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Project Summary

Treatment of Primary Effluent by Rapid Infiltration

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This study assessed the capability of a rapid infiltration system for upgrading primary effluent from a municipal wastewater treatment plant, and compared the performance with that obtained earlier on secondary effluent. This was done by monitoring the influent and effluent quality variations at a rapid infiltration demonstration facility over a period of one year. The site consisted of three basins ranging in size from 0.19 hectares (ha) [0.47 acres (ac)] to 0.35 ha (0.87 ac).

In general, the basins operated well during the entire period of primary effluent application. Hydraulic response was somewhat improved during the primary study despite increased solids loading. As in previous years, a significant leakage of ammonium occurred during the winter months. The pattern of nitrate discharge was also unchanged from previous years, with low nitrate levels in the winter and slug discharges during the spring. All three basins demonstrated good organic removals throughout the period of primary effluent application. Effluent values for chemical oxygen demand (COD) were generally in the 8-20 milligrams/liter (mg/l) range for both study periods. Renovated water phosphate levels seldom exceeded 1.0 mg/l during the primary study. Bacterial removals in the basins were excellent, with fecal coliform removals generally in excess of 99 percent.

Introduction

The 1972 Amendments to the Federal Water Pollution Control Act provided substantial impetus for the attainment of improved levels of water pollution control in the United States. Further, these amendments and subsequent legislation have encouraged the appropriate utilization of land treatment technology for achieving the indicated water quality improvement. As a result, there has been considerable interest in defining the capabilities and limitations of this form of treatment technology. Rapid infiltration systems provide one means of utilizing the treatment capabilities of soil systems. These systems involve the application of comparatively large quantities of wastewater (20-500 ft/yr) to a relatively permeable soil. The wastewater is renovated as it percolates through the soil prior to being recovered by a system of wells or underdrains, or entering the groundwater. The renovation mechanisms include a combination of physical, chemical, and biological processes within the soil profile.

Historically, land treatment systems generally have been considered acceptable only for upgrading the quality of secondary effluent discharges. This fact is reflected in the regulations of many states which require that conventional secondary treatment be provided prior to land application of wastewater. The purpose of the project reported in this paper was to assess the relative capabilities of rapid infiltration systems for providing either tertiary treatment, or a combined secondary and tertiary treatment in a single treatment stage. This assessment was made by applying primary and secondary effluent to a rapid infiltration system during different project phases.

Conclusions

The rapid infiltration system was shown to be capable of providing a high quality renovated water with minimum pretreatment ahead of the rapid infiltration basins. The application of primary effluent to rapid infiltration basins did not produce any operational or aesthetic difficulties during a one-year operational period at the Boulder site. The only observed difference between the application of primary and secondary effluents was an increased rate of plant growth in the basins during the period of primary effluent application.

The infiltration rates on the rapid infiltration basins were higher when primary effluent was applied to the system than when secondary effluent served as the influent water. This occurred despite higher suspended solids loads in all of the basins when primary effluent was applied, and a higher hydraulic loading rate in one of them. The postulation has been made that more rapid rates occurred with primary effluent because the solids were collected at the biologically active surface and then degraded more rapidly than the suspended solids in secondary effluent.

The organic concentration, as measured by the chemical oxygen demand (COD), was essentially the same in the renovated water when either primary effluent or secondary effluent was applied to the basins.

The basins demonstrated the capability for achieving a consistently low level of phosphorus in the product water when the rate of phosphorus application to the rapid infiltration system was consistent with the rate of the long term removal mechanisms.

With the basin loading schedule practiced in this study, most of the nitrogen applied to the basins was oxidized by nitrification and discharged as nitrate nitrogen in the renovated water. As a result, the nitrate concentrations in the renovated water occasionally exceeded the acceptable nitrate levels for drinking water.

Recommendations

At the beginning of the study involving primary effluent, the hydraulic loading rates were reduced well below what they had been during the period of secondary effluent application. This was done because it was anticipated that basin fouling would be a problem with the lower quality of applied water. Apparently, in light of the results of this study, the basins would be capable of treating primary effluent at a substantially higher hydraulic rate. A continuation study should be performed to investigate the impact of increased loadings on both the hydraulic and treatment performance of the basins.

With the loading sequence practiced in this investigation, most of the applied nitrogen was discharged from these beds as nitrate. Other investigators have demonstrated that substantial denitrification can be achieved in rapid infiltration systems if the loading sequence is appropriately managed. Modification of the loading sequence should be attempted at the Boulder facility for the purpose of maximizing the total nitrogen removal.

A study should be undertaken to identify the loading schedule which would provide the best combination of hydraulic loading and treatment performance in the ridge and furrow configuration. The aim of this effort should be to minimize the total land area requirements for providing this alternative application method.

Facilities, Operation, and Results

The rapid infiltration system utilized in this investigation was located on the site of the 75th Street wastewater treatment plant in Boulder, Colorado. The 75th Street plant was a trickling filter plant situated on the south bank of Boulder Creek, approximately 9.7 kilometers (6 miles) from the foothills of the Rocky Mountains.

Construction of the rapid infiltration site was accomplished between December 1975 and April 1976. The system consisted of three basins, designated Basin 1, Basin 2, and Basin 3, from south to north. The total site encompassed approximately 0.8 hectares (ha) [2.1 acres (ac)], and was divided between the three basins as shown in the site layout of Figure 1. As indicated in this figure, Basin 2 included a ridge and furrow configuration for distribution of the applied wastewater. Nine furrows were constructed in this basin, each of which was 0.46 m (18 in.) deep and 85.4 m (280 ft) long. These furrows were separated by ridges 1.02 m (40 in.) wide and 1.93 m (76 in.) on center. A channel was included on each end of Basin 2 to allow for rapid and even distribution of the applied wastewater.

With the high ground water conditions at the site, it was necessary to isolate the system from the ground water to obtain an accurate evaluation of rapid infiltration treatment

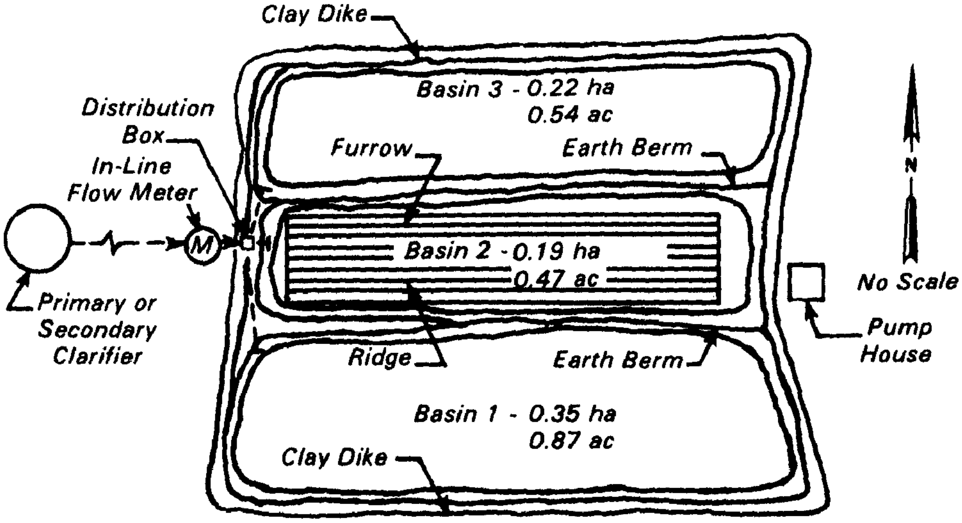

Figure 1. Modified basin configuration.

capabilities. As a result, the three basins were surrounded by a clay-core dike extending from 0.8 m (2.5 ft) above the ground surface to bedrock. In addition, a 0.8 m (2.5 ft) soil berm was constructed between the basins to contain the applied wastewater. An underdrain system was installed to remove existing ground water and collect renovated water. This system consisted of three pairs of 0.18 m (7 in.) perforated PVC pipe installed 2.4-3.0 m (8-10 ft) below the surface. These underdrains discharged into collecting manholes in each of the basins, and then into a central manhole.

The basins were loaded with secondary effluent from May 1976 to June 1978 and with primary effluent from November 1978 to October 1979. These secondary and primary effluent wastewaters comprised the influent source to the rapid infiltration basins during the indicated study periods. The discharge from the rapid infiltration basins constituted the renovated water from the system.

Basin 1 was loaded at a constant rate of 30.5 m/yr (100 ft/yr) during the period of secondary effluent application from October 1976 to June 1978. When primary effluent was applied to the surface of Basin 1, this rate was reduced to 15.2 m/yr (50 ft/yr) for the period November 1978 to October 1979. The reduced rate was employed with primary effluent in an effort to minimize fouling problems which were expected with the more concentrated wastewater. Basin 2 was loaded with secondary effluent at a rate of 12.8 m/yr (42 ft/yr) from April 1977 to June 1978 and with primary effluent at 43.9 m/yr (144 ft/yr) from November 1978 to October 1979. Similarly, Basin 3 was loaded with secondary effluent at a rate of 48.8 m/yr (160 ft/yr) from February 1977 to June 1978 and primary effluent at 36.6 m/yr (120 ft/yr) from November 1978 to October 1979.

The basins were operated on a cyclic pattern throughout the study. A cycle usually consisted of six weeks of loading, followed by a drying period of one to four weeks. The variable drying period was required to accommodate the impact of climatic variations on the basin drying time. Typically, four weeks were required for drying during the winter, and one week for drying in the summer. When this time was not provided, scarifying the beds was physically impossible. Once dry, Basins 1 and 3 were scarified with a tractor-drawn spring-tooth plow prior to being subjected to the next loading portion of the cycle. Basin 2, incorporating the ridge and furrow system, did not require scarification.

Samples of the basin influent were collected at the distribution box, and renovated water samples were collected at the central manhole. The renovated water was sampled at 0, 1, 4, 8, 12, 24, 36, 48, and 72 hours after loading. At each of these sampling times, a record was made of flow, temperature, and the dissolved oxygen concentration of the renovated water, as well as the depth of the applied wastewater remaining on the basin surface. Samples collected at these times were analyzed for nitrate, nitrite and ammonium nitrogen. A larger sample was collected 24 hours after loading and analyzed for the following constituents in the Water Quality Engineering Laboratory at the University of Colorado: total solids, suspended solids, phosphorus, COD, temperature, coliforms, alkalinity, pH, hardness, calcium, color, turbidity, and the nitrogen series.

In analyzing the data collected during this project, it became apparent that the change in the quality of applied wastewater, and in the hydraulic loading rates, presented some difficulties in making a direct comparison of the treatment performance of the basins during primary and secondary effluent application. As a result, a mass loading approach has been used to assist in the interpretation of results. The average mass loadings of four critical wastewater constituents have been included in Table 1, with the reduced concentration data from which these loadings were developed shown in Table 2. The reduced concentration data represent average applied wastewater concentrations for comparable calendar months in different years. As is apparent from these data, the applied influent sources represented relatively weak wastewater. This point will have significance in translating the experience of the Boulder site to other locations.

Infiltration rates during secondary effluent application were measured from February 8, 1977 through July 7, 1977. Comparable infiltration rates for primary effluent were measured from April 3, 1979 through October 4, 1979. The results of these measurements have been presented as cycle averages in Figure 2. Two significant points can be made from the data presented in this figure: (1) the basins achieved higher infiltration rates when loaded with primary effluent than when loaded with

Table 1. *Average Wastewater Constituent Loading Rates kilograms/hectare/week (kg/ha/wk)*

	Hydraulic Loading[a]	Basin	TKN	NH_4^+-N	PO_4-P	COD	SS
Nov. 76-	12.8 (42)	2	28.1	16.1	12.7	158.4	26.9
Sept. 77	30.5 (100)	1	84.2	53.8	34.7	454.3	103.7
Secondary	48.8 (160)	3	122.4	62.6	48.9	679.9	167.7
Nov. 78-	15.2 (50)	1	37.0	24.0	10.3	378.0	147.7
Sept. 79	36.6 (120)	3	84.6	54.3	25.9	860.6	304.2
Primary	43.9 (144)	2	108.4	68.9	25.4	1139.4	366.8

[a] *Nominal hydraulic loading rate in m/yr (ft/yr).*

Table 2. *Average Wastewater Constituent Concentrations (mg/l)*

	Basin	TKN	NH^+-N	Total PO -P	COD	SS
Nov. 76-	1	14.4	9.2	6.0	77.8	17.8
Sept. 77	2	11.5	6.6	5.2	64.6	10.9
Secondary	3	13.1	6.7	5.2	72.5	17.9
Nov. 78-	1	12.8	8.3	3.5	131	50.8
Sept. 79	2	12.9	8.2	3.2	135	43.6
Primary	3	12.0	7.7	3.7	122	42.9

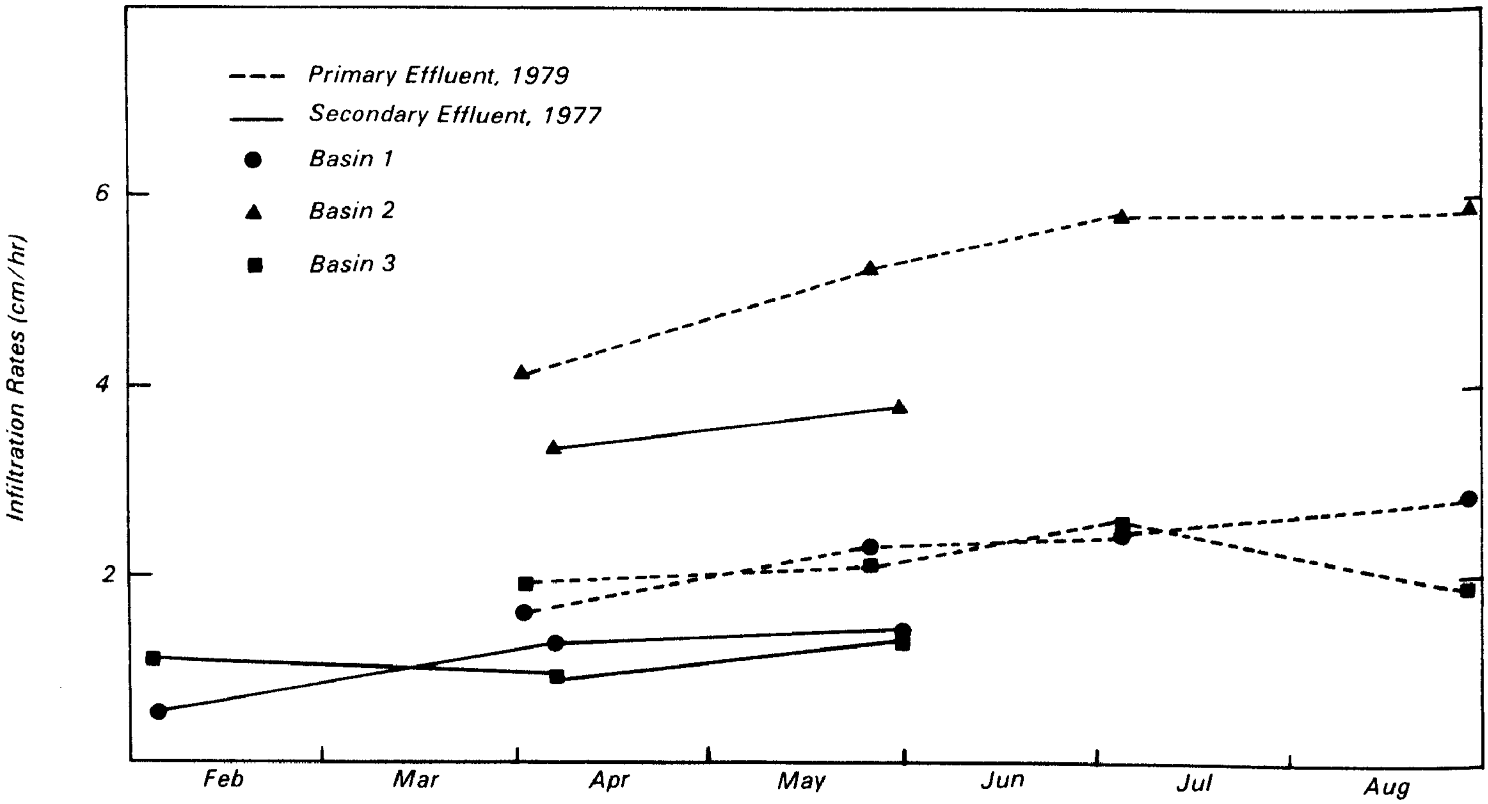

Figure 2. *Variation of infiltration rates with time.*

secondary effluent, and (2) a seasonal effect was noted in infiltration rates, with the highest rates occurring during the summer months.

All three basins demonstrated good organic removal capability during the periods of both primary and secondary effluent application. Examination of the COD removal pattern indicated that the basins with the highest hydraulic and COD mass loadings tended to release the highest effluent COD concentrations. In an effort to clarify the relative contributions of hydraulic load, organic load, and wastewater strength to effluent quality, influent and effluent COD concentrations have been presented in Figures 3 through 5 in a log-probability format. These figures present weekly influent and effluent COD values for approximately one year of secondary effluent application and one year of primary effluent application. The data appear to conform to a log-normal distribution.

Figure 3 indicates that Basin 1 produced a higher quality renovated water with respect to the organic pollutants during the primary effluent study, despite a higher concentration of organic material in the applied wastewater. However, Table 1 showed that the hydraulic load and organic load were both lower during the primary effluent loading phase of the study. Figure 4 shows that the COD concentrations in the renovated water from Basin 2 increased during the primary effluent study by an amount similar to the decrease achieved in Basin 1. During the primary effluent study phase, the hydraulic loading and mass loading to Basin 2 were approximately three times the levels applied during the secondary effluent phase of the study. The data from Basin 3 (Figure 5) demonstrated a decrease in renovated water COD during the primary ellfuent loading phase as compared to that observed during the secondary effluent loading phase. This pattern occurred under conditions of increased mass loading and decreased hydraulic loading, when primary effluent was applied to the basin.

The interpretation of nitrogen data in this type of study was complicated by the many nitrogen transformations which occur in soil system. As a result, the emphasis in this research was focused on characterizing those nitrogen forms remaining in the renovated water. The principal forms of nitrogen in the renovated water were nitrate and ammonium. Figure 6 and Figure 7 show cycle averages for these constituents during both the secondary effluent and primary effluent phases of the study. The weekly values used to calculate cycle averages were obtained by a flow weighting of the constituent concentrations at individual sampling times. The weighting process consisted of developing weekly hydraulic discharge and mass flow curves for each basin. Integration of these curves provided an average flow and an average mass flow. The proportional average was obtained by dividing the average mass flow (mg/sec) by the average hydraulic flow (l/sec).

From the data summarized in Figure 6 and 7, it is apparent that the rapid infiltration system at Boulder, Colorado was generally capable of producing a well-nitrified renovated water. The application of primary effluent had no significant effect on the nitrogen quality of the renovated water. Nitrate concentrations in the renovated water during the period of primary effluent application seemed to follow the trends established in previous years of

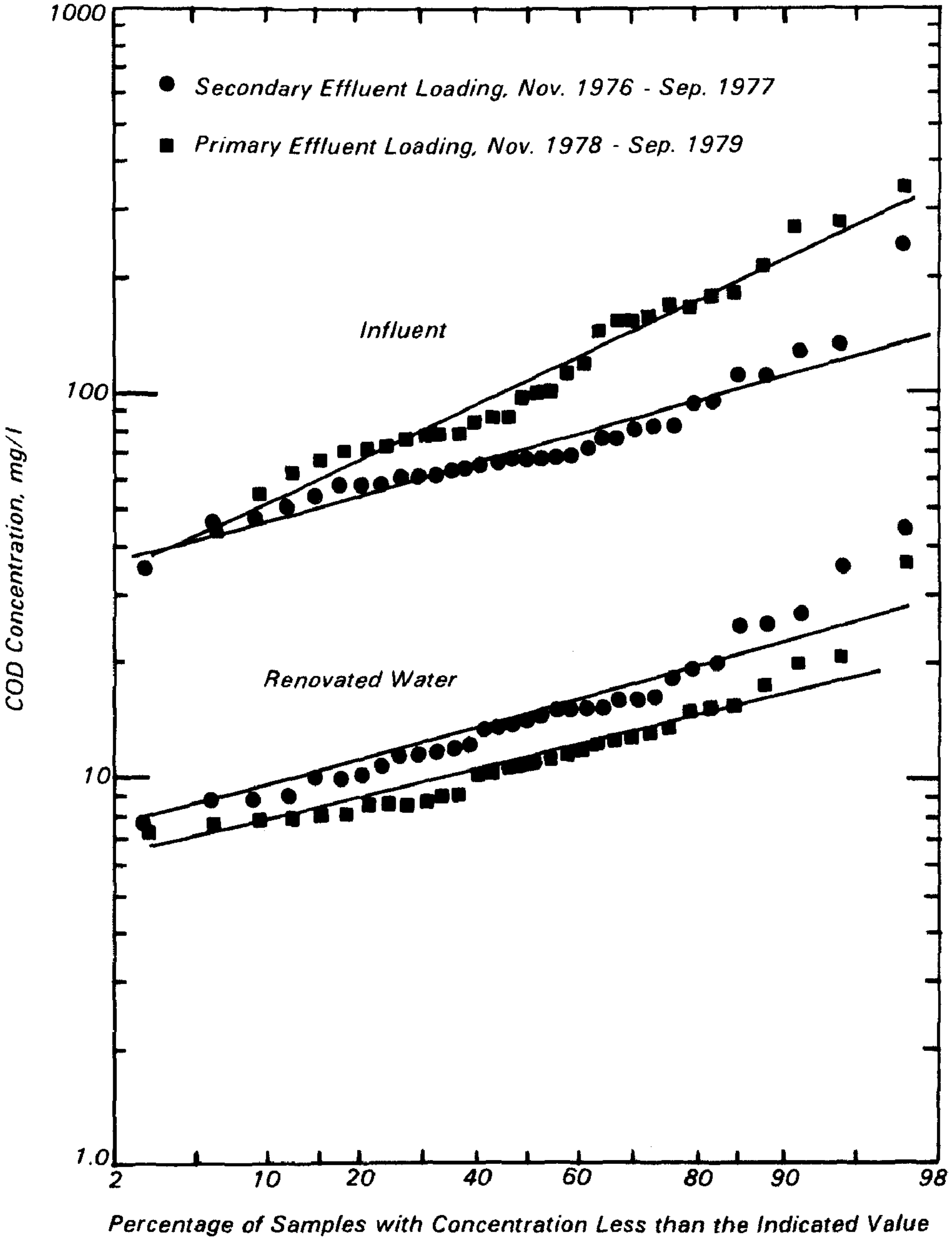

Figure 3. *COD concentration variations (Basin 1).*

secondary effluent application. The winter operating cycle typically produced renovated water with the lowest nitrate concentrations when the renovated water temperatures ranged from 4°C to 6°C. In March 1979, the basins discharged a concentrated nitrate peak with the first spring loading. During this loading, the average renovated water nitrate concentrations for the three basins were 28.0 mg/l, 31.8 mg/l, and 28.7 mg/l for Basins 1, 2, and 3, respectively. The appearance of a spring nitrate peak also occurred during each of the previous two years of the study. This pattern of discharge has been well documented in the literature, and is generally attributed to the higher rate of nitrification accompanying increased temperatures. Basin 1 demonstrated good ammonium removals throughout the study, with ammonium leakage levels of as low as 0.1 mg/l ammonium nitrogen (NH_4^+-N) during the summer when primary effluent was being applied. The maximum ammonium leakage occurred during the cold winter months when nitrification was inhibited.

The seasonal ammonium trends noted for Basin 1 also held true for Basins 2 and 3. Ammonium leakage generally peaked in January and February, the period of coldest air and wastewater temperatures. The most notable exception to this trend was the pattern observed in Basin 3 between September 1977 and June 1978. During this period, the effluent ammonium nitrogen levels increased steadily from 0.71 mg/l to 6.0 mg/l. At this time, Basin 3 was receiving the heaviest mass ammonium loading of the three basins.

In an effort to evaluate the effect of the mass/hydraulic loading rate on ammonium and nitrate leakage, influent and renovated water ammonium concentration levels, and effluent nitrate concentrations were plotted on a log-probability format in Figures 8 and 9. These data were compiled for comparable calendar periods during each phase of the study. These data show that the rapid infiltration system was very reliable in removing ammonium from both primary and secondary effluents, and that lower levels of ammonium leakage were obtained consistently during the period of primary effluent application. The data in Table 1 indicated that the hydraulic and mass loading rates during the primary effluent loading study were approximately one-half the rates applied during the secondary effluent phase of the study. These lower loadings were reflected in an average ammonium leakage level during the primary effluent loading period of about one-half that experienced when nitrogen was applied to the basin at the higher rate during secondary effluent application. A similar effect was not apparent in the nitrate data because the relative magnitude of the numbers would not readily reflect the effects of slightly altered levels of ammonium in the renovated water.

Phosphorus removals during the period of primary effluent application were generally between 60-90 percent and demonstrated the positive effects of low phosphorus loading rates and extended rest periods on effluent phosphorus concentrations. Total phos-

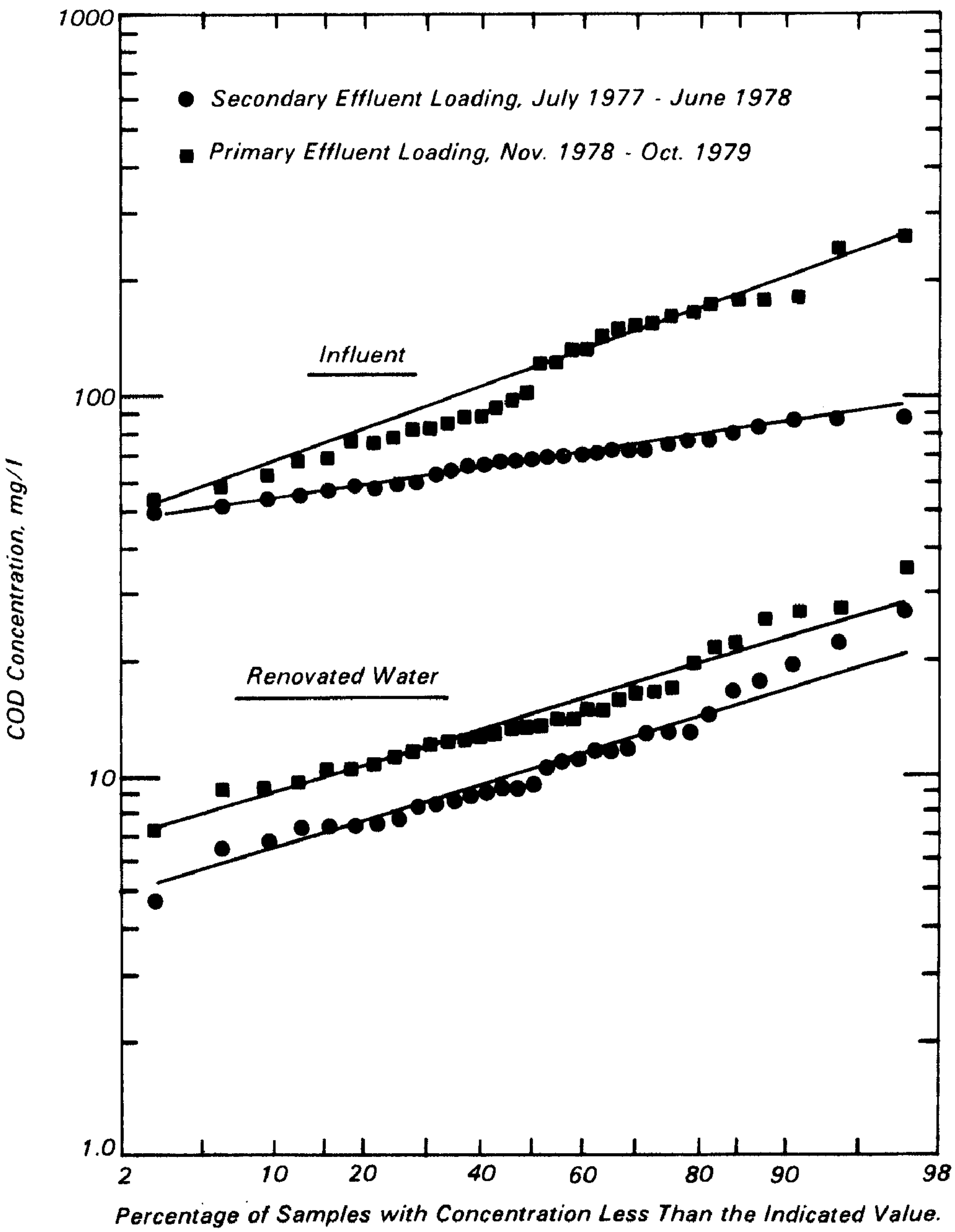

Figure 4. *COD concentration variations (Basin 2).*

phorus cycle averages have been presented for the influent and effluent in Figure 10. Based on data compiled during the first two years of study, several distinct trends were noted with respect to phosphorus removal: (1) some regeneration of phosphorus adsorption sites occurred during rest periods, (2) effluent phosphorus concentrations tended to increase within a cycle, and (3) leakage levels were highest during the winter periods of high phosphorus loading and low ambient temperatures.

Results obtained during the year of primary effluent application were not inconsistent with these trends and served to reinforce the first two. The partial regeneration of phosphorus adsorption sites was quite apparent during the start-up period of November 1978. As a result of the four month rest period between the two phases of the study, base phosphorus concentrations (effluent phosphorus concentration during the first week of a cycle) returned to 0.30 mg/l. This compared favorably with the 0.10 mg/l base concentration achieved during initial start-up in 1976.

As in previous years, effluent concentrations during the primary study tended to increase with each cycle. However, the magnitude of the increases was quite small. In fact, the low levels of phosphorus discharge achieved throughout the primary effluent study seemed to indicate that an equilibrium between phosphorus loading and removal could be achieved in a rapid infiltration system under appropriate loading conditions. The low level of discharge seen in the primary study seemed to be the result of low loadings and long rest periods.

With the promising treatment results which were developed in this study, it was considered appropriate to assess the economic feasibility of the rapid infiltration technology which was evaluated. This has been done by comparing several different approaches for providing wastewater treatment. The economic evaluation utilized EPA cost data found in EPA report EPA-430/9-75-022, the revised edition of EPA-430/9-75-003 and EPA-430/9-77-013, to make a preliminary cost comparison of a few alternatives available to a commmunity attempting to upgrade their treatment capability. The alternatives are listed below:

Existing Treatment	Alternative Treatment Required	
None	1	A-B-D-F-H-I
None	2	A-B-C-E-F-H-I
Primary	3	D-F
Primary	4	C-E-F
Secondary	5	F
Secondary	6	E-F
None	7	A-G-J
None	8	A-G-J-K-H
None	9	A-J-K-H
None	10	A-J
Primary	11	G
Primary	12	G-J-K
Primary	13	J-K
Primary	14	J
Secondary	15	J-K
Secondary	16	J

where: A - Preliminary treatment; includes flow metering, screening grit removal and influent pumping

B - Primary sedimentation

C - High-rate activated sludge; includes secondary clarifiers

D - Conventional activated sludge; includes secondary clarifiers

E - Biological nitrification; includes final clarifiers

F - Filtration

G - Partial mix aerated lagoon

H - Disinfection

I - Sludge handling; includes anaerobic digestion and mechanical dewatering

J - Rapid infiltration; transmission; storage (1 wk)

K - Surface discharge; includes recovery wells

Although this evaluation examined only a limited number of alternatives, it did become apparent that in situations requiring a nitrified effluent with low BOD and SS, the rapid infiltration system is quite comptetitive at the 1 MGD level. For purposes of comparison, the rapid infiltration system was assumed to have an effluent quality approximately equal to that of a secondary plant with nitrification and filtration.

Tables 3-5 indicate that even with a very conservative design (such as that used in the evaluation) a rapid infiltration system may offer high quality treatment at less than half the cost of comparable in-plant processes. With such obvious benefits at the 0.04 m^3/sec (1 MGD) level of operation, an additional evaluation was performed to determine the effect of large scale operations on the treatment costs of alternatives 2 and 8. These two alternatives were evaluated at the 0.4, 2.0, and 4.0 m^3/sec (10, 50 and 100 MGD) levels. The results of this comparison appear in Table 6. These results indicate that even with a conservative rapid infiltration design, total annual costs remain much less expensive than in-plant processes capable of producing the same quality effluent.

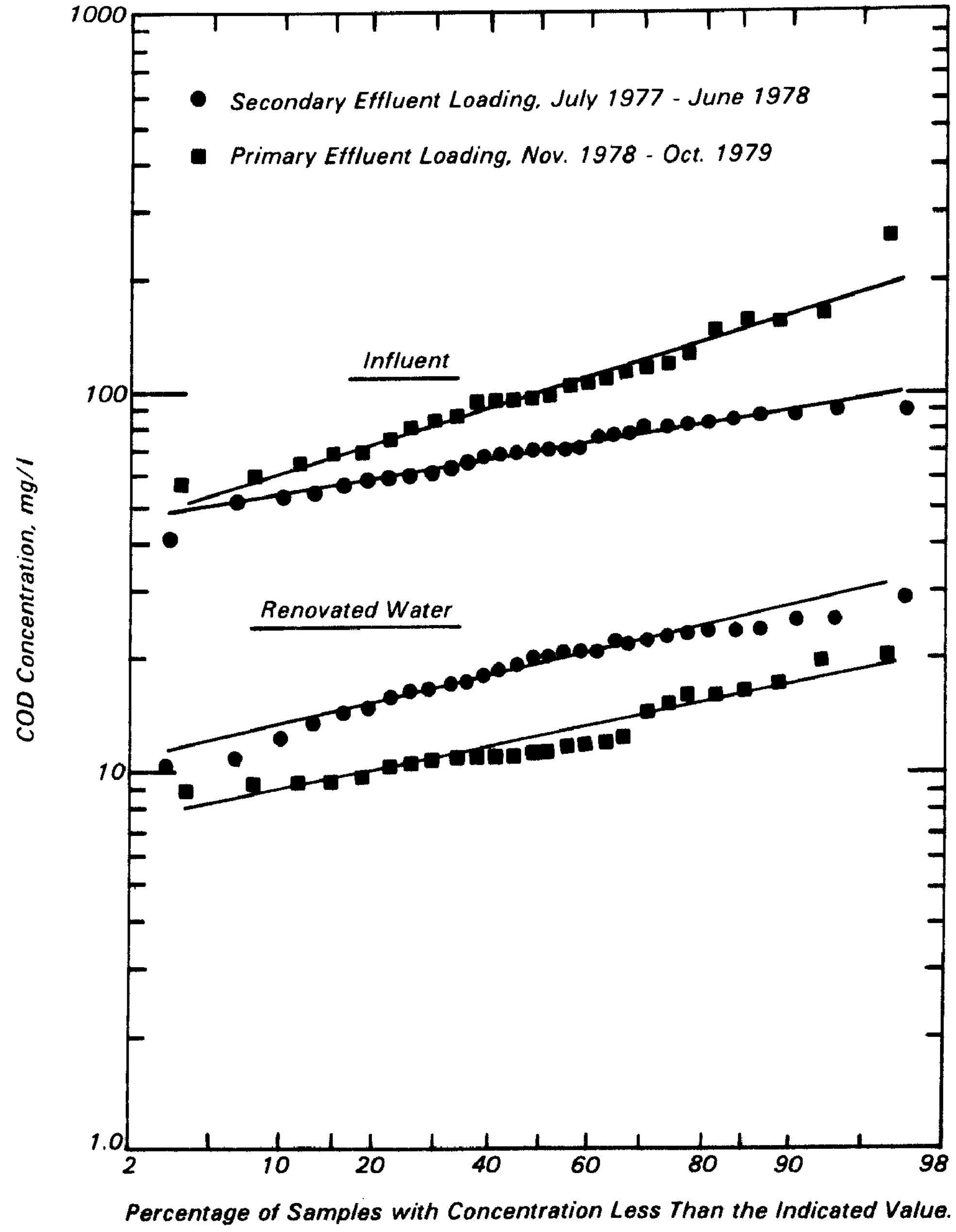

Figure 5. *COD concentration variations (Basin 3).*

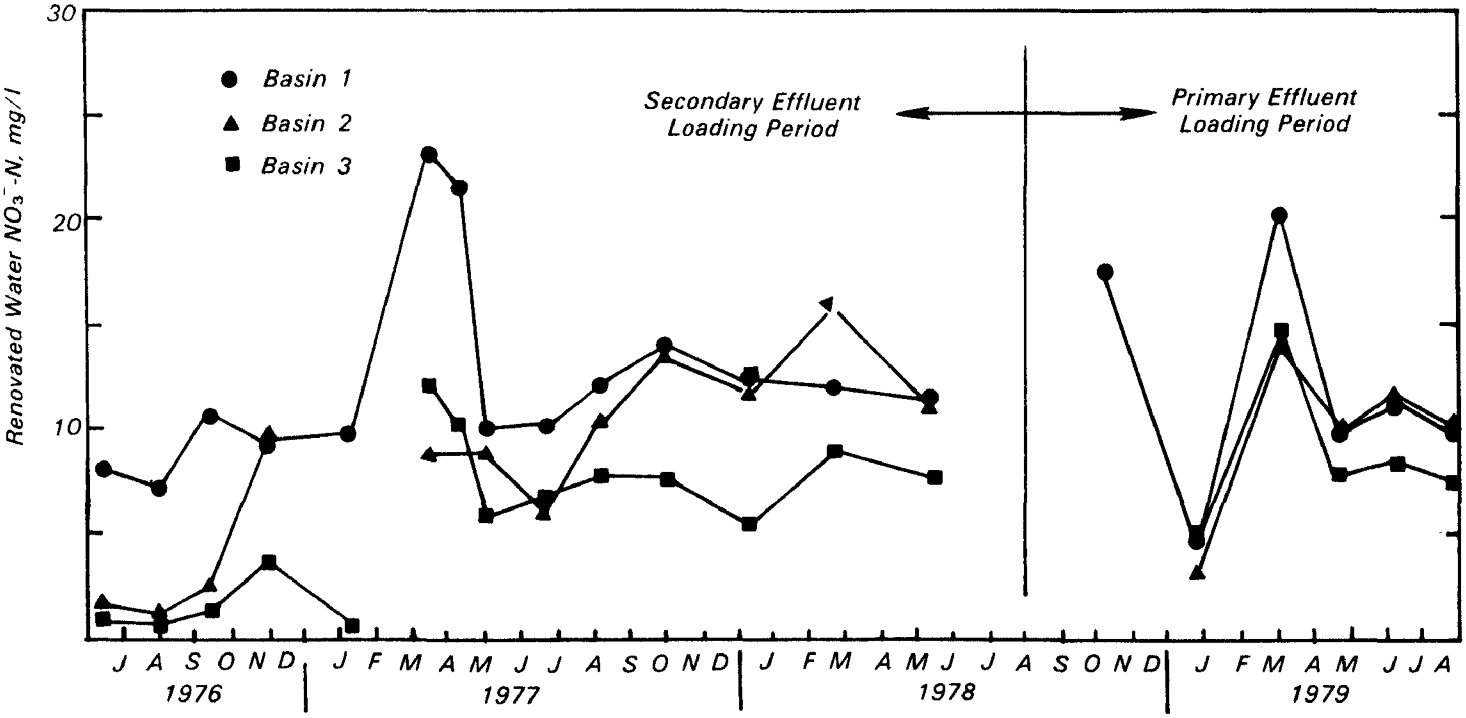

Figure 6. Renovated water nitrate nitrogen as a function of time.

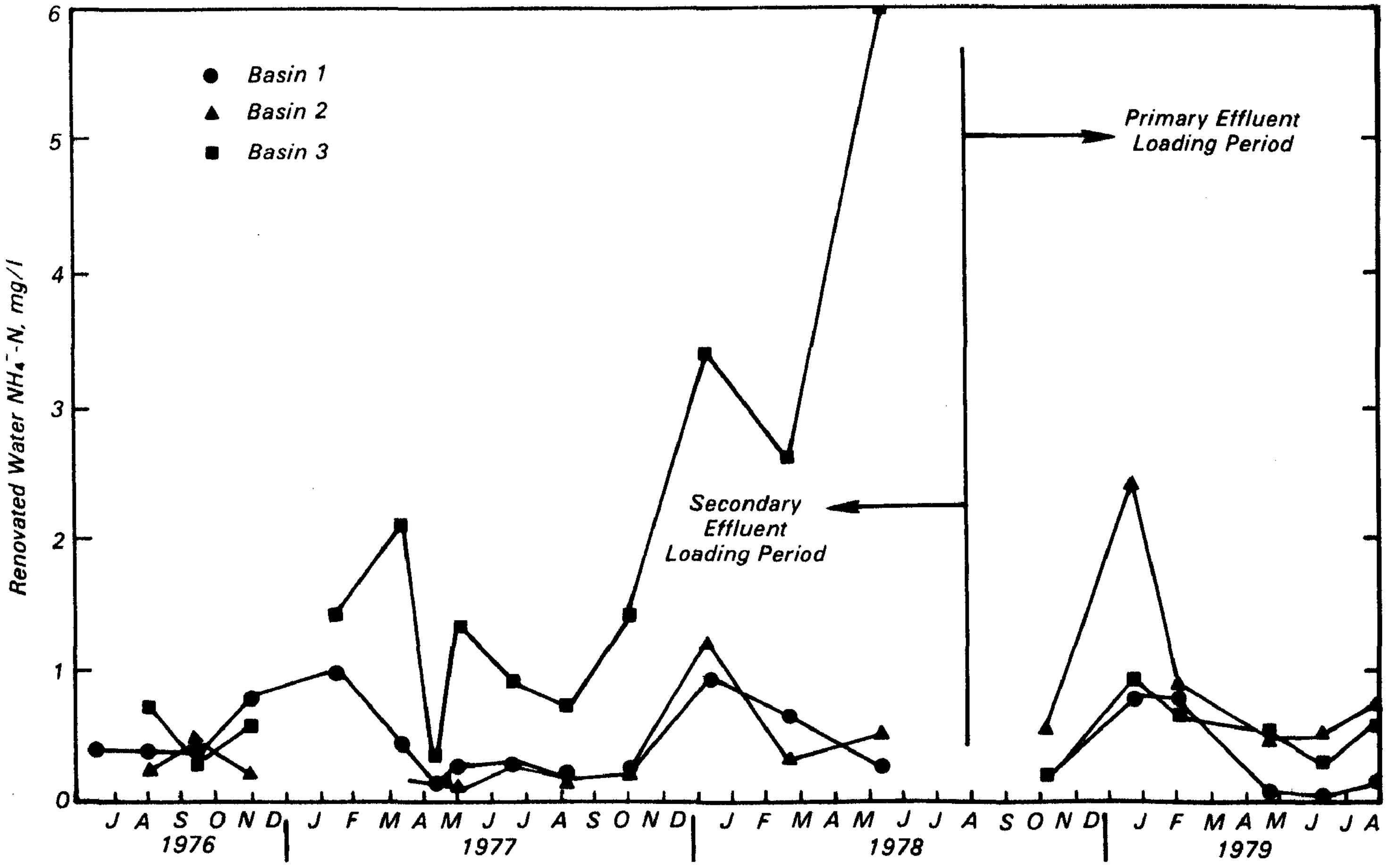

Figure 7. Renovated water ammonium nitrogen as a function of time.

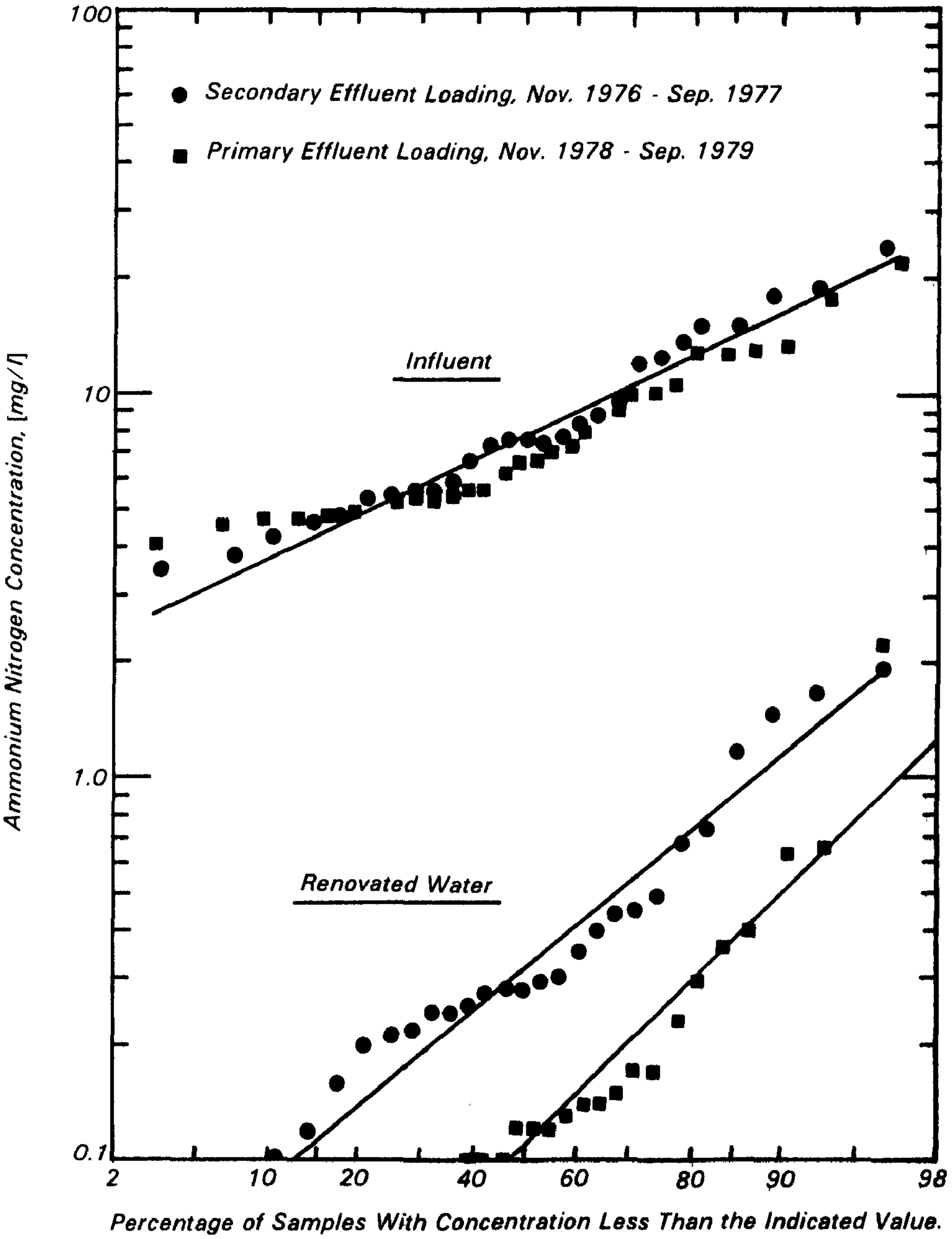

Figure 8. Ammonium concentration variations.

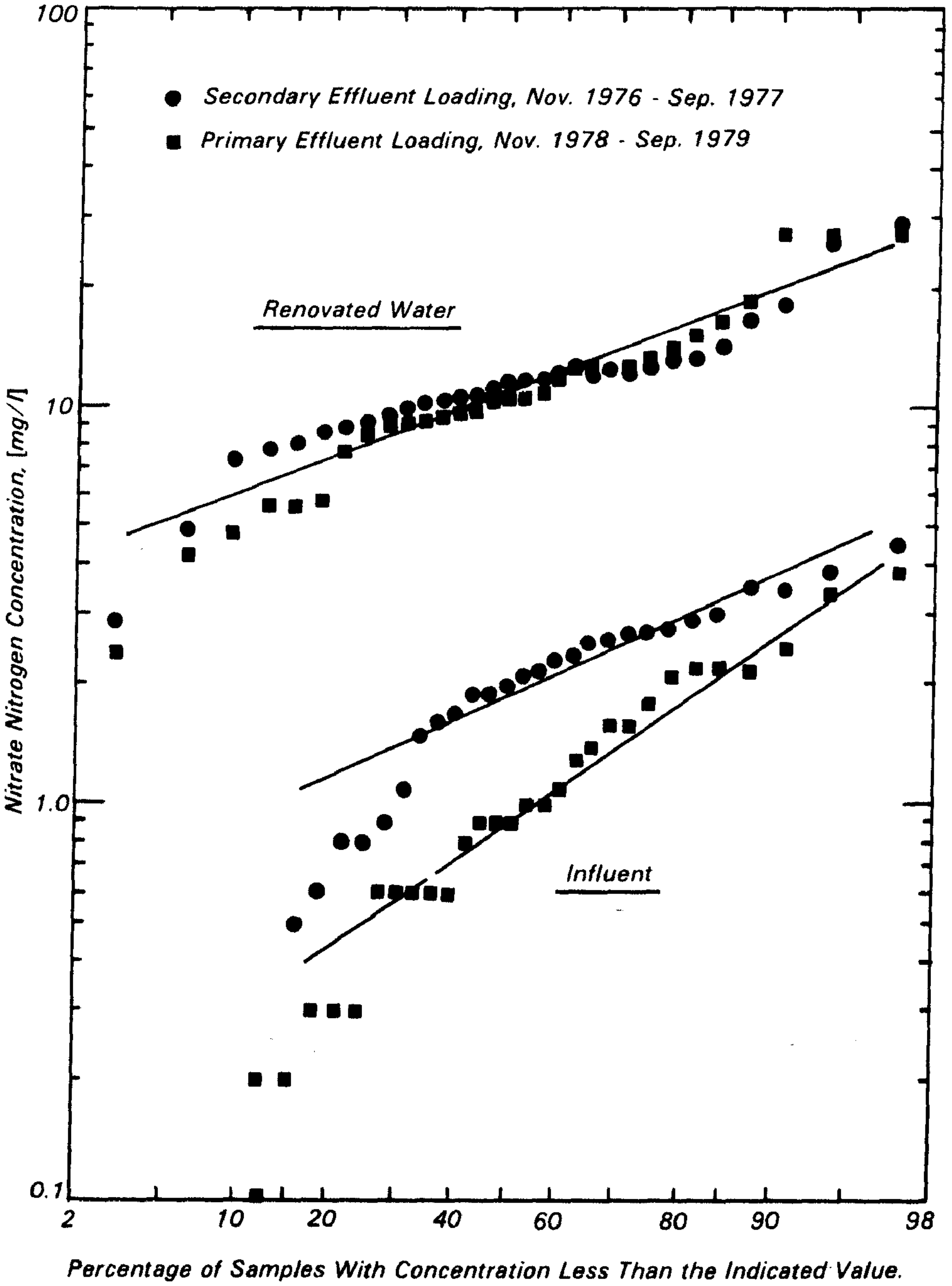

Figure 9. Nitrate concentration variations.

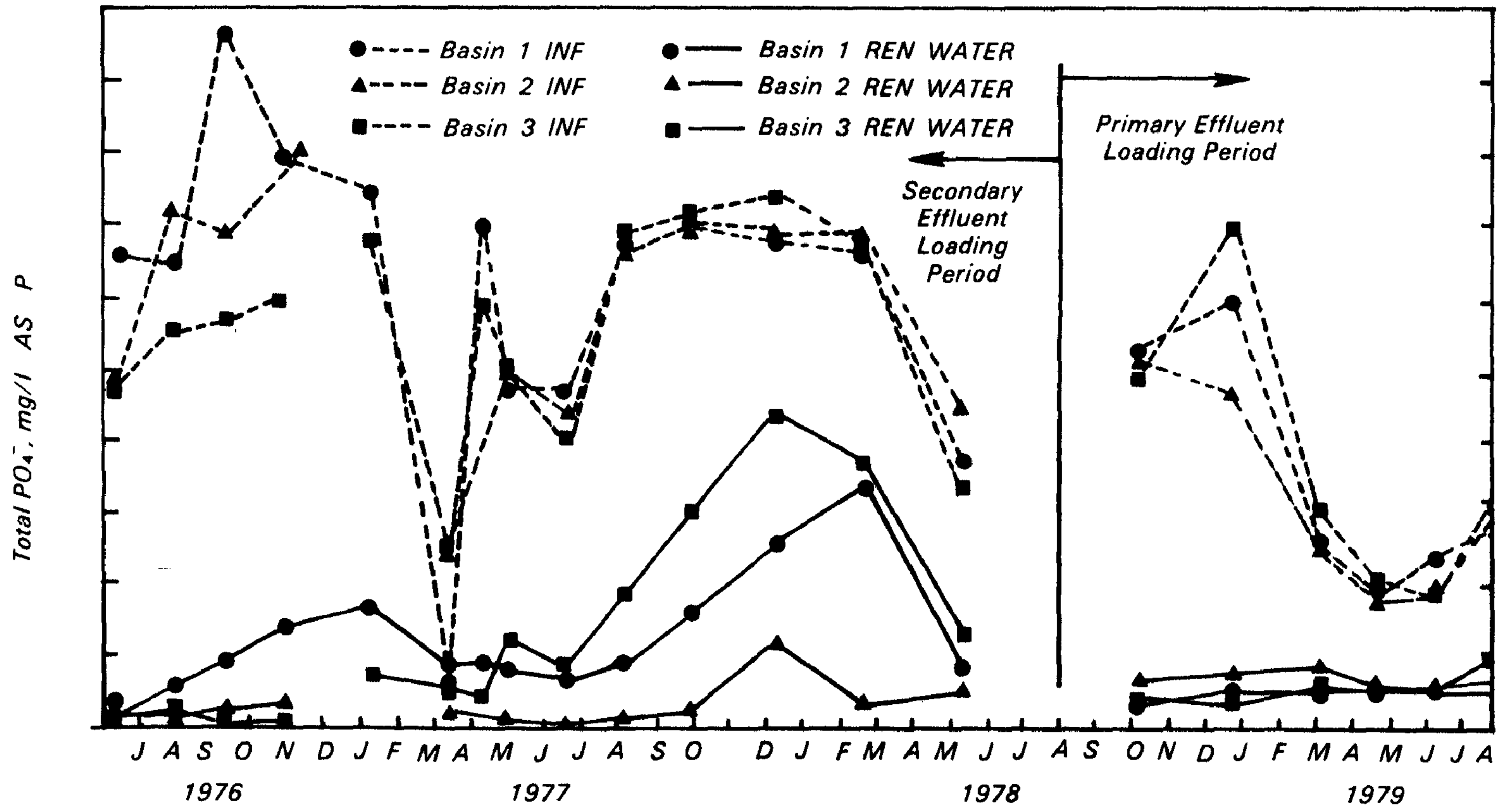

Figure 10. *Influent and renovated water phosphorus concentrations.*

Table 3. *Capital Costs of Treatment Alternatives cents/m³ (cents/1000 gal)*[a]

Alternative	Preliminary Treatment	Primary Sedimentation	Activated Sludge	Biological Nitrification	Filtration	Disinfection	Sludge Handling	Mx & Lab Facilities	Const. Component Costs	Non-Const. Costs	Land Cost	Total Capital
1	2.5 (9.5)	2.0 (7.6)	5.7 (21.6)		3.0 (11.2)	0.8 (3.2)	3.8 (14.4)	1.4 (5.3)	4.5 (16.9)	8.2 (31.4)	0.1 (0.2)	32.0 (121.3)
2	2.5 (9.5)	2.0 (7.6)	5.2 (19.6)	3.5 (13.1)	3.0 (11.2)	0.8 (3.2)	3.8 (14.4)	1.4 (5.3)	5.2 (19.7)	9.6 (36.3)	0.1 (0.2)	37.1 (140.1)
3			5.7 (21.6)		3.0 (11.2)				2.2 (8.2)	3.8 (14.4)	0.0 (0.0)	14.7 (55.4)
4			5.2 (19.6)	3.5 (13.1)	3.0 (11.2)				2.9 (11.0)	5.1 (19.2)	0.0 (0.0)	19.7 (74.1)
5					3.0 (11.2)				0.7 (2.8)	1.3 (4.9)	0.0 (0.0)	5.0 (18.9)
6				3.5 (13.1)	3.0 (11.2)				1.6 (6.1)	2.8 (10.6)		10.9 (41.0)

	Preliminary Treatment	Aerated Lagoon	Transmission & Pumping	Storage	Rapid Infiltration	Surface Discharge	Disinfection	Mx & Lab Facilities	Additional Costs	Non-Const. Costs	Land Cost	Total Capital
7	2.5 (9.5)	0.7 (2.7)	2.3 (8.8)	0.8 (2.9)	1.6 (6.0)			0.6 (2.4)	0.5 (1.8)	3.1 (11.9)	0.9 (3.5)	13.0 (49.5)
8	2.5 (9.5)	0.7 (2.7)	2.3 (8.8)	0.8 (2.9)	1.6 (6.0)	1.1 (4.1)	0.4 (1.7)	0.6 (2.4)	0.5 (1.8)	3.7 (14.0)	0.9 (3.5)	15.1 (49.4)
9	2.5 (9.5)		2.3 (8.8)	0.8 (2.9)	1.6 (6.0)	1.1 (4.1)	0.4 (1.7)	0.6 (2.4)	0.5 (1.8)	3.4 (13.0)	0.9 (3.5)	14.1 (51.7)
10	2.5 (9.5)		2.3 (8.8)	0.8 (2.9)	1.6 (6.0)			0.6 (2.4)	0.5 (1.8)	2.9 (11.0)	0.9 (3.5)	12.1 (45.9)
11		0.7 (2.7)								0.2 (0.9)	0.1 (0.2)	1.0 (3.8)
12		0.7 (2.7)	2.3 (8.8)	0.8 (2.9)	1.6 (6.0)	1.1 (4.1)			0.5 (1.8)	2.4 (9.2)	0.9 (3.5)	10.3 (39.0)
13			2.3 (8.8)	0.8 (2.9)	1.6 (6.0)	1.1 (4.1)			0.5 (1.8)	2.2 (8.3)	0.9 (3.5)	9.4 (35.4)
14			2.3 (8.8)	0.8 (2.9)	1.6 (6.0)				0.5 (1.8)	1.8 (6.8)	0.9 (3.5)	7.9 (29.8)
15				0.8 (2.9)	1.6 (6.0)	1.1 (4.1)			0.5 (1.8)	2.2 (8.3)	0.9 (3.5)	9.4 (35.4)
16			2.3 (8.8)	0.8 (2.9)	1.6 (6.0)				0.5 (1.8)	1.8 (6.8)	0.9 (3.5)	7.9 (29.8)

[a] *All costs adjusted to June 1979; capital costs amortized over 20 years @ 7%.*

Table 4. *Operation and Maintenance Costs cents/m^3 (cents/1000 gal)*[a]

Alternative	Preliminary Treatment	Primary Sedimentation	Activated Sludge	Biological Nitrification	Filtration	Disinfection	Sludge Handling	Mx & Lab Facilities	Total O & M	
1	1.9 (7.1)	1.5 (5.6)	4.7 (17.9)		2.8 (10.6)	0.5 (1.8)	3.5 (12.9)	2.0 (7.5)	16.8 (63.4)	
2	1.9 (7.1)	1.5 (5.6)	4.5 (17.0)	3.9 (14.6)	2.8 (10.6)	0.5 (1.8)	3.4 (12.9)	2.0 (7.5)	20.5 (77.1)	
3			4.7 (17.9)		2.8 (10.6)				7.5 (28.5)	
4			4.5 (17.0)	3.9 (14.6)	2.8 (10.6)				11.2 (42.2)	
5					2.8 (10.6)				2.8 (10.6)	
6				3.9 (14.6)	2.8 (10.6)				6.7 (25.2)	
	Preliminary Treatment	Aerated Lagoon	Transmission & Pumping	Storage	Rapid Infiltration	Surface Discharge	Disinfection	Mx & Lab Facilities	Additional O & M	Total O & M
7	1.9 (7.1)	1.2 (4.6)	0.7 (2.5)	0.0 (0.0)	1.6 (6.0)			1.0 (3.9)	0.2 (0.6)	6.6 (24.7)
8	1.9 (7.1)	1.2 (4.6)	0.7 (2.5)	0.0 (0.0)	1.6 (6.0)	0.6 (2.1)	0.5 (1.8)	1.0 (3.9)	0.2 (0.6)	7.7 (28.6)
9	1.9 (7.1)		0.7 (2.5)	0.0 (0.0)	1.6 (6.0)	0.6 (2.1)	0.5 (1.8)	1.0 (3.9)	0.2 (0.6)	6.5 (24.0)
10	1.9 (7.1)		0.7 (2.5)	0.0 (0.0)	1.6 (6.0)			1.0 (3.9)	0.2 (0.6)	5.4 (20.1)
11		1.2 (4.6)								1.2 (4.6)
12		1.2 (4.6)	0.7 (2.5)	0.0 (0.0)	1.6 (6.0)	0.6 (2.1)			0.2 (0.6)	4.3 (15.8)
13			0.7 (2.5)	0.0 (0.0)	1.6 (6.0)	0.6 (2.1)			0.2 (0.6)	3.1 (11.2)
14			0.7 (2.5)	0.0 (0.0)	1.6 (6.0)				0.2 (0.6)	2.5 (9.1)
15			0.7 (2.5)	0.0 (0.0)	1.6 (6.0)	0.6 (2.1)			0.2 (0.6)	3.1 (11.2)
16			0.7 (2.5)	0.0 (0.0)	1.6 (6.0)				0.2 (0.6)	2.5 (9.1)

[a] *All costs adjusted to June 1979.*

Table 5. *Total Costs of Treatment Alternatives cents/m^3 (cents/1000 gal)*[a]

Alternative	Preliminary Treatment	Primary Sedimentation	Activated Sludge	Biological Nitrification	Filtration	Disinfection	Sludge Handling	Mx & Lab Facilities	Const. Component Costs	Non-Const. Costs	Land Cost	Total Capital
1	4.4 (16.6)	3.5 (13.2)	10.4 (39.5)		5.8 (21.8)	1.3 (5.0)	7.2 (27.3)	3.4 (12.8)	4.5 (16.9)	8.3 (31.4)	0.1 (0.2)	48.8 (184.7)
2	4.4 (16.6)	3.5 (13.2)	9.7 (36.6)	7.3 (27.7)	5.8 (21.8)	1.3 (5.0)	7.2 (27.3)	3.4 (12.8)	5.2 (19.7)	9.6 (36.3)	0.1 (0.2)	57.3 (217.2)
3			10.4 (39.5)		5.8 (21.8)				2.2 (8.2)	3.8 (14.4)	0.0 (0.0)	22.1 (83.9)
4			9.7 (36.6)	7.3 (27.7)	5.8 (21.8)				2.9 (11.0)	5.1 (19.2)	0.0 (0.0)	31.0 (116.3)
5					5.8 (21.8)				0.7 (2.8)	1.3 (4.9)	0.0 (0.0)	7.8 (29.5)
6				7.3 (27.7)	5.8 (21.8)				1.6 (6.1)	2.8 (10.6)	0.0 (0.0)	17.4 (66.2)
	Preliminary Treatment	Aerated Lagoon	Transmission & Pumping	Storage	Rapid Infiltration	Surface Discharge	Disinfection	Mx & Lab Facilities	Additional Costs	Non-Const. Costs	Land Cost	Total Capital
7	4.4 (16.6)	1.9 (7.3)	3.0 (11.3)	0.8 (2.9)	3.2 (12.0)			1.7 (6.3)	0.6 (2.4)	3.1 (11.9)	0.9 (3.5)	19.8 (74.2)
8	4.4 (16.6)	1.9 (7.3)	3.0 (11.3)	0.8 (2.9)	3.2 (12.0)	1.6 (6.2)	0.9 (3.5)	1.7 (6.3)	0.6 (2.4)	3.7 (14.0)	0.9 (3.5)	22.8 (86.0)
9	4.4 (16.6)		3.0 (11.3)	0.8 (2.9)	3.2 (12.0)	1.6 (6.2)	0.9 (3.5)	1.7 (6.3)	0.6 (2.4)	3.4 (13.0)	0.9 (3.5)	20.8 (77.7)
10	4.4 (16.6)		3.0 (11.3)	0.8 (2.9)	3.2 (12.0)			1.7 (6.3)	0.6 (2.4)	3.0 (11.0)	0.9 (3.5)	17.8 (66.0)
11		1.9 (7.3)								0.2 (0.9)	0.1 (0.2)	2.2 (8.4)
12		1.9 (7.3)	3.0 (11.3)	0.8 (2.9)	3.2 (12.0)	1.6 (6.2)			0.6 (2.4)	2.4 (9.2)	0.9 (3.5)	14.4 (54.8)
13			3.0 (11.3)	0.8 (2.9)	3.2 (12.0)	1.6 (6.2)			0.6 (2.4)	2.2 (8.3)	0.9 (3.5)	12.3 (46.6)
14			3.0 (11.3)	0.8 (2.9)	3.2 (12.0)				0.6 (2.4)	1.8 (6.8)	0.9 (3.5)	10.3 (38.9)
15			3.0 (11.3)	0.8 (2.9)	3.2 (12.0)	1.6 (6.2)			0.6 (2.4)	2.2 (8.3)	0.9 (3.5)	12.3 (46.6)
16			3.0 (11.3)	0.8 (2.9)	3.2 (12.0)				0.6 (2.4)	1.8 (6.8)	0.9 (3.5)	10.3 (38.9)

[a] *All costs adjusted to June 1979.*

Table 6. *Total Costs for Large Scale Alternatives cents/m^3 (cents/1000 gal)*[a]

Alternative & Ave. Flow m^3/sec (MGD)	Preliminary Treatment	Primary Sedimentation	High-Rate A/S	Biological Nitrification	Filtration	Disinfection	Sludge Handling	Mx & Lab Facilities	Const. Component Costs	Non-Const. Costs	Land Cost	Total Cost
Alternative 2												
0.4 (10)	1.5 (5.7)	0.8 (3.1)	2.7 (10.4)	2.1 (8.0)	2.5 (9.6)	0.6 (2.3)	2.1 (8.0)	1.5 (5.5)	4.7 (17.9)	4.3 (16.2)	0.0 (0.1)	22.9 (86.8)
2.0 (50)	0.8 (3.0)	0.4 (1.6)	1.6 (6.2)	1.5 (5.5)	1.5 (5.5)	0.5 (1.9)	1.5 (5.8)	1.5 (5.7)	6.1 (23.0)	4.0 (15.3)	0.0 (0.1)	19.4 (73.6)
4.0 (100)	0.7 (2.5)	0.4 (1.4)	1.4 (5.2)	1.3 (5.0)	1.2 (4.4)	0.5 (1.9)	1.3 (4.9)	1.5 (5.8)	6.3 (23.9)	3.9 (14.9)	0.0 (0.1)	18.5 (70.0)

	Preliminary Treatment	Aerated Lagoon	Transmission & Pumping	Storage	Rapid Infiltration	Surface Discharge	Disinfection	Mx & Lab Facilities	Additional Cost	Non-Const. Cost	Land Cost	Total Cost
Alternative 8												
0.4 (10)	1.5 (5.7)	0.9 (3.5)	1.5 (5.8)	0.4 (1.6)	1.6 (6.1)	0.6 (2.1)	0.3 (1.1)	0.5 (1.9)	0.3 (1.0)	1.4 (5.4)	0.8 (3.0)	9.8 (37.2)
2.0 (50)	0.8 (3.0)	0.7 (2.8)	3.2 (12.1)	0.4 (1.4)	1.5 (5.7)	0.4 (1.6)	0.2 (0.7)	0.2 (0.9)	0.2 (0.6)	1.2 (4.7)	0.7 (2.8)	9.3 (36.3)
4.0 (100)	0.7 (2.5)	0.7 (2.6)	2.5 (9.4)	0.3 (1.3)	1.5 (5.7)	0.4 (1.4)	0.2 (0.7)	0.2 (0.7)	0.1 (0.5)	0.9 (3.5)	0.7 (2.8)	8.2 (31.1)

[a] All costs adjusted to June 1979; capital costs amortized over 20 years @ 7%.
cents/1000 gal (.264) = cents/m^3

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The complete report, entitled "Treatment of Primary Effluent by Rapid Infiltration," (Order No. PB 81-129 124; Cost: $11.00, subject to change) will be available only from:

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5285 Port Royal Road
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