EPA-600/2-76-082
MARCH 1976

Environmental Protection Technology Series

TERTIARY TREATMENT FOR PHOSPHORUS REMOVAL AT ELY, MINNESOTA AWT PLANT APRIL, 1973 THRU MARCH, 1974

Municipal Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into five series. These five broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The five series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment, and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EPA-600/2-76-082
March 1976

TERTIARY TREATMENT FOR PHOSPHORUS REMOVAL AT ELY, MINNESOTA AWT PLANT
April, 1973 thru March, 1974

by

John W. Sheehy
Francis L. Evans, III
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

Grant No. S-802309

Project Officer

Robert M. Brice
Shagawa Lake Research Project
Environmental Research Laboratory
Corvallis, Oregon 97330

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report shows that an effectively operated advanced wastewater treatment facility can reliably and continuously reduce total phosphorus to a very low concentration and in this way enhance the quality of the receiving body of water.

Louis W. Lefke
Acting Director
Municipal Environmental Research Laboratory

ABSTRACT

This report documents the first 12 months of continuous operation of the 1.5 mgd Ely tertiary wastewater treatment plant which reliably removed 99% of the influent total phosphorus and discharged an extremely low effluent total phosphorus concentration, averaging 0.045 mg/l. The tertiary treatment facility, consisting of flow equalization two-stage lime clarification, dual-media filtration and chlorination, was designed to reduce total phosphorus concentration in the existing trickling filter plant effluent to 0.05 mg/l. Operational costs for the tertiary plant averaged $\$0.24/m^3$ (\$0.91/1000 gallons). However, it is estimated that the facility could have been operated to achieve an effluent phosphorus concentration of 1 mg/l for approximately $\$0.13/m^3$ (\$0.50/1000 gallons).

This report includes performance data, operational data, maintenance requirements, and operating costs for the Ely AWT facility from April, 1973 through March, 1974. The report presents a thorough discussion of phosphorus performance data along with pertinent information on suspended solids, turbidity, TOC, calcium and iron removal. The report also includes a discussion of sludge treatment processes including data such as sludge volumes, vacuum filter yields, and sludge dryness. Operating data described includes wastewater flow, chemical dose, pH, clarifier solids volume and gravity filter head loss. The report further describes routine maintenance and manpower requirements, including major equipment breakdowns and repairs. Operating costs are divided into five categories and 27 sub-categories. The five cost categories are personnel, chemicals, utilities, laboratory and miscellaneous supplies, and equipment operation and repair.

CONTENTS

Page

FIGURES

TABLES

ACKNOWLEDGEMENTS

The construction and operation of the Ely AWT Plant was supported by the U.S. Environmental Protection Agency's Office of Research and Development for the City of Ely, Minnesota under the administration of the Honorable J. P. Grahek, Mayor.

The overall planning and execution was under the general direction of Mr. Robert M. Brice, EPA Project Officer for the Shagawa Lake Research Project.

The operation of the Ely AWT plant depended on the efforts of numerous individuals. Thanks are extended to these and especially to Glen Lindroos, City of Ely, for providing much of the background data on the operation and maintenance of the existing trickling filter plant and to Robert Randall, EPA, for supervising the chemistry laboratory where myriad analytical determininations were required. Particular thanks are extended to the twelve EPA operating personnel who in no small way contributed to the successful performance of the Ely AWT plant.

Appreciation is also expressed to Dr. R. L. Bunch, Messrs. Richard Brenner, J. M. Smith and James J. Westrick of the Municipal Environmental Research Center in Cincinnati Ohio, who provided program guidance and assistance in the conduct of this study.

SECTION I

SUMMARY AND CONCLUSIONS

1. The costs required to operate the Ely Wastewater Treatment Plant from April 1, 1973 through March 31, 1974 were $389,107.64. During this period $1.6 \times 10^6 m^3$ (427.7 million gallons) of wastewater were treated at a cost of $0.24/m^3 ($0.91/1000 gallons).

2. For the one-year period of operation from April 1, 1973 to March 31, 1974 the tertiary facilities at the Ely AWT plant performed as follows:

Parameter (mg/1)	2-Stage Lime Clarification			Dual-Media Filtration			Removal in
	INF	EFF*	% Removal	INF*	EFF	% Removal	Tert. Plt.
BOD	-	-	-	-	12.3	-	-
TOC	46	18	61	19.5	17.9	8	61%
Suspended Solids	70**	7.1	90	8.7	1.3	85	98%
Turb.-JTU	23	2.0	91	2.22	0.56	75	98%
Soluble P	2.68	0.033	99	0.038	0.037	3	98.6%
Particulate P	1.88	0.050	97	0.051	0.008	84	99.6%
Total P	4.56**	0.083	98	0.089	0.045	49	99.0%

* The difference between the clarifier effluent values and the filter influent values was due to the chemical reactions resulting from sulfuric acid and ferric chloride additions which were made between the sampling points in the second-stage clarifier overflow and the dual-media filters' splitter box.

** The tertiary plant influent values were greater than the secondary plant effluent values due to high solids and phosphorus in the waste flows which were returned to the head of the tertiary plant.

3. Tertiary plant recycle streams returned to the head of the high-rate trickling filter secondary treatment facilities most likely improved the performance of the secondary treatment facilities. For the one-year period of operation from April 1, 1973 to March 31, 1974 the secondary treatment facilities achieved the following performance.

	Influent (mg/l)	Effluent (mg/l)	% Reduction
BOD	90	39	57
Suspended Solids	202	44	78
Total Phosphorus	7.07	3.81	46

4. The 208 m^3 (55,000 gallon) wet well of the tertiary influent pump station was used as an equalization tank. In addition to secondary effluent, flow to the influent tank consisted of six sample waste streams and clarifier overflows. The tertiary influent tank, together with the manually operated pump controller, served to dampen hydraulic variations. Steady flows could be maintained for periods of time varying from one to eight hours, resulting in improved tertiary plant operation.

5. The first-stage lime clarifier removed an average of 93.5 percent of the total influent phosphorus in 12 months of continuous operation. The monthly median clarifier pH values varied from 11.84 to 12.07. The performance of the first-stage clarifier was related to the solids inventory carried in the mixing zone which in turn was determined by the speed of the turbine mixer.

6. The second-stage lime clarifier operated at a pH of 9.6 $\pm$ 0.1 and removed an average of 72.2 percent of the second-stage influent total phosphorus. Through two-stage clarification, total phosphorus removal averaged 98 percent. The addition of 3-6 mg/l iron (as Fe^{+3}) to the second-stage clarifier qualitatively improved coagulation/flocculation and enhanced the removal of phosphorus.

7. The removal of soluble phosphorus, particulate phosphorus, and total phosphorus through dual-media gravity filtration averaged 3 percent, 84 percent and 49 percent, respectively. The mean filter effluent suspended solids was less than 2 mg/l, and the mean effluent turbidity averaged 0.6 JTU. The adjustment of the filter influent pH to 7-8 prevented deposition of $CaCO_3$ on the filter and the addition of 2-4 mg/l iron (as Fe^{+3}) minimized the dissolution of particulate phosphorus. Filter runs up to 24 hours and hydraulic loadings up to 8.6 m/hr (3.5 gpm/sq ft) were achieved.

8. Sludge solids loading to the gravity thickener averaged 2780 kg/day (6130 lbs/day) of combined biological-chemical sludge at an average daily flow of 109 m^3/day (28,760 gpd). Of the total flow 12 percent was undigested combined raw and secondary sludge from the trickling filter plant at 7-10 percent solids; 62 percent was first-stage lime clarifier underflow at 0.8-1.0 percent solids; and 26 percent was second-stage lime clarifier underflow at 2.1 percent solids. Thickener underflow solids concentration averaged 15 percent. Sludge handling problems encountered were (a) high solids in the thickener overflow which was due to poor settling characteristics of the undigested combined raw and secondary sludges and (b) odors caused by processing undigested sludge from the secondary plant.

9. Prior to vacuum filtration, thickener underflow was conditioned with lime at the average rate of 33 gm/kg (66 lbs/ton) of dry solids. At an average loading of 47.0 kg/m^2/hr (9.6 lbs dry solids/sq ft/hr) the filter cake contained greater than 30 percent solids 95 percent of the time, and averaged 35.7 percent solids for a ten month period. Conditioning sludge with lime increased the filter yield by 81 percent from an average of 27.0 kg/m^2/hr (5.6 lbs/sq ft/hr) to an average of 49.0 kg/m^2/hr (10.0 lbs/sq ft/hr).

10. Operation of the secondary and tertiary facilities at the 5678 m^3/day (1.5 mgd) Ely AWT plant required an operating staff of 15-16 persons plus 3-4 laboratory personnel. Four shifts of two men each operated the tertiary facilities. While the vacuum filter was in operation, the full-time attention of one operator was required. In addition to routine maintenance, considerable time and money were expended for corrective maintenance of the comminutor, secondary bioligical clarifier, second-stage lime clarifier, sludge thickener, and sludge underflow pumps. Additional time was spent to improve safety conditions within the plant buildings and around the grounds.

Based on the operation of the 5678 m^3/day (1.5 mgd) Ely AWT plant, it is estimated that operation of a similarly designed 37,850 m^3/day (10 mgd) plant would require an operating staff of 18 to 20 persons plus 3-4 laboratory personnel.

SECTION II

RECOMMENDATIONS

1. Long term operation of the two-stage lime clarifier indicated that performance of the process with respect to clarifier effluent phosphorus and suspended solids concentrations was related to effluent turbidities. Automatic turbidity measurements with continuous read-out is suggested for both first and second-stage lime clarification process monitoring.

2. Performance of the sludge thickener was adversely affected in direct proportion to the amount of undigested combined raw and secondary sludge in the thickener. Poor settling characteristics of this sludge increased solids in the thickener overflow and decreased underflow solids concentration. The short-term use of a polymeric flocculant aid improved thickener performance and is suggested for continuous use.

3. Prior to plant start-up, safety training for supervisors and operating personnel should be provided because of the potential hazards which are associated with complex treatment equipment and chemical usage.

SECTION III

INTRODUCTION

The Shagawa Lake Restoration Project in Ely, Minnesota is a field activity of the Eutrophication and Lake Restoration Branch of EPA's Environmental Research Laboratory, Corvallis, Oregon. The Project is being carried out in cooperation with the Wastewater Research Division of EPA's Municipal Environmental Research Center in Cincinnati Ohio which has assumed primary responsibility for operation of the tertiary wastewater treatment plant. The objective of the project is the demonstration of the feasibility of improving the quality of a culturally eutrophic lake by removing phosphorus from the Ely municipal wastewater treatment plant effluent, the primary source of nutrient supply to that lake.

Eutrophication is the process whereby a body of water is enriched with aquatic plant nutrients to concentrations which result in nuisance levels of biological activity. During early stages of evolution, lakes are typically low in biological productivity and high in purity. As lakes age, biological productivity increases first through levels that are optimal for the propagation of desirable game fish but eventually levels are reached which result in a lowering of water quality to the point that a lake no longer provides adaquate habitat for desired species. In the final stages of evolution, they often undergo periods of low oxygen content, may possess undesirable tastes and odors, and develop recurring nuisance algal blooms. Lakes thus may lose their aesthetic properties, may become unacceptable as a source of water supply, and may become relatively useless for fishing, boating or swimming.

Natural eutrophication is generally a slow process requiring hundreds or thousands of years for objectionable water characteristics to develop. Cultural eutrophication, however, which is due to man's activities, proceeds much more rapidly. A major cause of cultural eutrophication is the discharge of municipal wastes to a body of water. Such discharges greatly increase the flow of nutrients to the body of water drastically accelerating the eutrophication process.

Cultural eutrophication is a major environmental problem. The concern of scientists and demands for remedial action have prompted investigations of techniques to reduce the productivity of culturally eutrophic lakes and to restore them to higher purity. Pilot or full-scale demonstrations have shown that diversion of wastewater effluent around a lake, in situ chemical treatment of a lake to precipitate nutrients, and dredging and aeration may be useful lake restoration techniques. Another technique, nutrient removal from wastewater entering a lake, appeared technically feasible. However, prior to initiation of the Shagawa Lake Project, its effectiveness had not been demonstrated.

Ely, Minnesota, which has a population of 5,000 persons, is located in northeastern Minnesota, about 160 km (100 miles) north of Duluth. Shagawa Lake, shown in Figure 3-1, is located adjacent to the City of Ely. It was formed, along with many other lakes in the region, during the retreat of the Wisconsin Glacier approximately 10,000 years ago. The lake has a surface area about 970 hectares (2397 acres), a maximum depth of 14 meters (46 ft) and an average depth of about 6 meters (20 ft). Burntside River, which flows out of oligotrophic Burntside Lake, is the major contributory, entering Shagawa Lake from the west. Several smaller tributaries flow into the lake on the southwest and the north. The only outlet is the Shagawa River on the eastern side of the lake.

There are few natural sources of algal growth-promoting nutrients, and the high productivity of Shagawa Lake has been attributed to the nutrients in the municipal wastewater which has been discharging into the lake since prior to 1900. The City employed primary wastewater treatment until 1954 when a high-rate trickling filter and secondary settling facilities were installed. During the period when secondary treatment plant effluent was being discharged to the lake, studies have shown that about 80 percent of the phosphorus entering the lake through surface flows came from this source. About one percent of the surface flow has been attributed to municipal wastewater and about 75 percent to Burntside River.

A number of factors influenced the selection of Shagawa Lake as the site for demonstrating the restoration of a eutrophic lake by phosphorus removal from a wastewater treatment plant effluent. (1) Shagawa Lake has had a history of nuisance algal blooms. (2) The lake water quality is of particular concern because its outflow passes through parts of the Superior National Forest, a National Wilderness Area (Boundary Waters Canoe Area) and Canada. (3) The eutrophic state of the lake was uncommon among the lakes in the area. (4) The major surface flow of water into Shagawa Lake is high purity water and the calculated hydraulic retention time in the lake is very short - about nine months. (5) Municipal wastewater was the major source of nutrients to the lake, there being no significant agriculture or industrial activity in the area.

The Shagawa Lake Restoration Project was initiated on a pilot plant scale in Ely, Minnesota in 1966. A 106 m^3/day (28,000 gpd) tertiary wastewater treatment plant processed effluent from the Ely municipal secondary (high-rate trickling filter) wastewater treatment plant. Using isolated test basins floating in the lake, the tertiary effluent was evaluated relative to algal growth potential. Concurrently, a limnological investigation was carried out to document the trophic state of the lake and to provide characterization for comparison of "before" and "after" quality. Results of the study have been published (1).

The tertiary wastewater treatment pilot plant included chemical clarification, multi-media filtration, carbon adsorption, and ion exchange. In these early studies, both lime and alum clarification followed by settling and filtration reduced the total residual phosphorus concentration to less than 0.05 mg/l. Carbon adsorption and ion exchange were not necessary in achieving the low residual phosphorus concentrations.

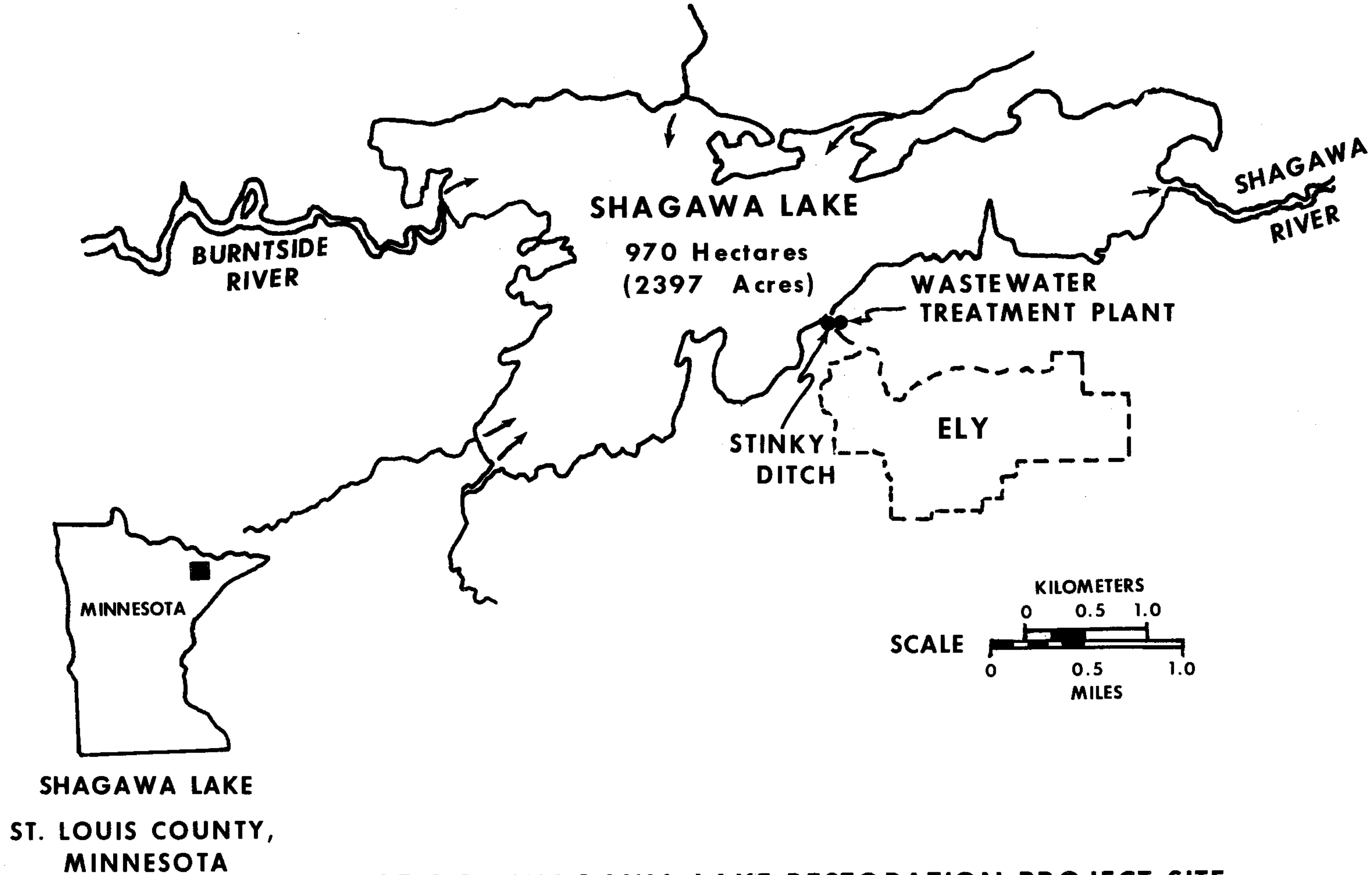


FIGURE 3-1. SHAGAWA LAKE RESTORATION PROJECT SITE.

The use of floating basins as "receiving ponds" for the tertiary effluent isolated segments of the lake and permitted evaluation of the pilot plant effluent in a simulated lake environment. The basin tests demonstrated that the tertiary treatment system substantially reduced the potential of the effluent to produce algal blooms when mixed with Shagawa Lake water or Burntside River water.

Based upon the positive results of these pilot studies, the Environmental Protection Agency considered a demonstration study for a tertiary wastewater treatment system in order that full-scale restoration of Shagawa Lake could be studied. The rate and extent of recovery of the lake would be documented and limnological studies would continue for several years. Background data describing biological, physical, and chemical characteristics of the lake had already been developed. These data would be used in determining the validity of several mathematical models to be developed in an attempt to describe the eutrophication process, and to simulate the lake water quality improvement expected to result from tertiary phosphorus removal from secondary effluent.

In 1971, a Research and Development grant was awarded by the EPA to the City of Ely, Minnesota to design a tertiary wastewater treatment facility. The primary objectives of this grant were the following:

1. To develop a complete set of engineering plans and specifications for a tertiary wastewater treatment system to remove phosphorus from secondary effluent to a residual of 0.05 mg/l of total phosphorus or less.

2. To build into the design of the phosphorus removal facilities the capability for upgrading the effluent quality to meet the State of Minnesota BOD and suspended solids standards. The standards proposed by the State for Ely's effluent discharge, which would guide the design of the proposed facilities, were 25 mg/l BOD_5 and 30 mg/l suspended solids.

3. To develop sound engineering estimates for construction and operating costs for the proposed facilities. The construction cost estimates were to be sufficiently detailed so that the cost of the phosphorus removal facilities could be considered apart from the cost of repairs to the existing plant. Likewise, operating costs were to be estimated separately for both the secondary trickling filter plant and the tertiary phosphorus removal facility.

The City of Ely engaged the architectural-engineering firm of Toltz, King, Duvall, Anderson and Associates, Inc., St. Paul, Minnesota, to carry out the design objectives. Plans and specifications for the AWT plant were completed in June of 1971.

In this same year funds for construction and operation of the tertiary wastewater treatment facility and for renovation of the existing high-rate trickling filter plant were provided by two EPA grants totalling $2,572,358.

The six primary objectives of the construction-operation grant are listed below:

1. Construct tertiary wastewater treatment facilities which would remove phosphorus from the effluent of the typical high-rate trickling filter plant at Ely, to a residual of 0.05 mg/l of total phosphorus or less.

2. Demonstrate that the effluent from the upgraded facility could meet an effluent BOD standard of 25 mg/l and a suspended solids standard of 30 mg/l as proposed by the State of Minnesota.

3. Begin construction of tertiary wastewater treatment facilities not later than September 1, 1971, and complete construction and have facilities ready for "start'up" and "shake-down" by May 31, 1972.

4. Repair and restore the existing conventional wastewater treatment facilities at Ely by July 31, 1972.

5. Provide facilities to return to the headworks of the existing conventional treatment facilities for subsequent treatment, the maximum practicable amount of runoff which drains into a channel known as "Stinky Ditch" from adjacent hillsides and which for many years flowed untreated into Shagawa Lake.

6. Operate the combined wastewater treatment complex to a high degree of efficiency with maximum practicable removal of phosphorus, BOD, and suspended solids for a continuous period of three years commencing on or around August 1, 1972, while concurrent limnological studies are conducted on Shagawa Lake.

Completion of construction was delayed until December 1972 because of adverse weather and labor strikes. Debugging and shakedown took about three months and the tertiary facility was put into operation on April 1, 1973.

Because of the unpredicted delays in completion of construction and start-up, the grant period was subsequently extended to January 31, 1976.

Although this construction-operation grant provided for construction, utility costs, chemicals, fuel, supplies, etc., it did not provide funds for operating personnel. Therefore, the Wastewater Research Division of the Municipal Environmental Research Center, Cincinnati provided funding for an engineer-superintendent, twelve plant operators, and four laboratory technicians. The laboratory technicians are part of an analytical laboratory staff that does all analytical work including that required for operation, for evaluation of the plant, and for the limnological studies.

All other project personnel, laboratory supplies, administrative services, and incidental costs not provided under the grant, or from MERL-Cincinnati were provided by the Environmental Research Center in Corvallis, Oregon.

SECTION IV

PROCESS DESCRIPTION

A. Primary and Secondary Facilities

The 5678 m^3/day (1.5 mgd) high-rate trickling filter plant consists of a grit chamber, trash rack, primary clarifier, trickling filter, secondary clarifier, chlorine contact chamber, and a high-rate anaerobic sludge digester. The secondary plant is shown schematically in Figure 4-1 and the design criteria are given in Table A-1.

The grit chamber is 10 m (32.5 ft) long x 1 m (3 ft) wide x 1.2 m (4 ft) deep. It is equipped with a proportional weir which maintains a constant flow rate of 0.30 m/s (1 fps) through the grit chamber. The comminutor, with 9.5 mm (3/8 in) horizontal slots, screens and shreds large solids into smaller particles prior to further treatment. The comminutor was designed for a flow of 5678 m^3/day (1.5 mgd) with a peak capacity of 26,500 m^3/day (7.0 mgd).

The primary clarifier has a diameter of 15.2 m (50 ft) and a sidewater depth of 2.4 (7 ft 10 in). At the design flow of 5678 m^3/day (1.5 mgd) the clarifier detention time is 2 hours, the overflow rate is 31 m/day (760 gpd/sq ft), and the weir overflow rate is 128 m^2/day (10,270 gpd/lf). The primary clarifier is equipped with mechanical scraper arms for sludge removal. Primary clarifier underflow, which consists of primary sludge and recirculated secondary sludge, is conveyed to the tertiary thickener by a piston pump. Floatable material in the primary clarifier, which includes recirculated scum from the secondary clarifier, is collected in a scum box and discharged for further treatment and disposal. The solids handling facilities for the secondary and tertiary treatment units are described later.

After primary settling, the sewage passes through a high-rate, stone media trickling filter that is 18 m (60 ft) in diameter and 1.8 m (6 ft) deep. The hydraulic loading at 5678 m^3/day (1.5 mgd) is 22 m/day (23 mgad) and the organic loading is 780 kg BOD/day/1000 m^3 (49 lbs BOD/day/1000 cu ft). Although the trickling filter was designed for recirculation, this method of operation is not used due to hydraulic limitations of the bypass Control Box #1 which is located between the primary clarifier and trickling filter.

The secondary clarifier is 15.2 m (50 ft) in diameter, and has a sidewater depth of 2 m (6 ft 10 in). At a plant flow of 5678 m^3/day (1.5 mgd) the clarifier has a detention time of 1.77 hours, an overflow rate of 31 m/day (760 gpd/sq ft) and a weir overflow rate of 128 m^2/day (10,270 gpd/lf). The secondary clarifier

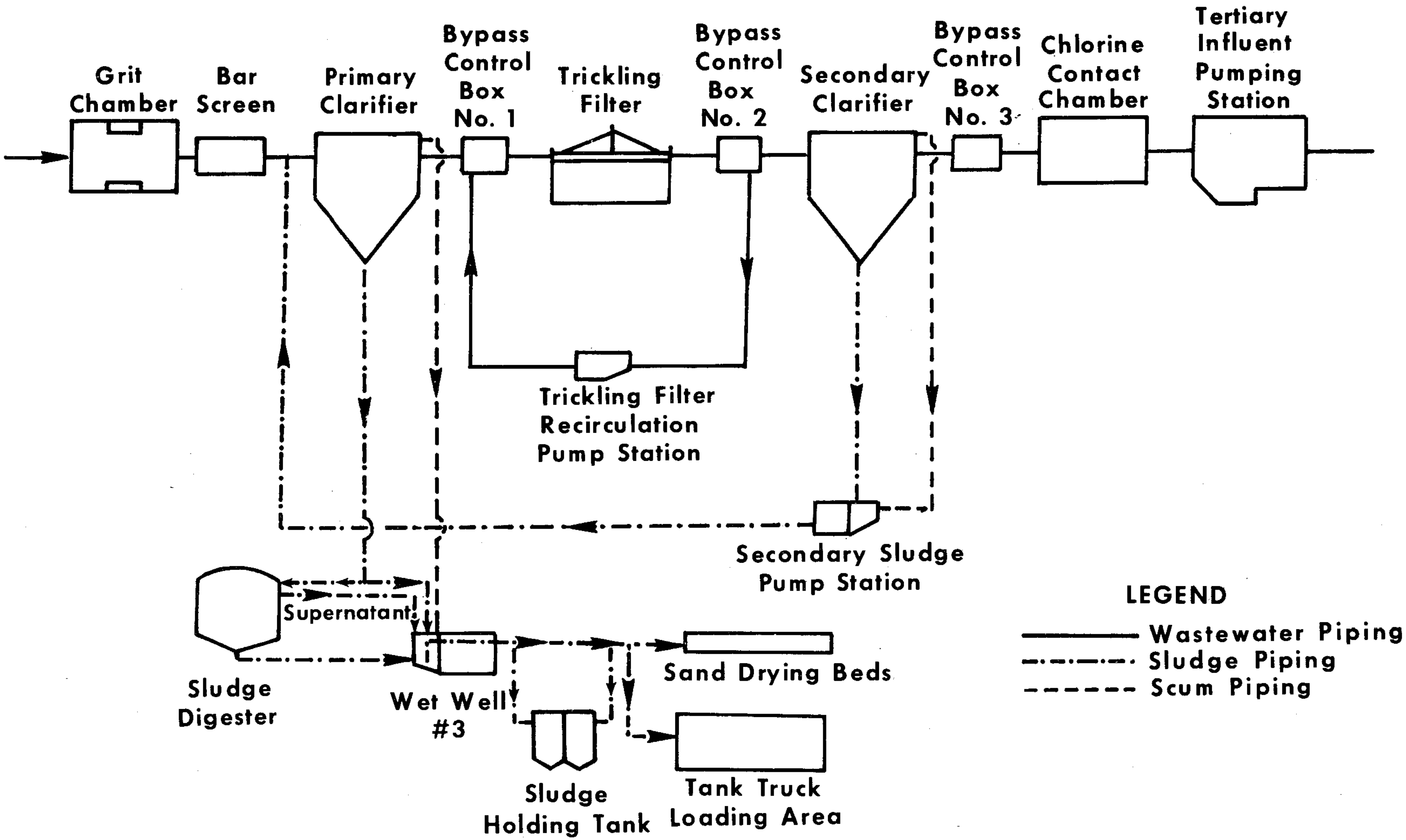


FIGURE 4-1. FLOW DIAGRAM OF ELY SECONDARY WASTEWATER TREATMENT PLANT

equipment includes a sludge rake, scum scraper arm, and scum collection box. Secondary sludge is pumped to the primary clarifier where it is resettled with the primary sludge.

The secondary clarifier effluent passes through the existing chlorine contact chamber of the secondary plant. The chlorine contact chamber has been modified to include flow measuring and sampling equipment. Chlorine is not added at any point in the chlorine chamber but instead is added subsequently in the tertiary plant.

B. Tertiary Treatment Unit Processes

Tertiary treatment includes flow equalization, two-stage lime clarification, dual media filtration and chlorination. Schematics of the tertiary facilities are shown in Figure 4-2 and in Figures A-1 and A-2. The design criteria are listed in Table A-1, and the hydraulic schematic is shown in Figure B-1. The influent wet well, which has a capacity of 208 m^3 (55,000 gallons) receives secondary effluent, overflows from the lime clarifiers, flow from the three tertiary plant sample sinks, and the flow from the north side floor drains. The wet well provides some equalization of flow. Two variable-speed centrifugal pumps controlled by a manually operated pump controller, lift the wastewater from the influent wet well to the mix zone of the first lime clarifier. Each pump has a maximum capacity of 4.2 m^3/min (1100 gpm) at a TDH of 20 m (65 ft).

The first-stage lime clarifier is 17 m (55 ft) in diameter with a sidewater depth of 6 m (19 ft 6 in) (Figure A-3). At a flow of 5678 m^3/day (1.5 mgd) the detention time is 5.3 hours and the overflow rate is 26 m/day (631 gpd/sq ft). The volumes of the mix zone, flocculation zone and clarification zone are 28 m^3 (7,330 gal), 92 m^3 (24,300 gal) and 1,135 m^3 (300,000 gal), respectively.

Secondary effluent, slaked lime, and polymer are pumped to the mix zone of the clarifier. Powdered carbon can also be fed at this point. A variable speed turbine creates an upward flow through the mix zone draft tube and draws solids into the mix zone for coagulation. A sludge scraper, two inches above the clarifier floor, rotates slowly and moves sludge gradually to the center sump.

Effluent from the first-stage lime clarifier flows by gravity to the second-stage lime clarifier (Figure A-4). Carbon dioxide dissolved in water is fed to the mix zone of the second stage to precipitate $CaCO_3$ and reduce the pH to about 9.6. Ferric chloride, slaked lime, polymer, and powdered carbon can also be added to the mix zone of the second-stage clarifier.

The design flow through the second-stage lime clarifier is 5678 m^3/day (1.5 mgd) plus a 757 m^3/day (0.2 mgd) feed stream of recycled tertiary effluent containing dissolved carbon dioxide for pH control. The surface area is identical to that of the first-stage lime clarifier, however, the overflow rate is 29 m/day (715 gpd/sq ft). The second stage has a sidewater depth of 5 m (16 ft 6 in) and a detention time of 4.5 hours. The mix zone volume,

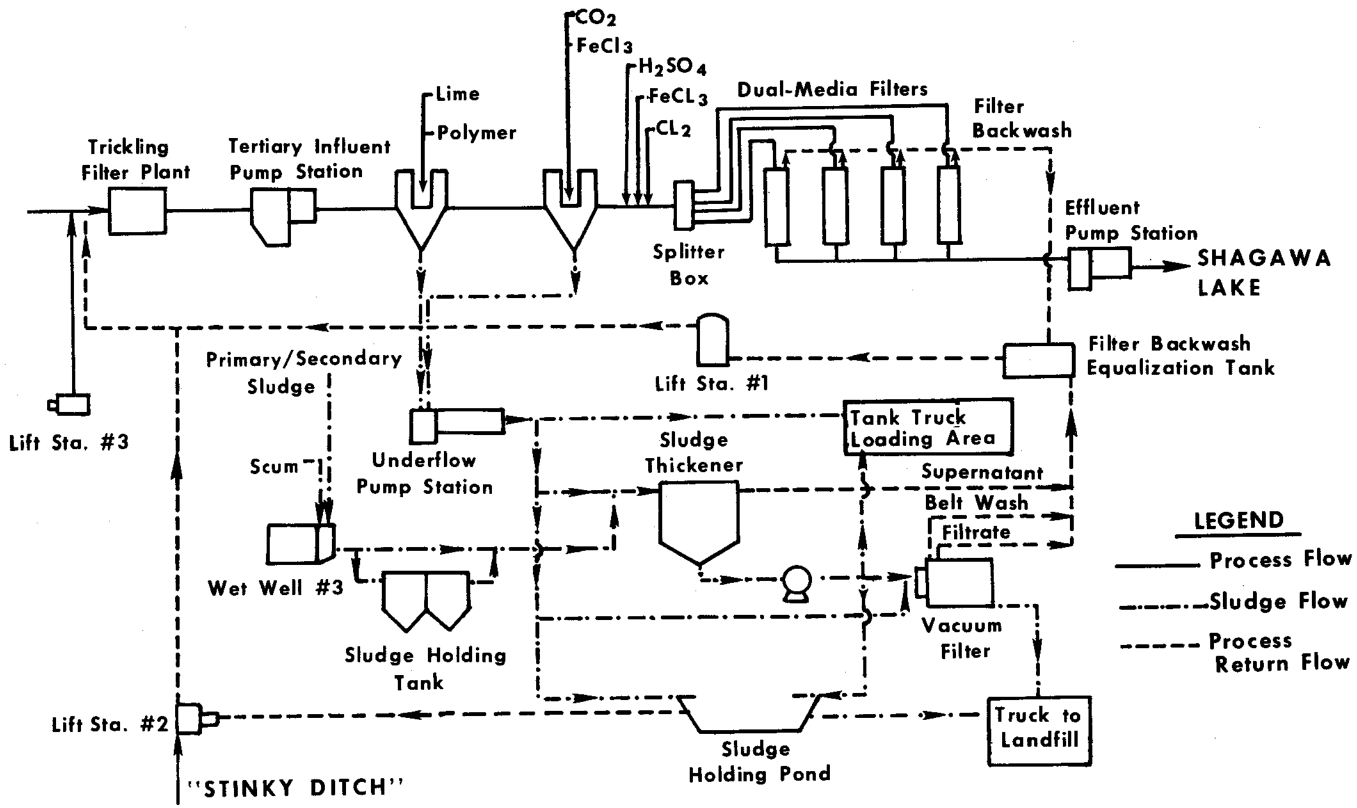


FIGURE 4-2. FLOW DIAGRAM OF ELY TERTIARY WASTEWATER TREATMENT PLANT

flocculation zone volume, and clarification zone volume are 23 m^3 (6,130 gallons), 77 m^3 (20,400 gallons) and 954 m^3 (252,000 gallons), respectively. Each lime clarifier has a maximum hydraulic capacity of 11,356 m^3/day (3.0 mgd). The two lime clarifiers each have overflow drains and each clarifier can be emptied by gravity to one foot above the floor level.

Affixed to each lime clarifier is a sample sink equipped with a pH meter and sample ports. Sample lines lead from the upper mix zone, lower mix zone, upper flocculation and lower flocculation zones, and effluent weir to the sample sink. A port for a variable depth sampler is also located at the sample sink. The pH, solids volume, and sludge blanket depth can be monitored at the sampling sinks.

The second-stage lime clarifier effluent flows by gravity to a splitter box which splits the wastewater into four equal streams and directs the wastewater to the gravity filters. Chlorine, sulfuric acid, and ferric chloride can be added to the second-stage effluent ahead of the splitter box. Each of the four gravity filters (Figure A-5) is 3.7 m (12 ft) in diameter, 4.9 m (16 ft) high, and has a surface area of 10.5 m^2 (113 sq ft). The design hydraulic loading is 5.6 m/hr (2.3 gpm/ft^2) at 5678 m^3/day (1.5 mgd) and the design maximum hydraulic loading to the filters is 8.6 m/hr (3.5 gpm/ft^2). The filter media consists of a 0.6 m (2 ft) layer of anthracite above a 0.3 m (1 ft) layer of sand. The anthracite has an effective size of 0.8 to 0.9 mm with a uniformity coefficient of 1.7. The effective size of sand is 0.4 to 0.5 mm with a uniformity coefficient of 1.4 minimum to 1.65 maximum.

The gravity filters can be backwashed automatically on the basis of either elapsed time or head loss, or backwashing can be initiated manually. Normally the filters are backwashed automatically every 24 hours. While one filter is being backwashed, the other three filters remain in service. The backwash water is held in a 26 m^3 (6,930 gallon) chamber on the top of each filter (Figure A-5). The backwash cycle includes 5 minutes of air scour at 1.5 m/min (4.9 scfm/ft^2) and a backwash rate of 0.61 m/min (15 gpm/ft^2) until the chamber is empty.

The effluent from the gravity filters flows to the effluent water pump station (Figure 4-2) and is either discharged to Shagawa Lake or is recycled through the tertiary plant. From 15 to 25 percent of the filtered wastewater is recycled through the tertiary plant as process water. The tertiary plant can use both city water or recycled effluent for the plant processes. Normally, recycled effluent is used for all process purposes except to mix polymer. Process water is used for:

- dissolution of CO_2 and Cl_2
- slaking CaO and as lime ejector water
- bearing water to the fiber bearings of the two lime clarifiers and the sludge thickener

- tertiary influent pump seal water
- sludge pump flushing water
- powdered carbon wetting and transport
- vacuum filter belt wash water
- tertiary plant cleanup

The treated wastewater not recycled passes through the parshall flume to Shagawa Lake. The parshall flume is both a flow metering station and a sampling station. The parshall flume meters and samples automatically the tertiary plant effluent and any tertiary plant bypass.

The tertiary plant is designed so that the treatment units can be combined into various treatment systems. The two-stage lime clarifiers are operated in series with the second-stage clarifier effluent being split among the four parallel gravity filters. The clarifiers are piped so that they may be operated in parallel. The lime clarifiers, gravity filters, and the effluent reservoir can each be bypassed for maintenance and repair.

Sludges from the first and second-stage lime clarifiers and sludge from the trickling filter plant are normally pumped to an 8 m (26 ft) diameter x 5 m (16 ft 6 in) high picket-type gravity thickener. The sludge can also be routed to a 757 m^3 (200,000 gallon) emergency holding pond, to a tank truck loading station, or to the vacuum filter.

Thickener underflow is pumped by a variable speed progressive cavity pump to a 1.8 m (6 ft) diameter, 2.5 m (8 ft) face belt type vacuum filter. Filter cake is discharged via conveyor to hoppers where it can be loaded by gravity into a dump truck for ultimate disposal in a sanitary landfill. Thickener underflow, in an emergency, can be discharged to the 757 m^3 (200,000 gallon) sludge holding pond. The thickener supernatant is pumped via lift station #1 to the head of the secondary plant.

C. Appurtenant Equipment

The chemical feed systems include lime, ferric chloride, sulfuric acid, carbon dioxide, chlorine, polymer, and powdered carbon. Pebble lime (CaO) is stored in two 18 ton (metric), (20 ton) storage bins. The bins discharge directly to duplicate paste slakers. The slaked lime is transported to the first-stage lime clarifiers by a system of hydraulic ejectors. The lime feeder belt speed is proportioned to the influent flow and the lime dose is set manually by means of a timer mechanism which turns the feeder on and off. The maximum capacity of each lime feeder is 454 kg/hr (1,000 lbs/hr). Lime usage is determined from reading the lime slaker totalizer daily.

Ferric chloride is stored in a 23 m^3 (6,000 gallon) tank which supplies two 0.11 m^3 (30 gallon) day tanks. Two flow-proportional diaphragm pumps feed

$FeCl_3$ to the second-stage lime clarifier and to the influent pipe to the splitter box. The iron dose is set by pump stroke frequency, which is proportional to the influent flow, and by manually adjusting the stroke length. A daily average $FeCl_3$ dose is calculated by measuring the drop in the day tank level.

Sulfuric acid is stored outside of the building housing the tertiary plant in a 15 m^3 (4,000 gallon) tank. The acid is pumped by a flow-proportional diaphragm pump to a point in the pipeline ahead of the splitter box.

Chlorine is purchased in 68 kg (150 lb) cylinders. Two cylinders are used simultaneously. A flow proportional chlorine feeder, using recycled plant effluent, feeds chlorine to the splitter box influent pipe and to the effluent from the gravity filters. Average daily chlorine dose is determined from change in weight of the chlorine cylinders.

Liquid carbon dioxide, used for pH control, is stored in a 22 metric ton (24 ton) refrigeration unit and is vaporized and dissolved in approximately 750 m^3/day (0.2 mgd) of recycled plant effluent. The CO_2 dosage in pounds/day is read from the gas feeder 24 times per day, and the calculated dosage is the average of the 24 readings.

Powdered activated carbon is purchased in 20 kg (45 lb) bags which are stored in a room with only non-spark switches and equipment. The powdered carbon feed system includes a hopper, a volumetric feeder, ejector system and piping to the mix zones of both clarifiers. The powdered carbon feeder is not flow proportional.

Dry polymer is dissolved in city water and pumped to the first-stage lime clarifier by a pump that is not flow proportional. Initially, a commercial polymer mixer was used but it often plugged and failed to operate. Polymer is now added by hand and mixed with city water in a day tank. There have been no maintenance problems using manual polymer makeup during a one year operating period. Polymer dosage is calculated from the daily inch drop in the day tank and the calculated concentration of polymer per inch of tank depth.

In case of power failure, a diesel-powered emergency generator ensures continued operation of the tertiary plant. Equipment connected to the emergency generator include:

- Lights in emergency generator room
- One influent sewage pump
- One lime slaker
- Boiler, heating units
- Air exchangers
- Two effluent pumps

- Turbine and sludge rake for both lime clarifiers
- Exhaust fan above gravity filter pit
- One underflow pump
- Thickener drive
- Carbon dioxide refrigerator and compressor
- All sump pumps
- Service water pumps

The tertiary plant is totally housed in a 2004 m^2 (21,570 sq ft) building. Included in the building are a 130 m^2 (1400 sq ft) office and analytical laboratory area, work bench, showers, rest rooms, operator control room; operational panel with an annunciator tied into the equipment, three large ventilating units, a boiler, emergency generator, and auxiliary equipment. Two additional storage areas were constructed because of the great need for a place to store spare parts, laboratory chemicals, emergency heaters, etc.

D. Analytical Program and Sample Scheduling

Flow proportional wastewater samples are composited at two locations in the secondary plant and six locations in the tertiary plant. Sample locations are between the comminutor and primary clarifier ("Raw Sewage"), the chlorine contact chamber ("Secondary Effluent"), the pipe ahead of the magnetic flow meter for the first-stage lime clarifier, the effluent weir of the first-stage clarifier ("Influent second-stage lime clarifier"), the effluent weir of the second-stage clarifier, the splitter box for gravity filter influent, the viewing well ("Gravity filter effluent"), and the effluent metering station ("Effluent-discharge to Shagawa Lake").

Sludge samples are taken of the combined primary-secondary sludge from the primary clarifier underflow ("Primary-secondary sludge"), from the first-stage lime clarifier underflow, second-stage lime clarifier underflow, and the vacuum filter sludge cake. A sample of the sludge thickener supernatant, which is recycled to the head of the secondary plant, is also taken. The plant operators obtain and composite flow-proportional samples from each location as described. The samples are picked up each midnight and delivered to the laboratory the next day. The analytical sampling and analysis schedule, shown in Table 4-1, indicates the sampling frequency, compositing method, and frequency of analytical testing.

TABLE 4-1 SAMPLING AND ANALYTICAL ANALYSIS SCHEDULE [a]

	Data Code	Note b.	BOD_5	SS	%S	TS	VSS	Settleable Solids	Turbidity	pH	Alkalinity	Conductivity	DO	TC	TOC	TIC	NH_3-N	NO_3-N	NO_2-N	TKN	Total P	Soluble P	Ortho-P	Sodium	Potassium	Magnesium	Calcium	Total Coliform	Fecal Coliform	Total Iron	Metals C.	Silica	Chloride	Sulfate
Raw Sewage	SRA	af	12	12		8	12			30	30	30		30	30	30	30	30	30	30	30		30	16	16	16	16				●[d]	30	●	
Secondary Effluent	SP	af	12	12		8	12			30	30			30	30	30	30	30	30	30	30		30	16	16	16	30				●	1	●	●
Tertiary Effluent	TP	af	12	12		8	12	30		30	30	30	30	30	30	30	30	30	30	30	30	30	30	1	1	1	30	30	4		●	30	30	●
Influent First-stage Lime Clarifier	TC1	mh		30					30		30			12	12	12					30	30				12	30			4				
Influent Second-stage Lime Clarifier	TC2	mh		30					30					12	12	12					30	30				12	30			4				
Effluent Second-stage Lime Clarifier	TS1	mh		30					30					12	12	12					30	30				4	30							
Influent Gravity Filter at Splitter	TS2	mh		30		12			30		30										30	30				12	30							
Effluent from Gravity Filter	TVW	mh		30					30				30	12	12	12					30	30				12	30	16	12	12				
Underflow First-stage Lime Clarifier	TT1	m		30																							12			12				
Underflow Second-stage Lime Clarifier	TT2	m		30																							12			12				
Underflow Primary/ Secondary Sludge	SPR	m			20																													
Sludge Thickener Supernatant	TTW	m4		30						30											30						30							
Vacuum Filter Sludge Cake	TVK	m			20																													

Notes

a. Numbers indicate sampling frequency per month

b. af = flow proportional samples composited automatically
mh = hourly samples composited manually on flow-proportional basis
m4 = sampled every four hours and manually composited
m = samples manually composited

c. metals include Al,Cu,Pb,Zn,Fe,Mn,Mo,Co,Ag

d. 0 indicates sample taken every three months

SECTION V

PROCESS PERFORMANCE

A. Secondary Plant

The influent flow to the trickling filter plant includes wastewater from the City of Ely and discharges through three package lift stations adjacent to the plant site as shown in Figure A-1. Tertiary plant return streams flow to the 208 m^3 (55,000 gallon) equalization sump of lift station #1 and are pumped to the plant influent. Lift station #2 pumps water from a creek, "Stinky Ditch", which contains some septic tank drainage, and also pumps the runoff from the sludge holding pond. Lift station #3 picks up the swamp water situated east of the trickling filter plant and discharges it to the plant influent sewage pipe.

Influent to the trickling filter plant averages 4,163 m^3/day (1.1 mgd). For eight months of data as shown in Table C-1, Appendix C, total phosphorus averaged 7.07 mg/l, SS averaged 202 mg/l, alkalinity averaged 181 mg/l as $CaCO_3$, BOD averaged 90 mg/l and the median pH was 7.9.

Eight months of trickling filter plant performance data, as shown in Tables C-2 and C-3, Appendix C, were obtained during the first year of the project. The trickling filter plant removed an average of 46 percent of the total phosphorus, 78 percent of the suspended solids, 21 percent of the alkalinity and 57 percent of the BOD. The concentrations in the trickling filter plant effluent averaged 3.81 mg/l total P, 44 mg/l SS, 139 mg/l alkalinity, and 39 mg/l BOD. The effluent median pH was 7.3.

B. Tertiary Plant

1. Two-Stage Lime Clarification

Phosphorus Removal

During normal operation the pH in the first-stage lime clarifier was raised to 11.8 or higher by the addition of slaked lime to precipitate hydroxyapatite and magnesium hydroxide. The operating pH, lime dose required, incoming alkalinity, and first-stage effluent total phosphorus concentration for the first year of operation are shown in Figure 5-1. As can be seen in the figure, the pH varied between 11.84 and 12.03 and the lime dose varied between 266 and 344 mg/l. For this period of operation, total phosphorus in the first-stage clarifier effluent averaged 0.298 mg/l.

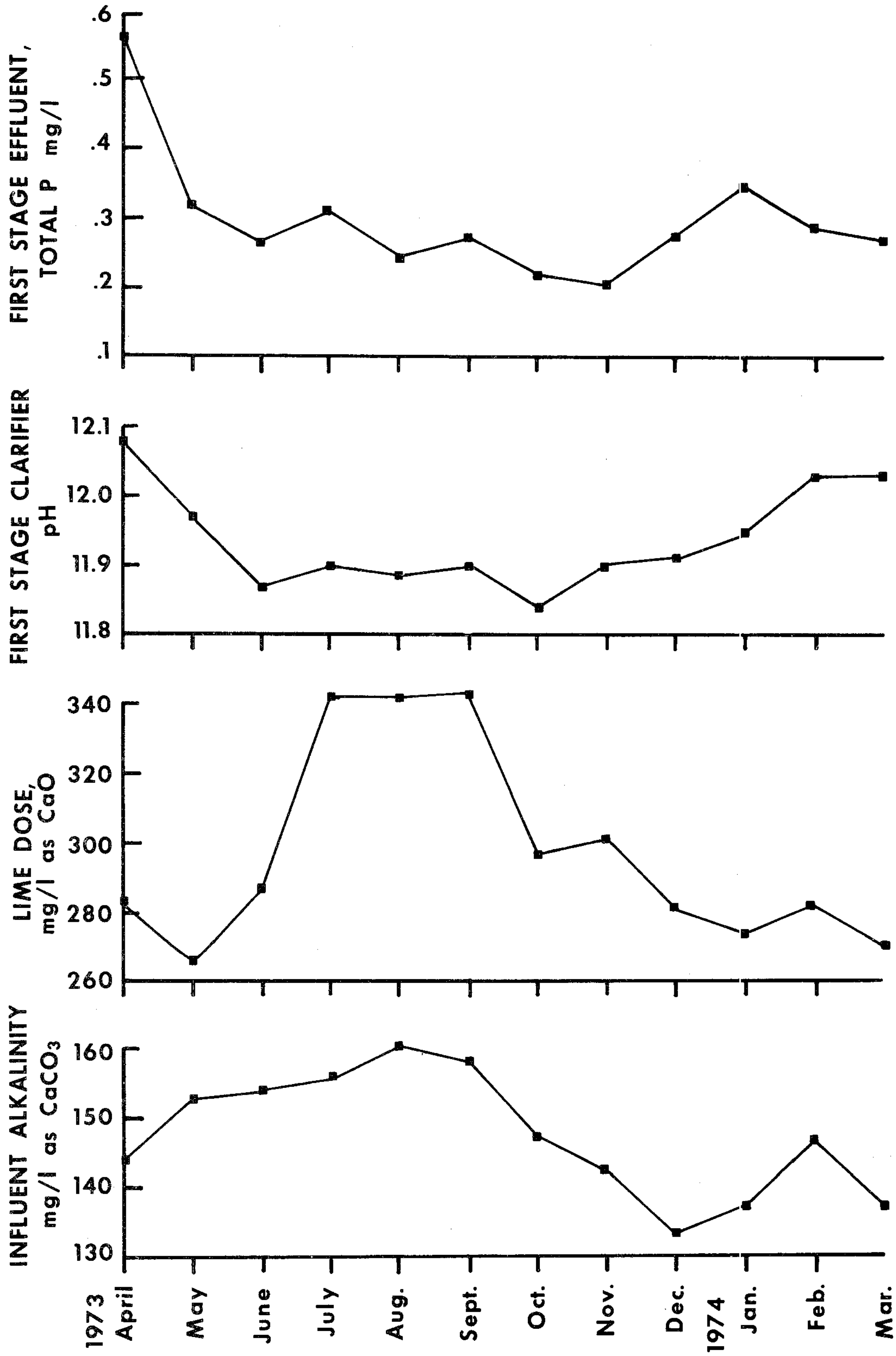


FIGURE 5-1. MONTHLY AVERAGE VALUES OF INFLUENT ALKALINITY, LIME DOSE, CLARIFIER pH, AND EFFLUENT TOTAL P FOR FIRST STAGE LIME CLARIFIER.

The second-stage lime clarifier was operated at a pH of 9.6 and was originally designed so that CO_2 following dissolution could be added to the influent of the second-stage clarifier. Shortly after start-up, the influent pipe plugged with $CaCO_3$ and had to be taken apart and cleaned. To avoid this frequent occurence, the situation was corrected by adding dissolved CO_2 directly to the second-stage mix zone instead of to the influent pipe. Also during start-up it was determined that the effluent from the second-stage clarifier was very unstable and $CaCO_3$ was being precipitated on the filter media. Although deposited $CaCO_3$ removed soluble phosphorus to very low levels, high head losses and short filter runs resulted. This problem was resolved after the sulfuric acid feed system was placed in operation to reduce the second-stage effluent pH from a range of 7.6 to 9.5 to a range of 7.5 to 7.8 thereby producing a negative Langelier index. While this resulted in dissolution of the carbonate deposit and prevented further precipitation, soluble phosphorus was no longer removed by the filters.

Effect of Solids Volume on Phosphorus Removal

During the initial stages of plant operation, it was observed that the volume of solids in the mix zone and the ratio of upper mix zone solids volume to lower mix zone solids volume were critical in the control of the performance of the two lime clarifiers. The solids brought into the mix zone provided surfaces which theoretically promote the completion of chemical reactions and improve flocculation.

Therefore, a procedure was initiated through which the solids volume in the mix zone of the lime clarifiers was controlled by sampling and testing the upper and lower mix zones on an hourly basis. The test involved filling a one liter graduate and allowing 30 minutes for the sample to settle. After 30 minutes the solids level in the graduate was read and recorded in milliliters per liter. Through this procedure, it was determined that a satisfactory upper mix zone solids volume in the first-stage lime clarifier ranged from 140 ml/liter to 280 ml/liter. As seen in Figure 5-2, the total phosphorus removal was 91 percent or greater when the upper mix zone solids volume averaged 140 ml/liter or more. When the upper mix zone solids volume decreased to 84 ml/liter, total phosphorus removal by the first-stage clarifier dropped to 84 percent.

In the second-stage lime clarifier sufficient solids in the upper mix zone also resulted in satisfactory total phosphorus reduction. As shown in Figure 5-3, when the upper mix zone solids volumes averaged less than 70 ml/liter, total phosphorus removal ranged from 51 to 67 percent. When the upper mix zone solids volume was greater than 140 ml/liter, total phosphorus removal ranged from 72 percent to 84 percent, and total phosphorus concentration in the clarifier effluent averaged 0.04 to 0.06 mg/l.

A second operational parameter used for clarifier operation was the ratio of upper mix zone solids volume to the lower mix zone solids volume. As an operational tool it indicated whether the turbine speed was great enough to pump

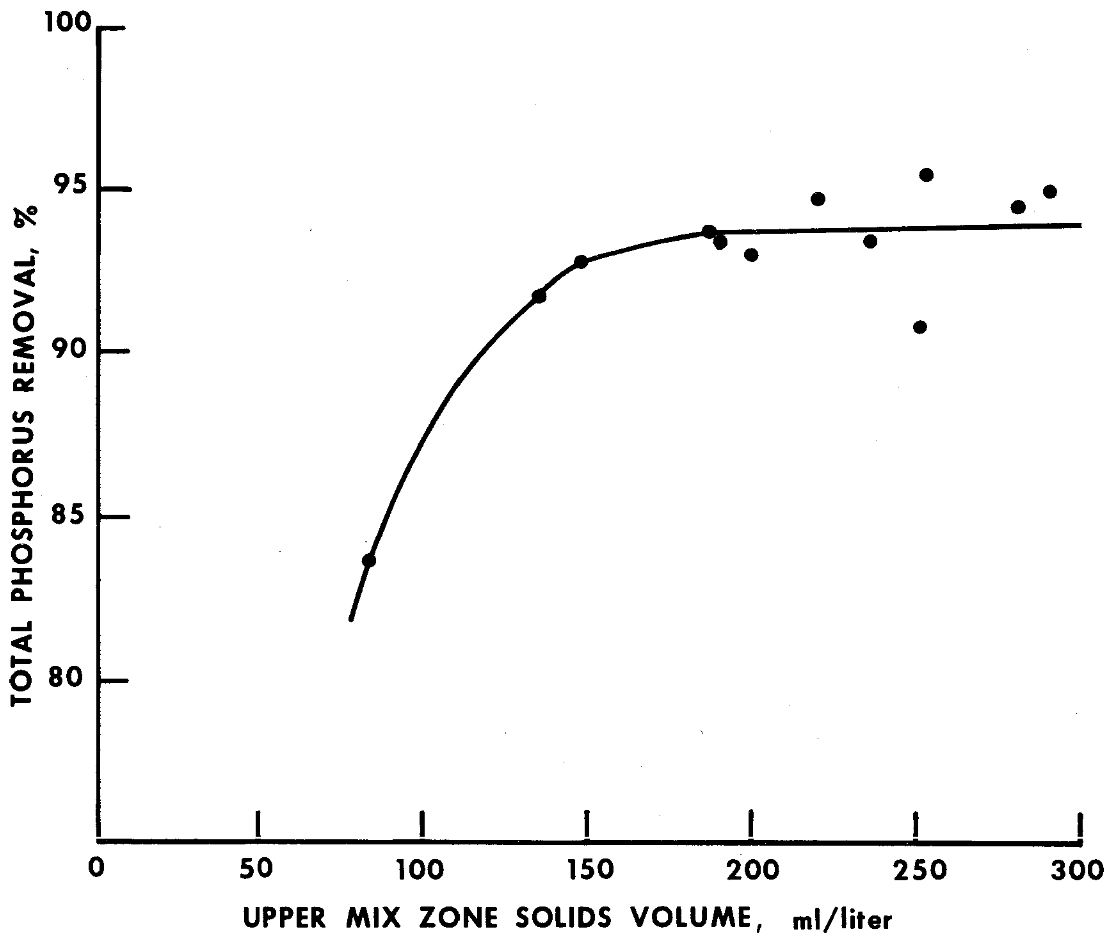


FIGURE 5-2. INFLUENCE OF UPPER MIX ZONE SOLIDS VOLUME ON TOTAL PHOSPHORUS REMOVAL IN FIRST STAGE LIME CLARIFIER.

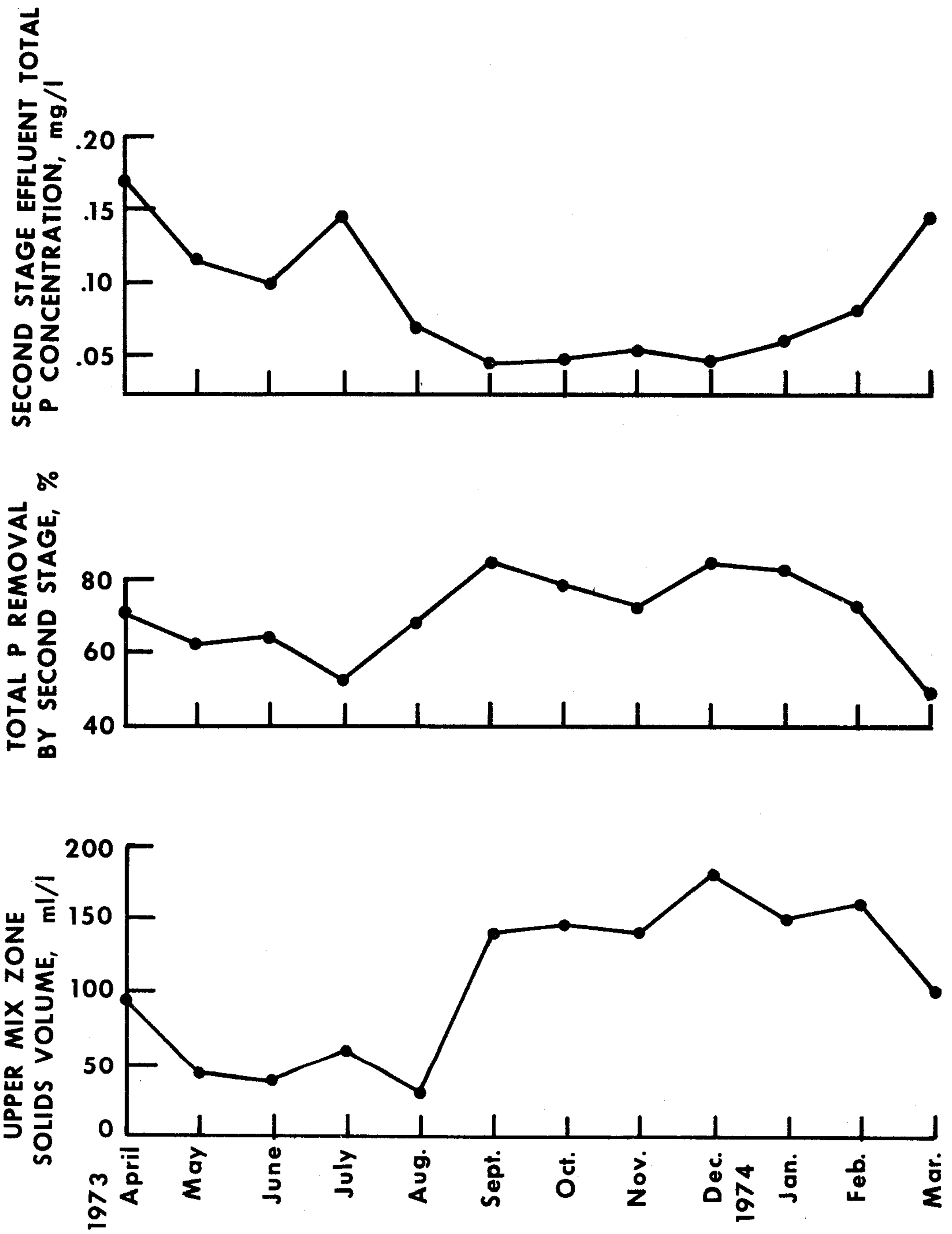


FIGURE 5-3. MONTHLY AVERAGE VALUES OF UPPER MIX ZONE SOLIDS VOLUME, PERCENT TOTAL PHOSPHORUS REMOVAL, AND TOTAL PHOSPHORUS CONCENTRATION IN SECOND STAGE LIME CLARIFIER EFFLUENT.

sufficient solids into the mix zone. Although the equipment supplier recommended a ratio of 0.95 for both clarifiers, operating experience proved otherwise. First-stage total phosphorus removal was satisfactory with a ratio above 0.72, and very good removal was attained at a ratio between 0.85 and 0.90. In the second-stage clarifier, the most effective ratio was normally between 0.75 and 0.90.

Because of the very good mixing in the second stage, the turbine speed was rarely adjusted in this unit. Occasionally the turbine would not pump sufficient solids to the upper mix zone of the second-stage presumably because the intake to the turbine was blocked by heavy solids. This situation was corrected by temporarily increasing the speed of the sludge rake and by increasing sludge withdrawal.

Control of the Solids Blanket

The sludge blanket depth in the lime clarifiers refers to the depth of solids which exist beneath the solids-liquid interface. It was necessary to control the blanket level so that it was high enough to provide solids for the mix zone, yet low enough to prevent solids carryover to the effluent weir. While the blanket depth was influenced by operating conditions, it was controlled principally by the sludge blowdown rate. The blowdown rate was regulated by the balance between sludge pumping rate and pumping interval. Ordinarily the pump speed was held constant while the blowdown rate was adjusted by increasing or decreasing the duration of the on/off pumping cycle.

In the first-stage lime clarifier the characteristics of the solids blanket depended on lime dosage, polymer addition, and flow, in addition to the sludge blowdown rate. Lime dosage was adjusted according to pH requirements however, a large increase in lime dosage increased solids and thus added to the blanket depth. As a general rule, lime dosages were not increased specifically to build the solids blanket. (Flow and polymer addition are discussed later.) The average depth of the first-stage solids blanket was 1.8 m (6 ft), ranging from 1.4 m (4.5 ft) to 2.7 m (9 ft).

In the second-stage clarifier, the solids blanket, a combination of heavy calcium carbonate and iron precipitate, varied from less than 0.6 m (2 ft) to 1.8 m (6 ft) in depth. Experience demonstrated that a blanket depth of 1.2 m (4 ft) provided optimum percent removal of total phosphorus by the unit. The solids blanket was held at this level during the months of September, October, and December, 1973 and January and February, 1974 when the percent removal of phosphorus was relatively high.

Although the clarification process could be operated either with or without a sludge blanket, the existence of a blanket in the second stage aided solids capture. However, it was observed that after the solids blanket had aged for several weeks, solids capture became optimum. For example, the second-stage clarifier was refilled October 31, 1973. By November 7, soluble phosphorus in the second-stage effluent was 0.029 mg/l and the particulate phosphorus was 0.045 mg/l. During the following two weeks, the sludge blanket depth stabilized at 1.2 m (4 ft) and particulate phosphorus decreased to a low of 0.017 mg/l. Only a slight increase in soluble phosphorus removal was noted. On another occasion when the second-stage clarifier was again refilled, supporting data were obtained further demonstrating that solids capture in the clarifier improved as the solids blanket aged.

Chemical Addition (Cationic Polymer in First Stage)

Polymer addition to the first-stage lime clarifier began in April 1973. Initially, a cationic polymer, Betz 1150, was used at a dosage level of 0.53 mg/l. In early May, Betz 1200 was substituted for Betz 1150. Betz 1200 was more viscous and difficult to dissolve so on May 10 polymer addition was discontinued. On May 23 an attempt was made to feed Betz 1130 but it too was difficult to dissolve and to pump. On June 1, addition of Betz 1150 to the first-stage clarifier began again at a dosage level of 0.20 mg/l. This dose appeared effective in controlling the solids blanket.

The addition of Betz 1150 improved process performance through better mangagement of the solids inventory, and by permitting a lower blowdown rate to maintain the proper sludge blanket depth. When polymer addition was stopped, the first-stage solids blanket rose rapidly. When polymer was again added, the blanket depth decreased and stabilized near 1.8 m (6.0 ft). Other than preventing solids carryover, polymer addition seemed to have no influence on first-stage clarifier effluent quality.

Chemical Addition (Iron in Second-Stage Clarifier)

Beginning in March 1973, ferric chloride was added to the mix zone of the second-stage lime clarifier. The dosage was 6.0 mg/l as Fe^{+3}.

Theoretically, some hydrolysis products of Fe^{+3} ion causes coagulation of phosphorus (2). Although $FePO_4$ is considered to be mostly soluble in neutral and alkaline wastewater, some hydrolyzed Fe^{+3} compound presumably coagulated the phosphorus at the second stage pH of 9.6 and thus aided in total phosphorus removal (3).

For a two-week period in June and July, the $FeCl_3$ dosage to the second lime clarifier was reduced significantly. The total phosphorus removal by the second-stage clarifier as a function of ferric chloride dosage is shown in Figure 5-4. From June 28 to July 7, when the $FeCl_3$ dosage was reduced from 5.2 mg/l to 2.2 mg/l, the total phosphorus removal deteriorated from an average of 65 percent to less than 50 percent. In addition, the solids volume in the upper mix zone decreased along with the decrease in the iron dose. Whether the decrease in the iron dose or the decrease in the solids volume caused the reduction in total phosphorus removal is not clear.

It was concluded that a minimum iron dosage, somewhere between 3.0 and 6.0 mg/l as Fe^{+3}, was needed to ensure adequate phosphorus removal and to improve clarification.

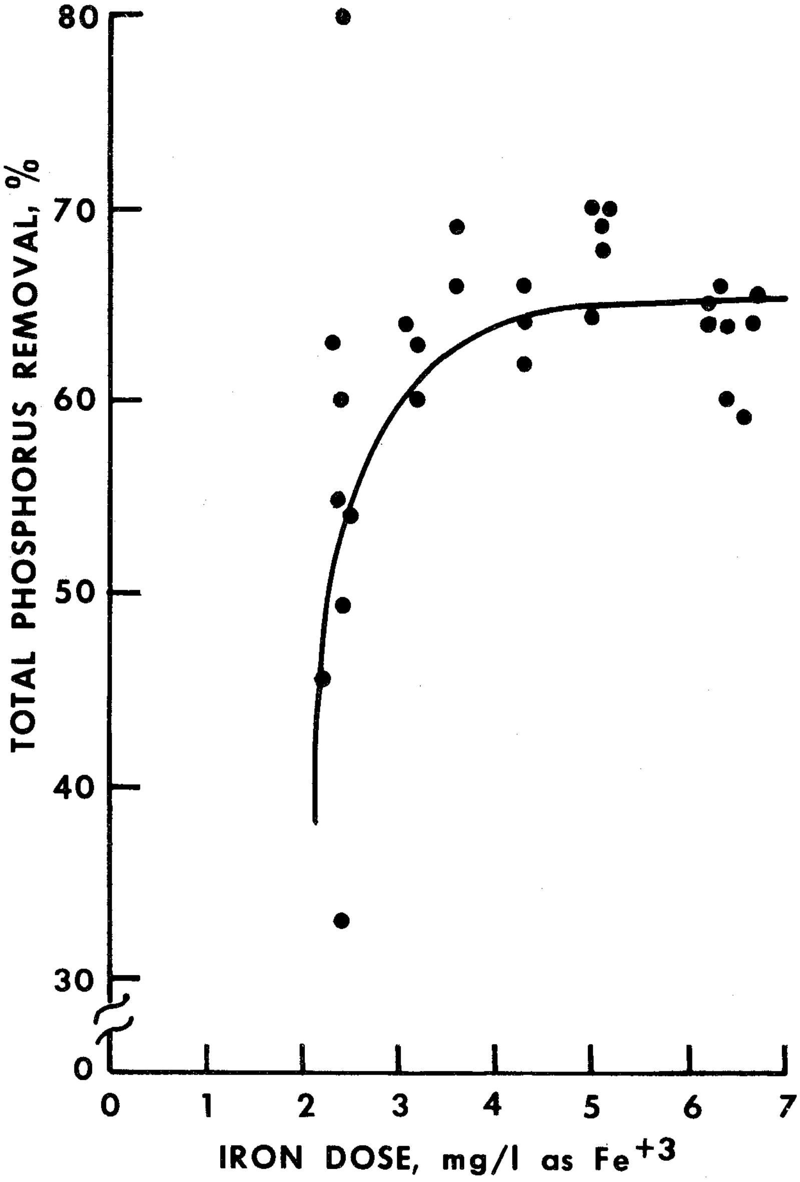


FIGURE 5-4. INFLUENCE OF IRON DOSE ON TOTAL PHOSPHORUS REMOVAL IN SECOND STAGE LIME CLARIFIER.

Effect of Flow on Performance of Lime Clarifiers

The tertiary plant influent flow averaged 4315 m^3/day (1.14 mgd) for 12 months and on a monthly average basis varied from 3104 m^3/day (0.82 mgd) to 5678 m^3/day (1.50 mgd). The minimum daily flow was 2877 m^3/day (0.76 mgd) and the maximum daily flow was 8706 m^3/day (2.3 mgd). The second-stage lime clarifier influent flow included the first stage flow plus 757 m^3/day (0.2 mgd) of recirculated tertiary treated water used for CO_2 dissolution.

There was some indication that large variations in the flow through the first-stage lime clarifier affected total phosphorus removals in the first-stage clarifier. High flows caused the solids blanket in the first-stage clarifier to rise rapidly. For example, when high flows were experienced in July, the solids blanket rose to over 4.8 m (16 ft) allowing carryover of particulate phosphorus. The first-stage effluent total phosphorus on July 18 was 0.83 mg/l, which was about three times the normal monthly average. On the other hand, in October when heavy rains again occurred, the sludge blowdown rates were increased soon enough to prevent the carryover of phosphorus-laden solids. The major difference in the operation of the first-stage lime clarifier during these two instances of high flows was the control of the solids blanket in order to prevent solids carryover.

Unlike the performance characteristics just described for the first-stage clarifier, large increases in plant flow did not greatly influence the solids blanket level in the second-stage lime clarifier nor did they greatly affect phosphorus removal in the second-stage clarifier. This contrast in clarifier performance is shown in Figure 5-5. When the daily flow averaged about 3780 m^3 (1.0 mgd) prior to October 8, total phosphorus removal was 95-96 percent in the first stage and 85 percent in the second stage. When the plant flow increased between October 8 and October 17, phosphorus removal in the first stage dropped from 95-96 percent to about 90 percent while phosphorus removal in the second stage remained fairly stable.

It should be noted that during the periods of high plant flows resulting from rainstorms, the chemical consumption for coagulation did not increase proportionately because there was a dilution of influent alkalinity.

Phosphorus Removal Summary

Two lime clarifiers operating in series removed 98.2 percent of the tertiary plant influent total phosphorus during a 12-month period. The first stage total phosphorus removal ranged from 84 percent to 95.5 percent. During the same period of time, the second-stage lime clarifier reduced total phosphorus in the effluent of the first lime clarifier by an average of 72.2 percent, ranging from a low of 49 percent to a high of 84 percent. Variation in plant operation, including draining of the second-stage clarifier, accounted for occasions of poor phosphorus removals. Total phosphorus concentration in the first-stage effluent varied from a low monthly average of 0.20 mg/l to a high of 0.57 mg/l (Appendix D). The second-stage lime clarifier effluent total phosphorus varied from a low of 0.034 mg/l to a high of 0.171 mg/l.

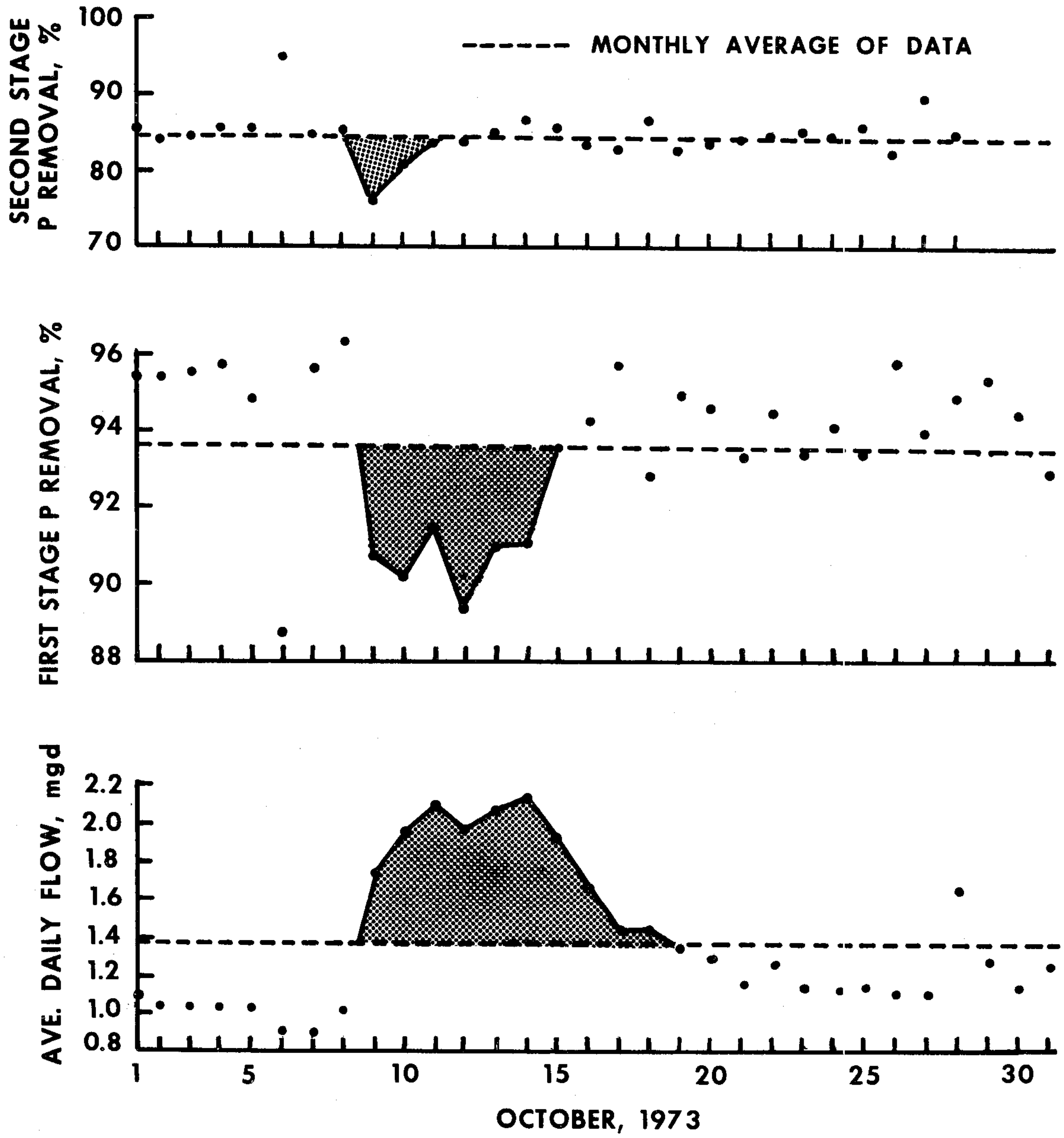


FIGURE 5-5. INFLUENCE OF TERTIARY PLANT FLOW ON TOTAL PHOSPHORUS REMOVAL BY FIRST STAGE AND SECOND STAGE CLARIFIERS.

Suspended Solids Removal

The monthly average suspended solids concentrations in the tertiary plant influent, the first-stage lime clarifier effluent, and the second-stage clarifier effluent are shown in Figure 5-6. The variability observed in the influent solids is due to the fact that the tertiary plant influent flow included the trickling filter plant effluent together with flow from the tertiary plant sample sinks and floor drains. The mean monthly tertiary plant influent suspended solids concentrations were as low as 36 mg/l and as high as 122 mg/l with a 12-month average of 70 mg/l.

Influent suspended solids increased significantly on four occasions when the second-stage lime clarifier was drained. Draining a lime clarifier returned the contents of the clarifier to the tertiary influent wet well. The points shown separately in Figure 5-6 for the months of October, February and March represent the increment added to the monthly average values by the clarifier solids.

Although the suspended solids to the first stage varied considerably, the concentrations in both the first-stage and second-stage effluents were stable, as shown in Figure 5-6. The first-stage effluent SS monthly average varied from 7 mg/l to 16 mg/l with a 12-month SS average of 9.6 mg/l; and the second stage solids varied from 3.5 mg/l to 12 mg/l with a 12-month average of 7.1 mg/l.

Optimum clarification in the second stage was desirable from the standpoint of both solids and phosphorus removal. Efficient solids removal was needed to prevent high solids loading to the gravity filters which would have resulted in shorter filter runs. Also, if particulate phosphorus was not settled out, it would have been resolubilized between the clarifier and filter when the second-stage effluent pH was adjusted from 9.6 to less than 8.0. This resolubilized phosphorus would have escaped filtration and been discharged in the final effluent to Shagawa Lake. During the year of operation, even in the month of poorest clarification by the lime clarifiers, the suspended solids concentration was 40 percent of the discharge standard (30 mg/l). This shows that the standard could have been met without the use of a filter.

Turbidity Removals

The influent turbidities to the first-stage lime clarifier were variable throughout the year. Minimum and maximum average monthly influent turbidities were 10 JTU and 41 JTU, respectively. The 12-month average was 23 JTU. The first-stage effluent turbidities were nearly constant after the initial months of operation in April and May. The average turbidity for those two months was 6.0 JTU, and the average turbidity during the remaining 10 months was 2.0 JTU, varying from 1.3 to 2.7 JTU. Maintaining good control of the solids inventory in the first-stage clarifier was the principal factor in lowering the turbidity levels in the first-stage effluent.

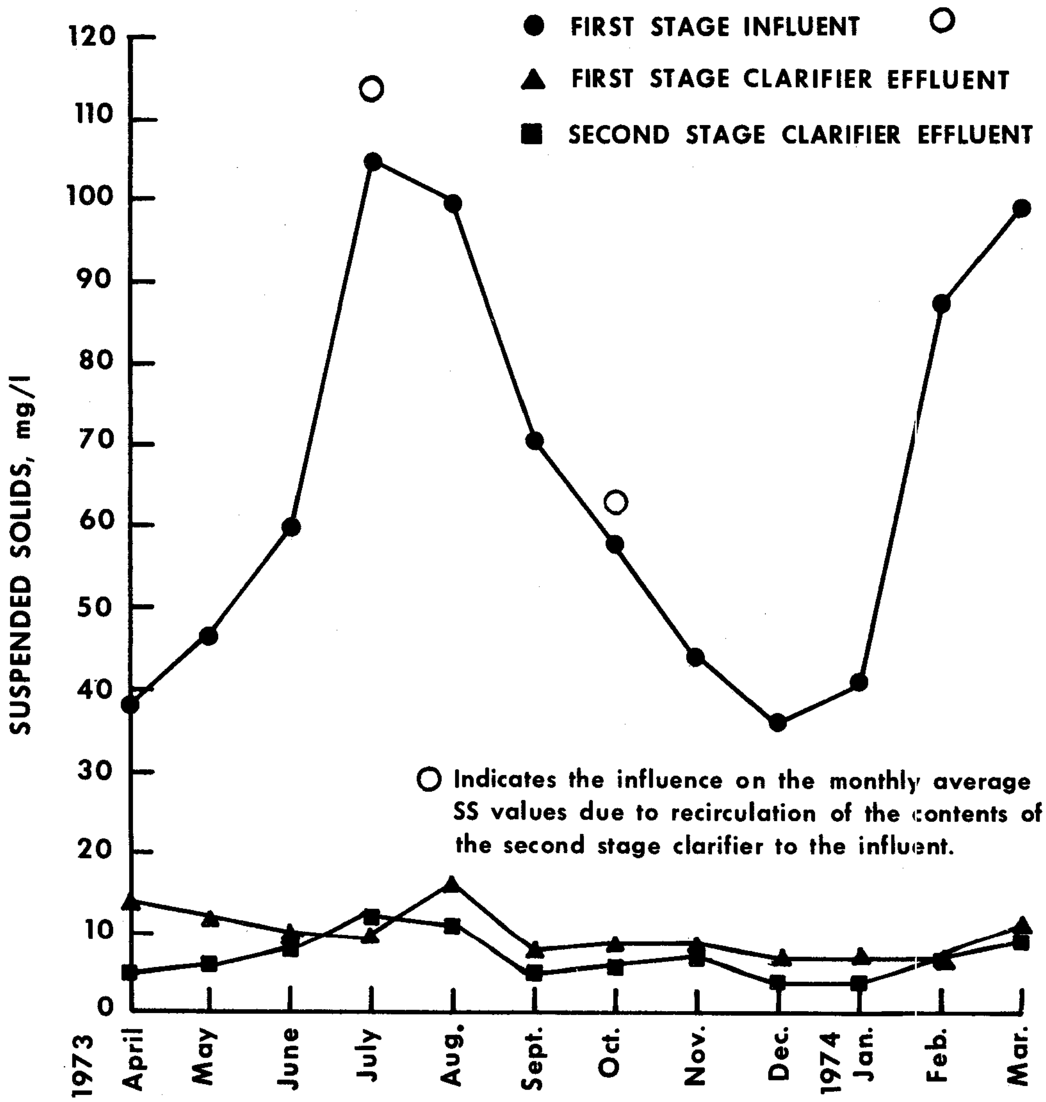


FIGURE 5-6. MONTHLY AVERAGE SUSPENDED SOLIDS IN FIRST STAGE INFLUENT, FIRST STAGE EFFLUENT AND SECOND STAGE EFFLUENT.

As previously discussed, cationic polymer was useful in stabilizing the solids blanket, which also resulted in lower first-stage effluent turbidities. Even with flows as high as 50 percent above design flow, turbidity levels in the first-stage effluent were consistently low except when the solids blanket was allowed to overflow the weir.

The second-stage effluent turbidity is shown in Figure 5-7 together with the total phosphorus and particulate phosphorus concentrations in the second-stage effluent. The second-stage effluent turbidity for 12 months averaged 2.0 JTU with monthly averages ranging from 0.85 JTU to 3.4 JTU. The U.S. Public Health Service limits turbidity in public water supplies to 5.0 units (4). Particulate phosphorus, which is the difference between the unfiltered and filtered phosphorus, was found to be directly related to effluent turbidity. This would suggest that the particulate phosphorus could conceivably be monitored by using a turbidimeter with a continuous readout. Turbidity measurements have been considered more relevant to water treatment than wastewater treatment (5). To achieve the desired effluent total phosphorus concentration, it was necessary to achieve a degree of clarification similar to that attained in the treatment of potable water. Turbidity measurement, therefore, became a valuable tool in process control. Turbidity analyses were also quicker and easier to perform than suspended solids tests. The first year's data indicate that turbidity measurements could be used for process control with less reliance on the more time consuming suspended solids analysis.

Organic Removal

Routine analysis for total organic carbon did not begin until December 1973. Thereafter, samples of first-stage lime clarifier influent, first-stage effluent, second-stage effluent, and tertiary plant effluent were analyzed twice per week for TOC. Table 5-1 shows the TOC removals through the two-stage clarification system. The first-stage influent averaged 46.0 mg/l for four months. First-stage effluent and second-stage effluent TOC averaged 23 mg/l and 18.5 mg/l, respectively. The first-stage lime clarifier removed an average of 49 percent of the influent TOC, while the second-stage lime clarifier removed only 9 percent of the tertiary plant influent TOC. Together, the two lime clarifiers removed 60 percent of the tertiary plant influent TOC. Whether TOC removal, based upon data obtained in the winter months, could be extrapolated for the whole year is not clear. From December through March the flow was relatively low and steady, unlike the rest of the year.

The TOC analysis schedule which was set up in December 1973 was expected to continue through 1974. During this time the effect of powdered carbon addition to the mix zone of the second lime clarifier was to be examined.

Chemical Addition Prior to Gravity Filters

The effluent from the second-stage lime clarifier passed through the splitter box to the gravity filters. Chemicals were injected into the wastewater in the pipe between the second-stage clarifier and the splitter box. The chemicals included sulfuric acid for pH adjustment, ferric chloride for phosphorus removal, and chlorine for disinfection. The pipeline turbulence was sufficient to ensure good mixing.

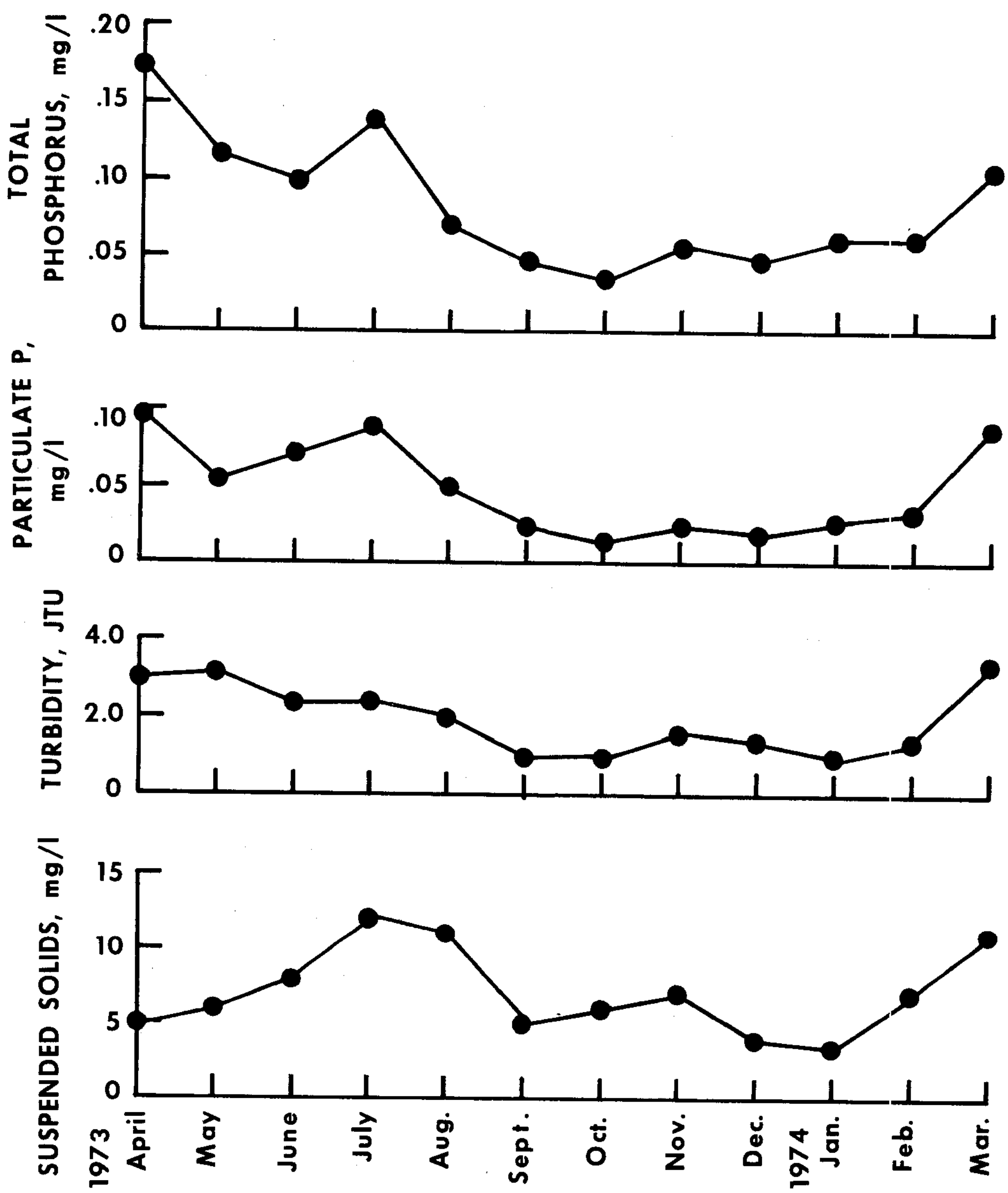


FIGURE 5-7. MONTHLY AVERAGE CONCENTRATIONS OF SUSPENDED SOLIDS, TURBIDITY, PARTICULATE PHOSPHORUS AND TOTAL PHOSPHORUS IN SECOND STAGE CLARIFIER EFFLUENT.

TABLE 5-1 TOTAL TOC REMOVAL BY TERTIARY LIME CLARIFICATION *

PROCESS	Influent (mg/l)		Effluent (mg/l)		% Reduction Thru Process	
	Range	Average	Range	Average	Range	Average
First-stage Clarifier	33-63	46	19-30	23	38-66	49
Second-stage Clarifier	19-30	23	14-25	18.5	9-27	19
Two-stage System	33-63	46	14-25	18.5	43-75	60

* Based on data Dec. 1973 - Mar. 1974

Sulfuric acid was added to the second-stage effluent which lowered the pH to about 7.5 prior to filtration. At this pH, a negative Langelier Index was achieved which prevented deposition of $CaCO_3$ on the filters. Acid addition also decreased the pH to within the 6.5 to 8.5 range required by the State of Minnesota, and no further pH adjustment was necessary before the treated wastewater was discharged to Shagawa Lake.

Subsequent to initiation of pH adjustment of the filter influent, large amounts of scale were removed from the filters. In April, the gravity filter influent and effluent Ca^{+2} concentrations were 57.3 mg/l and 65.7 mg/l, respectively. In May the filter influent and effluent Ca^{+2} averaged 39.3 mg/l and 49.7 mg/l, respectively (Appendix D). The increase in calcium through the gravity filters was due to the dissolution of $CaCO_3$ scale that had built up on the filters prior to April, 1973.

A negative effect of lowering the filter influent pH with acid was the resolubilization of a portion of the remaining particulate phosphorus. The extent to which resolubilization occurred resulted in an increase of soluble phosphorus in the filter influent from an average of 0.023 mg/l to an average of 0.065 mg/l. Such a concentration was unacceptable since soluble phosphorus is unaffected by filtration and a final effluent concentration of 0.065 mg/l exceeded the design goal of 0.050 mg/l total phosphorus.

In order to counteract the dissolution of particulate phosphorus, an average of 2.66 mg/l of ferric chloride (as Fe^{+3}) was added to the filter influent which served to precipitate a portion of the residual soluble phosphorus. Although dissolution was still experienced, the increase in soluble phosphorus was smaller, and the filter influent soluble phosphorus concentration was reduced to 0.043 mg/l.

Chlorine for disinfection was dissolved using treated wastewater before being fed to the filter influent stream. Adding the chlorine prior to the filters provided contact time for disinfection in the filtered backwash storage compartment (Figure A-5). The detention time in the backwash compartment at a flow of 5678 m^3/day (1.5 mgd) was 27 minutes.

Grab samples for coliform analysis were obtained from the effluent reservoir during the 10 months of operation between June 1973 and March 1974. The grab samples were analyzed four times each week for total coliform and once each week for fecal coliform. In seven of the 10 months the presence of total coliform was not reported in any of the 100 milliliter samples. In nine out of the 10 months there were no fecal coliform bacteria reported. Out of approximately 160 grab samples collected and analyzed for total coliforms, only six were found to have one or more total coliforms per 100 ml.

Without chlorination, coliform reappeared in the tertiary plant effluent. In October, no chlorine was added for 3 days. During this 3-day period, total coliforms were found in two of the three grab samples and fecal coliforms were present in one of two grab samples. The chlorine residual of the treated wastewater was checked by the orthotolidine method every 2 hours. From April to October 1973, the combined chlorine residual averaged 0.50 mg/l. When the problem of a chlorine shortage evolved in the autumn of 1973, a lower dose, resulting in a residual of 0.10 mg/l, was tried. However, because a zero residual was observed on several occasions, dosage at a slightly higher level was resumed. Thereafter, the combined chlorine residual from November 1973 through March 1974 averaged 0.18 mg/l.

Chlorine dosages for the year averaged 3.0 mg/l. From June to October the mean dosage was 3.6 mg/l. In November the chlorine dosage was reduced because of the potential chlorine shortage. The mean chlorine dosage for November through March was 2.7 mg/l.

2. Dual-Media Filtration

Phosphorus Removal by Dual-Media Gravity Filters

As seen in Table 5-2, an average of 85 percent of the influent particulate phosphorus, which comprised 68 percent of the total influent phosphorus, was removed by dual-media filtration. The effluent particulate phosphorus concentration averaged 0.008 mg/l, or 17 percent of the total phosphorus in the effluent.

As shown in Table 5-2, soluble phosphorus passed through the gravity filters, with the following exceptions. In April, a period which in part preceded the addition of H_2SO_4 to the filter influent for pH adjustment, soluble phosphorus was removed because of buildup of calcium on the filters. In May, therefore, during the period when $CaCO_3$ was dissolving off the filters, soluble phosphorus showed an increase. Upon achieving chemical equilibrium, the soluble phosphorus in the filter influent and effluent was essentially the same.

The effect of variation in hydraulic loading on total phosphorus removal by the gravity filters is shown in Figure 5-8. The points on the graph represent data from 20 days of operation in each of the three indicated months and the curve is an approximate fit to the averaged data for each of the three operating periods.

The trend of the data indicates that (a) a lower filter loading resulted in a greater percentage phosphorus removal while less phosphorus removal was achieved at high filter loadings, and (b) that during a period of operation in which wide fluctuations in hydraulic loading were experienced (as in August), a smaller percent phophorus removal resulted than when the filter loadings were low and consistent (as in January).

Suspended Solids, Turbidity, Iron, and TOC Removal

The performance of the gravity filters with respect to suspended solids, turbidity, iron, and total organic carbon is shown in Table 5-3. The suspended solids concentration in the filter influent ranged from 5 to 15 mg/l, averaging 9 mg/l for the year, and effluent suspended solids averaged less than 1.3 mg/l. Average suspended solids removal was greater than 85 percent. It will be recalled that the filters also removed 85 percent of particulate phosphorus.

TABLE 5-2 PARTICULATE AND SOLUBLE PHOSPHORUS REMOVAL BY DUAL-MEDIA FILTRATION

Month	PARTICULATE PHOSPHORUS *			SOLUBLE PHOSPHORUS **		
	Influent (mg/1)	Effluent (mg/1)	Percent Removal	Influent (mg/1)	Effluent (mg/1)	Percent Removal
April, 1973	0.097	0.012	88	0.074	0.058	22
May	0.093	0.014	85	0.022	0.046	--
June	0.055	0.013	76	0.043	0.033	23
July	0.069	0.014	80	0.073	0.062	15
August	0.034	0.003	91	0.039	0.038	3
September	0.027	0.006	78	0.016	0.016	0
October	0.027	0.006	78	0.019	0.017	11
November	0.027	0.003	89	0.027	0.029	--
December	0.028	0.004	86	0.017	0.017	0
January, 1974	0.040	0.004	90	0.021	0.022	--
February	0.045	0.007	84	0.036	0.036	0
March	0.079	0.012	85	0.065	0.065	0
Average	0.052	0.008	85	0.038	0.037	3

* Particulate phosphorus = (total phosphorus) - (soluble phosphorus)

** Soluble phosphorus refers to that portion of the total phosphorus which passes through a 0.45μ membrane filter.

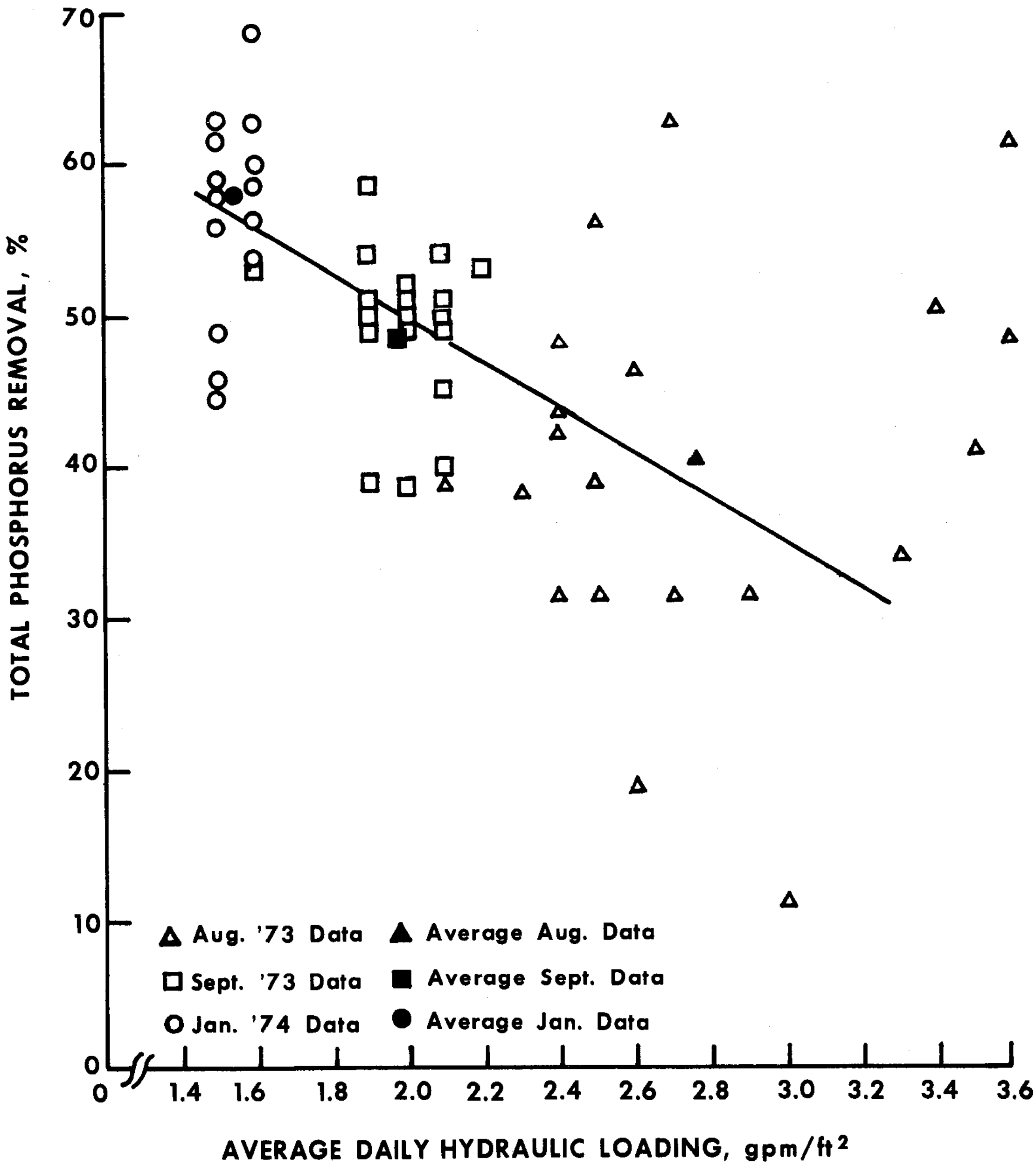


FIGURE 5-8. EFFECT OF HYDRAULIC LOADING ON TOTAL PHOSPHORUS REMOVAL BY DUAL-MEDIA FILTRATION.

TABLE 5-3 GRAVITY FILTER PERFORMANCE

Month	Suspended Solids (mg/l)		Turbidity (JTU)		Iron as Fe^{+3} (mg/l)		TOC (mg/l)	
	Influent	Effluent	Influent	Effluent	Influent	Effluent	Influent	Effluent
April 1973	5	<2	3.1	2.6				
May	15	<1	5.9	1.2				
June	7	<0.8	2.4	0.45				
July	8	<1.6	1.53	0.17				
August	7	<1	1.21	0.11				
September	7	<1	1.30	0.33				
October	6	<1.7	1.48	0.44	3.15	0.20		
November	7	<1	1.45	0.33	2.98	0.21		
December	9	<1.4	1.83	0.32	3.40	0.17	18.8	16.7
January 1974	9	<1	1.43	0.14	3.47	0.176	17.5	15.0
February	10	<1.5	2.19	0.20	3.23	0.175	16.1	16.2
March	14	<2	2.8	0.43	4.24	0.30	25.5	23.8
Average	8.7	<1.3	2.22	0.56	3.41	0.21	19.5	17.9
Percent Removal	>85%		75%		94%		8%	

The turbidity data indicate a yearly average removal of 75 percent, and a yearly average effluent turbidity level of 0.56 JTU. However, it should be recalled that during the first two months of operation the procedures for chemical addition prior to filtration were being tested and the filtration system had not yet attained equilibrium. Therefore, during that period turbidity removal averaged only 58 percent with an average effluent turbidity of 1.9 JTU. After stable operation was achieved, turbidity removal increased to an average of 83 percent and the effluent turbidity averaged a low 0.29 JTU. These latter values are more representative of typical operation at the Ely plant.

As shown in Table 5-3, the filters removed an average of 94 percent of the analytically determined iron from the filter influent. There is some qualitative indication that higher influent iron concentrations produce higher effluent iron concentrations. In March 1974, for example, the influent iron concentration was 25 percent greater than the mean, and the effluent iron concentration was 43 percent above the mean.

Based upon four months of data, as shown in Table 5-3, the gravity filters removed negligible amounts of TOC from the wastewater. Average removal was 8 percent and, at best, was 14 percent. It would appear from the data that TOC remaining at this point in the treatment train would be soluble and therefore unaffected by filtration. Potentially, additional TOC could be removed by powdered carbon adsorption in the second-stage lime clarifier with subsequent removal of the powdered carbon carryover by filtration.

Filter Hydraulics

The hydraulic loading on the gravity filters varied considerably during the one-year period of operation due to long-term seasonal variations in the wastewater flow and also to short-term flow increases resulting from stormwater runoff. The filters were designed for a loading of 5.6 m/hr (2.3 gpm/sq ft) at a flow of 237 m^3/hr (1.5 mgd) with a design maximum peak loading of 8.6 m/hr (3.5 gpm/sq ft). In practice, the lowest and highest average daily hydraulic loadings were 3.4 m/hr (1.4 gpm/sq ft) and 9.3 m/hr (3.8 gpm/sq ft), respectively. The monthly mean hydraulic loadings ranged from 3.7 m/hr (1.5 gpm/sq ft) to 6.4 m/hr (2.6 gpm/sq ft).

The permissible head loss across the filter was about 3.0 m (10 ft). The filters were backwashed automatically every 24 hours and only rarely was it necessary to backwash more often. In the low-flow months the pressure loss buildup seldom exceeded 2.1 m (7 ft) during a 24-hour filter run. In December, January, and February, the typical head loss for a 24-hour filter run was 1.9 m (6.2 ft), 1.6 m (5.2 ft) and 1.6 m (5.2 ft), respectively, which was well below the 3.0 m (10 ft) allowable head loss. In the months of April to November, the 24-hour filter head loss generally varied from 2.4 m (8 ft) to 3.0 m (10 ft). On one occasion, when the hydraulic loading reached a maximum of 9.3 m/hr (3.8 gpm/sq ft) the 24-hour head loss buildup was above 3.0 m (10 ft).

In terms of treatment plant capacity, the gravity filters were the limiting element. As the pressure loss across the filters increased and as filter loading approached 7.6 m/hr (3.1 gpm/sq ft), some of the flow was bypassed back to the head of the trickling filter plant. While the lime clarifiers were capable of treating flows up to 11,355 m^3/day (3.0 mgd), the gravity filters could only accommodate a flow of 8700 m^3/day (2.3 mgd).

C. Summary of Tertiary Plant Performance; Plant Reliability and Effluent Variability

The 12-month mean total phosphorus removed by the tertiary treatment plant was 99 percent. For the year the influent total phosphorus to the tertiary plant averaged 4.56 mg/l and the effluent averaged 0.045 mg/l of total phosphorus.

The daily and average monthly total phosphorus concentrations at 7 sampling points including raw sewage, secondary effluent, tertiary plant samples, and the discharge to Shagawa Lake are tabulated in Appendix E. Also tabulated are the daily and monthly percent removals of total phosphorus by various wastewater unit processes. Daily total phosphorus concentrations from April 1, 1973 through March 1974 are plotted in Figure E-1. The three curves represent the first-stage lime clarifier influent total phosphorus, the first-stage effluent total phosphorus, and the second-stage effluent total phosphorus.

Table 5-4 summarizes the mean monthly total phosphorus concentrations at several sampling locations in the tertiary plant. Also shown is the cummulative percent total phosphorus removal through the tertiary plant as a function of the total phosphorus concentration in the influent to the first-stage lime clarifier.

A summary of daily total phosphorus concentrations in the effluent from the second-stage lime clarifier and the gravity filters is shown in Figure 5-9. The probability curves for total phosphorus are based upon 12 months of daily average data obtained between April 1, 1973 and March 31, 1974. Each point shown represents an aggregation of up to 15 daily sample data points.

The tertiary plant effluent quality for 12 months is summarized in Appendix D and probability curves for turbidity and suspended solids concentrations in the second-stage clarifier effluent and the filter effluent are shown in Figures 5-10 and 5-11, respectively. The mean suspended solids concentration in the tertiary effluent was less than 1.3 mg/l, the mean TOC concentration was 16 mg/l, the average alkalinity (as $CaCO_3$) was 42 mg/l, and the median effluent pH was 7.5.

The coefficient of variation (% CV) was calculated for the total phosphorus removal by various treatment plant units. The % CV reflects the percentage variability and is equal to the monthly standard deviation divided by the monthly mean. Lower coefficient values indicate more consistent unit process performance. The percent Coefficient of Variation is shown in Figure 5-12 for the first and second-stage lime clarifiers, and the gravity filters, as well as for all three units in series. The general interpretation attached to

TABLE 5-4 TOTAL PHOSPHORUS REMOVAL SUMMARY - APRIL 1973 THRU MARCH 1974

Month	First Stage Lime Clarifier			Second Stage Lime Clarifier		Gravity Filters		Percent Remaining
	Influent (mg/l)	Effluent (mg/l)	Percent Removal	Effluent (mg/l)	Cumul. Percent Removal	Effluent (mg/l)	Cumul Percent Removal*	
April 1973	3.62	0.568	84.3	0.171	95.3	0.070	98.1	1.9
May	3.61	0.318	91.2	0.115	96.8	0.060	98.3	1.7
June	4.96	0.267	94.6	0.097	98.0	0.046	99.1	0.9
July	5.22	0.306	94.1	0.137	97.4	0.076	98.5	1.5
August	4.66	0.249	94.6	0.070	98.5	0.041	99.1	0.9
September	3.83	0.269	93.0	0.046	98.8	0.022	99.4	0.6
October	3.65	0.217	94.0	0.034	99.1	0.023	99.4	0.6
November	4.04	0.205	94.2	0.056	98.6	0.032	99.2	0.8
December	4.13	0.270	93.5	0.046	98.9	0.021	99.5	0.5
January 1974	4.44	0.347	92.2	0.060	98.6	0.026	99.4	0.6
February	6.59	0.284	95.7	0.060	99.1	0.043	99.3	0.7
March	5.98	0.279	95.3	0.105	98.2	0.077	98.7	1.3
Mean	4.56	0.298	93.5	0.083	98.2	0.045	99.0	1.0

* Cumulative percent removal as a function of first stage clarifier influent total phosphorus concentration

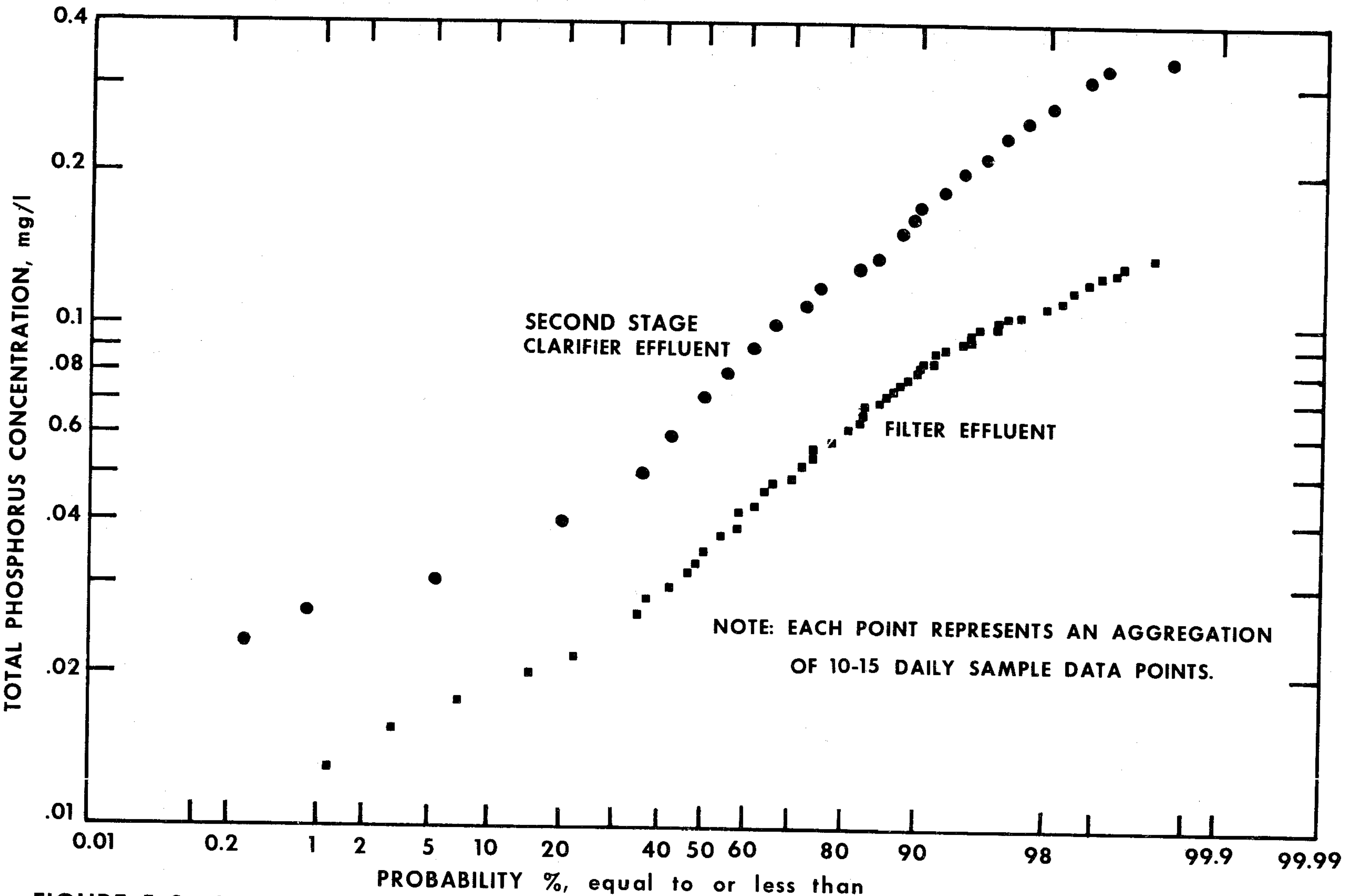


FIGURE 5-9. VARIABILITY OF TOTAL PHOSPHORUS IN SECOND STAGE CLARIFIER EFFLUENT AND FILTER EFFLUENT, APRIL 1, 1973 TO MARCH 31, 1974.

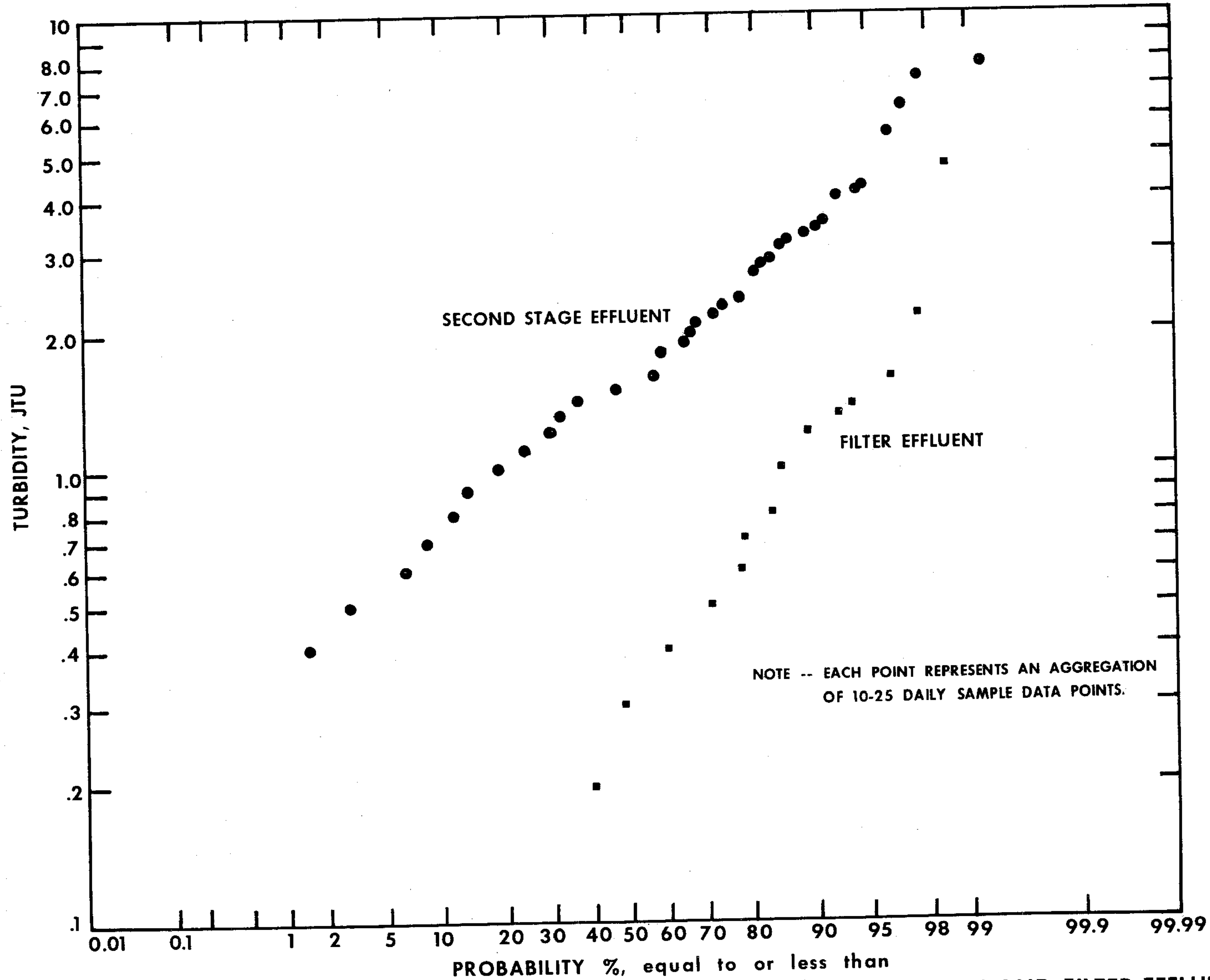


FIGURE 5-10. VARIABILITY OF TURBIDITY IN SECOND STAGE CLARIFIER EFFLUENT AND FILTER EFFLUENT APRIL 1, 1973 TO MARCH 31, 1974.

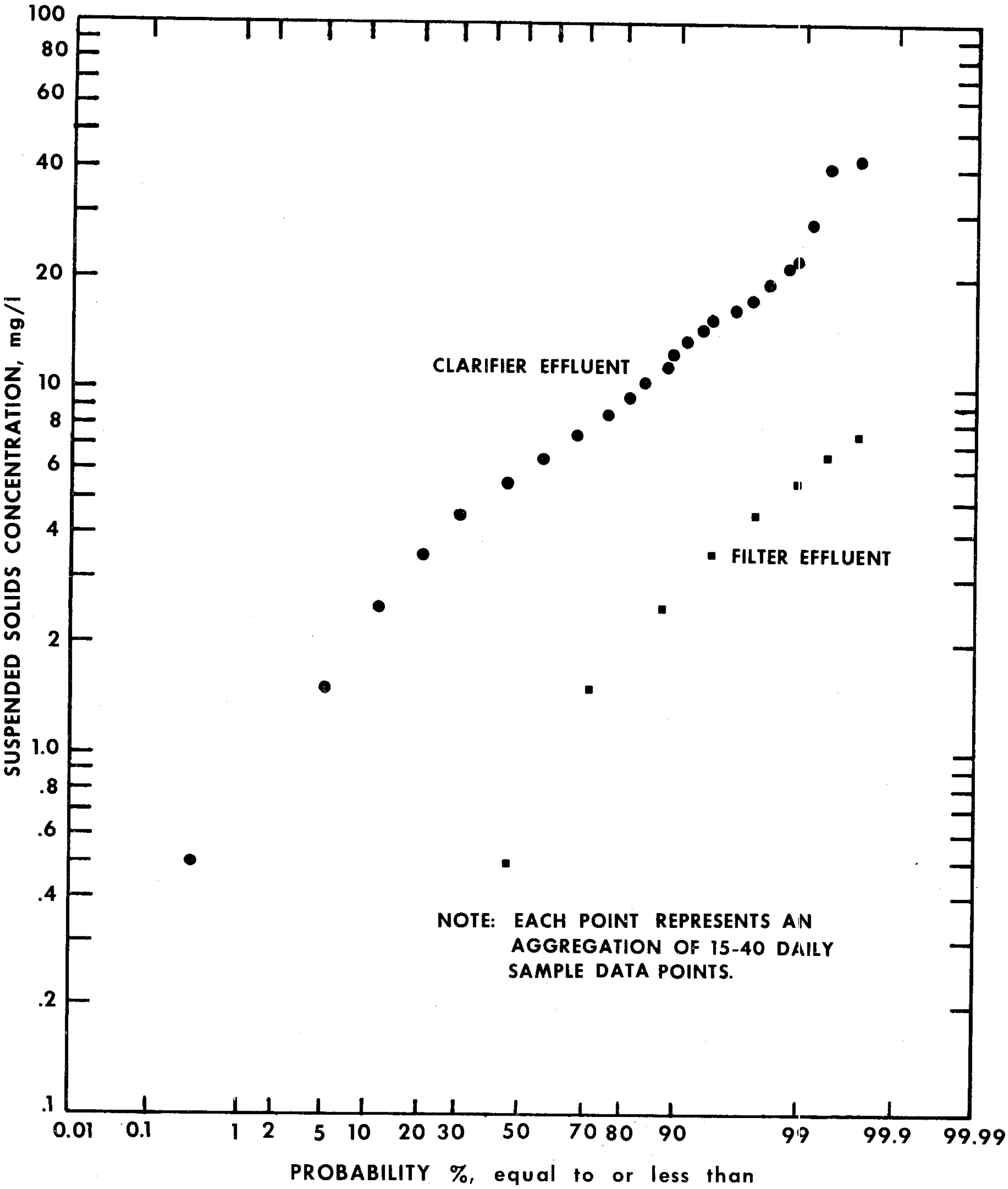


FIGURE 5-11. VARIABILITY OF SUSPENDED SOLIDS IN SECOND STAGE CLARIFIER EFFLUENT AND FILTER EFFLUENT, APRIL 1, 1973 TO MARCH 31, 1974.

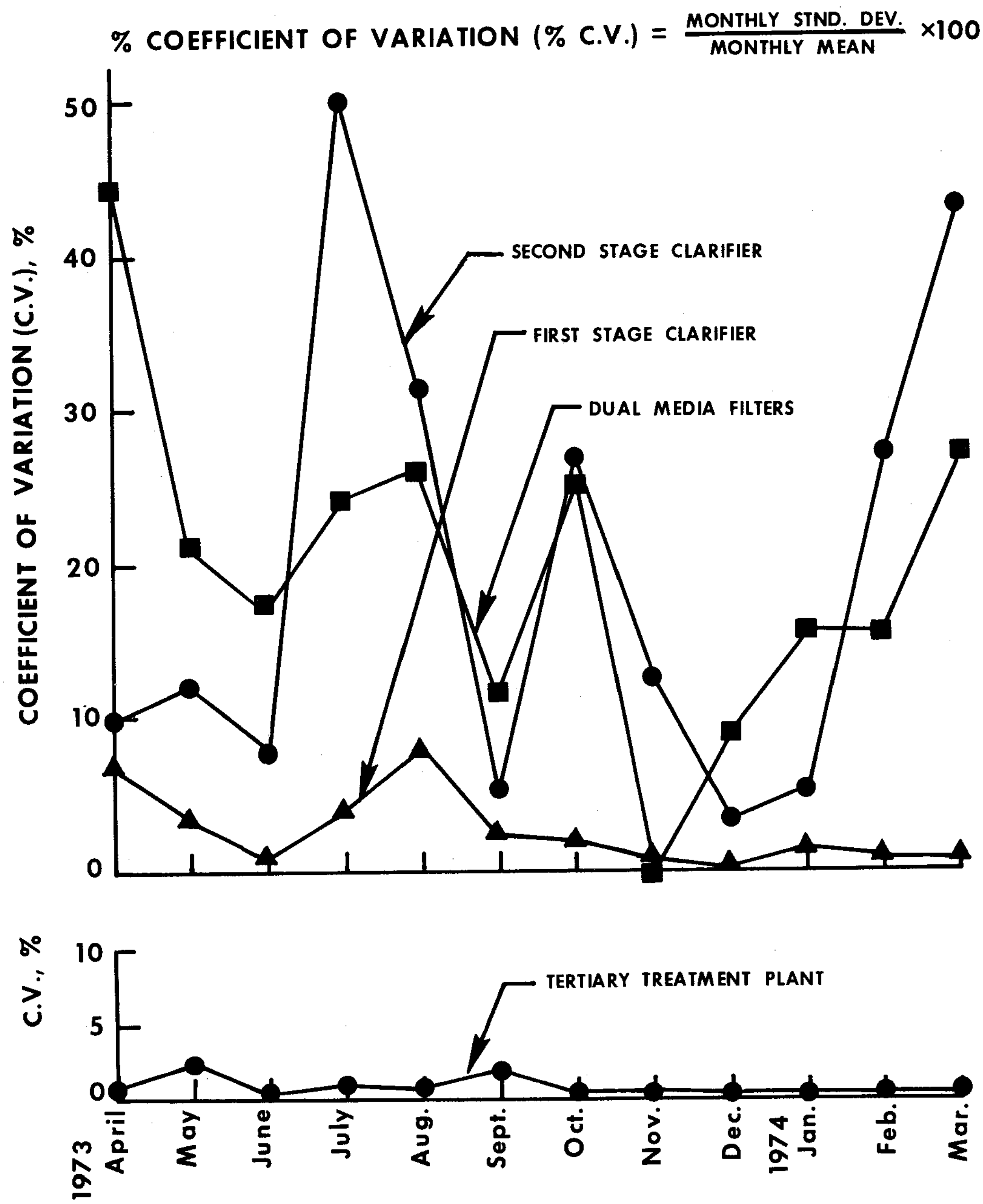


FIGURE 5.-12. MONTHLY VALUES OF COEFFICIENT OF VARIATION FOR TOTAL PHOSPHORUS REMOVAL BY EACH TERTIARY UNIT PROCESS AND BY TERTIARY TREATMENT SYSTEM.

% CV values is as follows;

20	Highly consistent
20-39	Fairly consistent
40-59	Inconsistent
60 and above	Highly variable to unpredictable

The performance of the first-stage lime clarifier was highly consistent in each month. The second-stage total phosphorus removal was highly consistent to fairly consistent except for July and March. The performance of all three units in series was highly consistent. The performance was particularly smooth in the last seven months due largely to improved process control.

SECTION VI

SLUDGE TREATMENT AND DISPOSAL

A. Sludge Handling

Biological sludge from the secondary clarifier was recirculated to the head of the secondary plant and resettled with raw sludge in the primary sedimentation basin. During the initial months of study, the combined primary/secondary sludge was pumped to the digester, and then to the tertiary thickener. At average sludge flows, detention time in the 225 m^3 (59,500 gal) thickener was 50 hours. In an emergency the sludge could be pumped to one of two 284 m^3 (75,000 gallon) sludge holding tanks (Figures 4-1 and 4-2, and A-1.) In June 1973 the digester failed and the combined primary/secondary sludge was rerouted directly to the tertiary thickener. Within the next few months piping modifications were made which permitted the piston pump to replace the centrifugal sludge pump. Through these changes, the volume of combined primary/secondary sludge could be calculated from the pumping rate by knowing the length of the piston stroke, strokes per minute, and pumping duration.

Chemical sludge from the two lime clarifiers normally was pumped to the tertiary thickener by two, variable speed, progressive cavity pumps (Figures 4-2 and A-6). Alternatively, the chemical sludge could also be pumped directly to the vacuum filter, to the sludge holding pond, or to the tank truck loading area.

The tertiary thickener supernatant was returned to the head of the trickling filter plant via the filter backwash equalization tank and lift station #1 (Figure 4-2). Normally, the sludge thickener underflow was conditioned with lime and pumped to the vacuum filter. However, the thickener underflow could also be discharged to a tank truck without vacuum filtering or to the sludge holding pond (Figures 4-2 and A-6). After vacuum filtration, the sludge cake was conveyed to a truck for ultimate disposal. The vacuum filter filtrate, belt wash water, and vat rinse water were returned to the filter backwash equalization tank and pumped by lift station #1 to the head of the trickling filter plant.

B. Sludge Thickener Influent Characteristics

An average of 13 m^3/day (3360 gpd) of combined primary-secondary sludge was pumped to the thickener from November 1973 (when the piston pump was installed) through March 1974 (Table 6-1).

TABLE 6-1 BIOLOGICAL AND CHEMICAL SLUDGE FLOWS TO TERTIARY SLUDGE THICKENER

	Combined Primary/Secondary Sludge (gallons/month)	Chemical Sludge		
		Volume (gallons/month)	Percent from 1st Stage Clarifier	Percent from 2nd Stage Clarifier
April 1973	*	348,000		
May	*	588,000		
June	*	623,000		
July	*	1,043,000		
August +	*	916,000	77	23
September +	*	777,000	81	19
October +	*	827,000	79	21
November	101,000	664,000		
December	104,000	1,012,000		
January 1974 +	104,000	1,019,000	51	49
February +	94,000	718,000	69	31
March +	104,000	737,000	74	26
Monthly Average	101,000	773,000	70	30

* Sludge volume not directly quantified

\+ Daily average sludge flow to thickener:

Primary sludge - 3,360 gpd
Chemical sludge - 1st stage clarifier 17,900 gpd
Chemical sludge - 2nd stag clarifier 7,500 gpd

The volume of chemical sludge pumped from the tertiary clarifiers averaged 96 m^3/day (25,400 gpd). This amounted to 2.2 percent of the average daily wastewater flow. As seen in Table 6-1, sludge withdrawal from the lime clarifiers varied from month to month. It ranged from 44 m^3/day (11,600 gpd) during plant startup to 127 m^3/day (33,600 gpd). About 70 percent of the total chemical sludge volume came from the first-stage clarifier; the remainder from the second stage. The percentages derived are based on the hours of pumping and are not adjusted for the pumping speed which was usually, but not always, the same for both underflow pumps.

The total sludge flow to the thickener (Table 6-1) averaged 109 m^3/day (28,760 gpd) of which 13 m^3/day (3360 gpd) represented combined primary/secondary sludge, 68 m^3/day (17,900 gpd) was from the first-stage lime clarifier and 28 m^3/day (7500 gpd) was from the second-stage clarifier.

Operating experience demonstrated that variations in the volume of primary/secondary sludge had a much greater effect on thickener performance than variations in the amounts of chemical sludge. The combined primary/secondary sludge discharged to the thickener averaged 7 to 10 percent solids.

The monthly mean solids concentrations of the chemical sludge ranged from 0.8 to 1.1 percent in the first-stage underflow and from 0.3 to 3.5 percent in the second stage as shown in Table 6-2. From 35 to 51 percent of the chemical sludge was calcium as Ca^{+2}. In the first stage the calcium concentration was 4 to 5 g/l and in the second stage 11 to 18 g/l. The iron (Fe^{+3}) concentration in the second-stage underflow was 1 to 2 g/l or about 10 times the iron concentration in the first-stage underflow. Total phosphorus concentration averaged 0.17 to 0.27 g/l in the first-stage underflow and about 20 percent of that in the second-stage underflow.

From a quantitative standpoint, the chemical sludge data in Table 6-2 should be used cautiously since manually-composited sludge samples are only semi-representative of actual chemical sludge. But from a qualitative standpoint, some observations can be made. The second-stage underflow SS were relatively dense in February and March which was probably due to the heavy calcium carbonate sludge. On the other hand, low solids concentrations, as occurred in January, may have resulted from "coning." "Coning" occurs when sludge withdrawal, normally on a periodic pumping basis of 5 minutes per hour, creates a draw-down profile in the sludge blanket through which clarified wastewater is also drawn into the suction line of the underflow pump. "Coning" was eliminated by temporarily speeding up the sludge rake and continuously withdrawing sludge for about 30 minutes.

C. Tertiary Thickener Performance

The thickener supernatant was sampled and analyzed for suspended solids, pH, calcium, and total phosphorus. These analyses describe the degree of clarification provided by the thickener and also point out the composition of a large portion of wastewater that was returned to the head of the trickling filter

TABLE 6-2

CHEMICAL SLUDGE CHARACTERISTICS* (mg/l)

1974	First Stage Underflow			
	Total P	SS	Ca^{++}	Iron**
January	260	8,330	-	79
February	177	9,660	4,940	99
March	268	10,900	3,870	156
	Second Stage Underflow			
	Total P	SS	Ca^{++}	Iron**
January	59	3,150	-	269
February	65	35,570	18,240	1,580
March	45	24,730	11,040	1,750

* Results based on three samples per week except for iron

** Samples analyzed for iron once per week plant. The monthly averages for the four parameters are shown in Table 6-3. The thickener overflow was typically very high in solids, the 8-month mean being 14.8 g/l with a range of 0.11 g/l to 28.8 g/l. The high solids concentration led to plugging of the overflow weir, which in turn led to short-circuiting. Withdrawal of sludge for vacuum filtration temporarily improved the quality of the thickener overflow, but as soon as sludge withdrawal and vacuum filtering stopped, the overflow again increased in solids concentration.

Operating experience demonstrated that without the primary/secondary sludge from the primary clarifier the thickener overflow was relatively low in solids, and the chemical sludge settled rapidly in the thickener. This was observed on several occasions when the combined sludge from the primary clarifier was not pumped to the thickener and a well-clarified thickener overflow was produced within a few days. Jar tests also illustrated the relatively poor settling character of the undigested primary/secondary sludge. The addition of a polymer, Betz DK-522, to the undigested primary/secondary sludge appeared to improve settling in the thickener. However, Betz DK-522 was available for only a brief time because of inadequate supplies.

In practice, the thickener was operated to maximize the underflow solids concentration while avoiding septic conditions in the thickened sludge.

D. Vacuum Filtration and Landfill Disposal

The solids concentration in the underflow was greatest during the first hour of pumping the underflow to the vacuum filter and varied between 15 percent and 36 percent. As the sludge continued to be withdrawn for the duration of vacuum filter operation, the underflow solids concentration decreased. When the underflow concentration had decreased to 5 percent to 8 percent, the vacuum filter was shut down.

The vacuum filter was operated to produce a sludge cake of at least 30 percent dry solids without using excess amounts of lime for conditioning. An operating procedure was established whereby the filter operation began at the same time of day, 6 days each week, and remained in operation until the filter cake solids had decreased to 32 percent. Through this mode of operation, the filter cake dry solids averaged 35.7 percent for the reporting period.

The vacuum filter performance for the first year of operation is shown in Table 6-4. The yield averaged 49 kg/m^2/hr (10 lbs/sq.ft/hr) and the sludge production averaged 690 kg/hr (0.72 tons/hr) on a dry weight basis with lime addition. The minimum average yield was 27 kg/m^2/hr (5.6 lbs/sq.ft/hr) when lime conditioning was not employed. The maximum yield with lime addition was 79 kg/m^2/hr (16.2 lbs/sq.ft/hr). Figure 6-1 shows that the filter yield varied directly with the feed solids level except for the month of July. This apparent inconsistency was a result of increased chemical sludge production resulting in high initial thickener underflow concentration for the first hour of vacuum filter operation. This led to the production of very thick filter cake (1 to 1 1/2 inches compared to normal cake thickness of 3/8 inch) for the first hour of vacuum filter operation, thus increasing the average filter yield. In April and May the combined primary/secondary sludge was digested prior to combining

TABLE 6-3 TERTIARY SLUDGE THICKENER OVERFLOW CHARACTERISTICS

Month	Total Phosphorus (mg/1)	Suspended Solids (mg/1)	Calcium (mg/1)	pH
August 1973	404	28.8	842	9.76
September	1.88	.106	103	9.62
October	117	8.9	374	11.00
November	392	20.3	802	9.66
December	489	19.1	882	9.45
January 1974	407	10.2	598	9.51
February	414	17.4	926	9.31
March	318	13.7	1,570	9.20
Average *	318	14.8	762	9.69
Average +	363	16.9	856	9.70

* Average of data from August 1973 through March 1974

\+ Average does not include data of September 1973.

TABLE 6-4 VACUUM FILTRATION OF COMBINED PRIMARY/SECONDARY AND CHEMICAL SLUDGES

APRIL 1973 THRU MARCH 1974

Parameter	April 1973	May	June	July	October	November	December	January 1974	February	March	10-Month Average +
Yield - lbs dry solids/sq ft/hr	5.6	8.4	10.4	14.1	16.2	12.04	11.7	8.33	7.1	6.56	10.04
Drum Speed - min/rev	5.29	5.60	3.95	2.19	2.76	2.49	2.69	3.81	3.85	3.70	3.60
Operating Time - hrs	116.5	71.0	99.5	149.0	110.0	116.0	102.4	137.1	88.9	85.3	1076.3 *
Feed Solids - percent	15.0	16.0	16.4	13.2	17.8	18.0	16.6	13.3	14.0	11.6	15.2
Cake Solids - percent	31.9	39.0	39.2	38.0	39.1	36.9	35.5	33.0	31.1	33.7	35.7
Wet Product - tons/hr	1.32	1.55	1.98	2.71	3.10	2.42	2.45	1.67	1.71	1.33	2.02
Dry Product - tons/hr	0.42	0.64	0.78	1.06	1.32	0.90	0.88	0.56	0.53	0.49	0.76
Total Wet Yield - tons (including lime)	151	108	226	399	333	286	246	224	149	114	2180 *
Total Dry Yield - tons (including lime)	49.2	43.5	87.4	155.0	133.0	105.8	87.5	72.7	46.6	39.7	820 *
Lime Dose - lbs/ton dry solids	0	41	95	61	34	49	57	76	72	62	61
Lime Usage - lbs	0	1775	8275	9510	4000	4300	4950	6800	2825	2350	44,785 *

+ Except as noted
* Ten-month total

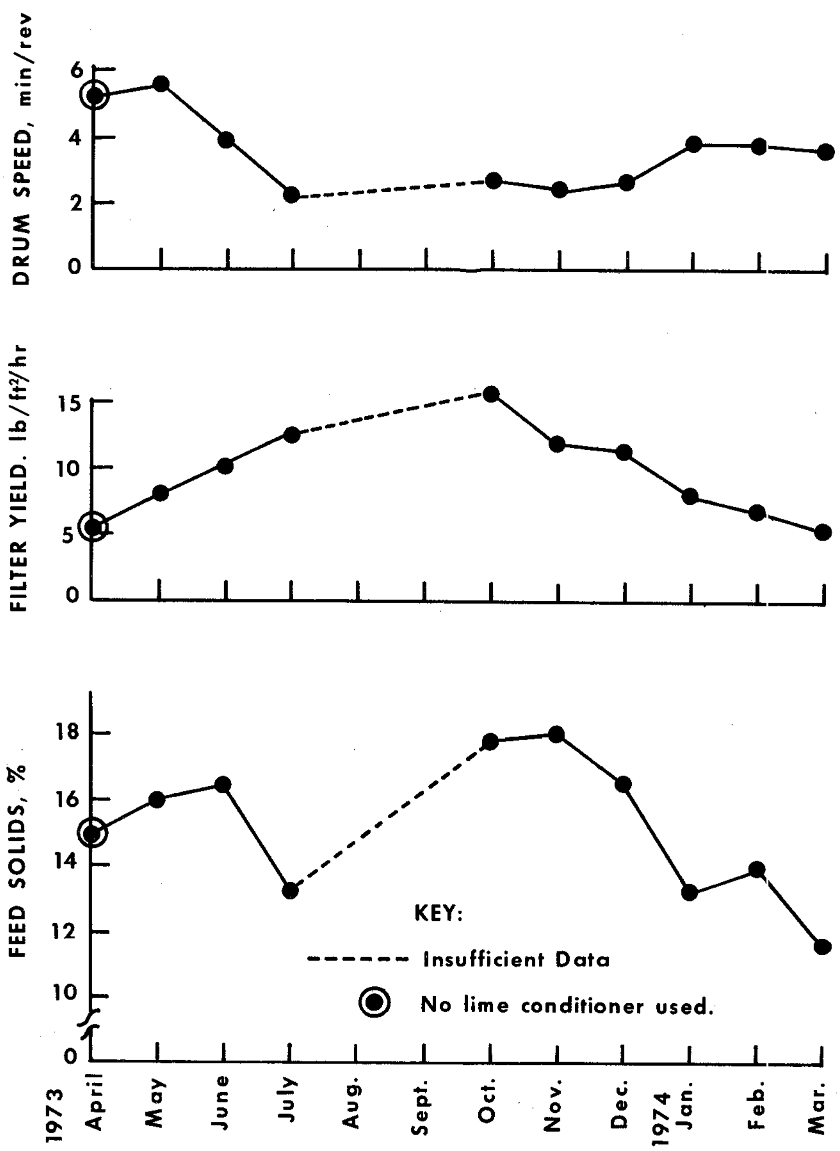


FIGURE 6-1. MONTHLY AVERAGES OF FEED SOLIDS CONCENTRATION, FILTER YIELD, AND DRUM SPEED FOR VACUUM FILTRATION OF LIME CONDITIONED COMBINED BIOLOGICAL-CHEMICAL SLUDGE.

with the chemical sludge for thickening and vacuum filtration. In June 1973 the sludge digester broke down and has not been in operation since that time. Consequently, the combined primary/secondary biological sludge is not being digested prior to thickening and vacuum filtration.

As previously stated, the filter was operated to produce a sludge cake of at least 30 percent dry solids. This was to meet a State requirement of a minimum cake solids concentration of 30 percent necessary for the disposal of this sludge to landfill. The filter operation produced a sludge cake of 35 percent solids or better. For 10 months, the cake mean dry solids content averaged 35.7 percent (Table 6-4), ranging from 31.1 percent to 39.2 percent. During April 1973, when no lime conditioning agent was added, the cake solids averaged 31.9 percent.

An average of 74.4 metric tons (82 tons) of sludge (dry weight) was vacuum filtered each month. The total production for the year was approximately 893 metric tons (984 tons) of sludge including 24 metric tons (26 tons) of lime. Production ranged from 36 metric tons (40 tons) to 141 metric tons (155 tons) per month. Increased sludge production in the summer months resulted from increased wastewater flows and increased chemical dosages. For example, lime dosage (CaO) to the first-stage lime clarifier was only 282 mg/l in February (43 metric tons sludge produced) but was 340 mg/l in July (141 metric tons sludge produced).

Table 6-4 also shows that for 10 months, the total wet sludge production was 1978 metric tons (2,180 tons). From April 1, 1973 to March 31, 1974 disposal of this sludge required 350 trips to the sanitary landfill. Using 6.8 metric tons (7.5 tons) as a typical truckload, 20 trips were made to the landfill in February compared with 53 trips in July.

During the 12-month operating period from April 1, 1973 to March 31, 1974, the vacuum filter produced 893 metric tons (984 tons) of dry solids including 24 metric tons (26 tons) of hydrated lime. The average filter yield was 49 $kg/m^2/hr$ (10.0 lbs/sq ft/hr). The filter sludge cake was typically 35 percent dry solids. The dry solids content was at least 30 percent in greater than 95 percent of the truck loads. A higher rate of sludge withdrawal from the primary clarifier should improve vacuum filtration by eliminating septic sludge. The vacuum filter operation is considered to have been satisfactory; however, the clarity of the thickener supernatant was considered marginal.

SECTION VII

OPERATION AND MAINTENANCE

A. Personnel Organization and Tasks

The tertiary plant personnel consisted of 13 people. There was a plant engineer, an operator supervisor, a plant foreman, a maintenance and boiler operator, and nine tertiary plant operators. Three additional employees operated the trickling filter plant and performed in-plant and up-stream maintenance and repairs.

The tertiary plant maintenance and repair work was performed by the maintenance person, plant foreman, and City of Ely chief operator. Sample preparation and collection was the responsibility of the plant foreman or one operator-helper. Safety was the responsibility of project safety officer, plant foreman, and plant engineer. Operator supervision, pay records, purchasing, clerical, and some maintenance were the duties of operator supervisor. Staff meetings, process control, overall supervision, written summaries, and quarterly and annual reports were the responsibility of the plant engineer.

Day-to-day operation of the tertiary plant was the duty of the EPA operators and operator-helpers. Two operators were on hand 24 hours per day, seven days per week in the tertiary plant. Each shift included one trained operator and one operator-helper.

The duties of the shift operators were operating the tertiary plant, operating the vacuum filter, and other assigned tasks. Once each hour an operator collected and composited samples at five locations and recorded totalizer readings, wet well levels, chemical feed rates, pH meter readings, and solid blanket levels. The clarifier mix zone percent solids test was set up on the half-hour and read on the hour. Chlorine residuals were determined every two hours. Every four hours the temperature, gravity filter pressure loss, and effluent clarity were recorded, and the thickener overflow was sampled. The operators adjusted wastewater flow rates, chemical feed rates, recirculation flow, and sludge withdrawal rates as needed. Operators inspected lime slakers for excessive lime buildup.

Almost all mechanical and electrical systems were tied into the main control panel. When a piece of equipment failed, a light and an annunciator alerted the operator. The operator was expected to perform minor repairs as needed. If repairs could not be made by the operator, the plant staff was notified.

The operators kept a log of all readings and recordings, but significant developments were written in a separate log book. The written log book included any change in chemical dosages, equipment breakdowns or repairs, and unusual observations.

The vacuum filter, while in operation, required full time attention of one operator. This operator prepared the lime for conditioning and started the vacuum filter. While the filter was operating, samples of the influent and the dry cake were collected for solids analysis. The operator saw to it that the lime additon was correct, that the sludge depth in the vat was maintained, that the filter cloth was straight, that the sludge cake formed was dry, and that the sludge cake did not stick to the cloth. The operator emptied the sludge into the truck for ultimate disposal at the sanitary landfill.

Additional duties performed by the operators included cleaning the bar screen and checking the trickling filter plant when the City of Ely operators were off duty. Operators inspected the three lift stations and pumps in the vicinity of the tertiary plant. In addition, each operator shift was assigned a cleaning and maintenance schedule.

B. Plant and Equipment Problems

Major Equipment Breakdowns

The major equipment problems experienced during the first year of operation of the Ely plant included the second-stage lime clarifier, the sludge thickener, the boiler, and the secondary clarifier. A description of each failure and the corrective action taken is given below.

Second-Stage Lime Clarifier - Both the first and second-stage lime clarifiers are equipped with a double shaft driver for the impeller and sludge rake as shown in Figure A-4. A water-lubricated fiber bearing separates the impeller shaft from the shaft of the sludge rake.

In October 1973 the fiber bearing developed an unusual noise. Upon investigating the cause, it was determined that a pipe which supplied lubricating water to the fiber bearing had failed because of inadequate support. When the water pipe was repaired, additional pipe supports were used. However, damage to the fiber bearing had resulted, and within five months it was necessary to replace the bearing because of excessive wear.

On another occasion a high-pitched noise developed in the second-stage clarifier. Upon investigation, it was determined that two grease fittings located near the top of the sludge scraper main shaft had not been properly serviced. The result was that the main-shaft bearings were not being lubricated. Once the grease fittings were installed, proper lubrication was applied to the bearings and the high-pitched noise was no longer heard.

In March 1974 vibrations developed in the second-stage lime clarifier. The vibrations became severe enough to take the clarifier out of operation and to drain it for inspection. Upon inspection, it was found that the mid-joint fiber bearing was loose and that the sludge agitator paddle had twisted 90 degrees. With the assistance of a millwright a new fiber bearing was installed and a new sludge agitator paddle was constructed to replace the one which was damaged.

Tertiary Sludge Thickener - On two occasions repairs were required on the tertiary sludge thickener. On one occasion unusual noises suddenly developed in the thickener. Before the thickener could be inspected, the shaft of the hydraulic jack snapped. This jack was used to adjust the operating depth of the sludge rake. Extensive repairs to the jack were completed at the factory and new parts including a new fiber bearing and larger washer, roller bearing and pin were installed. It was also necessary to machine a large cylinder and the shaft of the rake mechanism since both these parts had been scored.

Before two months elapsed, noises from the thickener were again heard. When the thickener was drained and inspected the noises were found to be caused by the bearing assembly which was binding on the thickener bridge. The resulting damage, which was a slight scoring of the inside surface of the cylinder surrounding the bearing assembly, was minimal. Adjustments were made to prevent the bearing assembly from binding on the bridge and no further difficulties were experienced.

Boiler - The boiler used to heat the tertiary building was equipped with an automatic low-water cut-off switch which shuts off the boiler when water service to the boiler is interrupted. In November 1973 the automatic cut-off failed to function which allowed a "dry-firing" of the boiler. The excessive heat which resulted from insufficient water warped 52 of the heat exchanger tubes. Because it was wintertime, emergency repairs were made immediately. In the following March all the damaged boiler tubes were replaced.

Secondary Clarifier - In the biological treatment plant, the scum rake in the secondary clarifier fell off its track which caused damage to the scum rake and bull gear. When repairs were being made, cracks in the clarifier floor were found. The cracked protion of the clarifier floor was repaired, the scum rake repaired, and a new bull gear was installed.

Comminutor and motor - The communitor which had been added to the head of the secondary plant when the tertiary plant was constructed was repaired at a cost of almost $2,000. After only two years of operation it became necessary to replace all the cutting teeth and shear bars. The comminutor motor also burned out and had to be replaced. While the unit was out of operation for repair, a rag problem developed which resulted in repeated plugging of the thickener underflow pumps. This problem was temporarily circumvented by removing rag debris by three bar screens located in series in the grit chamber of the secondary plant.

Sludge pumps - The Moyno pumps, which removed thickened sludge from the tertiary thickener, regularly became plugged with rags. This problem was aggravated when the comminutor was out of service. The rag problem increased the wearing rate of the stators. The stators on all four sludge pumps were excessively worn within 1 1/2 years of operation and the installation of new stators was required.

Polymer Mixer - For three months a polymer; Betz 1150, was mixed automatically with a mechanical mixer. The mixer required excessive cleaning and maintenance because the dry polymer feed opening, which was installed in the mixer, regularly became plugged by wetted polymer particles. After using the mixer for three months, the practice was discontinued. Thereafter, the polymer was periodically batch-mixed in a day tank, which resulted in an efficient, low-maintenance, operation.

Miscellaneous repairs - The minor repairs required included the following:

(1) The carbon dioxide primary regulator leaked and had to be tightened with new bolts.

(2) The wear plate on the vacuum filter had to be replaced frequently.

(3) Factory repair of the chlorine detector and the torque overload control on the first-stage lime clarifier sludge scraper was required.

Design Considerations

Hindsight demonstrates that many changes and additions could have been designed into the tertiary wastewater plant to improve plant operation and reliability of equipment. During the first one and one-half years of operation, a number of process modifications and safety improvements were made. Among them are the following:

(1) CO_2 feed pipe - During the first months of operation the wastewater influent pipe to the second-stage lime clarifier became completely plugged with calcium carbonate. To correct the situation, the CO_2 line, which had been feeding into the influent pipe, was moved so that CO_2 could be fed directly to the mix zone of the second stage. This eliminated the buildup of $CaCO_3$ in the pipe between the first and second-stage lime clarifiers.

(2) Boiler - Two smaller boilers should have been provided instead of one large boiler for heating the Ely plant. The winter temperature in Ely, Minnesota can reach -40°C (-40°F) or lower, and a boiler failure in such weather could cause extensive damage to the tertiary plant. Recognizing this risk, turbine heaters and electric heaters were purchased in October 1973 for emergency heating. On November 15 the boiler failed in moderate subfreezing weather, but the emergency heaters provided sufficient heat. Had the temperature been extreme, the turbine and electric heaters would probably have been inadequate. In such a situation and with a two boiler arrangement, one boiler could prevent the tertiary plant from freezing if the other boiler had failed.

(3) Vacuum filter lime conditioning agent - No provisions had been made in the original design for feeding a sludge conditioning agent to the vacuum filter. When it was determined lime conditioning was necessary, a day tank, pump, mixer, and related equipment were installed in the vacuum filter room as an interim lime-feeding system. For the permanent system the lime slaker discharge piping was modified to allow slaked lime to be pumped to the day tank in the vacuum filter room.

(4) Ventilation in the VF room - No exhaust fan had been included in the design of the filter room. A large stand-up fan, exhausting to the main plant, was added and provided very good ventilation.

(5) Glass piping - Glass piping which was used to feed sulfuric acid and ferric chloride proved to be both unreliable and dangerous. Occasionally a length of glass pipe would break and fall to the ground, or a glass valve would break off while being turned. Maintenance personnel could not work near the glass piping for fear of breaking it. As a result, sulfuric acid piping was replaced with CPVC piping and ferric chloride lines were replaced with CPVC tubing.

(6) Storage - Two new storage areas were developed. (a) A metal shed was constructed to store spare parts, tubing, piping, tanks, welders, fittings, etc. (b) The carbon storage room was divided to create a storage area for laboratory chemicals in one section and powdered carbon in the other.

(7) Water hammer - In general, tertiary plant effluent was used for the 757 m^3/day (200,000 gpd) process water required in the tertiary plant. City water was used for process water only one percent of the time. On those occasions, however, a water hammer was created that damaged hot water heaters in the vicinity of the Ely plant. A pressure relief valve was put ahead of the break tank to protect against the water hammer. The relief valve ended further damage to the hot water heaters, although fluctuations in water pressure continued when the city supply was used for tertiary process water.

(8) Additional modifications were made or were suggested to improve operation of the Ely plant. (a) The plant effluent totalizer range was increased from 11,356 m^3/day (3.0 mgd) to 18,925 m^3/day (5.0 mgd) in order to record flows that bypass the tertiary plant. (b) A wet well level indicator was installed in the operator control room. (c) Controls to activate the sludge hopper doors were repositioned to improve plant safety and maintenance. (d) Individual underflow metering devices for each lime clarifier are recommended to replace the combined underflow totalizer. (e) Chemical feed pumps should be connected to the emergency power source. (f) The capacity of each of the two effluent recycle pumps should be greater, since one pump was inadequate about half the time. (g) The probe for the high-level alarm on the CaO bins was too short to provide sufficient warning when filling the CaO bins. The probe has been lengthened. (h) Tertiary plant effluent water is now used for all non-potable purposes except polymer makeup. This has resulted in a considerable savings in costs.

Despite these design and equipment difficulties, the processes and equipment performed well enough to meet the design effluent total phosphorus requirements.

C. Maintenance Requirements

Routine maintenance duties were performed by the City of Ely operators, EPA operators, and EPA day shift personnel. The City of Ely operators shoveled snow in the winter, cut the grass in the summer, and kept the wastewater plant grounds orderly. The city operators cleaned the bar screen and grit chamber, cleaned the trickling filter distributors and moving parts, inspected and repaired the secondary plant pumps, and lubricated all secondary plant pumps and mechanical equipment. The city operators assisted the EPA personnel with the tertiary plant maintenance, thereby familiarizing themselves with the tertiary plant equipment.

Maintenance of the trickling filter plant and the tertiary plant was the responsibility of the day shift personnel. Each week the plant engineer compiled a list of maintenance problems. The operator supervisor, the foreman, the maintenance man, and the City of Ely chief operator saw to it that required maintenance was performed. The routine maintenance duties included cleaning out plugged sludge pumps; lubricating equipment; ordering spare parts; repairing or cleaning hoses, pipes, tanks, fittings, valves, stand pipes, and rotameters; and performing some custodial duties. The day shift personnel operated a welder, torch, grinder, compressor and other equipment needed in making repairs. The vacuum filter required maintenance which included lubrication, sewing and glueing replacement filter cloths, replacing filter springs, changing the wear plate, removing lime scale from the filter grids and drum, and repainting the drum. The filter cloth was changed three times in the initial five months; however, the most recent filter cloths lasted six and seven months, respectively.

The shift operators contended with high maintenance items as the lime slakers, chemical feed pumps, and underflow pumps. The operators cleaned around the slaker paddle shaft and weigh belt, and checked the lime paste consistency every four hours. The lime feed piping, particularly the valves and the ejectors, became plugged or coated with lime and had to be disassembled and cleaned. The operators replaced valves, gaskets, diaphragms, etc. in the chemical feed pumps as the parts wore out. Operators unplugged the thickener underflow pumps that regularly bound with rags or heavy sludge. The chemical sludge underflow pumps on occasion required both unplugging and replacement of shear pins.

Preventive maintenance performed by the operators involved inspecting the package lift stations, lubricating some equipment, checking and sometimes bleeding the influent pumps and effluent recycle pumps, inspecting the powdered carbon unit, testing for chlorine leaks, observing the temperature of the chlorine room and the emergency generator room, and checking the boiler.

The custodial duties of the operators were mopping halls and floors, hosing down the floors in the main process area, the chemical rooms, the dry wells, and the gravity filter pit, cleaning the vacuum filter room and equipment, cleaning the truck room, and general housekeeping.

The distribution of operation and maintenance duties is shown in Table 7-1.

TABLE 7-1 MANPOWER REQUIREMENTS FOR ELY AWT PLANT

	MAN-YEARS/YEAR						
Unit Process	Admins.	Operation	Prev. Maint.	Corr. Maint.	Sampling & Analysis	Custodial	Total
Grit Chamber and Comminutor		.29	.02	.04			.35
Secondary Treatment **		.25	.11	.54			.90
First-stage lime clarifier		.77	.06	.02			.85
Second-stage lime clarifier		.78	.06	.11			.95
Gravity filters		.09	.05	.06			.20
Other process equipment		1.00	.20	.20			1.40
Lime storage and feeding		.18	.25	.22			.65
Ferric chloride, sulfuric acid, polymer		.40	.15	.05			.60
Carbon dioxide, chlorine		.47	.14	.04			.65
Underflow pumps		.08	.02	.90			1.00
Sludge Thickener		.06	.03	.11			.20
Vacuum filter		1.15	.06	.09			1.30
Sludge disposal		.29	.02	.04			.35
Tertiary Building Systems			.35	.15		1.15	1.65
Emergency Generator			.08	.02			.10
Plant Grounds				.20		.30	.50
Sample collection and preparation			.04	.14	.92		1.10
Laboratory analysis	.60		.15	.15	2.80		3.70
Administration	1.20						1.20
Process control and data analysis	.60						.60
Reports	.40						.40
Totals	2.80	5.81	1.79	3.08	3.72	1.45	18.6

* 1 man-year = 2080 hours

** primary settler, trickling filter, and secondary settler

Maintenance - Electrical, Boiler, and Instruments

The duties of the designated maintenance man involved electrical work, instrumentation, heating, air-conditioning, and ventilation. Besides routine duties, the maintenance man installed electrical conduit and did some welding. The maintenance man was assisted by other personnel as needed.

Electrical work included checking and greasing motors in both the trickling filter plant and tertiary plant, along with maintaining motor controllers, the diesel emergency generator, and the gravity filter backwash cycle and valve sequence.

Any instrumentation such as calibrating pH meters, the flow proportional system, and flow meters was the responsibility of the maintenance man.

During the heating season the boiler was regularly inspected for CO_2, smoke and draft. Every two weeks low and high water cut-offs were tested. Filters to the air exchangers, the boiler air supply, and the air-conditioning system were changed as needed. Steam traps were inspected and cleaned every other season. The maintenance man was expected to perform his duties without specific supervision.

Safety

The purpose of the safety program at the tertiary wastewater plant was to create safety awareness, maintain a safe work area, provide safety training, and seek participation by all personnel in safety discussions and in detection of hazards.

A safety committee, including the tertiary plant foreman, was established and acted to bring all work areas, including the tertiary plant building, up to at least OSHA standards. As part of directing the safety program, the safety committee inspected work areas for hazards, put up posters concerning safety, organized first aid courses, encouraged good housekeeping to prevent accidents, and made recommendations to eliminate hazards in the working environment.

In order to reduce safety hazards in the tertiary plant, the following actions were taken. An access platform was constructed around the vacuum filter, safety showers and eye washes were installed in the laboratory and next to the sulfuric acid pump; glass piping for sulfuric acid and ferric chloride was replaced with CPVC piping; alarms for evacuation were mounted at five locations in the tertiary plant building; defective guards on machinery were replaced or repaired; steel mesh and non-slip tape were attached to slippery surfaces; and a railing was constructed around a drywell manhole as a substitute for a warning chain. Life jackets, safety lines, and harnesses were purchased for working above clarifiers. Rubber suits and an acid resistant hood were obtained for handling sulfuric acid. Hard hats and ear plugs were also purchased. The wearing of hard hats was required for anyone in the process area of the tertiary plant.

The safety committee as a group inspected the tertiary plant periodically; however, one safety committee member checked for hazards in the plant each week. The weekly inspection included checking fire extinguishers, safety showers, and the self-contained breathing apparatus. On one inspection dead flies were discovered blocking the air-flow to the mask of the self-contained breathing apparatus. The plant was also inspected for safety deficiencies by three safety experts from an insurance company.

Safety skills and awareness of personnel have been enhanced by various training courses and lectures. Two members of the safety committee attended one-week courses in safety. Six of the plant personnel have received first aid training at a 14-hour course sponsored by the Red Cross. Plant personnel participated in a seminar on chlorine safety. Listening to tapes on safety, safety meetings, evacuation drills and the distribution of memos and pamphlets on safety were also part of the safety program.

SECTION VIII

COSTS OF OPERATION AND MAINTENANCE

The costs required to operate the plant from April 1, 1973 through March 31, 1974 totaled $389,107.64. During this period 1.6 x 10^6 m^3 (427.7 million gallons) of wastewater were treated at a cost of $0.24/$m^3$ ($0.91/1000 gallons). The 12-months' operating costs and the percentages for 27 categories are shown in Table 8-1. The unit chemical costs and power costs are shown in Table 8-2.

The relative costs for personnel, chemicals, utilities, miscellaneous, and equipment operation and repair are shown in Figure F-1. The five principal cost categories are subdivided in Figures F-2 through F-6. The operational cost breakdowns which are shown in Appendix F are based on the cost information in Table 8-1.

Figure F-1 points out that more than 60 percent of the operational costs were for operating personnel. This reflects the need for a skilled staff. Chemical costs, including shipping, amounted to 15 percent of total operational costs or $58,000 per year. The cost of shipping in chemicals was high because of the distance from chemical suppliers. Chemical usage, which was confined almost entirely to the tertiary operation, was greater in the summer months while utility costs, particularly fuel oil costs, were highest in the winter months. Utility costs were 9.7 percent of total operational costs (Figure F-4). Miscellaneous supplies represented 5.8 percent of total costs (Figure F-5), and the cost to operate and repair plant and equipment was 8.3 percent (Figure F-6).

Personnel costs are apportioned in Figure F-2. Operator salaries amounted to about one-half of personnel costs and provided for two operators in the tertiary plant 24 hours per day, seven days per week. Two operators were required at all times to ensure high performance of the wastewater treatment process and for their own safety. Laboratory personnel performed a very large number of analyses during the 12-month period of tertiary plant operation. The wastewater stream was sampled daily at eight locations and the underflow streams were sampled several times per week. The wastewater samples were tested for more than a dozen parameters; some daily, some three times a week, and some weekly. Maintenance tasks were performed by the foreman, supervisor, and operators as well as the maintenance-boiler man and assistant. The maintenance-boiler assistant, along with the foreman, collected and prepared samples for the laboratory.

Figure F-3 indicates that 87 percent of the cost of chemicals was expended for lime, carbon dioxide, and ferric chloride. The category, "Other Chemicals," included chiefly the cost of powdered carbon. During five months of operation

TABLE 8-1

OPERATION AND MAINTENANCE COSTS FOR ELY WASTEWATER TREATMENT PLANT

APRIL 1973 THRU MARCH 1974

Category	12-month Costs	Percent of Category	Percent of Total	Unit ¢/m^3	Costs ¢/1000 gal
Personnel (December 1974 wage rates)					
Operators	116,215.34	48.7	29.87	7.17	27.17
Maintenance & Boiler	30,608.67	12.8	7.87	1.88	7.16
Foreman, Supervisor	30,291.81	12.7	7.78	1.86	7.08
Engineer	14,696.00	6.2	3.78	0.91	3.44
Laboratory	45,000.00	18.9	11.56	2.78	10.52
Accounting	1,678.00	.7	.43	0.13	0.39
Subtotal	238,489.82	100.0	61.29	14.73	55.76
Chemicals					
CaO	15,406.04	26.5	3.96	0.95	3.60
Cl_2	1,655.25	2.9	.43	0.10	0.39
CO_2+Rental	18,606.51	32.1	4.78	1.16	4.35
$FeCl_3$	16,459.39	28.3	4.23	1.03	3.85
H_2SO_4	2,815.89	4.8	.72	0.16	0.66
Poly	1,931.96	3.3	.50	0.12	0.45
Other chemicals	1,195.03	2.1	.31	0.07	0.28
Subtotal	58,070.07	100.0	14.92	3.59	13.58
Utilities					
Electricity	20,088.54	53.2	5.16	1.24	4.69
Water	440.47	1.2	.11	0.03	0.10
Heating-fuel oil, propane	15,653.77	41.5	4.02	0.97	3.67
Telephone	1,553.50	4.1	.40	0.09	0.36
Subtotal	37,736.28	100.0	9.70	2.33	8.82
Supplies					
Laboratory	20,450.00	90.6	5.26	1.26	4.79
Sampling	1,743.92	7.7	.45	0.11	0.41
Custodial	232.76	1.0	.06	0.01	0.05
Grease & oil	145.58	.7	.04	0.01	0.03
Subtotal	22,572.26	100.0	5.80	1.39	5.28
Equipment Operation & Repair					
Replacement & spare parts	16,497.36	51.2	4.24	1.03	3.87
Misc. repair & maintenance	7,777.67	24.1	2.00	0.48	1.82
Equip. repairs & maintenance	3,702.29	11.5	.95	0.23	0.86
New Equipment - Structures	2,517.68	7.8	.65	0.15	0.59
Safety Equipment	906.44	2.8	.23	0.05	0.21
Sludge Truck O&M	837.77	2.6	.22	0.05	0.19
Subtotal	32,239.21	100.0	8.29	1.99	7.54
TOTAL COSTS	389,107.64		100.00	24.03	90.98

TABLE 8-2 UNIT COSTS OF CHEMICALS AND POWER FOR ELY AWT PLANT OPERATION

Chemical Costs	
Lime:	Low - \$25.25 per ton High - \$32.77 per ton Freight - included
Ferric chloride:	Low - \$80.00 per ton High - \$90.00 per ton Freight - \$40.08 per ton
Sulfuric acid:	Low - \$45.15 per ton High - \$50.90 per ton Freight - included
Carbon dioxide:	Low - \$65.00 per ton High - \$75.00 per ton Freight - included
Polymer (Betz 1150):	Low - \$2.38 per lb. High - \$3.32 per lb. Freight - included
Power Costs	
Electricity:	Low - 2.05¢/kWh High - 2.06¢/kWh
#2 fuel oil:	Low - 23.6¢/gal High - 29.95¢/gal
Propane:	Low - 25.9¢/gal High - 38¢/gal

ferric chloride was shipped in drums rather than by tank truck, which significantly increased the cost of ferric chloride. The carbon dioxide costs included $3,000 per year rental of a CO_2 refrigerator-storage unit.

The cost of water as shown in Figure F-4 was kept very low by utilizing tertiary plant effluent for all tertiary plant processes except polymer make-up water.

In Figure F-5, laboratory expenses, excluding laboratory personnel costs, accounted for almost all miscellaneous costs. Laboratory expenses were large because considerable analytical work was necessary for research and quality control in the tertiary plant.

Equipment replacement and spare parts totaled 51 percent of the total maintenance costs as shown in Figure F-6. A large spare parts inventory was obtained to allow repairs to be made promptly and prevent downtime caused by a slow delivery and/or shortage of parts. Some equipment required periodic replacement of parts such as the underflow pumps and chemical feed pumps. The plant staff minimized repair and maintenance costs by making the repairs themselves. Repair costs were increased due to extensive repairs needed in the 20-year-old trickling filter plant. New equipment purchases included emergency heaters, a storage shed, and a pump with a motor to route slaked lime to the vacuum filter room.

SECTION IX

REFERENCES

1. "Shagawa Lake Project: Lake Restoration by Nutrient Removal from Wastewater Effluent," Environmental Protection Agency, Report No. EPA R3-73-026, January, 1973.

2. Fair, G.M., Geyer, J.C., and Okun, D.A., Water Purification and Wastewater Treatment and Disposal, John Wiley & Sons, Inc., 1968, pg. 30-11.

3. IBID, pg. 29-22.

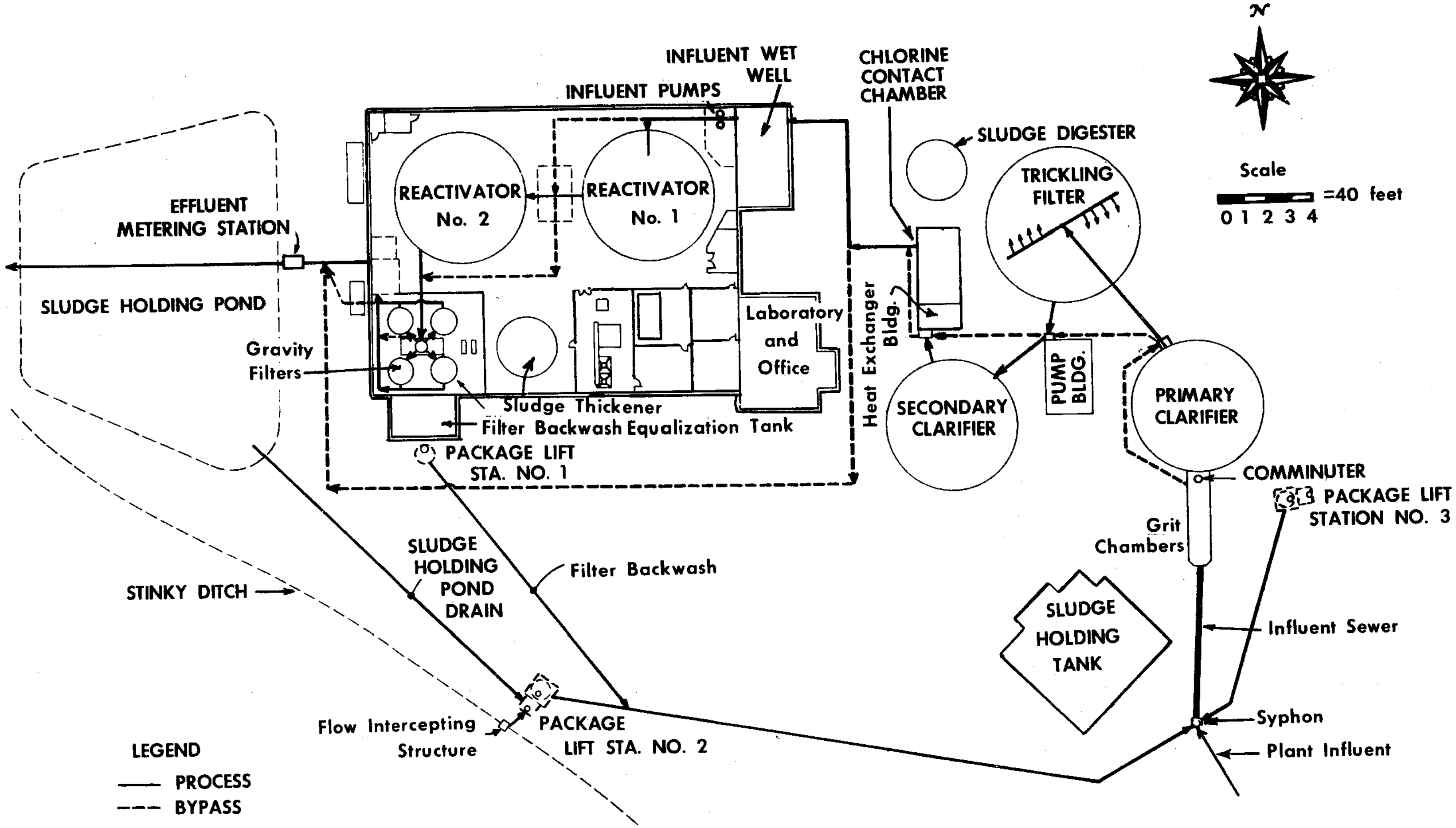
4. Sawyer, C.N., and McCarty, P.L., Chemistry for Sanitary Engineers, McGraw-Hill, Inc., 1967, pg. 292.

5. IBID, pg. 297.

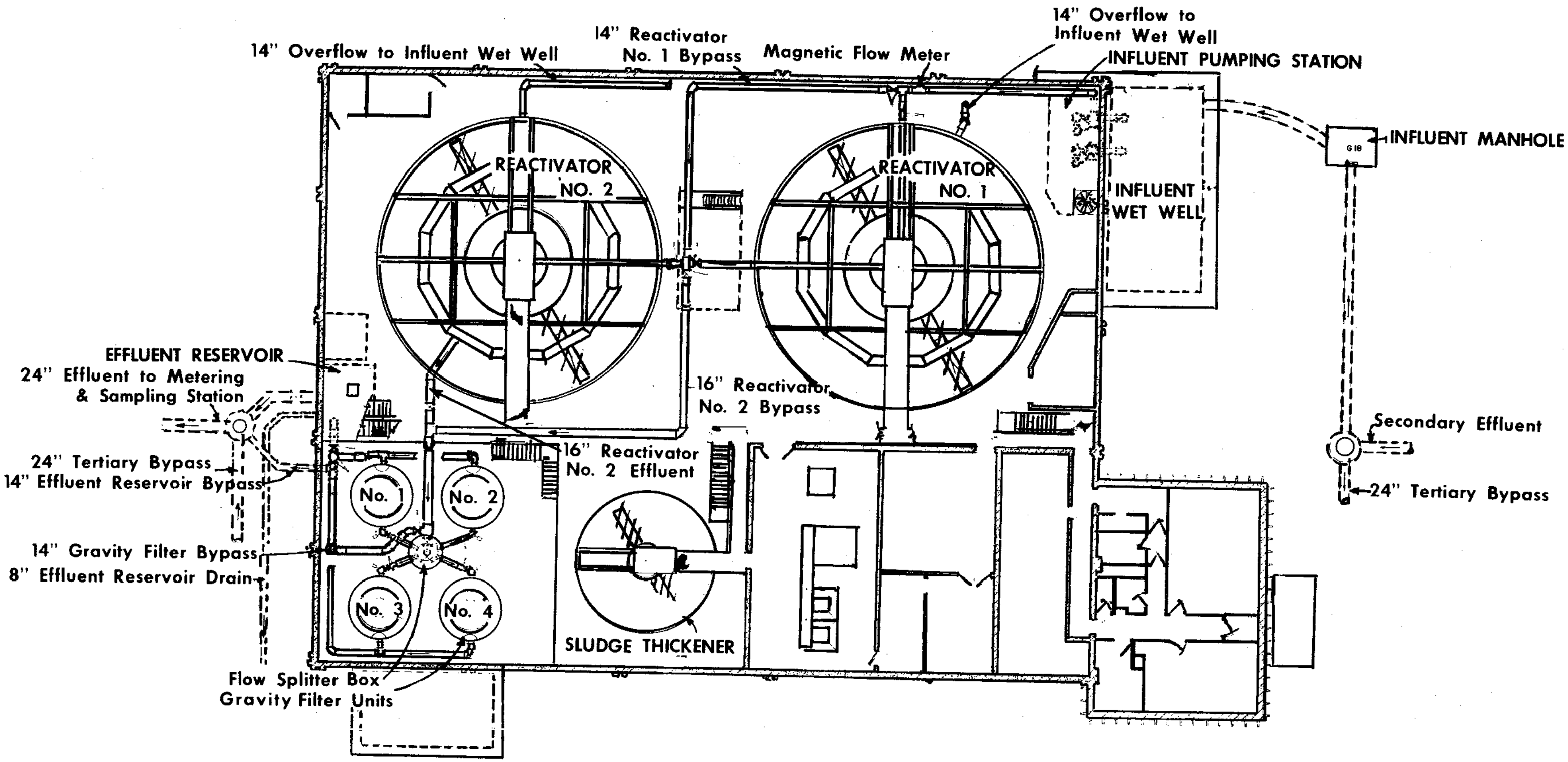
APPENDICES

APPENDIX A

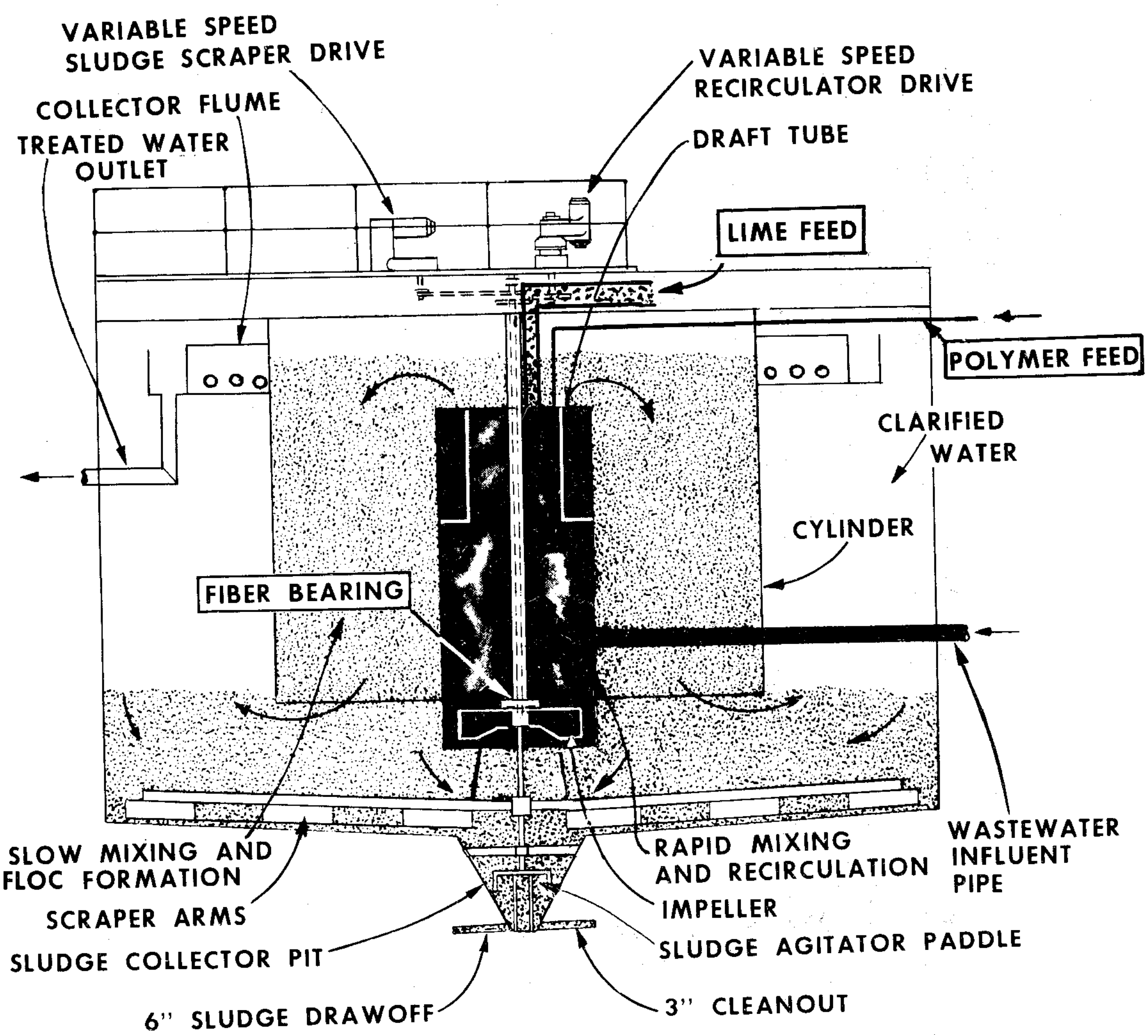
TREATMENT PLANT LAYOUT PLANS AND DESIGN CRITERIA



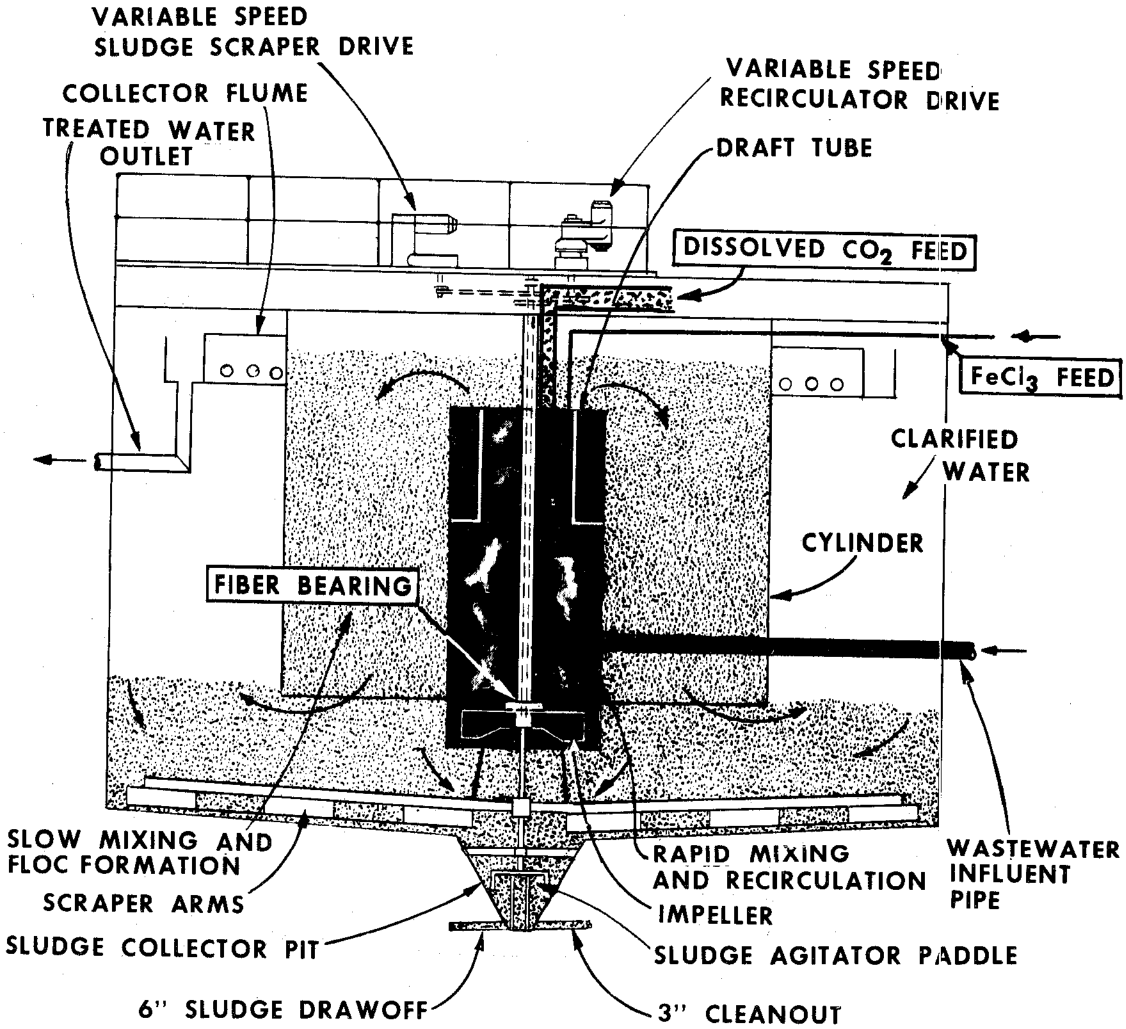
APPENDIX A, FIGURE A-1. WASTEWATER TREATMENT PLANT LAYOUT PLAN



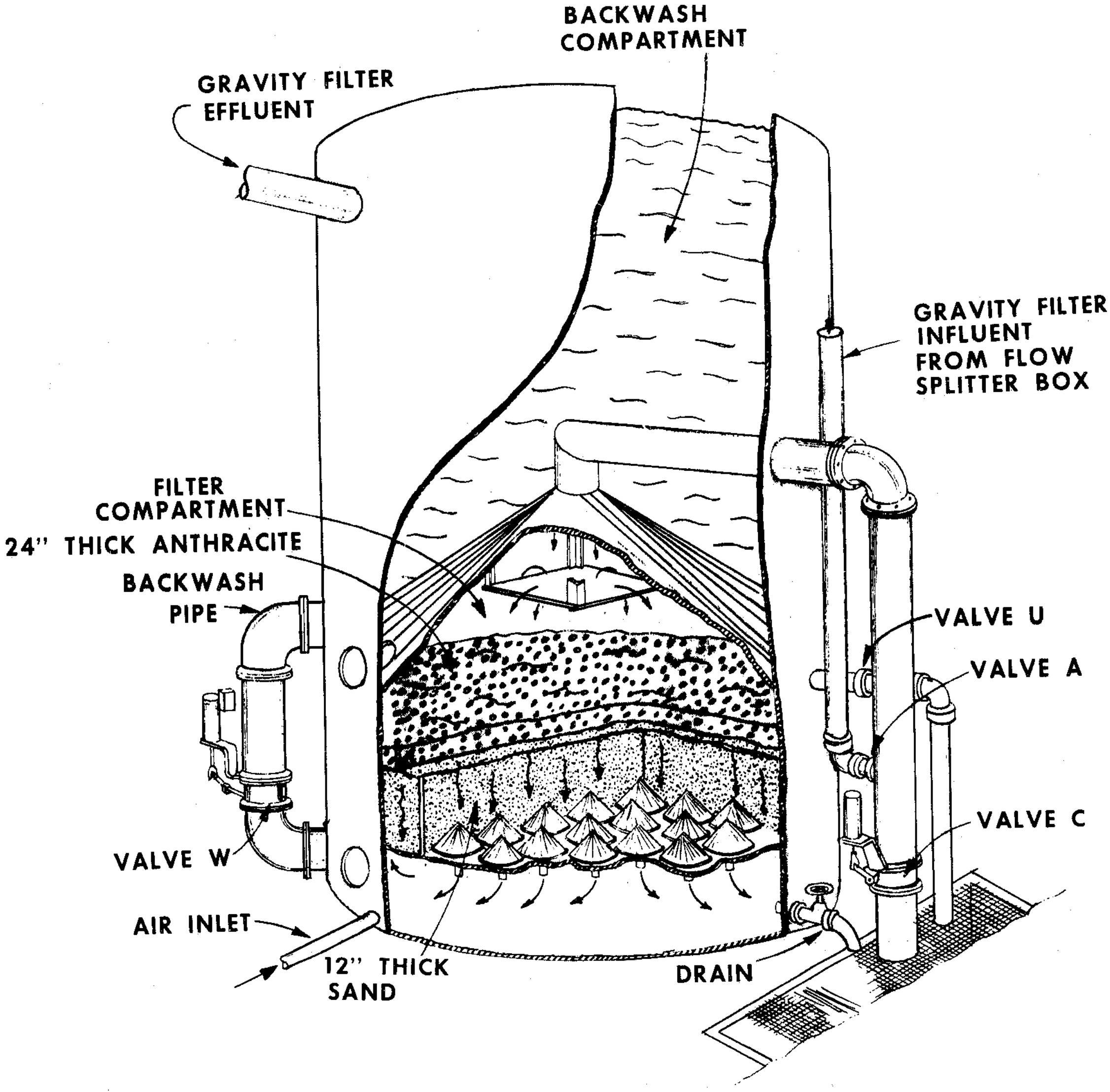
APPENDIX A, FIGURE A-2. TERTIARY PLANT LAYOUT PLAN SHOWING WASTEWATER PIPING



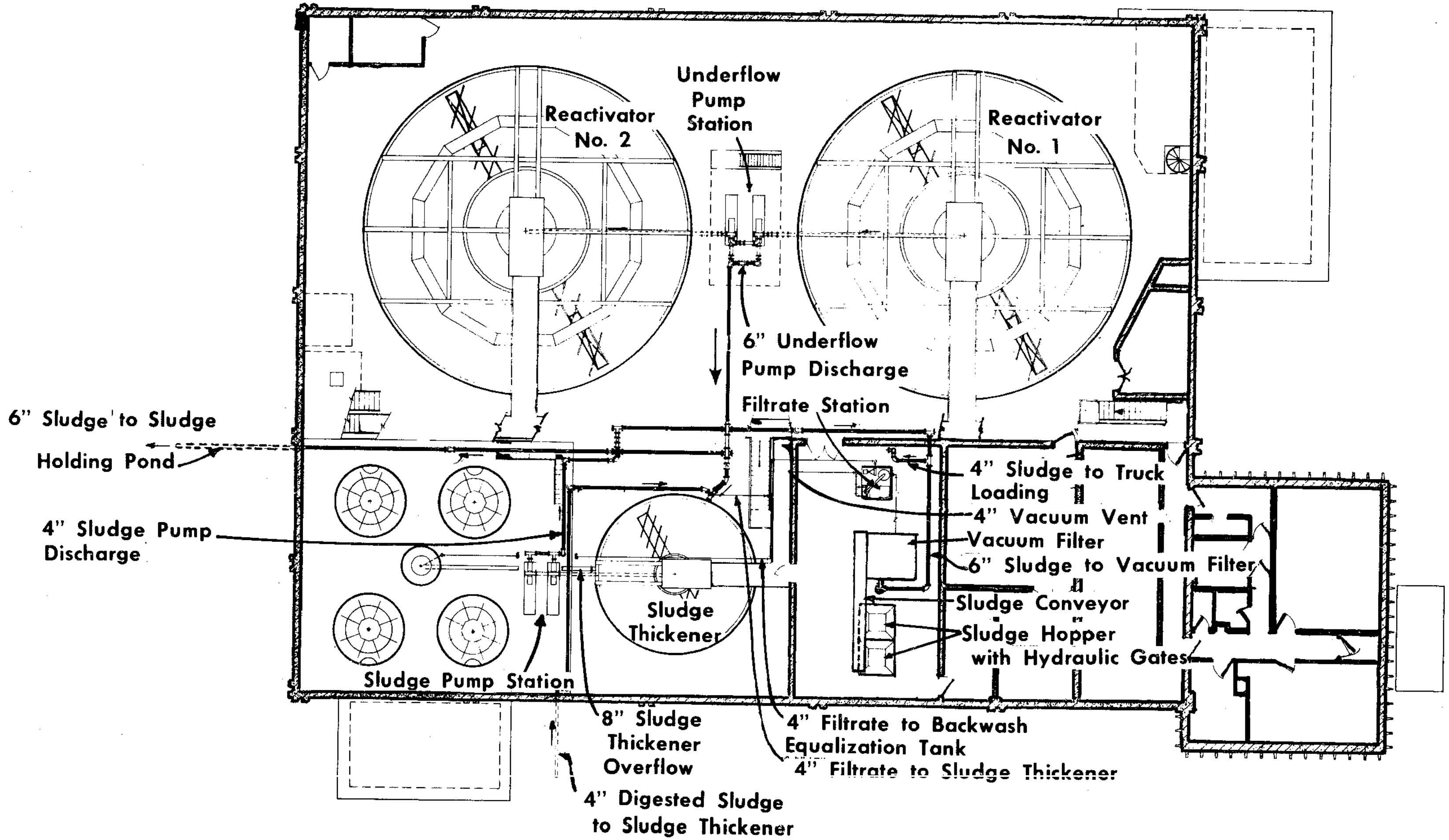
APPENDIX A, FIGURE A-3. FIRST STAGE LIME CLARIFIER



APPENDIX A, FIGURE A-4. SECOND STAGE LIME CLARIFIER



APPENDIX A, FIGURE A-5. GRAVITY FILTER UNIT



APPENDIX A, FIGURE A-6. TERTIARY PLANT PLAN SHOWING SLUDGE PIPING

APPENDIX A

Table A-1

DESIGN CRITERIA

1. Grit Chambers (2)	
Velocity Control	Proportional Weir
Length	10 m (32'-6")
Width	0.9 m (3'-0")
Depth	1.2 m (4'-0")
2. Comminuter	
Design Flow	5678 m^3/day (1.5 mgd)
Peak Flow	28,387 m^3/day (7.5 mgd)
3. Primary Clarifier	
Diameter	15.2 m (50')
Sidewall Depth	2.4 m (7'-10")
Volume	473 m^3 (16,700 cf)
Detention Time	
@ 1893 m^3/day (0.5 mgd)	6 hrs.
@ 3785 m^3/day (1.0 mgd)	3 hrs.
@ 5678 m^3/day (1.5 mgd)	2 hrs.
Overflow Rate	
@ 1893 m^3/day (0.5 mgd)	10 m/day (255 gpd/sq ft)
@ 3785 m^3/day (1.0 mgd)	21 m/day (510 gpd/sq ft)
@ 5678 m^3/day (1.5 mgd)	31 m/day (765 gpd/sq ft)
Weir Length	44.5 m (146')
Weir Overflow Rate @ 5678 m^3/day (1.5 mgd)	128 m^2/day (10,270 gpd/lf)
4. Trickling Filter	
Diameter	18.3 m (60')
Rock Depth	1.8 m (6')
No. of Distributor Arms	4
Surface Area	263 m^2 (2830 sq ft)
Hydraulic Loading @ 5678 m^3/day (1.5 mgd)	21.6 m/day (530 gpd/ sq ft)
5. Secondary Clarifier	
Diameter	15.2 m (50'-0")
Sidewall Depth	2.1 m (6'-10")
Volume	417 m^3 (14,700 cf)
Detention Time	
@ 1893 m^3/day (0.5 mgd)	5.3 hrs.
@ 3785 m^3/day (1.0 mgd)	2.65 hrs.
@ 5678 m^3/day (1.5 mgd)	1.77 hrs.

Overflow Rate	
@ 1893 m^3/day (0.5 mgd)	10.4 m/day (255 gpd/sq ft)
@ 3785 m^3/day (1.0 mgd)	20.8 m/day (510 gpd/sq ft)
@ 5678 m^3/day (1.5 mgd)	31.2 m/day (765 gpd/sq ft)
Weir Length	44.8 m (147')
Weir Overflow Rate @ 5678 m^3/day (1.5 mgd)	128 m^2/day (10,270 gpd/lf)

6. Chlorine Contact Chamber

Length	12.8 m (42')
Width	4.8 m (16')
Depth	1.5 m (5')
Volume	95.12 m^3 (3360 cf)
Detention Time	
@ 1893 m^3/day (0.5 mgd)	72 min.
@ 3785 m^3/day (1.0 mgd)	36 min.
@ 5678 m^3/day (1.5 mgd)	24 min.

7. Solids Contact Unit No. 1 (Graver Reactivator No. 1)

Diameter	16.76 m (55')
Sidewall Depth	5.94 m (19'-6")
Volume	
Mixing Zone	27.74 m^3 (980 cf)
Flocculation Zone	92.0 m^3 (3250 cf)
Clarifier Zone	1135.2 m^3 (40,100 cf)
Detention Time	
@ 5678 m^3/day (1.5 mgd) (Design Flow)	5.3 hrs.
@ 11,355 m^3/day (3.0 mgd) (Hydraulic Design Flow)	2.65 hrs.

8. Solids Contact Unit No. 2 (Graver Reactivator No. 2)

Diameter	16.76 m (55')
Sidewall Depth	5.03 m (16'-6")
Volume	
Mixing Zone	23.21 m^3 (820 cf)
Flocculation Zone	77.28 m^3 (2730 cf)
Clarifier Zone	952.63 m^3 (33,650 cf)
Detention Time	
@ 5678 m^3/day (1.5 mgd) (Design Flow)	4.45 hrs.
@ 11,355 m^3/day (3.0 mgd)	2.23 hrs.

9. Automatic Gravity Filters (Graver Mono-Scour Filters)

Number	4
Diameter	3.7 m (12')
Unit Height	4.9 m (16')
Filter Media Depths	
Anthracite	0.61 m (24")
Sand	0.30 m (12")
Surface Area	10.5 m^2 (113 sq ft)

Design Flow	0.0164 m^3/s (260 gpm) per filter 0.00156 m/s (2.3 gpm/sq ft)
Max. Peak Flow	0.0249 m^3/s (396 gpm) per filter 0.0023 m/s (3.5 gpm/sq ft)
Average Backwash Flow	0.11 m^3/s (1690 gpm) 0.0101 m/s (15 gpm/sq ft)
Backwash Air Compressor	
@ 0.031 Pa (4.5 psi)	0.26 m^3/s (550 cfm)
Motor (1800 rpm)	15 hp
Backwash Chamber Volume	26.3 m^3 (930 cf)
10. Sludge Digester	
Diameter	7.3 m (24')
Sidewall Depth	4.51 m (15')
Volume	205.2 m^3 (7250 cf)
Heat Exchange	300,000 BTU hr.
Gas Compressor @ 0.055 Pa (8.0 psi)	73.6 m^3/hr (2600 cfh)
11. Sludge Thickener (Graver Rota-Rake)	
Diameter	7.9 m (26')
Sidewall Depth	5.029 m (16'-6")
Volume	225.34 m^3 (7960 cf)
Design Flow	0.0037 m^3/s (60 gpm)
Detention Time @ 0.0037 m^3/s (60 gpm)	16.5 hrs.
12. Vacuum Filter	
Diameter	1.8 m (6')
Face Width	2.4 m (8')
Surface Area	13.93 m^2 (150 sq ft)
Drum Speed	0.14 to 0.94 rpm
Vacuum Pump @ 0.508 m (20")Hg	0.2595 m^3/s (550 cfm)
Motor (1750 rpm)	30 hp
Filtrate Pump @ 11.58 m (38' TDH)	0.0075 m^3/s (120 gpm)
Motor (1150 rpm)	3 hp

13. Pumps	No.	HP	RPM	TDH ft.	Design Flow (gpm)
A. Sewage					
Recirculation	2	7.5	1150	37	500
Influent	2	30.0	1150	65	1100
Effluent Water	2	15.0	3500	170	150
Tert. Serv. Water	2	20.0	1750	120	300
Sec. Serv. Water	1	1.5			
Lift Sta. No. 1	2	10	1150	55	200
Lift Sta. No. 2	2	5	1150	40	100
Lift Sta. No. 3	2	3	1150	30	100
B. Sludge					
Primary (PD[2])	1	2	48.6	23	85
Secondary	1	2	1150	37	50
Digested	1	2	1150	37	50
Recirculation (HE[3])	1			25	150
Underflow	2	7.5	Var. Speed (84-420)		
Transfer	2	7.5	Var. Speed (84-420)		

TDH - Total Dynamic Head [2]Positive Displacement [3]Heat Exchanger

	No.	HP	RPM	TDH ft.	Design Flow (gpm)
C. Sump Pumps					
Influent					
Drywell	2	1		46	50
Effluent					
Drywell	2	1		46	50
Underflow					
Drywell	2	1		46	50
Lift Sta. No. 1	1	1/3	1725	18	21
Lift Sta. No. 2	1	1/3	1725	14	34
Lift Sta. No. 3	1	1/3	1725	14	34

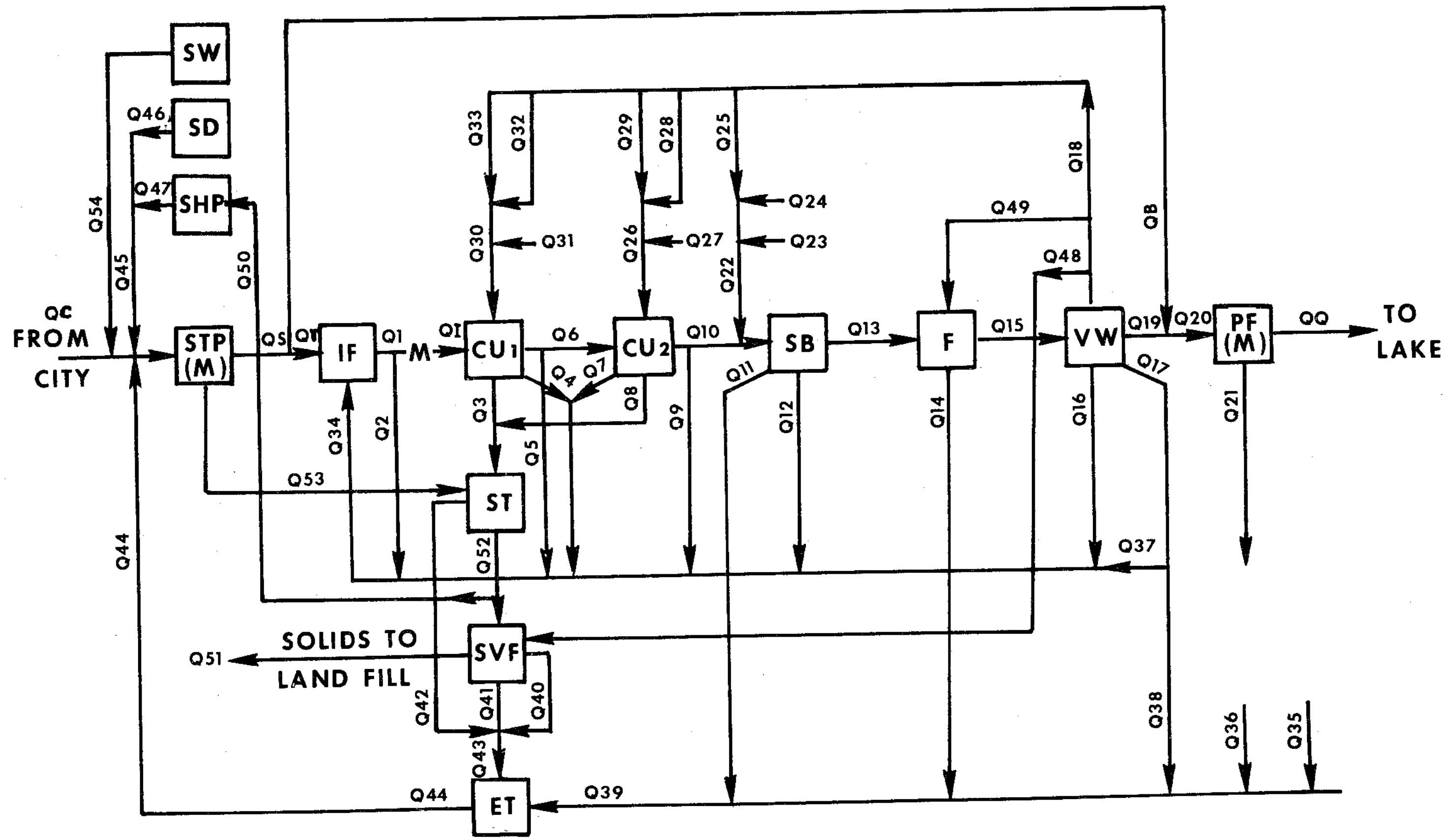
14. Chemical Feed Systems

A. Chlorine	
Storage Units	68.02 kg (150 lbs)
Tertiary Chlorinator	181.4 kg/day (400 lbs/day)
Rotameter-Tertiary	90.7 kg/day (200 lbs/day)
Adjustable Range	20 to 1
@ 5678 m^3/day (1.5 mgd)	16 mg/l to 0.8 mg/l
Secondary Chlorinator	
Rotameter-Secondary	45.35 kg/day (100 lbs/day)
Adjustable Range	20 to 1
@ 5678 m^3/day (1.5 mgd)	8 mg/l to 0.4 mg/l
B. Carbon Dioxide	
Storage Unit (Cardox Rental)	21.8 metric tons (24 tons)
Feeder	2721 kg/day (6000 lbs/day)
Rotameter	2040.75 kg/day (4500 lbs/day)
Adjustable Range	20 to 1
@ 5678 m^3/day (1.5 mgd)	360 mg/l to 18 mg/l
C. Lime	
Storage (2 bins)	50.95 m^3 (1800 cf)
Gravimetric Slakers (2)	
Capacity (Max. Each)	453.5 kg/hr (1,000 lbs/hr)
Accuracy	$\pm$ 1%
Range (Each)	0 to 453.5 kg/hr (0 to 1000 lbs/hr)
@ 5678 m^3/day (1.5 mgd)	0 to 1920 mg/l
Ejector Pumps (2) 36.57 m (120' TDH)	0.0378 m^3/s (60 gpm)
Motor (3450 rpm)	5 hp
D. Powdered Activated Carbon	
Storage Hopper	2.123 m^3 (75 cf)
Volumetric Feeder	0.2095 m^3/hr (7.4 cf/hr)
	34 kg/hr (75 lbs/hr)
Range	20 to 1
@ 0.0657 m^3/s (1.5 mgd)	144 mg/l to 7.2 mg/l
Slurry Feed Pump @ 39.0 m (128' TDH)	0.00144 m^3/s (23 gpm)
Motor (3500 rpm)	5 hp
Dust Collector	0.2359 m^3/s (500 cfm)
Motor	3/4 hp

E. Miscellaneous Chemicals	
Acid Storage (66° Baume')	16,655.8 ℓ (4400 gal)
Polymer Storage	
Dry Storage (Portable Chemix)	0.2547 m^3 (9 cf)
Batch Size (Chemix)	94.61 ℓ (25 gal)
Alum Room Day Tank	208.2 ℓ (55 gal)
Alum Storage 22.6 m^3	(800 cf) 22712.4 ℓ (6000 gal)
Metering Pumps (4) 0.861 Pa (125 psi)	5 to 79 ℓ (1.3 to 20.8 gal)
@ 0.0657 m^3/s (1.5 mgd)	0.87 mg/l to 13.87 mg/l
Motor (DC)	1/4 hp
15. Plant Flow Meters	
Trickling Filter - Recirculation - Propeller	
Chlorine Tank Effluent - Rectangular Weir	
Tertiary Plant Influent - 25.4 cm (10")Magnetic Meter	0.0126 to 0.1373 m^3/s (200 to 2180 gpm)
Underflow Sludge Flow Rate 7.62 cm (3") Magnetic Meter	0.00067 to 0.01008 m^3/s (11 to 160 gpm)
Plant Effluent Parshall Flume 228.6 mm (9") Throat	0.0316 to 0.0945 m^3/s (500 - 1500 gpm)
16. Emergency Generator	
KW Rating @ 0.8 Power Factor	200 kw
Engine Type 6 cylinder in line diesel	4 cycle
Engine Speed	1800 rpm
Brake Horsepower Available	311 hp
Fuel Consumption (100% load)	0.0617 m^3/hr (16.3 gph)
17. Boiler	
Horsepower	200 hp
Steam Production	0.8687 kg/s (6900 lbs/hr)
Fuel Consumption (150,000 BTU/gal)	0.211 m^3/hr (55.8 gph)
18. Fuel Oil System	
Storage (Buried)	
Generator	2119.83 ℓ (560 gal)
Boiler (2)	30283.29 ℓ (8,000 gal) each
Boiler Fuel Oil Pumps (2)	
Type	Gear

APPENDIX B

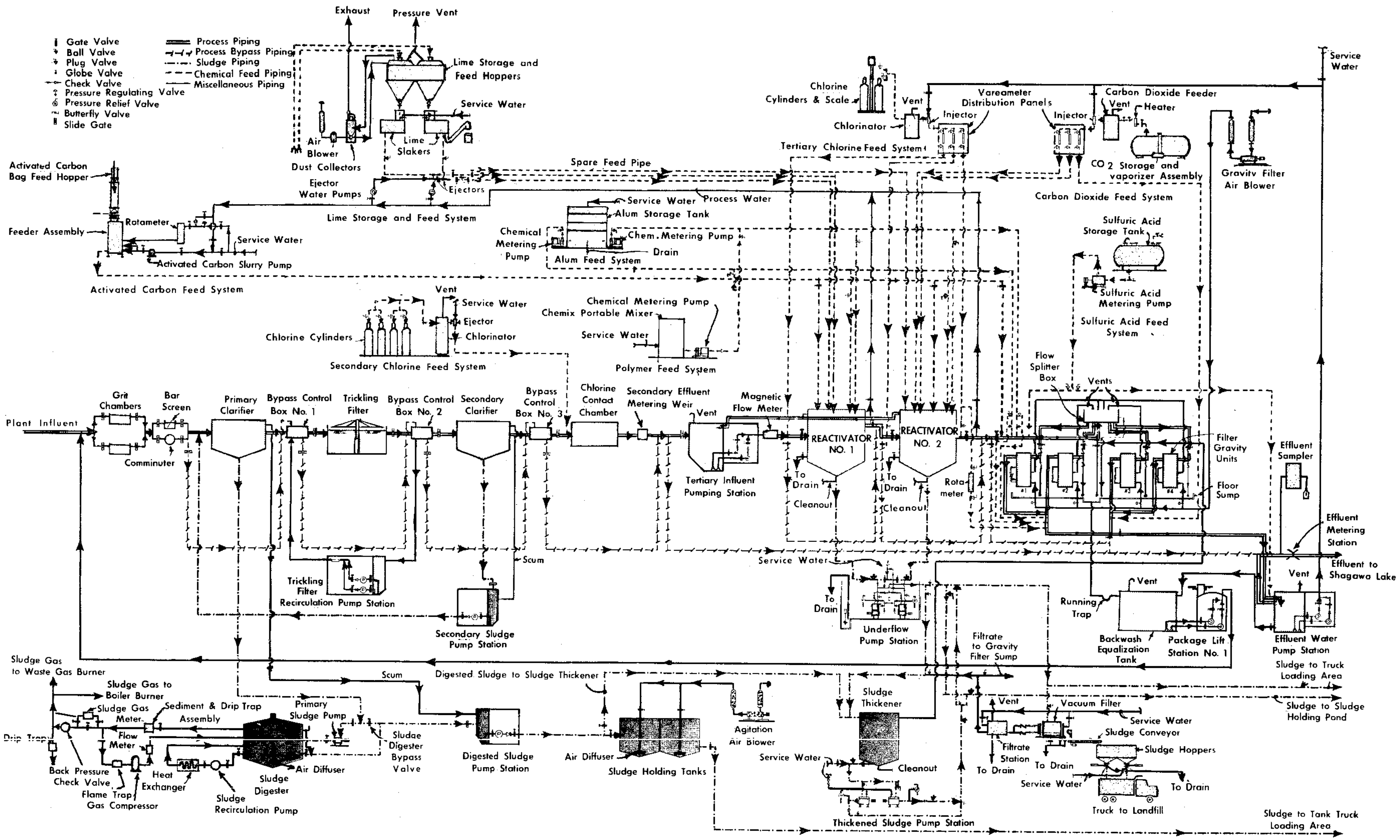
SCHEMATICS OF LIQUID AND SLUDGE FLOWS



STP=City Secondary Wastewater Treatment Plant
IF=Influent Tank
M=Flow Meter
CU_1 =#1 Contact Unit
CU_2 =#2 Contact Unit
ST = Sludge Thickener
SVF = Sludge Vacuum Filter

ET = Equalization Tank
SB = Splitter Box
F = Gravity Filter
VW = Viewing Well
PF = Parshall Flume
SD = Stinky Ditch
SHP = Sludge Pond
SW = Swamp East Side of Plant

APPENDIX B, FIGURE B-1.



APPENDIX B FIGURE B-2. WASTEWATER TREATMENT PLANT FLOW SCHEMATIC

APPENDIX B

Water Budget Equation

$Q_{\emptyset} = Q_I + Q_B - (Q_3 + Q_8) - (Q_5 + Q_9 + Q_{12} + Q_{16} + Q_{21}) - (Q_{14} + Q_{17} + Q_{48}) - (Q_4 + Q_7 + Q_{11}) + (Q_{23} + Q_{24} + Q_{27} + Q_{31})$

$Q_{\emptyset}$ = Discharge to Lake - Metered and Recorded

Q_I = Influent to Tertiary Treatment Process - Metered and Recorded

Q_B = AWT Plant By-Pass - Not Metered

$Q_3 + Q_8$ = 27,707 GPD Sludge Withdrawal from CU_1 + CU_2 (6-73 thru 3-74 average - nearly constant)

$Q_5 + Q_9 + Q_{12} + Q_{16} + Q_{21}$ = 18,039 Constant

$Q_{14} + Q_{17} + Q_{48}$ = 24,376 GPD Constant

$Q_4 + Q_7 + Q_{11} = CU_1 + CU_2 + SB$ Overflows rarely occur

$Q_{23} + Q_{24} + Q_{27} + Q_{31}$ = 200 GPD Constant

$Q_{\emptyset} = Q_I + Q_B - 27{,}707 - 18{,}039 - 24{,}376 + 200$

$Q_{\emptyset} = Q_I + Q_B - 70{,}000$

Q_C = Flow from City Collection System - Not Metered

Q_S = Secondary Effluent - Metered and Recorded

Q_I = Influent to Tertiary Treatment Process - Metered and Recorded

$Q_{\emptyset}$ = Discharge to Shagawa Lake - Metered and Recorded

Q_B = AWT Plant By-Pass - Not Metered

Q_T = Influent to AWT Plant

Q_1 = Pumped from Influent Tank to CU_1

Q_2 = Sample Flow (TC_1)

Q_3 = Sludge Withdrawal from CU_1

Q_4 = Overflow from CU_1

Q_5 = Sample Flow (TC_2)

Q_6 = Effluent from CU_1, Influent to CU_2

Q_7 = Overflow from CU_2

Q_8 = Sludge Withdrawal from CU_2

Q_9 = Sample Flow (TS_1)

Q_{10} = Effluent from CU_2, Influent to SB

Q_{11} = Overflow from SB

Q_{12} = Sample Flow (TS_2)

Q_{13} = Effluent from SB, Influent to F

Q_{14} = Filter Backwash Water

Q_{15} = Effluent from F, Influent to VW

Q_{16} = Sample Flow (TVW)

Q_{17} = General Use Flow (like washing down floors)

Q_{18} = Special Use Flow (slaking lime, CO_2 feed, etc.)

Q_{19} = Effluent from VW

Q_{20} = Influent to PF

Q_{21} = Sample Flow (TP)

Q_{22} = Chemical Feed Prior to SB

Q_{23} = Sulfuric Acid Feed

Q_{24} = Ferric Chloride Feed

Q_{25} = Chlorine Feed, Part of Q_{22}

Q_{26} = Water & Chemical Feed to CU_2

Q_{27} = Ferric Chloride Feed

Q_{28} = Fiber Bearing Water

Q_{29} = Carbon Dioxide Feed

Q_{30} = Water & Chemical Feed to CU_1

Q_{31} = Polyelectrolyte (Uses City Service Water)

Q_{32} = Fiber Bearing Water

Q_{33} = Lime Feed

Q_{34} = Wastewater (Not Secondary) Influent to IF

Q_{35} = Internal Plant Sewer - Showers, Toilets, etc.

Q_{36} = Seepage into Equalization Tank

Q_{37} = North Side Floor Drains

Q_{38} = South Side Floor Drains

$Q_{39} = Q_{11} + Q_{14} + Q_{38} + Q_{36} + Q_{35}$

Q_{40} = Sludge Vacuum Filter Belt Wash Water

Q_{41} = Sludge Vacuum Filter Filtrate

Q_{42} = Sludge Thickener Overflow

$Q_{43} = Q_{40} + Q_{41} + Q_{42}$

Q_{44} = Equalization Tank Contents Pumped to City Plant

$Q_{45} = Q_{46} + Q_{47}$

Q_{46} = Stinky Ditch

Q_{47} = Drainage from Sludge Holding Pond

Q_{48} = Sludge Vacuum Filter Belt Wash Water

$Q_{49} = Q_{14}$

Q_{50} = Sludge from Thickener (Use only when Sludge Vacuum Filter is down.)

Q_{51} = Solids to Sanitary Land Fill

Q_{52} = Sludge from Thickener to Vacuum Filter

Q_{53} = Primary Sludge from City Plant to Sludge Thickener

Q_{54} = Swamp, East Side of Plant (Receives Septic Tank Effluent)

APPENDIX C

SECONDARY PLANT DATA

Table C-1 Primary Influent (mg/l)

Month	Total Phosphorus	Suspended Solids	Alkalinity as $CaCO_3$	B.O.D.	pH
July 1973	7.08	276	181	136	7.54
August	4.47	297	187	66	8.18
September	4.14	74	137	60	7.36
October	4.05	68	148	39	7.66
November	11.01	357	235	80	8.24
December	---	---	---	---	---
January 1974	9.09	177	204	113	8.25
February	9.00	203	186	120	8.12
March	7.72	162	172	109	7.89
Average	7.07	202	181	90	7.90

Table C-2 Secondary Effluent (mg/l)

Month	Total Phosphorus	Suspended Solids	Alkalinity as $CaCO_3$	B.O.D.	pH
July 1973	4.39	79	142	68	---
August	3.16	75	149	23.5	7.43
September	3.36	16	143	23.9	7.22
October	2.93	23	136	18.1	7.26
November	2.96	30	133	40	7.43
December	---	--	---	---	---
January 1974	4.33	58	142	---	7.44
February	4.78	33	135	46	7.30
March	4.57	42	130	56	7.22
Average	3.81	44	139	39	7.33

Table C-3 Removal Through Trickling Filter Plant (%)

Month	Total Phosphorus	Suspended Solids	Alkalinity as $CaCO_3$	B.O.D.
July 1973	46.0%	72.0%	22.0%	50.0%
August	34	75	20	64
September	20	78	-7	60
October	27	66	8	53
November	68	92	43	50
December	--	--	--	--
January 1974	51	67	30	--
February	48	84	27	62
March	41	74	24	49
Average	45.6%	76%	21%	55%

APPENDIX D

YEARLY DATA SUMMARY - PLANT OPERATION AND PERFORMANCE *

Influent to Tertiary Plant

Parameters	1973 April	May	June	July	August	September
Total Phosphorus Unfiltered	3.62	3.61	4.96	5.22	4.66	3.83
Total Phosphorus Filtered	2.42	2.30	3.34	2.74	2.30	1.93
Suspended Solids	37.0	46.0	60.1	105.0	100.0	71.0
Turbidity (JTU)	25.0	31.4	16.7	30.3	22.8	25.0
TOC	29.9	28.5	40.4	39.8	35.8	
TIC						
Calcium	39.8	47.8	53.9	56.8	53.4	47.4
Magnesium	6.3	8.62	8.3	7.2	7.5	6.7
Alk as $CaCO_3$	144.0	153.0	154.0	156.0	161.0	159.0
Iron						

* All units mg/l unless otherwise noted.

Influent to Tertiary Plant (Continued)

Parameters	October	November	December	1974 January	February	March	Yearly Average
Total Phosphorus Unfiltered	3.61	4.04	4.13	4.44	6.59	5.98	4.56
Total Phosphorus Filtered	1.79	2.74	2.96	3.03	3.49	3.10	2.68
Suspended Solids	63.0	44.0	36.0	41.0	122.0	110.0	70.3
Turbidity (JTU)	16.9	10.3	10.67	11.4	34.51	41.47	23.0
TOC			33.4	34.7	62.87	53.25	39.9
TIC				27.2	35.63		31.4
Calcium	54.0	45.0	30.0	34.7	27.0	27.93	43.2
Magnesium	6.86	6.8	6.1	5.6	5.4	5.65	6.75
Alk as $CaCO_3$	148.0	143.0	134.0	137.0	147.0	138.0	148.0
Iron	5.30	2.31		1.93	3.12	3.84	3.3

First-Stage Lime Clarifier - Operation and Performance Data

Parameters	1973 April	May	June	July	August	September
Flow (MGD)	1.164	1.356	1.107	1.302	1.50	1.33
Overflow rate (gpd/sq ft)	490	571.0	466.0	548.0	631.0	560.0
Lime (CaO)	283.0	266.0	287.0	340.0	342.0	343.0
Polymer (Betz 1150)	0.53	0.33	0.19	0.24	0.21	0.20
pH	12.07	11.96	11.87	11.90	11.88	11.90
Upper Mix Zone Solids Vol. (ml/l)	84.0	249.0	280.0	236.0	199.0	147.0
Lower Mix Zone Solids Vol. (ml/l)	249.0	388.0	351.0	299.0	275.0	191.0
Blanket (ft)	4.7	6.8	7.6	9.1	6.5	4.9
Total P - Unfiltered	0.568	0.318	0.267	0.306	0.249	0.269
Total P - Filtered	0.108	0.122	0.148	0.123	0.107	0.093
Suspended Solids	14.0	12.0	9.8	9.5	16.0	8.0
Turbidity (JTU)	6.0	6.1	2.67	2.11	1.86	1.89
TOC	-	-	-	-	19.7	-
TIC	-	-	-	-	-	-
Calcium	122.0	109.0	105.2	154.0	149.0	153.0
Magnesium	-	0.49	-	-	0.12	0.14
Iron	-	-	-	-	-	-
Alk as $CaCO_3$	-	-	-	-	-	-

First-Stage Lime Clarifier - Operation and Performance Data (Continued)

Parameters	October	November	December	1974 January	February	March	Yearly Average
Flow (MGD)	1.38	1.046	0.92	0.85	0.82	0.88	1.14
Overflow rate (gpd/sq ft)	581.0	440.0	387.0	358	345	371	479
Lime (CaO)	296.0	301.0	281.0	274.0	282.0	271.0	297.0
Polymer (Betz 1150)	0.19	0.17	0.21	0.19	0.21	0.23	0.24
pH	11.84	11.90	11.91	11.95	12.03	12.03	11.94
Upper Mix Zone Solids Vol. (ml/1)	185.0	220.0	188.0	134.0	253.0	289.0	205
Lower Mix Zone Solids Vol. (ml/1)	236	259	215	151	283	332	269
Blanket (ft)	5.4	5.3	5.0	4.6	5.5	6.22	6.0
Total P - Unfiltered	0.217	0.205	0.27	0.347	0.284	0.279	0.298
Total P - Filtered	0.089	0.085	0.091	0.094	0.127	0.126	0.109
Suspended Solids	8.3	8.5	6.5	7.0	7.0	9.0	9.6
Turbidity (JTU)	1.82	1.41	1.27	1.53	2.41	2.17	2.60
TOC	-	-	20.8	19.3	21.57	29.46	22.2
TIC	-	-	-	3.72	4.31	-	4.01
Calcium	140	115	101	94.2	98.6	101.05	120
Magnesium	0.23	1.27	0.95	0.6	0.2	0.25	0.47
Iron	0.12	0.071	0.105	0.92	0.089	0.119	0.099
Alk as $CaCO_3$	-	-	-	-	-	-	-

Second-Stage Lime Clarifier - Operation and Performance Data

Parameters	1973 April	May	June	July	August	September
Flow (MGD)	1.164	1.356	1.107	1.302	1.50	1.33
Recirculation (MGD)	0.183	0.208	0.196	0.199	0.199	0.198
Overflow rate (gpd/sq ft)						
CO_2	118	95	82	125	131	122
$FeCl_3$ as Fe	5.60	6.07	5.57	4.50	5.79	6.56
pH	9.60	9.56	9.56	9.66	9.64	9.61
Solids Vol. (ml/l) UMZ	95	45	40	61	31	140
Solids Vol. (ml/l) LMZ	106	55	46	74	41	162
Blanket (ft)	6	1.9	2.9	2.8	2.8	3.8
Total P - Unfiltered	0.171	0.110	0.097	0.137	0.070	0.046
Total P - Filtered	0.074	0.060	0.024	0.047	0.020	0.019
Suspended Solids	5	6	8	12	11	5
Turbidity (JTU)	3.1	3.2	2.53	2.40	1.88	0.85
TOC	20.5	15.4	-	-	-	-
TIC	-	-	-	-	-	-
Calcium	57.3	47.7	25.4	40.9	46.6	26.4
Iron	-	-	-	-	-	-
Alk as $CaCO_3$	89.4	74.2	68.9	72.7	55.8	47.8

Second-Stage Lime Clarifier - Operation and Performance Data (Continued)

Parameters	October	November	December	1974 January	February	March	Yearly Average
Flow (MGD)	1.38	1.05	0.92	0.85	0.82	0.88	1.14
Recirculation (MGD)	0.174	0.159	0.166	0.164	0.160	0.166	0.181
Overflow Rate (gpd/sq ft)							556
CO_2	108	98	79	81	82	80	100
$FeCl_3$ as Fe	5.87	6.07	5.79	5.88	7.13	7.19	6.0
pH	9.60	9.60	9.59	9.55	9.62	9.65	9.60
Solids Vol. (ml/1) UMZ	146	140	180	148	160	99	107
Solids Vol. (ml/1) LMZ	173	160	194	160	177	113	122
Blanket (ft)	4.0	3.4	4.3	3.9	4.0	3.3	3.6
Total P - Unfiltered	0.034	0.056	0.046	0.060	0.060	0.105	0.083
Total P - Filtered	0.018	0.031	0.024	0.031	0.027	0.017	0.033
Suspended Solids	6	7	4	3.5	7	11	7.1
Turbidity (JTU)	0.94	1.63	1.28	0.99	1.38	3.38	1.96
TOC	-	-	19.0	14.6	15.7	24.58	18.3
TIC	-	-	7.04	10.0	12.68	-	9.9
Calcium	27.8	23.1	27.4	34.7	36.0	36.7	35.8
Iron	-	0.44	0.43	0.544	0.590	0.717	0.544
Alk as $CaCO_3$	-	-	-	-	-	-	68

Gravity Filter Influent Data

Parameters	1973 April	May	June	July	August	September
Total P - Unfiltered	0.171	0.115	0.098	0.142	0.073	0.043
Total P - Filtered	0.074	0.022	0.043	0.073	0.039	0.016
Suspended Solids	5	15	7	8	7	7
Turbidity (JTU)	3.1	5.9	2.4	1.53	1.21	1.30
TOC	-	-	-	-	-	-
TIC	-	-	-	-	-	-
Calcium	57.3	39.3	28.0	36.6	42.8	27.0
Magnesium	0.65	0.59	-	-	-	-
Alk as $CaCO_3$	-	57.0	40.0	43.4	40.4	24.0
Iron	-	-	-	-	-	-
Total Solids	303	224	-	-	-	-
Temperature (°C)	-	-	13.0	15.1	15.4	16.2
$FeCl_3$ as Fe^{+3} (dosage)[1]	0	2.38	2.12	2.20	2.24	2.42
Cl_2 (dosage)	1.92	3.08	2.98	3.80	4.84	3.65

(1) Starting May 10, 1973

Gravity Filter Influent Data (Continued)

Parameters	October	November	December	1974 January	February	March	Yearly Average
Total P - Unfiltered	0.046	0.054	0.045	0.061	0.081	0.144	0.089
Total P - Filtered	0.019	0.027	0.017	0.021	0.036	0.065	0.038
Suspended Solids	6	7	8.7	9	10	14	8.6
Turbidity (JTU)	1.48	1.45	1.83	1.43	2.19	2.8	2.22
TOC	-	-	18.8	17.5	16.08	25.53	19.5
TIC	-	-	5.9	9.1	10.37	-	8.5
Calcium	38.0	25.0	29.7	36.2	41.09	52.5	37.8
Magnesium	-	-	-	-	-	-	0.62
Alk as $CaCO_3$	20.5	22.8	33.5	49.9	42.7	44.8	38.1
Iron	3.15	2.98	3.40	3.47	3.23	4.24	2.25
Total Solids	239	176	154	205	274	-	225
Temperature °C	14.8	11.7	9.6	8.82	8.66	7.68	12.10
$FeCl_3$ as Fe^{+3} (dosage)	2.32	2.88	3.23	3.24	3.41	5.51	2.66
Cl_2 (dosage)	2.79	2.85	2.62	2.34	2.40	3.17	3.04

Tertiary Plant Effluent Data

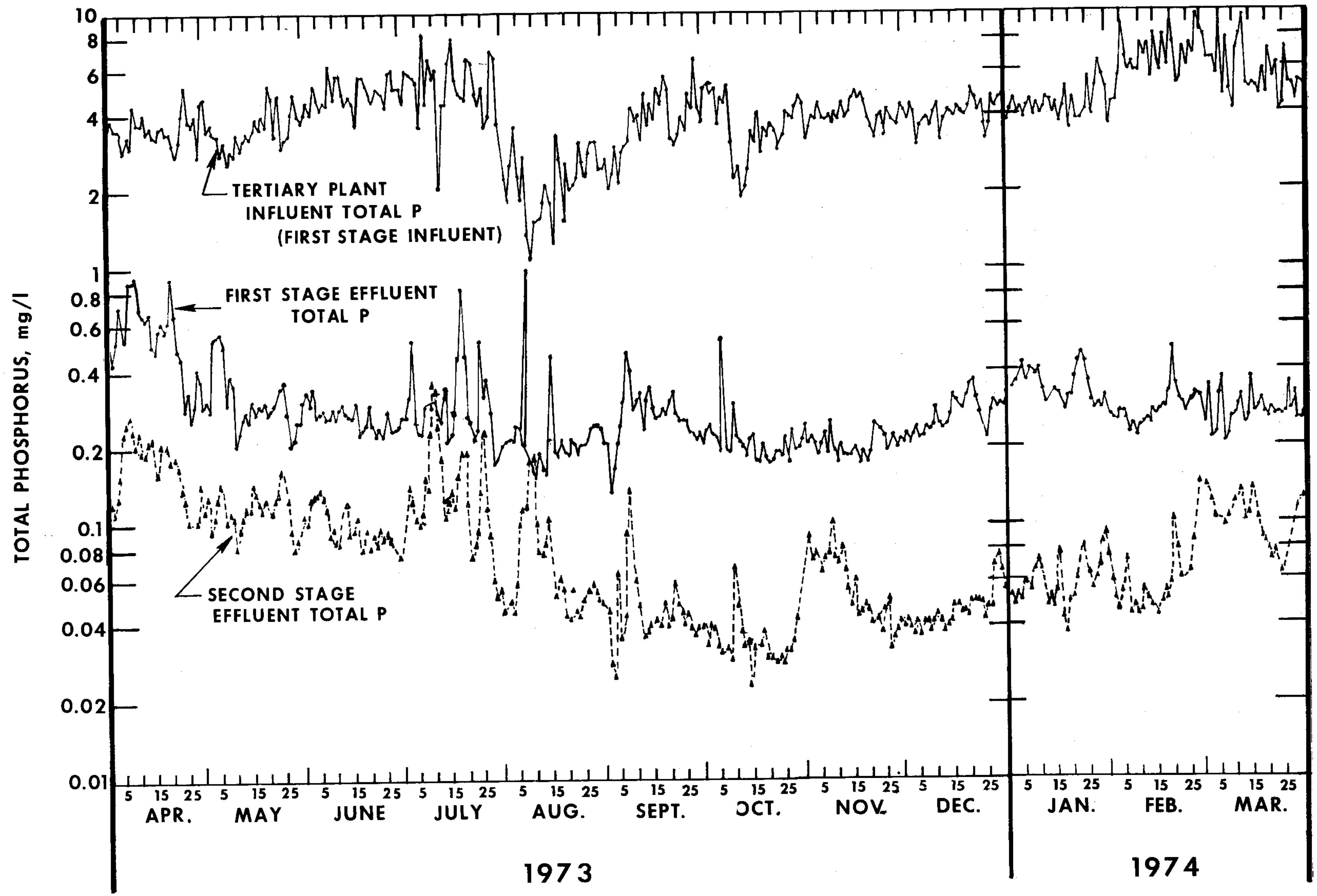
Parameters	1973 April	May	June	July	August	September
Total P - Unfiltered	0.070	0.060	0.046	0.076	0.041	0.022
Total P - Filtered	0.058	0.046	0.033	0.062	0.038	0.016
Suspended Solids	2	1	0.76	1.6	1	1
Turbidity (JTU)	2.6	1.2	0.45	0.17	0.11	0.33
TOC	19.9	18.4	16.0	12.1	8.9	-
TIC	-	-	-	-	-	-
Calcium	65.7	49.7	28.7	36.6	37.6	27.4
Magnesium	0.58	0.57	0.3	0.2	0.3	0.11
Alk as $CaCO_3$	90.4	59.6	38.7	42.2	32.4	23.9
Iron	-	-	-	-	-	-
BOD	-	-	23.8	10.3	-	-
Total Coliform (No./100 ml)	-	-	0	0	0	0
Fecal Coliform (No./100 ml)	-	-	0	0	0	0
D.O.	-	-	9.1	9.3	9.3	8.9
Residual Chlorine	0.46	0.52	0.55	0.45	0.41	0.51
pH	7.67	7.55	7.42	7.53	7.50	7.51

Tertiary Plant Effluent Data (Continued)

Parameters	October	November	December	1974 January	February	March	Yearly Average
Total P - Unfiltered	0.023	0.032	0.021	0.026	0.043	0.077	0.045
Total P - Filtered	0.017	0.029	0.017	0.022	0.036	0.065	.037
Suspended Solids	1.7	1.0	1.4	1.0	1.5	2	1.3
Turbidity (JTU)	0.44	0.33	0.32	0.14	0.20	0.43	0.56
TOC	-	-	16.7	15.0	16.2	23.75	16.3
TIC	-	-	5.88	-	9.98	-	7.9
Calcium	40.4	24.8	27.4	36.3	41.53	53.51	39.1
Magnesium	0.15	1.27	0.43	0.56	0.3	0.28	.42
Alk as $CaCO_3$	22.3	22.1	33.7	49.9	42.7	44.8	41.9
Iron	0.20	0.21	0.17	0.176	0.175	0.300	0.21
BOD	-	-	-	3.78	11.27	-	12.3
Total Coliform (No./100 ml)	0.6	0	0.1	0.3	0	0	0.10
Fecal Coliform (No./100 ml)	0.16	0	0	0	0	0	0.02
D.O.	9.25	10.04	10.3	10.6	10.83	11.4	9.9
Residual Chlorine	0.51	0.25	0.17	0.14	0.16	0.18	0.36
pH	7.45	7.53	7.54	7.50	7.40	7.47	7.50

APPENDIX E

TOTAL PHOSPHORUS DATA: APRIL, 1973 THRU MARCH, 1974



APPENDIX E, FIGURE E-1. DAILY TOTAL P CONCENTRATION FROM APRIL 1, 1973 TO MARCH 31, 1974 (mg/l).

Table E-1

TOTAL PHOSPHORUS DATA FOR 24–HOUR COMPOSITE SAMPLES

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
April 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL–MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1			3.42	0.582	0.122	0.030		83.0	79.0	75.4	99.1	
2			3.89	0.439	0.111	0.022	0.032	88.7	74.7	80.2	99.4	
3			3.59	0.535	0.127	0.028	0.035	85.1	76.3	78.0	99.2	
4			3.57	0.729	0.155	0.032	0.038	79.6	78.7	79.4	99.1	
5			3.49	0.539	0.224	0.030	0.035	84.6	58.4	86.6	99.1	
6		4.74	2.92	0.540	0.249	0.026	0.035	81.5	53.9	89.6	99.1	
7		3.70	3.31	0.903	0.267	0.032	0.036	72.7	70.4	80.0	99.0	
8		3.79	3.07	0.902	0.238	0.035	0.035	70.6	73.6	85.3	98.9	
9		6.26	4.43	0.943	0.205	0.024	0.039	78.7	78.3	88.3	99.5	
10		4.18	3.73	0.717	0.232	0.039	0.043	80.8	67.6	83.2	99.0	
11		4.35	3.78	0.674	0.191	0.078	0.065	80.2	71.7	59.2	97.9	
12		4.24	4.04	0.641	0.190	0.072	0.074	84.1	70.4	62.1	98.2	
13		4.27	3.52	0.688	0.208	0.079	0.075	80.5	69.8	62.0	97.8	
14		3.99	3.63	0.514	0.217	0.091	0.077	85.8	57.8	58.1	97.5	
15			3.39	0.488	0.184	0.073	0.070	85.6	62.3	60.3	97.8	
16		3.61	3.34	0.586	0.159	0.080	0.080	82.5	72.9	49.7	97.6	
17		4.45	3.64	0.627	0.201	0.100	0.096	82.8	67.9	50.2	97.3	
18		4.56	3.70	0.579	0.197	0.101	0.104	84.4	66.0	48.7	97.3	
19		4.09	3.46	0.629	0.208	0.107	0.102	81.8	66.9	48.6	96.9	
20		3.57	3.49	0.935	0.179	0.091	0.085	73.2	80.9	49.2	97.4	
21		3.67	3.14	0.665	0.186	0.105	0.114	78.8	72.0	43.5	96.7	
22			2.80	0.494	0.169	0.101	0.090	82.4	65.8	40.2	96.4	
23		4.09	3.20	0.454	0.138	0.101	0.083	85.8	69.6	26.8	97.4	
24			4.02	0.280	0.126	0.089	0.079	93.0	55.0	29.4	98.0	
25		4.40	5.25	0.331	0.101	0.078	0.073	93.7	69.5	22.8	98.6	
26		4.03	3.81	0.259	0.100	0.079	0.068	93.2	61.4	21.0	98.2	
27		3.81	3.60	0.295	0.100	0.078	0.065	91.8	66.1	22.0	97.8	
28		3.17	4.07	0.413	0.101	0.078	0.078	89.9	75.5	22.8	98.1	
29		4.06	2.83	0.371	0.143	0.114	0.100	86.9	61.5	20.3	96.0	
30		5.11	4.54	0.294	0.111	0.094	0.094	93.5	62.2	15.3	97.9	
MEAN		4.188	3.622	0.5682	0.1713	0.0695	0.0690	83.84	68.54	54.61	98.07	
STD DEV		0.6323	0.5149	0.1938	0.0494	0.0305	0.0251	5.988	7.201	24.24	0.9340	
%CV		15.1	14.2	34.1	28.9	43.9	36.4	7.14	10.5	44.4	0.952	

EPA-280 (Cin)
(12-75)

Table E-1 (continued)

TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
May 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1		4.74	4.74	0.307	0.129	0.108	0.103	93.5	58.0	16.3	97.7	
2			3.64	0.280	0.094	0.072	0.059	92.3	66.4	23.4	98.0	
3			3.70	0.530	0.102	0.053	0.049	85.7	80.8	48.0	85.7	
4		3.70	3.49	0.557	0.125	0.058	0.048	84.0	77.6	53.6	98.3	
5		3.45	3.39	0.572	0.140	0.076	0.062	83.1	75.5	45.7	97.8	
6		2.29	2.88	0.500	0.147	0.079	0.196	82.6	70.6	46.3	97.3	
7			3.20	0.295	0.101	0.053		90.8	65.8	47.5	98.3	
8		2.45	2.63	0.384	0.109	0.046	0.091	85.4	71.6	57.8	98.3	
9		2.77	2.91	0.352	0.105	0.073	0.089	87.9	70.2	30.5	97.5	
10		2.22	2.85	0.208	0.080	0.053	0.059	92.7	61.5	33.8	98.1	
11		2.81	3.42	0.230	0.093	0.051	0.062	93.3	59.6	45.2	98.5	
12		3.01	2.95	0.260	0.108	0.051	0.059	91.2	58.5	52.8	98.3	
13		2.99	3.28	0.277	0.114	0.053	0.049	91.6	58.8	53.5	98.4	
14		3.38	3.49	0.252	0.114	0.051	0.049	92.8	54.8	55.3	98.5	
15			3.30	0.302	0.143	0.065	0.053	90.8	52.6	54.5	98.0	
16		3.32	3.53	0.276	0.130	0.064	0.043	92.2	52.9	50.8	98.2	
17		3.55	3.85	0.298	0.120	0.050	0.043	92.3	59.7	58.3	98.7	
18		4.04	3.52	0.288	0.112	0.061	0.051	91.8	61.1	45.5	98.3	
19		4.68	4.04	0.298	0.122	0.065	0.057	92.6	59.1	46.7	98.4	
20		3.30	3.66	0.274	0.115	0.068	0.051	92.5	58.0	40.9	98.1	
21			5.26	0.281	0.111	0.058	0.048	94.7	60.5	47.7	98.9	
22		3.74	4.63	0.298	0.125	0.065	0.048	93.6	58.1	48.0	98.6	
23		2.78	3.37	0.301	0.130	0.064	0.052	91.1	56.8	50.8	98.1	
24			4.81	0.346	0.162	0.086	0.070	92.8	53.2	46.9	98.2	
25		2.91	3.06	0.367	0.152	0.073	0.057	88.0	58.6	52.0	97.6	
26		3.32	3.28	0.277	0.125	0.065	0.058	91.6	54.9	48.0	98.0	
27		3.43	3.35	0.209	0.094	0.047	0.050	93.8	55.0	50.0	98.6	
28		4.74	4.17	0.219	0.080	0.036	0.040	94.7	63.5	55.0	99.1	
29		3.94	4.99	0.253	0.086	0.033	0.038	95.0	66.0	61.6	99.3	
30			4.11	0.253	0.091	0.039	0.036	93.8	64.0	57.1	99.1	
31		3.60	3.79	0.309	0.108	0.047	0.044	91.8	65.0	56.5	98.8	
MEAN		3.384	3.655	0.3178	0.1151	0.0601	0.0605	90.97	62.22	47.74	97.89	
STD DEV		0.7069	0.6635	0.9650	0.0207	0.0154	0.0298	3.457	7.319	9.998	2.310	
%CV		20.9	18.2	30.4	18.0	25.6	49.2	3.8	11.76	20.9	2.4	

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
June 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1			4.10	0.331	0.109	0.044	0.041	91.9	67.1	59.6	98.9	
2		4.78	4.63	0.296	0.125	0.048	0.041	93.6	57.8	61.6	99.0	
3		3.64	4.10	0.341	0.127	0.048	0.037	91.7	62.8	62.2	98.8	
4		5.18	5.33	0.269	0.122	0.039	0.049	95.0	54.6	68.0	99.3	
5			4.71	0.273	0.136	0.058	0.053	94.2	50.2	57.4	98.8	
6			4.29	0.280	0.133	0.060	0.052	93.5	52.5	54.9	98.6	
7			4.57	0.260	0.114	0.050	0.052	94.3	56.2	56.1	98.9	
8		4.53	4.45	0.262	0.097	0.053	0.042	94.1	63.0	45.4	98.8	
9			6.34	0.285	0.094	0.046	0.038	95.5	67.0	51.1	99.3	
10			4.65	0.260	0.089	0.039	0.035	94.4	65.8	56.2	99.2	
11			5.72	0.288	0.086	0.043	0.040	95.0	70.1	50.0	99.2	
12			5.69	0.299	0.107	0.048	0.043	94.7	64.2	55.1	99.2	
13			4.93	0.278	0.118	0.050	0.053	94.4	57.6	57.6	99.0	
14			4.50	0.269	0.094	0.048	0.042	94.0	65.1	48.9	98.9	
15			4.79	0.263	0.089	0.046	0.028	94.5	66.2	48.3	99.0	
16			4.52	0.306	0.109	0.050	0.045	93.2	64.4	54.1	98.9	
17			3.70	0.229	0.083	0.043	0.032	93.8	63.8	48.2	98.8	
18			5.65	0.237	0.083	0.033	0.053	95.8	65.0	60.2	99.4	
19			5.66	0.245	0.100	0.050	0.050	95.7	59.2	50.0	99.1	
20			5.32	0.291	0.080	0.035	0.040	94.5	72.5	56.3	99.3	
21			4.89	0.249	0.089	0.044	0.040	94.9	64.3	50.6	99.1	
22			4.49	0.222	0.084	0.039	0.043	95.1	62.2	53.6	99.1	
23			5.11	0.238	0.093	0.060	0.047	95.3	60.9	35.5	98.8	
24			4.99	0.224	0.083	0.062	0.063	95.5	62.9	25.3	98.8	
25			4.97	0.259	0.089	0.053	0.053	94.8	65.6	40.4	98.9	
26			4.29	0.278	0.084	0.048	0.047	93.5	69.8	42.9	98.9	
27			5.96	0.233	0.079	0.039	0.049	96.1	66.1	50.6	99.3	
28			6.08	0.238	0.073	0.042	0.039	96.1	69.3	42.5	99.3	
29			5.17	0.242	0.082	0.037	0.036	95.3	66.1	54.9	99.3	
30			5.06	0.263	0.094	0.038	0.037	94.8	64.3	59.6	99.2	
MEAN		4.532	4.955	0.2669	0.0982	0.0464	0.044	94.51	63.22	51.90	99.04	
STD DEV		0.6524	0.6401	0.0296	0.0176	0.0075	0.0076	1.065	5.20	8.65	0.2125	
%CV		14.4	12.92	11.10	17.9	16.2	17.4	1.13	8.23	16.66	0.21	

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
July 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1			4.54	0.265	0.122	0.044	0.043	94.2	54.0	63.9	99.0	
2			5.87	0.319	0.120	0.053	0.044	94.6	62.4	55.8	99.1	
3			5.80	0.525	0.105	0.057	0.057	90.9	80.0	45.7	99.0	
4			5.60	0.255	0.102	0.053	0.032	95.4	60.0	48.0	99.0	
5			5.29	0.229	0.103	0.051	0.051	95.7	55.0	50.5	99.0	
6	5.93		3.60	0.229	0.124	0.065	0.065	93.6	45.9	47.6	98.2	98.9
7			8.37	0.291	0.149	0.093	0.093	96.5	48.8	37.6	98.9	
8			4.40	0.222	0.147	0.075	0.075	95.0	33.8	49.0	98.3	
9			6.66	0.288	0.337	0.138	0.138	95.7	17.0	59.0	97.9	
10	7.63	5.66	5.48	0.302	0.323	0.104	0.104	94.5	6.9	67.8	98.1	98.6
11	11.5	4.14	5.93	0.295	0.289	0.118	0.123	95.0	2.0	59.2	98.0	99.0
12			2.08	0.256	0.219	0.118	0.118	87.7	14.4	46.1	94.3	
13			4.45	0.345	0.149	0.097	0.097	92.2	56.8	34.9	97.8	
14			4.43	0.215	0.151	0.105	0.105	95.1	29.8	30.5	97.6	
15			6.40	0.229	0.131	0.091	0.091	96.4	42.8	30.5	98.6	
16			7.83	0.270	0.132	0.083	0.083	96.6	51.1	37.1	98.9	
17	5.53	4.83	5.42	0.447	0.166	0.127	0.127	91.8	62.9	23.5	97.7	97.7
18	11.0	5.18	4.83	0.828	0.199	0.132	0.132	82.9	76.0	33.7	97.3	98.8
19			4.79	0.463	0.176	0.104	0.104	90.3	62.0	40.9	97.8	
20			4.61	0.267	0.118	0.069	0.069	94.2	55.8	41.5	98.5	
21			6.65	0.255	0.078	0.044	0.044	96.2	69.4	43.6	99.3	
22			6.40	0.216	0.065	0.043	0.043	96.6	69.9	33.8	99.3	
23		4.40	4.82	0.235	0.101	0.063	0.063	95.1	57.0	37.6	98.7	
24	5.11	5.35	4.43	0.525	0.142	0.089	0.089	88.1	72.9	37.3	98.0	98.3
25	3.82	3.27	5.07	0.317	0.252	0.100	0.100	93.7	20.5	60.3	98.0	97.4
26	6.16	2.29	3.66	0.371	0.129	0.074	0.660	89.9	65.2	42.6	98.0	98.8
27			4.00	0.274	0.090	0.053	0.114	93.2	67.2	41.1	98.7	
28			7.19	0.173	0.054	0.035	0.036	97.6	68.8	35.2	99.5	
29			6.69	0.180	0.044	0.021	0.025	97.3	75.6	52.3	99.7	
30			3.74	0.195	0.042	0.025	0.024	94.8	78.5	40.5	99.3	
31			2.81	0.201	0.042	0.024	0.024	92.8	79.1	42.9	99.1	
MEAN	7.085	4.390	5.221	0.3059	0.1420	0.0757	0.1125	93.66	51.41	44.19	98.41	98.44
STD DEV	2.785	1.139	1.408	0.1337	0.07616	0.0333	0.1958	3.227	25.59	10.59	0.9896	0.593
%CV	39.3	25.9	26.97	43.7	53.6	44.0	174.0	3.44	49.78	23.96	1.01	0.60

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Aug. 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1			5.62	0.211	0.047	0.024	0.025	96.2	77.7	48.9	99.6	
2			4.18	0.214	0.066	0.029	0.027	94.9	69.2	56.1	99.3	
3			6.91	0.211	0.048	0.029	0.028	96.9	77.2	39.6	99.6	
4			4.99	0.241	0.053	0.031	0.037	95.2	78.0	41.5	99.4	
5	4.00	2.73	5.33	0.240	0.104	0.068	0.074	95.5	56.7	34.6	98.7	98.3
6	4.56	3.10	3.50	0.205	0.110	0.076	0.080	94.1	46.3	30.9	97.8	98.3
7			4.43	0.493	0.115	0.093	0.135	88.9	76.7	19.1	97.9	
8			2.91	1.00	0.189	0.096	0.637	65.6	81.1	49.2	96.7	
9			2.24	0.168	0.178	0.068	0.277	92.5	6.0	61.8	97.0	
10			3.14	0.154	0.110	0.058	0.069	95.1	28.6	47.3	98.2	
11			--	0.190	0.093	0.054	0.066	99.5	51.0	41.9	98.0	
12			2.69	0.163	0.078	0.068	0.060	93.9	52.1	12.8	97.5	
13		3.31	3.99	0.158	0.137	0.048	0.057	96.0	13.3	65.0	98.8	
14	2.94	3.02	4.71	0.215	0.083	0.055	0.055	95.4	61.4	33.7	98.8	98.1
15			3.96	0.471	0.067	0.044	0.049	88.1	85.8	34.3	98.9	
16			3.91	0.191	0.044	0.030	0.025	95.1	77.0	31.8	99.2	
17			9.02	0.184	0.050	0.029	0.031	98.0	72.8	42.0	99.7	
18			5.30	0.213	0.052	0.029	0.032	96.0	75.6	44.2	99.4	
19			2.98	0.190	0.046	0.024	0.024	93.6	75.8	47.8	99.2	
20			5.71	0.187	0.040	0.024	0.029	96.7	78.6	40.0	99.6	
21	1.20	3.17	6.23	0.216	0.046	0.025	0.033	96.5	78.7	45.6	99.6	
22	9.74	3.16	4.02	0.208	0.045	0.026	0.027	94.8	78.4	42.2	99.3	99.7
23			4.82	0.186	0.043	0.023	0.023	96.1	76.9	46.5	99.5	
24			4.97	0.205	0.048	0.030	0.029	95.9	76.6	37.5	99.4	
25			4.85	0.205	0.051	0.032	0.032	95.8	75.1	37.2	99.3	
26			3.99	0.215	0.049	0.030	0.032	94.6	77.2	38.8	99.2	
27			5.11	0.240	0.056	0.034	0.036	95.3	76.7	39.3	99.3	
28			5.51	0.242	0.060	0.035	0.036	95.6	75.2	41.7	99.4	
29	4.96	3.70	5.75	0.249	0.051	0.029	0.027	95.7	79.5	43.1	99.5	99.4
30	3.89	3.07	5.15	0.238	0.047	0.021	0.028	95.4	80.2	55.3	99.6	99.5
31			3.82	0.209	0.046	0.024	0.048	94.5	78.0	47.8	99.4	
MEAN	4.47	3.1575	4.658	0.2488	0.0726	0.0415	0.0699	93.14	67.14	41.85	98.93	98.88
STD DEV	2.6335	0.2753	1.373	0.1576	0.0393	0.0213	0.1157	7.117	21.119	10.63	0.8149	0.722
%CV	58.91	8.72	29.48	63.34	54.16	51.25	165.41	8.285	31.46	25.40	0.8237	0.730

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24–HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Sept. 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL–MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1			2.71	0.209	0.038	0.022	0.554	92.29	81.82	42.10	99.19	
2			2.08	0.134	0.027	0.016	0.382	93.56	79.85	40.74	99.23	
3			2.35	0.166	0.023	0.014	0.109	92.94	86.14	39.13	99.40	
4			3.05	0.205	0.062	0.036	0.070	93.28	69.76	41.94	98.82	
5			2.19	0.242	0.033	0.018	0.078	88.95	86.36	45.45	99.18	
6	3.85	3.02	2.87	0.306	0.043	0.022	0.066	89.34	85.95	48.84	99.23	99.4
7	3.63	4.20	3.01	0.467	0.083	0.033	0.050	84.48	82.23	60.24	98.90	99.1
8			3.21	0.400	0.111	0.056	0.036	87.54	72.25	49.54	98.26	
9			4.35	0.280	0.057	0.023	0.025	93.56	79.64	59.65	99.47	
10			3.79	0.301	0.045	0.023	0.029	98.81	85.05	48.89	99.39	
11			4.00	0.321	0.042	0.020	0.026	91.98	86.92	52.38	99.50	
12			3.19	0.238	0.034	0.017	0.020	92.54	85.71	50.00	99.47	
13	4.43	2.63	4.83	0.309	0.035	0.021	0.020	93.60	88.67	40.00	99.56	99.5
14	3.60	2.83	3.67	0.341	0.039	0.019	0:021	90.71	88.56	51.28	99.48	99.5
15	3.71	3.14	4.45	0.288	0.037	0.017	0 .021	93.53	87.15	54.05	99.62	99.5
16	3.73	2.73	3.84	0.262	0.034	0.016	0.018	93.18	87.02	52.94	99.58	99.6
17	5.21	4.18	5.11	0.269	0.033	0.014	0.019	94.74	87.73	57.58	99.73	99.7
18	4.18	3.12	4.43	0.288	0.038	0.019	0.022	93.50	86.81	50.00	99.57	99.5
19	4.40	3.32	5.66	0.269	0.037	0.017	0.022	95.25	86.24	54.05	99.70	99.6
20	5.50	3.32	5.17	0.307	0.042	0.022	0.028	94.06	86.32	47.62	99.57	99.6
21	3.96	2.80	3.25	0.330	0.054	0.032	0.031	89.85	83.64	40.74	99.02	99.2
22	3.71	3.03	3.05	0.273	0.047	0.025	0.024	91.05	82.78	46.81	99.18	99.3
23	3.85	3.13	3.32	0.254	0.040	0.025	0.024	92.35	84.25	37.50	99.25	99.4
24	5.60	4.02	3.92	0.259	0.037	0.019	0.025	93.39	85.71	48.65	99.52	99.7
25	4.10	3.03	3.46	0.253	0.041	0.020	0.024	92.69	83.79	51.22	99.42	99.5
26	3.16		4.85	0.230	0.035	0.017	0.020	95.26	84.78	51.43	99.65	99.5
27			4.38	0.229	0.035	0.018	0.019	94.77	84.72	48.57	99.59	
28	4.35	7.20	6.76	0.217	0.035	0.019	0.020	96.79	83.87	45.71	99.72	99.6
29	3.60	1.41	4.35	0.230	0.040	0.020	0.020	94.71	82.61	50.00	99.54	99.4
30			3.74	0.206	0.035	0.019	0.019	94.49	83.01	45.71	99.49	
MEAN	4.143	3.359	3.8347	0.2694	0.0431	0.0220	0.0614	92.77	83.98	48.76	99.07	99.48
STD DEV	0.68027	1.1827	1.0603	0.0655	0.01708	0.00827	0.1148	2.782	4.210	5.662	1.759	0.159
%CV	16.42	35.21	27.65	24.31	39.63	37.59	186.97	2.999	5.013	11.61	1.776	0.160

EPA-280 (Cin)
(12-75)

Table E-1 (continued)

TOTAL PHOSPHORUS DATA FOR 24–HOUR COMPOSITE SAMPLES

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Oct. 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL–MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1	5.54	3.74	5.10	0.234	0.034	0.019	0.022	95.4	85.5	44.1	99.6	99.7
2	4.82	3.88	5.25	0.241	0.038	0.024	0.027	95.4	84.2	36.8	99.5	99.5
3	4.99	3.07	4.90	0.222	0.034	0.021	0.024	95.5	84.7	38.2	99.6	99.6
4	4.31	3.61	5.06	0.219	0.032	0.018	0.020	95.7	85.4	43.8	99.6	99.6
5	4.39	3.38	3.75	0.193	0.028	0.014	0.017	94.8	85.5	50.0	99.6	99.7
6	5.14	3.73	4.68	0.530	0.027	0.014	0.015	88.7	94.9	48.1	99.7	99.7
7	3.86	2.68	4.45	0.195	0.030	0.015	0.017	95.6	84.6	50.0	99.7	99.6
8	5.17	3.22	5.25	0.193	0.028	0.014	0.112	96.3	85.5	50.0	99.7	99.7
9	1.70	1.68	3.17	0.296	0.071	0.052	0.790	90.7	76.0	26.8	98.4	--
10	1.97	--	2.29	0.224	0.043	0.031	0.851	90.2	80.8	27.9	98.6	98.4
11	2.49	1.46	2.49	0.211	0.034	0.024	1.20	91.5	83.9	29.4	99.0	99.0
12	1.28	1.26	1.90	0.202	0.033	0.023	0.632	89.4	83.7	30.3	98.8	98.2
13	3.06	1.92	2.08	0.188	0.028	0.019	0.334	91.0	85.1	32.1	99.1	99.4
14	3.25	2.14	2.45	0.218	0.029	0.017	0.049	91.1	86.7	41.4	99.3	99.5
15	2.64	2.57	3.42	0.222	0.032	0.018	0.060	93.5	85.6	43.8	99.5	99.3
16	2.72	2.18	3.10	0.179	0.029	0.020	0.028	94.2	83.8	31.0	99.4	99.3
17	3.00	2.49	4.09	0.175	0.030	0.019	0.024	95.7	82.9	36.7	99.5	99.4
18	3.06	2.47	2.88	0.207	0.028	0.016	0.023	92.8	86.5	42.9	99.4	99.5
19	2.96	2.50	3.54	0.181	0.031	0.016	0.023	94.9	82.9	48.4	99.5	99.5
20	3.18	2.86	3.22	0.174	0.029	0.018	0.022	94.6	83.3	37.9	99.4	99.4
21	3.24	5.27	2.65	0.177	0.028	0.016	0.019	93.3	84.2	42.9	99.4	99.5
22	5.28	3.31	3.46	0.190	0.029	0.016	0.019	94.5	84.7	44.8	99.5	99.7
23		2.63	2.93	0.193	0.029	0.017	0.018	93.4	85.0	41.4	99.4	
24		2.72	3.13	0.185	0.028	0.019	0.018	94.1	84.9	32.1	99.4	
25		2.77	3.32	0.220	0.031	0.017	0.019	93.4	85.9	45.2	99.5	
26		3.74	4.17	0.177	0.031	0.018	0.018	95.8	82.5	41.9	99.6	
27	4.86	3.16	3.91	0.234	0.036	0.017	0.019	94.0	84.6	52.8	99.6	99.7
28	5.46	3.81	3.81	0.195	0.039	0.021	0.027	94.9	80.0	46.2	99.4	99.6
29	13.2	3.78	4.35	0.199	0.187	0.036	0.054	95.4	6.0	80.7	99.2	99.7
30	3.73	2.60	3.78	0.211	0.202	0.069	0.049	94.4	4.3	65.8	98.2	98.2
31	3.61	3.29	3.46	0.246	0.132	0.047	0.063	92.9	46.3	64.4	98.6	98.7
MEAN	4.050	2.931	3.614	0.2171	0.0464	0.0227	0.1488	93.65	78.06	43.48	99.31	99.35
STD DEV	2.230	0.8448	0.9489	0.0637	0.4411	0.01237	0.2972	2.054	20.826	11.637	0.3964	0.462
%CV	55.06	28.82	26.26	29.34	95.06	54.40	199.73	2.193	26.68	26.76	0.3992	0.465

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Nov. 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1	3.85	2.39	3.22	0.207	0.082	0.049	0.039	93.6	60.4	40.2	98.5	98.7
2	4.30	2.97	3.64	0.218	0.072	0.049	0.044	94.0	67.0	31.9	98.6	98.9
3	3.54	3.67	3.95	0.207	0.075	0.058	0.047	94.8	63.8	22.7	98.5	98.4
4	5.69	3.48	3.86	0.189	0.072	0.052	0.046	95.1	61.9	27.8	98.6	99.1
5	11.1	4.04	4.49	0.206	0.066	0.044	0.045	95.4	68.0	33.3	99.0	99.6
6	16.5	2.94	3.86	0.227	0.073	0.057	0.055	94.1	67.8	21.9	98.5	99.7
7	26.0	2.91	3.88	0.190	0.076	0.055	0.050	95.1	60.0	27.6	98.6	99.8
8	13.7		3.91	0.252	0.102	0.057	0.058	93.6	59.5	44.1	98.5	99.6
9		2.67	3.77	0.194	0.071	0.047	0.047	94.8	63.4	33.8	98.8	
10			4.14	0.176	0.071	0.040	0.041	95.7	59.7	43.7	99.0	
11			3.88	0.205	0.075	0.040	0.041	94.7	63.4	46.7	99.0	
12		3.35	4.56	0.188	0.064	0.035	0.033	95.9	66.0	45.3	99.2	
13	4.18	4.18	3.91	0.186	0.054	0.024	0.027	95.2	71.0	55.6	99.4	99.4
14	8.06	1.98	4.13	0.187	0.047	0.025	0.024	95.5	74.9	46.8	99.4	99.7
15	6.37		4.76	0.199	0.045	0.024	0.024	95.8	77.4	46.7	99.5	99.6
16	6.84	3.17	4.97	0.197	0.046	0.021	0.022	96.0	76.6	54.3	99.6	99.7
17	10.0	2.04	4.75	0.177	0.045	0.022	0.024	96.3	74.6	51.1	99.5	99.8
18	5.97	2.34	4.85	0.191	0.045	0.022	0.023	96.1	76.4	51.1	99.5	99.6
19	21.7	2.33	4.57	0.173	0.039	0.021	0.028	96.2	77.4	46.1	99.5	99.9
20	10.7		3.92	0.193	0.040	0.023	0.024	95.1	79.3	42.5	99.4	99.8
21	21.0		3.60	0.249	0.038	0.020	0.021	93.1	84.7	47.4	99.4	99.9
22	5.86		3.28	0.241	0.039	0.021	0.021	92.6	83.8	46.1	99.4	99.6
23	15.1		3.93	0.235	0.036	0.020	0.022	94.0	84.7	44.4	99.5	99.9
24	9.06		4.06	0.222	0.044	0.024	0.025	94.5	80.2	45.4	99.4	99.7
25	4.85		3.31	0.194	0.038	0.020	0.021	94.1	80.4	47.4	99.4	99.6
26	21.9		4.31	0.197	0.034	0.019	0.023	95.4	82.7	44.1	99.6	99.9
27	9.96		3.86	0.222	0.033	0.018	0.019	94.2	85.1	45.4	99.5	99.8
28	18.0		3.74	0.199	0.037	0.021	0.023	94.7	81.4	43.2	99.4	99.9
29			3.71	0.215	0.036	0.019	0.022	94.2	83.3	47.2	99.5	
30			4.45	0.209	0.037	0.018	0.020	95.3	82.3	51.3	99.6	
MEAN	11.010	2.964	4.042	0.2048	0.0544	0.0322	0.0320	94.837	73.237	42.50	99.163	99.57
STD DEV	6.6949	0.6879	0.2131	0.0208	0.0185	0.0145	0.01213	0.94522	8.9600	8.8158	0.4097	0.399
%CV	60.807	23.209	5.274	10.171	34.062	45.104	37.942	0.99668	12.234	0.20743	0.4132	0.400

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Dec. 1973	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1			4.21	0.226	0.037	0.018	0.019	94.6	83.6	51.3	99.6	
2			3.88	0.205	0.037	0.018	0.019	94.7	81.9	51.3	99.5	
3			4.42	0.222	0.036	0.016	0.019	95.0	83.8	55.6	99.6	
4			4.13	0.240	0.040	0.019	0.020	94.2	83.3	52.5	99.5	
5			3.06	0.217	0.035	0.013	0.011	92.9	83.9	62.9	99.6	
6			3.70	0.220	0.039	0.020	0.019	94.0	82.3	48.7	99.5	
7			3.88	0.240	0.038	0.018	0.018	93.8	84.2	52.6	99.5	
8			3.91	0.235	0.037	0.016	0.018	94.0	84.3	56.8	99.6	
9			3.60	0.242	0.039	0.019	0.019	93.3	83.9	51.3	99.5	
10			4.11	0.288	0.039	0.019	0.017	93.0	86.5	51.3	99.5	
11			4.42	0.248	0.041	0.019	0.019	94.4	83.5	53.7	99.6	
12			3.12	0.238	0.037	0.015	0.019	92.4	84.4	59.5	99.5	
13			3.88	0.244	0.039	0.019	0.019	93.7	84.0	51.3	99.5	
14			4.16	0.268	0.047	0.018	0.019	93.6	82.5	61.7	99.6	
15			4.04	0.324	0.045	0.020	0.021	92.0	86.1	55.6	99.5	
16			3.97	0.303	0.045	0.021	0.020	92.4	85.1	53.3	99.5	
17			4.38	0.288	0.044	0.018	0.019	93.4	84.7	59.1	99.6	
18			4.18	0.283	0.044	0.019	0.021	93.2	84.4	56.8	99.5	
19			4.00	0.320	0.042	0.019	0.021	92.0	86.9	54.8	99.5	
20			4.29	0.356	0.047	0.021	0.022	91.7	86.8	55.3	99.5	
21			5.10	0.363	0.050	0.020	0.022	92.9	86.2	60.0	99.6	
22			4.67	0.310	0.048	0.022	0.022	93.4	84.5	54.2	99.5	
23			4.16	0.271	0.049	0.020	0.020	93.5	81.9	59.2	99.5	
24			4.47	0.241	0.042	0.020	0.020	94.6	82.6	52.4	99.6	
25			3.23	0.217	0.040	0.020	0.021	93.3	81.6	50.0	99.4	
26			3.70	0.277	0.044	0.024	0.024	92.5	84.1	45.4	99.4	
27			4.71	0.305	0.069	0.038	0.040	93.5	77.4	44.9	99.2	
28			4.29	0.287	0.073	0.043	0.037	93.3	74.6	41.1	99.0	
29			4.63	0.292	0.065	0.031	0.029	93.7	77.7	52.3	99.3	
30			4.76	0.291	0.055	0.024	0.025	93.9	81.1	56.4	99.5	
31			4.81	0.321	0.049	0.021	0.023	93.3	84.7	57.1	99.6	
MEAN			4.125	0.27039	0.0449	0.0209	0.0214	93.426	83.306	53.819	99.493	
STD DEV			0.23373	0.04222	0.00940	0.0061	0.00544	0.82622	2.7227	4.8624	0.12893	
%CV			5.6662	15.614	20.935	29.244	25.470	0.88436	3.2683	9.0347	0.12959	

Table E-1 (continued)

TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Jan. 1974	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1			3.82	0.321	0.052	0.021	0.021	91.6	83.8	59.6	99.4	
2			4.18	0.349	0.049	0.019	0.002	91.6	86.0	61.2	99.5	
3			4.61	0.360	0.050	0.019	0.022	92.2	86.1	62.0	99.6	
4			4.14	0.404	0.051	0.023	0.028	90.2	87.4	54.9	99.4	
5			4.24	0.421	0.059	0.029	0.037	90.1	86.0	50.8	99.3	
6	9.97	3.97	3.84	0.364	0.060	0.046	0.025	90.5	83.5	23.3	98.8	99.5
7		4.63	4.39	0.407	0.059	0.022	0.023	90.7	85.5	62.7	99.5	
8			4.60	0.399	0.065	0.023	0.024	91.3	83.7	64.6	99.5	
9			3.99	0.381	0.069	0.024	0.025	90.4	81.9	65.2	99.4	
10			4.43	0.404	0.069	0.023	0.024	90.9	82.9	66.7	99.5	
11			4.06	0.334	0.065	0.024	0.024	91.8	80.5	63.1	99.4	
12			4.28	0.299	0.052	0.019	0.022	93.0	82.6	63.5	99.6	
13			4.63	0.302	0.052	0.021	0.022	93.5	82.8	59.6	99.5	
14			4.58	0.303	0.047	0.018	0.020	93.4	84.5	61.7	99.6	
15	19.3	3.23	4.03	0.332	0.056	0.024	0.025	91.8	83.1	57.1	99.4	99.9
16	16.4	4.22	4.43	0.321	0.055	0.024	0.025	92.7	82.9	56.4	99.5	99.9
17	5.83		3.71	0.307	0.044	0.021	0.019	91.7	85.7	52.3	99.4	99.6
18	5.68		4.32	0.277	0.035	0.014	0.022	93.6	87.4	60.0	99.7	99.8
19	5.22		5.10	0.313	0.045	0.019	0.021	93.9	85.6	57.8	99.6	99.6
20	5.00		3.59	0.319	0.051	0.020	0.023	91.1	84.0	60.8	99.4	99.6
21	5.98	6.09	4.61	0.373	0.059	0.023	0.027	91.9	84.2	61.0	99.5	99.6
22	7.04	4.14	3.88	0.432	0.071	0.029	0.031	88.9	83.6	59.2	99.2	99.6
23	12.6		3.88	0.463	0.080	0.029	0.029	88.1	82.7	63.8	99.2	99.8
24	10.4		3.96	0.428	0.074	0.025	0.024	89.2	82.7	66.2	99.4	99.8
25	6.09		4.18	0.366	0.065	0.021	0.024	91.2	82.2	67.7	99.5	99.7
26	10.7		5.54	0.306	0.058	0.023	0.021	94.5	81.0	60.3	99.6	99.8
27			3.97	0.288	0.063	0.026	0.023	92.7	78.1	58.7	99.3	
28	8.79	5.68	5.10	0.294	0.075	0.038	0.040	94.2	74.5	49.3	99.2	99.6
29	7.41	3.81	6.41	0.284	0.087	0.048	0.046	95.6	69.4	44.8	99.2	99.4
30		3.97	5.68	0.312	0.090	0.048	0.046	94.5	71.1	46.7	99.2	
31		3.56	5.32	0.302	0.079	0.045	0.043	94.3	73.8	43.0	99.2	
MEAN	9.094	4.330	4.4355	0.3473	0.0608	0.0261	0.0261	91.97	82.232	57.548	99.403	99.68
STD DEV	4.266	0.9062	0.6407	0.05158	0.0130	0.00916	0.00875	1.804	4.453	8.973	0.1816	0.147
%CV	46.914	20.928	14.444	14.852	21.334	35.155	33.569	1.961	5.415	15.592	0.1827	0.148

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24-HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Feb. 1974	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL-MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1		3.50	3.61	0.269	0.062	0.033	0.030	92.5	77.0	46.8	99.1	
2	9.83	4.40	4.40	0.259	0.052	0.027	0.026	94.1	79.9	48.1	99.4	99.7
3	9.32	4.03	4.45	0.252	0.052	0.024	0.025	94.3	79.4	53.8	99.5	99.7
4	8.01	4.96	5.54	0.278	0.050	0.025	0.042	95.0	82.0	50.0	99.5	99.7
5	9.79	4.02	9.54	0.273	0.238	0.094	0.090	97.1	12.8	60.5	99.0	99.0
6	6.12	4.17	6.51	0.259	0.128	0.071	0.070	96.0	50.6	44.5	98.9	98.8
7	8.37	4.99	5.86	0.229	0.044	0.029	0.030	96.1	80.8	34.1	99.5	99.7
8	7.22	4.70	6.34	0.245	0.044	0.028	0.029	96.1	82.0	36.4	99.6	99.6
9	7.15	4.40	5.82	0.220	0.045	0.026	0.025	96.2	79.5	42.2	99.6	99.6
10	9.28	4.43	5.86	0.241	0.044	0.023	0.027	95.9	81.7	47.7	99.6	99.8
11	8.99	4.70	7.42	0.249	0.044	0.023	0.025	96.6	82.3	47.7	99.7	99.7
12	7.80	4.21	6.79	0.253	0.048	0.025	0.027	96.3	81.0	47.9	99.6	99.7
13	10.10	4.18	7.44	0.247	0.047	0.025	0.027	96.7	81.0	46.8	99.7	99.8
14	6.98	4.04	5.53	0.276	0.046	0.025	0.027	95.0	83.3	45.6	99.5	99.6
15	4.61	5.03	8.09	0.267	0.045	0.028	0.027	96.7	83.1	37.8	99.6	99.4
16	11.9	4.46	6.34	0.273	0.052	0.028	0.029	95.7	80.9	46.1	99.6	99.8
17	12.9	4.04	5.82	0.288	0.055	0.030	0.030	95.0	80.9	45.4	99.5	99.8
18	10.0	5.64	8.06	0.283	0.052	0.029	0.029	96.5	81.6	44.2	99.6	99.7
19	7.87	6.76	6.16	0.328	0.057	0.030	0.039	94.7	82.6	47.4	99.5	99.6
20	10.7	5.03	9.38	0.488	0.101	0.055	0.053	94.8	79.3	45.5	99.4	99.5
21	8.45	5.12	7.65	0.350	0.078	0.051	0.043	95.4	77.7	34.6	99.3	99.4
22	9.60	5.10	5.29	0.307	0.064	0.041	0.039	94.2	79.1	35.9	99.2	99.6
23	5.50	8.48	5.50	0.295	0.062	0.035	0.037	94.6	79.0	43.5	99.4	99.4
24	10.2		7.24	0.270	0.059	0.033	0.036	96.3	78.1	44.1	99.5	99.7
25	11.3	5.79	6.11	0.303	0.064	0.038	0.039	95.0	78.9	40.6	99.4	99.7
26	11.7	4.70	7.48	0.306	0.185	0.066	0.088	95.9	39.5	64.3	99.1	99.4
27	13.6	4.57	6.80	0.321	0.255	0.127	0.127	95.3	20.6	50.2	98.1	99.1
28	5.73	3.59	9.61	0.317	0.193	0.122	0.088	96.7	39.1	36.8	98.7	97.9
29												
30												
31												
MEAN	9.0007	4.7793	6.5943	0.2838	0.0809	0.0425	0.0430	95.525	71.918	45.304	99.361	99.50
STD DEV	2.2475	1.0136	1.4908	0.0506	0.0608	0.0286	0.0258	1.041	19.687	6.9932	0.34996	0.405
%CV	24.970	21.209	22.608	17.830	75.152	67.337	59.903	1.0896	27.375	15.436	0.35221	0.407

EPA-280 (Cin)
(12-75)

Table E-1 (continued) **TOTAL PHOSPHORUS DATA FOR 24–HOUR COMPOSITE SAMPLES**

DATE	TOTAL PHOSPHORUS CONTRATION – mg/l							REMOVAL THRU INDICATED PROCESS – PERCENT				
Mar. 1974	RAW WASTE	SEC. EFFL.	1st STAGE CLAR. INF.	1st STAGE CLAR. EFFL.	2nd STAGE CLAR. EFFL.	D.M. FILTER EFFL.	EFFL. TO LAKE	1st STAGE LIME CLAR.	2nd STAGE LIME CLAR.	DUAL–MEDIA FILTER	TERTIARY PLANT	SEC. PLUS TERT. PLANT
1	5.12	4.02	8.19	0.247	0.161	0.095	0.065	97.0	34.8	41.0	98.8	98.1
2	5.78	4.42	6.55	0.345	0.140	0.089	0.065	94.7	59.4	36.4	98.6	98.5
3	5.30	4.10	6.58	0.217	0.134	0.091	0.065	96.7	38.2	32.1	98.6	98.3
4	6.08	5.17	6.48	0.224	0.114	0.078	0.053	96.5	49.1	31.6	98.8	98.7
5	5.79	4.54	5.62	0.319	0.301	0.109	0.076	94.3	5.6	63.8	98.1	98.1
6	4.93	3.99	9.60	0.373	0.335	0.160	0.082	96.1	10.2	52.2	98.3	96.8
7	5.25	4.75	4.74	0.209	0.105	0.057	0.052	95.6	49.8	45.7	98.8	98.9
8	5.08	4.82	7.92	0.220	0.107	0.069	0.053	97.2	51.4	35.5	99.1	98.6
9	4.54	3.46	4.99	0.260	0.121	0.083	0.058	94.8	53.5	31.4	98.3	98.2
10	4.47	3.99	4.11	0.267	0.129	0.088	0.074	93.5	51.7	31.8	97.9	98.0
11	6.65	4.90	7.15	0.290	0.133	0.080	0.069	95.9	54.1	39.8	98.9	98.8
12	7.06	4.14	8.12	0.319	0.134	0.090	0.086	96.1	58.0	32.8	98.9	98.7
13	11.4	4.43	9.78	0.249	0.130	0.087	0.063	97.4	47.8	33.1	99.1	99.2
14	8.82	4.99	5.15	0.263	0.105	0.070	0.070	94.9	60.1	33.3	98.6	99.2
15	5.54	4.47	5.01	0.370	0.133	0.051	0.070	92.6	64.0	61.6	99.0	99.1
16	6.65	5.39	5.12	0.271	0.122	0.062	0.061	94.7	55.0	49.2	98.8	99.1
17	6.99	4.40	5.03	0.285	0.100	0.048	0.049	94.3	64.9	52.0	99.0	99.3
18	7.29	4.85	4.70	0.307	0.086	0.040	0.041	93.5	72.0	53.5	99.1	99.5
19	7.51	4.71	5.98	0.270	0.084	0.040	0.040	95.5	68.9	52.4	99.3	99.5
20	8.02	4.40	4.76	0.259	0.082	0.043	0.041	94.6	68.3	47.6	99.1	99.5
21	7.81	4.53	7.12	0.280	0.072	0.037	0.040	96.1	74.3	48.6	99.5	99.5
22	11.7	4.49	5.48	0.265	0.069	0.034	0.038	95.2	74.0	50.7	99.4	99.7
23	10.6	4.70	6.23	0.269	0.069	0.035	0.047	95.7	74.3	49.3	99.4	99.7
24	14.5	3.59	4.07	0.263	0.129	0.060	0.076	93.5	51.0	53.5	98.5	99.6
25	7.92	5.47	4.34	0.270	0.263	0.105	0.089	93.8	2.6	60.1	97.6	98.7
26	11.9	6.63	7.20	0.355	0.308	0.129	0.091	95.1	13.2	58.1	98.2	98.9
27	9.46	4.68	5.26	0.278	0.272	0.106	0.099	94.7	2.2	61.0	98.0	98.9
28	8.81	5.29	5.11	0.321	0.146	0.107	0.055	93.7	54.5	26.7	97.9	98.8
29	9.70	3.93	4.60	0.256	0.132	0.109	0.049	94.4	48.4	17.4	97.6	98.9
30	8.69	4.00	5.33	0.252	0.131	0.067	0.044	95.3	48.0	48.8	98.7	99.2
31	9.85	4.31	5.17	0.267	0.124	0.082	0.063	94.8	53.6	33.9	98.4	99.2
MEAN	7.7161	4.5664	5.9835	0.2787	0.1442	0.0774	0.0621	95.103	48.803	44.029	98.655	98.88
STD DEV	2.5075	0.62198	1.5200	0.04230	0.07215	0.03002	0.01663	1.1915	21.196	11.858	0.52079	0.620
%CV	32.497	13.621	25.404	15.176	50.026	38.760	26.798	1.2528	43.431	26.932	0.52789	0.627

EPA-280 (Cin)
(12-75)

APPENDIX F

DISTRIBUTION OF OPERATION AND MAINTENANCE COSTS

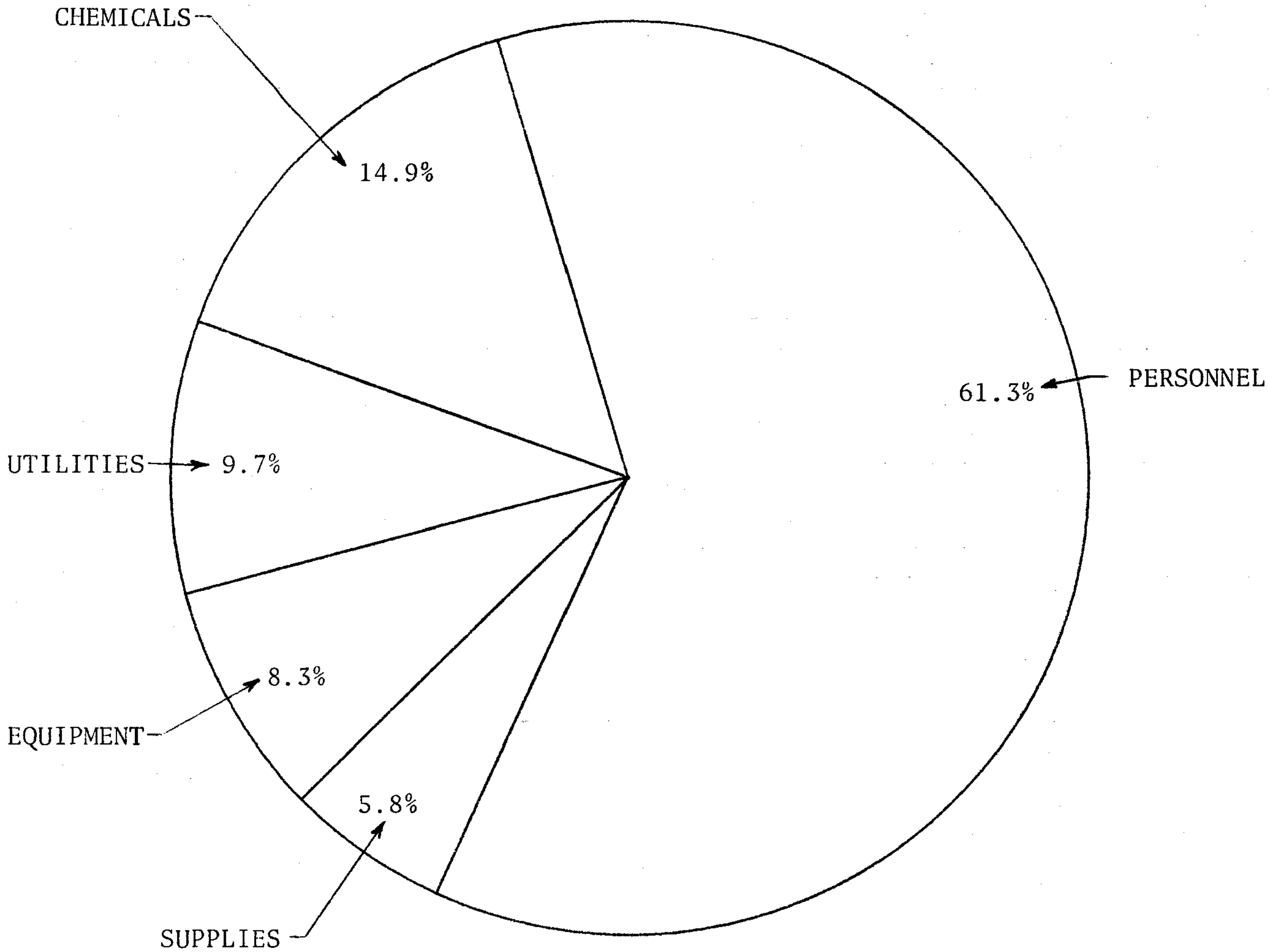


FIGURE F-1. DISTRIBUTION OF OPERATION AND MAINTENANCE COSTS

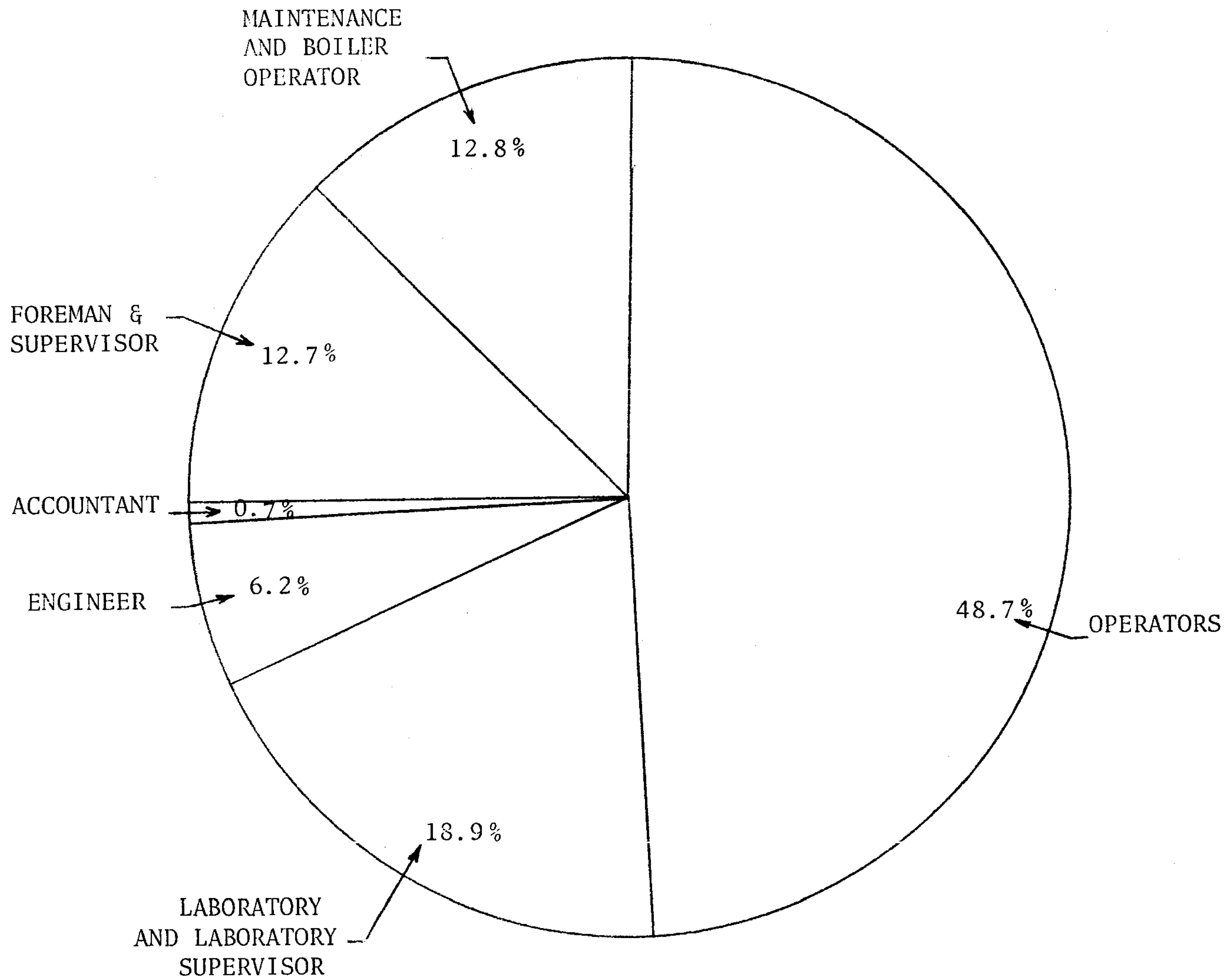


FIGURE F-2. DISTRIBUTION OF PERSONNEL COSTS

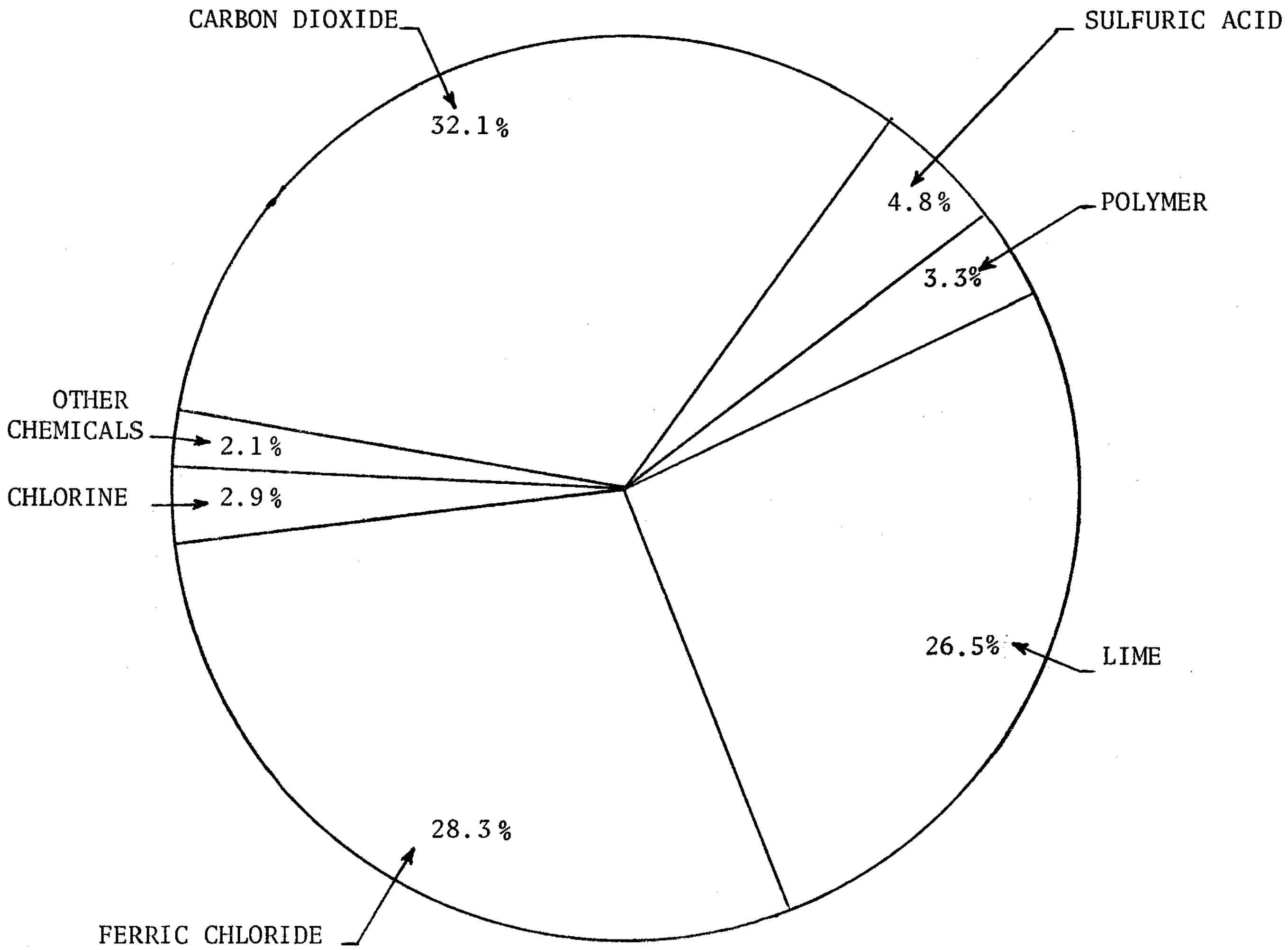


FIGURE F-3. DISTRIBUTION OF CHEMICAL COSTS

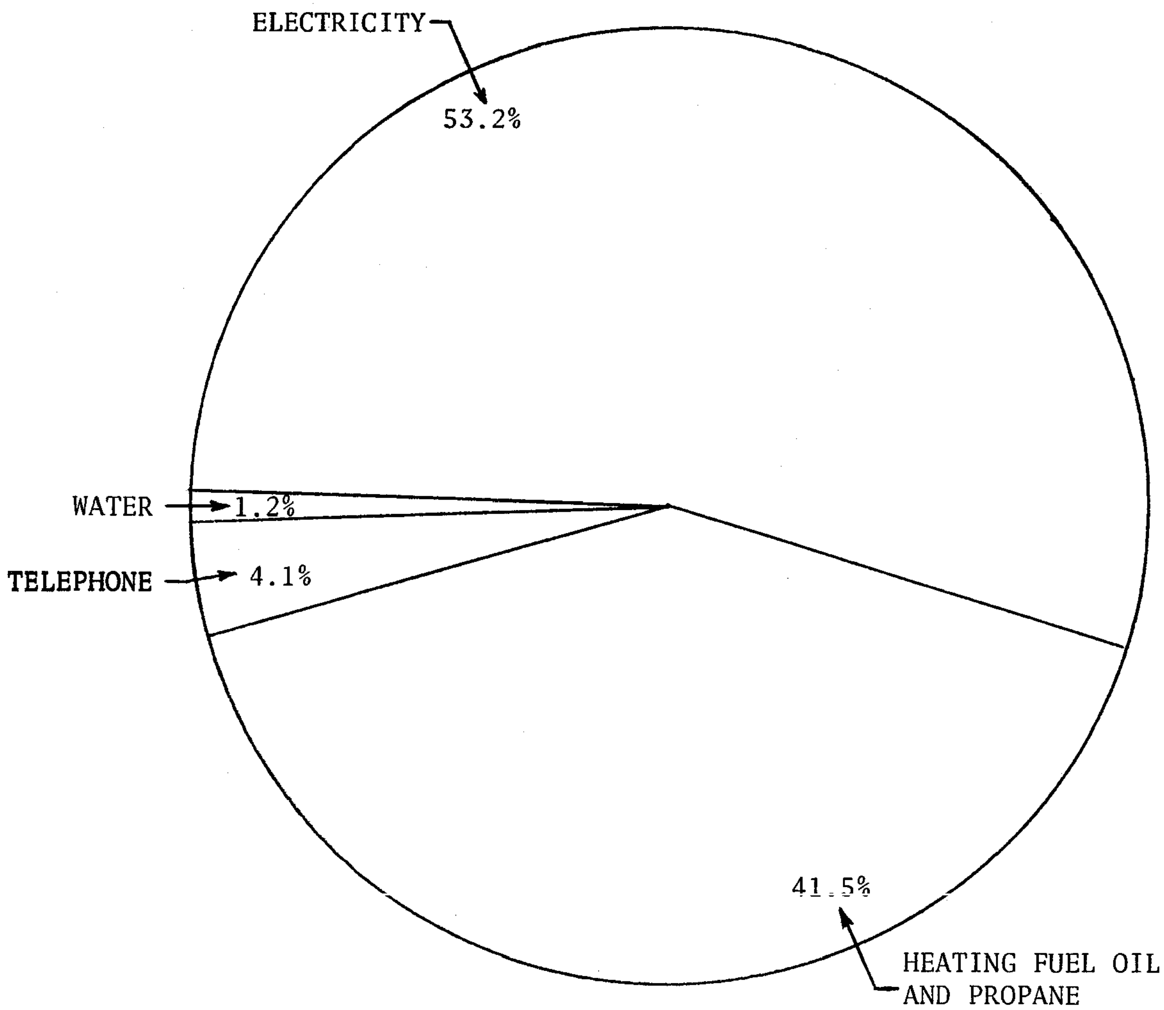


FIGURE F-4. DISTRIBUTION OF UTILITY COSTS

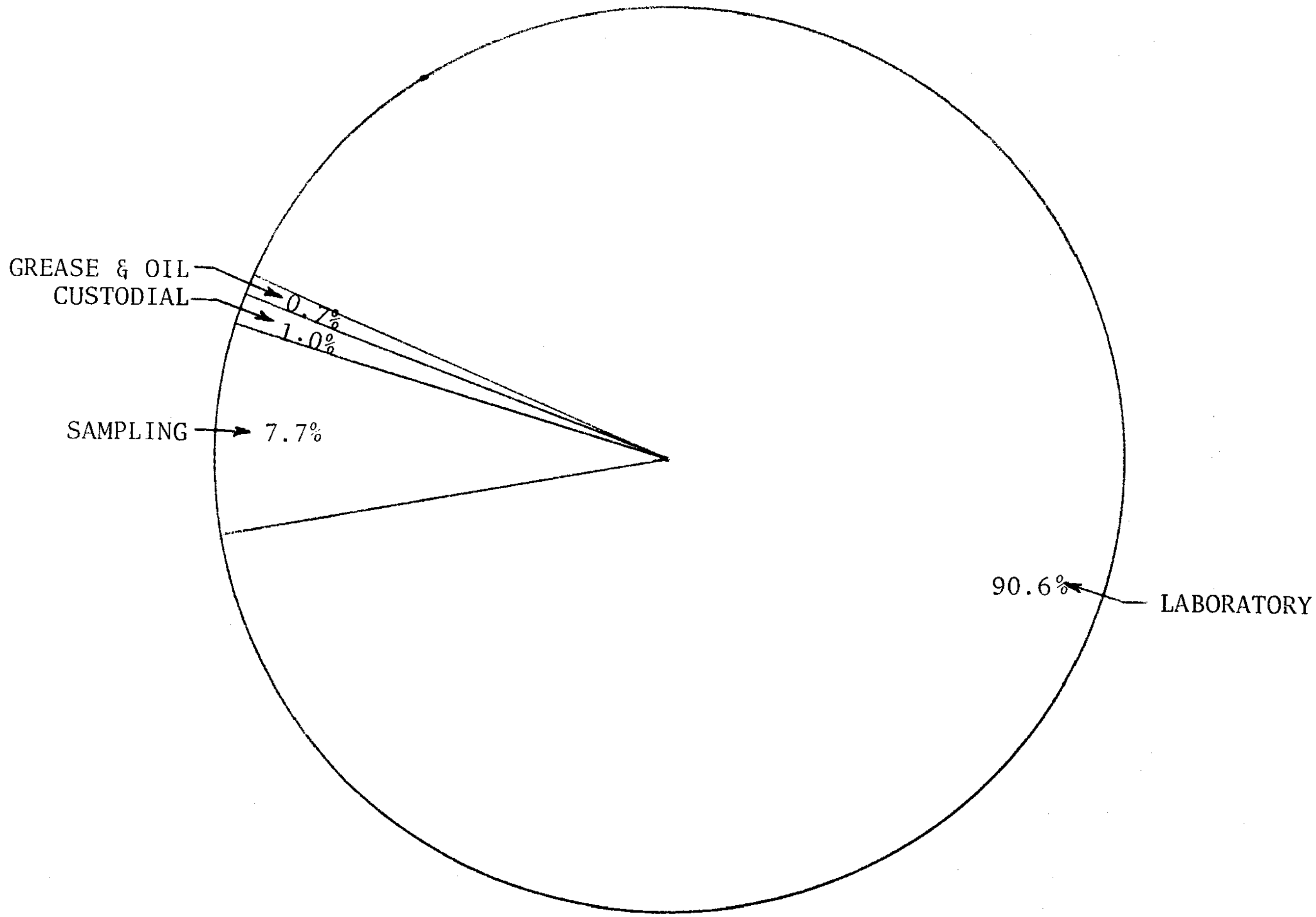


FIGURE F-5. DISTRIBUTION OF MISCELLANEOUS COSTS

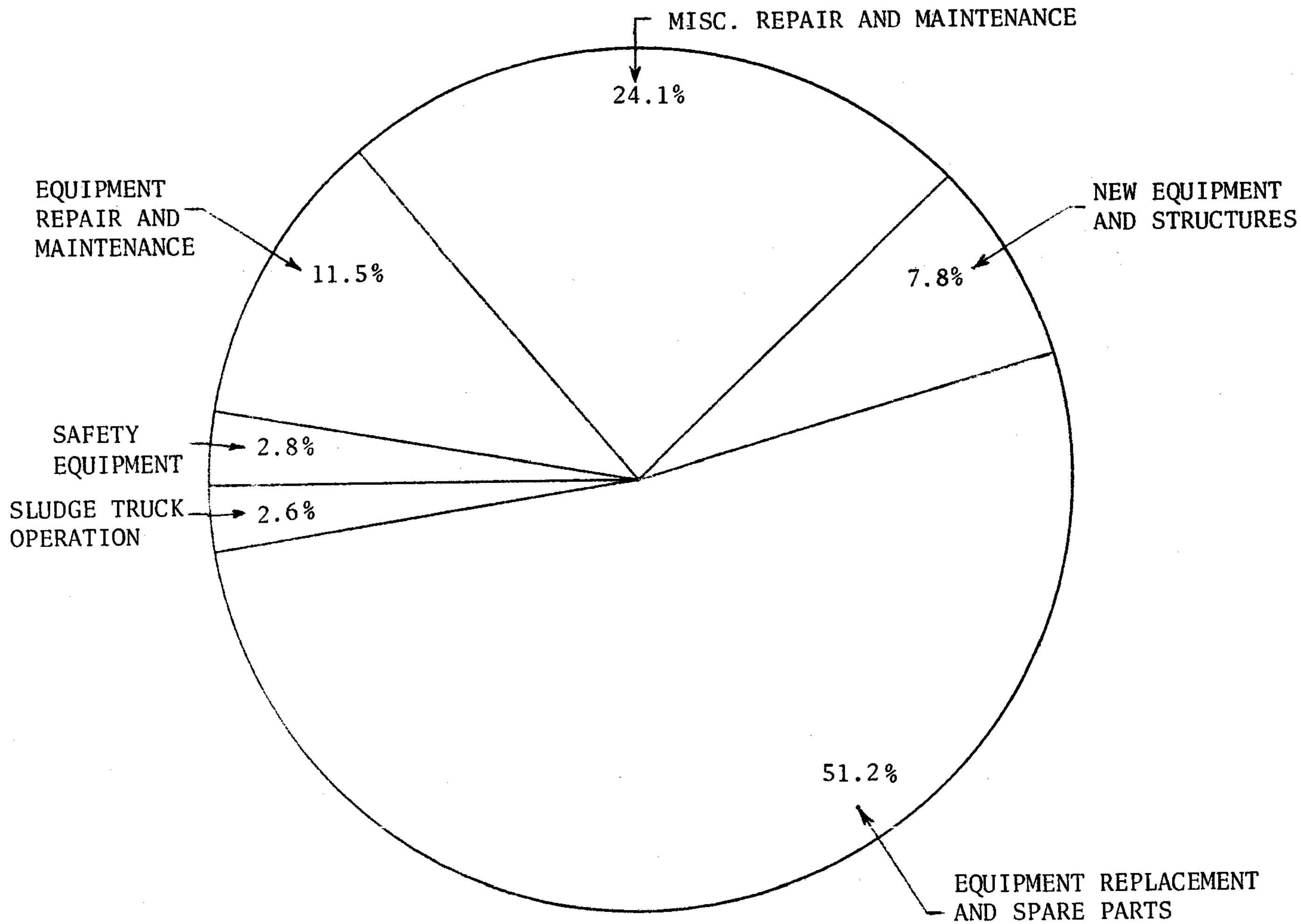


FIGURE F-6. DISTRIBUTION OF EQUIPMENT OPERATION AND REPAIR COSTS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-76-082	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE TERTIARY TREATMENT FOR PHOSPHORUS REMOVAL AT ELY, MINNESOTA AWT PLANT, April, 1973 thru March, 1974		5. REPORT DATE March 1976 (Issuing Date)
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) John W. Sheehy and Francis L. Evans, III		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Municipal Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268		10. PROGRAM ELEMENT NO. 1 BB033
		11. CONTRACT/GRANT NO. S-802309
12. SPONSORING AGENCY NAME AND ADDRESS Same as above		13. TYPE OF REPORT AND PERIOD COVERED Interim 4/1/73 - 3/31/74
		14. SPONSORING AGENCY CODE EPA - ORD
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This report discusses the design, the construction and the first year's operation of the 1.5 mgd tertiary treatment plant located in Ely, Minnesota. The tertiary treatment plant was constructed to reduce the phosphorus concentration from the existing trickling filter plant effluent, a point source constituting 80 percent of the phosphorus entering culturally eutrophic Shagawa Lake. The tertiary plant was designed and constructed to reduce the total phosphorus concentration in the trickling filter plant effluent to 0.05 mg/l. The tertiary facility consists of flow equalization, two-stage lime clarification followed by dual-media filtration and chlorination.

This report includes performance data, operational data, maintenance requirements, and operating costs for the Ely AWT facility. The report presents a thorough discussion of phosphorus performance data. There is a discussion of sludge treatment processes. Operating data described includes wastewater flow, chemical dose, pH, and clarifier solids volume. Frequent and routine maintenance items are included. Operating costs are divided into five categories and 27 sub-categories.

In the first 12 months of continuous operation, the tertiary plant discharged an effluent total phosphorus concentration averaging 0.045 mg/l. Operational costs for the 1.5 mgd plant averaged $0.24/m^3$ ($0.91/1000 gallons).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sewage Treatment Sludge Disposal Phosphorus Chemical Removal (Sewage Treatment) Operating Costs	Shagawa Lake (Minnesota) Lime-Clarification Dual-media Filtration Tertiary Wastewater Operation and Maintenance	13B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 133
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1976-657-695/5371 Region No. 5-11