EVALUATION OF ARS AND SCS CONSTRUCTED WETLAND/ANIMAL WASTE TREATMENT PROJECT at HERNANDO, MISSISSIPPI[1]

Interim Report
1990-1991

A portion of the
Demonstration Erosion Control Project (DEC) in the
Yazoo Basin

by
Water Quality/Ecology & Watershed Processes Units
National Sedimentation Laboratory
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Personnel
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1 Contribution of the National Sedimentation Laboratory, Agricultural Research Service, U. S. Department of Agriculture, Oxford, Mississippi and the U. S. Department of Agriculture, Soil Conservation Service, Jackson, Mississippi.

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INTRODUCTION

During the past two decades the beneficial role of aquatic plants for improving water quality has been thoroughly documented (Boyd, 1970; Sheffield, 1967; Yount, 1964). The production-trapping system of wetlands had been shown to remove nutrients, organic chemicals, heavy metals, and sediments from inflowing waters. Environmental engineers have recommended the re-establishment of wetlands where water quality has deteriorated since wetland removal (Kloetzli, 1981; Jones and Lee, 1980). Seidel (1976) and Wolverton and McDonald (1975, 1976, and 1981) documented the efficiency of aquatic plants in removing organic chemicals from water. Simpson et al. (1983) and Peverly (1985) demonstrated the effective role that wetlands play in trapping heavy metals. Wiedler and Lang (1984) described how wetlands help regulate stream chemistry and minimize acid mine drainage impact.

One result of natural wetlands research has been the knowledge that physical, chemical, and biological processes which occur in wetlands are similar to those occurring in mechanical sewage treatment plants. These processes also result in an efficient uptake of chemicals and metals. Thus, many recent nutrient uptake and cycling studies conducted on wetlands have been concerned with their potential use as natural sewage treatment systems (Simpson et al., 1983; Boyt et al., 1976; Dolan et al., 1981) or as water purifiers (Sloey et al., 1978; Nichols, 1983).

Recent research interests have begun to focus on practical, applied uses of natural and constructed wetlands in the area of waste processing (Reed, 1991). Small municipalities are finding constructed wetlands an alternative to more costly conventional waste treatment plants (Gearheart, et al., 1989). Processing and disposing of concentrated on-farm animal waste, a major source of water quality deterioration, is a primary concern of the Soil Conservation Service and regulatory agencies. Thus, several projects for evaluating the ability of constructed wetlands to process animal waste have been initiated across the United States. The Mississippi Soil Conservation Service (SCS) and the Agricultural Research Service (ARS), National Sedimentation Laboratory in Oxford, Mississippi are cooperating on an on-farm dairy waste treatment project in DeSoto County, Mississippi. By agreement, SCS designed and constructed a lagoon and wetland cells and ARS is evaluating wetland cell processing efficiency.

This report provides:

1) A brief overview of project history
2) Summaries of measured environmental and water quality parameters

Following initial inflow from the anaerobic lagoon to the cells, bulrushes exhibited distinct browning of the culm tips, ranging from 0 to 4 inches from the tip down the culm on 26 April 1991. On 29 April, continuing heavy rain threatened to cause back flow to the milking barn, and Mr. Scott opened all valves to discharge water from the lagoon through the cells to prevent contamination of the milking facility. This emergency flushing had no additional visible affect on plant growth. At this time, bulrushes in Cell 1 appeared in good condition with most flowering and only a very small percentage exhibiting brown culm tips. In Cell 2, very few plants were flowering, and most culms were browned up to 1/3 their length from the tip. Conditions were intermediate in Cell 3, with approximately 1/3 of the plants flowering, and only about 1/2 showing browning of the culm tops. Plant density in Cell 2 was also only about 1/2 of that in Cells 1 and 3.

By May 13, 1991 plants in all cells appeared to have stabilized, but death of browned culms created sparser stands in some portions of Cells 1 and 2. By late May, acute effects from wastewater loading in cells were less marked, and no further browning of the culms was observed. Most unaffected plant culms in all cells were flowering, and plant densities were high in all cells with the exception of some notable sparsity in the lower 1/4 of Cell 2. No further evidence of plant stress was noted; conversely, during June large numbers of new emergent shoots developed flowering heads, and plant densities in all cells remained very high for the remainder of the year.

The variability of hydrologic and environmental conditions reduced ability to maintain constant inflow to wetland cells. Control of inflow rates to the 3 cells from the lagoon reflected problems associated with fluctuating lagoon water levels, settling and clogging of solids in supply pipes, and high evaporation rates in the cells. Greater ability to control inflow was attained by the addition of 2" ball valves in-line on wetland cell inflow standpipes during May, 1991. Rapid water level decline (Table 3) in the anaerobic lagoon during June, July, and early August, 1991 prompted a reduction of cell inflow rates to 0.5 liters per minute, but, at such a low rate, settling and clogging of pipes and valves accelerated. During August, after consulting with Ross Ulmer (SCS), inflow ball valves were removed, and standpipes were fitted with threaded end caps with orifices. End caps with different sized orifices could be used to achieve desired flow rates. Using this method, a cell inflow rate of 1.0 liter per minute was implemented.

In October, 1991, water level in the anaerobic lagoon fell to near the minimum level for feeding the wetland cells by gravity flow. A constant head tank was placed on the lagoon levee and plumbed to feed the outflow pipe. An electric impeller pump controlled by a timer maintained water in the tank, allowing the cells to receive consistent pressure and, consequently, consistent inflow. Because of the greater stability associated with this configuration, data has been analyzed separately for the period following its implementation.

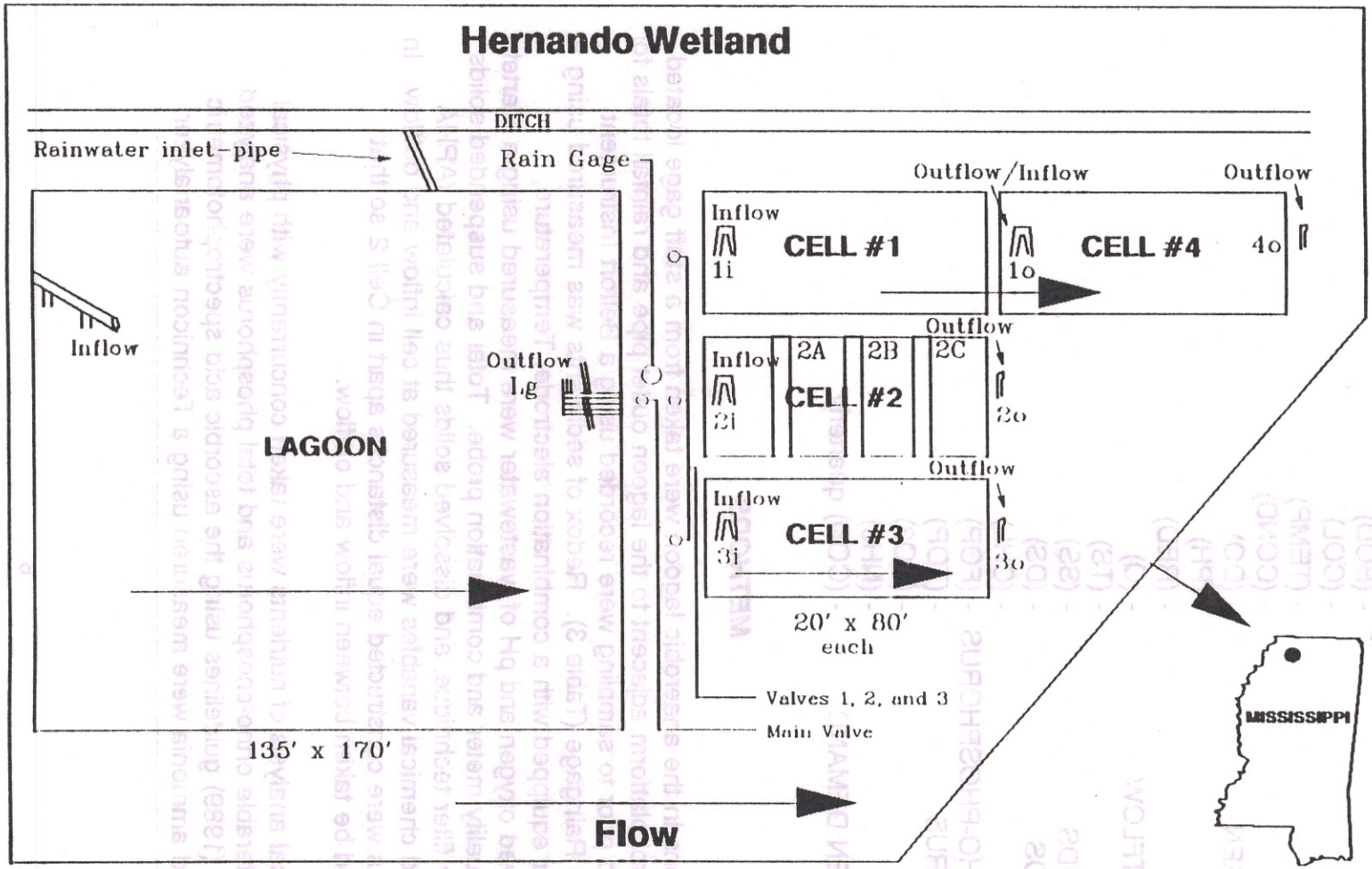

Fig. 1 Drawing of lagoon/wetland cell construction at Hernando wetland on Allan Scott Farm, DeSoto County.

Biological oxygen demand, chlorophyll, and total coliforms were also measured according to APHA guidelines (1989). Five-day carbonaceous biological oxygen demand, CBOD-5, was measured using a YSI Model 50B oxygen meter with model 5730 probe. Addition of a nitrification inhibitor (TCMP, Hach Corporation) was used to allow only carbonaceous oxygen demand to be measured. Coliforms were enumerated using the membrane filter technique with filters and media supplied by Sartorius Corporation (M-FC media). Coliform counts given are number of colony forming units (CFU's) per 100 ml sample.

PHYSICAL DATA

Maximum, mean, and minimum values obtained for physical parameters to date are given in Table 4. Data obtained after implementation of the threaded end caps to control cell inflows (August through December, 1991) has been referred to as "Stable" data, and is presented separately in Table 5.

Physical parameter values generally decreased from cell inflow to cell outflow, with exception of redox, which varied greatly (Figure 2). As seen in Figure 3, dissolved solids composed the majority of total solid exports from the lagoon to wetland cells. This might be expected from the settling action which occurred inside the lagoon. Concentration of dissolved oxygen decreased (Figure 4). This decrease was most likely due to very high oxygen demand and only sparse growth of green algae in the cells because of shading from bulrushes and duckweed which formed early in the growing season. Mean values for solids moving through Cell 2 decrease gradually with increased distance from the inflow, but overall reduction is small (Figure 5). Decrease in suspended solids accounts for most of this reduction, which occurs in the first half of the cell. Dissolved solids dynamics are much less pronounced. The disparity of suspended solid reduction seen between Cell 1 and Cells 2 and 3 (Table 4, Table 5) appears to have been caused by longer retention time and higher water level in cell. The outflow riser pipe of Cell 1 was replaced with an incorrect length of pipe during construction of Cell 4, resulting in the noted differences. This inconsistency has been corrected.

NUTRIENT DATA

Nutrient removal efficiencies for the wetland cells were high for ortho-phosphorus, total phosphorus, and ammonia (Figure 6). Nitrate concentrations were much lower than those of phosphorus and ammonia, as portrayed in Figure 7. Actual increases in levels of nitrate (with attendant negative removal efficiencies) in wastewater flowing through Cell 3 may represent biological transformation of ammonia and other nitrogenous compounds to nitrate.

Overall mean values for each nutrient are presented in Table 6. Again, "stable" data obtained after more consistent inflows to the wetland cells were established (August through December, 1991) are presented separately (Table 7).

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TABLE 3. Lagoon Level and Rainfall Data

DATE	GAGE (ft)	RAIN (in)
05-07-91	8.14	1.8
05-14-91	8.09	1.4
05-22-91	8.16	1.75
05-29-91	8.08	1.35
06-04-91	7.88	0.05
06-11-91	7.62	0.05
06-24-91	7.42	0.65
07-08-91	7.04	0.3
07-22-91	6.7	0
08-19-91	6.4	2.05
09-03-91	6.05	ns
09-16-91	6.1	1.4
10-07-91	5.7	0.48
10-21-91	5.5	0.6
11-04-91	6.4	3.2
11-18-91	6.15	0
12-02-91	8.0	6.0
12-16-91	8.07	4.7
12-30-91	8.05	0.55

TABLE 5. Stable Physical Data

STA	MAX TEMP (°C)	MAX COND (µmhos/cm)	MAX DO (mg/L)	MAX PH	MAX REDOX mV	MAX TS (mg/L)	MAX DS (mg/L)	MAX SS (mg/L)
1i*	27.10	378	2.90	8.09	225	717	409	345
1o	25.60	285	3.09	6.54	343	491	432	76
2i	26.90	384	5.38	7.18	242	592	424	190
2A	23.40	383	2.65	6.80		900	427	498
2B	23.40	357	5.31	6.70		583	420	271
2C	23.40	338	5.40	6.75		673	413	419
2o	24.60	296	4.90	6.47	239	605	467	183
3i	26.90	381	3.24	7.19	182	670	445	266
3o	26.20	337	2.64	6.85	150	505	400	144
Lg	27.50	400	7.71	7.32	197	795	447	421

STA	TEMP	COND	DO	PH	REDOX	TS	DS	SS
1i	17.67	303	2.06	7.25	28	532	373	150
1o	14.54	208	1.02	6.24	102	324	304	28
2i	17.65	300	3.15	6.94	-73	509	382	127
2A	12.60	253	1.31	6.45		521	373	125
2B	12.44	238	2.08	6.34		439	353	76
2C	12.43	232	3.08	6.40		433	336	82
2o	11.81	210	2.50	6.20	104	405	324	65
3i	17.67	303	2.23	6.85	-114	487	374	119
3o	14.31	248	1.24	6.28	-53	420	354	63
Lg	17.52	313	1.80	6.97	-44	522	387	132

STA	MIN TEMP	MIN COND	MIN DO	MIN PH	MIN REDOX	MIN TS	MIN DS	MIN SS
1i	9.90	218	1.25	6.65	-115	327	299	28
1o	5.90	109	0.20	5.89	-173	258	225	0
2i	9.10	208	1.22	6.59	-188	381	300	81
2A	5.30	119	0.40	6.06		385	240	19
2B	4.70	115	0.43	5.99		336	267	18
2C	4.30	116	0.52	6.09		371	254	13
2o	2.10	118	0.23	5.88	-182	330	219	19
3i	9.50	200	1.16	6.62	-259	339	289	12
3o	1.50	140	0.26	5.80	-208	336	242	0
Lg	8.00	197	0.18	6.65	-191	417	300	9

% Reduction after moving through cell

	TEMP	COND	DO	PH	REDOX	TS	DS	SS
Cell 1	17.71%	31.44%	50.41%	13.92%	-266.07%	39.20%	18.69%	81.33%
Cell 2	33.07%	30.02%	20.49%	10.73%	241.86%	20.42%	15.24%	48.82%
Cell 3	19.02%	17.91%	44.42%	8.29%	53.31%	13.83%	5.56%	47.06%

* i is inflow; o is outflow, A, B, C are 1/4, 1/2, 3/4 cell length from inflow; Lg is Lagoon.

TABLE 7. Stable Nutrient Data

STA	MAX FOP (mg/L)	MAX TOP (mg/L)	MAX NO_3 (mg/L)	MAX NH_3 (mg/L)
1i*	6.03	9.36	0.10	15.92
1o	3.67	3.34	0.15	1.37
2i	6.03	9.58	0.24	15.54
2A	5.44	6.56	1.05	8.76
2B	3.71	5.71	0.52	5.71
2C	2.19	6.31	1.93	5.38
2o	1.42	4.06	0.12	1.28
3i	6.27	9.66	0.11	10.67
3o	2.43	5.56	0.61	5.01
Lg	6.45	11.58	0.08	27.73

STA	FOP	TOP	NO_2	NH_3
1i	2.47	5.20	0.04	5.68
1o	0.62	1.61	0.03	0.32
2i	2.64	5.45	0.08	5.81
2A	2.13	4.56	0.37	2.31
2B	1.50	3.23	0.12	0.67
2C	0.83	2.29	0.12	0.60
2o	0.61	1.79	0.04	0.38
3i	2.75	5.57	0.04	5.56
3o	1.40	2.72	0.06	0.85
Lg	2.76	6.32	0.04	6.62

STA	MIN FOP	MIN TOP	MIN NO_3	MIN NH_3
1i	0.99	1.77	0.00†	0.14
1o	0.15	0.25	0.00	0.00
2i	1.00	1.88	0.00	0.55
2A	1.01	1.86	0.00	0.13
2B	0.57	1.37	0.00	0.00
2C	0.24	0.87	0.00	0.00
2o	0.22	0.36	0.00	0.00
3i	1.23	2.64	0.00	0.55
3o	0.52	0.91	0.00	0.00
Lg	1.56	2.76	0.00	0.55

% Reduction after moving through cell

	FOP	TOP	NO_3	NH_3
Cell 1	74.88%	68.97%	31.46%	94.45%
Cell 2	76.84%	67.24%	52.52%	93.46%
Cell 3	49.12%	51.22%	-45.52%	84.72%

* i is inflow; o is outflow, A, B, C are 1/4, 1/2, 3/4 cell length from inflow; Lg is Lagoon.
† Minimum limit of detection is 0.01 mg/L.

TABLE 9. Coliform Data

Overall Coliform Data (CFU/100 ml)*

STA	MAX COL	x̄ COL	MIN COL
1i	76000	10860	0
1o	8500	1146	0
2i	101000	17660	0
2A	11000	1367	0
2B	2900	349	0
2C	900	232	0
2o	533	202	0
3i	80000	14494	0
3o	2000	525	0
Lg	105000	27487	0

% Reduction after moving through cells

Cell 1	89.45%
Cell 2	98.86%
Cell 3	96.38%

Stable Coliform Data (CFU/100 ml)

STA	MAX COL	x̄ COL	MIN COL
1i	76000	26000	6000
1o	8500	2700	0
2i	101000	45666	5000
2A	11000	3587	0
2B	2900	760	0
2C	800	350	0
2o	467	266	0
3i	80000	30550	9000
3o	2000	1006	0
Lg	105000	44650	7600

% Reduction after moving through cells

Cell 1	89.62%
Cell 2	99.42%
Cell 3	96.71%

* CFU - Colony forming units.

TABLE 10 Chlorophyll Data

Overall Chlorophyll Data (mg/L)

STA	MAX CHL	x̄ CHL	MIN CHL
1i	860	188	13
1o	700	119	2
2i	654	276	61
2A	441	146	5
2B	579	125	3
2C	906	144	3
2o	759	101	3
3i	1505	319	15
3o	508	77	1
Lg	2065	584	32

% Reduction after moving through cells

Cell 1	36.50%
Cell 2	63.43%
Cell 3	75.81%

Stable Chlorophyll Data (mg/L)

STA	MAX CHL	x̄ CHL	MIN CHL
1i	564	159	13
1o	95	28	2
2i	654	296	71
2A	338	113	5
2B	579	137	3
2C	906	156	3
2o	104	23	3
3i	585	289	15
3o	312	59	1
Lg	1723	399	32

% Reduction after moving through cells

Cell 1	82.67%
Cell 2	92.27%
Cell 3	79.57%

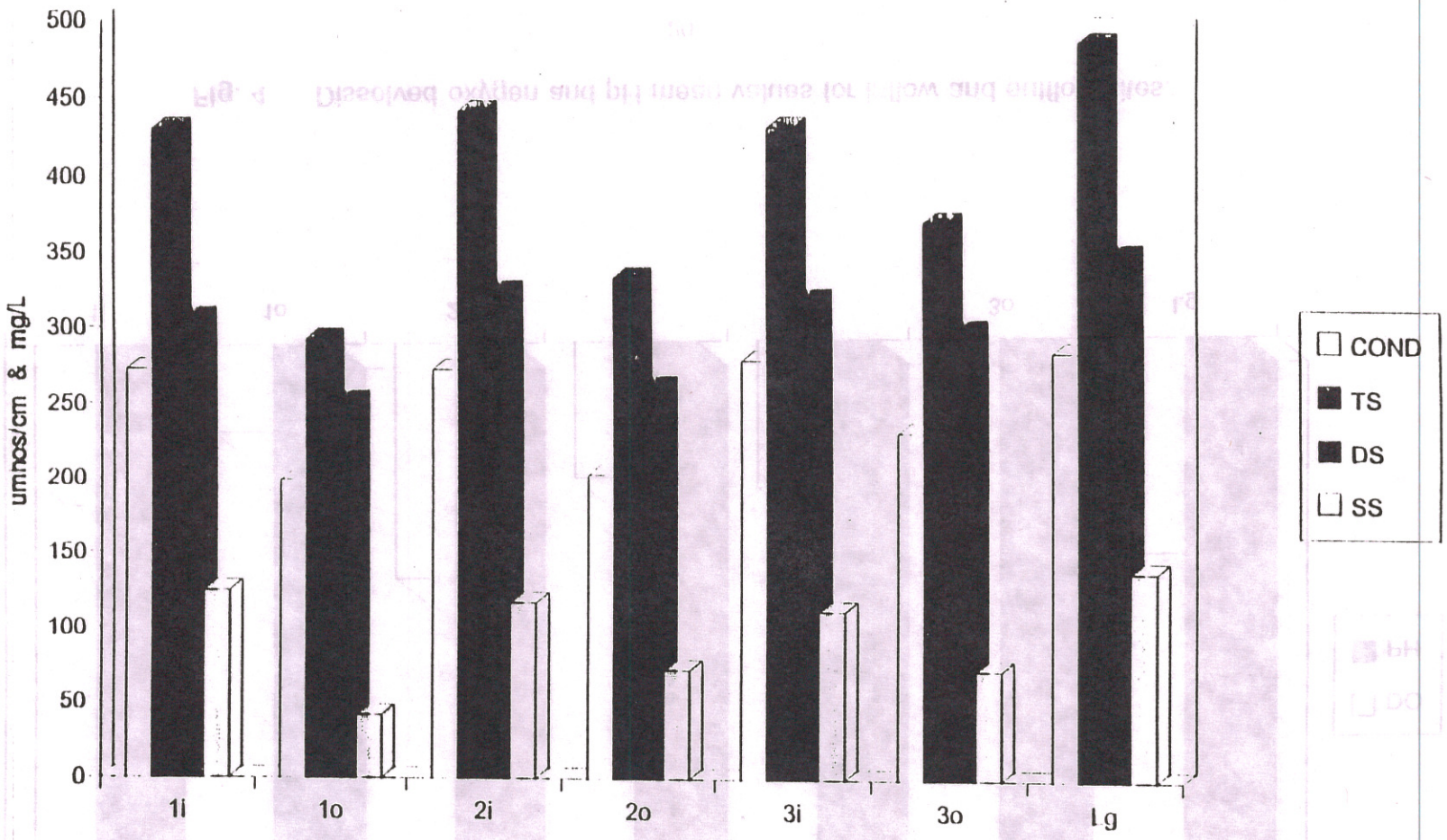

Fig. 3 Water conductivity and solids mean values for inflow and outflow sites.

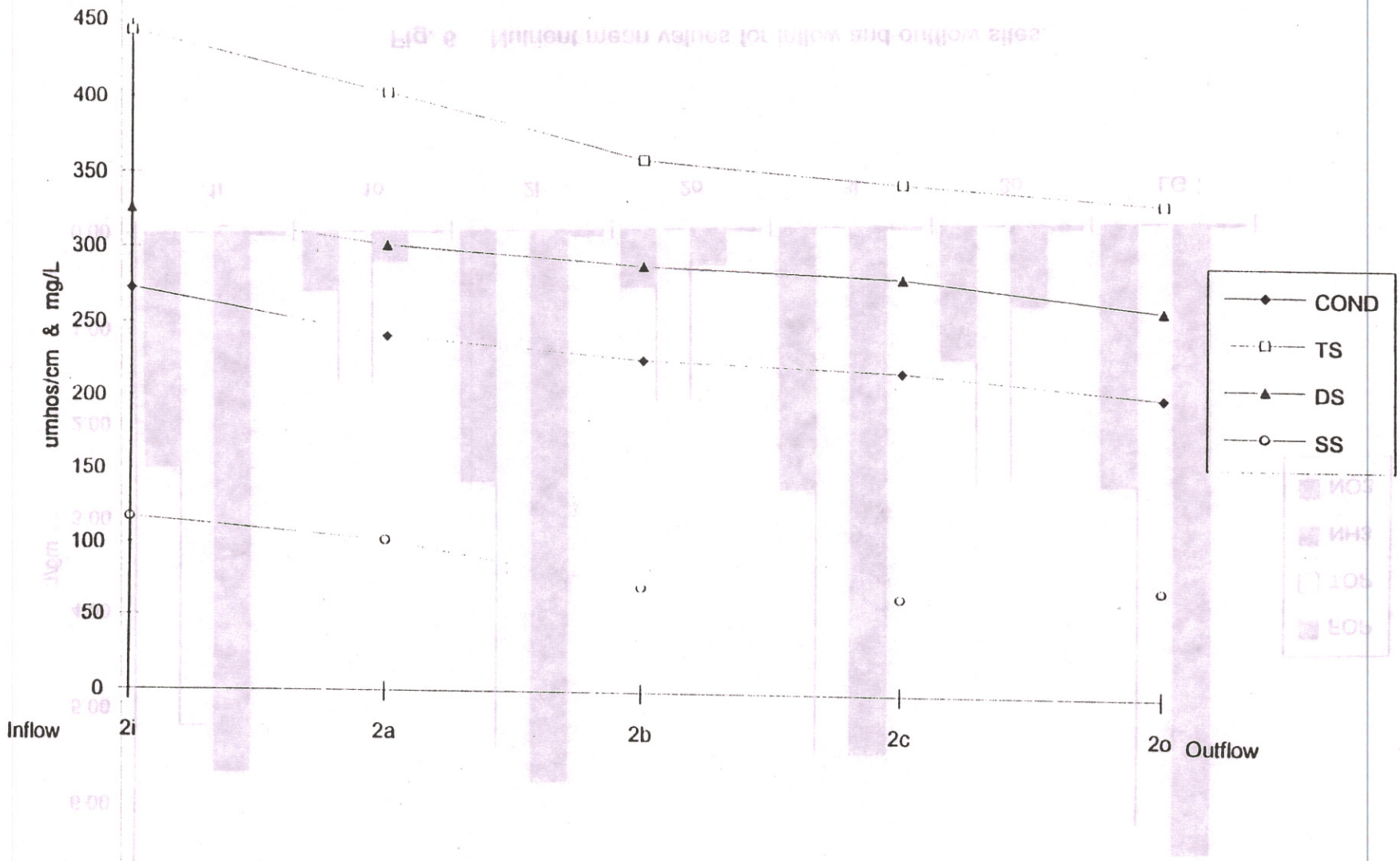

Fig. 5 Mean conductivity, total solids, dissolved solids, and suspended solids through Cell 2.

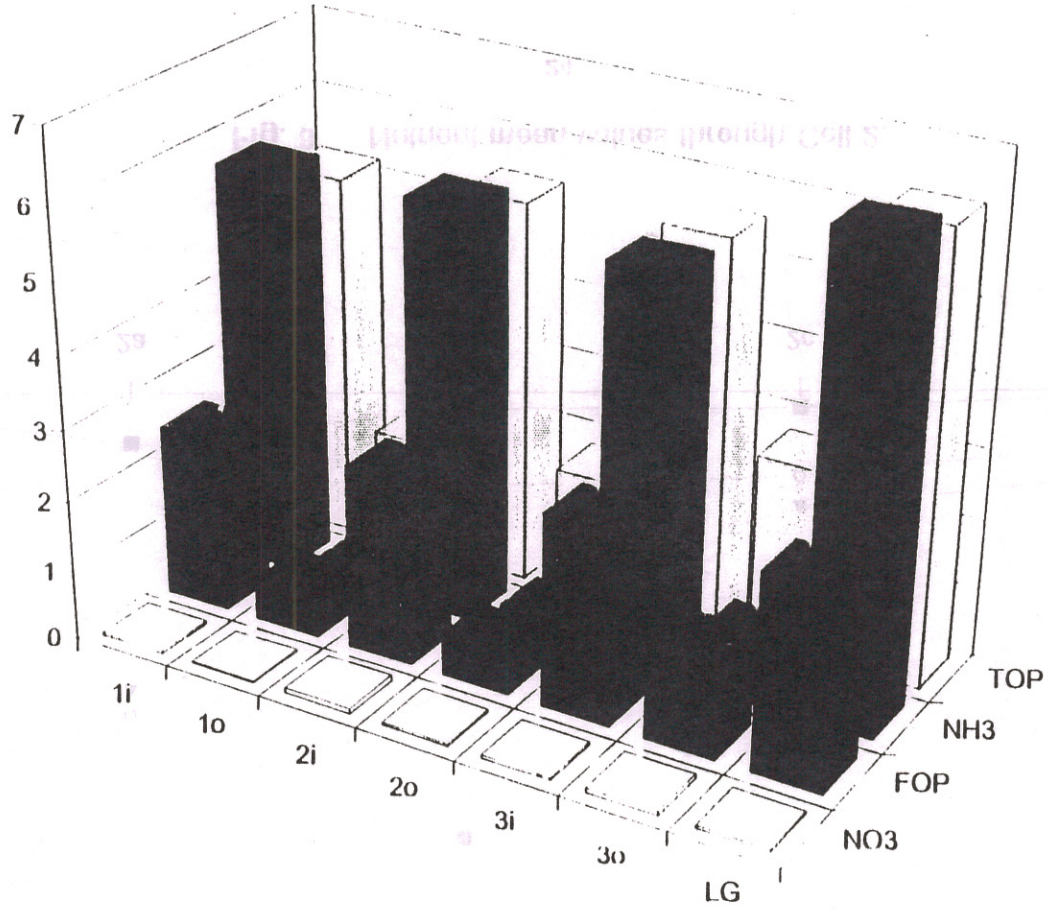

Fig. 7 Nutrient mean values for inflow and outflow sites.

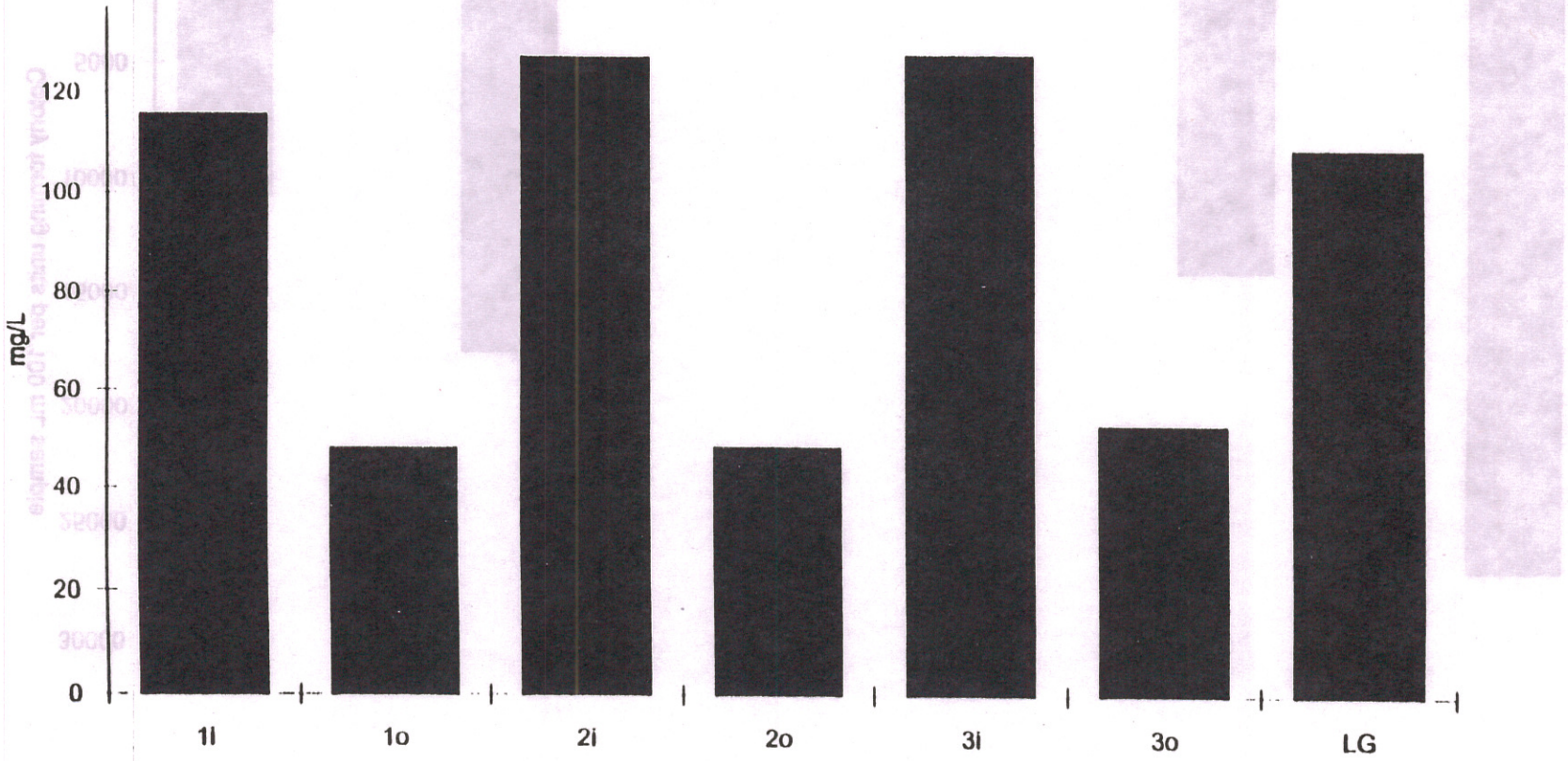

Fig. 9 Mean carbonaceous biological oxygen demand for inflow and outflow sites.

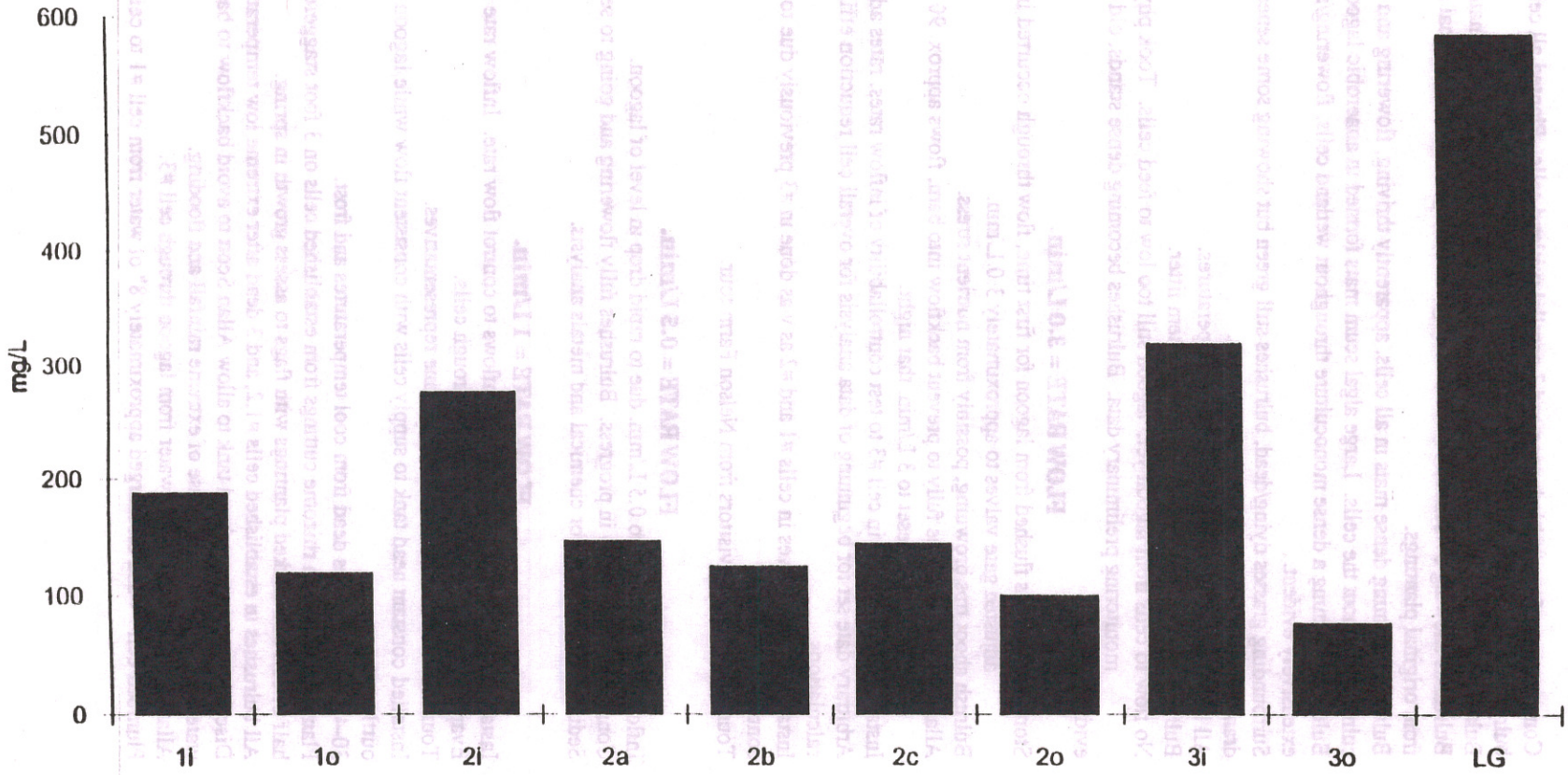

Fig. 11 Mean chlorophyll values for sampling sites.