd year 70	Baughman et al. 1989
		TN TP COD,TOC,Fe,Cu, Mn,Mg,P,K,Ga	26-55 12-28 >99	Sunblad and Wittgren 1989
		Cd Cr Cu Zn Pb Ni	43-47 28-53 0-52 0-51 0-31 0	Dubinski, Simpson, and Good 1986
		Cd Cr Cu Pb Zn	43 (only 15% 5 months after treatment) 53 (only 12% 5 months after treatment) 52 31 51	Simpson et al. 1984
	Constructed	TSS	72-94	Dawson 1989; DeBusk, Burgoon, and Reddy 1989; Gersberg, Gearheart, and Ives 1989; Gersberg et al. 1986; Gersberg, Elkins, and Goldman 1985; James and Bogaert 1989; Kingsley, Maddox, and Giordano 1989; Knight, Winchester, and Higman 1985; Stowell et al. 1985; Roser et al. 1987; Miller 1989; Pride, Nohrstedt, and Benefield 1990
		TSS Local Coliform Bacteria	72 >80	Kingsley, Maddox, and Giordano 1989

Sheet 1 of 5

[1] TSS = Total Suspended Solids; BOD = Biological Oxygen Demand; TOC = Total Organic Carbon; UOD = Ultimate Oxygen Demanding; TN = Total Nitrogen; TP = Total Phosphorus; TIN = Total Inorganic Nitrogen; COD = Chemical Oxygen Demand.

Table 1 (Continued)				
Wasteload Type	**Wetland Type**	**Contaminant**	**Removal Efficiency, percent**	**Author**
Wastewater and domestic municipal sewage	Constructed	BOD TSS NH_3-N	90 90 94-bulrush 78-reeds 28-cattails 11-unvegetated	Gersberg, Gearheart, and Ives 1989; Gersberg et al. 1986; Gersberg, Elkins, and Goldman 1985
		TP BOD TSS	57 80 69	Miller 1989
		BOD TSS TN	95 94 67	Roser et al. 1987
		TN TKN TP TIN	25-93 75-95 21-57 80	Brix and Shierup 1989a,b,c; Davido and Conway 1989; James and Bogaert 1989; Kingsley, Maddox, and Giordano 1989; Knight, Winchester, and Higman 1985; Dawson 1989
		COD	95	Miller 1989; Nichols 1990; Pride, Nohrstedt, and Benefield 1990; Roser et al. 1987; Stengel and Schultz-Hock 1989
		TN TP	91 38	Wolverton 1987
		Nitrogen, Phosphorus	>50 >50	Brix and Schierup 1989a,b
		Cu Zn Cd	>95 >90 >95	Gersberg et al. 1984
		Fecal Coliform Bacteria MS2 Phage, Poliovirus, F-specific Phage	99.1-wetland 95.7-unvegetated 98-99	Gersberg, Gearheart, and Ives 1989; Gersberg et al. 1987a,b

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Table 1 (Continued)

Wasteload Type	Wetland Type	Contaminant	Removal Efficiency, percent	Author
Stormwater	Natural	MS2 Phage	98	Kulzer 1990
		TSS,Pb,Zn	41-73	Martin 1988
		TSS Pb Zn TN TP	55 83 70 36 43	Martin and Smoot 1986
	Constructed	TSS TP TN BOD Na Cd Cr Cu Pb Hg Zn	80-95 60-85 40-70 50-80 0 50 50-90 50-90 80-95 50-90 50-90	Daukas, Lowry, and Walker 1989
		TSS	60-65	Esry and Cairns 1989
		TP TN BOD Pb Zn Cu TSS Pb Cr Ni Zn Cu	53 41 40 72 40 40 42-45 30-83 40-53 12-34 6-51 5-32	Linker 1989
Industrial	Natural	COD TS Ni Cu	76 82 85 70	Winter and Kickuth 1989
	Constructed	TSS	42-100	Guida and Kugelman 1989
		BOD COD Sulfides Phenols Oil-grease TN TP	29-100 92 100 99.9 98 69-98 30-73	Thut 1989; Litchfield and Schatz 1989; Wolverton 1987; Guida and Kugelman 1989; Boardman, Guida, and Kugelman 1986

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Table 1 (Continued)

Wasteload Type	Wetland Type	Contaminant	Removal Efficiency, percent	Author
Industrial	Constructed	Cu Fe Mn	90 85-97 Up to 9	Sen and Mondal 1990; Brodie, Hammer, and Tomljanovich 1987a,b
		Cu,Pb,Hg,Mn, Fe,K	Up to 6.5	Yuduan et al. 1988
		Benzene Toluene p-Xylene Chloroform Tetrachloro-ethylene	89-98 98-99.9 92-97 69 75	Wolverton 1987
Agriculture	Constructed	Sediment	92	Chescheir et al. 1988
		TSS	82	Maddox and Kingsley 1989
		TSS	54	Mingee and Crites 1989
		TKN Nitrate nitrogen TP	79 82 81	Chescheir et al. 1988
		Nitrate Orthophosphate NH_3-N Chloride BOD	96 91 95 74 97	Costello 1989
		BOD COD TKN TP Fecal coliform bacteria	75 69 66 66 62	Maddox and Kingsley 1989
		Na K Fecal coliform bacteria	72 97 62	Costello 1989
Mining Activity	Constructed	TSS	71-95	Brodie, Hammer, and Tomljanovich 1987, 1989b
		Sulfate	8-20	Brodie, Hammer, and Tomljanovich 1987; Wieder 1989
		Fe	50-99	Wieder 1989; Morea, Olsen, and Wildeman 1990

Sheet 4 of 5

Table 1 (Concluded)				
Wasteload Type	**Wetland Type**	**Contaminant**	**Removal Efficiency, percent**	**Author**
Mining Activity	Constructed	Mn Al	34-77 48	Henrot and Wieder 1990; Wildeman and Laudon 1989; Tomljanovich et al. 1988b
		Zn Cu Pb Ni	Up to 98 84-99 94 92	Brodie, Hammer, and Tomljanovich 1987; Fennessy and Mitsch 1989; Dunababin, Pokorny, and Bowmer 1988; Henrot et al. 1989; Kolbash and Romanoski 1989; Kleinmann 1985; Karathanasis and Thompson 1990; Wieder, Linton, and Heston 1990

Nutrients. Wetlands can provide reductions in biological oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP). In Sweden, a grass (*Glyceria maxima*) wetland system removed 26 to 55 percent of the TN applied and 12 to 28 percent of the TP applied over a 3-year period. Influent to Central Slough in South Carolina had an average BOD of 13 mg/L the first year and 19 mg/L the second. Ammonia averaged 6.1 mg/L and 10.2 mg/L in the 2 years. Ultimate oxygen-demanding constituents were reduced by 90 percent the first year and 84 percent the second. This system provided at least a 70-percent reduction in BOD, NH_3-N, TN, and TP (Baughman et al. 1989; Sunblad and Wittgren 1989).

A reed (*Phragmites australis*) was treated with sewage sludge in Japan. It incorporated large amounts of nitrogen, phosphorus, and other nutrients from polluted water and from the sludge (Kurihara and Suzuki 1988).

Reed canary grass (*Phalaris arundinacea*) facilitated rapid reductions in total organic carbon (TOC), chemical oxygen demand (COD), and TN in Massachusetts. Mean hydraulic retention times of 3 to 10 days resulted in a 99-percent + reduction in COD and TOC concentrations (Lavigne 1989).

In North Carolina, studies were conducted in the Coastal Plain bottomland forested swamps. One, conducted in the Piedmont forested swamp, demonstrated that the uptake of nitrogen and phosphorus by the wetland systems accounted for all the sewage load to the systems within a few kilometers of the outfall. Another demonstrated that only for phosphate was there a significant amount of net removal. It was estimated that the Clarkton Wastewater Treatment Plant discharges 331 kg of phosphate and 295 kg of TP into the 0.2-ha Brown Marsh spray field. Estimates were that each hectare of the soil of this marsh could absorb nearly 2 years of annual phosphate discharge from the Clarkton plant in the upper 15 cm of soil alone. Data suggested the swamp could remove current loading rates of phosphate for hundreds of years if wastewater were discharged evenly over the entire year. One study reported that 98 percent of the trees in a swamp forest died within 18 months when struck directly by the spray from municipal sewage (Kuenzler 1988a, b; Kuenzler, Carberry, and Tzeng 1990; Richardson, Walbridge, and Burns 1988).

Heavy Metals. Reed canary grass removed more than 99 percent of the heavy metals applied. In Delaware, low (25 g/m^2/week) and high (100 g/m^2/week) treatments of sewage sludge containing heavy metals (Cr, Cu, Pb, Ni, Cd, Zn) were applied to a freshwater tidal wetland. Except for chromium, metal standing stocks did not increase in the vegetation or litter on treatment sites. The soil was found to play a major role in heavy metal retention. The top 5 cm of soil retained 47 percent and 43 percent, respectively, of the high and low treatments of cadmium; 53 percent and 28 percent of the chromium; 52 percent and 0 percent of the copper; 51 percent and 0 percent of the zinc; 31 percent and 0 percent of the lead; and none of the nickel applied. Only cadmium (15 percent and 46 percent, respectively) and chromium (12 percent and 28 percent, respectively) were still retained 6 months after the treatments were stopped. Differences in the aboveground macrophyte standing crops were not found except in June when high and low treatment sites had significantly higher standing crops than control sites (Dubinski, Simpson, and Good 1986; Lavigne 1989).

A large wetland system east of Calcutta, India, the largest of its kind in the world, has been used for purifying sewage, growing food, and generating employment (Mukherjee 1988). However, information was not available summarizing treatment efficiencies for various loadings and design criteria used.

One study was performed on fluxes of heavy metals in a freshwater tidal wetland in Delaware. A significant positive correlation was found to exist between percent of silt and chromium, cadmium, nickel, and lead. Direct sedimentation and the litter are the major pathways for a long-term accumulation of heavy metals in these wetlands. The vegetation did not respond to application of sewage sludge enriched with the heavy metals. Soils of the high nutrient sites (100 g/m^2/week sludge) retained about 43 percent of the cadmium 53 percent of the chromium, 52 percent of the copper, 31 percent of the lead, and 51 percent of the zinc at the end of the treatment period, but only 15 percent of the cadmium and 12 percent of the chromium were present 5 months later. Soils of the low treatment sites (25 g/m^2/week sludge) retained only 43 percent of the cadmium and 28 percent of the chromium in October, but retained them at the same level through the next March (Simpson et al. 1984).

Constructed wetlands

Constructed wetland systems vary from use of cattails (*Typha*), to a cellular approach (use of a variety of aquatic and emergent plants in separate compartments), to the use of gravel beds with marsh plants planted in them. In some systems, aquatic plants are inserted in the reservoirs of wastewater.

Suspended solids. A number of studies have shown that suspended solids are removed from wastewater after passing through the wetlands. In some of the studies, only the reduction in these solids was mentioned. In several studies, specific amounts of solids removal were mentioned (i.e., 21 to 116 mg/L), depending on the sediment load of the influent, the flow rate, and the wetland system used. Percentage of solids removal varied from 72 to 94 percent. Most studies reported that the suspended solids levels were well below the secondary effluent objective of 15 mg/L (Dawson 1989; DeBusk, Burgoon, and Reddy 1989; Gersberg, Gearheart, and Ives 1989; Gersberg et al. 1986; Gersberg, Elkins, and Goldman 1985; James and Bogaert 1989; Kingsley, Maddox, and Giordano 1989; Knight, Winchester, and Higman 1985; Miller 1989; Pride, Nohrstedt, and Benefield 1990; Roser et al. 1987; Stowell et al. 1985).

In one study, 1 mg/day was cleaned in a three-cell system (Dawson 1989). In another study, the optimum flow rate of secondary effluent was 8.1 to 16.2 cm/day, which reduced suspended solids 72 percent, BOD 60 percent, and fecal coliform bacteria more than 80 percent (Kingsley, Maddox, and Giordano 1989).

In one study, hydraulic loading rates of 169, 289, and 345 m^3/ha/day were used for 9 months. The monthly average total suspended solids (TSS) influent to effluent concentration ratio was 135:19, while that for BOD was 38:8. Total Kjeldahl nitrogen (TKN) removal was more effective at loading rates of 2.6 mg/ha/day (15:4 ratio) (Pride, Nohrstedt, and Benefield 1990).

In one study, loading rates of 10 cm/day were used in 3,000-L outdoor raceways. The greatest reductions in wastewater contaminant concentrations were attained in raceways containing the plant pennywort. BOD and suspended solids (SS) removal rates averaged 145 kg/ha/day and 41 kg/ha/day, respectively, during the 6-month study (DeBusk, Burgoon, and Reddy 1989).

Municipal wastewaters were applied to a bulrush cell system at a loading rate of 5 cm/day. This corresponded to a hydraulic residence time of 5.5 days. BOD removal averaged 90 percent for 120 months. SS removal averaged 90 percent. Ammonia removal averaged 94 percent for bulrush, 78 percent for reeds, 28 percent for cattails, and 11 percent for an unvegetated bed (Gersberg, Gearheart, and Ives 1989).

In another experiment, municipal wastewater was applied to constructed bulrush, reed, and cattail beds at a rate of 4.7 cm/day (corresponding to a hydraulic residence time of 6 days). The mean ammonia concentration of

24.7 mg/L in the primary wastewater influent was reduced to mean effluent levels of 1.4 mg/L for bulrush, 5.3 mg/L for reeds, 17.7 mg/L for cattails, and 22.1 mg/L for the unvegetated bed (Gersberg et al. 1986).

This same group blended primary and secondary wastewaters at a ratio of 6 cm/day primary:12 cm/day secondary. Bulrush beds effected an 80-percent removal of TN, 80-percent removal for total organic nitrogen, 93-percent removal for BOD, and 88-percent removal for SS. Mean wetland effluent values for BOD and SS were below the 10-mg/L standard for advanced secondary treatment. When primary effluent was the sole source of influent, the optimum treatment was obtained with a flow rate of 6 to 8.3 cm/day.

One system was designed with a single cell using cattails. Loading of raw sewage approximated 170 m^3/ha/day. Retention time was nearly 7 days. BOD was reduced 80 percent. SS removal was 69 percent, well below the secondary effluent objective of 15 mg/L. TP removal averaged 57 percent. Fecal streptococci and coliforms were lower in almost all tests (Miller 1989).

In another study, detention times of 2 to 10 days were used to attain 95-percent removal of BOD, 94-percent removal of SS, and 67-percent removal of TN (Roser et al. 1987).

Nutrients. All studies reported that ammonia, TN, TP, TKN, BOD, and COD were reduced to acceptable standards. All removal efficiencies varied with loading rates and detention times in the wetlands.

Among the studies that quantified results, TN removal varied from 25 to 93 percent; TKN removal varied 75 to 95 percent; TP removal varied from 21 to 57 percent; total inorganic nitrogen removal was 80 percent (one study); and ammonia removal rates varied from 94 percent for bulrush (*Scirpus*), 78 percent for rush (*Phragmites*), 28 percent for cattails, and 11 percent for an unvegetated (control) bed (Brix and Schierup 1989a, b, c; Davido and Conway 1989; Dawson 1989; Gersberg, Gearheart, and Ives 1989; Gersberg et al. 1986; Gersberg, Elkins, and Goldman 1985; James and Bogaert 1989; Kingsley, Maddox, and Giordano 1989; Knight, Winchester, and Higman 1985; Mestan 1986; Miller 1989; Nichols 1990; Pride, Nohrstedt, and Benefield 1990; Roser et al. 1987; Stengel and Schultz-Hock 1989).

In India, the efficiency of COD removal in water hyacinth ponds was 15 to 20 percent higher than in the facultative ponds. One study in western Pennsylvania demonstrated a COD removal of 93 percent by a wetland (Davido and Conway 1989; Kumar and Garde 1990).

BOD-removal efficiencies were highest in bulrush and reed beds, and lowest in unvegetated beds. The values were equal to or better than those for secondary treatment water quality. BOD-removal efficiencies of wetlands for all studies varied from 60 to 95 percent (Brix and Schierup 1989a, b; Davido and Conway 1989; Dawson 1989; DeBusk, Burgoon, and Reddy 1989; Gersberg, Gearheart, and Ives 1989; Gersberg et al. 1986; Gersberg, Elkins, and

Goldman 1985; James and Bogaert 1989; Kingsley, Maddox, and Giordano 1989; Knight, Winchester, and Higman 1985; Kumar and Garde 1990; Miller 1989; Nichols 1990; Pride, Nohrstedt, and Benefield 1990; Roser et al. 1987; Stengel and Schultz-Hock 1989; Stowell et al. 1985; Wolverton 1987).

A system using water hyacinth was designed that treated 100,000 gpd with a retention time of 6 days. TN levels were reduced by 91 percent, while TP levels were reduced by 38 percent. Bulrush systems were also used with retention times of 5 to 7 days. One system with a surface area of 4 ha and a depth of 38 cm treated 350,000 gpd of municipal wastewater (Wolverton 1987).

In one study, a marsh/pond/meadow system treated 45,360 L/day from 62 homes. The reduction of TKN was 95 percent with COD reduced 93 percent (Davido and Conway 1989).

Removals of nitrogen and phosphorus of over 50 percent were only attained in one study using reed beds where loading rates <2 cm/day were used. These loading rates were required to provide an adequate retention time (Brix and Schierup 1989a.)

Heavy metals. One study reported that while some metals such as lead may be retained by wetlands under conditions of low loading rates, the majority of metals such as zinc and cadmium may pass through the wetland ecosystem. However, another study demonstrated that the wetland systems showed a mean metal removal efficiency of >95 percent for copper (mean influent concentration was 10 mg/L), >90 percent for zinc (mean influent concentration was 10 mg/L), and >95 percent for cadmium, and that the wetland plants were resistant to the toxic effects of copper and zinc at influent levels as high as 10 mg/L. The application rate for the wetland system varied between 4 to 8 cm/day (Gersberg et al. 1984; Giblin 1985).

Other water quality constituents (bacteria, pathogens). Following treatment of wastewater by constructed wetlands, fecal coliform bacteria were described as below discharge standards, with >80-percent removal, and a reduction up to five orders of magnitude; it was lower in 32 out of 33 paired comparisons (effluent from marsh met swimming and bathing water quality objectives) and reduced to, at, or below the 1,000-total coliform/100 mL standard when treating secondary wastewaters. However, for the treatment of raw or primary wastewaters, further disinfection is necessary after wetland treatment to attain the 1,000/100 mL total coliform standard. At the hydraulic application rate of 5 cm/day, a constructed wetland removed 99.1 percent of the total coliform bacteria from influent wastewater, as compared with only 95.7 percent from an unvegetated bed. This wetland had a surface area of 64.75 m^2 (18.5 x 3.5 m) and was 0.75 m deep. Hydraulic residence time was 5.5 days (Dawson 1989; Gersberg, Gearheart, and Ives 1989; Gersberg 1987a, b; Kingsley, Maddox, and Giordano 1989; Miller 1989; Roser et al. 1987).

A limited amount of work has been done on the effectiveness of wetlands to remove viruses. Using seeded MS2 bacteriophage (viral indicator), seeded poliovirus, and indigenous F-specific bacteriophages (F-specific RNA and F-specific DNA phages), the wetland system removed 98 to 99 percent of these phages from the influent wastewater. The decay rate (k) of MS2 in a stagnant system (k = 0.012 to 0.028/hr) was lower than that for a flowing system (k = 0.44 to 0.052/hr), reflecting the enhanced capacity for filtration or adsorption of viruses by the root-substrate complex and the associated biofilm. This wetland had the same dimensions, hydraulic application rate, and residence time as described above for coliform bacteria (Gersberg, Gearheart, and Ives 1989; Gersberg 1987a, b).

Stormwater

Much of the related literature pertains to the use of wetlands for wastewater treatment. However, the use of natural wetlands for the treatment of urban stormwater runoff has increased in the past 5 years. The following principles were enumerated for water quality improvements using wetlands for stormwater treatment:

a. Sedimentation of particulates and associated pollutants is a major mechanism in water quality improvement.

b. Longer detention times (20 to 36 hr) improve water quality more than shorter times.

c. Traditional detention times for flood control of 1 to 12 hr are too short to substantially improve water quality.

d. The size of the wetland is important.

e. Sheet flow is preferred over channel flow for water quality improvements.

f. Dense vegetative growth throughout the wetland reduces flow velocity.

g. Wetlands should not be used as sedimentation basins.

h. Controlling the first flush of stormwater is not an effective management tool in western Washington State.

Wetlands are not necessarily final sinks for nutrients, heavy metals, and other substances that are discharged to them. Wetlands improve water quality by transforming, removing, storing, and releasing those substances at modified rates and times. In the Puget Sound region of Washington State, wetlands receiving urban runoff were compared with those that did not. The conclusions were as follows:

a. Affected sites had significantly elevated concentrations of lead, cadmium, and zinc.

b. Nutrient levels did not significantly differ.

c. Mean fecal coliform levels violated Washington State water quality standards in the affected wetlands.

d. The emergent zones of affected sites exhibited a prevalence of reed canary grass and lacked *Carex* spp.

e. Plant tissue metal concentrations were not statistically different between the two sites.

f. Soils from some areas in the affected wetlands were significantly more toxic.

g. Larvae of invertebrate species differed between affected and unaffected sites. (See Stockdale (1986); Stockdale and Horner (1989); and Wetland Areas: Natural Water Treatment Systems (1989).)

Natural wetlands

Characteristics of stormwater runoff and a performance summary of wetland studies for pollutant removal from stormwater runoff were compiled (Lakatos and McNemar 1988). As a part of a long-term research study of the effects of urban stormwater on wetlands, a baseline vegetation study was conducted in 1988 in western Washington State. The average percentage reduction in pathogenic bacteria after 2 hr contact with various macrophytes was listed. Viruses (as measured by the MS2 bacteriophage) were reduced from 5.35×10^5 Plaque Forming Units (PFU)/mL to 8.9×10^3 PFU/mL, a 98-percent reduction (Lakatos and McNemar 1988; Kulzer 1990).

Suspended solids. A detention pond/wetlands system was effective in reducing loads of suspended solids in the range of 42 to 66 percent. A pond/wetlands system reduced solids in the range of 55 to 83 percent of the influent loading. In another study, a new method of calculating the efficiency of pollutant removal, the regression efficiency, was devised to determine the effectiveness of a detention pond/wetland system for removing 22 constituents. System regression efficiencies were 55 percent for total solids (Martin 1988; Martin and Smoot 1986).

Nutrients. A limited number of studies demonstrated removal efficiencies of 21 to 36 percent for TN, 17 to 83 percent for TP, and 96 percent for total ammonia (Martin and Smoot 1986; Barten 1986). Schiffer (1989) found that phosphorus concentration at the inlet was 0.23 mg/L, which decreased to 0.04 mg/L at 100 ft away, and total ammonia was 0.23 mg/L at the inlet, which decreased to 0.01 mg/L at 100 ft. Martin (1988) used a detention pond but did not list retention times or loading rates.

Heavy metals. One study utilized only the wetland. Two studies utilized a detention pond/wetland system and a trash retainer area/wetland system. Zinc retention ranged from 66 to 97 percent, while lead retention varied from 42 to 97 percent (Schiffer 1989; Martin 1988; Martin and Smoot 1986).

Constructed wetlands

Suspended solids. Three studies reported efficiencies of suspended solids removal. Efficiencies ranged from 30 to 95 percent. Two separate studies concluded that the best overall reductions for pollutants (i.e., nutrients and toxic substances) are strongly associated with particulate material and are removable by sedimentation. Meiorin (1989) used a 22-ha system with wastewater coming from a 1,200-ha source with a capacity of 71,700 m^3. Esry and Cairns (1989) used a 20-acre impoundment for detention where water goes to 4-acre wetland filter to a 9-acre planted marsh. Daukas, Lowry, and Walker (1989) used detention ponds but gave no retention times or loading rates. Oberts and Osgood (1991) and Meyer (1986) used detention basins but gave no retention times or loading rates.

Nutrients. Removal efficiencies reported for nutrients are as follows: TP - 53 to 85 percent, TN - 40 to 70 percent, and BOD - 40 to 80 percent (Esry and Cairns 1989; Meiorin 1989; Daukas, Lowry, and Walker 1989; Linker 1989; Athanas and Shaver 1988).

Heavy metals. Removal efficiencies are quite variable for heavy metals in stormwater in created wetlands: sodium - 0 percent, cadmium - 50 percent, chromium - 40 to 90 percent, copper - 5 to 90 percent, lead - 30 to 90 percent, mercury - 50 to 90 percent, zinc - 6 to 90 percent, aluminum - 77 to 96 percent, and nickel - 12 to 34 percent (Linker 1989; Wieder et al. 1988; Daukas, Lowry, and Walker 1989; and Meiorin 1989).

Industrial Wastewater

Natural wetlands

A bibliography was constructed with citations concerning the ability of marshlands, bogs, and other wetland areas to degrade, absorb, filter, consume, or mitigate natural and human-related pollution and wastes, while still providing refuge and breeding grounds for wildlife (Wetland Areas: Natural Water Treatment Systems 1989).

Nutrients. Only one study quantified COD and total sulfur removal efficiencies. Using a root zone method with reed, 76 percent of COD and 82 percent of total sulfur were removed from the influent (Winter and Kickuth 1989).

Heavy metals. In one study conducted in South Africa, the uptake of metals was monitored in the water fern, *Azolla filiculoides*. Manganese was absorbed up to 2,065 percent, followed by lead (607 percent), nickel (85 percent), and copper (70 percent). Iron and manganese reached the highest levels of concentration in the water fern. In another study, incinerator ash residue was deposited on a wetland. Post experiment soil analyses indicated an increase of calcium, manganese, phosphorus, zinc, and cadmium in soil near the residue site, and an even greater increase of phosphorus, potassium, calcium, magnesium, boron, zinc, copper, manganese, aluminum, cadmium, and lead in the soil directly beneath the residue (de Wet et al. 1990; Mika et al. 1985).

Constructed wetlands

Suspended solids. Using a cordgrass, cattail, or reed wetland system, suspended solids were removed from 42 to 100 percent (Thut 1989; Guida and Kugelman 1989). In the study by Thut (1989), the retention time was 15 hr (four of the eight marshes). Flow rates tested were 3.2 m^3/day and 0.8 m^3/day. Removal efficiencies were a function of retention time, but there was little increase in efficiency even when the retention time increased from 15 to 24 hr. They recommended a constructed marsh of 20 to 40 ha for a typical pulp mill with a 15-ha detention time.

Nutrients. Depending on the source of the wastewater, removal efficiencies for several nutrients varied widely. In polishing pulp mill wastewater, BOD removal was 41 percent, ammonia varied from 52 to 88 percent, organic nitrogen varied from 24 to 27 percent, and phosphorus varied from 19 to 31 percent.

Following passage of wastewater from an oil refinery through an initial treatment with an American Petroleum Institute (API) separator, the effluent was passed to a 6-ha lagoon for initial secondary treatment, then through a series of cascading ponds and ditches (6 of 11 ponds). Between the lagoon and the first pond, the wastewater passed through an 0.8-km-long earthen canal with a heavy growth of vegetation, including reeds and bulrushes. In the primary 6-ha lagoon, reductions in pollutants of 36 to 99.9 percent were obtained. Concentrations were further reduced 70 to 100 percent in the cascading ponding system, which furnished polishing to the final effluent as it entered the Missouri River. All components were well below the National Pollutant Discharge Elimination System (NPDES) limits. The individual pollutants and their percentage reduction between the initial API separator discharge and the final pond discharge were as follows: BOD - 98 percent; COD - 92 percent; NH3-N - 90 percent; sulfides - 100 percent; phenols - 99.9 percent; and oil-grease - 98 percent. BOD concentrations were reduced

91 percent in one study done in Mississippi. In New Jersey, BOD removal varied from 29 to 100 percent, while TN and TP removal ranged between 69 to 98 percent and 30 to 73 percent, respectively (Thut 1989; Litchfield and Schatz 1989; Wolverton 1987; Guida and Kugelman 1989; and Boardman, Guida, and Kugelman 1986).

Heavy metals. In India, the water fern (*Salvinia*) removed 90 percent of the copper in 24 hr when the concentration was below 50 mg/L. From 85 to 97 percent of the iron and little to 9 percent of the manganese were removed from coal ash seepage in Tennessee and Alabama (Brodie, Hammer, and Tomljanovich 1987; Sen and Mondal 1990). In the study by Brodie et al. (1987), flow rates of 500 to 2,000 L/min were used. Loading rates were 100 to 200 mg/L of total iron and 5 to 10 mg/L of total manganese. The total iron content varied between 300 and 400 mg/L, while the manganese rate varied from 70 to 80 mg/L.

In China, sediments were collected from mangroves. Up to 6.5 percent of the copper, lead, mercury, manganese, iron, and phosphorus were found to be removed by the sediment from the influent water (Yuduan et al. 1988).

Toxic organics. One study reported the levels of toxic organic materials removed by constructed wetlands to be as follows: benzene - 89 to 98 percent, toluene - 98 to 99.9 percent, p-xylene - 92 to 97 percent, chloroform - 69 percent, and tetrachloroethylene - 75 percent (Wolverton 1987).

Other water quality constituents. One corporation in Maryland was able to utilize thermal effluents in raising nursery stock of estuarine and freshwater wetland plant species. In the process, the effluent water was cooled to NPDES standards, nursery stock was generated for sale, and employment was generated for local students. The loading rate was 284,000 L/ha (Ailstock 1989).

Agriculture

Reports on the treatment by wetlands of agricultural wastewater appear to be few. Therefore, the information for natural and constructed wetlands are combined.

Suspended solids

In natural wetlands, a wetland buffer in North Carolina resulted in a 92-percent reduction in sediment in agricultural drainage water (Chescheir et al. 1988). In California, a wetland system was created using cattails, with one large cell measuring 12 by 275 m. Suspended solids removal was 54 percent. This system used a loading rate of 4,542 m^3/day (one-third from domestic-industrial and two-thirds from dairy industries) with a detention time of 28 to 45 days, depending on the season (Mingee and Crites 1989). In Alabama, a test facility demonstrated 82-percent removal of solids using a 10-day retention time and three loading rates (160, 100, and 150 L/m^2/day) (Maddox and Kingsley 1989).

Nutrients

Estimates for nutrient removal in natural wetlands range from general statements of BOD and phosphate removal to quantified amounts. In North Carolina, a wetland buffer removed an estimated 79 percent of the TKN, 82 percent of the nitrate nitrogen, and 81 percent of TP. A wetland system in Ireland removed the following estimated concentrations of nutrients: nitrate - 96 percent, orthophosphate - 91 percent, ammonia - 95 percent, chloride - 74 percent, BOD - 97 percent (Chescheir et al. 1988; Costello 1989; Hebicha 1989).

In the work done by Costello (1989), the daily loading rate was 7,500 L for feces and urine, 7,500 L for milking parlor washings, 5,000 L for rain washings in unroofed yards, and 4,000 L for rainfall in slurry in collected canals for a daily total of 24,000 L. The filtered liquid (3,000 m^3/year) was fed first into a 6.4-ha wetland and secondly into a 5.5-ha wetland.

The City of Gustine, California, treats approximately 4,542 m^3/day of wastewater in a constructed wetland. One-third originates from domestic and commercial sources and the remainder from three dairy products industries. One large cell, built around an existing stand of cattails and measuring 12 by 275 m (3,300 m^2 in surface area), removed an estimated 66 percent of the BOD concentration. Mass loading in the cell was 11 to 220 kg/ha/day BOD (usually 112 kg/ha/day). Water depth in the wetland cell was kept to 0.15 m, and detention times ranged from 28 to 54 days (shorter times in summer, longer times in winter).

In Alabama, a constructed wetland system was designed using sand filtration beds lined with two layers of 6-mil greenhouse clear plastic with bottom drain and level control standpipes and filled with 30.5 cm (12 in.) of masonry sand. Water depth was maintained at 5.1 cm above the sand. Water detention times were 2.3 days, 3.5 days, and 5 days for irrigation rates corresponding to 150 L/m^2/day (test bed 4.5 m^2) , 100 L/m^2/day (test bed 2.7 m^2) and 60 L/m^2/day (test bed 1.8 m^2). Water chestnuts (*Eleocharis dulcis*) that had been grown in a hothouse for 59 days were then planted in the test units. For the spring/summer/fall period, the wetland system reduced BOD concentrations in the influent wastewater 75 percent, COD 69 percent, TKN 66 percent, and TP 66 percent (Maddox and Kingsley 1989; Mingee and Crites 1989; Soeder et al. 1987).

Metals

In a natural wetland in Ireland, a reduction in sodium (72 percent) and potassium (97 percent) was achieved in the influent. In Texas, selenite, the predominant form of selenium in agricultural drainage water, was significantly reduced in laboratory-scale experiments (Costello 1989; Owens and Malina 1989).

Other water quality constituents

Wastewater from a dairy farm in Ireland was treated in a wetland. Fecal coliform concentrations were reduced 62 percent. In Alabama, livestock waste was treated in a constructed system. Fecal coliform concentrations were reduced 74 percent (Maddox and Kingsley 1989; Costello 1989).

Mining Activity

The main concern is acid mine drainage (AMD), which develops in both coal and metal mining. In coal mining areas, pyrite is the mineral responsible for AMD; it also causes most problems in metal mining systems. Where pyrite is absent, water pollution is significantly reduced. With pyrite present, almost every type of heavy metal contaminant may be present in acid drainage from metal mine operations. Among various possible removal mechanisms, the precipitation of metals catalyzed by bacterial activity is postulated as the most likely. Limiting factors are availability of suitable organic matter (carbon source) and dissolved sulfate. Other major mechanisms of metal removal are probably adsorption and ion exchange with organic and inorganic materials and chemical transformations. Wetlands likely provide the physical and chemical milieu for this microbial and bacterial activity, resulting in AMD cleanup in the wetland (Hedin, Hammack, and Hyman 1989; Henrot and Wieder 1990; Portier and Palmer 1989; Sencindiver and Skousen 1991; Wildeman and Laudon 1989). In the study performed by Hedin, Hammack, and Hyman (1989), the loading rates on the wetland were 14.3 mg/L for total iron, 4.8 mg/L for total manganese, and 24 mg/L for TSS.

Only one report mentioned the use of a natural wetland in treating waste from a mine (lead-zinc mine). Thus, this section will be concerned almost entirely with the use of constructed wetlands for treatment of mining activity.

Suspended solids

A wetland constructed in Alabama reduced TSS content of influent water from 71 to 95 percent from a coal mine (Brodie, Hammer, and Tomljanovich 1987, 1989b).

Nutrients

A review of 20 inventoried sites revealed that sulfate in AMD was reduced 8 to 20 percent (Brodie, Hammer, and Tomljanovich 1987; Wieder 1989).

Heavy metals

Several studies demonstrated little change in manganese concentrations in passage of effluent through the wetland system. One study showed that over 11 percent of the constructed wetlands yielded greater concentrations of metals in the effluent from the wetland than were present in the influent AMD. The results of several studies showed that iron concentrations were reduced from 50 to 99 percent, manganese concentrations reduced from 34 to 77 percent, aluminum concentrations reduced 48 percent, zinc concentrations reduced up to 98 percent, copper concentrations reduced 99 percent, and lead concentrations reduced 94 percent. Iron, manganese, and zinc had high affinity for residual retention, while aluminum and copper had high affinity for organic retention. A peat moss system (*Sphagnum*) reduced total iron concentrations from 50 to 70 percent. In Minnesota, copper concentrations were reduced 84 percent, while those of nickel were reduced 92 percent in a natural wetland. In Montana, lead and zinc concentrations were reduced in a natural wetland, while in a constructed wetland, iron and acidity concentrations were not reduced (Wieder 1989; Morea, Olsen, and Wildeman 1990; Henrot and Wieder 1990; Wildeman and Laudon 1989; Tomljanovich et al. 1988a; Brodie, Hammer, and Tomljanovich 1987; Fennessy and Mitsch 1989; Dunbabin, Pokorny, and Bowmer 1988; Henrot et al. 1989; Kolbash and Romanoski 1989; Kleinmann 1985; Karathanasis and Thompson 1990; Wieder, Linton, and Heston 1990).

Wieder, Linton, and Heston (1990) reported loading rates of 78.8 mg/L for iron, 10.0 mg/L for aluminum, 5.2 mg/L for manganese, 12.0 mg/L for calcium, and 4.5 mg/L for magnesium. The flow rate was 90 mL/min for 6 hr/day, 5 day/week for 16 weeks. Iron reached saturation at 235 mg/gal in 157 days. Fennessy and Mitsch (1989) used a loading rate of 340 L/min (15 to 35 m^3/day) on a 0.22-ha constructed wetland. No retention times were given. Henrot et al. (1989) used loading rates of 50 and 100 mg/L with a retention time of 8 days.

Other water quality constituents

Some studies demonstrated little change in pH of the AMD water in its passage through the wetland, while others showed dramatic increases in the pH. In Colorado, pH of the water increased from 3.0 to greater than 6.5. In Alabama, the pH was elevated following passage through the wetland. After inventorying 20 sites, it was noted that pH rose, on the average, from 4.9 to 6.0 as influent water passed through the wetland (Brodie, Hammer, and Tomljanovich 1987; Henrot and Wieder 1990; Morea, Olsen, and Wildeman 1990;

Tomljanovich, Brodie, and Hammer 1988b; Wieder 1989; Wildeman and Laudon 1989).

Latitudinal Differences

Literature is not available that treats the research concerning wetlands and wastewater on a latitudinal basis. For this report, the wetlands/wastewater treatment literature has been arbitrarily divided into northern and southern wetlands. Wetlands were classified as northern if they are north of the Ohio River and east of the Mississippi River, and southern wetlands if they are south of the Ohio River. There has been virtually no wetlands/wastewater research performed in southern wetlands west of the Mississippi River. A small amount of work has been done in California. These wetlands will be regarded as southern. The wetlands of Puget Sound in Washington State are regarded as northern wetlands.

A comparison was made of the percentage reductions in the various components of the different wasteload types by northern or southern wetlands. There does not appear to be any difference between northern and southern wetlands in wastewater treatment for any wasteload type or for any component (i.e., suspended solids, nutrients, heavy metals, toxic organic materials, and other water quality constituents). Several factors appeared to influence the effectiveness of the wetland/wastewater treatment: plant species used (natural wetland), design of the constructed system (number of cells, bed construction of the cells), loading rate of influent, and detention time.

Only references that indicate northern wetlands and southern wetlands are listed by wastewater and constituent type for natural and constructed wetlands in the following list:

Northern Wetlands

Natural Wetlands

Wastewater/Stormwater

Suspended Solids	-	Wotzka and Oberts 1988 - Minnesota.
Nutrients	-	Barten 1986 - Minnesota; Lavigne 1989 - Massachusetts; Sunblad and Wittgren 1989 - Sweden; Kurihara and Suzuki 1988 - Japan.
Heavy Metals	-	Lavigne 1989 - Massachusetts; Dubinski et al. 1986 - Delaware; Simpson et al. 1984 - Delaware.

Industrial

Nutrients	-	Winter and Kickuth 1989 - Germany.

Heavy Metals	-	Mika et al. 1985 - Massachusetts.

Agricultural

Nutrients	-	Costello 1989 - Ireland.
Heavy Metals	-	Costello 1989 - Ireland.
Other Water Quality Constituents	-	Costello 1989 - Ireland.

Constructed Wetlands

Wastewater/Stormwater

Suspended Solids	-	Meiorin 1989 - Michigan; Daukas, Lowry, and Walker 1989 - Massachusetts; Oberts and Osgood 1991 - Minnesota; Meyer 1986 - Rhode Island; Miller 1989 - Canada.
Nutrients	-	Brix and Schierup 1989a, b - Denmark; Miller 1989 - Canada; Stengel and Schultz-Hock 1989 - Germany; Davido and Conway 1989 - Pennsylvania; Meiorin 1989 - Michigan; Daukas, Lowry, and Walker 1989 - Massachusetts; Athanas and Shaver 1988 - Maryland; Linker 1989 - Maryland.
Heavy Metals	-	Linker 1989 - Maryland; Wieder et al. 1988 - Maryland; Daukas, Lowry, and Walker 1989 - Massachusetts; Meiorin 1989 - Michigan.
Other Water Quality Constituents	-	Miller 1989 - Canada; Roser et al. 1987 - Australia.

Industrial

Suspended Solids	-	Thut 1989 - Washington; Guida and Kugelman 1989 - New Jersey.
Nutrients	-	Thut 1989 - Washington; Litchfield and Schatz 1989 - North Dakota; Guida and Kugelman 1989 - New Jersey; Boardman, Guida, and Kugelman 1986 - Maryland.
Other Water Quality Constituents	-	Ailstock 1989 - Maryland.

Agricultural

Nutrients	-	Soeder et al. 1987 - Germany.

Mining

Nutrients	-	Wieder 1989 - Pennsylvania.
Heavy Metals	-	Wieder 1989 - Pennsylvania; Wieder, Linton, and Heston 1990 - Pennsylvania; Henrot and Wieder 1990 - Pennsylvania; Wildeman and Laudon 1989 - Minnesota, Colorado, Montana; Morea, Olsen, and Wildeman 1990 - Colorado; Sencindiver and Skousen 1991 - West Virginia; Girts and Kleinmann 1986 - Pennsylvania, West Virginia; Kleinmann 1985 - Pennsylvania, West Virginia; Henrot et al. 1989 - Pennsylvania; Kolbash and Romanoski 1989 - West Virginia; Fennessy and Mitsch 1989 - Ohio.
Other Water Quality Constituents	-	Girts and Kleinmann 1986 - Pennsylvania, West Virginia; Morea, Olsen, and Wildeman 1990 - Colorado; Wieder 1989 - Pennsylvania; Wildeman and Laudon 1989 - Minnesota, Colorado, Montana; Henrot and Wieder 1990 - Pennsylvania.

Southern Wetlands

Natural Wetlands

Wastewater/Stormwater

Suspended Solids	-	Baughman et al. 1989 - South Carolina; Martin 1988 - Florida; Martin and Smoot 1986 - Florida.
Nutrients	-	Baughman et al. 1989 - South Carolina; Martin 1988 - Florida; Martin and Smoot 1986 - Florida; Schiffer 1989 - Florida; Richardson, Walbridge, and Burns 1988 - North Carolina; Kuenzler 1988a,b - North Carolina; Kuenzler, Carberry, and Tzeng 1990 - North Carolina.
Heavy Metals	-	Schiffer 1989 - Florida; Martin 1988 - Florida; Martin and Smoot 1986 - Florida; Mukherjee 1990 - south India.

Industrial

Heavy Metals	-	De Wet et al. 1990 - South Africa.

Agricultural

Suspended Solids	-	Chescheir et al. 1988 - North Carolina.
Nutrients	-	Chescheir et al. 1988 - North Carolina; Hebicha 1989 - Alabama.

Constructed Wetlands

Wastewater/Stormwater

Suspended Solids	-	Roser et al. 1987 - Australia; Dawson 1989 - Kentucky; Knight, Winchester, and Higman 1985 - Florida; DeBusk, Burgoon, and Reddy 1989 - Florida; Esry and Cairns 1989 - Florida; Kingsley, Maddox, and Giordano 1989 - Alabama; Pride, Nohrstedt, and Benefield 1990 - Alabama; James and Bogaert 1989 - California; Stowell et al. 1985 - California; Gersberg, Elkins, and Goldman 1985; Gersberg et al. 1986 - California.
Nutrients	-	Roser et al. 1987 - Australia; Kumar and Garde 1990 - India; Dawson 1989 - Kentucky; Nichols 1990 - Florida; Knight, Winchester, and Higman 1985 - Florida; Esry and Cairns 1989 - Florida; DeBusk, Burgoon, and Reddy 1989 - Florida; Mestan 1986 - Florida; Wolverton 1987 - Mississippi; Kingsley, Maddox, and Giordano 1989 - Alabama; Pride, Nohrstedt, and Benefield 1990 - Alabama; Gersberg, Elkins, and Goldman 1985; Gersberg et al. 1986; Gersberg, Gearheart, and Ives 1989 - California; James and Bogaert 1989 - California; Stowell et al. 1985 - California.
Heavy Metals	-	Gersberg et al. 1984 - California.
Other Water Quality Constituents	-	Dawson 1989 - Kentucky; Kingsley, Maddox, and Giordano 1989 - Alabama; Gersberg et al. 1987a,b

Industrial

Nutrients	-	Wolverton 1987 - Mississippi.
Heavy Metals	-	Sen and Mondal 1990 - India; Yuduan et al. 1988 - China; Brodie, Hammer, and Tomljanovich, 1989a,b - Alabama.
Toxic Organic Materials	-	Wolverton 1987 - Mississippi.

Agricultural

Suspended Solids	-	Maddox and Kingsley 1989 - Alabama; Mingee and Crites - 1989 - California.
Nutrients	-	Maddox and Kingsley 1989 - Alabama; Mingee and Crites 1989 - California.
Heavy Metals	-	Owens and Malina 1989 - Texas.

Mining

Suspended Solids	-	Brodie, Hammer, and Tomljanovich 1987, 1989a,b - Alabama.
Nutrients	-	Brodie, Hammer, and Tomljanovich 1987 - Alabama.
Heavy Metals	-	Dunbabin,Pokorny, and Bowmer 1988 - Australia; Karathanasis and Thompson 1990 - Kentucky; Brodie, Hammer, and Tomljanovich 1987, 1989b - Alabama; Tomljanovich et al. 1988a,b - Alabama.
Other Water Quality Constituents	-	Brodie, Hammer, and Tomljanovich 1987 - Alabama; Tomljanovich et al. 1988a,b - Alabama.

3 Design Literature

The uptake by plants of dissolved nutrients from the water has been recognized for a long time. However, it appears that only since about 1970 have scientists utilized the nutrient uptake and heavy metal and solids filtering functions of wetlands in the treatment of wastewaters. In the beginning, wastewaters were released directly to naturally occurring wetlands. In the later 1970s and throughout the 1980s, scientists and engineers experimented with and used combinations of initial retention-detention ponds followed by cells with gravel, limestone, or sediment with or without plants, and finally released the wastewater effluent through a constructed wetland to "polish" it before releasing it to a natural body of water. The cells are lined with clay or with plastic sheets to make them impermeable to wastewater leakage. In almost all cases where the final effluent was monitored, it was found to be slightly below to well below the accepted NPDES quality objective for each nutrient and heavy metal component. In almost all cases, the costs of using constructed wetlands to treat or polish wastewaters have been from one to several orders of magnitude lower than the traditional physical facility design.

Unfortunately, few of the references list the retention times of the wastewater as it is applied to the wetland system. Few references list loading rates and pollutant loads by wasteload types. These data are crucial in determining the effectiveness of the wetland in treating wastewater using a given wetland system. A reference was not found that distinguished the effectiveness of the wetland system in treating wastewater on a latitudinal basis. References were sorted that reported on northern and southern wetland/wastewater activity, but these references reported only on overall percentage reductions in specific pollutant types. They did not report whether activity was diminished during the winter die-back period. A reference was not found that identifies threshold levels of pollutants that wetlands can assimilate before they show signs of stress.

The literature is too voluminous to list the specific design features of each investigator, project, and wasteload type. For purposes of simplicity, a few of the better or newer studies will be listed that encompass most of the designs available. All references listed in Table 2 include design features. Readers should obtain and read the many papers included in the two large volumes by Reddy and Smith (1987) and Hammer (1989).

Table 2
Organization of Literature on Latitudinal Variations in Wetland Ability to Treat Wastewater

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or County
Northern					
	Natural	Wastewater/Stormwater	Suspended Solids	Wotzka and Oberts 1988	MN
			Nutrients	Barten 1986	MN
				Lavigne 1989	MA
				Sunblad and Wittgren 1989	Sweden
				Kurihara and Suzuki 1988	Japan
			Heavy Metals	Lavigne 1989	MA
				Dubinski et al. 1986	DE
				Simpson et al. 1984	DE
		Industrial	Nutrients	Winter and Kickuth 1989	Germany
			Heavy Metals	Mika et al. 1985	MA
		Agriculture	Nutrients	Costello 1989	Ireland
			Heavy Metals	Costello 1989	Ireland
			Other Water Quality Constituents	Costello 1989	Ireland
	Constructed	Wastewater/Stormwater	Suspended Solids	Meiorin 1989	MI
				Daukas, Lowry, and Weeker 1989	MA
				Oberts and Osgood 1991	MN
				Meyer 1985	RI

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Table 2 (Continued)

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or Country
Northern					
	Constructed	Wastewater/Stormwater	Suspended Solids	Miller 1989	Canada
			Nutrients	Davido and Conway 1989	PA
				Meiorin 1989	MI
				Daukas, Lowry, and Walker 1989	MA
				Athanas and Shaver 1988	MD
				Linker 1989	MD
				Brix and Schierup 1989a,b	Denmark
				Miller 1989	Canada
				Stengel and Schultz-Hock 1989	Germany
			Heavy Metals	Linker 1989	MD
				Wieder et al. 1989	MD
				Daukas, Lowry, and Walker 1989	MA
				Meiorin 1989	MI
			Other Water Quality Constituents	Miller 1989	Canada
				Roser et al. 1987	Australia
		Industrial	Suspended Solids	Thut 1989	WA
				Guida and Kugelman 1989	NJ

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Table 2 (Continued)

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or Country
Northern					
	Constructed	Industrial	Nutrients	Thut 1989	WA
				Litchfield and Schatz 1989	ND
				Guida and Kugelman 1989	NJ
				Boardman, Guida, and Kugelman 1986	MD
			Other Water Quality Constituents	Ailstock 1989	MD
		Agriculture	Nutrients	Soeder et al. 1987	Germany
		Mining	Nutrients	Wieder 1989	PA
			Heavy Metals	Wieder 1989	PA
				Wieder, Linton, and Heston 1990	PA
				Henrot and Wieder 1990	PA
				Wildeman and Laudon 1989	MN, CL, MT
				Morea, Olsen, and Wildeman 1990	CO
				Sencindiver and Skousen 1991	WV
				Girts and Kleinmann 1986	PA, WV
				Kleinmann 1985	PA, WV
				Henrot et al. 1989	PA
				Kolbash and Romanoski 1989	WV
				Fennessy and Mitsch 1989	OH

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Table 2 (Continued)

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or Country
Northern					
	Constructed	Mining	Other Water Quality Constituents	Girts and Kleinmann 1986	PA, WV
				Morea, Olsen, and Wildeman 1990	CO
				Wieder 1989	PA
				Wildeman and Laudon 1989	MN, CO, MT
				Henrot and Wieder 1990	PA
Southern					
	Natural	Wastewater/Stormwater	Suspended Solids	Baughman et al. 1989	SC
				Martin 1988	FL
				Martin and Smoot 1986	FL
			Nutrients	Baughman et al. 1989	SC
				Martin 1988	FL
				Martin and Smoot 1986	FL
				Schiffer 1989	FL
				Richardson, Walbridge, and Burns 1988	NC
				Kuenzler 1988a,b	NC
				Kuenzler, Carberry, and Tzeng 1990	NC
			Heavy Metals	Schiffer 1989	FL
				Martin 1988	FL

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Table 2 (Continued)

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or Country
Southern					
	Natural	Wastewater/Stormwater	Heavy Metals	Martin and Smoot 1986	FL
				Mukherjee 1988	South India
		Industrial	Heavy Metals	de Wet et al. 1990	South Africa
		Agriculture	Suspended Solids	Chescheir et al. 1988	NC
			Nutrients	Chescheir et al. 1988	NC
				Hebicha 1989	AL
	Constructed	Wastewater/Stormwater	Suspended Solids	Dawson 1989	KY
				Knight, Winchester, and Higman 1985	FL
				DeBusk, Burgoon, and Reddy 1989	FL
				Esry and Cairns 1989	FL
				Kingsley, Maddox, and Giordano 1989	AL
				Pride, Nohrstedt, and Benefield 1990	AL
				James and Bogart 1989	CA
				Stowell et al. 1985	CA
				Gersberg, Elkins, and Goldman 1985; Gersberg et al. 1986	CA
				Roser et al. 1987	Australia
			Nutrients	Dawson 1989	KY

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Table 2 (Continued)

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or Country
Southern					
	Constructed	Wastewater/Stormwater	Nutrients	Nichols 1990	FL
				Knight, Winchester, and Higman 1985	FL
				Esry and Cairns 1989	FL
				DeBusk, Burgoon, and Reddy 1989	FL
				Mestan 1986	FL
				Wolverton 1987	MS
				Kingsley, Maddox, and Giordano 1989	AL
				Pride, Nohrstedt, and Benefield 1990	AL
				Gersberg, Elkins, and Goldman 1985; Gersberg et al. 1986; Gersberg, Gearheart, and Ives 1989	CA
				James and Bogaert 1989	CA
				Stowell et al. 1985	CA
				Roser et al. 1987	Australia
				Kumar and Garde 1990	India
			Heavy Metals	Gersberg et al. 1984	CA
			Other Water Quality Constituents	Dawson 1989	KY
				Kingsley, Maddox, and Giordano 1989	AL
				Gersberg et al. 1987a,b, 1989	CA

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Table 2 (Continued)

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or Country
Southern					
	Constructed	Industrial	Nutrients	Wolverton 1987	MS
			Heavy Metals	Brodie, Hammer, and Tomljanovich 1987, 1989a,b	AL
				Sen and Mondal 1990	India
				Yuduan et al. 1988	China
			Toxic Organic Materials	Wolverton 1987	MS
		Agriculture	Suspended Solids	Maddox and Kingsley 1989	AL
				Mingee and Crites 1989	CA
			Nutrients	Maddox and Kingsley 1989	AL
				Mingee and Crites 1989	CA
			Heavy Metals	Owens and Malina 1989	TX
		Mining	Suspended Solids	Brodie, Hammer, and Tomljanovich 1987, 1989a,b	AL
			Nutrients	Brodie, Hammer, and Tomljanovich 1987	AL
			Heavy Metals	Karathanasis and Thompson 1990	KY
				Brodie, Hammer, and Tomljanovich 1987, 1989a,b	AL
				Tomljanovich et al. 1988a,b	AL
				Dunbabin, Pokorny, and Bowmer 1988	Australia

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Table 2 (Concluded)

Location	Wetland Type	Wastewater Type	Constituent	Reference	Geographic Area State or Country
Southern					
	Constructed	Mining	Other Water Quality Constituents	Brodie, Hammer, and Tomljanovich 1987	AL
				Tomljanovich et al. 1988a,b	AL

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Basically, three different methods are used for constructing wetlands for treatment of wastewater (Table 3). The water hyacinth method is limited to areas where the climate is warm year-round. Emergent species may be grown in the ponds or lagoons with the water hyacinth. In colder northern areas, the cattail-bulrush system is generally employed. The actual system constructed may vary from a single cell using a plant species or a combination of species in an excavation lined with clay or plastic to a multicellular system with an initial retention-detention pond with no plants, which leads by way of channels or trenches to a series of ponds, each lined and planted. These ponds usually have a gravel or limestone substrate. The trenches connecting the ponds usually are planted with emergent species. The third type is the root zone method described in Table 3. A fourth type of wetland is listed that utilizes *Sphagnum* moss for AMD.

Table 3
Design Criteria and Loading Capabilities of Wetlands Used for Wastewater Treatment

System Components	Loading Capacity	Reference
1. Water Hyacinth--single-cell lagoon	160,000 gpd	Wolverton 1987
5-cell lagoon	100,000 gpd	Wolverton 1987
2. Bulrush and duckweed (suited for temperate and semitropical areas)	350,000 gpd	Wolverton 1987
Bulrush in gravel in pit lined with plastic (3 beds, each 18.5 m long, 3.5 m wide, and 0.76 m deep)	5 cm/day (corresponding to a hydraulic residence time of about 5.5 days)	Gersberg et al. 1987a
3. Root Zone Method--integration of emergent aquatic plants with microbial rock filters. Wastewater trickles over rocks and roots. Metals complex with roots	350,000 gpd and 4,000,000 gpd facilities now operating	Wolverton 1987
Root Zone Method	>2 cm/day	Brix and Schierup 1989a,c; Winter and Kickuth 1989
4. Sphagnum moss for AMD		Henrot and Wieder 1990; Henrot et al. 1989; Kleinmann 1985; Holm and Jones 1985

A relatively recent manual has been prepared by the Tennessee Valley Authority entitled "Constructed Wetlands Wastewater Treatment Systems for Small Users, Including Individual Residences." The system is designed for "Small Users," defined as those with flows up to 10,000 gpd. Design options include one-celled and two-celled systems. Both designs include excavations lined with plastic or with concrete blocks. Both use a gravel base with mulch at the cell surface. In the one-cell design, the wastewater influent enters through cattail-bulrush vegetation and flows out through the other end. In the two-cell system, the influent flows through the first cell (described for the one-cell system) into a second cell with topsoil over the gravel base and mulch at the surface. A variety of emergent ornamental wetland plants are utilized in this cell.

Plant species commonly utilized in northern constructed wetlands are cattail (*Typha latifolia*), bulrush (*Scirpus* sp.), and reed (*Phragmites* sp., in Europe). A variety of wetland plants may be used with these plants. Duckweed (*Lemna minor*), reed canarygrass (*Phalaris arundinacea*), water lily (*Nymphaea* sp., *Nuphar* sp.), and others may be used (Haberl and Perfler 1989; Bavor et al. 1989; Brix and Schierup 1989a,b,c; Butler, Loveridge, and Bone 1989; Conway and Murtha 1989; Daukas, Lowry, and Walker 1989; Davido and Conway 1989; Donlan 1989; Eger and Lapakko 1989; Fennessy and Mitsch 1989; Girts and Kleinmann 1986; Herskowitz et al. 1986; Kolbash and Romanoski 1989; Lavigne 1989; Meyer 1985; Miller 1989; Morea, Olsen, and Wildeman 1990; Oberts and Osgood 1991; Roser et al. 1987; Soeder and Schultz-Hock 1987; Stengel and Schultz-Hock 1989; Thut 1989; Trautmann et al. 1989; Wieder, Linton, and Heston 1990; Winter and Kickuth 1989; Wotzka and Oberts 1988).

Plant species commonly utilized in southern constructed wetlands are cattails, bulrush, and rush (*Juncus effusus*). Other wetland plants may be used with these three main species, i.e., arrowhead (*Sagittaria latifolia*), pennywort (*Hydrocotyle umbellata*), duckweed (*Lemna* spp.), frog's-bit (*Limnobium spongia*), burr reeds (*Sparganium eurycarpum*), canna lily (*Canna flaccida*), arrow-arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), and green taro (*Colocasia esculenta*) (Baughman et al. 1989; Brodie, Hammer, and Tomljanovich 1989a,b; Burgoon, Reddy, and DeBusk 1989; Dawson 1989; DeBusk, Burgoon, and Reddy 1989; Esry and Cairns 1989; Gearheart, Klopp, and Allen 1989; Gersberg et al. 1984, 1986; Gersberg, Elkins, and Goldman 1985; Gersberg, Gearheart, and Ives 1989; Jackson 1989; James and Bogaert 1989; Karathanasis and Thompson 1990; Kingsley, Maddox, and Giordano 1989; Knight, Winchester, and Higman 1985; Martin and Smoot 1986; Meiorin 1989; Mingee and Crites 1989; Pride, Nohrstedt, and Benefield 1990; Reddy and Smith 1987; Silverman 1989; Tomljanovich, Brodie, and Hammer 1988a,b; Wolverton 1987).

A small number of references (Table 2) were found that described the design of the study and loading rates using natural wetlands. For northern wetlands, see Costello (1989) and Simpson et al. 1984. For southern wetlands see Chescheir et al. (1988), Gambrell, Khalid, and Patrick (1987), Hebicha (1989), and Yuduan et al. (1988).

References

Ailstock, M. S. Utilization and Treatment of Thermal Discharge by the Establishment of a Wetlands Plant Nursery. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 719-726, 3 fig, 1 tab, 15 ref. Note: Anne Arundel Community Coll., Arnold, MD. SWRA2305.
The Nevamar Corporation, in Odenton, Maryland, manufactures decorative building materials in a process that generates 284,000 L of heated water per hour. Permits for discharge of this water into the Severn River have lowered the acceptable discharge temperature to 32.2 C. As part of the permit process, a study 0was conducted of ways to improve holding pond cooling efficiency. Possibilities include increasing pond depth, surface area, and equalization and retention time as suitable modifications. These improvements were compatible with and would be optimized by a wetlands plant nursery, which is described here. Wetland plants can be grown in 4-L to 12-L containers placed in channels filled with gravel and receiving the heated water. The flow provides continuous irrigation and, with the exception of an occasional supplementary application of slow-release fertilizer, the plants are maintenance free. Availability of warm water greatly extends the growing season and significantly enhances belowground growth. Two wetlands projects have been installed with plants produced using this wetland nursery (Spartina spp. marshes, a 111 sq m area and a 610 m shoreline stabilization area requiring 25,000 plants). Numerous applications for the plants grown in this type of nursery suggest that the concept has wide potential application. (See also W90-04392) (Rochester-PTT).

Athanas, C. and E. Shaver. The Creation and Use of Wetlands for Stormwater Treatment. 1988. Proceedings of the National Wetland Symposium: Wetland Hydrology. Chicago, IL. Edited by J.A. Kusler.
The pattern of stormwater runoff changes greatly as a watershed is developed. The increase in such impervious surfaces as parking lots and roads results in a greater volume of surface runoff leaving the watershed immediately after a storm. This rapid runoff rate can result in downstream erosion. The most basic treatment of stormwater runoff involves retarding the rate of runoff. A common method of doing this is to impound the runoff so that it leaves the basin at a more acceptable rate. One of the drawbacks to this type of treatment is that stormwater runoff is detained for only several hours in the basin. This is not enough time for particulate material to settle

out. To increase the amount of time available for sedimentation, outlets have been made smaller in many basins. This results in extended periods of detention, often as long as 24 hours. This extended detention significantly increases the removal of suspended solids from stormwater runoff, but appears to have little effect on the dissolved nutrient component of stormwater runoff. These nutrients must be removed biologically. For nitrogen, there is a steady increase in removal rate up to about 50% for the pond area that is about 3% of the area of the catchment. The removal rate for phosphorus is similar.

Barten, J. Stormwater runoff treatment in a wetland filter: Effects on the water quality of Clear Lake. Sixth Annual International Symposium. Lake and Reservoir Management: Influences of Nonpoint Source Pollutants and Acid Precipitation. November 5-8, 1986 Portland, Oregon. 1986; Note: City of Waseca, Waseca, MN, USA Summary Language - English; Summary only. English.
Clear Lake is a 257-ha body of water located in south central Minnesota. A heavily used recreational lake, it became eutrophic from the inflow of nutrient-rich runoff water from the adjacent city of Waseca. In 1981, 50% of the hydraulic load and 55% of the phosphorus load to the lake were diverted into a 21.4-ha marsh. The marsh system reduced the annual phosphorus load to Clear Lake by 44% (1,073 kg). In 1986 construction was completed on a second marsh system that will filter urban and agricultural runoff carrying 20% of the phosphorus load into Clear Lake. The mean total phosphorus concentration in Clear Lake has been reduced 32% from 147 ug/L to 100 ug/L, since 1981. The total nitrogen to total phosphorus (TN:TP) ratio increased from 10:1 to 22:1 since the diversion began.

Baughman, D. S.; Knight, R. L.; Dunn, W. J.; Schwartz, L. Use of a Forested Wetland in South Carolina for Tertiary Treatment of Municipal Wastewater. IN: Water: Laws and Management. American Water Resources Association, Bethesda, Maryland, 1989. p 7A-25--7A-37, 5 tab, 14 ref. Note: CH2M Hill, Charleston, SC. SWRA2404.
The Grand Strand Water and Sewer Authority (GSWSA) began a pilot study in June 1986 with 400,000 gpd of treated wastewater discharged to a forested wetland called Central Slough on the Waccamaw River in Horry County, South Carolina. This pilot study was conducted to test the assimilative capacity of a cypress-gum wetland and to assess the potential biological effects of the wastewater discharge. Two years of operational monitoring of surface and groundwater quality, and biota have been conducted and are summarized in this paper. The effluent discharged to Central Slough had an average biochemical oxygen demand (BOD) of 13 and 19 mg/L in year 1 and year 2, respectively, while ammonia averaged 6.1 and 10.2 mg/L during the same years. As the effluent flowed through the 32-hectare wetland, ultimate oxygen demanding (UOD) constituents were reduced by 90% in year 1 and 84% in year 2. These estimates are equivalent to mass removal rates of 0.15 and 0.20 g/sq m/d in 1986 and 1987. Overall, the wetland provided at least a 70% reduction for BOD, total suspended solids, NH3-N, total nitrogen, and total phosphorous. No changes in

water quality in the Waccamaw River downstream of the wetland were observed during this period, and groundwater monitoring indicated no impacts from the discharge of treated wastewater. The vegetation strata were also monitored over the study period with no changes in the canopy, subcanopy, and shrub importance values of the dominant species observed during the two years of treated wastewater discharge. Ground cover changes were limited to an increase in duckweed. (See also W91-03032) (Author's abstract).

Bavor, H. J.; Roser, D. J.; Fisher, P. J.; Smalls, I. C. Performance of Solid-Matrix Wetland Systems, Viewed as Fixed-Film Bioreactors. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 646-656, 3 fig, 4 tab, 3 ref. Note: Hawkesbury Agricultural Coll., Richmond (Australia). Faculty of Food and Environmental Sciences. SWRA2305.
Wastewater treatment performance of solid-matrix, constructed wetland systems was investigated during the design, operation, and maintenance of seven large-scale units at Richmond, Australia, over a 3.5-yr period. The design and construction of these constructed wetlands, the effect of loading rate on pollutant removal, the effect of seasonality on pollutant removal, nitrification potential of the macrophyte system microbial populations, denitrification, and hydraulic behavior are described. The systems consisted of lined trenches planted with Typha orientalis or Scirpus validus in gravel and a floating macrophyte, Myriophyllum aquaticum, growing in open water with no solid matrix. Domestic sewage and primary (settled) and secondary effluent from a trickling filter/maturation pond were used at hydraulic loadings from 0.2 to 1.4 mL/ha/day. Effective removal of BOD5 (annual mean 95%), suspended solids (94%), and total nitrogen (67%) was achieved by the systems when operating at hydraulic detention times of 2-10 days. Indicator bacteria were reduced by up to 5 orders of magnitude. Phosphorus removal, however, was low (15%). The Myriophyllum system was the least effective of the design formats tested. Removal of suspended solids, BOD5, N, P, and fecal coliforms was investigated in relation to loading, detention time, and temperature to allow predictive modeling of system performance, assuming first-order removal kinetics and treating the units as fixed-film bioreactors. For a number of effluent constituents, first-order removal kinetics may not describe adequately the removal performance. Improved models are being developed. (See also W90-04392) (Rochester-PTT).

Boardman, G.D., V.G. Guida, and I.J. Kugelman. Activated Sludge Ttreatment and Salt Marsh Polishing for Seafood Processing Wastewater: An Experimental Investigation. 1986. 18 Mid-Atlantic Industrial Waste Conference.

Brix, H.; Schierup, H. -H. Danish Experience with Sewage Treatment in Constructed Wetlands. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989a. p 565-753, 3 fig, 2 tab, 2 ref. Note: Aarhus Univ. (Denmark). Botanical Inst. SWRA2305.

The concept of treating wastewaters with emergent aquatic macrophytes (the root-zone process) was introduced in Denmark in 1983. Basically, this process depends on a horizontal subsurface flow through the rhizosphere of the common reed (Phragmites australis). During passage of wastewater through the rhizosphere, organic matter content of wastewater theoretically should be decomposed by aerobic and anaerobic microorganisms; microbial nitrification and subsequent denitrification should release N to the atmosphere; and P should be removed by chemical coprecipitation with Fe, Al, and Ca compounds in the soil. Reed beds supply oxygen to the aerobic microorganisms in the rhizosphere and increase/stabilize the hydraulic permeability of the soil. Direct assimilation of nutrients by vegetation is considered to be of no significance for the purification ability of the systems because the maximum amount of nutrients that can be removed by harvesting the aboveground biomass is less than 5% of the load on a yearly basis. The root-zone process was introduced as a low-cost, low-technology, decentralized solution capable of producing an effluent quality equivalent to or exceeding conventional tertiary treatment technology. Performance for BOD5, as well as N and P, was claimed to be better than 90%. The first full-scale treatment facilities were constructed in Denmark during winter 1983-84. The first four years of experience with these constructed reed beds demonstrated the following: (1) performance with respect to BOD5 typically was 70-90%, producing a consistent effluent concentration of less than 20 mg/L after one growing season; (2) typical reduction of total N and total N is 25-50% and 20-40%, respectively; (3) N and P removal depends on hydraulic loading rate and consequent retention time within the reed beds (only facilities with loading rates >2 cm/day show removals of N and P over 50%); and (4) hydraulic permeability of the soil develops slowly, if ever, with overland flow predominating after 4 growing seasons, forming a pattern covering only part of the reed bed area. (See also W90-04392) (Rochester-PTT).

Brix, H.; Schierup, H. H. Sewage Treatment in Constructed Reed Beds-Danish Experiences. Water Science and Technology WSTED4, Vol. 21, No. 12, p 1665-1668, 1989b. 1 fig, 1 tab, 7 ref. Note: Aarhus Univ. (Denmark). Botanical Inst. SWRA2306.

Twenty-five reed beds constructed in Denmark for wastewater disposal were evaluated. The majority of the reed treatment beds were constructed to treat only mechanically pretreated domestic sewage. Removal efficiency with respect to BOD was typically 70 to 90% after one growing season, producing an effluent concentration of less than 20 mg/L. Total nitrogen and total phosphorus were reduced by 25 to 50% and 20 to 40%, respectively. The poor performance of nutrient removal was attributed to low soil permeability and insufficient release of oxygen from the root systems for adequate nitrification. Only reed beds with loading rates of <2 cm/d produced nitrogen and phosphorus removal of >50%. Soil permeability did not improve significantly even after 4 growing seasons. Overland flow predominated. (Cassar-PTT).

Brix, H.; Schierup, H. H. Use of Aquatic Macrophytes in Water-Pollution Control. AMBIO AMBOCX, Vol. 18, No. 2, p 100-107, 1989a. 4 fig, 35 ref. Note: Aarhus Univ. (Denmark). Botanical Inst. SWRA2305.
Ecosystems dominated by aquatic macrophytes are among the most productive in the world. Aquatic plants possess an outstanding ability for assimilating nutrients and crating favorable conditions for microbial decomposition of organic matter. This ability can be exploited in the restoration process of natural streams, lakes and wetlands, and in wastewater-treatment systems. Four different types of macrophyte-based wastewater-treatment facilities are discussed. Floating macrophyte treatment systems use plants not rooted in the substrate. Of these, water hyacinth and duckweed appear most promising. Water hyacinth has been used successfully in the tropics and subtropics, however it is not cold resistant therefore limiting their use in temperate regions. Duckweed is used mainly for recovering nutrients and can provide animal fodder. It is subject to wind damage, however. Submerged macrophyte treatment systems require oxygenated water thereby limiting their use to 'polishing' of secondarily treated wastewaters. It is still in the experimental stage with species like egeria, elodea, hornwort, and hydrilla being the most promising. Emergent macrophyte treatment systems (artificial and natural wetlands) have large internal air spaces for transportation of oxygen to roots and rhizomes. In 1983 a macrophyte-based system named the Root-Zone method was introduced in Denmark. It depends on the sub-surface flow of water through the rhizosphere using the common reed (Phragmites australis). This allows microbial decomposition, dinitrification, as well as soil fixation of nitrogen and heavy metals. In addition the reeds supply oxygen to the heterotrophic microorganisms while increasing and stabilizing the hydraulic conductivity of the soil. The Root-Zone method costs between 10- 50% of convention technology. Integrated macrophyte treatment systems involves combination of the above described systems with each other or with conventional technology. The potential for resource recovery by harvesting and utilization of the plant material produced can be regarded as a step in the direction of a holistic solution where waste products will be regarded and utilized as a resource. (Author's abstract).

Brodie, G. A.; Hammer, D. A.; Tomljanovich, D. A. Constructed Wetlands for Treatment of Ash Pond Seepage. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 211-219, 2 fig, 5 tab, 6 ref. Note: Tennessee Valley Authority, Chattanooga. Div. of Power System Operations. SWRA2305.
Typically, Tennessee Valley Authority (TVA) ash pond seeps have pH of 3-6, total Fe of 100-200 mg/L and total Mn of 5-10 mg/L, however Fe may be as high as 300-400 mg/L and Mn may be as high as 70-80 mg/L. Widows Creek Steam Plant, Alabama, is a 2000-megawatt station with 129 of retired and 39 ha of active ash pond storage within a 399-ha site. Seepage at one point emanated from a reclaimed ash pond dike and reached Guntersville Reservoir. In April 1986, this seepage was routed through a constructed 0.5-ha wetland with Typha latifolia (cattail) and Juncus effusus

(rush) in one cell and cattail and Scirpus cyperinus (bulrush) and some other plants in cells 2 and 3. Fertilizer (Nutra Nuggets) was applied after planting at 6.75 MT/ha and Lorsban was aerially applied to control armyworms (Simyra henrici). At Kingston Steam Plant, Tennessee, a cattail and bulrush marsh (0.9 ha) was established in a similar manner. At Colbert Steam Plant, Alabama, a natural wetland was expanded by construction of dikes (total treatment area 1 ha). Construction costs for three treatment systems ranged from $6.98 to $14.21/sq m of treatment area, whereas typical mine site costs range from $3.58 to 14.12/sq m of treatment area. The wetlands system at Widows Creek removed 97% of the Fe, but only 9% of the Mn, and average discharge pH decreased 2.1 s.u. during the first 8 mo of operation. A drip-feed NaOH system was installed and discharges have met compliance standards since. At Kingston, total Fe was reduced 85%, but there was little Mn removal and pH has consistently dropped 3 s.u. from the influent to the proposed discharge point. Colbert effluent had good pH (6.6), low total Fe (<1 mg/L), but high total Mn (22.5 mg/L) immediately after wetland construction. NaOH treatment was continued to reduce Mn to permit limits. Mn levels within the system have dropped consistently, however, suggesting that the initial high Mn levels resulted from disturbance of previously deposited Mn. (See also W90-04392) (Rochester-PTT).

Brodie, G. A.; Hammer, D. A.; Tomljanovich, D. A. Treatment of Acid Drainage with a Constructed Wetland at the Tennessee Valley Authority 950 Coal Mine. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 201-209, 5 fig, 3 tab, 6 ref. Note: Tennessee Valley Authority, Chattanooga. Div. of Power System Operations. SWRA2305.
Impoundment 3, a sedimentation basin operated by the Tennessee Valley Authority in Alabama, had had persistent problems with effluent quality compliance, resulting in pollution of Kash Creek. Among the reasons for these problems were inadequate capacity of the basin, variations in flows, influent chemistry, and weather, and vandalism of chemical treatment equipment. A three-cell wetland was conducted to treat the effluent from the 950 coal mine. It included cattails (Typha latifolia) and woolgrass (Scirpus cyperinus) and cost $41,200 to construct and $3,700 for annual operation and maintenance costs. These figures contrasted with $28,500 in annual operating costs over 10 yr for the previous chemical treatment system. Since initial system operation, effluent quality has met permit limits. Generally, the wetland increased pH from 6.1 to 6.9 and reduced total Fe from 14.3 mg/L to 0.8 mg/L, total Mn from 4.8 mg/L to 1.1 mg/L, and total suspended solids from 24 mg/L to 7 mg/L. The number of invertebrate taxa downstream from impoundment 3 in Kash Creek increased from 2 to 19 within six months of wetland construction. The wetlands, which were originally planted with two plant species, contained 20 plant species 13 mo after construction. One observed problem was muskrat burrowing, which caused dike failure and bypass of wetlands water about a year after construction. The dike was repaired and dike slopes were

armored with coarse rip-rap from 0.7 m below to 1.0 m above the waterline. (See also W90-04392) (Rochester-PTT).

Brodie, G.A., D.A. Hammer, and D.A. Tomljanovich. Treatment of Acid Drainage from Coal Facilities with Man-Made Wetlands. 1987. Aquatic Plants for Water Treatment and Resource Recovery. Magnolia Publishing Inc., Orlando, FL. Edited by K.R. Reddy and W.H. Smith.
A series of shallow impoundments planted with a variety of wetland emergents was constructed in May 1985 to treat acidic drainage emanating from the toe of a fine coal refuse impoundment dike at the Tennessee Valley Authority's Fabius Coal Preparation Plant in northeastern Alabama. Flora and fauna within the wetlands (both transplants and invaders) showed rapid growth and expansion. Comparisons between the seeps and final effluent showed substantial reductions in Mn, Fe, and suspended solids during July 1985 through June 1986 and increases in pH and dissolved O2. In December 1985, an additional 75-150 L/min of pH 3.5 water discharged into the wetlands reduced treatment efficiency, but the system gradually recovered after the acidic flow was terminated.

Burgoon, P. S.; Reddy, K. R.; DeBusk, T. A. Domestic Wastewater Treatment Using Emergent Plants Cultured in Gravel and Plastic Substrates. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 536-541, 2 fig, 3 tab, 5 ref. Note: Florida Univ., Gainesville. Dept. of Soil Science. SWRA2305.
Wetland plant growth and wastewater treatment were compared in two plastic substrates and in 1-cm-diameter gravel. The gravel had a high specific surface area, 48% porosity and the two sizes of plastic media were 2.5 cm and 5.0 cm diameter, medium and low specific surface area, both with high porosity (66-83%). Microcosms (22 L) were filled with substrates and then planted with four emergent plant species: Typha latifolia, Phragmites australis, Scirpus pungens, and Sagittaria latifolia. All plants were grown in gravel but T. latifolia was not grown in either plastic substrate. Sewage was pumped directly from the effluent weir of the primary sedimentation tank at the University of Florida Wastewater Treatment Plant. Effluent was applied at BOD5 and total Kjeldahl N (TKN) mass loading rates of 210 and 45 kg/ha/day. Average influent concentrations of BOD5, TKN, and total P (TP) were 120, 25.4, and 5.1 mg/L. Effluent BOD5 was below 30 mg/L for all treatments. Removal of TKN and TP was highest in the gravel treatments. TP removal averaged 45% for the gravel control, whereas S. latifolia in gravel removed a higher percentage of TP than the other treatments. Effluent concentrations of TKN and TP for S. latifolia and T. latifolia in gravel were both less than 5 mg/L and 3 mg/L, respectively. S. latifolia and S. pungens grew poorly in plastic substrates, whereas P. australis grew well in all three substrates. S. latifolia was very susceptible to a fungus, which was controlled with biweekly applications of the fungicide Benomyl. Biomass production for S. latifolia, P. australis, and S. pungens in gravel averaged 344.2, 223.2, an 10.8 kg/ha/day, respectively. Of the N and P removed from the wastewater, 22% and 18%, respectively,

were stored in aboveground biomass of S. latifolia. Wastewater contaminant removal generally was better in the high-specific-surface-area gravel substrate than in the plastic substrates. This was consistent with the three substrate controls, where the gravel effluent had the highest effluent quality. (See also W90-04392) (Rochester-PTT).

Butler, J. E.; Loveridge, R. F.; Bone, D. A. Crop Production and Sewage Treatment Using Gravel Bed Hydroponic Irrigation. Water Science and Technology WSTED4, Vol. 21, No. 12, p 1669-1672, 1989. 6 tab, 6 ref. Note: Portsmouth Polytechnic (England). Dept. of Civil Engineering. SWRA2306.
A field-scale two-stage sewage treatment/crop production system was constructed using a series of gently sloping channels, each lined with an impermeable membrane and filled with gravel aggregate. The primary stage was planted with a selection of reeds and grasses and fed with settled sewage. The secondary stage was planted with a commercial crop of sugar beets, which received effluent from the reed system. BOD removal (125 mg/l in the influent) was 34% in the Phragmite planting, 25% in the thin Spartina stand, 32% in the dense Spartina stand, and 43% in the Carex planting. Suspended solids removal (97 mg/l in the effluent) was 34% in the Phragmite planting, 53% in the thin Spartina stand, 41% in the dense Spartina stand, and 51% in the Carex planting. The sugar beet secondary system consisted of inclined gravel beds fed with effluent from the reed system. Removals of substances from this secondary system were as follows: BOD, 68% (to 27 mg/l); suspended solids, average 41% (to 30 mg/l); ammonia, 29% (to 5.0 mg/l); phosphate, 6% (to 11.3 mg/l). The sugar beets obtained from the reed-fed system had a mean root weight of 380 g compared with 846 g in the conventionally fed crop. These disappointing results were attributed to an under-designed primary stage which delivered a too-strong feed. (Cassar-PTT).

Chescheir, G. M.; Skaggs, R. W.; Gilliam, J. W.; Broadhead, R. G. Wetland Buffer Areas for Treatment of Pumped Agricultural Drainage Water. IN: Coastal Water Resources. Proceedings of a Symposium held in Wilmington, North Carolina. American Water Resources Association, Bethesda, Maryland. 1988. p 255-263, 1 fig, 4 tab, 10 ref. Note: North Carolina State Univ., Raleigh. Dept. of Biological and Agricultural Engineering. SWRA2312.
The hydrology and pollutant removal effectiveness of wetland buffer areas receiving agricultural drainagewater are analyzed. Field experiments were conducted on two wetland buffer areas. Duringselected pumping events, water level measurements and water quality samples were taken over a network of stations. Automatic water samplers and water level recorders were used to monitor water quality and water table elevations between sampling events. Rhodamine dye studies were conducted to determine water velocities and wetland roughness coefficients. The hydrology of the buffer areas was simulated using a model for overland flow through vegetated areas. A routine was added to the model to calculate the residence time of the water on the wetland and to calculate the percent removal of nutrients

and sediment. The water management model, DRAINMOD was used to determine the frequency and intensity of pumping events by calculating drainage and runoff volumes from the drained agricultural areas. Results from the two models compared well to the field data. If was found that pumping agricultural drainage water through wetland buffer areas will significantly reduce the concentration of sediments and other nutrients in the water before it reaches an outlet. The effectiveness of removing these pollutants can be increased by facilitating even distribution of the water over the buffer area with a diffuser canal. Lower water velocities were observed on the Laurel Bay buffer than on the Northwest Fork buffer. Of the two buffers, the Laurel Bay buffer was larger with less gradient and greater resistance to flow. Estimates of the percent of nutrient removal from the total mass of nutrient pumped onto the buffer over a 20 year period was 79% for total Kjeldahl nitrogen, 82% for nitrate nitrogen, 81% for total phoshporus, and 92% for sediment. (See also W90-10584) (Author's abstract).

Conway, T. E.; Murtha, J. M. Iselin Marsh Pond Meadow. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 139-144, 1 fig, 6 ref. Note: Indiana Univ. of Pennsylvania. SWRA2305.
The Iselin Marsh Pond Meadow project was conducted in Indiana County, Pennsylvania, to examine the feasibility of a wetlands type wastewater treatment system for small towns. The capital cost of the system was $350,000. The system was designed serve an average daily flow of 45 cu m/day from 62 houses and consisted of the following elements: (1) a small comminutor and bar screen, (2) an aeration cell with a floating surface aerator, (3) a lateral-flow marsh with cattails (Typha latifolia) in a sand medium, (4) a facultative pond with mixed plants (Lemna, Sagittaria, Nuphar, and Amacharis) and fish (Cyprinus carpio, Ictalurus nebulosis, and Lepomis) to remove the plants, (5) a meadow planted with reed canary grass (Phalaris arundinacea) to provide final filtration, treatment, and nutrient uptake, (6) a concrete trough to collect and discharge the treated effluent, and (7) an erosion chlorinator and contact tank (120 min) to control bacteria. The start-up date was February 1983. The system was capable of exceeding secondary discharge requirements of 30 mg/L suspended solids, 30 mg/L BOD5, and effective disinfection. Average yearly reductions of suspended solids were 89% and BOD5 were 97%, with yearly fecal coliform reduction exceeding 99%. These three parameters did not change significantly seasonally but the effectiveness of the system in reducing ammonia N and total P varied between summer and winter conditions. Several physical modifications of the system have been made based on operational experience and seven similar or modified systems are under development in Pennsylvania. (See also W90-04392) (Rochester-PTT).

Costello, C. J. Wetlands Treatment of Dairy Animal Wastes in Irish Drumlin Landscape. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989.

p 702-709, 3 fig, 1 tab, 5 ref. Note: Lough Gara Farms Ltd., Boyle (Ireland). SWRA2305.
Lough Gara Farms Limited produces approximately 450,000/yr of milk on a site that drains into Lough Gara, a 1700-ha, shallow, bog-fringed lake of 13 m maximum depth in Ireland. Problems with pollution from the site were approached by a three-part program: (1) an independent environmental study of the lake's physical, chemical, microbiological, and ecological characteristics to determine the impact, if any, of the existing wastewater treatment system on the lake; (2) a design study aimed at improving the design, functioning, and operation the existing system; (3) prepare, with costing, plans to carry out works requested by the Sligo County Council (SCC); and (4) reinvestigate the suitability of land for the spreading of slurry as requested by SCC. The waste treatment system begins with delivery of slurry to interlinked 2-m-deep by 2.5-m-wide trenches on impervious soil with a capacity of 800 cu m. The daily volume of material fed into this system consists of feces and urine, 7500; milking parlor washings 7500 L; rain washings in unroofed yard areas, 5000 L; and rainfall in the slurry collection channels, 4000 L, a total of 24,000 L/day. A gate controls flow so that the liquid fraction can undergo a second anaerobic fermentation in a chamber of 200 cu m with limestone filter at the outlet. Filtered liquid (3600 cu m/yr) is fed into the wetlands treatment area. The wetlands treatment area is divided into two zones: a former lake bed of 6.4 ha, with peat and vegetation, and a zone of 5.5 ha that falls 1 m to the Lough Gara level. Effluent treatment produced a 99.1-99.95% reduction in BOD5 concentrations, although on some occasions levels exceeded 200 mg/L. Ammonia concentrations were reduced by up to 94.5%; nitrate concentrations were reduced up to 95.4%; and orthophosphate concentrations were reduced up to 91.3%. (See also W90-04392) (Rochester-PTT).

Daukas, P.; Lowry, D.; Walker, W. W. Design of Wet Detention Basins and Constructed Wetlands for Treatment of Stormwater Runoff from a Regional Shopping Mall in Massachusetts. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 686-694, 3 fig, 1 tab, 2 ref. Note: IEP, Inc., Northborough, MA. SWRA2305.
Runoff from parking lots and roadways contains high concentrations of suspended solids, nutrients, trace metals, oil and grease, and deicing salts. A case study is presented of water quality mitigation measures for the 83,600-cu m Emerald Square Mall, North Attleborough, Massachusetts. The project site encompasses 23 ha and is located within the watershed of the Sevenmile River, which contributes to the drinking water supply of the City of Attleboro. For controlling stormwater runoff quality, the design and operation of the Emerald Square Mall include the following measures: wet detention ponds, constructed wetland basins, catch basins equipped with oil and grease traps, parking lot sweeping, sodium-free deicing salts, and restricted use of herbicides, pesticides, and fertilizers. Wetland basins were established during the first construction phase to provide at least one full growing season prior to receiving parking lot runoff. The basins are designed as shallow marsh communities on organic soil. Approximately 35,000 tubers

of indigenous marsh emergents were planted at the following percentages: 30% cattail (Typha latifolia), 25% arrowhead (Sagittaria latifolia), 25% bulrush (Scirpus validus), and 20% sweet flag (Acorus calumus). Side slopes were seeded with millet (Echinochloa sp.) and reed canary grass (Phalaris arundinacea). Wetland shrubs also were planted to enhance the 'edge' effect around the wetlands. A range of pollutant removal efficiencies was estimated as follows: suspended solids, 80-95%; total P, 60-85%; total N, 40-70%; BOD5, 50-80%; sodium, 0; cadmium, 50-50%; chromium, 50-90%; copper, 50-90%; lead, 80-95%; mercury, 50-90%; and zinc, 50-90%. Mass balance calculations suggested that development of Emerald Square Mall with the described runoff measures should not affect adversely the use of Sevenmile River for water supply. Long-term monitoring of treated runoff will be used to detect water problems that may develop during mall operation. (See also W90-04392) (Rochester-PTT).

Davido, R. L.; Conway, T. E. Nitrification and Denitrification at Iselin Marsh/Pond/Meadow Facility. In: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 477-483, 3 fig, 1 tab, 13 ref. Note: Moon Township Municipal Authority, Coraopolis, PA. SWRA2305.
The Iselin Marsh/Pond/Meadow (MPM) is an example of an active wetlands system that has proven effective in removing N from wastewater. The Iselin MPM was designed to treat 45,360 L/day from 62 homes in Iselin, a rural mining town in western Pennsylvania. The present study aimed to define zones of nitrification and denitrification within the Iselin MPM to serve as a basis for optimizing removal capacity at this site. The Iselin MPM consists of a comminutor, an aeration basin, two marsh areas, a pond, two meadow areas, and a chlorination chamber. Samples were collected daily from 10 sites throughout the MPM system from August 9-22, 1985. Temperature, pH, and dissolved oxygen varied little throughout the system. Nitrate-N decreased from the influent to postaeration. Because carbon demand is easily met for denitrifiers in the aeration basin (COD >800 mg/L and a small anoxic zone in the bacterial floc), the decrease in NO3-N during area probably is due to denitrification. Ammonia-N concentrations decreased at all depths across the marsh. This corresponds with an overall NO3-N increase at all depths. Ammonia-N levels are low at the pond surface, but substantial concentrations were present near the bottom. The increase in NH3-N at the pond bottom results from ammonification of decomposing plant material. Ammonia-N concentrations decreased to less than 0.5 mg/L at the meadow surface. Highest concentrations of NH3-N at the meadow bottom near the inlet resulted from decomposing solids that had been deposited in the meadow media. Overall reduction of total Kjeldahl nitrogen (TKN) from marsh influent to meadow effluent was 95%, producing discharge levels of less than 1 mg/L NH3-N and NO3-N. The MPM system also could remove 93% of the average 860 mg/L COD entering the system. The most effective nitrification component is the marsh. Denitrification occurs within the sludge floc and anaerobic microsites throughout the marsh and may occur in the pond sediments. Denitrification

appears to be minimal in the upper ond strata and in the meadow. (See also W90-04392) (Rochester-PTT).

Dawson, B. High Hopes for Cattails. Civil Engineering CEWRA9, Vol. 59, No. 5, p 48-50, May 1989. Note: Barge, Waggoner, Sumner, and Cannon, Nashville, TN. SWRA2211.
In theory, wetlands are the perfect 'wastewater plant' for small communities. In Benton, Kentucky about 1 mgd are cleaned in three different cells, one for cattails, bulrushes, and a mixture of plants. Suspended solids settle to the bottom, creating anaerobic conditions, while aerobic conditions are present around the roots and stalks. Suspended solids, BOD, and fecal coliform counts are all below discharge standards, and nitrogen and phosphorus are also being removed to acceptable standards. Typically, the wetlands consist of shallow, free surface basins with an impermeable liner. In some instances, only one type of plant is sufficient. Other times, combinations of emergent, submerged and floating species are used. The two major problems with man-made wetlands are the large land areas required and concerns about heavy metal accumulation. Wetlands are also being constructed to treat stormwater runoff, refining wastes, polluted rivers, agricultural wastes, and in some cases acid mine wastes. A major advantage of the wetlands system is the low cost when compared with conventional treatment. (White-Reimer-PTT).

De Wet, L. P. D.; Schoonbee, H. J.; Pretorius, J.; Bezuidenhout, L. M. Bioaccumulation of Selected Heavy Metals by the Water Fern, Azolla filiculoides Lam. in a Wetland Ecosystem Affected by Sewage, Mine and Industrial Pollution. Water SA WASADV, Vol. 16, No. 4, p 281-286, October 1990. 1 fig, 3 tab, 46 ref. Note: Rand Afrikaans Univ., Johannesburg (South Africa). Dept. of Zoology. SWRA2405.
The bioaccumulation of the heavy metals Fe, Cu, Ni, Pb, Zn, Mn and Cr by the water fern Azolla filiculoides Lam. in a polluted wetland ecosystem was investigated. The Blesbok Spruit wetlands, Transvaal, has received effluents and seepage waters from surrounding mines and industries as well as discharges of treated sewage effluent for the past 80 y. The sequence of heavy metals from the sediments at four localities in the wetlands was, in descending order of concentration: Fe>Zn>Mn>Ni>Cr>Cu>Pb. Extremely high values of iron occurred in the sediments at all four locations (7,528-59,598 mg/g). The metals reaching the highest concentration levels in A. filiculoides were Fe and Mn. In terms of bioaccumulation factor, Mn was best absorbed (2,065%) followed by Pb (607%), Ni (85%), and Cu (70%). It is concluded that if an active cropping program of A. filiculoides can take place throughout the year, substantial quantities of heavy metals can be removed with the plant material from the aquatic environment. (MacKeen-PTT).

DeBusk, T. A.; Burgoon, P. S.; Reddy, K. R. Secondary Treatment of Domestic Wastewater Using Floating and Emergent Macrophytes. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 525-529, 1 fig, 1 tab, 5 ref.

Gas Research Institute (Chicago) Contract 5082-223-0762. Note: Reedy Creek Utilities Co., Inc., Lake Buena Vista, FL. SWRA2305.
The rates of removal of BOD5 and suspended solids (SS) from primary effluent using floating and emergent macrophytes cultured in pond and gravel-bed systems were examined. The study was conducted in central Florida, with 3000-L outdoor raceways fed primary domestic effluent at a hydraulic loading of 10 cm/day. Four treatments were established in duplicate tanks: a gravel (1-3 cm river rock)-filled bed with no macrophytes; a gravel bed planted with swordgrass (Scirpus pungens = S. americanus); a gravel bed planted with arrowhead (Sagittaria latifolia); and an open-water system stocked with the floating macrophyte pennywort (Hydrocotyle umbellata). Greatest reductions in wastewater contaminant concentrations were attained in raceways containing pennywort. BOD5 and SS removal rates in pennywort-containing raceways averaged 145 and 41 kg/ha/day, respectively, during the 6-mo study. While mean treatment performance of the gravel-bed system was poorer than that of the pennywort tanks, effluent quality in the raceways containing gravel gradually improved during the study. After 6 mo of operation, effluent wastewater BOD5 and SS concentrations from the arrowhead raceways resembled that of those of the pennywort systems. Although shoot and root standing crop increased contemporaneously with the improvements in the treatment effectiveness of the gravel-bed systems, it is noted that BOD5 and SS concentrations also improved in the unvegetated gravel bed during this period. The time lag observed in the gravel-bed systems may represent the time required for bacterial colonization. Whereas gravel-bed systems, whether vegetated or not, exhibit a gradual improvement in treatment efficiency over the 6-mo study, floating aquatic macrophyte-based systems appeared to operate at peak efficiency immediately following startup. (See also W90-04392) (Rochester-PTT).

Donlan, R. Constructed Wetlands for the Treatment of Acid Mine Drainage. Water Pollution Control Association of Pennsylvania Magazine, Vol. 22, No. 2, p 26-30, March/April 1989. 2 tab, 2 fig.
Note: SWRA2209.
In 1980, the Soil Conservation Service/Armstrong Conservation District Office designed its first wetland to treat a mine drainage problem. Since then, nine additional wetland projects involving treatment of mine drainage have been completed, and six more wetlands are in the advanced design stage. Details are given on how to get started in wetland planning, design, and construction. The NuMine wetland system, for example, was designed to improve water quality near deep mine refuse piles created during coal mining. First, all upslope surface water was separated by installation of diversions and a water control structure. This runoff water was used in the 3.5 acre polishing chamber or pond. The NuMine Wetland System includes 3 wetland chambers and 7 constructed anaerobic zones. Although diversity is the most important factor in design of wetlands to treat mine drainage, sizing, travel time of the water, wetland shape, and planning to minimize groundwater contamination should also be considered. In all cases where

proper design and construction techniques for wetlands have been followed, wetlands have improved water quality. (VerNooy-PTT).

Dubinski B J; Simpson R L; Good R E. The Retention Of Heavy Metals In Sewage Sludge Applied To A Freshwater Tidal Wetland. Estuaries. 111 Sep; . Coden: Estud. Note: Coll. Marine Studies, Univ. Delaware, Lewes, DE 1971. English.

The hypothesis that freshwater tidal wetlands act as sinks for heavy metals was tested using sewage sludge applied biweekly from March to October 1981 at low treatment (25 g m-2 wk-1) and high treatment (100 g m-2 wk-1) levels. No differences in aboveground macrophyte standing crop were found except in June when high and low treatment sites had significantly higher ($p = 0.05$) standing crops than control sites. Except for chromium, metal standing stocks in the vegetation on treatment sites did not increase as a result of sludge application. The March litter had significantly higher ($p = 0.05$) concentrations of chromium, copper, lead, and nickel at all sites than the October vegetation, but only high and low treatment litter chromium levels were significantly higher ($p = 0.05$) than control litter. When sludge application terminated in October, the top 5 cm of soil at the high and low treatment sites had retained, respectively, 47 and 43% of the cadmium, 53 and 28% of the chromium, 52 and 0% of the copper, 51 and 0% of the zinc, 31 and 0% of the lead, and 0 and 0% of the nickel applied; only cadmium (15 and 46%, respectively) and chromium (12 and 28%, respectively) were still retained the following March. Thus, freshwater tidal wetlands can retain significant quantities of heavy metals associated with sewage sludge. The vegetation and litter play minor roles while the soil plays a major role in heavy metal retention.

Dunbabin, J. S.; Pokorny, J.; Bowmer, K. H. Rhizosphere Oxygenation by Typha domingensis Pers. in Miniature Artificial Wetland Filters used for Metal Removal From Wastewaters. Aquatic Botany AQBODS, Vol. 29, No. 4, p 303-317, January 1988. 4 fig, 4 tab, 24 ref. append. Note: Commonwealth Scientific and Industrial Research Organization, Griffith (Australia). Centre for Irrigation Research. SWRA2112.

Miniature artificial wetland filters were used to treat a metal-enriched synthetic effluent by upward percolation through a gravel substratum. The systems were either planted with Typha domingensis Pers., or unplanted, and were with or without lactic acid or ground leaves as carbon amendments to enhance biological oxygen demand. Oxygen concentration, pH, redox potential and metal retention were higher in planted systems than in systems without plants. Respiration was increased by carbon amendments in all filters. Oxygen concentration in unplanted filters declined, but rhizosphere aeration maintained oxygenated conditions in all planted filters. Available carbon supply improved heavy metal removal in the artificial wetland filters and affected the rate of rhizosphere oxygenation. Rhizosphere oxygenation, calculated from the sum of respiration and net oxygenation observed in static assay, was of the order of at least 80-300 micrograms/l/h, or 210-750 micrograms/h/filter. (Author's abstract).

Eger, P.; Lapakko, K. Use of Wetlands to Remove Nickel and Copper from Mine Drainage. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 780-787, 3 fig, 3 tab, 7 ref. Note: Minnesota Dept. of Natural Resources, St. Paul. Minerals Div. SWRA2305.
Drainage form mineralized Duluth Complex stockpiles located at the Dunka Mine in northeastern Minnesota contains elevated concentrations of Ni, Cu, Co, and Zn and has increased metal concentrations in nearby receiving waters up to 400 times the natural background concentrations. A passive treatment approach involving wetlands appears to be capable of treating all the drainage 600 ML/yr at less than half the capital cost and less than a twentieth the annual maintenance cost of a conventional treatment plant. To determine the capability of wetlands to treat stockpile drainage, a survey of local peat wetlands and their peats was conducted. The wetlands ranged in size from 1-20 ha, with average depths of 0.2-1.2 m. Peat was generally well decomposed, with decomposition increasing with depth. It was primarily a sedge peat with wood fragments. Metal concentrations varied depending on the sites' proximity to the existing stockpile drainage. Cu ranged from 40-724 mg/kg, Ni from 19-740 mg/kg, and pH from 5.25-7.45. Ash content was 10-60%, with the highest ash content in the areas with the shallowest peat. Metal retention capacities and total removal capabilities for the peat wetlands were estimated. Dividing the total removal capacity by the annual Ni loading resulted in estimated treatment system lifetimes of 20 to several hundred years. Further detailed research was conducted on a individual wetland area with the objectives of (1) optimizing treatment efficiency with different flow distribution methods and vegetation types, (2) measuring system life, and (3) developing data for application to full-scale treatment systems. Four treatment cells (6 m by 30.5 m) have been constructed and will be used to evaluate four treatments: two low-water (5 cm) treatments with natural vegetation (Carex sp. and grasses) and two high-water (15 cm) treatments with cattails (Typha sp.). Flow paths will be different in the different cells. Based on laboratory experiments, residence times in all cells will be 48 hr. Surface water and groundwater will be monitored monthly in each of the four plots. (See also W90-04392) (Rochester-PTT).

Esry, D. H.; Cairns, D. J. Overview of the Lake Jackson Restoration Project with Artificially Created Wetlands for Treatment of Urban Runoff. IN: Wetlands: Concerns and Successes. Proceedings of a Symposium held September 17-22, 1989, Tampa, Florida. American Water Resources Association, Bethesda, Maryland. 1989. p 247-257, 3 fig, 9 ref. Note: Northwest Florida Water Management District, Havana. Water Resources Div. SWRA2312.
The Northwest Florida Water Management District engaged in a federally funded Clean Lakes Restoration Project for Lake Jackson in Tallahassee, Florida, during the late 1970s. Construction of this experimental $2.6 million stormwater treatment facility was begun in 1981 with completion in 1983. The design employed a three step process to remove sediment and nutrients from urban runoff prior to entering the lake. The first two steps

entail the detention of the stormwater in a twenty acre impoundment followed by passage through a 4 acre filter with an underdrain collection system. The final step consists of the partially treated stormwater flowing to a 9 acre artificial marsh for further sediment removal and nutrient assimilation. The entire process has been monitored to determine the effectiveness of the various steps within the project. A recent report concludes that while the stormwater facility works well (>90% removal of solids by the filter; 60-65% removal of nutrients by the marsh) there remain operational deficiencies. One of the major deficiencies cited was the excedence of the total volume of the impoundment by more than half of the large storms monitored. These larger storms also bypass treatment by the created wetlands in the artificial marsh. Several proposed projects address this concern and would implement measures to help alleviate the current burden on the facility. (See also W90-10912) (Author's abstract).

Fennessy M S; Mitsch W J. Treating Coal Mine Drainage With An Artificial Wetland. J. Water Pollut Control Fed. Journal Water Pollution Control Federation. 1701 12; . Coden: Jwpfa. Note: Sch. Natural Resources, 2021 Coffey Road, Ohio State Univ., Columbus, Ohio 43210. 1989 English.

A 0.22-ha constructed wetland dominated by Typha Latifolia was evaluated for its ability to treat approximately 340 L/min of coal mine drainage from an underground seep in eastern Ohio [USA]. Loading of mine drainage to the wetland ranged from 15 to 35 cm/d. Conductivity, pH, manganese, and sulfate were little changed by the wetland. Iron decreased by 50 to 60%, with slightly higher decreases during the growing season. Comparisons are made to a volunteer Typha marsh receiving mine drainage where iron was found to decrease by approximately 89%. Design considerations of loading rates of created wetlands suggest that improved treatment of mine drainage is correlated with longer retention times and lower iron loading rates. Preliminary design criteria for construction of these types of Typha wetlands for removal of iron are suggested as 5 cm/d hydrologic loading and 2 to 40 g Fe/m2 .cntdot. d for iron loading, depending on the treatment desired.

Gambrell, R. P.; Khalid, R. A.; Patrick, W. H. Capacity of a Swamp Forest to Assimilate the TOC Loading from a Sugar Refinery Wastewater Stream. Journal - Water Pollution Control Federation JWPFA5, Vol. 59, No. 10, p 897-904, October 1987. 2 fig, 8 tab, 10 ref. Note: Louisiana State Univ., Baton Rouge. Center for Wetland Resources. SWRA2105.

An investigation was carried out to determine the potential impact of a sugar refinery effluent on a receiving swamp and the nearby Blind River in southern Louisiana. The study included field investigations to determine the rate and direction of water flow and organic carbon levels in the receiving swamp, and laboratory studies to determine the rates of organic degradation in the swamp sediment-water system. Laboratory column studies were conducted on the swamp sediments as were aerial photographic and dye tracer observations of the wastewater in the swamp. Based on the results, the climatic conditions, and the refinery discharge volume, it is suggested that 80 to 160 ha of swamp area is needed to completely degrade the organic carbon loading from the refinery if a 15- to 30-cm water depth is maintained for 8 days. (Author's abstract).

Gearheart, R. A.; Klopp, F.; Allen, G. Constructed Free Surface Wetlands to Treat and Receive Wastewater: Pilot Project to Full Scale. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 121-137, 8 fig, 5 tab, 22 ref. Note: Humboldt State Univ., Arcata, CA. Dept. of Environmental Resources Engineering. SWRA2305.
Four years of pilot studies and two years of full-scale operation have been completed with a constructed freshwater wetlands treatment system for polishing secondary-treated wastewater at Arcata, California. The first pilot study involved 12 experimental wetlands receiving oxidation pond effluent at hydraulic loadings of 0.02 to 0.24 cu m/sq m daily. The second pilot study involved 10 experimental cells that were operated at variable depths and hydraulic loadings and with various harvesting techniques applied. The full-scale plant employed a primary digester with cogeneration capability, cellularized oxidation ponds (2.3 ha of treatment wetlands), a chlorination/dechlorination facility, and 13.6 ha of effluent polishing wetlands. In the three different projects, reductions in BOD5 were 56%, 73%, and 55%, to final values of 11.4, 13.8, and 12.0 mg/L, respectively. Suspended solids (SS) were reduced 85%, 80%, and 54%, respectively, to effluent values of 5.3, 10.8, and 14.0 mg/L, respectively. Dissolved oxygen was reduced 73%, 76%, and 27%, respectively, to final output values of 1.5, 1.1, and 5.0 mg/L. The use of 375-sq m pilot cells was effective in predicting the behavior of the larger scaled wetland systems. BOD5 and fecal coliform removal can be modelcd effectively by first-order kinetics. Effluent BOD5 from a wetland is a function of organic loading rates, whereas SS effluent level is a function of some minimal detention time. Wetland treatment systems are effective and reliable for treating oxidation pone effluent to 30 mg/L BOD5 and SS standard and can be designed and operated to produce 10 mg/L BOD5 and SS effluents. (See also W90-04392) (Rochester-PTT).

Gersberg, R. M.; Brenner, R.; Lyon, S. R.; Elkins, B. V. Survival of bacteria and viruses in municipal wastewaters applied to artificial wetlands. IN: Aquatic Plants For Water Treatment and Resource Recovery. 1987; Edited by K.R. Reddy and W.H. Smith. Note: San Diego State University, San Diego, CA English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

Gersberg, R. M.; Elkins, B. V.; Goldman, C. R. Wastewater Treatment by Artificial Wetlands. Water Science and Technology. 1985; vol. 17, no. 4/5. Coden: Wsted4; ISSN: 0273-1223. Note: Ecological Research Associates San Diego Region Water Reclamation Agency University of California-Davis, Division of Environmental Studies 10 references, table, figures English.

This report describes studies of artificial wetlands at Santee, California, which demonstrate the capacity of these systems for integrated secondary treatment (BOD and suspended solids removal) and advanced treatment (nitrogen removal) of municipal wastewater effluents. When receiving a blend of primary and secondary wastewaters at a blend ratio of 1:2 (6 cm per day primary: 12 cm per day secondary), mean removal efficiencies for a complete year of operation from July, 1982 through July, 1983 were eighty percent for total nitrogen (TN) and eighty percent for total inorganic nitrogen, with the mean inflow TN level of 21.5 mg/L reduced to a mean value of 4.3 mg/L in the wetland effluent. The BOD and suspended solids removal efficiencies were 93 percent and 88 percent respectively. The mean wetland effluent values for both BOD and suspended solids were below the 10/10 mg/L standard for advanced secondary treatment. When primary effluent was the sole source of inflow to the artificial wetlands, BOD and suspended solids levels approaching the quality of a secondary treated effluent (30/30 mg/L) could be attained at an application rate of 6-8.3 cm per day. In this case, mean BOD and suspended solids removal efficiencies for the complete year from July, 1982 through August, 1983, were 78 percent and eighty percent respectively, with the effluent levels reduced to mean values of 33 mg/L for BOD and 10 mg/L for suspended solids. At the application rate of 6 cm per day, our study shows that only 16 acres (6.5 ha) of constructed wetlands would be required to treat 3785 cubic meters of primary wastewaters to secondary treatment levels. Data on capital and O&M cost show that artificial wetlands are competitive with other treatment technologies available to small to medium sized communities.

Gersberg, R. M.; Elkins, B. V.; Lyon, S. R.; Goldman, C. R. Role of Aquatic Plants in Wastewater Treatment by Artificial Wetlands. Water Research. 1986, Mar; vol. 20, no. 3. CODEN: WATRAG; ISSN: 0043-1354. Note: San Diego Region Water Reclamation Agency University of California-Davis, Division of Environmental Studies 23 references, tables, figures English.
This report describes investigations using artificial wetlands which quantitatively assess the role of each of three higher aquatic plant types, Scirpus validus (bulrush), Phragmites communis (common reed) and Typha latifola (cattail), in the removal of nitrogen (via sequential nitrification-denitrification), BOD and TSS from primary municipal wastewaters. During the period August 1983-December 1984, the mean ammonia concentration of 24.7 mg/L in the primary wastewater inflow (hydraulic application rate = 4.7 cm/day) was reduced to mean effuent levels of 1.4 mg/L for the bulrush bed, 5.3 mg/L for the reed bed and 17.7 mg/L for the cattail bed, as compared to a mean value of 22.1 mg/L for the unvegetated (control) bed. For all three vegetated beds, the mean effluent ammonia values were significantly below that for the unvegetated bed and for the inflow. The bulrushes and reeds (in that order) proved to be superior at removing ammonia, both with mean effluent levels significantly below that for the cattail bed. The high ammonia-N (and total N) removal efficiencies shown by the bulrush and reed beds are attributed to the ability of these plants to translocate O2 from the shoots to the roots. The oxidized rhizosphere so formed stimulates

sequential nitrification-denitrification. Similarly BOD removal efficiencies were highest in the bulrush and reed beds, both with mean effluent BOD levels (5.3 and 22.2 mg/L, respectively) significantly below that for the unvegetated bed (36.4 mg/L) and equal to or better than secondary treatment quality (30 mg/L). Our results demonstrate that higher aquatic plants can indeed play a significant role in secondary and advanced (N removal) wastewater treatment by wetland systems, a role that is completely distinct from that associated with their pollutant uptake capacity.

Gersberg, R. M.; Gearheart, R. A.; Ives, M. Pathogen Removal in Constructed Wetlands. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 431-445, 5 fig, 4 tab, 42 ref. Note: San Diego State Univ., CA. Graduate School of Public Health. SWRA2305.
An assessment of human health risks posed by municipal wastewater treatment using constructed wetlands involves delineating pathogen content of inflowing water, degree of removal/inactivation of pathogens in wetland environments, and level of exposure of receptor (human) population to treated wastewaters. The use of constructed wetlands to reduce human health risks associated with bacteria and viruses is reviewed. Data developed from two types of constructed wetland systems, a gravel-based constructed wetlands in Santee, California, and marshes created from excavations in natural soils in Arcata, California, are presented. The overall objectives of these studies were to assess the degree of removal of (1) the conventional indicators of fecal contamination (total and fecal coliforms) and Salmonella and (2) an indicator of viral pollution, MS-2 bacteriophage. Both the Santee and Arcata constructed wetlands were capable of removing bacterial and viral indicators of pollution at efficiencies of 90-99%. Wastewater treatment by constructed wetlands could typically reduce total coliform levels to at or below 1000 total coliform/100 mL standard when treating secondary wastewaters. However, for the treatment of raw or primary wastewaters, further disinfection is necessary after wetland treatment to attain the 1000/100 mL total coliform standard. Constructed wetlands can make important contributions as wastewater treatment systems not only through their ability to reduce bacteria and virus levels, but due to their ability to remove suspended solids and ammonia, both of which interfere with efficient disinfection. It appears that a hydraulic residence times of three to six days, constructed wetlands are at least equivalent and, in most cases, more effective than conventional wastewater treatment systems for the removal of disease-causing bacteria and viruses. (See also W90-04392) (Rochester-PTT).

Gersberg, R. M.; Lyon, S. R.; Brenner, R.; Elkins, B. V. Fate of Viruses in Artificial Wetlands. Applied and Environmental Microbiology AEMIDF, Vol. 53, No. 4, p 731-736, April 1987. 3 fig, 3 tab, 27 ref. California Dept. of Water Resources Grant B-54835. Note: San Diego Region Water Reclamation Agency, Santee, CA. SWRA2010.
Little is known about the ability of wetlands to remove disease-causing viruses from municipal wastewater. In this study we examined the survival

of several indicators of viral pollution (indigenous F-specific bacteriophages, seeded MS2 bacteriophage, and seeded human poliovirus type 1) applied in primary municipal wastewater to artificial wetland ecosystems. Only about 1% of the indigenous F-specific RNA bacteriophages survived flow through the vegetated wetland beds at a 5-cm/day hydraulic application rate during the period from June through December 1985. The total number of indigenous F-specific bacteriophages (F-specific RNA and F-specific DNA phages) was also reduced by about 99% by wetland treatment, with the mean inflow concentration over the period of an entire year reduced from 3,129 to 33 PFU/ml in the outflow of a vegetated bed and to 174 PFU/ml in the outflow of an unvegetated bed. Such superior treatment by the vegetated bed demonstrates the significant role of higher aquatic plants in the removal process. Seeded MS2 bacteriophage and seeded poliovirus were removed more efficiently than were the indigenous bacteriophages, with less than 0.2% of MS2 and 0.1% of the poliovirus surviving flow at the same hydraulic application rate. The decay rate (k) of MS2 in a stagnant wetlands (k = 0.012 to 0.028/h) was lower than that for flowing systems (k = 0.44 to 0.052/h), reflecting the enhanced capacity for filtration or adsorption of viruses by the root-substrate complex (and associated biofilm). Artificial wetlands may offer an attractive alternative to conventional land treatment systems for reducing the load of disease-causing viruses to the aquatic environment. (Author's abstract).

Gersberg, R. M.; Lyon, Stephen R.; Elkins, Bert V.; Goldman, Charles R. The Removal of Heavy Metals by Artificial Wetlands. Proceedings Water Reuse Symposium III: Future of Water Reuse; 1984 Aug 26; San Diego, CA. vol 2, p 639-648. ISBN: 0-915295-02-4. Note: Ecological Research Associates San Diego Region Water Reclamation Agency University of California, Davis 20 references, figures English.

This report presents operational data for advanced treatment (heavy metal removal) of secondary municipal wastewater effluents by artificial wetlands constructed at the Santee Water Reclamation Facility in Santee, California. The artificial wetlands consist of plastic-lined excavations containing emergent vegetation (cattails and bulrushes) growing in gravel. Two wetland beds, supplied with secondary wastewaters (application rate of 4-8 cm per day) and enriched to a mean influent copper (Cu) concentration of about 10 mg/L showed a mean metal removal efficiency of greater than 95 percent, the mean Cu level reduced to approximately 0.075 mg/L in the wetland effluent. Similarly, a wetland bed with its secondary wastewater inflow (application rate of 4 cm per day) enriched by zinc (Zn) to a mean inflow level of 10 mg/L, showed greater than 90 percent removal over the period from June, 1983, thorugh October, 1983. Removal efficiency for the more toxic heavy metal, cadmium (Cd) was also very high in the wetland system (>95 percent). The studies show that the artificial wetlands can serve as integrated systems for simultaneous metal removal and nitrogen removal, and that both the wetland vegetation and the endogenous denitrifying population are resistant to the toxic effects of Cu and Zn at influent levels as high as 10 mg/L. Mechanisms for the removal of metals in the artificial wetlands are assessed, with the aim of partitioning total removal

into that fraction removed by plant uptake, bacterial reduction, or precipitation-adsorption phenomena. Information on construction and O&M cost show that the wetlands aternative is competitive with other treatment technologies (lime precipitation, foam flotation) for metal removal. The process design of these wetlands is relatively simple and they utilize little energy and few chemicals.

Giblin, A. E. Comparisons of the Processing of Elements by Ecosystems, II: Metals. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 158-179, 7 fig, 3 tab, 66 ref. Note: Marine Biological Lab., Woods Hole, MA. SWRA2202.
Metal-budget and metal-flux data for wetland ecosystems show that the percentage of metal removed by passage through the ecosystem varies widely between metals and among wetlands. While some metals, such as Pb, may be well retained by wetlands under conditions of low loading rates, the majority of metals, such as Zn and Cd, may pass through the ecosystem. Although in a geochemical sense, wetlands are 'sinks' for some metals, these studies indicate that they may not function as efficient 'traps' for all metals. By better understanding the biogeochemical processes that alter metal retention, it may be possible to manipulate wastewater release to maximize metal removal in natural and artificial wetlands. Previous studies have shown that some of the assumptions that have been made in order to construct metal budgets may not be true, and improved budgets could yield a more accurate picture of what is occurring. Analytical techniques for measuring metals have improved tremendously in the last ten years, and complete budgets by input/output studies are now possible in ecosystems where accurate water budgets can be constructed. (See also W89-01827) (Lantz-PTT).

Girts, Michelle A.; Kleinmann, Robert L. P. CONSTRUCTED WETLANDS FOR TREATMENT OF ACID MINE DRAINAGE: A PRELIMINARY REVIEW. Proceedings - 1986 Symposium on Mining, Hydrology, Sedimentology, and Reclamation.University of Kentucky, Office of Engineering Services, (Bulletin) UKY BU 1986. Publ by Univ of Kentucky, Lexington, KY, USA p 165-171. 1986; CODEN: 1986 Dec 8-11 UKOBDS; ISSN: 0270-6504.Note: West Virginia Univ, Morgantown, WV, USA Univ of Kentucky, Lexington, KY, USA Alabama Surface Mining Commission, AL, USA ASAE, St. Joseph, MI, USA American Soc of Landscape Architects, Washington, DC, USA Assoc of Mining & Reclamation Professionals et al English 8709.
Experimental wetlands are being constructed on mined lands in the United States as an inexpensive alternative to conventional acid mine water treatment facilities. Over 25 wetlands constructed prior to 1986 in Pennsylvania, West Virginia, Ohio, and Maryland are currently functioning. These wetlands are being inventoried to determine the effect of alternative designs and water conditions on treatment efficiency, maintenance requirements and construction costs. Preliminary data analysis indicates that water flow rate has been a primary factor determining wetland design. For example,

wetlands designed to handle low flow seepage generally do not have water collection and inflow structures and are relatively shallow, to encourage the activity of transplanted Sphagnum moss. Wetlands designed to handle higher flows have point source inflow structures and are planted with Typha (cattails), Equisetum (horsetails) and sedges. Flow extremes have caused problems at many sites. Reduced efficiency, siltation, vegetation disturbance, and channelization were reported as a result of high flows; occasionally these necessitated reconstruction of the wetland. (Edited author abstract) 12 refs.

Guida, V. G.; Kugelman, I. J. Experiments in Wastewater Polishing in Constructed Tidal Marshes: Does it Work. Are the Results Predictable. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 727-734, 4 tab, 15 ref. Note: Lehigh Univ., Bethlehem, PA. Center for Marine and Environmental Studies. SWRA2305.
Three environmental factors relevant to the potential success of constructed tidal marshes are discussed based on experimental results: (1) whether tidal flooding frequency, which shortens wastewater residence to a few hours, can prevent effective treatment; (2) whether the behavior of pristine tidal marshes is a good indicator of their ability to polish wastewater; and (3) whether the outcome of polishing is readily predictable in a variable natural marsh. Experiments were performed at the Wetlands Institute near Stone Harbor, New Jersey. Clam processing wastewater was treated by extended aeration activated sludge in two 440-L fill-and-draw units. Polishing experiments were performed on outdoor marsh microcosms. Tidal flooding was simulated to follow the schedule of natural flooding using water pumped from a tidal creek. Water quality measurements were made on three occasions and mass balance analyses were conducted. The predictability of removal results was estimated using linear regression analysis. With appropriate corrections, BOD5 removal from effluents in January, May, and August experiments ranged from 29% to 100%; total suspended solids, 58-108%; total N, 69-98%; and total P, 30-73%. These results are comparable to those obtained with other marsh polishing systems and improve activated sludge effluents enough to meet direct discharge standards. (See also W90-04392) (Rochester-PTT).

Haberl, R.; Perfler, R. Root-Zone System: Mannersdorf. New Results. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 606-621, 11 fig, 6 tab, 17 ref. Note: Universitaet fuer Bodenkultur, Vienna (Austria). Inst. fuer Wasserwirtchaft. SWRA2305.
The Mannersdorf (Austria) experimental sewage treatment system is one of the first research-oriented wetland plants. Four experimental plots of equal size (10 x 15 m) were laid out and sealed with vertical membrane barriers. Individual plots were supplied from a receptacle with a measuring weir having aboveground distribution of PVC pipeline with branching manifolds. Humus deposits interlaced with reed (Phragmites australis) rhizome shoots from the bankside area of the neighboring receiving stream were applied to

a depth of 0.3 m. Since June 1984, plot 1 has been fed raw sewage, plot 2 with settled sewage, and plots 3 and 4 with biologically treated sewage effluent. Feed rate per plot was initially 20-30 mm/day. The feed rate has been increased in line with treatment performance of the system to 50-60 mm/day. Inlet concentrations of communal sewage to the plots varied widely, but daily variation causes no immediate influence on effluent quality. Varying feed rates (20-60 mm/day) hardly affected the plant removal efficiency. Increased influent caused enhanced superficial runoff and required a longer travel distance for a given reduction in contamination. Retention time, determined from tracer experiments with uranine and NaCl, showed no consistent pattern. Maximal values may be severely affected by water losses from evapotranspiration. Tracer experiment results in plots 1 and 2 indicated that most of the flow (60-80%, depending on the rate of feed) occurs in the near-surface region or in the litter layer. Only plot 3 has predominantly deeper flow layers (80%). Rates of elimination of saprophytes and coliforms were (1) raw sewage plot, 96-98% and 92-96%, (2) settled sewage plot, 95-99% and 98%, and (3) biologically treated sewage plot, 89-95% and 93-97%. Of a total of 72 samples, 24 were contaminated with Salmonella. Results of the research plant in Mannersdorf of Lower Austria demonstrate that root-zone systems may contribute to the solution of wastewater treatment in areas with 100-500 person-equivalents (PE). It seems necessary to have a mechanical pretreatment before the wetland plant. The treatment area for 1 PE should be 5-10 sq m. (See also W90-04392) (Rochester-PTT).

Hammer, D. A. (Ed.) Constructed Wetlands for Wastewater Treatment. 1989. Lewis Publ., Inc., Chelsea, MI. Hebicha, Hussien ABD EL Moniem Ahmed, Ph.D. Catfish Pond Harvesting Pollution Control And Costs For West Central Alabama. 1989; 50/08-A of Dissertation Abstracts International. Note: Order No: AAD89-25621 Auburn University.
There has been a rapid increase in the number of catfish farms in Alabama during the last decade. Also, there has been an increasing trend in production intensification with higher stocking and feeding rates. This has caused concern over the potential pollution problems associated with the discharge of fish farm effluents. As a result, the EPA considered aquacultural facilities as point sources of pollution subject to the Federal Water Pollution Control Act of 1972. However, there is lack of information and uncertainty over the type of treatment needed, treatment costs, and the time when farmers will be required to upgrade fish farm effluents. Possible pollution treatment methods were evaluated for potential use in treating catfish harvesting effluents. These methods included: wetlands, intermittent sand filters, dilution, and caged fish culture. Wetlands and intermittent sand filters removal efficiencies for BOD and phosphate were estimated using regression analysis. Costs associated with using these methods to obtain various degrees of effluent quality were estimated. Dilution had the lowest cost, followed by wetlands and then intermittent sand filters. Linear programming was used to investigate the effects of different environmental constraints on treatment costs, farm profit, and pond size utilizing different farm situations. Also, the effects of different per unit charges for effluent

BOD on treatment levels and costs were evaluated. Model results indicated that larger production ponds were preferred over smaller ones when dilution or dilution plus wetland system were used for effluent treatment. Per unit effluent charge ranged from \$1.28 to \\$12.13 depending on the desired percentage removal and treatment method used.

HEBICHA, HUSSIEN ABD EL MONIEM AHMED, PH.D. CATFISH POND HARVESTING POLLUTION CONTROL AND COSTS FOR WEST CENTRAL ALABAMA. 1989; 50/08-A OF DISSERTATION ABSTRACTS INTERNATIONAL.Note: ORDER NO: AAD89-25621 AUBURN UNIVERSITY.

There has been a rapid increase in the number of catfish farms in Alabama during the last decade. Also, there has been an increasing trend in production intensification with higher stocking and feeding rates. This has caused concern over the potential pollution problems associated with the discharge of fish farm effluents. As a result, the EPA considered aquacultural facilities as point sources of pollution subject to the Federal Water Pollution Control Act of 1972. However, there is lack of information and uncertainty over the type of treatment needed, treatment costs, and the time when farmers will be required to upgrade fish farm effluents. Possible pollution treatment methods were evaluated for potential use in treating catfish harvesting effluents. These methods included: wetlands, intermittent sand filters, dilution, and caged fish culture. Wetlands and intermittent sand filters removal efficiencies for BOD and phosphate were estimated using regression analysis. Costs associated with using these methods to obtain various degrees of effluent quality were estimated. Dilution had the lowest cost, followed by wetlands and then intermittent sand filters. Linear programming was used to investigate the effects of different environmental constraints on treatment costs, farm profit, and pond size utilizing different farm situations. Also, the effects of different per unit charges for effluent BOD on treatment levels and costs were evaluated. Model results indicated that larger production ponds were preferred over smaller ones when dilution or dilution plus wetland system were used for effluent treatment. Per unit effluent charge ranged from \$1.28 to \\$12.13 depending on the desired percentage removal and treatment method used.

Hedin, R. S.; Hammack, R.; Hyman, D. Potential Importance of Sulfate Reduction Processes in Wetlands Constructed to Treat Mine Drainage. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 508-514, 3 tab, 12 ref. Note: Bureau of Mines, Pittsburgh, PA. SWRA2305.

The importance of sulfate reduction in natural or constructed wetlands receiving acid mine drainage (AMD) is uncertain because of contradictory findings from different studies. Several research projects are exploring the use of dissimilatory sulfate reduction (DSR) and metal sulfide formation processes for the treatment of coal mine drainage. DSR is accomplished by heterotrophic anaerobic bacteria that, in the absence of oxygen, decompose simple organic compounds using sulfate as the terminal electron acceptor. DSR bacteria are active only under anaerobic conditions. The most common factors limiting

DSR in anoxic sediments are availability of suitable organic matter and dissolve sulfate. Metal sulfides can be destroyed by acidic and aerobic conditions. Acidic conditions cause the resolubilization of iron monosulfides (FeS). In most natural systems, extreme acidification of the organic substrate does not occur. The more common cause of sulfide destruction is oxidation. All forms of elemental and reduced sulfur are subject to oxidation under aerobic conditions. Constructed wetlands for AMD have conditions that should promote DSR and the accumulation of iron sulfides. They contain an excess of high-quality organic matter and high concentrations of dissolved sulfate and iron. With proper maintenance, the organic substrate always will be submerged and never be exposed to aerobic conditions. To aid in designing AMD wetlands, the theoretical significance of sulfide formation was evaluated in a hypothetical constructed wetland in which flow of AMD through anoxic substrates is maximized and sulfide oxidation is minimized. On a yearly basis, the wetland receives 2628 kg Fe, 26,280 kg SO4(2-), and 13,140 kg of acidity (CaCO3 equivalent). Complete removal of all the dissolved iron by pyrite formation requires a minimum reduction of 9010 kg of SO4(2-) and oxidation of 2253 kg of C. DSR and FeS formation are biogeochemical processes that could significantly affect mine drainage chemistry. The sizing of wetlands being constructed today is within an order of magnitude of satisfying the theoretical organic needs of such a system. (See also W90-04392) (Rochester-PTT).

Henrot, J.; Wieder, R. K. Processes of Iron and Manganese Retention in Laboratory Peat Microcosms Subjected to Acid Mine Drainage. Journal of Environmental Quality JEVQAA, Vol. 19, No. 2, p 312-320, April/June 1990. 9 fig, 1 tab, 41 ref. Note: Villanova Univ., PA. Dept. of Biology. SWRA2311.

Despite increasing use of constructed wetlands for treatment of metal-enriched acid coal mine drainage, the biotic and abiotic mechanisms of metal retention in such wetlands are poorly understood. The processes responsible for Fe and Mn retention in peat and the effects of microbial activity, pH, temperature, and metal concentration in acid coal mine drainage were studied in laboratory microcosms. The 30 g of fresh sphagnum peat was repeatedly flushed (up to 108 times) with 20 ml of synthetic acid mine drainage water at pH 3.5. Of the four major processes of metal cation retention in peat (cation exchange, complexation with peat organic matter, precipitation as oxide, and precipitate as sulfide), Fe oxidation and Fe binding on peat organics were predominant, with Fe oxides and organically bound Fe making up, respectively, 62 and 22% of the total Fe in the peat at the end of the experiment. Fe complexation reached saturation at 12 mg Fe/g of dry peat; Fe oxide concentration in peat increased steadily throughout the experiment. At pH 3.5 Fe oxide precipitation was depressed by the addition of formaldehyde (an antimicrobial agent), suggesting that the process was microbially mediated. Iron oxide precipitation was greater at pH 5.5 than at 3.5 and less depressed at pH 5.5 than 3.5 by the presence of formaldehyde. Low temperature (<15 C) diminished the efficiency of peat to remove Fe from the drainage water as did a high Fe concentration (>100 mg/liter). Manganese retention in peat was much less than that of Fe; the chemical form was almost exclusively exchangeable Mn(++). Retention

of Fe(++) in peat was not affected by the presence of MN(++). Iron oxides accumulated in peat were not readily resolubilized by photoreduction, microbial Fe(+++) reduction under reducing conditions, and exposure to simulated acid precipitation. (Cassar-PTT).

Henrot, J.; Wieder, R. K.; Heston, K. P.; Nardi, M. P. Wetland Treatment of Coal Mine Drainage: Controlled Studies of Iron Retention in Model Wetland Systems. In: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 793-800, 3 fig, 1 tab, 15ref. Note: Villanova Univ., PA. Dept. of Biology. SWRA2305.
A pilot study was initiated to evaluate Fe retention in wetlands under controlled conditions. Six model wetlands (2.40 x 0.15 m) filled with Sphagnum substrate were subjected to influent water at a pH of 4.0 and Fe concentrations of either 0, 50, or 100 mg/L. At the end of the 8-day treatment period, effluent Fe concentrations were approximately equal to influent Fe concentrations. Peat chemical analysis indicated that (1) Fe retention was more pronounced at the inflow end and (2) accumulated Fe was mainly present as organically bound Fe (63.8% of total Fe) and Fe oxides (29.1%), with little accumulation as exchangeable Fe. This study and field studies suggest that a key process involved in Fe retention in wetland systems is Fe oxide formation. Microbially-mediated Fe oxidation, which probably was inhibited in this pilot study by high greenhouse temperatures, may play an important role in Fe retention and increase the 'effective' life of wetlands created for the treatment of acid mine drainage. (See also W90-04392) (Rochester-PTT).

Herskowitz, J. M.; Black, S. A.; Lewandowski, W. Listowel artificial marsh treatment project. Technology Transfer ConferenceTECHNOLOGY TRANSFER CONFERENCE. PART B: WATER QUALITY RESEARCH. 1986; Note: Water Resour. Branch, MOF, 1 St. Clair Ave. W. Toronto, Ont., Canada SUMMARY LANGUAGE - ENGLISH ENGLISH.
Five separate cattail (Typha spp.) marsh treatment systems, occupying a total area of 8670 m super(2), were operated for four years (1980-1984). Several different marsh designs and two-pre-treatment types, namely, complete-mix aeration cell effluent (average BOD5 = 60 mg L super(-1)) and lagoon effluent (average BOD5 = 20 mg L super(-1)), diverted from the existing Town of Listowel sewage works, were tested. The method of pretreatment was shown to influence marsh operation and the quality of the final marsh effluent. Channelized marshes yielded the highest treatment efficiencies as this configuration provided greater control flow distribution and wastewater retention time. Removal efficiencies declined when the hydraulic detention time, regulated by seasonal adjustments in water depth, deviated from the range of 7-14 days.

Holm, J. David; Jones, Scott. PASSIVE MINE DRAINAGE TREATMENT: AN EFFECTIVE LOW-COST ALTERNATIVE. Proceedings - 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. University of Kentucky, Office of Engineering Services, (Bulletin)

UKY BU 139. Publ by Univ of Kentucky, Office of Engineering Services, Lexington, KY, USA, 1985 p 115-120. 1985; . CODEN: 1985 Dec 9-13 UKOBDS; ISSN: 0270-6504. Note: Colorado Mined Land Reclamation Div, CO, USA Univ of Kentucky, Office of Continuing Education & Extension, Lexington, KY, USA Univ of Kentucky, Dep of Forestry, Lexington, KY, USA Univ of Kentucky, Dep of Agricultural Engineering, Lexington, KY, USA Univ of Kentucky, Dep of Civil Engineering, Lexington, KY, USA Univ of Kentucky, Dep of Mining Engineering, Lexington, KY, USA et al English 8607.
Two prototype Passive Mine Drainage Treatment Systems have been designed and constructed in Colorado. These projects have addressed acid mine drainage from inactive coal mines. Metal removal for both systems is accomplished using simulated peat bogs composed of sphagnum moss and hypnum moss retained by loose rock check dams. Acid neutralization is accomplished using crushed limestone filled channels. Neutralization and aeration are enhanced with drop structures and waterfalls placed in the drainage channel. Preliminary water quality results show dramatic treatment effects with the PMDT system. This investigation presents cost data for design and construction of the two PMDT systems. Cost projections for periodic maintenance requirements are provided along with a suggested method for financing maintenance costs. Performance data for the first system installed are presented. (Author abstract) 14 refs.

Jackson, J. Man-Made Wetlands for Wastewater Treatment: Two Case Studies. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 574-580, 2 fig, 2 tab, 3 ref. Note: Post, Buckley, Schuh and Jernigan, Inc., Orlando, FL. SWRA2305.
Wastewater treatment plant owners and engineers must develop more creative effluent disposal methods using lower-lying or otherwise less desirable lands while adequately protecting surface water resources. Two innovative designs that meet both these needs have been constructed in Lakeland and Orlando, Florida. Prior to its purchase for wastewater treatment, 566 ha of the 650-ha Lakeland site had been used as clay settling ponds for the phosphate mining industry, thus creating an impermeable liner. The constructed wetlands built on this site were designed for a flow of 0.61 cu m/sec, equivalent, to a hydraulic application rate of 1 cm/day. Design criteria included reducing influent concentrations of 20 mg/L BOD5), 20 mg/L total suspended solids (TSS), and 8 mg/L total ammonia as nitrogen (NH3-N) to 5 mg/L BOD5, 10 mg/L TSS, and 1.0 mg/L NH3-N. Total P removals of 50% also were expected. The chosen disposal option was creation of a 494-ha man-made wetlands on an improved pasture to further treat water prior to discharge to the St. Johns River. The pasture was segmented by berms into small cells, with weir structures to control flow distribution, depth, and detention time. A wet prairie (170 ha) was planted primarily with cattail (Typha latifolia) and bulrush (Scirpus californicus). From the wet prairie, water flows into a 154-ha mixed marsh, which was started with 10 spp. but now has about 60 spp. The final community is a 162-ha hardwood swamp that includes a 49-ha lake. The swamp was

planted with seedlings of bald cypress, red maple, loblolly bay (Gordonia lasianthus), water oak, dahoon holly (Ilex cassine), and other tree species. The constructed wetlands site was designed to receive 0.88 cu m/sec of water with 6 mg/L total N and 0.75 mg/L total P. For the 494-ha site, this is equivalent to nutrient loadings of 0.92 kg/ha/day and 0.11 kg/ha/day for total N and total P. Both the Lakeland and Orlando wetland systems have achieved permitted effluent requirements, although loaded at less than design conditions. Based on the present treatment occurring in the first cells, as flows are increased, more of the system will be used for treatment, but continued compliance with permitted effluent limits is expected. (See also W90-04392) (Rochester-PTT).

James, B. B.; Bogaert, R. Wastewater Treatment/Disposal in a Combined Marsh and Forest System Provides for Wildlife Habitat and Recreational Use. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 597-605, 4 fig, 1 tab, 3 ref. Note: James Engineering, Inc., El Cerrito, CA. SWRA2305.
The Mt. View Sanitary District in Martinez, California, established 3.6 ha of freshwater wetlands in 1973 to process secondary effluent. It was expanded to 8.5 ha in 1977. In 1979, a pilot project combining a forest area and marsh was added. In 1984 and 1987, respectively, 9 ha and 16 ha of seasonal wetlands were added, bringing the total size to approximately 37 ha. Operating experience on two wetlands constructed in the 1970s and the marsh/forest pilot project, which receives secondary effluent from the district's wastewater treatment plant as the sole water source. The system reduces BOD5, suspended solids, and ammonia N, although the wetland tends to have higher suspended solids level than the influent water in summer due to algal growth. The algae are removed in the marsh/forest. A measure of the success of the wetland project is its ability to sustain a diverse community of plants and animals. Over 70 spp. of plants and 123 spp. of water fowl have been identified on the site. The area also supports a diverse community of invertebrates, fish, amphibians, reptiles, and small mammals, including river otters (Lutra canadensis). Fifteen years of operating wetlands and marsh/forest reclamation systems has demonstrated that it is possible to provide a richly varied aquatic habitat through careful management of reclaimed wastewater. The area now provides a valued wildlife habitat that is a popular recreation spot. Nine years experience with a prototype marsh/forest evapotranspiration system has shown that a marsh system can be designed and managed to provide a high quality water as well as wildlife habitat. It also demonstrates that it is possible to take advantage of the high water demand of selected trees to reduce or eliminate reclaimed water discharge to sensitive receiving waters. (See also W90-04392) (Rochester-PTT).

Karathanasis, A. D.; Thompson, Y. L. Metal Speciation and Immobilization Reactions Affecting the True Efficiency of Artificial Wetlands to Treat Acid Mine DrainageResearch rept. 1990 Aug; Note: Kentucky Water Resources Research Inst., Lexington. 063998000 Geological Survey,

Reston, VA. Water Resources Div. English GRAI9102 Sponsored by Geological Survey, Reston, VA. Water Resources Div. United States.
The ability of constructed wetlands to lower total Al, Cu, Fe, Mn, and Zn concentrations and organically complex the metals in acid mine drainage (AMD) was investigated under greenhouse and field conditions. In the greenhouse study, Typha plants grown in six different substrates received simulated acid mine drainage of low metal load for five months. Most effluents, especially those from ground flows, showed significant decreases in acidity and metal concentrations. The pine needle and hay substrates most effectively reduced acidity and total Al levels. The metal concentration and acidity of a very high metal load AMD were also reduced substantially during the first six months of treatment with a wetland which was constructed by the U.S. Forest Service in McCreary County, KY and used mushroom compost as a substrate. After 8 months of operation, however, and during periods of high flow rates (> 10 gallons/min) the efficiency of the wetland was drastically reduced, apparently due to reduced residence time, insufficient size and metal overloading. The metals in Fe, Mn, and Zn showed the highest tendency for residual retention, while Al and especially Cu showed high affinity for organic retention. Exchangeable and sorbed forms were present in very small concentrations and in many cases were almost negligible.

Kingsley, J. B.; Maddox, J. J.; Giordano, P. M. Aquatic Plant Culture for Waste Treatment and Resource Recovery. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 542-549, 2 fig, 4 tab, 12 ref. Note: National Fertilizer Development Center, Muscle Shoals, AL. SWRA2305.
A project was conducted to demonstrate the potential of three aquatic plants to remove pollutants from wastewater and produce useful crops. Demonstrations were conducted in Florence, Alabama, where two types of earthen facilities were built: (1) five units to demonstrate sludge as plant fertilizer in soil flooded with secondary effluent and (2) four units to conduct flow-through demonstrations. Flow-through units were continuously irrigated with secondary effluent. Demonstrations conducted were (1) sludge demonstrations of water chestnut (Eleocharis dulcis) and chestnut hay yields (2 years) and cattail (Typha spp.) (2) flow through demonstrations of water chestnut yields (2 years), cattail and reed (Phragmites australis) yields, and water quality in wetlands (2 years). Artificial wetland water treatment using aquatic plants to absorb nutrients from water can effectively remove pollutants from wastewater and produce an economically valuable crop. Plants recover valuable nutrients lost in conventional wastewater treatment systems, and crops produced can help offset wastewater treatment costs. Optimum flow rate of secondary effluent for waste treatment was 8.1 to 16.2 cm/day, which reduced BOD5 60%, suspended solids 72%, and fecal coliform bacteria >80%. Aquatic plants can recover nutrients from wet sludge (3.5% solids) and sludge is at least as effective as inorganic fertilizer for aquatic plant production. (See also W90-04392) (Rochester-PTT).

Kleinmann, Robert L. P. Treatment Of Acid Mine Water By Wetlands. Control of Acid Mine Drainage. Proceedings of a Technology Transfer Seminar. Information Circular - United States, Bureau of Mines 9027 1985 p 48-52. 1985; . CODEN: 1985 Apr 3-4 XIMIAL; ISSN: 0096-1914. Note: US Bur of Mines, Pittsburgh, PA, USA US Bur of Mines, Washington, DC, USA English 8704.
Wetlands are a potential natural treatment system for small flows of acid mine water. Previous studies of mine water flowing through bogs dominated by Sphagnum moss indicate that such a wetland removes the iron and reduces acidity, without harm to the moss. The Bureau of Mines is now involved in field evaluation of the wetland approach at mine sites in Pennsylvania and West Virginia. The wetlands have been constructed by the respective mining companies for water treatment; the Bureau is facilitating monitoring and evaluation of the sites so that others can learn from these efforts. The results from the pilot plant show that the Sphagnum bed typically removed 50 to 70 pct of the total iron. Acidity was not significantly affected by flow through the Sphagnum mat, but decreased 43 to 90 pct as the water passed through the coarsely crushed limestone. The 90-pct reduction in acidity was observed when the initial acidity of the influent water exceeded 605 mg/L (as CaCO//3); the 43-pct reduction was observed hen acidity at the inlet was less than 150 mg/L. 5 refs.

Knight, R. L.; Winchester, B. H.; Higman, J. C. Ecology, hydrology, and advanced wastewater treatment potential of an artificial wetland in north-central Florida. Wetlands. 1985; Vol. 5. Note: CH2M Hill, 7201 N.W. 11th Pl., Gainesville, FL 32605, USA Summary Language - English.
Two artificial marsh/pond systems with a combined area of 21 ha were studied during a one-year period. Since their construction in 1978, volunteer plant colonization has resulted in a shifting mosaic of cattails (Typha spp.), water pennywort (Hydrocotlye umbellata), frog's-bit (Limnobium spongia), duckweed (Lemna spp.) and other less abundant species. At least 45 bird species were observed to use the wetlands during this study with very dense populations noted for several wetland-dependent species. Alligators, fish, turtles, and snakes were abundant in the ponds. The ponds operate as flow-through systems, receiving an average treated wastewater application of 4.8 cm per week. Mass balances indicated significant percent removals for biochemical oxygen demand (82%), total suspended solids (80%), and total nitrogen (93%). Removal of total phosphorus was lower, averaging 31% over the one year study.

Kolbash, R. L.; Romanoski, R. L. Windsor Coal Company Wetland: An Overview. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 788-792, 4 fig. Note: American Electric Power Corp., Lancaster, OH. SWRA2305.
A wetland has been constructed at Windsor Coal Company's Beech Bottom Mine (West Virginia) with the goal of minimizing refuse pile seepage at the Schoolhouse Hollow Refuse Area. Contaminated seepage is collected and channeled into a small pond at the toe of the refuse pile. Collected seepage

is treated with caustic soda, which results in fluctuating pH levels with occasional elevations of iron. The wetland consists of 0.5-cm limestone, 46 cm of sterile mushroom compost, and cattail (Typha) plants, all resting on a Hypalon liner. The wetland rests in an excavated area of 3.4 m by 26 m, with a total surface area of 117 sq m. A rock/pipe drain was installed to carry water from a 4 L/min seep. Cattails were installed on 46-cm centers and seep water was directed into the wetland. Even with less than one growing season, the Windsor wetland has removed 50% of the incoming iron. Inlet and outlet total Mn and pH are generally similar, although on three occasions outlet pH was substantially elevated above inlet pH. The Hypalon liner seems to be enhancing algae growth. Continuing monitoring will measure sulfate and inlet flow and will evaluate the long-term effects of the Hypalon liner on the wetland. (See also W90-04392) (Rochester-PTT).

Kuenzler, E. J. Impacts of Sewage Effluent on Tree Survival, Water Quality and Nutrient Removal in Coastal Plain Swamps. Available from the National Technical Information Service, Springfield, VA. 1988a, as PB88-164090/AS. Price codes: A06 in paper copy; A01 in microfiche. North Carolina Water Resources Research Institute, Raleigh, Completion Report No. 235, (UNCWRRI-8. Note: North Carolina Univ. at Chapel Hill. Dept. of Environmental Sciences and Engineering. SWRA2111.
An investigation was conducted of the impacts of sprayed municipal sewage on swamp tree survival and the effects of the swamp system on nutrient concentrations below the outfalls on two streams on the coastal plain of North Carolina. The swamp forest was clearly dominated by Nyssa aquatica; the other important species were N. sylvatica v. biflora, Populus heterophylla, Fraxinus spp., Taxodium distichum, Acer rubrum, and Liquidambar styraciflua. Effluent was discharged to one swamp stream by aerial spraying and to the other stream by way of a small ditch. Ninety-eight percent of the trees which were struck directly by the spray were dead within 18 months of the date spraying began. The sewage significantly increased the concentrations of chloride and nutrients at the outfalls. Nitrogen and phosphorus concentrations in stream water decreased below the outfalls on both streams. Although much of the concentration decrease could be attributed to dilution in winter, a simple graphical comparison of nutrient and chloride concentrations downstream showed net nutrient removal during most of the year. At times, however, there was net ammonium transfer to the water. Rates and fractions of nutrient net removal were calculated assuming that chloride is a conservative element in swamp water. Processing rates were fastest close below the outfalls, but slow rates over larger distances are probably also important for ultimate reduction of concentrations to background stream concentrations. Both swamp systems removed sufficient quantities of nitrogen and phosphorus within a few kilometers to account for virtually all of the sewage nutrient load to the swamps. (Lambert-UNC-WRRI).

Kuenzler, E. J. Sewage Nutrient Removal by North Carolina Swamp Systems. IN: Coastal Water Resources. Proceedings of a Symposium held in

Wilmington, North Carolina. American Water Resources Association, Bethesda, Maryland. 1988. p 281-292, 2 fig, 2 tab, 40 ref. Note: North Carolina Univ., Chapel Hill. Dept. of Environmental Sciences and Engineering. SWRA2312.
Domestic sewage adds nutrients and other soluble and particulate matter to many coastal plain streams. Decreases in N and P below the outfalls result both from dilution by tributary and groundwater inputs and from net removal processes. Concentrations of nutrients and other factors were measured below outfalls in two forested swamp stream systems. A graphical comparison of chloride and nutrient concentrations downstream showed rapid removal of N and P from the water during most of the year, although net flux of ammonium to the water often occurred. Net nutrient removal rates were calculated assuming that chloride is a conservative element in swamp water. Removal rates were highest close to the outfall, and essentially all of the sewage nutrient load to these two swamp systems was removed from the water within a few kilometers of the outfall. By monitoring net removal of sewage nutrients in swamp waters, water resource managers can make better-informed decisions regarding acceptable future loads to the wetland. (See also W90-10584) (Author's abstract).

Kuenzler, E. J.; Carberry, A. B.; Tzeng, S. Nutrient Processing and Water Quality in a Piedmont Bottomland Receiving Urban Wastewater. 1990 Feb; Note: North Carolina Water Resources Research Inst., Raleigh. 058521000 North Carolina Univ. at Chapel Hill. Dept. of Environmental Sciences and Engineering. Geological Survey, Reston, VA. Water Resources Div. English GRAI9017 Prepared in cooperation with North Carolina Univ. at Chapel Hill. Dept. of Environmental Sciences and Engineering. Sponsored by Geological Survey, Reston, VA. Water Resources Div. United States.
Nutrient concentrations above and below a municipal wastewater outfall on a Piedmont stream were analyzed to assess the effectiveness of its bottomland forest system in removing nutrients from the water. The wastewater significantly increased the conductivity and raised the chloride and nutrient concentrations. Dilution by stream water decreased the concentrations of most constituents added by sewage but, contrary to results in the Coastal Plain, only for phosphate was there a significant amount of net removal. The drought conditions during the study were probably important because natural inundation of the floodplain occurred only rarely and briefly, markedly decreasing the opportunity for nutrient trapping. Even winter flooding of a greentree impoundment about 3 km below the outfall did not provide significant nutrient removals. There was a significant increase in soil sorptive capacity along both transects that were flooded, whereas the transect that was not flooded showed no change in sorptive capacity.

Kulzer, L. Water Pollution Control Aspects of Aquatic Plants: Implications for Stormwater Quality Management. 1990. Office of Water Quality, Municipality of Metropolitan Seattle. 821 Second Ave., Seattle, WA.
Aquatic plants have been found effective in treatment of a number of types of pollution problems, including nutrient removal, uptake of metals and organics, reductions of pathogenic bacteria, and in neutralizing extremes of

pH. Potential exists for use of these properties of aquatic plants in stormwater quality applications. Highlights concerning pollutant removal patterns are: 1. Metal concentrations are higher in plants growing in higher environmental exposure situations; 2. metal concentrations are generally higher in the roots and rhizomes than in the shoots, or leafy parts, of aquatic plants; 3. older tissues tend to accumulate higher metal concentrations than young tissue except in the case of mercury, which tends to accumulate at higher levels in new growth; 4. heavier metals such as mercury and lead seem to accumulate more readily in plant tissue; 5. plants which grow from a basal meristem, such as ruches (Juncus spp.) show particularly good ability to take up organics, particularly oils; and, 8. dramatic reductions in pathogenic bacteria have been documented in several emergent species which occur locally.

Kumar, P.; Garde, R. J. Upgrading Wastewater Treatment by Water Hyacinth in Developing Countries. Water Science and Technology WSTED4, Vol. 22, No. 7/8, p 153-160, 1990. 8 fig, 3 tab, 11 ref. Note: Roorkee Univ. (India). Dept. of Civil Engineering. SWRA2405.
With increasing stress on existing wastewater treatment systems, it is necessary either to upgrade existing unit(s) or to install entirely new treatment plant(s). Obviously, upgrading is preferred over the alternative of having a new system. Keeping this in view, an attempt was made to explore the possibility of upgrading existing facultative ponds using water hyacinth. Bench-scale batch studies were designed to compare the performance of a hyacinth treatment system with facultative ponds. Investigations were carried out with synthetic wastewater having COD in the range of 32.5-1090 mg/L. The efficiency of COD removal in water hyacinth ponds was 15-20 percent more than the facultative ponds. Based on the results, an empirical model has been proposed for COD removal kinetics. In the second phase of the project a hyacinth pond was continuously operated. Biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), total nitrogen (TN), total phosphorus (TP), pH, and dissolved oxygen (DO) were regularly monitored. The DO of the effluent from the hyacinth treatment system was considerably reduced. The effluent should be aerated before it is discharged. The results indicate that existing facultative ponds can be stocked with water hyacinth to improve their performance and hyacinth treatment systems can be installed to support the conventional treatment. (Author's abstract).

Kurihara, Y.; Suzuki, T. Effects of Harvesting on Regeneration and Biological Production of Phragmites australis in Wetlands. IN: Proceedings of the International Symposium on the Hydrology of Wetlands in temperate and Cold Regions. Joensuu, Finland, 6-8 June 1988. Vol. 1. The Academy of Finland, Helsinki, Finland. 1988. p 249-255, 6 fig, 1 tab, 7 ref. Note: Tohoku Univ., Sendai (Japan). Biological Inst. SWRA2205.
Since reed, Phragmites australis, grows so densely as to constitute an obstacle in rivers during the flood season, its removal becomes a highly important step in the control of the flow of water. Another reason for harvesting the reed is the fact that it incorporates fairly large amounts of nitrogen,

phosphorus and other nutrients from the polluted water and nutrient-rich mud substratum, thus benefiting the environment. The regrowth of reeds, Phragmites australis, harvested at different stages of the growing season was examined in pots and in situ to establish the best time for harvesting. The tendency for height and biomass in plots harvested later in the season to increase was recognized. For cutting 30 cm above the water surface, regrowth after one year was quite satisfactory. In the pot experiment, the amounts of nitrogen and phosphorus in the underground parts of reeds were very low at the early stages and rose remarkably at about 100 days after supplying nutrients, corresponding to August in situ. Therefore, harvesting in August by cutting stems above the water level was found to maximize total biomass that could be removed from the stand. However, there still remains the problem as to how to use the harvested material. Its application to agricultural land with sludge discharged from a sewage treatment plant is expected to become an important means for disposing of sludge and using this material. (See also W89-04689) (Author's abstract).

Lakatos, D.F. and L.J. McNemar. Wetlands and Stormwater Pollution Management. 1988. Proceedings of the National Wetlands Symposium: Wetland Hydrology. Chicago, IL. Edited by J.A. Kusler and G. Brooks. The final consensus of the experts contacted for the paper was that wetland systems may be an extremely important part of a water quality management effort for an area. Their ability to effectively 'cleanse' storm runoff is well documented and generally accepted. However, there are also major concerns about the misuse of these systems. This appeared to be especially true is wetland use grows significantly to the point that many are designed by individuals who do not have the capability and the experience (or necessary sensitivity to environmental importance) to do so in an acceptable fashion. Many experts feel that, despite potential problems, the emphasis on wetland use and/or enhancement may halp to promote a higher level of concern for wetland areas. Some feel that the benefits of new wetland area development, particularly in urban areas, outweigh the potential for environmental problems. All experts, however, point to a need to move very cautiously in the beginning stages of wetland system use, paying particularly close attention to at least those types of problems that we know can occur. In addition, the need for more research and testing/evaluation was emphasized, as well as monitoring of demonstration-type sites. Despite the potential for problems, the use of wetland systems for stormwater quality management was generally endorsed.

Lavigne, Ronald L., Ph.D. A Design Model For The Treatment of Landfill Leachate With a Microbially-Enriched Soil and Reed Canarygrass. 1989; 50/08-B of Dissertation Abstracts International. Note: Order No: AAD90-01528 University Of Massachusetts.
The disposal of municipal solid waste continues to be one of the major environmental problems facing the world today. "Sanitary landfilling" became the accepted method of refuse disposal during the early 1970's, when open burning dumps, wind blown litter, flies and rodents were perceived to be the solid waste issue of the day. Little or no attention was

given to the process of refuse decomposition and the liquid waste that is subsequently produced (i.e., leachate). Today lined landfills are replacing older unlined facilities and the practice of collecting leachate has become commonplace. An appropriate technology to treat collected leachate, however, has yet to be developed. Current landfill designs generally require the utilization of municipal wastewater treatment facilities for leachate disposal; but this practice is costly and it may be environmentally less desirable. This research project investigated the use of a new technique for treating landfill leachate on site. It utilizes a low technology "living filter" approach that models biological, chemical and physical processes known to be occurring in natural wetlands. The system takes advantage of the root zone aeration capabilities of reed canarygrass; and it maximizes the development of the fixed film biomass on peatmoss surfaces. Aerobic and anaerobic environments within the treatment medium facilitate a rapid reduction of Total Organic Carbon (TOC) and Chemical Oxygen Demand (COD); which both exist at high concentrations in leachate. The environment is also conducive to the precipitation of leachate metals. Peatmoss and reed canarygrass treatment beds were operated in both the batch and continuous flow mode to evaluate the reaction order and rate constants for leachate degradation. COD and TOC were used as modeling parameters. Mean hydraulic retention times of 3-10 days resulted in a 99%+ reduction in COD and TOC concentrations. Similar reductions were realized for heavy metals and total nitrogen. Grass clippings and peat samples were analyzed for Fe, Cu, Mn, Mg, P, K, and Ga before, during, and after 3 years of landfill leachate application. Leachate influent and effluent were also analyzed for the same metals. In each case, more than 99% of the cations measured were removed by the treatment system. Data indicates that a root zone method using peatmoss and reed canarygrass can be an effective method for creating landfill leachate if unsaturated flow conditions are maintained. Toxicity testing using reed canarygrass seedlings indicated that leachate is initially toxic, but with time plants are able to recover and flourish in the leachate-peatmoss environment.

Linker, L. C. Creation of Wetlands for the Improvement of Water Quality: A Proposal for the Joint Use of Highway Right-of-Way. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 695-701, 1 fig, 2 tab, 5 ref. Note: Environmental Protection Agency, Annapolis, MD. Chesapeake Bay Liaison Office. SWRA2305.

A proposal is described to incorporate public lands through joint use of highway right-of-way. The proposal identifies a potential highway site in Maryland for joint use as an engineered wetland to control urban nonpoint source (NPS) pollution from highly developed, established urban areas and provides preliminary analysis of the site's control effectiveness and design life costs. Several right-of-way sites within the Chesapeake Bay basin have been identified that (1) have large area and (2) intersect an urban stream. A portion of the Interstate 695 intersection with the Southeast Throughway and the Windlass Freeway in Middle River east of Baltimore was chosen as representative and calculations of pollutant removal efficiencies and

pollutant removal costs were done. Removal efficiencies were predicted as follows: total P, 53%; total N, 41%; BOD5, 40%; Pb, 72%; Zn, 40%, and Cu, 40%. Based on the quantities of pollutants remove, a 50-yr design life, and estimates of routine and nonroutine maintenance, the estimated total cost, or net present cost, $1,420,000. Economies of scale, construction economies, and land acquisition economies make this the most cost-effective urban best management practice. Wetlands engineered to improve urban water quality on a basinwide scale also require large tracts of land. Objectives of transportation and water quality improvement may be compatible in many areas of highway right-of-way. Public benefits accrue from three aspects of a joint use program: (1) basinwide control provides considerable economies of scale in both construction and maintenance; (2) the 'cut and fill' structure of major interchanges provides appropriate topography for engineered wetland; and (3) joint use of public land avoids the social and economic expense of condemning private land to assemble a separate tract of land for NPS control. (See also W90-04392) (Rochester-PTT).

Litchfield, D.K. and D.D. Schatz. Constructed Wetlands for Wastewater Treatment at Amoco Oil Companys Mandan, North Dakota Refinery. 1989. Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural. Lewis Publ., Inc. Chelsea, Michigan. Edited by D.A. Hammer. Following passage of wastewater from an oil refinery through an initial treatment with an API separator, the effluent was passed to a 6 ha lagoon for initial secondary treatment, then through a series of cascading ponds and ditches (6 of 11 ponds). Between the 6 ha lagoon and the first pond, the wastewater passed through an 0.8 km long earthem canal with a heavy growth of vegetation, including reeds and bulrushes. In the primary 6 ha lagoon, reductions in pollutants of 36% to 99.9% were obtained. Concentrations were further reduced 70% to 100% in the cascading pond system, which furnished polishing to the final effluent as it entered the Missouri River. All components were well below the NPDES limits. The individual pollutants and their percentage reduction between the initial API separator discharge and the final pond discharge were: 1. BOD -98%; 2. COD - 92%; 3. NH3-N - 90%; 4. Sulfides - 100%; 5. Phenols - 99.9%; 6. Oil-grease - 98%.

Maddox, J. J.; Kingsley, J. B. Waste Treatment for Confined Swine with an Integrated Artificial Wetland and Aquaculture System. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 191-200, 1 fig, 4 tab, 16 ref. Note: National Fertilizer Development Center, Muscle Shoals, AL. SWRA2305.
Livestock waste treatment is described that uses fish culture and sand bed filtration in artificial wetlands to circumvent problems of algae harvesting. Sand beds are planted with Chinese water chestnuts (Eleocharis dulcis) to receive suspended solids and dissolved plant nutrients. A test facility was set up in which a serial water flow was maintained from a groundwater source through a swine manure-fertilized fish culture tank and onto sand

filtration beds where water chestnuts were grown. Test tanks were 0.001 ha, 76 cm deep, lined with Hypalon and equipped with PVC plumbing. Tilapia nilotica, silver carp, and bighead carp were stocked at 35,000 fish/ha. Fish wastewater effluent (10-days retention time) was applied to three test sizes of water chestnut sand filtration beds (1.8 sq m, 2.7 sq m, and 4.5 sq m), with irrigation rates equivalent to 60, 100, and 150 L/sq m daily. Net fish production after 160 days of culture was 4300 kg/ha. Flowing water systems produced 31% more when compared with static water trials during the same period. Yields of water chestnuts and hay compared favorably with results obtained in a previous test (1978). Plant response to irrigation rate was correlated linearly with irrigation rates and did not depend on fish pond wastewater retention time. Effective removal rates achieved were 75% for BOD5, 69% for COD, 82% for suspended solids, 74% for fecal coliforms, 66% for total Kjeldahl N, and 66% for total P, compared to the fish pond wastewater source. Water treatment improvements achieved at lower irrigation rates probably are not justified because of reduced yields of water chestnuts. Economic analysis of this type of system must be site specific. Biomass harvesting can provide resource recovery through the production of marketable fish, water chestnuts, and hay. Generally, these systems are cost effective compared with alternative wastewater treatment methods that give comparable water quality results. However, waste treatment is not usually practiced at present and farm experience with these systems is lacking. (See also W90-04392) (Rochester-PTT).

Martin, E. H. Effectiveness of an Urban Runoff Detention Pond-Wetlands System. Journal of Environmental Engineering (ASCE) JOEDDU, Vol. 114, No. 4, p 810-827, August 1988. 4 fig, 5 tab, 11 ref. Note: Geological Survey, Altamonte Springs, FL. SWRA2201.
The effectiveness of a detention pond and wetlands in series in reducing constituent loads carried in runoff was determined. The detention pond was effective in reducing loads of suspended solids and suspended metals. Suspended-phase efficiencies for solids, lead, and zinc ranged between 42 and 66%. Nutrient efficiencies were variable, ranging for all species and phases from less than 0 to 72%. The wetlands generally were effective in reducing both suspended and dissolved loads of solids and metals. Total (dissolved + suspended) solids, lead, and zinc efficiencies ranged between 41 and 73%. Efficiencies for total nitrogen and phosphorus were 21 and 17%. The system, by combining the treatment of the pond and wetlands, was very effective in reducing loads of most constituents. Total solids, lead, and zinc efficiencies ranged between 55 and 83%. Total nitrogen and phosphorus efficiencies were 36 and 43%. (Author's abstract).

Martin, E. H.; Smoot, J. L. Assimilative Capabilities of Retention Ponds. Available from the National Technical Information Service, Springfield, VA. 22161, as PB88-180153. Price codes: A04 in paper copy, A01 in microfiche. Report No. FHWA/DOT/BMR-303-86, April 1986. 75p, 19 fig, 10 tab, 17 ref. Note: Geological Survey, Tallahassee, FL. SWRA2203.
The efficiency of a detention pond and wetlands temporary storage system to reduce constituents loads in urban runoff was determined. The reduction

efficiencies for 22 constituents, including the dissolved, suspended and total phases of many of the constituents were investigated. A new method not previously discussed in technical literature was developed to determine the efficiency of a temporary storage system unit such as a detention pond or wetlands. The method provides an efficiency, called the regression efficiency, determined by a regression made of loads-in against loads-out of a unit with the intercept of the regression constrained to zero. The regression efficiency of the treatment unit is defined as unity minus the regression slope. The system (pond and wetlands) achieved appreciable reductions of loads for most constituents. Significant positive regression efficiencies for the system were found for all constituents except the nutrients dissolved nitrate and dissolved orthophosphate.
Systems regression efficiencies were 55% for total solids, 83% for total lead, 70% for total zinc, 36% for total nitrogen, and 43% for total phosphorus. (Author's abstract).

Meiorin, E. C. Urban Runoff Treatment in a Fresh/Brackish Water Marsh in Fremont, California. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 677-685, 3 fig, 2 tab, 8 ref. Note: Association of Bay Area Governments, Oakland, CA. SWRA2305.
A temporary stormwater detention system for improvement of water quality was constructed in Fremont, California, in 1983. The wetland system and its control structures receive water from approximately 1200 ha: 66% low-density residential, 28% agricultural open space, 5% high-density residential, and 1% commercial and urban road. The marsh was monitored during the wet seasons of 1984-85 and 1985-86 to document marsh development and treatment effectiveness. The wetland system covers approximately 22 ha and consists of three separate subsystems: (A) a lagoon flow-through system with 1:4 slope on lagoon margins and depth ranging from 1.8 to 2.4 m; (B) an overflow area (0.5% slope, dry between storms), which leads to a pond with underwater sills vegetated with cattails and (C) a system of braided channels into which the other systems drain (4.7 ha open water, 4.2 ha vegetated with bulrushes and cattails). Measured stormwater runoff volumes from 11 storms entering the marsh ranged from 13,400 to 69,200 cu m, with calculated peak flows of 0.22 to 1.2 cu m/sec. Static capacity of the DUST (Demonstration of Urban Stormwater Treatment) marsh is 71,700 cu m. Trap efficiency for suspended constituents was 42-45% for solids, 30-83% for Pb, 40-53% for Cr, 12-34% for Ni, 6-51% for Zn, and 5-32% for Cu. For total dissolved solids, BOD5, and manganese, trap efficiencies were negative. Bioaccumulation of heavy metals was apparent in both plants and fish. Heavy metal concentrations in fish (carp, Gambusia) tissues generally were below the ambient soil and sediment concentrations for Cr, Pb, Mn, and Ni. The source of the metal contamination appears to be the sediments, but other factors than stormwater input may be involved. Overall, the DUST marsh was effective in reducing total suspended solids and inorganic N, P, and Pb, regardless of the system. Because the degree and significance of bioaccumulation of pollutants in the food chain is as yet unclear, use of wetlands to treat urban stormwater

runoff should be limited to constructed wetlands. (See also W90-04392) (Rochester-PTT).

Mestan, Richard John, Ph.D. The Nature Of Phosphorus Uptake And Release By Organic Soils Under Laboratory Conditions (Histosols, Wastewater, Wetlands). 1986; 47/11-B Of Dissertation Abstracts International. Note: Order No: AAD87-04194 The University Of Florida.
Results of past field studies involving the treatment of domestic wastewater using wetlands have demonstrated a poor understanding of the role that soils play in regard to uptake and release of phosphorus. The main objective of this laboratory study was to investigate the phosphorus uptake characteristics of wetland organic soils to aid in future predictions concerning the fate of phosphorus-using wetland treatment. The initial phase of this study was devoted to finding a suitable procedure for determining the total phosphorus content of organic soils. A number of different techniques were compared using marsh peat and EPA sludge. The second phase of the study was devoted to determining the phosphorus uptake capabilities of various organic soils under batch laboratory conditions. An attempt was made to identify soil components responsible for phosphorus uptake by statistically correlating uptake with measurable properties that included pH, ash content, native phosphorus, total iron and aluminum as well as extractable iron and aluminum. The third phase of the study was devoted to organic soil phosphorus uptake and retention under leaching conditions. This was accomplished by performing batch laboratory and column tests using artificial wastewater spiked with inorganic phosphates. Results of the initial phase of this work showed that a slightly modified version of the ignition digestion method as outlined by Anderson (1976) to be the best of four methods compared when considering factors such as accuracy, precision, simplicity and safety. Results of the second phase of this work showed the phosphorus uptake characteristics of organic soils were related to their mineral contents but the correlations between uptake and extractable iron and aluminum were not significantly higher than those obtained with total iron and aluminum. Results of the third phase of this work demonstrated that low ash organic soils had small phosphorus uptake capacities and could not retain phosphorus under leaching conditions. Higher ash peat soils could fix and retain more phosphorus, but significant amounts could be still leached using rainwater. It also appeared that the phosphorus uptake capacities of the organic soils were positively related to temperature and pH within the acid range.

Meyer J L. A Detention Basin-Articicial Wetland Treatment System To Renovate Stormwater Runoff From Urban Highway And Industrial Areas. Wetlands. Pages 135-146 May. Coden: Wetle. Note: Wetland Management Specialists Inc., 70 Bath ST., Providence, Rhode Island 02908. English.
Stormwater runoff from urban, highway, industrial, residential, and commercial areas has become recognized as an important non-point source pollutant. Many nutrients and toxic substances present in stormwater runoff are strongly associated with particulate material and are removable by sedimentation. Design criteria for a detention basin/artificial wetland treatment

system (DBAWTS) to renovate stormwater runoff from urban, highway, and industrial areas have been developed. A detention basin with an underdrain filter coupled to an artificial wetland consisting of a shallow marsh planted with Typha spp. is used to filter and absorb nutrients and contaminants in stormwater runoff. Phosphorus, heavy metals, hydrocarbons, and toxic refractory organic substances will be removed through sedimentation and absorption within the wetland. Anaerobic sediments in the Typha marsh will remove nitrates through denitrification. This system will provide effective, low-cost, low maintenance treatment of stormwater runoff from urban, highway, and industrial areas.

Mika, J. S.; Frost, K. A.; Feder, W. A.; Puccia, C. J. Impact of Land-Applied Incinerator Ash Residue on a Freshwater Wetland Plant Community. Environmental Pollution (Series A), Vol. 38, No. 4, p 339-360. 1985. 6 Fig, 3 Tab, 24 Ref. Note: Massachusetts Univ., Waltham. Suburban Experiment Station. SWRA1905.
In 1977, 60-70 tons of incinerator ash residue were deposited adjacent to a freshwater wetland. These residues are known to contain elevated concentrations of soluble cations and toxic elements. The impact on the wetland plant community was monitored over a 6-year period. Changes in species abundance and diversity were assessed both over time and distance from the residue deposition. A methodology from the marine benthic pollution literature as used to identify possible indicator species from the group of moderately adapted plants. Distance from the residue did not account for the overall increase in community richness, but appeared to be a factor in the increased relative abundance of moderately adapted species near the residue site, as a result of decreased relative abundance of dominant species. Acute phytotoxic effects were undetected, with the possible exception of the decline of Asclepia syriaca (milkweed). Post-experiment soil analyses indicated an increase of Ca, Mn, P, Zn and Cd in wetlands soils near the residue site and an even greater increase in P, K, Ca, Mg, B, Zn, Cu, Mn, Al, Cd, and Pb in the soil directly beneath the residue. If residue landfills are not properly designed or maintained, the cumulative impact of daily residue deposition could eventually disrupt sensitive ecosystems and pollute adjacent soils and groundwater. (Author's abstract).

Miller, G. Use of Artificial Cattail Marshes to Treat Sewage in Northern Ontario, Canada. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 636-642, 2 fig, 2 tab, 2 ref. Note: Hanna (J.E.) Associates, Inc., Pickering (Ontario). SWRA2305.
In July 1980, the Listowel Marsh wastewater treatment project was begun in southwestern Ontario. The project showed that a properly configured cattail (Typha) marsh could significantly improve the quality of sewage wastewaters. The present report concerns an attempt made in 1981 to transfer the Listowel approach to the community of Cobalt, more than 300 miles farther north. Marsh design was based on information from the Listowel facility. A cell of in situ materials lined with off-site clay was constructed 310 m by 3 m (0.1 ha) with a serpentine configuration. Plot loading

approximated 0.2 L/sec (170 cu m/ha/day, 19.00 mm/day) fo raw sewage. Depth was maintained at 15 cm to keep retention time near the seven-day period used at Listowel; this was increased in winter to maintain 15 cm of water under an ice layer. One year after planting, cattail covered most of the marsh area, and bulrush (Scirpus) and smartweed (Polygonum) had invaded. Muskrat tunneled through the berms during the winter, causing the channel to dry and the cattails to die. They were replanted after repairs were made, but this was unnecessary because seedlings recolonized the area. The BOD5 in raw sewage averaged 21.7 mg/L. Passage through the marsh reduced BOD5 by 80%, producing an average effluent of 4.1 mg/L with maximum levels below 15 mg/L. Suspended solids in raw sewage averaged 31.9 mg/L. Excluding three anomalies, effluent suspended solids averaged 10.9 mg/L, well below the secondary effluent objective of 15 mg/L. Total P in treated sewage averaged 1.53 mg/L; in marsh outflow it was 0.66 mg/L, 57% less and within the design objective of 1 mg/L. Bacterial counts were consistently high going into the plots, but output counts varied. Out of 33 paired input/output samples for fecal streptococci, 29 showed lower bacterial populations in the outflow. Similarly, fecal coliforms were lower in 32/33 paired comparisons. Under the best of conditions, the marsh is capable of discharging an effluent that meets swimming and bathing water quality objectives. (See also W90-04392) (Rochester-PTT).

Mingee, T. J.; Crites, R. W. Constructed Wetlands for Secondary Treatment. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 622-627, 1 fig, 2 tab. Note: Nolte (George S.) and Associates, Sacramento, CA. SWRA2305. Gustine, CA, is a small agricultural town on the west side of the San Joaquin Valley, with a population of about 4000. Climate in the area is characterized by hot, dry summers and cool winters. Average annual rainfall is about 0.29 m, mainly from November through March. The city treats approximately 4542 cu m/day of wastewater, of which one-third originates from domestic and commercial sources and the remainder comes from three dairy products industries. Analysis of alternatives to upgrade the wastewater plant showed that an oxidation pond/constructed wetland system was most cost-effective. Advantages included availability of suitable land, compatibility of the treatment method with the surrounding area lowest life-cycle cost, consumption of very little energy. A pilot study was conducted from December 1982 to October 1983 to verify the efficacy of constructed wetland to develop design criteria. An existing stand of cattail near the treatment was modified by constructing enclosure berms, piping, and pumps to simulate a portion of the constructed wetlands envisioned for the full-scale project. The wetlands systems consists of 14 cells operated in parallel, each measuring 11.6 m by 337 m (0.4 ha). Depth is adjustable at cell outlet weirs over a range of 0.1 to 0.45 m. Levees, 3 m wide and 0.6 m high, separate the cells. The wetlands system and other treatment plant improvements were constructed in 1986 and 1987. Project specifications required 18 cells to be planted with cattail (Typha) on 0.9-m centers and 6 cells with bulrush (Scirpus fluviatilis) on 0.5-m centers. Without full plant coverage,

the wetland portion of the treatment plant is still in the startup phase of operation. Performance of the system as a whole has not reached design expectations, partly because flow and BOD5 entering the treatment plant are significantly higher than design values. However, reduction of BOD5 (66%) and suspended solids (54%) are significant. Exclusive of land (9.7 ha), which was city-owned, project costs were $882,000 to treat a design loading 3785 cu m/day amount to $233/cu m/day. (See also W90-04392) (Rochester-PTT).

Morea, S.; Olsen, R.; Wildeman, T. Passive Treatment Technology Cleans Up Colorado Mining Waste. Water Environment & Technology WAETEJ, Vol. 2, No. 12, p 6, 9, December 1990. Note: Camp, Dresser and McKee, Inc., Denver, CO. SWRA2405.
The artifacts of prospecting in Colorado--tunnels, shafts, and slag piles--have been abandoned, and hazardous metals are being released through acidic mine drainage, threatening aquatic life and posing health risks to human populations. In 1985, a remedial investigation and feasibility study was conducted at five abandoned tunnels that discharged heavy metal loads into Clear Creek, 35 miles west of Denver, Colorado. The study evaluated the full range of potential treatment technologies, from conventional treatment using active-lime precipitation to plugging mines. It was concluded that a natural or passive treatment technology offered the only economically feasible alternative. Passive treatment involves a range of abatement techniques that rely on artificial wetlands to promote natural geochemical mechanisms (neutralization, reduction, adsorption, and precipitation) to raise the pH of mine drainage and remove metals. A pilot-scale passive treatment module was built at the portal of an abandoned mining tunnel. The module was designed to treat 15% of the acidic mine drainage flowing from the tunnel. The design consisted of a reinforced concrete trough with treatment cells. Each cell contained a layer of river rock, a layer of compost material or substrate, and rushes and cattails transplanted from nearby. During 3 years of operation, various configurations, substrate materials, hydraulic loading rates, and microbiological parameters were tested at the pilot plant. At optimum conditions, passive treatment removed up to 98% of the zinc in the mine drainage, 99% of the copper, 94% of the lead, and 86% of the iron. It also increased pH from 3.0 to a value greater than 6.5. Based on the pilot plant's success, EPA and the Colorado Department of Health have contracted for construction of full-scale passive treatment plants to treat drainage from 5 tunnels near Idaho Springs and Central City, Colorado. (Mertz-PTT).

Mukherjee, Goutam. Wetland management in the context of regional planning, east Calcutta. A case study. Unesco/IHP International Symposium on URBAN WATER '88 Hydrological Processes and Water Management in Urban Areas. International Association of Hydrological Sciences Publication, No. 198. Publ by Int Assoc of Hydrological Sciences, Institute of Hydrology, Wallingford, Engl. p 341-345, 1990. Coden: 1988 Apr IAPUEP. Note: C.M.D.A., Calcutta, India English A (Applications) M (Management Aspects) 9106.

Purposeful study of wetland ecosystems is essential in the urban fringe where the wetlands are being lost due to severe settlement pressure. Even today wetlands are too commonly considered as marshy wastes fit only for reclamation or dumping of materials. The waste recycling wetland east of Calcutta, largest of its kind in the world, is a unique system for purifying sewage, growing food and generating employment. Here fisheries are directly using raw sewage to become more efficient, effective and economically viable. The problems, issues and results in the context of emerging concepts of wetland management, highlighting their varying impact on environmental, ecological, socio-economic and managerial aspects are described in the paper. (Author abstract) 4 Refs.

Nichols, A. B. Wastewater treatment plant: Where wildlife and natural systems abound. OPER. FORUM. 1990; VOL. 7, NO. 9. Note: English V22N1. The effluent is filtered through these beds of sand which purify the wastewater through physical and biological treatment. Here, ammonia is converted to nitrate, and biochemical oxygen demand and suspended solids are reduced. The wastewater is pumped through these beds over and over. With each circulation, 80% of the volume is recycled and 20% is conveyed to a series of gravity-fed constructed emergent wetlands. These wetlands consist of planted bulrushes and cattails. Here denitrification occurs both by plant uptake and bacterial action at the root of the plants.

Oberts, G. L.; Osgood, R. A. Water-Quality Effectiveness of a Detention/ Wetland Treatment System and *Its Effect on an Urban Lake. Environmental* Management EMNGDC, Vol. 15, No. 1, p 131-138, January/February 1991, 1 fig, 6 tab, 12 ref. Note: Metropolitan Council, St. Paul, MN. SWRA2406. A newly installed combined detention/wetland stormwater treatment facility upstream from Lake McCarrons, Roseville, Minnesota, was monitored for 21 months to evaluate its effectiveness and the response of the lake to decreased phosphorus loads. The treatment facility consists of a 1.0-ha detention pond that discharges into a series of six constructed wetland 'chambers'. Flow was continuously monitored from September 1986 through May 1988 and was automatically sampled during 21 rainfall and four snowmelt events at the outflow of the detention pond and at the wetland system outflow. Event samples were flow-composited and analyzed for total suspended solids, volatile suspended solids, chemical oxygen demand, total phosphorus, dissolved phosphorus, total Kjeldahl nitrogen, nitrate nitrogen, and total lead. Data collected for the wetland treatment system show that the best overall reductions are for pollutants associated with solids and with the particulate portion of the nutrient load. Soluble nutrients are not as easily removed because of their tendency to move quickly through the system. Data from the lake show very little change in its water quality from three years prior to restoration (1984-1986) to three years following restoration (1987-1989): the lake's phosphorus and chlorophyll has actually increased. (Author's abstract).

Owens, Lawrence P.; Malina, Joseph F. Jr. Anaerobic biological reduction of selenate. Environmental Engineering: Proceedings of the 1989 Specialty

ConferenceEnviron Eng Proc 1989 Spec Conf. Publ by ASCE, New York, NY, USA. p 616-618. 1989; . CODEN: 1989 Jul 10-12. Note: Univ of Texas at Austin, Austin, TX, USA ASCE, Environmental Engineering Div, USA Univ of Texas at Austin, Civil Engineering Dep, Austin, TX, USA ASCE, Texas Sect, Austin, TX, USA American Acad of Environmental Engineers, USA English X (Experimental) 8911.
When soils with high concentrations of naturally-occuring selenium are irrigated and drained, selenium is leached from the soil and appears in the drainage water. Selenium has caused death and deformity among birds nesting in wetlands receiving agricultural drainage water. Selenate, the predominant form of selenium in agricultural drainage water, is a chemical analog of sulfate and has been shown to enter the biochemical pathways of sulfate. Efficient reduction of selenate will occur in a laboratory-scale upflow anaerobic sludge blanket reactor in which a population of sulfate-reducing bacteria is established. (Author abstract) 3 Refs.

Portier, R. J.; Palmer, S. J. Wetlands Microbiology: Form, Function, Processes. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 89-105, 4 fig, 2 tab, 37 ref. Note: Istituto di Ricerca sulle Acque, Rome (Italy). SWRA2305.
Microorganisms have a substantial role in transformation of organic and inorganic substances critical to all life on earth. Microbial processes are reviewed in relation to the use of constructed wetlands for wastewater treatment, with emphasis on bacteria, but with information included on fungi and actinomycetes as well. Topics include: microbial forms, microbial functions, habitat requirements within constructed wetlands (temperature, pH, salt concentration); reproduction of bacteria and population growth; kinetics of microbial growth, geochemical influences of microbial processes in wetlands (metals requirements and metals toxicity, metal toxicity resistance, and accumulation of heavy metals), and implications of anthropogenic organics (petroleum aromatic hydrocarbons and aromatic and aliphatic hydrocarbons in constructed wetlands). The most important parameter for aquatic microorganisms is nutrient availability. Most aquatic environments are oligotrophic (starvation conditions) and their inhabitants must cope with uncertain, often unsuitable conditions for survival. Below threshold concentration, onset of starvation survival is characterized by bacterial division without concurrent growth to produce ultramicrocells. The complexity and diversity of aquatic microorganisms and their environments makes it virtually impossible for optimal conditions to exist for each organism. At any one time, most microbes are surrounded by waters lacking sufficient nutrients from which ATP can be produced, that is, lacking sufficient energy-yielding substrates. Biodegradable organics are the energy-yielding substrates for heterotrophic bacteria. Many microorganisms can become dormant (up to many years) waiting until external conditions improve. Microbes can be considered living catalysts, converting dissolved organic carbon to particulate organic carbon suitable for higher-order consumers. As the base of the food web, microbes facilitate the flow of organics through the system. By increasing efficiency, microbes affect the rate of carbon

cycling through the system. As catalysts, they are the central focus of biological treatment within a constructed wetlands system. (See also W90-04392) (Rochester-PTT).

Pride, R. E.; Nohrstedt, J. S.; Benefield, L. D. Utilization of Created Wetlands to Upgrade Small Municipal Wastewater Treatment Systems. Water, Air and Soil Pollution WAPLAC, Vol. 50, No. 3/4, p 371-385, 1990. 7 fig, 3 tab, 12 ref. Note: Black and Veatch, Ashboro, NC. SWRA2312.
Created wetlands offer a low cost, low maintenance, and practical alternative for upgrading secondary municipal wastewater treatment systems. The removal efficiencies, effects of seasonal temperature variations, and effects of increased loading rates on contaminant removal within such a system was studied at a created wetland site in Hurtsboro, Alabama. The 0.16 ha system consisted of a two cell wetlands planted with cattails (Typha latifolia), bulrush (Scirpus validus), arrow duck potatoes (Sagitaria latifolis), burr reeds (Spargaminum eurycarpun), water pennywort (Hydrocotyl ranunculoides), and parrotfeather (Myriophyllum brasiliense). Testing occurred from January through September of 1988 at hydraulic loading rates of 169, 289, and 345 cu m/ha/day. The monthly average total suspended solids influent:effluent milligrams/liter concentration ratio during the study period was 135:19 while the monthly average total BOD5 influent:effluent milligram/liter concentration ratio was 38:8. Once the system stabilized, the monthly average total BOD5 effluent concentration remained essentially constant over the range of average BOD5 loading rates employed in this study. Total Kjeldahl N (TKN) removal was more effective at loading rates of 2.6 milligrams/ha/day. The monthly average influent:effluent TKN milligrams/liter concentration ratio was 15:4. (Author's abstract).

Reddy, K. R.; DeBusk, T. A. State-of-the-Art Utilization of Aquatic Plants in Water Pollution Control. Water Science and Technology WSTED4, Vol. 19, No. 10, p 61-79, 1987. 2 fig, 9 tab, 59 ref. Note: Central Florida Research and Education Center, Sanford, FL. SWRA2106.
Research, pilot-scale and operational studies conducted within the past 15 years have shown that aquatic macrophyte-based treatment system offer a promising, low-cost method for removing contaminants from wastewaters and polluted natural waters. The vascular plants cultured in such treatment systems perform several functions, including assimilating and storing contaminants, transporting O2 to the root zone, and providing a substrate for microbial activity. For wastewater treatment, two types of systems are typically utilized: (1) floating aquatic macrophytes cultured in ponds or channels, and (2) emergent macrophytes cultured in artificial wetlands using gravel or soil substrate. For floating macrophyte systems using water hyacinths and the system receiving primary sewage effluent, a 6-day hydraulic retention time (HRT), water depth of 60 cm, and a hydraulic loading of 1860 cu m ha/day are adequate for meeting secondary treatment standards. In such a system, BOD and suspended solids have been reduced by 80-90%. Similarly, systems receiving conventional secondary sewage effluent, HRT of 6 days, and hydraulic loading of 800 cu m ha/day were found to be adequate for achieving advanced secondary treatment. Similar results have

also been observed for artificial wetlands using emergent macrophytes. Aquatic plants remove pollutants by: (1) directly assimilating them into their tissue; and (2) providing a suitable environment for microorganisms to transform pollutants and reduce their concentrations. Plant harvest is needed to enhance P removal, and it may also influence oxygen transfer into the root zone, thus enhancing N and BOD removal. Removal of heavy metals from wastewaters can also be accomplished when plants are harvested. Biomass produced can be utilized as a source of feedstock for producing methane, cattle feed, or composted and used as organic manures. Economics of utilization will depend on the costs of conventional materials used for the same purpose. Operating costs for crop management and harvesting may be offset by biomass product resources. (Lantz-PTT).

Reddy, K.R. and W.H. Smith. (Eds.) Aquatic Plants for Water Treatment and Resource Recovery, 1987. Magnolia Publ., Inc., Orlando, FL.

Richardson, C. J.; Walbridge, M. R.; Burns, A. Soil Chemistry and Phosphorus Retention Capacity of North Carolina Coastal Plain Swamps Receiving Sewage Effluent. Water Resources Research Institute of The University of North Carolina Report No. 241, November 1988. 96p, 7 fig, 11 tab, 72 ref, 2 append. WRRI Project 70063. Note: Duke Univ., Durham, NC. School of Forestry and Environmental Studies. SWRA2303.
The soil chemical properties and P sorption potentials of three North Carolina coastal plain swamps were analyzed for: (1) characterization of their soil chemistries; (2) both short-term and long-term effects of wastewater addition on soil chemistry; (3) determination of their P sorption capacities and the relationships between P sorption and soil chemistry; and (4) development of a predictive index to evaluate the P sorption potentials of other coastal plain swamps. At Brown Marsh Swamp, soils were analyzed both before and after the initiation of wastewater discharge. At Cashie Swamp, which has been receiving wastewater additions for approximately 30 years, soils were collected both above and below the discharge point. Soils from nearby non-impacted Wahtom Swamp were analyzed for comparison. Wastewater additions at Brown Marsh Swamp resulted in significant increases in soil pH, available PO4-P, extractable NH4-N, and total P, and significant decreases in microbial biomass PO4-P and extractable NO3-N. At Cashie Swamp, soils collected below the discharge point had significantly higher concentrations of extractable P, and significantly lower percent organic matter and concentrations of extractable Ca, Mg, and K, total N, total P, and N:P ratios than soils collected above the discharge point. It is estimated that the Clarkton Wastewater treatment plant discharges 221 kg of PO4-P and 295 kg of total P annually into the 0.2 ha Brown Marsh spray field. Based on a modified Langmuir equation estimate of maximum P sorption potential, each hectare of Brown Marsh Swamp soil could sorb nearly two years of annual phosphate discharge from the Clarkton plant in the upper 15 cm of the soil alone. These calculations of maximum sorption potential suggest that this swamp could remove current loading rates for hundreds of years if wastewater P was discharged evenly over the entire swamp. Maximum utilization of wetlands for phosphate removal from

wastewater with minimum ecosystem impact can only be achieved under conditions which maximize retention time and the effective surface area of the wetland, and minimize the average impact per unit area. This could be achieved by adding acidified wastewater using a well designed diffusion system. (Lantz-PTT).

Roser, D. J.; McKersie, S. A.; Fisher, P. J.; Breen, P. F.; Bavor, H. J. Sewage Treatment Using Aquatic Plants and Artificial Wetlands. Water. 1987 Sep; vol.14, no.3; ISSN: 0310-0367. Note: Hawkesbury Agricultural College, Richmond, NSW, Australia Water Board, Sydney, NSW, Australia CSIRO Center of Irrigation Research, Griffith, NSW, Australia 38 references, table, figures English.
The potential of aquatic plants to treat sewage has been demonstrated bv the design, operation and performance of seven large pilot scale macrophyte systems receiving secondary treated effluent. The systems, constructed at Richmond near Sydney, consisted of lined trenches containing dense growths of Typha spp. and Schoenoplectus spp. growing in gravel and open water stocked with Myriophyllum spp. in various configurations. In a two year study, effective removal of BOD (maximum annual mean removal of 95%), suspended solids (94%) and total mean nitrogen (67%) was achieved by the systems when operating at hydraulic detention times of 2 to 10 days. Under these conditions indicator bacteria were reduced by up to five orders of magnitude. The study indicated macrophytes offer a technically simple, energy efficient method of treating sewage.

Schiffer, D. M. Water-Quality Variability in a Central Florida Wetland Receiving Highway Runoff. IN: Water: Laws and Management. American Water Resources Association, Bethesda, Maryland, 1989. p 7A-1--7A-11, 3 fig, 3 tab, 5 ref. Note: Geological Survey, Altamonte Springs, FL. SWRA2404.
Constituent concentrations were measured at the stormwater inlet and outlet, and at 9 other sites within a wetland receiving highway runoff, located north of Orlando, Florida. Most of the reduction in constituent concentrations in water observed in the wetland occurred within 100 feet of the stormwater inlet. Constituent concentrations measured in the wetland bed sediments indicate that the primary removal mechanism may be sedimentation. The 9 sampling sites within the wetland, in groups of three, were about 30, 100, and 250 ft from the stormwater inlet. Statistical analysis of the data collected at the sampling sites indicate that for 26 of the 40 water quality variables, the mean values differ significantly (alpha equal to 0.05) with distance from the inlet. These differences were most frequently detected between the sites that are within 30 ft and 100 ft from the inlet. Constituents that generally decreased in concentration with distance from the inlet include total phosphorous, ammonia, lead and zinc. The median total phosphorous concentration at the inlet was 0.23 mg/l at 100 ft, and decreased to 0.04 mg/l at 100 ft. Total ammonia was 0.23 mg/l at the inlet, decreasing to 0.01 mg/l 100 ft away. Median concentrations decreased from 18 micrograms/l at the inlet to 4 micrograms/l at a distance of 100 ft, and

median zinc concentrations decreased from 75 micrograms/l to 20 micrograms/l over the same distance. (Author's abstract).

Sen, A. K.; Mondal, N. G. Removal and Uptake of Copper (II) by Salvinia natans from Waste Water. Water, Air and Soil Pollution WAPLAC, Vol. 49, No. 1/2, p 1-6, January 1990. 3 tab, 12 ref. Note: Visva-Bharati Univ., Santiniketan (India). Dept. of Chemistry. SWRA2310.
Copper is a widely used valuable metal. It is an essential trace element, but it is toxic to plants, algae, and human beings at moderate levels. The permissible limit of copper (II) in drinking water is 1.0 micrograms/L. The sources of copper pollution are metal plating, industrial and domestic wastes, mining and mineral leaching. Recently aquatic plants have been used for the removal of heavy metals from water bodies. The plant, Salvinia natans L., was found to be very useful in the removal of copper (II) from wastewater. Effluents from the India Copper Complex, Hindustan Copper Ltd., Ghatshila, Bihar, India, which drain into the Subarnarekha River were collected and analyzed. The water was found to contain 0.75 to 1.2 microgram/ml of Cu(II). When 1 L of water was treated with 20 g of Salvana natans for one day, Cu(II) was completely removed and taken up by the plants from the water. Maximum accumulation was noted within one day and maximum removal (about 90%) was recorded below 50 micrograms/L of copper (II). The results indicate that the mode of uptake is possibly absorption and the metal taken up by the plants forms stable complexes perhaps with the protein molecules within the plant in such way that once they (metal ions) are taken up, they cannot be brought back into solution without destruction of the plant. (Brunone-PTT).

Sencindiver, John C.; Skousen, Jeffrey G. Wetlands for acid mine drainage treatment. Proceedings of the ASCE Energy Division Specialty Conference on EnergyEnergy in the 90's Proc ASCE Energy Div Spec Conf Energy. Publ by ASCE, New York, NY, USA. p 294-299. 1991; . CODEN: 1991 Mar 10-13. Note: West Virginia Univ, Morgantown, WV, USA ASCE, Energy Div English A (Applications) 9106.
Wetlands are being constructed on mined lands to treat acid mine drainage. Most of these wetlands remove a substantial amount of iron and sulfate from the water, but manganese removal has been erratic. Increases in water pH have also been reported. Major mechanisms of metal removal are probably adsorption and ion exchange with organic and inorganic materials and microbial and chemical transformations. Currently, sulfate reduction is receiving increased attention by researchers. Much has been learned about wetland construction by trial and error, but more well-organized studies are needed to determine optimum size and design for water treatment. (Author abstract).

Simpsom, R. L.; Good, R. E.; Dubinski, B. J.; Pasquale, J. J.; Philipp, K. R. Fluxes of Heavy Metals in Delaware River Freshwater Tidal Wetlands. Available from the National Technical Information Service, Springfield, VA 22161 as PB84-190057, Price codes: A05 in paper copy, A01 in microfiche. Center for Coastal and Environmental Studies Completion Report,

Rutgers Univ., New Brunswick, N. J. 1984. Note: Rider Coll., Lawrenceville, NJ. Dept. of Biology. SWRA1804.
A survey of ten wetlands showed soil heavy metals were generally lowest in rural areas and highest in urbanized and industrialized areas. Cr, Cu, and Cd levels were highest at transects nearest the Delaware River while Ni and Pb were highest near the tidal boundary indicating a differential importance of riverine and upstream inputs to these wetlands. Regression analysis showed significant ($P <$ or $= .05$) positive relationships between % silt and Cr, Cd, Ni, and Pb. The high marsh through sites with the highest % silt likewise had the highest metal concentrations. Extensive studies at Woodbury Creek Marsh showed little seasonal pattern in soil metal concentrations, but distinct concentration gradients with depth and distance from a storm drain discharging nonpoint source runoff. The vegetation, while accumulating metals especially below ground, had much lower metal levels than the soil although the pattern of accumulation, Zn > Pb > Cu nearly = Ni > Cd, closely paralleled soil metal levels. Litter was enriched up to 20-fold as it decomposed with Cd and Ni levels reaching ambient soil levels while Cu and Pb were half to two-thirds those in the soil. Except for increases in Cr, the vegetation did not respond to the application of sewage sludge enriched with heavy metals. The soils of the high treatment sites (100 g/sq m/wk sludge) retained Cd (43%), Cr (53%), Cu (52%), Pb (31%), and Zn (51%) in the sludge at the end of the application period in October, but only Cd (15%) and Cr (12%) were still present the following March. The soils of the low treatment sites (25 g/sq m/wk sludge) retained only Cd (43%) and Cr (28%) in October, but these metals remained in the soil at the same level through the next March. Delaware River freshwater tidal wetlands have the capacity to sequester additional metals, but at a slow rate. Direct sedimentation and the litter are the major pathways for a long-term accumulation of heavy metals in these wetlands.

Smith, A.J. Wastewaters: A Perspective. 1989. IN D.A. Hammer (ed.), Constructed Wetlands for Wastewater Treatment, pp.3-4, Lewis Publ. Inc., Chelsea, MI.

Soeder; Stengel; Schultz-Hock; Obermann; Barrenstein. Aufbereitung von nitrathaltigem Grundwasser mit Hilfe denitrifizierendem Wasserpflanzen-Boden-Filter und nachgeschalteter Bodenpassage. Schlussbericht. (Processing of nitrate-contaminated groundwater by a nitrate-reducing artificial wetland and following underground-passage. Final report). 1987; Note: Ruhr Univ., Bochum (Germany, F.R.). Inst. fuer Geologie. 004202015 Kernforschungsanlage Juelich G.m.b.H. (Germany, F.R.). Inst. fuer Biotechnologie Stadtwerke Viersen G.m.b.H. (Germany, F.R.) Bundesminis terium fuer Forschung und Technologie, Bonn (Germany, F.R.). German GRAI8812 In German, With 12 refs., 14 figs. Germany, Federal Republic of.
The experimental denitrification lay-out in the Suechteln waterworks, belonging to the Stadtwerke Viersen GmbH, is a so-called artificial wetland. It consists of a shallow basin lined with plastic sheeting, filled with loam and sand and planted with common reed (Phragmites). Groundwater with a

high nitrate content is passed through the artificial wetland and a partial denitrification takes place due to the activity of bacteria located on the roots of the plants. The dissolved organic carbon needed by the bacteria is supplied by senescent roots and decaying plant debris. The water flowing out of the artificial wetlands is reintroduced into the water table through wells. The most important parameters have been continually recorded and stored by an automatic monitoring station since the start of the investigations on 16.09.1985. Nitrate elimination increased during the growth period of the plants but declined again in winter which was in agreement with the annual fluctuation already found in parallel experiments. The results show so far that autochthonous production of organic reduction potential is not sufficient in winter. The addition of allochthonous organic material is, therefore, necessary. The possibility of adding a straw percolate from a straw filter to the inlet of the artificial wetland in Suechteln is in preparation. (orig./RHM). (TIB: FR 650.) (Copyright (c) 1988 by FIZ. Citation no. 88:080316.).

Stengel, E.; Schultz-Hock, R. Denitrification in Artificial Wetlands. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 484-484, 6 fig, 14 ref. Note: Kernforschungsanlage Juelich G.m.b.H. (Germany, F.R.). Inst. fuer Biotechnologie. SWRA2305.
The aeration function of macrophyte horizons with horizontal flow-through was investigated in artificial wetlands. Denitrification in relation to oxygen concentration, organic carbon sources, and temperature, and oxygen conditions in the root horizon are reported. Measurements were performed in outdoor artificial wetlands with U-shaped channels 0.4 m deep, 0.6 m wide, and 16 m long and total surface are of 9.6 sq m. Channels were filled with grave and vegetated beds were dominated by Phragmites australis (shoot densities 350-580/sq m). An unvegetated control was used. Several conclusions could be drawn as a result of these studies: (1) nitrate elimination in artificial wetlands is possible throughout the whole year, when specific conditions are fulfilled (low O2 concentration in the water, available organic carbon); (2) high denitrification rates were verified even at low temperatures; (3) in summer, when oxygen concentration in the inflowing water is low, denitrification occurs in the whole plant bed; (4) observations on oxygen conditions in the root zone did not show addition of oxygen to the through-flowing water; and (5) the concept that particular plant species control oxygen levels in their surroundings in a predictable way has to be further examined and, if true, this concept of 'controlled aeration' should assist in proper use of macrophytes for diverse ecological and technological purposes. (See also W90-04392) (Rochester-PTT).

Stockdale, E.C. The Use of Wetlands for Stormwater Management and Nonpoint Pollution Control: a Review of the Literature. 1986. Rept. 87-7A. Washington State Department of Ecology, Olympia, WA Certain principles for water quality improvements can be summarized from the literature: 1. Sedimentation of particulates and associated pollutants is a major mechanism in water quality improvement; 2. Longer detention times (20-36 hrs) improve water quality more than shorter detention times; 3. Traditional detention times for flood control of 1-12 hours are too short to substantially improve water quality; 4. The size of the wetland is important; 5. Sheet flow is preferred over channel flow for water quality improvements; 6. Dense vegetative growth throughout the wetland reduces flow velocity; 7. Wetlands should not be used as sedimentation basins. Increased rates of sedimentation within wetlands increase the natural succession process; 8. Controlling the 'first flush' of stormwater is not an effective management tool in Western Washington. There are many uncertainties regarding the long-term consequences of using freshwater wetlands for urban stormwater management: 1. The hydrological impacts associated with changes in detention time and water levels are uncertain, especially on emergent non-woody species; 2. The risks of contaminating groundwater with toxicants or pathogens in stormwater are unknown, as are the groundwater recharge/discharge characteristics of most wetlands; 3. It is uncertain if nonpoint toxicants in stormwater will be bioaccumulated in the biota, or will accumulate in the soils; 4. Public health risks of exposure to pathogenic microorganisms in stormwater are unknown; 5. The impacts to systems downstream from wetlands that depend on normal wetland functions are unknown.

Stockdale, E.C. and R.R. Horner. Using Freshwater Wetlands for Stormwater Management: A Progress Report. 1989. Proceedings of an International Symposium. Wetlands and River Corridor Management. Charleston, So. Carolina. Edited by J.A. Kusler and S. Daly.
This single year data set (1987) provides a mixed picture of what is occurring in wetlands receiving urban runoff. Some of it will remain inconclusive until further sampling and interpretation is completed: 1. A number of the sites were found to have significantly elevated concentrations of lead, cadmium, and zinc. This was largely associated with the most intensely developed watersheds (those with 95% high density residential or commercial land uses). Elevated concentrations were found primarily at or near the wetland inlet, and in emergent (PEM) zones. Copper concentrations exhibited no differences between groups; 2. nutrient levels in soil samples were not found to contrast between the two groups, presumably because of relatively rapid cycling processes; 3. mean fecal coliform levels in affected wetlands violated Washington State water quality standards for Class AA and A waters (50 and 100 organisms/100 ml, respectively). These findings correlated with commercial land use, and concentrations were inversely proportional with unforested/undeveloped land. The enterococci mean was below the proposed EPA criterion of 33/100 ml; 4. the emergent zones of affected sites exhibited a prevalence of canaryreed grass and lacked Carex spp. Reedcanary grass is known to be an opportunist that tends to monoculture. The unaffected sites exhibited a more diverse composition of species; 5. plant tissue metal concentrations were not found to be statistically significant between the two groups. A number of values were below the detection limit, especially for lead, and a proper hypothesis test could not be conducted in several cases. There were also no significant correlations between sediment and plant tissue metals concentrations in the various

wetland zones; 6. the soil samples from some zones in urban sites were found to be significantly more toxic; 7. several larvae of invertebrates were more prevalent in unaffected wetlands (caddis fly, Anabolia, families Chironomidae and Heptageniidae, and subfamily Lestidae, a damselfly). Some larvae were more prevalent at affected sites (Dicosmoecus, a caddis fly, and two Hemiptera families); and, 8. qualitative characteristics were also observed and found to distinguish the two groups. Wetlands in urban areas exhibited highly significantly more frequent instances of human intrusion, debris, and sediment deposition. Significant prequencies of channelization, placement of fill, scum or foam, and odor were also observed. Evidence of wetland drainage and visible oil was also observed.

Stowell, R.; Weber, S.; Tchobanoglous, G.; Wilson, B. A.; Townzen, K. R. Mosquito Considerations in the Design of Wetland Systems for the Treatment of Wastewater. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 38-47, 5 fig, 1 tab, 5 ref. Note: Dewante and Stowell, Sacramento, CA. SWRA2202.
In the Central Valley of California, water hyacinth systems have produced year-round an effluent containing consistently < 10 mg/L of biochemical oxygen demand (BOD) and 10 mg/L of suspended solids (SS) at costs substantially lower than other technologies, including overland flow. Recently, several local hyacinth systems have been taken out of service because of mosquitoe production problems, the major drawback of the systems. Mosquito-production research data from the Roseville, California, hyacinth systems is presented. Ways to minimize hyacinth-system mosquito production by design are discussed and design strategies for hyacinth and other wetland-type systems. The wetlands options for new (pretreatment, plug flow reactor design) or existing (secondary sedimentation, plug flow reactor design) wastewater treatment systems represent a departure from what has been done in the past. The documented performance and lower cost of these systems make it clear that where the conditions are suitable, these systems should be considered in any cost-effective analysis of wastewater treatment alternatives. However, before the widespread use of wetland wastewater treatment systems can be recommended routinely, research and surveillance of additional pilot projects are needed to determine the mosquito-production potential of wetland systems as a function of design, operation, and mosquitoe-abatement measures. (See also W89-01827) (Lantz-PTT).

Sundblad, K.; Wittgren, H. B. Glyceria maxima for Wastewater Nutrient Removal and Forage Production. Biological Wastes BIWAED, Vol. 27, No. 1, p 29-42, 1989. 1 fig, 5 tab, 27 ref. Note: Linkoeping Univ. (Sweden). Dept. of Water and Environmental Research. SWRA2301.
Potential biomass yield, nutrient uptake capacity and forage quality of Glyceria maxima were tested in four field lysimeters receiving municipal wastewater. Wastewater was applied during 3 years at different frequencies in order to achieve maximum N-reduction in the system. Accordingly two lysimeters were ponded for part of the week. Harvesting (in June and

August) progressively favored competing terrestrial species in the nonponded lysimeters. In year 3 the other species accounted for 65-70% of the harvested biomass in these non-ponded lysimeters. In the ponded lysimeters, reducing conditions in the soil probably prevented terrestrial species from establishing. The total annual yields of the single-species stands in the ponded lysimeters were 870-1165 g/sq m. Energy, protein, P, K, and Ca content of the harvested biomass indicated a high nutritional value. NO3(-)-N concentration in the harvested biomass varied from 0.08 to 0.32% of dry wt, but did not generally exceed 0.2%. Maximum N and P removed with the harvested biomass was 32 and 4.8 g/sq m respectively. The relative removal of nutrients in ponded lysimeters varied from 26 to 55% of the amount of N applied and from 12 to 28% of P applied, which illustrated the possibilities of adjusting the load for optimization of nutrient re-use rather than disposal. (Author's abstract).

Thut, R. N. Utilization of Artificial Marshes for Treatment of Pulp Mill Effluents. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 239-244, 4 tab, 8 ref. Note: Weyerhaeuser Co., Tacoma, WA. Technology Center. SWRA2305.

Treatment of pulp mill effluents was investigated. Eight artificial marshes were constructed in galvanized steel watering troughs, with epoxy-painted interiors to prevent leaching of zinc. A 0.4-m-deep rock substrate was placed in the troughs. The substrate was marl (10-20 mm), a locally abundant rock composed mainly of calcium carbonate and clay. The independent variables considered in the study were presence/absence of plants, plant type, and retention time. The plants tested were cattail (Typha latifolia), reed (Phragmites australis), and cordgrass (Spartina cynosuroides). The experiment was conducted over 3 yr, with most of the studies of independent variables done in the first year and long-term performance evaluated in the second and third years. Four of the eight artificial marshes were left unaltered throughout the experiment, with a retention time adjusted to 15 hr. The other four were reconstructed in various ways in the second year to test the effects of different substrate depths and configurations. The parameters pH, temperature, conductivity, and color did not change appreciably in transit through the marsh systems. The reactors were more effective at 24-hr retention times than at 6-hr retention times, although more pollutant was removed at shorter retention times because more total material passed through the basins. The presence of plants had no substantial effect on removal efficiencies for most pollutants, although plants did enhance the removal of ammonia and phosphorus. Dissolved oxygen and oxidation-reduction potential readings from within the rock substrate indicated an anaerobic, strongly reducing environment. Differences in removal efficiency among the three types of plants were not striking. Removal efficiencies did not change substantially over the 3-yr study period. Removal efficiencies were a function of retention time in the 6-24 hr range, but the increment of improvement from 15-24 hr was slight. A facility sized for about 15 hr of treatment probably would be adequate for most purposes. At

15 hr, a full-scale artificial marsh at a typical pulp mill in the United States would be 20-40 ha. (See also W90-04392) (Rochester-PTT).

Tomljanovich, D. A.; Brodie, G. A.; Hammer, D. A. Constructed Wetlands for Treating Acid Drainage at TVA (Tennessee Valley Authority) Facilities: Progress Report. 1988a Mar; Note: Tennessee Valley Authority, Knoxville. Office of Natural Resources and Economic Development. 021113044 9517029 English GRAI8905 NSA1300 Portions of this document are illegible in microfiche products. United States.
A comprehensive overview is presented of TVA's use of constructed wetlands to naturally treat water quality problems associated with acid drainage at its fossil plants and the inactive Fabius Coal Mine and Preparation Plant in Jackson County, Alabama. TVA constructed its first wetland in May 1985. As of December 1987, a total of eight constructed wetlands, one enhanced natural wetland receiving acid drainage, and one former chemical treatment pond were being monitored as treatment wetlands. Some measure of success is being achieved at all the wetland systems. However, to achieve compliance quality effluent (total Fe <3.0 mg/L, total Mn <2.0 mg/L, pH 6.0--9.0 s.u., and total suspended solids <32.0 mg/L) interim chemical treatment is being used at COF to treat manganese, and at WCF to treat low pH. At KIF, water is being pumped from the final cell of the wetland to the active ashpond as an interim measure until it is shown to consistently yield compliance quality effluent. Chemical treatment is also being used to augment wetlands treatment at the Fabius Impoundment 2 and Impoundment 4 wetlands. Where chemical treatment is required, reduced chemical costs result from some level of wetlands treatment. Successful wetlands treatment has been demonstrated at three sites, where no chemical treatment is required. In the remaining two newly constructed wetlands, insufficient data exist to assess their treatment capability. Overall average construction cost based on nine wetlands was $1.13/ft sup 2 ($49,223/ac). Before converting one chemical treatment pond (Fabius Impoundment 3) to a wetland, TVA was annually spending $12,000 to $15,000 for chemicals and $10,000 for pond maintenance that failed to maintain complying discharges. Complying discharges and an annual wetland maintenance cost of about $1000 make the wetland an attractive and cost-beneficial treatment method. 2 refs., 15 figs., 10 tabs. (ERA citation 13:050532).

Tomljanovich, D. A.; Brodie, G. A.; Hammer, D. A.; McDonough, T. A. Preliminary Results of an Experiment to Assess the Effect of Substrate Type on Treatment of Acid Drainage Using Constructed Wetlands. Available from the National Technical Information Service, Springfield, VA 22161, as DE88-016102. Price codes: A06 in paper copy, A01 in microfiche. Report No. TVA/ONRED/WRF--8/2, February 1988b. 140p, 2 tab, 8 append. Note: Tennessee Valley Authority, Knoxville. Div. of Air and Water Resources. SWRA2306.
Constructed wetlands are a viable alternative to more costly chemical treatment of acid drainage and are rapidly gaining acceptance, or at least interest of the mining industry, utilities, and regulators. In response to the need for

basic information applicable to designing treatment wetlands, the Tennessee Valley Authority (TVA) in 1986 constructed an experimental wetlands facility in Jackson County, AL. The Acid Drainage Wetlands Research Facility consists of twenty 9.1 sq m wetland cells made of half-round fiberglass pipe. A nearby acidic seep was impounded and routed through the cells at controlled rates. Water samples taken biweekly of the influent and wetland cell discharges were compared to assess treatment (reduction in dissolved Fe, Mn, and total suspended solids and elevation of pH) among five substrate types. Secondary comparisons included growth of cattails among substrate types and treatment effects between bulrush and cattail wetlands in the same substrate type. Significant treatment of dissolved Fe and total suspended solids occurred for all substrate types, and a significant rise in pH of about half a standard unit occurred for all substrate types. Significant Mn treatment occurred in four of the six wetland types. However, reduction in concentration was < 1 mg/L in all types. Significant differences among substrate types, by season were rare and inconsistent. Treatment of all parameters improved with time. With one exception, growth and numbers of vegetatively produced cattail stems were not significantly different among substrate types. Comparisons of treatment between cattail and bulrush wetlands were not significant. Preliminary results from the first year of continuous testing suggested substrate type is relatively unimportant in treatment of acid drainage. (Author's abstract).

Trautmann, N. M.; Martin, J. H.; Porter, K. S.; Hawk, K. C. Use of Artificial Wetlands for Treatment of Municipal Solid Waste Landfill Leachate. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 245-251, 2 fig, 10 ref. Note: Cornell Univ., Ithaca, NY. Center for Environmental Research. SWRA2305.

A potentially cost-effective and energy-efficient prototype system for onsite treatment of landfill leachate has been designed for the town of Fenton, New York. Leachate will be pretreated using overland flow followed by horizontal flow through the root zone in a bed of wetland plants. In the absence of previous experience treating landfill leachate with this technique, its efficacy is not know. Theoretically, overland flow will remove much of the dissolved iron and manganese, readily oxidizable organic matter, ammonia nitrogen, and volatile organics such as benzene. Additional removal of nitrogen and organic matter as well as removal of phosphorus and metal ions will occur in the root-zone bed, producing an effluent that can be discharged directly to surface waters. Through a combination of laboratory studies and evaluation of the prototype system performance, the feasibility of this approach will be determined. Initial laboratory experiments on changes in soil hydraulic conductivity have been conducted. In a 7-month study using Typha glauca Gadr and Scirpus acutus Muhl planted in boxes of sand and grown in a greenhouse, saturated hydraulic conductivity decreased over time in both vegetated and nonvegetated systems, with a significantly greater decrease in the vegetated systems. Saturated hydraulic conductivity declined by 41% in the control systems, probably because of sand settling, and by 55% in the vegetated systems. Ammonia nitrogen and nitrate nitrogen were supplied in ranges of rates comparable to municipal wastewater. Systems with vegetation reduced ammonia nitrogen and nitrate nitrogen concentrations significantly better than those without vegetation. Typha and Scirpus showed comparable rates of nitrogen removal. (See also W90-04392) (Rochester-PTT).

Wetland Areas: Natural Water Treatment Systems. January 1970-May 1989 (Citations from Pollution Abstracts) Rept. for Jan 70-May 89. 1989 Jun; Note: National Technical Information Service, Springfield, VA. 055665000 English GRAI8919 Prepared in cooperation with Cambridge Scientific Abstracts, Washington, DC. United States.
This bibliography contains citations concerning the ability of salt marshes, tidal flats, marshlands, bogs, and other wetland areas to degrade, absorb, filter, consume, or mitigate natural and man-made pollution and wastes, while still providing refuge and breeding grounds for wildlife. The ecology, biochemistry, and viability of naturally occuring and artificially established wetlands as water-treatment systems and wildlife areas is considered. The effects of individual pollutants, environmental factors, species diversity, and cleansing ability of wetland areas on the potential for wildlife refuge, sewage treatment, treatment of industrial and municipal wastes, handling agricultural runoff, mitigating accidental spills, and flooding are discussed. (Contains 271 citations fully indexed and including a title list.).

Wetland Areas: Natural water treatment systems. January 1978 - August 1989 (a bibliography from Pollution Abstracts). 1990; Note: 0664714% SUMMARY LANGUAGE - ENGLISH; NTIS Order No.: PB90-862244/GAR. 243 ref.l. ENGLISH V28N1.
This bibliography contains citations concerning the ability of salt marshes, tidal flats, marshlands, bogs, and other wetland areas to degrade, absorb, filter, consume, or mitigate natural and man-made pollution and wastes, while maintaining their ability to provide refuge and breeding grounds for wildlife. The ecology, biochemistry, and viability of naturally occurring and artificially established wetlands as water-treatment systems and wildlife areas are considered. The effects of individual pollutants, environmental factors, species diversity, and cleansing ability of wetland areas on the potential for wildlife refuge, sewage treatment, treatment of industrial and municipal wastes, handling agricultural runoff, mitigating accidental spills, and flooding are discussed. (Prepared in cooperation with Cambridge Scientific Abstracts, Washington, DC.).

Wieder R K; Heston K P; O'Hara E M; Lang G E; Whitehouse A E; Hett J. Aluminum Retention In A Man-Made Sphagnum Wetland. Water, Air and Soil Pollution. 1922; Coden: Wapla. Note: Dep. Biol., Villanova Univ., Villanova, Pa. 19085, USA. English.
Runoff from a highway interchange in western Maryland had Al concentrations averaging about 50 mg L-1, with a maximum of 206 mg L-1. As an alternative to expensive chemical treatment of this Al-rich water, in August 1984, the drainage was diverted through a 500 m2 man-made wetland, constructed from organic peat. For a 10 week period, Al concentrations in

water leaving the wetland averaged 1.5 mg L-1, as compared to Al concentrations at the two major inflows to the wetland of 35.3 and 6.6 mg L-1. However, effective treatment of the drainage by the wetland was not observed over the entire 27 mo sampling period. Peat chemical analysis indicated that over the 27 mo, total Al concentration in the peat increased from 2375 .mu.g g-1 to 13 634 .mu.g g-1. Of this increase 5.5% was contributed by exchangeable Al, 4.3% by adsorbed Al, 39.8% by organically bound Al, 33.1% by oxide bound Al, and 17.2% by precipitated and residual Al. Changes in Fe, Mn, Ca, Mg, K, and Na chemistry in the peat associated with Al retention are discussed.

Wieder, R. K. A survey of constructed wetlands for acid coal mine drainage treatment in the eastern United States. WETLANDS. 1989; VOL. 9, NO. 2. Note: Dep. Biol., Villanova Univ., Villanova, PA 19085, USA SUMMARY LANGUAGE - ENGLISH ENGLISH V21N6.
The oxidation of pyritic minerals, exposed to oxygen and water during the mining of coal, results in the formation of acid mine drainage (AMD), which is characterized by low pH and high concentrations of dissolved sulfate, iron, and other metals. Recently, man-made wetlands have been proposed as a low-cost, low-maintenance alternative to chemical treatment of AMD. Over 11% of the constructed wetlands yielded greater concentrations in the effluent from the wetland than were present in the influent AMD for one or more of these 6 chemical parameters. Treatment efficiency generally was not correlated with design criteria (e.g., area of wetland, depth of the organic substrate in the wetland, AMD flow rate, metal loading rates). Also, treatment efficiency was generally not affected by either the type of organic substrate used in wetland construction or the addition of lime and/or fertilizer to the constructed wetland. The effectiveness of wetland treatment of AMD is not only extremely variable, but also presently not predictable.

Wieder, R. K.; Linton, M. N.; Heston, K. P. Laboratory Mesocosm Studies of Fe, Al, Mn, Ca, and Mg Dynamics in Wetlands Exposed to Synthetic Acid Coal Mine Drainage. Water, Air and Soil Pollution WAPLAC, Vol. 51, No. 1/2, p 181-196, May 1990. 5 fig, 1 tab, 31 ref. Note: Villanova Univ., PA. Dept. of Biology. SWRA2403.
To evaluate the potential for constructed wetlands to treat acid coal mine drainage, six model wetland mesocosms (each 2.4 m by 15 cm) were filled with Sphagnum peat (15 cm deep), planted either with cattails (Typha latifolia) and living Sphagnum, living Sphagnum only, or left as bare peat (2 mesocosms per treatment). The model wetlands were exposed to synthetic acid coal mine drainage (pH 3.5, concentrations of iron, aluminum, manganese, calcium and magnesium ions of 78.8, 10.0, 5.2, 12.0 and 4.5 mg/L, respectively) at a rate of 90 ml/min, 6 hours/day, 5 days/week over a 16 week period. Chemical analyses of peat at periodic intervals indicated that the model wetlands were net sources of aluminum, manganese, calcium, and magnesium, but net sinks for iron. Type of vegetation had no significant effect on iron retention; of the 204 g of iron added to the model wetland systems, 162 g were retained. Formation of iron oxides

accounted for 73 to 86% of the iron retention, with exchangeable iron contributing 0.2 to 1.2%, organically bound iron contributing 4 to 19%, and residual iron contributing 7 to 15% of total iron retention. Iron retention was greatest at the inflow ends of the model wetlands where iron retention appeared to reach saturation at a final iron concentration in the peat of 235 mg/g. At the rate of application of the synthetic acid mine drainage, the model wetland systems would have reached an estimated complete iron saturation after 157 days. The mesocosm approach could be useful in generating site-specific data that can be applied to the formulation of cost-benefit analyses that can compare a proposed wetland treatment system with alternative conventional chemical methods for treating acid mine drainage. (Author's abstract).

Wildeman, T. R.; Laudon, L. S. Use of Wetlands for Treatment of Environmental Problems in Mining: Non-Coal-Mining Applications. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 221-231, 3 tab, 37 ref. Note: Colorado School of Mines, Golden. Dept. of Chemistry and Geochemistry. SWRA2305.
Wetland treatment of environmental problems is used in the coal industry far more than in non-coal mining applications. In coal mining areas, pyrite is the mineral responsible for acid mine drainage problems and it causes most problems in metal mining systems. Fe, Mn, and SO4(2-) dominate the constituents in coal mine drainage, whereas drainages from metal mines is dominated by Cu, Zn, Cd, Pb, and As, as well as Fe, Mn, and SO4(2-). In mining situations where pyrite is absent, water pollution is significantly reduced. With pyrite present, almost every type of heavy metal contaminant may be present in acid drainage from metal mine operations. Acid drainage from metal mines is a more severe problem than that from coal mines because priority pollutants such as As, Cd, Pb, Hg, Cu, and Zn may be present in hazardous concentrations. Low-cost immobilization of pollutants for long periods of time is the goal of using wetlands for mine drainage treatment. Among various possible removal mechanisms, precipitation of metals catalyzed by bacterial activity is postulated as the most likely. Existing metal mine drainage site wetlands can be divided into two types: (1) primary, where the wetland is the only type of treatment in use, and (2) secondary, where the wetland is used as the polishing step. At a tailings site in Sudbury, Ontario, precipitation of oxides appears to be the main removal mechanism in wetlands, with metal uptake by algae secondary. At a taconite mine in northeastern Minnesota, a naturally-occurring white cedar wetland removes 84% of Cu and 92% of Ni, with peat uptake accounting for most of the metal removal. In Montana, effluent from an abandoned lead-zinc mine was reduced in metals by a natural wetland, whereas constructed wetlands did not remove iron or acidity. At Big Five Tunnel, Colorado, mushroom compost had the highest metal removal efficiency and effluent pH compared to peat and limestone rock covered with peat. (See also W90-04392) (Rochester-PTT).

Winter, M.; Kickuth, R. Elimination of Sulphur Compounds from Wastewater by the Root Zone Process: I. Performance of a Large-Scale Purification Plant at a Textile Finishing Industry. Water Research WATRAG, Vol. 23, No. 5, p 535-546, May 1989. 10 fig, 8 tab, 45 ref. Note: Gesamthochschule Kassel (Germany, F.R.). Dept. of Ecochemistry. SWRA2212.
The Root Zone methods removes sulfur from wastewater by sending effluent through a sealed bed of soil planted with helophytes. Operational experiences in the purification of textile finishing effluent on beds of Phragmites communis Trin. using the Root Zone system are considered. In a 0.44 ha section of a Root Zone plant of 19 ha on average 76% of COD and 82% of total-sulfur load, equivalent to 27 t O2/ha/yr and 3.5 t sulfur/ha/yr, respectively, were removed from the wastewater. Despite a lack of nutritive salts in the effluent there has so far been no need to use fertilizers to support the process. The Root Zone system can adapt to a different effluent quality in 1-3 wk. Over the 12-yr operational period there have been no breakdowns in purification performance despite loading with a broad and often changing variety of industrial chemicals. (Author's abstract).

Wolverton, B.C. Aquatic Plants and Wastewater Treatment (an Overview). 1987. Proceedings of a Conference on Research and Applications of Aquatic Plants for Water Treatment and Resource Recovery. Magnolia Publishing Inc., Orlando, FL. Edited by K. R. Reddy and W.H. Smith.
The technology for using water hyacinth to upgrade domestic sewage effluent from lagoons and other wastewater treatment facilities to secondary and advanced secondary standards has been sufficiently developed to be used where the climate is warm year round. The technology of using emergent plants, such as bulrush, combined with duckweed, is also sufficiently developed to make this a viable wastewater treatment alternative. This system is suited for both temperate and semi-tropical areas found throughout most of the U.S. The newest technology in artificial marsh wastewater treatment involves the use of emergent plant roots in conjunction with high surface area rock filters. Smaller land areas are required for these systems because of the increased concentration of microorganisms associated with the rock and plant root surfaces. Approximately 75% less land area is required for the plant-rock system than is required for a strict artificial wetland to achieve the same level of treatment.

Wotzka, P.; Oberts, G. Water Quality Performance of a Detention Basin-Wetland Treatment System in an Urban Area. IN: Nonpoint Pollution: 1988-Policy, Economy, Management, and Appropriate Technology. Proceedings of a Symposium. American Water Resources Association, Bethesda, Maryland. 1988. p 237-247, 8 fig, 3 tab, 9 ref. Note: Metropolitan Council, St. Paul, MN. SWRA2404.
The McCarrons Treatment System is a surface water management facility consisting of a detention pond followed by six 'chambered' wetlands designed to improve the water quality of Lake McCarrons in Roseville, Minnesota. The system is located at the bottom of a 243 hectare urban watershed. Most of the reduction in pollutants occurs in the detention pond. Performance conclusions are based on results from 21 of the 57 rainfall

events and 4 periods of snowmelt. Climatic conditions and the precipitation during the 21 months of study were not 'normal,' but rather reflective of a mild, dry period with a major rainfall event and two very wet months. The detention pond is considered to be currently performing at the best level that can be expected. Attributes thought to contribute positively to treatment levels in the pond include diffuse inflow from three separate tributaries, a low dissolved phosphorus to total phosphorus (DP:TP) ratio, and newly exposed peat soils with a high affinity for attracting TP. Changes in the design of the outlet structure could improve the effectiveness of the detention pond in treating snowmelt. The post-detention wetland system was intended to 'polish' outflows from the detention pond before the water discharged to the lake. The wetland continues the process of settling solids begun in the pond, but is less effective in removing soluble nutrients. This situation is partially related to additional inputs to the wetlands from another tributary, overland runoff, and atmospheric deposition. Even though nutrient removal in the wetland is not high, there is a net reduction so the wetland is performing as expected. (See also W91-03704) (Author's abstract).

Yuduan, W.; Changyi, L.; Jiandong, H.; Yuling, L. Removal of Heavy Metals from Sediments by Mangroves in Jiulong Estuary, Xiamen Harbour, China. Water Science and Technology WSTED4, Vol. 20, No. 6/7, p 49-54, 1988. 3 fig, 2 tab, 11 ref. Note: Xiamen Univ. (China). Inst. of Environmental Science. SWRA2206.
Sediment samples were collected from Jiulong Estuary (Xiamen Harbor, Fujian, China), where five major species of mangrove grow well, even though the levels of the heavy metals Cu, Pb, and Hg from anthropogenic sources in the sediments of the region are as high as 18.1 ppm, 59.2 ppm, and 0.14 ppm, respectively. The concentrations of Cu, Pb, Hg, Mn, Fe, and P in leachate from sediment leached with 0.5 N HCl, as well as the total carbon (TC) content and analysis was used to assess the experimental data. The removal of such heavy metals as Hg from sediments by mangroves was estimated to be up to 6.5% of the weakly bound species. The authors suggest that mangrove ecosystems may be used as a cheap method of treating industrial waste containing low levels of heavy metals. (Author's abstract)

Appendix A
Bibliography

WASTEWATER AND DOMESTIC MUNICIPAL SEWAGE - NATURAL WETLANDS

BIBLIOGRAPHY

1. Alexander, F. M.; Keck, L. A.; Conn, L. G.; Wentz, S. J. Drought-Related Impacts on Municipal and Major Self-Supplied Industrial Water Withdrawals in Tennessee, (Part A and Part B). Available from OFSS, USGS, Box 25425, Lakewood, Co 80225. USGS Water-Resources Investigation Report 84-4074, 1984. 414 p, 47 fig, 55 tab, 44 ref. Note: Geological Survey, Nashville, TN. Water Resources Div. SWRA1909. A state-wide water use survey was conducted of all public water suppliers and large, self-supplied industries in Tennessee. This report contains a summation of the data received from 463 public-water suppliers and 129 self-supplied water users. Analysis of the study results and findings indicate that many communities in Tennessee do experience occasional water supply, quantity-related shortages. A total of 142 problems were reported by 107 of the public water suppliers. However, only 22 of the problems were a result of inadequate source supply. Although only three industries reported a water shortage problem, 20 were identified as having a potential water-supply source problem. West Tennessee was the only section of the state where all communities and industries surveyed reported an adequate water supply. The effects of a drought on the environment--specifically, wetlands, fish wildlife, and recreational-users--are briefly described, although there was no evidence that water withdrawn by communities or industry would directly affect the environment. This study appears to verify the conclusion that an extended drought, although directly affecting the supply to some communities and industries, may actually affect water quality and wastewater treatment more accurately by decreasing the ability of the source to assimilate wastes. (USGS).

2. Asano, T. Water Reclamation and Reuse. Journal-Water Pollution Control Federation JWPFA5, Vol. 61, No. 6, p 841-844, June 1989. 74 ref.

Note: California State Water Resources Control Board, Sacramento. SWRA2212.

Wastewater reclamation and reuse are reviewed, concentrating on 'big picture' developments and technologies which contributed more to water supply benefits than pollution control measures. The proceedings of the Water Reuse Symposium IV contained 89 papers and has shown that wastewater reclamation and reuse are both technically and economically feasible. Health risk issues related to water reuse have also been reviewed. Water reuse planning and analysis include market assessment and user contracts, feasibility, cost estimates, implementation of the reclaimed water uses for flushing toilets and urinals in high-rise office buildings, surveys of public acceptance, and agricultural water reuse. In the area of groundwater recharge and municipal wastewater reuse, projects in several U.S. cities were discussed. Industrial recycling and reuse projects include wastewater generated from heated caustic stripping baths; reuse of wastewater for industrial cooling systems; membrane technologies of microfiltration, ultrafiltration, and reverse osmosis for metal-finishing rinse water; and use of reclaimed municipal wastewater for energy station cooling, lake, wetland enhancement and power plant cooling, and industrial cooling systems. Recent technological developments are reported for toxicology testing; aquaculture wastewater treatment using water hyacinth, advanced water treatment, and energy recovery; and the selection of coagulants, their interaction with humic substances, and filtration. (White-Reimer-PTT).

3. Borofka, B. P.; Cousins-Leatherman, C. S.; Kelley, R. D. Developing a State Ground Water Policy in the Corn Belt: the Iowa Case. IN: Ground Water Quality and Agricultural Practices. Lewis Publishers, Chelsea, Michigan. 1987. p 389-395, 3 fig. Note: IT Corp., Monroeville, PA. SWRA2203.

An overall groundwater protection strategy which assesses all potential sources of groundwater contamination including those associated with agriculture was developed in Iowa. Surveys indicate that 68 percent of all municipal drinking water in Iowa is derived from groundwater as well as approximately 100 percent of the private rural drinking water. There are several studies which indicate that nitrate contamination is more than a surface water or runoff problem in Iowa. The problem is getting more serious as rates of fertilizer appreciation increase. The problem may not be limited to shallow groundwater exclusively. Due to the presence of fractured bedrock in parts of Iowa, agricultural drainage wells were commonly used for draining wetlands to create cultivated farmland. A preliminary survey of public water supplies found detectable residues of commonly used pesticides in 57 percent of the wells sampled. Several types of pesticides have been routinely detected, including five herbicides and three insecticides: atrazine, bladex, sencor, dual, lasso, dyfonate, counter, and bolstar. A goal has been set for Iowa's Ground Water Protection Strategy: to develop a unified approach among all federal, state, and local programs in Iowa in order to prevent groundwater contamination, to restore groundwater quality in areas where pollution has occurred and to maintain an adequate supply of acceptable quality groundwater for Iowa's projected uses and demands. The strategy development steps include: identification of the problem; identification of policy and program alternatives; selection of management options; application of the technical assessment. Several pieces of environmental legislation were passed by the Iowa House and Senate. Several bills are waiting for the governor's signature: landfill ban by 1997; a one-time test of municipal water supplies for pesticides; testing of bottle water for contaminants; testing/certification of home water treatment devices; and proposed use of the Exxon Rebate for education and demonstration project. The end results would lead to conservation of natural gas and gasoline, as well as protection of the groundwater. (See also W89-02654) (Davis-PTT).

4. Bowen, G. E.; Gangaware, T. R. Land Development and Water Quality: The Cayman Islands Study. IN: Tropical Hydrology and Caribbean Water Resources. Proceedings of the International Symposium on Tropical Hydrology and Fourth Caribbean Islands Water Resources Congress, San Juan, Puerto Rico, July 22-27, 1990. American Water Resources Associat. Note: Tennessee Univ., Knoxville. SWRA2406. Teams of planners, ecologists, engineers and business students from the University of Tennessee studied the relationship between economic development and environmental protection in the Cayman Islands. They found the most interrelated elements were land development and water quality, with specific factors such as: water lenses and potable water supply, stormwater runoff and erosion, wetlands and swampland reclamation, and water clarity and reef ecology. The overall conclusion of the assessments was that the terrestrial and coral ecologies are interrelated with and dependent on water quality. The health of the coral reefs are related to the preservation of swamplands. Potable water is dependent on land development practices, waste disposal practice and swamp hydrology. Beach erosion is related to storm water removal, land development practices and reef decomposition. In the Caymans the mangrove swamps are ecologically productive and environmentally sensitive. Swampland reclamation and dredging are creating irreversible environmental damage to reef ecology. (See also W91-05611) (Author's abstract).

5. Brix, H. Applicability of the Wastewater Treatment Plant in Othfresen as Scientific Documentation of the Root-Zone Method. Water Science and Technology WSTED4, Vol. 19, No. 10, p 19-24, 1987. 1 fig, 1 tab, 9 ref. Danish Natural Science Research Council Project No. 11-4591. Note: Aarhus Univ. (Denmark). Botanical Inst. SWRA2106. Documentation for the functioning of the root-zone method of wastewater treatment is based almost exclusively on data from the Othfresen plant in West Germany, a 22.5 ha wetland, which since 1974 has received municipal wastewater. The present paper describes the working experiences from Othfresen, and evaluates the applicability of the data from Othfresen as basis for the scientific documentation of the

root-zone method in general. It is concluded that the data from Othfresen are useless in the documentation of the root-zone method for the following reasons: (a) The loaded area has not been well-defined until 1985, (b) the soil in the treatment plant is very atypical (old mine debris), (c) a major proportion of the wastewater does not penetrate the soil, but distributes on the surface as overland flow, (d) the quality of the water in the 'defined' outlet, i.e., a well consisting of a PVC-tube, has no relation to the treatment of wastewater in the area, and (e) the true effluent to the the receiving stream (Innerste) is of varying quality, especially as far as nitrogen is concerned. It is therefore necessary to await results from well-controlled experimental treatment plants before the functioning and the applicability of the root-zone method can be properly evaluated. (Author's abstract).

6. Brix, Hans. HIGH ORGANIC LOAD STABILIZATION POND USING WATER HYACINTH - A 'BAHIA' EXPERIENCE. Water Science and Technology v 19 n 10 1987, Use of Macrophytes in Water Pollut Control, Proc of an IAWPRC Spec Semin, Piracicaba, Braz, Aug 24-28 1986 p 25-28. 1986; . CODEN: WSTED4; ISSN: 0273-1223. Note: Univ of Aarhus, Risskov, Den English A (Applications) X (Experimental) 8805.
Up to the present time documentation for the functioning of the root-zone method was almost exclusively based on data from the Othfresen plant in Western Germany, a 22. 5 ha large wetland, which since 1974 has received municipal wastewater. The present paper describes the working experiences from Othfresen, and evaluates the applicability of the data from Othfresen as basis for the scientific documentation of the root-zone method in general. It is concluded that the data from Othfresen are useless in the documentation of the root-zone method for the following reasons: (a) the loaded area has not until 1985 been well-defined, (b) the soil in the treatment plant is very atypical (old mine debris), (c) a major proportion of the wastewater does not penetrate the soil, but distributes on the surface as overland flow, (d) the quality of the water in the 'defined' outlet, i. e. a well consisting of a PVC-tube, has no relation to the treatment of wastewater in the area, and (e) the true effluent to the recipient is of varying quality, especially as far as nitrogen is concerned. (Edited author abstract) 9 refs.

7. Chale, F. M. M. Plant Biomass and Nutrient Levels of a Tropical Macrophyte (Cyperus papyrus L.) Receiving Domestic Wastewater. Hydrobiological Bulletin HYBUD9, Vol. 21, No. 2, p 167-170, December 1987. 1 tab, 19 ref. Note: Dar es Salaam Univ. (Tanzania). Dept. of Zoology and Marine Biology. SWRA2205.
The aboveground biomass and nutrient content of C. papyrus were determined in a small tropical swamp receiving domestic wastewater. The biomass (4,955 g/sq m dry wt) was the highest ever reported for papyrus. The levels of both N and P in the plant organs were very high. The N concentrations were 4.8% roots, 8.4% rhizomes, 4.5% scales, 4.8% culms, and 6.2% umbels on dry weight basis. The

P concentrations were 0.09% roots, 0.11% rhizomes, 0.09% scales, 0.10% culms, and 0.13% umbels. The high biomass and nutrient contents of the plants may have been caused by the high nutrient levels in the surrounding water. Comparison of the N to P ratios in the plants to those in the surrounding water showed that the plants stored very high amounts of N. (Author's abstract).

8. Criteria for Municipal Solid Waste Landfills (40 CFR Part 258). Subtitle D of Resource Conservation and Recovery Act (RCRA). Location Restrictions (Subpart B)Draft rept. 1988 Jul;
Note: NUS Corp., Rockville, MD. 064680000 Environmental Protection Agency, Washington, DC. Office of Solid Waste. English GRAI8822 Portions of this document are not fully legible. Sponsored by Environmental Protection Agency, Washington, DC. Office of Solid Waste. United States.
In August 1988, the U.S. Environmental Protection Agency proposed Solid Waste Disposal Facilities Criteria (40 CFR Part 258) for municipal solid waste landfills. The background document provides the technical support for Subpart 'B' - Location Restrictions of Part 258. The document contains a discussion of the legislative and regulatory background for understanding the current status of Subtitle D. A discussion of other Federal laws, besides the Resource Conservation and Recovery Act (RCRA), that impact the siting of municipal waste landfills also is presented. The document also presents detailed information on the revised location restrictions. The location restrictions include the following: airport safety; floodplains; wetlands; fault areas; seismic impact areas; and unstable areas.

9. Crites, R. W.; Mingee, T. J. Economics of aquatic wastewater treatment systems. Aquatic plants for water treatment and resource recovery/ edited by K.R. Reddy and W.H. Smith. Note: Nolte and Associates, Sacramento, CA English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

10. Davis, D. G.; Montgomery, J. C. EPA's regulatory and policy considerations on wetlands and municipal wastewater treatment. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith. Note: U.S. Environmental Protection Agency, Washington, D.C. English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

11. DeBoer, J. Overview of Water Reuse for Developing Countries. IN: Non-Conventional Water Resources Use in Developing Countries. Proceedings of the Interregional Seminar, Willemstad, Curacao, Netherlands Antilles, April 22-28, 1985. p 160-178, 4 fig, 5 tab, 11 ref.

Note: American Water Works Association Research Foundation, Denver, CO. SWRA2109.
Reuse of municipal wastewater for beneficial purposes has been practiced for many years throughout the world. Several economic, social, legal, and technical factors affect water reuse. As the demand for water increases in developing countries, the demand for a reclaimable wastewater also increases. The technology available for water reuse is a combination of existing wastewater treatment and water supply treatment technologies, with the addition of some industrial treatment technologies. Besides conventional treatment systems for the treatment of wastewater for reuse, aquaculture ponds, wetlands disposal systems, and other land disposal methods are available. Advanced wastewater treatment systems offer nutrient removal, and enhanced solids removal. Dual distribution systems, supplying potable water through a primary system, and a lower quality, reclaimed wastewater through a secondary system, have been used at many sites in the United States. Health effect implications of water reuse for potable purposes are being investigated in numerous studies. Health effects are also a concern when reclaimed wastewater is used for non-potable purposes, such as agricultural irrigation, urban irrigation or industrial applications. Some representative treatment process costs for water reuse are presented. (See also W88-07850) (Geiger-PTT).

12. DeBoer, J.; Linstedt, K. D. ADVANCES IN WATER REUSE APPLICATIONS. Water Research v 19 n 11 1985 p 1455-1461. 1985; . CODEN: WATRAG; ISSN: 0043-1354. Note: AWWA, Research Foundation, Denver, CO, USA ENGLISH G (General Review) X (Experimental) 8511.
Industrial recycling has developed to the extent that it is a routine operation in many industrial facilities. This article presents a general review of wastewater reuse and recycling in metal industries, in industrial cooling and energy production, and in fiber, paper, and food industries. Detailed attention is also given to irrigation of municipal facilities and crop irrigation with municipal wastewater, and to the use of wetlands and aquaculture for wastewater treatment. Refs.

13. Dierberg, Forrest E.; Brezonik, Patrick L. TERTIARY TREATMENT OF MUNICIPAL WASTEWATER BY CYPRESS DOMES. Water Research v 17 n 9. 1983 p 1027-1040. 1983; . CODEN: WATRAG; ISSN: 0043-1354. Note: Florida Inst of Technology, Dep of Environmental Science & Engineering, Melbourne, Fla, USA ENGLISH 8401.
The feasibility of using cypress domes as an alternative to physical-chemical methods for tertiary treatment of sewage effluent was demonstrated over a 5-year period. Surface water quality in domes receiving effluent was degraded compared to control domes, and the degree of treatment within the dome surface waters was relatively small. However, water samples indicated that the underlying organic soils and clay sands served as an effective barrier to the transport of biochemical oxygen demand, nitrogen, phosphorus, sulfate, fluoride, potassium,

sodium, calcium, and magnesium to the shallow aquifer immediately below. High percentage removals were observed for all measured water quality parameters between the surface and groundwater stations. Standing water quality following the cessation of sewage puming did not return to the same quality as found for the natural dome within 20 months. Refs.

14. Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. 473p. Edited by Paul J. Godfrey, Edward R. Kaynor, Sheila Pelczarski, and Jay Benforado. Contract No. RFP FWS-9-82-001. Note: SWRA2202. Thirty-one papers are presented within the format of seven topical 'sessions' and an eight session that attempts to pull together and synthe size the diverse findings and conclusions of the conference. Session I deals with state-of-the-art engineering applications of wastewater to wetlands. Session II deals with the multiplicity of environmental values and perspectives that must be considered. Session III shifts the emphasis to specifics of ecosystem dynamics, particularly the interaction between hydrology and nutrients. Session IV addresses the general topic of possible wetland community changes resulting from wastewater applications. Session V focuses on environmental health problems for humans and wildlife that could result from accumulations of pathogens or toxic materials. Session VI considers the question of long-term effects by examining several case histories of wetlands that have received wastewater or simulated wastewater and have been studied for many years. Session VII returns in part to engineering considerations by addressing the topic of wetland management potential. Session VIII attempts to synthesize the varying points of view and scientific documentation contained in the papers of the preceding sessions. (See W89-01828 thru W89-01858) (Lantz-PTT).

15. Edsall, T. A.; Manny, B. A.; Raphael, C. N. St. Clair River and Lake St. Clair, Michigan: An Ecological Profile. Fish and Wildlife Service, Washington, DC. Biological Report 85(7.3), April 1988. 130p, 75 fig, 40 tab, 218 ref. Note: Fish and Wildlife Service, Ann Arbor, MI. Great Lakes Fishery Lab. SWRA2202.
The St. Clair system is an extremely valuable resource that provides quality recreational opportunities to many people in southeast Michigan and the bordering areas of Ontario. Much of the St. Clair Delta remains in its natural state and more than 42,000 acres of wetlands in the delta support a large and diverse flora and fauna. The St. Clair system is heavily used by recreational boaters, waterfowl hunters, and anglers. Fishing through the ice is a popular winter activity in some parts of the system. The waters of the St. Clair system are also used for navigation and for the disposal of municipal and industrial wastes, while the shorelines support industrial and residential development and agriculture. Recognition of potentially severe use conflicts has focused concern on preparation by Michigan and Ontario of Remedial Action Plans designed to control pollution by toxic substances and restore all

beneficial uses to each affected area, consistent with a continued, multiple-use philosophy for the system. This profile is a synthesis of available information on this waterway, especially information pertinent to managing the biological resources of the river and lake. Information gaps are identified and accommodated by reference to research done elsewhere or to management plans for other similar rivers and lakes. Wherever possible, the river and lake are described from a systems viewpoint as an intact, integrated unit of the Great Lakes ecosystem. (Lantz-PTT).

16. Ellis, J. B. URBAN RUNOFF QUALITY AND CONTROL. Advances in Water Engineering.Publ by Elsevier Applied Science Publ, London, Engl and New York, NY, USA p 234-240. 1985; . CODEN: 1985 Jul 15-19. Note: Middlesex Polytechnic, Enfield, Engl Univ of Birmingham, Dep of Civil Engineering, Birmingham, Engl English 8612. The quality of separate stormwater runoff and storm sewage overflows are reviewed and their receiving water impacts evaluated in terms of oxygen depletion, metal accumulation and bacterial violations. Cost-effective control strategies are outlined and source control engineering practices are recommended to achieve environmental quality objectives. (Author abstract) 33 refs.

17. Environmental Program for the Mediterranean: Preserving a Shared Heritage and Managing a Common Resource. 1990; Note: International Bank for Reconstruction and Development, Washington, DC. 063877000 European Investment Bank, Luxembourg. English GRAI9014 Library of Congress catalog card no. 90-12072. Sponsored by European Investment Bank, Luxembourg. Microfiche copies only. Paper copy available from World Bank Publications, P.O. Box 7247-8619, Philadelphia, PA 19170-8619. Phone: (201) 225-2165. United States. Contents: (1) A Strong Regional Identity: The Guiding Principle for Collective Action; (2) Taking Stock: The Nature and Extent of Environmental Degradation; (3) The Causes of Environmental Degradation; (4) Toward a Program of Environmental Action; (5) The Environmental Program for the Mediterrean: How the Strategies of the Banks Will Support Regional Action.

18. Felley, J. D. Nekton Assemblages of the Calcasieu River/Lake Complex. IN: Ecosystem Analysis of the Calcasieu River/Lake Complex (CALECO). Report No. DOE/EP/31111--1-Vol. 2, June 26, 1987. Final Report Sampling Dates: October 1983-August 1986. p 406-496, 7 fig, 6 tab, 49 ref. DOE Grant DE-FG01-83EP31111. Note: McNeese State Univ., Lake Charles, LA. Dept. of Biological and Environmental Sciences. SWRA2206. Species of nekton were sampled monthly by trawl in Calcasieu Lake, a chenier-plain estuary, from October 1983 to August 1986. Additionally, nekton species were sampled monthly by seine in Calcasieu Lake and in three bayous that feed into the estuary, from September 1985 to

August 1986. For each sample, number of individuals and total biomass of each species was recorded. Also, individuals of commercially important species (penaeid shrimps, Brevoortia spp., sciaenids) were weighed and measured. For purposes of analysis, three different data sets were defined, as follows: (a) trawl samples from Calcasieu Lake; (b) seine samples from Calcasieu Lake; and (c) seine samples from three bayous (bayous Choupique, Contraband and d'Inde). For each data set, detrended correspondence analysis (DCA) was performed on a species by-sample matrix containing numbers of individuals of all species sampled. Of the three bayous sampled, Choupique Bayou was comparatively unaffected by human activities. Contraband Bayou and Bayou d'Inde have been highly modified by human activities; both have been dredged and channelized along portions of their lengths, and both receive wastes from municipal sewage treatment plants. In addition, Bayou d'Inde receives industrial waste from a large petrochemical complex. Choupique Bayou was quite rich in species, with an average of 23.7 species sampled each month. The species found in Contraband Bayou were a subset of those found in Choupique Bayou. Samples from Contraband Bayou averaged 14.8 species each month, but lacked many oxygen-sensitive species found in Coupique Bayou. Species found in Bayou d'Inde were a restricted subset of those found in Contraband Bayou (average of 10.1 species sampled each month). Most of the species inhabiting Bayou d'Inde were relatively less abundant than in Contraband Bayou. The results of this study suggest that human activities dramatically reduced the number of species found in a bayou, and reduced the value of the bayou as a nursery area for commercially important species. (See also W89-06605) (Lantz-PTT).

19. Finn, J. T. Energy Flow in Wetlands. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 112-126, 13 fig, 13 ref.
Note: Massachusetts Univ., Amherst. Dept. of Forestry and Wildlife Management. SWRA2202.
The ecosystem dynamics unique to each wetland pose the difficult problem of predicting the impacts of management for treatment of municipal wastewater so that undesirable changes may be avoided. Few of the available analytical tools will permit the evaluation of wetlands models or the general prediction of the consequences of wetland modification. An analytical technique called flow analysis is proposed as a method for such evaluations. Demonstrations illustrate the types of information that can be gained from analysis of energy and carbon (C) flow in two wetlands. Flow analysis allows dissection of complex flow networks, so that flows from a particular compartment to any other compartment can be analyzed. In analyzing wetlands energy-flow models, indirect flows are often more important than direct flows. Moreover, energy cycling can be an important component of indirect energy flow. Flow analysis can also provide estimates of the timing of flows -- that is, how long it takes for energy to get from organism A to organism B. In Barataria Bay, for example, an increase in primary

production would still have large effects on marsh detritus three years later and on aquatic fauna four years later. Maximum effect on marsh detritus would be expected in year one, and on aquatic fauna in year two. The exact timing of impact effects cannot be determined without a time series of measurements or a simulation model because flow structure will change, but these approximations will be close. Finally, flow analysis can also be used to address questions of elemental cycling and toxin fate. For both elements and toxins, indirect effects are much more important than for energy. (See also W89-01827) (Lantz-PTT).

20. Fiscal Year 1989 Program Report (California Water Resources Research Center). Available from National Technical Information Service, Springfield, VA 22161 as PB91-104331. Price codes: A03 in paper copy, A03 in microfiche. Program Report G-1550-01, 1990. 37p. USGS Contract No. 14-08-0001-G1550. USGS Project No. G-15. Note: California Univ., Riverside. Water Resources Center. SWRA2405.
This report contains a synopsis of the results of research projects sponsored under Grant No. 14-08-0001-G1550, the 1989 Water Research Institute Program (WRIP) for the University of California Water Resources Center. It also contains summaries of water problems and issues in California and the Water Resources Center's Program Goals and Priorities, Information Dissemination Activities and Cooperative Arrangements. The California WRIP package is a subset of the Center's overall research program and consists of five projects investigating the following topic areas: Mixing in Bay/Delta Flows, Dynamics of Selenium and Arsenic Oxidation in Water-Sediment Systems, Wetland Treatment of Urban Runoff, Adaptive Grid Refinement for Groundwater Contaminant Transport Simulation, Innovative Approaches to Wastewater Management Along the California-Mexico Border. (USGS).

21. Fiscal Year 1989 Program Report (California) Water Resources Center. 1990;
Note: California Univ., Riverside. Water Resources Center. 005433048 Geological Survey, Reston, VA. Water Resources Div. English GRAI9101 See also report for 1988, PB90-138595. Sponsored by Geological Survey, Reston, VA. Water Resources Div. United States.
The report contains a synopsis of the result of research projects investigating the following topic areas: Mixing in Bay/Delta Flows, Dynamics of Selenium and Arsenic Oxidation in Water-Sediment Systems, Wetland Treatment of Urban Runoff, Adaptive Grid Refinement for Groundwater Contaminant Transport Simulation, Innovative Approaches to Wastewater Management Along the California-Mexico Border.

22. Gearheart, R. A.; Wilbur, Steven; Hull, David; Finney, Brad A. REDUCTION OF PUBLIC HEALTH SIGNIFICANT ORGANISMS THROUGH WETLAND TREATMENT PROCESS. Environmental Engineering, Proceedings of the 1984 Specialty Conference.National Conference on Environmental Engineering 1984. Publ by ASCE, New York, NY, USA p 585-590. 1984; . CODEN: 1984 Jun 25-27

NCEEDO. Note: Humboldt State Univ, Engineering Dep, Arcata, Calif, USA ASCE, Environmental Engineering Div, New York, NY, USA Univ of Southern California, Dep of Civil Engineering, Los Angeles, Calif, USA ASCE, Los Angeles Section, Los Angeles, Calif, USA English 8408.

23. General Management Plan Amendment, Development Concept Plan/Environmental Assessment, Indiana Dunes, National Lakeshore, IndianaDraft rept. 1990 Sep; Note: Indiana Dunes National Lakeshore, Porter, IN. 087267000 English GRAI9109 Also available from Supt. of Docs. See also PB81-212821. United States.
The General Management Plan Amendment and West Unit Development Concept Plan/Environmental Assessment updates the February 1980 General Management Plan (GMP) considering the full range of issues that will affect the West Unit through the year 2000. The management issues include boundary adjustments to protect the valuable dune and wetland environments, use of lands adjacent to Lake Michigan and the Portage/Burns Waterway formerly used for hazardous waste disposal, access to West Beach, and impacts of increased traffic and visitation on adjacent communities. Issues that were not known or not a concern in the 1980 GMP are the need to coordinate access improvement proposals for West Beach with the proposed Gary marina and Marquette Park, the feasibility of the GMP West Beach access proposal because of its cost and possible environmental impacts, and planning for lands included in the national lakeshore since the GMP was approved - i.e., lands between the Douglas Center and Broadway in Gary.

24. Godfrey, Paul J. _1940-. Ecological considerations in wetlands treatment of municipal wastewaters edited by Paul J. Godfrey ... [et al.]. --. Note: English Includes bibliographies and index. New York OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

25. Grimes, D. J. Microbiological Studies of Municipal Waste Release to Aquatic Environments. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 270-276, 4 fig, 10 ref.
Note: Maryland Univ., College Park. Dept. of Microbiology. SWRA2202.
Studies on the disposal of municipal wastes to aquatic environments have shown that both human pathogens and fecal indicator bacteria can survive in water for a long time. Many bacteria are able to survive, even to grow, in sediments. Sedimented bacteria are subject to resuspension by a variety of physical forces, including wave action, animal disturbance, swimming, and dredging. A study of the disposal of pharmaceutical wastes in the Atlantic Ocean near Puerto Rico shows that rather than settling into deep water, the effluent tends to move toward the northern shore of Puerto Rico. These data are all from environments that have currents or wave action to dilute and dissipate many of the

entering pollutants, including bacteria. Wetlands do not have this advantage. Accordingly, introduction of improperly treated wastes could have severe deleterious impacts on the health status of such wetlands. Both pathogenic bacteria and the nutrients to support those bacteria could accumulate, thereby creating a disease reservoir. (See also W89-01827) (Lantz-PTT).

26. Gunnerson, C. G.; Stuckey, D. C. Anaerobic Digestion: Principles and Practices for Biogas Systems World Bank technical paper. 1986; Note: International Bank for Reconstruction and Development, Washington, DC. 063877000 English GRAI8615 See also PB86-115417. Library of Congress catalog card no. 86-5577. Microfiche copies only. Paper copy available from World Bank, 1818 H St., NW, Washington, DC 20433. United States.
The report is part of a joint global research, development and demonstration effort of the United Nations Development Programme and the World Bank. It explores the history, technology, and applications of anaerobic digestion, the biological process by which organic materials are degraded in the absence of oxygen to produce a combustible gas, methane (CH4), and carbon dioxide (CO2). The process occurs naturally in wet, decaying organic matter (biomass) found in swamps, bottom muds of streams, and garbage dumps. Since about 1900, it has been used in engineered systems for treatment and stabilization of municipal or industrial sludges. Starting around 1920, systems have been operated so as to capture the biogas, identical to marsh gas which contains about 55-75 percent methane, as an energy source. In addition to producing a fuel substitute, benefits of digestion include reduction or elimination of pathogens in human and animal wastes and production of a stable, generally environmentally acceptable slurry or sludge which can bY@used as a fertilizer and soil conditioner. (Copyright (c) 1986, The International Bank for Reconstruction).

27. Hammer, D. E. An engineering model of wetland/wastewater interactions. DISS. ABST. INT. PT. B - SCI. & ENG. 1985; VOL. 45, NO. 7. Note: Diss. Ph.D. Order No.: FAD DA8422244. ENGLISH.
Application of wastewater to wetland areas has been practiced at a number of sites, in some cases for more than fifty years. In most instances, natural wetland ecosystem mechanisms remove residual phosphorus, nitrogen and other pollutants from these waters down to low levels, accomplishing advanced wastewater treatment. The design of such facilities has not however been reduced to practice. A simple, tractable mathematical model is developed which permits dynamic simulation of wetland hydrology and of interactions between secondary treated municipal wastewater and the wetland ecosystem. Spatial variations due to surface water flow are described, and material balance calculations carried out for phosphorus, nitrogen, and chloride. Hydrology model features include predictions of overland flow. Ecosystem phenomena are represented, using a one-dimensional, spatially distributed compartmental model.

28. Health Assessment for Ludlow Landfill National Priorities List (NPL) Site, Clayville, Oneida County, New York, Region 2. CERCLIS No. NYD013468939 Final rept. 1988 Aug 25; Note: Agency for Toxic Substances and Disease Registry, Atlanta, GA. 092477000 English GRAI9006 United States.
The Ludlow Landfill is a National Priorities List site located in Clayville, Oneida County, New York. The landfill was in operation for over 20 years and was closed February 15, 1988. At the time of its closure only municipal refuse was being accepted for disposal, but in the past, some industrial wastes were deposited in the landfill. The primary contaminants found at the site are polychlorinated biphenyls (PCBs) and volatile organic compounds. Off-site migration of contaminants can occur via ground water, surface water and suspended sediments. Potential adverse effects on public health could occur if PCBs or other site-related chemicals migrated off-site in ground water and contaminated downgradient potable well supplies. Human exposure to PCB-contaminated soils in the wetlands or the consumption of biota from the wetlands are also pathways of potential public health concern.

29. Heidinger, R. C. Fishes in the Illinois Portion of the Upper Des Plaines River. Transactions of the Illinois Academy of Science TISAAH, Vol. 82, No. 1-2, p 85-96, 1989. 6 tab, 10 ref. Note: Southern Illinois Univ., Carbondale. Dept. of Zoology. SWRA2304.
The Des Plaines River Wetlands Demonstration Project is the reconstruction of a riverine wetland on a 182 ha site bordering a 4.67 km stretch of the Upper Des Plaines River. The site is in Wadsowrth, Illinois, 58 km north of Chicago. The river, which drains a 5400 sq km watershed (80% is agricultural and 20% urban), is polluted with non-point source contaminants from both urban and agricultural activities. The composition and relative abundance of fish species in the upper portion of the Des Plaines River are reported. Ninety percent of the fish biomass in this section of the river is carp. Standing crop estimates of carp indicate 371 kg/km of river. By almost any measure, the fish habitat in the upper Des Plaines River has been seriously degraded since the pre-settlement era due to channelization, urbanization, and agricultural practices. This has lead to a reduction in or loss of many pollution-sensitive species. (Mertz-PTT).

30. Illinois Water Quality Report: 1986-1987. Available from the National Technical Information Service, Springfield, VA 22161, as PB88-223342. Price codes: E14 in paper copy, A01 in microfiche. Report No. IEPA/WPC/88-002, April 1988. 305p, 27 fig, 107 tab, 40 ref, 14 append. Note: Illinois State Environmental Protection Agency, Springfield. Div. of Water Pollution Control. SWRA2207.
This report addresses the quality of the waters of the State of Illinois for the period of 1986 and 1987 in fulfillment of Section 305(b) of the Clean Water Act (CWA). Waterbodies including rivers, streams, inland lakes, and Lake Michigan are assessed for degree of designated use support and attainment of fishable/swimmable Clean Water Act goals.

Brief discussions of the State's wetland resources and groundwater protection programs are also provided. A total of 2,993.6 river miles are assessed for attainment of the swimmable CWA goal. The major causes of less than full support include nutrients, siltation, habitat/flow alteration, organic enrichment/DO, ammonia/chlorine and metals. The major sources include agriculture, point sources, hydrologic/habitat modification, construction/urban runoff, and resource extraction. The primary causes of use impairment for lakes are suspended solids, siltation, organic enrichment/DO deficiencies, and nutrients. Nuisance aquatic plants and taste and odor are the next most important causes impacting impaired lakes; toxics and other causes are of relatively minor importance statewide. Lake Michigan includes a total of 63 shoreline miles, forming the northeastern portion of Illinois' border. All 63 shoreline miles are assessed to be partially supporting designated uses with minor impairment. The causes for full support include total phosphate concentrations in water column samples and priority organics based on the sport fish advisory. Major sources include atmospheric deposition, urban runoff, and in-place contaminants. Groundwater monitoring and assessment information to date indicate statewide groundwater quality is generally good. However, major sources of identified contamination and the relative priority of activity in the State surround leaking underground storage tanks, abandoned hazardous waste sites, and municipal and industrial landfills. Substances identified as contaminants include organic and inorganic chemicals, metals, radioactive materials, pesticides and other agricultural chemicals, arsenic, brine, and petroleum products. (Lantz-PTT).

31. Kaczynski, V. W. Considerations for Wetland Treatment of Spent Geothermal Fluids. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 48-65, 2 fig, 4 tab. Note: CH2M, Inc., Portland, OR. SWRA2202.
Most wetlands treatment studies have dealt with the disposal of partially treated municipal sewage effluent; industrial applications are not common. A generic research study was recently performed that investigated the feasibility of disposing spent industrial geothermal fluids by wetlands treatment. The main objectives of this paper are: (1) to present two sets of ecological criteria for effluent application in wetlands in order to discuss their appropriateness (especially in terms of industrial effluents or municipal effluents with major industrial contributors that do not have pretreatment programs) and (2) to present some general design environmental effects, and ecological factors associated with selecting sites and designing wetlands for effluent treatment. The reference studies were directed primarily toward creating and managing wetlands as alternative treatment systems, with secondary objectives of providing waterfowl and wildlife habitat. These studies were done mainly in relatively water-short western areas. (See also W89-01827) (Lantz-PTT).

32. Kadlec R H. Wetlands For Treatment Of Municipal Wastewater. Majumdar, S. K., ET AL. (ED.). PENNSYLVANIA ACADEMY OF SCIENCE PUBLICATIONS: WETLANDS ECOLOGY AND CONSERVATION: EMPHASIS IN PENNSYLVANIA. XIV+395P. PENNSYLVANIA ACADEMY OF SCIENCE: EASTON, PENNSYLVANIA, USA. ILLUS. MAPS. ISBN 0-945809-01-8. 314; . CODEN: 28377. Note: DEP. CHEM. ENG., UNIV. MICH., ANN ARBOR, MI 48109-2136. ENGLISH.

33. KADLEC R H; LI X-M. PEATLAND ICE-WATER QUALITY. WETLANDS Wetlands. 106 Oct; . CODEN: WETLE. Note: DEP. CHEM. ENGINEERING, UNIV. MICH., ANN ARBOR, MICH. 48109-2136. ENGLISH.
Freezing of the shallow water in a northern peatland caused downward movement of solutes. Nutrients and tracers were rejected from overlying water, with lesser effects in a wetland receiving treated municipal wastewater. Concentration profiles within the ice are controlled by starting concentrations and rate of freezing. High concentrations near the ice top are caused by initial fast freezing, but solute accumulations near the soil surface can cause high concentrations at the lower ice surface also. Chloride partitions most strongly; nutrients or biologically active species partition less strongly. Complex mass and energy balance calculations can provide reasonable estimates of chloride concentrations, but sufficient field data would rarely be available to execute detailed predictions for other ions. Processes involving ice are important in the reallocation of dissolved species within peatlands. Ice formation can cleanse closed-basin wetland once each year.

34. Kadlec, R. H. The hydrodynamics of wetland water treatment systems. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith. Note: The University of Michigan, Ann Arbor, MI English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

35. Kadlec, R. H. Northern natural wetland water treatment systems. Aquatic plants for water treatment and resource recovery/edited by K. R. Reddy and W.H. Smith. Note: The University of Michigan, Ann Arbor, MI English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

36. Kadlec, Robert H.; Hammer, David E. Wastewater Renovation in Wetlands: Six Years at Houghton Lake. Proceedings Water Reuse Symposium III: Future of Water Reuse; 1984 Aug 26; San Diego, CA. vol 2, p 596-616. ISBN: 0-915295-02-4. Note: University of Michigan,

Department of Chemical Engineering 16 references, tables, figures English. This paper discusses the use of wetlands to treat wastewater. Since 1978, secondary municipal wastewater has been discharged to a 700 hectare peatland, at an average annual rate of 106 million gallons. Sewage collected from the community of Houghton Lake, Michigan, is aerated and held for summer pumping. The unchlorinated effluent arrives at the wetland with approximately 3 parts per million (ppm) ammonium nitrogen, 3 ppm total phosphorus, 20 ppm total suspended solids, and 15 ppm biochemical oxygen demand (BOD). Total removal of added nutrients occurs within a 40 hectare region enclosing the gated discharge pipe, with only background amounts remining. Suspended solids deposit in this zone of influence, but large amounts of detritus are generated in the wetland and partly settle there. Some fine organic solids exit the wetland, so no net solids removal is achieved. BOD is reduced, but not eliminated, in passage of water through the ecosystem. Water flows slowly downgradient in a thin sheet. This water is flushed on the average of about once per year, which leads to similar delay times for tracers, such as chloride, to reach the wetland outfalls. During dry periods, backflow can be significant, but no edge leakage has been observed. Nitrogen, phosphorus, and other mobile constituents are incorporated, during the growing season, into an increased living biomass pool, composed chiefly of grasses, sedges, and cattails, plus willow and bog birch (woody shrubs). In addition, large summer growth of algae and duckweed contribute sediments. Sorption of pollutants on soils and sediments also occurs. Some pollutants, such as nitrogen, can also be converted to gaseous forms and released to the atmosphere. As a result, a frontal progression of some materials, notably phosphorus, expands the area of influence until permanent mechanisms, s,x@as added peat formation, can accomodate the added inputs. Data clearly define this phenomena. The speed of a saturation front depends on the immobilization and removal mechanism and differs greatly from substance to substance. This water treatment alternative has proven successful, easy to operate, and economical.

37. Kaldec, R. H.; Alvord, H. Mechanisms of Water Quality Improvement in Wetland Treatment Systems. IN: Wetlands: Concerns and Successes. Proceedings of a Symposium held September 17-22, 1989, Tampa, Florida. American Water Resources Association, Bethesda, Maryland. 1989. p 489-498, 6 fig, 4 tab, 14 ref. Note: Michigan Univ., Ann Arbor. Dept. of Chemical Engineering. SWRA2312.
The Houghton Lake, Michigan wetland treatment system has consistently treated < 400,000 cu m/yr of secondary municipal wastewater to < 0.1 mg/L total phosphorus and < 0.3 mg/L ammonium nitrogen over an 11 year period. Removals have averaged 96% for P and 97% for ammonium within an area that has increased to 60 ha. Sulfur was reduced to natural wetland levels within the same area. Species composition shifted to cattail (Typha latifolia) and duck weed (Lemna minor), and above ground biomass increased by a factor of four. Sediment deposition in the duckweed zone buries a significant portion of the

nutrients. Gasification of nitrogen and sulfur compounds accounts for another important fraction. The remainder of the added N, S, and P is utilized to construct the new expanding biomass. Root biomass decreased in the presence of greater nutrient availability, partially counteracting the above ground increase. Denitrification was efficient enough to entirely remove nitrate from the wetland waters. The accumulation of microdetritus and macrophyte litter are comparable, and the microdetritus is richer in nutrients. Sufficient accumulation occurred after ten years to affect water levels by several centimeters. (See also W90-10912) (Author's abstract).

38. LAVIGNE, RONALD L., PH.D. A DESIGN MODEL FOR THE TREATMENT OF LANDFILL LEACHATE WITH A MICROBIALLY-ENRICHED SOIL AND REED CANARYGRASS. 1989; 50/08-B OF DISSERTATION ABSTRACTS INTERNATIONAL. Note: ORDER NO: AAD90-01528 UNIVERSITY OF MASSACHUSETTS.
The disposal of municipal solid waste continues to be one of the major environmental problems facing the world today. "Sanitary landfilling" became the accepted method of refuse disposal during the early 1970's, when open burning dumps, wind blown litter, flies and rodents were perceived to be the solid waste issue of the day. Little or no attention was given to the process of refuse decomposition and the liquid waste that is subsequently produced (i.e., leachate). Today lined landfills are replacing older unlined facilities and the practice of collecting leachate has become commonplace. An appropriate technology to treat collected leachate, however, has yet to be developed. Current landfill designs generally require the utilization of municipal wastewater treatment facilities for leachate disposal; but this practice is costly and it may be environmentally less desirable. This research project investigated the use of a new technique for treating landfill leachate on site. It utilizes a low technology "living filter" approach that models biological, chemical and physical processes known to be occurring in natural wetlands. The system takes advantage of the root zone aeration capabilities of reed canarygrass; and it maximizes the development of the fixed film biomass on peatmoss surfaces. Aerobic and anaerobic environments within the treatment medium facilitate a rapid reduction of Total Organic Carbon (TOC) and Chemical Oxygen Demand (COD); which both exist at high concentrations in leachate. The environment is also conducive to the precipitation of leachate metals. Peatmoss and reed canarygrass treatment beds were operated in both the batch and continuous flow mode to evaluate the reaction order and rate constants for leachate degradation. COD and TOC were used as modeling parameters. Mean hydraulic retention times of 3-10 days resulted in a 99%+ reduction in COD and TOC concentrations. Similar reductions were realized for heavy metals and total nitrogen. Grass clippings and peat samples were analyzed for Fe, Cu, Mn, Mg, P, K, and Ga before, during, and after 3 years of landfill leachate application. Leachate influent and effluent were also analyzed for the same metals. In each case, more than 99%

of the cations measured were removed by the treatment system. Data indicates that a root zone method using peatmoss and reed canarygrass can be an effective method for creating landfill leachate if unsaturated flow conditions are maintained. Toxicity testing using reed canarygrass seedlings indicated that leachate is initially toxic, but with time plants are able to recover and flourish in the leachate-peatmoss environment.

39. Loewgren, M.; Sundblad, K.; Wittgren, H. B. Wastewater Treatment or Resource Management: a Comparison Between Centralized and On-site Systems. Journal of Environmental Management JEVMAW, Vol. 28, No. 1, p 71-84, January 1989. 4 fig, 4 tab, 25 ref. Note: Linkoeping Univ. (Sweden). Dept. of Water and Environmental Research. SWRA2207.
Swedish environmental policies have aimed at connecting even small point source discharges to tertiary treatment plants, either by large scale collection and treatment systems or by small scale separate plants. The cost-effectiveness of the strategy for a number of urban areas with less than 1000 inhabitants was evaluated in one municipality (115,000 inhabitants) in the south of Sweden. By combining the total cost regression equations, a relationship was established to show treatment capacities and distances at which local tertiary treatment was economically equivalent to the centralized system for two different cost allocations. Average costs per person for small separate tertiary treatment plants were about the same magnitude as those for connection to the main municipal system at the present level of capacity utilization. A different on-site treatment technique, the wetland filter, which has been experimentally adapted to Swedish conditions, was compared to the existing system. In the wetland filter, pre-sedimented wastewater is applied by surface irrigation to reed sweetgrass, Glyceria maxima, growing in loamy sand. Part of the nutrients is recovered by harvest of the grass. Besides reaching tertiary requirements for phosphorus and BOD removal, the wetland filter removed more nitrogen than the ordinary treatment plants. Investment costs for wetland filters were estimated to be somewhat lower than those for existing technology. Operation and maintenance costs would be considerably lower. Further, there are potential revenues from the utilization of the grass for forage or energy purposes by integrating wastewater treatment into a farming system. The principal differences in regarding wastewater constituents as pollutants to be removed or resources to be managed are discussed. (Author's abstract).

40. Management Alternatives Report on the Diagnostic Feasibility Study for Medicine Lake, Hennepin County, Minnesota Final rept. 1987 Apr; Note: Barr Engineering Co., Minneapolis, MN. 057370000 Environmental Protection Agency, Chicago, IL. Region V. Bassett Creek Water Management Commission, Minneapolis, MN. Minnesota Pollution Control Agency, Roseville. English GRAI8921 Sponsored by Environmental Protection Agency, Chicago, IL. Region V, Bassett Creek Water

Management Commission, Minneapolis, MN., and Minnesota Pollution Control Agency, Roseville. United States.
The results of the Medicine Lake Diagnostic Study indicate that lake water quality suffers from: inputs of high levels of nutrients via urban stormwater runoff which lead to increased algal growth and decreased transparency; hypolimnetic oxygen depletion and subsequent sediment phosphorus release (internal loading); and an imbalance in the biology of the lake which contributes to internal phosphorus loading and poor water quality. The study suggests that a lake restoration project including hypolimnetic aeration in combination with watershed management (wetlands improvements) and biomanipulation (fisheries renovation) would benefit Medicine Lake water quality most cost-effectively. Additional watershed management activities in the future are also recommended and are expected to preserve and to improve lake water quality as the watershed develops.

41. Maristany, A. E.; Bartel, R. L. Wetlands and Stormwater Management: A Case Study of Lake Munson. Part I: Long-Term Treatment Efficiencies. IN: Wetlands: Concerns and Successes. Proceedings of a Symposium held September 17-22, 1989, Tampa, Florida. American Water Resources Association, Bethesda, Maryland. 1989. p 215-229, 7 fig, 6 tab, 8 ref.
Note: CH2M Hill, Deerfield Beach, FL. SWRA2312.
The use of wetlands or wet detention ponds for stormwater management represents a relatively new approach that has been successfully applied in recent years to address water quality problems in urban areas. Since most systems have been in operation for only a few years, questions have been raised concerning their long-term performance. It has been speculated that once these systems reach a state of dynamic equilibrium, nutrient removal may decline due to the reduced nutrient uptake of a mature ecosystem. A recent study was conducted by the Northwest Florida Management District of a 255 acre wetland/lake system which has received wastewater effluent and storm water discharges for over 30 years. Nutrient and pollutant removal rates were estimated for a wide range of parameters based on concurrent sampling of stormwater inflows, outflows and lake water quality. Long-term removal rates for Lake Munson, Florida, compared favorably with rates reported for relatively new facilities. An important conclusion from this study is that wet detention systems designed for minimum treatment storage capacity and which are not properly maintained, will experience significant water quality problems due to eutrophication. It would be advisable to increase storage capacity beyond the point of diminishing returns by either deepening the pond or expanding its surface area to prevent the pond from being overwhelmed by typical storm events as is the case with Lake Munson. The average storm event replaces the entire wet detention volume in the lake. A better design criteria would be to provide twice the volume if the average storm event in order to reduce the impact of any one storm on pond water quality. Drawdowns should also be implemented on a periodic basis as part of the over all

maintenance program in order to stabilize bottom sediments and reduce the amount of orthophosphorous released from the sediments to the water column. (See also W90-10912) (Lantz-PTT).

42. Martin, E. H. Effectiveness of an Urban Runoff Detention Pond-Wetlands System. Journal of Environmental Engineering (ASCE) JOEDDU, Vol. 114, No. 4, p 810-827, August 1988. 4 fig, 5 tab, 11 ref. Note: Geological Survey, Altamonte Springs, FL. SWRA2201.
The effectiveness of a detention pond and wetlands in series in reducing constituent loads carried in runoff was determined. The detention pond was effective in reducing loads of suspended solids and suspended metals. Suspended-phase efficiencies for solids, lead, and zinc ranged between 42 and 66%. Nutrient efficiencies were variable, ranging for all species and phases from less than 0 to 72%. The wetlands generally were effective in reducing both suspended and dissolved loads of solids and metals. Total (dissolved + suspended) solids, lead, and zinc efficiencies ranged between 41 and 73%. Efficiencies for total nitrogen and phosphorus were 21 and 17%. The system, by combining the treatment of the pond and wetlands, was very effective in reducing loads of most constituents. Total solids, lead, and zinc efficiencies ranged between 55 and 83%. Total nitrogen and phosphorus efficiencies were 36 and 43%. (Author's abstract).

43. Martin, E. H.; Smoot, J. L. Assimilative Capabilities of Retention Ponds. Available from the National Technical Information Service, Springfield, VA. 22161, as PB88-180153. Price codes: A04 in paper copy, A01 in microfiche. Report No. FHWA/DOT/BMR-303-86, April 1986. 75p, 19 fig, 10 tab, 17 ref. Note: Geological Survey, Tallahassee, FL. SWRA2203.
The efficiency of a detention pond and wetlands temporary storage system to reduce constituents loads in urban runoff was determined. The reduction efficiencies for 22 constituents, including the dissolved, suspended and total phases of many of the constituents were investigated. A new method not previously discussed in technical literature was developed to determine the efficiency of a temporary storage system unit such as a detention pond or wetlands. The method provides an efficiency, called the regression efficiency, determined by a regression made of loads-in against loads-out of a unit with the intercept of the regression constrained to zero. The regression efficiency of the treatment unit is defined as unity minus the regression slope. The system (pond and wetlands) achieved appreciable reductions of loads for most constituents. Significant positive regression efficiencies for the system were found for all constituents except the nutrients dissolved nitrate and dissolved orthophosphate. Systems regression efficiencies were 55% for total solids, 83% for total lead, 70% for total zinc, 36% for total nitrogen, and 43% for total phosphorus. (Author's abstract).

44. McDougall, B. K.; Ho, G. E. Study of the Eutrophication of North Lake, Western Australia. Water Science and Technology WSTED4, Vol. 23, No. 1/3, p 163-173, 1991. 4 fig, 1 tab, 34 ref.
Note: Murdoch Univ. (Western Australia). School of Biological and Environmental Sciences. SWRA2407.
North Lake is an urban freshwater wetland, and like other wetlands in the Perth metropolitan area, Western Australia, it has become nutrient enriched with the accompanying problems of algal blooms, decay, odor, infestation of midges. and aesthetic deterioration. A study of the water quality of the lake was undertaken to quantify the variation of phosphorus, nitrogen and chlorophyll-a, and the sediment store of nutrients and their release with pH. Ten sites around the lake were sampled weekly from September 1987 to May 1988. Samples were analyzed for pH, conductivity, chlorophyll-a, and various nutrients. A Secchi disc was used to monitor light penetration. Sediment samples were collected at three different times during the study and evaluated for pH, water content, organic content, carbonate content, and several states of phosphorus. The dominant algae in the lake, Microcystis, was found to be limited in growth by nitrogen because of the high availability of phosphorus (greater than 0.1 mg/L), and likely by light because of self-shading (chlorophyll-a greater than 0.3 mg/L). Sediments released a substantial amount of nutrients as pH rose above 8.5. Together with a parallel study of the nutrient budget of the lake, a management strategy has been derived to overcome the problem of nutrient enrichment that could be applied to other wetlands in the metropolitan region. Possible nutrient reduction strategies include treatment of runoff, nutrient inactivation, dredging, and chemical control of algae. (Author's abstract).

45. McLindon, G. J. Dredged Material Disposal: What is in the Future. IN: Beneficial Uses of Dredged Material. Proceedings of the Gulf Coast Regional Workshop, April 26-28, 1988, Galveston, Texas. Technical Report D-90-3, February 1990. p 207-229. 9 ref. Note: SWRA2312.
Disposing of dredged material introduces a unique set of environmental and economic problems. Much of the early development and filling process occurred in ignorance of the ecological and hydrological systems impacted. With the advent of the Clean Water Act of 1966 and other environmental studies on wetland habitat, steps were taken to reduce the impact of using dredged materials for beneficial uses. The Intergovernmental Cooperation Act of 1968 required that the Federal Executive establish its planning and development programs with balanced consideration of all public interests. The National Environmental Policy Act called for maintaining conditions under which man and nature could exist in productive harmony and fulfill the social, economic, and other requirements of present and future generations of Americans. To implement the new construction-environmental ethic, the US Army Corps of Engineers has developed a multidisciplinary staff of professionals to address the engineering, economic, social, environmental, and aesthetic issues of every project. To reduce the amount of dredging needed in channels, soil conservation methods such as bank

stabilization and revegetation programs should be of primary concern. Soil conservation methods should be practiced in urban and industrial areas as well as at agricultural sites. Ships should be designed with shallow drafts to reduce the need for continual channel dredging. Changes in loading facilities and warehousing are needed to update ports to lower dredging requirements. More research is needed on the effects of oil development in wetlands and on creating a national program for the reduction of dredging, beneficial use of dredged materials, and reduction of environmental impact of dredging. (See also W90-11316) (Geiger-PTT).

46. McMillan, Tom. Speech (Discours): Notes for an Address by the Honorable Tom McMillan, P.C., M.P., Canadian Minister of the Environment. 1987 Joint Annual Conference, Ontario Section, American Water Works Association, and Ontario Municipal Water Association. 1987; Note: Canadian Ministry of the Environment English.
This speech gives an overview of Canada's water problems including: water shortages in population centers; water pollution problems caused by pesticides, acid rain, toxic materials, erosion, and destruction of wetlands; lack of sewage treatment in many areas; underpricing of water; lack of water conservation programs; and deterioration of the country's distribution system infrastructure. This paper also emphasizes the need to shift the burden of financing improvements in these areas from the federal government to the customers, primarily through price increases for water service.

47. Melear, E. L.; Homblette, D. J.; Davis, R. A. An exemption for the experimental use of Marshall Swamp for advanced effluent recycling. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith. Note: Boyle Engineering Corporation, Orlando, FL English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

48. Moreau, D. H. Fiscal Year 1988 Program Report: North Carolina Water Resources Research Institute. 1989 May; Note: North Carolina Water Resources Research Inst., Raleigh. 058521000 Geological Survey, Reston, VA. Water Resources Div. English GRAI9002 See also report for 1987, PB88-235759. Sponsored by Geological Survey, Reston, VA. Water Resources Div. United States.
The North Carolina Water Resources Research Institute program for 1988-89 focused on several research areas of high priority for the state and southeast region: water supply, waste management, surface water quality, groundwater and technology transfer. Support from the U.S. Geological Survey through the Water Resources Institute Program (WRIP) was supplemented by the Urban Water Consortium, contracts with the North Carolina Department of Natural Resources and Community Development and with the U.S. Environmental Protection Agency.

A high level of university support continued. A total of twenty-two research projects were funded with these combined resources. Three WRIP research projects were supported in FY 88. One evaluated soils and saprolite in the Piedmont Region to assess the movement of various pollutants, especially those found in domestic wastewater and landfill leachates, another examined the role of wetlands in removing nutrients from streams receiving wastewater discharges, and the third will determine the effectiveness of vegetated buffer areas in removing sediment and phosphorus. The information transfer for the Institute focused on emerging water resources issues and used the following strategies: reviewed and published reports; research reviews; published a bi-monthly newsletter; and organized and co-sponsored 8 workshops and conferences.

49. Mukherjee, Goutam. Wetland management in the context of regional planning, east Calcutta. A case study. Unesco/IHP International Symposium on URBAN WATER '88Hydrological Processes and Water Management in Urban Areas IAHS Publication (International Association of Hydrological Sciences) n 198. Publ by Int Assoc of Hydrological Sciences, Institute of Hydrology, Wallingford, Engl. p 341-345. 1990; . CODEN: 1988 Apr IAPUEP. Note: C.M.D.A., Calcutta, India English A (Applications) M (Management Aspects) 9106.
Purposeful study of wetland ecosystems is essential in the urban fringe where the wetlands are being lost due to severe settlement pressure. Even today wetlands are too commonly considered as marshy wastes fit only for reclamation or dumping of materials. The waste recycling wetland east of Calcutta, largest of its kind in the world, is a unique system for purifying sewage, growing food and generating employment. Here fisheries are directly using raw sewage to become more efficient, effective and economically viable. The problems, issues and results in the context of emerging concepts of wetland management, highlighting their varying impact on environmental, ecological, socio-economic and managerial aspects are described in the paper. (Author abstract) 4 Refs.

50. Municipal Wastewater Conveyance and Treatment: Technological Progress and Emerging Issues 1988. 1988 Sep; Note: Environmental Protection Agency, Washington, DC. Office of Municipal Pollution Control. 031287624 English GRAI8909 See also PB87-230165. United States.
The report provides an overview of technological progress and emerging issues in the conveyance and treatment of municipal wastewater. It is a successor to EPA's annual 'Innovative and Alternative Technology Progress Reports'. The three major topics covered in the report are: toxics, conveyance and treatment technology, and operation and maintenance.

51. Nace, R.; Jennison, M. A.; Wilder, D.; Faison, G.; Miller, L. Criteria for Municipal Solid Waste Landfills (40 CFR Part 258). Subtitle D of Resource Conservation and Recovery Act (RCRA). Background Document: Location Restrictions (Subpart B). Available from the National

Technical Information Service, Springfield, VA 22161, as PB88-242425. Price codes: A06 in paper copy, A01 in microfiche. Report No. EPA/530-SW-88-036, July 1988. 142p, 60 ref, append. EPA contract 68-01-7310. Note: NUS Corp., Rockville, MD. SWRA2209.
The 1984 Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) directed EPA to revise the Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR Part 257) for facilities that may receive household hazardous waste (HHW) or hazardous waste from small generators (SQGs). In carrying out this mandate, EPA has undertaken efforts to revise the current Criteria. EPA is initially limiting the Criteria revisions to municipal solid waste landfills (MSWLFs) because these are the only facilities for which the Agency has complete and reliable data. Section II of this document provides a discussion on the legislative and regulatory background and their status. Section III addresses other Federal laws that impact the design, operation, and location of MSWLFs. Section IV contains detailed information on the development of the standards addressing restricted locations, including airport areas,, floodplains, wetlands, fault areas, seismic impact zones, and geologically unstable areas (prone to landslides, subsidence). (Lantz-PTT).

52. Pennington, J. C. Feasibility of Using Mycorrhizal Fungi for Enhancement of Plant Establishment on Dredged Material Disposal Sites: A Literature Review. Available from the National Technical Information Service, Springfield, VA. 22161 as AD-A170 443, A08 in paper copy, A01 in microfiche. Miscellaneous Paper D-86-3, June 1986. 167 p, 9 fig, 485 ref, append. Note: Army Engineer Waterways Experiment Station, Vicksburg, MS. Environmental Lab. SWRA2004.
Mycorrhizal fungi are one of the most extensively occurring groups of beneficial soil microorganisms. Few plants lack them. Mycorrhizal fungi form an intimate mutualistic association with plant roots (mycorrhizae) that extends the absorptive area of the roots (sometimes thousands of times) and contributes greatly to mineral nutrition, water absorption, and root system stabilization of the host plant. The literature documents increased plant tolerance to adverse or toxic soil conditions by mycorrhizal plants in revegetation of strip-mined sites, kaolin spoils, iron tailings, and processed oil shale. Mycorrhizal plants are consistently more successful in these areas, sometimes exhibiting shoot dry weights 1370 to 1528 percent higher than nonmycorrhizal plants. Not only do mycorrhizae contribute to plant success in adverse substrate conditions, but also have been shown to sequester and store certain heavy metals, thereby detoxifying soils. The extensive external mycelium together with an amorphous polysaccharide secretion are a dominant factor in the aggregation of soil particles by mycorrhizal plants. The effectiveness of these two mechanisms is especially evident in stabilization of sand dunes. These same mechanisms, assisted by additional absorption mechanisms, account for increased soil moisture retention and enhanced water availability and uptake by host plants. This literature review discusses the potential role of mycorrhizal plants

in the development of upland, marsh, and aquatic habitats. Tremendous potential exists for enhancing the establishment and growth of vegetation on upland dredged material disposal sites with mycorrhizae. Although much less is known about the mycorrhization of marsh plant species, the limited research available suggests that use of mycorrhizae has some potential for enhancing establishment and growth of marsh plants on dredged material disposal sites. Very few studies of the mycorrhizal status of aquatic plants were found; therefore, the potential for using mycorrhizae to enhance development of aquatic habitat is not known. (Lantz-PTT).

53. Perham, R. E. Elements of Floating-Debris Control Systems. Available from the National Technical Information Service, Springfield, VA 22161. Technical Report REMR-HY-3, September 1988. Final Report. 66p, 35 fig, 34 ref, 3 append. Note: Cold Regions Research and Engineering Lab., Hanover, NH. SWRA2306.
Floating debris is a continual problem for all users of water bodies. Some of the damage caused by debris is minor, but too often it is quite costly. It is destructive to locks, dams, bridges, electric plants, municipal water systems, and even to recreational boaters. Wetlands, fish-spawning grounds, and streambanks can be disturbed by debris. A floating-debris control system consists of collecting, removing, and disposing of the debris. Various types of booms, trash racks, trash struts, and deflectors have been used effectively for collecting floating debris. Hand-powered, self-powered, and gantry crane-operated rakes are used to remove the debris from intake gates, bulkheads, deck gratings, and trash rack sections. Heavy debris, such as water-soaked logs or fallen trees, are removed with cranes and hoists, supplemented by such implements as bolt hooks, log chains, and chain saws. Some of the removed debris has value. Many logs are large enough to be used as structural materials: supports for small buildings, guard posts for parking lots, and supports for soil stabilization. Also, some of it can be dried and cut up for firewood. The debris that cannot be used must be burned, buried, or dumped on the ground surface. All of these processes require careful monitoring so that they are not and do not create health hazards. Surface dumping should be used only as a last resort. An effective floating-debris control system requires time, effort, and money; however, its benefits more than offset its requirements. (Lantz-PTT).

54. Perham, R. E. Repair, Evaluation, Maintenance, and Rehabilitation Research Program: Elements of Floating-Debris Control SystemsFinal rept. 1988 Sep; Note: Cold Regions Research and Engineering Lab., Hanover, NH. 006594000 037100 English GRAI8905 United States.
Floating debris is a continual problem for all users of water bodies. It is destructive to locks, dams, bridges, electric plants, municipal water systems, and even recreational boaters. Wetlands, fish-spawning grounds, and streambanks can be disturbed by debris. This report contains a summary of the various methods for collecting, controlling,

removing, and disposing of floating debris. Keywords: Debris booms; Debris and ice deflectors; Debris disposal; Debris transport; Removal equipment; Trash rakes. (edc).

55. Pride, Robert E.; Nohrstedt, J. Steve; Benefield, Larry D. Utilization of created wetlands to upgrade small municipal wastewater treatment systems. Water, Air, and Soil Pollution. 1990 VOL. 50, NO. 3-4 (April).

56. Reidy, B. L.; Samson, G. W. Assessment of a Low-Cost Wastewater Disposal System After Twenty-five Years of Operation. Water Science and Technology WSTED4, Vol. 19, Nos. 5/6, p 701-710, 1987. 4 fig, 6 tab. Note: Latrobe Valley Water and Sewage Board, Traralgon (Australia). SWRA2105.
A low-cost wastewater disposal system was commissioned in 1959 to treat domestic and industrial wastewaters generated in the Latrobe River valley in the province of Gippsland, within the State of Victoria, Australia. The Latrobe Valley is the center for large-scale generation of electricity and for the production of pulp and paper. In addition, other industries have utilized the brown coal resource of the region, e.g., gasification process and char production. Consequently, industrial wastewaters have been dominant in the disposal system for the past 25 years. The mixed industrial-domestic wastewaters were to be transported some 80 km to be treated and disposed of by irrigation to land. Several important lessons have been learned during 25 years of operating this system. First, the composition of the mixed waste stream has varied significantly with the passage of time and the development of the industrial base in the Valley, so that what was appropriate treatment in 1959 is not necessarily acceptable in 1985. Second, the magnitude of adverse environmental impacts engendered by this low-cost disposal procedure was not imagined when the proposal was implemented. As a consequence, clean-up procedures which could remedy the adverse effects of 25 years of impact are likely to be costly. The Latrobe Valley Water and Sewerage Board: (1) Initiated construction of an ocean outfall, essentially as proposed 25 years ago; (2) Required significant improvements in the quality and control of wastewaters discharged to the system; (3) Assessed the cost of rehabilitation of degraded soils. Approximately 1000 ha at a minimum cost of $2000/ha, i.e. $2,000,000; and (4) Assessed the possibility of rehabilitation of degraded wetlands having a volume of the order of 250,000 megaliters. (Lantz-PTT).

57. Richardson, C. J.; Davis, J. A. Natural and aritificial wetland ecosystems: ecological opportunities and limitations. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith. Note: Duke University, Durham, NC English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida.

Literature review. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

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58. Richardson, C. J.; Nichols, D. S. Ecological Analysis of Wastewater Management Criteria in Wetland Ecosystems. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 351-391, 7 fig, 9 tab, 117 ref. Note: Duke Univ., Durham, NC. School of Forestry and Environmental Studies. SWRA2202.
A series of ecological management criteria should be addressed prior to the decision to use any wetland ecosystem for treatment of secondary municipal effluent. These criteria include the value of the effluent as a resource, the capacities and limitations of wetlands to accomplish wastewater treatment, wastewater management objectives, wastewater suitability for wetland discharge, and wetland values. Also presented are discussions of wetland hydrology, productivity, cycling of nutrients and heavy metals, and estimates of efficiencies of wastewater nutrient removal by wetlands and the wetland area needed for specific levels of nutrient removal. The key to utilizing any wetland ecosystem for N, P, BOD, and organic removal is low loading rates coupled with sufficient wetland area. A minimum of 1 ha/60 people is suggested for a 50% removal efficiency of N and P. (See also W89-01827) (Lantz-PTT).

59. Richardson, David L.; Daigger, Glen T. Aquaculture: The Hercules Experience. Journal of Environmental Engineering. 1984 Oct; v110 n5. CODEN: JOEEDU; ISSN: 0733-9372. Note: 6 references, tables, figures English.
The results of an evaluation of the City of Hercules, California, 0.35 'mgd (1,325 m3/day) aquaculture demonstration wastewater treatment plant are presented. This treatment plant was one of the first facilities designed to provide secondary treatment to raw municipal wastewater in this country. Failure of this facility was attributed to a series of process and physical design deficiencies. The results of this evaluation should be of interest to those working in the development and implementation of aquaculture technology for wastewater treatment.

60. Roesner, Larry A. (Ed.); Urbonas, Ben (Ed).; Sonnen, Michael B. (Ed.). Proceedings of an Engineering Foundation Conference on Current Practice and Design Criteria for Urban Quality Control. Proceedings of an Engineering Foundation Conference on Current Practice and Design Criteria for Urban Quality ControlProc Eng Found Conf Curr Pract Des Criter Urban Qual Control 1989. Publ by ASCE, New York, NY, USA. 490p. 1989; . CODEN: 1988 Jul 10-15. Note: Camp Dresser & McKee, Water Resources, Maitland, FL, USA US EPA, USA English A (Applications) T (Theoretical) X (Experimental) 8911.
The volume contains 33 papers presented at the conference. The papers are grouped under session topics that include pollution control, Water Quality Act of 1987, detention basins, infiltration devices, receiving

water responses to urban runoff, institutional issues, retrofitting storm sewers, source controls, and wetlands as treatment systems.

61. Ruhl, J. F. Water Resources of the White Earth Indian Reservation, Northwestern Minnesota. Available from the US Geological Survey, Books and Open-File Reports Section, Box 25425, Federal Center, Denver, CO 80225-0425. Water-Resources Investigations Report 89-4074, 1989. 73p, 30 fig, 8 tab, 35 ref. Note: Geological Survey, St. Paul, MN. Water Resources Div. SWRA2401.
Water resources in the White Earth Indian Reservation meet the present (1988) needs for potable supply and other household use and provide valuable ecological, recreational, and aesthetic benefits. Total annual water use in the reservation is about 460 million gallons per year. Domestic supply from privately-owned wells and municipal systems accounts for roughly 75% of the water use, and irrigation of croplands and nurseries accounts for approximately 25%, depending on rainfall. Glacial-drift aquifers are the source of groundwater in the reservation. Unconfined-drift aquifers consist of two superficial outwash deposits that extend over approximately 20% of the reservation. Confined-drift aquifers are discontinuous lenses of sand and gravel that are poorly connected to each other. The aquifers are 50 to 300 feet below land surface and 5 to 25 feet thick. Yields from these aquifers typically range from 10 to 100 gallons per minute. Surface water in the reservation consists of numerous lakes, wetlands, prairie potholes, and streams. The larger, deeper lakes in the eastern and southern parts of the reservation support game fish and provide recreational opportunities for swimming and boating. The shallower lakes and prairie potholes are used to produce wild rice and also are managed to provide waterfowl habitat. Groundwater is mostly a calcium magnesium bicarbonate type. Dissolved solids concentration of the groundwater generally is greater in the deeper confined-drift aquifers than in the shallower unconfined-drift aquifers. Except for elevated concentrations of iron and manganese, groundwater quality meets Environmental Protection Agency drinking water criteria. Surface water also is a calcium magnesium bicarbonate type. Lake waters are hard and alkaline and mesotrophic to eutrophic. Quality of the lake and stream water is suitable for native forms of freshwater biota, although the concentration of mercury exceeds the 0.012 micrograms per liter maximum contaminant level. Available information, however, indicates that the amount of mercury in edible tissue from fish in alkaline lakes of northwestern Minnesota is within safe limits. The concentrations of phosphorus and nitrate in the streams are below levels that indicate pollution problems. (Author's abstract).

62. Rusincovitch, F. Use of Wetlands for Wastewater Treatment and Effluent Disposal: Institutional Constraints. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 427-432. Note: Environmental Protection Agency, Washington, DC. SWRA2202.

The Environmental Protection Agency's (EPA) Office of Federal Activities (Policy and Procedures Branch and 404 Branch) and the Office of Water Programs, in conjunction with the U.S. Fish and Wildlife Service, are considering the use of wetlands to treat municipal wastewater. The impetus for such use is that many small communities have found that 'high-technology,' conventional municipal sewage treatment systems are not well suited to their limited needs. While there does not appear to be any unequivocal constraint in any existing laws, regulations, or guidelines that would prevent the sensible use of wetlands in a municipal wastewater treatment system, the idea is new, and it requires a reassessment of whether or not wetlands serve their greatest value when left completely alone. Wetlands used for wastewater treatment promote their multiple use, hopefully, to the benefit of both the residents of the community and the wetland. However, there are those who believe that people and their wastes do not belong in wetlands because the wetland should be left completely natural; or that the only 'real' way to treat sewage is in concrete tanks with mechanical mixers and pumps where the chemistry and biology of waste treatment can be carefully controlled and monitored to prove the best-possible level of treatment. Proponents of these arguments have the potential to exert strong pressures on communities to pursue the more-established, conventional wastewater treatment routes, simply because they will seem easier or safer in the absence of complete knowledge about all wetland impacts. No doubt, over time, the use of wetlands in the treatment and disposal of municipal wastewater by small communities with appropriate land resources and soils will become an established procedure. However, the amount of time that the establishment of wetlands treatment takes will depend to a great on how quickly EPA can satisfy a community's concerns for what they perceive as the institutional, engineering, and biological constraints to wetland use for municipal waste treatment. (See also W89-01827) (Lantz-PTT).

63. Schiffer, D. M. Water-Quality Variability in a Central Florida Wetland Receiving Highway Runoff. IN: Water: Laws and Management. American Water Resources Association, Bethesda, Maryland, 1989. p 7A-1--7A-11, 3 fig, 3 tab, 5 ref. Note: Geological Survey, Altamonte Springs, FL. SWRA2404.
Constituent concentrations were measured at the stormwater inlet and outlet, and at 9 other sites within a wetland receiving highway runoff, located north of Orlando, Florida. Most of the reduction in constituent concentrations in water observed in the wetland occurred within 100 feet of the stormwater inlet. Constituent concentrations measured in the wetland bed sediments indicate that the primary removal mechanism may be sedimentation. The 9 sampling sites within the wetland, in groups of three, were about 30, 100, and 250 ft from the stormwater inlet. Statistical analysis of the data collected at the sampling sites indicate that for 26 of the 40 water quality variables, the mean values differ significantly (alpha equal to 0.05) with distance from the inlet. These differences were most frequently detected between the sites that

are within 30 ft and 100 ft from the inlet. Constituents that generally decreased in concentration with distance from the inlet include total phosphorous, ammonia, lead and zinc. The median total phosphorous concentration at the inlet was 0.23 mg/l at 100 ft, and decreased to 0.04 mg/l at 100 ft. Total ammonia was 0.23 mg/l at the inlet, decreasing to 0.01 mg/l 100 ft away. Median concentrations decreased from 18 micrograms/l at the inlet to 4 micrograms/l at a distance of 100 ft, and median zinc concentrations decreased from 75 micrograms/l to 20 micrograms/l over the same distance. (Author's abstract).

64. Schuhmacher, H. Urban Streams as a Place to Live (Stadtbache als Lebensraum). Naturwissenschaften NATWAY, Vol. 76, No. 11, p 505-511, November 1989. 2 fig, 25 ref. English summary. Note: Gesamthochschule Essen (Germany, F.R.). Inst. fuer Oekologie. SWRA2307.
A historic overview of stream management is presented. Urban streams have been drastically altered, usually not in accordance with modern stream theory. The secondary biotopes of streams, such as standing water and groundwater, are included in a River Continuum Theory. Measures are proposed to meet both human needs and needs for ecological restoration. The problems are complex and require a knowledge of lotic ecology before resource management decisions can be made. Contamination must be avoided to maintain in the upper course of a stream the uniformly high pH and low nutrient content which correspond to its place in the river continuum. Before uncontrolled disturbance of urban soils a warning is necessary: these soils are still largely unknown regarding many of their natural characteristics, such as their adsorption properties for ions and other compounds. Of equal importance with actions which are good for the water itself, are those for natural habitat development. The restoration of a streamside wetland can run into difficulties greater than land requirements, therefore such remediation can be accomplished only to a small extent in the short term. However, the speedy restoration of extensive riparian wetlands serves not only to produce or increase faunal and floral diversity in congested urban areas, it improves or maintains water quality, restrains floodwaters, improves the urban climate, and increases recreational values. These general effects go hand-in-hand with the economic effect: the ongoing maintenance expenditure for near-natural streams decreases in return for benefits which can scarcely be measured in monetary terms. (Brunone-PTT).

65. Showers, W. J.; Eisenstein, D. M.; Paerl, H.; Rudek, J. Stable Isotope Tracers of Nitrogen Sources to the Neuse River, North Carolina. Available from National Technical Information Service, Springfield, VA 22161 as PB90-235342/AS. Price codes: A03 in paper copy, A01 in microfiche. North Carolina Water Resources Research Institute, Raleigh, Completion Report No. 253, (UNC-WRR. Note: North Carolina State Univ. at Raleigh. Dept. of Marine, Earth and Atmospheric Sciences. SWRA2403.

Stable nitrogen isotopic analyses were conducted on dissolved nitrate in surface water samples collected over a two-year period from the lower Neuse River, North Carolina, to assess temporal variation of nitrate sources to the watershed. Nitrate samples collected at the Raleigh and Durham Municipal Sewage Treatment Plants have nitrogen isotopic values in the +9 to +14/mil range. Nitrate samples collected from agricultural drainage areas in the lower portion of the Neuse River basin have nitrogen isotopic values in the +4 to +9/mil range. These nitrogen isotopic values correspond well to literature values published for point and nonpoint nitrate sources, respectively, and confirm that there is a well defined isotopic difference between point and nonpoint nitrate inputs to the Neuse River Basin. The nitrogen isotopic values of nitrate from the lower Neuse, which integrates the nutrient loading trends over the entire basin, show an annual cycle. Surface water nitrate during low discharge periods is isotopically enriched and is in the point range of +9 to +14/mil. Surface water nitrate collected during high discharge periods is isotopically depleted and is in the nonpoint source range of +4 to +9/mil. Over the entire annual hydrological cycle, surface water nitrate nitrogen isotopic values are exponentially related to river discharge rate. This relationship suggests that a residence time delay factor in an intermediate reservoir (groundwater, wetlands) plays an important role in the transfer of nonpoint source nitrate to the riverine system during the falling discharge (spring) period. The enhanced fertilizer loading in wet years during the critical spring period can influence the biological species succession and would therefore play a significant role in enhancing nuisance algae bloom potential in late summer. (USGS).

66. Silverman, G. S. Development of an Urban Runoff Treatment Wetlands in Fremont, California. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 669-676, 2 tab, 5 ref. Note: Bowling Green State Univ., OH. Environmental Health Program. SWRA2305.
A 20-ha fallow agricultural field in Fremont (Alameda County), California, was converted into a seasonal freshwater wetlands for managing urban stormwater runoff traveling in Crandall Creek. Institutional considerations, treatment mechanisms, design, and potential for stormwater wetlands are discussed. Three distinct systems were incorporated into the wetlands: (A) a long, narrow pond containing a long island, and with vegetation (mainly Typha latifolia) encouraged along the pond margins; (B) a spreading pond draining into an overland flow system (inundated only during storms), followed by a pond with berms supporting aquatic vegetation; and (C) a common third system into which the others drain, which provides meandering channels to maximize contact with various types of wetlands, and drains into another section of the Coyote Hills Regional Park, ultimately returning to Crandall Creek. Hydraulic considerations included sizing the diversion structure and channels to accommodate the 10-yr, 6-hr storm, with greater flows causing diversion structure failure, with most of the flow remaining in Crandall Creek. Development of this wetlands provided a number of

benefits. An attractive wetlands has been created in an urbanized region badly needing additional 'natural' areas and a facility to study potential and future designs for urban runoff treatment systems has been provided. Another important benefit is the practical demonstration for implementation of other wetlands development projects. Development of the Fremont wetlands required active efforts from the regional council of governments and park district, financial support from the state and federal governments, and the cooperation of a host of local agencies and special districts. It demonstrated the need and potential for obtaining diverse support for wetlands projects. (See also W90-04392) (Rochester-PTT).

67. Silverman, G. S. Seasonal freshwater wetlands development and potential for urban runoff treatment in the San Francisco Bay area. DISS. ABST. INT. PT. B - SCI. & ENG. 1983; VOL. 44, NO. 5. Note: SUMMARY LANGUAGE - ENGLISH; Diss. Ph.D.: Order No.: FAD DA8322029. ENGLISH.
Wetlands development offers an attractive means of reducing the pollutant load from urban runoff into the San Francisco Bay while creating valuable ecosystems. Design principles for pollutant removal have not been the focus of substantial study for wetlands systems receiving stormwater runoff. Furthermore, no comprehensive system exists to coordinate the activities of the many levels of government, agencies and groups that regulate or are interested in wetlands. An analysis is presented in this paper of the potential for development of urban runoff treatment wetlands, including a case study of the design and subsequent creation of a prototype wetlands system.

68. Smith, A. J. Wastewaters: A Perspective. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 3-4. Note: Environmental Protection Agency, Atlanta, GA. Region IV. SWRA2305.
The 1987 Water Quality Act amendments to the Clean Water Act established a new direction in wastewater management. The federal grants program for municipal wastewater treatment works will be phased out in 1990 and replaced with a State Revolving Loan Program funded through 1994. Although federal funds will be declining, problems remain to be solved, including: (1) treatment works construction for communities of less than 10,000 population, estimated to cost between $10 and $15 billion nationwide; (2) agricultural nonpoint pollution, which is a cause of serious water quality problems in 24 states; (3) impaired water quality in lakes and reservoirs, mainly due to agricultural pollution; (4) large treatment needs in the industrial sector (e.g., acid mine drainage in Appalachia); (5) landfill leachates from both industrial and municipal solid wastes; and (6) industrial toxic chemical and hazardous waste treatment. Wetland systems represent one way to attempt to deal with these problems in an era of declining federal funding and increased concerns about water quality. (See also W90-04392) (Rochester-PTT).

69. Stiefel, R. C. Fiscal Year 1984 Program Report (Ohio Water Resources Center). Available from the National Technical Information Service, Springfield, VA 22161, as PB86-157021/AS. Price codes: A04 in paper copy, A01 in microfiche. Program Report G-926-01, September 1984. 35 p, append. Contract No. 14-08-0001-G926. USGS Proj. Note: Ohio State Univ., Columbus. Water Resources Center. SWRA2012.
Water is one of Ohio's most important natural resources, and the State has an abundant supply to meet its immediate needs. Most of Ohio's water problems are associated with water quality. Of concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas and the toxic and hazardous wastes that threaten the ground and surface waters. The focus of the 1984 State Water Research Program was directed at some of these needs. One project investigated the operational parameters of a fluidized bed bioreactor for the treatment of a wastewater to establish the optimal design and operating criteria for the unit. Three of the projects explored the significance of phosphorus to the State's surface water quality: one developed a technique to estimate the amount of dissolved phosphorus being transported by agricultural runoff; a second better defined the role that agricultural herbicides have in inhibiting photosynthesis and the removal of nutrients in streams in the Lake Erie Basin, and a third project investigated the relationships that exist between bioavailable and non-bioavailable particulate phosphorous in Lake Erie. Other projects attempted to manipulate the fish population in Lake Erie by changing the type of habitat within the regions managed wetlands by altering the depth of water; and exploring the quantities of materials involved in the transport of sediment and nutrients from the Lake Erie shoreline to the offshore waters. The Center's technology transfer program assisted in the development of a computer program to estimate the soil loss resulting from surface runoff on agricultural lands. (USGS).

70. Sundblad, K.; Wittgren, H. B. Glyceria maxima for Wastewater Nutrient Removal and Forage Production. Biological Wastes BIWAED, Vol. 27, No. 1, p 29-42, 1989. 1 fig, 5 tab, 27 ref. Note: Linkoeping Univ. (Sweden). Dept. of Water and Environmental Research. SWRA2301.
Potential biomass yield, nutrient uptake capacity and forage quality of Glyceria maxima were tested in four field lysimeters receiving municipal wastewater. Wastewater was applied during 3 years at different frequencies in order to achieve maximum N-reduction in the system. Accordingly two lysimeters were ponded for part of the week. Harvesting (in June and August) progressively favored competing terrestrial species in the non-ponded lysimeters. In year 3 the other species accounted for 65-70% of the harvested biomass in these non-ponded lysimeters. In the ponded lysimeters, reducing conditions in the soil probably prevented terrestrial species from establishing. The total annual yields of the single-species stands in the ponded lysimeters were 870-1165 g/sq m. Energy, protein, P, K, and Ca content of the harvested biomass indicated a high nutritional value. NO3(-)-N concentration in the harvested biomass varied from 0.08 to 0.32% of dry wt,

but did not generally exceed 0.2%. Maximum N and P removed with the harvested biomass was 32 and 4.8 g/sq m respectively. The relative removal of nutrients in ponded lysimeters varied from 26 to 55% of the amount of N applied and from 12 to 28% of P applied, which illustrated the possibilities of adjusting the load for optimization of nutrient re-use rather than disposal. (Author's abstract).

71. Superfund Record of Decision: Ringwood Mines/Landfill, VA. Available from the National Technical Information Service, Springfield, VA 22161, as PB89-206312. Price codes: A03 in paper copy, A01 in microfiche. Report No. EPA/ROD/R02-88/075, September 1988. 45p, 4 fig, 6 tab. Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. SWRA2407.
The Ringwood Mines/Landfill site consists of approximately 500 acres in a historic mining district in Ringwood Borough, Passaic County, New Jersey. The site is characterized by abandoned mine shafts and surface pits, an inactive landfill, an industrial refuse disposal area, small surficial dumps, a municipal recycling center and approximately 50 residences. In 1976, the New Jersey Department of Environmental Protection (NJDEP) closed the landfill after determining that leachate emanating from the landfill was contaminating surface water in the area. In July 1982, NJDEP detected moderate levels of VOCs, as well as naturally occurring heavy metals, in groundwater in the northern section of the site. The site was subsequently divided into four discrete areas for investigation. From October 1987 to February 1988 removal action was conducted which entailed excavation and off-site disposal of 7000 cu yd of surficial paint sludge containing lead and total petroleum hydrocarbons in excess of health based levels. Furthermore, there is sporadic and moderate groundwater contamination generally confined to paint sludge locations, exceeding maximum contaminant levels (MCLs) for lead and arsenic. Primary contaminants affecting soil and groundwater are arsenic, lead, and petroleum hydrocarbons. Selected remedial action for this site includes: confirmatory sampling of all soil with excavation and off-site disposal of any soil exceeding health-based levels, followed by backfilling and revegetation; and groundwater, surface water and wetlands monitoring. Since groundwater in the vicinity of paint sludge areas is not used as a drinking water source and natural attenuation is expected to reduce contamination of below health based levels after removal of the source, groundwater will not be treated. (Lantz-PTT).

72. Superfund Record of Decision: Wildcat Landfill, DE. Available from the National Technical Information Service, Springfield, VA 22161, as PB89-196752. Price codes: A04 in paper copy, A01 in microfiche. Report No. EPA/ROD/R03-88/052, June 1988. 56p, 10 fig, 2 tab, 2 append. Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. SWRA2404.
The Wildcat Landfill site is located 2.5 mi southeast of Dover in Kent County, Delaware. The 44-acre site is bordered to the north and east by

the St. Jones River and its associated wetlands, and to the south and west by residential and commercial developments. A pond created by construction of the landfill, is located directly adjacent to the site along the northwestern edge. The pond is the subject of a second operable unit for the site. Portions of the site lie within the 100-year floodplain of the St. Jones River. The site was operated as a permitted sanitary landfill between 1962 and 1973, accepting both municipal and industrial wastes. Industrial wastes suspected to have been disposed include latex waste and paint sludges. Throughout its 11 years of operation, the facility routinely violated operating and other permits issued by regulating agencies. EPA began investigating the site in 1982. Typical wastes encountered at the site included municipal refuse latex in strips and sheets; scattered crushed, empty, or intact drums; and manufactured plastic items. Much of the waste is located on low-lying wetland. Consequently, in that area of the landfill, wastes are in direct contact with the, surficial sand aquifer. The primary contaminants of concern affecting the soil and groundwater are volatile organic compounds including benzene, other organics including PCBs, and metals including arsenic and lead. The selected remedial action for this site includes: grading, installation of a soil cover, and revegetation of onsite direct contact risk areas; removal and offsite disposal of drums containing wastes by landfilling (if not hazardous) or incineration (if hazardous); replacement of two domestic wells adjacent to the site; institutional controls including well and land use restrictions; and groundwater monitoring. The estimated present worth cost for this remedial action is $5,400,000. (Author's abstract).

73. Superfund Record of Decision (EPA Region 1): Baird and McGuire, Holbrook, Massachusetts, September 1986 Final rept. 1986 Sep 30; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8720 Portions of this document are not fully legible. United States.
The Baird & McGuire site encompasses approximately twenty acres in Holbrook, Norfolk County, MA. Wetlands occupy approximately 44 percent of the site with approximately 66 percent of the site lying within a 100-year flood plain. Baird & McGuire, Inc. (BMI) operated a chemical mixing and batching company from 1912 to 1983. BMI's disposal practices were the source of ground water and wetlands contamination. In 1983 heavy rains caused a breach of the creosote collection lagoon resulting in an EPA-initiated Immediate Removal Action. Dioxin, detected in surficial soil samples in 1985, prompted an EPA-initiated second removal response involving the installation of 5700 feet of fencing and extensive soil, ground water, surface water, and air sampling. The primary contaminants of concern include: VOCs, organics, PAHs, dioxin, pesticides, and metals. The remedial action includes excavation in 'hot areas' to remove approximately 191,000 cubic yards of contaminated soils, onsite incineration of excavated soils, ground water extraction and onsite treatment with discharge to an onsite aquifer; restoration of wetlands, construction of levees and

ground water monitoring. The estimated capital costs are $44,386,000 with 30-year O&M costs of $4,132,000.

74. Superfund Record of Decision (EPA Region 5): Arrowhead Refinery, Duluth, Minnesota, September 1986 Final rept. 1986 Sep 30; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8719 Portions of this document are not fully legible. United States.
The Arrowhead Refinery site is located in Hermantown, St. Louis County, Minnesota. The operation generated waste by-products which were discharged into an uncontained 2-acre lagoon and a waste water ditch in a wetland area. Investigations conducted by EPA in 1979 revealed that onsite surface water was transporting contaminants to nearby wetlands areas and navigable waters. The primary contaminants of concern are VOCs, PAHs, and lead, and they are found in onsite soils, sediments, surface waters and ground water. The selected remedial action for the Arrowhead Refinery site are cited.

75. Superfund Record of Decision (EPA Region 5): Burrows Sanitation Site, Hartford, Van Buren County, Michigan, September 1986Final rept. 1986 Sep 30; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8718 United States.
The Burrows Sanitation site is a ten-acre site located on 54th Avenue in Hartford Township, Van Buren County, Michigan. The site was used for dewatering and disposing of metal hydroxide sludges, waste coolants, and soluble oils. Sampling of these areas indicates that the former source materials were removed so they no longer present a potential health threat via direct contact or ingestion. Wastes similar to the excavated wastes remain in the newly identified Spill Area No. 2. Principal contaminants include chromium, copper, lead, nickel, zinc, and cyanide. Test results also indicate that the surface water and sediments in the Northwest Wetland and drainage canal have been impacted by the site. In addition, onsite monitoring wells indicate a limited chemical plume or plumes related to site activities.

76. Superfund Record of Decision (EPA Region 1): Industri-Plex, Woburn, Massachusetts, September 1986 Final rept. 1986 Sep 30; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8718 United States.
The Industri-plex site is a 245-acre industrial park located in Woburn, Massachusetts. Various manufacturing facilities operated on the site from 1853 to 1968. The presence of hazardous substances was detected in 1979. Portions of stockpiled wastes sloughed off, releasing hydrogen sulfide gases to the atmosphere and toxic metals and solids to the pond and wetlands. Large areas of the contaminated soils are exposed at the surface thereby allowing individuals and animals to come in direct contact with arsenic, chromium and lead. Other contaminants of concern include benzene and toluene. The selected remedial alternatives for this site were recommended and are included in this report.

77. Superfund Record of Decision (EPA Region 6): Cleve Reber, Ascension Parish, Louisiana (First Remedial Action), March 1987Final rept. 1987 Mar 31; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8806 United States.
The Cleve Reber site is located in Ascension Parish between Baton Rouge and New Orleans, Louisiana. Originally a burrow pit for the construction of a local highway, it was subsequently used as a landfill for both municipal and industrial waste. There are an estimated 6,400 drums buried at shallow depths on this 24.6 acre site. The site ties within a 100 year flood plain and the area surrounding the site may fall within the wetlands classification. The site currently contains four surface water ponds. Between 1970 and 1974, it was used as a landfill for both municipal and industrial waste. No records of the waste received at the site are available. The wastes were reportedly segregated into municipals, chemical waste piles and landfilled. Numerous drums containing chemical wastes were buried onsite. Volatile chemical wastes during handling and disposal reportedly resulted in nausea and illness to the landfill employees. In 1974, the site was abandoned and in 1979 declared an abandoned hazardous waste site by the State. In 1983, the State fenced in the site due to local concern; and in July 1983, EPA conducted an emergency removal.

78. Superfund Record of Decision (EPA Region 4): Tower Chemical Company Site, Clermont, Florida, July 1987 Final rept. 1987 Jul 9; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8806 Portions of this document are not fully legible. United States.
The Tower Chemical Company (TCC) site is an abandoned manufacturing facility located along the eastern edge of Lake County, Florida. The TCC owned and utilized two separate parcels of land: a main facility and a spray irrigation field approximately 16 residences, located within a 1.2 mile radius of the site, tap the underlying aquifer for their water supply. Wetlands and swamps are also nearby the site. From 1957 to 1981, the TCC manufactured, formulated and stored various pesticides, acidic wastewaters, produced during the manufacturing process were discharged into the unlined percolation/evaporation pond located at the main facility. In July 1980, the pond overflowed and discharge was diverted to the spray irrigation field. In June 1980, as a result of damages caused by the wastewater pond overflow, the Florida Department of Environmental Regulation (FDER) ordered TCC to cease all discharges from the site studies, initiated by both EPA and FDER, indicated high concentrations of DDT and associated pesticide compounds in the main facility and a below normal fish population in the unnamed stream onsite.

79. Superfund Record of Decision (EPA Region 1): Re-Solve, Inc. Site, North Dartmouth, Massachusetts (Second Remedial Action), July 1987Final rept. 1987 Jul 24; Note: Environmental Protection Agency,

Washington, DC. 031287000 English GRAI8817 See also PB85-213627. Portions of this document are not fully legible. United States. The Re-Solve, Inc. site is a former waste chemical reclamation facility situated on six-acres of land in North Dartmouth, Massachusetts. Bounded by wetlands to the north and east, the land surrounding the site is predominantly zoned for single family residential use. All residences obtain their water from private wells located on their property. The Copicut River, located about 500 feet from the site, has been designated for protection. Between 1956 and 1980, Re-Solve, Inc. handled a variety of hazardous materials including solvents, waste oils, organic liquids and solids, acids, alkalies, inorganic liquids and solids and PCBS. Residues from the distillation tower, liquid sludge waste, impure solvents and burnt tires were disposed of in four onsite unlined lagoons. An oil waste that accumulated at the bottom of the degreaser distillation still was disposed of on one portion of the site through landfarming. In 1974 the Massachusetts Division of Water Pollution Control issued Re-Solve, Inc. a license to collect and dispose of hazardous waste. In December 1980 the Massachusetts Division of Hazardous Waste agreed to accept Re-Solve's offer to surrender its disposal license.

80. Superfund Record of Decision (EPA Region 4): Independent Nail Company, Beaufort, South Carolina (First Remedial Action), September 1987Final rept. 1987 Sep 28; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8812 United States.
The Independent Nail Company site, occupying 24.6 acres, is located near Beaufort, South Carolina. Land use in the vicinity of the site is a combination of fields, woodlands and wetlands. Endangered and threatened species may occur within the area of influence of the site, although habitation has not been confirmed. The previous owners of the site, the Blake and Johnson Company, manufactured metallic screws and fasteners. In part of the manufacturing process, the company discharged approximately 33,000 gallons per day of plating wastewater into an unlined infiltration lagoon. The lagoon was in use from approximately 1969 to 1980. The South Carolina Department of Health and Environmental Control (SCDHEC) reported that the wastewater contained some organic cleaning solvents, phosphate, cyanide, chromium, cadmium, lead, mercury, nickel, zinc, copper and iron. In April 1980 the Blake and Johnson Company ceased operation. Two months later the Independent Nail Company purchased the plant. They currently operate a paneling nail coating process at the plant, but do not discharge any wastewater to the lagoon. The primary contaminants of concern to the soil and sediment include: cadmium, chromium, nickel and zinc.

81. Superfund Record of Decision (EPA Region 1): Davis Liquid Waste Site, Smithfield, Rhode Island (First Remedial Action), September 1987 Final rept. 1987 Sep 29; Note: Environmental Protection Agency,

Washington, DC. 031287000 English GRAI8806 Portions of this document are not fully legible. United States.
The Davis Liquid Waste site is located in a rural section of the Town of Smithfield, Providence County, Rhode Island. The 15-acre site, bounded on the north and south by wetlands and swamp areas, is within one-half mile of 38 homes. Throughout the 1970s, the site served as a disposal location for various hazardous liquid and chemical wastes including: paint and metal sludge; oily wastes; solvents; acids; caustics; pesticides; phenols; halogens; metals; fly ash; and, laboratory pharmaceuticals. Liquid wastes were accepted at the site in drums and bulk tank trucks and were dumped directly into unlined lagoons and seepage pits. The dumping has resulted in soil, surface and ground water contamination that still persists. Periodically the semi-solid lagoon materials were excavated and dumped in several onsite locations and covered with available site soil. Other site operations included the collection of junked vehicles, machine parts, metal recycling and tire shredding. In 1977 the discovery of offsite well contamination prompted the State Superior Court to prohibit dumping of hazardous substances on the Davis property.

82. Superfund Record of Decision (EPA Region 5): Schmalz Dump, Harrison, Wisconsin, (Second Remedial Action), September 1987Final rept. 1987 Sep 30; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8808 Portions of this document are not fully legible. United States.
The Schmalz Dump site occupying approximately seven acres of the Waverly Beach wetlands area, is located on the north shore of Lake Winnebago in the town of Harrison, Wisconsin. Industries dumped wastes at various locations along the north shore of Lake Winnebago for several years. Mr. Gerald Schmalz, the previous site owner, began filling his property in 1968. Records show that wastes hauled there consisted of solid wastes, car bodies, stone, trees, pulp chips and mash. Between 1972 and 1973 the site accepted fly ash and bottom ash from Menasha Utility, and in 1978 and 1979 Schmalz accepted the demolition debris of a building owned by the Allis-Chalmers Corporation. Initial onsite sampling in early 1979 determined that an area containing the Allis-Chalmers debris was contaminated with concentrations of PCBs as high as 3,100 ppm with lead and chromium also detected in relatively high concentrations. In August 1985, a ROD was signed approving an operable unit to address the PCB contamination. This second operable unit addresses soil contamination with lead and chromium +3.

83. Superfund Record of Decision (EPA Region 5): Rose Township, Demode Road Site, Oakland County, Michigan, (First Remedial Action), September 1987Final rept. 1987 Sep 30; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8808 Portions of this document are not fully legible. United States.

The Rose Township Dump site is located in rural Rose Township, Oakland County, Michigan. The 110-acre site comprises an upland area almost completely surrounded by wetlands, with an abundance of wildlife onsite. From 1966 to 1968 an unknown number of drums containing solvents, paint sludges and PCBs were buried in a 12-acre portion of the site. Bulk wastes were also discharged to the surface or into shallow lagoons or pits in the area. In June 1979, the Michigan Department of Natural Resources (MDNR) tested domestic wells in the area and found low level TCE and PCE contamination. The contamination made it necessary to supply bottled water to residents. Based on 1979 drum sampling results, funds were appropriated for an immediate removal action, which disposed of over 5,000 drums offsite. Further testing between 1980 and 1982 indicated the presence of organic chemical contamination in the ground water. Currently, the primary contaminants of concern affecting the soil and ground water include: VOCs, PAHs, PCBs, organics and inorganics.

84. Superfund Record of Decision (EPA Region 4): Alpha Chemical, Alpha Resins Corporation Site, Lakeland, Florida, May 1988. First Remedial ActionFinal rept. 1988 Mar; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8910 Portions of this document are not fully legible. United States.
The Alpha Chemical site, located in Kathleen, Florida, consists of over 32 acres, that comprise the Alpha Resins Corporation (ARC), a facility of the Alpha Chemical Corporation. Surface water from the site drains into a swampy, low-lying wetland area. The facility has produced unsaturated polyester resin for fiberglass manufacturers since 1967. After switching to incineration, Pond 4 dried up. A waste stream, referred to as the 'water of reaction,' is produced as a by-product of polyester resin formation. The percolation ponds have not been used since 1976. At that time, a thermal oxidizer was installed to incinerate the waste stream rather than place it in the percolation ponds. It was then used for one year as a solid waste landfill by ARC. In April 1983, a ground water assessment report indicated industrial impacts on the surficial aquifer. The selected remedial action for the site is discussed. The estimated capital cost for the remedial action is $142,400, with present worth O&M of $186,200.

85. Superfund Record of Decision (EPA Region 5): Forest Waste Disposal, MI. (Second Remedial Action), March 1988. 1988 Mar 31; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8923 See also PB87-189890. United States.
The Forest Waste Disposal site consists of an 11-acre, abandoned municipal and industrial waste landfill and 9 surface impoundments. It is located in Genesee County, Michigan, 20 miles northeast of Flint, and is surrounded by agricultural land and undeveloped woodlands and wetlands. Forest Waste Disposal conducted landfill operations from

1972-1978, receiving limited types of liquid industrial waste, general household refuse, and drummed waste until 1978. Specific waste material found within the landfill includes PBB-contaminated feed, septic sludge, and drums containing primarily solid and liquid VOCs in high concentrations. The primary contaminants of concern affecting the soil and ground water are VOCs including toluene and TCE; other organics including pesticides, PAHs and PBBs; and metals including arsenic and lead. The selected remedial action for the site includes: removal and incineration of contaminated soil; installation of a containment system including a RCRA cap, slurry wall, dewatering system and a leachate collection system; and treatment and disposal of collected leachate; deed restrictions to prevent use of the ground water as a drinking water source; access restrictions; and ground water monitoring.

86. Superfund Record of Decision (EPA Region 3): Southern Maryland Wood Treating Site, Hollywood, Maryland (First Remedial Action) June 1988Final rept. 1988 Jun 29; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8919 Portions of this document are not fully legible. United States.
The Southern Maryland Wood Treating (SMWT) site is located in Hollywood, St. Mary's County, Maryland. The site is situated within a wetland area in a drainage divide such that runoff from the site discharges into Brooks Run and McIntosh Run tributaries, which flow into the Potomac River. The area surrounding the site is predominantly used for agricultural and residential purposes. Currently, part of the site is being used as a retail outlet for pretreated lumber and crab traps. The waste generated at the site included retort and cylinder sludges, process wastes, and material spillage. These wastes were in six onsite unlined lagoons. The primary contaminants of concern affecting the onsite ground water, soil, surface water, sediments, and debris include: VOCs, PNA, and base/neutral acid extractables. The selected remedial action for the site is included.

87. Superfund Record of Decision (EPA Region 5): Fort Wayne Reduction, Fort Wayne, Indiana (First Remedial Action) August 1988Final rept. 1988 Aug 28; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8919 Portions of this document are not fully legible. United States.
The 35-acre Fort Wayne site (FW) is a former municipal landfill/waste disposal facility located along the Maumee River just east of the city of Fort Wayne, Allen County, Indiana. Two onsite areas are designated as wetlands. In addition, the site lies within a 100-year flood plain. The site accepted residential and industrial wastes from 1967 to 1976. From May 1967 to August 1970, FW was issued a county permit for public disposal of garbage and rubbish. Wastes were incinerated and the residual ash disposed of onsite. In 1970, FW changed its name to National Recycling Corporation. All solid waste was to be processed through the

plant. It was torn down in 1985. Inspection reports indicated that deposited refuse included: industrial and liquid wastes, municipal wastes, garbage, paper, and wood. The site consists of two characteristically different areas reflecting its historical use: the eastern half of the site was used as the municipal/general refuse landfill (approximately 15 acres), and the western half of the site (approximately 5 acres) was used for disposal of industrial wastes, building debris, barrels of unidentified wastes, and residual ash from earlier incineration operations. Presently, soil and ground water are contaminated with 43 chemicals of concern including: metals, organics, PCBs, PAHs, phenols, and VOCs. The selected remedial action for the site is included.

88. Superfund Record of Decision (EPA Region 2): Burnt Fly Bog Superfund Site, Marlboro Township, Monmouth County, New Jersey (Second Remedial Action) September 1988. 1988 Sep 29; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8919 United States.
The Burnt Fly Bog site is located in Marlboro Township, Monmouth County, New Jersey. The area is affected by contamination from the 10-acre parcel where waste was originally deposited (Uplands Area Operable Unit). The site includes both flood plains and wetlands. Contamination has been detected in the surface water, surface soil, and the shallow subsurface soil as a result of uncontrolled discharges and runoff from the Uplands Area waste sources. The Uplands Area includes several abandoned oil storage and treatment lagoons containing residual oil sludges and aqueous wastes, contaminated waste piles, and buried or exposed drummed wastes. The primary contaminants of concern affecting the surface water, soil and sediments are PCBs and lead. The selected remedial action for the site is included.

89. Superfund Record of Decision (EPA Region 1): Charles George Landfill, Massachusetts (Third and Fourth Remedial Actions), September 1988 Final rept. 1988 Sep 29; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8919 United States.
The Charles George Landfill site is located approximately one mile southwest of the Town of Tyngsborough, Massachusetts. The 70-acre site is bounded by Flint Pond Marsh (wetland area) and Flint Pond, Dunstable Brook, and the Cannongate Condominium complex. Land use in the vicinity is predominantly rural and residential includes some light industry and seasonal livestock grazing. The landfill contains municipal waste disposed of onsite from the mid-1950s until the landfill closed in 1983. Hazardous industrial waste was also disposed of primarily in the western area of the site from 1973 until at least 1976. The site came to the attention of the Massachusetts Department of Environmental Quality Engineering when the deep bedrock wells in use by the Cannongate Condominium complex became contaminated with VOCs. The wells closed in 1982. EPA conducted ground water monitoring in 1981 and 1982 and also undertook emergency removal actions

beginning in August 1983 and continuing through March 1984. The ROD encompasses the third and fourth operable units and focuses on the control and cleanup of contaminants that have spread or are spreading from the site, including the treatment of leachate collected as part of the cap system. The selected remedial action for this site is outlined.

90. Superfund Record of Decision (EPA Region 3): Bendix Superfund Site, Bridgewater Township, South Montrose, Susquehanna County, Pennsylvania (First Remedial Action) September 1988Final rept. 1988 Sep 30; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8919 Portions of this document are not fully legible. United States.
The Bendix site is an aircraft instruments manufacturing plant located near the Village of South Montrose, Bridgewater Township, Susquehanna County, Pennsylvania. The 60-acre site is situated in a sparsely populated area (approximately 500 people) atop a topographic divide between the Meshoppen Creek and Wyalusing Creek watersheds. Natural ground water discharge areas exist east of the site in a wetlands area of Meshoppen Creek, and west of the site at the headwaters of Wyalusing Creek. South Montrose is solely dependent on private ground water wells for water. Investigations performed by Bendix from 1984 through 1987 indicated that as a result of past disposal practices, contamination from subsurface soil has been leaching into the underlying ground water. Five source areas of contamination have been identified at the site: a TCE storage tank area, the pet/trench area, an old landfill area, the area of a former solvent evaporation facility, and a former drum storage area behind the plant building. The primary contaminants of concern affecting the ground water and soil are VOCs including TCE. The selected remedial action for the site is included.

91. Superfund Record of Decision (EPA Region 4): Flowood, Rankin County, Mississippi (First Remedial Action), September 1988Final rept. 1988 Sep 30; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8917 United States.
The Flowood site consists of 225 acres of mostly wetlands and lowlands, is located in the Town of Flowood, Rankin County, Mississippi on the east side of the Pearl River. The site includes wastewater discharge areas and downstream areas adjacent to two industrial manufacturing facilities. Two manufacturing facilities have been owned and operated by a series of companies at the Flowood site since the 1950s. The northernmost facility manufactured corrugated boxes, and the southernmost facility produced ceramic tiles through the 1970s and stoneware cooking pots from the mid-1970s to the present. A routine industrial wastewater inspection conducted by the Mississippi Department of Natural Resources (MDNR) in the fall of 1982 revealed the unpermitted discharge of hazardous substances to the onsite canal. Subsequent sampling detected lead contamination in water and

sediments from the canal. The MDNR began an emergency treatment and removal process to address the contaminated wastewater, but discontinued the process when higher levels of lead were found in the canal adjacent to one of the manufacturing sites. In 1983, EPA investigations revealed high lead levels in onsite sludges, sediments, and surface soil. The primary contaminant affecting the soil and sediments is lead. The selected remedial action for the site is included.

92. Superfund Record of Decision (EPA Region 2): Clothier Disposal Site, Oswego County, New York, December 28, 1988. First Remedial Action. 1988 Dec 28; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8923 United States.
The Clothier Disposal site is located in a rural area near the Town of Granby, Oswego County, New York. In 1973, drums of chemical waste were discovered on the Clothier property, despite State denial of a landfill permit application. After the New York Department of Environmental Conservation brought suit, the owner made several attempts to clean up the property. These attempts resulted in drums being broken and drained. Subsequently, additional dumping of roofing materials, household wastes and junked vehicles occurred at the site. Based on the remedial investigation and State sampling, EPA established the need for a removal action for 2,200 drums located onsite. The primary contaminants of concern affecting the soil are VOCs including toluene, xylene, and PCE; other organics including PAHs, PCBs and phenols; and metals. The selected remedial action for the site includes: placement of a one-foot soil cover over the contaminated areas and regrading and revegetation of the site; installation of rip-rap, as needed, on the embankment sloping towards Ox Creek to prevent soil erosion; construction and post-construction air monitoring; institutional controls preventing the utilization of the underlying ground water, or any land use involving significant disturbance of the soil cover; and long-term ground water, soil, sediment and surface water monitoring.

93. Superfund Record of Decision (EPA Region 1): Baird and McGuire, MA. (Third Remedial Action), September 1989. 1989 Sep 14; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9012 United States.
The Baird and McGuire site is a former chemical manufacturing facility in northwest Holbrook, Massachusetts, approximately 14 miles south of Boston. From 1912 to 1983 the company operated a chemical manufacturing and batching facility on the property. Manufactured products included herbicides, pesticides, disinfectants, soaps, floor waxes and solvents. Waste disposal methods at the site included direct discharge into the soil, nearby brook and wetlands, and a former gravel pit (now covered) in the eastern portion of the site. EPA conducted a removal action at the site in 1983 after a waste lagoon overflowed spreading contaminants into the Cochato River. The company ceased operating shortly thereafter. A second removal action was conducted in 1985,

following the discovery of dioxin in site soils. EPA also conducted an Initial Remedial Measure at the site from 1985 through 1987 which involved constructing a new water main to direct water away from the site, removing building structures, and installing a temporary cap. The primary contaminants of concern affecting the sediment are organics including PAHs and pesticides, and metals including arsenic.

94. Superfund Record of Decision (EPA Region 1): Baird and McGuire, Holbrook, Massachusetts (Third Remedial Action), September 1989. 1989 Sep 14; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9008 See also PB87-189981. United States.
The Baird & McGuire site is a former chemical manufacturing facility in northwest Holbrook, Massachusetts, approximately 14 miles south of Boston. From 1912 to 1983 the company operated a chemical manufacturing and batching facility on the property. Manufactured products included herbicides, pesticides, disinfectants, soaps, floor waxes and solvents. Waste disposal methods at the site included direct discharge into the soil, nearby brook and wetlands, and a former gravel pit (now covered) in the eastern portion of the site. Underground disposal systems were also used. EPA also conducted an Initial Remedial Measure at the site from 1985 through 1987 which involved constructing a new water main to direct water away from the site, removing building structures, and installing a temporary cap. In 1986 a Record of Decision (ROD) was signed to address onsite ground water treatment and incineration of contaminated soil. This ROD addresses the Cochato River sediment contamination. The primary contaminants of concern affecting the sediment are organics including PAHs and pesticides, and metals including arsenic. The selected remedial action for the site are included.

95. Superfund Record of Decision (EPA Region 1): Wells G and H, Woburn, Massachusetts (First Remedial Action), September 1989. 1989 Sep 14; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9007 Portions of this document are not fully legible. United States.
The Wells G&H site encompasses 330 acres within the zone of contribution of two municipal drinking water wells known as Well G and Well H, commonly referred to as Wells G&H, in Woburn, Massachusetts. The Aberjona River flows through the site, and a substantial onsite wetlands area is associated with the river's floodplain. Wells G&H were developed in the 1960s and provided over one quarter of the Woburn community water supply. In 1979 the State closed the wells and provided the community with an alternate water supply after detecting several chlorinated volatile organic compounds (VOCs) in the wells. EPA investigations beginning in 1981 resulted in the site being divided into three discrete operable units. Between 1983 and 1989 EPA issued several Administrative Orders to site property owners requiring cleanup activities including limiting site access and removing drums and debris. This Record of Decision (ROD) addresses remediating

contaminated soil and groundwater found at the first operable unit, the five properties identified as principal sources of contamination, and further evaluating the remaining operable units. The primary contaminants of concern affecting the soil, sludge, debris, and groundwater are VOCs including PCE and TCE; other organics including carcinogenic PAHs (cPAHs), PCBs, and pesticides; and metals including lead. The selected remedial action for this site are included.

96. Superfund Record of Decision (EPA Region 1): South Municipal Water Supply Well, NH. (First Remedial Action), September 1989. 1989 Sep 27; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9009 United States.
The 250-acre South Municipal Water Supply Well site is near the Town of Peterborough, in Hillsborough County, New Hampshire. Also on the site are the New Hampshire Ball Bearings Incorporated (NHBB) manufacturing facility, several commercial establishments, and several apartments. The town of Peterborough discontinued use of the South Well in May 1983 after the State discovered VOC contamination in water samples taken from the well. Subsequent investigations revealed that a plume of contaminated ground water extended from under the NHBB property to the vicinity of the South Well. VOC contamination was also detected in soil on the NHBB property, and wetlands sediment was found to be contaminated with PCBs, metals, and PAHs. Investigations attributed the contamination to in-house chemical releases that were subsequently washed out through floor drains or slop sinks to outfalls, or washed out through facility doors. Exterior releases contributed to contamination at the site through the draining of a truck-mounted waste solvent tank. The primary contaminants of concern affecting the soil and ground water are VOCs including PCE, TCE, and toluene; the primary contaminants of concern affecting the sediment are organics including PCBs and PAHs, and metals.

97. Superfund Record of Decision (EPA Region 2): BEC Trucking, Town of Vestal, Broome County, New York (First Remedial Action), September 1989Final rept. 1989 Sep 28; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9010 United States.
The BEC Trucking site, also known as the Binghamton Equipment Company, is in the town of Vestal, Broome County, New York. The 3.5-acre site is an open lot which overlies a Class II aquifer. Land use neighboring the site is primarily commercial/industrial, but includes wetlands or marsh area to the west. The original owner, Haial Trucking, later to become BEC Trucking, filled some of the marshlands with various fill materials, including fly ash from a local power company. BEC Trucking, Haial Trucking's successor, operated a combination truck body fabrication and truck maintenance facility. Paint thinners and enamel reducers used during operations, and waste hydraulic oil and waste motor oil reportedly generated during operations were stored in a

drum storage area. A 1982 State inspection identified approximately 50 drums, 20 of which contained waste engine or cutting oils, enamel reducers, paint thinners, and waste solvents. In 1988 extensive sampling of ground water, surface water, and soil revealed low-level contamination. The suspected source of onsite ground water and surface water contamination appears to be a leaking underground storage tank on a neighboring property. Remedial activities are currently being undertaken at the neighboring site to address any ground water or surface water contamination at the site resulting from the tank's leakage.

98. Superfund Record of Decision (EPA Region 2): Caldwell Trucking Company, Fairfield Township, Essex County, New Jersey (Second Remedial Action), September 1989Final rept. 1989 Sep 28; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9008 See also PB87-190112. United States.
The 11-acre Caldwell Trucking site is in Fairfield Township, Essex County, New Jersey. The site is situated on an extensive 100-year floodplain of the Passaic River and neighbors Deepavaal Brook and numerous wetlands, as well as residential and commercial properties. From the 1950s to 1984 the Caldwell Trucking Company dumped, and allowed others to dump, septic wastes into unlined lagoons and later into steel holding tanks at the site. An EPA investigation conducted between 1984 and 1986 revealed that onsite soil and a municipal well were contaminated with VOCs, PCBs, and metals. The investigation resulted in a 1986 Record of Decision (ROD) which provided for soil remediation, restoration of a municipal well, and residential hookups to municipal water. Ground water, however, remains contaminated because of a TCE-contaminated plume which extends 4,000 feet from the site towards the Passaic River. The primary contaminants of concern affecting the ground water are VOCs including TCE. The selected remedial action for this site includes pumping and treatment of offsite ground water using air stripping with offsite discharge to the Passaic River.

99. Superfund Record of Decision (EPA Region 9): South Bay Asbestos Area, CA. (Second Remedial Action), September 1989 Final rept. 1989 Sep 29; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9010 See also PB89-204846. United States.
The South Bay Asbestos Area site is at the northern end of the Santa Clara Valley and at the southern end of the San Francisco Bay, in San Jose, California. From 1953 to 1982 the site operated as an asbestos-cement pipe manufacturing plant with asbestos-contaminated waste being disposed of onsite in three landfills. In 1983 the State collected soil samples which revealed that asbestos was randomly distributed throughout AAlviso, including the Alviso Rim levee. The State also determined that the Guadalupe River levee contained sbestos-contaminated waste debris and soil. The first ROD addressed contamination at the rim levee. The second and final ROD addresses the

asbestos contamination found at the remainder of the site. The primary contaminant of concern affecting the soil, debris, and air is asbestos. The selected remedial action includes paving approximately 128,500 square yards of an asbestos-contaminated truck yard and industrial yard; controlling dust emissions through monthly wet sweeping of streets; offsite disposal of asbestos-contaminated debris; air monitoring; and implementation of deed restrictions and other institutional controls.

100. Superfund Record of Decision (EPA Region 5): Onalaska Municipal Landfill Site, Lacrosse County, Wisconsin (First Remedial Action), Final Report, August 14, 1990. 1990 Aug 14; Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI9114 Paper copy available on Standing Order, deposit account required (minimum deposit $150 U.S., Canada, and Mexico; all others $300). Single copies also available in paper copy or microfiche. United States.
The 11-acre Onalaska Municipal Landfill site includes a 7-acre landfill owned by the Township of Onalaska, which is located in central-western Wisconsin. The Black River and its associated wetlands are 400 feet west of the site and lie within a wildlife and fish refuge. Approximately 320,000 gallons of liquid solvent waste and approximately 1,000 drums of solvent waste were either burned with other trash onsite or poured directly into holes for burial in the southwestern portion of the landfill. The primary contaminants of concern affecting the soil and ground water are VOCs, including benzene, toluene, xylenes, and TCE; other organics including PAHs; and metals including arsenic and lead. The selected remedial action for the site includes in-situ bioremediation of the solvent-contaminated soil and, if feasible, a portion of the landfill debris; pumping and treatment of the ground water plume using aeration, clarification, and filtration, followed by discharge of the treated ground water into the Black River and onsite disposal of the sludge.

101. Sutherland, J. C. Wetland-Wastewater Economics. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 417-426, 3 fig, 2 tab, 4 ref. Note: Williams and Works, Grand Rapids, MI. SWRA2202.
In the mid-1970s, there was a great need in Michigan for economical, postsecondary wastewater treatment, including phosphorus (P) removal. Wetland application for removal of P from this community's stabilization pond effluent seemed an affordable alternative. By early 1976, four years of research at the Porter Ranch peatland near Houghton Lake, Michigan indicated excellent renovation of wastewater and nitrogen (N) species by wetland application. EPA funded the design and construction of a wetland treatment project through the Municipal Construction Grants program, and state and federal review agencies had understandable concerns for the integrity of this pristine natural wetland. The factors that brought success to the project were excellent Premoval potential, prospects for net positive environmental responses,

an informed local populace, and great projected savings in wastewater treatment costs. The construction cost for the wetland at Houghton Lake was projected in 1976 to be $600,000. The construction of the upland irrigation alternative was projected at $1.1 million, or 83% higher. The construction of the wetland wastewater facilities, in fact, cost approximately $400,000 (1978 dollars). Labor at Houghton Lake, including overhead and administration, is $4,320. Electrical energy costs last year were $2,200. The most significant factor in the Houghton Lake electrical budget is friction losses in the forceline. Equipment, repair, and replacement are relatively minor, costing $1500 last year. Environmental monitoring costs were $10,000 last year, $5,000 for wildlife studies and $5,000 for vegetation-related studies. Costs of operation are also discussed for a wetland system in Vermontville, Michigan. (See also W89-01827) (Lantz-PTT).

102. Technical Support Document: Landfilling of Sewage Sludge. Available from the National Technical Information Service, Springfield, VA 22161, as PB89-136584. Price codes: A14 in paper copy, A01 in microfiche. 1988. 324p, 5 fig, 20 tab, 3 append. Note: Environmental Protection Agency, Washington, DC. Office of Water Regulations and Standards. SWRA2305.
The report describes good landfill management practices, but does not refer to specific regulatory requirements. Landfilling is a sludge disposal method in which sludge is deposited in a dedicated area, alone or with solid waste, and buried beneath a soil cover. Landfilling is primarily a disposal method, with no attempt to recover nutrients and only occasional attempts to recover energy from the sludge. About 41% of the municipal wastewater sludge generated in the United States is landfilled. When siting a monofill, special consideration must be given to evaluating sites near airports, 100-yr floodplains, wetlands, fault areas, seismic impact zones, and unstable areas. Requirements for siting monofills in each of these types of locations have been established by the proposed sewage sludge regulations to prevent adverse impacts to human health and the environment. Six areas of management practice requirements are specified by the proposed sewage sludge regulations. One of these six, pathogen reduction, is covered under separate title. The remaining five--landfill cover requirements, disease vector controls, explosive gases controls, access controls, and run-on/runoff controls are discussed. These management practices are required under Subtitle D or C of the Resource Conservation and Recovery Act and have been incorporated to some extent into the proposed sewage sludge regulation. (Lantz-PTT).

103. Urbonas, Ben; Roesner, Larry. CONFERENCE OVERVIEW. Urban Runoff Quality - Impact and Quality Enhancement Technology, Proceedings of an Engineering Foundation Conference.Publ by ASCE, New York, NY, USA p 1-9. 1986; . CODEN: 1986 Jun 23-27. Note: Urban Drainage & Flood Control District, Denver, CO, USA ASCE, Technical Council on Research, Urban Water Resources Research

Council, New York, NY, USA NSF, Washington, DC, USA American Public Works Assoc, Chicago, IL, USA US EPA, Washington, DC, USA English 8703.
An Engineering Foundation Conference organized by the ASCE Urban Water Resources Research Council was held at New England College in Henniker, New Hampshire, June 22-27, 1986. This paper provides a general overview of topics presented and discussed. Subjects covered include data collection, pollution sources and impacts, institutional issues, retention, detention, wetlands, treatment, research workshops, and future activities. 9 refs.

104. Urbonas, Ben (Ed).; Roesner, Larry A. (Ed.). URBAN RUNOFF QUALITY - IMPACT AND QUALITY ENHANCEMENT TECHNOLOGY, PROCEEDINGS OF AN ENGINEERING FOUNDATION CONFERENCE. Urban Runoff Quality - Impact and Quality Enhancement Technology, Proceedings of an Engineering Foundation Conference.Publ by ASCE, New York, NY, USA 477p. 1986; . CODEN: 1986 Jun 23-27. Note: Urban Drainage & Flood Control District, Denver, CO, USA ASCE, Technical Council on Research, Urban Water Resources Research Council, New York, NY, USA NSF, Washington, DC, USA American Public Works Assoc, Chicago, IL, USA US EPA, Washington, DC, USA English 8703.
The volume contains 35 papers presented at the meeting and two session discussions. The papers are grouped under general topics that include data needs and collection technology, pollution sources and potential impacts, impacts on receiving waters, institutional issues, effectiveness of best management practices, detention, retention, wetlands and other treatment, and a summary report on research and future activity needs. Also included are related topic supplemental papers on case studies of need-based quality-quantity control projects, lognormality of point and nonpoint source pollutant concentrations, and estimation of pollution from highway runoff.

105. Walsh, G. E.; Weber, D. E. Use of marsh plants in testing of sediment and pore water toxicity. 8. Int. Ocean Disposal Symp.EIGHTH INTERNATIONAL OCEAN DISPOSAL SYMPOSIUM, 9-13 OCTOBER 1989, INTER-UNIVERSITY CENTRE OF POSTGRADUATE STUDIES, DUBROVNIK, YUGOSLAVIA. PROGRAM AND ABSTRACTS. 1989; Note: U.S. EPA, Environ. Res. Lab., Gulf Breeze, FL 32561, USA SUMMARY LANGUAGE - ENGLISH; Summary only. ENGLISH V27N3.
Two species of freshwater marsh plants were exposed to liquid industrial and municipal effluents in water, natural sediment, and simulated sediment prepared from commercially available clay, silt, sand, and organic matter (particulate and dissolved). Only 10-60 ml of water is needed for testing of toxicity to seeds and seedlings, thus allowing tests on pore water derived from wet or flooded sediment. Seeds and seedlings are especially useful for sediment toxicity analysis because they depend on sediment as substratum and on pore water for nutrients. The

plant species were Echinochloa crusgalli (barnyard grass, Japanese millet) and Scirpus paludosus (alkali bullrush). Use of the estuarine plant Spx8pani@alterniflora (smooth cord grass) is also reported with dredged sediments.

106. Walters, R. R. Dade County, Florida, Case Study. IN: Planning for Groundwater Protection. Academic Press, Inc., New York. 1987. p 205-239, 12 fig, 3 tab, 10 ref. Note: Dade County Planning Dept., Miami, FL. SWRA2209.
Lakes and wetlands abound in southeastern Florida, the E_ + V>c $skV,xyY 4hPone-third of Dade County. Yet southeastern Florida communities are becoming hard-pressed to meet their ever-increasing demands for potable water. One of the reasons is that these Florida communities are building directly on top of their drinking water reservoir, the Biscayne Aquifer. This poses significant water quality problems, and given the emerging knowledge regarding the contamination of groundwater with synthetic organic chemicals and the potential health effects of this contamination, the challenge to local governments is becoming obvious whereas the solutions are not. Dade County has instituted a program to protect the quality of this sole source potable water supply, the Biscayne Aquifer. The water quality problem currently being addressed is that of contamination by synthetic organic chemicals (SOCs). There are five elements in Dade County's program to protect wellfield areas: (1) groundwater control through installation of hydraulic engineering structures, (2) water and wastewater treatment facilities, (3) land use policies and controls, (4) environmental regulation and enforcement, and (5) public awareness and involvement. It is evident that ways must be found to accommodate inevitable urban growth. But in doing so, encroachment on areas amenable to development of future public water supplies, areas in the Everglades that are ecologically sensitive, or areas that are devoted to productive agricultural activities may be necessary. In making long-range land use decisions, Dade County encounters these competing objectives whichever way it turns. So a decision to prevent or discourage expansion into one area to achieve one objective causes tradeoffs in other areas. It is, however, becoming evident how much more difficult the problems that will have to be solved will become in the future. (See also W89-10123) (Fish-PTT).

107. Watershed Plan For English Coulee Watershed, Grand Forks County, North Dakota. : Bismarck, North Dokota Department Of Agriculture, Soil Conservation Service, January 1983 (EPA: June 23, 1983). 113 Pages. Note: City Of Grand Forks, North Dakota Eastern Grand Forks County Soil conservation District Grand Forks County Water Resource District Western Grand Forks County Soil Conservation District Department Of Agriculture Soil Conservation Service English USDA Employees Request Documents From National Agricultural Library Others Order From Information Resources Press, 1700 North Moore Street, Suite 70 0, Arlington, VA 22209 North Dakota ENV

(Environmental Impact Statements) Other US (Not EXP STN, EXT, USDA; SINCE 12/76).
(PUR) Implementation Of A Flood Control And Land Treatment Plan for the 73,664-acre English Coulee watershed in Grand Gorks County of eastern North Dakota is proposed. The preferred plan would involve provision of accelerated technical assistance in installation of resource management systems on 14,260 acres of cropland and 1,760 acres of range, pasture, and hayland; construction of a rolled earthfill dam with reservoi storage reserved for sediment and floodwater; construction of a diversion structure to convey outflows from the floodwater-retarding dam and the runoff from 8.7 Miles of uncontrolled drainage area; and development of three miles of floodway to join two existing floodways that have a combined length of 10.5 Miles. land treatment actions would include conservation cropping systems on 14,260 acres, 139,500 linear feet of field windbreaks, conservation tillage systems on 8,130 acres, permanent hayland planting on 440 acres, planting of grasses and legumes in rotation on 560 acres, crop residue use on 14,260 acres, 900 linear feet of diversions, planting of grasses on 9 acres within waterways, enforcement of proper grazing use on 1,430 acres of grassland, pasture and hayland management practices on 160 acres, range reseeding on 80 acres, 9 livestock watering ponds, 22,500 linear feet of cross fencing, wildlife management on 190 acres of wetland, and wildlife management practices on 360 acres of upland. The floodwater-retarding structure, which would control drainage on 57.1 Square miles (or nearly 50 percent) of the watershed, would extend 6.5 Miles and have an average height of 8 feet; the structure would require 500,000 cubic yards of fill. The floodway would complete a 13.5-Mile system that would convey diverted water to the red river of the north. Cost of structural measures is estimated at $3.5 Million, and technical assistance costs are estimated at $34,000. Estimated benefit-cost ratio for the project is 1.13. (Pos)both urban and rural properties .

108. Weeks, C. R.; Crockett, J. A. URBAN STORMWATER POLLUTION AND ABATEMENT. Workshop on Non-Point Sources of Pollution in Australia, Proceedings. Workshop on Non-Point Sources of Pollution in Australia, Proceedings.Australian Water Resources Council Conference Series n 9. Publ by Australian Government Publ Service, Canberra, Aust p 190-202. 1983; . CODEN: 1983 Mar 7-10 AWRSDQ; ISSN: 0725-4695. Note: Gutteridge Haskins & Davey Pty Ltd Australian Water Resources Council, Aust English 8503.
A simple model for estimation of pollutants exported by stormwater runoff from urban catchments is described. Typical annual export rates are presented. Typical pollutant concentrations are also given to indicate the likely impact of pollutant exports on receiving waters and to enable possible abatement options to be considered in context. Various abatement options are discussed, however many of these employ local controls which are not applicable to developed urban areas because to be successful they need to be implemented at the outset of urbanisation.

Emphasis has therefore been given to abatement methods that can be introduced into existing urban areas. These are generally limited to storage/detention systems, and even then adequate land must be available and the topography suitable. Chemical treatment systems and wetland filters are examined as particular cases of storage/detention systems. Refs.

109. Wiswall, K. C.; Marasco, A. L.; Gesalman, C. M.; Elliott, M. Reference Handbook on Small-Scale Wastewater Technology. 1985 Apr; Note: Synectics Group, Inc., Washington, DC. 078733000 Weston (Roy F.), Inc., West Chester, PA. Department of Housing and Urban Development, Washington, DC. Office of Policy Development and Research. English GRAI8803 Prepared in cooperation with Weston (Roy F.), Inc., West Chester, PA. Sponsored by Department of Housing and Urban Development, Washington, DC. Office of Policy Development and Research. United States.
Small-scale wastewater systems have been installed and studied in many communities. The handbook synthesizes the experience with small-scale wastewater systems that has been amassed over the past 15-20 years. It is designed to: Identify wastewater technology alternatives, their advantages and constraints, and their best applications; Describe the regulatory requirements that normally apply to these systems; Identify operation and maintenance (O&M) concerns related to alternative technology as a whole and to the specific technologies discussed; and Direct readers to other sources of information.

110. Wotzka, P.; Oberts, G. Water Quality Performance of a Detention Basin-Wetland Treatment System in an Urban Area. IN: Nonpoint Pollution: 1988-Policy, Economy, Management, and Appropriate Technology. Proceedings of a Symposium. American Water Resources Association, Bethesda, Maryland. 1988. p 237-247, 8 fig, 3 tab, 9 ref. Note: Metropolitan Council, St. Paul, MN. SWRA2404.
The McCarrons Treatment System is a surface water management facility consisting of a detention pond followed by six 'chambered' wetlands designed to improve the water quality of Lake McCarrons in Roseville, Minnesota. The system is located at the bottom of a 243 hectare urban watershed. Most of the reduction in pollutants occurs in the detention pond. Performance conclusions are based on results from 21 of the 57 rainfall events and 4 periods of snowmelt. Climatic conditions and the precipitation during the 21 months of study were not 'normal,' but rather reflective of a mild, dry period with a major rainfall event and two very wet months. The detention pond is considered to be currently performing at the best level that can be expected. Attributes thought to contribute positively to treatment levels in the pond include diffuse inflow from three separate tributaries, a low dissolved phosphorus to total phosphorus (DP:TP) ratio, and newly exposed peat soils with a high affinity for attracting TP. Changes in the design of the outlet structure could improve the effectiveness of the detention pond in treating snowmelt. The post-detention wetland system was intended to

'polish' outflows from the detention pond before the water discharged to the lake. The wetland continues the process of settling solids begun in the pond, but is less effective in removing soluble nutrients. This situation is partially related to additional inputs to the wetlands from another tributary, overland runoff, and atmospheric deposition. Even though nutrient removal in the wetland is not high, there is a net reduction so the wetland is performing as expected. (See also W91-03704) (Author's abstract).

WASTEWATER AND DOMESTIC MUNICIPAL SEWAGE CONSTRUCTED WETLANDS

BIBLIOGRAPHY

1. Anon. Sewage and industrial waste treatment: Wetlands. January 1977-July 1989 (citations from the Selected Water Resources Abstracts database). 1989;
Note: SUMMARY LANGUAGE - ENGLISH; NTIS Order No.: PB89-865745/GAR. 112 ref. Supersedes PB88-866470. ENGLISH V21N5.
This bibliography citations concerning developments, operations, and evaluations of natural and artificial wetlands treatment of wastewater and sludge. Aquaculture treatments of industrial, municipal, and domestic wastewater are examined. Topics include nutrient removal, heavy metal recovery, and case studies of wetlands being used for wastewater treatment. (This updated bibliography contains 112 citations, 19 of which are new entries to the previous edition). (Prepared in cooperation with office of Water Research and Technology, Washington, DC (USA).).

2. Bastian, R. K.; Shanaghan, P. E.; Thompson, B. P. Use of Wetlands for Municipal Wastewater Treatment and Disposal: Regulatory Issues and EPA Policies. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 265-278, 1 fig, 27 ref.
Note: Environmental Protection Agency, Washington, DC. Office of Municipal Pollution Control. SWRA2305.
Wetlands provide high levels of wastewater treatment, but concern has been expressed over (1) possible effects from of toxic materials and pathogens in wastewaters and (2) long-term degradation of wetlands from wastewater discharges. Constructed wetlands employ wetland vegetation to assist in treating wastewater in a more controlled environment than occurs in natural wetlands. Regulatory issues and Environmental Protection Agency (EPA) policies involved in wastewater treatment with constructed wetlands are considered. Both natural and constructed treatment systems have achieved high removal efficiencies for BOD5, suspended solids, nutrients, heavy metals, trace organic compounds, and pathogens from municipal wastewater. In many areas, natural wetlands serve as receiving waters for permitted discharges of treated wastewater. More than 400 such discharges exist in the Southeast and another 100 occur in the Great Lakes States. In arid regions, wastewater effluents are often used to create, maintain, restore, or enhance wetlands. There are several circumstances under which wetlands are considered 'waters of the United States' under 40 CFR Part 122.2; most natural wetlands are included, but most constructed wetlands are excluded from this definition. In addition to meeting minimum technology requirements, discharges to waters of the United States must comply with applicable state water quality standards. Very few

states have established separate water quality standards for wetlands, and EPA has not developed water quality criteria specifically for wetlands. When altering natural wetlands for use in wastewater treatment, it generally is necessary to obtain a permit under section 404 of the Clean Water Act. A recent EPA task force concluded that natural wetlands should be viewed primarily as protected water bodies and that, in the absence of water quality criteria for wetlands, it is impossible to identify broadly conditions where they could be safely regarded as part of the 'treatment system.' EPA encourages the use of constructed (artificial) wetlands through the innovative and alternative technology provisions of its construction grants program. (See also W90-04392) (Rochester-PTT).

3. Brodie, G. A. Selection and Evaluation of Sites for Constructed Wastewater Treatment Wetlands. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 307-317, 2 fig, 13 ref.
Note: Tennessee Valley Authority, Chattanooga. Div. of Power System Operations. SWRA2305.
Constructed wetlands are practical alternatives to conventional treatment of domestic and municipal sewage, industrial and agricultural wastes, stormwater runoff, and acid mine drainage. Siting a constructed wetland is often dictated by the location of the wastewater source (eg, a public sewage treatment works or an acidic seep at a coal mine). The wastewater source seldom can be relocated, thus forcing the wetland to be located nearby, often at a mediocre or poor site. Nevertheless, siting can be optimized through a comprehensive site investigation process, including site selection, temporary or permanent engineered works design, environmental effects analyses, construction evaluation, remedial works design and construction, and operational and safety checks. Site selection is based on geological, geotechnical, hydrological, and other environmental information that could affect construction, performance, and effects of a wetlands treatment system. Site selection is constrained by the availability of a suitable site and geotechnical merits, eg, well-developed soils, good access, or low flood potential. Despite these constraints, idealized site selection considerations and investigative techniques can be described. A methodology for selecting and evaluating sites for constructed wetlands is presented here in the form of a flow chart. Major steps include: deciding whether or not to use wetland treatment, a preliminary office study with published materials, preliminary design, air photo interpretation, field survey, refined design, data collection (limited or detailed, as needed), data evaluation, final wetland design, pilot testing, design modifications, and, ultimately, construction. Site selection and evaluation should be tailored to the degree of complexity and magnitude of the project. Limited site evaluation followed by a design based on an excessive safety factor is generally wasteful and imprudent. Conversely, conducting a detailed site investigation is unnecessary for siting a small wetland. Regardless of the site-selection methodology employed, a 'walkover' survey is

necessary for assessment of candidate sites. This survey should include site inspection and local inquiries. Data from earlier surveys should be confirmed during the site visit. (See also W90-04392) (Rochester-PTT).

4. Brown, M. T. Managing Landscapes for Humanity and Nature: The Role of Wetlands in Regional Nutrient Dynamics. IN: Wetlands of the Chesapeake. Proceedings of the Conference Held April 9-11, 1985, Easton, Maryland. 1985. p 63-75, 3 fig, 1 tab, 52 ref.
Note: Florida Univ., Gainesville. Center for Wetlands. SWRA2106.
Concerned primarily with the spatial manifestations of landscape processes, the new 'science of the landscape' is striving to generate theoretical principles to better understand large-scale spatial and temporal phenomena. Management strategies are beginning to reflect this new awareness of and emphasis on landscape, as evidenced by incorporation of a broader systems approach. The impact of humanity on regional nutrient budgets and cycling is widespread and pervasive. Conversion of forests and meadows to agricultural and urban uses has altered regional nutrient dynamics by changing soil chemistry and increasing soil erosion and the harvesting of forest products. In the process, by-products are released to the environment. This concentrated consumption and eventual release of by-products has influenced the chemical character of the larger environment. The relatively recent rise of human influence in the landscape has not changed the basic processes, only the speed at which they occur. While some new and unfamiliar chemical species have been released to the environment, the major influence is the spatial concentration of chemicals. Effective management of the entire landscape can be facilitated by utilizing a wide range of new 'values' possessed by wetlands, including processing wastewater and attenuating floods. 'Artificial' wetlands can be used to reverse trends in wetland loss and add new values to the landscape mosaic. (See also W88-04934) (Lantz-PTT).

5. Burton, T. M.; Ulrich, K. E. Establishment and Management of Freshwater Marshes for Maximum Enhancement of Water Quality for Reuse. Available from the National Technical Information Service, Springfield, VA 22161, as PB84169390, Price codes: A04 in paper copy, A01 in microfiche. Completion Report, September, 1983. 65 p, 22 Fig, 8 Tab, 44 Ref. Project No. OWRT B-055.
Note: Michigan State Univ., East Lansing. Dept. of Zoology. SWRA1711.
The objective of this study was to provide information (1) on growth and nutrient uptake responses of marsh plants to variable loading rates of N, P, and K and (2) on the response of these plants to various harvest regimes as background information for the design, maintenance, and operation of natural or artificial marshes for water quality enhancement. Five species of highly productive common marsh plants were grown in large pots with various loading rates of nitrogen, phosphorus, and potassium plus an excess of other necessary plant nutients. The five species were the common reed (Pragmites australis), wild rice (Zizania

aquatic), two species of cattail (Typha latifolia and T. angustifolia), and burreed (Sparganium eurycarpum). In general, all five species responded with increased growth to increases of N and P alone or especially in combination up to a maximum of 468 N/ha and 125 kg P/ha. Growth of S. eurycarpum was inhibited at loading rates of 936 kg N/ha. The two species of cattail were the most productive of the five species at higher loading rates. The potassium contained in the low nutrient and medium used in these experiments was adequate for growth of all species, and added K caused little or no increase in growth. Experiments on establishment and harvest of these five species plus prairie cordigrass (Spartina pectinata) were attempted. Successful establishment and harvest of the two species of cattail and burreed was achieved. These three species only tolerated one harvest per year; multiple harvesting led to decline in biomass the following year. Nutrient budgets for three 0.47 artificial marshes indicated excellent removal of N by these marshes, but little P removal occurred.

6. Castleberry, D. T.; Cech, J. J. Mosquito Control in Wastewater: A Controlled and Quantitative Comparison of Pupfish (Cyprinodon nevadensis amargosae), Mosquitofish (Gambusia affinis) and Guppies (Poecilia reticulata) in Sago Pondweed Marshes. Journal of the American Mosquito Control Association JAMAET, Vol. 6, No. 2, p 223-228, June 1990. 2 fig, 2 tab, 25 ref.
Note: California Univ., Davis. Dept. of Wildlife and Fisheries Biology. SWRA2402.
Vascular aquatic plants can provide a remarkably efficient and inexpensive means of treating municipal, agricultural and industrial wastewater. Unfortunately, mosquito control is difficult in artificial marsh environments. The abilities of pupfish, mosquitofish and guppies to control mosquitoes in wastewater marshes was compared. Sago pondweed was planted in 210 liter fiberglass tanks through which secondary wastewater was passed at 4 to 6 ml/second. Groups of 10 to 30 fish were placed in each of 15 tanks (plus 5 controls), along with large mosquito egg rafts. All species of fish reduced mosquito emergence ($p <$ or $= 0.05$). When fish population densities were similar, fish reduced emergence to similar levels. As experiments progressed, guppies developed greater population densities and provided better mosquito control than mosquitofish, which developed greater densities and better control than pupfish. Fish also reduced numbers of zooplankton, and guppies increased total plant biomass, suggesting fish may influence the ability of wastewater marshes to treat wastewater. (Author's abstract).

7. Choate, K. D.; Watson, J. T.; Steiner, G. R. Demonstration of constructed wetlands for treatment of municipal wastewaters, monitoring report for the period, March 1988-October 1989. 1990 Aug;
Note: Tennessee Valley Authority, Knoxville. Div. of Water Resources. 021113041 9512364 English GRAI9111 ERA9123 United States.
To evaluate the constructed wetland technology, the Tennessee Valley Authority (TVA) implemented a municipal wastewater demonstration

project in western Kentucky. Using combined city, State, and TVA appropriated funds, three constructed wetland systems were built at Benton, Hardin, and Pembroke, Kentucky. Demonstration objectives include evaluating relative advantages and disadvantages of these types of systems; determining permit compliance ability; developing, evaluating, and improving basic design and operation criteria; evaluating cost effectiveness; and transferring technology to users and regulators. A demonstration monitoring project was implemented with a partnership of funds from the Environmental Protection Agency (EPA) Region IV, other EPA funds through the National Small Flows Clearinghouse (NSFC), and TVA appropriations. TVA is managing the project in cooperation with an interagency team consisting of EPA, Kentucky Division of Water and NSFC. This report, which supersedes the first monitoring report (Choate, et. al., 1989) of these demonstration projects, describes each constructed wetland system, its status, and summarizes monitoring data and plans for each system. 5 refs., 30 figs., 26 tabs.

8. Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Proceedings from the First International Conference on Constructed Wetlands for Wastewater Treatment held in Chattanooga, Tennessee on June 13-17, 1988. Lewis Publishers, Chelsea, Michigan. 1989. Edited by Donald A. Hammer. 831p.
Note: SWRA2305.
Widespread use of constructed wetlands may provide a relatively simple and inexpensive solution for controlling many water pollution problems facing small communities, industries, and agricultural operations. Adoption of this technology has been inhibited by a lack of guidelines and instructions supported by adequate information on important system components and basic wetlands ecology. The goal of the present volume is to provide information to improve acceptance and increase application of constructed wetlands for water quality improvements. The book represents the proceedings of the First International Conference on Constructed Wetlands for Wastewater Treatment, held at Chattanooga, Tennessee, on 13-17 June 1988. Besides wetlands treatment of municipal wastewater, which has been the subject of other conferences, this volume includes applications with acid mine drainage, urban runoff, agricultural wastes, and industrial effluents. Topics include: general principles (hydrology, chemistry, physics, ecology, and microbiology); case histories (pilot and full-scale plants); design, construction, and operation; and recent results from field and laboratory (dynamics of inorganic and organic materials in wetlands, efficiencies of substrates, vegetation, water levels, and microbial populations, management of domestic and municipal wastewaters, nonpoint source pollutants (urban runoff and agricultural wastes), applications to industrial and landfill wastewaters, and control of acid mine drainage including coal pile and ash pond seepage). (See W90-04393 thru W90-04476) (Rochester-PTT).

9. Daukas, P.; Lowry, D.; Walker, W. W. Design of Wet Detention Basins and Constructed Wetlands for Treatment of Stormwater Runoff from a Regional Shopping Mall in Massachusetts. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 686-694, 3 fig, 1 tab, 2 ref.
Note: IEP, Inc., Northborough, MA. SWRA2305.
Runoff from parking lots and roadways contains high concentrations of suspended solids, nutrients, trace metals, oil and grease, and deicing salts. A case study is presented of water quality mitigation measures for the 83,600-cu m Emerald Square Mall, North Attleborough, Massachusetts. The project site encompasses 23 ha and is located within the watershed of the Sevenmile River, which contributes to the drinking water supply of the City of Attleboro. For controlling stormwater runoff quality, the design and operation of the Emerald Square Mall include the following measures: wet detention ponds, constructed wetland basins, catch basins equipped with oil and grease traps, parking lot sweeping, sodium-free deicing salts, and restricted use of herbicides, pesticides, and fertilizers. Wetland basins were established during the first construction phase to provide at least one full growing season prior to receiving parking lot runoff. The basins are designed as shallow marsh communities on organic soil. Approximately 35,000 tubers of indigenous marsh emergents were planted at the following percentages: 30% cattail (Typha latifolia), 25% arrowhead (Sagittaria latifolia), 25% bulrush (Scirpus validus), and 20% sweet flag (Acorus calumus). Side slopes were seeded with millet (Echinochloa sp.) and reed canary grass (Phalaris arundinacea). Wetland shrubs also were planted to enhance the 'edge' effect around the wetlands. A range of pollutant removal efficiencies was estimated as follows: suspended solids, 80-95%; total P, 60-85%; total N, 40-70%; BOD5, 50-80%; sodium, 0; cadmium, 50-50%; chromium, 50-90%; copper, 50-90%; lead, 80-95%; mercury, 50-90%; and zinc, 50-90%. Mass balance calculations suggested that development of Emerald Square Mall with the described runoff measures should not affect adversely the use of Sevenmile River for water supply. Long-term monitoring of treated runoff will be used to detect water problems that may develop during mall operation. (See also W90-04392) (Rochester-PTT).

10. Desjardins, R. M.; Seyfried, P. L.; Palmateer, G. A. Heavy metals and their effects on marsh systems used to treat municipal sewage. Eastern Region Conference of the Canadian Association on Water Pollution Research and ControlEASTERN REGION CONFERENCE OF THE CANADIAN ASSOCIATION ON WATER POLLUTION RESEARCH AND CONTROL. 1986;
Note: Dep. Microbiol., Fac. Med., Univ. Toronto, Toronto, Ont. M5S 1A8, Canada SUMMARY LANGUAGE - ENGLISH ENGLISH.
The artificial marsh treatment system is a viable method of wastewater treatment in small communities. Although several marsh facilities have been constructed in Ontario, the marsh located in Cobalt is unique

because it is constructed on a mine tailing basin. The purpose of this study was to determine if elution of metals from mine tailings would have an adverse effect on the microflora of a marsh treatment system.

11. DUFFIELD J M. WATERBIRD USE OF AN URBAN STORMWATER WETLAND SYSTEM IN CENTRAL CALIFORNIA USA. COLON WATERBIRDSColonial Waterbirds. 235 Sep; . CODEN: COWAE. Note: TIBURON CENT. ENVIRONMENTAL STUDIES, P.O. BOX 855, TIBURON, CALIF. 94920 USA. ENGLISH.
I determined the abundance, diversity and relative abundance of waterbirds at a 16 hectare wetland complex designed to control urban stormwater runoff from the city of Fremont, California, USA. This demonstration project for an urban stormwater treatment (DUST) wetland complex consisted of three adjacent marshes, which differed in size, shape, water depth and amount of vegetation. For comparative purposes the waterbird population at DUST Marsh was compared to Main Marsh, a nearly natural marsh. Weekly bird censuses were conducted from January to June 1984 and from November 1984 to June 1985 at the two sites located within Coyote Hills Regional Park, Fremont, Alameda County, California. Biweekly censuses were conducted from June to November 1984. DUST Marsh had greater abundance ($p < 0.05$) and species diversity ($p < 0.001$) in 1984; Main Marsh had greater abundance ($p < 0.05$) in 1985. Winter abundance was greater at Main Marsh ($p < 0.05$); DUST Marsh had greater species numbers during spring and summer ($p < 0.005$). Dabbling and diving ducks preferred Main Marsh, whereas shorebirds, gulls and terns preferred the stormwater control marsh. Percentage of open water, emergent vegetation and water depth accounted for differences in marsh utilization. Of the three DUST Marshes, the moist mudflats of the overland flow received the greatest waterbird utilization.

12. Esry, D. H.; Cairns, D. J. Overview of the Lake Jackson Restoration Project with Artificially Created Wetlands for Treatment of Urban Runoff. IN: Wetlands: Concerns and Successes. Proceedings of a Symposium held September 17-22, 1989, Tampa, Florida. American Water Resources Association, Bethesda, Maryland. 1989. p 247-257, 3 fig, 9 ref.
Note: Northwest Florida Water Management District, Havana. Water Resources Div. SWRA2312.
The Northwest Florida Water Management District engaged in a federally funded Clean Lakes Restoration Project for Lake Jackson in Tallahassee, Florida, during the late 1970s. Construction of this experimental \$2.6 million stormwater treatment facility was begun in 1981 with completion in 1983. The design employed a three step process to remove sediment and nutrients from urban runoff prior to entering the lake. The first two steps entail the detention of the stormwater in a twenty acre impoundment followed by passage through a 4 acre filter with an underdrain collection system. The final step consists of the partially treated stormwater flowing to a 9 acre artificial marsh for

further sediment removal and nutrient assimilation. The entire process has been monitored to determine the effectiveness of the various steps within the project. A recent report concludes that while the stormwater facility works well (>90% removal of solids by the filter; 60-65% removal of nutrients by the marsh) there remain operational deficiencies. One of the major deficiencies cited was the excedence of the total volume of the impoundment by more than half of the large storms monitored. These larger storms also bypass treatment by the created wetlands in the artificial marsh. Several proposed projects address this concern and would implement measures to help alleviate the current burden on the facility. (See also W90-10912) (Author's abstract).

13. Gersberg, R. M.; Lyon, S. R.; Brenner, R.; Elkins, B. V. Integrated Wastewater Treatment Using Artificial Wetlands: A Gravel Marsh Case Study. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 145-152, 2 fig, 1 tab, 19 ref. California Department of Water Resources Grant B-54835, EPA Grant CR 8.
Note: San Diego State Univ., CA. Graduate School of Public Health. SWRA2305.
Tests of the use of artificial wetlands for performing secondary treatment of municipal wastewaters and the mechanisms of nitrogen and total coliform removal were examined. The test system consisted of beds containing aquatic plants growing in gravel. In the larger artificial wetland (Scirpus cover) at an application rate of about 5 cm/day (7.5-8 ha per 3785 cu m/day), the mean BOD5 removal efficiency for an October to August period was 90%, with the mean effluent level of 113 mg/L reduced to 11 mg/L in the wetland effluent. On four sampling dates in the winter, effluent BOD5 exceeded 30 mg/L. The wetlands also removed about 90% of the influent suspended solids (70 mg/L reduced to 6.8 mg/L). Capital costs for a facility capable of treating 3785 cu m/day (1 mgd) is estimated at $1.7 million compared to $2.5 million for an equivalent conventional secondary treatment facility. Estimated operation and maintenance expense of $137 per 3785 cu m treated is less than half the corresponding cost for conventional secondary treatment. Ammonia removal rates of 94% were measured for bulrush, 78% of reeds, and 28% for cattails, compared to 11% for an unvegetated bed. It is suggested that nitrifying bacteria can be stimulated by the oxidizing abilities of the plant rhizome, which performs a function analogous to that of an air compressor in an activated sludge tank. The ability of artificial wetlands to perform integrated wastewater treatment by removing bacterial indicators as well as BOD5, suspended solids, and nitrogen makes them an attractive alternative for meeting treatment needs of small-to-medium-sized communities. Where land is available, artificial wetlands offer a simple process design, lower operating and maintenance expense, and wildlife enhancement value, and represent an innovative solution to cost-effective wastewater treatment. (See also W90-04392) (Rochester-PTT).

14. Gillette, B. Revolution in Wastewater Treatment. Biocycle BCYCDK, Vol. 29, No. 3, p 48, 50-51, March 1988. 1 fig.
Note: NASA, NSTL, Building 2423, NSTL, MS 39529. SWRA2109.
Collins, MS, San Diego, CA, Monterey, VA, and Haughton, LA are just a few of the many cities in the U.S. that are joining a quiet revolution in wastewater treatment. Plants are being used as a key element in artificial marshland wastewater treatment systems that take advantage of natural processes to make a significant difference in the purity of wastewater effluent. In most cases, the natural systems work better and are less expensive to build, operate and maintain than the mechanical systems replaced. Some of the aquatic plants that have been studied for use in wastewater treatment are hyacinths, duckweed, bulrush and several ornamental plants. Artificial marsh design, and the effectiveness of the system in winter is also discussed. (VerNooy-PTT).

15. Guntenspergen, G. R.; Stearns, F.; Kadlec, J. A. Wetland Vegetation. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 73-88, 1 tab, 104 ref. NSF Grant BSR-8604556.
Note: Louisiana State Univ., Baton Rouge. Dept. of Botany. SWRA2305.
Natural wetlands have been used to treat wastewater with varying efficiency. Concern over environmental impacts on natural systems and the need for an empirically-based wetlands wastewater treatment technology led to emphasis on constructed wetlands. Wetland vegetation is reviewed, including: classification, adaptations of plants to the aquatic environment, production and growth, nutrient uptake, adaptations to anaerobic conditions, factors limiting plant growth, and vegetation interactions with wastewater. Over 1000 species of plants have been found that are from entirely aquatic plant families, yet less than 1% of the available taxa have been tried in wastewater treatment projects. Emergent and floating-leaved species have been used preferentially in pilot studies of constructed wetlands. Floating-leaved species have been used because of their high growth rates, large standing crops, and ability to strip nutrients directly from the water column. Potentially useful emergent species include many members of the cattail, reed, rush, sedge, and grass families. Phalaris, Spartina, Carex, and Juncus all have potentially high uptake and production rates. They are widespread, able to tolerate a range of environmental conditions, and can alter their environment in ways suitable for wastewater treatment. Rhizosphere processes are largely unknown, but presumably have positive impacts (e.g., through oxygenation). Submerged aquatic plants do not appear to have attributes useful in wastewater treatment. They have low production rates and many species are intolerant of eutrophic conditions and/or have detrimental interactions with algae in the water column. However, some species do possess large surface areas, oxygenate the rhizosphere, and are adapted to eutrophic disturbed systems. Submergents may be useful in conjunction with other species. Because different types of wastewater treatment (e.g., municipal, stormwater, acid mine drainage)

have different treatment needs, one plant species or set of species will not be applicable in all cases. (See also W90-04392) (Rochester-PTT).

16. HAMMER D A. CONSTRUCTED WETLANDS FOR TREATMENT OF AGRICULTURAL WASTE AND URBAN STORMWATER. MAJUMDAR, S. K., ET AL. (ED.). PENNSYLVANIA ACADEMY OF SCIENCE PUBLICATIONS: WETLANDS ECOLOGY AND CONSERVATION: EMPHASIS IN PENNSYLVANIA. XIV+395P. PENNSYLVANIA ACADEMY OF SCIENCE: EASTON, PENNSYLVANIA, USA. ILLUS. MAPS. ISBN 0-945809-01-8. 348; . CODEN: 28377.
Note: TENNESSEE VALLEY AUTHORITY, WASTE TECHNOL., VALLEY RESOURCE CENTER, 2D46 OLD CITY HALL BUILDING, KNOXVILLE, TN 37902. ENGLISH.

17. Hammer, Donald A. Constructed wetlands for wastewater treatment ^municipal, industrial, and agricultural [edited by] Donald A. Hammer. International Conference on Constructed Wetlands for Wastewater Treatment_ (1st :_ 1988 :_ Chattanooga, Tenn.).
Note: English "Proceedings from the First International Conference on Constructed Wetlands for Wastewater Treatment held in Chattanooga, Tennessee on June 13-17, 1988"--Pref. Includes bibliographical references. Michigan OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

18. Hantzsche, N. N. Wetland Systems for Wastewater Treatment: Engineering Applications. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 7-25, 4 tab, 37 ref.
Note: Ramlit Associates, Inc., Berkeley, CA. SWRA2202.
The use of wetlands for treatment of various wastewaters has attracted considerable interest and research attention during the past 10 to 15 years. What can generally be concluded on the basis of the experience to date is that: (1) Wetland systems can provide measurable renovation of wastewaters and storm waters, but the necessary understanding and criteria to take the best advantage of these processes on a routine basis do not currently exist; (2) Natural wetlands are highly variable in characteristics, making it difficult, if not impossible, to apply study results to different geographical areas; (3) The use of artificial or constructed wetlands appears to have the greatest promise for general application because of better reliability and process control; (4) There is a substantial amount of interest in creating or restoring wetlands simply for environmental enhancement. There are also strong desires to couple environmental enhancement with programs for treatment of municipal wastewaters, stormwaters, agricultural return flows, and various types of industrial wastewaters; and (5) Pilot or demonstration studies are still needed before engineers can confidently proceed with design and implementation of full-scale wetland-wastewater systems. (See also W89-01827) (Lantz-PTT).

19. Hardy, J. W. Land Treatment of Municipal Wastewater on Mississippi Sandhill Crane National Wildlife Refuge for Wetlands/Crane Habitat Enhancement: A Status Report. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 186-190, 4 ref.
Note: Mississippi Sandhill Crane National Wildlife Refuge, Gautier. SWRA2305.
The Ocean Springs Regional Land Treatment site is located along the northern edge of the Mississippi Sandhill Crane (Grus canadensis pulla) National Wildlife Refuge. The disposal site has two major components: (1) a lagoon system, including facultative lagoon/storage facilities and screening and distribution pump station facilities and (2) a land treatment system, consisting of distribution and sprinkler facilities and underdrain and wetland cell facilities. The treated effluent is pumped to the disposal site and distributed through gun-type sprinklers. An effluent application rate of 0.76 cm/hr is intended to yield zero surface runoff from the 150-ha site. The site has coastal bermuda grass (Cynodon dactylon) with fall overseeding of annual ryegrass (Lolium temulentum) for a potential nitrogen removal capacity of 80-100 kg/ha/yr. Three wetland cells, located 500-1500 m downgrade were constructed to receive underdrain percolate from the treatment site. Spray field operation trials began in January 1986 and became fully operational in October 1987. Several problem areas as well as successes have been noted. Considerable surface runoff of primary treated effluent from one section of the site contaminated and damaged 4-6 km of refuge service roads and ditches. Unseasonably high soil saturation levels curtailed timber harvests. Although normal rainfall restricts woodlands access during rainy periods and causes some roadway erosion, heavy flows from spray field runoff exacerbated these problems. Wetlands operated at less than 25% of predicted efficiency. Major structural erosion problems plagued all three cells. Little percolate reached the cells. The grassland sod in the treatment area may require 3 yr to develop full percolate capacity. However, clearing heavy slash-pine forests and the haying operations in the treatment area resulted in increased crane use. Since 1985, spray fields have become a major feeding area for birds. The success of this cooperative effort in using municipal wastewater for wetlands and sandhill crane habitat enhancement will require several years of evaluation. (See also W90-04392) (Rochester-PTT).

20. Hyde, H. C.; Ross, R. S.; Demgen, F. Technology Assessment of Wetlands for Municipal Wastewater Treatment Final rept. 1984 Sep;
Note: Waste and Water International, Emeryville, CA. 081727000 Demgen Aquatic Biology, Vallejo, CA. Municipal Environmental Research Lab., Cincinnati, OH. English GRAI8501 Prepared in cooperation with Demgen Aquatic Biology, Vallejo, CA. United States.
The innovative and alternative technology provisions of the Clean Water Act of 1977 (PL 95-217) provide financial incentives to communities that use wastewater treatment alternatives to reduce costs or

energy consumption over conventional systems. Some of these technologies have been only recently developed and are not in widespread use in the United States. In an effort to increase awareness of the potential benefits of such alternatives and to encourage their implementation where applicable, the Municipal Environmental Research Laboratory has initiated this series of Emerging Technology Assessment reports. This document discusses the applicability and technical and economic feasibility of using natural and artificial wetland systems for municipal wastewater treatment facilities.

21. Kadlec, R. H. Decomposition in Wastewater Wetlands. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 459-468, 5 fig, 3 tab, 13 ref.
Note: Michigan Univ., Ann Arbor. Wetlands Ecosystem Research Group. SWRA2305.
The rates of key biomass processes and the amounts of nutrients and biomass involved in decomposition in wetlands used for treatment of wastewater have been previously ignored in performance discussions. Although all assimilable constituents are affected by growth, litter fall, litter decomposition, and leaching and mineralization N and P are analyzed as illustrative of the general processes occurring in an unharvested constructed wetland receiving secondary municipal wastewater. The startup phase of a constructed wetland may take several years: 2-3 yr for vegetation establishment and another 2-3 yr to establish the litter-sediment compartment. During this phase, significant nutrient quantities and other biologically active constituents are stored in new live and dead biomass pools. For a wetland of 10 days' detention, a loading of 2.0 cm/day, and 10 mg/L each of N and P, establishment of the biomass pools (2.0% N and 0.4% P) would require 5 yr and use 60% of the applied N and 12% of the applied P. However, other processes, such as microbial denitrification and phosphorus sorption, function in parallel with biomass generation. Competition for nutrients will prolong the startup phase and cause longitudinal stratification of biomass and litter. Such phenomena have been documented and modeled for natural wetland systems. After a stationary state is reached, only the burial component of the biomass contributes to the removal of nutrients. For the preceding example, deposition of 2.5 mm/yr of new soil at 2.0% N and 0.4 % N would account for 1.4% of the N applied and only 0.7% of the applied P. These calculations assume that all of the applied nutrients are available to plants, which is not generally true. It may be concluded that probable startup times for constructed wetlands are 5-10 yr, which exceeds any record of operational experience established for a constructed wetland. Early reports probably are too optimistic because saturable mechanism are operative during startup. It is possible, however, that microbial processes are establishing themselves at the same time that the saturable mechanisms are being depleted because the litter compartment is the locus of attachment for

most of the active microorganisms. (See also W90-04392) (RochesterPTT).

22. Kadlec, R. Overview of wetlands treatment in the United States. U.S. Environmental Protection Agency Municipal Wastewater Treatment Technology ForumU.S. ENVIRONMENTAL PROTECTION AGENCY MUNICIPAL WASTEWATER TREATMENT TECHNOLOGY FORUM. 1990;
Note: Univ. Michigan, Ann Arbor, MI 55812, USA ENGLISH V22N3. About 450 types of wetlands systems exist for treating a variety of wastes, including municipal wastes, mine water waste, stormwater, and various industrial wastewaters. Wetlands treatment can take place in natural or constructed wetlands sites. Principal categories of constructed wetlands systems include densely vegetated overland flows, underground systems, pond and island systems, and channels with floating plants. The forested wetland is a natural treatment system.

23. Livingston, E. H. Use of Wetlands for Urban Stormwater Management. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 253-262, 17 ref.
Note: Florida State Dept. of Environmental Regulation, Tallahassee. SWRA2305.
Use of wetlands for urban stormwater management should not be considered a panacea. Little scientific information is available concerning the short-term or long-term effects on wetlands, their natural functions, or associated fauna from the addition of stormwater. Most water quality effects of stormwater result from 'first flush.' In Florida, this corresponds to the first 2.5 cm of rainfall, which carries 90% of the pollution load from a storm event. Pretreatment removes heavy sediment loads and other pollutants such as hydrocarbons that can damage the wetland. Pretreatment also attenuates stormwater volumes and peak discharge rates to maintain the wetland hydroperiod and reduce scour and erosion. Wetland plants have specific tolerances to levels and types of pollutants. Polluted stormwater contains increased nutrients, which may change the plant community. Since new dominants reflect more efficient use of added nutrients or are more tolerant to pollutants, the plant changes should benefit pollutant removal. In 1982, Maryland legislation required development of stormwater management regulations to ensure that stormwater from new developments was treated to reduce the pollutant discharged to receiving water. The same year, the Florida Stormwater Rule was implemented, requiring all newly constructed stormwater discharges to use appropriate best management practices (BMPs) to treat the first flush of runoff. Vegetated systems, wet detention, or wetlands are commonly used BMPs. Wetlands have great potential to help solve stormwater management problems. However, more information is needed to ascertain possible effects on wetlands and their fauna from addition of untreated stormwater. Little is known about the potential for bioaccumulation of heavy metals or other toxics

typical of stormwater. Monitoring of wetland stormwater systems also is essential#= etermine relations between design variables and pollutant removal efficiency. (See also W90-04392) (Rochester-PTT).

24. Lowgren M; Sundblad K; Wittgren H. B. Wastewater Treatment or Resource Management A Comparison Between Centralized and On-Site Systems. J Environ Manage Journal of Environmental Management. 1984; . Coden: Jevma. Note: dep. Water environ. Studies, linkoping univ., S-581 83 linkoping, sweden. English.
Swedish environmental policies have aimed to connecting even small point source discharges to tertiary treatment plants, either by large scale collection and treatment systems or by small scale separate plants. The cost-effectiveness of the strategy for a number of urban areas with less than 1000 inhabitants was evaluated in one municipality (115000 inhabitants) in the south of Sweden. By combining the total cost regression equations, a relationship was established to show treatment capacities and distances at which local tertiary treatment was economically equivalent to the centralized system for two different cost allocations. Average costs per person for small separate teritary treatment plants were about the same magnitude as those for connection to the main municipal system at the present level of capacity utilization. A different on-site treatment technique, the wetland filter, which has been experimentally adapted to Swedish conditions, was compared to the existing system. In the wetland filter, pre-sedimented wastewater is applied by surface irrigation to reed sweetgrass, Glyceria maxima, growing in loamy sand. Part of the nutrients is recovered by harvet of the grass. Besides reaching tertirary requirements for phosphorus and BOD removal, the wetland filter removed more nitrogen than the ordinary treatment plants. Investment costs for wetland filters were estimated to be somewhat lower than those for the existing technology. Operation and maintenance costs would be considerably lower. Further, there are potentials revenues from the utilization of the grass for forage or energy purposes by integrating wastewater treatment into a farming system. The principal differences in regarding wastewater constituents as pollutants to be removed or resources to be managed are discussed.

25. Meyer, J. A detention-sedimentation basin/artificial wetland treatment system to renovate stormwater runoff from urban, highway, and industrial areas. 8. Biennial International Estuarine Research ConferenceESTUARIES. 1985; VOL. 8, NO. 2B.
Note: Wetland Manage. Specialists, Inc., Smithfield, RI, USA SUMMARY LANGUAGE - ENGLISH; Abstract only. ENGLISH V22N5.
Site-specific design criteria for a detention-sedimentation basin/artificial wetland treatment system to renovate stormwater runoff from urban, highway, and industrial areas have been developed. A detention-sedimentation basin with a rock filter dike coupled to an artificial wetland ranging in depth from meadow to open water, planted with Phragmites communis and Typha spp., is used to filter and absorb

nutrients and contaminants in stormwater runoff. This system will provide effective, low-cost, low-maintenance treatment of stormwater runoff from urban, highway, and industrial areas.

26. Moreno-Grau, Stella, Ph.D. Pilot Plant Treatment Of Urban Wastewater With Macrophytes: Biochemical Study And Mathematical Modelling (Artificial Wetland, Ecological Modelling, depurmodelling Dcion De Aguas Residuales Urbanas De Cartagena Con Macrofitas En Planta Piloto: Estudio Bioquimico Y Modelizacion. 1989; 51/02-C of Dissertation Abstracts International. Note: Order No: Not available from University Microfilms Int'l. Universit 'De Valencia (SPAIN) Spanish.
The main objective of this study is to improve the quality of stabilization pond effluents through the use of macrophytes, especially with respect to the content of suspended solids. The experimental facility consisted of three channels operating in parallel which received raw wastewater coming from Cartagena (Spain). The macrophyte species selected initially for this study were Phragmites communis Trin and Lemna gibba L. The third channel was used as a control and was thus maintained as a microphyte wastewater pond throughout the experiments. The evolution of the wastewater in the pilot plant was monitored through the measurement of 21 parameters. The productivity and composition of the macrophytes have also been studied. A unidimensional simulation model of the resulting artificial wetland has been developed. The model consists of thermal and biochemical submodels. Mass balances were written for every one of the parameters, as well as an energy balance for the temperature calculations. Every balance involved diffusion, advection and transformation processes. The resulting system of non-linear, partial differential equations has been solved numerically using a finite differences scheme. The simulation model predicts the influence of several meteorological variables, as well as the composition of the influent, on the evolution over time of macrophytes, microphytes, zooplankton, bacterial biomass, COD, dissolved oxygen, nutrients and detrital mass. The agreement between computed and experimental data has been satisfactory. The results obtained in this study allow us to conclude that wastewater treatment with Pragmites communis is an efficient method that significantly reduces the effluent content in suspended solids. Other positive aspects of this system are the potential use of the biomass and the ecological value of biotope regeneration.

27. Palmer, C. N.; Hunt, J. D. Greenwood Urban Wetland: A Manmade Stormwater Treatment Facility. IN: Wetlands: Concerns and Successes. Proceedings of a Symposium held September 17-22, 1989, Tampa, Florida. American Water Resources Association, Bethesda, Maryland. 1989. p 205-214, 2 fig, 12 ref.
Note: Dyer, Riddle, Mills and Precourt, Inc., Orlando, FL. SWRA2312.
The Greenwood Urban Wetland ; s built to alleviate flooding in a 522-acre drainage basin in Orlando, Florida to pretreat stormwater runoff prior to disposal down drainage wells and to use water collected in the storage basins for irrigation of an adjacent cemetery and park. Vacant

city-owned land was excavated to form a series of ponds and a bypass stream leading to 5 drainage wells. A 25 to 30 foot wide littoral zone was established for each pond and planted with 10 species of native macrophytes. A riverine flood plain was established in the bypass canal consisting of seven species of hardwood swamp trees. A 26 acre park with walkways and bridges built over hydraulic control structures was landscaped with 7 species of native upland trees. Hydraulic control structures were built to maximize storm water detention time. Aeration devices were established in each pond to improve the system's capacity to assimilate incoming organic contaminants in the storm water runoff. A sediment control device was built upstream of the project to reduce both nutrient and solids loading. Skimmers and floatable debris collectors were installed upstream of the drainage well intake structures to control oils and grease and floating trash. A 4-ft diameter wet well, intake plume and pump station were installed to provide irrigation water for adjacent lands. According to the trophic state indices the lake exhibited eutrophic to hyper-eutrophic conditions before and during construction. After completion of the project, lake trophic state indices are in the mesotrophic range indicating a preliminary improvement in surface water quality. (See also W90-10912) (Lantz-PTT).

28. Proceedings of the U.S. Environmental Protection Agency Municipal Wastewater Treatment Technology Forum - 1990. U.S. Environmental Protection Agency Municipal Wastewater Treatment Technology Forum. 1990; Note: SUMMARY LANGUAGE - ENGLISH ENGLISH V22N3.
The 1990 Municipal Wastewater Technology Forum, sponsored by EPA's Office of Municipal Pollution Control (OMPC), provided the opportunity for wastewater treatment professionals from the Federal and State governments as well as Canada to discuss foremost wastewater treatment technology development and transfer issues. Presentations were made on sludge management, secondary treatment technologies, operations and maintenance (O&M) issues for publicly owned treatment works (POTWs), constructed wetlands, disinfection, toxicity management, and small community wastewater technologies.

29. Reed, S. Inventory of constructed wetlands systems in the United States and WPCF manual of practice on natural systems. U.S. Environmental Protection Agency Municipal Wastewater Treatment Technology Forum U.S. ENVIRONMENTAL PROTECTION AGENCY MUNICIPAL WASTEWATER TREATMENT TECHNOLOGY FORUM. 1990; Note: Environ. Eng. Consult., Norwich, VT, USA SUMMARY LANGUAGE - ENGLISH ENGLISH V22N3.
EPA's Risk Reduction Engineering Laboratory (RREL) is compiling an inventory of wetlands systems in the United States that are being used to treat municipal wastewater. The inventory contains information on system location and design parameters. This information will be used to

compare and assess the different systems in operation, focusing on the common factors found throughout. The universe for this inventory is relatively small and only includes constructed wetlands with emergent vegetation for treating wastewater. About 300 questionnaires were sent to EPA Regional offices and State agencies. Data for over 102 systems have been returned and logged into a computer data base that will be used to summarize and analyze the data.

30. Reed, S. C.; Bastian, R. K. Wetlands for Wastewater Treatment: An Engineering Perspective. IN: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters. Van Nostrand Reinhold Company, New York. 1985. p 444-450, 3 ref.
Note: Cold Regions Research and Engineering Lab., Hanover, NH. SWRA2202.
Under the right conditions, wetland systems can achieve high removal efficiencies for biochemical oxygen demand (BOD), suspended solids (SS), trace organics, and heavy metals. They have considerable potential as a low-cost, low-energy technique for upgrading wastewater effluent. Ecological considerations are a major concern where natural wetlands are involved in wastewater treatment or disposal of treated effluents, or where wastewater is involved in the enhancement or restoration of wetlands. Ecological aspects are less critical for constructed, or artificial, wetland systems than for natural wetland treatment systems. From a regulation standpoint, the use or discharge of treated effluents and providing wastewater treatment are not always the same thing. Natural wetlands are usually considered as a part of the adjacent water body and, therefore, under the Clean Water Act, discharges of municipal effluents to a natural wetland must be treated to at least the level of secondary treatment. This restriction limits the potential use of natural wetlands for municipal wastewater treatment. Rather than a single concept for the involvement of wetlands in wastewater treatment, there appear to be a continuum of possibilities for the tolerable (if not beneficial), as well as functional, combining of wastewater and wetlands. Four major categories of wetland-wastewater combinations have been observed that have been successful on the basis of ecological, engineering, economic, political, and social criteria: Category A, use of natural wetlands for the disposal of treated effluent; Category B, use of wastewater for wetland enhancement, restoration, or creation; Category C, use of natural wetlands for wastewater renovation; and Category D, use of a constructed wetland for relatively high rate wastewater treatment. Although the emphasis shifts from optimization of a wetland's overall values to optimization of the costs of wastewater treatment, all four categories either directly or indirectly do provide for some treatment of the wastewater. (See also W89-01827) (Lantz-PTT).

31. Reed, Sherwood C. Constructed wetlands for wastewater treatment. BioCycle, The Journal of Waste Recycling. 1991 VOL. 32, NO. 1 (January).

32. Report on the Use of Wetlands for Municipal Wastewater Treatment and Disposal. 1987 Oct;
Note: Environmental Protection Agency, Washington, DC. Office of Municipal Pollution Control. 031287624 English GRAI8821 United States.
The report reviews current knowledge of the use of both natural and constructed wetlands for municipal wastewater treatment and disposal. The extent and circumstances of this practice are reviewed and summaries of the regulatory issues involved as well as EPA policies are presented.

33. Roesner, L. A. Aesthetic Implementation of Nonpoint Source Controls. IN: Nonpoint Pollution: 1988-Policy, Economy, Management, and Appropriate Technology. Proceedings of a Symposium. American Water Resources Association, Bethesda, Maryland. 1988. p 213-223, 5 fig, 2 tab, 14 ref.
Note: Camp, Dresser and McKee, Inc., Cincinnati, OH. SWRA2404.
To many people, nonpoint source (NPS) pollution controls are unsightly, necessary evils that are required to protect our receiving waters from pollution by this source. However, such a condition need not exist if the designer will integrate these facilities into the overall landscaping design of a development. Approximately four percent of the developed land is required for NPS controls. If properly designed, these facilities can serve dual recreational/aesthetic functions, as well as provide effective NPS controls. But effective NPS pollution reduction requires that the rate at which runoff is allowed to enter and pass through the drainage system is slowed, and that as much direct runoff as possible is eliminated. This means that NPS controls should be used wherever possible to encourage on-site infiltration. Nonpoint source controls such as these can be grouped into three classes: (1) detention ponds, including both wet and dry basins; (2) infiltration devices such as basins and trenches; and (3) surface filtration devices like buffer strips, grasslined channels or swales, and wetlands. In general, the most efficient are the infiltration devices. Detention basins, particularly wet detention ponds, are second to infiltration devices in efficiency. Surface filtering is the least effective, and is generally used only in combination with one or both of the other kinds of controls. To create aesthetically pleasing NPS control devices, it is not surprising to find that functional design must go hand in hand with landscaping considerations; this is particularly true in the case of detention ponds and wetlands, where the plantings are most visible. (See also W91-03704) (Fish-PTT).

34. Sewage and Industrial Waste Treatment: Wetlands (Jan 77 - Dec 89). Available from the National Technical Information Service, Springfield, VA 22161, as PB90-853722. Price codes: N01 in paper copy, N01 in microfiche. December 1989. 78p.

Note: National Technical Information Service, Springfield, VA. SWRA2311.
This bibliography contains citations concerning developments, operations, and evaluations of natural and artificial wetlands treatment of wastewater and sludges. Aquaculture treatments of industrial, municipal, and domestic wastewater are examined. Topics include nutrient removal, heavy metal recovery, and case studies of wetland being used for wastewater treatment. (This updated bibliography contains 135 citations, 23 of which are new entries to the previous edition). (Author's abstract).

35. Sewage and Industrial Waste Treatment: Wetlands, January 1977-July 1988: Citations from the Selected Water Resources Abstracts Database. Available from National Technical Information Service, Springfield, VA 22161 as PB88-866470, Price codes: N01 in paper copy, N01 in microfiche. August 1988. 39p.
Note: National Technical Information Service, Springfield, VA. SWRA2211.
This bibliography contains 93 citations concerning developments, operations, and evaluations of natural and artificial wetlands treatment of wastewater and sludge. Aquaculture treatments of industrial, municipal, and domestic wastewater are examined. Topics include nutrient removal, heavy metal recovery, and case studies of wetlands being used for wastewater treatment. (Author's abstract).

36. Sewage and Industrial Waste Treatment: Wetlands. January 1977-December 1989 (Citations from the Selected Water Resources Abstracts Database)Rept. for Jan 77-Dec 89. 1989 Dec;
Note: National Technical Information Service, Springfield, VA. 055665000 English GRAI9004 Supersedes PB89-865745. Prepared in cooperation with Office of Water Research and Technology, Washington, DC. United States.
This bibliography contains citations concerning developments, operations, and evaluations of natural and artificial wetlands treatment of wastewater and sludge. Aquaculture treatments of industrial, municipal, and domestic wastewater are examined. Topics include nutrient removal, heavy metal recovery, and case studies of wetlands being used for wastewater treatment. (This updated bibliography contains 135 citations, 23 of which are new entries to the previous edition.).

37. Staubitz, W. W.; Surface, J. M.; Steenhuis, T. S.; Peverly, J. H.; Lavine, M. J. Potential Use of Constructed Wetlands to Treat Landfill Leachate. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 735-742, 1 fig, 2 tab, 22ref.
Note: Geological Survey, Tacoma, WA. SWRA2305.
Infiltration of precipitation and migration of water through municipal solid waste landfills produce leachate that contains undesirable or toxic

organic and inorganic chemicals. The feasibility of constructed wetlands for landfill-leachate treatment is under investigation in New York State by several agencies. The study is designed to investigate the fate and transport of landfill leachate in a constructed wetland and provide engineering design data for construction and operation of full-size leachate treatment systems. Specific objectives are to examine: (1) the efficiency of leachate treatment as a function of substrate material, plant growth, leachate quality, and seasonal change in climate; (2) the effects of leachate application and plant growth on the hydraulic characteristics of the beds; (3) the effect of leachate on plant viability; and (4) the physical and chemical processes by which metals are fixed and transformed. The wetlands are modified versions of root-zone or rock-reed filter systems. They have gently sloping beds lined with an impermeable barrier and planted with emergent hydrophytes such as reeds (Phragmites), bulrush (Scirpus), or cattails (Typha). The wetlands generally have an inlet zone of crushed stone to distribute wastewater evenly over the bed width and an outlet zone of crushed stone to collect and discharge effluent. Construction of eight wetland plots (30 m long x 3 m wide x 0.6 m deep and planted with Phragmites australis) began in the spring of 1988. Plans are underway for monitoring these constructed wetlands so that water and chemical mass loadings and treatment efficiency of each plot can be calculated. Hydraulic conductivity experiments on bed materials and greenhouse studies of plant tolerance for transplantation, plant nutrient requirements, and effects of rhizome growth on hydraulic conductivity. Growth in loamy sand was excellent, but complete inorganic fertilizer was needed to prevent chlorosis. Root or rhizome growth for 3 mo had little or no effect on hydraulic conductivities. (See also W90-04392) (Rochester-PTT).

38. Steiner, G. R.; Watson, J. T.; Hammer, D. A.; Harker, D. F. Jr. Municipal wastewater treatment with artificial wetlands--a TVA/Kentucky demonstration. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith.
Note: Tenneessee Valley Authority, Chattanooga, TN English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

39. Steiner, Gerald R.; Watson, James T.; Hammer, Donald A. Constructed wetlands for municipal wastewater treatment prepared for presentation at the Mississippi Water Resources Conference, Jackson, Mississippi, March 29-30, 1988 /^by Gerald R. Steiner, James T. Watson, and Donald A. Hammer.
Note: English Cover title. "March 1982." Bibliography: p. 11-12. Tennessee OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

40. Stockdale, Erik C.; Horner, Richard R. PROSPECTS FOR WETLANDS USE IN STORMWATER MANAGEMENT. Coastal Zone '87, Proceedings of the Fifth Symposium on Coastal and Ocean Management.v 4. Publ by ASCE, New York, NY, USA p 3701-3714. 1987; . CODEN: 1987 May 26-29.
Note: King County Resource Planning Section, Seattle, WA, USA ASCE, New York, NY, USA American Fishing Tackle Manufacturers Assoc, Arlington Heights, IL, USA American Petroleum Inst, Washington, DC, USA American Shore & Beach Preservation Assoc, Berkeley, CA, USA American Soc for Environmental Education, Durham, NH, USA et al English 8709.
It is well established that wetlands under certain circumstances improve water quality. There is a limited literature on the long-term effects of using freshwater wetlands for stormwater storage and nonpoint pollution control. Much of this literature pertains to the use of wetlands for sewage effluent treatment. Some work has been done utilizing natural or artificial wetlands for flood control and/or water quality management. Water quality improvements from these studies show promise, but their direct application to the Pacific Northwest is limited. Some researchers believe the characteristics of wastewater and urban runoff are similar enough that some findings in the wastewater literature may be analogous to stormwater systems. These findings can be confirmed by careful studies in the Northwest to help fill the gaps in present knowledge. This paper summarizes wetlands water quality improvement principles from the literature, and areas of greatest uncertainty regarding the use of wetlands for urban stormwater management. (Author abstract) 38 refs.

41. Tomasek, M. D.; Johnson, G. E.; Mulloy, P. J. Minnesota's .xperience with the biologically activated soil filtration unit. 6. Annual International Symposium. Lake and Reservoir Management: Influences of Nonpoint Source Pollutants and Acid Precipitation6th ANNUAL INTERNATIONAL SYMPOSIUM. LAKE AND RESERVOIR MANAGEMENT: INFLUENCES OF NONPOINT SOURCE POLLUTANTS AND ACID PRECIPITATION. NOVEMBER 5-8, 1986 PORTLAND, OREGON. 1986;
Note: Water Qual. Div., Minnesota Pollut. Control Agency, Roseville, MN, USA SUMMARY LANGUAGE - ENGLISH; Summary only. ENGLISH.
This article discusses the use of an artificially constructed wetland to help treat stormwater. During 1985, a Biologically Activated Soil Filtration Unit (BASFU) was built to evaluate the feasibility of using an experimental peat/sand biofilter to provide additional treatment for urban stormwater. This paper summarizes Minnesota Pollution Control Agency's experience with the design, construction, and operation of the Moore Lake BASFU. Moore Lake's BASFU showed severe operational problems following initial construction, and mitigative measure had to be taken. After corrective actions were completed, a monitoring

program was begun to study filter efficiency over a range of hydraulic and nutrient loading rates. These data are presented along with a discussion on the use of BASFU systems to augment sedimentation basins in lake restoration projects.

42. Tomljanovich, D. A.; Perez, O. Constructing the Wastewater Treatment Wetland: Some Factors to Consider. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 399-404, 7 ref.
Note: Tohoku Univ., Sendai (Japan). Biological Inst. SWRA2305.
Constructed wetlands for wastewater treatment may range in size from several square meters to several hectares. Design parameters vary with size, site characteristics, hydrologic soil group, pollutant type and loading rate, geographic locale, watershed characteristics, proximity to residential development, and anticipated operation and maintenance requirements. The construction of wastewater treatment wetlands involves: construction plans, preconstruction site activities, cost estimate preparation, construction, inspection, testing, and startup. Construction includes access road building; clearing; dike building; spillway construction; piping and valving; planting; and seeding, liming, fertilizing, and mulching of dikes and disturbed areas. Close communication between owner/operator, designer, and contractor is crucial throughout the process. Correct type and size of heavy equipment is crucial to ensuring cost-effective, proper construction. If the wetland is built on an existing wet area, two bulldozers (and operators) rather than one should be used because one will get mired down and require the other to free it. In most municipal waste treatment wetlands, construction must follow precisely the engineering plan to achieve proper functioning of the system. Permeability specifications must be followed carefully to prevent leakage into or out of the ponds. If native soils are adequate, dozers and sheepsfoot rollers usually are sufficient to achieve desired compaction. Subsurface flow systems dependent on high hydraulic conductivity in the substrate require special provisions to avoid compacting the substrate during construction or planting. Adequate sizing and installation of spillway and discharge pipe are critical to ensuring dike integrity and safe and proper operation of the wetland. In some areas, muskrats and beavers burrow into dikes or obstruct discharge pipes. Acidic drainage can destroy metal tile, pipes, pumps, and valves. Emergent vegetation must be planted with care and proper guidance to ensure plant survival. An initial maintenance program that includes frequent and thorough inspection and immediate correction of problems is critical to ensuring successful operation of wastewater treatment wetlands. (See also W90-04392) (Rochester-PTT).

43. Trautmann, N. M.; Martin, J. H.; Porter, K. S.; Hawk, K. C. Use of Artificial Wetlands for Treatment of Municipal Solid Waste Landfill Leachate. IN: Constructed Wetlands for Wastewater Treatment:

Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 245-251, 2 fig, 10 ref.
Note: Cornell Univ., Ithaca, NY. Center for Environmental Research. SWRA2305.
A potentially cost-effective and energy-efficient prototype system for on-site treatment of landfill leachate has been designed for the town of Fenton, New York. Leachate will be pretreated using overland flow followed by horizontal flow through the root zone in a bed of wetland plants. In the absence of previous experience treating landfill leachate with this technique, its efficacy is not know. Theoretically, overland flow will remove much of the dissolved iron and manganese, readily oxidizable organic matter, ammonia nitrogen, and volatile organics such as benzene. Additional removal of nitrogen and organic matter as well as removal of phosphorus and metal ions will occur in the root-zone bed, producing an effluent that can be discharged directly to surface waters. Through a combination of laboratory studies and evaluation of the prototype system performance, the feasibility of this approach will be determined. Initial laboratory experiments on changes in soil hydraulic conductivity have been conducted. In a 7-month study using Typha glauca Gadr and Scirpus acutus Muhl planted in boxes of sand and grown in a greenhouse, saturated hydraulic conductivity decreased over time in both vegetated and nonvegetated systems, with a significantly greater decrease in the vegetated systems. Saturated hydraulic conductivity declined by 41% in the control systems, probably because of sand settling, and by 55% in the vegetated systems. Ammonia nitrogen and nitrate nitrogen were supplied in ranges of rates comparable to municipal wastewater. Systems with vegetation reduced ammonia nitrogen and nitrate nitrogen concentrations significantly better than those without vegetation. Typha and Scirpus showed comparable rates of nitrogen removal. (See also W90-04392) (Rochester-PTT).

44. Watson, J. T.; Diodato, F. D.; Lauch, M. Design and performance of the artificial wetlands wastewater treatment plant at Iselin, Pennsylvania. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith.
Note: Tenneessee Valley Authority, Chattanooga, TN English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

45. Watson, J. T.; Reed, S. C.; Kadlec, R. H.; Knight, R. L.; Whitehouse, A. E. Performance Expectations and Loading Rates for Constructed Wetlands. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 319-351, 7 tab, 73 ref.
Note: Tennessee Valley Authority, Chattanooga. Water Quality Dept. SWRA2305.

Constructed wetlands are emerging as low-cost, easily-operated, efficient alternatives to conventional treatment for a variety of wastewaters. Most common uses are for treatment of municipal wastewaters and acid mine drainage. There are two major types of systems: surface flow systems with vegetation planted in a shallow pool of water, and subsurface flow systems with vegetation in a permeable soil, gravel, or sand, and water levels below the medium surface. Wetland systems are effective on many contaminants, including BOD, suspended solids (SS), N, P, trace metals, trace organics, and pathogens. The effectiveness is due to the diversity of treatment mechanisms, including sedimentation, filtration, chemical precipitation, and adsorption, microbial interactions with contaminants, and uptake by vegetation. Reductions in BOD5 and SS generally are high, whereas N and P reductions tend to vary on a site-specific basis. Current knowledge is sufficient for design of systems that substantially reduce targeted contaminants but inadequate to optimize the design and operation for consistent compliance. Hydraulic loading factors are the primary design basis for sizing municipal constructed wetlands. Loading rates vary (0.8 to 62 cm/day), indicative of various treatment and project objectives, system types and configurations, and performance levels. Surface flow systems typically are loaded less than subsurface systems. Hydraulic loading rates of 4.7 cm/day for subsurface flow systems and 1.9 cm/day for surface flow systems should treat primary effluent to at least secondary levels if the systems are otherwise properly designed, constructed, and operated. Hydraulic loading rates for acid mine drainage systems range from 0.81 to 8640 cm/day. A rule of thumb of 29.4 cm/day has been suggested. Many reactions responsible for pollutant reductions in wetland treatment systems follow first-order kinetics. This provides the opportunity to provide a credible, scientific design basis for many of the pollutants of interest. (See also W90-04392) (Rochester-PTT).

46. Wegener, Kevin; Kunkel, James R.; Wulliman, James T. Shop creek stormwater quality enhancement project. Hydraulic Engineering - Proceedings of the 1990 National Conference Part 1 (of 2)Hydraulic Engineering - Proceedings of the 1990 National Conference. Publ by ASCE, Boston Society of Civil Engineers Sect, Boston, MA, USA. p 85-90. 1990; . CODEN: 1990 Jul 30-Aug 3.
Note: City of Aurora, Aurora, CO, USA ASCE, Hydraulics Div English A (Applications) 9102.
The advent of NPDES regulations for stormwater discharges creates a need to verify, on a regional basis, the effectiveness of emerging water-quality control technologies such as extended detention ponds, wetlands, and infiltration basins. The construction of the Shop Creek water quality enhancement project, which uses a combination of these three treatment technologies, was completed in July 1989. This project, located in a 640-acre urban watershed draining into Cherry Creek Reservoir in southwest Denver, is one of the first in Colorado to be

designed and constructed with a specific water-quality treatment objective. This paper describes the design, construction, operation, and monitoring of the Shop Creek project in its initial year of operation. The description includes an overview of the purpose of the project, an examination of the design features of the facilities, and a description of the monitoring program. (Author abstract) 7 Refs.

47. Wetland Areas: Natural Water Treatment System (Jan 78 - Aug 89). Citations from the Pollution Abstracts Database. Available from the National Technical Information Service, Springfield, VA 22161, as PB90-862244. Price codes: N01 in paper copy, N01 in microfiche. March 1990. 99p.
Note: Davis (J.J.) Associates, Inc., McLean, VA. SWRA2403.
This bibliography contains citations concerning the ability of salt marshes, tidal flats, marshlands, bogs, and other wetland areas to degrade, absorb, filter, consume, mitigate natural and man-made pollution and wastes, while maintaining their ability to provide refuge and breeding grounds for wildlife. The ecology, biochemistry, and viability of naturally occurring and artificially established wetlands as water-treatment systems and wildlife areas are considered. The effects of individual pollutants, environmental factors, species diversity, and cleansing ability of wetland areas on the potential for wildlife refuge, sewage treatment, treatment of industrial and municipal wastes, handling agricultural runoff, mitigating accidental spills, and flooding are discussed. This updated bibliography contains 243 citations, 21 of which are new entries to the previous edition. (Author's abstract).

48. Wetland Areas: Natural Water Treatment Systems. January 1970-May 1989 (Citations from Pollution Abstracts)Rept. for Jan 70-May 89. 1989 Jun;

Note: National Technical Information Service, Springfield, VA. 055665000 English GRAI8919 Prepared in cooperation with Cambridge Scientific Abstracts, Washington, DC. United States.
This bibliography contains citations concerning the ability of salt marshes, tidal flats, marshlands, bogs, and other wetland areas to degrade, absorb, filter, consume, or mitigate natural and man-made pollution and wastes, while still providing refuge and breeding grounds for wildlife. The ecology, biochemistry, and viability of naturally occuring and artificially established wetlands as water-treatment systems and wildlife areas is considered. The effects of individual pollutants, environmental factors, species diversity, and cleansing ability of wetland areas on the potential for wildlife refuge, sewage treatment, treatment of industrial and municipal wastes, handling agricultural runoff, mitigating accidental spills, and flooding are discussed. (Contains 271 citations fully indexed and including a title list.).

49. Wieder, R. K.; Tchobanoglous, G.; Tuttle, R. W. Preliminary Considerations Regarding Constructed Wetlands for Wastewater Treatment. IN:

Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 297-305, 1 tab, 24 ref.
Note: Office of Surface Mining Reclamation and Enforcement (DI), Pittsburgh, PA. Eastern Field Operations. SWRA2305.
Preliminary design factors are reviewed that are important in considering constructed wetland treatment of municipal wastewaters and of coal mine drainage. Free water surface wetlands with emergent plants used for municipal wastewater treatment consist of basins or channels with a subsurface barrier to prevent seepage; a suitable medium to support emergent vegetation; and water flowing through at a shallow depth. Cattails, bulrushes, and various sedges are used commonly. In subsurface flow systems, unlined or lined trenches or basins are filled with a permeable packing medium, and are planted with emergent plants, including cattails, bulrushes, native sedges, and other local species. The root-zone method and rock-reed-filter are the two principal categories of subsurface flow systems. Although physical design features of wetland treatment systems are site-specific, three general features should be incorporated into the design of any wetland treatment system: (1) division into segments; (2) provision for step-feeding of the influent wastewater; and (3) provision for effluent recycling. Two operational considerations associated with wetlands for wastewater treatment are mosquito control and plant harvesting. Considerable site-to-site variability exists in apparent water quality improvement among wetlands constructed for mine drainage treatment. Two key topics in this field are the area of wetland needed for a particular flow and chemistry of mine drainage, and the cost of wetland treatment relative to more conventional chemical treatment. A comparison between the Bureau of Mines (BOM) 'rule of thumb' for wetland sizing and the Tennessee Valley Authority (TVA) recommendations suggests that the latter, which yields wetlands 2-74 times larger, tend to be less likely to fail to improve water quality. However, reported construction costs are more for the wetlands designed with the TVA method. If properly designed, installed, and managed, constructed wetlands can introduce an important functional and aesthetic element into the landscape. (See also W90-04392) (Rochester-PTT).

50. Wilhelm, M.; Lawry, S. R.; Hardy, D. D. Creation and Management of Wetlands Using Municipal Wastewater in Northern Arizona: A Status Report. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 179-185, 2 tab, 7 ref.
Note: Apache-Sitgreaves National Forests, Lakeside, AZ. SWRA2305.
The Apache-Sitgreaves National Forests, on the Mogollon Rim in northeastern Arizona, have been the subject of a 10-yr management plan aimed at improving wildlife and recreational uses. The Wetlands Management Program raised ducklings hatched from 9 in 1979 to 2819

in 1982 using a combination of improvements to natural wetlands and creation of new wetlands receiving municipal effluent. The new wetlands provide large evaporation ponds for disposal of wastewater from the city of Show Low, Arizona and for developments known as Pinetop and Lakeside. Marsh disposal for Show Low's secondary-treated effluent cost 32% less than the lowest nonmarsh alternative, and annual operating costs were 47% less with the marsh. Effluent marshes have been an obvious success for wildlife habitat. Several improvements are planned or in progress for this disposal system, including: expansion of effluent production rates from 2200 to 7550 cu m/day for Show Low and 1514 to 9643 for Pinetop-Lakeside by 2025. In addition, effluent storage for winter has been added at Show Low, with a riparian growth area and forage enhancement for wildlife and livestock. At Pinetop and Lakeside developments, a 16-ha storage facility has been added, with flexible water distribution and water level control in the marsh, as well as an overland irrigation area for elk forage. (See also W90-04392) (Rochester-PTT).

51. Wood, A.; Hensman, L. C. Research to Develop Engineering Guidelines for Implementation of Constructed Wetlands for Wastewater Treatment in Southern Africa. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 581-589, 4 tab, 7 ref.
Note: Steffen, Robertson and Kirsten, Inc., Johannesburg (South Africa). SWRA2305.
Natural wetlands form an important barrier against nonpoint source discharges of most heavily industrialized areas of South Africa. Research is now underway at a number of locations to evaluate the potential for constructed wetlands in wastewater treatment as a simple, low-cost, low-technology approach to the problem. Studies investigating the controlling factors responsible for efficient operation and design of wetland systems include (1) the substrata responsible for most nutrient removal and hydraulic capacity of the system; (2) macrophyte species responsible for aeration and enhancing permeability; and (3) effluent characteristics, loading rates, and retention times in the operational regime. A former fish dam, 5 m x 5 m x 1 m, was lined with hyper-plastic membrane (Carbofol 500 micrometer) protected by a 50-mm sand layer prior to filling with coarse gravel (19 mm) and planted with local Arundo donax receiving septic sewage at 10 cm/sq m/day. Arundo fully occupied the be within 4 mo. Two other lined dams were converted to wetlands in upgrading studies of 12 small-scale units. One system with power-station waste ash is planted with Phragmites and loaded with raw sewage. Effluent flows into a Phragmites bed with a local soil covered in a layer of coarse ash. In another study, a combined artificial wetland and high-rate algal pond was constructed that consisted of two units, each 22 m x 11 m x 40 cm. Septic sewage is loaded to the wetland at a rate of 135 L/sq m/day. Effluent from the bed is pumped from the sump into the algal pond. The gravel bed is

planted with Typha (for denitrification) and A. donax. Over 1 yr, effluent COD levels were reduced 59%, NH4-N 34%, PO4-P 31%, and suspended solids 77%. Other projects of various designs have been constructed at Mpophomeni, Grootvlei Power Station, Olifansvlei Sewage Works, Johannesburg, and in two rural areas of Gazankulu. Constructed wetlands have considerable potential in southern Africa for treatment of raw wastewaters emanating from rural communities, for upgrading oxidation pond and secondary effluents to general and special discharge standards, and for treatment of industrial effluents. (See also W90-04392) (Rochester-PTT).

STORMWATER - NATURAL WETLANDS

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1. Anon. Natural systems vs. the 'black box'. BioCycle v 30 n 6 Jun 1989 p 68-69. 1989; . CODEN: BCYCDK; ISSN: 0276-5055.
Note: English A (Applications) G (General Review) 9009.
After nearly 20 years of research, Woody Reed is more enthusiastic than ever about the efficiency of aquatic, wetland and terrestrial systems for managing wastes. Free-water-surface wetland in Gustine, CA treats 1 mgd lagoon effluent. In the Appalachian area, about a hundred of these free-water-surface wetlands are in place treating acid mine drainage. In aquacultural systems, duckweed has many advantages over water hyacinths in treating wastewater, not the least of which is that there are strains native to all regions of the country.

2. Anon. Sewage and industrial waste treatment: Wetlands. January 1977-July 1989 (citations from the Selected Water Resources Abstracts database). 1989;
Note: SUMMARY LANGUAGE - ENGLISH; NTIS Order No.: PB89-865745/GAR. 112 ref. Supersedes PB88-866470. ENGLISH V21N5.
This bibliography citations concerning developments, operations, and evaluations of natural and artificial wetlands treatment of wastewater and sludge. Aquaculture treatments of industrial, municipal, and domestic wastewater are examined. Topics include nutrient removal, heavy metal recovery, and case studies of wetlands being used for wastewater treatment. (This updated bibliography contains 112 citations, 19 of which are new entries to the previous edition). (Prepared in cooperation with office of Water Research and Technology, Washington, DC (USA).).

3. Bowmer, K. H. Nutrient Removal from Effluents by an Artificial Wetland: Influence of Rhizosphere Aeration and Preferential Flow Studied Using Bromide and Dye Tracers. Water Research WATRAG, Vol. 21, No. 5, p 591-599, 1987. 6 fig, 7 tab, 19 ref.
Note: Commonwealth Scientific and Industrial Research Organization, Griffith (Australia). Centre for Irrigation Research. SWRA2104.
Effluents from rural industry can be treated by percolation through the root zones of emergent macrophytes growing in a gravel substratum. The hydrology of these systems is complex, being driven by both gravity and transpiration, and so measurements of nutrient transformations within the systems are complicated by incomplete mixing. Pulse addition of dye and bromide tracers concurrently with nutrients has been used in one such experimental artificial wetland to investigate the rates and processes of nutrient removal. The tracer was used for comparison to compensate for incomplete mixing and concentration caused by evapotranspiration. Nitrogen removal efficiency is dependent on

sequential mineralization of organic nitrogen to ammonium nitrogen, followed by nitrification of the ammonium to nitrate or nitrite and denitrification of nitrate or nitrite to gaseous nitrogen products. The effluent from a rendering plant was dominated by organic and ammonium-nitrogen, and efficiency of nitrogen removal was probably impaired by inadequate rates of mineralization and nitrification. Aeration is required for the latter process. Apparently the macrophytes were not introducing sufficient oxygen into the effluent for nitrification to be complete. This may reflect an inadequate outward radial diffusion of oxygen into the rhizosphere, or the effects of channeling of the effluent in preferential flow paths around the aerating root masses, requiring changes in system design. (Author's abstract).

4. Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Proceedings from the First International Conference on Constructed Wetlands for Wastewater Treatment held in Chattanooga, Tennessee on June 13-17, 1988. Lewis Publishers, Chelsea, Michigan. 1989. Edited by Donald A. Hammer. 831p.
Note: SWRA2305.
Widespread use of constructed wetlands may provide a relatively simple and inexpensive solution for controlling many water pollution problems facing small communities, industries, and agricultural operations. Adoption of this technology has been inhibited by a lack of guidelines and instructions supported by adequate information on important system components and basic wetlands ecology. The goal of the present volume is to provide information to improve acceptance and increase application of constructed wetlands for water quality improvements. The book represents the proceedings of the First International Conference on Constructed Wetlands for Wastewater Treatment, held at Chattanooga, Tennessee, on 13-17 June 1988. Besides wetlands treatment of municipal wastewater, which has been the subject of other conferences, this volume includes applications with acid mine drainage, urban runoff, agricultural wastes, and industrial effluents. Topics include: general principles (hydrology, chemistry, physics, ecology, and microbiology); case histories (pilot and full-scale plants); design, construction, and operation; and recent results from field and laboratory (dynamics of inorganic and organic materials in wetlands, efficiencies of substrates, vegetation, water levels, and microbial populations, management of domestic and municipal wastewaters, nonpoint source pollutants (urban runoff and agricultural wastes), applications to industrial and landfill wastewaters, and control of acid mine drainage including coal pile and ash pond seepage). (See W90-04393 thru W90-04476) (Rochester-PTT).

5. Dawson, B. High Hopes for Cattails. Civil Engineering CEWRA9, Vol. 59, No. 5, p 48-50, May 1989.
Note: Barge, Waggoner, Sumner, and Cannon, Nashville, TN. SWRA2211.

In theory, wetlands are the perfect 'wastewater plant' for small communities. In Benton, Kentucky about 1 mgd are cleaned in three different cells, one for cattails, bulrushes, and a mixture of plants. Suspended solids settle to the bottom, creating anaerobic conditions, while aerobic conditions are present around the roots and stalks. Suspended solids, BOD, and fecal coliform counts are all below discharge standards, and nitrogen and phosphorus are also being removed to acceptable standards. Typically, the wetlands consist of shallow, free surface basins with an impermeable liner. In some instances, only one type of plant is sufficient. Other times, combinations of emergent, submerged and floating species are used. The two major problems with man-made wetlands are the large land areas required and concerns about heavy metal accumulation. Wetlands are also being constructed to treat stormwater runoff, refining wastes, polluted rivers, agricultural wastes, and in some cases acid mine wastes. A major advantage of the wetlands system is the low cost when compared with conventional treatment. (White-Reimer-PTT).

6. FENNESSY M S; MITSCH W J. TREATING COAL MINE DRAINAGE WITH AN ARTIFICIAL WETLAND. J WATER POLLUT CONTROL FEDJournal Water Pollution Control Federation. 1701 12; CODEN: JWPFA.
Note: SCH. NATURAL RESOURCES, 2021 COFFEY ROAD, OHIO STATE UNIV., COLUMBUS, OHIO 43210. ENGLISH.
A 0.22-ha constructed wetland dominated by Typha latifolia was evaluated for its ability to treat approximately 340 L/min of coal mine drainage from an underground seep in eastern Ohio [USA]. Loading of mine drainage to the wetland ranged from 15 to 35 cm/d. Conductivity, pH, manganese, and sulfate were little changed by the wetland. Iron decreased by 50 to 60%, with slightly higher decreases during the growing season. Comparisons are made to a volunteer Typha marsh receiving mine drainage where iron was found to decrease by approximately 89%. Design considerations of loading rates of created wetlands suggest that improved treatment of mine drainage is correlated with longer retention times and lower iron loading rates. Preliminary design criteria for construction of these types of Typha wetlands for removal of iron are suggested as 5 cm/d hydrologic loading and 2 to 40 g Fe/m2 .cntdot. d for iron loading, depending on the treatment desired.

7. Gillette, B. Artificial marsh treats industrial wastewater. BioCycle. Feb 1989. v. 30 (2). CODEN: BCYCDK; ISSN: 0276-5055.
Note: English OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

8. Hammer, Donald A. Constructed wetlands for wastewater treatment ^municipal, industrial, and agricultural [edited by] Donald A. Hammer. International Conference on Constructed Wetlands for Wastewater Treatment_ (1st :_ 1988 :_ Chattanooga, Tenn.).

Note: English "Proceedings from the First International Conference on Constructed Wetlands for Wastewater Treatment held in Chattanooga, Tennessee on June 13-17, 1988"--Pref. Includes bibliographical references. Michigan OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

9. Hey, D. L. Wetlands: A Future Nonpoint Pollution Control Technology. IN: Nonpoint Pollution: 1988-Policy, Economy, Management, and Appropriate Technology. Proceedings of a Symposium. American Water Resources Association, Bethesda, Maryland. 1988. p 225-235, 1 fig, 4 tab, 6 ref.
Note: Wetlands Research, Inc., Chicago, IL. SWRA2404.
Nonpoint pollution encompasses more than just the washoff of contaminants and the dispersion of those contaminants in the receiving water body. it also involves the capacity of the terrestrial and aqueous environments to detain and process the contaminants without adverse effects. Accordingly, control technologies must encompass both washoff and effective treatment. Wetlands, serving as the transition between land and water, uniquely combine these components. The Des Plaines River Wetlands Demonstration Project in Wadsworth, Illinois, is testing the economic efficiency and political acceptability of building and managing wetlands for nonpoint pollution control. A full-scale, 450-acre research facility is being constructed with financial support from industries, foundations, private contributors, and local, state, and federal agencies. The supporters, regardless of political philosophy, recognize the need for managing our water resources more efficiently and effectively. Wetlands offer a technology for achieving this goal. The Des Plaines project offers a means for developing this technology. The objectives of this project are to: demonstrate the benefits of wetland restoration for water quality improvement, flood control, and fish and wildlife habitat enhancement; formulate and evaluate restoration and maintenance techniques; and develop alternatives to existing environmental investment strategies and regulatory programs. A significant portion of these wetlands can be replaced or restored so that they provide the desired benefits more efficiently. Replacing 10 percent of the lost wetlands would be a modest beginning. (See also W91-03704) (Author's abstract).

10. Hicks, D. B.; Stober, Q. J. Monitoring of Constructed Wetlands for Wastewater. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 447-455, 17 ref.
Note: Environmental Protection Agency, Athens, GA. Environmental Services Div. SWRA2305.
Use of constructed wetlands for the disposal and treatment of wastewater is emerging as an alternative to conventional approaches for small communities and industries. Operation and maintenance of any

process control system depend on a monitoring plan that provides information for judging the attainment of treatment objectives, performance, efficiency, and the long-term viability of the system. As the complexity of wastes treated by a wetland increases, so do the monitoring requirements, because more variables are introduced which may result in system failure or lead to undesirable side effects. Cost and effort of monitoring increase with chemical complexity of the influent to be treated and ecological diversity of the wetlands to be maintained. Monitoring strategies are presented here in hierarchical orders according to increasing complexity and implementation effort. Topics include: monitoring plan (compliance monitoring, wetlands system performance and treatment efficiency, and monitoring wetland viability and health). An appropriately designed and implemented monitoring plan is essential to the successful management, operation, and maintenance of constructed wetlands for treatment of wastewater. The monitoring plan has numerous components, including clearly stated objectives, technical and management responsibilities, quality assurance procedures, resources, and schedules. Scope of monitoring activities is a function of treatment goals, project benefits, and diversity of plant and animal communities involved in the wetland system. Results of monitoring determine compliance of the wetland discharge with permit limits established by pollution control agencies. Monitoring of the plant and animal communities provides surveillance data necessary to determine health and viability of the wetlands and identify early signs of stress to the aquatic communities of plants and animals. Early detection of a failing wetland system is essential to the operation and maintenance of the treatment system. Engineered wetlands as treatment systems are appealing because of their low costs of construction and simplicity of operation and maintenance needs. However, appropriate monitoring, though it adds costs, is a necessity and must be viewed as a priority over the life of the project. (See also W90-04392) (Rochester-PTT).

11. Holm, J. David; Jones, Scott. PASSIVE MINE DRAINAGE TREATMENT: AN EFFECTIVE LOW-COST ALTERNATIVE. Proceedings - 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation.University of Kentucky, Office of Engineering Services, (Bulletin) UKY BU 139. Publ by Univ of Kentucky, Office of Engineering Services, Lexington, KY, USA, 1985 p 115-120. 1985; . CODEN: 1985 Dec 9-13 UKOBDS; ISSN: 0270-6504.
Note: Colorado Mined Land Reclamation Div, CO, USA Univ of Kentucky, Office of Continuing Education & Extension, Lexington, KY, USA Univ of Kentucky, Dep of Forestry, Lexington, KY, USA Univ of Kentucky, Dep of Agricultural Engineering, Lexington, KY, USA Univ of Kentucky, Dep of Civil Engineering, Lexington, KY, USA Univ of Kentucky, Dep of Mining Engineering, Lexington, KY, USA et al English 8607.
Two prototype Passive Mine Drainage Treatment Systems have been designed and constructed in Colorado. These projects have addressed

acid mine drainage from inactive coal mines. Metal removal for both systems is accomplished using simulated peat bogs composed of sphagnum moss and hypnum moss retained by loose rock check dams. Acid neutralization is accomplished using crushed limestone filled channels. Neutralization and aeration are enhanced with drop structures and waterfalls placed in the drainage channel. Preliminary water quality results show dramatic treatment effects with the PMDT system. This investigation presents cost data for design and construction of the two PMDT systems. Cost projections for periodic maintenance requirements are provided along with a suggested method for financing maintenance costs. Performance data for the first system installed are presented. (Author abstract) 14 refs.

12. Hyde, H. C.; Ross, R. S.; Demgen, F. Technology Assessment of Wetlands for Municipal Wastewater Treatment Final rept. 1984 Sep;
Note: Waste and Water International, Emeryville, CA. 081727000 Demgen Aquatic Biology, Vallejo, CA. Municipal Environmental Research Lab., Cincinnati, OH. English GRAI8501 Prepared in cooperation with Demgen Aquatic Biology, Vallejo, CA. United States.
The innovative and alternative technology provisions of the Clean Water Act of 1977 (PL 95-217) provide financial incentives to communities that use wastewater treatment alternatives to reduce costs or energy consumption over conventional systems. Some of these technologies have been only recently developed and are not in widespread use in the United States. In an effort to increase awareness of the potential benefits of such alternatives and to encourage their implementation where applicable, the Municipal Environmental Research Laboratory has initiated this series of Emerging Technology Assessment reports. This document discusses the applicability and technical and economic feasibility of using natural and artificial wetland systems for municipal wastewater treatment facilities.

13. Jackson, J. Man-Made Wetlands for Wastewater Treatment: Two Case Studies. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 574-580, 2 fig, 2 tab, 3 ref.
Note: Post, Buckley, Schuh and Jernigan, Inc., Orlando, FL. SWRA2305.
Wastewater treatment plant owners and engineers must develop more creative effluent disposal methods using lower-lying or otherwise less desirable lands while adequately protecting surface water resources. Two innovative designs that meet both these needs have been constructed in Lakeland and Orlando, Florida. Prior to its purchase for wastewater treatment, 566 ha of the 650-ha Lakeland site had been used as clay settling ponds for the phosphate mining industry, thus creating an impermeable liner. The constructed wetlands built on this site were designed for a flow of 0.61 cu m/ sec, equivalent, to a hydraulic

application rate of 1 cm/day. Design criteria included reducing influent concentrations of 20 mg/L BOD5), 20 mg/L total suspended solids (TSS), and 8 mg/L total ammonia as nitrogen (NH3-N) to 5 mg/L BOD5, 10 mg/L TSS, and 1.0 mg/L NH3-N. Total P removals of 50% also were expected. The chosen disposal option was creation of a 494-ha man-made wetlands on an improved pasture to further treat water prior to discharge to the St. Johns River. The pasture was segmented by berms into small cells, with weir structures to control flow distribution, depth, and detention time. A wet prairie (170 ha) was planted primarily with cattail (Typha latifolia) and bulrush (Scirpus californicus). From the wet prairie, water flows into a 154-ha mixed marsh, which was started with 10 spp. but now has about 60 spp. The final community is a 162-ha hardwood swamp that includes a 49-ha lake. The swamp was planted with seedlings of bald cypress, red maple, loblolly bay (Gordonia lasianthus), water oak, dahoon holly (Ilex cassine), and other tree species. The constructed wetlands site was designed to receive 0.88 cu m/sec of water with 6 mg/L total N and 0.75 mg/L total P. For the 494-ha site, this is equivalent to nutrient loadings of 0.92 kg/ha/day and 0.11 kg/ha/day for total N and total P. Both the Lakeland and Orlando wetland systems have achieved permitted effluent requirements, although loaded at less than design conditions. Based on the present treatment occurring in the first cells, as flows are increased, more of the system will be used for treatment, but continued compliance with permitted effluent limits is expected. (See also W90-04392) (Rochester-PTT).

14. Kadlec, R. Overview of wetlands treatment in the United States.
U.S. Environmental Protection Agency Municipal Wastewater Treatment Technology ForumU.S. ENVIRONMENTAL PROTECTION AGENCY MUNICIPAL WASTEWATER TREATMENT TECHNOLOGY FORUM. 1990;
Note: Univ. Michigan, Ann Arbor, MI 55812, USA ENGLISH V22N3.
About 450 types of wetlands systems exist for treating a variety of wastes, including municipal wastes, mine water waste, stormwater, and various industrial wastewaters. Wetlands treatment can take place in natural or constructed wetlands sites. Principal categories of constructed wetlands systems include densely vegetated overland flows, underground systems, pond and island systems, and channels with floating plants. The forested wetland is a natural treatment system.

15. Meehan, T. Constructed Wetlands for Sewage Treatment: An Overview.
Water Pollution Control Association of Pennsylvania Magazine, Vol. 22, No. 5, p 37-42, September/October 1989. 4 fig, 8 ref.
Note: SWRA2304.
Constructed Wetlands for sewage treatment provide a practical alternative to conventional treatment of domestic wastewater from small communities, residences, and industries. Constructed wetlands treatment

systems (CWTs) offer several advantages over conventional technology, including lower capital, operating, and maintenance costs; ease of operation; reliable, efficient treatment; flexibility for load variations; and various indirect benefits, such as wildlife habitat and pleasing aesthetics. Disadvantages include large land requirements, lack of design guidelines, and unfamiliarity by consulting engineers. There are, however, numerous constructed wetlands in successful operation. (Cutty-PTT).

16. Meyer, J. A detention-sedimentation basin/artificial wetland treatment system to renovate stormwater runoff from urban, highway, and industrial areas. 8. Biennial International Estuarine Research ConferenceESTUARIES. 1985; VOL. 8, NO. 2B.
Note: Wetland Manage. Specialists, Inc., Smithfield, RI, USA SUMMARY LANGUAGE - ENGLISH; Abstract only. ENGLISH V22N5.
Site-specific design criteria for a detention-sedimentation basin/artificial wetland treatment system to renovate stormwater runoff from urban, highway, and industrial areas have been developed. A detention-sedimentation basin with a rock filter dike coupled to an artificial wetland ranging in depth from meadow to open water, planted with Phragmites communis and Typha spp., is used to filter and absorb nutrients and contaminants in stormwater runoff. This system will provide effective, low-cost, low-maintenance treatment of stormwater runoff from urban, highway, and industrial areas.

17. MEYER J L. A DETENTION BASIN-ARTIFICIAL WETLAND TREATMENT SYSTEM TO RENOVATE STORMWATER RUNOFF FROM URBAN HIGHWAY AND INDUSTRIAL AREAS. WETLANDS Wetlands. 146 May; . CODEN: WETLE.
Note: WETLAND MANAGEMENT SPECIALISTS INC., 70 BATH ST., PROVIDENCE, RHODE ISLAND 02908. ENGLISH.
Stormwater runoff from urban, highway, industrial, residential, and commercial areas has become recognized as an important non-point source pollutant. Many nutrients and toxic substances present in stormwater runoff are strongly associated with particulate material and are removable by sedimentation. Design criteria for a detention basin/artificial wetland treatment system (DBAWTS) to renovate stormwater runoff from urban, highway, and industrial areas have been developed. A detention basin with an underdrain filter coupled to an artificial wetland consisting of a shallow marsh planted with Typha spp. is used to filter and absorb nutrients and contaminants in stormwater runoff. Phosphorus, heavy metals, hydrocarbons, and toxic refractory organic substances will be removed through sedimentation and absorption within the wetland. Anaerobic sediments in the Typha marsh will remove nitrates through denitrification. This system will provide effective, low-cost,

low maintenance treatment of stormwater runoff from urban, highway, and industrial areas.

18. Mingee, T. J.; Crites, R. W. Constructed Wetlands for Secondary Treatment. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 622-627, 1 fig, 2 tab.
Note: Nolte (George S.) and Associates, Sacramento, CA. SWRA2305.
Gustine, CA, is a small agricultural town on the west side of the San Joaquin Valley, with a population of about 4000. Climate in the area is characterized by hot, dry summers and cool winters. Average annual rainfall is about 0.29 m, mainly from November through March. The city treats approximately 4542 cu m/day of wastewater, of which one-third originates from domestic and commercial sources and the remainder comes from three dairy products industries. Analysis of alternatives to upgrade the wastewater plant showed that an oxidation pond/constructed wetland system was most cost-effective. Advantages included availability of suitable land, compatibility of the treatment method with the surrounding area lowest life-cycle cost, consumption of very little energy. A pilot study was conducted from December 1982 to October 1983 to verify the efficacy of constructed wetland to develop design criteria. An existing stand of cattail near the treatment was modified by constructing enclosure berms, piping, and pumps to simulate a portion of the constructed wetlands envisioned for the full-scale project. The wetlands systems consists of 14 cells operated in parallel, each measuring 11.6 m by 337 m (0.4 ha). Depth is adjustable at cell outlet weirs over a range of 0.1 to 0.45 m. Levees, 3 m wide and 0.6 m high, separate the cells. The wetlands system and other treatment plant improvements were constructed in 1986 and 1987. Project specifications required 18 cells to be planted with cattail (Typha) on 0.9-m centers and 6 cells with bulrush (Scirpus fluviatilis) on 0.5-m centers. Without full plant coverage, the wetland portion of the treatment plant is still in the startup phase of operation. Performance of the system as a whole has not reached design expectations, partly because flow and BOD5 entering the treatment plant are significantly higher than design values. However, reduction of BOD5 (66%) and suspended solids (54%) are significant. Exclusive of land (9.7 ha), which was city-owned, project costs were $882,000 to treat a design loading 3785 cu m/day amount to $233/cu m/day. (See also W90-04392) (Rochester-PTT).

19. Pistilli, A. D. Industrial and Commerical Applications: An Overview of Industrial and Commerical Uses of Dredged Material. IN: Beneficial Uses of Dredged Material, Proceedings of the First Interagency Workshop, October 7-9, 1986, Pensacola, Florida. Technical Report No. D-81-1, March 1987. Final Report. p 176-178.
Note: American Dredging Co., Camden, NJ. SWRA2104.
Significant scientific advances have been made to understand and explore the beneficial uses of dredged material. Several airports and

highways have been built on meadows and marshes filled by disposed dredged material. Practically all of the inlets in New Jersey have been used as a source of borrow material for beach nourishment. Dredged material has also been used for mussel beds. All the major refineries on the Delaware River are constructed on former dredged material disposal area sites. Half the sanitary landfills today are being capped by maintenance dredging from the upper Delaware River. By making the use of dredged materials commercially and economically attractive, the practice of dredging is likely to continue in the future. (See also W88-02563) (Geiger-PTT).

20. Reed, Sherwood C. Constructed wetlands for wastewater treatment. BioCycle, The Journal of Waste Recycling. 1991 VOL. 32, NO. 1 (January).

21. Sen, A. K.; Mondal, N. G. Removal and Uptake of Copper (II) by Salvinia natans from Waste Water. Water, Air and Soil Pollution WAPLAC, Vol. 49, No. 1/2, p 1-6, January 1990. 3 tab, 12 ref.
Note: Visva-Bharati Univ., Santiniketan (India). Dept. of Chemistry. SWRA2310.
Copper is a widely used valuable metal. It is an essential trace element, but it is toxic to plants, algae, and human beings at moderate levels. The permissible limit of copper (II) in drinking water is 1.0 micrograms/L. The sources of copper pollution are metal plating, industrial and domestic wastes, mining and mineral leaching. Recently aquatic plants have been used for the removal of heavy metals from water bodies. The plant, Salvinia natans L., was found to be very useful in the removal of copper (II) from wastewater. Effluents from the India Copper Complex, Hindustan Copper Ltd., Ghatshila, Bihar, India, which drain into the Subarnarekha River were collected and analyzed. The water was found to contain 0.75 to 1.2 microgram/ml of Cu(II). When 1 L of water was treated with 20 g of Salvana natans for one day, Cu(II) was completely removed and taken up by the plants from the water. Maximum accumulation was noted within one day and maximum removal (about 90%) was recorded below 50 micrograms/L of copper (II). The results indicate that the mode of uptake is possibly absorption and the metal taken up by the plants forms stable complexes perhaps with the protein molecules within the plant in such way that once they (metal ions) are taken up, they cannot be brought back into solution without destruction of the plant. (Brunone-PTT).

22. Sewage and Industrial Waste Treatment: Wetlands (Jan 77 - Dec 89). Available from the National Technical Information Service, Springfield, VA 22161, as PB90-853722. Price codes: N01 in paper copy, N01 in microfiche. December 1989. 78p.
Note: National Technical Information Service, Springfield, VA. SWRA2311.

This bibliography contains citations concerning developments, operations, and evaluations of natural and artificial wetlands treatment of wastewater and sludges. Aquaculture treatments of industrial, municipal, and domestic wastewater are examined. Topics include nutrient removal, heavy metal recovery, and case studies of wetland being used for wastewater treatment. (This updated bibliography contains 135 citations, 23 of which are new entries to the previous edition). (Author's abstract).

23. Sewage and Industrial Waste Treatment: Wetlands. January 1977-December 1989 (Citations from the Selected Water Resources Abstracts Database)Rept. for Jan 77-Dec 89. 1989 Dec;
Note: National Technical Information Service, Springfield, VA. 055665000 English GRAI9004 Supersedes PB89-865745. Prepared in cooperation with Office of Water Research and Technology, Washington, DC. United States.
This bibliography contains citations concerning developments, operations, and evaluations of natural and artificial wetlands treatment of wastewater and sludge. Aquaculture treatments of industrial, municipal, and domestic wastewater are examined. Topics include nutrient removal, heavy metal recovery, and case studies of wetlands being used for wastewater treatment. (This updated bibliography contains 135 citations, 23 of which are new entries to the previous edition.).

24. Thut, R. N. Utilization of Artificial Marshes for Treatment of Pulp Mill Effluents. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 239-244, 4 tab, 8 ref.
Note: Weyerhaeuser Co., Tacoma, WA. Technology Center. SWRA2305.
Treatment of pulp mill effluents was investigated. Eight artificial marshes were constructed in galvanized steel watering troughs, with epoxy-painted interiors to prevent leaching of zinc. A 0.4-m-deep rock substrate was placed in the troughs. The substrate was marl (10-20 mm), a locally abundant rock composed mainly of calcium carbonate and clay. The independent variables considered in the study were presence/absence of plants, plant type, and retention time. The plants tested were cattail (Typha latifolia), reed (Phragmites australis), and cordgrass (Spartina cynosuroides). The experiment was conducted over 3 yr, with most of the studies of independent variables done in the first year and long-term performance evaluated in the second and third years. Four of the eight artificial marshes were left unaltered throughout the experiment, with a retention time adjusted to 15 hr. The other four were reconstructed in various ways in the second year to test the effects of different substrate depths and configurations. The parameters pH, temperature, conductivity, and color did not change appreciably in transit through the marsh systems. The reactors were more effective at 24-hr retention times than at 6-hr retention times, although more

pollutant was removed at shorter retention times because more total material passed through the basins. The presence of plants had no substantial effect on removal efficiencies for most pollutants, although plants did enhance the removal of ammonia and phosphorus. Dissolved oxygen and oxidation-reduction potential readings from within the rock substrate indicated an anaerobic, strongly reducing environment. Differences in removal efficiency among the three types of plants were not striking. Removal efficiencies did not change substantially over the 3-yr study period. Removal efficiencies were a function of retention time in the 6-24 hr range, but the increment of improvement from 15-24 hr was slight. A facility sized for about 15 hr of treatment probably would be adequate for most purposes. At 15 hr, a full-scale artificial marsh at a typical pulp mill in the United States would be 20-40 ha. (See also W90-04392) (Rochester-PTT).

25. Tomljanovich, D. A.; Brodie, G. A.; Hammer, D. A. Constructed Wetlands for Treating Acid Drainage at TVA (Tennessee Valley Authority) Facilities: Progress Report. 1988 Mar;
Note: Tennessee Valley Authority, Knoxville. Office of Natural Resources and Economic Development. 021113044 9517029 English GRAI8905 NSA1300 Portions of this document are illegible in microfiche products. United States.
A comprehensive overview is presented of TVA's use of constructed wetlands to naturally treat water quality problems associated with acid drainage at its fossil plants and the inactive Fabius Coal Mine and Preparation Plant in Jackson County, Alabama. TVA constructed its first wetland in May 1985. As of December 1987, a total of eight constructed wetlands, one enhanced natural wetland receiving acid drainage, and one former chemical treatment pond were being monitored as treatment wetlands. Some measure of success is being achieved at all the wetland systems. However, to achieve compliance quality effluent (total Fe <3.0 mg/L, total Mn <2.0 mg/L, pH 6.0--9.0 s.u., and total suspended solids <32.0 mg/L) interim chemical treatment is being used at COF to treat manganese, and at WCF to treat low pH. At KIF, water is being pumped from the final cell of the wetland to the active ashpond as an interim measure until it is shown to consistently yield compliance quality effluent. Chemical treatment is also being used to augment wetlands treatment at the Fabius Impoundment 2 and Impoundment 4 wetlands. Where chemical treatment is required, reduced chemical costs result from some level of wetlands treatment. Successful wetlands treatment has been demonstrated at three sites, where no chemical treatment is required. In the remaining two newly constructed wetlands, insufficient data exist to assess their treatment capability. Overall average construction cost based on nine wetlands was $1.13/ft sup 2 ($49,223/ac). Before converting one chemical treatment pond (Fabius Impoundment 3) to a wetland, TVA was annually spending $12,000 to $15,000 for chemicals and $10,000 for pond

maintenance that failed to maintain complying discharges. Complying discharges and an annual wetland maintenance cost of about $1000 make the wetland an attractive and cost-beneficial treatment method. 2 refs., 15 figs., 10 tabs. (ERA citation 13:050532).

26. Tomljanovich, D. A.; Brodie, G. A.; Hammer, D. A.; McDonough, T. A. Preliminary Results of an Experiment to Assess the Effect of Substrate Type on Treatment of Acid Drainage Using Constructed Wetlands. Available from the National Technical Information Service, Springfield, VA 22161, as DE88-016102. Price codes: A06 in paper copy, A01 in microfiche. Report No. TVA/ONRED/WRF--8/2, February 1988. 140p, 2 tab, 8 append.
Note: Tennessee Valley Authority, Knoxville. Div. of Air and Water Resources. SWRA2306.
Constructed wetlands are a viable alternative to more costly chemical treatment of acid drainage and are rapidly gaining acceptance, or at least interest of the mining industry, utilities, and regulators. In response to the need for basic information applicable to designing treatment wetlands, the Tennessee Valley Authority (TVA) in 1986 constructed an experimental wetlands facility in Jackson County, AL. The Acid Drainage Wetlands Research Facility consists of twenty 9.1 sq m wetland cells made of half-round fiberglass pipe. A nearby acidic seep was impounded and routed through the cells at controlled rates. Water samples taken biweekly of the influent and wetland cell discharges were compared to assess treatment (reduction in dissolved Fe, Mn, and total suspended solids and elevation of pH) among five substrate types. Secondary comparisons included growth of cattails among substrate types and treatment effects between bulrush and cattail wetlands in the same substrate type. Significant treatment of dissolved Fe and total suspended solids occurred for all substrate types, and a significant rise in pH of about half a standard unit occurred for all substrate types. Significant Mn treatment occurred in four of the six wetland types. However, reduction in concentration was < 1 mg/L in all types. Significant differences among substrate types, by season were rare and inconsistent. Treatment of all parameters improved with time. With one exception, growth and numbers of vegetatively produced cattail stems were not significantly different among substrate types. Comparisons of treatment between cattail and bulrush wetlands were not significant. Preliminary results from the first year of continuous testing suggested substrate type is relatively unimportant in treatment of acid drainage. (Author's abstract).

27. Wetland Areas: Natural Water Treatment System (Jan 78 - Aug 89). Citations from the Pollution Abstracts Database. Available from the National Technical Information Service, Springfield, VA 22161, as PB90-862244. Price codes: N01 in paper copy, N01 in microfiche. March 1990. 99p.
Note: Davis (J.J.) Associates, Inc., McLean, VA. SWRA2403.

This bibliography contains citations concerning the ability of salt marshes, tidal flats, marshlands, bogs, and other wetland areas to degrade, absorb, filter, consume, mitigate natural and man-made pollution and wastes, while maintaining their ability to provide refuge and breeding grounds for wildlife. The ecology, biochemistry, and viability of naturally occurring and artificially established wetlands as water-treatment systems and wildlife areas are considered. The effects of individual pollutants, environmental factors, species diversity, and cleansing ability of wetland areas on the potential for wildlife refuge, sewage treatment, treatment of industrial and municipal wastes, handling agricultural runoff, mitigating accidental spills, and flooding are discussed. This updated bibliography contains 243 citations, 21 of which are new entries to the previous edition. (Author's abstract).

28. Wetland areas: Natural water treatment systems. January 1978 - August 1989 (a bibliography from Pollution Abstracts). 1990;
Note: 0664714% SUMMARY LANGUAGE - ENGLISH; NTIS Order No.: PB90-862244/GAR. 243 ref.l. ENGLISH V28N1.
This bibliography contains citations concerning the ability of salt marshes, tidal flats, marshlands, bogs, and other wetland areas to degrade, absorb, filter, consume, or mitigate natural and man-made pollution and wastes, while maintaining their ability to provide refuge and breeding grounds for wildlife. The ecology, biochemistry, and viability of naturally occurring and artificially established wetlands as water-treatment systems and wildlife areas are considered. The effects of individual pollutants, environmental factors, species diversity, and cleansing ability of wetland areas on the potential for wildlife refuge, sewage treatment, treatment of industrial and municipal wastes, handling agricultural runoff, mitigating accidental spills, and flooding are discussed. (Prepared in cooperation with Cambridge Scientific Abstracts, Washington, DC.).

29. Wildeman, T. R.; Laudon, L. S. Use of Wetlands for Treatment of Environmental Problems in Mining: Non-Coal-Mining Applications. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 221-231, 3 tab, 37 ref.
Note: Colorado School of Mines, Golden. Dept. of Chemistry and Geochemistry. SWRA2305.
Wetland treatment of environmental problems is used in the coal industry far more than in non-coal mining applications. In coal mining areas, pyrite is the mineral responsible for acid mine drainage problems and it causes most problems in metal mining systems. Fe, Mn, and SO4(2-) dominate the constituents in coal mine drainage, whereas drainages from metal mines is dominated by Cu, Zn, Cd, Pb, and As, as well as Fe, Mn, and SO4(2-). In mining situations where pyrite is absent, water pollution is significantly reduced. With pyrite present, almost every

type of heavy metal contaminant may be present in acid drainage from metal mine operations. Acid drainage from metal mines is a more severe problem than that from coal mines because priority pollutants such as As, Cd, Pb, Hg, Cu, and Zn may be present in hazardous concentrations. Low-cost immobilization of pollutants for long periods of time is the goal of using wetlands for mine drainage treatment. Among various possible removal mechanisms, precipitation of metals catalyzed by bacterial activity is postulated as the most likely. Existing metal mine drainage site wetlands can be divided into two types: (1) primary, where the wetland is the only type of treatment in use, and (2) secondary, where the wetland is used as the polishing step. At a tailings site in Sudbury, Ontario, precipitation of oxides appears to be the main removal mechanism in wetlands, with metal uptake by algae secondary. At a taconite mine in northeastern Minnesota, a naturally-occurring white cedar wetland removes 84% of Cu and 92% of Ni, with peat uptake accounting for most of the metal removal. In Montana, effluent from an abandoned lead-zinc mine was reduced in metals by a natural wetland, whereas constructed wetlands did not remove iron or acidity. At Big Five Tunnel, Colorado, mushroom compost had the highest metal removal efficiency and effluent pH compared to peat and limestone rock covered with peat. (See also W90-04392) (Rochester-PTT).

30. Wolverton, B. C. Artificial marshes for wastewater treatment. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith.
Note: National Aeronautics and Space Administration, MS English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Literature review. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

31. Wood, A.; Hensman, L. C. Research to Develop Engineering Guidelines for Implementation of Constructed Wetlands for Wastewater Treatment in Southern Africa. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 581-589, 4 tab, 7 ref.
Note: Steffen, Robertson and Kirsten, Inc., Johannesburg (South Africa). SWRA2305.
Natural wetlands form an important barrier against nonpoint source discharges of most heavily industrialized areas of South Africa. Research is now underway at a number of locations to evaluate the potential for constructed wetlands in wastewater treatment as a simple, low-cost, low-technology approach to the problem. Studies investigating the controlling factors responsible for efficient operation and design of wetland systems include (1) the substrata responsible for most nutrient removal and hydraulic capacity of the system; (2) macrophyte species responsible for aeration and enhancing permeability; and (3) effluent characteristics, loading rates, and retention times in the operational

regime. A former fish dam, 5 m x 5 m x 1 m, was lined with hyper-plastic membrane (Carbofol 500 micrometer) protected by a 50-mm sand layer prior to filling with coarse gravel (19 mm) and planted with local Arundo donax receiving septic sewage at 10 cm/sq m/day. Arundo fully occupied the be within 4 mo. Two other lined dams were converted to wetlands in upgrading studies of 12 small-scale units. One system with power-station waste ash is planted with Phragmites and loaded with raw sewage. Effluent flows into a Phragmites bed with a local soil covered in a layer of coarse ash. In another study, a combined artificial wetland and high-rate algal pond was constructed that consisted of two units, each 22 m x 11 m x 40 cm. Septic sewage is loaded to the wetland at a rate of 135 L/sq m/day. Effluent from the bed is pumped from the sump into the algal pond. The gravel bed is planted with Typha (for denitrification) and A. donax. Over 1 yr, effluent COD levels were reduced 59%, NH4-N 34%, PO4-P 31%, and suspended solids 77%. Other projects of various designs have been constructed at Mpophomeni, Grootvlei Power Station, Olifansvlei Sewage Works, Johannesburg, and in two rural areas of Gazankulu. Constructed wetlands have considerable potential in southern Africa for treatment of raw wastewaters emanating from rural communities, for upgrading oxidation pond and secondary effluents to general and special discharge standards, and for treatment of industrial effluents. (See also W90-04392) (Rochester-PTT).

STORMWATER - CONSTRUCTED WETLANDS

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1. Allen, George H.; Gearheart, Robert A.; Higley, Mark. Renewable Natural Resources Values Enhanced by Use of Treated Wastewaters Within Arcata Treatment and Disposal System. Proceedings Water Reuse Symposium IV: Implementing Water Reuse; 1987 Aug 2; Denver, Colorado; 1987. p 1223-1245. ISBN: 0-915295-16-4.
   Note: City of Arcata, California Humboldt State University 28 references, tables, figures English.
   In July 1986, a redesigned Arcata sewage treatment plant (STP) with effluent disposal to Humboldt Bay via Butcher's Slough and a wetland effluent receiving area (Arcata Marsh and Wildlife Sanctuary - AMWS) was placed into operation. The system successfully integrates sewage treatment and wastewater disposal requirements and policies of the California State Water Quality Control Board and the coastal zone wetlands enhancement program of the California Coastal Commission. This paper reviews the present status of the integrated treatment and disposal system, outlines the enhanced wildlife and aquaculture values resulting from wastewater use and reuse, details the current status of water quality within the system, and finally discusses new management strategies required for a system integrating wastewater treatment with a wide variety of other public objectives.

2. Anon. Saltmarshes in wastewater research. BIOCYCLE. 1988; VOL. 29, NO. 1.
   Note: ENGLISH V19N3.
   As an alternative to costly, high-tech treatment, professors at Lehigh University's Environmental Studies Center are evaluating use of New Jersey coastal salt marshes to purify clam processing wastewater.

3. Antoine, S. E. Studies on the Bottom Sediments of Al-Hammara Marsh Area in Southern Iraq. Limnologica (Berlin), Vol. 16, No. 1, p 25-28, September, 1984. 1 Tab. 15 Ref.
   Note: University Coll., Cardiff (Wales). Dept. of Plant Science. SWRA1810.
   The sediments of Al-Hammara marsh were collected and analyzed for the first time. The organic matter content was high, mainly due to the death and disintegration of sedimented plankton and the decay of dead benthic animals and plants. Allochthonous organic input with sewage from a small village at site III also increased the load, resulting in the largest quantity of organic material at that site. The calcareous substances were remarkably abundant due to the presence of large amounts of calcareous shells and shell fragements in the sediments. Macrophytic growth may also contribute calcareous substances as they are usually covered with calcified felts of blue-green algae. The allochthonous

material and diatom silica content were lower than that of calcareous substances. Diatom silica constitutes the major part of the HCl-insoluble fraction of the sediment (allochthonous material plus diatom silica). The nutrient content of the sediments was found in adequate quantities. Slow currents or almost stagnant water in the area give the sediments a better chance to absorb more nutrients. The nutrient content varied directly with that of the organic matter. The highest nutrient content at site III, was partly due to sewage disposal. Lower nitrate values were found than for phosphate because nitrate ions are readily lost to the deeper sediment layers, and the phosphate ones are firmly absorbed on the sediment particles. Phosphates were positively correlated with the calcium. The silica contents are mainly affected by the amounts of diatom frustules found in the sediments. High calcium contents were correlated with the high calcareous substances of the sediments. Calcium and magnesium contents were also correlated with the high organic matter contents. Disintegration of dead benthic green plants and settled dead phytoplankton may replenish some of the magnesium of the sediments. Sodium and potassium were found adequately, particularly the latter, mainly due to the fact that significant amounts of these ions are still available from the deeper sediment layers to the superficial ones since the past transgressions of the sea have left a residue of the marine salt in the sediments of the lower plain of Iraq. Surface runoff and seepage may also add some of these ions to the sediment load. (Baker-IVI).

4. Constant, W. D. Fiscal Year 1989 Program Report: Louisiana Water Resources Research Institute. 1990 Nov;
Note: Louisiana Water Resources Research Inst., Baton Rouge. 064085000 Geological Survey, Reston, VA. Water Resources Div. English GRAI9106 See also report for FY 1988, PB90-202169. Sponsored by Geological Survey, Reston, VA. Water Resources Div. United States.
The 1989 cooperative research program of the Louisiana Water Resources Research Institute (LWRRI) addressed priority water resources problem areas identified for Louisiana - management of surface water supplies, ground water control and restoration, and wastewater treatment alternatives. Four research projects funded to address these priority issues were: (1) Nature and Rates of Bacterial Metabolism in the Aquifers of Southeastern Louisiana, (2) Aquaculture/Marine Fisheries Process Wastewaters, (3) The Importance of Denitrification to the Efficiency of Wastewater Treatment in Forested Wetlands, and (4) Field Testing of Rock-Reed Filters for Small Domestic Wastewater Flows.

5. Daiber, F. C.; Hardisky, M. A.; Wolf, P. L. Evaluation of High and Prolonged Levels of Sewage Wastewater on Marsh Vegetation. Available from the National Technical Information Service, Springfield, VA

22161 as PB84-128610, Price codes: A04 in paper copy, A01 in microfiche. Completion Report, September 1983. 70 p, 15 Fig, 9 Tab, 47 Ref. OWRT A-054-DEL(1).
Note: Delaware Univ., Newark. Coll. of Marine Studies. SWRA1702.
A Spartina cynosuroides marsh bordering a tidal gut receiving sewage effluent was compared with a similar marsh on a tidal gut receiving no sewage effluent. S. cynosuroides annual net aerial primary productivity ranged from 313-746 gdw m-2 yr-1 and was similar for the effluent and control marshes. If all plant species are included in the primary production calculation, the marsh on the effluent creek averaged 1050 gdw m-2 yr-1 and the marsh on the control creek averaged 800 gdw m-2 yr-1. The decomposition of S. cynosuroides leaves and stems from litter bags suggested that decomposition in the effluent marsh was significantly faster than in the control marsh. Analysis of plant tissue indicated plants in the effluent marsh had a significantly higher nitrogen concentration than plants from the control marsh early in the growing season. Near the end of the growing season, plants from the effluent marsh had lower or similar nitrogen concentrations to the plants from the control marsh. Despite very high concentrations of ammonia in the tidal water flooding the effluent marsh, luxury uptake of nitrogen by S. cynosuroides apparently did not occur. Lower soil salinities resulting from the large input of sewage effluent also contributed to the observed differences between the control and effluent marshes.

6. DUBINSKI B J; SIMPSON R L; GOOD R E. THE RETENTION OF HEAVY METALS IN SEWAGE SLUDGE APPLIED TO A FRESHWATER TIDAL WETLAND. ESTUARIESEstuaries. 111 Sep; . CODEN: ESTUD.
Note: COLL. MARINE STUDIES, UNIV. DELAWARE, LEWES, DE 19711. ENGLISH.
The hypothesis that freshwater tidal wetlands act as sinks for heavy metals was tested using sewage sludge applied biweekly from March to October 1981 at low treatment (25 g m-2 wk-1) and high treatment (100 g m-2 wk-1) levels. No differences in aboveground macrophyte standing crop were found except in June when high and low treatment sites had significantly higher (p = 0.05) standing crops than control sites. Except for chromium, metal standing stocks in the vegetation on treatment sites did not increase as a result of sludge application. The March litter had significantly higher (p = 0.05) concentrations of chromium, copper, lead, and nickel at all sites than the October vegetation, but only high and low treatment litter chromium levels were significantly higher (p = 0.05) than control litter. When sludge application terminated in October, the top 5 cm of soil at the high and low treatment sites had retained, respectively, 47 and 43% of the cadmium, 53 and 28% of the chromium, 52 and 0% of the copper, 51 and 0% of the zinc, 31 and 0% of the lead, and 0 and 0% of the nickel applied; only cadmium (15 and 46%, respectively) and chromium (12 and 28%, respectively) were still retained the following March. Thus, freshwater

tidal wetlands can retain significant quantities of heavy metals associated with sewage sludge. The vegetation and litter play minor roles while the soil plays a major role in heavy metal retention.

7. Inland Wetlands Legislation and Management. January 1970-July 1988 (Citations from the NTIS Database) Rept. for Jan 70-Jul 88. 1988 Jul; Note: National Technical Information Service, Springfield, VA. 055665000 English GRAI8819 Supersedes PB87-854576. United States. This bibliography contains citations concerning Federal and state laws and management programs for the protection and use of inland wetlands. Utilization of wetlands to control highway runoff and community wastewater is discussed. Wetlands protection programs, restoration projects, resource planning, and wetlands identification methods are cited. References to coastal and salt water wetlands are excluded from this bibliography. (This updated bibliography contains 179 citations, 11 of which are new entries to the previous edition.).

8. Kuenzler, E. J. Sewage Nutrient Removal by North Carolina Swamp Systems. IN: Coastal Water Resources. Proceedings of a Symposium held in Wilmington, North Carolina. American Water Resources Association, Bethesda, Maryland. 1988. p 281-292, 2 fig, 2 tab, 40 ref.
Note: North Carolina Univ., Chapel Hill. Dept. of Environmental Sciences and Engineering. SWRA2312.
Domestic sewage adds nutrients and other soluble and particulate matter to many coastal plain streams. Decreases in N and P below the outfalls result both from dilution by tributary and groundwater inputs and from net removal processes. Concentrations of nutrients and other factors were measured below outfalls in two forested swamp stream systems. A graphical comparison of chloride and nutrient concentrations downstream showed rapid removal of N and P from the water during most of the year, although net flux of ammonium to the water often occurred. Net nutrient removal rates were calculated assuming that chloride is a conservative element in swamp water. Removal rates were highest close to the outfall, and essentially all of the sewage nutrient load to these two swamp systems was removed from the water within a few kilometers of the outfall. By monitoring net removal of sewage nutrients in swamp waters, water resource managers can make better-informed decisions regarding acceptable future loads to the wetland. (See also W90-10584) (Author's abstract).

9. Kuniansky, E. L. Hydrology of Fritchie Marsh in Coastal Louisiana and Application of Finite-Element Modeling to Determine Flow. Available from USGS, OFSS, Box 25425, Denver, CO 80225. USGS Water-Resources Investigations Report 84-4324, 1985. 23 p, 10 fig, 2 tab, 13 ref.

Note: Geological Survey, Baton Rouge, LA. Water Resources Div. SWRA2104. Fritchie Marsh, near Slidell, Louisiana, is being considered as a disposal site for sewage effluent. A two-dimensional, finite element, surface water modeling systems was used to solve the shallow water equations for flow. Factors affecting flow patterns are channel locations, inlets, outlets, islands, marsh vegetation, marsh geometry, stage of the West Pearl River, flooding over the lower Pearl River basin, gravity tides, wind-induced currents, and sewage discharge to the marsh. Four steady-state simulations were performed for two hydrologic events at two rates of sewage discharge. The events, near tide with no wind or rain and neap tide with a tide differential across the marsh, were selected as worst-case events for sewage effluent dispersion and were assumed as steady state events. Because inflows and outflows to the marsh are tidally affected, steady state simulations cannot fully define the hydraulic characteristics of the marsh for all hydrologic events. Model results and field data indicate that, during near tide with little or no rain, large parts of the marsh are stagnant; and sewage effluent, at existing and projected flows, has minimal effect on marsh flows. (USGS).

10. Mika, J. S.; Frost, K. A.; Feder, W. A.; Puccia, C. J. Impact of Land-Applied Incinerator Ash Residue on a Freshwater Wetland Plant Community. Environmental Pollution (Series A), Vol. 38, No. 4, p 339-360. 1985. 6 Fig, 3 Tab, 24 Ref.
Note: Massachusetts Univ., Waltham. Suburban Experiment Station. SWRA1905.
In 1977, 60-70 tons of incinerator ash residue were deposited adjacent to a freshwater wetland. These residues are known to contain elevated concentrations of soluble cations and toxic elements. The impact on the wetland plant community was monitored over a 6-year period. Changes in species abundance and diversity were assessed both over time and distance from the residue deposition. A methodology from the marine benthic pollution literature as used to identify possible indicator species from the group of moderately adapted plants. Distance from the residue did not account for the overall increase in community richness, but appeared to be a factor in the increased relative abundance of moderately adapted species near the residue site, as a result of decreased relative abundance of dominant species. Acute phytotoxic effects were undetected, with the possible exception of the decline of Asclepia syriaca (milkweed). Post-experiment soil analyses indicated an increase of Ca, Mn, P, Zn and Cd in wetlands soils near the residue site and an even greater increase in P, K, Ca, Mg, B, Zn, Cu, Mn, Al, Cd, and Pb in the soil directly beneath the residue. If residue landfills are not properly designed or maintained, the cumulative impact of daily residue deposition could eventually disrupt sensitive ecosystems and pollute adjacent soils and groundwater. (Author's abstract).

11. Nester, R. D. Thin-Layer Disposal: A Modification of Conventional Overboard Disposal of Dredged Material. IN: Water Quality 88: Seminar Proceedings. February 23-25, 1988, Charleston, South Carolina. (1988). p 390-397, 1 ref.
Note: Corps of Engineers, Mobile, AL. Coastal Environment Section. SWRA2212.
In an effort to reduce impacts associated with the open water disposal of dredged material, a test was initiated to determine the feasibility and impact of thin-layer open water disposal. The concept of thin-layer open water disposal suggests that the active spreading of dredged material in a 6-12 inch lift would reduce the short-term impact on bottom resources such that recovery of these affected resources would be faster. The test case for the thin-layer disposal was an existing Federally authorized navigation project known as the Fowl River navigation project. The project provides an 8-ft by 100-ft channel for commercial fishing and recreational boating interests and is a small coastal stream which meanders through extensive wetland areas along the western shore of Mobile Bay in Alabama. Based on the results of the bathymetric surveys and vertical sediment profiling, dredging material was disposed in the deeper portion of the disposal area and south fringe area. The depth of the material was observed to be 2 ft or greater in only 1% of the disposal area. The materials were detectable throughout all post-disposal sampling efforts including the 52-week sampling effort. There was evidence that the materials were slowly drifting in a southeasterly direction and were being reworked mainly by physical forces. Transient impact to water quality was observed during dredged materials disposal in terms of elevated total suspended solids. The impacts were localized to a small area around the dredge discharge during the disposal operation. A slight reduction in total macroinfauna abundance was observed following the dredged material disposal within the disposal area. However, this reduction was not verified statistically. The impact of the dredging operation on the utilization of the area by fishes was not statistically verified. Some fish species were extremely abundant in the disposal area during the 2 and 6 week post-disposal sampling efforts and some species present in the disposal area prior to disposal were not found at all. Changes in fish communities appeared to follow the usual temporal and seasonal trends observed in estuaries. No net decrease in the utilization of the study area by the fisheries resources was seen. (See also W89-13231) (Lantz-PTT).

12. Richardson, C. J.; Walbridge, M. R.; Burns, A. Soil Chemistry and Phosphorus Retention Capacity of North Carolina Coastal Plain Swamps Receiving Sewage Effluent. Water Resources Research Institute of The University of North Carolina Report No. 241, November 1988. 96p, 7 fig, 11 tab, 72 ref, 2 append. WRRI Project 70063.
Note: Duke Univ., Durham, NC. School of Forestry and Environmental Studies. SWRA2303.

The soil chemical properties and P sorption potentials of three North Carolina coastal plain swamps were analyzed for: (1) characterization of their soil chemistries; (2) both short-term and long-term effects of wastewater addition on soil chemistry; (3) determination of their P sorption capacities and the relationships between P sorption and soil chemistry; and (4) development of a predictive index to evaluate the P sorption potentials of other coastal plain swamps. At Brown Marsh Swamp, soils were analyzed both before and after the initiation of wastewater discharge. At Cashie Swamp, which has been receiving wastewater additions for approximately 30 years, soils were collected both above and below the discharge point. Soils from nearby non-impacted Wahtom Swamp were analyzed for comparison. Wastewater additions at Brown Marsh Swamp resulted in significant increases in soil pH, available PO4-P, extractable NH4-N, and total P, and significant decreases in microbial biomass PO4-P and extractable NO3-N. At Cashie Swamp, soils collected below the discharge point had significantly higher concentrations of extractable P, and significantly lower percent organic matter and concentrations of extractable Ca, Mg, and K, total N, total P, and N:P ratios than soils collected above the discharge point. It is estimated that the Clarkton Wastewater treatment plant discharges 221 kg of PO4-P and 295 kg of total P annually into the 0.2 ha Brown Marsh spray field. Based on a modified Langmuir equation estimate of maximum P sorption potential, each hectare of Brown Marsh Swamp soil could sorb nearly two years of annual phosphate discharge from the Clarkton plant in the upper 15 cm of the soil alone. These calculations of maximum sorption potential suggest that this swamp could remove current loading rates for hundreds of years if wastewater P was discharged evenly over the entire swamp. Maximum utilization of wetlands for phosphate removal from wastewater with minimum ecosystem impact can only be achieved under conditions which maximize retention time and the effective surface area of the wetland, and minimize the average impact per unit area. This could be achieved by adding acidified wastewater using a well designed diffusion system. (Lantz-PTT).

13. Schiffer, D. M. Effects of Pretreatment of Highway Runoff on Quality of Wetland Bed Sediments. IN: Coastal Water Resources. Proceedings of a Symposium held in Wilmington, North Carolina. American Water Resources Association, Bethesda, Maryland. 1988. p 293-298, 2 fig, 1 tab, 2 ref.
Note: Geological Survey, Altamonte Springs, FL. SWRA2312.
A study of lead and zinc in bed sediments of two wetlands in central Florida indicates that providing a detention time of 5 to 15 minutes prior to discharging the runoff to the wetland greatly reduces concentrations of these metals in wetland sediments. Preliminary treatment of runoff to a cyprus dome is effected by a detention pond whereas as trash retainer area provides little or no pretreatment of runoff to a freshwater marsh. At the cypress dome site, the median lead concentrations

were 620 microg/g in pond sediments, and 20 microg/g in wetland sediments (ratio of about 31:1); median zinc concentrations were 250 microg/g in pond sediments; and 14 microg/g in wetland sediments (ratio of about 18:1). Constituent concentrations in pond bed sediments were highest on the east side, where water overflows a berm into the wetland, concentrations did not differ significantly with location. Median concentrations in bed sediments in the freshwater marsh were much higher than in the detention pond at the cyprus dome site. Median concentrations in sediments in the freshwater marsh were: lead, 390 microg/g; and zinc, 175 microg/g; these concentrations, when compared to those of the cyprus dome, yielded ratios of about 20:1, and 12:1, respectively. Constituent concentrations in bed sediments generally decreased with distance from the inlet of the freshwater marsh and were lowest at the outlet. (See also W90-10584) (Author's abstract).

14. Swift, D.; J; P.; Stubblefield, W.; L.; Clarke, T.; L.; Young, R. A.; Freeland, G. L. Sediment Budget Near the New York Bight Dumpsites: Implications for Pollutant Dispersal. IN: Wastes in the Ocean, Volume 6: Nearshore Waste Disposal, John Wiley and Sons, New York, New York. 1985. p 319-355, 20 fig, 9 tab, 63 ref. Note: National Oceanic and Atmospheric Administration, Miami, FL. Atlantic Oceanographic and Meteorological Labs. SWRA2010. The fine-sediment transport system of the New York Bight apex is highly dispersive; the residence time of particles subject to storm current and tidal current transport, excluding those involved in the high-speed productivity cycle, is 10.6 d. Transport in the New York Bight is tidally induced in estuaries, lagoons, and tidal inletes but storm-induced on the open shelf. Intense winter storms can resuspend 10,000 t/sq km of fine sediment over several hours, and the particles follow mean trajectories of tens of kilometers for several days before settling out. Fine-sediment transport may be modelled as a diffusion-advection system, in which time and space scales are in the order of tens of kilometers and hundreds of years. Three important pathways of the sediment transport system are the southwesterly directed along-shelf flux, conservatively estimated at 1,000,000 t/yr; the Hudson River input of 1,000,000 t/yr; and the portion of dumped material that escapes burial and joins the transport system (300,000 t/yr). The productivity cycle (14,000,000 t/yr) from living organisms to organic matter and back overwhelms most other pathways. Marshes, estuaries, and lagoons in the bight apex are important sinks (estimated to receive 2,400,000 t/yr of fine sediment). Coprostanol ratios reveal significant sewage sludge contamination of lagoons and estuaries, although the point of entry of the sewage cannot be established. At least 1,000,000 t of fine sediment escapes south along the New Jersey coast each year. Other sinks for suspended fine sediment include the Christiaensen Basin, where ocean dumping occurs (2,300,000 t/yr), and the floor of the adjacent shelf valley. Depositional rates away from the

dumpsites are lower (< 100,000 t/yr), but the sediments reveal elevated coprostanol and trace metal values. (See also W87-07729) (Author's abstract).

15. Thomson, A. D.; Webb, K. L. The Effect of Chronic Oil Pollution on Salt-Marsh Nitrogen Fixation (Acetylene Reduction). Estuaries, Vol. 7, No. 1, p 2-11, March, 1984. 2 Fig, 5 Tab, 39 Ref.
Note: William and Mary Coll., Gloucester Point, VA. Inst. of Marine Science. SWRA1711.
Annual acetylene reduction rates associated with intertidal communities in a chronically oil polluted Virginia salt marsh were compared to rates measured in an undisturbed marsh. Chronic oil treatment resulted in visible damage to the higher plants of the Spartina alterniflora zones; however, vegetation-associated acetylene reduction was not different from the untreated control. Sediment rates generally were affected little by oil application, except during the summer when rates in the median tidal elevation zones were considerably higher than those of the control. Acetylene reduction occurred in all transects, each of which extended from upper mudflat to the Spartina patens zone. Intertidal sediment acetylene reduction was patchy, both spatially and seasonally. Estimated rates were greater near the surface; free-living bacterial N2 fixation activity averaged 2.23 mg N per sq m per d (range = undetectable to 365 mg N per sq m per d) in the untreated and 3.17 mg N per sq m per d (range = undetectable to 564 mg N per sq m per d) *in the oil-treated* marsh during the year. Vegetation-associated N2 fixation activity yielded highest overall mean rates (156 mg N per sq m per d). The seasonal pattern of sediment and vegetation-associated fixation may be controlled by temperature and availability of oxidizable substrates. (Author's abstract).

16. Waddell, D. C.; Kraus, M. L. Effects of CuCl2 on the Germination Response of Two Populations of the Saltmarsh Cordgrass, Spartina alterniflora. Bulletin of Environmental Contamination and Toxicology BECTA6, Vol. 44, No. 5, p 764-769, May 1990. 3 fig, 7 ref.
Note: Felician Coll., Lodi, NJ. SWRA2310.
The saltmarsh cordgrass (Spartina alterniflora) is the dominant vascular plant in tidal marshes along the east and gulf coasts of the United States. It has been demonstrated that although copper (Cu) concentrations as high as 100 mg/L do not affect the germination response, seedlings grown in Cu solution exhibit 100% mortality within 56 days. This study was designed to examine population differences in the germination response of S. alterniflora to various concentrations of Cu. Seeds were collected from a polluted estuary (Sawmill Creek (SMC) near Lyndhurst, NJ) and a relatively non-polluted creek (Big Sheepshead Creek (BSC) near Tuckerton, NJ). Average values of Cu in SMC soil, leaf and seed samples collected were 164.5 mg/kg, 45.3 mg/kg, and 37.1 mg/kg. BSC values were 42.6 mg/kg, 13.0 mg/kg, and 5.4 mg/kg. Germination rates in the BSC control group were significantly greater

(I < 0.05) than in 50 mg Cu/L treatments, while no significant difference in germination rates existed between the BSC control and the 25, 100 or 150 mg/L treatment groups. All germinated seeds in both groups exhibited epicotyl growth, although radicles did not always emerge. Seeds from both populations germinated equally as well in the control treatments, but SMC seeds produced shorter epicotyls, and fewer radicles than did BSC seeds. Both populations of S. alterniflora produced equivalent seed weights. The heightened germination of BSC seeds, and the elongation of SMC epicotyls in the higher Cu concentrations, is probably due to physiological responses to Cu stress. It is possible that the lower concentration of Cu inhibited germination and growth, but higher Cu concentrations stimulated the seedlings, and caused them to over compensate due to the stress. (VerNooy-PTT).

INDUSTRIAL WASTEWATER - NATURAL WETLANDS

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Note: Lough Gara Farms Ltd., Boyle (Ireland). SWRA2305.
Lough Gara Farms Limited produces approximately 450,000/yr of milk on a site that drains into Lough Gara, a 1700-ha, shallow, bog-fringed lake of 13 m maximum depth in Ireland. Problems with pollution from the site were approached by a three-part program: (1) an independent environmental study of the lake's physical, chemical, microbiological, and ecological characteristics to determine the impact, if any, of the existing wastewater treatment system on the lake; (2) a design study aimed at improving the design, functioning, and operation the existing system; (3) prepare, with costing, plans to carry out works requested by the Sligo County Council (SCC); and (4) reinvestigate the suitability of land for the spreading of slurry as requested by SCC. The waste treatment system begins with delivery of slurry to interlinked 2-m-deep by 2.5-m-wide trenches on impervious soil with a capacity of 800 cu m. The daily volume of material fed into this system consists of feces and urine, 7500; milking parlor washings 7500 L; rain washings in unroofed yard areas, 5000 L; and rainfall in the slurry collection channels, 4000 L, a total of 24,000 L/day. A gate controls flow so that the liquid fraction can undergo a second anaerobic fermentation in a chamber of 200 cu m with limestone filter at the outlet. Filtered liquid (3600 cu m/yr) is fed into the wetlands treatment area. The wetlands treatment area is divided into two zones: a former lake bed of 6.4 ha, with peat and vegetation, and a zone of 5.5 ha that falls 1 m to the Lough Gara level. Effluent treatment produced a 99.1-99.95% reduction in BOD5 concentrations, although on some occasions levels exceeded 200 mg/L. Ammonia concentrations were reduced by up to 94.5%; nitrate concentrations were reduced up to 95.4%; and orthophosphate concentrations were reduced up to 91.3%. (See also W90-04392) (Rochester-PTT).

2. Finlayson, C. Max. Use of Aquatic Plants to Treat Wastewaters in Irrigation Areas of Australia. Australian Water & Wastewater Association Technical Papers, Tenth Federal Convention; 1983 Apr 11; Sydney, Australia. ; 1983 Apr. 10 p.
Note: 13 references, tables English A04.
This paper reports on experiments which examined the effectiveness of three aquatic plants to treat effluents from rural based industries in Australia. The plants used in the experiments were of the genera Typha, Phragmites, and Schoenoplectus. These plants were utilized to treat

effluents from a poultry abattoir, a piggery, and a rendering plant. In each case, the plants were grown in trenches into which the effluent was pumped and allowed to percolate. Retention time was between 3 and 5 days. Results vary in each case but indicate that such plants are capable of reducing turbidity, suspended solids, total nitrogen, total phosphorus, and chemical oxygen demand. However, the role of the plants in the treatment process is not entirely clear, and harvesting to remove most nutrients does not appear worthwhile. (For other papers presented at this conference, TYPE DIALOG accession numbers 0013622 - 0013686).

3. Gambrell, R. P.; Khalid, R. A.; Patrick, W. H. Capacity of a Swamp Forest to Assimilate the TOC Loading from a Sugar Refinery Wastewater Stream. Journal - Water Pollution Control Federation JWPFA5, Vol. 59, No. 10, p 897-904, October 1987. 2 fig, 8 tab, 10 ref.
   Note: Louisiana State Univ., Baton Rouge. Center for Wetland Resources. SWRA2105.
   An investigation was carried out to determine the potential impact of a sugar refinery effluent on a receiving swamp and the nearby Blind River in southern Louisiana. The study included field investigations to determine the rate and direction of water flow and organic carbon levels in the receiving swamp, and laboratory studies to determine the rates of organic degradation in the swamp sediment-water system. Laboratory column studies were conducted on the swamp sediments as were aerial photographic and dye tracer observations of the wastewater in the swamp. Based on the results, the climatic conditions, and the refinery discharge volume, it is suggested that 80 to 160 ha of swamp area is needed to completely degrade the organic carbon loading from the refinery if a 15- to 30-cm water depth is maintained for 8 days. (Author's abstract).

4. Kalin, M. Study of the treatment of acidic seepages employing a combination of wetland ecology and microbiology. 1989;
   Note: Canada Centre for Mineral and Energy Technology, Ottawa (Ontario). 058811000 Boojum Research Ltd., Toronto (Ontario). English GRAI9102 Canada.
   The promotion of wetlands is essential in providing a biological solution to the problem of acid mine drainage. Cattails constitute a great portion of these wetlands and contribute much to the accumulation of organic matter that is essential to the success of a biological polishing system. The 1st part of this report examines the use of a foliar fertilizer to establish cattails. Two types of fertilizers were applied to a natural and a transplanted stand of cattails using 2 different dilutions. In the 2nd part of the report, the treatment of acid mine drainage (AMD) through the use of alkali generating microbes as an alternative to conventional lime treatment was examined. Organic matter, a source of fixed carbon for the alkali generating microbial ecosystem, was tested

in 6 different types of AMD ranging in acidity from 2 mg/l to 900 mg/l (CaCO3 equivalent), while sulphate concentrations ranged from 75-7300 mg/l. The 3d and 4th parts of the report discuss work in progress at Boojum Research Ltd. and at Dearborn Microbiology Laboratory.

5. Koussouris, T. S.; Diapoulis, A. C.; Bertahas, I. T.; Gritzalis, K. C. Self-Purification Processes Along a Polluted River in Greece. Water Science and Technology WSTED4, Vol 21, No. 12, p 1869-1872, 1989. 2 fig, 5 ref.
Note: National Centre for Marine Research, Athens (Greece).
SWRA2306.
Pollution sources in the agricultural basin of the Louros River in Greece include fertilizers, pesticides, agricultural industry wastes, livestock, and domestic sewage (no treatment plants in the area). The river flood plain consists of wetlands and lagoons populated with reeds. Water quality parameters for May and October 1987 were reported for sampling stations from the mouth to 36.5 km upstream. Dissolved oxygen was 54 to 155%; temperature, 18 C; pH 6.5 to 8.3; total hardness, 210 to 450 mg/l; alkalinity, 150 to 200 mg/l CaCO3; salt, 500 to 600 mg/l. Nitrates, phosphates, and ammonia had high concentrations in March, May and November. Nitrification was blocked over the last 5.3 km of river for most of the year; in summer these conditions extended to 18.5 km. Rates of self-purification did not follow any patterns, presumably from the irregularity in discharges with respect to time and space and the variability in water flow. Invertebrate communities showed stresses at some seasons and especially where tributaries enter the river. The overall self-purification properties were rated average. (Cassar-PTT).

6. LAVIGNE, RONALD L., PH.D. A DESIGN MODEL FOR THE TREATMENT OF LANDFILL LEACHATE WITH A MICROBIALLY-ENRICHED SOIL AND REED CANARYGRASS. 1989; 50/08-B OF DISSERTATION ABSTRACTS INTERNATIONAL.
Note: ORDER NO: AAD90-01528 UNIVERSITY OF MASSACHUSETTS.
The disposal of municipal solid waste continues to be one of the major environmental problems facing the world today. "Sanitary landfilling" became the accepted method of refuse disposal during the early 1970's, when open burning dumps, wind blown litter, flies and rodents were perceived to be the solid waste issue of the day. Little or no attention was given to the process of refuse decomposition and the liquid waste that is subsequently produced (i.e., leachate). Today lined landfills are replacing older unlined facilities and the practice of collecting leachate has become commonplace. An appropriate technology to treat collected leachate, however, has yet to be developed. Current landfill designs generally require the utilization of municipal wastewater treatment facilities for leachate disposal; but this practice is costly and it may be

environmentally less desirable. This research project investigated the use of a new technique for treating landfill leachate on site. It utilizes a low technology "living filter" approach that models biological, chemical and physical processes known to be occurring in natural wetlands. The system takes advantage of the root zone aeration capabilities of reed canarygrass; and it maximizes the development of the fixed film biomass on peatmoss surfaces. Aerobic and anaerobic environments within the treatment medium facilitate a rapid reduction of Total Organic Carbon (TOC) and Chemical Oxygen Demand (COD); which both exist at high concentrations in leachate. The environment is also conducive to the precipitation of leachate metals. Peatmoss and reed canarygrass treatment beds were operated in both the batch and continuous flow mode to evaluate the reaction order and rate constants for leachate degradation. COD and TOC were used as modeling parameters. Mean hydraulic retention times of 3-10 days resulted in a 99%+ reduction in COD and TOC concentrations. Similar reductions were realized for heavy metals and total nitrogen. Grass clippings and peat samples were analyzed for Fe, Cu, Mn, Mg, P, K, and Ga before, during, and after 3 years of landfill leachate application. Leachate influent and effluent were also analyzed for the same metals. In each case, more than 99% of the cations measured were removed by the treatment system. Data indicates that a root zone method using peatmoss and reed canarygrass can be an effective method for creating landfill leachate if unsaturated flow conditions are maintained. Toxicity testing using reed canarygrass seedlings indicated that leachate is initially toxic, but with time plants are able to recover and flourish in the leachate-peatmoss environment.

7. Lewis, R. R.; Estevez, E. D. Ecology of Tampa Bay, Florida: An Estuarine Profile. Available from the National Technical Information Service, Springfield, VA. 22161, as PB89-130488. Price codes: A06 in paper copy, A01 in microfiche. Biological Report 85(7.18), September 1988. 132p, 85 fig, 27 tab, 275 p. Note: Mangrove Systems, Inc., Tampa, FL. SWRA2306.
Tampa Bay is Florida's largest open-water estuary and one of the most highly urbanized. This report summarizes and synthesizes many years of scientific investigation into Tampa Bay's geology, hydrology and hydrography, water chemistry, and biotic components. The estuary is a phytoplankton-based system, with mangroves being the second most important primary producer. Benthic organisms are abundant and diverse, although in parts of the bay the benthos consists of a relatively few opportunistic and pollution tolerant species. The estuary provides habitat for the juveniles and adults of a number of commercial and recreational fishery species. Significant changes occurring as a result of urbanization and industrialization includes significant declines in intertidal wetlands and seagrass meadows, changes in circulation and flushing, and degradation of water quality. Important management issues

include dredge and fill operations, restoration of fisheries, increasing freshwater flow to the bay, and eutrophication. (Author's abstract).

8. Snyder, B. D.; Snyder, J. L. Feasibility of Using Oil Shale Wastewater for Waterfowl Wetlands. 1984 Jan; Note: Engineering-Science, Inc., Denver, CO. 063789000 Fish and Wildlife Service, Washington, DC. D'v. of Biological Services. English GRAI8416 United States.
This ecological, engineering, and institutional research study evaluated the use of selected wastewaters from oil shale development to establish wetland habitats for waterfowl. It also evaluated the capability of the wetlands as an innovative wastewater treatment system. The first phase of this two-phase study included inventorying the physical and chemical properties of the potential wastewater sources, evaluating the wastewater capacity of wetlands, and determining the availability of each wastewater source. Critical waterfowl habitat requirements and effects of wastewater on wetlands were used, along with wastewater chemical characterizations, to establish minimum environmental standards for water quality and quantity. The second phase involved selecting candidate sites suitable for possible demonstration projects, including comparing the cost and effectiveness of wetland wastewater treatment with conventional treatment technologies.

9. Superfund Record of Decision (EPA Region 1): Baird and McGuire, Holbrook, Massachusetts, September 1986 Final rept. 1986 Sep 30; Note: Environmental Protection Agency, Washington, DC. 031287000 English GRAI8720 Portions of this document are not fully legible. United States.
The Baird & McGuire site encompasses approximately twenty acres in Holbrook, Norfolk County, MA. Wetlands occupy approximately 44 percent of the site with approximately 66 percent of the site lying within a 100-year flood plain. Baird & McGuire, Inc. (BMI) operated a chemical mixing and batching company from 1912 to 1983. BMI's disposal practices were the source of ground water and wetlands contamination. In 1983 heavy rains caused a breach of the creosote collection lagoon resulting in an EPA-initiated Immediate Removal Action. Dioxin, detected in surficial soil samples in 1985, prompted an EPA-initiated second removal response involving the installation of 5700 feet of fencing and extensive soil, ground water, surface water, and air sampling. The primary contaminants of concern include: VOCs, organics, PAHs, dioxin, pesticides, and metals. The remedial action includes excavation in 'hot areas' to remove approximately 191,000 cubic yards of contaminated soils, onsite incineration of excavated soils, ground water extraction and onsite treatment with discharge to an onsite aquifer; restoration of wetlands, construction of levees and ground water monitoring. The estimated capital costs are $44,386,000 with 30-year O&M costs of $4,132,000.

10. Superfund Record of Decision (EPA Region 5): Fort Wayne Reduction, Fort Wayne, Indiana (First Remedial Action) August 1988Final rept. 1988 Aug 28;
Note: Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. 031287614 English GRAI8919 Portions of this document are not fully legible. United States.
The 35-acre Fort Wayne site (FW) is a former municipal landfill/waste disposal facility located along the Maumee River just east of the city of Fort Wayne, Allen County, Indiana. Two onsite areas are designated as wetlands. In addition, the site lies within a 100-year flood plain. The site accepted residential and industrial wastes from 1967 to 1976. From May 1967 to August 1970, FW was issued a county permit for public disposal of garbage and rubbish. Wastes were incinerated and the residual ash disposed of onsite. In 1970, FW changed its name to National Recycling Corporation. All solid waste was to be processed through the plant. It was torn down in 1985. Inspection reports indicated that deposited refuse included: industrial and liquid wastes, municipal wastes, garbage, paper, and wood. The site consists of two characteristically different areas reflecting its historical use: the eastern half of the site was used as the municipal/general refuse landfill (approximately 15 acres), and the western half of the site (approximately 5 acres) was used for disposal of industrial wastes, building debris, barrels of unidentified wastes, and residual ash from earlier incineration operations. Presently, soil and ground water are contaminated with 43 chemicals of concern including: metals, organics, PCBs, PAHs, phenols, and VOCs. The selected remedial action for the site is included.

11. Wolverton, B. C.; McCaleb, R. C. Pennywort and duckweed marsh system for upgrading wastewater effluentfrom a mechanical package plant. Aquatic plants for water treatment and resource recovery / edited by K.R. Reddy and W.H. Smith.
Note: National Aeronautics and Space Administration, MS English Paper presented at the "Conference on Research and Application of Aquatic Plants for Water Treatment and Resource Recovery," July 20-24, 1986, Orlando, Florida. Includes references. OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76).

12. Yuduan, W.; Changyi, L.; Jiandong, H.; Yuling, L. Removal of Heavy Metals from Sediments by Mangroves in Jiulong Estuary, Xiamen Harbour, China. Water Science and Technology WSTED4, Vol. 20, No. 6/7, p 49-54, 1988. 3 fig, 2 tab, 11 ref.
Note: Xiamen Univ. (China). Inst. of Environmental Science. SWRA2206.
Sediment samples were collected from Jiulong Estuary (Xiamen Harbor, Fujian, China), where five major species of mangrove grow well, even though the levels of the heavy metals Cu, Pb, and Hg from anthropogenic sources in the sediments of the region are as high as 18.1 ppm, 59.2 ppm, and 0.14 ppm, respectively. The concentrations of Cu, Pb, Hg, Mn, Fe, and P in leachate from sediment leached with 0.5 N HCl, as well as the total carbon (TC) content and analysis was used to assess

the experimental data. The removal of such heavy metals as Hg from sediments by mangroves was estimated to be up to 6.5% of the weakly bound species. The authors suggest that mangrove ecosystems may be used as a cheap method of treating industrial waste containing low levels of heavy metals. (Author's abstract).

AGRICULTURE

BIBLIOGRAPHY

1. Ailstock, M. S. Utilization and Treatment of Thermal Discharge by the Establishment of a Wetlands Plant Nursery. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 719-726, 3 fig, 1 tab, 15 ref.
Note: Anne Arundel Community Coll., Arnold, MD. SWRA2305.
The Nevamar Corporation, in Odenton, Maryland, manufactures decorative building materials in a process that generates 284,000 L of heated water per hour. Permits for discharge of this water into the Severn River have lowered the acceptable discharge temperature to 32.2 C. As part of the permit process, a study was conducted of ways to improve holding pond cooling efficiency. Possibilities include increasing pond depth, surface area, and equalization and retention time as suitable modifications. These improvements were compatible with and would be optimized by a wetlands plant nursery, which is described here. Wetland plants can be grown in 4-L to 12-L containers placed in channels filled with gravel and receiving the heated water. The flow provides continuous irrigation and, with the exception of an occasional supplementary application of slow-release fertilizer, the plants are maintenance free. Availability of warm water greatly extends the growing season and significantly enhances belowground growth. Two wetlands projects have been installed with plants produced using this wetland nursery (Spartina spp. marshes, a 111 sq m area and a 610 m shoreline stabilization area requiring 25,000 plants). Numerous applications for the plants grown in this type of nursery suggest that the concept has wide potential application. (See also W90-04392) (Rochester-PTT).

2. Garskof, I. Pennsylvania's Wetlands: Urbanization and Watercourse Modification. IN: Wetlands of the Chesapeake. Proceedings of the Conference Held April 9-11, 1985, Easton, Maryland. 1985. p 237-239. Note: Corps of Engineers, Beach Creek, PA. Foster Joseph Sayers Dam. SWRA2106.
Regulation of Pennsylvania's wetlands has been complicated by their diversity and wide geographic distribution. Although figures are not available for wetlands acreage within the Susquehanna River Basin, National Wetlands Inventory calculations indicate approximately 400,000 acres within the entire State. Based upon drainage area and wetlands density, there are probably 200,000-250,000 acres within the Susequehanna River Watershed (including New York). In order to qualify this problem in terms of Wetlands impact investigations conducted since January 1983 were divided into broad categories. These are: filling of wetlands for commercial development - 24 filling of wetlands for residential development - 24%; filling or dredging of wetlands for agricultural development or peat mining - 21%; filling of wetlands to dispose of solid waste - 16%; filling of wetlands for roads or utility

construction - 7.4% and stream modifications which alter or destroy wetlands - 3.6%. These figures represent percentages of cases, not total acreage of wetlands impacted. Section 404 of the Clean Water Act only partially protects these wetlands from the effects of urbanization because it regulates neither dredging nor the discharge of waste materials into wetlands when the object is not to create fastland. Because wetlands protection depends ultimately on public support, public education is a priority of the regulatory program. (See also W88-04934) (Lantz-PTT).

3. Kurihara, Y.; Suzuki, T. Effects of Harvesting on Regeneration and Biological Production of Phragmites australis in Wetlands. IN: Proceedings of the International Symposium on the Hydrology of Wetlands in temperate and Cold Regions. Joensuu, Finland, 6-8 June 1988. Vol. 1. The Academy of Finland, Helsinki, Finland. 1988. p 249-255, 6 fig, 1 tab, 7 ref.
Note: Tohoku Univ., Sendai (Japan). Biological Inst. SWRA2205.
Since reed, Phragmites australis, grows so densely as to constitute an obstacle in rivers during the flood season, its removal becomes a highly important step in the control of the flow of water. Another reason for harvesting the reed is the fact that it incorporates fairly large amounts of nitrogen, phosphorus and other nutrients from the polluted water and nutrient-rich mud substratum, thus benefiting the environment. The regrowth of reeds, Phragmites australis, harvested at different stages of the growing season was examined in pots and in situ to establish the best time for harvesting. The tendency for height and biomass in plots harvested later in the season to increase was recognized. For cutting 30 cm above the water surface, regrowth after one year was quite satisfactory. In the pot experiment, the amounts of nitrogen and phosphorus in the underground parts of reeds were very low at the early stages and rose remarkably at about 100 days after supplying nutrients, corresponding to August in situ. Therefore, harvesting in August by cutting stems above the water level was found to maximize total biomass that could be removed from the stand. However, there still remains the problem as to how to use the harvested material. Its application to agricultural land with sludge discharged from a sewage treatment plant is expected to become an important means for disposing of sludge and using this material. (See also W89-04689) (Author's abstract).

4. Lowe, E. F.; Stites, D. L.; Battoe, L. E. Potential Role of Marsh Creation in Restoration of Hypertrophic Lakes. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 710-717, 3 fig, 2 tab, 13 ref.
Note: Saint Johns River Water Management District, Palatka, FL. SWRA2305.
A novel approach is proposed and an example is described of a plan for hypertrophic lakes. In a typical sewage treatment wetland, water high in inorganic nutrients passes through the system once, and the management goal is to maximize the nutrient removal efficiency. In the present

application, water to be treated has high concentrations of nutrients associated with particles and dissolved organic molecules. Water is passed through the system many times rather than once. The goals of this approach are to maximize nutrient quantity removed per unit of time (power) and nutrient permanently stored (capacity) rather than nutrient fraction removed in single pass (efficiency). Lake Apopka, located in central Florida, is a large (124 sq km), shallow (mean depth 1.7 m) and hypertrophic lake (trophic state index 86), which has been the subject of a design study concerning construction of a 32 sq km wetland. The project has three main goals: (1) establishment and maintenance of a hydrologic regime and vegetation that maximizes the wetland's power and capacity for nutrient storage; (2) creation of a broad and persistent biological connection between the lake and the created marsh; and (3) establishment and maintenance of a diverse wetland habitat to support aquatic and wetland wildlife. Expected benefits include elimination of nearly 45% of the agricultural discharge to the lake, approximately 41% of the total annual loading of P and increased nutrient export from the lake because water flow will be into and through the wetland, with discharge to downstream lakes. (See also W90-J4392) (Rochester-PTT).

5. Silverman, G. S. Development of an Urban Runoff Treatment Wetlands in Fremont, California. IN: Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea, Michigan. 1989. p 669-676, 2 tab, 5 ref. Note: Bowling Green State Univ., OH. Environmental Health Program. SWRA2305.
A 20-ha fallow agricultural field in Fremont (Alameda County), California, was converted into a seasonal freshwater wetlands for managing urban stormwater runoff traveling in Crandall Creek. Institutional considerations, treatment mechanisms, design, and potential for stormwater wetlands are discussed. Three distinct systems were incorporated into the wetlands: (A) a long, narrow pond containing a long island, and with vegetation (mainly Typha latifolia) encouraged along the pond margins; (B) a spreading pond draining into an overland flow system (inundated only during storms), followed by a pond with berms supporting aquatic vegetation; and (C) a common third system into which the others drain, which provides meandering channels to maximize contact with various types of wetlands, and drains into another section of the Coyote Hills Regional Park, ultimately returning to Crandall Creek. Hydraulic considerations included sizing the diversion structure and channels to accommodate the 10-yr, 6-hr storm, with greater flows causing diversion structure failure, with most of the flow remaining in Crandall Creek. Development of this wetlands provided a number of benefits. An attractive wetlands has been created in an urbanized region badly needing additional 'natural' areas and a facility to study potential and future designs for urban runoff treatment systems has been provided. Another important benefit is the practical demonstration for implementation of other wetlands development projects. Development of the Fremont wetlands required active efforts from the regional council of governments and park district, financial support from the state

and federal governments, and the cooperation of a host of local agencies and special districts. It demonstrated the need and potential for obtaining diverse support for wetlands projects. (See also W90-04392) (Rochester-PTT).

6. van der Valk, A. Effective Wetlands Policy: Sticks or Carrots. Environmental Forum ENVFEN, Vol. 6, No. 1, p 21-26, 1989. Note: Iowa State Univ., Ames. Dept. of Botany. SWRA2302.
Despite a history of scattered and incongruent programs addressing agricultural wetlands, the recent proposals of the National Wetlands Policy Forum may provide the guidance that has been so sorely lacking. This Forum suggest that in order for future federal wetlands policy to have force against agricultural interests, it must provide economic incentives to preserve existing wetlands and to restore those that have been drained. The Conservation Reserve Program has produced unexpected benefits for wetlands. This program, with the help of the U.S. Fish and Wildlife Service, Soil Conservation Service, Ducks Unlimited and other state and county agencies, has encouraged farmers to voluntarily restore hundreds of prairie potholes in Iowa, the Dakotas, and Minnesota. The National Agricultural Wetlands Reserve Program has been proposed by the National Wetlands Policy Forum for the next farm bill. It would ensure the protection of lands in the Conservation Reserve Program even if there is an increase in crop prices. This program would make provisions of the Food Security Act more palatable to farmers by compensating them for leaving their wetlands alone. The preservation or restoration of certain wetlands may greatly reduce environmental impacts of agriculture. For example, by using wetlands to absorb agricultural runoff, contamination of surface and groundwater can be lessened. There is no point, however, in establishing a National Agricultural Wetlands Reserve Program if the land it covers will eventually be destroyed or become so contaminated by agricultural runoff that it will become a hazard for waterfowl or other animals. To avoid the latter, research is needed immediately to determine the sustainable loading rates of nitrate, sediment, and various pesticides, as well as the long-term effects of these contaminants in wetlands. (Mertz-PTT).

7. Winnett, G.; Marucci, P.; Reduker, S.; Uchrin, C. G. Fate of Chlorothalonil in Ground Water in Commercial Cranberry Culture in the New Jersey Pine Barrens. Journal of Environmental Science and Health (A) JESEDU, Vol. 25, No. 6, p 587-595, August 1990. 2 fig, 2 tab, 6 ref. Note: Cook Coll., New Brunswick, NJ. Dept. of Environmental Science. SWRA2404.
The fate of the agricultural pesticide chlorothalonil in groundwater was studied in an experimental cranberry bog in the Pine Barrens, New Jersey. Clusters of monitoring wells were sunk at depths of 0.5, 1.0, and 1.5 m. Chlorothalonil was applied to the experimental bog 3-4 times per growing season at 5-16 pints per acre for 1985-1987. Groundwater and surface waters were sampled weekly or biweekly for two years and samples were analyzed for chlorothalonil residues by gas chromatography. In general, the chlorothalonil treatments to the

experimental bog, which followed the recommendation of the New Jersey Agricultural Station to the state's cranberry growers, showed no discernible vertical movement of the pesticide from the surface to the groundwater. In the few cases where there was a groundwater residue, levels were so small and inconsistent that they may have been the result of channeling along the well casing. Instances of chlorothalonil residues in surface waters may be explained by occurrence of a spill and drift of the pesticide during application. Where residues of chlorothalonil were found in the soil, they were limited to the top 1-2 inches. It is concluded that chlorothalonil application to cranberry bogs in the Pine Barrens poses little risk of contaminating the underlying Cohansey aquifer system. (MacKeen-PTT).

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This report summarizes a literature review of the effectiveness of wetlands for enhancing wastewater quality. Results from the review were categorized by the type of wastewater (i.e., municipal domestic, stormwater, industrial, agricultural, and mining) and wetland (i.e., natural and constructed). For each type of wastewater and wetland, the following constituents were addressed: suspended solids, nutrients, heavy metals, toxic organic materials, and other constituents (e.g., bacteria and pathogens). The report also contains a bibliography of the most pertinent literature categorized by wastewater type. Each literature citation includes an abstract.

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