To the Graduate School:

I am submitting herewith a thesis written by Saunooke K. Pedigo entitled "A Comparative Analysis of the Knoxville and Surrounding Area Waste-Water Treatment Facilities: Implications for Science Education in East Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Science Education.

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# A COMPARATIVE ANALYSIS OF THE KNOXVILLE AND SURROUNDING AREA WASTE-WATER TREATMENT FACILITIES: IMPLICATIONS FOR SCIENCE EDUCATION IN EAST TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

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Saunooke K. Pedigo

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## ABSTRACT


The purpose of this study was dual in nature. First, the study was designed to analyze and compare the Knoxville and immediate surrounding area waste-water treatment facilities in order to determine their effectiveness in effluent removal, their impact on water pollution, and their provision of a course for solution. Second, by analyzing the waste-water treatment plants, the researcher has developed a teaching procedure using modern equipment and the surrounding geographic area which can be useful to high school science teachers in the East Tennessee region.

The primary methods of obtaining data in this research were in the form of interviewing waste-water plant engineers and laboratory personnel, guided plant visitations, documented correspondence between plant directors and the Department of Public Health, reference books, and personal letters written to the researcher from plant engineers.

In order to thoroughly analyze the efficiency of each waste-water treatment plant and fully develop a teaching procedure, the researcher obtained water samples immediately above each plant and five miles below the effluent input location. The tests which were performed on these samples included: pH, dissolved oxygen, nitrate, and phosphate.

These particular tests provided a good indication of the general water quality in terms of fish and other aquatic life.

The major findings of the research were that a definite relationship exists between eutrophic conditions present in the water and the waste-water treatment plants with the most primitive type of sewage treatment. If these inadequate types of waste-water treatment remain in the next decade, fish and other aquatic life will significantly decrease in population.

It is the belief of the researcher that the methods used in analyzing the waste-water treatment plants would be of great significance if similar procedures described in this study were implemented in local or regional secondary science classes. This would increase public awareness and most importantly create within students a genuine concern for their environment.

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# CHAPTER I

## INTRODUCTION

In this age of increasing pollution one of the more encouraging developments is the work that is being done in sewage treatment. Although no massive reductions in water pollution have occurred, there have been a few cases of successful pollution abatement. The construction of new sewage treatment plants, while not spectacular, has kept up with the population increase. From 1940 until 1962, the number of new facilities just kept abreast with or fell slightly behind population increases; however, from 1962 to 1968 the population served by sewers increased from 60 to 68 percent.[1]

Perhaps the most significant advances have been made in research and development regarding sewage treatment. Since 1960 the federal government has gained more than twenty-five million dollars for waste water treatment research.[2] The future, then, of waste water treatment is dependent upon further research, active community involvement and federal and/or local funding.[3]

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[1]Robert W. Holcomb, "Waste-water treatment: The tide is turning," Our Chemical Environment (San Francisco: Canfield Press, 1972), pp. 103-104.

[2]Ibid.

[3]Ibid., p. 105.

## A. PROBLEM

Water pollution has become an increasingly serious problem in the rivers and lakes in East Tennessee. The citizens of this area have begun to visualize the repercussions from inadequate treatment at the level of sewage disposal.

These insufficient (primary) methods of "treatment" are leading to serious side effects. For example, the phosphate and nitrates contained in most detergents are not eliminated at the sewage plants unless an advanced (tertiary) method is used.[4] In fact, the substances are turned from organic forms to mineral forms which are usable by algae and plants. Thus, these chemicals cause a tremendous increase in the growth of algae and other plant life. When these plants die they fall to the bottom of the lake, decay, and hence, use up much of the oxygen contained in the water. This oxygen is defined as "dissolved oxygen" or DO. A significant decrease (below .6 ppm (parts per million)) in oxygen will cause "game" fish such as trout to decrease in number and eventually die out completely.[5] The loss of these "game" fish will have an indirect effect on man (an interruption of the food chain). The eutrophic (excessive algae growth and depleted oxygen

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[4] Ibid., p. 106.

[5] Ibid.

supply) condition of the rivers and lakes will also decrease the desirability of the water for drinking purposes and recreational boating and fishing.

Therefore, this relatively new area of research would be of vital importance to the citizens in and around Knoxville, as well as to science programs in local schools.

## B. PURPOSE

The purpose of this study was dual in nature. First, this study was designed to analyze and compare the Knoxville and immediate surrounding area waste water treatment facilities in order to determine their effectiveness in effluent removal, their impact on water pollution, and their provision of a course for solution to waste water treatment. Second, by analyzing the treatment plants, the researcher has developed a teaching procedure to be taught in conjunction with water pollution using modern equipment and the surrounding geographic area which can be useful to high school science teachers in the East Tennessee region.

## C. HYPOTHESIS

The researcher believed that a thorough assessment of waste water treatment plants in the prescribed area would clearly prove their inadequacies in contaminant removal and thus their contribution to eutrophication. The researcher also believed that through the process of this assessment, specific techniques for teaching water pollution can be developed and utilized by area high school teachers.

## D. METHOD/PROCEDURE

The method of obtaining data in this research study was in the form of interviewing waste water plant engineers and laboratory personnel, guided plant visitations, documented correspondence between plant directors and the Department of Public Health, reference books, and personal letters written to the researcher from plant engineers.

In order to thoroughly analyze the efficiency of each treatment plant, the researcher obtained triplicate water samples immediately above each plant and five miles below the input location. (Five miles is the specified sampling location because flowing bodies of water normally remove impurities after five miles.)[6] The tests the researcher performed on each sample consisted of: pH, dissolved oxygen, nitrate, and phosphate. These particular tests were chosen because they illustrate whether eutrophic conditions are present in the streams. The instrument used in testing the dissolved oxygen was a portable HACH Dissolved Oxygen Meter made by HACH Chemical Company, Ames, Iowa. The pH, nitrate

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[6]Ibid., p. 107.

and phosphate tests were performed in duplicate by James Christy Bird in the University of Tennessee Environmental Engineering Department. A portable pH meter made by the HACH Company was also utilized in these tests. The researcher noted that these particular methods provided maximum accuracy in testing. The exact procedure for each test is referred to in Chapter V. These specific methods also allowed the researcher to develop feasible techniques of teaching about water pollution which can be used by high school science teachers and students.

# CHAPTER II

# BACKGROUND INFORMATION CONCERNING THE RESEARCH

Within the past fifteen to twenty years there has been virtually no change in the sewage treatment plants in and around Knoxville. The standards for effluent discharge have been revised by the Environmental Protection Agency; however, federal and local funds have not been sufficient to support changes necessary to meet such revisions.[7]

Efficient sewage treatment is, therefore, an area of concern where research would be valuable to the citizens of the Knoxville region. It is also an area in which virtually no teaching procedures and materials have been developed for use in the East Tennessee schools. The researcher exhausted all available science teaching literature and found no such specific method described in this study to be utilized in the school systems of East Tennessee.

## A. TYPES OF TREATMENT PLANTS

There are traditionally three ways in which sewage is treated. These methods include the primary, secondary

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[7]Statement by John Kincaid, Director, City of Knoxville Waste-Water Control System, personal interview, November 1, 1978.

(activated sludge or trickling filter), and tertiary.[8] These range in order of increasing effectiveness. However, there are other more advanced sewage treatment methods which have been used successfully in areas of the United States which were reviewed for this study but not included.

Before a discussion of the types of treatment plants, it is necessary to clarify an important term, which is BOD or biochemical oxygen demand.

The oxidation processes of nature in the purification of water deserve special attention. After many uses, water has an increased concentration of organic material. Even in the natural state, life forms associated with natural waters are constantly putting organic debris into the water. Thus all natural bodies of water supporting life have a biochemical oxygen demand (BOD), the amount of oxygen required to oxidize the organic material to simple inorganic molecules.[9] The oxygen is required by microorganisms such as many bacterial forms which utilize organic matter as food in their metabolic reactions.[10] The waste waters of modern

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[8]City of Knoxville Wastewater Treatment Department, Understanding Sewage and Sewage Treatment, Section 1 (U.T. Press: Knoxville, Tenn., 1975), pp. 5-6.

[9]James L. Wood, Chemistry, Man, and Society (W. B. Saunders Co.: Philadelphia, 1972), pp. 438-439.

[10]Ibid.

society often have very high concentrations of organic material, which have a very large biochemical oxygen demand. In extreme cases, more oxygen is required than is available from the environment. Ultimately, given near normal conditions and enough time, the microorganisms will convert huge quantities of organic matter into the following undesirable chemical end-products: organic carbon, organic hydrogen, organic oxygen, organic hydrogen.[11]

In the extreme cases, when the BOD is higher than the oxygen available, radical changes occur in the chemistry and biology of the system. Thus, the BOD is high when eutrophic conditions (caused by increased phosphate and increased nitrate) are present. When harmful conditions such as decreased $O_2$ result, fish and other fresh water aquatic life can no longer survive.[12]

Primary

At the treatment plant, the sewage first flows through a metal bar screen, that catches bulky objects, such as branches, cartons, etc., which are removed and disposed of. The sewage then enters a relatively long but narrow tank called a grit chamber. The sewage passes through the grit chamber quite slowly, while inorganic matter, such as sand

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[11] Ibid.

[12] Ibid., p. 440.

cinders, settles to the bottom of the chamber to be removed.[13]

From the grit chamber, the sewage enters a much larger tank called a primary settling tank. Here the sewage remains for 5 to 6 hours while many of the suspended solids in the sewage settle to the bottom. Everything that remains or settles in a device such as the settling tank is called sludge. Everything that is drawn off the top is called effluent.[14]

From the settling tank sludge is drawn off the bottom, and sent to a large, cylindrical and sealed tank, called a digester, in which oxygen is almost entirely absent. Here anaerobic bacteria work to stabilize the sludge. The gases generated (a characteristic of anaerobic bacteria) in the process are drawn off to be disposed of or are used to power pumps, and other equipment in the plant. Sludge usually remains in the digester for about thirty days. After this period of time it becomes stable enough to be drawn off and taken to a sludge drying bed. Upon drying the sludge is eventually sold or carried off to perform the role of soil fertilization. The effluent is chlorinated minimumly (enough

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[13]City of Knoxville, Wastewater Treatment Department, pp. 11-12.

[14]Ibid.

to kill deadly bacteria) and released into the water system. The nitrates and phosphates remain in the effluent.[15]

Secondary (Trickling Filter and/or Activated Sludge)

If the waste-water plant is described as having a secondary type treatment the effluent (rather than being released into the water system) is drawn off the top and sent to a trickling filter, which is a very large bed of stone and loose gravel, approximately four to six feet thick. The effluent is then spread over the bed with rotary or stationary sprinklers. Coated with aerobic bacteria, the bed breaks down the dissolved solids and utilizes organic and nutrient material in the effluent as the effluent trickles down to underdrains beneath the bed. Some of the sewer beds use plastic in the shape of honeycombs instead of stone to provide the aerobic bacteria with more oxygen.[16]

The effluent flows from the underdrains to a stream, river, lake or pond, sometimes passing through a final settling tank on the way to reduce further the amount of suspended solid matter that may still be present in the effluent.[17]

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[15]Ibid., p. 13.

[16]Holcomb, p. 105.

[17]City of Knoxville, Wastewater Treatment Department, p. 13.

Aeration ponds are also used by some treatment plants. Here, effluent is given a further opportunity to absorb oxygen, both from the atmosphere and from oxygen piped in. Additional chlorine is also added prior to the release of the effluent.[18]

A treatment plant based on the activated sludge process normally uses metal bar screens and a grit chamber. In many cases, a primary settling tank is also used.[19]

The basic difference between the trickling filter and activated sludge method system is that in the activated sludge process no trickling filter is used. Sewage is passed directly from the grit chamber or primary settling tank into an aeration tank. In essence, this tank is one in which filtered air is continually being blown into it from the bottom and sides to supply oxygen, which in turn keeps the aerobic bacteria alive.[20]

The sewage then goes to a settling tank where the sludge settles to the bottom within two-three hours. The effluent is then drawn off and returned to the waterway, the dissolved solids having been treated with the suspended solids in the tank. Some of the sludge from the secondary settling tank is transferred to the aeration tanks because it is coated with aerobic bacteria. This keeps the bacteria in the

[18] Ibid., p. 14. [19] Ibid. [20] Ibid., p. 15.

tanks sufficiently populous, and in other ways hastens the stabilization process. The remainder of the sludge is sent to a digester.[21]

The main differences between primary and secondary treatment are the addition of more aeration basins, a secondary settling tank, and effluent chlorination. (See Figure 1.)[22]

Tertiary/Advanced

Tertiary sewage treatment is similar to the treatment given a community's drinking water. The effluent is sent to a tank called a filter gallery. The base of the tank is composed of a "multimedia" bed, usually anthracite coal and sand. The effluent drains through this bed where microscopic solids are filtered out and thus aerobic bacteria further convert to inorganic matter. (See Figure 2.)[23]

In summary, this method (tertiary) potentially removes approximately 80 to 90 percent of phosphates and nitrates, while secondary biological treatment seldom lowers concentration sufficiently to meet standards set by the Federal Water Quality Act (FWQA). These standards state that a certain concentration of $PO_4$ or $NO_3$ will lead to eutrophication of a given body of water. Also, the activated sludge method typically removes only about 30 percent of the

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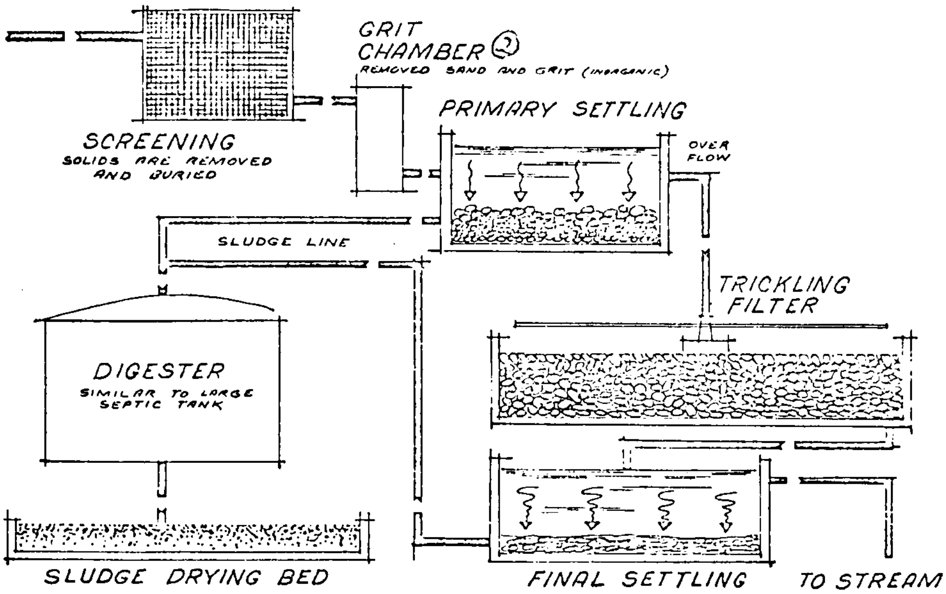
[21]Ibid., p. 13. [22]Ibid., p. 19. [23]Holcomb, p. 105.




ACTIVATED SLUDGE SYSTEM

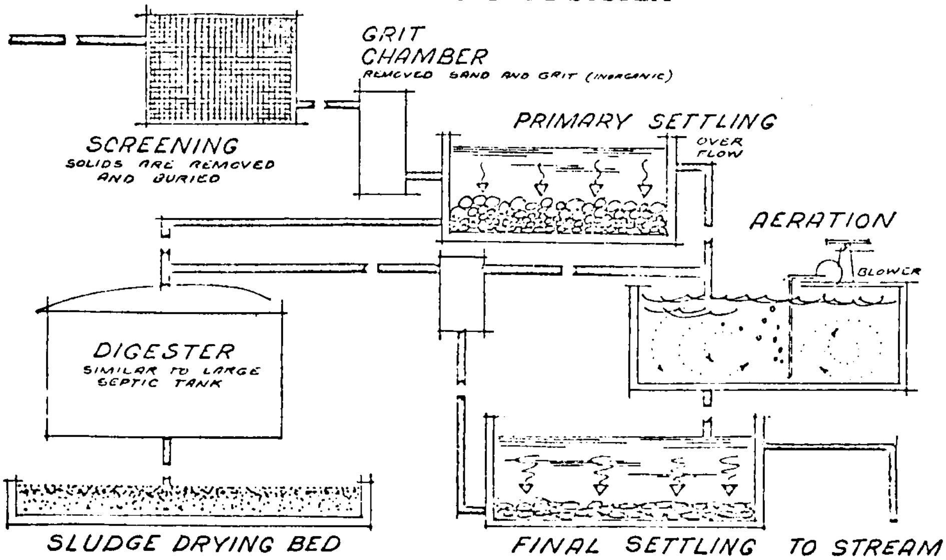



Figure 1. Trickling Filter Process.

Source: City of Knoxville Wastewater Treatment Department.

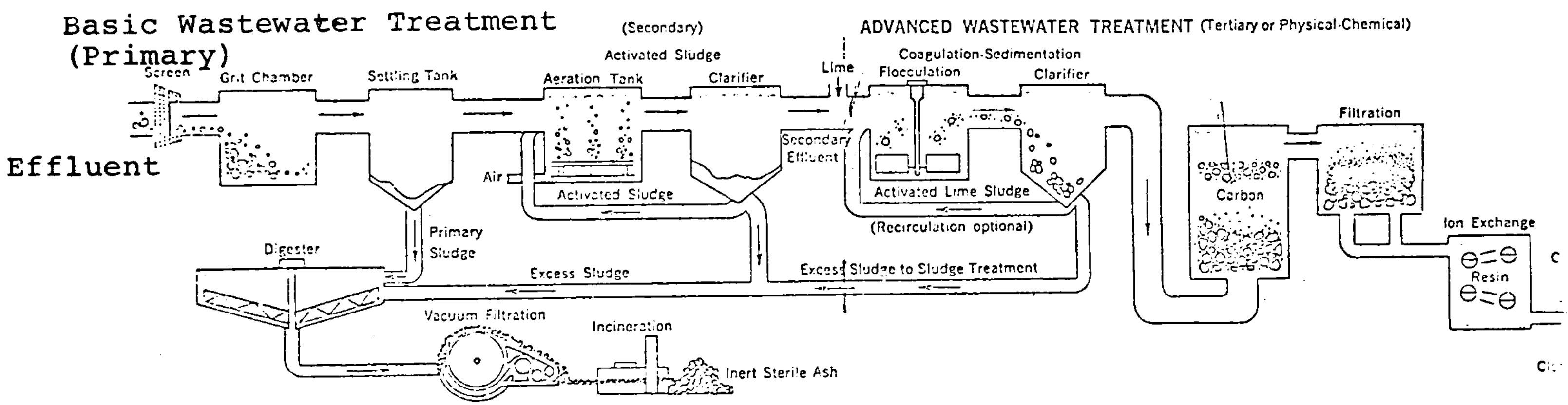



Figure 2. Diagram of Ideal Treatment.

Source: City of Knoxville Wastewater Treatment Department.

phosphates in sewage. It must also be recognized that primary treatment removes about one-third of the BOD and suspended solids but does nothing in the removal of the phosphate and nitrate.[24]

Other more advanced methods are being developed. Some have proven to be very effective in all "waste" removal; however, these methods are not universally used due to the prohibitive cost factor. At present they are used only for specialized needs in industry.[25]

## B. LAWS CONCERNING SEWAGE TREATMENT

> The Water Quality Control Act of 1971, Section 70-324 through Section 70-342, Tennessee Code Annotated, makes it the duty of the Water Quality Control Board to study and investigate all problems concerned with the pollution of the waters of the State and with its prevention, abatement, and control and to establish such standards of quality for any waters of the State in relation to their reasonable and necessary use as the Board shall deem to be in the public interest and establish general policies relating to existing or proposed future pollution as the Board shall deem necessary to accomplish the purpose of the Control Act.[26]

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[24]City of Knoxville, Wastewater Treatment Department, p. 15.

[25]Holcomb, p. 107.

[26]Tennessee Water Quality Control Board, Water Quality Criteria for the Definition and Control of Pollution in the Waters of Tennessee, Act of 1971, Section 70-342, December 14, 1971 (Nashville: Government Printing Office, 1971), pp. 1-2.

The Quality Control Board has provided the following standards.

Domestic Raw Water Supply

(a) Dissolved Oxygen - There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

(b) pH - The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

(c) Hardness or Mineral Compounds - There shall be no substances added to the waters that will increase the hardness or mineral content of the waters to such an extent to appreciably impair the usefulness of the water as a source of domestic water supply.

(d) Total Dissolved Solids - The total dissolved solids shall at no time exceed 500 mg/l.

(e) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily sleek, or the formation of slimes, bottom deposits or sludge banks of such size or character as may impair the usefulness of the water as a source of domestic water supply.

(f) Turbidity or Color - There shall be no turbidity or color added in amounts or characteristics that cannot be reduced to acceptable concentrations by conventional water treatment processes.

(g) Temperature - The maximum water temperature change shall not exceed 3C° relative to an upstream control point. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

(h) Coliform - The concentration of the fecal coliform group shall not exceed 1,000 per 100 ml as the logarithmic mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 5,000 per 100 ml.

(i) Taste or Odor - There shall be no substances added which will result in taste or odor that prevent the production of potable water by conventional water treatment processes.

(j) Toxic Substances - There shall be no toxic substances added to the waters that will produce toxic conditions that materially affect man or animals or impair the safety of a conventionally treated water supply.

(k) Other Pollutants - Other pollutants shall not be added to the water in quantities that may be detrimental to public health or impair the usefulness of the water as a source of domestic water supply.[27]

They have also compiled a list for fish and aquatic life which states the following:

Fish and Aquatic Life

(a) Dissolved Oxygen - The dissolved oxygen shall be a minimum of 5.0 mg/l except in limited sections of streams where (1) present technology cannot restore the water quality to the desired minimum of 5.0 mg/l dissolved oxygen, (2) the cost of meeting the standards is economically prohibitive when compared with the expected benefits to be obtained, or (3) the natural qualities of the water are less than the desired minimum of 5.0 mg/l. Such exceptions shall be determined on an individual basis but in no instance shall the dissolved oxygen concentration be less than 3.0 mg/l. The dissolved oxygen concentration shall be measured at mid-depth in waters having a total depth of ten (10) feet or less and at a depth of five (5) feet in waters having a total depth of greater than ten (10) feet. The dissolved oxygen concentration of recognized trout streams shall not be less than 6.0 mg/l.

(b) pH - the pH value shall lie within the range of 6.5 to 8.5 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

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[27] Ibid., pp. 2-3.

(c) Solids, Floating Materials and Deposits - There shall be no distinctly visible solids, scum, foam, oily sleek, or the formation of slimes, bottom deposits or sludge banks of such size or character that may be detrimental to fish and aquatic life.

(d) Turbidity or Color - There shall be no turbidity or color added in such amounts or of such character that will materially affect fish and aquatic life.

(e) Temperature - The maximum water temperature change shall not exceed 3C° relative to an upstream control point. The temperature of the water shall not exceed 30.5C° and the maximum rate of change shall not exceed 2C° per hour. The temperature of recognized trout waters shall not exceed 20C°. There shall be no abnormal temperature changes that may affect aquatic life unless caused by natural conditions. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

(f) Taste or Odor - There shall be no substances added that will impart unpalatable flavor to fish or result in noticeable offensive odors in the vicinity of the water or otherwise interfere with fish or aquatic life.

(g) Toxic Substances - There shall be no substances added to the waters that will produce toxic conditions that affect fish or aquatic life.

(h) Other Pollutants - Other pollutants shall not be added to the waters that will be detrimental to fish or aquatic life.

(i) Coliform - The concentration of the fecal coliform group shall not exceed 1,000 per 100 ml as the logarithmic mean based on a minimum of 10 samples collected from a given sampling site over a period of not more than 30 consecutive days with individual samples being collected at intervals of not less than 12 hours. In addition, the concentration of the fecal coliform group in any individual sample shall not exceed 5,000 per 100 ml.[28]

The researcher noted that these standards set by the Water Quality Control Board apply to all treatment plants in East Tennessee. These came into effect in December of 1973 and there are no immediate plans for revision.[29] It was also noted that these standards made no mention of acceptable phosphate and/or nitrate concentration level.[30]

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[28]Ibid., pp. 4-5. [29]Kincaid, November 3, 1978.

[30]Ibid.

## CHAPTER III

## TREATMENT PLANTS USED IN THIS STUDY

This chapter will be devoted to developing information concerning each of the specified treatment plants used in this study. These plants were chosen because they immediately surround Knoxville. These plants are also easily accessible to local high schools. Figure 3 illustrates the area of concentration.[31] (Statistical information for each plant was not available.)

### A. KNOXVILLE

Knoxville has four main treatment plants which are: Third Creek, Fourth Creek, Loves Creek, and East Creek. All of these plants eventually empty into the Fort Loudon Reservoir with the exception of the largest plant, Third Creek, which empties directly into the Reservoir. The types of treatment used at the plants are as follows: East Creek—activated sludge, Loves Creek—trickling filter, and Fourth Creek—activated sludge.

The treatment process at Third Creek was primary until 1970, at which time additional aeration basins and settling

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[31]Map prepared by Tennessee Valley Authority: Division of Water Control Planning, Open and Regulated Streams in Tennessee Valley, September, 1971.

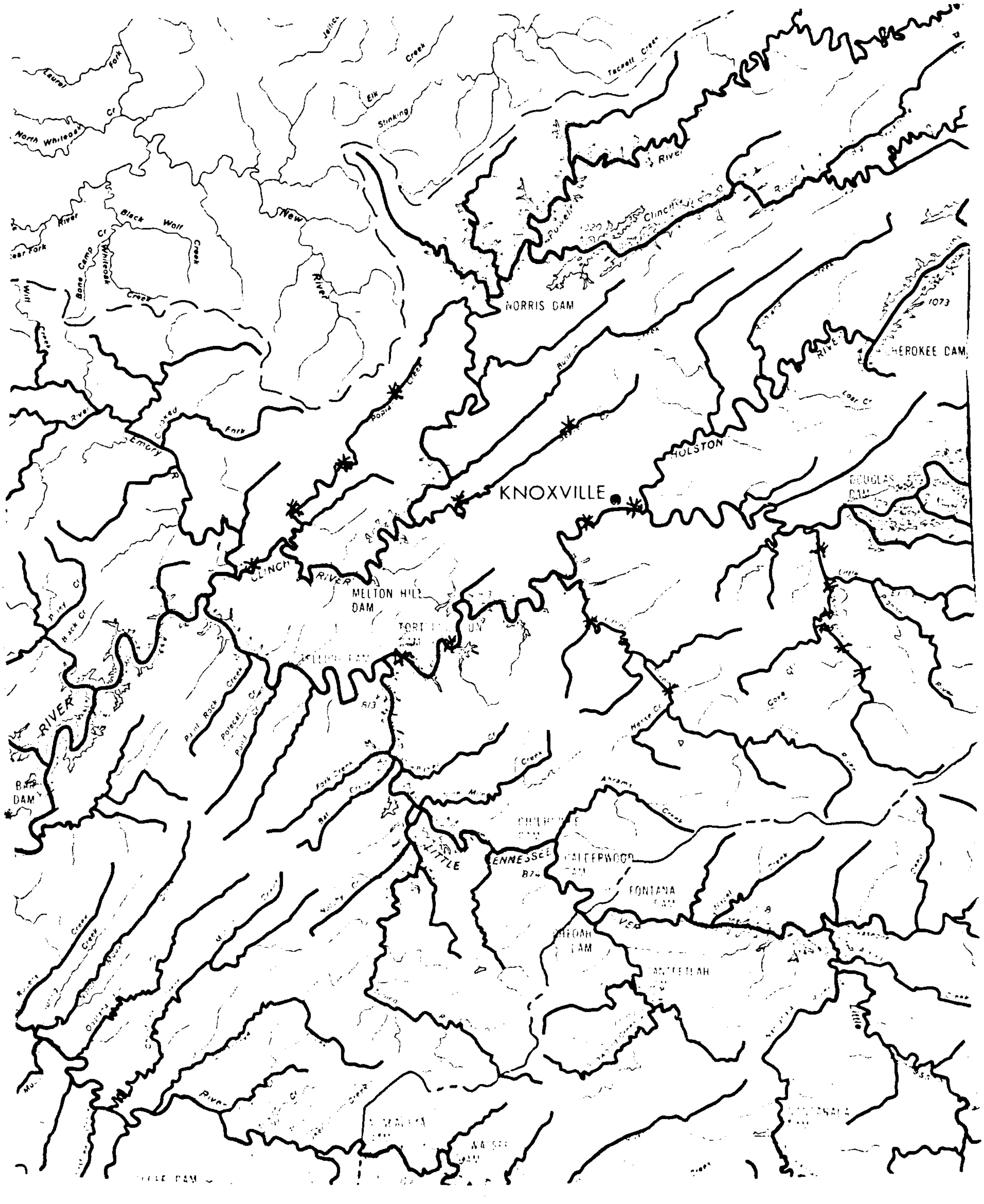


Figure 3. Map of Treatment Plant Locations.

Source: Tennessee Valley Authority. Division of Water Control Planning.

tanks were installed. The treatment today is considered secondary treatment, which is still minimal considering the size area it must handle. In fact, Knoxville is three or four times larger than the other cities in this study. Therefore, its facilities must handle much more raw sewage even though it has one of the most primitive methods of treatment.[32] (A new plant is under construction and is discussed in the conclusion.)

The researcher interviewed John Kincaid, Director of the Knoxville Wastewater Control System. He held some optimism concerning the installation of more efficient, advanced equipment, but not within the next ten years. The reason for this he states is,

> Although water samples and statistical data have been sent to the Public Health Department in Nashville clearly illustrating the dissolved oxygen to be below acceptable standards, they (P.H.D.) have suggested that "their" tests do not show a low dissolved oxygen figure and, therefore, Third Creek engineers must be using faulty equipment in their tests.[33]

The Public Health Department also stated in a letter to Don Parnell, Director of Metropolitan Planning Commission in Knoxville, that "secondary treatment at Third Creek will adequately protect the Fort Loudon Reservoir."[34]

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[32]Statement by Ronald L. Bond, Deputy Director of Wastewater Control System, personal interview, Knoxville, Tennessee, October 30, 1978.

[33]Kincaid, November 3, 1978. [34]Bond, October 30, 1978.

Table 1 and Figure 4 describe the process of treatment at Third Creek and provide general statistical data.[35]

B. CONCORD

Concord, Tennessee, a West Knox County residential area, has almost doubled in population in the last several years. This increase is due to the development of numerous subdivisions (Fox Den, Concord Hills, Rivermist, etc.).

Until recently (1976) the sewage treatment plant was located on Campbell Station Road. However, due to construction of a new school and complaints from subdivisions, the plant was moved to the point at which Turkey Creek empties into Fort Loudon Reservoir.[36]

The new plant is definitely an improvement over the old inadequate equipment. The method used at this plant is secondary activated sludge. As was found in this study, this method has the potential of removing 70 to 90 percent of phosphates. A pipe leads from the plant under water and releases the product in the middle of the reservoir. By doing this the impurities still contained in the water are

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[35]City of Knoxville, Wastewater Treatment Department, p. 20.

[36]Statement by Robert Ivy, Director of Water Quality Control System (Concord), personal interview, Concord, Tennessee, November 4, 1978.

TABLE 1

DESIGN CRITERIA, THIRD CREEK WASTEWATER TREATMENT PLANT

| | |
|---|---|
| **Design Flow, MGD** | |
| Average dry weather | 40 |
| Maximum dry weather | 70 |
| Peak storm rate | 120 |
| **Design Loadings** | |
| $BOD_5$ | |
| Average concentration, mg/l | 300 |
| Average total, lb/day | 100,100 |
| Suspended solids | |
| Average concentration, mg/l | 350 |
| Average total, lb/day | 116,800 |
| Ammonia nitrogen | |
| Average concentration, mg/l | 12 |
| Total nitrogen | |
| Average concentration, mg/l | 26 |
| **Bar Screens** | |
| Number | 3 |
| Average capacity each unit, MGD | 40 |
| Average flow through velocity, fps | 2.5 |
| Open area each unit, $ft^2$ | 25 |
| **Raw Waste Pumps** | |
| Number | 4 |
| Firm pumping capacity, MGD | 70 |
| Total installed pumping capacity, MGD | 120 |
| **Grit Tanks** (Aerated) | |
| Number | 4 |
| Width, ft. | 15 |
| Length, ft. | 45 |
| Average water depth, ft. | 15 |
| Detention time, minutes | 3.6 |
| Air supplied per tank, $ft^3$min. | 225 |
| Total hydraulic capacity, MGD | 120 |
| **Preaeration Tanks** | |
| Number | 1 |
| Width, ft. | 20 |
| Length, ft. | 160± |
| Average water depth, ft. | 15 |
| Detention time, minutes (avg.) | 13 |
| Hydraulic capacity, MGD | 70 |

TABLE 1 (continued)

| | |
|---|---|
| **Primary Clarifiers** | |
| Number | |
| Existing | 8 |
| New | 10 |
| Width, ft. | 19.75 |
| Length, ft. | 144 |
| Average water depth | 13 |
| Effluent weir length per tank, ft. | 225 |
| Weir loading, gpd/ft. (avg.) | 10,000 |
| Dention time, hrs. (avg.) | 3.0 |
| Overflow rate, gal/day/ft$^2$ (avg.) | 782 |
| Hydraulic capacity, MGD | 70 |
| **Primary Treatment** | |
| Estimated BOD reduction, percent | |
| Effluent $BOD_5$, mg/l | 25 |
| Effluent $BOD_5$, lb/day | 75,100 |
| Estimated suspended solids reduction, percent | 55 |
| Effluent suspended solids, mg/l | 160 |
| Effluent suspended solids, lb/day | 53,400 |
| Ammonia nitrogen | |
| Average concentration, mg/l | 12 |
| Total nitrogen | |
| Average concentration, mg/l | 26 |
| **Activated Sludge Aeration Tanks** | |
| Number | 6 |
| Width, ft. | 37 |
| Length, ft. | 157 |
| Average water depth, ft. | 10 |
| Detention time, hrs. | 1.54 |
| Oxygen required, tons/day | 42 |
| Volume per tank, ft$^3$ | 57,353 |
| Volumetric loading, lb BOD/1000 ft$^3$ day | 218 |
| Return sludge, percent | 50 |
| **Secondary Clarifiers** | |
| Number | |
| Existing | 3 |
| New | 2 |
| Width, ft. | |
| Existing | 71 |
| New | 71 |
| Length, ft. | |
| Existing | 144 |
| New | 144 |
| Average water depth, ft. | 12 |

TABLE 1 (continued)

| | |
|---|---|
| Effluent weir length, ft. | 800 |
| Weir loading, gpd/ft. (avg.) | 10,000 |
| Detention time, hrs. (avg.) | 2.7 |
| Overflow rate, gal/day/ft$^3$ (avg.) | 783 |
| Hydraulic capacity, MGD | 70 |
| <u>Secondary Activated Sludge Treatment</u> | |
| Estimated BOD reduction, percent | 87-93 |
| Effluent $BOD_5$, mg/l | 15-30 |
| Effluent $BOD_5$, lb/day | 5,000-10,000 |
| Estimated suspended solids reduction, percent | 81.94 |
| Effluent suspended solids, mg/l | 10-30 |
| Effluent suspended solids, lb/day | 3,400-10,000 |
| Ammonia nitrogen, mg/l | 15-18 |
| <u>Nitrification Activated Sludge Aeration Tanks</u> | |
| Number | 6 |
| Average water depth, ft. | 33 |
| Detention time, hrs. | 5.0 |
| Volume/million gallons | 8.3 |
| Volumetric loading, lb/BOD/1,000 ft$^3$/day | |
| Return sludge, percent | 50-100 |
| <u>Final Clarifiers</u> | |
| Number | 5 |
| Diameter, ft. | 135 |
| Average water depth, ft. | 12 |
| Effluent weir length per tank, ft. | 800 |
| Weir loading, gpd/ft. (avg.) | 10,000 |
| Detention time, hrs. (avg.) | 3.85 |
| Overflow rate, gal/day/ft$^2$ (avg.) | 559 |
| Hydraulic capacity, MGD | 559 |
| Equipped with skimmers | 70 |
| <u>Waste Activated Sludge Thickeners</u> (DAF) | |
| Number | 3 |
| Solids loading rate, lb/ft$^2$/day | 48 |
| Area required, ft$^2$ | 1,100 |
| Unit size, ft$^2$ | 500 |
| Underflow concentration, percent | 3-5 |
| <u>Waste Activated Sludge Transfer Pumping</u> | |
| (DAF to digesters) | |
| Percent solids | 3-5 |
| Firm pumping capacity, gpm | 200 |
| <u>Anaerobic Digesters</u> | |
| Number | 5 |
| Side water depth, ft. | 35 |

TABLE 1 (continued)

| | |
|---|---|
| Design loading, lbs VSS/$ft^3$/day | |
| First stage | 0.008 |
| Second stage | 0.03 |
| Maximum detention time, days | |
| First stage | 8 |
| Second stage | 22 |
| <u>Filter Press Dewatering</u> | |
| Solids loading lbs/day dry solids | 91,600 |
| Chemical conditioning lbs/day | 18,300 |
| Capacity of unit required, $yds^3$/day at 40% solids and 75 pcf | 156 |
| Hours of operation | |
| Hrs/day | 16 |
| Days/wk | 7 |
| Cake solids, percent solids | 40-50 |
| Type of disposal | Landfill |
| <u>Plant Effluent Requirements</u> | |
| $BOD_5$ | |
| Average concentration, mg/l | 30 |
| Average total, lb/day | 10,000 |
| Suspended solids | |
| Average concentration, mg/l | 30 |
| Average total, lb/day | 10,000 |
| <u>Disinfection</u> | |
| Number | 2 |
| Average water depth, ft. | 15 |
| Number of channels | 6 |
| Contact time, minutes at 70 MGD | 30 |
| Contact time, minutes at 40 MGD | 54 |
| Contact time, minutes at 120 MGD | 18 |
| Volume, $ft^3$ | 195,000 |
| Chlorine dosage rate, mg/l (avg.) | 10 |
| Chlorine dosage rate, lb/day (avg.) | 3,400 |
| <u>Dechlorination</u> | |
| Number | 1 |
| Length, ft. | 30 |
| Width, ft. | 75 |
| Average water depth, ft. | 15 |
| Contact time, minutes at 70 MGD | 5 |
| Contact time, minutes at 40 MGD | 8.8 |
| Contact time, minutes at 120 MGD | 2.9 |
| $SO_2$ dosage rate, mg/l (avg.) | 10 |
| $SO_2$ dosage rate, lb/day (avg.) | 3,400 |

TABLE 1 (continued)

| | |
|---|---|
| Primary Sludge Pumping | |
| Percent solids (probably 4%) | 2-5 |
| Firm pumping capacity, gpm | 500 |
| Secondary Sludge Pumping - Recirculation | |
| Percent solids | 0.5-1.5 |
| Firm pumping capacity, MGD | 70 |
| Tertiary Sludge Pumping - Recirculation | |
| Percent solids | 0.4 |
| Firm pumping capacity, MGD | 70 |
| Primary Sludge Thickeners | |
| Number | 1 |
| Solids loading rate, lb/ft$^2$/day | 20 |
| Underflow concentration, percent | 8-10 |
| Actual solids loading, lb/ft$^2$/day | 8.4± |
| Primary Sludge - Transfer Pumping (Thickener to digesters) | |
| Percent solids | 5-7 |
| Firm pumping capacity, gpm | 250 |
| Ammonia nitrogen | |
| Average concentration, mg/l | 5 |
| Average total, lb/day | 1,668 |
| Coliforms, colonies/100 ml | 200 |
| Chlorine residual, mg/l | 0.5 |

Source: City of Knoxville Wastewater Treatment Department.

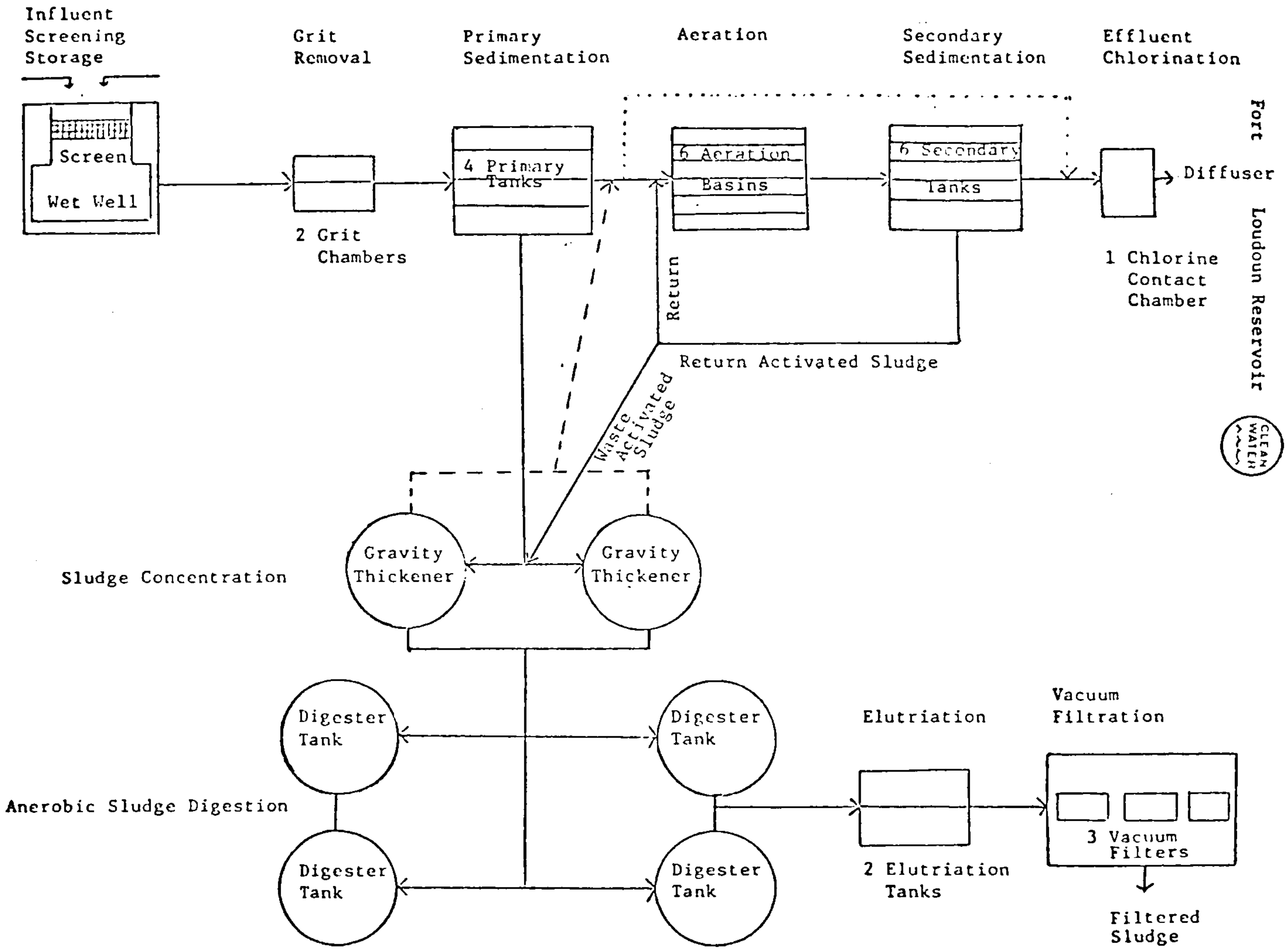


Figure 4. Process Diagram, Third Creek Treatment Plant.

Source: City of Knoxville Wastewater Treatment Department.

subject to greater water flow and are less likely to wash to shore.

One of the major aspects of this system is the addition of a special unit which is designed to remove ammonia nitrogen.[37] (Figure 5 illustrates a schematic design of this plant.)

## C. MARYVILLE/ALCOA

The city of Maryville built a new sewage treatment plant two years ago. It was designed to process sewage for Alcoa and Maryville. The plant currently processes 7.5 million gallons per day and the type of treatment is activated sludge. The effluent is emptied into the Little River which eventually flows into the Tennessee River. The director of this plant, Mr. Rex Ogle, stated that they do not routinely test for nitrate or phosphate levels in the effluent because it was not required by the Tennessee Water Quality Control Board or the Environmental Protection Agency.[38]

## D. LENOIR CITY

Lenoir City utilizes primary treatment for their raw sewage. The solid materials are placed in digester tanks,

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[37] Ibid.

[38] Statement by Rex Ogle, Director of Water Quality Control, personal interview, Maryville, Tennessee, November 10, 1978.

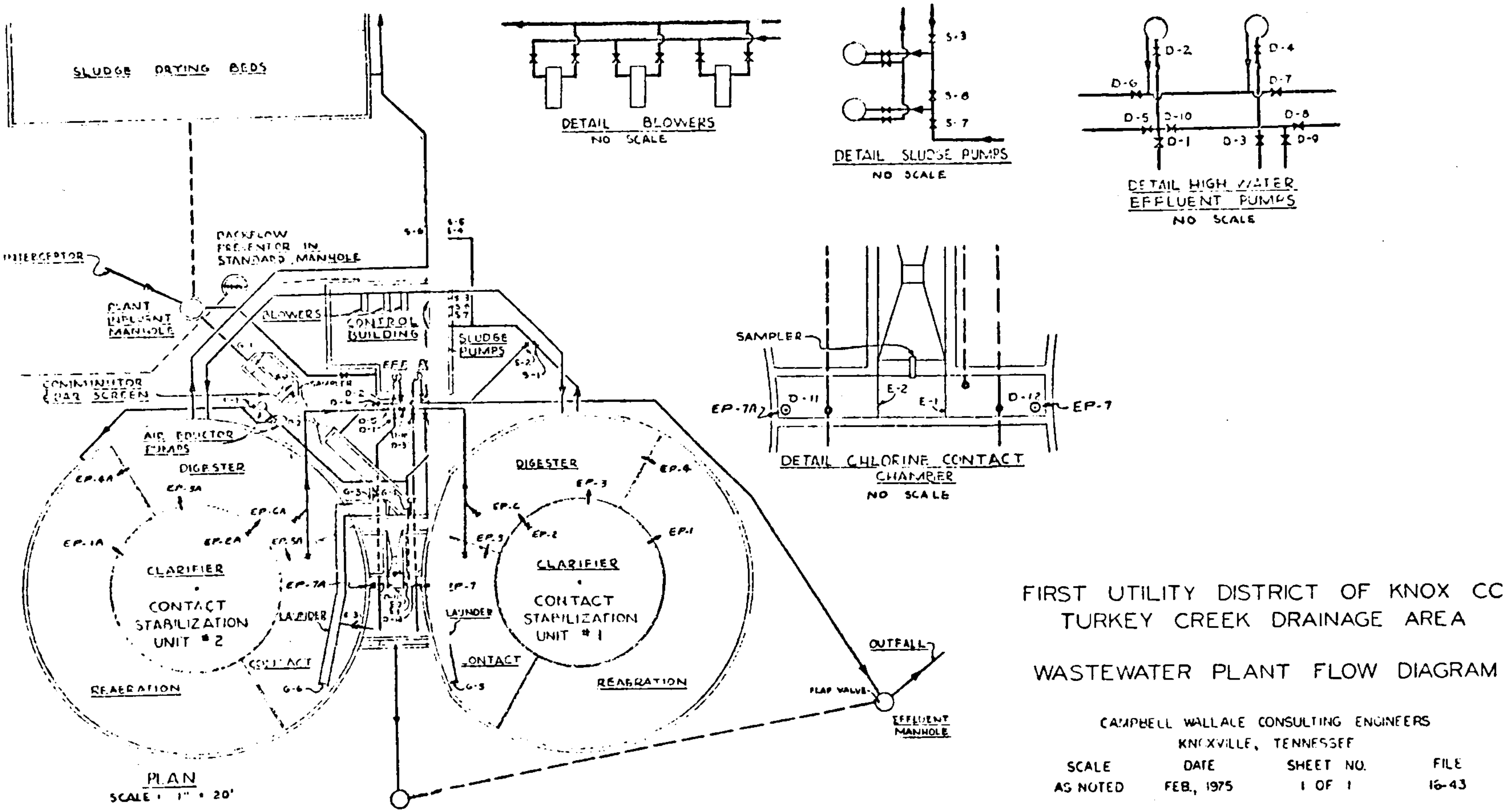


Figure 5. Wastewater Plant Flow Diagram of Turkey Creek.

Source: Robert Ivy, First Utility District of Knox County, Concord, Tennessee.

dried and given to farmers to be used as soil fertilizer. The liquids are emptied into the Tennessee River.[39]

## E. GREENBACK

Greenback, which is located near Lenoir City, does not have a water-waste treatment system. It is one of the few communities in East Tennessee which relies solely upon septic tanks for sewage disposal. This method prevents pollutants from entering the major water systems, but it has severe sanitation problems in ground water. For example, fecal coliforms such as <u>E. coli</u> are left untreated and can be deadly.[40]

## F. CLINTON

Clinton is a rather small area, but uses a much more efficient method of sewage treatment than larger areas such as Knoxville. Their plant uses a secondary trickling filter method.[41] If this system were carried a step further (tertiary), the water would almost qualify for "drinking" water.

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[39] Letter from Lenoir City Wastewater Treatment Plant, November 11, 1978.

[40] Letter from Greenback Utility District, November 12, 1978.

[41] Letter from the staff of Clinton Wastewater Treatment Plant, November 13, 1978.

## G. HALLSDALE-POWELL

The Beaver Creek Wastewater Treatment Plant of the Hallsdale-Powell Utility District is an activated sludge type secondary treatment plant with tertiary treatment by rapid sand filters. It is designed for 96 percent removal of raw BOD at 250 mg/l and 98 percent suspended solids at a 300 mg/l, respectively, in the influent. The design average daily flow is 2.1 MGD (million gallons per day). Peak hydraulic cacacity of the plant is 5.7 MGD with any single unit out of service.[42]

The plant is designed to satisfy the discharge certificate which requires a monthly average of the daily average effluent characteristics to meet the standards established by EPA (see Table 2).

## H. SEVIERVILLE

The city of Sevierville Sewage Treatment Plant is an activated sludge type secondary treatment plant. It is designed for 90 percent removal of raw BOD and suspended solids at a concentration of 155 mg/l and 200 mg/l, respectively, in the influent and at a daily average flow of

[42]Letter from Beaver Creek Wastewater Treatment Plant, November 21, 1978.

TABLE 2

EPA STANDARDS FOR HALLSDALE-POWELL TREATMENT PLANT*

| Effluent | Effluent Monthly Average | Effluent Weekly Average |
|---|---|---|
| BOD (5 day) | 8.0 | 12.0 |
| Suspended solids | 30.0 | 45.0 |
| $NH_3$-N minimum | 3.0 | 3.0 |
| Dissolved oxygen | 1.0 | |

*Concentration mg/l effluent.

Source: Statement by Mr. Ronald Qualls, Head Engineer of Beaver Creek Wastewater Treatment Plant, personal interview, Powell, Tennessee, November 27, 1978.

1.5 MGD. Peak hydraulic capacity of the plant is 2.07 MGD.[43]

This plant design is intended to satisfy the discharge certification which requires a daily average effluent BOD and suspended solids not to exceed a concentration of 30 mg/l and 40 mg/l, respectively. (See Figure 6.)[44]

Two of the major problems in Sevierville's system are (1) being located downstream from Gatlinburg, thus receiving their effluent, and (2) serving such a growing area with a small body of water as an outlet.

Unfortunately, the East Fork of the Little Pigeon River is now showing the effect of these problems: many game fish are dying off and being replaced by scavengers.

No plans are currently being made for improvement to the system.

## I. OAK RIDGE

Oak Ridge has two sewage treatment plants. An East Plant processes two million gallons of sewage per day. This plant uses a secondary (activated sludge) method and empties the effluent into the Clinch River. The West Plant uses

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[43] _City of Sevierville Wastewater Treatment Plant Manual_, pp. 2-4.

[44] Ibid.

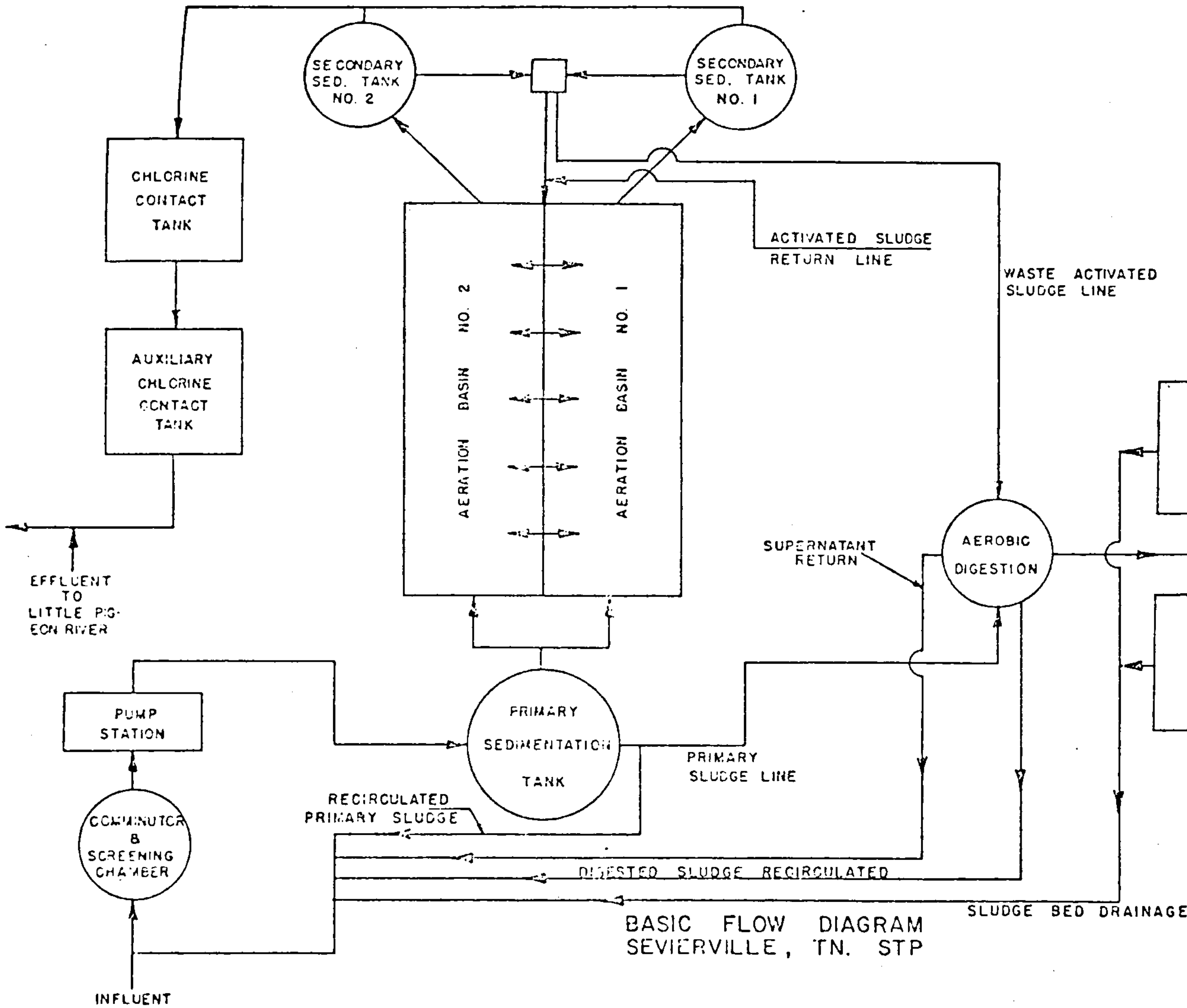


Figure 6. Basic Flow Diagram, Sevierville, Tennessee.

Source: City of Sevierville Wastewater Treatment Plant.

primary treatment, and processes approximately 3.5 million gallons of sewage per day. The effluent is released into Poplar Creek which eventually merges into the Clinch River and then into the Tennessee River.

These two plants are not required by the EPA to check for phosphate and nitrate concentration in the effluent; however, their records indicate such tests have been performed. (High levels: greater than 7 ppm were recorded for each.)

According to Director Thomas Fortner, one new plant which will contain secondary and some tertiary treatment and will encompass six to possibly twelve million gallons per day will be under construction in March, 1980.[45] (See Figure 7.)

## J. GATLINBURG

Gatlinburg was at one time considered a small village which served as a seasonal tourist attraction. They developed plans for a simple secondary sewage system in 1952-53 on the basis of their small size. Today this "village" is now a town which is growing at an extremely rapid rate. The permanent population has increased steadily;

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[45]Statement by Mr. Thomas Fortner, Director of Oak Ridge Water and Water Waste Treatment Plant, personal interview, Oak Ridge, Tennessee, May 8, 1979.

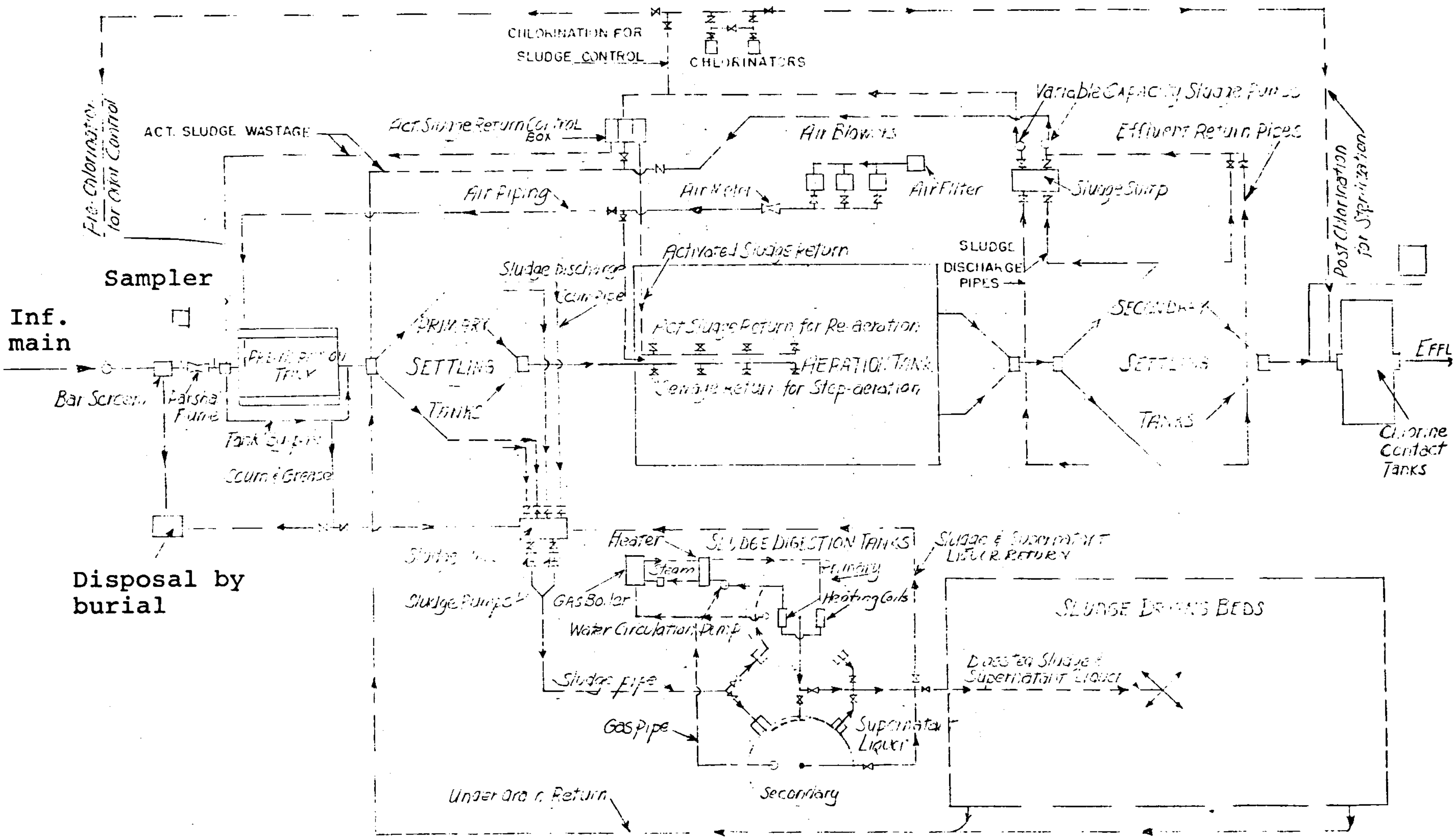


Figure 7. Basic Flow Diagram, East Plant, Oak Ridge, Tennessee.

Source: Thomas Fortner, Oak Ridge, Tennessee.

in addition, the tourists have also increased and are no longer seasonal but yearly. At the present time, the treatment plant developed in 1953 still remains. They encompass a "secondary method" (trickling filter) which is minimal considering the increased population. Another aspect which makes their sewage system inadequate is the fact that they have been releasing this partially treated sewage into a small stream (West Prong of the Little Pigeon River). This stream does not have the capacity to dilute impurities received from this type of treatment.[46]

In the last five years the EPA has pressured this city into improvement of their system.[47] Finally, in 1977, plans were approved and construction began for a new treatment plant. This plant is designed to handle 300 MGD of raw sewage. It is an activated sludge method, but contains tertiary units which remove 50 percent of the phosphate and nitrate. Completion of this new plant is scheduled for July, 1979.[48]

K. PIGEON FORGE

The Pigeon Forge Treatment Plant is located approximately eight miles downstream from the Gatlinburg plant on the West

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[46]Statement by Mr. James Davey, Head Engineer of Gatlinburg Wastewater Treatment Plant, personal interview, Gatlinburg, Tennessee, November 12, 1978.

[47]Ibid.

[48]Ibid.

Prong of the Little Pigeon River. According to Director William Stinnett, this plant utilizes an activated sludge method with added tertiary treatment which removes 98 percent of nitrogen. This plant processes approximately 1.25 MGD of raw sewage. It was also noted this plant does not remove phosphate nor do the engineers check for phosphate concentration in the effluent.[49]

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[49]Statement by Mr. William Stinnett, Director of the Wastewater Treatment Plant in Pigeon Forge, personal interview, Pigeon Forge, Tennessee, May 1, 1979.

## CHAPTER IV

## ANALYSIS OF THE DATA

In order to more accurately analyze the effectiveness of each treatment plant in waste removal and determine their contribution to eutrophication, water samples were collected and tested.

Each water sample was collected in triplicate immediately above the treatment plant and five miles below. There are certain procedures to use when taking the water samples which are discussed in Chapter V.

These samples were collected on April 1, 1979, by the researcher. The dissolved oxygen test was performed on site using the HACH Dissolved Oxygen Meter. The pH, nitrate and phosphate tests were performed in the University of Tennessee Environmental Engineering Laboratory by James Bird and the researcher.

Table 3 shows the results of the various water samples utilized in this study in terms of temperature, pH, DO, phosphate and nitrate concentration.[50]

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[50] Data compiled by James Christy Bird, graduate student in Environmental Engineering, University of Tennessee, and the researcher. Personal interview with James Christy Bird, April 26, 1979.

TABLE 3

CORRELATION BETWEEN WATER SAMPLES TAKEN ABOVE AND FIVE MILES BELOW EACH TREATMENT PLANT

| Sample Location | Water Temp. °C | pH[a] | DO mg/l | Total Phosphate[b] | $NO_3$ mg/l[c] |
|---|---|---|---|---|---|
| Gatlinburg | | | | | |
| Above | 10° | 6.05 | 10.4 | .06 | 1.05 |
| Below | 10° | 6.40 | 9.0 | .46 | .92 |
| Pigeon Forge | | | | | |
| Above | 10° | 6.60 | 9.0 | .15 | 1.00 |
| Below | 11° | 7.10 | 9.8 | .11 | 1.11 |
| Sevierville | | | | | |
| Above | 9° | 7.00 | 10.4 | .08 | 1.05 |
| Below | 11° | 7.10 | 9.0 | .09 | .95 |
| Hallsdale-Powell | | | | | |
| Above | 13° | 7.50 | 6.0 | .10 | 5.93 |
| Below | 14° | 7.50 | 5.8 | .22 | 6.19 |
| Clinton | | | | | |
| Above | 7° | 7.95 | 6.0 | .14 | 4.10 |
| Below | 8° | 8.00 | 5.0 | .11 | 4.20 |
| Oak Ridge-E. Plant | | | | | |
| Above | 16° | 7.80 | 5.0 | .12 | 9.01 |
| Below | 17° | 7.20 | 4.0 | .63 | 15.62 |
| W. Plant | | | | | |
| Above | 17° | 7.9 | 5.4 | .60 | 8.99 |
| Below | 18° | 8.0 | 4.0 | .70 | 15.59 |
| Concord | | | | | |
| Above | 17° | 7.55 | 5.0 | 1.00 | 1.49 |
| Below | 18° | 7.70 | 4.5 | 1.00 | 2.91 |
| Lenoir City | | | | | |
| Above | 16° | 7.70 | 4.0 | .09 | 1.31 |
| Below | 18° | 7.85 | 3.0 | .10 | 2.72 |
| Maryville/Alcoa | | | | | |
| Above | 13° | 7.65 | 6.0 | 0.00 | .68 |
| Below | 14° | 7.65 | 5.8 | .07 | .70 |
| Knoxville-Third Creek | | | | | |
| Above | 15° | 7.90 | 5.0 | .15 | 7.75 |
| Below | 16° | 8.00 | 3.0 | .16 | 7.78 |

TABLE 3 (continued)

[a]pH measurements at location temperature.

[b]Phosphate measured as total phosphate as P, mg/l, by persulfatel acid digestion procedure.

[c]Nitrate measurements by selective ion electrode.

It should be noted that for a more complete evaluation of the water quality at these plant locations a series of tests must be performed over a given period of time to counteract influences such as increased rainfall or accidental chemical spills. However, for the purposes of this study one sampling period was sufficient.

The results of this study indicate a strong relationship between eutrophic conditions found in the streams the effluent was piped into and the type of sewage treatment facilities available at each plant.

There appeared to be no other extraneous factors involved such as local industries or large-scale farming which could have influenced the results of the water analysis. Therefore the researcher must maintain that any high levels of pollutants found in the water samples taken below the plants were a direct result of inadequate removal of these substances in the treatment plant.

During sampling, the first function performed by the researcher was to take the temperature of the water. This was necessary to calibrate the dissolved oxygen meter and for general information in illustrating any pattern which might exist. The results of the temperatures taken at each plant above and five miles below indicated a general increase in the water temperature below each plant. In fact, all plants demonstrate a one to two degree increase in water temperature below each plant with the exception of Gatlinburg. This stable, cool temperature in the Gatlinburg stream is characteristic of fast-moving mountain streams even in the presence of high pollution levels.

The Water Quality Act referred to in Chapter II stated that the pH value of water for fish and aquatic life must be within the range of 6.5 to 8.5. All of the water samples taken above and below each treatment plant contain pH values within the prescribed range with the exception of the Gatlinburg stream which was found to be slightly acidic above and below the treatment plant. Therefore, this acidity was not removed by the type of treatment in this particular plant. This acid condition will perhaps have a negative effect upon the game fish which presently occupy this stream.

The Water Quality Act states also the dissolved oxygen contained in the water for fish and aquatic life should be a minimum of 5.0 mg/l except where (1) present technology cannot restore the water quality to the desired minimum of 5.0 mg/l dissolved oxygen, (2) the cost of meeting the standards is economically prohibitive when compared with the excepted benefits to be obtained, or (3) the natural qualities of the water are less than the desired minimum of 5.0 mg/l. The dissolved oxygen concentration of recognized trout streams should not be less than 6.0 mg/l.

The results of the water analysis indicated lower than minimum standards of dissolved oxygen in the waters flowing by both Oak Ridge plants (East and West), which are Poplar Creek and the Clinch River, the Concord plant which empties effluent directly into the Fort Loudon Reservoir, the Lenoir City plants which empty effluent directly into the Fort Loudon Reservoir, and the Knoxville Third Creek plant which also pipes effluent into the Fort Loudon Reservoir. The lowest readings of DO were noted in Lenoir City with 4.0 mg/l upstream and 3.0 mg/l downstream. Knoxville's Third Creek plant had the next lowest readings with 5.0 mg/l upstream and 3.0 mg/l downstream. The levels of high DO readings in Gatlinburg, Pigeon Forge, and Sevierville are not unusual but frequent in fast-moving streams which are aerated constantly.

During the next decade, game fish will die out while scavengers which require less oxygen will greatly increase in number under existing treatment plants.

The total phosphate levels were considered to be low in all sampling locations with Concord the highest. The EPA has varying standards concerning phosphate levels; however, any reading above 5.0 mg/l is considered above normal.[51]

These low readings could be due to several factors: (1) the use of low phosphate detergents by area residents,

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[51]Ibid.

(2) the increase in rainfall that occurred during the sampling period which would dilute the water, thus giving a lower reading, or (3) an error in testing which is not likely because the samples were tested in duplicate.

For a more accurate reading, the phosphate tests should be performed in the summer dry months in order that the dilution factor may be decreased.

The EPA standards for nitrate concentrations in waters also varies. However, the Agency agrees that any reading above 5.0 ml/l is not normally found in unpolluted waters. The personnel at the Oak Ridge waste water treatment facilities also consider 5.0 mg/l to be high, thus eventually leading to eutrophic conditions.

The nitrate levels of concentration were found to be over the recommended level in Beaver Creek (Hallsdale-Powell plant), in the Fort Loudon Reservoir (Knoxville Third Creek plant, and extremely high in Poplar Creek and the Clinch River (East and West plants of Oak Ridge). The lowest nitrate reading was found in the Little River (Maryville/Alcoa plant).

These high levels of nitrate will eventually lead to eutrophic conditions in these waters, thus creating a rapid increase in plant growth and decay causing undesirable aesthetic conditions for recreational purposes and a decrease in game fish population as the oxygen content becomes depleted.

## A. CONCLUSIONS

The results of the water analysis appear to clearly demonstrate eutrophic conditions present in the water associated with the treatment plants that have the most primitive type of sewage treatment.

In the event these primitive waste water facilities are not replaced with advanced tertiary methods of treatment, eutrophic conditions will dramatically increase leaving virtually no desirable fish population and very few attractive qualities in the waters included in this study.

It is the belief of the researcher that this type of action research can have a more profound effect upon the student than the usual textbook approach. The use of this methodology in secondary science classes would create in students: (1) a sense of control, in that they are performing the actual tests and witnessing the immediate results, (2) a feeling of contributing to a worthwhile environmental concern, and (3) an understanding of man's effect on the environment.

Further, it is the expectation that this type of research would lead to more involvement in community awareness and provide a course for legislative action.

# CHAPTER V

# IMPLICATIONS FOR SCIENCE EDUCATION, CONCLUSIONS, AND RECOMMENDATIONS

This research of local waste water treatment plants can provide an enrichment study to high school science classes. For example, this could be ideally utilized as an action research project taught in conjunction with a unit on water pollution.

The following steps can provide a logical format to such a unit for science teachers.

## A. BEGINNING IN THE CLASSROOM

1. Provide a discussion of the dynamics of water pollution including the major causes globally and the major causes in this area. (Material on this information may be obtained by contacting the Knoxville Water Quality Control Board.)

2. Illustrate the chemical reactions which occur during eutrophication. (An excellent example of this is found in a book which was used in preparation of this study entitled Chemistry, Man, and Society. See bibliographical entries.)

3. List the effects of eutrophic conditions on man and aquatic life such as a tremendous increase in plant growth

leading to decay, decreased oxygen supply which eventually leads to unpleasant odors and an unaesthetic aquatic environment.

4. Discuss thoroughly the meaning of terms such as sewage, BOD, DO and pH. Good working definitions for these terms can be found in a booklet published by the City of Knoxville entitled Understanding Sewage and Sewage Treatment (see bibliographical entries).

5. Explain the different types of waste water treatment in detail including very advanced methods being proposed for use in certain areas of the United States where water quality is very poor. Include the use of diagrammatic charts to illustrate the mechanics involved in each type of treatment (flow charts similar to the ones contained in this study are available by contacting Mr. John Kincaid, Director, City of Knoxville Wastewater Treatment Facility).

6. Discuss how to correctly obtain water samples by taking them in mid-stream at mid-depth, washing the bottle out with sample water and then filling it by allowing it to overflow. Additional materials for this procedure can be found in a book entitled Standard Methods: For the Examination of Water and Wastewater.[52]

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[52] American Public Health Association and others, Standard Methods: For the Examination of Water and Wastewater (New York: American Public Health Association Press, 1971), pp. 34, 233, 283.

7. Explain and demonstrate how the dissolved oxygen meter operates and why it is advantageous to take the DO readings on site. (The meters may be ordered by the school from the HACH Chemical Company or they may be borrowed from University of Tennessee Fisheries and Wildlife Department upon advance notice—specific detailed instructions for operating this meter are contained within a booklet which comes with the meter.)

8. Explain other tests such as nitrate, phosphate and pH. The HACH Chemical Company can provide this information in other booklets or use the Standard Methods book.

9. On a map locate the major treatment plants in the area, noticing what body of water the effluent from each plant is piped into and where each river or stream eventually flows. Maps of the area water systems can be obtained with no expense from the Tennessee Valley Authority Map Sales Department.

10. Make arrangements with the plant directors to visit specified plants for a guided tour. The names of local plant directors are listed in Chapter III.

11. Plan a special discussion on the laws concerning water quality and if possible include a guest speaker from the EPA. A copy of the laws concerning water quality may be obtained by contacting Mr. John Kincaid.

## B. IN THE FIELD

1. If available, make use of equipment such as a canoe, boots, waders, and long poles for collecting water samples.

2. Group students having no more than five to a group (this allows for more individual activity).

3. Assign each group an activity to perform:

   a. Temperature taking—which is necessary to calibrate the DO meter.

   b. Collection of samples in duplicate or triplicate.

   c. Labeling of bottles (labels can be found at the University of Tennessee Book and Supply Store).

   d. Dissolved oxygen testing using the HACH DO meter.

   e. pH testing using a HACH pH meter.

   f. Recording of data at sampling sites.

4. Plan to take the samples back to the school laboratory and perform the nitrate or phosphate tests.

It should be noted that these tests may be performed with the large nonportable HACH water analysis machine or they may be performed using the method described in the *Standard Methods* book. If the method in *Standard Methods* is used, special reagents and equipment must be obtained. The reagents may be purchased by contacting the University of Tennessee Environmental Engineering Department or Stewart Laboratories. The equipment may be borrowed or used at either place. The HACH water analyzer may be obtained directly from the company or by contacting a local school which has one.

5. With the results from the tests, prepare a graph similar to the one listed in this study and note the differences in water quality above the treatment plant and five miles below (if unexpected results are obtained, have students explain what might account for this).

6. Make a correlation between highly polluted waters and the type of treatment existing near the waters.

7. Have the students investigate who is responsible for finances and improvements in waste water plants (information concerning this may be obtained by contacting local City Council members).

8. Go through the motions of preparing an Environmental Impact Statement with the students (the University of Tennessee Environment Center located in South Stadium Hall may be of assistance; also contact the University of Tennessee College of Law).

## C. CONCLUSIONS

The ideas and methods for teaching supplementary units on water pollution have not been completely exhausted in this study. However, it is the belief of the researcher that this study can provide a logical framework which science teachers may rely upon when planning a similar unit. This type of active, individual research is believed to have a greater effect upon the student than merely performing experiments within the school laboratory. This research would create within the student a sense of control in that the students themselves would be the research team and the validity of the results depends primarily upon their actions and their ability to cooperate with one another in a joint effort to perform a worthwhile task. This research is also designed to create a feeling of making a significant contribution to the community as a whole.

The researcher also believes these activities will develop in students responsibility, mechanical dexterity, team work, mental thought processes, and a genuine sense of concern toward their environment.

## D. RECOMMENDATIONS

It is evident from this research that areas such as Knoxville, Lenoir City and Oak Ridge, with existing primitive types of waste water treatment, are contributing significantly to rapidly increasing eutrophic conditions in the streams and rivers which surround them. In the event these inadequate types of treatment remain for the next decade, eutrophication will increase, thus fish and aquatic life will decrease and eventually cease completely.

It is also evident from this research that the science programs in local and regional schools would profit greatly by using such methodology in researching the waste water treatment facilities in local areas. This type of environmental research not only optimally utilizes the prime resources in the surrounding geographic locations, but it provides a movement toward public awareness, environmental concern, and legislative action.

The researcher recommends that science teachers in the East Tennessee area be encouraged to utilize this type of action research when teaching a similar unit on water pollution. The primary objective this will accomplish would be to bring science into a more realistic point of view instead of a theoretically based subject.

It is also recommended that similar units using action research be developed for other types of environment concerns, e.g., noise pollution, solid waste disposal.

The future of improved waste water treatment is dependent upon education of the public through the school systems. Once aware of this increasing problem, concerned citizens of this area should formulate Environmental Impact Statements for possible legislation and contact state representatives or City Council members for future action to eliminate the problem of inadequate waste water treatment.

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# VITA

Saunooke Kimberly Pedigo was born in Knoxville, Tennessee. She is the daughter of Mr. and Mrs. Pete Pedigo and the sister of Dr. Randall Pedigo.

She entered the University of Tennessee, Knoxville, in June of 1972 and graduated in March of 1977 with a Bachelor of Science degree in Biological Science Education. In June of the same year she entered the Graduate School at the University of Tennessee at Knoxville in the College of Education in the area of Science Education. She plans to receive a Master of Science degree in June, 1979.

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