THE POWER TO MAKE A DIFFERENCE.

Final Report

Treatment of Nonpoint Source Pollution with Wetland/Aquatic Ecosystem Best Management Practices

prepared for:

Texas Water Development Board
Austin, Texas

by:

Lower Colorado River Authority
Austin, Texas

Principal Investigators:
Geoffrey P. Saunders
Mary P. Gilroy

April, 1997

Lower Colorado River Authority

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Executive Summary

A demonstration project was conducted to test the feasibility, pollutant removal efficiency, and biological viability of wetland/aquatic ecosystem best management practices. The type of treament structure studied was a wetpond, which is a stormwater detention pond containing a permanent pool of water at least four feet deep and a shallow marsh around the perimeter to support an aquatic ecosystem. Wetponds are considered innovative practices in semi-arid climates, because of the difficulty of maintaining a permanent pool of water.

The Mansfield Wetpond was designed by the Lower Colorado River Authority (LCRA) and constructed by the Texas Department of Transportation (TxDOT), on the east bank of Lake Austin downstream from the newly constructed Highway 620 bridge. The wetpond was designed to contain and treat the first one inch of runoff from the bridge surface and a 25-acre drainage area containing an undeveloped park facility. The facility was constucted in 1993 prior to erection of the bridge over Lake Austin. Biological monitoring commenced in 1994 after a period allowing flora and fauna to become established, and hydrologic monitoring of the wetpond commenced in 1995 after reclamation of the construction site.

The facility was equipped with systems to augment the wetpond by pumping water from Lake Austin, measure rainfall and monitor stormwater inflow and outflow from the wetpond, monitor shallow ground water beneath the wetpond, and measure the amount of consumptive water loss from the wetpond. A total of twenty-one storm events were monitored over a period of two years using automated stormwater sampling equipment. Several sets of sediment samples were collected. Biological monitoring consisted of periodic assessment of zooplankton, phytoplankton, total productivity, benthic macroinvertebrates, fish and aquatic vegetation. Most of the biological monitoring was conducted for a period of one year.

Of the twenty-one measured storm events, eighteen were completely contained by the wetpond with no discharge. Differences in antecedent moisture conditions prior to storms, variations in rainfall amounts and storm intensity, and changes in stormwater retention capacity due to variable pond levels resulted in highly variable rainfall-runoff relationships and inconsistent inflow-outflow conditions. Generally, the wetpond was effective in removing suspended solids and nutrients including phosphorus and nitrogen. Differences in dissolved constituents between water in the wetpond and groundwater beneath the wetpond indicated no detectable impact of pond seepage on ground water quality. Sediment analyses showed no hazardous concentrations of toxic metals in the sediment trapped by the wetpond.

Biological monitoring identified the population of an aquatic community which was typical of small ponds in Central Texas. Biological monitoring was hampered by the short duration of study and lack of a control ecosystem for comparison. There were two significant results of the biological studies. First, after stocking the wetpond with a diverse grouping of plants and fish, the flora quickly evolved toward a monoculture and phytoplankton and macroinvertebrates showed a distinct community shift toward more pollution-tolerant groups. Second, certain species of dragonfly naaid (*Celithemis* sp., *Dythemis* sp., and *Tramea* sp.) were identified as possible indicators of nonpoint source pollution impacted waters.

Executive Summary, cont.

The wetpond was found to require 2.60 acre-feet of augmentation per year to maintain a permanent pool of only 0.24 acre-feet. Maintenance costs, including augmentation to replace water lost to consumptive use, were estimated to be in excess of $20,000 per year. The benefit of maintaining a viable aquatic ecosystem for the purpose of stormwater treatment did not justify the cost of operation and maintenance.

The City of Austin Drainage Utility has issued guidelines for the design of wetponds. The LCRA recommends additional study before recommending wetponds as a best management practice under its Highland Lake Nonpoint Source Pollution Control Ordinance.

Treatment of Nonpoint Source Pollution
with Wetland/Aquatic Ecosystem
Best Management Practices

I. Introduction

On August 1, 1992, the Texas Water Development Board awarded a Water Research grant contract to the Lower Colorado River Authority (LCRA). The grant authorized the construction, monitoring and analysis of a wetland/aquatic ecosystem (wetpond) for treatment of stormwater runoff from a major highway bridge over Lake Austin.

Construction of a bridge and associated section of Highway 620 at Mansfield Dam required the installation of a nonpoint source pollution control structure. The structure was modified to act as a wetpond, an innovative practice in the LCRA Nonpoint Source Pollution Control Ordinance Technical Manual (LCRA, 1991). A wetpond is considered innovative in semi-arid climates because of the high ratio of evaporation to precipitation, requiring the pond to be augmented to support an aquatic ecosystem. The structure was built on LCRA land in 1993 under an agreement with the Texas Department of Transportation, and has been maintained by the LCRA.

The research grant allowed modification of the structure and installation of data collection equipment to determine the pollutant removal capacity and augmentation requirements of the wetpond. The grant also provided funds to establish an assemblage of aquatic plants and fish, and to monitor stormwater inflow, sediment toxicity, and shallow ground water in the vicinity of the wetpond.

A total of 21 stormwater events were sampled during the course of this study. Sediments accumulated within the Mansfield wetpond were sampled and analyzed for toxic pollutants contained in stormwater runoff. Four ground water monitor wells, one upgradient and three downgradient from the wetpond, were installed and sampled after storm events to determine possible leakage from the Mansfield wetpond to the underlying water table. Infiltration tests and a short-term pumping test were conducted to evaluate the potential for leakage to the alluvial aquifer.

Operation of the Mansfield wetpond was simulated using the SEDIMOT II hydrology and sedimentology model, to determine its efficiency in capturing sediment under various storm event scenarios. This model, combined with an analysis of consumptive loss by evapotranspiration requiring augmentation, were used in evaluating the feasibility of wetponds as best management practices for nonpoint source pollution control.

The biological component of the research grant was a multi-disciplinary effort to assess the viability of the Mansfield wetpond as a self-sustaining ecosystem. Quarterly samples were taken for benthic macroinvertebrates, phytoplankton and zooplankton. Fish populations were surveyed two times after the initial stocking. Pond vegetation was identified and mapped for changes throughout the project period. Productivity was measured for both phytoplankton and periphyton. To characterize the water quality of the pond and its recovery from storm events, field parameters (diel data) were collected after storm events as well as during baseline conditions. In addition, pond water samples were collected periodically and analyzed for the same parameters as stormwater inflow and ground water samples.

The hydrologic and biological components of the study were jointly evaluated to provide a complete picture of the Mansfield wetpond ecosystem. Conclusions and recommendations, derived from the joint evaluation, are provided at the end of this report.

Acknowledgments

This study was proposed, designed and implemented by Mr. Bruce Melton, now with Bury-Pittman Consultants in Austin, Texas. The Mansfield wetpond was constructed by the Texas Department of Transportation. The hydrologic components of the study were performed by LCRA staff, including Geoffrey Saunders (project manager; storm water modeling, ground water, consumptive use), Jeff Garrett (storm water monitoring) and Jeremy Smith (storm water analysis). The biological components of the study were performed by LCRA environmental scientists including Mary Gilroy (project coordinator; sediment, phytoplankton, zooplankton, water quality), John Trevino (benthic macroinvertebrates), Doyle Mosier (fish), Jerry Guajardo (primary productivity), Karen Pugh (vegetation) and Cynthia Gorham (diel measurements). Chemical analyses were performed by the LCRA Environmental Laboratory.

II. Background

This project was funded by the Texas Water Development Board (TWDB) under its Research and Planning Fund, to provide information on the feasibility and viability of wetponds in treating nonpoint-source pollution in stormwater runoff. A wetpond is an innovative structural control, or "best management practice" (BMP), listed in the LCRA Nonpoint Source Pollution Control Ordinance Technical Manual (LCRA, 1991). Innovative BMPs are the subject of several research projects funded by the Texas Water Development Board in recent years.

Conceptually, a wetpond is a wetland/aquatic ecosystem incorporating the capabilities of sedimentation ponds and wetlands in removing the types of pollutants typically contained in stormwater runoff. Wetponds differ from artificial marshes in that they feature a permanent pool more than four feet deep. The pollutants of concern are suspended solids, nutrients, oil and grease, toxic metals and hazardous compounds. Suspended solids (sediments) are removed by filtration in the dense vegetation surrounding the wetpond and by detention. Nutrients (dissolved phosphorus and nitrogen) are removed by plant consumption and denitrification. Oil and grease are removed by adsorption on sediment particles and by bacteriological action. Toxic metals in alkaline waters are removed by precipitation and sedimentation. Hazardous compounds are removed by adsorption and bacteriological action.

Wetponds are commonly used for nonpoint-source pollution control in the eastern United States (Schueler, 1987). Wetponds have been found to be moderately to highly effective in removing both particulate and soluble pollutants (Schueler, Kumble and Heraty, 1992). However, construction costs of wetponds are 25-40% greater than conventional BMPs, the longevity of wetponds depend on sediment loading and performance will decline over time (Galli, 1992). Wetponds are considered experimental in Central Texas due to the difficulty of maintaining a permanent pool, especially if augmentation water must be purchased. In terms of water conservation and cost, wetponds may not be considered a preferred method if other methods are available. The purpose of this study was to evaluate the feasibility of small wetpond structures.

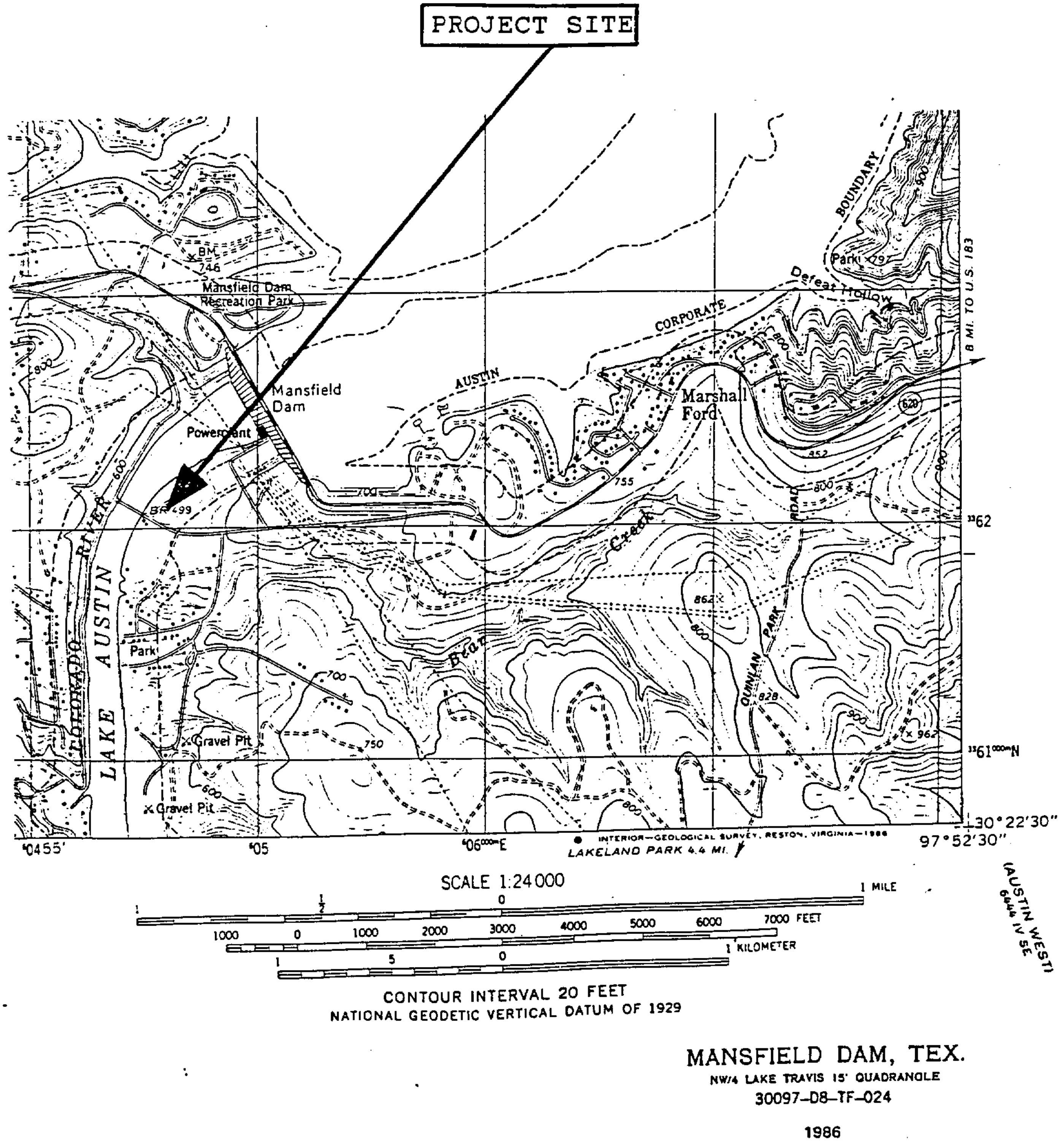
II.A Study Area

The area under study is the Mansfield Tract owned by the LCRA in Travis County, Texas (see Figure 1, Location Map). The study area is on the banks of Lake Austin, immediately downstream of Mansfield Dam. The study area is accessed via Low Water Crossing Road off Highway 620. A newly constructed bridge and associated section of Highway 620 required the construction of a structural control for stormwater runoff. After initial approval of the TWDB grant, the Mansfield wetpond was constructed by the Texas Department of Highways using designs supplied by the LCRA. The Mansfield wetpond was constructed downstream on the east bank of Lake Austin, downstream from the Highway 620 bridge.

Figure 1

NONPOINT SOURCE POLLUTION RESEARCH STRUCTURE WETLAND/AQUATIC ECOSYSTEM

TEXAS WATER DEVELOPMENT BOARD GRANT
Contract no. 92-483-333
LOWER COLORADO RIVER AUTHORITY



The drainage area tributary to the wetpond is shown in Figure 2. This drainage area is bounded by the Highway 620 bridge roadway to the north and east, Low Water Crossing Road to the south, and the wetpond embankment and an outer levee for the channel directing water from the bridge into the wetpond to the west. The wetpond received runoff from the entire 9-acre bridge surface via a curb drain system, and a 25-acre undeveloped park area. Total area tributary to the wetpond was 34 acres, 9 acres of which was impervious cover (26.5%). The slope, soils and vegetation of the remaining 25 acre drainage area were typical of conditions in the Texas hill country.

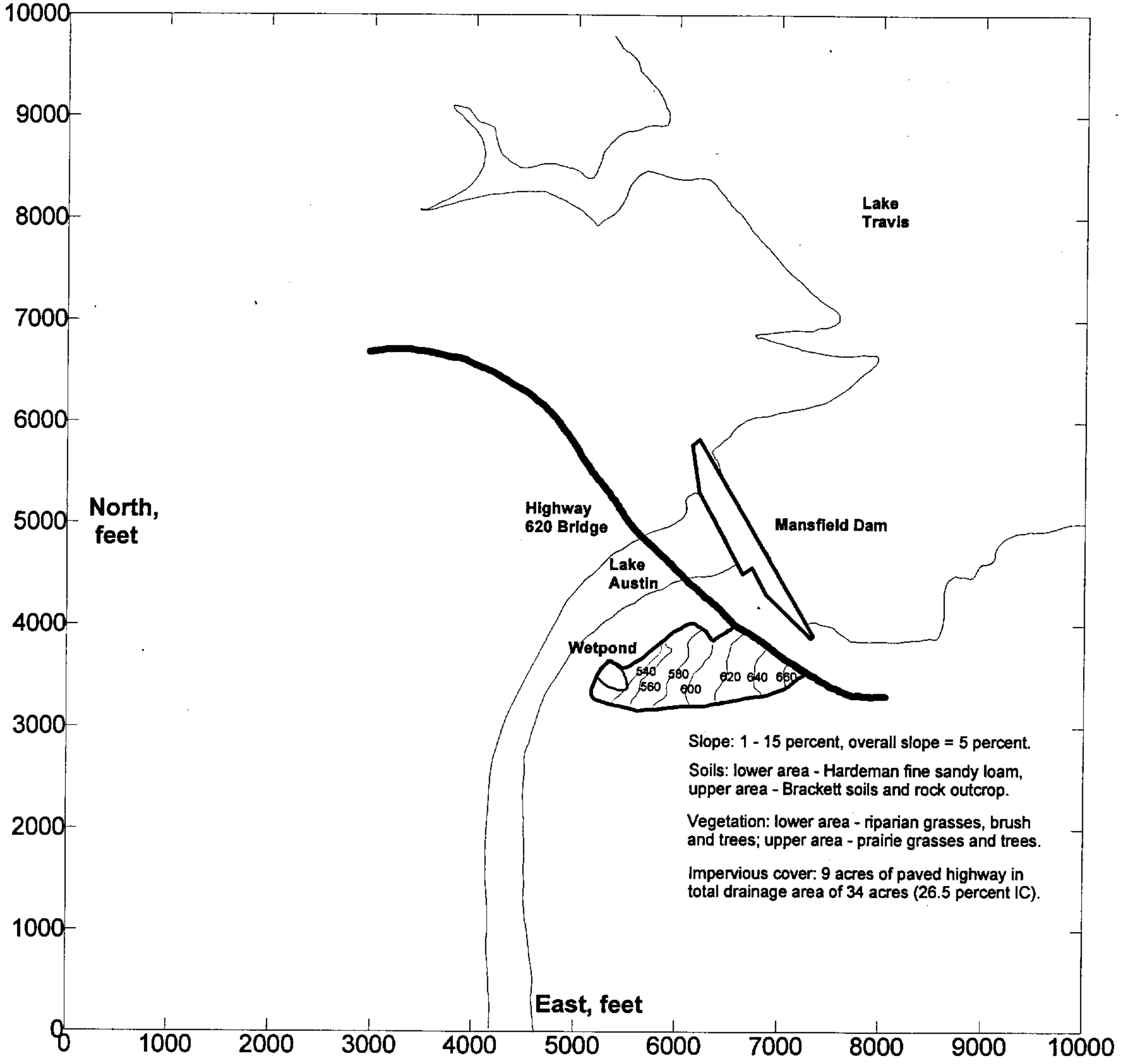
Construction of the detention pond began in 1992 before the bridge was erected, so that construction runoff would be captured instead of draining into Lake Austin. TXDOT later performed maintenance including installation of a concrete liner at the bottom of the permanent pool area, and revegetation of the construction site. Upon completion of earthwork, the Mansfield wetpond was vegetated using native plants and stocked with endemic fish species by the LCRA. Monitoring stations were installed, an observation deck was constructed, and monitor wells were drilled upgradient and downgradient from the pond.

Costs of construction were difficult to determine because of the use of TxDOT equipment and personnel already on-site. Since the Mansfield wetpond was constructed in a natural depression and access was readily available, excavation and regrading costs were minimal. The concrete liner mentioned earlier was actually made using excess material from bridge construction. Likewise, revegetation of the grass-lined inflow channel was done by hydromulching in conjunction with similar activities at the bridge construction project. A rough estimate of earthwork and revegetation after construction of the Mansfield wetpond was $100,000.

Operation and maintenance costs included efforts to augment to wetpond with water from Lake Austin, and replanting of aquatic vegetation after initial transplant failures, weed control and pest management. Although the facility was equipped with automated water-level controls and pump actuation circuits for augmentation, this system was found to require frequent maintenance. These activities were conducted by LCRA personnel, eventually requiring one man-day per week to maintain the system at a cost of approximately $10,400 plus $5,000 in equipment replacement per year. The cost of augmentation water was conservatively estimated at $5,200 per year, for a total O&M cost of $20,600 (rounded to $20,000 per year). This was considered to be an excessive O&M cost for a relatively small stormwater treatment facility.

Figure 2

MANSFIELD WETPOND TRIBUTARY DRAINAGE AREA



Slope: 1 - 15 percent, overall slope = 5 percent.

Soils: lower area - Hardeman fine sandy loam, upper area - Brackett soils and rock outcrop.

Vegetation: lower area - riparian grasses, brush and trees; upper area - prairie grasses and trees.

Impervious cover: 9 acres of paved highway in total drainage area of 34 acres (26.5 percent IC).

II.B Grant Requirements

The grant contract describes several objectives of this study:

- identify and quantify nonpoint-source pollution from a given watershed in the Lower Colorado River Authority (LCRA) jurisdiction;
- determine the nonpoint-source pollution removal efficiency of a wetland/aquatic ecosystem (wetpond) BMP;
- determine the feasibility of wetponds in semi-arid regions;
- construct a model to aid in the design of wetponds in semi-arid regions;
- identify and quantify the impacts of nonpoint-source pollution on the productivity, diversity and ambient toxicity of native or indigenous species used or found in the wetpond;
- designate native or indigenous species as indicators of nonpoint-source pollution impacted waters; and
- analyze sediment toxicity in a wetpond nonpoint-source pollution treatment structure.

The project was conducted in two phases. The first phase was to include the design, construction and creation of a wetpond BMP, installation of monitoring equipment, and development of a design model. The second phase was to include the study of the effectiveness of the BMP, and of the impacts of nonpoint-source pollution, the identification of indicator species, and the dissemination of learned information.

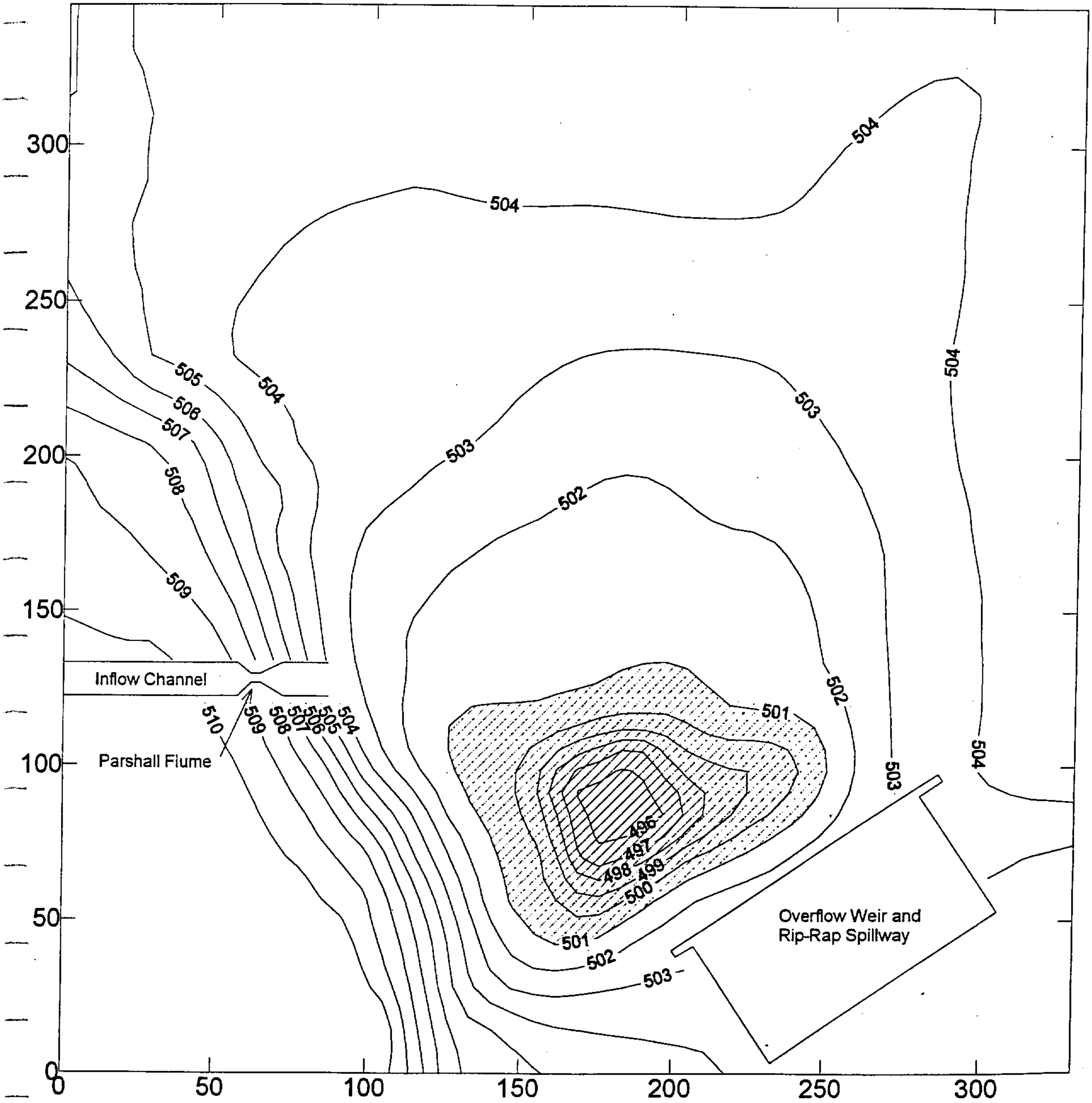
II.C Study Design

The wetland/aquatic ecosystem studied was referred to as the Mansfield wetpond. The wetpond was constructed in a natural depression near the low water crossing bridge over Lake Austin. A topographic map of the structure was produced based on certified as-built drawings (Figure 3, As-Built Wetpond Topography). This figure shows the permanent pool and surrounding pond area, and construction features of the wetpond.

The Mansfield wetpond was constructed in the floodplain of the Colorado River adjacent to Lake Austin. The floodplain contains a small, isolated deposit of alluvium underlain by the Glen Rose limestone formation. The wetpond was constructed by excavating a 5-foot deep depression. The surficial material surrounding the wetpond is alluvial silt and clay.

Figure 3

Mansfield Wetpond As-Built Topography



The Mansfield wetpond was surveyed after construction and an as-built topographic map was produced. The topographic map was digitized in a contouring program which allowed volumetric calculations to be performed. From these calculations, as-built dimensions were determined as shown in Table 1.

Table 1 As-Built Wetpond Dimensions
Permanent Pool @ Elevation = 501.0 ft., Volume = 0.29 ac-ft
Stormwater Detention Volume @ Elevation = 503.5 ft., Volume = 1.26 ac-ft
Overflow Weir @ Elevation = 503.5 ft., Total Volume = 1.55 ac-ft

The Mansfield wetpond was constructed to have the capacity to store 1.26 acre-feet of stormwater. The drainage area tributary to the wetpond was about 9.5 acres, including 3.2 acres of pavement along the Highway 620 bridge. Assuming that runoff accounted for approximately 80 percent of total rainfall for any single storm event, the Mansfield wetpond was constructed to contain and treat a 2-inch storm event.

Following construction of the wetpond, monitoring equipment was installed, including recording rain gauges, runoff measurement devices, automatic stormwater samplers, and a recording lysimeter for measurement of evapotranspiration. Four ground water monitoring wells were installed, one equipped with a water level recorder. Finally, an observation dock was constructed to allow access to the permanent pool area of the wetpond.

The monitoring facilities were designed to measure and sample stormwater events. Volumetric and tipping-bucket type rain gauges were used to measure the volume and intensity of precipitation. Runoff from the Highway 620 bridge was measured at the inflow point to the wetpond, using a Parshall flume and pressure transducer to measure stage and flow rate. Outflow from the Mansfield wetpond was measured at the outflow point using a rectangular weir with end contractions, and a pressure transducer to measure stage and flow rate. Rainfall and runoff data were recorded using data loggers equipped with modems for remote access via telephone lines. The data loggers were also programmed to control refrigerated automatic samplers, which were programmed to collect flow-proportioned discrete samples throughout each storm event. The discrete samples were composited and preserved in the field after each storm event and transported to the LCRA Environmental Laboratory.

The stormwater samples were analyzed for the following parameters:

Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)
Settleable Solids (SS)
Total Phosphorus (TP)
Ortho Phosphorus (Ortho-P)
Nitrate/Nitrite Nitrogen (NO_3-N)
Total Kjeldahl Nitrogen (TKN)
Ammonia Nitrogen (NH_3)
Biochemical Oxygen Demand (BOD)
Oil & Grease (O&G)
Total Petroleum Hydrocarbon (TPH)
Total Organic Carbon (TOC)
Total Cadmium (Cd)
Total Chromium (Cr)
Total Iron (Fe)
Total Lead (Pb)
Total Zinc (Zn)

III. Storm Water Analysis

Nonpoint-source pollution in stormwater runoff was monitored as part of the grant study. Rainfall, runoff, inflow and outflow was measured. Samples of inflow to the Mansfield wetpond were collected during 21 storm events from June 1995 through September 1996. The flow-proportional discrete samples were composited to represent event mean concentrations (EMCs) in stormwater, for direct comparison with EMC values in the LCRA nonpoint-source ordinance and for use in pollutant loading calculations.

III.A Methodology

Automated monitoring stations were installed at the inflow and outflow points of the wetpond. Electronic data loggers, equipped with modems for remote access by telephone, were used to record readings and control the automatic sampling equipment.

At the inflow point, stormwater runoff was measured using a 24-inch galvanized steel Parshall flume, set in the inflow channel as shown in Figure 2. The Parshall flume was calibrated for a range of flow between 0.7 and 33.1 cubic feet per second (cfs). Stage in the flume was measured using a submerged pressure transducer. The submerged probe was wired to a data logger programmed to convert stage to flow using an empirical flow conversion table for the Parshall flume. The data logger was programmed to collect flow data every 10 minutes in an electronic file, which could be downloaded after each storm event. The data logger was also programmed to send a signal pulse to an automatic sampler when stage reached a certain level in the flume, and additional pulses when pre-programmed volumes of water passed through the flume.

At the outflow point, rainfall was measured using a tipping-bucket rain gauge which measured precipitation in increments of 0.01", connected to a data logger which was programmed to collect rainfall data every 5 minutes in an electronic file. Discharge was measured using a 23-foot long sharp-crested steel weir. The overflow weir, located as shown in Figure 2, was calibrated for a range of flow between 0.9 and 27.0 cfs, using the following equation for a rectangular weir with end contractions:

$$Q = 3.33\,(L-0.2H)H^{3/2}$$

where: Q = flow, cfs
L = weir length, ft.
H = height of water (stage), ft.

Stage behind the weir was measured using a submerged pressure transducer. The submerged probe was wired to a data logger programmed to convert stage to flow using a flow conversion table generated from the above equation. The data logger was programmed to collect flow data every 10 minutes in a scrolling file, which could be downloaded after each storm event. The data logger was also programmed to send a signal pulse to an automatic sampler when stage reached a certain level behind the weir, and additional pulses when pre-programmed volumes of water passed through the weir.

The refrigerated automatic samplers utilized a peristaltic pump to draw a small amount storm water through a vinyl tube into 1-liter plastic bottles, and keep the samples at a constant temperature of 4° C. This procedure resulted in a set of discrete flow-proportioned samples. The discrete samples from each storm event were combined in a rinsed 5-gallon bucket and an aliquot of the composite sample was transferred into laboratory sample bottles. The bottles in the sampler were rinsed with distilled water and the sampler was reset for the next storm event.

III.B Results

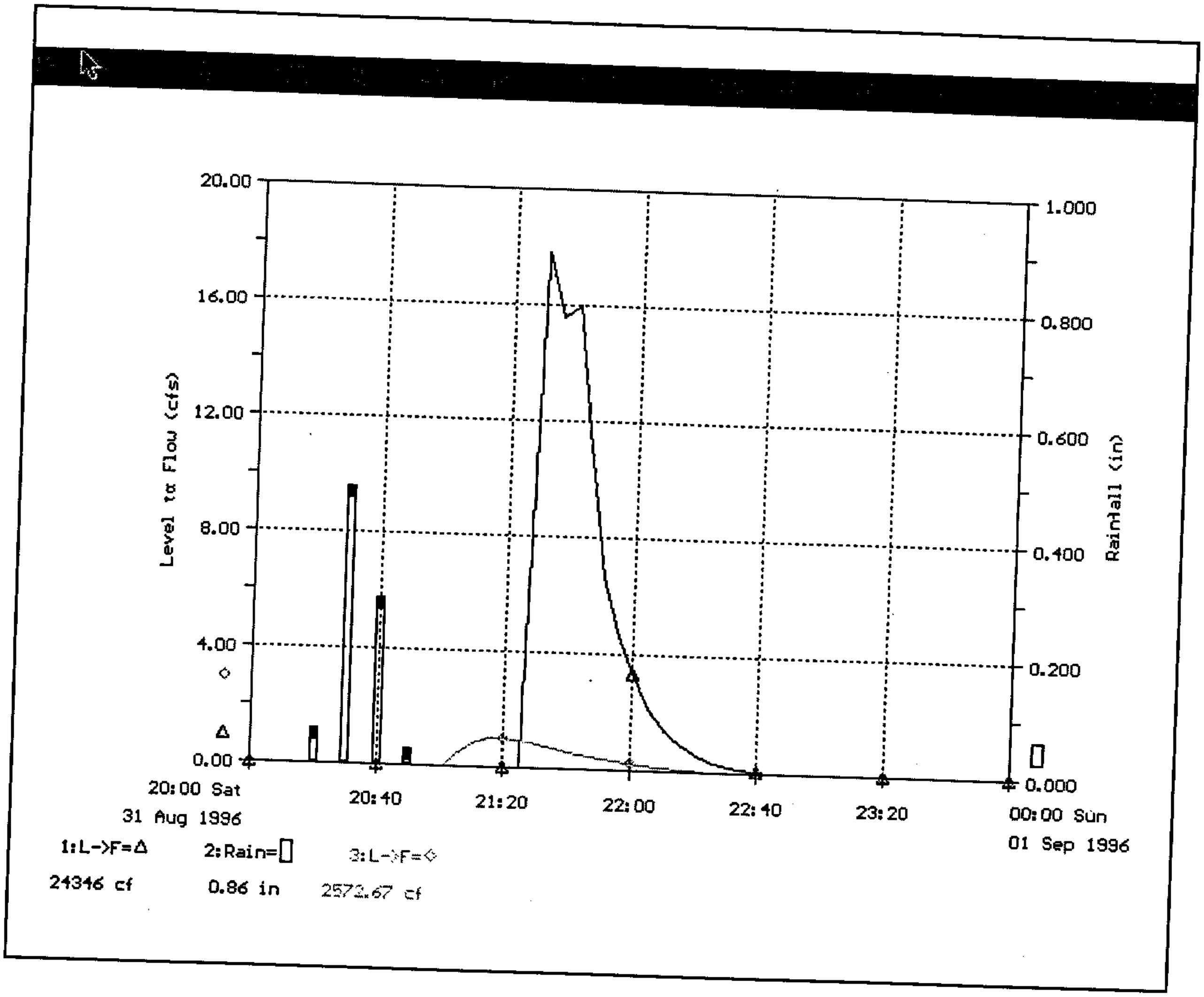
The results of stormwater monitoring at the Mansfield wetpond are presented in Appendix A. Twenty-one storm events were monitored during this study. Table 2 is a summary of the events.

Table 2
Storm Event Monitoring Summary

Date	Rainfall, in.	Inflow, c.f.	Outflow, c.f.
6/29/95		25150	0
7/30/95	1.95	7920	0
9/7/95	0.74	12690	0
9/19/95	0.4	5249	0
9/2195	0.83	11385	0
10/31/95	1.58	13840	0
2/29/96		4120	0
4/5/96	0.53	3570	0
4/20/96	0.20	570	0
4/22/96	0.36	1410	0
5/28/96	0.93	10680	0
5/30/96	1.90	35370	340
6/4/96	0.56	3680	0
6/7/96	0.93	7630	0
6/26/96	0.57	2510	0
8/8/96	1.87	13230	0
8/19/96	0.40	2450	0
8/30/96	2.00	35400	1120
9/4/96	0.43	2400	0
9/18/96	1.11	22190	0
9/20/96	1.72	22320	310

Rainfall, inflow and outflow were monitored during each storm event. A typical storm hydrograph for the Mansfield wetpond is shown in Figure 4.

Figure 4
Typical Storm Hydrograph



III.C Discussion

The storm events monitored as part of this study were generally small in size and short in duration. A severe meteorological drought occurred in the Austin area during the course of this study in the spring of 1996. These conditions limited the range of measured storm events.

Laboratory analyses of the composite samples represented event mean concentrations (EMCs). The typical EMC for total suspended solids (TSS) in the Austin area is 130 mg/L for developed areas (LCRA, 1991). Of the 21 storm events sampled, 29 percent of the events produced TSS concentrations that exceeded 130 mg/L and 71 percent of the events fell at or below that level. These results are predominantly low due to the grassy channel that pretreats the inflow to the pond. Three of the storm events produced enough runoff to cause of the pond to overflow. All three of the outflow events fell below the prescribed TSS level of 48 mg/L for background conditions (LCRA, 1991).

The typical EMC for total phosphorus (TP) in the Austin area is 0.26 mg/L for a developed condition (LCRA, 1991). Of the 21 stormwater events that were sampled, 55 percent of these events produced TP concentrations that exceeded 0.26 mg/L and 45 percent of the events were below that level.

Of the three outflow events, two had phosphorus concentrations in the outflow which exceeded that of the inflow. Similar results were observed for total nitrogen. These results were anomalous; therefore it was necessary to consider cumulative effects of closely spaced storm events. The outflow event on May 30, 1996 was a result of inflows in May 28 and May 30. The inflow event of May 28 was retained in the pond with no outflow. The storm events occurred less than 36 hours apart, so water loss to evaporation, transpiration and infiltration was probably minimal. Therefore, the loading of nutrients from both storm events accumulated in the wetpond. By adding the nutrient load of both storm events and dividing by total inflow volume, cumulative inflow concentrations were calculated. These concentrations were higher than the outflow concentrations measured on May 30.

Event mean concentrations for TSS were used to calculate the total mass loading from each storm event, using the following equation:

$$\text{Mass Load (grams)} = \text{Total Inflow (liters)} * \text{EMC (mg/L)} / 1000$$

The values of mass load derived from this equation were converted from metric grams to English units (pounds). Using mass load values of suspended solids and an estimated density of wetted sediment of 60 pounds per cubic foot, the volume of sediment was calculated for each storm event. These calculations are shown in Table 3.

Table 3
Sediment Mass Loading Calculations

Date	Inflow, c.f.	Inflow, L	EMC, mg/L	Volume, c.f.
6/29/95	25150	712098	728	19.1
7/30/95	7920	224247	138	1.1
9/7/95	12690	359305	246	3.2
9/19/95	5249	148620	44	0.2
9/2195	11385	322355	26	0.3
10/31/95	13840	391866	122	1.8
2/29/96	4120	116654	38	0.2
4/5/96	3570	101081	88	0.3
4/20/96	570	16139	374	0.2
4/22/96	1410	39923	78	0.1
5/28/96	10680	302394	185	2.1
5/30/96	35370	1001468	66	2.4
6/4/96	3680	104196	30	0.1
6/7/96	7630	216036	15	0.1
6/26/96	2510	71068	19	0
8/8/96	13230	374595	38	0.5
8/19/96	2450	69369	12	0
8/30/96	35400	1002317	49	1.8
9/4/96	2400	67954	5	0
9/18/96	22190	628289	261	6
9/20/96	22320	631969	75	1.7
			Total Load, c.f.	41.2

As shown in the Table 3, a total of 41.2 cubic feet of sediment was washed into the wetpond during the course of study. Observations of depth in the open area of the pond indicated that more than two feet of sediment had accumulated. To check the sediment accumulation in the wetpond, a bathymetric survey of the permanent pool area was conducted on November 5, 1996. The Mansfield wetpond had been in operation for approximately three years when the survey was conducted. Volumetric calculations were performed using the survey results. These calculations are shown in Table 4.

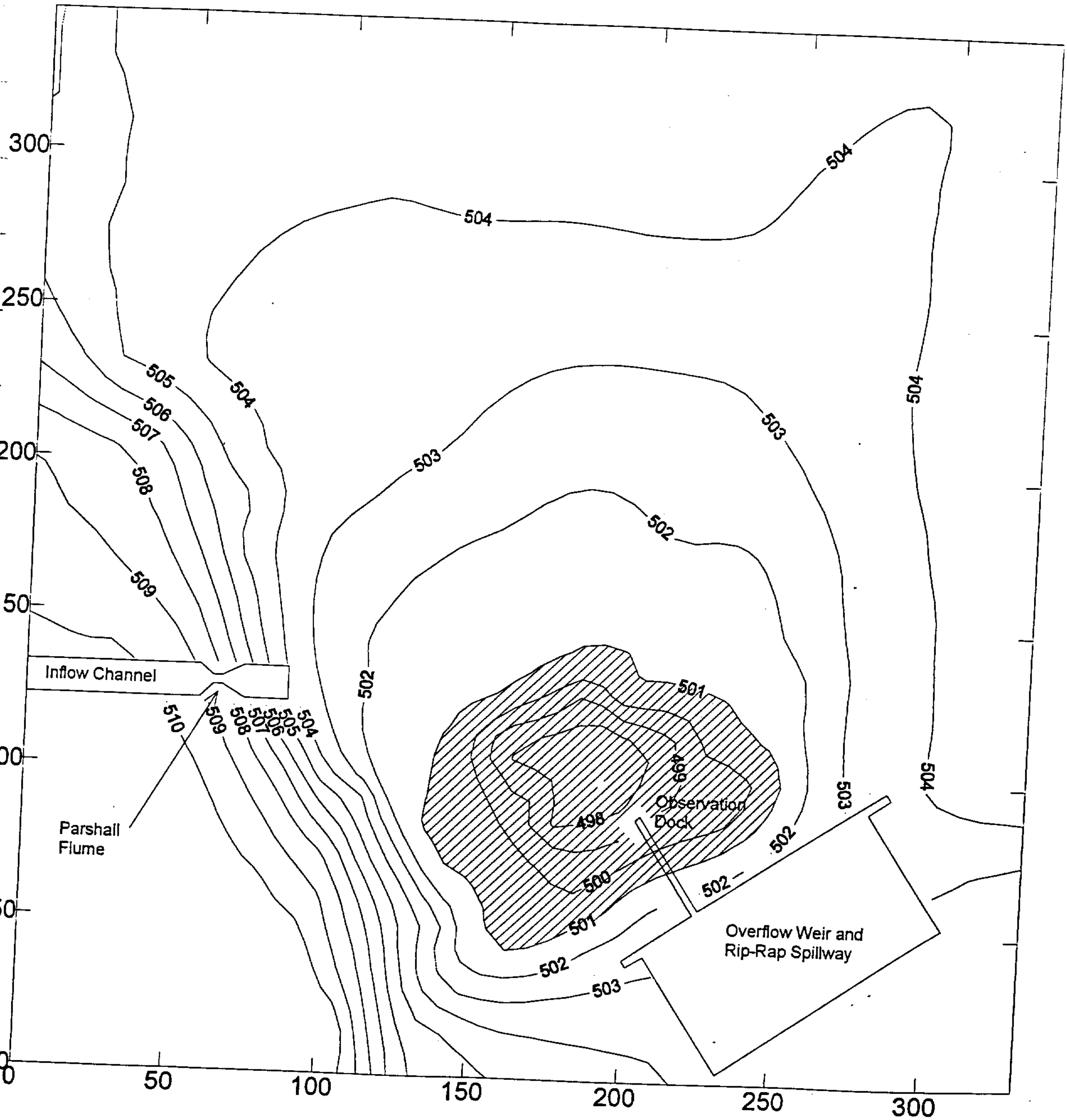
Table 4
Stage-Area-Capacity Table

Elevation, ft. MSL	Surface Area, sq.ft.	Volume, c.f.	Volume, ac-ft
496.0	0	0	0
497.0	0	0	0
498.0	910.8	335.6	0.01
499.0	2122.9	1835.4	0.04
500.0	3985.9	4854.9	0.11
501.0	7595.9	10281.2	0.24
502.0	17066.5	22268.9	0.51
503.0	33356.8	46613.1	1.07
503.5	44528.8	65951.7	1.51
504.0	59794.4	91799.1	2.11
Permanent Pool @ Elevation = 501.0 ft., Volume = 0.24 ac-ft			
Stormwater Detention Volume @ Elevation = 503.5 ft., Volume = 1.27 ac-ft			
Overflow Weir @ Elevation = 503.5 ft., Total Volume = 1.51 ac-ft			

The results of the survey was a new contour map of the Mansfield wetpond, shown in Figure 5, Nov. 1996 Bathymetric Survey.

Figure 5

Mansfield Wetpond Bathymetric Survey, Nov. 5, 1996



As indicated in the summary statistics in Table 4, the volume of the permanent pool had decreased by 2,335 cubic feet, from 12616 to 10281 c.f., due to sediment accumulation in the pond. The stormwater detention volume did not change; therefore the pond was still functional in capturing runoff from the Highway 620 bridge.

As noted above, the total sediment load of the storm events measured between June 1995 and September 1996 was 41.2 cubic feet. This indicates that 98 percent of the 2,335 cubic feet of sediment in the Mansfield wetpond had accumulated prior to this period. Since construction of the Highway 620 bridge was completed in July 1993 before stormwater monitoring began, most of the sediment came from erosion during the construction period. The first major storm event after construction, sampled on June 29, 1995 was indicative of increased rates of sedimentation prior to reclamation. Relatively little sedimentation occurred after revegetation of the construction site, as shown in the sediment mass loading calculations in Table 3, for the storm events after June 29, 1995.

Three outflow events occurred; on May 30, August 31 and September 20, 1996, when just under 2 inches of rain fell in the Austin area. Very small amounts of outflow were measured. During the three outflow events, samples of the outflow were collected and analyzed. The average reduction in TSS concentration between inflow and outflow was 69%. This compares well with the minimum requirement of 70% removal in the LCRA Nonpoint Source Pollution Control Ordinance. There were an insufficient number of outflow samples to perform removal efficiency calculations for nutrients. At times when there was no outflow from storm events, stormwater was retained in the wetpond with 100% removal efficiency.

IV. Storm Water Modeling

The SEDIMOT II sedimentology and hydrology model (Wilson et al., 1981) was used to analyze the sediment trap efficiency of the wetpond. SEDIMOT II, a deterministic model developed by the University of Kentucky, has been used in surface mining and other applications involving erosion and sedimentation control after land disturbance. The model incorporates methods of runoff analysis including the Rational and SCS TR-55 procedures, erosion estimates including the modified universal soil loss equation and sediment delivery ratio methods, flood routing procedures for small ponds and sedimentation rates based on Stokes law.

Basic inputs to the model were:

1. Stage-area table
2. Watershed characteristics and rainfall-runoff coefficients
3. Particle size distribution and specific gravity
4. Stage-discharge table
5. Inflow sediment concentration distribution or sediment mass
6. Fluid viscosity coefficent

7. Stage-discharge table
8. Dead storage and short-circuiting factors

Model outputs include:

1. Inflow hydrograph
2. Discharge hydrograph
3. Influent and effluent TSS and settleable solids concentrations
4. Stage-area and stage-capacity curves after sedimentation
5. Average stage-depth curve
6. Average depth during detention and stage during outflow
7. Theoretical detention time
8. Total trap efficiency

IV.A Methodology

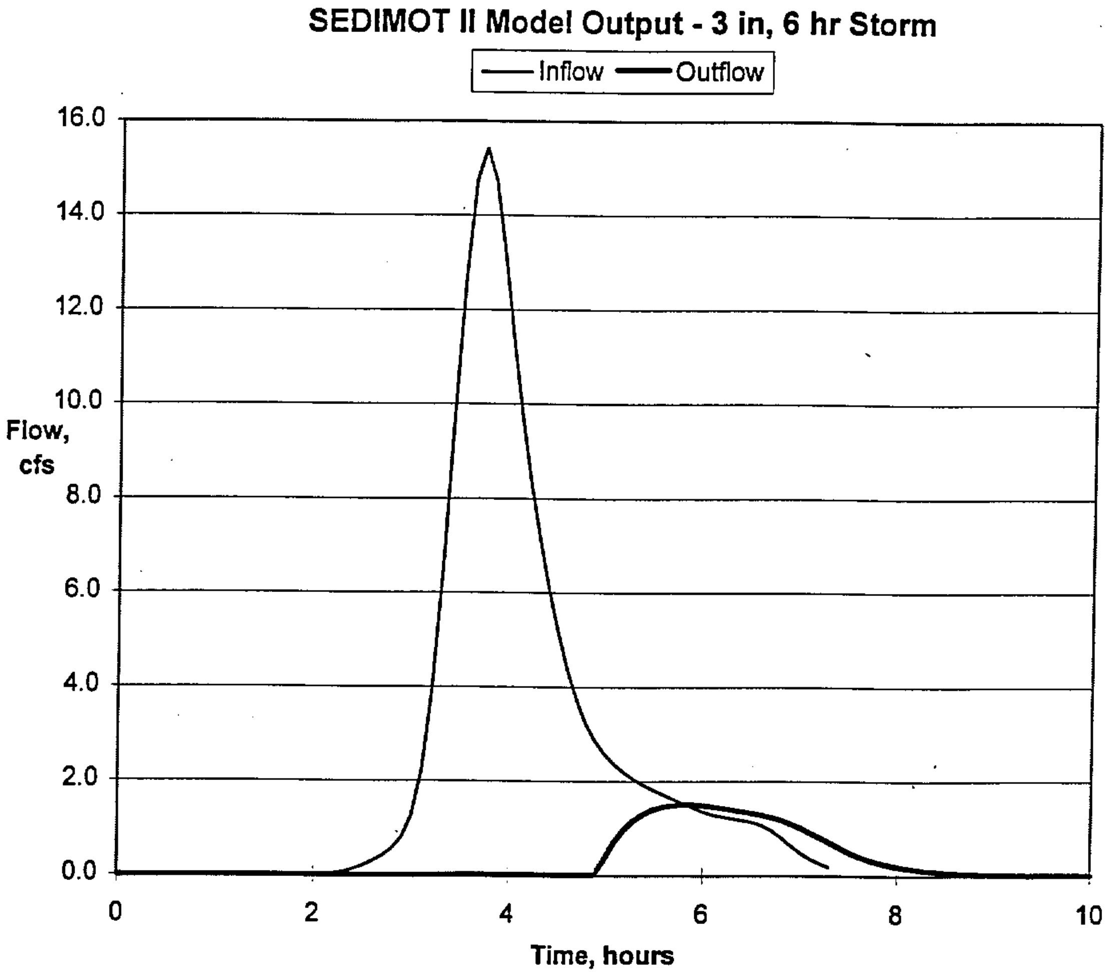
Pond dimensions, including the stage-area-capacity table, were derived from the bathymetric survey conducted in November 1996. Inflow rates were calculated by the model using inputs required for SCS Type II storm events of variable size and duration. Inflow sediment mass was provided from empirical data collected during storm events as part of this study. Particle size distribution was provided from a sieve-hydrometer analysis of sediment accumulated in the wetpond. Fluid viscosity was assumed to be 1.0 for natural water. Finally, a stage-discharge table was calculated for the rectangular overflow weir and input to the model.

As noted above, the variable factor in the modeling analysis was the size and duration of storm events. This provided information on the trap efficiency of the Mansfield wetpond during small storms which could be verified by comparison to storms monitored as part of this study, and allowed extrapolation of the analysis to larger storms.

IV.B Results

SEDIMOT II modeling runs were conducted for rainfall amounts of 1, 2, 3 and 4 inches in size, and for storm durations of 6 and 24 hours. A total of 8 simulations were performed. The model printouts for these simulations are included in Appendix B. A graph was prepared showing typical relationships of inflow and outflow rates and suspended solids concentrations (Figure 6, SEDIMOT II Model Output).

Figure 6


SEDIMOT II Model Output - 3 in, 6 hr Storm
Inflow
Outflow
Flow, cfs
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
2
4
6
8
10
Time, hours

IV.C Discussion

The average annual storm event in Austin is a 2-inch rain with a duration of 6 hours (LCRA, 1991). Several storms approximating this condition were monitored during this study. The SEDIMOT II model for the 2-inch, 6-hour storm accurately simulated the runoff and sediment inflow to the Mansfield wetpond as compared with empirical measurements. Therefore, the model was considered to be representative.

The SEDIMOT II model predicted that storm events of less than 2-inch size would not fill the Mansfield wetpond. This prediction was verified by observations made during the course of this study. Sediment trap efficiency under these conditions was 100 percent. Larger storm events, especially those of longer duration, were predicted to overfill the wetpond and cause a discharge. Under these conditions, incremental detention times were calculated as part of the flood routing procedure and Stokes law was applied to determine sediment trap efficiency.

Overall, the SEDIMOT II model determined that the Mansfield wetpond was highly efficient in removing suspended solids from small storm events. This conclusion was in agreement with storm event monitoring collected during this study, and other published studies on the efficiency of wetponds (Schueler, 1987; Galli, 1992; Schueler, 1992). Removal of sediment also implied removal of associated pollutants including metal oxides, nutrients in particulate form and some organic compounds. The SEDIMOT II model could not be used to predict removal of dissolved nutrients and organics.

V. Ground Water Analysis

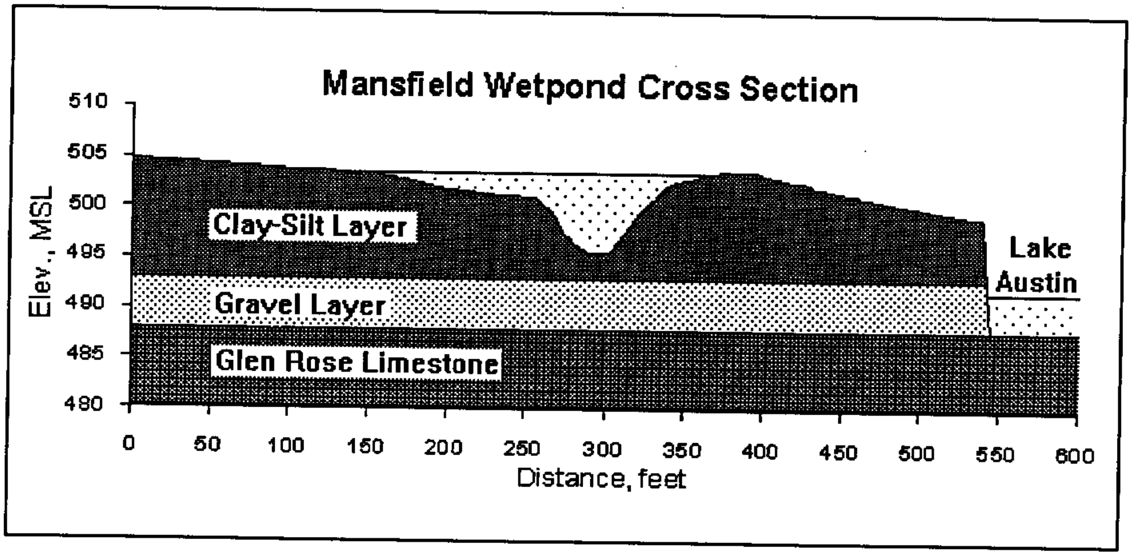
The Mansfield wetpond was constructed within the floodplain of the Colorado River. The Geologic Atlas of Texas, Austin Sheet (Barnes, 1974), shows an isolated deposit of Quaternary alluvium at the site of the wetpond. Anticipating that the wetpond might lose water due to infiltration to the underlying alluvium, a ground water monitoring plan was developed including water level measurement, ground water sampling and infiltration testing.

V.A Methodology

Four monitoring wells were installed in the vicinity of the Mansfield wetpond in June 1993. A report of monitor well installation, including lithologic logs and a water table map, is presented in Appendix C. The well locations were chosen to provide one well upgradient from the wetpond for background and three wells downgradient from the pond for determination of water table slope and ground water flow direction.

The geology of the Mansfield wetpond area is shown in a schematic cross-section derived from lithologic logs of the monitor wells and surficial geology (Figure 7).

Figure 7
Geologic Cross-Section



As shown in Figure 7, the alluvial deposits of the Colorado River have distinct layers, consisting of an upper layer of clay-silt and a lower layer of gravel. The wetpond was constructed in the upper clay-silt layer. The water table is within the gravel layer. Therefore, the permanent pool of the wetpond was higher in elevation than the water table and there was a potential for percolation of water in the wetpond to the underlying water table.

The wells were sampled before and after storm events, to determine if there was an effect on ground water quality. Pond water was also sampled at the time of monitor well sampling, to allow direct comparison of pond water chemistry with ground water chemistry. The schedule of sampling was flexible to coincide with storm events. When it was possible to predict a storm event by the approach of a weather front, the wells were sampled before the storm, a day or two after the storm, and a week after that.

Infiltration tests were performed to evaluate the potential for leakage of water from the Mansfield wetpond to the surrounding soils. The infiltration tests were performed using standard Soil Conservation Service (SCS) equipment and procedures. Two-ring, constant-head infiltrometer devices with continuous stage recorders were utilized. The results were compared with published soils data.

V.B Results

The ground water data collected as part of this study is presented in Appendix D.

Ground water levels in the four monitor wells consistently showed a gradient of 0.001 ft/ft to the west-southwest toward Lake Austin. A constant-drawdown pumping test was performed on well MW-2, which indicated the permeability of the gravel layer to be 2.8×10^{-2} cm/sec. This relatively high value of permeability is within expected ranges for alluvial gravel deposits (Freeze and Cherry, 1979).

Generally, there was a distinct difference in chemistry between pond water and the underlying ground water. The pond water was relatively higher in organic nitrogen concentration (indicated by TKN minus NH_3) and low in nitrate concentrations. The ground water in all four monitor wells was just the opposite. Phosphorus concentrations were consistently lower in ground water compared to pond water.

Three sites were selected for infiltration testing. Site-specific soil descriptions were provided by Mr. Glen Chervenka, SCS soil scientist. Site #1 was located outside the backwater area of the pond. At Site #1, soils were described as clay loam with 20- to 50% gravel and cobbles of 1 to 5 inch diameter. This description was consistent with drill hole logs from nearby monitor wells, that of alluvial sand and gravel in clay matrix. At Sites #2 and #3, located within the backwater area, the clay loam was covered with 2 to 3 inches of silty mud. In exploration holes dug next to the infiltration test sites, water was encountered at a depth of 10 inches.

Three infiltration tests were performed concurrently by filling the inner and outer rings of the infiltrometer with water, maintaining the level of water in the outer rings with a nurse tank, and maintaining the level of water in the inner rings using a reservoir of the same diameter gauged by a water level recorder. Saturation and lateral migration of water in the soil was controlled by the outer ring. Downward infiltration from the inner ring was measured by decline of water level in the supply reservoir. The tests were conducted for a period of approximately 16 hours. The data were evaluated using trends established after the initial wetting of the soil, and after 8 hours representing infiltration under saturated conditions. Results are listed in Table 5.

Table 5
Infiltration Test Results

	Site #1 (native)	Site #2 (backwater)	Site #3 (backwater)
Unsaturated soil	0.60 in/hr	0.15 in/hr	0.15 in/hr
Saturated soil	0.72 in/hr	0.36 in/hr	0.12 in/hr

V.C Discussion

Ground water sampling results were difficult to interpret. As shown on Figure 7, the gravel layer containing shallow ground water was interconnected with Lake Austin. Changes in lake levels and water quality in Lake Austin had associated effects upon ground water in the gravel layer. These effects were indiscernable from effects of infiltration from the Mansfield wetpond. As a result, only a few consistent patterns could be recognized in the ground water quality data:

- Downgradient wells usually had higher concentrations of phosphorus than the background well; Well MW-1 (nearest to the wetpond) usually had the highest phosphorus concentration, and TP concentrations in ground water were usually lower than TP concentrations in pond water.

- Downgradient wells usually had lower concentrations of nitrate-nitrogen (NO_3-N) than the background well, and much lower NO_3-N concentrations in ground water than NO_3-N concentrations in pond water.

- There were no consistent patterns in Total Kjeldahl Nitrogen (TKN) data from ground water sampling, other than the fact that TKN concentrations in ground water were usually lower than TKN concentrations in pond water.

As indicated by water level elevations, the direction of ground water flow beneath the Mansfield wetpond was toward the southwest toward Lake Austin. Water levels in the wells did not rise significantly after storm events, with the exception of levels measured on June 5, 1996. These measurements were taken the day after a one-half inch storm, and less than a week after a one-inch storm event. On that day, water levels in all four wells were more than a foot higher than previous measurements. Water levels returned to normal levels by the time of the next measurement in October 1996. The decline in water levels to normal may have been due to infiltration from the wetpond.

The small amount of vertical leakage from the wetpond into the gravel layer had no apparent effect on water levels in the adjacent monitor wells set in the gravel layer, probably because the gravel layer had sufficient permeability to readily transmit ground water without significant increases in water table gradient. In order to determine whether the pond was losing water by percolation, infiltration testing was conducted in the soils surrounding the Mansfield wetpond.

The Hardeman soil series was mapped in the area of the wetpond. According to the Soil Survey of Travis County, Texas, "*The Hardeman series consists of deep, well-drained soils that developed over old river alluvium. In a representative profile, the surface layer is about 16 inches of brown fine sandy loam. The next layer is light-brown fine sandy loam about 22 inches thick. It is underlain to a depth of 60 inches by reddish-yellow silt loam. The soil is calcareous and friable throughout. Permeability is moderately rapid, and the available water capacity is high.*" (SCS, 1974). The listed permeability for the Hardeman series is 2.0 - 6.3 inches per hour.

The surficial materials in the vicinity of the wetpond, while derived from native soils, were disturbed and compacted by construction activities. In the backwater area of the pond, sediment had been deposited over the native materials.

The infiltration test results indicated the following:

- Measured infiltration rates were an order-of-magnitude lower than published data for the Hardeman soil series.
- Saturated infiltration rates were about the same or slightly higher than unsaturated rates.
- The backwater areas of the pond, where 2- to 3 inches of sediment was deposited, had lower infiltration rates than native soils.

To summarize, the Mansfield wetpond was excavated within Hardeman soil to a depth of 5 feet. The soil survey (SCS, 1974) listed the Hardeman series as having severe limitations for farm pond reservoirs, due to moderately rapid permeability. However, construction activities disturbed and compacted the native soils surrounding the pond, and sediment deposited in the wetpond had lower permeability, causing infiltration rates to be less than expected.

Seepage losses from the wetpond were estimated using the "Flow From Wells And Recharge Pits (WELL&PIT)" program (Sunada, Colorado State University, 1985). This is a two-dimensional ground water flow model which can be used to simulate vertical and horizontal components of recharge (leakage) from a surface water basin to the water table. As the basin (wetpond) continually losses water to the underlying sediments, the water table beneath the wetpond is raised to form a "mound" of saturated material. The mound extends upward until it reaches the surface, or in this case the bottom of the wetpond, forming a perpetually saturated zone beneath the wetpond. Horizontal flow is accounted for, however this component is minimal because the driving force is gravity. The leakage rate becomes constant if the wetpond has a permanent pool and the if aquifer is able to receive recharge without change in water table elevation and gradient. From the ground water monitoring data collected during this study, these conditions were met at the wetpond site.

The WELL&PIT program was calibrated using geologic and hydraulic data available from lithologic logs, monitor well measurements, infiltration test results and SCS soil survey data (SCS, 1974). The program was run to simulate a sufficient amount of time to form a water table mound under the wetpond. Simulation results are presented in Appendix D. The model indicated that a mound of saturated material was formed 3.2 days the pond was filled, after which time the leakage rate would be governed by the rate of infiltration under saturated conditions.

A value of vertical permeability was estimated from the infiltration rate measure under saturated conditions in the backwater area, and the steady-state vertical leakage of water from the wetpond was calculated using the Darcy equation:

$$Q = K\,I\,A$$

where:

Q = leakage, cubic feet per day
K = vertical permeability, ft/day
I = hydraulic gradient, ft/ft
A = area of pond bottom, sq. ft.

Vertical permeability was estimated from grain-size distributions to be 0.05 ft/day. Hydraulic gradient was estimated as the head differential between the permanent poll level and the water table (6 feet) divided by the average thickness of the clay-silt layer beneath the pond (2 feet). As shown in Figure 5, the bottom of the wetpond had an area of 910 square feet. Leakage from the Mansfield wetpond was estimated as follows:

$$Q = (0.05\ \text{ft/day})\ (6\ \text{ft.}/2\ \text{ft.})\ (910\ \text{s.f.})$$

$$Q = 182\ \text{c.f./day}$$

At a constant leakage rate of 182 cubic feet per day, the pond level was lowered by approximately 0.25 to 1 inches per day. These results are consistent with observations made during the study by project staff. The remaining loss of water from the wetpond was consumed by evaporation and transpiration.

VI. Consumptive Use Analysis

Loss of water from the Mansfield wetpond was considered in a consumptive use analysis. This involved measurement of the rate of evaporation and transpiration loss, and the augmentation required to keep the pond at a level which would support the wetland ecosystem.

VI.A Methodology

Augmentation of the Mansfield wetpond was monitored during this study. The wetpond was augmented by pumping water from nearby Lake Austin until the water level in the wetpond reached the permanent pool level. This level was controlled by a float valve, although manual augmentation was frequently required. The pump was fitted with a totalizing water meter, which was read and recorded periodically to document the amount of augmentation required to keep the wetpond level relatively stable.

Evapotranspiration losses were estimated from the amount of water necessary to maintain a community of wetland plants, using a device called an evapotranspirometer. Many such devices have been used in agricultural studies (Chow, 1964). An evapotranspirometer was installed adjacent to the wetpond. The device consisted of a 6-ft diameter, shallow stock tank buried so that the lip of the tank was at ground level. The stock tank was partially filled with native soil, and wetland plants were transplanted into the tank. A constant supply of water was provided from a reservoir vessel. A float valve was installed to control the flow of water from the reservoir to the stock tank, and to maintain a constant water level in the stock tank. A water stage recorder was installed over the reservoir vessel to measure the decline in water level. The decline in water level in the reservoir vessel was converted to volume of water usage over time. The rate of evapotranspiration, in inches per day, was calculated by dividing the volume of water usage by the known area of the stock tank. This rate was then applied to the larger area of the wetpond, to determine the quantitative loss of water from the wetpond due to evapotranspiration.

VI.B Results

Actual pond augmentation data was derived from periodic readings of the totalizing flow meter attached to the pump, which pumped water from Lake Austin into the wetpond. Due to equipment problems, only the data collected from October 1995 through July 1996 was usable. This readings were converted to water quantities as shown in Table 6.

Table 6
Wetpond Augmentation Data

Date	Elapsed Days	Meter, tot. gal	Quantity, c.f.	Rate, cf/day
10/13/95		1102800		
10/14/95	1	1103000	27	27
10/20/95	6	1103100	13	2
12/20/95	61	1104200	147	2
12/30/95	10	1133500	3917	392
1/3/95	4	1135800	307	77
1/4/95	1	1136000	27	27
2/6/95	33	1158300	2981	90
3/13/96	35	1180300	2941	84
4/15/96	33	1188800	1136	34
4/23/96	8	1210900	2955	369
5/17/96	24	1222500	1551	65
7/23/96	67	1265000	5682	85
Totals:	283		21684	

VI.C Discussion

Records of evapotranspiration (ET) were available for intermittent periods from November 20, 1995 to November 18, 1996. These values were compared to net lake evaporation rates measured in Lake Travis at Mansfield Dam, assuming that lake evaporation was equal to pond evaporation. The best records of daily rates of ET loss were in June and July of 1996. Total ET measured at the wetpond from June 21 to July 22, 1996 was 10.1 inches. The lake evaporation rate during this period was 7.4 inches. This equates to a ratio of 1.35. Therefore, transpiration accounted for approximately 35 percent of total ET from the wetpond during the period of measurement.

Using this relationship, total ET loss from the wetpond was calculated. The average annual evaporation rate in the Austin area is 54 inches. Increasing this amount by 35 percent yields an annual ET loss of 73 inches (6.1 ft.) per year. This rate of ET was applied to the surface area

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Mansfield wetpond (7596 square feet), yielding a total ET loss of 46,200 cubic feet per year, or 127 c.f./day.

The total amount of augmentation for the period from October 13, 1995 to July 23, 1996 was 21,684 cubic feet. The total stormwater inflow for this period was 107,980 cubic feet. Therefore, the total water inflow to the pond was 129,664 cubic feet, giving an overall consumptive use for this 283-day period of 458 cu. ft. per day. The required annual augmentation for the Mansfield wetpond was calculated as follows:

Evapotranspiration rate: 73 in/yr / 12 in/ft * 7596 sq. ft. = 46,200 cf/yr
Leakage rate: 182 c.f./day * 365 day/yr = 66,430 c.f./yr
Total water loss: 46,200 cf/yr + 66,430 cf/yr = 112,600 c.f./yr = 2.6 ac-ft/yr

Therefore, the Mansfield wetpond was estimated to require 2.6 acre-feet of augmentation per year to support the wetland ecosystem.

VII. Sediment Analysis

To evaluate the impact of nonpoint source pollution on the sediment quality of the wetpond, sediments were sampled for a variety of organics and toxics. Sampling was done three times throughout the project in an effort to characterize accumulation of materials.

VII.A Methodology

For each sampling event, two sets of sediment samples were collected using a sediment corer. The first set was a composite sample from three sites in the shallow littoral zone of the pond, and the second set was a composite sample from three sites in the deeper, open water zone of the pond. For each set of samples, three complete cores were placed in a bucket, stirred completely, and then subsampled. Subsamples were placed in one liter glass containers and placed on ice for transport to the LCRA Environmental Lab for analysis.

The samples were analyzed for the following parameters:

Total Organic Carbon (TOC)
Herbicides (8150)
Pesticides/PCBs (8080)
Total Petroleum Hydrocarbons (TPH)
Priority Pollutant Metals

VII.B Results

Sediment samples were collected in December 1994, December 1995 and September 1996. Only the shallow zone of the pond was sampled in December 1994, but both the December 1995 and September 1996 were complete samples, with shallow and deep samples. A total of five data sets were analyzed for the parameters listed above. Only those parameters that had at least one value above the detection limit were examined in this report. Of the pesticides, 4,4' DDT (1,1,1-trichloro- 2,2- bis(p-chlorphenyl) ethane) and Alpha BHC (1,2,3,4,5,6 hexachlorocyclohexane) had values above the detection limit. Total organic carbon (TOC) and total petroleum hydrocarbon (TPH) had values above the detection limit, as did the metals arsenic, cadmium, chromium, copper, lead, nickel, and zinc.

Values for metals, DDT and alpha BHC were compared to sediment quality criteria; results and criteria values are presented in Table 7, Sediment Data.

Table 7
Sediment Data

		12/20/94	12/8/95		9/24/96		ERL-ERM	% Incidence Adverse Effects	TNRCC
Parameter	Units	Shallow	Shallow	Deep	Shallow	Deep			
TOC	%	0.7	1.3	1.3	14.1	11.2	na	na	na
TPH	mg/Kg	202.0	182.2	182.3	56.0	66.0	na	na	na
4,4'-DDT	ug/Kg	<29.30	<16.10	<21.10	68.00	6.80	1.58 - 46.1	53.6	3.00
Alpha- BHC	ug/kg	<29.30	<8.07	<10.50	17.00	<3.30	na	na	1.00
Arsenic	mg/Kg	nm	<5.50	7.82	<60.00	<60.00	8.2- 70	5	17.60
Cadmium	mg/Kg	1.21	<1.50	<1.50	<1.00	<1.00	1.2- 9.6	36.6	2.00
Chromium	mg/Kg	12.55	16.12	10.45	8.80	9.30	81- 370	2.9	34.00
Copper	mg/Kg	nm	11.07	8.55	7.20	7.50	34- 270	9.4	33.00
Lead	mg/Kg	7.82	<5.50	<5.50	<20.00	<20.00	46.7- 218	8	61.50
Nickel	mg/Kg	nm	20.79	15.63	8.70	9.40	20.9- 51.6	1.9	25.00
Zinc	mg/Kg	32.37	36.70	33.46	32.40	26.30	150- 410	6.1	120.00

VII.C Discussion

National sediment quality criteria are in draft form only, and there are several sources for these criteria. After reviewing many of these, two sources were chosen for comparison with wetpond sediment data. First, the marine and estuarine sediment guideline values from the National Oceanographic and Atmospheric Administration (NOAA) were used because they are based not only on sediment chemistry but biological effects data. (Long, 1995) This data includes modeling, lab spiked-sediment bioassays and field studies of sediment toxicity and benthic community composition. Although NOAA guidelines were developed for marine sediments, TNRCC staff recommended their use, as the Environmental Protection Agency considers them to be virtually the same as for fresh water sediments.

Additional criteria were gathered from screening levels for freshwater reservoirs from Texas Natural Resource Conservation Commission (TNRCC). These screening levels were developed from a statewide 10-year period of record (September1984-November 1994) and were based on the 85th percentile value for each specific toxic substance. The additional biological effects data makes the NOAA criteria a more useful interpretive tool than TNRCC screening levels, so where possible, NOAA criteria were used.

The NOAA criteria define two guideline values: the lower 10th percentile of the effects data for each chemical is considered the effects range-low (ERL). The median of the effects data is referred to as the effects range-median (ERM). These guidelines define three categories for any one chemical: (1) a minimal effects range for concentrations below the ERL, (2) a possible effects range for concentrations equal to and greater than the ERL but less than the ERM, and (3) a probable effects range equal to and above the ERM. This is the effects range in which adverse biological effects would frequently occur.

Adverse biological effects from this study that could be seen in the wetpond include:

- measures of altered benthic communities (depressed species richness or total abundance)
- significant or relatively elevated sediment toxicity
- histopathological disorders in demersal fish

Although seven metals had one or more values above the detection limit, all but cadmium had values below both NOAA guidelines and TNRCC screening limits. These values fall into the minimal effects range, in which biological effects would be rarely observed. Cadmium was detectable only in the December 1994 sample. However, that value of 1.21 ug/kg was only .01 above the ERL of 1.20 ug/kg, and no other detectable amount of cadmium was found in subsequent samples. Because of these low detectable values, metals are not cause for concern in the wetpond sediments. However DDT and alpha- BHC had at least one value above both the NOAA guidelines and the TNRCC screening limits.

In September 1996, both shallow and deep water samples showed measurable levels of DDT ranging from 68 ug/kg in shallow water to 6.8 ug/kg in deep water. 6.8 ug/kg is in the possible effects range (ERL of 1.58 ug/kg, ERM 46.1 ug/kg), within which effects would occasionally occur. The shallow water value of 68 ug/kg is of the most concern, as it is higher than the ERM of 46.1 ug/kg. This value is in the probable effects range, where adverse effects would frequently occur. DDT was used as a broad spectrum insecticide and banned by the EPA in 1972, but has a long half life for biodegradation in soil. DDT is absorbed by aquatic organisms, then bioaccumulated in larger fish, possibly affecting the nervous system.

As with DDT, the September 1996 sample had the only measurable value of alpha BHC, found in the shallow water sample. The NOAA guidelines do not include this insecticide, but the measured value of 17.00 ug/kg was higher than the 1996 TNRCC screening criteria of 1.00 ug/kg for freshwater reservoirs. Alpha BHC is a broad spectrum insecticide, used until 1978 on animals, buildings, living plants, seeds and soils and used in water for mosquito control.

Total Petroleum Hydrocarbons (TPH) levels were found to be above detectable limits in all samples, but concentrations decreased throughout the study period. There are no sediment criteria for these substances, which include all hydrocarbons. The decrease is probably due in part to lowered input, as the initial runoff to the pond was from bridge construction sediment, which would contain higher TPH than routine highway run off. In addition, much of the TPH could have volatilized or been consumed by bacteria in the sediment.

Total organic carbon (TOC) values steadily increased throughout the study period. This parameter measures all organic carbon, including that found in living plant material as well as detritus. TOC doubled in the first year and then showed more than a tenfold increase in the second year. This is to be expected, as the pond sediment was initially silt and clay from bridge construction and held little organic material. As the pond biota developed, the organic input to the sediment naturally increased. The high values in September 1996 are probably indicative of the decay resulting from the filamentous algae (*Cladophora sp.*) bloom in the warmer summer months.

Although receiving run off from a major highway, the current sediment toxicity of the pond is minimal. The levels of metals present in the sediment are well below concern, and at the current rate of accumulation, will remain so for some time. The pesticides have probably accumulated through run off from areas that had exposure to these chemicals when they were still in common use. As the scope of this study did not include toxicity testing of the sediment, the effect of the pesticides on the pond's biota is not documented. A potential problem could exist for future dredging and disposal of the pond's sediments, however, leachate tests would have to be run on the sediment for risk assessment at the time of disposal.

VIII. Biological Component

The main focus for data analysis for all portions of the biological component of the Mansfield wetpond was for baseline characterization of the wetpond ecosystem. In addition, where possible, the grant's target goals were addressed. These include:

a. identify and quantify the impacts of nonpoint pollution on productivity, diversity, and ambient toxicity of native or indigenous species in wetlands
b. designate native or indigenous species as indicators of nonpoint pollution impacted waters
c. analyze sediment toxicity in a wetland NPS pond

Both quantifying the impacts of NPS pollution and identifying NPS-indicator species in the ecosystem (goals a and b) involve comparison with a non-impacted system. A non-impacted wetpond was not available for side by side studies with the impacted pond, as there was no designated 'control' ecosystem in the project design. In lieu of this, data from previous studies involving wetponds or ecosystems similar to them were used for comparison.

Other factors that affected the ability to pin-point effects of NPS pollution included pond augmentation and the short term nature of the study. Being located in central Texas, the pond required frequent augmentation with water from Lake Austin (the reservoir adjacent to the wetpond) to offset the evapotranspiration loss and maintain a permanent pool for aquatic habitat. This augmentation potentially introduced additional plankton, benthos and fish to the pond with each event. Also, the biological portion of the study only spanned one full year, making it difficult to determine the effect of natural seasonality on community structure. In effect, seasonal changes, the introduction of Lake Austin water to the pond's ecosystem as well as the impact of runoff from storm events were all factors affecting the wetpond's biological communities.

In general, the biological community can be characterized by a variety of indices. These may vary according to the component sampled (fish, invertebrates, phytoplankton), but ones that are good general indications of ecosystem health include:

Species Richness - the number of distinct taxa present at a given station. Generally, the taxa richness of a community increases with increasing water quality, habitat diversity, and habitat suitability.

Standing Crop - the number of individuals collected per station per unit effort. This measurement is often related to the productivity of a community.

Percent Contribution of Dominant Family - the percent contribution of the dominant family to the total number of organisms in a sample. This metric is intended to be a measure of evenness. A community dominated by few families would generally indicate environmental stress.

Shannon Weaver or Diversity Index - a measure of the diversity of a community which is determined by species richness and the equitability of the standing crop of individuals among the species present. This index is often interpreted as a measure of ecological and environmental stability and was calculated for all plankton and benthic data sets. This index runs from 0 to 4 and is based on two things: the taxa richness or number of taxa in a sample, and the evenness of distribution across the taxa. Low diversity (< 1.0) means a dominance by one to three taxa. The higher values represent samples with greater numbers of taxa and more equal distribution of organisms in those taxa.

Equitability- a measure of the evenness or allotment of individuals among the species, was also calculated for all plankton samples. Running from 0-1, the greater the equitability, the more even the distribution of individuals among species, and presumably, the less stress present in the ecosystem.

IX. Plankton

Plankton are a large and diverse group of microscopic free-swimming or floating organisms, comprised of phytoplankton (algae) and zooplankton (animals). Phytoplankton, along with other aquatic plants, are the basis for the aquatic food chain, producing organic matter through photosynthesis. Zooplankton often form the next step in the chain, feeding on phytoplankton and other microscopic organisms and providing an important food source for other larger organisms. Both of these groups were characterized in an effort to understand their functional roles in the wetpond ecosystem and to possibly discover any impacts of NPS runoff on these communities.

Both phytoplankton and zooplankton were sampled qualitatively and quantitatively in an effort to characterize this portion of the wetpond's biological community. Samples were collected in December 1995, then in February, May and July of 1996 in an effort to capture the seasonality of the wetpond biota. Although not optimum, the intervals between sampling were designed to capture fall, winter, spring and summer conditions as best as possible within the time constraints of the project.

There was limited information on the plankton of an unimpacted system available for comparison. One previous study of Lake Austin, conducted by the Texas Water Quality Board in February 1976 (Ottmers, 1976), did provide sufficient data for use in the phytoplankton section of this report. However, it must be recognized that there are limitations to this comparison. The differences in physical habitat caused by higher velocities and flows in the lake ecosystem undoubtably affect the plankton community composition. While only data from the same season (February) is used in the comparison, the studies were not conducted within the same year, and conditions could vary. However, the frequent augmentation of the pond with Lake Austin water adds a factor of comparability between the two ecosystems.

A. Zooplankton

A. 1. Methodology

Zooplankton were collected from the shallow water macrophyte beds as well as the deeper, open water in the center of the pond. Since the macrophyte beds differed around the circumference of the pond, a composite of several areas was made to ensure a representative sample. The deeper water in the central area of the pond was free of vegetation and less than three feet deep. Because of this, it was assumed to be fairly homogenous, so a single grab sample was collected from this area. To ensure comparison of data, the same volume of sample was collected from each area.

For the shallow water zooplankton collection, 12 one liter samples collected from macrophyte beds throughout the circumference of the pond were filtered and then composited into a single sample. A wide mouth glass one liter jar was lowered so the mouth was a few inches below the surface, to avoid disturbing the sediment. If the sample was more turbid than the surrounding undisturbed water column it was discarded and a nearby area was sampled. The 63 m plankton net and collection bucket from the Schindler Patalas sampling apparatus was used for filtering the sample, then rinsed well into a 125 ml plastic sample bottle. An estimate of the volume of the sample was made using an identical sample bottle and a graduated cylinder. After preservation in the field by the addition of 100% formalin to a final concentration of 10%, all samples were stored in the dark for transport to a contracted lab for identification and enumeration.

The open water zooplankton collection involved one grab sample from the open water area of the pond, using the Schindler Patalas apparatus equipped with a 63 m net. The apparatus was deployed to collect a discrete sample of 12 liters from the water column between 1 and 2 feet below the surface. Sample preservation and disposition were identical to the shallow water zooplankton described previously.

A. 2. Results

Zooplankton were collected from two distinct habitats, shallow water macrophyte beds and deeper open water. Collections occurred seasonally, in December 1995, and February, May and July 1996. A total of eight data sets (four open water, four shallow water) were collected. Raw data is presented in Appendix E. Diversity and equitability were calculated for each data set, along with density as individuals per liter. This information, plus overall taxa richness and abundance is presented in Table 8. Percent contribution and taxa richness of major groups was also determined and is presented in Table 9. Raw data include a large number of nauplius and copepodite, or larval forms, of copepods peaking in May. Because larval forms are not identifiable beyond order, these data were not included in the calculations.

Table 8 - Zooplankton Summary Statistics

Shallow water samples

	20 Dec., 1995	13 Feb., 1996	2 May, 1996	2 Jul., 1996
No. of Taxa	12	20	27	26
Diversity	3.2171	3.3402	2.9558	2.6410
Equitability	0.8974	0.7729	0.6216	0.5619
Density, Ind/liter	26	123	1674	3167

Open water samples

	20 Dec., 1995	13 Feb., 1996	2 May, 1996	2 Jul., 1996
No. of Taxa	7	10	13	14
Diversity	2.2695	0.7648	1.8473	2.4773
Equitability	0.8084	0.2302	0.4992	0.6507
Density, Ind/liter	33	283	622	199

Table 9 - Percent Contribution and Taxa Richness of Zooplankton

Shallow water sample

	20 Dec.,1995		13 Feb., 1996		2 May, 1996		2 Jul., 1996	
	%	# taxa	%	# taxa	%	# taxa	%	# taxa
Copepoda	25	2	25	4	18	4	0	3
Rotifera	46	4	65	9	61	10	68	14
Cladocera	11	3	1	2	10	7	1	2
Other	18	3	9	5	11	7	30	7

Open water sample

	20 Dec., 1995		13 Feb., 1996		2 May, 1996		2 Jul., 1996	
	%	# taxa	%	# taxa	%	# taxa	%	# taxa
Copepoda	61	2	2	1	26	2	0	0
Rotifera	5	2	97	6	9	6	94	9
Cladocera	34	3	1	2	59	4	1	2
Other	0	0	0	1	6	3	4	3

A. 3. Discussion

Standing crop densities ranged from 26 individuals/L in December to 3167 individuals/L in July. Figure 1 in Appendix F shows these densities for shallow water and open water samples. Overall, densities were very low (less than 300 individuals/liter) in December and February, with populations increasing markedly in May and July, especially in shallow water samples.

In winter and early spring, open water populations were higher than shallow water samples. Then in late spring and summer, shallow water densities steadily increased, first by a factor of more than ten between February and May, and then nearly doubling between May and July to 3167 individuals/liter. The deep water density doubled from February to May, but decreased by two thirds in July to 200 individuals/liter.

The zooplankton community composition was statistically different between shallow water and open water samples throughout the study, with the least difference in December (when populations were very low) and July (when populations were very high.) In general, the shallow water samples were dominated by rotifers, (greater than 45% of the community) throughout the study period, while adult copepods were never greater than 25 % of the population. Cladocerans were the least numerous group, ranging from 1 % to 11 %. Other invertebrates in the shallow water community included oligochaetes, ostracods, nematodes, *Ceratium* sp., gastrotrichs and very small numbers of insect larvae, predominantly chironomids. In the shallow water samples, contribution from these other groups was greater than cladocerans, reaching 30% in the July sample. These relationships are shown in Appendix, Figure 2.

Open water communities varied greatly throughout the study period. The very low numbers in December were dominated by copepods, with greater than 60 % composition. In February, the community was almost completely dominated by one family of rotifers, Synchaetidae. In May, rotifers were only 9% of the community, and cladocerans dominated, primarily *Bosmina longirostris*. Copepods were 25 % of the community, the same two taxa found in the shallow water during this period. In July, along with the drop in density came dominance by rotifers, with 94 % of community represented by this order. The community contribution by 'other' as described earlier was negligible in open water samples, never reaching above 6 % of the community. These relationships are shown in Appendix F, Figure 3.

Taxa richness increased for all samples throughout the study period, from 7 to 14 in open water, and from 12 to 27 shallow water (Appendix F, Figure 4.) However, in shallow water, numbers of individuals in those taxa increased dramatically, driving diversity down over time (Appendix F, Figure 5.) In the open water samples, diversity dropped in February with the dominance of one family of rotifers, then increased through the remainder of the study period, ending slightly higher than it began. Diversities were approximately the same between shallow and open water samples by the end of the study period.

The low winter and spring densities and taxa richness of zooplankton throughout the pond is an expected seasonal phenomenon, as winter and early spring populations are mainly of overwintering females or individuals hatching from resting eggs. As water temperatures warm, active reproduction begins and populations increase dramatically. The data on copepod larvae support this, as the large numbers of larvae in May, both in shallow and open water, indicate a large hatch. Larval numbers decrease by more than 90% in July, as populations mature.

Diversity, taxa richness and equitability were all higher in the shallow water macrophyte communities than in open water communities for all sample events. The main pressures on zooplankton populations include predation, and food and habitat availability. The dense growth of aquatic plants in the shallow water provided increased habitat, food and predator refuge for zooplankton, compared to the relatively unprotected areas of open water. Of zooplankton groups represented, most are omnivores, ingesting organic detritus as well as algae and protozoa. The macrophyte beds would be a better source for these food types than open water. Also, planktivores were one of the major feeding types of fish found in the pond, so a larger and more diverse population of zooplankton could develop within the macrophyte communities where some protection from predators is afforded.

In addition, the large decrease in numbers in the open water July sample may reflect a substantial algae (*Cladophora* sp) bloom during this period. The thick mats of filamentous algae grew on the surface and throughout the macrophyte beds, possibly driving the fish into the open water, thus increasing the predation pressure on the zooplankton population in this area.

The presence of planktivorous fish is an important factor in regulating zooplankton community composition. Both *Gambusia* sp. and *Lepomis* sp. are insectivorous/planktivorous sight feeders, with the younger fish being primarily planktivores. Their food would be primarily larger zooplankton, favoring a population shift towards survival of smaller species. This helps explain the paucity of most species of copepods and cladocerans, as they are some of the largest zooplankton, ranging from 0.2 to 3.2 mm in size. The main genera of cladocerans and copepods that are present (*Bosmina* sp, *Microcyclops* sp) are relatively small-sized, from 0.5 to 1 mm and more likely to escape notice by predators. Rotifers, by far the most numerous group in the zooplankton community in most samples, are microscopic in size, ranging from 100 to 500 m. This small size makes them difficult prey for the fish, and although they often serve as a major food source for copepods and cladocerans, these groups were probably being preyed upon heavily by fish, allowing rotifers to dominate the zooplankton community.

Water quality had an effect on zooplankton community composition. Dissolved oxygen (D.O.) was relatively high throughout the study period until July, when levels dropped to well below 1.0 mg/l. In addition, sediments were noticeably anoxic (black in color, distinct rotten egg odor). For the shallow water sample, diversity dropped slightly, but density more than doubled, as more tolerant organisms, especially nematodes and oligochaetes, increased. Normal residents of sediments, these organisms could have been driven into the water column as sediments became anoxic during this period. pH can be a factor in composition of rotifer populations, but although the pond's pH decreased steadily over the course of the project, values were never low enough to create the acidic conditions necessary to cause a major change in zooplankton communities . Possibly more important than water quality factor to this particular pond's zooplankton population is the augmentation of the pond with water from Lake Austin. Augmentation occurred continually throughout the project, based on the level of the pond (see Table 6.) As the Lake Austin water certainly contained zooplankton, this could have affected the pond's population. No concurrent studies of lake and pond plankton were done, but the total quantity of water brought into the pond from Lake Austin (21,684 ft^3 over the ten month period of record) would indicate the potential for influence. An intensive survey of Lake Austin in February 1976 found four genera of rotifers; two of these (*Keratella* sp and *Asplancha* sp) were also found in February as part of this study of the wetpond. They are both are considered to be limnetic genera, and augmentation helps explain their presence in a small pond. In addition, lake copepods were dominated by nauplius larvae, as was the pond during this period, probably indicating a seasonal phenomenon. No other zooplankton species were found in common between the two systems, probably due to extreme differences in physical habitat and flow.

B. Phytoplankton

B. 1. Methodology

The phytoplankton samples were collected as a whole water sample from the deeper open water of the pond. Macrophyte beds were not sampled for phytoplankton, as these areas were assumed to be habitat primarily for attached algae, or periphyton.

Phytoplankton collection involved two liter whole water samples collected from the open water area of the pond. A grab sample was taken with a stainless steel bucket, approximately two feet off the end of the dock and one foot below the surface. The water in the bucket was swirled well and poured into two one-liter plastic bottles. 30 ml of a modified Lugol's iodine solution was added to each sample bottle as preservative. After preservation, all samples were stored in the dark for transport to a contracted lab for identification and enumeration.

B. 2. Results

Phytoplankton were collected simultaneously with zooplankton, in December 1995, and February, May and July 1996. Four data sets were collected. Raw data is presented in Appendix G. Diversity, equitability and density were calculated for each data set and are presented in Table 10. Percent contribution of major groups, by phyla, is presented in Table 11.

Table 10
Phytoplankton Summary Statistics

	12/20/95	2/13/96	5/2/96	7/2/96
# Taxa	15	15	16	30
# of Ind.	133	459	687	558
Diversity	2.39	2.25	2.53	3.60
Equitability	0.6116	0.5765	0.6324	0.7334
Density, Ind/ml	2866	10435	7321	5947

Table 11
Percent Contribution and Taxa Richness of Major Groups of Phytoplankton

	12/20/95		2/13/96		5/2/96		7/2/96	
	%	# taxa	%	# taxa	%	# taxa	%	# taxa
Chlorophyta	19	5	6	4	14	6	13	12
Euglenophyta	10	2	2	3	4	2	29	5
Pyrrophyta	3	1	2	1	1	1	1	1
Cryptophyta	56	1	44	1	61	2	12	2
Chrysophyta	1	1	16	2	0	0	0	1
Cyanophyta	2	1	0	1	18	3	44	7
Bacillariophyta	10	4	28	3	2	2	1	2

B.3. Discussion

Phytoplankton standing crop densities ranged from 2866 to 10,435 cells per milliliter. The minimum was in December, and the population density peaked in February. After February, there was a steady decline in numbers through July.

From December through May, the community's standing crop was dominated by organisms of the phylum Cryptophyta, represented at the most by two taxa. The numbers of Cryptophyta decreased by more than 80 % in July, although taxa richness remained the same (2). In contrast, in July, Euglenophyta experienced a five fold increase in numbers, and its taxa richness doubled while Cyanophyta doubled in numbers and in taxa richness. Chlorophyta never contributed more than 20 % of the standing crop but always had the highest taxa richness, doubling from 6 taxa in May to 12 in July.

Overall, taxa richness remained fairly stable, between 15 and 16, for the first three quarters, then nearly doubled in July to 30. Diversity ranged from 2.25 to 3.60, with the maximum occurring in July; equitability ranged from .5765 to .7334, with the maximum also occuring in July.

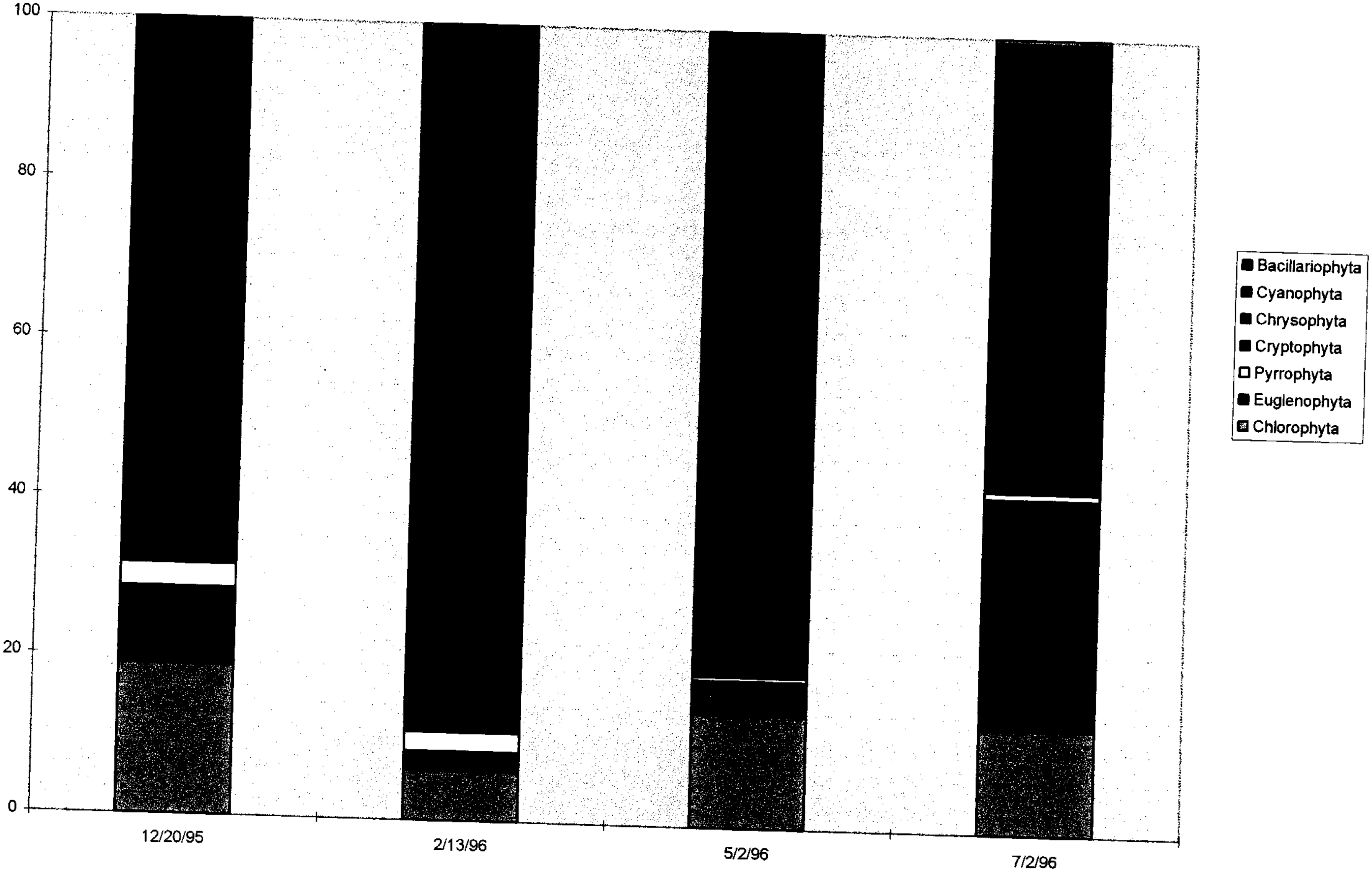
Phytoplankton showed fairly high standing crop densities throughout the study period, ranging from 2866 individuals/ml in December to a peak of 10435 individuals/ml in February. After this peak, the population steadily declined through May to less than 6000 individuals/ml in July (Appendix H, Figure 1.) For reference, phytoplankton values from Lake Austin ranged from 170 individuals/ml to 3099 ind/ml. A low count is usually assumed at less than 500 cells per mL, and under bloom conditions can go up to more than 15,000 cells per mL (Amand, 1993). However, counting cells can sometimes be a misleading indication of algal biomass, as it introduces a high degree of variability, depending on size of cells or filaments.

Diversity for the first three quarters was fairly stable, ranging from 2.25 to 2.52. In July, the diversity index increased to 3.60. Taxa richness doubled, from 15 and 16 in winter and spring to 30 in July. See Appendix H, Figure 2 for diversity and taxa richness. Equitability follows the same pattern, dipping slightly in February and then peaking in July.

Composition of the phytoplankton community follows patterns most probably dictated by seasonal and organic enrichment changes. Figure 8 shows percent contribution of major group by phyla. Most algae taxa present in wetpond samples are tychoplankton; these are algae that are unattached, but caught among filamentous algae and other vegetation and reproduce in shallow water. From December through May, the community was dominated by organisms from phylum Cryptophyta; these are unicellular flagellates, able to develop in cold periods, with low light conditions (Prescott, 1982.) The two types of cryptophytes (*Chroomonas* sp. and *Cryptomonas* sp.) abundant in May are shallow water tychoplankters, common in algae masses and decaying vegetation.

The population of Crytophyta dropped considerably in July, as representatives from Cyanophyta and Euglenophyta became the dominant groups. These algae increase proportionately in organically enriched lakes, and Euglenophyta are most often found in shallow water that is rich in organic matter. The pond experienced a large input of nutrients from a rain event in late May. In addition, an extensive filamentous algae (*Cladophora* sp.) bloom was documented beginning in June. Whether this bloom was in response to nutrient input from the rain event or triggered by seasonal changes, as the bloom progressed, it is possible that the input of nutrients from the decaying *Cladophora* sp. bloom allowed the dominance of phytoplankton to shift to Cyanophyta and Euglenophyta. In addition to this shift in dominance, there was a considerable increase in taxa richness for most phyla, especially Chlorophyta. This increase in number of taxa can be an indication of increased competition, as light was precluded and nutrients were used up by existing macrophytes.

Figure 8



Percent Contribution of Phytoplankton Groups

In an effort to isolate NPS pollution as a factor in the phytoplankton community, a comparison with data from an unimpacted ecosystem was made. Data from an intensive survey of Lake Austin in February, 1976 was compared to the wetpond data collected in February. This comparison is shown in Table 12. Unfortunately, the trend in the wetpond towards more pollution tolerant phytoplankton taxa was not apparent as early in the year as February, but a valid comparison requires similar seasonal conditions. The methodology for the survey is similar to that used for this report, as samples were vertically integrated throughout the photic zone. There were seven stations located along the length of the reservoir. For the purposes of this report, the data from these seven stations are combined, with ranges and averages presented where appropriate.

Table 12
Comparison of Lake Austin and 620 Wetpond Plankton

	Lake Austin		620 Wetpond	
Phytoplankton Density, Ind/ml range (avg)	172-3099 (1368)		10,435	
Phytoplankton, # taxa range (avg)	8-20 (13)		15	
Phytoplankton, Diversity Index range (avg)	2.71- 3.69 (3.22)		2.25	
Zooplankton Density	1866		123 (shallow) 283 (deep)	
Phytoplankton groups	%Composition	# Taxa	%Composition	# Taxa
Diatoms	52.6 %	14	28%	3
Chlorophyta	42.7%	11	6%	4
Cyanophyta	1.8%	2	<.01%	1
Pyrrophyta	.2%	1	2%	1
Euglenophyta	.3%	1	2%	3
Chrysophyta	2.4%	1	16%	2
Cryptophyta	0(none present)	0	44%	1

The phytoplankton population of the wetpond in February has a much higher density than that of Lake Austin. Since the previous rain event occured in October, nutrient loading from a storm event was probably not a factor in the increase in phytoplankton. In addition, nutrient levels were well within ambient conditions, as shown in Table 13. The community in the wetpond was dominated by a single taxa of cryptophytes, and secondarily by the diatom genus *Nitzchia.* The Lake Austin phytoplankton community was made up mainly of green algae and diatoms, a typical winter assemblage in Texas reservoirs (Brasier, 1976.) Cryptophyta include unicellular flagellates that often develop dense populations in cool, low light conditions. TSS was measured previous to the February collection and ranged from 13 to 28 mg/L. The water was also noted as turbid in field records, possibly due to recent nocturnal activity of nutria in the wetpond. TSS was noted as being low (<10) at all Lake Austin stations. It is possible that the suspended sediments played a role in the dominance of the wetpond's phytoplankton by cryptophytes.

Table 13
Nutrient Data, February

	2/12/96	2/22/96
NO2/NO3	.016	<.010
TKN	.321	.296
TP	.053	<0.010

Diversity index values were high at all stations in the Lake Austin study, characteristic of moderately clean water. The wetpond had a lower diversity index in February than any site in the Lake Austin, due to the dominance by cryptophytes. This might indicate a decline in water quality, but again, in the absence of any rain for over 3 months, it is difficult to draw a connection between these conditions and stormwater runoff.

Another possible factor driving size and composition of phytoplankton populations is grazing by zooplankton. Many of these organisms are filter feeders and the particle size ingested is limited by the structure of their filtering mechanism. Table 12 also shows the zooplankton densities in Lake Austin and the 2 wetpond stations. Small algae such as the unicellular Cryptophyta would be reduced as zooplankton populations increased. This offers another possible explanation for the difference in the wetpond phytoplankton community and that of Lake Austin. Although sampled during the same season, with cool temperatures conducive to cryptophyte dominance, predation by the lake's zooplankton could have contributed to the absence of Cryptophyta. The increase in zooplankton in the wetpond between February and May could also explain the shift away from Cryptophyta at that time.

While unicellular algae are easy prey for zooplankton, many blue greens (Cyanophyta) are either too large for ingestion or have gelatinous sheaths and are unpalatable to zooplankters (Wetzel, 1983.) This could help explain the dominance of Cyanophyta in July despite the increase in zooplankton during this period. The drop in total phytoplankton density from over 10000 ind/ml

(February) to less than 6000 ind/ml (July) despite warming temperatures and increasing nutrients could also be explained by the dramatic increase in zooplankton populations.

X. Productivity

Primary production is the means by which inorganic carbon is chemically reduced to organic matter. Primary production is accomplished through the process known as photosynthesis. In photosynthesis, carbon dioxide is converted to a six carbon sugar, with oxygen being produced in the process. The higher the community's productivity, the greater the amount that is likely to end up as biomass. Consequently, biomass determinations have been applied as estimates of determining the trophic state of lentic systems. Trophic state of a pond may be thought of as the combined effects of organic matter supplied to the pond. Little organic matter is produced in an oligotrophic system, characterized by low productivity. A eutrophic or highly productive pond is characterized as producing much organic matter. A mesotrophic system's primary production is between an oligotrophic and eutrophic system.

Primary production is important because it drives an ecosystem. Very little biomass will be found in an ecosystem with very low total productivity, because the organic carbon produced by primary production forms the base of the ecosystem's food chain. Heterotrophs can not manufacture their own food and thus rely on primary producers, or autotrophs, to provide organic matter that they use either directly or indirectly for their food. Autotrophs can be classified into four categories:

1.Planktonic algae (phytoplankton)
2.Planktonic phototrophic bacteria
3.Attached algae (periphyton)
4.Rooted macrophytes.

X. A. Methodology

Two methods were used to determine primary productivity in this study. The contribution of phytoplankton, phototrophic bacteria and periphyton was measured directly by measuring oxygen production. In addition, the productivity of the pond was measured by the accrual of periphyton biomass.

Direct measurements of dissolved oxygen (D.O.) production were made using the light/dark bottle method. This method determines the difference in D.O. production between a bottle incubated in the pond in the dark and one incubated at ambient light conditions.

To measure phytoplankton production, water samples were collected from the open water area of the pond, using 300 ml BOD bottles. Each sample consisted of a pair of bottles, one clear and one with a dark coating to prevent light penetration. The initial D.O. was determined with a dissolved oxygen meter that fits directly into the BOD bottles. The meter was calibrated immediately prior to use, with ambient temperature, barometric pressure and a nomograph used to determine the correct dissolved oxygen. The BOD bottles were placed horizontally in a rack, then lowered in the pond to a depth corresponding to the Secchi depth (representing approximately one-fourth the depth of the euphotic zone). The bottles were incubated underwater in ambient light conditions for six hours, and final D.O. concentration was measured with the D.O. meter.

For periphyton production, a microscope slide with periphyton growth was placed in a one liter chamber. Periphyton was collected using a floating sampler with glass microscope slides as substrate. The sampler allows the slides to hang vertically, approximately one inch below water level, and was deployed in the open water of the pond. The sampler was deployed twice for a period of 60-99 days, once in winter conditions and once in the summer. Oxygen production from periphyton was measured at the end of the deployment period. For this measurement, two slides were placed in separate one liter glass chambers (one clear, one with a dark coating) from which all air had been excluded. The chambers were incubated and oxygen production was measured using the same methods described previously for phytoplankton.

Periphyton biomass accrual was measured periodically throughout each deployment period by scraping two slides to remove all the periphyton and then rinsing the slurry into a sample bottle. Samples were placed on ice for transportation to the LCRA Environmental Laboratory for chlorophyll determination.

Pond water quality field parameters, light intensity and turbidity were measured at the time the light/dark bottles production method was determined.

X. B. Results

To calculate production from phytoplankton and periphyton with the light/dark bottle method, the following formulas were used:

Net photosynthesis (mg/l/hour) = L-I/t
Community respiration (mg/l/hour)= I-D/t
Gross photosynthesis = L-D/t
Gross primary productivity (mg C/m^3 day)=L-D/t x 12/32 x 1000 x 12,
where:

I = initial D.O. concentration, (mg/l)
D= D.O. concentration of dark bottle after incubation, (mg/l)
L= D.O. concentration of light bottle after incubation, (mg/l)
t = incubation period, (hours)
12/32 = the atomic weight of carbon/molecular weight of oxygen
1000 = the conversion factor for liters to cubic meters
12 = the hypothetical number of hours of light per day

Calculations for phytoplankton and periphyton are presented in Table 14. Total combined productivity from phytoplankton and periphyton is presented in Table 15.

Table 14
Phytoplankton and Periphyton Productivity

Calculation	Units	Feb. 9, 1996		Oct. 30, 1996	
		phytoplankton	periphyton	phytoplankton	periphyton
Gross Photosynthesis	mg O_2/l/hour	0.10	0.05	0.46	0.22
Net Photosynthesis	mg O_2/l/hour	0.03	-0.33	0.37	0.03
Community Respiration	mg O_2/l/hour	0.08	0.12	0.09	0.18
Gross Primary Productivity	mg C/m3 day	450	225	2070	990

Table 15
Total productivity due to Phytoplankton and Periphyton

Month	Phytoplankton Productivity	Periphyton Productivity	Total Productivity mg C/m^3 day
February	450	225	675
October	2070	990	3060

The low and high D.O. concentration measured in the pond at the time of the productivity determinations was multiplied by the total volume of the pond to determine the total D.O. production of oxygen in the pond. Dissolved oxygen for the pond was calculated using the following basic formula:

D.O. (in mg/l) x Volume of Pond (10281 ft^3) = D.O. of the pond (grams)
The data is presented in Table 16.

Table 16 Total D.O. content of Pond		
Month	mg/l D.O.	grams of D.O.
February, low D.O.	8.84	2574
February, high D.O.	11.46	3337
October, low D.O.	4.08	1188
October, high D.O.	8.24	2399

To estimate the productivity of the pond due to periphyton accrual, the following formula was used:

$$P = \frac{\text{g chlorophyll/slide}}{tA}$$

where:
P = net productivity, g chlorophyll/square meter/day
t = exposure time, days
A = area of slide, 0.00375 M^2

The data from the biomass accrual is presented in Table 17.

Table 17 Periphyton Productivity Biomass Accumulation				
Season	Replicates	Avg. Concentration (g/slide)	Incubation Days	Accumulation ($g/M^2/day$)
Winter	2	1.0	18	14.8
	2	1.2	23	13.9
	2	12.8	32	107
	2	43.0	36	318
	2	20.4	46	118

	2	16.6	52	85.1
	2	28.0	60	124
Summer	2	not measured	28	not measured
	2	571.4	58	2627
	2	6.4	73	23.4
	3	82.4	99	222

The applicable water quality field parameters measured during the time of the light/dark bottle production method are listed below in Table 18.

Table 18
Water Quality Field Parameter Ranges

Parameter	February Range	October Range
pH	7.76 to 8.08	7.38 to 7.71
Dissolved oxygen	8.84 to 11.46	4.08 to 8.24
Percent saturation (D.O.)	82.0 to 108.2	42.2 to 65.4
Temperature	11.4 to 12.4	20.10 to 23.33

X. C. Discussion

Greater gross photosynthesis, net photosynthesis and community respiration was measured in October than February. The negligible, -0.03 mg O_2/l/hour, periphyton net photosynthesis may be attributable to the greater oxygen demand due to respiration. Greater photosynthesis and gross primary productivity was measured from phytoplankton than periphyton. In this study, greater respiration was measured from periphyton than from phytoplankton.

Periphyton productivity in February was 225 milligrams of carbon per cubic meter day. The February periphyton productivity was 23 percent of the October periphyton productivity. Periphyton productivity in October was 990 milligrams of carbon per cubic meter day.

The combined phytoplankton and periphyton productivity was 22 percent less in February than in October. The phytoplankton community respiration and net phytoplankton photosynthesis in February was relatively low when compared to the October values. There was greater measurable planktonic respiration and photosynthesis in October. This is reflected in the higher October gross primary productivity of 2070 milligrams of carbon per cubic meter day. The February gross phytoplankton primary productivity, 450 milligrams of carbon per cubic meter day is 22 percent of the October productivity. The February periphyton gross productivity was 23 percent less than the October 990 mg C/M^3 day.

According to Liken's classification, as modified by Wetzel, of primary productivity in lakes, the pond may be classified as mesotrophic during the February sampling and eutrophic during October (Wetzel, 1983.) The phytoplankton and periphyton February production of 675 mg C/m^3 day is within the mesotrophic range of 250 to 1000 mg C/m^3 day. The phytoplankton and periphyton October production of 3060 mg C/m^3 day is well above what would be called eutrophic.

Though there was greater productivity in October than in February, the total grams of dissolved oxygen present in the pond was greater in February than in October. This difference is attributable to the higher solubility of oxygen in the colder February water than in the warmer October pond water.

Periphyton production as measured by biomass accumulation proved to be quite variable. Some of the variability may be attributable to differences in colonization rates, sampling error, position of the substrate or grazing. The summer periphyton accumulation was greater than the winter accumulation. The summer periphyton accrual peaked at 2627 g chlorophyll. The greatest winter periphyton accrual, meanwhile, was 318 g chlorophyll. Winter and summer periphyton accumulation rate charts can be found in Appendix I. Greater sample frequency during the summer incubation would have aided in the characterization of the periphyton accrual rate, as fewer slides were collected during the summer months. One set of slides was not analyzed in the laboratory because extremely high temperatures had compromised the integrity of the sample.

In February the pH increased from 7.76 to 8.08 throughout the six hours that the water quality field parameters were collected. This pH increase indicates that photosynthesis was occurring and a concomitant loss of carbon dioxide was taking place. The D.O. varied from 8.84 to 11.46 mg/l, while the percent D.O. saturation increased from 82.0 to 108.2. The temperature ranged from 11.4 to 12.4 C. Not surprisingly, the highest temperature noted in February was less than the lowest temperature found in the October productivity study.

The pH measured in October was more variable and lower than that measured in February, ranging from 7.38 to 7.71 standard units. The lowest pH value measured in February was 7.76 while the highest pH value in October was 7.71. This decrease in pH was also shown throughout the project period during the diel measurements. Average pH decreased overall from 8.6 in December to 7.1 in July. This was probably a result of the increase of microbial decomposition of organic matter, causing an increase in CO_2 concentrations and associated decrease in pH. The D.O. varied from 4.08 to 8.24 mg/l. The value of 9.60 that was measured at 1400 hours is assumed to be an anomalous reading, as a change from 5.22 to 9.60 mg/l within one hour is unlikely. The percent D.O. saturation changed from 42.2 to 65.4. In October the highest percent saturation, 65.4, was less than the lowest percent saturation measured in February, 82.0. In October the temperature varied from 20.10 to 23.33 C. Again, as with total D.O. production in the pond, the decrease in % saturation is likely from the lowered solubility of oxygen in the warmer water in October.

Because of the ubiquitous presence of filamentous algae and macrophytes in the pond, it is unlikely that phytoplankton dominated the primary productivity in the pond. Periphyton and phytoplankton likely produced less carbon than macrophytes. Emergent macrophytes are highly productive and use the resources of both the terrestrial and aquatic habitats. They absorb nutrients from the water through their foliage while their roots provide nutrients from the sediments. Their emerging and floating foliage also provides them with better surface area for capturing light. Because of this competitive advantage, it is likely that macrophytes dominated the productivity in the pond and will continue to do so in the future. Excreted organic compounds of macrophyte origin may function in an inhibitory antibiotic way on the growth of phytoplankton. In addition, increasing the pH of the water, as occurs with a reduction in available CO_2 in dense stands of actively photosynthesizing macrophytes, may reduce the rates of phytoplankton productivity.

Primary productivity in this and similar ponds show extreme temporal variation. The pond is currently mesotrophic to eutrophic, indicating an increase in organic matter, both from internal production (photosynthesis by plants and assimilation by animals) and external input through runoff. Due to the shallow nature of the pond, other vegetation including the submersed and emergent macrophytes and the emergent wetland plants are major sources of organic matter not included in this productivity study. Ultimately, the magnitude of these inputs will determine the pond's trophic level.

XI. Benthic macroinvertebrates

The composition of aquatic communities are determined by the structural, chemical, and biological attributes of their environment. Consequently, long-term measurement of specific components of the biological community may be an effective method for evaluating the integrated impact of pollution on Best Management Practices (BMPs), such as storm water retention ponds. In lotic systems, macroinvertebrates have been widely used as reliable water quality indicators (Shackleford 1988, Plafkin et al. 1989). This is not true for lentic systems. Indicators for lentic systems such as wetponds are still under development. In the absence of such indicators, scientists frequently use metrics developed for flowing systems on lentic environments (Karouna-Renier 1995). This approach provides a meaningful summary of the ecological condition of a wetpond. Important indices described previously include species diversity, species richness, and percent contribution of dominant groups.

Additional indices/analyses are described below:

Sensitive Group Analysis - An attempt was made to compare any relevant existing data from similar ecosystems to the macroinvertebrate data collected for this study. Alternatively, the presence of individuals in sensitive groups (recognized in lotic systems) within submerged plant types will be tracked in the wetpond. Sensitive groups in lotic systems include organisms in the orders Ephemeroptera, Plecoptera, and Tricoptera.

Most Suitable vs. Most Probable Macroinvertebrate Community - Most macroinvertebrates are habitat specific. The two major habitats within the study wetpond are submergent vegetation and sediment. Since sediment macroinvertebrates are typically considered more tolerant than other habitat dwellers, data from submergent vegetation will be best able to identify the most suitable community. For this report, the most suitable macroinvertebrate community is defined as the most diverse community with the highest number of sensitive organisms (EPT). It is highly probable that as the wetpond goes through the initial stages of succession, competition among submerged plant species will determine which predominant plant species will remain. However, if the best vegetation type is short-lived or out competed, it may not be economically feasible to sustain the vegetation. The most probable macroinvertebrate community is the community which inhabits the remaining plant species or mixed mosiac of species after competition. In any event, long-term monitoring of macroinvertebrates in submergent vegetation is essential to determine the most suitable and probable community.

Functional Feeding Group Analysis - Macroinvertebrates can be categorized into functional groups based on their feeding habitats. The six functional feeding groups that are generally recognized by (Merritt and Cummins 1996) include:

1. Scrapers
2. Gatherers
3. Filterers
4. Predators
5. Shredders
6. Miners

Merritt and Cummins (1996) is an excellent reference which contains relevant information for both lentic and lotic systems.

Scrapers are organisms that normally feed on attached algae and associated material. These organisms are mostly herbivores which are adapted with mouthparts to scrape algae from mineral and organic surfaces.

Gatherers are detritivores that feed on decomposing fine particulate organic matter (FPOM). Gatherers generally feed on deposited FPOM in the sediment.

Filterers are detritivores that feed on FPOM. Filterers normally feed on suspended FPOM in the water column.

Predators are carnivores that feed on living animal tissue. Two types are recognized: Engulfers -

organisms that attack their prey and swallow them whole or in parts. Piercers - organisms that attack their prey, pierce the tissues or cells, and suck the fluids out.

Shredders are mostly herbivores that feed on living or decomposing vascular plant tissue. Most of these organisms are adapted with chewing mouthparts to shred leaf material.

Miners are detritivores that feed on deposited FPOM in the sediment and other areas prone to sediment accumulation.

XI. A. Methodology

Macroinvertebrates were sampled qualitatively from the wetpond in an effort to characterize the benthic community. Submerged macrophytes and pond sediment were the two main habitats targeted for collection. The frequency of sampling consisted of quarterly collections for about a year, four to five datasets.

Since most macroinvertebrates are habitat specific, local emergent and submergent vegetation were introduced into the wetpond as habitat structures. The vegetation was planted around the shallow peripheral areas of the pond. Miller et. al. (1989), Engel (1985), Dvorak and Best (1982), among others, have shown that aquatic macrophytes are heavily colonized by macroinvertebrates. Among the vegetation planted were two obligate wetland plant species (Westerdahl and Getsinger 1988) predicted to do well in these types of systems, *Elodea canadensis* (waterweed) and *Myriophyllum spicatum* (eurasian watermilfoil). A third obligate wetland macrophyte, *Najas guadalupensis* (southern naiad) established itself unexpectedly in the middle of the study. All three species are adaptable to quiet lentic characteristics such as low flow velocities and low turbulence. An attempt was made to collect samples from colonies made up of an individual macrophyte species. In the event that different plant species were intermixed, areas representing mostly one species were sampled, with other species noted. Other significant plant colonies that developed unexpectedly within the wetpond were also sampled. Duplicate samples were taken if separate colonies of the same plant species were found. Macroinvertebrates within macrophytes were collected with a standard 500 micron mesh dipnet.

Wetpond sediment was sampled from two locations, shallow and deep areas. The shallow area was about 1 to 2.5 feet deep and coincided with the vegetated littoral area. The deep area was mostly vegetation free and was about 3 to 5 feet deep. Sediment macroinvertebrates were taken from the described area with a petite ponar dredge.

Vegetation macroinvertebrates were collected in the field using the following procedures:

1. One meter areas of each colony were thoroughly swept with a dip net for a duration of 1 minute. Duplicate samples of the colonies were taken when possible. The samples were rinsed thoroughly in the net with pond water to remove any accumulated sediment.

2. The samples were transferred into a white plastic tray. The dip net was handed picked to remove any remaining macroinvertebrates caught in the net.

3. Vegetation in the samples were separated and removed from the organisms by rinsing the vegetation with water and hand picking it out. The remaining samples were transferred into a 1 liter glass jar.

The following procedures were used to collect sediment macroinvertebrates:

1. Sediment samples were collected with a petite ponar dredge from a shallow and deep area.

2. The sediment samples were transferred into a 350 micron mesh metal tray sieve. The ponar dredge was rinsed with pond water to wash any remaining sample into the tray sieve.

3. The samples in the sieve tray were spread out evenly on the tray and rinsed with pond water to remove most of the finer sediment. Larger rocks and any rootballs were rinsed and removed. The remaining sample was transferred into a 1 liter glass jar.

Both vegetation and sediment sample jars were labeled externally, preserved in 10% formalin, sealed, and transported to a contracted lab for final separation, identification, and enumeration of macroinvertebrate taxa. Macroinvertebrate samples were identified to the lowest possible taxonomic level using taxonomic keys from Merritt and Cummins taxonomic (1996).

XI. B. Results

Macroinvertebrate samples were collected from submerged macrophytes and sediment between November 11, 1994 through July 2, 1996. Five sets of data were collected for *E. canadensis* and *M. spicatum*. Three sets of data were collected for an unexpected macrophyte called *Najas guadalupensis* (southern naiad). One dataset each was collected for *H. dubia* and another unexpected bloom of *Cladophora* sp., a filamentous algae. Finally, four sets of data were collected for both shallow and deep sediment areas.

N. guadalupensis, showed up unexpectedly within the study period and was sampled only three times. The naiad plant existed only around the extreme shallow peripheral areas of the wetpond and appeared to be drastically influenced by the water level within the pond. A fourth sample for the naiad plant was not collected at the end of the study period because it had dried up due to the low water level. *H. dubia* rapidly disappeared after the first sample event, therefore, only one sample was collected. An expected bloom of *Cladophora* sp. showed up in July 1996. A macroinvertebrate sample was collected from the *Cladophora* due to its magnitude and availability for habitat.

Thirteen duplicate samples (only in vegetation habitat) were taken throughout the study period. Student's two sample t-tests were applied to datasets (ex. Nov. 11, 1994 datasets: *E. canadensis*-original vs. *E. canadensis*-duplicate) to determine if the macroinvertebrate community populations were equal or unequal. The assumptions of the two-sample t-test for these data include (Pimental, 1990):

1. The collected samples within the different habitats are random samples.
2. The populations within the different habitats follow a normal distribution.
3. Collections are independent both within and between samples.
4. The populations variances between similar habitat types are equal.

Results of the t-tests indicated that all thirteen comparisons had similar or equal populations (Table 19.) When P, the probability or observed significant level is greater than (>) 0.05, the community population variances are considered equal. Since the community populations among same plant types were statistically equal, the original and duplicate samples were combined into one sample for analysis purposes.

Table 19
Two sample t-test comparisons of macroinvertebrate populations between vegetation types.

Date	*E. canadensis* original vs. duplicate	*M. spicatum* original vs. duplicate	*N. guadalupensis* original vs. duplicate	*H. dubia* original vs. duplicate
11/18/94	0.57	0.13	N/A	0.36
12/20/96	0.85	0.98	0.39	N/A
02/14/96	0.84	0.63	0.36	N/A
05/02/96	0.48	0.15	0.19	N/A
07/02/96	0.21	N/A	N/A	N/A

Appendix J contains the tables of macroinvertebrate data collected for this study. An asterisk by the macrophyte indicates that a replicate sample was collected and combined into one sample. Each table also contains a data reduction section at the bottom which includes calculations for the number of taxa or species richness, number of individuals, species diversity, EPT index, percent dominant group, percent sensitive groups (EPT), and feeding group analysis.

XI. C. Discussion

Macroinvertebrates in Submerged Macrophytes

In freshwater systems, submerged macrophytes serve as a significant substrate or habitat for epiphytic macroinvertebrates. Miller et. al. (1989), Engel (1985), Dvorak and Best (1982), among others, have shown that macrophytes are heavily colonized by macroinvertebrates.

Although there may be much information on macroinvertebrate community structure in natural lentic systems, little information exists on storm water wetpond assemblages in semi arid climates. In Texas, even less data exists on control type ponds which are naturally perennial or augmented by a water supply. Natural ponds in Texas tend to go through a dry period at one time or another from year to year. A literature search revealed limited data on macroinvertebrate communities in storm water treatment ponds.

To facilitate the understanding of the discussion section, it is helpful to restate the data sets collected for this study. Macroinvertebrate populations were tracked consistently for *E. canadensis*, *M. spicatum*, and *N. guadalupensis*. Five sets of data were collected for *E. canadensis* and *M. spicatum* while three were collected for *N. guadalupensis*. One data set was collected for *H. dubia* and *Cladophora* sp.. Fewer samples were collected for *N. guadalupensis* because it had dried out. *N. guadalupensis* was most susceptible to drying out because of its peripheral location and frequent pond water fluctuations. For the most part, trend and other comparisons will not be discussed for *H. dubia* and *Cladophora* sp. because of their brief existence and limited data.

Species richness and diversity

In general, species richness was highest in *N. guadalupensis*, followed by *M. spicatum* and *E. canadensis* (Appendix K, Figure 1). Species diversity was highest in *M. spicatum*, then *N. guadalupensis* and *E. canadensis* (Appendix K, Figure 2). The species richness and diversity pattern between vegetation types was similar except for the beginning and ending samples in *E. canadensis* and *M. spicatum*. Taxa richness was highest in *N. guadalupensis* probably due to its location in the wetpond. This macrophyte existed only around the outermost, shallow, peripheral areas of the wetpond, closest to the edge. It is commonly known that interactive areas like water to land areas or edges are very productive, species rich and diverse. The shallower water depth (< 1 foot) may have contributed to higher species composition in *N. guadalupensis*. Ball and Hayne (1952) reported that macrophyte densities and water depth were important factors contributing to invertebrate populations.

Percent individuals in sensitive (EPT) groups and indicator groups

Research on stormwater wetpond assemblages in semi arid climates is limited at best. Indicator organisms for lentic systems are also lacking. Because of this dilemma, Mitchell (1995), proposed the potential use of dragonfly naiads or odonates as possible indicators of water quality in lentic systems. In preliminary studies, his results show that some dragonfly naiads, like *Tramea* sp., *Celithemis* sp. and *Dythemis* sp. , may prefer cleaner water ponds.

The quality of the stormwater runoff entering the wetpond was characterized from 21 storm events. Of the parameters analyzed, total suspended solids (TSS) is a typical pollutant found in urban and suburban runoff. The average TSS in runoff from this study was 125 mg/l. Storm event mean concentrations for TSS in the Austin, Texas area is 130 mg/l for developed areas (LCRA 1991). A total of 41.2 cubic feet of sediment was washed into the wetpond during the course of the study. Baseline water quality in the wetpond itself was determined from 3 collection events. The baseline TSS average in the wetpond was 23 mg/1. TSS values from a study of impacted wetponds in Stephenville, Texas were in the same range, 14 to 70 mg/l (Mitchell et.al. 1995). Impacts of suspended and deposited sediment to the aquatic environment are well documented (Schueler 1997). Deposited sediment can impact the benthic macroinvertebrate community by causing physical smothering. Suspended sediment impacts the epiphytic macroinvertebrate community by limiting light penetration to macrophytes and reducing habitat.

Table 20. compares two data sets from this study to that of Mitchell's study. The data sets were collected during similar time frames (November through December 1994 and 1995) using similar methodology. The comparison describes the presence and absence of the proposed indicator dragonfly naiads (species and numbers).

Table 20.
Comparison of odonate data sets in impacted and unimpacted (reference) wetponds

Collection Period	Odonate Genera	Hwy. 620 Wetpond, impacted*	Mule Pasture Wetpond, impacted**	Upper Wetlands Wetpond, impacted**	Hort Wetpond, unimpacted**	Peanut Irrigation Wetpond, unimpacted**
Oct-Nov 94	*Celithemis* sp.	0	0	0	46	43
Oct-Nov 94	*Dythemis* sp.	1	0	0	8	68
Oct-Nov 94	*Tramea* sp.	2	0	0	9	9
Oct-Dec 95	*Celithemis* sp.	0	0	0	29	8
Oct-Dec 95	*Dythemis* sp.	0	0	0	20	18
Oct-Dec 95	*Tramea* sp.	0	0	0	61	0

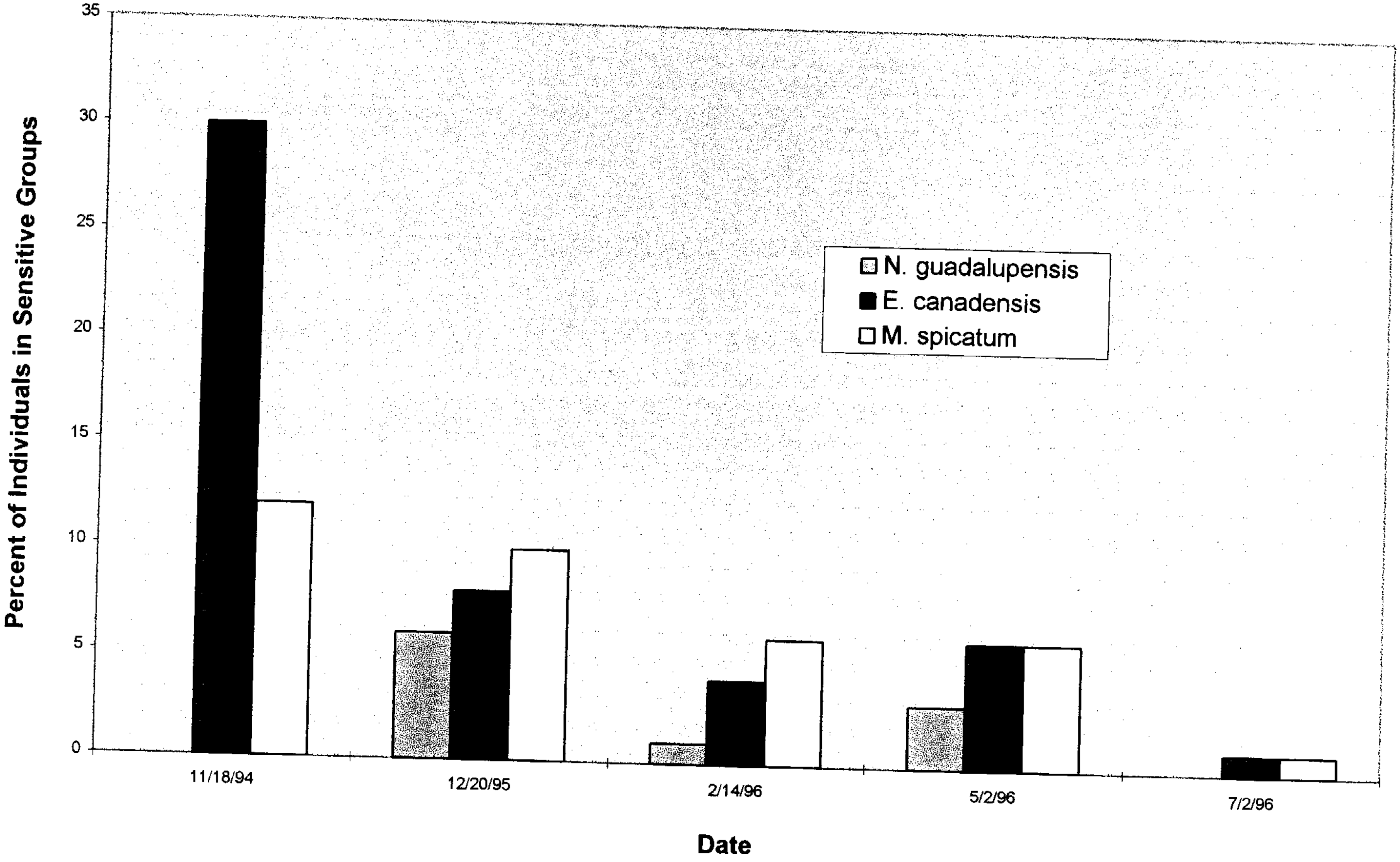
* Collection method: Four one-meter Dnet drags through submerged vegetation. Duration of each drag equaled one minute. Wetpond perennial, augmented by Lake Austin. Wetpond receives mostly highway and bridge runoff.

** Mitchell et. al. 1995, Lasswell et. al. 1997. Collection method: Five two-meter Dnet drags through submerged vegetation and other pond material. All wetponds perennial. Hort and Peanut Irrigation wetponds augmented by well water, Mule Pasture and Upper Wetlands wetponds receive agricultural runoff.

Celithemis sp., *Dythemis* sp., and *Tramea* sp. were absent or in very low numbers in impacted wetponds, including the Hwy. 620 wetpond, and numerous in unimpacted control type wetponds. Results from this study indicate *Celithemis* sp., *Dythemis* sp., and *Tramea* sp. are possible indicator organisms for NPS pollution in lentic systems.

As mentioned earlier, indicator groups established for lotic systems may not be the most applicable method to look at in lentic systems but one that commonly is tracked (Karouna-Renier 1995). Striking results can be seen by looking at the short-term trend of the number of sensitive (EPT) groups. *E. canadensis* started out with the largest number of sensitive individuals, followed by *M. spicatum* and then *N. guadalupensis* (Figure 9). A consistent downward trend or loss of sensitive individuals is fairly obvious among all vegetation types. The cause of this trend could be the effect of one or a combination of many factors. Some of the factors which could produce this trend include the continued input of nonpoint source pollutants from stormwater runoff, seasonal changes, and/or effects caused by early pond succession. The latter two factors were difficult to substantiate due to the short-term duration of the study.

Figure 9. Percent of individuals in sensitive groups (EPT) in macroinvertebrate communities within submerged vegetation in wetpond over time.



Percent contribution of dominant group and feeding group analysis

The dominant macroinvertebrate groups found in the vegetation types were fairly typical (Appendix K, Figure 3). *E. canadensis* was initially dominated by odonates (dragonflies and damselflies), then gastropods (snails), followed by dipterans (midges) and finally by oligochaetes (worms). *M. spicatum* was dominated by gastropods (snails) then by dipterans (biting midges). Finally, *N. guadalupensis* was dominated by gastropods (snails). In general, the submerged vegetation in the wetpond harbored mostly gastropods, dipterans, oligochaetes or odonates at one point or another. Miller et. al. (1989) notes that the most common macroinvertebrates inhabiting submerged macrophytes include gastropods, chironomids (midges), oligochaetes and crustaceans. The one exception, the odonates in *E. canadensis*, may be slightly unusual but periodically encountered in predator-prey imbalances. Odonates are notable predators.

In most cases it is not surprising that the functional feeding group analysis is inherently tied to the dominant group analysis. In terms of functional feeding groups, macroinvertebrates within *E. canadensis* (Appendix K, Figure 4) were initially dominated by predators (dragonflies and damselflies), shifted to scrapers (snails) then dipterans (midges) in the middle of the study period, and ended with miners (worms). *M. spicatum* (Appendix K, Figure 5) was dominated by scrapers (snails) through most of the study period and shifted to predators (biting midges) by the end. *N. guadalupensis* (Appendix K, Figure 6) was dominated by scrapers (snails) throughout the study period.

The main point that should be derived from the dominant and functional feeding group analysis is the start to end community shift in the two submerged macrophytes present throughout the study period, *E. canadensis* and *M. spicatum*. The two plants started with slightly tolerant macroinvertebrates, odonates and snails, and progressively shifted to more tolerant organisms, (oligochaetes and dipterans) when the study ended.

Most suitable vs. most probable communities

As defined earlier, the most suitable macroinvertebrate community is the most diverse community with the highest number of sensitive organisms (EPT). The most probable macroinvertebrate community is the community which inhabits the remaining plant species or mixed mosaic of species after competition. Only the most persistent submerged macrophytes that were present from the beginning of the study to the end were considered for this analysis. *E. canadensis* and *M. spicatum* satisfied this criteria. Of these two macrophytes, *E. canadensis* (Appendix K, Figure 2) started and ended with the highest species diversity (3.44 to 2.49). *M. spicatum* started with a species diversity of 2.59 and ended with a diversity of 2.42. Similarly, *E. canadensis* started with a higher percentage of sensitive EPT groups, 30 %, compared to *M. spicatum*, 12 % (Figure 9). Both plants decreased to less than 1 % sensitive EPT groups at the end of the study. At the beginning of the study, *E. canadensis* and *M. spicatum* started out as individual colonies. Midway through the study and by the end, *E. canadensis* appeared to out compete and decrease *M. spicatum*. The wetpond appeared to be evolving into a monoculture of

E. canadensis. Based on this analysis, *E. canadensis* contained the most suitable and most probable macroinvertebrate community.

Macroinvertebrates in shallow vs. deep sediment areas

Species richness and diversity

In general, species richness and diversity followed the same pattern over time in shallow and deep sediment areas of the wetpond (Appendix K, Figures 7 and 8). Initially, both attributes were slightly higher in the shallow littoral area than the deeper unvegetated area. By the end of the study, richness and diversity decreased to similar numbers. Studies in lotic and lentic systems frequently show higher species diversities and densities in areas containing vegetation as compared to unvegetated areas (Miller et. al. 1989). A factor that may account for the decrease over time may include the potential for increased pollutant accumulation and their effects in both areas.

Percent contribution of dominant group and feeding group analysis

The shallow sediment areas of the wetpond were dominated by oligochaetes (worms) throughout the study period (Appendix K, Figure 9). The deep sediment areas were initially dominated by dipterans (midges), then oligochaetes (worms) midway through the study, and finally by crustaceans at the end.

The functional feeding group analysis reflects the dominant group composition in the shallow and deep sediment areas (Appendix K, Figure 10). The shallow sediment areas were dominated by miners (worms) throughout the study period. The deep sediment areas were initially dominated by gatherers (midges), then by miners (worms) midway through the study, and finally by scavengers (crustaceans) in the end. In general, the shallow and deep sediment areas of the pond were dominated by oligochaetes (worms) and dipterans (midges).

XII. Fish Analysis

The initial strategy for introducing fishes into the wetpond was to utilize native fish species with different habitat preferences in anticipation that appropriately adapted native species would survive and develop sustaining populations in the artificial pond.

XII.A Methods

Fish were collected from the Colorado River near Webberville, transported, and released into the Mansfield wetpond in November 1994. The number of individuals of each species included in the initial stocking also varied, depending on availability.

Fish communities were surveyed using a backpack electrofisher on two occasions following the initial stockings. The amount of fishing effort was restricted to fifteen minutes since the amount of habitat available in the pond and the associated fish community was limited in size. Since the population sampled included a significant number of juvenile sunfishes, it was necessary to preserve specimens for later identification. Larger specimens were identified and released in the field.

XII.B Results

At least thirteen species were collected from the Colorado River and introduced into the Mansfield wetpond in November 1994. These species are listed in Table 21 and included fishes with a broad range of habitat requirements. Since eight unidentified minnows were introduced the number of different species included in the initial stocking is uncertain. Three individuals of the nonnative redbreast sunfish (*Lepomis auritus*) were also included in the introduction.

Four species of fish were collected during a survey of the fish population on 12 August 1995. *Gambusia affinis*, the western mosquitofish, was the most abundant species present (Table 21). Three species of sunfishes were also collected. *Lepomis megalotis*, which was not listed in the initial stocking, was numerically the most abundant sunfish in the pond. *Lepomis punctatus* and *L. cyanellus* were taken in equal numbers.

The second and final survey on 16 November 1996 included only two species; *Gambusia affinis* and *Lepomis punctatus* (Table 21). *Gambusia affinis* remained the most abundant species present; the population was numerically similar to the previous survey. *Lepomis punctatus* was the only other species collected and a slight increase in numbers was observed.

Table 21
Fish species stocked and collected

	Common Name	*Species*	Initial Stocking	8/12/95	Size		11/16/96	Size	
Family			N	N	Min	Max	N	Min	Max
Suckers (Catostomidae)									
	Grey Redhorse Sucker	*Moxostoma congestum*	5						
Minnows (Cyprinidae)									
	Stoneroller	*Campostoma anomalum*	10						
	Blacktail shiner	*Notropis venustus*	26						
	Unidentified shiners	*Notropis spp.*	8						
Catfishes (Ictaluridae)									
	Channel Catfish	*Ictalurus punctatus*	15						
	Flathead Catfish	*Pylodictus olivaris*	2						
Livebearers (Poeciliidae)									
	Mosquitofish	*Gambusia affinis*	29	164	15	40	147	20	40
Perches (Percidae)									

	Dusky Darter	*Percina sciera*	1						
Sunfishes (Centrarchidae)									
	Bluegill Sunfish	*Lepomis macrochirus*	3						
	Redbreast Sunfish	*Lepomis auritus*	3						
	Spotted Sunfish	*Lepomis punctatus*	1	9	44	48	37	30	75
	Green Sunfish	*Lepomis cyanellus*	13	9	35	80			
	Longear Sunfish	*Lepomis megalotis*	0	26	17	55			
	Largemouth Bass	*Micropterus salmoides*	6						

XI.C Discussion

It should be noted that the dusky darter (*Percina sciera*), grey redhorse sucker (*Moxostoma congestum*), stoneroller (*Campostoma anomalum*), and the blacktail shiner (*Cyprinella venusta*), which were included in the initial stocking are stream fishes and would not have been expected to survive and reproduce in the habitat provided by the wetpond. Additionally, several species were not stocked in sufficient numbers to be reasonably expected to develop reproducing populations.

Although the channel catfish is capable of surviving and reproducing in standing waters, it requires sheltered areas such as old stumps and rock ledges to reproduce. This type of habitat was not present in the wetpond. Channel catfish are typically stocked in small ponds and lakes as a sportfish.

Only two species with appropriate habitat requirements for the wetpond were introduced into the 620 wetpond in sufficient numbers to reasonably expect successful reproduction. Twenty-nine mosquitofish (*Gambusia affinis*) and thirteen green sunfish (*Lepomis cyanellus*) were included in the initial introduction.

The size distribution of *Lepomis cyanellus* and *Lepomis megalotis* collected in August 1995 suggest that there was reproductive success of these species during the 1995 spawning season. There were adults present, but the collection was dominated by probable juveniles. The *Lepomis punctatus* collected were all about the same size subadults (Table 21), indicating that they were probably spawned at about the same time in late spring or early summer.

From the final collection in November 1996, the size distribution of the spotted sunfish present indicated successful reproduction during the summer of 1996. Several obvious young of year individuals were present in the collection. The larger adults (75mm) probably represent the year class that was prevalent in the 1995 collection.

The fish community that developed in the Mansfield wetpond bears little resemblance to the original stocking. This is in part due to the number of species that were introduced that simply would not reproduce in the standing water environment of the wetpond and in part due to the small size and limited habitat availability in the wetpond. The western mosquitofish (*Gambusia affinis*) predictably became the most abundant species present; this species has been introduced all over the world because of its dietary habits (primarily mosquito larvae) and its ability to survive in small, stagnant pools. The wetpond provides an ideal habitat for this species.

The development of the sunfish community was unexpected. Of the three species collected in 1995, only the green sunfish (*Lepomis cyanellus*) was introduced in adequate numbers to expect reproductive success. Since only one spotted sunfish (*Lepomis punctatus*) and no longear sunfish (*Lepomis megalotis*) were included in the original introduction, it is not possible for these to have reproduced unless 1) there were subsequent, incidental introductions, either from local fisherman or augmentation from Lake Austin 2) there were mis-identifications during the original stocking. *Lepomis cyanellus* is the most tolerant sunfish to low dissolved oxygen and pollution, and it usually is the dominant sunfish in stressed environments. Less is known about the tolerance of the less common *Lepomis punctatus*, but it is more specific in its physical habitat preferences. The heavy submergent and emergent vegetation around the wetpond provided an ideal habitat for this species, and it is likely that *Lepomis punctatus* was simply more competitive in the wetpond than either *L. cyanellus* or *L. megalotis*.

The sunfishes collected during the August 1995 survey were heavily infested with black grubs, a larval trematode. Fish serve as an intermediate host for this parasite; the adult form develops in birds that feed on fish such as herons and kingfishers. It is not unusual to find heavy infestations of this parasite in small, closed environments that are heavily utilized by wading birds. Given the confined nature of the wetpond, it is reasonable to assume that there could have been significant predation by birds. No infested fish were observed in the November 1996 survey.

The results observed were limited due to the size of the initial stocking, uncertain identification of individuals stocked to the species level, augmentation of the pond with water from Lake Austin and the inability to control public access to the site which is frequented by fishermen from the nearby Lake Austin. Further studies should be more directed toward species that will realistically survive in the target environment. Adequate numbers of specimens should be stocked to ensure reproduction of the species stocked and information on the size and sex (if determinable) of the individuals stocked should be recorded. Since this site was situated adjacent to a popular fishing area and was completely accessible to the public, it is probable that fish are released into the pond by fishermen. In addition, the periodic augmentation of the pond with water from Lake Austin could have introduced juvenile fish. This lack of control over the origin of the stocks in the pond make it unrealistic to attempt to follow changes in community structure over time.

XIII. Vegetation Analysis

The Mansfield wetpond was designed as a shallow marsh stormwater wetland system which functions to facilitate the uptake and retention of pollutants and sediment retention (Schueler, et.al., 1992). A shallow marsh system is designed to incorporate microtopography and water depths that can support the growth of hydrophytic vegetation. The vegetation's tolerance of differing water regimes creates dominant plant zones or communities.

XIII. A. Methodology

The wetpond was designed to contain three (3) distinct vegetative zones: Upland, Emergent, and Aquatic Bed. Plant species were selected for each hydrologic zone based on their ability to tolerate varying water regimes, habitat value, native/non-native status, and known pollutant removal capabilities. Twenty four-different species were transplanted in and around the pond area to ensure initial plant diversity. The majority were transplanted from naturally occurring wetlands in the area. Table 22 lists the wetland plants installed in the pond in the fall of 1994.

Table 22
Installed Wetland Plant List and Characteristics

Plant Name (Latin)	Zone	Tolerance (water depth,ft)	Native	Wildlife Value
Juncus *(Juncus sp.)*	Emergent	≤1.0	Yes	*
Arrowhead *(Saggitaria latifolia)*	Emergent	1.0-1.5	Yes	Food for waterfowl
Water Primrose *(Jussiaea uruguayensis)*	Aquatic	*	No	*
Water Hyssop *(Bacopa Monnieri)*	Aquatic	≤ 1.0	Yes	*
Elodea (*Elodea canadensis*)	Aquatic	≤ 12.0	No	Food and cover for aquatic organisms
Iris *(Iris sp.)*	Emergent	≤ 2.0	*	*
Eurasian watermilfoil *(Mryriophyllum spicatum)*	Aquatic	≤ 12.0	No	Food for waterfowl
Water star grass *(Heteranthera dubia)*	Aquatic	≤ 6.0	*	*
Soft-stemmed bulrush *(Scirpus validus)*	Emergent	≤ 1.5	Yes	Food for waterfowl

Illinois pondweed *(Potamageton illinoisensis)*	Aquatic	≤12.0	Yes	Food and cover for aquatic organisms
Common reed (*Phragmites australis*)	Emergent	≤ 1.5	No	Cover and roosting sites for birds

* Information not available

Vegetational communities were assessed by identifying community types and locations. More extensive vegetational analysis and sampling, such as quadrat or random sampling, were considered not applicable for the scope of this study and therefore, were not used.

XII. B. Results

Although man-made, the existing wetpond ecosystem can be classified as a non-tidal, freshwater palustrine wetland. The pond is dominated by hydrophytic, persistent emergent and aquatic species, with an augmented, permanently flooded water regime and an unconsolidated bottom consisting of mud and silt. It is classified as a PEM/AB41K (Cowardin Classification, et.al.,1979).

The vegetation within the wetland can be classified into two (2) dominant plant communities; emergent and macrophyte. Appendix I contains maps that illustrate the areal coverage and succession of each plant community from December 1994 through October 1996. The most recent vegetation map is shown in Figure 10. Table 23 summarizes this information.

Figure 10

Mansfield Wetpond Vegetation - October, 1996

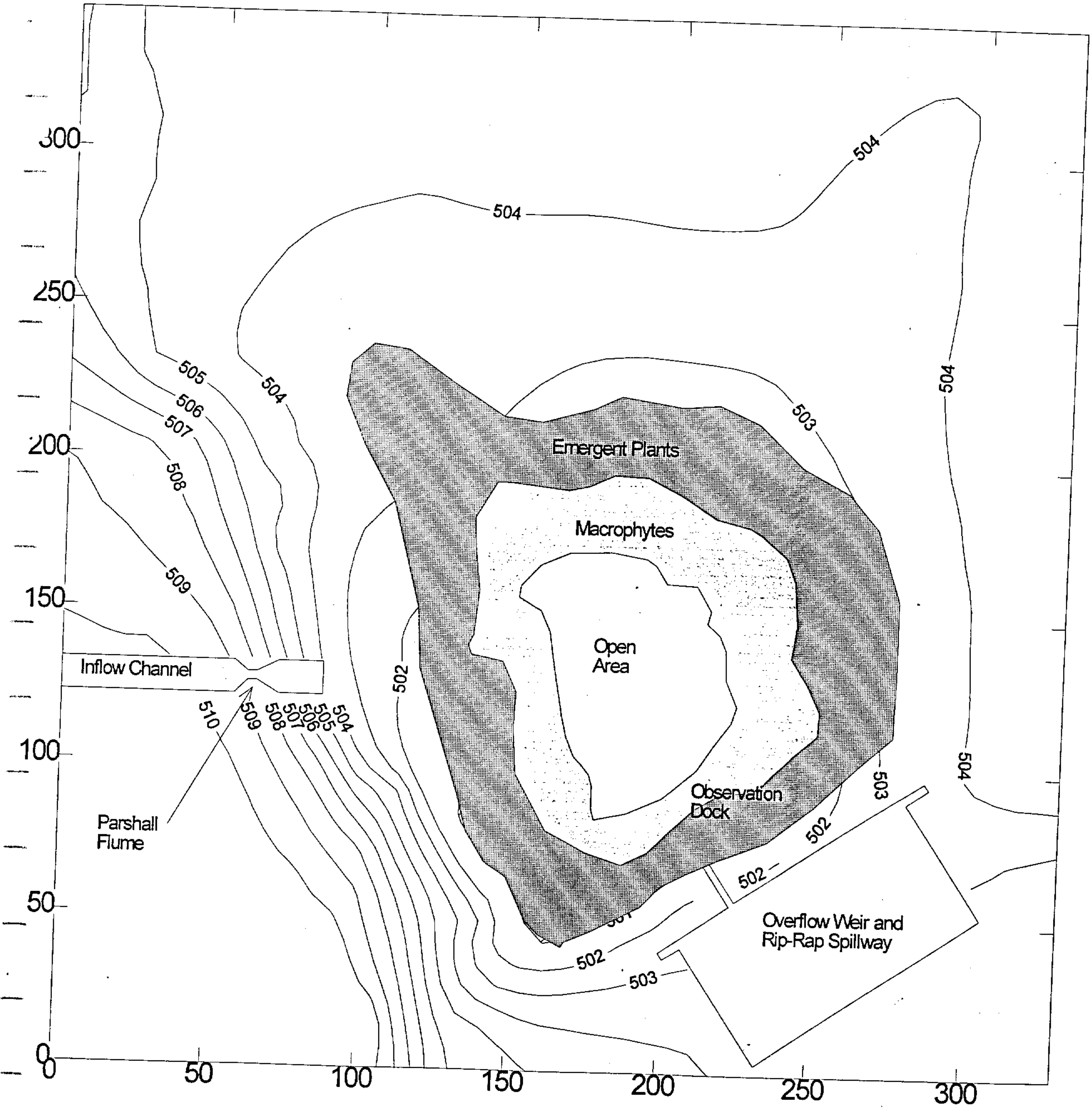


Table 23
Vegetation Coverage Patterns

Area, in acres							
	Dec-94	Feb-95	May-95	Dec-95	Mar-96	Jul-96	Oct-96
Emergent Plants	0.22	0.05	0.29	0.17	0.17	0.23	0.30
Macrophytes	0.11	0.10	0.11	0.16	0.20	0.16	0.16
Open Area	0.19	0.19	0.12	0.11	0.12	0.11	0.12
Total	0.52	0.34	0.52	0.44	0.49	0.50	0.58

Percent Coverage							
	Dec-94	Feb-95	May-95	Dec-95	Mar-96	Jul-96	Oct-96
Emergent Plants	42.3	14.7	55.8	38.6	34.7	46.0	51.7
Macrophytes	21.2	29.4	21.2	36.4	40.8	32.0	27.6
Open Area	36.5	55.9	23.1	25.0	24.5	22.0	20.7

The emergent zone is currently dominated by pioneer wetland species commonly found in newly constructed wetlands. Species include *Typha angustifolia* (Narrow-leaved cattail), *Phragmites australis* (Common reed), *Scripus validus* (Soft-stemmed bulrush), and *Cyperus strigosus* (Umbrella sedge). The emergent zone encompasses a fringe around the perimeter of the pond and extends within areas containing 0.8-1.5 feet of surface water.

The aquatic zone is currently dominated by *Elodea canadensis* and *Myriophyllum spicatum*. *Heteranthera dubia* (water star grass), included in the initial planting disappeared completely from the pond by the December 1995. *Najas guadalupensis* (southern naiad) was found within the shallow peripheral areas of the wetpond up through the May sampling period, but disappeared by July 1996. A bloom of *Cladophora sp.* appeared in July 1996 after a large storm event.

The composition of both the emergent and aquatic zones changed throughout the study period. Initially, distinct clumps of *E. canadensis* and *M. spicatum* were present in the open areas of the pond. In July 1996, an extensive bloom of the filamentous algae, *Cladophora sp.* covered most of the macrophyte clumps. Subsequently, *M. spicatum* suffered a reduction in coverage while *E. canadensis* became the dominant macrophyte within all clumps.

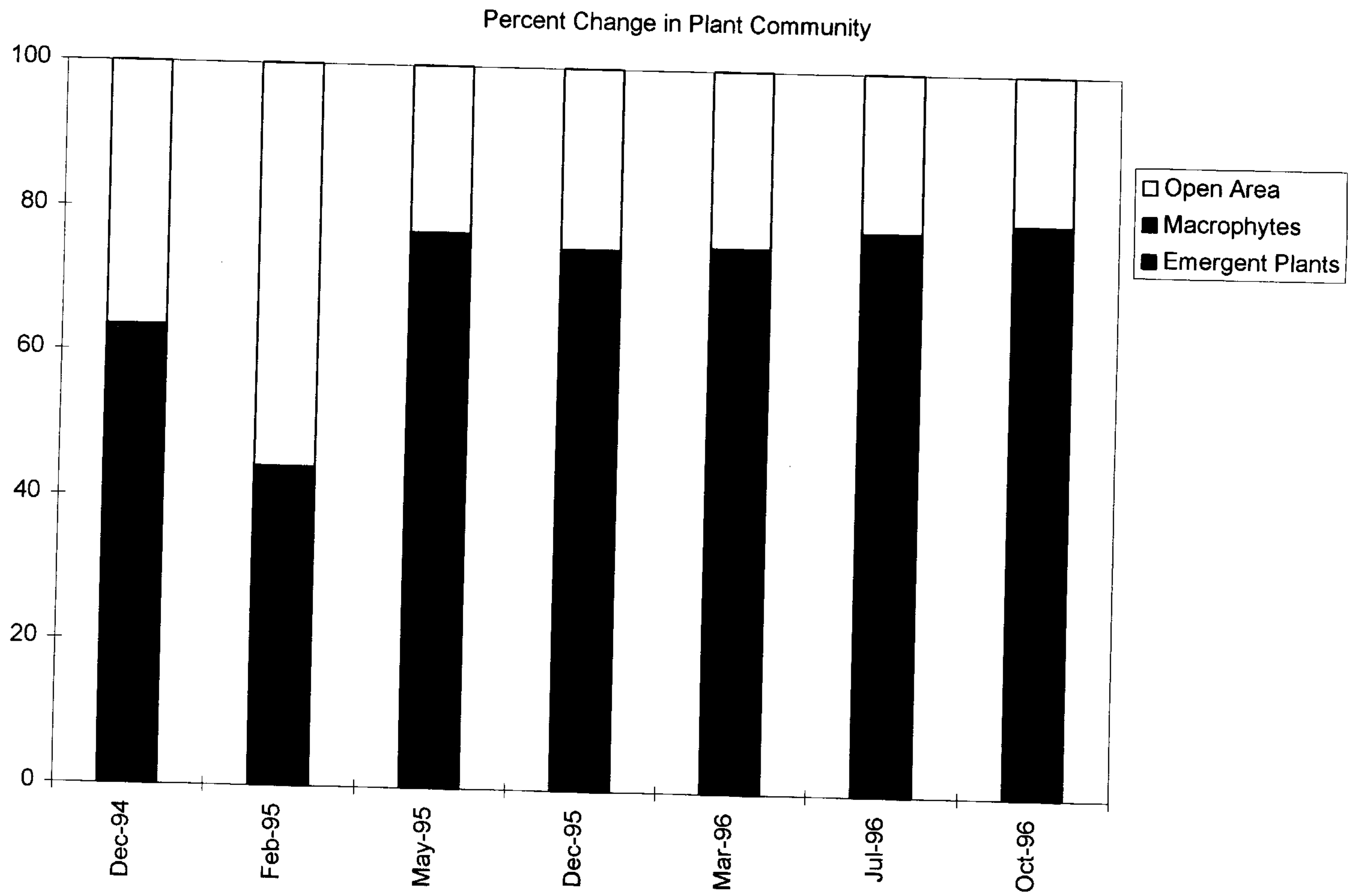
XIII. C. Discussion

It is difficult to determine the specific factors that influence plant diversity and community composition in the wetland without a reference wetland or extensive study. Plant populations and species, regardless of location, are influenced by an array of interdependent and independent factors including competition, predation, nutrient availability, precipitation, etc. Wetland plant communities are subject to additional influences including fluctuating water levels, continuously changing water quality and nutrient levels, anaerobic soil and ambient conditions. For the purpose of this study, plant establishment and successional rationale is based on wetland plant ecology principles and observations of similar ecosystems.

The initial establishment of wetland plant species is primarily influenced by the hydrology and soils of the area. Plants have specific tolerance ranges for hydrologic periodicity and inundation and nutrient levels in the soil. Once the individual is established, competition between species affects community dominance, species richness and standing crop. In the wetpond, hydrology is probably the dominant factor influencing plant community composition since water levels within the pond continually fluctuated.

The original planting plan contained approximately 20% macrophyte and 40% emergent plant species. By October 1996, the percent species composition had changed to 30% macrophyte and 50% emergent plant species. Figure 11 illustrates the percent change in the wetland plant community from December 1994 to October 1996. The plant survey completed in October 1996 showed that both the emergent and aquatic communities included transient species that were not included in the initial planting (e.g., *Typha angustifolia* and *Cladophora* sp.) These species may have entered the pond via the soil seedbank, water from Lake Austin during augmentation, or through airborne seed. These species are typically found in newly constructed wetlands and often eventually form monocultures.

Figure 11


Percent Change in Plant Community
100
80
60
40
20
0
Dec-94
Feb-95
May-95
Dec-95
Mar-96
Jul-96
Oct-96
☐ Open Area
■ Macrophytes
■ Emergent Plants

Expansion of the emergent and aquatic plant zones has probably been influenced by:

1) rapid sedimentation of the pond immediately after construction;
2) sporadic hydrologic augmentation during drought conditions; and
3) volunteer introduction of an aggressive, tolerant emergent species (*Typha angustifolia*).

Post-construction erosion and settling contributed a large percent of the sediment now in the pond. This resulted in expansion of the shallow areas of the pond. This expanded the tolerance range and area of both emergent and floating macrophytes. Sporadic augmentation of the pond during drought conditions resulted in lower water levels allowing the emergent plant zone to expand into shallower areas. Species with less tolerance to fluctuating water levels may have been replaced by *Typha angustifolia* or other more tolerant species. Increased precipitation in the fall of 1996 again resulted in changing water levels, an increase in *Typha angustifolia* individuals and an increase in the emergent plant community.

The macrophyte community remained relatively constant in areal coverage throughout the life of the study. A 5-10% increase in the areal coverage of the macrophyte community with a corresponding decrease in the emergent plant community was noted during the winter of 1995-6. This decrease in emergent plant community areal coverage is probably due to the seasonal disappearance of persistent emergent species. This results in decreased competition for physical space and an increase in nutrients in the water column from decaying emergent plants. This community shift has been noted in other, similar communities during the winter months.

The increase in dominance of *Elodea canadensis* toward the end of the study period is possibly due to increased shading of the macrophyte community by filamentous algae. *E. canadensis* is probably more shade tolerant than *M. spicatum*. The loss of *Heteranthera dubia* was probably due to the habitat requirements of this species; it is more commonly found in fast moving waters. *Najas guadalupensis* was lost from the pond after an extensive dry period in which water levels in the pond dropped.

In a wetpond, the shallow, vegetated, littoral zone functions as a biological filter for pollutants and sediments and is of primary importance for water quality enhancement. Biological removal of dissolved stormwater pollutants includes uptake by aquatic plants, metabolism by phytoplankton and microorganisms that inhabit the bottom sediments. Sediments are an important source of nutrients, particularly nitrogen (N) and phosphorus (P). Plants remove nutrients from the sediment and therefore, the water column. Effective removal of nutrients from stormwater runoff is a major function of stormwater management facilities designed for water quality control.

XIV. Conclusions and Recommendations

XIV. A. Biological Conclusions

The biological component of the Mansfield wetpond focussed on baseline characterization of the wetpond's ecosystem. Appropriate comparisons were made with unimpacted ecosystems to identify the impacts of NPS pollution on the biota of the pond. In addition, potential NPS indicator species were identified from the benthic macroinvertebrate portion of the study. Sediment toxicity was also analyzed.

The Mansfield wetpond showed a gradual, but not severe, trend toward eutrophication over the course of the study, as would be expected for a shallow pond in central Texas. This indicates an increase in organic matter, both from internal processes and the external source of runoff. Runoff from storm events resulted in sediment accumulation and an input of nutrients. This nutrient loading combined with warmer temperatures resulted in a filamentous algae bloom; as this material died and decayed, causing oxygen levels to drop in mid-summer. The gradual decrease in pH could be attributed to an increase in CO_2 from the microbial decomposition of organic material in the pond. There was a substantial increase in total organic carbon (TOC) in the sediments, also indicating an accumulation of organic material. The baseline TSS average in the wetpond was in the same range as other studies of NPS impacted ponds (Mitchell et.al. 1995).

The benthic macroinvertebrate community showed a decrease in diversity and sensitive taxa in all types of vegetative habitats. Phytoplankton community composition showed a distinct shift toward more pollution tolerant groups, while primary production increased, with the final values being intermediate between mesotrophic and eutrophic. The emergent vegetation became dominated by *Typha angustifolia*, as the shallow areas of the pond increased due to sediment accumulation.

The fish community changed considerably during the study, but this was not attributed to any NPS impact. The results instead were attributed to the limited size of the initial stocking, predation by wading birds, and lack of control over introduction of additional fish, whether from fisherman or augmentation with Lake Austin water. Collections of fish at an intermediate point in the study showed infestations of black grubs, a larval trematode, but this is not uncommon in the small, closed environments, especially ones that are heavily utilized by wading birds, as the wetpond certainly was. The grubs were not present in the final collection. This lack of control over the origin of the stocks in the pond make it unrealistic to attempt to follow changes in community structure over time.

The sediment shows no accumulation of metals above levels of concern, in fact, many metals had levels that decreased through the period of study, probably due to uptake by emergent plants. The two detectable pesticides (4,4,-DDT and Alpha-BHC) both have levels above both state and national guidelines. There was no testing done to determine the effects of these chemicals on the biota of the pond.

However, some groups showed signs of maintaining a healthy ecosystem. In the plankton community, taxa richness increased substantially (although tolerant phytoplankton groups increased) and diversity increased for all but shallow water zooplankton. It is possible that competition for resources (between macrophytes and phytoplankton) and predation pressures drove these communities towards higher diversity. In spite of a serious filamentous algae (*Cladophora* sp.) bloom in early summer covering a large amount of the surface area of the pond, the macrophyte community remained fairly stable, maintaining consistent area of cover throughout the study period.

It is evident that no one single factor had a dominant influence on the Mansfield wetpond ecosystem. Although the input of NPS pollutants (including sediment and nutrients) could be important in the pond's evolution, it is more likely that there were a combination of factors creating the trends documented here. Seasonal changes, effects caused by early pond succession and augmentation of the pond with Lake Austin water were all factors in the pond's biological community development. Separating these factors is possible, but would require a longer term study.

Developing indicator macroinvertebrates for nonpoint source pollution impacted waters such as storm water wetponds proved to be difficult. Little information exists on impacted or unimpacted wetpond assemblages in semi-arid climates. Even fewer studies existed which were conducted within a similar time frame and study design. However, data from this study did corroborate Mitchell's proposal (Mitchell et. al. 1995) of using some dragonfly naiads as indicator organisms for lentic systems such as wetponds. Using the absence of *Celithemis* sp., *Dythemis* sp., and *Tramea* sp. as indicator organisms for nonpoint source pollution impacted waters such as storm water wetponds warrants further study.

XIV. B. Biological Recommendations

To separate the various factors impacting wetpond ecosystems, the following recommendations should be incorporated into future studies. Minimizing or isolating seasonal effects requires a longer study period; a minimum of two years is recommended, assuming rainfall amounts are comparable for those two years. Pond succession could also be documented in a longer term study. If augmentation of the pond is necessary (which is likely in central Texas), and the source of augmentation (i.e., surface water) supports a biological community, it should be sampled in conjunction with the target pond.

To determine NPS-indicator species, further studies should include side by side collections with an unimpacted pond, identified from the onset of the study. Additional study on the use of some dragonfly naiads as indicator organisms for lentic systems is highly recommended. Because their populations are more dependent on habitat availability and predation rather than changes in water quality, zooplankton did not prove to be useful as indicator species and should not necessarily be included in future studies. Fish stocking should be directed more toward species that are habitat specific for the target environment, with adequate numbers stocked.

Although levels of certain toxics in the sediment were measured and compared to screening levels or other standards, the actual toxicity of the chemicals in the sediment was not examined in this study. Other studies should include laboratory toxicity testing to determine the effects of intermediate levels of chemicals on the biota.

XIV. C. Hydrologic Conclusions

The Mansfield wetpond was found to provide effective treatment of pollutants in stormwater runoff, especially for total suspended solids (TSS) and nutrients. Treatment was achieved by extended detention and sedimentation in the wetpond, and consumption of nutrients by adsorption and plant uptake. The efficiency of the wetpond in removing petroleum hydrocarbons and toxic chemicals was not determined due to limited data.

Wetponds are considered experimental in semi-arid climates because augmentation is required to replace water lost to evaporation and transpiration. In the Austin area, annual precipitation is about 32 inches per year, and the net evaporation rate in Austin is 37 inches per year. Gross lake-surface evaporation is about 54 inches per year, and total evapotranspiration is about 35 percent higher, at about 73 inches per year. Since losses to evapotranspiration exceed contributions from precipitation and runoff, augmentation is required to sustain a viable wetpond ecosystem. A study of "Removal Efficiencies of Stormwater Control Structures" (City of Austin, 1990) found that the Woodhollow wetpond could not maintain a permanent pool because of water loss through evaporation, infiltration, and leakage.

Wetponds can be augmented naturally or mechanically. For example, the St. Elmo Retention Pond at Meinardus Drive in Austin is augmented by natural groundwater contribution (City of Austin Drainage Utility field tour, 1997). This pond had a constant level throughout the meteorological drought in 1995-1996, which indicated the pond has a perennial source of water other than rainfall and runoff. The presumed source is groundwater seepage in an area where the water table is near land surface. Since this augmentation source is without cost, a wetpond at the site is hydrologically feasible. Based partially on that experience the City of Austin has issued guidelines to developers for the design of wetponds as optional alternative stormwater control facilities (City of Austin, 1996).

The LCRA has had experience with wetponds which are apparently different than the City of Austin. The Mansfield wetpond is one of three experimental wetponds studied by the LCRA. The other examples are a wetpond at the LCRA office complex and a wetpond at the Walmart Superstore in Marble Falls. Each of these wetponds have mechanical means of augmentation. Water levels in these ponds are maintained by adding water from an artificial source. The costs of providing augmentation water mechanically from artificial sources should be accounted for in assessing the hydrologic feasibility of wetponds in Central Texas.

Augmentation costs have two components; the cost of operation and maintenance (O&M), and the cost of the water itself. All mechanical methods of augmentation have O&M costs, but these costs will vary depending on the system. The Mansfield wetpond was equipped with a semi-automatic system of water-level controls and a pump to deliver water from Lake Austin. This was found to be a high-maintenance system, eventually requiring weekly visits to repair float controls, clogged intakes and pump failures. O&M costs were estimated to be $10,400 in labor plus $5,000 in equipment replacement costs per year (total of aproximately $15,400). The cost of water is highly dependent on the water source; a conservative purchase price during periods of drought is $2,000 per acre-foot ($5,200 for consumptive use of 2.6 acre-feet per year). The total cost of augmentation of the Mansfield Wetpond was approximately $20,600 per year. This O&M cost was considered excessive for a relatively small stormwater control facility.

XIV. D. Hydrologic Recommendations

Recommendations for construction and operation of wetponds are summarized in the City of Austin guidelines (City of Austin, 1996). These guidelines are written to aid planners and developers in the proper design of wetponds, but do not address the cost-efficiency of wetponds.

As an alternative to other best management practices (BMPs), wetponds appear to be a poor choice in semi-arid climates. Other options, including dry extended detention, filtration and infiltration practices, are preferrable in terms of water conservation. These BMPs release treated water to receiving streams or aquifers for subsequent beneficial use, with minimal loss of water to evaporation and transpiration. Consumption is a major principle in the mechanics of a wetpond. To support an aquatic ecosystem in which pollutants (nutrients and organic compounds) are consumed, a wetpond must be augmented to maintain a permanent pool of water. The permanent pool is a constant source of water loss due to evaporation and seepage. Emergent plants, including hydrophilic species, are adapted to transpire large amounts of water. Wetponds may be considered inefficient from the standpoints of water conservation and the cost-benefit of consumptive water use in a semi-arid environment. The LCRA would recommend additional study of the requirements and costs of wetpond augmentation in semi-arid climates.

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Appendix A

Stormwater Monitoring Results

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	6/29/95	
Rainfall (in):	*	
Inflow #1(cf):	25150	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd692.95
Parameter	Inflow Concentration	Load(in), g
BOD 5	*	
COD	*	
Cadmium, Total	0.005	
Carbon,Tot. Organic	11.5	8189.24
Chromium, Total	0.02	14.24
Lead, Total-AA	0.025	17.80
Nit., nitrite/nitrate	0.443	315.46
Nitrogen, Kjeldahl	1.357	966.33
Nitrogen, Total	1.8	1281.79
Phosphorus,Total	0.534	380.27
Phosphorus, Ortho	0.09	64.09
Residue, Non-filt-TSS	728	518414.42
Solids, Settleable	*	#VALUE!
Zinc, Total	0.1	71.21
Special Notes:		
Entered by (initials)	JMS	
Date entered	8/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	7/30/95	
Rainfall (in):	1.95	
Inflow #1(cf):	7920	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd07.3095
Parameter	Inflow Concentration	Load(in), g
BOD 5	*	
COD	87	
Cadmium, Total	0.0005	
Carbon,Tot. Organic	20	4485.00
Chromium, Total	0.005	1.12
Lead, Total-AA	0.011	2.47
Nit., nitrite/nitrate	0.019	4.26
Nitrogen, Kjeldahl	1.064	238.60
Nitrogen, Total	1.083	242.86
Phosphorus,Total	0.144	32.29
Phosphorus, Ortho	*	#VALUE!
Residue, Non-filt-TSS	138	30946.53
Solids, Settleable	*	#VALUE!
Zinc, Total	0.04	8.97
Special Notes:		
Entered by (initials)	JMS	
Date entered	8/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	9/8/95	
Rainfall (in):	0.74	
Inflow #1(cf):	12690	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd09.085
Parameter	Inflow Concentration	Load(in), g
BOD 5	11	
COD	54	
Cadmium, Total	0.005	
Carbon,Tot. Organic	13	4671.03
Chromium, Total	0.02	7.19
Lead, Total-AA	0.008	2.87
Nit., nitrite/nitrate	0.551	197.98
Nitrogen, Kjeldahl	0.95	341.34
Nitrogen, Total	1.501	539.32
Phosphorus,Total	0.201	72.22
Phosphorus, Ortho	0.129	46.35
Residue, Non-filt-TSS	246	88390.27
Solids, Settleable	*	#VALUE!
Zinc, Total	0.06	21.56
Special Notes:		
Entered by (initials)	JMS	
Date entered	10/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Suanders		
Structure:	620 wetpond	
Event Date:	9/19/95	
Rainfall (in):	0.4	
Inflow #1(cf):	5249	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd09.195

Parameter	Inflow Concentration	Load(in), g
BOD 5	14	
COD	54	
Cadmium, Total	0.005	
Carbon,Tot. Organic	14.4	2140.16
Chromium, Total	0.005	0.74
Lead, Total-AA	0.009	1.34
Nit., nitrite/nitrate	0.238	35.37
Nitrogen, Kjeldahl	0.861	127.96
Nitrogen, Total	1.099	163.34
Phosphorus,Total	0.151	22.44
Phosphorus, Ortho	0.09	13.38
Residue, Non-filt-TSS	44	6539.39
Solids, Settleable	0.05	7.43
Zinc, Total	0.005	0.74

Special Notes:	
Entered by (initials)	JMS
Date entered	6/25/96

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	9/21/95	
Rainfall (in):	.83 *	
Inflow #1(cf):	11385	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd09.215
Parameter	Inflow Concentration	Load(in), g
BOD 5	8	
COD	25	
Cadmium, Total	0.005	
Carbon,Tot. Organic	10.5	3384.78
Chromium, Total	0.005	1.61
Lead, Total-AA	0.0025	0.81
Nit., nitrite/nitrate	0.132	42.55
Nitrogen, Kjeldahl	0.722	232.74
Nitrogen, Total	0.854	275.30
Phosphorus,Total	0.195	62.86
Phosphorus, Ortho	0.085	27.40
Residue, Non-filt-TSS	26	8381.35
Solids, Settleable	0.05	16.12
Zinc, Total	0.03	9.67
Special Notes:		
Entered by (initials)	JMS	
Date entered	10/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	10/31/95	
Rainfall (in):	1.58"	
Inflow #1(cf):	13840	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd10.315
Parameter	Inflow Concentration	Load(in), g
BOD 5	10	
COD	41	
Cadmium, Total	0.005	
Carbon,Tot. Organic	9.8	3840.34
Chromium, Total	0.005	1.96
Lead, Total-AA	0.006	2.35
Nit., nitrite/nitrate	0.225	88.17
Nitrogen, Kjeldahl	0.642	251.58
Nitrogen, Total	0.867	339.75
Phosphorus,Total	0.294	115.21
Phosphorus, Ortho	0.14	54.86
Residue, Non-filt-TSS	122	47808.34
Solids, Settleable	0.2	78.37
Zinc, Total	0.03	11.76
Special Notes:		
Entered by (initials)	JMS	
Date entered	6/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	2/29/96	
Rainfall (in):		
Inflow #1(cf):	4120	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd02.296
Parameter	Inflow Concentration	Load(in), g
BOD 5	20	
COD	87	
Cadmium, Total	0.005	
Carbon,Tot. Organic	24.2	2823.06
Chromium, Total	0.005	0.58
Lead, Total-AA	0.025	2.92
Nit., nitrite/nitrate	0.556	64.86
Nitrogen, Kjeldahl	3.068	357.90
Nitrogen, Total	3.624	422.76
Phosphorus,Total	0.596	69.53
Phosphorus, Ortho	0.483	56.34
Residue, Non-filt-TSS	38	4432.91
Solids, Settleable	0.05	5.83
Zinc, Total	0.07	8.17
Special Notes:		
Entered by (initials)	JMS	
Date entered	6/25/96	

Raw Data : Standard Parameters					
Water Dveelopment Board Grant					
LCRA Project Manager: Geoff Saunders					
Structure:	620 wetpond				
Event Date:	4/5/96				
Rainfall (in):	~~143~~	.53			
Inflow #1(cf):	3570				
Inflow #2(cf):					
Outflow (cf):	*				
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd04.066			
Parameter	Inflow Concentration	Load(in), g			
BOD 5	9				
COD	47				
Cadmium, Total	0.005				
Carbon,Tot. Organic	13	1314.07			
Chromium, Total	0.005	0.51			
Lead, Total-AA	0.025	2.53			
Nit., nitrite/nitrate	0.314	31.74			
Nitrogen, Kjeldahl	1.121	113.31			
Nitrogen, Total	1.435	145.05			
Phosphorus,Total	0.293	29.62			
Phosphorus, Ortho	0.144	14.56			
Residue, Non-filt-TSS	88	8895.26			
Solids, Settleable	*	#VALUE!			
Zinc, Total	0.05	5.05			
Special Notes:					
Entered by (initials)	JMS				
Date entered	6/25/96				

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	4/20/96	
Rainfall (in):	.20	
Inflow #1(cf):	570	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd04.206
Parameter	Inflow Concentration	Load(in), g
BOD 5	21	
COD	130	
Cadmium, Total	0.005	
Carbon,Tot. Organic	43.3	698.83
Chromium, Total	0.01	0.16
Lead, Total-AA	0.025	0.40
Nit., nitrite/nitrate	0.213	3.44
Nitrogen, Kjeldahl	3.306	53.36
Nitrogen, Total	3.519	56.79
Phosphorus,Total	0.638	10.30
Phosphorus, Ortho	0.108	1.74
Residue, Non-filt-TSS	374	6036.07
Solids, Settleable	0.7	11.30
Zinc, Total	0.2	3.23
Special Notes:		
Entered by (initials)	JMS	
Date entered	6/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	4/22/96	
Rainfall (in):	.36	
Inflow #1(cf):	1410	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd04.226

Parameter	Inflow Concentration	Load(in), g
BOD 5	23	
COD	64	
Cadmium, Total	0.005	
Carbon,Tot. Organic	22.5	898.28
Chromium, Total	0.005	0.20
Lead, Total-AA	0.025	1.00
Nit., nitrite/nitrate	0.543	21.68
Nitrogen, Kjeldahl	1.636	65.31
Nitrogen, Total	2.179	86.99
Phosphorus,Total	0.282	11.26
Phosphorus, Ortho	0.101	4.03
Residue, Non-filt-TSS	78	3114.02
Solids, Settleable	0.3	11.98
Zinc, Total	0.09	3.59

Special Notes:	
Entered by (initials)	JMS
Date entered	6/25/96

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	5/28/96	
Rainfall (in):	0.93	
Inflow #1(cf):	10680	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd05.276
Parameter	Inflow Concentration	Load(in), g
BOD 5	19	
COD	76	
Cadmium, Total	0.005	
Carbon,Tot. Organic	43.7	13214.79
Chromium, Total	0.005	1.51
Lead, Total-AA	0.025	7.56
Nit., nitrite/nitrate	0.546	165.11
Nitrogen, Kjeldahl	2.434	736.04
Nitrogen, Total	2.98	901.15
Phosphorus,Total	0.558	168.74
Phosphorus, Ortho	0.033	9.98
Residue, Non-filt-TSS	185	55943.64
Solids, Settleable	0.5	151.20
Zinc, Total	0.11	33.26
Special Notes:		
Entered by (initials)	JMS	
Date entered	6/25/96	

Raw Data : Standard Parameters		
water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	5/30/96	
Rainfall (in):	1.9	
Inflow #1(cf):	35370	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd05.306
Parameter	Inflow Concentration	Load(in), g
BOD 5	12	
COD	41	
Cadmium, Total	0.005	
Carbon,Tot. Organic	13.6	13620.14
Chromium, Total	0.05	50.07
Lead, Total-AA	0.025	25.04
Nit., nitrite/nitrate	0.661	661.98
Nitrogen, Kjeldahl	1.344	1345.99
Nitrogen, Total	2.005	2007.97
Phosphorus,Total	0.277	277.41
Phosphorus, Ortho	0.144	144.21
Residue, Non-filt-TSS	66	66097.75
Solids, Settleable	0.2	200.30
Zinc, Total	0.07	70.10
Special Notes:		
Entered by (initials)	JMS	
Date entered	6/25/96	

MWPND06.046

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	6/4/96	
Rainfall (in):	.56"	
Inflow #1(cf):	3680	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd06.046
Parameter	Inflow Concentration	Load(in), g
BOD 5	17	
COD	38	
Cadmium, Total	0.005	
Carbon,Tot. Organic	14.9	1552.54
Chromium, Total	0.11	11.46
Lead, Total-AA	0.025	2.60
Nit., nitrite/nitrate	0.781	81.38
Nitrogen, Kjeldahl	1.214	126.50
Nitrogen, Total	1.995	207.87
Phosphorus,Total	0.21	21.88
Phosphorus, Ortho	0.211	21.99
Residue, Non-filt-TSS	30	3125.91
Solids, Settleable	0.05	5.21
Zinc, Total	0.05	5.21
Special Notes:		
Entered by (initials)	JMS	
Date entered	7/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	6/7/96	
Rainfall (in):	0.93	
Inflow #1(cf):	7630	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd06.076
Parameter	Inflow Concentration	Load(in), g
BOD 5	8	
COD	43	
Cadmium, Total	0.005	
Carbon,Tot. Organic	10.8	2333.22
Chromium, Total	0.005	1.08
Lead, Total-AA	0.025	5.40
Nit., nitrite/nitrate	0.365	78.85
Nitrogen, Kjeldahl	1.035	223.60
Nitrogen, Total	1.4	302.45
Phosphorus,Total	0.206	44.50
Phosphorus, Ortho	0.133	28.73
Residue, Non-filt-TSS	15	3240.59
Solids, Settleable	0.05	10.80
Zinc, Total	0.03	6.48
Special Notes:		
Entered by (initials)	JMS	
Date entered	7/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	6/26/96	
Rainfall (in):	.57	
Inflow #1(cf):	2510	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd06.266
Parameter	Inflow Concentration	Load(in), g
BOD 5	13	
COD	50	
Cadmium, Total	0.005	
Carbon,Tot. Organic	14.9	1058.93
Chromium, Total	0.005	0.36
Lead, Total-AA	0.025	1.78
Nit., nitrite/nitrate	0.299	21.25
Nitrogen, Kjeldahl	*	#VALUE!
Nitrogen, Total	#VALUE!	#VALUE!
Phosphorus,Total	0.201	14.28
Phosphorus, Ortho	0.14	9.95
Residue, Non-filt-TSS	19	1350.31
Solids, Settleable	0.05	3.55
Zinc, Total	0.04	2.84
Special Notes:		
Entered by (initials)	JMS	
Date entered	7/25/96	

MWPND08.086

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	8/8/96	
Rainfall (in):	1.87"	
Inflow #1(cf):	13230	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd08.086
Parameter	Inflow Concentration	Load(in), g
BOD 5	21	
COD	63	
Cadmium, Total	0.005	
Carbon,Tot. Organic	15.3	5731.38
Chromium, Total	0.005	1.87
Lead, Total-AA	0.025	9.36
Nit., nitrite/nitrate	0.562	210.53
Nitrogen, Kjeldahl	1.657	620.71
Nitrogen, Total	2.219	831.24
Phosphorus,Total	0.398	149.09
Phosphorus, Ortho	0.196	73.42
Residue, Non-filt-TSS	38	14234.79
Solids, Settleable	0.05	18.73
Zinc, Total	0.07	26.22
Special Notes:		
Entered by (initials)	JMS	
Date entered	9/25/96	

MWPND08.196

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	8/19/96	
Rainfall (in):	0.40"	
Inflow #1(cf):	2450	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		8/19/96

Parameter	Inflow Concentration	Load(in), g
BOD 5	14	
COD	14	
Cadmium, Total	0.005	
Carbon,Tot. Organic	19.6	1359.66
Chromium, Total	0.005	0.35
Lead, Total-AA	0.05	3.47
Nit., nitrite/nitrate	0.644	44.67
Nitrogen, Kjeldahl	0.4	27.75
Nitrogen, Total	1.044	72.42
Phosphorus,Total	0.2	13.87
Phosphorus, Ortho	0.197	13.67
Residue, Non-filt-TSS	12	832.44
Solids, Settleable	0.05	3.47
Zinc, Total	0.05	3.47

Special Notes:	
Entered by (initials)	JMS
Date entered	9/25/96

MWPND08.316

Raw Data : Standard Parameters		
Water Developmet Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	8/30/96	
Rainfall (in):	2.00"	
Inflow #1(cf):	35400	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd8.3096

Parameter	Inflow Concentration	Load(in), g
BOD 5	*	
COD	2	
Cadmium, Total	0.005	
Carbon,Tot. Organic	7	7016.31
Chromium, Total	0.005	5.01
Lead, Total-AA	0.05	50.12
Nit., nitrite/nitrate	0.2	200.47
Nitrogen, Kjeldahl	0.1	100.23
Nitrogen, Total	0.3	300.70
Phosphorus,Total	0.3	300.70
Phosphorus, Ortho	0.17	170.40
Residue, Non-filt-TSS	49	49114.20
Solids, Settleable	*	#VALUE!
Zinc, Total	0.06	60.14
Special Notes:		
Entered by (initials)	JMS	
Date entered	9/25/96	

Raw Data : Standard Parameters		
Water Developmet Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	9/4/96	
Rainfall (in):	.43"	
Inflow #1(cf):	2400	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd9.046
Parameter	Inflow Concentration	Load(in), g
BOD 5	*	
COD	4	
Cadmium, Total	0.005	
Carbon,Tot. Organic	10	679.55
Chromium, Total	0.005	0.34
Lead, Total-AA	0.05	3.40
Nit., nitrite/nitrate	0.7	47.57
Nitrogen, Kjeldahl	2	135.91
Nitrogen, Total	2.7	183.48
Phosphorus,Total	0.2	13.59
Phosphorus, Ortho	0.19	12.91
Residue, Non-filt-TSS	130	8834.10
Solids, Settleable	5	339.77
Zinc, Total	0.06	4.08
Special Notes:		
Entered by (initials)	JMS	
Date entered	9/25/96	

MWPND09.186

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunders		
Structure:	620 wetpond	
Event Date:	9/18/96	
Rainfall (in):	1.11	
Inflow #1(cf):	22190	
Inflow #2(cf):		
Outflow (cf):	*	
Filename: I:\BMELTON\SWQDATA\RAWDATA\		mwpnd9.1896
Parameter	Inflow Concentration	Load(in), g
BOD 5	8	
COD	2	
Cadmium, Total	0.005	
Carbon,Tot. Organic	8	5026.38
Chromium, Total	0.005	3.14
Lead, Total-AA	0.05	31.41
Nit., nitrite/nitrate	0.482	302.84
Nitrogen, Kjeldahl	0.5	314.15
Nitrogen, Total	0.982	616.99
Phosphorus,Total	0.4	251.32
Phosphorus, Ortho	0.177	111.21
Residue, Non-filt-TSS	261	163985.53
Solids, Settleable	0.5	314.15
Zinc, Total	0.05	31.41
Special Notes:		
Entered by (initials)	JMS	
Date entered	10/25/96	

Raw Data : Standard Parameters		
Water Development Board Grant		
LCRA Project Manager: Geoff Saunder		
Structure:	620 wetpond	
Event Date:		
Rainfall (in):	9/20/96	
Inflow #1(cf):	1.72	
Inflow #2(cf):	22320	
Outflow (cf):		
Filename: I:\BMELTON\SWQDATA\RAWDATA\	*	
		mwpnd09.206
Parameter		
	Inflow Concentration	Load(in), g
BOD 5		
COD	8	
Cadmium, Total	5	
Carbon,Tot. Organic	0.005	
Chromium, Total	7	4423.85
Lead, Total-AA	0.005	3.16
Nit., nitrite/nitrate	0.05	31.60
Nitrogen, Kjeldahl	0.409	258.48
Nitrogen, Total	1	631.98
Phosphorus,Total	1.409	890.46
Phosphorus, Ortho	*	#VALUE!
Residue, Non-filt-TSS	*	#VALUE!
Solids, Settleable	75	47398.34
Zinc, Total	0.1	63.20
	0.04	25.28
Special Notes:		
Entered by (initials)		
Date entered	JMS	
	10/25/96	

Appendix B

SEDIMOT II Modeling Results

```
************************************************************
                     SEDIMOT II
************************************************************



     *********************************************
       WATERSHED IDENTIFICATION CODE
       ------------------------------
       WETP0306.OUT
     *********************************************



============================= STORM  INPUT =============================

QUESTION
  NO.

   1. STORM TYPE -                       SCS'S TYPE 2
   2. RAINFALL DEPTH -                       3.00 INCHES
   3. STORM DURATION -                        6.00 HOURS
   4. TIME INCREMENT -                       0.10 HOURS

=========================================================================



============================ WATERSHED DATA ============================

QUESTION
  NO.
   1. NUMBER OF JUNCTIONS - 1
   2. JUNCTION     NUMBER OF BRANCHES

       1           1
   3. COMPUTATION - BOTH HYDROLOGY AND SEDIMENTOLOGY

=========================================================================



========================= SEDIMENTOLOGY INPUTS =========================
```

```
QUESTION
 NO.
  1. SPECIFIC GRAVITY -                              2.60
  2. COEFFICIENT FOR DISTRIBUTING SEDIMENT LOAD -             2.00
  3. SUBMERGED BULK SPECIFIC GRAVITY -                   1.18
  4. NUMBER OF PARTICLE SIZE DISTRIBUTIONS -              1
  5. NUMBER OF DATA VALUES PER PARTICLE SIZE DISTRIBUTION -     15

==================================================================================


=================== INPUT PARTICLE SIZE DISTRIBUTIONS ====================

            VALUE
             NO.     SIZE, MM

              1      0.4100
              2      0.3000
              3      0.1800
              4      0.1600
              5      0.0750
              6      0.0180
              7      0.0110
              8      0.0090
              9      0.0070
             10       0.0050
             11       0.0038
             12       0.0028
             13       0.0020
             14       0.0012
             15       0.0001

==================================================================================


===================== PERCENT FINER DISTRIBUTIONS =======================

VALUE              PARTICLE SIZE #
 NO.
      1
 1    99.00
 2    98.50
 3    98.00
```

```
   4   97.00
   5   96.00
   6   89.90
   7   87.00
   8   80.00
   9   74.90
  10   67.50
  11   61.00
  12   54.00
  13   48.00
  14   40.00
  15    0.00

 ==========================================================================


 ================== STRUCTURE INPUT FOR JUNCTION #1 ====================

           BRANCH      NUMBER OF STRUCTURES

             1            1

 ==========================================================================


 ================ BETWEEN STRUCTURE ROUTING PARAMETERS ================
 BRANCH         BETWEEN                  PARAMETERS
  NO.                      1      2      3
                         TIME  MUSK. K   MUSK. X,
  1  PRIOR J OR S TO STRUCTURE 1   0.50    0.50    0.25
 ==========================================================================


 ================== STRUCTURE DATA FOR JUNCTION #1 ====================
 QUESTION
  NO.
  1. NUMBER OF SUBWATERSHEDS -                 1
  2. TYPE OF SEDIMENT CONTROL STRUCTURE -           POND
```

```
         ************************
           JUNCTION  1, BRANCH  1, STRUCTURE  1
         ************************


      *** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

 WATER   AREA   CURVE    TC     TT  ROUTING COEFFICIENTS  UNIT
 SHED    ACRES  NUMBER   HR     HR     K-HRS     X,     HYDRO
 ----------------------------------------------------------------
   1     9.50   90.00  0.500  0.000   0.500     0.25    1.0


      *** SEDIMENT INPUT VALUES FOR SUBWATERSHEDS ***

 WATER  SEG   SOIL   LENGTH   SLOPE   CP     PART   SURF
 SHED   NUM    K      FEET     PCT   VALUE   OPT    COND
 -------------------------------------------------------------------
   1     1   0.50    500.0    0.10   0.003   1.0    0.0


      ***** GENERATED DATA FOR INPUT INTO STRUCTURE 1  *****


        *** PARTICLE SIZE DISTRIBUTION OF SEDIMENT ***

 SIZE,MM           0.4100   0.3000   0.1800   0.1600   0.0750   0.0180
 PERCENT FINER   100.0000 100.0000 100.0000 100.0000 100.0000 100.0000

 SIZE,MM           0.0110   0.0090   0.0070   0.0050   0.0038   0.0028
 PERCENT FINER   100.0000  99.1568  92.8355  83.6635  75.6070  66.9308

 SIZE,MM           0.0020   0.0012   0.0001
 PERCENT FINER    59.4941  49.5784   0.0000


         *** HYDROGRAPH AND SEDIMENT GRAPH ***
          (TWO CONSECUTIVE VALUES PER LINE)
```

```
TIME   DISCHARGE   SED DISC ******* TIME   DISCHARGE   SED DISC
(HR)   (CFS)       (MG/L)   *   (HR)   (CFS)       (MG/L)
--------------------------------*----------------------------------
0.00    0.000       0.000   *   0.10    0.000       0.000
0.20    0.000       0.000   *   0.30    0.000       0.000
0.40    0.000       0.000   *   0.50    0.000       0.000
0.60    0.000       0.000   *   0.70    0.000       0.000
0.80    0.000       0.000   *   0.90    0.000       0.000
1.00    0.000       0.000   *   1.10    0.000       0.000
1.20    0.000       0.000   *   1.30    0.000       0.000
1.40    0.000       0.000   *   1.50    0.000       0.000
1.60    0.000       0.000   *   1.70    0.000       0.000
1.80    0.000       0.000   *   1.90    0.001       0.006
2.00    0.005       0.030   *   2.10    0.016       0.099
2.20    0.039       0.238   *   2.30    0.076       0.467
2.40    0.129       0.793   *   2.50    0.200       1.228
2.60    0.292       1.793   *   2.70    0.409       2.517
2.80    0.562       3.456   *   2.90    0.795       4.883
3.00    1.257       7.726   *   3.10    2.232      13.716
3.20    3.995      24.552   *   3.30    6.602      40.576
3.40    9.720      59.738   *   3.50   12.688      77.978
3.60   14.752      90.666   *   3.70   15.426      94.807
3.80   14.730      90.531   *   3.90   13.175      80.973
4.00   11.374      69.907   *   4.10    9.725      59.772
4.20    8.330      51.197   *   4.30    7.130      43.819
4.40    6.074      37.333   *   4.50    5.157      31.696
4.60    4.383      26.941   *   4.70    3.750      23.048
4.80    3.247      19.956   *   4.90    2.863      17.598
5.00    2.578      15.843   *   5.10    2.362      14.516
5.20    2.189      13.456   *   5.30    2.044      12.560
5.40    1.919      11.792   *   5.50    1.811      11.131
5.60    1.714      10.534   *   5.70    1.619       9.950
5.80    1.523       9.360   *   5.90    1.431       8.793
6.00    1.350       8.299   *   6.10    1.286       7.907
6.20    1.239       7.615   *   6.30    1.204       7.402
6.40    1.175       7.219   *   6.50    1.136       6.983
6.60    1.069       6.568   *   6.70    0.958       5.885
6.80    0.806       4.952   *   6.90    0.637       3.914
7.00    0.479       2.943   *   7.10    0.350       2.148
7.20    0.252       1.549   *   7.30    0.180       1.108


================================ POND INPUT ================================
QUESTION
  NO.
```

```
 1. TIME INCREMENT OF THE ROUTED HYDROGRAPH -          0.10 HOURS
 2. NON-IDEAL SETTLING CORRECTION FACTOR -           1.00
 3. PERCENT OF PERMANENT POOL THAT IS DEAD SPACE -     16.00
 4. OUTFLOW WITHDRAWAL OPTION -                    UNIFORM
 5. INFLOW VERTICAL CONCENTRATION -                  COMP. MIXED
 6. NUMBER OF STAGE POINTS -                  14
 7. NUMBER OF ROUTED HYDROGRAPH POINTS -            250
 8. STAGE-DISCHARGE OPTION -                  INPUT
 9. OUTPUT OPTION -                      GRAPHS
10. NUMBER OF CONTINUOUS STIRRED REACTORS             0

==========================================================================

=========================== POND STAGE DATA ===========================

            STAGE POINT       VALUE

                 1          0.00
                 2          1.00
                 3          2.00
                 4          3.00
                 5          4.00
                 6          5.00
                 7          6.00
                 8          7.00
                 9          7.50
                10          7.60
                11          7.70
                12          7.80
                13          7.90
                14          8.00

==========================================================================

=========================== POND AREA DATA ===========================

            AREA POINT        VALUE

                 1          0.00
                 2          0.00
                 3          0.02
```

4	0.05
5	0.09
6	0.17
7	0.39
8	0.77
9	1.02
10	1.09
11	1.16
12	1.23
13	1.30
14	1.37

POND DISCHARGE DATA

DISCHARGE POINT	VALUE
1	0.00
2	0.00
3	0.00
4	0.00
5	0.00
6	0.00
7	0.01
8	0.01
9	0.01
10	2.42
11	6.84
12	12.55
13	19.31
14	26.96

```
  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                POND RESULTS

  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *



          ***** BASIN GEOMETRY *****

 STAGE     AREA    AVERAGE DEPTH  DISCHARGE    CAPACITY
 (FT)    (ACRES)     (FT)     (CFS)    (ACRES-FT)
-----------------------------------------------------------
  0.00    0.000     0.00      0.00       0.00
  1.00    0.001     0.50      0.00       0.00
  2.00    0.021     0.63      0.00       0.01
  3.00    0.049     1.25      0.00       0.05
  4.00    0.092     1.80      0.00       0.12
  5.00    0.174     2.23      0.00       0.25
  6.00    0.392     2.41      0.01       0.53
  7.00    0.766     2.55      0.01       1.11
  7.50    1.022     2.67      0.01       1.56
  7.60    1.092     2.69      2.42       1.66
  7.70    1.162     2.71      6.84       1.78
  7.80    1.233     2.74     12.55       1.90
  7.90    1.303     2.76     19.31       2.02
  8.00    1.373     2.78     26.96       2.16



          ***** STORM EVENT SUMMARY *****
          ------------------------------

TURBULENCE FACTOR                   =    1.00
PERMANENT POOL CAPACITY                =    0.250 ACRE-FT
DEAD STORAGE                    =   16.00 PERCENT
TIME INCREMENT OUTFLOW                 =    0.10   HRS
VISCOSITY                   =   0.009  CM**2/SEC
INFLOW RUNOFF VOLUME                 =    1.571  ACRE-FT
OUTFLOW ROUTED VOLUME                  =    0.276  ACRE-FT
STORM VOLUME DISCHARGED                 =    0.073  ACRE-FT
POND VOLUME AT PEAK STAGE               =    1.625  ACRE-FT
PEAK STAGE                    =    7.562  FT
```

```
PEAK INFLOW RATE                          =    15.426  CFS
PEAK DISCHARGE RATE                       =     1.508  CFS
PEAK INFLOW SEDIMENT CONCENTRATION        =    94.81   MG/L
PEAK EFFLUENT SEDIMENT CONCENTRATION      =    22.34   MG/L
PEAK EFFLUENT SETTLEABLE CONCENTRATION    =     0.0000 ML/L
PEAK EFFLUENT SETTLEABLE CONCENTRATION    =     0.01   MG/L
STORM AVERAGE EFFLUENT CONCENTRATION      =    11.79   MG/L
AVERAGE EFFLUENT SEDIMENT CONCENTRATION   =     3.05   MG/L
BASIN TRAP EFFICIENCY                     =    98.99   PERCENT
DETENTION TIME OF FLOW WITH SEDIMENT      =    20.94   HRS
DETENTION TIME FROM HYDROGRAPH CENTERS    =     2.62   HRS
DETENTION TIME INCLUDING STORED FLOW      =    20.76   HRS
SEDIMENT LOAD DISCHARGED                  =     0.00   TONS
PERIOD OF SIGNIFICANT CONCENTRATION       =    18.00  HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE
 CONCENTRATION DURING PERIOD OF
 SIGNIFICANT CONCENTRATION                =     0.00   ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE
 CONCENTRATION DURING PEAK 24 HOUR
 PERIOD                         =     0.00   ML/L
ARITHMETIC AVERAGE SETTLEABLE
 CONCENTRATION DURING PERIOD OF
 SIGNIFICANT CONCENTRATION                =     0.00   ML/L
ARITHMETIC AVERAGE SETTLEABLE
 CONCENTRATION DURING PEAK 24 HOUR
 PERIOD                         =     0.00   ML/L


        *** PARTICLE SIZE DISTRIBUTION OF SEDIMENT ***

SIZE,MM          0.4100   0.3000   0.1800   0.1600   0.0750   0.0180
PERCENT FINER    100.0000 100.0000 100.0000 100.0000 100.0000 100.0000

SIZE,MM          0.0110   0.0090   0.0070   0.0050   0.0038   0.0028
PERCENT FINER    100.0000 100.0000  99.7801  96.6674  91.2589  83.7455

SIZE,MM          0.0020   0.0012   0.0001
PERCENT FINER    75.2818  63.0812  0.0000


        *** HYDROGRAPH AND SEDIMENT GRAPH ***
         (TWO CONSECUTIVE VALUES PER LINE)

TIME   DISCHARGE   SED DISC ******* TIME   DISCHARGE   SED DISC
(HR)   (CFS)       (MG/L)   *       (HR)   (CFS)       (MG/L)
```

```
--------------------------------*--------------------------------
   0.00      0.000      0.000  *   0.10      0.000      0.000
   0.20      0.000      0.000  *   0.30      0.000      0.000
   0.40      0.000      0.000  *   0.50      0.000      0.000
   0.60      0.000      0.000  *   0.70      0.000      0.000
   0.80      0.000      0.000  *   0.90      0.000      0.000
   1.00      0.000      0.000  *   1.10      0.000      0.000
   1.20      0.000      0.000  *   1.30      0.000      0.000
   1.40      0.000      0.000  *   1.50      0.000      0.000
   1.60      0.000      0.000  *   1.70      0.000      0.000
   1.80      0.000      0.000  *   1.90      0.000      0.000
   2.00      0.000      0.000  *   2.10      0.000      0.000
   2.20      0.000      0.000  *   2.30      0.000      0.000
   2.40      0.000      0.000  *   2.50      0.000      0.000
   2.60      0.000      0.000  *   2.70      0.000      0.000
   2.80      0.000      0.000  *   2.90      0.001      0.000
   3.00      0.001      0.000  *   3.10      0.001      0.000
   3.20      0.002      0.000  *   3.30      0.004      0.000
   3.40      0.006      0.000  *   3.50      0.010      0.000
   3.60      0.010      0.000  *   3.70      0.010      0.000
   3.80      0.010      0.000  *   3.90      0.010      0.000
   4.00      0.010      0.000  *   4.10      0.010      0.000
   4.20      0.010      0.000  *   4.30      0.010      0.000
   4.40      0.010      0.000  *   4.50      0.010      0.000
   4.60      0.010      0.000  *   4.70      0.010      0.000
   4.80      0.010      0.000  *   4.90      0.010      0.000
   5.00      0.316      0.000  *   5.10      0.687      0.000
   5.20      0.960      0.000  *   5.30      1.159      0.000
   5.40      1.300      0.000  *   5.50      1.397      0.000
   5.60      1.460      0.000  *   5.70      1.495      0.000
   5.80      1.508      0.000  *   5.90      1.503      0.000
   6.00      1.483      0.000  *   6.10      1.455      0.000
   6.20      1.422      0.000  *   6.30      1.387      0.000
   6.40      1.353      0.000  *   6.50      1.319      0.000
   6.60      1.281      0.000  *   6.70      1.235      0.000
   6.80      1.174      0.000  *   6.90      1.096      0.000
   7.00      1.003      0.483  *   7.10      0.902      2.101
   7.20      0.798      4.326  *   7.30      0.698      6.876
   7.40      0.593      9.629  *   7.50      0.491     12.132
   7.60      0.407     14.273  *   7.70      0.337     16.029
   7.80      0.279     17.407  *   7.90      0.231     18.452
   8.00      0.191     19.283  *   8.10      0.158     19.957
   8.20      0.131     20.502  *   8.30      0.108     20.940
   8.40      0.090     21.290  *   8.50      0.074     21.567
   8.60      0.061     21.785  *   8.70      0.051     21.954
```

8.80	0.042	22.083	*	8.90	0.035	22.179
9.00	0.029	22.249	*	9.10	0.024	22.296
9.20	0.020	22.325	*	9.30	0.016	22.339
9.40	0.014	22.341	*	9.50	0.011	22.333
9.60	0.010	22.318	*	9.70	0.010	22.299
9.80	0.010	22.280	*	9.90	0.010	22.261
10.00	0.010	22.243	*	10.10	0.010	22.226
10.20	0.010	22.209	*	10.30	0.010	22.193
10.40	0.010	22.177	*	10.50	0.010	22.160
10.60	0.010	22.144	*	10.70	0.010	22.129
10.80	0.010	22.115	*	10.90	0.010	22.101
11.00	0.010	22.088	*	11.10	0.010	22.075
11.20	0.010	22.063	*	11.30	0.010	22.051
11.40	0.010	22.039	*	11.50	0.010	22.028
11.60	0.010	22.017	*	11.70	0.010	22.007
11.80	0.010	21.997	*	11.90	0.010	21.987
12.00	0.010	21.978	*	12.10	0.010	21.969
12.20	0.010	21.960	*	12.30	0.010	21.950
12.40	0.010	21.940	*	12.50	0.010	21.931
12.60	0.010	21.922	*	12.70	0.010	21.913
12.80	0.010	21.905	*	12.90	0.010	21.896
13.00	0.010	21.888	*	13.10	0.010	21.881
13.20	0.010	21.873	*	13.30	0.010	21.866
13.40	0.010	21.858	*	13.50	0.010	21.850
13.60	0.010	21.843	*	13.70	0.010	21.836
13.80	0.010	21.829	*	13.90	0.010	21.822
14.00	0.010	21.816	*	14.10	0.010	21.809
14.20	0.010	21.803	*	14.30	0.010	21.798
14.40	0.010	21.792	*	14.50	0.010	21.787
14.60	0.010	21.782	*	14.70	0.010	21.777
14.80	0.010	21.772	*	14.90	0.010	21.768
15.00	0.010	21.763	*	15.10	0.010	21.759
15.20	0.010	21.755	*	15.30	0.010	21.752
15.40	0.010	21.748	*	15.50	0.010	21.745
15.60	0.010	21.742	*	15.70	0.010	21.739
15.80	0.010	21.737	*	15.90	0.010	21.734
16.00	0.010	21.732	*	16.10	0.010	21.730
16.20	0.010	21.729	*	16.30	0.010	21.727
16.40	0.010	21.726	*	16.50	0.010	21.724
16.60	0.010	21.723	*	16.70	0.010	21.722
16.80	0.010	21.722	*	16.90	0.010	21.721
17.00	0.010	21.720	*	17.10	0.010	21.724
17.20	0.010	21.727	*	17.30	0.010	21.731
17.40	0.010	21.735	*	17.50	0.010	21.739
17.60	0.010	21.743	*	17.70	0.010	21.747

```
  17.80    0.010    21.751  *  17.90    0.010    21.755
  18.00    0.010    21.760  *  18.10    0.010    21.764
  18.20    0.010    21.769  *  18.30    0.010    21.773
  18.40    0.010    21.778  *  18.50    0.010    21.783
  18.60    0.010    21.788  *  18.70    0.010    21.793
  18.80    0.010    21.798  *  18.90    0.010    21.804
  19.00    0.010    21.809  *  19.10    0.010    21.815
  19.20    0.010    21.820  *  19.30    0.010    21.826
  19.40    0.010    21.831  *  19.50    0.010    21.837
  19.60    0.010    21.843  *  19.70    0.010    21.849
  19.80    0.010    21.855  *  19.90    0.010    21.861
  20.00    0.010    21.867  *  20.10    0.010    21.874
  20.20    0.010    21.880  *  20.30    0.010    21.886
  20.40    0.010    21.893  *  20.50    0.010    21.899
  20.60    0.010    21.906  *  20.70    0.010    21.913
  20.80    0.010    21.920  *  20.90    0.010    21.927
  21.00    0.010    21.934  *  21.10    0.010    21.941
  21.20    0.010    21.949  *  21.30    0.010    21.956
  21.40    0.010    21.964  *  21.50    0.010    21.971
  21.60    0.010    21.979  *  21.70    0.010    21.986
  21.80    0.010    21.994  *  21.90    0.010    22.002
  22.00    0.010    22.010  *  22.10    0.010    22.018
  22.20    0.010    22.026  *  22.30    0.010    22.034
  22.40    0.010    22.042  *  22.50    0.010    22.050
  22.60    0.010    22.058  *  22.70    0.010    22.066
  22.80    0.010    22.074  *  22.90    0.010    22.083
  23.00    0.010    22.091  *  23.10    0.010    22.099
  23.20    0.010    22.108  *  23.30    0.010    22.116
  23.40    0.010    22.125  *  23.50    0.010    22.134
  23.60    0.010    22.142  *  23.70    0.010    22.151
  23.80    0.010    22.160  *  23.90    0.010    22.168
  24.00    0.010    22.177  *  24.10    0.010    22.186
  24.20    0.010    22.195  *  24.30    0.010    22.202
  24.40    0.010    22.206  *  24.50    0.010    22.208
  24.60    0.010    22.211  *  24.70    0.010    22.213
  24.80    0.010    22.216  *  24.90    0.010    22.218




         *** RUN COMPLETED ****
```

Appendix C

Monitoring Well Installation Report

JN JONES AND NEUSE, INC.
Environmental and Engineering Services

July 9, 1993

Mr. Jeff Saunders
Clean Colorado Project
Lower Colorado River Authority
P.O. Box 220
Austin, Texas 78767-0220

Re: Installation of Monitor Wells Near Mansfield Dam
LCRA Purchase Order No. 109317; Blanket Release No. ES108
JN026423.1

Dear Mr. Saunders:

This letter report documents the installation of four (4) monitor wells by Jones and Neuse, Inc. (JN) for the Lower Colorado River Authority (LCRA) near Mansfield Dam on June 23 and 24, 1993. The well installations were conducted under the direction of Mr. Bruce Melton - LCRA Project Manager and Mr. Jeff Saunders who served as field geologist for the LCRA during this project. This report provides a brief introduction to the project and summarizes the procedures used to install the monitor wells. A site map showing the location of the wells is included in the report as well as Monitor Well Construction Reports and Driller's Records of Completion.

INTRODUCTION

The Texas Department of Transportation (TxDOT) is currently constructing improvements to a section of RR 620 near Mansfield Dam. In addition to widening the highway, the project includes a new four-lane bridge over Lake Austin immediately downstream of the dam. The LCRA has received a Matching Fund Grant from the Texas Water Development Board (TWDB) to construct a water quality basin which will collect and treat stormwater runoff from the new bridge as well as a portion of the improved highway. The location of the project is shown on Figure 1. The TWDB grant provides for the construction of a wet retention pond designed to provide an artificial wetland as well as "treatment of non-point source pollution using wetland/aquatic ecosystem best management practices". The wet pond will allow the LCRA to monitor stormwater runoff from the roadway for contaminants such as petroleum hydrocarbons and nutrients which adversely impact water quality in the Colorado River.

JN was retained by the LCRA to install monitor wells on the perimeter of the wet pond. The purpose of the monitor wells is to allow the LCRA to determine if any contaminants are migrating through subsurface soils and potentially into Lake Austin and also to assess what impact, if any, the pond may have on the potentiometric surface of the groundwater. Three (3) monitor wells were placed downgradient of the pond. The fourth well was installed upgradient of the pond. This well is required to establish a hydraulic gradient and will also provide an indication of background conditions. The location of the monitor wells were staked in the field prior to drilling by Mr. Melton and Mr. Saunders. The exact location of each well is shown on Figure 2.

MONITOR WELL INSTALLATION PROCEDURES

Each of the monitor wells was installed using JN's Mobile B-57 truck-mounted drill rig. The driller and the driller's helper on this project are both licensed by the Texas Water Well Drillers Board. Mr. Saunders served as the field geologist. All equipment used on this project was decontaminated prior to mobilization. The initial borehole was drilled utilizing 8 ¾-inch diameter, continuous flight, hollow-stem augers. Split spoon core barrels were used to provide a soil boring log describing the lithologies encountered during drilling. The borehole was over-reamed to the desired depth (auger refusal) using 12-inch diameter hollow stem augers to accommodate the installation of the four-inch diameter monitor well components through the larger augers.

The appropriate interval to be screened in each well was determined based on field observations of depth to saturation made during the soil core sampling activities. Screen material consisted of 0.010-mil slotted PVC pipe. Upon determining the appropriate depth interval for well screen placement, the well casing and well screen were assembled and lowered into the borehole through the hollow stem augers. A pre-sieved (10-20 sieve) silica sand pack was then placed into the annulus space through the hollow-stem augers as they were removed from the borehole. The sand pack was placed into the annulus space to a minimum of two feet above the top of the well screen. A minimum of two feet of one-quarter inch diameter bentonite pellets were then placed above the sand filter pack. Potable water was added to the bentonite pellets allowing sufficient time to hydrate and expand prior to sealing the upper portion of the well annulus with a bentonite/cement grout. Each well was properly developed by hand bailing and then equipped with an air-tight locking cap. The surface completion for each well consists of a flush-mounted 12-inch diameter cast iron manhole with a bolted cover set in a concrete pad measuring five feet by five feet.

RELATED ACTIVITIES

On June 25, 1993, the location and relative elevation of each monitor well was surveyed by a JN survey crew. Since horizontal and vertical control has not been established at the site, arbitrary coordinates and elevations were used to complete this task. Table 1 provides coordinates for each well based on the coordinate system established in the field by the survey crew. The instrument setup point was assigned coordinates of 600.0 Northing and 700.0 Easting. The backsight used to establish a reference bearing was the northeast corner of the overflow structure. This bearing was arbitrarily assigned a bearing of N 19°00' E. All coordinates and distances shown in Table 1 were calculated using coordinate geometry based on the instrument point and backsight described above. The location of the wells was established relative to each other, the four corners of the wet pond and the overflow structure and the east bank of the Colorado River (Lake Austin).

Relative elevations for each well were established based on a benchmark found on the northeast concrete abutment of the low water crossing bridge as shown on Figure 2. The benchmark was assigned an elevation of 100.00′. The elevations for top of casing, top of manhole and natural ground adjacent to the concrete pad were surveyed for each well. This information is summarized in Table 1. The water surface elevation for Lake Austin was also surveyed. In addition, water levels were measured in each well by LCRA personnel on June 29, 1993. These water levels were converted to elevations relative to site datum and are summarized on Table 1. A potentiometric surface map was developed from these elevations and is included in this report as Figure 3.

We are pleased to have the opportunity to serve the LCRA on this very important project. Hopefully the information obtained from this project will enable the LCRA to further its efforts to address non-point source pollution in the Colorado River. Please do not hesitate to contact me at (512) 327-9840 (Ext. 122) if you need additional information. Please let me know if I can assist you with water quality sampling and water level guaging or other matters pertaining to this or other Clean Colorado Projects.

Sincerely,

JONES AND NEUSE, INC.

Kevin R. Kadlecek

Kevin R. Kadlecek, P.E.
Project Engineer

KRK/kfd:59/SAUNDERS

Attachments

cc: Mr. Bruce Melton

SOURCE: HIGHLAND LAKES OF CENTRAL TEXAS,
CONTENTIAL MAP INC., (1982)

SCALE IN MILES

0 0.5 1.0

N

LCRA THE POWER TO MAKE A DIFFERENCE

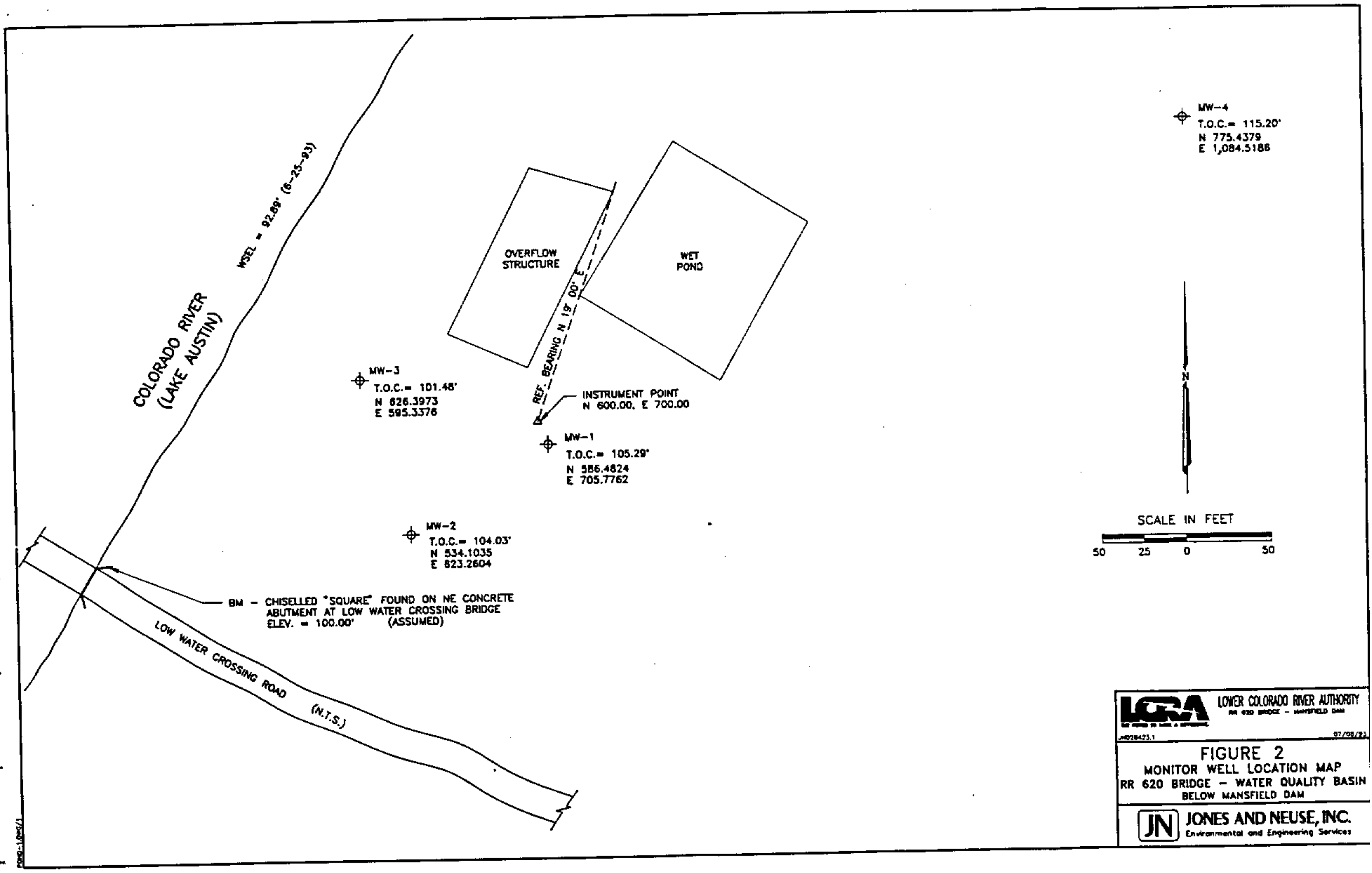
LOWER COLORADO RIVER AUTHORITY
RR 620 BRIDGE-WATER QUALITY BASIN

JN 01-0264-23.1

FIGURE 1

SITE LOCATION MAP

JN JONES AND NEUSE, INC.
Environmental and Engineering
Services



LOWER COLORADO RIVER AUTHORITY
RR 620 BRIDGE - MANSFIELD DAM

JN928423.1
07/08/93

FIGURE 2
MONITOR WELL LOCATION MAP
RR 620 BRIDGE - WATER QUALITY BASIN
BELOW MANSFIELD DAM

JONES AND NEUSE, INC.
Environmental and Engineering Services

TABLE 1
MONITOR WELL COORDINATES, ELEVATIONS, WATER LEVELS LCRA WET POND AT MANSFIELD DAM

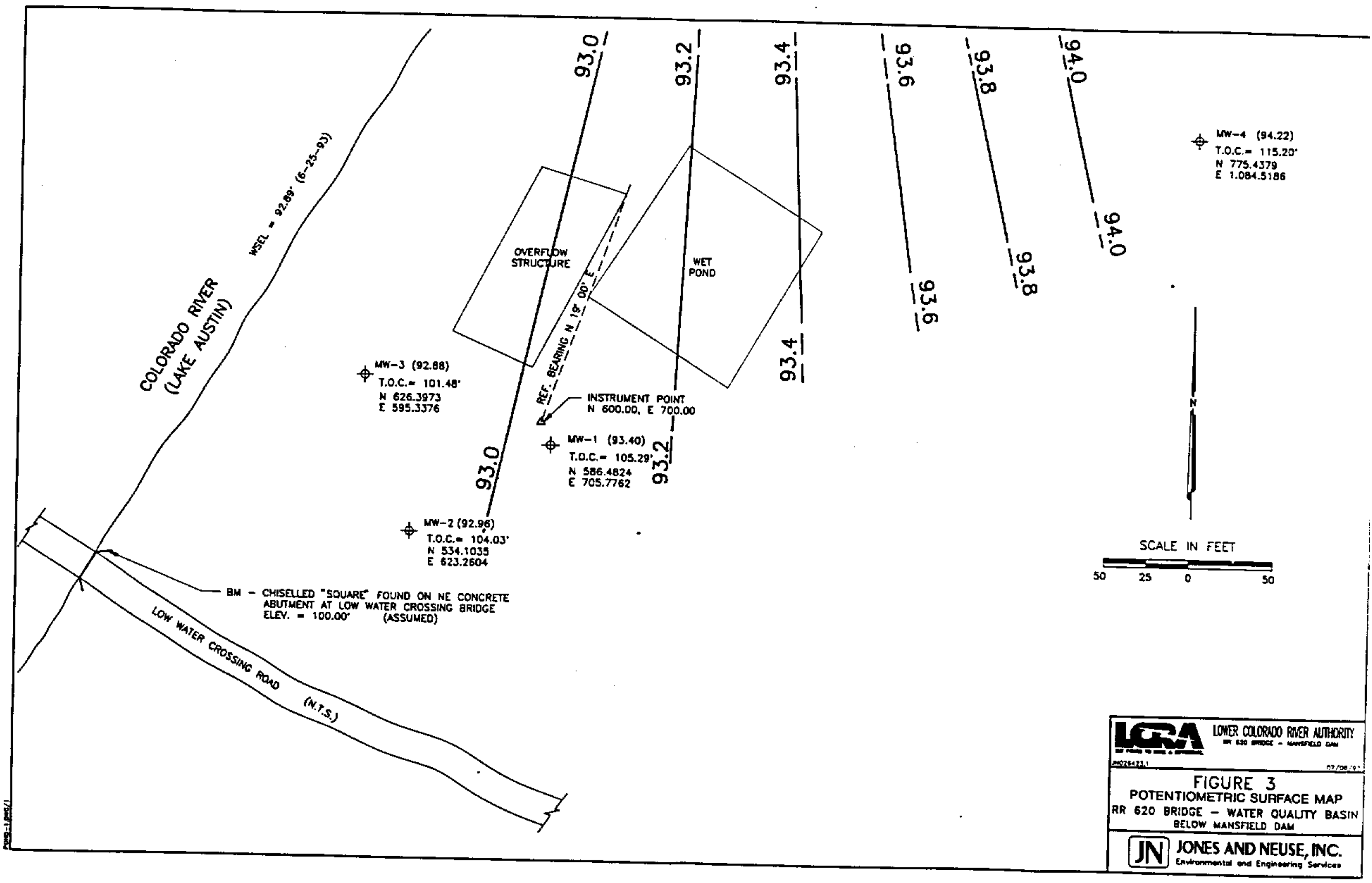
	Coordinates[1]		Horizontal Distance To (ft)				Elevations[2]			Water Levels[3] (6-29-93)	
	Northing	Easting	MW-1	MW-2	MW-3	MW-4	Top of Casing	Top of Manhole	Natural Ground	Depth Below T.O.C.	Elevation
MW-1	586.4824	705.7762	---	97.74	117.43	423.26	105.29	105.46	105.2	12.25	93.04
MW-2	534.1035	623.2604	97.74	---	96.42	520.58	104.03	104.21	104.1	11.07	92.96
MW-3	626.3973	595.3376	117.43	96.42	---	511.38	101.48	101.66	101.5	8.60	92.88
MW-4	775.4379	1,084.5186	423.26	520.58	511.38	---	115.20	115.49	115.2	20.98	94.22

NOTES:

(1) Based on instrument point at N 600.0, E 700.0; backsight NE corner of overflow structure, assumed bearing N 19° E.

(2) Benchmark found on NE concrete abutment at low water crossing bridge; "square" chiselled in concrete; assumed elevation = 100.00'.

(3) Lake Austin water surface elevation = 92.89 (6/25/93).



LOWER COLORADO RIVER AUTHORITY

RR 620 BRIDGE - MANSFIELD DAM

07/08/93

FIGURE 3

POTENTIOMETRIC SURFACE MAP

RR 620 BRIDGE - WATER QUALITY BASIN
BELOW MANSFIELD DAM

JONES AND NEUSE, INC.
Environmental and Engineering Services

ATTACHMENT A

MONITOR WELL CONSTRUCTION REPORTS

MONITOR WELL CONSTRUCTION

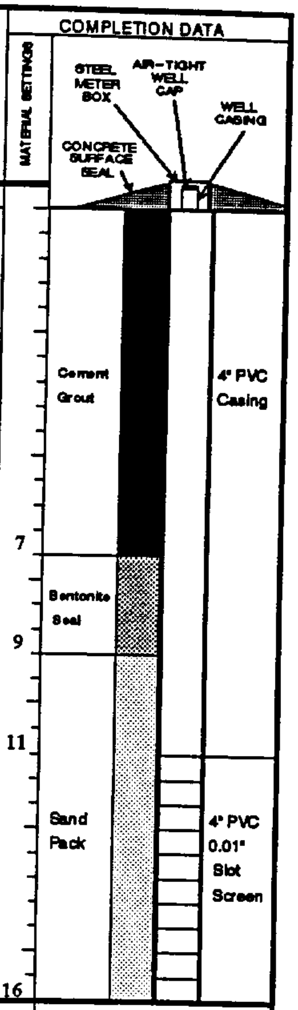
CLIENT: LCRA
JOB NO: 026423.1
WELL NO. MW-1
SITE: HWY 620 Bridge Wetpond
SHEET 1 OF 1
GEOLOGIST: Jeff Saunders
DRILLER: Mike McNitt
DATE: START: 6/23/93
FINISH: 6/23/93
DRILLING METHODS: Hollow Stem Auger with Core Barrel
DRILLING RIG TYPE: Mobile B-57
WELL COORDINATES: N 586.4824 E 705.7762
TOTAL DEPTH: 16 Feet
HOLE DIAMETER: 12 Inches
ELEVATIONS: GROUND: 105.20
PAD: N/A
TOC: 105.29
PROT. CSG: 105.46
WATER LEVEL: DEPTH: 12.25 Feet btoc
DATUM (2): 93.04
DATE: 6/29/93
TIME: 16:10

JN JONES AND NEUSE, INC.
Environmental and Engineering Consultants

LITHOLOGIC DESCRIPTION

DEPTH (FEET)	SAMPLE TYPE	SATURATED	ORGANIC VAPOR READING (ppm)	USCS SYMBOL (1)	STRATIGRAPHY	LITHOLOGIC DESCRIPTION
0.0						**Fill –** unconsolidated clay, sand and rock
5				SC		**Clayey Sand –** fine to medium grained, red-brown clay matrix, stiff, dry, occasional limestone cobbles, well-rounded
10						
12	▨			GP		**Gravel –** 1 mm – 3 mm quartz and chert, well-rounded, occasional cobbles up to 10 mm, no matrix
15	▨			SC		**Clayey Sand –** fine to medium grained, red-brown clay matrix moderately to highly plastic, saturated
						Limestone (Glen Rose Formation) Refusal at 16 Feet
17						BORING TERMINATED AT 16.0 FEET
20						
25						

COMPLETION DATA



(1) UNIFIED SOIL CLASSIFICATION SYSTEM
(2) BENCHMARK ELEVATION ESTABLISHED AT 100 FEET (ASSUMED)

LCRA-MW1.WK3

MONITOR WELL CONSTRUCTION

WELL NO. MW – 2

CLIENT: LCRA
JOB NO: 026423.1
SHEET 1 OF 1
SITE: HWY 620 Bridge Wetpond
DATE: START: 6/23/93 FINISH: 6/23/93
GEOLOGIST: Jeff Saunders
DRILLER: Mike McNitt
DRILLING RIG TYPE: Mobile B–57
DRILLING METHODS: Hollow Stem Auger with Core Barrel
TOTAL DEPTH: 17 Feet
HOLE DIAMETER: 12 Inches
SITE COORDINATES: N 534.1035 E 623.2604
ELEVATIONS: GROUND: 104.10 PAD: N/A TOC: 104.03 PROT. CSG: 104.21
WATER LEVEL: DEPTH: 11.07 Feet btoc
DATUM(2): 92.96
DATE: 6/29/93 TIME: 16:20

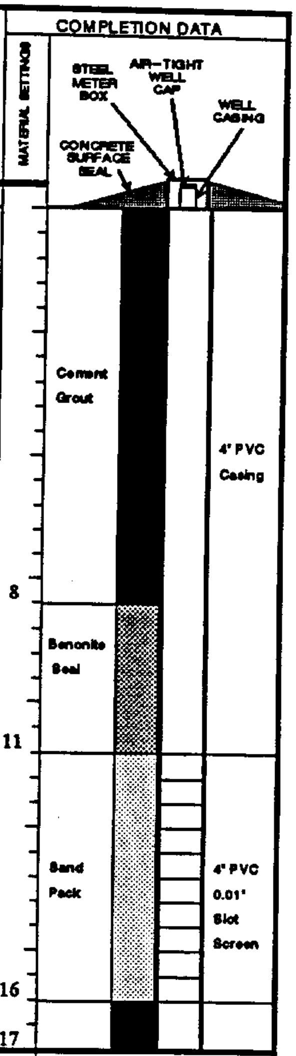
JN JONES AND NEUSE, INC.
Environmental and Engineering Consultants

LITHOLOGIC DESCRIPTION

DEPTH (FEET)	SAMPLE TYPE	SATURATED	ORGANIC VAPOR READING (ppm)	USCS SYMBOL (1)	STRATIGRAPHY	LITHOLOGIC DESCRIPTION
0.0						
4				SC		Clayey Sand – very fine to fine grained sand in clay matrix, red–brown, stiff, dry
6				SW		Sand – fine grained, no clay, friable, brown, dry
9				GC		Gravel – clay matrix, up to 2 mm pebbles in red–brown clay, stiff, moist
11				SC		Clayey Sand – very fine to fine grained sand in clay matrix, brown, moist
12		▨		CH		Gravely Clay – 1 mm to 2 mm pebbles in clay matrix, gray with tan mottling, stiff, moist
		▨		GP		Gravel – 1 mm to 5 mm pebbles, well–rounded quartz, fledspar, chert, and granite, no clay matrix, loose, unconsolidated
17		▨				Limestone (Glen Rose Formation) Refusal at 17 Feet

BORING TERMINATED AT 17.0 FEET

COMPLETION DATA



(1) UNIFIED SOIL CLASSIFICATION SYSTEM
(2) BENCHMARK ELEVATION ESTABLISHED AT 100 FEET (ASSUMED)

MONITOR WELL CONSTRUCTION

WELL NO. MW – 3
CLIENT: LCRA
JOB NO: 026423.1
SHEET 1 OF 1
SITE: HWY 620 Bridge Wetpond
DATE: START: 6/24/93 FINISH: 6/24/93
GEOLOGIST: Jeff Saunders
DRILLER: Mike McNitt
DRILLING RIG TYPE: Mobile B–57
DRILLING METHODS: Hollow Stem Auger with Core Barrel
TOTAL DEPTH: 12.5 Feet
HOLE DIAMETER: 12 Inches
SITE COORDINATES: N 626.3973 E 595.3376
ELEVATIONS: GROUND: 101.50 PAD: N/A TOC: 101.48 PROT. CSG: 101.66
WATER LEVEL: DEPTH: 8.60 Feet btoc
DATUM(2): 92.88
DATE: 6/29/93
TIME: 16:35

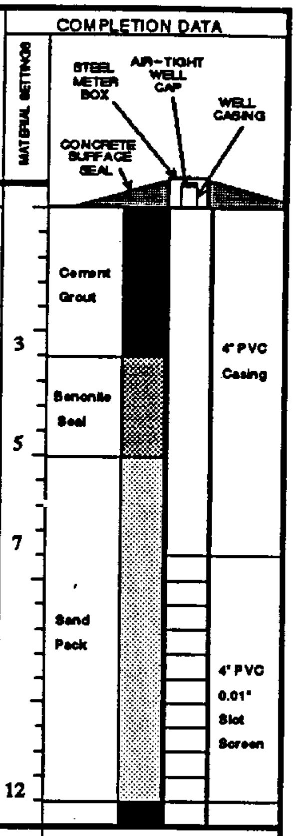
JN JONES AND NEUSE, INC.
Environmental and Engineering Consultants

LITHOLOGIC DESCRIPTION

DEPTH (FEET)	SAMPLE TYPE	SATURATED	ORGANIC VAPOR READING (ppm)	USCS SYMBOL (1)	STRATIGRAPHY	LITHOLOGIC DESCRIPTION
0.0						Fill – mixed sand, gravel and limestone rock
2				SC		Clayey Sand – very fine to fine grained, clay matrix, >50% sand, red–brown, dry
7				GW		Gravel – cobbles 10 mm to 30 mm, well–rounded quartz, dry
7.5				SW		Sand – medium grained, rounded quartz, no clay contents, loose, moist
8.5		▨		GP		Sandy Gravel – 50 mm cobbles with coarse sand, poorly graded, well–rounded quartz, feldspar, and chert, saturated
12.5						Limestone (Glen Rose Formation) Refusal at 12.5 Feet

BORING TERMINATED AT 12.5 FEET

COMPLETION DATA



(1) UNIFIED SOIL CLASSIFICATION SYSTEM
(2) BENCHMARK ELEVATION ELSTABISHED AT 100 FEET (ASSUMED)

LCRA–MW3.WK3

MONITOR WELL CONSTRUCTION

WELL NO. MW – 4
SHEET 1 OF 1
CLIENT: LCRA
JOB NO: 026423.1
SITE: HWY 620 Bridge Wetpond
DATE: START: 6/24/93 FINISH: 6/24/93
GEOLOGIST: Jeff Saunders
DRILLER: Mike McNitt
DRILLING RIG TYPE: Mobile B–57
DRILLING METHODS: Hollow Stem Auger with Core Barrel
TOTAL DEPTH: 23 Feet
HOLE DIAMETER: 12 Inches
SITE COORDINATES: N 775.4379 E 1884.5186
ELEVATIONS: GROUND: 115.20 PAD: N/A TOC: 115.2 PROT. CSG: 115.49
WATER LEVEL: DEPTH: 20.98 Feet btoc
DATUM(2): 94.22 DATE: 6/29/93 TIME: 16:45

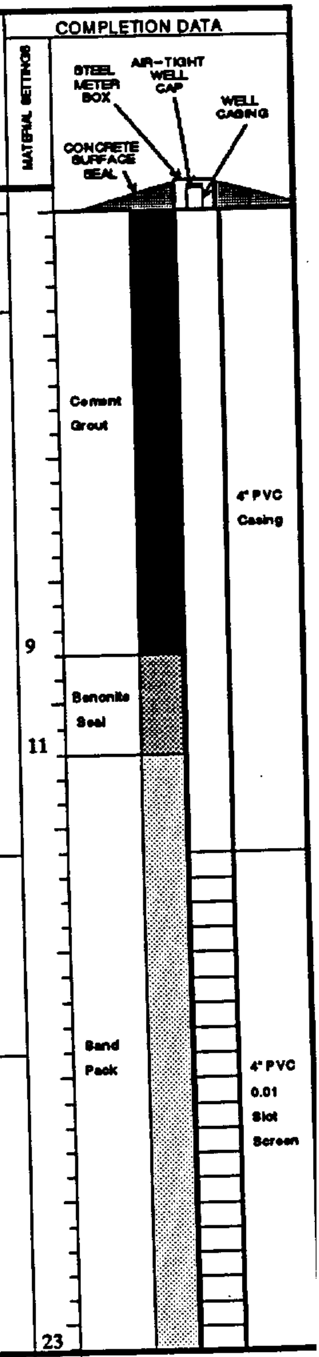
JN JONES AND NEUSE, INC.
Environmental and Engineering Consultants

LITHOLOGIC DESCRIPTION

DEPTH (FEET)	SAMPLE TYPE	SATURATED	ORGANIC VAPOR READING (ppm)	USCS SYMBOL (1)	STRATIGRAPHY	LITHOLOGIC DESCRIPTION
0.0						Topsoil – sandy loam, very fine to fine grained sand, 30 to 50% clay content, black to brown, root zone
1.5				SC		Clayey Sand – fine grained sand in clay matrix, occasional cobbles of quartz and weathered limestone regolith, well–rounded, moist, brown to dark brown
13						Sandy Clay– fine grained sand in clay matrix, occasional cobbles of quartz and weathered limestone regolith, balls up when brought up in auger >50% clay, damp, rust to light brown
17				SC		Clayey Sand – medium grained sand in clay matrix, occasional cobbles of quartz and weathered limestone regolith, <50% clay, red–brown, wet
21		▨				
23						Limestone (Glen Rose Formation) Refusal at 23 Feet

BORING TERMINATED AT 23.0 FEET

COMPLETION DATA



(1) UNIFIED SOIL CLASSIFICATION SYSTEM
(2) BENCHMARK ELEVATION ESTABLISHED AT 100 FEET (ASSUMED)

LCRA–MW4.WK3

ATTACHMENT B

DRILLER'S RECORDS OF COMPLETION

Send original copy by certified mail to: **Texas Water Commission, P.O. Box 13087, Austin, Texas 78711**

Please use black ink.

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas
WELL REPORT

Texas Water Well Drillers Board
P.O. Box 13087
Austin, Texas 78711

1) OWNER LCRA (Name) ADDRESS PO Box 220 (Street or RFD) Austin (City) Tx (State) 78767 (Zip)

2) LOCATION OF WELL:
County Travis 12 miles in WNW (NE, SW, etc.) direction from Austin (Town)

Driller must complete the legal description below with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

☐ LEGAL DESCRIPTION:

Section No. ______ Block No. ______ Township ______ Abstract No. ______ Survey Name ______

Distance and direction from two intersecting section or survey lines ______

☑ SEE ATTACHED MAP

3) TYPE OF WORK (Check):
☑ New Well ☐ Deepening
☐ Reconditioning ☐ Plugging

4) PROPOSED USE (Check):
☐ Domestic ☐ Industrial ☑ Monitor ☐ Public Supply
☐ Irrigation ☐ Test Well ☐ Injection ☐ De-Watering

5) DRILLING METHOD (Check):
☐ Driven
☐ Mud Rotary ☐ Air Hammer ☐ Jetted ☐ Bored
☐ Air Rotary ☐ Cable Tool ☐ Other HSA

6) WELL LOG:
Date Drilling:
Started 6/24 1993
Completed 6/24 1993

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
12	Surface	25
12		12

7) BOREHOLE COMPLETION:
☐ Open Hole ☐ Straight Wall ☐ Underreamed
☐ Gravel Packed ☑ Other Sand
If Gravel Packed give interval ... from 5 ft. to 12 ft.
MW#4 → 11' to 23'

From (ft.)	To (ft.)	Description and color of formation material
		See Att Logs
		2 wells
		MW #4 Drilled to 25' Set @ 23
		MW #3 Drilled to 12' Set @ 12

(Use reverse side if necessary)

8) CASING, BLANK PIPE, AND WELL SCREEN DATA:

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
4	N	Sch 40 PVC	0	7	
4	N	Screen	7	12	0.010
4	N	Sch 40 PVC	0	13	
4	N	Screen	13	23	0.010

9) CEMENTING DATA [Rule 287.44(1)]
Cemented from 0 ft. to 3 ft. No. of Sacks Used 2
0 ft. to 4 ft. No. of Sacks Used 3
Method used [illegible]
Cemented by Self

10) SURFACE COMPLETION
☑ Specified Surface Slab Installed [Rule 287.44(2)(A)]
☐ Specified Steel Sleeve Installed [Rule 287.44(3)(A)]
☐ Pitless Adapter Used [Rule 287.44(3)(B)]
☐ Approved Alternative Procedure Used [Rule 287.71]

11) WATER LEVEL: 7
Static level 7 ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) PACKERS: Type Depth

13) TYPE PUMP:
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) WELL TESTS:
Type Test: ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

15) WATER QUALITY:
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☑ No If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Jones & Neuse (Type or print) WELL DRILLER'S LICENSE NO. 3283-W

ADDRESS 1904 [illegible] (Street or RFD) Austin (City) Tx (State) 7872[illegible] (Zip)

(Signed) ______ (Licensed Well Driller) (Signed) ______ (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

For TWC use only: Well No. ______ Located on map ______

WWD-012 (Rev. 05-18-90)

WELL OWNER'S COPY

Send original copy by certified mail to: **Texas Water Commission, P.O. Box 13087, Austin, Texas 78711**

Please use black ink.

ATTENTION OWNER: *Confidentiality Privilege Notice on Reverse Side*

State of Texas
WELL REPORT

Texas Water Well Drillers Board
P.O. Box 13087
Austin, Texas 78711

1) **OWNER** LCRA (Name) **ADDRESS** P.O. Box 220 (Street or RFD) Austin (City) Tx (State) 78767 (Zip)

2) **LOCATION OF WELL:** County Travis 12 miles in WNW (NE, SW, etc.) direction from Austin (Town)

Driller must complete the legal description below with distance and direction from two intersecting section or survey lines, or he must locate and identify the well on an official Quarter- or Half-Scale Texas County General Highway Map and attach the map to this form.

☐ **LEGAL DESCRIPTION:**

Section No. ______ Block No. ______ Township ______ Abstract No. ______ Survey Name ______

Distance and direction from two intersecting section or survey lines ______

☑ **SEE ATTACHED MAP**

3) **TYPE OF WORK (Check):**
☑ New Well ☐ Deepening
☐ Reconditioning ☐ Plugging

4) **PROPOSED USE (Check):**
☐ Domestic ☐ Industrial ☑ Monitor ☐ Public Supply
☐ Irrigation ☐ Test Well ☐ Injection ☐ De-Watering

5) **DRILLING METHOD (Check):**
☐ Driven
☐ Mud Rotary ☐ Air Hammer ☐ Jetted ☐ Bored
☐ Air Rotary ☐ Cable Tool ☐ Other/HSA

6) **WELL LOG:**
Date Drilling:
Started 6-23 19 93
Completed 6-23 19 93

DIAMETER OF HOLE

Dia. (in.)	From (ft.)	To (ft.)
12	Surface	17
12''		16

7) **BOREHOLE COMPLETION:**
☐ Open Hole ☐ Straight Wall ☐ Underreamed
☐ Gravel Packed ☑ Other Sand
If Gravel Packed give interval . . . from 9 ft. to 16 ft.
9 17'

From (ft.)	To (ft.)	Description and color of formation material
See All Logs		
		2 wells
MW#1		
" " #2		
		2 wells
		1 to 17'
		1 to 16'

(Use reverse side if necessary)

8) **CASING, BLANK PIPE, AND WELL SCREEN DATA:**

Dia. (in.)	New or Used	Steel, Plastic, etc. Perf., Slotted, etc. Screen Mfg., if commercial	Setting (ft.) From	Setting (ft.) To	Gage Casting Screen
4	N	Sch 40 PVC	0	11	
4	N	Screen	11	16	0.010

9) **CEMENTING DATA** [Rule 287.44(1)]
Cemented from 0 ft. to 7 ft. No. of Sacks Used 2
______ ft. to ______ ft. No. of Sacks Used ______
Method used Moyno Pump
Cemented by Self

10) **SURFACE COMPLETION**
☑ Specified Surface Slab Installed [Rule 287.44(2)(A)]
☐ Specified Steel Sleeve Installed [Rule 287.44(3)(A)]
☐ Pitless Adapter Used [Rule 287.44(3)(B)]
☐ Approved Alternative Procedure Used [Rule 287.71]

11) **WATER LEVEL:**
Static level 7 ft. below land surface Date ______
Artesian flow ______ gpm. Date ______

12) **PACKERS:** Type Depth

13) **TYPE PUMP:**
☐ Turbine ☐ Jet ☐ Submersible ☐ Cylinder
☐ Other ______
Depth to pump bowls, cylinder, jet, etc., ______ ft.

14) **WELL TESTS:**
Type Test: ☐ Pump ☐ Bailer ☐ Jetted ☐ Estimated
Yield: ______ gpm with ______ ft. drawdown after ______ hrs.

15) **WATER QUALITY:**
Did you knowingly penetrate any strata which contained undesirable constituents?
☐ Yes ☑ No If yes, submit "REPORT OF UNDESIRABLE WATER"
Type of water? ______ Depth of strata ______
Was a chemical analysis made? ☐ Yes ☐ No

I hereby certify that this well was drilled by me (or under my supervision) and that each and all of the statements herein are true to the best of my knowledge and belief. I understand that failure to complete items 1 thru 15 will result in the log(s) being returned for completion and resubmittal.

COMPANY NAME Jones & Neuse (Type or print) **WELL DRILLER'S LICENSE NO.** 3283-W

ADDRESS 1904 [illegible] (Street or RFD) Aust (City) Tx (State) 78728 (Zip)

(Signed) ______ (Licensed Well Driller) (Signed) ______ (Registered Driller Trainee)

Please attach electric log, chemical analysis, and other pertinent information, if available.

For TWC use only: Well No. ______ Located on map ______

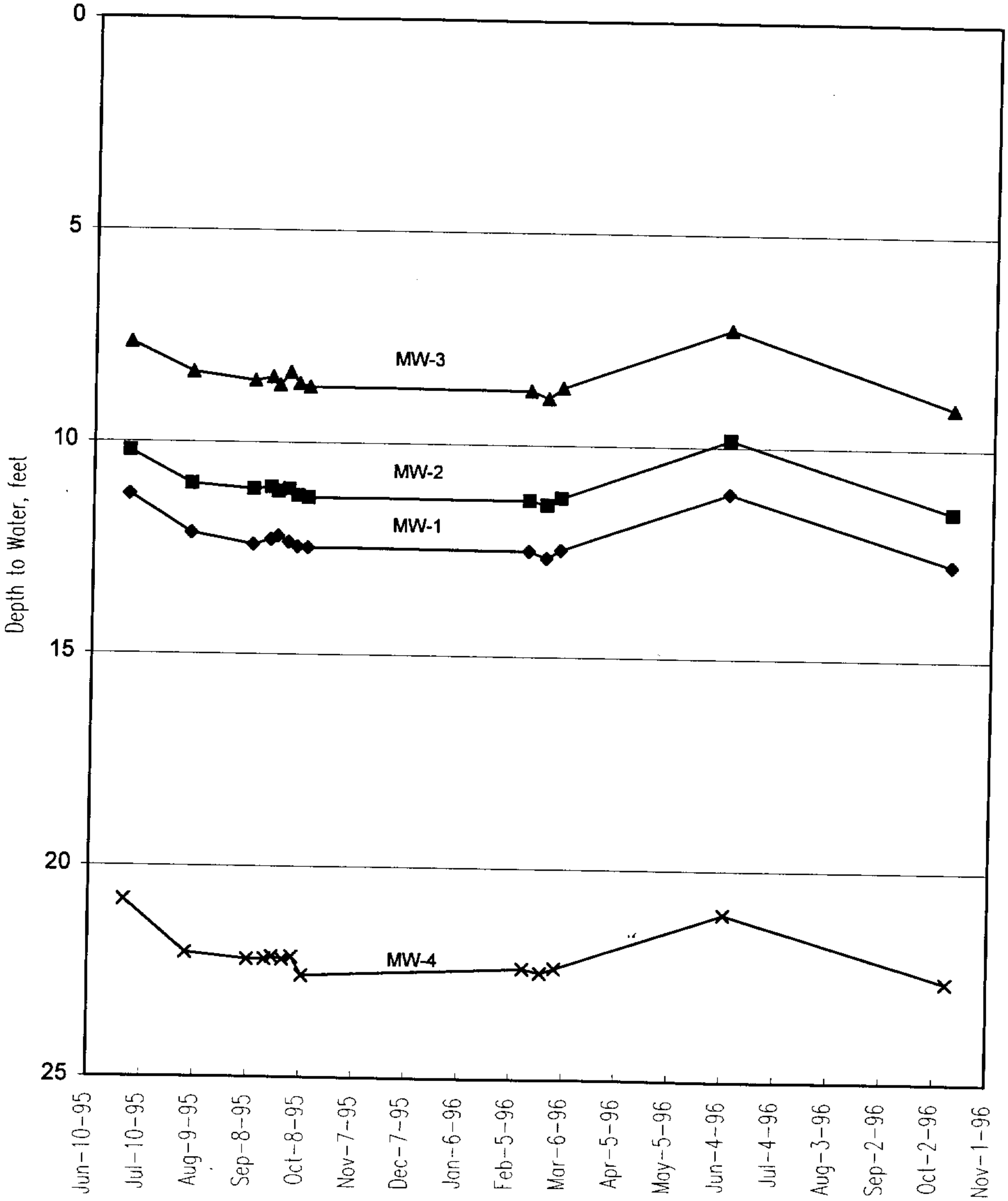
WWD-012 (Rev. 05-18-90)

WELL OWNER'S COPY

Appendix D

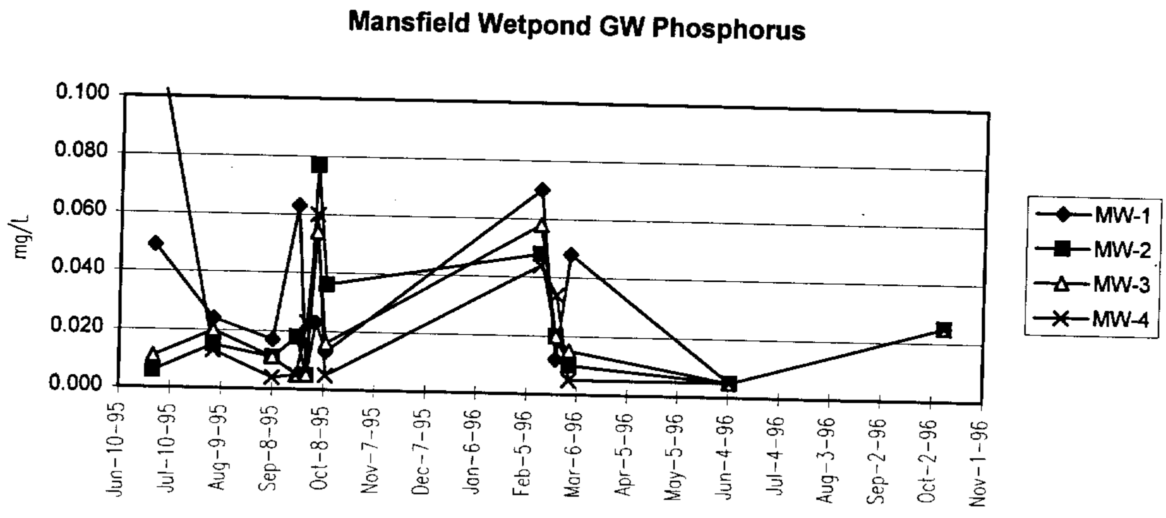
Ground Water Monitoring Results

Mansfield Wetpond Well Water Levels

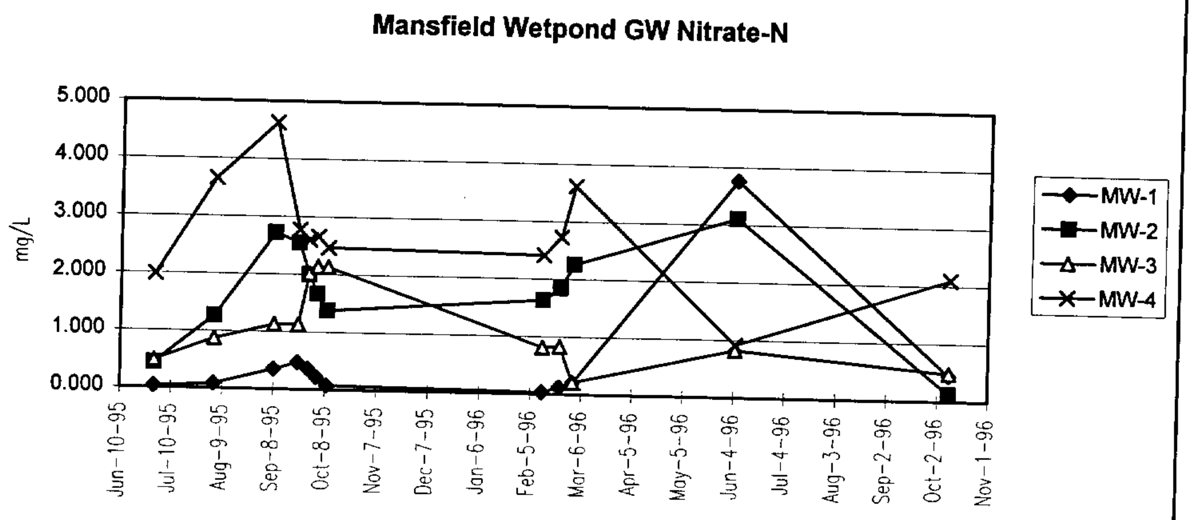


	Mansfield Wetpond Well Water Levels			
Date	MW-1	MW-2	MW-3	MW-4
Jul-13-93	12.47	11.29	8.69	21.59
Dec-20-94	12.71	11.47	8.95	22.55
Jun-30-95	11.23	10.20	7.65	20.80
Aug-4-95	12.15	10.98	8.35	22.05
Sep-8-95	12.41	11.10	8.55	22.20
Sep-18-95	12.29	11.05	8.46	22.19
Sep-22-95	12.21	11.15	8.65	22.14
Sep-28-95	12.35	11.09	8.35	22.20
Oct-3-95	12.46	11.25	8.61	22.14
Oct-9-95	12.48	11.30	8.69	22.58
Feb-12-96	12.50	11.31	8.72	22.37
Feb-22-96	12.66	11.41	8.89	22.47
Mar-1-96	12.47	11.24	8.64	22.36
Jun-5-96	11.10	9.82	7.24	21.03
Oct-9-96	12.75	11.51	9.04	22.61

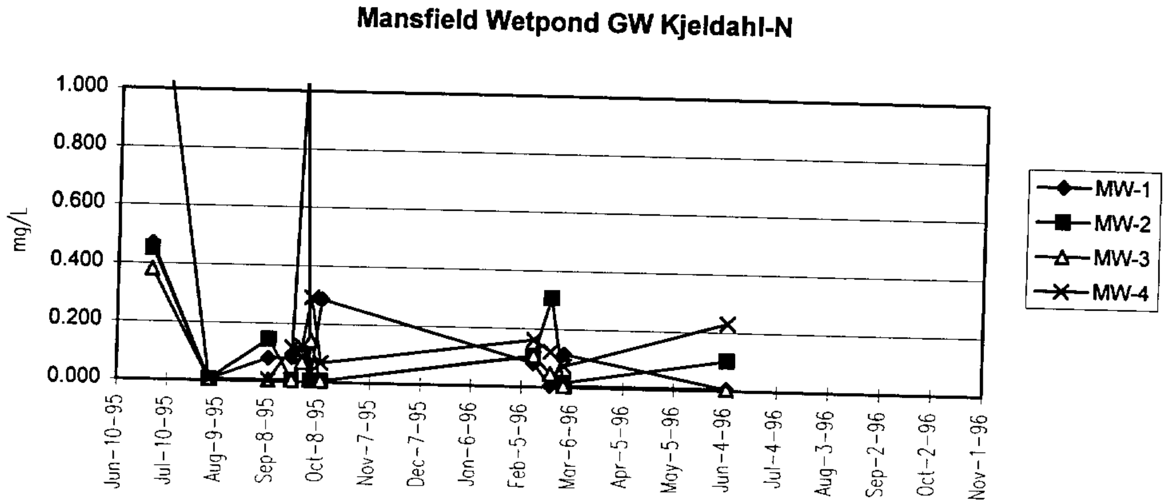
	Mansfield Wetpond Well Total Phosphorus				
Date	MW-1	MW-2	MW-3	MW-4	Pond
Jul-13-93	0.076	0.077	0.079	0.084	
Dec-20-94	0.036	0.028	0.028	0.094	
Jun-30-95	0.049	0.006	0.011	0.117	
Aug-4-95	0.024	0.015	0.020	0.013	
Sep-8-95	0.017	0.011	0.011	0.004	
Sep-22-95	0.063	0.018	0.005	0.005	0.099
Sep-28-95	0.005	0.005	0.005	0.023	
Oct-3-95	0.023	0.077	0.054	0.060	0.166
Oct-9-95	0.013	0.036	0.016	0.005	
Feb-12-96	0.070	0.048	0.058	0.044	0.053
Feb-22-96	0.012	0.020	0.020	0.034	0.005
Mar-1-96	0.048	0.010	0.015	0.005	0.014
Jun-5-96	0.005	0.005	0.005	0.005	
Oct-9-96	0.025	0.025	0.025	0.025	



	Mansfield Wetpond Well Nitrate+Nitrite-N							
Date	MW-1	MW-2	MW-3	MW-4	Pond			
Jul-13-93	0.738	0.851	1.228	6.428				
Dec-20-94	0.005	0.491	0.340	2.690				
Jun-30-95	0.033	0.439	0.481	1.990				
Aug-4-95	0.086	1.266	0.872	3.656				
Sep-8-95	0.349	2.723	1.129	4.628				
Sep-22-95	0.468	2.548	1.130	2.780	0.033			
Sep-28-95	0.363	2.000	2.017	2.605				
Oct-3-95	0.219	1.666	2.139	2.660	0.005			
Oct-9-95	0.079	1.377	2.133	2.474				
Feb-12-96	0.035	1.633	0.809	2.414	0.016			
Feb-22-96	0.122	1.843	0.830	2.736	0.005			
Mar-1-96	0.198	2.262	0.209	3.616	0.110			
Jun-5-96	3.766	3.110	0.824	0.914				
Oct-9-96	0.445	0.127	0.484	2.108				



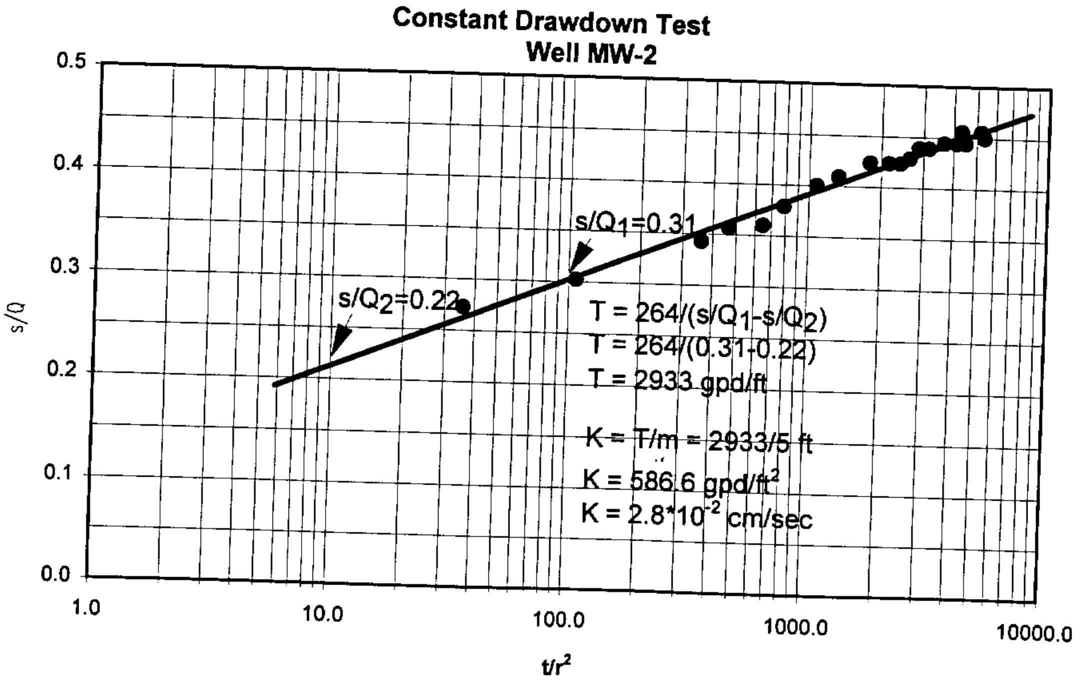
	Mansfield Wetpond Well TKN				
Date	MW-1	MW-2	MW-3	MW-4	Pond
Jul-13-93	0.313	0.343	0.271	0.446	
Dec-20-94	0.082	0.053	0.044	0.249	
Jun-30-95	0.469	0.451	0.381	1.402	
Aug-4-95	0.005	0.005	0.005	0.005	
Sep-8-95	0.081	0.146	0.005	0.005	
Sep-22-95	0.084	0.005	0.005	0.118	0.569
Sep-28-95	1.065	0.087	0.067	0.124	
Oct-3-95	0.005	0.005	0.144	0.290	0.391
Oct-9-95	0.285	0.005	0.005	0.067	
Feb-12-96	0.082	0.106	0.108	0.162	0.321
Feb-22-96	0.005	0.306	0.046	0.122	0.296
Mar-1-96	0.115	0.017	0.005	0.074	0.362
Jun-5-96	0.005	0.103	0.005	0.231	
Oct-9-96					



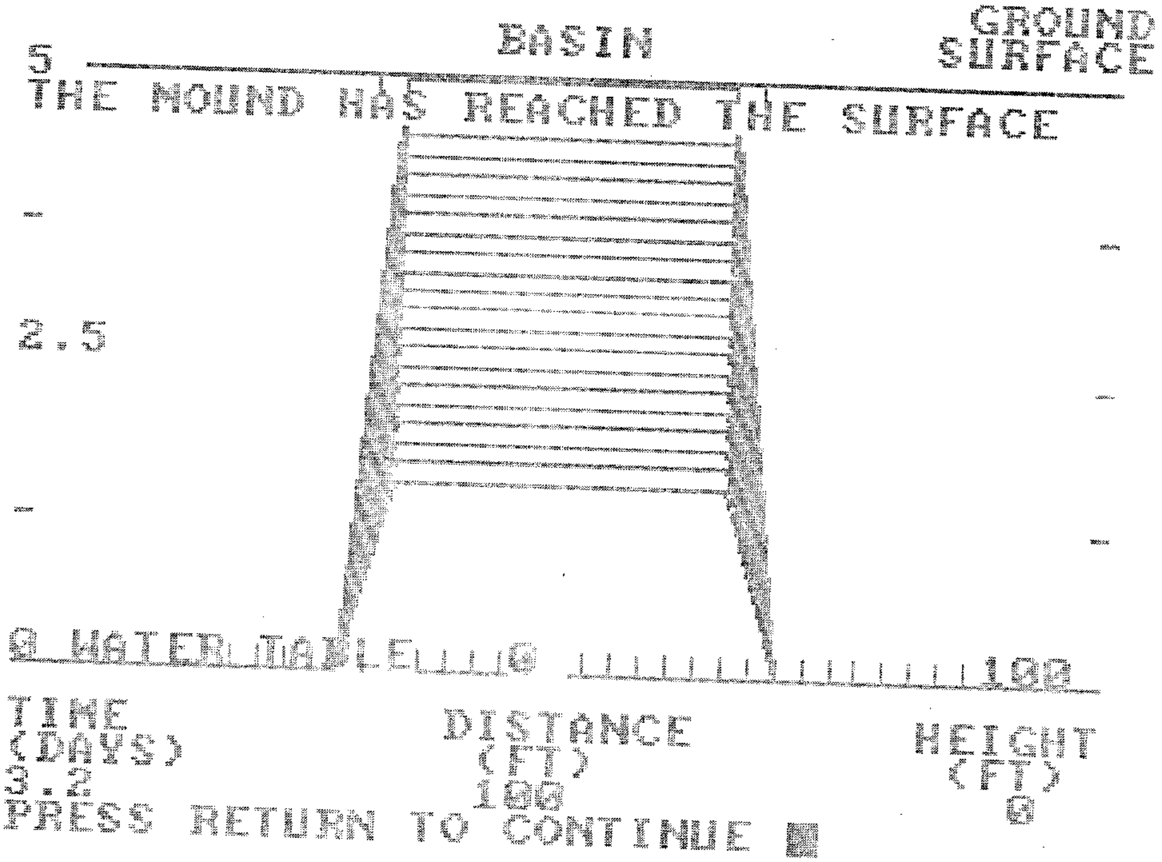
CONSTANT DRAWDOWN TEST - WELL MW-2, HWY 620 WETPOND

Static W.L. = 11.50 ft, Radius = 0.17 ft, Drawdown (s) = 3.6 ft.

Time	Pumping t	t/r^2	Q, gpm	s/Q
11:45	pump on			
11:46	1	35.9	13.2	0.27
11:48	3	107.6	11.9	0.30
11:55	10	358.6	10.5	0.34
11:58	13	466.1	10.1	0.36
12:03	18	645.4	10.0	0.36
12:07	22	788.8	9.5	0.38
12:15	30	1075.7	9.0	0.40
12:22	37	1326.7	8.8	0.41
12:35	50	1792.8	8.5	0.42
12:45	60	2151.4	8.5	0.42
12:52	67	2402.4	8.5	0.42
12:58	73	2617.5	8.4	0.43
13:05	80	2868.5	8.2	0.44
13:13	88	3155.4	8.2	0.44
13:27	102	3657.4	8.1	0.44
13:40	115	4123.5	8.1	0.44
13:45	120	4302.8	7.9	0.46
13:55	125	4482.1	8.1	0.44
14:15	145	5199.2	7.9	0.46
14:20	150	5378.5	8.0	0.45



ref: Lohman, 1972, USGS Prof. Paper 708, p. 23-25.



```
THE MOUND HAS REACHED THE SURFACE

TIME                 DISTANCE                HEIGHT
(DAYS)                 (FT)                   (FT)
3.2                    100                     0
PRESS RETURN TO CONTINUE
```

Appendix E

Zooplankton Raw Data and Data Reduction Table

Italics indicate data not included in calculations								
	20 Dec., 1995		13 Feb., 1996		2 May, 1996		2 Jul., 1996	
Station	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Taxa								
Copepoda								
nauplius	58	571	348	401	1242	2518	98	14
copepodite	72	28	150		948	926	6	
Calanoid copepods								
Leptodiaptomus moorei		15	1					
Cyclopoid copepod								
Cyclops scutifer							2	
Microcyclops sp.	10		38		472	384	8	
Macrocyclops albidus	4				4			
Paracyclops sp.					2			
Thermocyclops sp.		30	18	12	202	10	12	
Tropocyclops sp.			9					
Rotifera								
Class Digononta								
Order Bdelloidea								
Philodina sp.							60	28
Rotaria sp.			6		12		2	
Class Monogononta								
Order Ploima	3	3	2				86	24
Fam. Notommatidae							70	
Fam. Dicranophoridae				6				
Fam. Synchaetidae			54	550	6			
Polyarthra sp.					14	10	512	24
Synchaeta sp.				3		2	6	
Fam. Trichocercidae								
Trichocera sp.					14		1854	256
Fam. Asplanchidae			63		42			
Asplanchna sp.			3	6			12	20
Fam. Brachionidae								
Brachionus sp.	7		2		62	2	78	40
Keratella sp.			22	32	18	92	12	2
Platyias sp.	12	1	6		1596	10	4	2
Fam. Euchlanidae							6	
Beauchampiella eudactylota							40	
Fam. Mytilinidae					8			
Fam. Lecanidae								
Lecane sp.	4		18	1	482	12	1980	130

	20 Dec., 1995		13 Feb., 1996		2 May, 1996		2 Jul., 1996	
	Shallow	Deep	Shallow	Deep	Shallow	Deep	Shallow	Deep
Cladocera								
adolescent		3			50		4	4
Fam. Sididae								
Diaphanosoma brachyurum		12		3		20		
Fam. Chydorinae			1		154			
Camptocercus sp.					4			
Chydorus sp.	3							
Fam. Daphnidae					36	14		
Daphnia ambigua		10		2		2		
Ceriodaphnia sp.	2		3					
Fam. Moinidae								
Moina sp.	1							
Fam. Bosminidae								
Bosmina coregoni					72			
Bosmina longirostris					16	844	78	4
Eubosmina sp.					46			
Oligochaeta	2		2				408	
Ostracoda	7		12		12		24	
Sarcomastigophora								
Ceratium sp.	1		7	3	6	90		
Hydracarina			1		8		4	
Insecta								
Chironomidae larvae			1		30		12	
unknown larvae							6	6
Nematoda					158		1574	12
Gastrotricha							62	6
Unknown larvae					176			
Data Reduction								
No. of Taxa	12	7	20	10	27	13	26	14
No. of Ind.	56	74	269	618	3702	1492	6916	558
Diversity	3.22	2.27	3.34	0.76	2.96	1.85	2.64	2.48
Equitability	0.897	0.808	0.773	0.230	0.622	0.499	0.562	0.651
Individuals per liter	26	33	123	283	1674	622	3167	199

Appendix F

Zooplankton Graphs

Figure 1

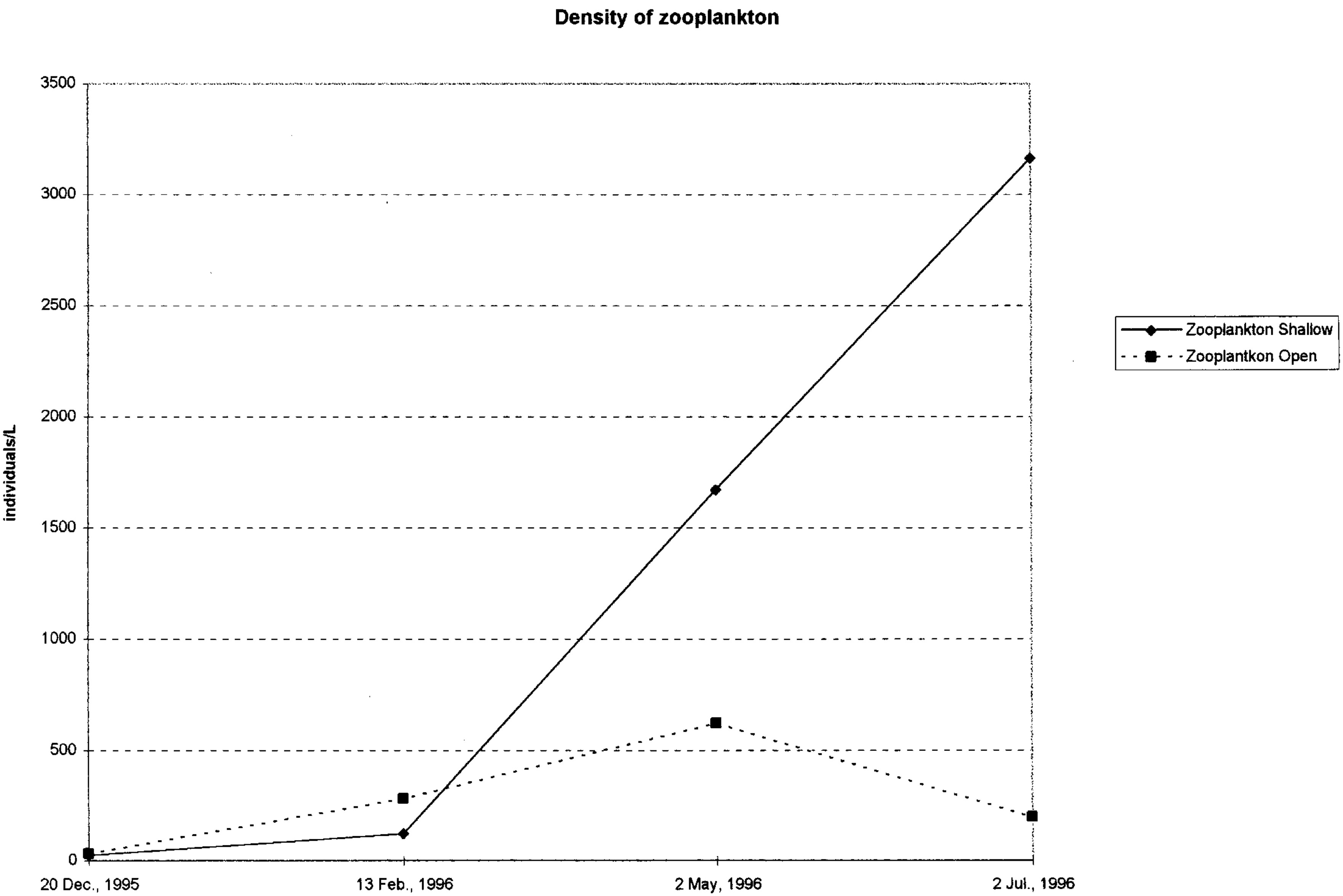

Density of zooplankton
individuals/L
3500
3000
2500
2000
1500
1000
500
0
20 Dec., 1995
13 Feb., 1996
2 May, 1996
2 Jul., 1996
Zooplankton Shallow
Zooplantkon Open

Figure 2

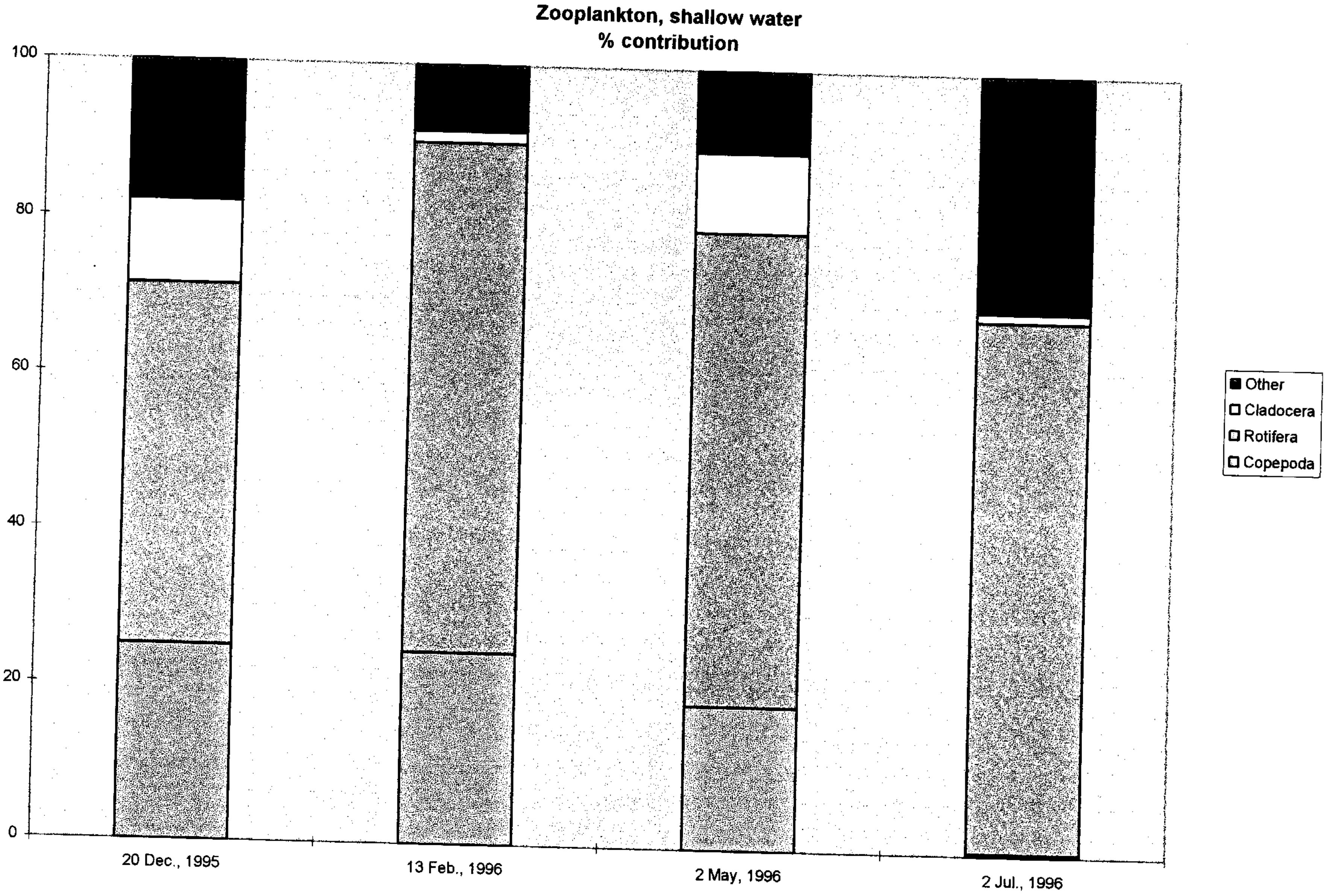
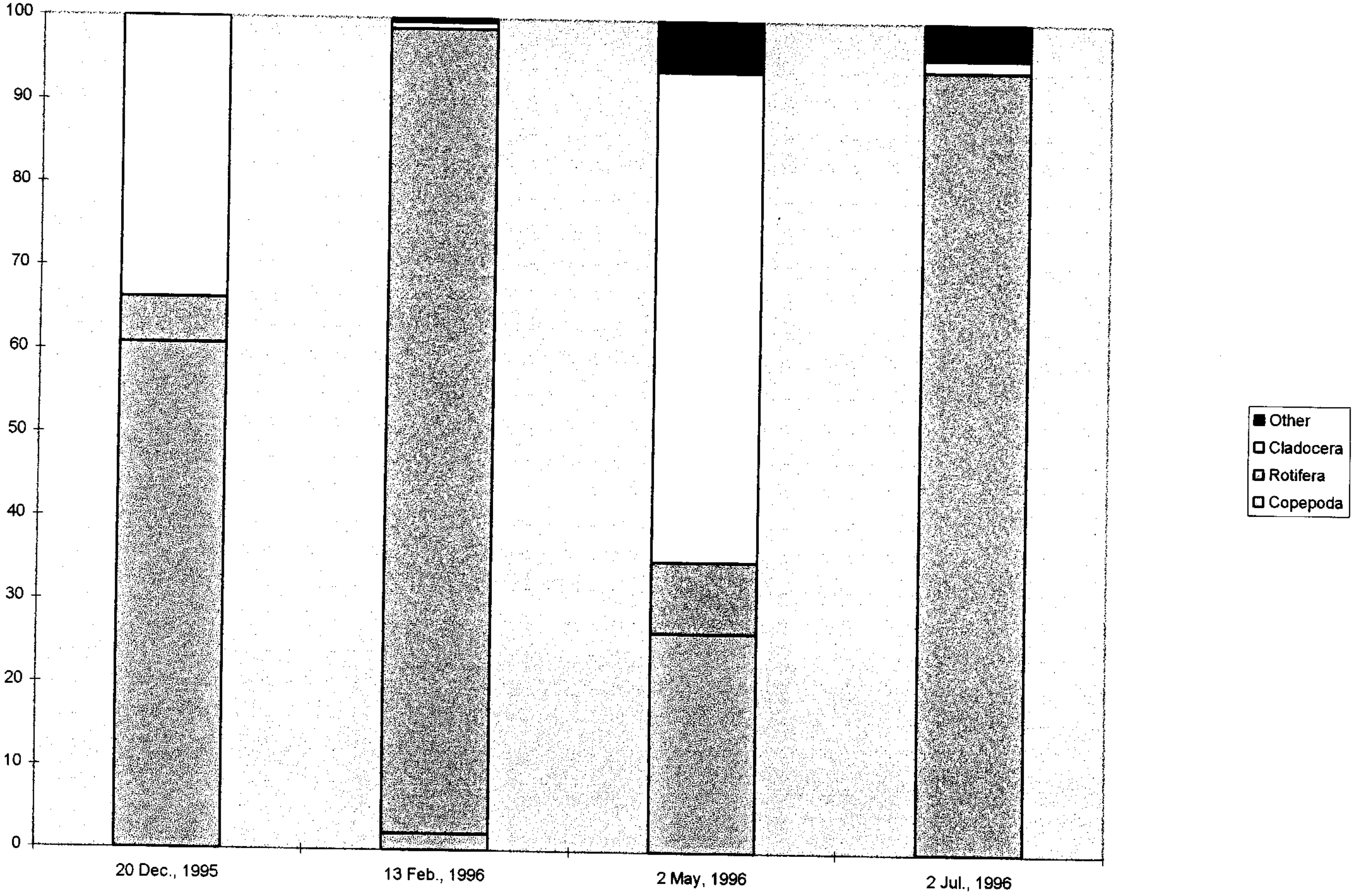

Zooplankton, shallow water
% contribution
100
80
60
40
20
0
20 Dec., 1995
13 Feb., 1996
2 May, 1996
2 Jul., 1996
■ Other
☐ Cladocera
☐ Rotifera
☐ Copepoda

Figure 3



Zooplankton, open water
% contribution,

Figure 4

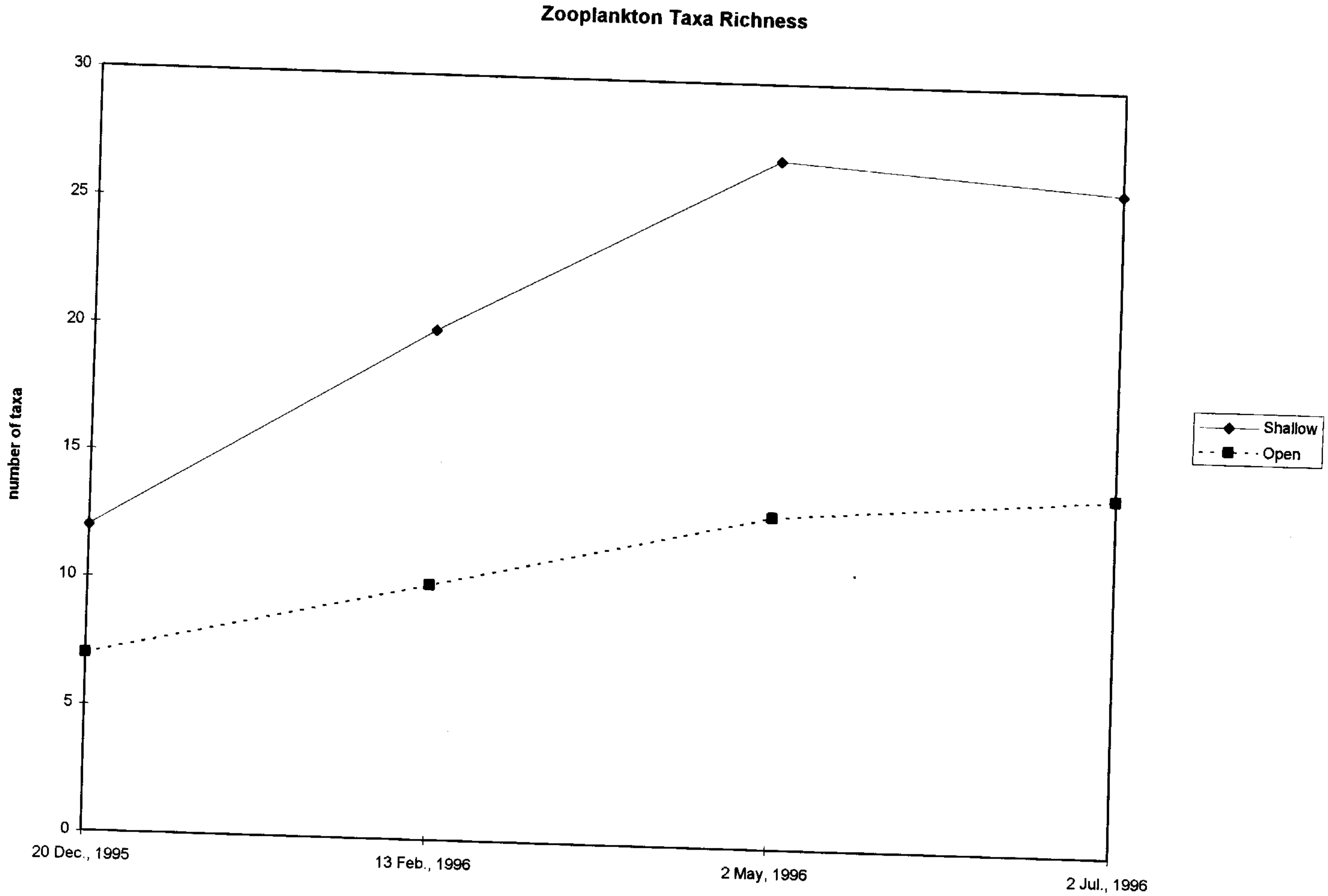
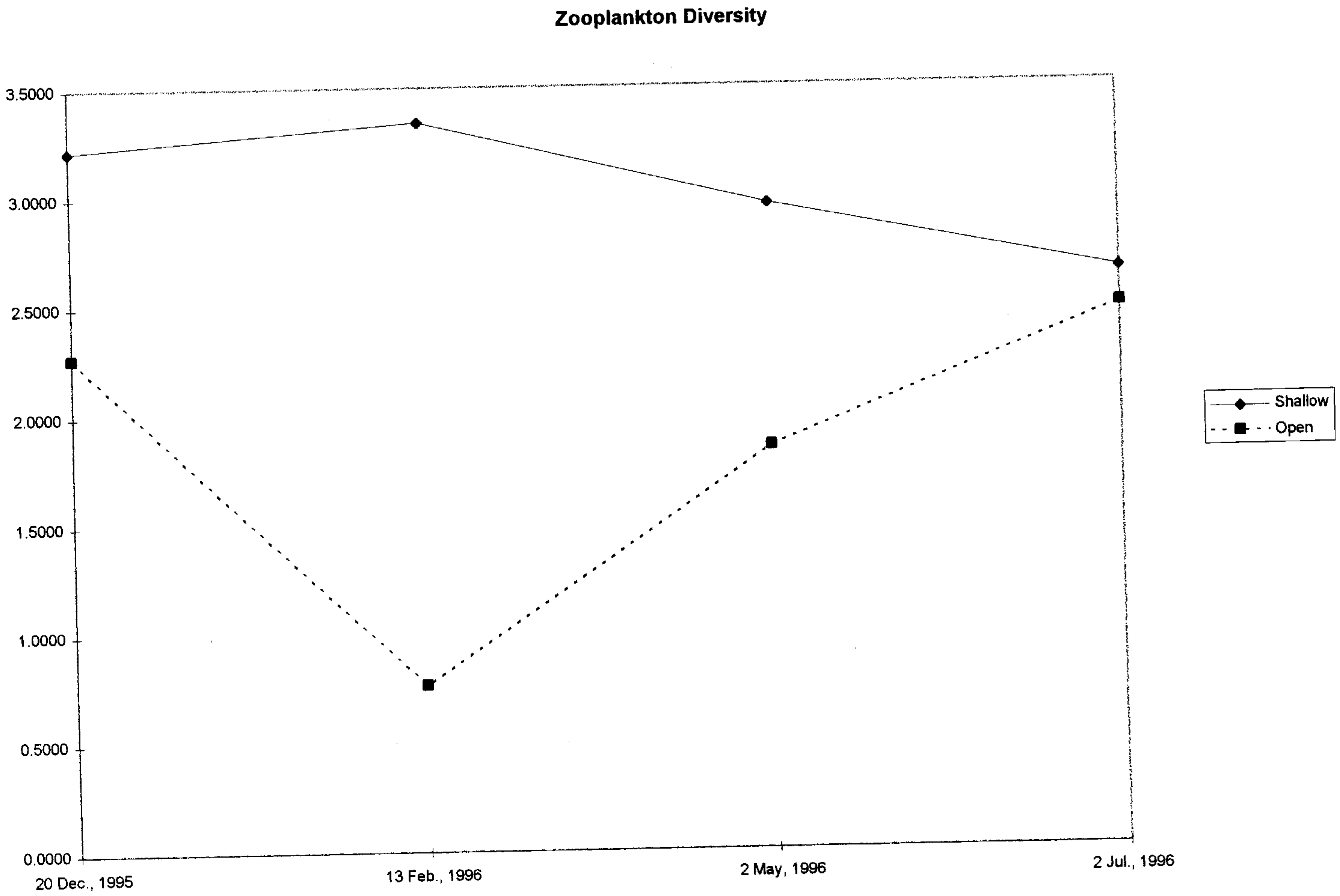

Zooplankton Taxa Richness
number of taxa
0
5
10
15
20
25
30
20 Dec., 1995
13 Feb., 1996
2 May, 1996
2 Jul., 1996
Shallow
Open

Figure 5


Zooplankton Diversity
3.5000
3.0000
2.5000
2.0000
1.5000
1.0000
0.5000
0.0000
20 Dec., 1995
13 Feb., 1996
2 May, 1996
2 Jul., 1996
Shallow
Open

Appendix G

Phytoplankton Raw Data and Data Reduction Table

Date	20 Dec., 1995	13 Feb., 1996	2 May, 1996	2 Jul., 1996
	12/20/95	2/13/96	5/2/96	7/2/96
Taxa				
Chlorophyta				
Ankistrodesmus sp.		9	4	
Ankistrodesmus falcatus				2
Chlamydomonas sp.	16	23	36	21
Closterium sp.	5			
Coelastrum sp.				1
Cosmarium sp.	2	1	2	5
Dictosphaerium sp.				8
Kirchneriella obesa				1
Mougeotia sp.				1
Oocystis sp.	1		4	4
Pandorina morum			51	17
Scenedesmus sp.		4		12
Schroederia serigera			4	1
Sphaerocystis sp.	1			
Unidentified Green Algae				3
Euglenophyta				
Euglena sp.		3	5	19
Lepocinclis ovum				3
Phacus sp.				70
Phacus longicauda	1	1		
Trachelomonas sp.	12	7	24	50
Trachelomonas volvocina				19
Pyrrophyta				
Dinoflagellate	4	11	4	5
Cryptophyta				
Chroomonas sp.			348	2
Cryptomonacidaceae	75	199		
Cryptomonas sp.			67	65
Chrysophyta				
Dinobryon sp.		72		
Mallomonas sp.	1	1		1
Cyanophyta				
Anabaena sp.				3
Chroococcus sp.			90	
Coelosphaerium sp. (one colony)				60
Merismopedia glauca				4
Microcystis sp.				8
Oscillatoria sp.			18	
Synechococcus sp.				148

Schizothrix sp.	2	2	13	19
Lyngbya sp.				1
Bacillariophyta				
Navicula sp.	3			
Nitzschia acicularis	4	123		
Nitzschia palea	2	1		
Nitzschia sp.	4	2		
Diatoms, centric			6	3
Diatoms, pennate			11	2
Spores	157	218	170	413
Total number (no spores)	133	459	687	558
Data Reduction				
	12/20/95	2/13/96	5/2/96	7/2/96
Diversity	2.3895	2.2522	2.5295	3.5986
# Taxa	15	15	16	30
# of Ind counted	133	459	687	558
Density, Ind/ml	2866	10435	7321	5947
Equitability	0.6116	0.5765	0.6324	0.7334

Appendix H

Phytoplankton Graphs

Fig. 1	Phytoplankton Density
Fig. 2	Phytoplankton Diversity and Taxa Richness

Figure 2

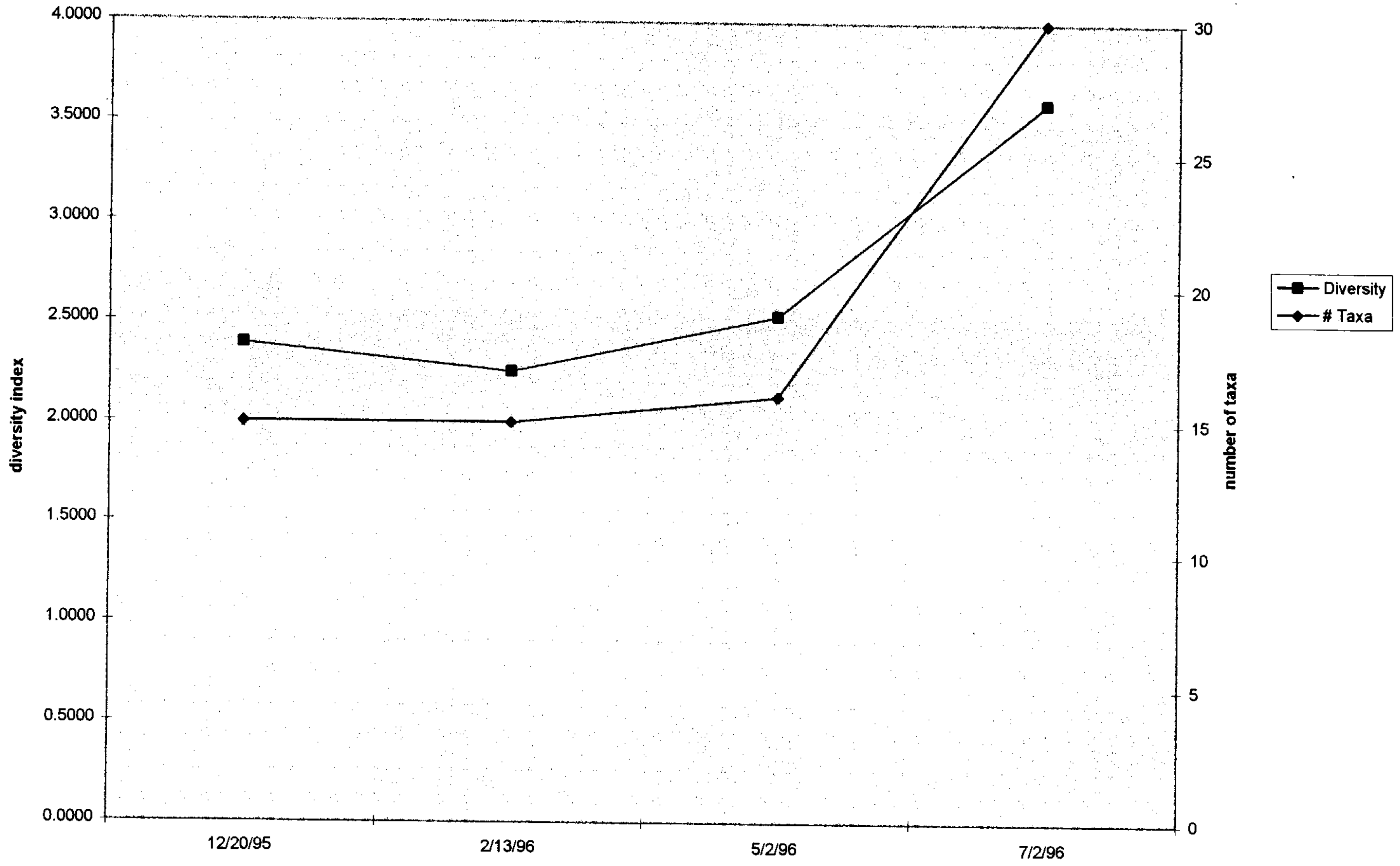
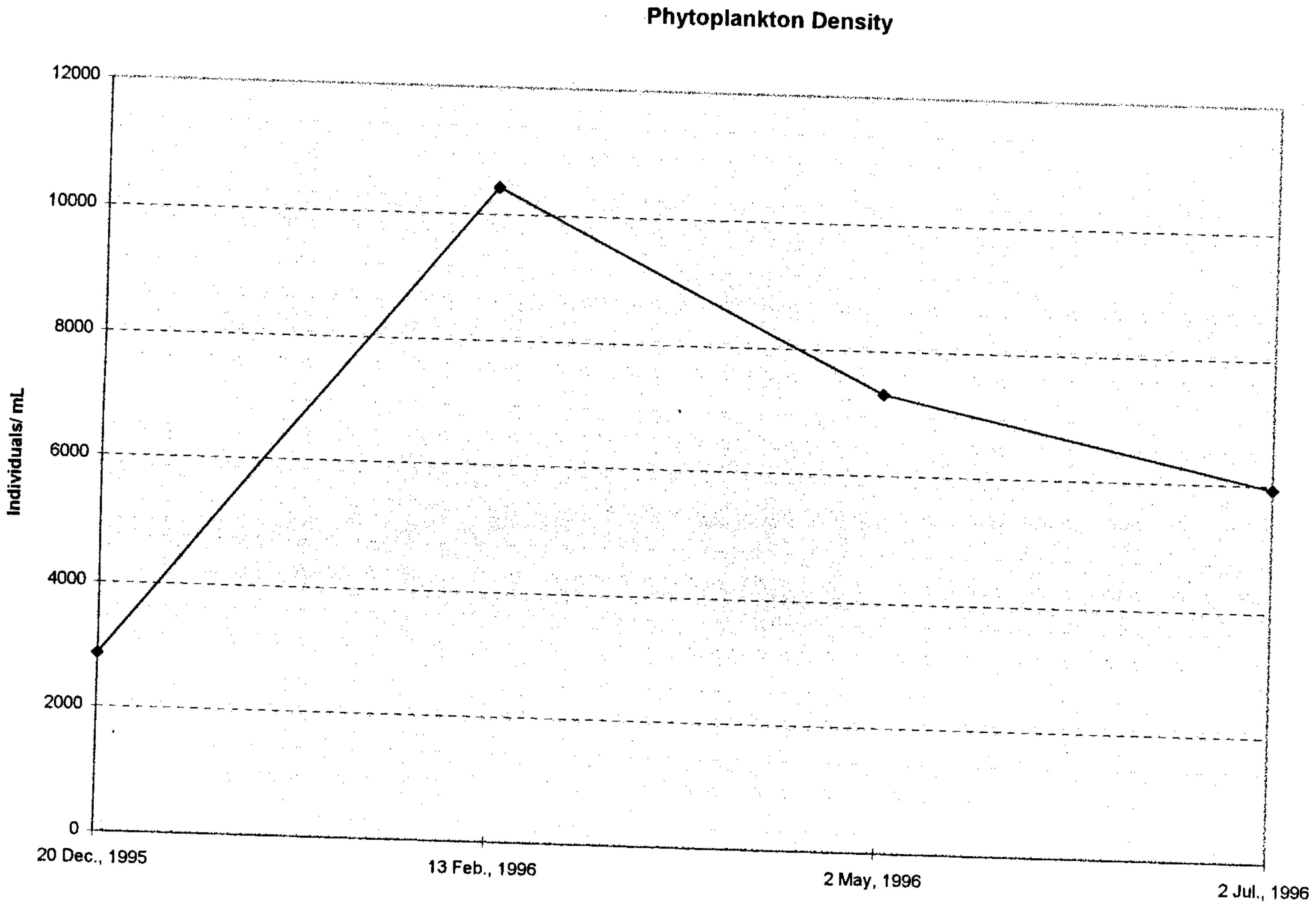

Phytoplankton Diversity and Taxa Richness

Figure 1


Phytoplankton Density
Individuals/ mL
12000
10000
8000
6000
4000
2000
0
20 Dec., 1995
13 Feb., 1996
2 May, 1996
2 Jul., 1996

Appendix I

Periphyton Accumulation Graphs

Figure 1

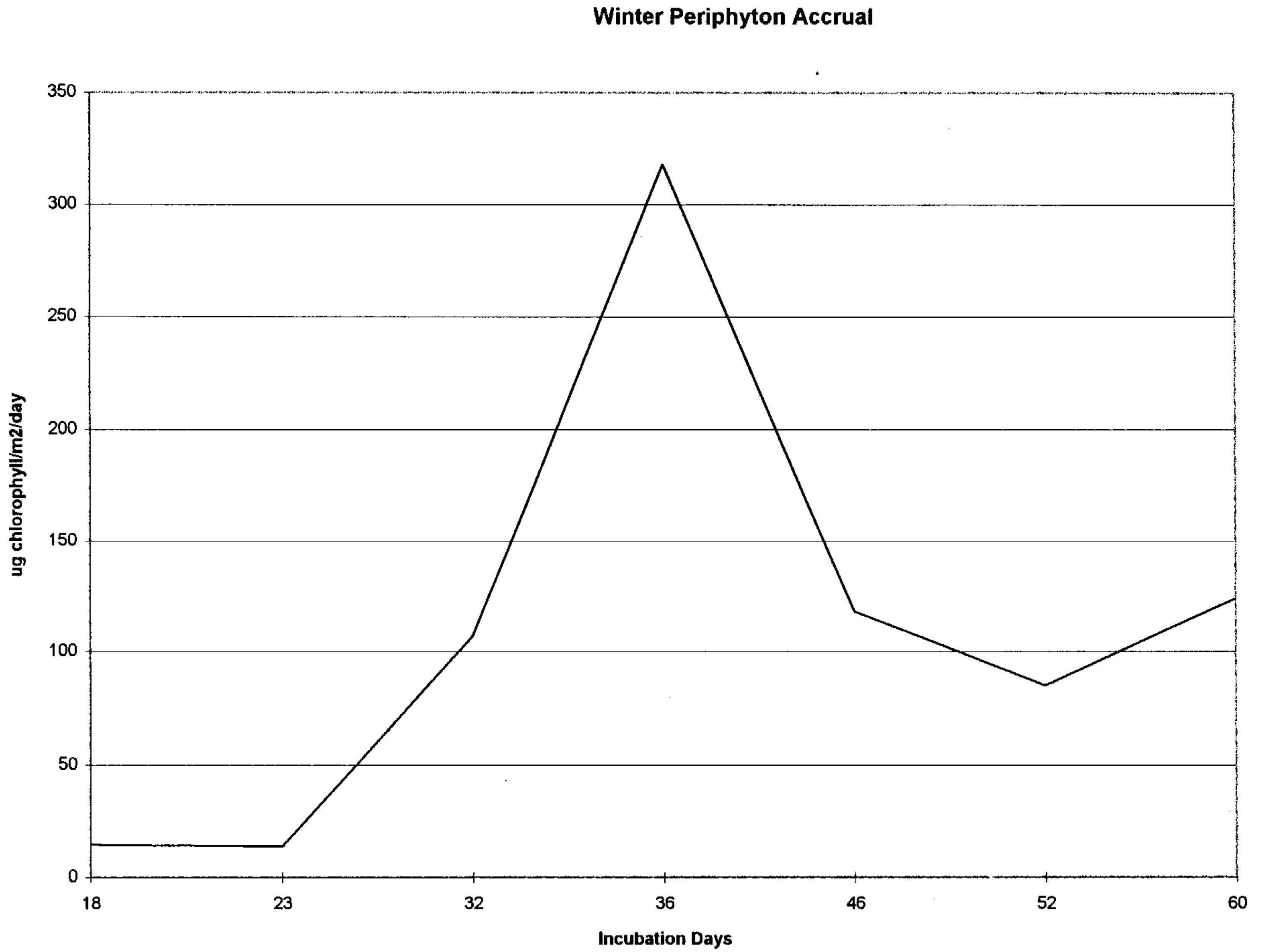
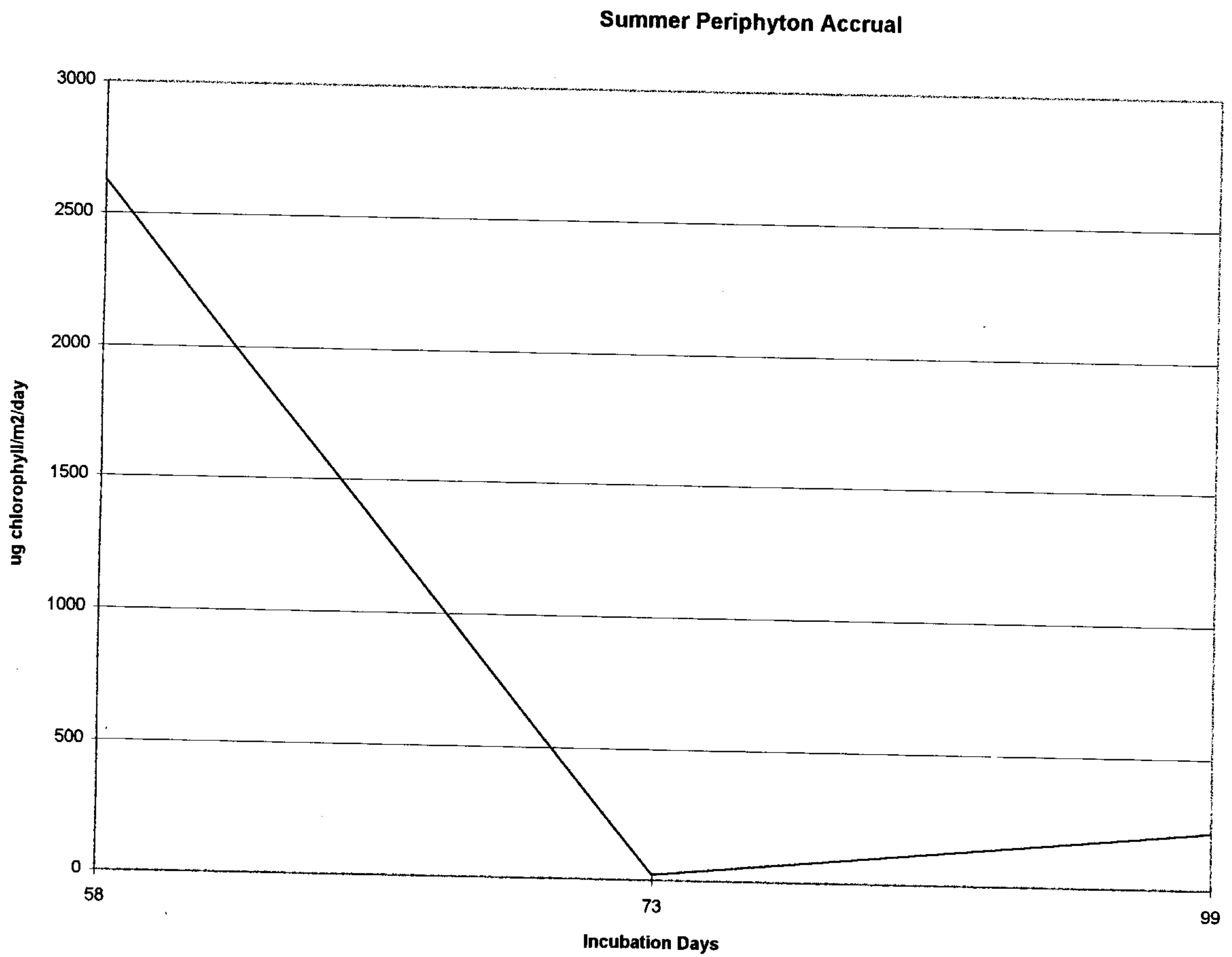

Winter Periphyton Accrual
ug chlorophyll/m2/day
350
300
250
200
150
100
50
0
18
23
32
36
46
52
60
Incubation Days

Figure 2


Summer Periphyton Accrual
ug chlorophyll/m2/day
3000
2500
2000
1500
1000
500
0
58
73
99
Incubation Days

Appendix J

Benthic Macroinvertebrate Raw Data and Data Reduction Tables

Table 1. Macroinvertebrate population within 2 square meters of submerged vegetation in wetpond: November 18, 1994

Date			**18 Nov., 1994**	
Plant Species		**E. canadensis ***	**M. spicatum ***	**H. dubia ***
Taxa	**Feeding Group**	**Number**	**Number**	**Number**
Annelida	miner		1	
Hirudinea	scavenger		1	
Mollusca				
Gastropoda				
Gyraulus sp.	scraper	24	146	46
Helisoma sp.	scraper	11	1	16
Physella sp.	scraper	13	17	4
Malacostraca				
Amphipoda				
Hyalella azteca	shredder	61	77	90
Cambaridae	scavenger		1	
Arachnida				
Hydracarina	?	6		
Insecta				
Ephemeroptera				
Baetidae	gatherer	52		151
Caenidae				
Caenis sp.	gatherer	7		3
Callibaetis sp.	gatherer	87	46	44
Odonata				
Anisoptera		1		
Aeshnidae	predator	14	13	18
Anax sp.	predator	9	4	1
Libellulidae	predator	77	57	58
Erythemis sp.	predator		5	5
Dythemis sp.	predator	1		
Pachydiplax sp.	predator		1	
Tramea sp.	predator	2		
Zygoptera				
Coenagrionidae	predator	60	8	141
Argia sp.	predator			1
Coenagrion sp.,Enallagma sp.	predator	1		2
Hemiptera	predator			1
Corixidae	predator	2		
Hebridae				
Merragata sp.	predator			2
Naucoridae				
Pelocoris sp.	predator			1
Notonectidae	predator			2
Notonecta sp.	predator		1	
Buenoa sp.	predator	55		1
Saldidae	predator			2
Trichoptera				
Hydroptilidae				
Oxyethira sp.	gatherer	1		
Diptera				
Chironomidae	gatherer	2		
Chironominae	gatherer	1		
Tanypodinae	predator	4		1
Culicidae	filterer			1
Anophales sp.	filterer		1	4
Stratiomyidae				
Odontomyia,Hedriodiscus sp.	gatherer		1	
Data Reduction Section				
No. of Taxa		22	17	23
No. of Individuals		491	381	595
Diversity		3.44	2.59	3.00
EPT Index		3	0	2
Percent Dominant Group		33 (Odonates)	40 (Gastropods)	40 (Odonates)
Percent Sensitive Groups (EPT)		30	12	33
Feeding Group Analysis, percent of				
scrapers		10	43	11
gatherers		31	12	31
predators		46	23	46
shredders		13	20	15
scavengers		0	1	0
filterers		0	0.5	1
miners		0	0.5	0
* denotes macrophytes where duplicate samples were combined.				

Table 2. Macroinvertebrate population within 2 square meters of submerged vegetation in wetpond: December 20, 1995

Date			20 Dec., 1995	
Plant Species		E. canadensis *	M. spicatum *	N. Guadalupensis *
Taxa	Feeding Group	Number	Number	Number
Annelida				
Oligochaeta				
Tubificidae	miner	10	33	26
Turbellaria	scavenger		1	
Hirudinea	scavenger			2
Mollusca				
Gastropoda				
Gyraulus sp.	scraper	312	119	265
Helisoma sp.	scraper	80	119	56
Physella sp.	scraper	68	107	218
Malacostraca				
Amphipoda				
Hyalella azteca	shredder		1	
Decapoda				
Cambaridae	scavenger	2	1	1
Arachnida				
Hydracarina	?	10	40	6
Insecta				
Ephemeroptera	gatherer			11
Baetidae	gatherer	1	5	17
Caenidae				
Caenis sp.	gatherer	8	7	7
Callibaetis sp.	gatherer	44	34	24
Odonata				
Anisoptera	predator		1	8
Aeshnidae	predator		14	16
Libellulidae	predator	13	9	12
Erythemis sp.	predator			9
Pachydiplax sp.	predator	2		14
Zygoptera	predator			1
Coenagrionidae	predator	91	71	177
Coenagrion sp.,Enallagma sp.	predator			2
Ischnura sp.	predator			2
Hemiptera				
Naucoridae				
Pelocoris sp.	predator	1	1	
Trichoptera	gatherer			1
Leptoceridae				
Oecetis sp.	predator		3	
Hydroptilidae				
Oxyethira sp.	gatherer	12	20	31
Lepidoptera				
Pyralidae	shredder			14
Munroessa,Neocataclysta,Synclita sp.	shredder	1		
Coleoptera	predator		1	
Dytiscidae				
Hygrotus sp.	predator			1
Haliplidae				
Haliplus sp.	shredder	1	2	
Helophoridae				2
Hydrophilidae				
Berosus sp.	predator		1	2
Tropisternus sp.	?		3	5
Diptera				
Ceratopogonidae	predator	2		14
Chironomidae	gatherer	5		3
Chironominae	gatherer	119	88	467
Zavreliella sp.	gatherer			1
Tanypodinae	predator	12	11	27
Tipulidae				
Lemnophila,Hydrellia,Notiphila sp.	predator			2
Data Reduction Section				
No. of Taxa		20	24	33
No. of Individuals		794	692	1444
Diversity		2.83	3.41	3.14
EPT Index		3	4	3
Percent Dominant Group		58 (Gastropods)	50 (Gastropods)	37 (Gastropods)
Percent Sensitive Groups (EPT)		8	10	6
Feeding Group Analysis, percent of				
scrapers		58	50	37
gatherers		24	22	39
predators		16	16	20.5
shredders		0.5	0.5	1
scavengers		0.5	0.5	0.5
filterers		0	0	0
miners		1	5	2

* denotes macrophytes where duplicate samples were combined.

Table 3. Macroinvertebrate population within 2 square meters of submerged vegetation in wetpond: February 14, 1996

Date			**14 Feb., 1996**	
Plant Species		**E. canadensis ***	**M. spicatum ***	**N. Guadalupensis ***
Taxa	**Feeding Group**	**Number**	**Number**	**Number**
Annelida	miner		2	
Turbellaria	scavenger		1	
Hirudinea	scavenger			5
Mollusca				
Gastropoda				
Gyraulus sp.	scraper	56	23	151
Helisoma sp.	scraper	15	44	41
Physella sp.	scraper	11	28	47
Malacostraca				
Amphipoda				
Hyalella azteca	shredder		1	
Decapoda				
Cambaridae	scavenger	2		
Arachnida				
Hydracarina		13	10	
Insecta				
Ephemeroptera				
Caenidae				
Caenis sp.	gatherer	3	8	1
Callibaetis sp.	gatherer	4	5	3
Odonata				
Anisoptera				
Aeshnidae	predator			1
Libellulidae	predator		1	20
Erythemis sp.	predator		2	8
Libellula sp.	predator			1
Pachydiplax sp.	predator	3	3	11
Tramea sp.	predator		1	
Zygoptera				
Coenagrionidae	predator	18	49	48
Enallagma sp.	predator		1	
Hemiptera				
Hebridae				
Merragata sp.	predator			1
Trichoptera				
Hydropsychidae	filterer			1
Hydroptilidae				
Oxyethira sp.	gatherer		1	
Lepidoptera				
Pyralidae	shredder			1
Coleoptera				
Haliplidae				
Peltodytes sp.	shredder		2	1
Hydrophilidae				
Tropisternus sp.	?			3
Diptera				
Ceratopogonidae	predator			2
Chironomidae	gatherer		14	4
Chironominae	gatherer	42	16	18
Tanypodinae	predator	1	5	2
Simulidae	filterer	1		4
Simulium sp.	filterer			1
Tipulidae				
Lemnophila,Hydrellia,Notiphila sp.	predator			1
Data Reduction Section				
No. of Taxa		12	20	24
No. of Individuals		169	217	376
Diversity		2.72	3.33	2.95
EPT Index		1	2	2
Percent Dominant Group		48 (Gastropods)	44 (Gastropods)	63 (Gastropods)
Percent Sensitive Groups (EPT)		4	6	1
Feeding Group Analysis, percent of				
scrapers		49	45	64
gatherers		29	21	8
predators		13	29	25
shredders		0	1.5	0.5
scavengers		1	0.5	1
filterers		0.5	0	1.5
miners		0	1	0

* denotes macrophytes where duplicate samples were combined.

Table 4. Macroinvertebrate population within 2 square meters of submerged vegetation in wetpond: May 2, 1996

Date			2 May, 1996	
Plant Species		E. canadensis *	M. spicatum *	N. Guadalupensis *
Taxa	Feeding Group	Number	Number	Number
Annelida				
Oligochaeta	miner	3		2
Mollusca				
Gastropoda				
Gyraulus sp.	scraper	11	2	2
Helisoma sp.	scraper	86	247	337
Helisoma (Pierosoma) sp.	scraper	39	43	98
Physella sp.	scraper	33	71	120
Malacostraca				
Amphipoda				
Hyalella azteca	shredder		2	5
Arachnida	?			1
Hydracarina	?	13	14	18
Arrenurus sp.?	?		12	
Insecta				
Ephemeroptera				
Baetidae	gatherer		2	
Caenidae				
Caenis sp.	gatherer	22	19	15
Callibaetis sp.	gatherer	5	23	9
Heptageniidae	scraper		1	
Odonata				
Anisoptera	predator			6
Aeshnidae	predator	1		1
Libellulidae	predator		1	3
Erythemis sp.	predator			2
Libellula sp.	predator		2	
Pachydiplax sp.	predator		3	
Sympetrum sp.	predator			1
Tramea sp.	predator		2	
Zygoptera				
Coenagrionidae	predator	2	30	30
Argia sp.	predator		1	2
Coenagrion sp.,Enallagma sp.	predator	2		10
Enallagma sp.	predator	1	5	
Ischnura sp.	predator	1		
Hemiptera				
Belostomatidae	predator		1	
Trichoptera				
Hydropsychidae				
Cheumatopsyche sp.	filterer			6
Coleoptera				
Dytiscidae	predator			1
Celina sp.?	predator		6	
Cybister sp.	predator		1	
Hydrovatus sp.	predator	1	1	3
Laccophilus sp.	?			1
Laccornis,Hydrovatus sp.?	predator			5
Uvarus sp.	predator			15
Hydrophilidae				
Berosus sp.	predator			1
Tropisternus sp.	?			1
Diptera				
Cyclorrhaphus-Brachycera (Pupae)	?		1	
Ceratopogonidae	predator	16	57	12
Forcipomyia sp.	predator		2	
Chironomidae	gatherer	10	25	21
Chironominae	gatherer	141	96	68
Zavreliella sp.	gatherer		1	
Orthocladiinae	gatherer		4	
Tanypodinae	predator	9	18	13
Culicidae	filterer			2
Data Reduction Section				
No. of Taxa		18	30	31
No. of Individuals		396	693	811
Diversity		2.92	3.28	3.03
EPT Index		1	3	2
Percent Dominant Group		44 (Dipterans)	52 (Gastropods)	69 (Gastropods)
Percent Sensitive Groups (EPT)		6	6	3
Feeding Group Analysis, percent of				
scrapers		43	53	69
gatherers		45	25	14
predators		8.5	18.5	12.5
shredders		0	0.5	1
scavengers		0	0	0
filterers		0	0	1
miners		0.5	0	0.5

* denotes macrophytes where duplicate samples were combined.

Table 5. Macroinvertebrate population within 2 square meters of submerged vegetation in wetpond: July 2, 1996

Date			2 Jul., 1996	
Plant Species		**E. canadensis** *	**M. spicatum**	**Cladophora sp.**
Taxa	**Feeding Group**	**Number**	**Number**	**Number**
Annelida				
Oligochaeta	miner	94		14
Tubificidae	miner	157	71	
Mollusca				
Gastropoda				
Gyraulus sp.	scraper	162	127	55
Hebetancylus sp.?	scraper		2	
Helisoma sp.	scraper			59
Helisoma (Pierosoma) sp.	scraper	2	6	1
Physella sp.	scraper	2	2	
Arachnida	?			3
Hydracarina	?	4	11	1
Arrenurus sp.?	?		2	
Insecta				
Ephemeroptera				
Caenidae				
Caenis sp.	gatherer	1	1	
Odonata				
Anisoptera				
Libellulidae	predator	3	2	
Erythemis sp.	predator		1	1
Zygoptera				
Coenagrionidae	predator	3		3
Argia sp.	predator	1		
Hemiptera	predator			5
Belostomatidae	predator	2		
Lepidoptera				
Pyralidae				
Munroessa, Neocataclysta, Synclita sp.	shredder	1		1
Coleoptera				
Hydrophilidae	predator	2		5
Lacobius sp.	?			4
Georyssidae?	?			13
Diptera				
Ceratopogonidae	predator	151	152	204
Chironomidae	gatherer	6	7	7
Chironominae	gatherer	13	14	14
Orthocladiinae	gatherer		11	
Tanypodinae	predator	8	9	4
Culicidae	filterer			2
Culex sp.	filterer			2
Stratiomyidae				
Odontomyia, Hedriodiscus sp.	gatherer	2		16
Tipulidae	predator			1
Data Reduction Section				
No. of Taxa		18	15	21
No. of Individuals		614	418	415
Diversity		2.49	2.42	2.62
EPT Index		1	1	0
Percent Dominant Group		41 (Oligochaetes)	46 (Dipterans)	61 (Dipterans)
Percent Sensitive Groups (EPT)		<1 (0.16)	<1 (0.24)	0
Feeding Group Analysis, percent of				
scrapers		27	33	29
gatherers		3.5	8	9
predators		28	39	54
shredders		0.5	0	0.5
scavengers		0	0	0
filterers		0	0	1
miners		41	17	3.5
* denotes macrophytes where duplicate samples were combined.				

Table 6. Macroinvertebrate population within shallow and deep areas of wetpond (0.5 ft ^{2}).

Date		20 Dec., 1995		14 Feb., 1996		2 May, 1996		2 Jul., 1996	
		Benthic Grab		Benthic Grab		Benthic Grab		Benthic Grab	
Location		Sediment (Shallow)	Sediment (Deep)	Sediment (Shallow)	Sediment (Deep)	Sediment (Shallow)	Sediment (Deep)	Sediment (Shallow)	Sediment (Deep)
Taxa	**Feeding Group**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Annelida	miner			7	2				
Oligochaeta	miner		1						
Branchiura sowerbyi	miner	17	1			6	6	4	2
Tubificidae	miner	2		1		1		2	
Mollusca	filterer					2	1		
Gastropoda									
Gyraulus sp.	scraper	4	1	3					
Helisoma sp.	scraper	6		3					
Physella sp.	scraper	2	2						
Crustacea	scavenger						2		4
Insecta									
Ephemeroptera	gatherer							1	1
Caenidae									
Caenis sp.	gatherer	2							
Odonata									
Coenagrionidae	predator	1	1						
Diptera									
Ceratopogonidae	predator		34						
Chaoboridae	predator		1		3				
Chironominae	gatherer	4	51	3	44				
Tanypodinae	predator	3		3	8				
Data Reduction Section									
No. of Taxa		9	8	6	4	3	3	3	3
No. of Individuals		41	92	20	57	9	9	7	7
Diversity		2.63	1.48	2.39	1.08	1.71	1.58	1.38	1.38
EPT Taxa		0	0	0	0	0	0	0	0
Percent Dominant Group		46(oligocha)	93(Dipterans)	40(oligocha)	96(Dipterans)	78(oligocha)	67(oligocha)	86(oligocha)	57(crustace)
Feeding Group Analysis, percent of									
scrapers		29	3	30	0	0	0	0	0
gatherers		15	55	15	77	0	0	14	14
predators		10	39	15	19	0	0	0	0
shredders		0	0	0	0	0	0	0	0
scavengers		0	0	0	0	0	22	0	57
filterers		0	0	0	0	22	11	0	0
miners		46	2	40	4	78	67	86	29

Appendix K

Benthic Macroinvertebrate Graphs

Figure 1. Macroinvertebrate species richness within submerged vegetation in wetpond over time.

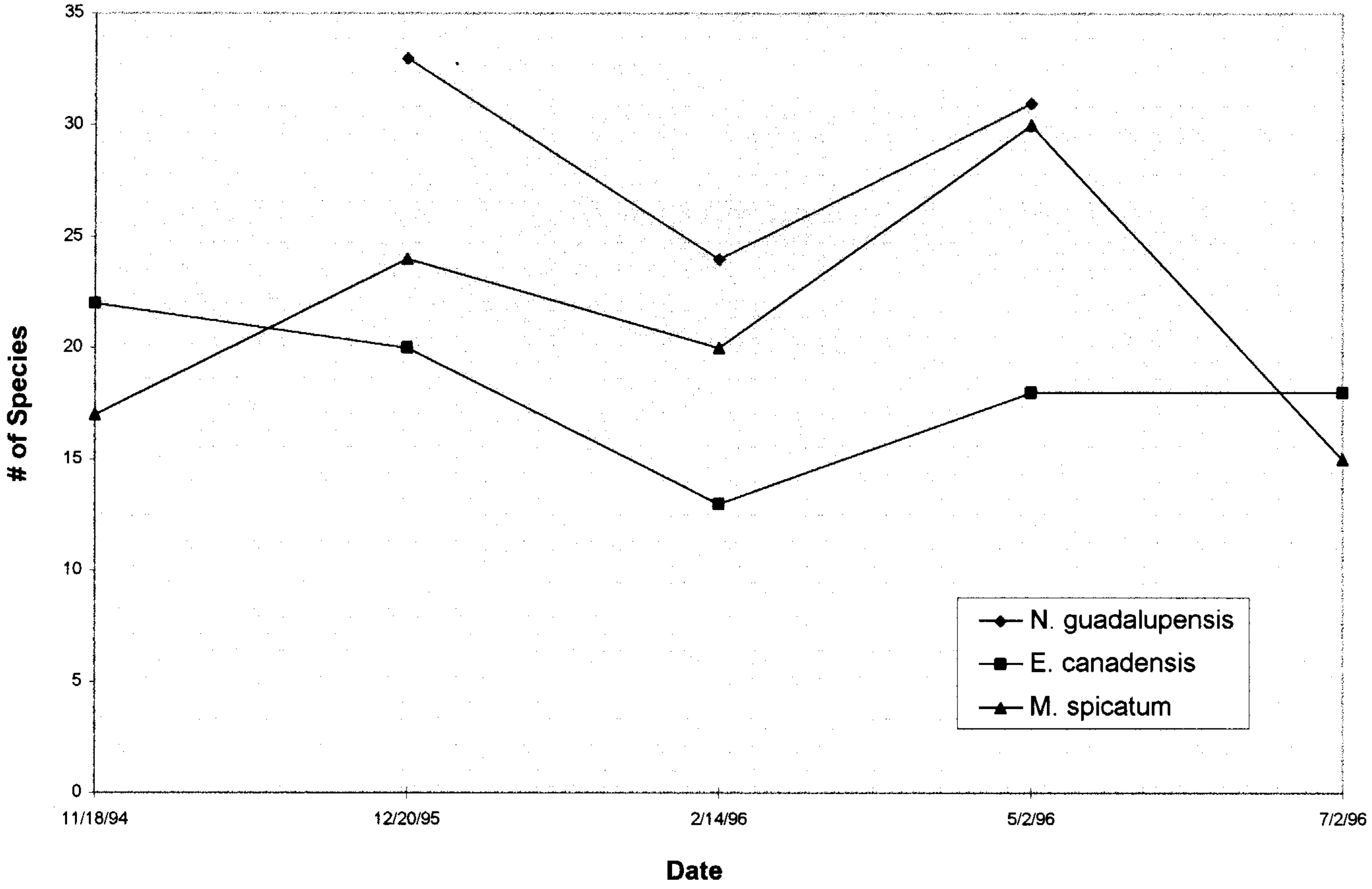


Figure 2. Macroinvertebrate species diversity within submerged vegetation in wetpond over time.

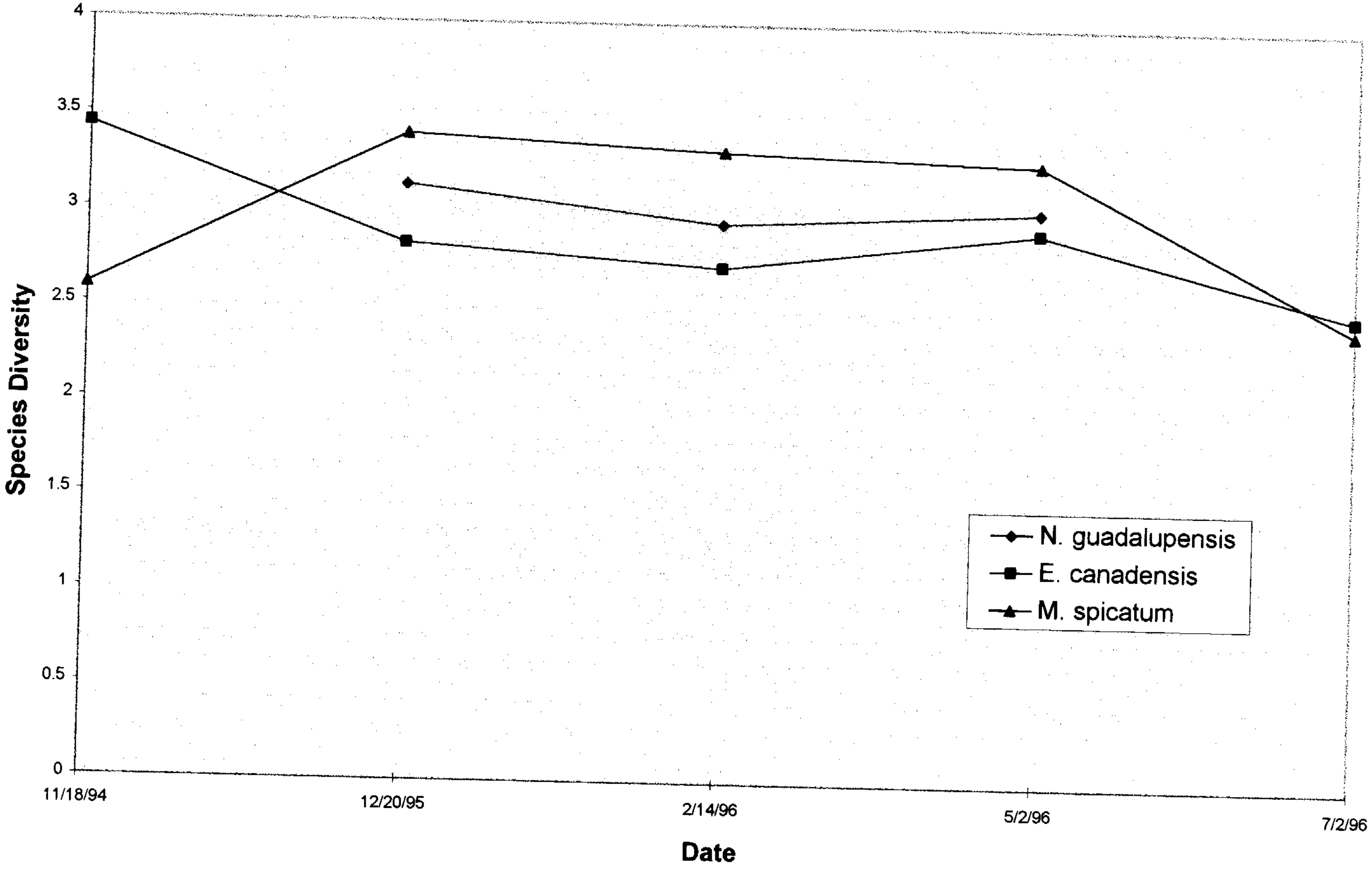


Figure 3. Percent dominant group in macroinvertebrate community within submerged vegetation of wetpond over time.

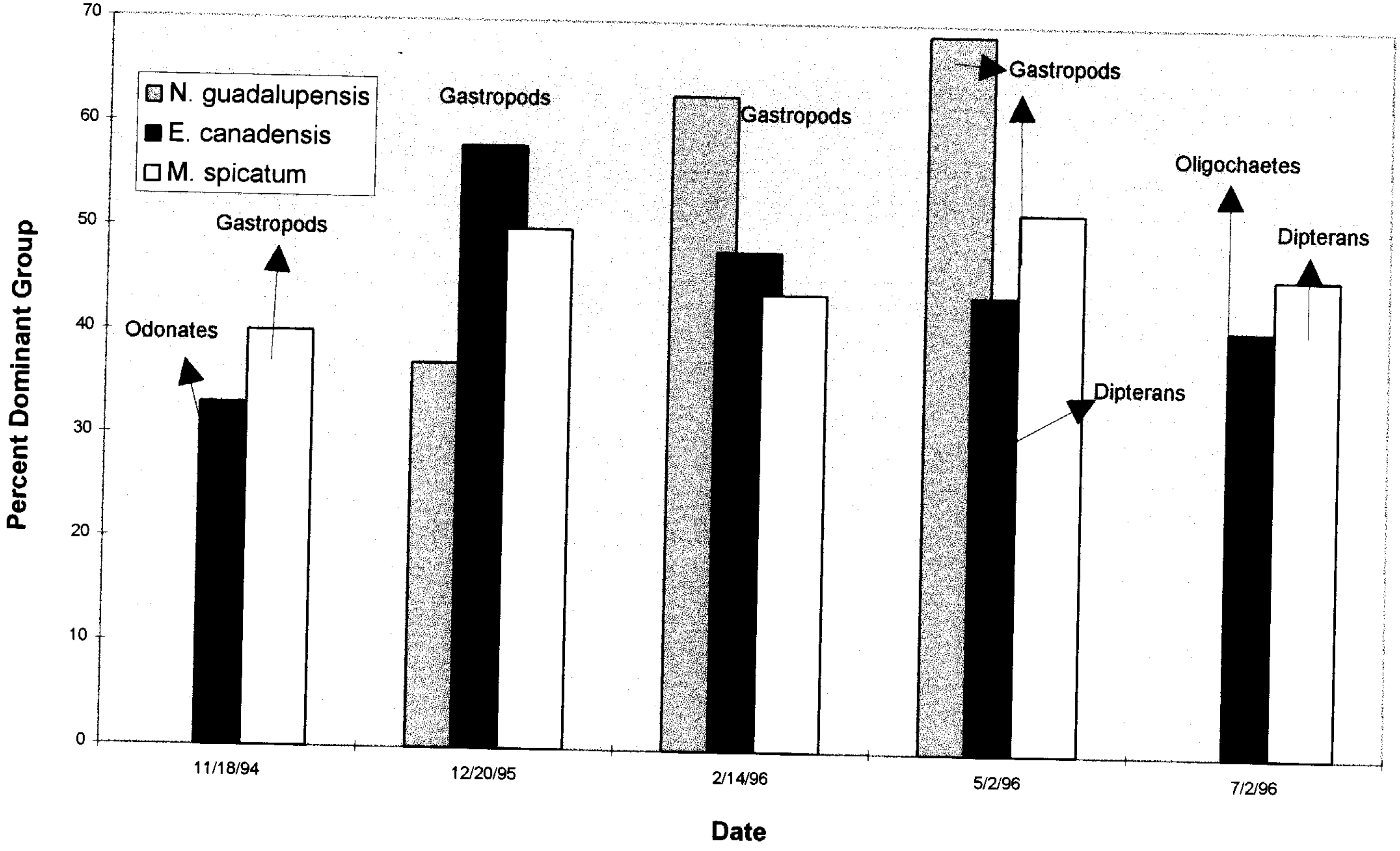


Figure 4. Feeding group analysis of macroinvertebrate community within E. canadensis over time.

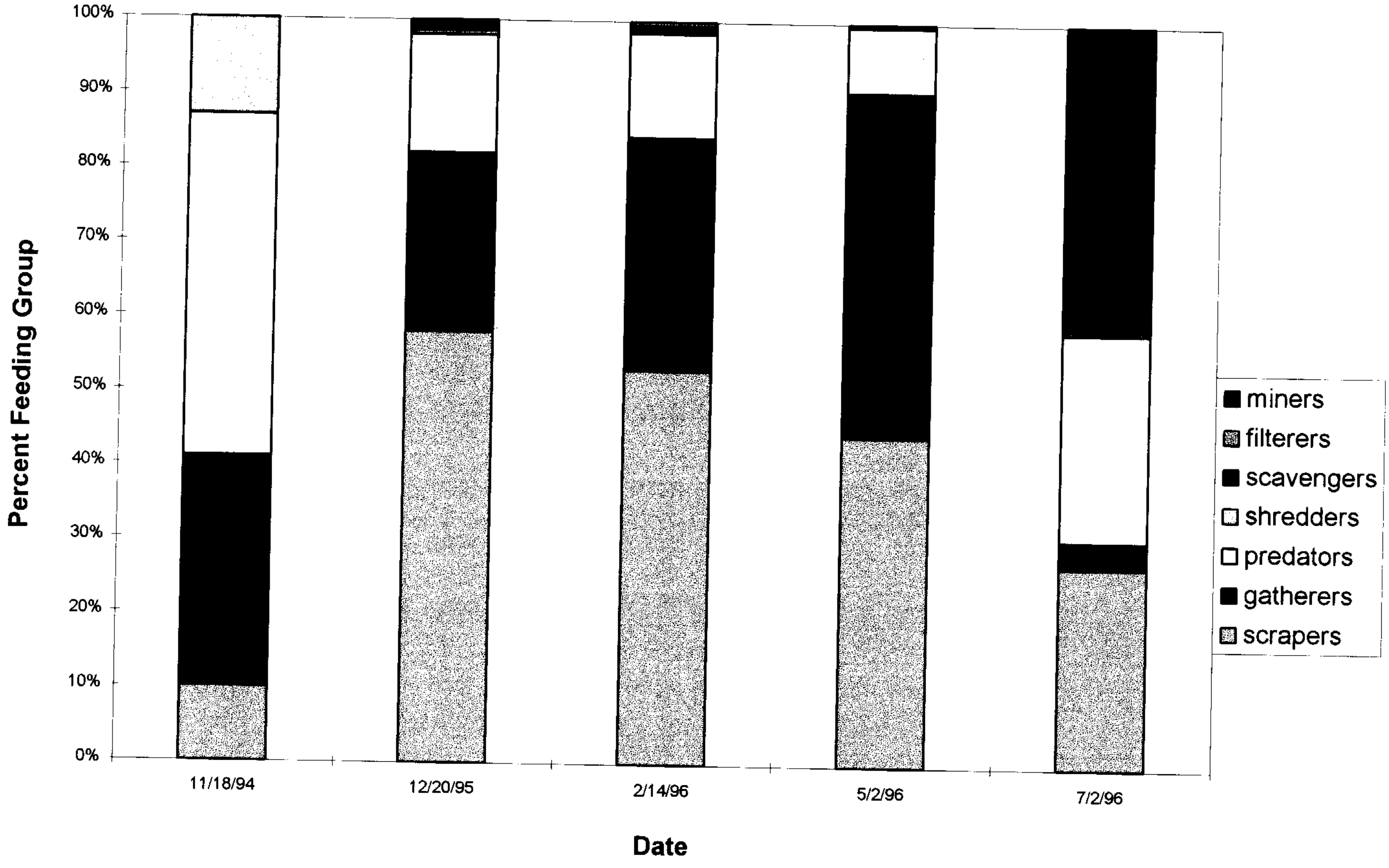


Figure 5. Feeding group analysis of macroinvertebrate communtiy within M. spicatum over time.

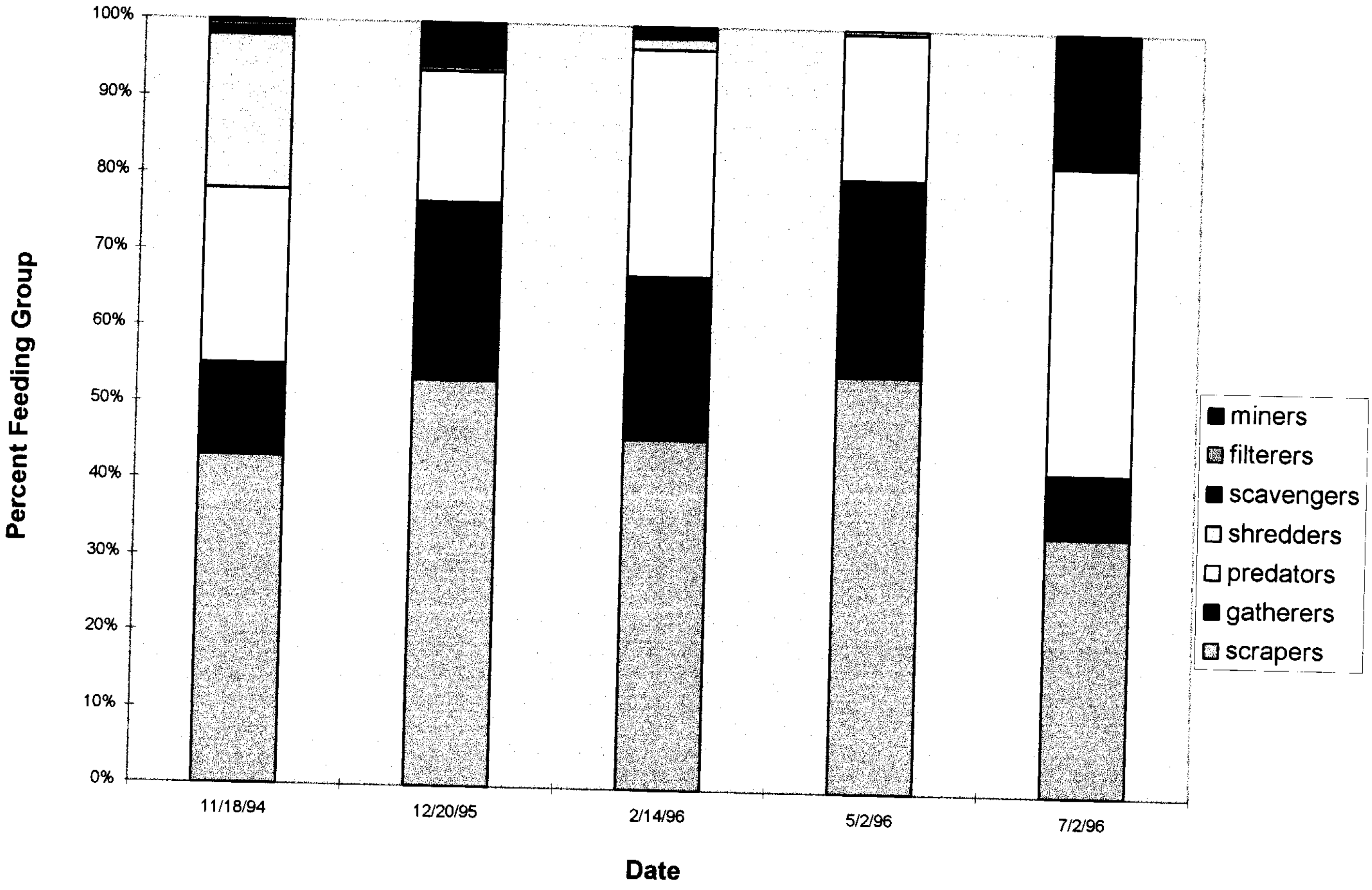


Figure 6. Feeding group analysis of macroinvertebrate community within N. guadalupensis over time.

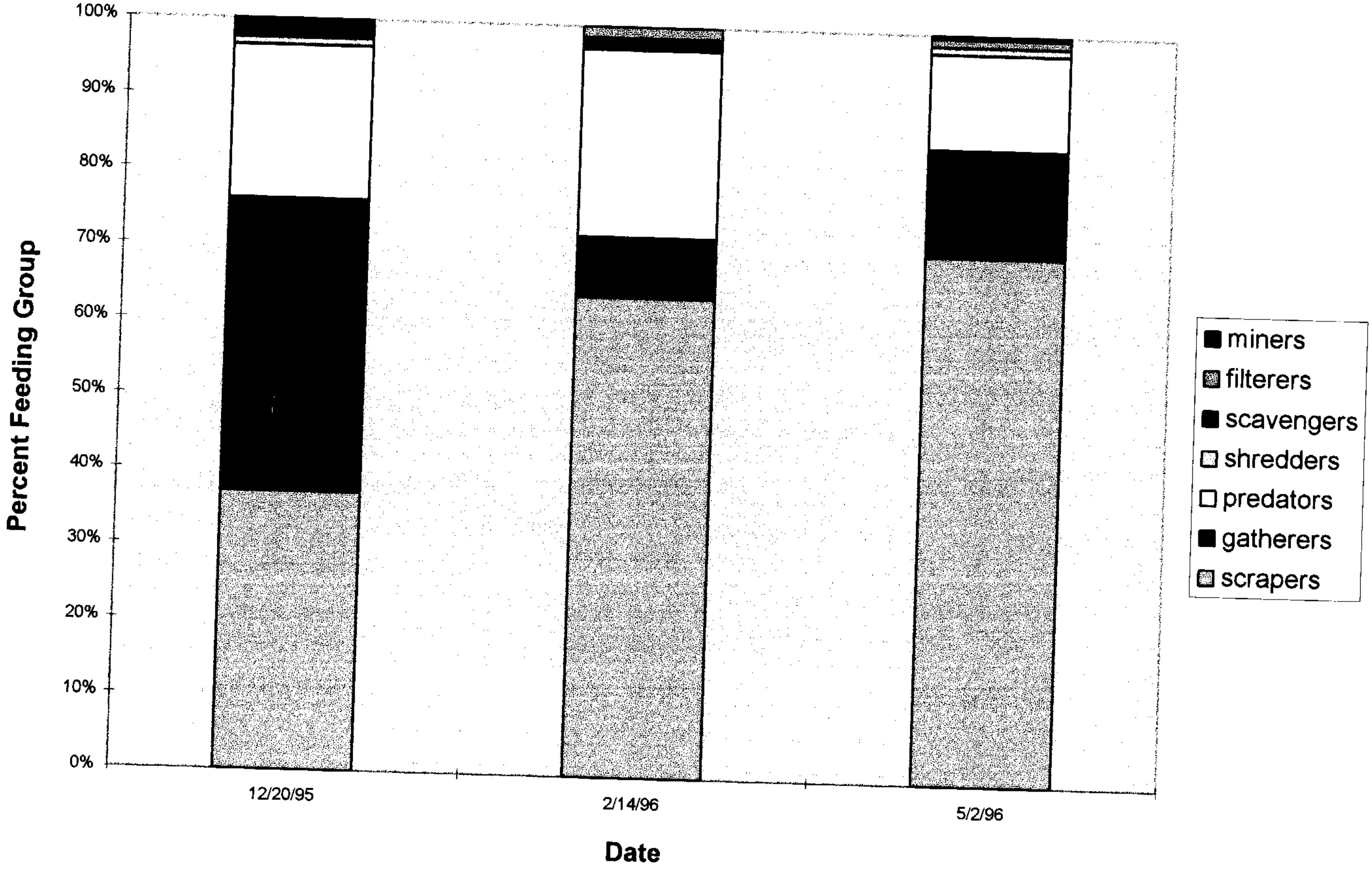


Figure 7. Macroinvertebrate species richness within shallow and deep sediment areas of wetpond over time.

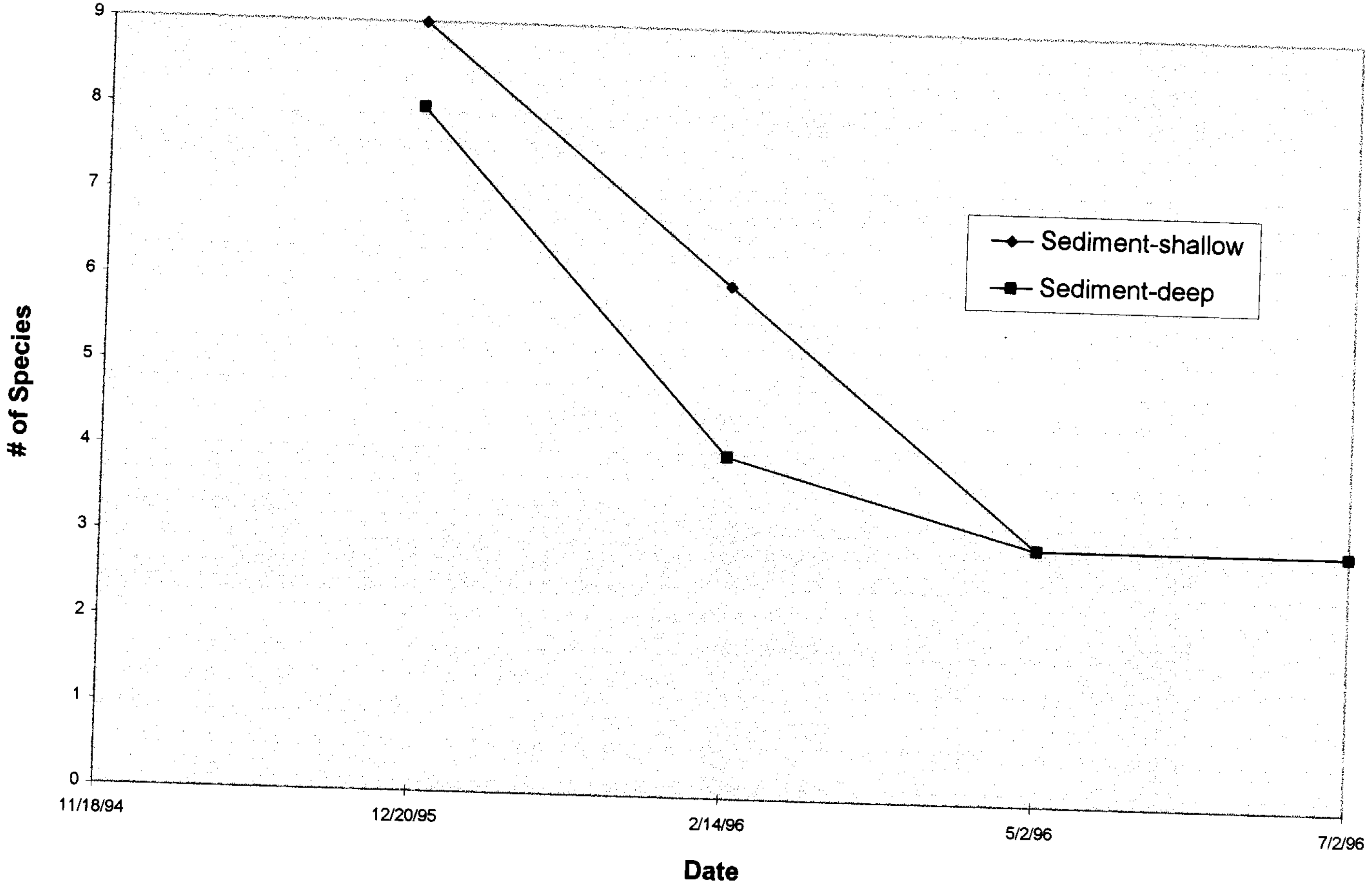


Figure 8. Macroinvertebrate species diversity within shallow and deep sediment areas of wetpond over time.

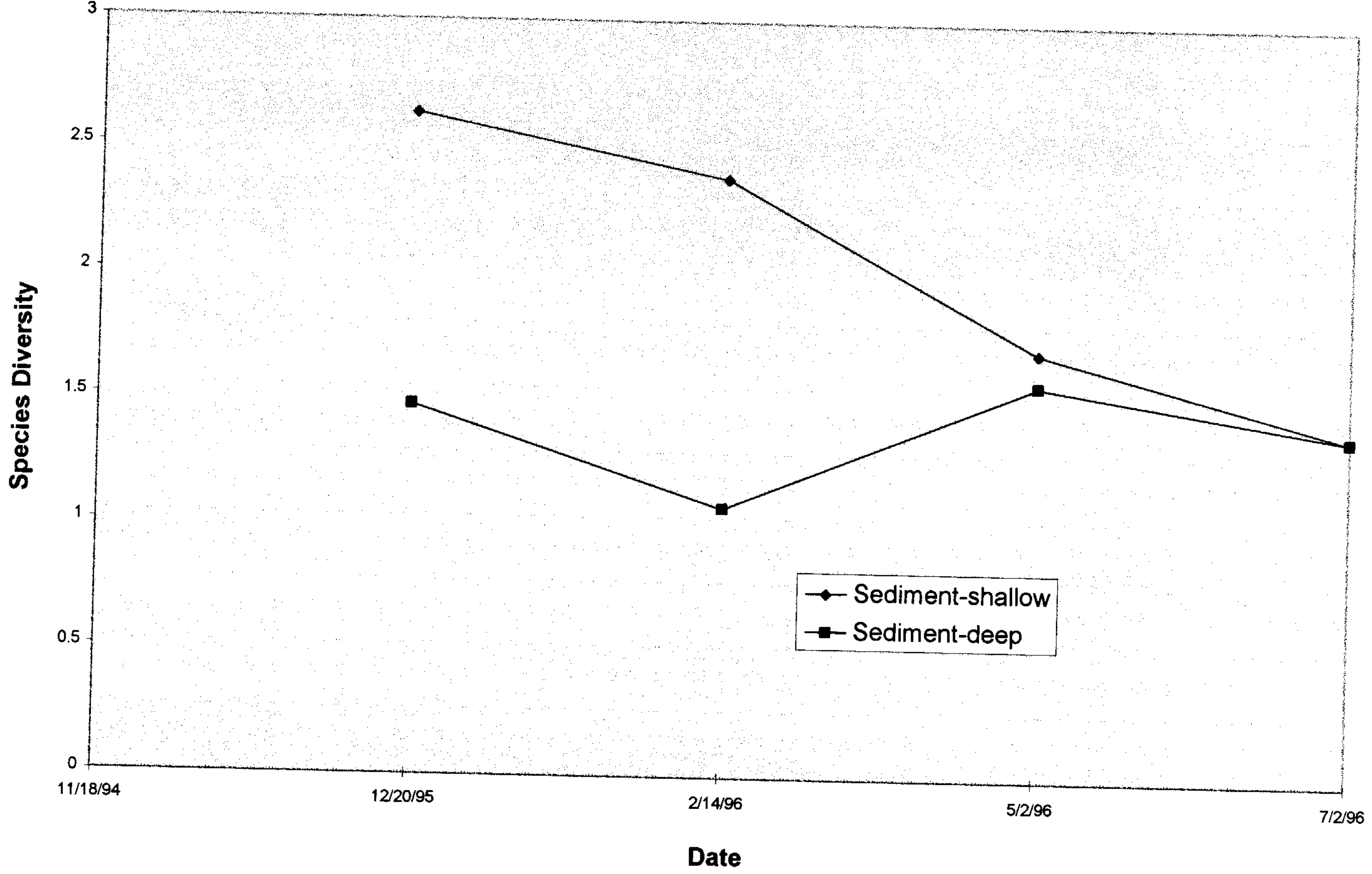


Figure 9. Percent dominant group in macroinvertebrate community within shallow and deep sediment areas of wetpond over time.

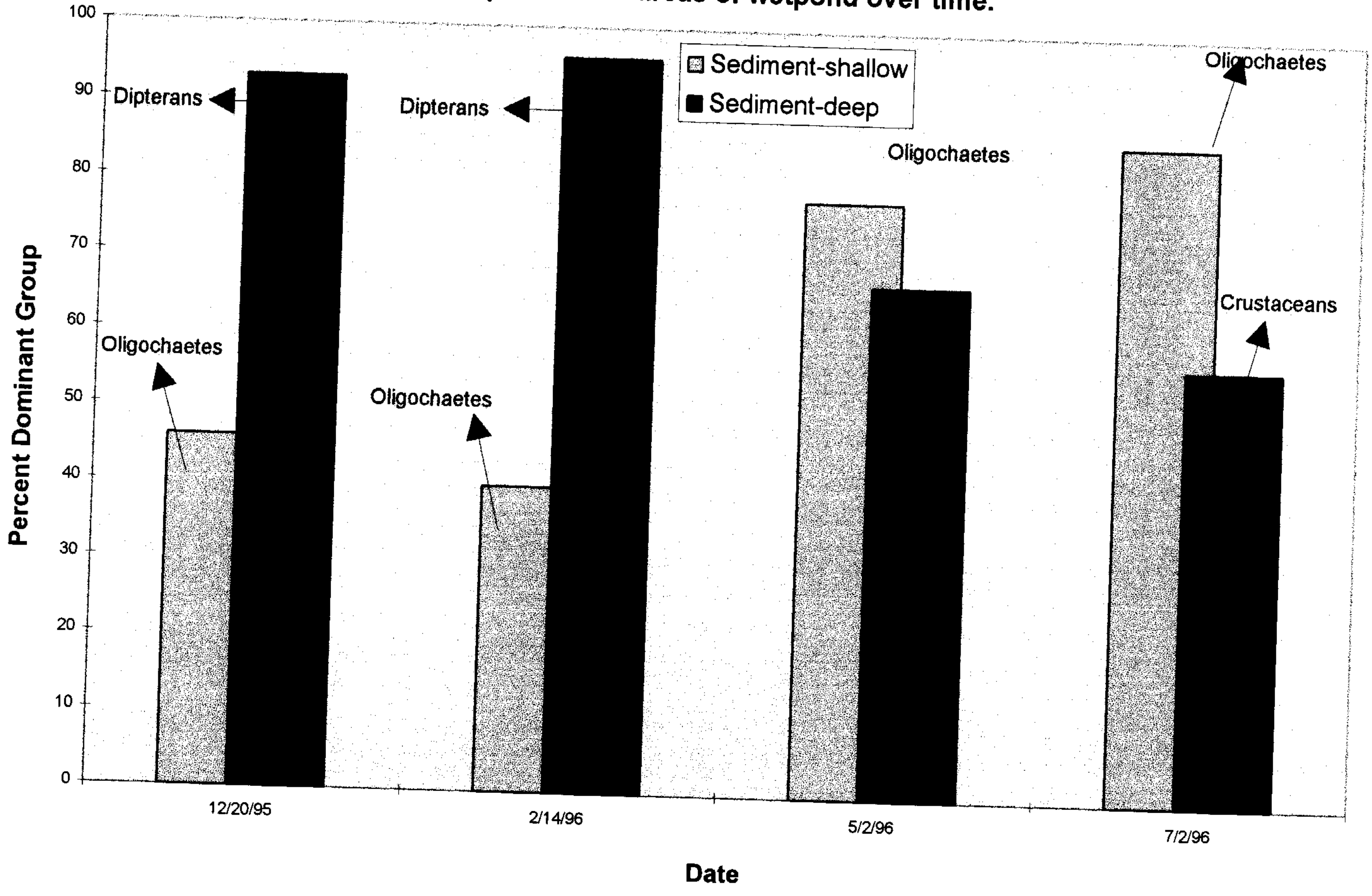
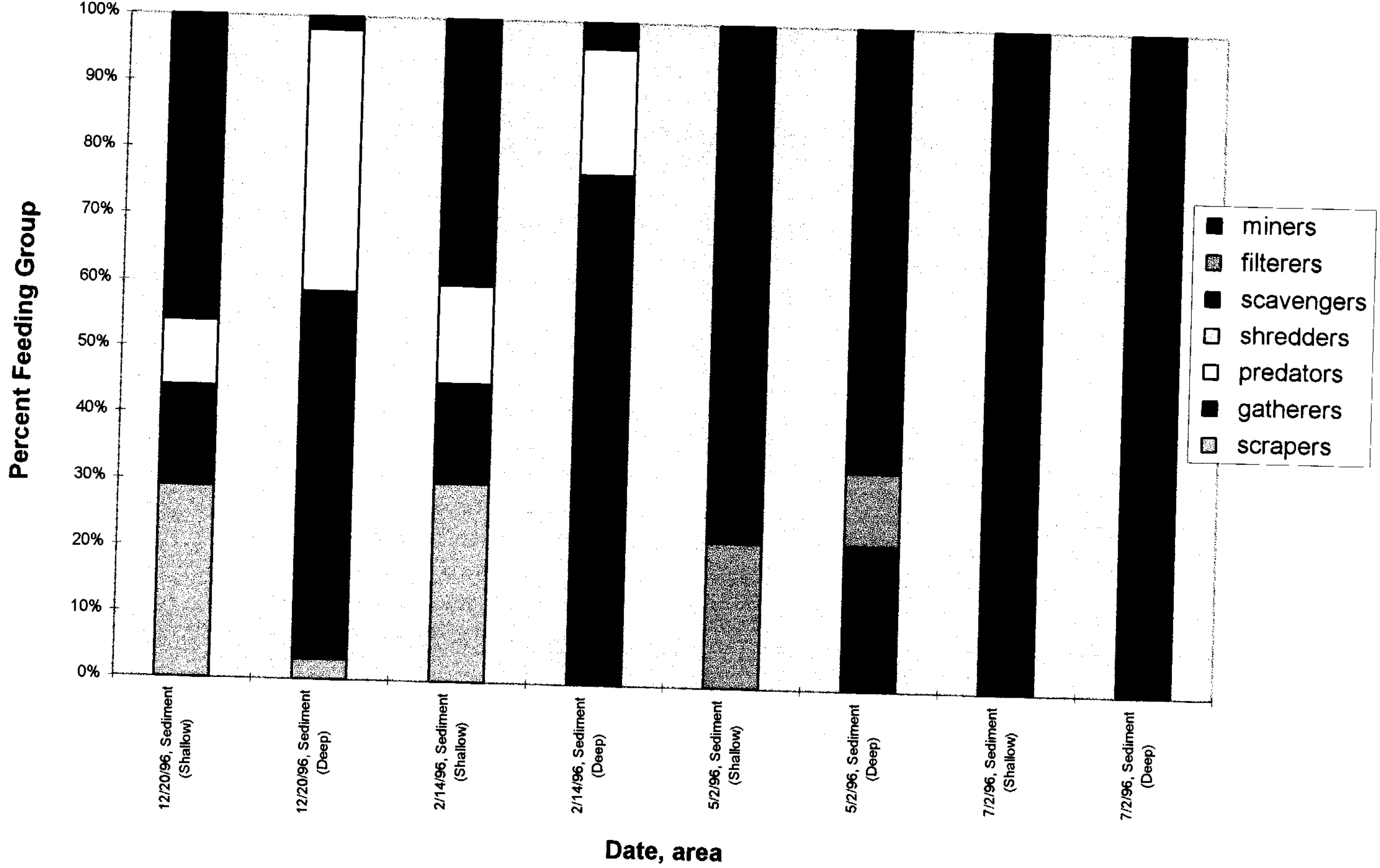


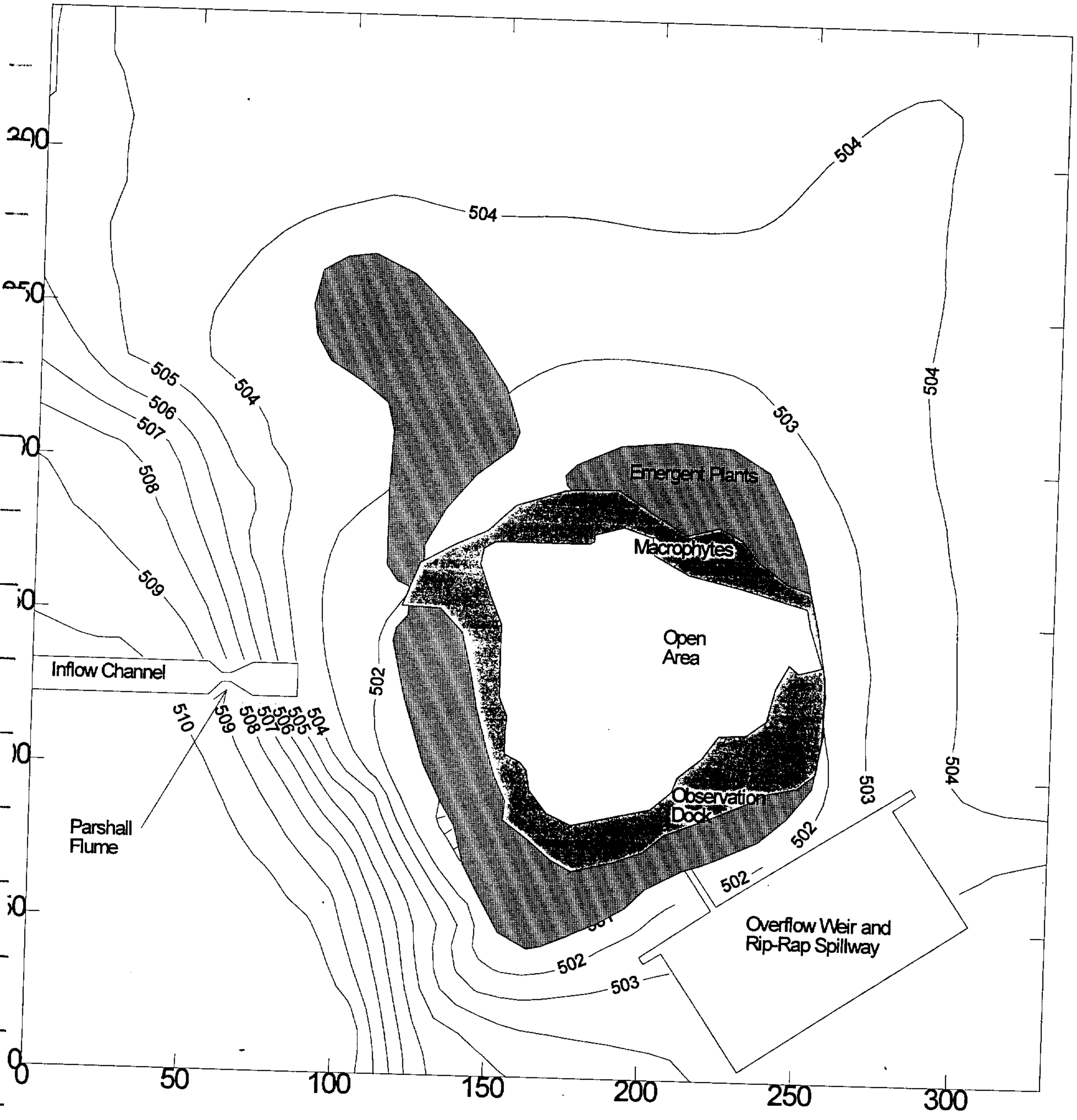
Figure 10. Feeding group analysis of macroinvertebrates within shallow and deep sediment areas of wetpond over time.



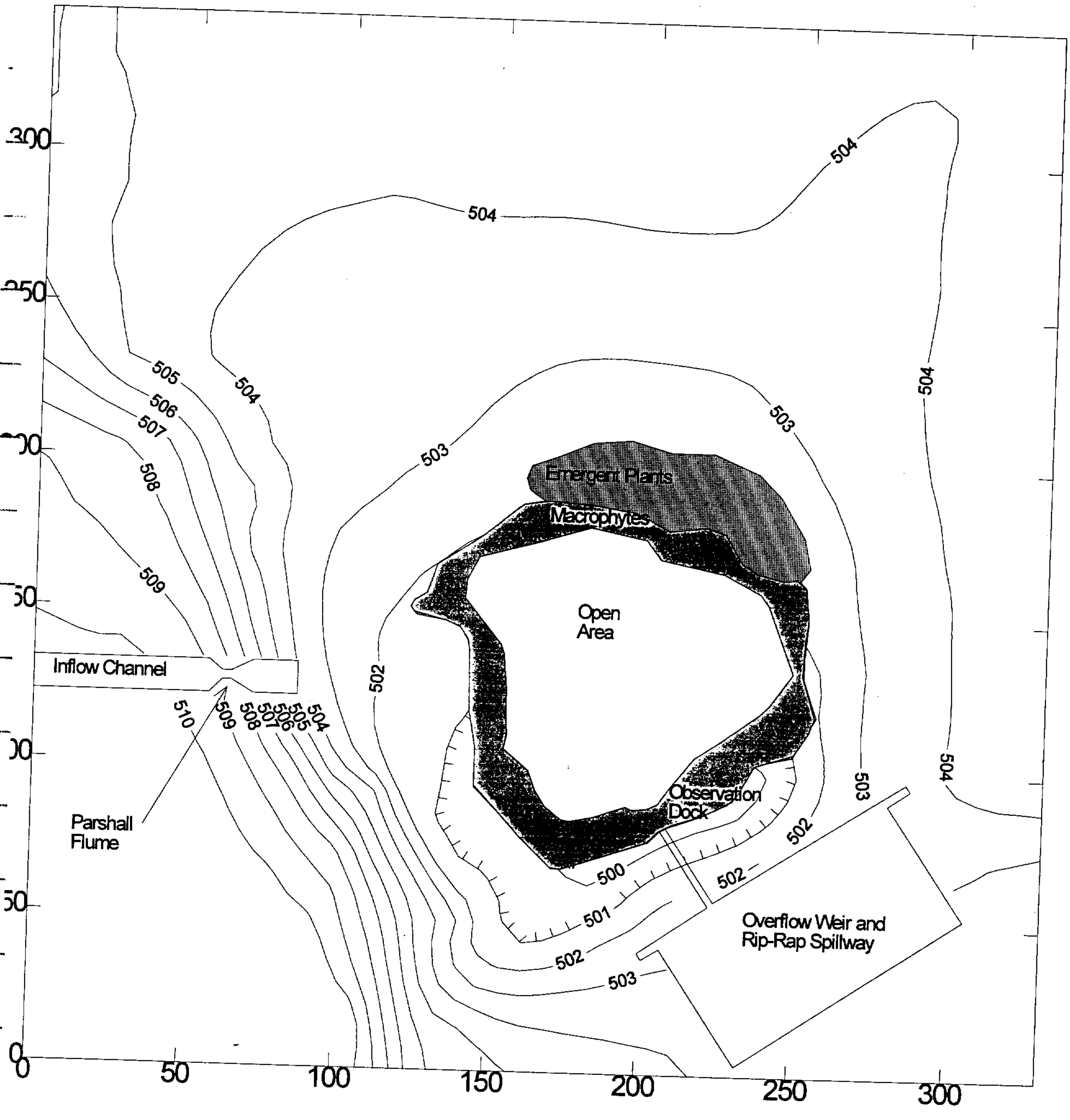
Appendix L

Vegetation Maps

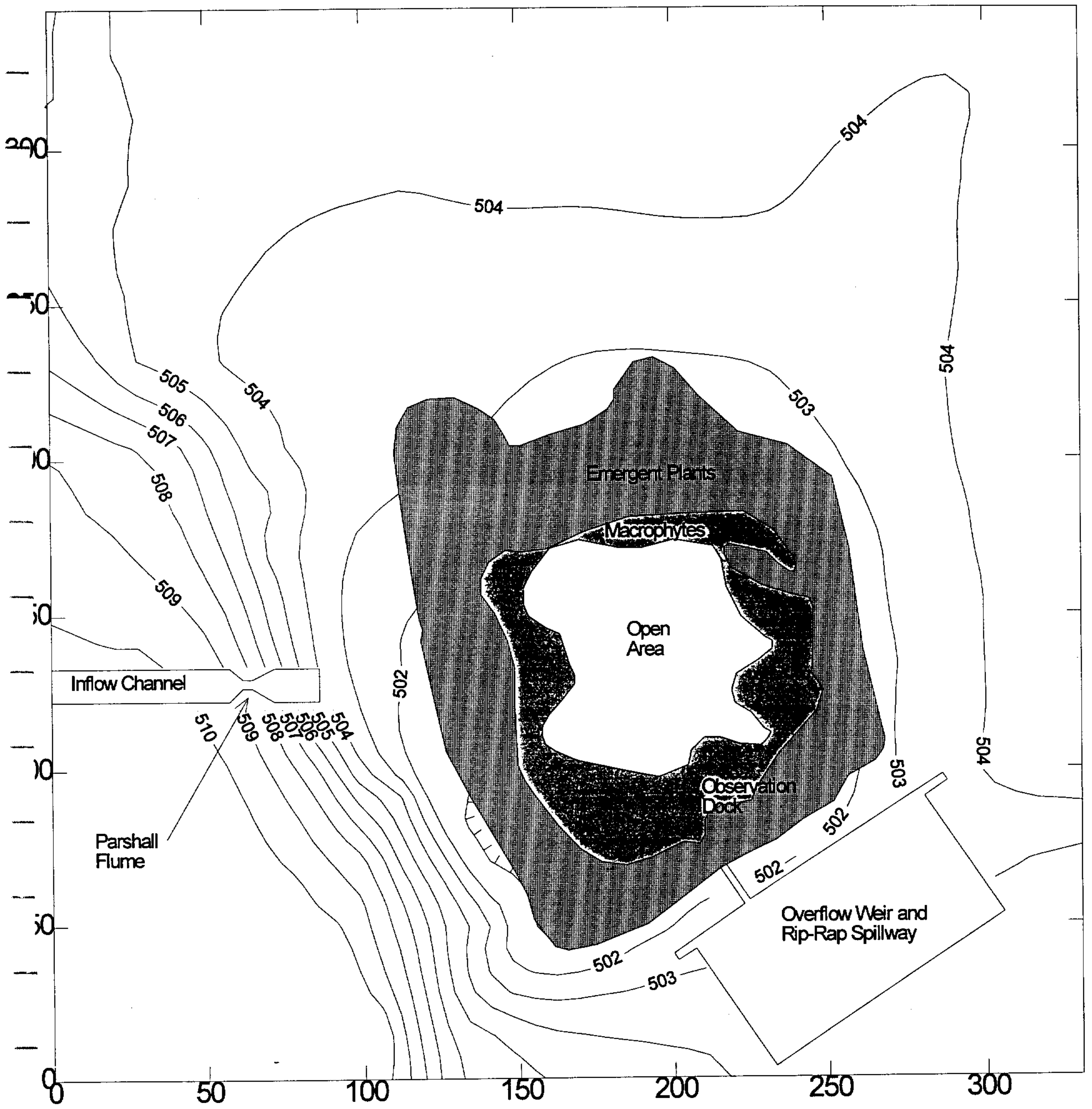
Mansfield Wetpond Vegetation - December 1994



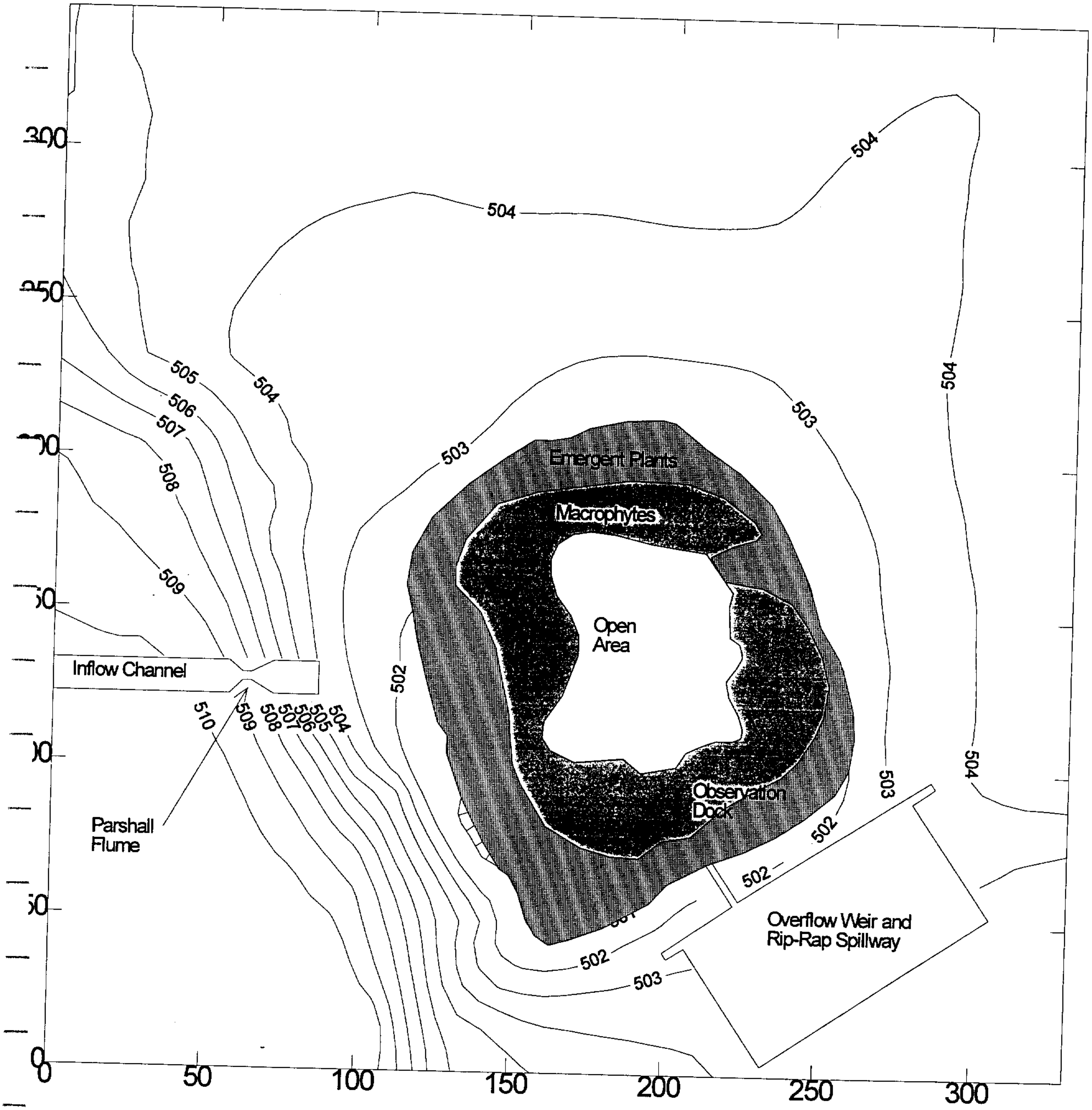
Mansfield Wetpond Vegetation - February 1995



Mansfield Wetpond Vegetation - May 1995

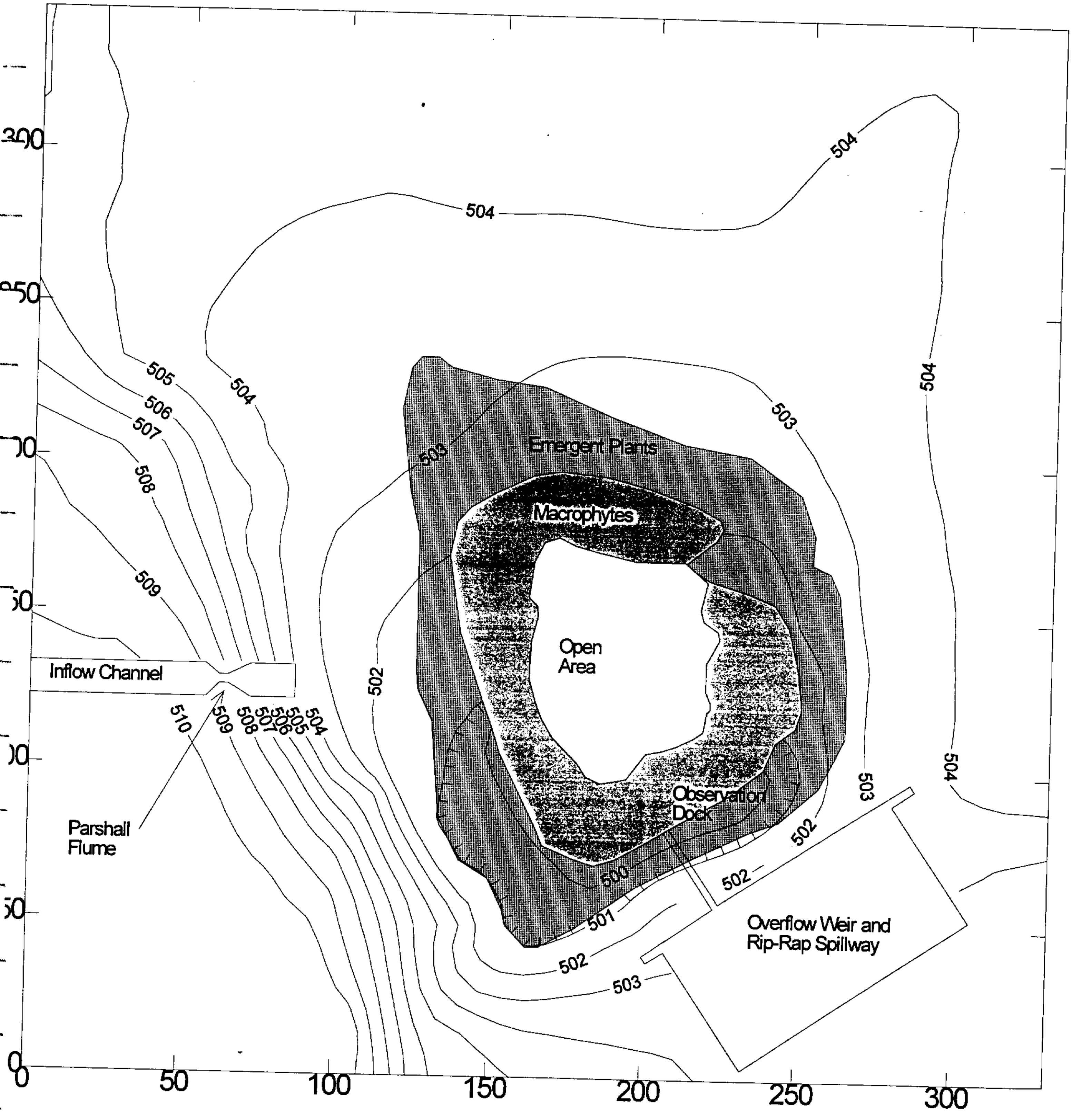


Mansfield Wetpond Vegetation - December, 1995



Mansfield Wetpond Vegetation - March, 1996

Mansfield Wetpond Vegetation - July, 1996



Mansfield Wetpond Vegetation - October, 1996