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Sewer system and treatment plant for Middlesboro, Kentucky.

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UNIVERSITY OF LOUISVILLE

SEWER SYSTEM AND TREATMENT PLANT

FOR

MIDDLESBORO, KENTUCKY

A Dissertation

Submitted to the Faculty

Of the Speed Scientific School of the

University of Louisville

In Partial Fulfillment of the

Requirements for the

Professional Degree of Civil Engineer

By

Robert E. Martin
B.S. in C.E., June 1931

June, 1941

Ref.

July '41

9

TABLE OF CONTENTS

PROFESSIONAL HISTORY	PAGE A
LIST OF ILLUSTRATIONS	PAGE B
ACKNOWLEDGEMENT	PAGE C
INTRODUCTION	PAGE D
CHAPTER 1 - BRIEF HISTORY OF THE CITY OF MIDDLESBOROUGH	PAGE 1
CHAPTER 2 - LOCATION AND GENERAL DESCRIPTION OF THE CITY	PAGE 8
CHAPTER 3 - NEED OF SEWER SYSTEM AND DISPOSAL PLANT	PAGE 11
CHAPTER 4 - APPLICATION TO THE UNITED STATES GOVERNMENT FOR FEDERAL AID	PAGE 15
CHAPTER 5 - PRELIMINARY LOCATION SURVEYS ON THE COLLECTING SYSTEM	PAGE 18
CHAPTER 6 - LOCATION OF TREATMENT PLANT AND PUMPING STATION	PAGE 25
CHAPTER 7 - PRELIMINARY INVESTIGATION AND CHEMICAL TESTS	PAGE 28
CHAPTER 8 - DESIGN	PAGE 43
CHAPTER 9 - CONSTRUCTION OF COLLECTING SYSTEM	PAGE 51
CHAPTER 10- CONSTRUCTION OF TREATMENT PLANT AND PUMPING STATION	PAGE 63
CHAPTER 11- CONCLUSIONS	PAGE 75

PROFESSIONAL HISTORY

Upon graduating from the Speed Scientific School of the University of Louisville I was employed by D. X. Murphy, Architect. I was employed for the purpose of making road location surveys in Calvary Cemetery in Louisville, Kentucky. This particular assignment lasted for two months and I was responsible for all instrument work and note recording. My immediate superior was Mr. A. F. Giese, Civil Engineer, now deceased.

This assignment was followed by employment by the Southern Bell Telephone and Telegraph Company from July, 1930, to May, 1932. The duties performed included sales, collections and general office work. Sales work involved the selling of residential and commercial service, and special equipment such as teletypewriters and automatic private branch exchanges.

Later, I was promoted to the position of Collection Clerk. In this capacity I was in charge of the collection of over 10,000 accounts in a city of 70,000 population. General office work was one of the duties of this position. My immediate superior

was Mr. T. C. Crouch, Manager, Southern Bell Telephone and Telegraph Company, Columbia, South Carolina.

From January, 1932, until January, 1933, I was employed by the City of Louisville in the Engineering Department. My first assignment included location and construction of sewers. After a period of two months I was placed in charge of sewer design, which position was held until January, 1933. My immediate superior was Mr. J. B. Wilson, Chief Engineer, City Hall, Louisville, Kentucky.

In January, 1933, I accepted a position with the Road Department of Jefferson County, Kentucky. I was employed as Engineer in charge of a road location and construction crew for a period of five years. My immediate superior was Mr. H. N. Wood, County Engineer, Jefferson County Armory, Louisville, Kentucky.

From January, 1938, until January, 1939, I was employed by the Kentucky State Department of Highways with Junior Engineer rating. I was Chief of Party and worked on location and construction of state and rural highways. My superior was Mr. Lee Puryear, District Engineer, Kentucky Home Life Building, Louisville, Kentucky.

In January, 1939, I accepted a position with Mr. J. S. Watkins, Consulting Engineer of Lexington, Kentucky, as Resident Engineer. I was in charge of the Middlesborough, Kentucky, Sewer System during construction of the entire project. In addition to the above I was responsible for the planning of the entire collecting system. My immediate superior was Mr. J. S. Watkins, Consulting Engineer, McClelland Building, Lexington, Kentucky.

At the present time I am employed by Havens and Emerson, Consulting Engineers, as Designing Engineer.

In 1936, I accepted the position of Engineer of the Louisville Memorial Park, a position that I have held for the past five years. This position requires only part time. I am responsible for the design of this cemetery and I have supervised all construction work that has been done. My immediate superior is Mr. Bruce Head, President, Louisville Memorial Park, Shively, Kentucky.

LIST OF ILLUSTRATIONS

Illustration #1

Illustration #1 is a photostatic copy of a typical plan and profile sheet. The plan shows the location of the sewer with respect to the paved street and houses. The profile shows the original ground grades, rock profile and proposed sewer gradients. The scales have been reduced from the following: Horizontal: 1"=100' and Vertical: 1"=10'.

Illustration #2

Illustration #2 is a Part Plan sheet showing a portion of the city. It will be noted that each sewer is designated by a plan number and that the sheet is cross-referenced.

Illustration #3

Illustration #3 shows the plot plan and flow chart of the treatment plant.

Illustration #4

Illustration #4 shows the flume-weir design mentioned in Chapter 9.

Illustration #5

Illustration #5 is a sketch showing method

of supporting pipe where quicksand was encountered.

Illustration #6

Illustration #6 is an aerial photograph of the entire treatment plant site. All structures located between the canal and the railroad track are included in the treatment plant.

Illustration #7

Illustration #7 is a photograph showing a typical 8" sewer line located on the center line of Cumberland Avenue. Note the straightness of the sewer.

Illustration #8

Illustration #8 is a photograph showing the sewer trench located in the side walk along Edgehill Road.

Illustration #9

Illustration #9 is a photograph showing a sewer located between gasoline tanks. These tanks had been built on the dedicated right of way of the Alley North of Cumberland Avenue. Rather than have the owner of these tanks move them, the sewer was located as shown. All sheeting and bracing were left in place.

Illustration #10

Illustration #10 is a close up view of Illustration #9 showing the condition of the trench bottom.

Illustration #11

Illustration #11 shows the method used in bracing an 8" cast-iron sewer preparatory to placing the permanent concrete piers. Reinforcing steel can be seen extending up from the footings.

Illustration #12

This photograph shows a cast-iron sewer supported by concrete piers. Note the road fill on each side of the sewer.

Illustration #13

Illustration #13 is a photograph showing the sewer trench located between the paved alley and a building in the Alley South of Cumberland Avenue. The sheeting and bracing were left in place. Note that the boom on the trenching machine is offset in order to allow clearance adjacent to the building.

Illustration #14

Illustration #14 shows the north trickling filter under construction.

Illustration #15

Illustration #15 shows the two trickling filters under construction.

Illustration #16

Illustration #16 is a view inside the north trickling filter. Note the wall reinforcing and the filter block on bottom of filter.

Illustration #17

Illustration #17 shows the method of placing stone in the filters. This is a particularly good view of the filter block arrangement.

Illustration #18

Illustration #18 is a view of the two completed filters. Note the double walls and the rotary distributors.

Illustration #19

Illustration #19 shows the reinforcing steel in the sludge digester circular base.

Illustration #20

Illustration #20 is a view of the sludge digester under construction. Note the ramp on the left used for conveying concrete.

Illustration #21

Illustration #21 shows the completed sludge digester.

Illustration #22

Illustration #22 is a view showing the floating cover on the sludge digester.

Illustration #23

Illustration #23 shows the start of excavation at the Pumping Station. Note the condition of the bottom of the pit.

Illustration #24

Illustration #24 is a photograph showing construction of the bottom slab of the pumping station. Note the elevation of the canal at the top of the picture.

Illustration #25

Illustration #25 is a view of the completed pumping station.

Illustration #26

Illustration #26 is a view of the tannery waste retention basin.

Illustration #27

Illustration #27 shows the secondary settling basin in the foreground. The south trickling filter is immediately above the settling basin in the photograph. The road bridge can be seen in the upper left corner of the picture.

Illustration #28

Illustration #28 is a photograph showing the sludge beds and part of the sludge digester. Note the road around the sludge beds.

Illustration #29

Illustration #29 is a view of the completed head house.

Illustration #30

Illustration #30 shows part of the primary settling basin in the foreground. At the extreme left of the picture the constant head orifice box can be seen. Immediately to the right of the orifice box is the acid storage tank. The structure in the center of the picture is the flocculating basin. The structure at the top of the picture is the dosing tank.

ACKNOWLEDGEMENT

Acknowledgement is made to Mr. J. Stephen Watkins, Consulting Engineer of Lexington, Kentucky, for granting permission to write a thesis on this project. Acknowledgement is made also to the Middlesborough Chamber of Commerce and to Mr. H. L. Malone for historical facts and data included in this thesis.

INTRODUCTION

It is not often that the average young engineer has an opportunity to be in charge of a project of this scope throughout its duration. The writer appreciates this fact and has therefore written a complete report covering in detail typical problems encountered in work of this nature. The purpose of this thesis is to record data that in some way might give assistance to persons interested in a similar project.

CHAPTER 1

BRIEF HISTORY OF THE CITY OF MIDDLESBOROUGH

Documentary evidence reveals that Cumberland Gap and the mountain basin wherein the City of Middlesborough is now located were discovered in 1750 by Dr. Thomas Walker of Virginia. Four years later, John Finley led an expedition into Kentucky and stayed there for six months. It was Finley who told Daniel Boone of the possibilities and resources of the new western lands. Between Indian attacks, Boone built the trail known as the "Wilderness Road" through Cumberland Gap.

Following Boone's road building exploits, the first white settlers came from the Valley of Virginia to occupy the basin along Yellow Creek. There are no records that would indicate or fix a definite date of the settling of the Creek by the Virginians. For years the hardy backwoodsmen fought off the savage attacks of the hostile tribes of Mingoos, Cherokees, Catawbias, Shawnees, Creeks, Delawares, and Wyandots, without aid from, or even contact with, the outside civilization.

The early settlers erected a blockhouse and

lived closely together for the sake of protection. They put a very small portion of the fertile basin into cultivation and lived chiefly on meats of wild game, buffalo, bear, elk, deer, wild duck, wild geese, and swan.

According to tradition, the Yellow Creek Blockhouse was abandoned in about 1810, and the settlers scattered out on small clearings. They helped one another put up cabins, until each family had a dwelling. Even though the Indians were becoming more scarce, each cabin was fully equipped with firearms for protection.

Removal from the blockhouse to small farms had a very definite effect on the social and economic life of the mountaineers. Shortly after this removal, hard drinking, riotous living, and high tempers prevailed. Petty jealousies were magnified, until families were thrown into feudal battles with one another. As the Yellow Creek settlement grew, however, there was an infiltration of ministers of the gospel, and law and order began to take shape. About this time the Civil War broke out, and Cumberland Gap became a strategic point, for the possession of which the contending

Union and Confederate forces fought for nearly the duration of the War. The majority of the mountaineers around Cumberland Gap were sympathetic with the northern army, and, as a reward, Abraham Lincoln endowed a University at Harrogate, Tennessee.

In 1887, Alexander Allen Arthur, a Canadian lumber man, visited Cumberland Gap to prospect for natural resources originally reported by Dr. Thomas Walker. Arthur immediately left for London, where he succeeded in securing financial support to build an industrial and commercial city on Yellow Creek near Cumberland Gap. English engineers were dispatched to begin construction of a railroad, linking existing lines through Cumberland Gap Tunnel. As has been mentioned, the English engineers planned the city to be large enough to accommodate 150,000 people, but the present day population is approximately 12,000.

The rectangular system of city planning was employed by the English engineers and the right of way for streets was laid out in generous widths. The fact that nearly all dedicated streets are wide had a very definite effect upon the design of the

present Sanitary Sewer System. In most cities, a single sewer is constructed near or on the center line of each street, with the necessary service lines extending from the sewers to the buildings on both sides of the streets. It was found more economical to construct two sewers close to the property lines in a great number of instances, as will be shown later in this thesis.

It was estimated that it would cost \$30,000,000.00 to build a railroad, lay off the streets, cut a canal to confine Yellow Creek, and exploit the natural advantages of the city and the surrounding sections. Productive construction was started in the spring of 1888, and the new community was called Middlesborough.

With the erection of churches, schools, and hotels, Middlesborough became a rapidly growing city. The English financiers having formed the American Association bought 150,000 acres of land in one boundary. The American Association executed twenty year leases and thus created opportunity for small investments.

Subsequently, a new organization, the Middles-

borough Towne Lands Company, divided the city into building lots. At an approximate cost of \$125,000.00, the Towne Lands Company changed the winding course of Yellow Creek by means of a canal. A combined Storm and Sanitary Sewer System was planned, and the Main Outfall Line was partially constructed, at an approximate cost of a half-million dollars. This sewer was never completed and was never used. Sections of this old sewer were excavated during the construction of the new sewer.

Business boomed and prices sky-rocketed until February, 1890, when the Barring Brothers Banking House of London failed. This bank had been the chief support of the Towne Lands Company, and every investor therein suffered a signal loss.

AFTER INCORPORATION

In May, 1890, the City of Middlesborough was incorporated. During that same month occurred a fire that destroyed the entire business section of the city. The municipality was totally bankrupt; and since there were no police officers, an orgy of crime broke out. Lawlessness was again rampant, and killings were common occurrences. Finally, public sentiment reestab-

lished law and order, and the city began to progress once more.

The City of Middlesborough, ideally located in the heart of rich mining and agricultural sections, is the trade center of ten counties, five in Kentucky, three in Tennessee, and two in Virginia. Within this scope of territory is a wealth of natural resources. Coal deposits are enormous in the region immediately surrounding Middlesborough. There are thirteen workable coal veins, from two to eight feet thick, in the territory tributary to Middlesborough. Only a very small portion of this coal has been mined.

In addition to workable coal mines, there are a number of iron deposits adjacent to Middlesborough. In Powells Valley there are outcrops of Clinton and Oriskany types of iron deposits. None of these deposits has been worked thoroughly, but it has been estimated that the Clinton veins will produce in excess of 22,000,000 tons per square mile. It has also been estimated that the Oriskany deposits will yield in excess of 9,000,000 tons per square mile.

The valley adjacent to Middlesborough is

admirably adapted to the cultivation of nearly all kinds of farm products. Limestone in the Middlesborough area is practically inexhaustable.

The City of Middlesborough is served with water and electricity by the Kentucky Utilities Company and has a complete telephone system. Water is supplied from an impounded reservoir located approximately two miles from the center of the city.

Middlesborough is governed by the Commission form of Government. A Mayor and two City Commissioners with equal voting power are elected every two years. The city has fared extremely well in the realization of many public works, and with all these conveniences and advantages Middlesborough should grow to become the largest city in the southeastern section of Kentucky.

CHAPTER 2

LOCATION AND GENERAL DESCRIPTION OF THE CITY

The City of Middlesborough, Bell County, Kentucky, is located in a level mountain basin in the southeastern part of the state, approximately two miles west of historic Cumberland Gap, where the boundary lines of Kentucky, Virginia, and Tennessee meet. This mountain basin was once a large lake, and succeeding floods have built up the floor of the basin with sedimentary deposits resulting in large areas of quicksand.

Middlesborough, located in the valley drained by Yellow Creek and its tributaries, is surrounded by rugged mountains that rise to an elevation of 1800 feet above the floor of the basin. Yellow Creek, a tributary of Cumberland River, flows into it approximately ten miles upstream from Pineville, Kentucky. Yellow Creek is formed by the union of Bennetts Fork, Stony Fork, Lick Fork, Fourmile Run, Little Yellow Creek, and other minor tributaries. Stony Fork, Lick Fork, and Bennetts Fork unite above the principal business section of the city. Little Yellow Creek unites with these waters below the business district, but well within the residential and

industrial areas. The old Towne Lands Company straightened the winding course of Yellow Creek through the business district by means of a canal. Through this area Yellow Creek Canal has a bottom width of about thirty feet and an average depth of about ten feet. Leaving the basin through a narrow mountain pass, Yellow Creek follows a tortuous route of approximately twenty miles to its confluence with the Cumberland River.

The basin in which the City of Middlesborough is located is very flat, having only a fifteen-foot fall in a distance of five miles from the southwest to the northeast edges of town. This lack of fall presented both a difficult and interesting problem to the engineer in the location and design of the sewer system.

The city streets are laid out almost due east, west, north, and south, with the exception of a few residential sections situated in the hills on the outskirts of the city. The entire city was planned and laid out by English engineers, and it is interesting to note that all the streets bear English names. Streets running east and west have a right

of way of eighty feet with the exception of the two main streets; Cumberland Avenue is one hundred feet wide, and Exeter Avenue has a right of way of ninety feet. The streets running north and south have a right of way of sixty feet. Through the city, the canal has a right of way that varies from one hundred to one hundred and ten feet.

Geographically, the City of Middlesborough is a large city, since it was originally planned to accommodate 150,000 people. Actually, there are approximately 12,000 people living within the corporate limits of the city. The population per acre, therefore, is not dense, although there are certain sections of town that are thickly populated. The fact that the population is small and the city geographically large also presented a difficult problem to the engineer.

CHAPTER 3

NEED OF SEWER SYSTEM AND DISPOSAL PLANT.

The City of Middlesborough, located at the source of Yellow Creek, heretofore discharged the commercial, industrial, and domestic wastes into Yellow Creek, thereby polluting that stream from its very source. From observation it has been noted that Yellow Creek becomes stagnant in hot weather, and mosquitoes and other insects thrive to such an extent that they become a definite menace to the health of the community. Middlesborough has been very fortunate, inasmuch as it has never experienced an epidemic. However, according to reputable local physicians, typhoid, cholera, and dysentery cases have been more numerous in the past, in Middlesborough, than in towns of comparable size, elsewhere.

A combined Storm and Sanitary Sewer System was planned and partially constructed by the English in the early days of the city's development. This system provided for a network of lateral and sub-main collectors discharging into the main outfall sewer that ran parallel to the canal throughout its entire length. None of the laterals was built, and only ap-

proximately seventy-five per cent. of the outfall sewer was completed when the Towne Lands Company failed. The completed portion of the outfall sewer was never utilized. Later, when the city began to recover from the financial setback, various groups of citizens banded together and built community sewers. These sewers discharged into Yellow Creek, and not into the Outfall Sewer, as was provided for by the original plan. Other lateral and sub-main collectors were constructed at various times by the city and the Works Progress Administration.

The resident engineer made a thorough investigation of all the existing sewers in Middlesborough in order to determine whether or not any of these sewers could be admitted into the new system. A former city engineer had compiled a book showing the recorded alignment and grades of some of the existing sewers. This set of plans aided the resident engineer materially in this investigation.

Every sewer was inspected to ascertain its classification: storm, sanitary, or combined sewer. Since the new system was designed as a sanitary system, storm water was excluded in order to prevent overload-

ing the lines and the Treatment Plant. Approximately eighty-five per cent. of the existing sewers were found to be combined storm and sanitary sewers.

Every existing sewer was investigated for alignment, grade, and general condition. Many of the existing sewers were found to have changes in grade and alignment at points between manholes, thereby making it impossible to obtain vision from manhole to manhole. Other sewers had been constructed on circular arcs to suit peculiar ground conditions. It was revealed frequently that laterals were admitted into sub-main sewers by means of "Wye" connections, instead of by manholes or junction boxes. The sewer lines in general were found to be clogged and crooked. Open joints caused excessive infiltration of ground water into many of these lines.

Inspection of the manholes revealed poor workmanship and poor design. None of the manholes contained steps, and they had no provision for entrance. Apparently the manhole exteriors were not well plastered with mortar, since leaks were found to be excessive, and tree roots were found growing through the barrels.

Some of the manholes were circular and others were rectangular, but nearly all of them had bottle-neck throats. In some instances, the effluent lines were found to be higher than the influent lines at the manholes.

The investigation revealed that none of the existing sewer lines could be admitted into the new system economically. Poor design and poor workmanship precluded the usage of any of the existing sewers.

From the foregoing it can be deduced that the city was in definite need of a disposal plant and a collecting system. Not only were the existing sewers found to be inadequate, but the practice of maintaining an open sewer through the heart of the city constituted a definite health menace.

CHAPTER 4
APPLICATION TO THE UNITED STATES GOVERNMENT
FOR
FEDERAL AID

The city commission and many of the prominent citizens of Middlesborough reached the decision that Middlesborough needed a complete Sewer System and a Treatment Plant. The city commissioners were familiar with the various governmental agencies and their methods of assisting municipalities in the construction of public works.

The services of Mr. J. S. Watkins, Consulting Engineer of Lexington, Kentucky, were obtained by the city for the purpose of securing federal aid and supervising the construction of the sewer system. A preliminary investigation was conducted by the consulting engineer to assemble data on cost estimates. A formal application accompanied by cost estimates were placed by the consulting engineer before the Administrator of the Public Works Administration for his consideration. This application requested financial assistance from the Public Works Administration in the form of a fifty-five per cent. loan and a forty-five per cent. grant of the total estimated cost

of the project. The original budget as set up by the consulting engineer was as follows:

<u>CLASSIFICATION OF PROJECT COSTS</u>	<u>ESTIMATED COSTS</u>
Preliminary	\$ 500.00
Lands and Right of Way	\$ 4,000.00
Construction	\$ 385,200.00
Engineering	\$ 22,612.00
Legal and Administrative	\$ 500.00
Interest	\$ 9,360.00
Miscellaneous	\$ 3,282.00
Total Estimated Cost	\$ 425,454.00

After due consideration of this application, the Public Works Administration recommended that the project be approved. The application was then submitted to the President of the United States for his approval. The President approved the application, and an allocation of funds was made.

The Federal Government through its agent, the Public Works Administration, made an offer to the city to aid in financing this project by means of a fifty-five per cent. loan and a grant of forty-five per cent. of the total estimated cost of the project. The grant amounted to \$191,454.00. The fifty-five per

cent. loan, amounting to \$234,000.00 constituted the purchasing by the Federal Government of Revenue Producing Bonds issued by the City of Middlesborough in the amount of \$234,000.00. These bonds bear an interest rate of four per cent. per annum and mature on a sliding scale upward from \$3,000.00 in 1943 to \$15,000.00 in 1969, inclusive.

After the City of Middlesborough accepted the government offer, work was officially started on the project on December 30, 1938.

CHAPTER 5
PRELIMINARY LOCATION SURVEYS
ON
THE COLLECTING SYSTEM

Preliminary location surveys for the collecting System were started on January 7, 1939. Since no contour maps of the city were available, reconnoissance was made somewhat hastily because of lack of time. After the results of previous surveys were examined the resident engineer elected to disregard entirely all previous work.

The original plans for the sewer system provided for collectors, mains, and all other appurtenances necessary to make the system complete and satisfactory. In addition, the plans provided for the construction, by contract, of house service lines, or house connections extending from the sewers to the property lines. All these conditions were given due consideration, and each had its effect on the location of the lines.

The fact that the dedicated street widths were greater than normal, coupled with the plan to construct house service laterals to the property lines, had to be borne in mind constantly. In most cities

it is common practice to construct one sewer on or near the center lines of the street, depending on local conditions. Had this practice been followed thoughtlessly in Middlesborough, the items of paving replacement and house connections would have been excessive.

Upon investigation it was found to be more economical, in numerous cases, to construct two sewers, one on each side of the street, close to the property lines. Such practice resulted in a considerable saving in house connections and paving replacement. A typical problem giving comparative costs follows:

GIVEN:

Length of city Block----- 450 feet

Width of Right of Way----- 80 feet

16 dwellings to be served (8 dwellings on each side
of street)

Type of Paving--rock asphalt on concrete base

Width of Paving----- 40 feet

PROBLEM:-

To determine the most economical method of serving the sixteen dwellings by means of 8" vitrified pipe sewer and 6" vitrified pipe house connections:-

SOLUTION:-

To use one sewer located on center line of street.

ITEM:-	COST
1-450 L. F. of 8" V.P.	@ .90 ----- \$405.00
2-16 X 40--640 L.F. of 6" V.P.	@ .70 ----- \$448.00
3-450 X 3 1/2 9--150 S.Y. Paving Replacement	
	@ 2.50----- \$375.00
4-2 Standard Manholes	@ 60.00----- \$120.00
5-16-8 X 6 Wyes	@ 2.50----- \$ 40.00
6-16-1/8 Bends	@ .70----- \$ 11.20
TOTAL ESTIMATED COST	\$1399.20

To use two sewers located parallel to, and ten feet from, the property lines in grass plots.

ITEM	COST
1-900 L.F. of 8" V.P.	@ .90----- \$810.00
2-16 X 10--160 L.F. of 6" V.P.	@ .70----- \$112.00
3-4 Standard Manholes	@ 60.00----- \$240.00
4-16- 8 X 6 Wyes	@ 2.50----- \$ 40.00
5-16-1/8 Bends	@ .70 ----- \$ 11.20
TOTAL ESTIMATED COST	\$1213.20

From the above it will be noted that the most economical method of serving the city block is the latter, with an estimated saving of \$186.00 over the former.

Existing storm sewers, water lines, and underground telephone conduits also had to be considered in the location of the new sewers. Since no correct maps showing the location of all of the existing sewers, water lines, and conduits were available, a thorough examination of the ground had to be made. The results of this examination proved to be generally successful, inasmuch as very few of the lines had to be shifted during actual construction.

Choosing the location for the Winchester Outfall Sewer was one of the most difficult problems encountered in the lay-out of the entire system. This line, generally speaking, had to be located on the lowest streets in the basin. In the southwest end of the city the most practical location of the outfall sewer was found to be approximately 1000 feet from and parallel to Yellow Creek Canal for an approximate distance of two and one-eighth miles. From this point the Winchester Outfall Sewer was located on the south bank of the canal and followed the alignment of the canal an approximate distance of one and one-half miles to the Treatment Plant site. Fortunately, the banks of the canal were terraced nearly its entire length, and the Outfall Sewer was located on a

flat bench instead of a slope.

The Winchester Outfall Sewer was located to serve the southwest section of the city, in addition to its function as the main outfall sewer. The remaining sections of the city were served by the East End Main, the North Main, and the Binghamtown Main. These four main sewers were located as a skeleton network into which all lateral sewers eventually discharged.

The East End Main was located, with few exceptions, along the general alignment of Little Yellow Creek and discharged into the Winchester Outfall Sewer at the confluence of Little Yellow Creek with the canal. In length approximately one and one-half miles, it serves the southeast section of the city.

The North Main was located on the north bank of the canal and followed the canal from the west end of the town to the central business section for a distance of approximately one mile, where it discharged into the Winchester Outfall Sewer.

The Binghamtown Main was located on the opposite bank of the canal from the Winchester Outfall Sewer. The Canal changes course near this point and flows

nearly due north past the section of the City known as Binghamtown. The Binghamtown Main was located, then, on the west bank of the canal for a distance of approximately one-half mile. At this point the canal intersects with a highway leading from the Binghamtown section. The Binghamtown Main follows this highway and serves the extreme northern section of the city.

A network of lateral sewers was located so that all laterals discharged into one of the four main sewers. Since the city streets are laid out according to the rectangular system, this network of sewers resembles a grid.

Twenty-three miles of main and lateral sewers were located and constructed in the city. In addition to the mains and laterals, over seven miles of house connections were installed. By locating the sewers close to the property lines in grass plots, it was found necessary to lay only approximately one mile of sewers under paved streets.

As the preliminary surveys progressed, care was taken to locate and record enough property boundaries so that accurate maps could be drawn. Sufficient ref-

erence points were established to insure the preservation of the surveys. Profiles of all sewer lines were taken. Elevations along the center line of the proposed trenches were taken every twenty-five feet and at ground breaks. Other elevations, such as basement, parallel ditch, canal and creek elevations, were taken. A network of benchmarks was established over the system. These benchmarks were established from a known United States Geodetic Survey Benchmark, using mean sea-level data. In establishing the network of benchmarks, double-rodged differential leveling was employed. Backsight and foresight distances were kept nearly equal by pacing, and these distances were kept at 300 feet or less, depending on air conditions. Care was taken that solid turnpoints were chosen always. Surprisingly good results were achieved by using the double-rodged method of leveling. The longest continuous line of levels was five miles, and the error was only one one-hundredth of a foot in this distance. All transit and level books were indexed as the surveys progressed, so that access to them at any time was facilitated.

CHAPTER 6

LOCATION OF TREATMENT PLANT AND PUMPING STATION

The treatment plant designed for the disposal of the sewage at Middlesborough can be described briefly as a primary settling plant with trickling filters, and separate sludge digestion with provisions for chemical precipitation. It was desirable to choose a plant site in open land close to a body of water. It was also desirable to locate the plant site within the corporate limits of the city, yet far enough from the built up sections of town to admit all present and future industrial, commercial, and community developments.

From previous investigations it had been determined that the wastes from one of the city's largest industries, the Union Tanning Company, would be admitted into the system. The Union Tanning Company is located on a tract of land adjacent to Yellow Creek, downstream, or north, approximately one mile from the heart of the city. The United States Government Flood Control Reservoir is immediately adjacent to the north side of the Tannery tract and the corporate limit of the city is just north of the Flood Control Reservoir.

In view of these circumstances a five and one-fourth acre tract of land located on the opposite side of Yellow Creek from the Tannery was chosen for the treatment plant site. The tract of land selected for the treatment plant is bounded on the west by Yellow Creek and on the east by the Louisville and Nashville Railroad. It is roughly rectangular in shape and is ideally located.

The five and one-fourth acre tract of land was purchased for \$1500.00 by the City of Middlesborough to be used for the Treatment Plant Site. Contours of the tract were obtained on two-foot intervals. Access to the plant site was obtained through the Union Tanning Company property. A road and a bridge were located, joining an existing road on the tannery property with the treatment plant site. The plant site has access to a railroad spur, which constitutes a distinct advantage for the unloading of materials, acids, and equipment.

LOCATION OF PUMPING STATION.

Profiles of the proposed Winchester Outfall Sewer and the flow line of the adjacent canal were plotted. A tentative hydraulic gradient was assigned the Winchester Outfall Sewer. Investigation revealed that

the gradient of the outfall line was greater than that of the canal. From the profiles it was also determined that gravity flow to the Treatment Plant could not be obtained with a permissible gradient and still retain the outfall gradient above the canal bed. Apprehensiveness of unfavorable underground conditions made it inadvisable to allow the gradient of the Outfall Sewer to fall below the bed of the canal. Such a condition would have necessitated costly construction methods.

The Pumping Station was located at a high point on the profile where the elevations of the Outfall Sewer and the bed of the canal were approximately the same. This point was found to be 2250 feet south of the Treatment Plant. The right of way of the canal was located in the field, and contours of the Pumping Station Site were obtained on one-foot intervals.

CHAPTER 7
PRELIMINARY INVESTIGATIONS
CHEMICAL TESTS

Considerable chemical and physical data were assembled in order to determine soil, creek water and groundwater conditions, and their effects on concrete, vitrified, and cast iron sewer pipe materials. Soil tests for titrations against both methyl orange and phenolphthalein indicators were accomplished by excavating to various depths, exposing blue litmus paper to freshly excavated soil, and noting the change in color together with the time of change. The following is a typical soil data sheet showing location of Test, Time of Test, Final Color of Litmus, Excavation Depth, and Remarks:-

Location	Station	Time of Test	Final color of Litmus	Depth	Remarks
Exeter Ave. N. Side	23+25	5 minutes	Red	4"	
Exeter Ave. N. Side	25+00	5 minutes	Red	3½'	
Exeter Ave. N. Side	27+00	5 minutes	Red	2½'	
Exeter Ave. N. Side	29+00	5 minutes	Red	3½'	
Exeter Ave.	30+00	5 minutes	Red	3½'	
Exeter Ave.	29+00	5 minutes	Red	3½'	

LOCATION	STATION	TIME OF TEST	FINAL COLOR OF LITMUS	DEPTH	REMARKS
Exeter Ave.	27+00	5 minutes	Red	2'	
Exeter Ave.	25+00	5 minutes	Red	2'	
Exeter Ave.	13+50	5 minutes	Red	1'	
Winchester Outfall	117+00	5 minutes	Red	1'	
Winchester Outfall	120+00	5 minutes	Red	1'	
Winchester Outfall	123+00	5 minutes	Red	1'	
Winchester Outfall	126+00	5 minutes	Red	1'	
Winchester Outfall	130+00	5 minutes	Red	1'	Very little Change in blue
Winchester Outfall	133+00	5 minutes	Red	1'	
Winchester Outfall	136+00	5 minutes	Red	1'	
Winchester Outfall	139+00	5 minutes	Red	1'	

The consulting engineer's chemist determined the pH at which litmus paper changes color to be between pH 6 and 7.

Throughout the 6 pH range litmus paper is red violet and below 6 it is red. It was determined from field data, such as the above, that the soil showed alkaline to methyl orange, which indicates that the pH of the samples could have been anything above 4.5 and below 6.0.

The consulting engineer's chemist further reported that "all earth samples showed low alkalinity reserves averaging 15 parts per million by weight. The ground water samples showed an average of about 130 parts per million by weight. The creek water samples showed an alkalinity of 30 parts per million by weight. All samples of earth and creek water showed carbon dioxide content of from 0 to 80 parts per million."

On the basis of the chemist's report of soil, ground water and creek water analysis, the consulting engineer concluded that it would be inadvisable to use concrete pipe in the Middlesborough Sewer System for the following reasons:

- " 1- The low alkalinity factor of both the soil and water and the presence of carbon dioxide in large amounts.
- 2- The fact that the Main Outfall Line is about three miles long and will be laid on a very flat gradient, so that sewage originating in the extreme west end of the city will remain in this line normally for a period of three hours or more, would in our opinion produce a severe condition on account of the septic action of the sewage on concrete pipe."

From the foregoing it was determined that vitrified and cast iron sewer pipe would withstand the chemical action of the soil and water to be encountered while concrete sewer pipe would not. The price advantage vitrified pipe holds over cast iron pipe was another salient factor in its selection for use on this project. However, there were several instances where cast iron sewer pipe was installed, reasons for which will be shown later.

TEST BORINGS

Representative test borings were made by the H.

C. Nutting Company of Cincinnati, Ohio. The resident engineer chose fourteen boring sites located at various points over the system in order to obtain fairly representative soil samples to be encountered in excavation. Three of the test borings were located at the Treatment Plant Site. One of these borings was made close to the center of the tract. The other two Plant Site borings were made at the proposed bridge abutment locations. One boring was made at the Pumping Station Site and the remaining ten test borings were scattered over the system so that soil samples were obtained from every low section of the city. The following is the test boring data sheet showing Location of Test, Description of Material, Elevation Limits of Materials, and Remarks:

Location	Elevations	Description of Materials	Remarks
East Main	1129.7		
Station 13+00		7.0 yellow sandy clay fill	
	1122.7	7.0'	Water at 1122.7
		7.0 blue clay and broken shale fill	
	1115.7	14.0'	

Location	Elevation	Description of Materials	Remarks
West Bridge abutment	1123.0	12.0' fine yellow sand and silt clay	
	1111.0	12.0'	Water at 1111.0
		7.0' fine gray sand and silt clay	Very soft
	1104.0	19.0'	
		4.0' medium course gray sand	
	1100.0	23.0' gray sandstone	
<hr/>			
East Bridge abutment	1128.8	10.0' fine sand and yellow silt clay	
	1112.8	10.0'	
		7.0' fine gray sand and soft muck	
	1105.8	17.0'	
		6.0' medium fine gray sand	
	1099.8	23.0'	
		1.0' soft gray shale	
	1098.8	24.0' gray shale	
<hr/>			
Treatment Plant Site	1118.4		Water at 1117.4
		10.0' brown muck and soft clay	

Location	Elevation	Description of Materials	Remarks
Treatment Plant Site (continued)	1108.4	10.0'	
		2.0' medium coarse yellow sand	
	1106.4	12.0'	
<hr/>			
Pump Station Site	1125.8	6.0' medium fine sand and clay	
	1119.8	6.0'	
		8.0' yellow sand and soft gray muck	
	111.8	14.0'	
<hr/>			
Winchester Outfall Sta. 118+50	1125.4	2.0' yellow sand and clay	
	1123.4	2.0'	
		3.0' yellow sandy clay	
	1120.4	5.0'	
		3.0' soft gray sand	
	1117.4	8.0'	
<hr/>			
Winchester Outfall Station 135+00	1123.1	6.0' yellow sand and clay	Water at 1119.1

Location	Elevation	Description of Materials	Remarks
27. Street Station 5+00 (continued)	1124.3	6.0'	

Each boring was carried to a depth well below the proposed sewer and structure grades, thereby supplying valuable foundation information. Samples from each stratum obtained from the above test borings were placed in glass jars, labelled, and displayed for inspection by prospective bidders.

Prior to the compilation of this test boring data, it was the general belief that the entire Middlesborough basin was underlaid with quick or running sand. Hence these test borings aided the contractors materially in making their cost estimates and resulted in a substantial saving to the city in contract bid prices.

SOUNDINGS

Test boring information was augmented by rock soundings. All proposed sewer lines in the higher areas were sounded for rock by means of the churn-rod method. From the sounding data, rock profiles were plotted and used in estimating rock excavation.

WASTES DATA

Investigation revealed that the usual domestic and industrial wastes would be admitted into the Sewerage System. Upon further investigation it was revealed that the wastes from at least one of the city's industries would require special consideration of treatment. This particular industry, a tannery, discharges a series of wastes from treating vats at various periods of time. The vats are emptied daily, biweekly, weekly, semimonthly, et cetera. With the assistance of the Tannery superintendent, the resident engineer computed the volume of each vat and arrived at an estimated average volume of discharge per nine hours of operation for each vat.

The following table gives the classification of each waste and the corresponding estimated discharge based on nine-hour operation:-

TANNERY WASTES AND THEIR ESTIMATED VOLUMES

Item	Classifications	Estimated volume in gallons per nine hours
* 1	Water Soaks	
2	Washing Compound #1	15,000
3	Washing Compound #2	188
4	Sponging Compound	375

Item	Classifications	Estimated volume in gallons per nine hours
5	Bleach Pool #1	1,000
6	Bleach Pool #2	375
7	Bleach Pool #3	565
8	Bleach Pool #4	1,890
9	Bate Paddle Wheel	8,450
10	White Stock Pool	12,000
11	Lime Soaks	32,500
12	Float Box	1,800
** 13	Miscellaneous	7,500

Total estimated nine-hour volume

*Total pounds of green hides soaked per
6-day week 120,000

Total pounds of green hides soaked per
day (actual) 24,000

**Item 13, Miscellaneous, contains wastes such
as water for cleansing the floors, waste from
wash wheels, and waste from the hair washers.

Samples of the above wastes were obtained
and analyzed. This information aided the con-
sulting engineer in arriving at his conclusions
on treatment of the Tannery wastes.

Similar data concerning the remainder of
the city's industries was assembled and submitted

to the consulting engineer as an aid in waste treatment.

CENSUS

A canvass of the city was made and the following pertinent information was assembled:

- 1-Population of each section of the city.
- 2-Types of business
- 3-Number of persons employed by or engaged in each factory, store, garage, hospital, hotel, business, et cetera.
- 4-Locations of schools and number of pupils.
- 5-Approximate amount of water used by each resident, store, factory, hotel, hospital, business, et cetera.

The above information served a twofold purpose. The population of the various sections of the city was needed as an aid in the determination of the required sizes of sewer pipe (see Chapter #8). The remainder of the information was essential in the establishment of the schedule of sewer rates and rentals.

One of the terms of the government offer required that a schedule of sewer rates and rentals be established showing that enough revenue would be produced to pay for the fifty-five per cent. loan. This requirement was met by the establishment of the fol-

lowing schedule of sewer rates and rentals:-

Private residence with under 7 rooms, 90¢ per month.

Private residence with over 6 rooms, \$1.25 per month.

Retail groceries, \$1.25 per month.

Wholesale groceries, candy and produce houses and milling houses, \$2.25 per month.

Cafes and restaurants, up to 2 employees, \$1.50 per month.

Cafes and restaurants, 3 to 4 employees, \$2.00 per month.

Cafes and restaurants, 5 employees or more, \$5.00 per month.

Hotels, under 11 rooms, \$3.00 per month.

Hotels, 11 rooms and over, \$3.00 per month plus 10¢ per room for all rooms over 10.

Boarding houses, \$3.00 per month.

Rooming houses and tourist homes, \$2.50 per month.

If more than 10 rooms for guests, boarding houses, rooming houses and tourist homes to be considered "hotel".

Drug stores without soda fountain, \$1.25 per month.

Confectionaries and drug stores with soda fountains, \$1.75 per month.

Barber shops and beauty parlors with not more than 2 chairs, \$1.50 per month.

Barber shops and beauty shops with more than 2 chairs, \$1.75 per month.

Service stations or garages or both, \$2.00 per month.

Churches, 90¢ per month.

Bakeries, \$2.00 per month.

Professional and business offices-not more than 3 room suites, 90¢ per month. Each office or suite of offices, if business or professional, to be considered a separate unit.

Professional and business offices-more than 3 room suites, \$1.25 per month. Each office or suite of offices, if business or professional, to be considered a separate unit.

Hospitals and infirmaries, \$3.00 per month plus 10¢ per room for all rooms over 10.

Banks, dry goods, department stores, furniture stores, hardware stores, and general mercantile stores up to 10 employees, \$2.00 per month. Over 10 employees, \$3.00 per month.

Poolrooms, theatres, and bowling alleys, \$2.50 per month.

Funeral homes, \$2.00 per month.

Schools, 50 pupils and less, \$5.00 per month.

Schools, more than 50 pupils and less than 100,
\$7.50 per month.

Schools with 100 or more pupils, \$10.00 per month.

City Hall, \$10.00 per month.

Post Office, \$2.50 per month.

Railroad and bus passenger station, \$2.50 per month.

Railroad and truck freight stations, \$1.50 per
month.

Telephone Exchange, \$2.00 per month.

Florist shops, \$1.25 per month.

Newspaper establishments, \$1.50 per month.

Dry cleaning sales offices, \$1.25 per month.

Dry cleaning plants with less than 5 employees,
\$2.00 per month.

Dry cleaning plants with 5 or more employees, \$2.50
per month.

Laundries, \$10.00 per month.

Laundries and dry cleaning plants combined, \$12.00
per month.

Clubs, associations, and fraternal orders, \$1.00
per month.

Saloons and beer parlors, \$2.50 per month.

Factories, under 10 employees, \$2.00 per month.

Factories, 10 to 30 employees, \$3.00 per month.

Factories, 31 to 50 employees, \$4.00 per month.

Factories, 51 to 100 employees, \$5.00 per month.

Factories, 101 to 150 employees, \$6.00 per month.

Factories, 151 to 250 employees, \$7.50 per month.

Factories, 251 to 500 employees, \$10.00 per month.

Factories with over 500 employees by special ordinance.

Packing plants, tanneries, food manufacturing, processing, and other industries having other than the usual domestic wastes, by special ordinance.

Dairies, cream stations, ice cream plants, pasteurizing plants and other milk and cream products plants by special ordinance.

Other mercantile establishments not enumerated, \$1.50 per month.

Theoretically, the above sewer rates and rentals will produce sufficient revenue annually to pay the principal and interest charges in addition to the estimated maintenance and operating costs.

CHAPTER 8

DESIGN

The plans for the Collecting System were drawn in the field. These plans were drawn on standard 24" X 36" plan and profile sheets, and care was exercised to keep the detailing uniform. (See Illustrations 1, 2 & 3) The following scales were used:-

Horizontal: 1"= 100'

Vertical : 1"= 10'

All property lines, existing buildings, structures, types of paving and other pertinent data were shown.

Tentative hydraulic gradients were assigned to each proposed sewer beginning with the Winchester Outfall Sewer and thence working into the network. Mathematical investigation revealed at once that, due to the lack of available fall and the subsequent employment of flat gradients, the use of oversize pipe would be generally necessary in order to obtain permissible velocities.

In sanitary sewers it is desirable to obtain velocities equal to or preferably greater than two feet per second. A number of factors materially

affect the velocity of flow in gravity sewers; some of these are:-

Shape of Pipe Section

Size of Pipe

Roughness of Pipe

Hydraulic Gradient

Hydraulic Radius

Since vitrified pipe was selected for use, the shape of the waterway was consequently circular.

The minimum size sewer was 8" in diameter.

The coefficient of roughness employed in Kutter's formula was assumed as 0.015.

Test-boring data showed the subsoil in the low areas to be sand, sandy clay, and silt; and provision was made for maximum infiltration of 2000 gallons per acre per day.

The future average density of population was estimated at twenty persons per acre.

The maximum rate of flow of sewage was estimated at sixty gallons per capita per day.

Maximum distance between manholes was five hundred feet.

Where change of alignment occurred, a drop of 0.1' was used across manhole bottoms containing curves to prevent checking of the velocity of flow through the manholes. Manhole bottoms were built up to the crown of the sewer to prevent disturbance of flow.

Considering an area of twenty-five acres and using the above data it can be deduced that the estimated quantity of discharge is

$$\frac{25(60 \times 20 + 2000)1.55}{1,000,000} = 0.125 \text{ Cu. ft. per second}$$

Using minimum size pipe diameter of 8" and minimum velocity of 2' per second it follows that

$$Q = Av$$

$$Q = 0.3421 \times 2$$

$$Q = 0.6841 \text{ or } 0.7 \text{ Cu. ft. per second}$$

The above typical problem shows that the quantity of discharge of the minimum size pipe greatly exceeds the estimated Q of an average area.

Using 12,000 as the population of the city, it follows that

$$12000 \times 60 = 720,000 \text{ gallons of sewage per day}$$

$$\text{or } 1.1 \text{ cu. ft. per second.}$$

By assuming a velocity of 2' per second and using hydraulic charts based on Kutter's formula it is readily revealed that a 10" pipe on a 0.41% gradient would meet the above requirements. However, the maximum available fall per one hundred feet on the Winchester Outfall Sewer was 0.1'. From the same charts using $n=0.015$, a 24" pipe on a 0.1% gradient would have a quantity of discharge of 6 cubic feet per second with a velocity of 1.9 feet per second. Using $n=0.013$ from the same charts it is found that $Q=7.1$ cubic feet per second and $v=2.2$ feet per second.

If the lower value of $Q=6$ cubic feet per second is selected it follows that a 24" pipe on a 0.1% gradient will have a velocity of 1.9 feet per second and a capacity of $6 \times 60 \times 60 \times 24 \times 7.48$ or 3,877,632 gallons per day.

In order to obtain a permissible velocity in the Winchester Outfall Sewer it was found necessary, therefore, to use oversize pipe.

In some instances it was found feasible to obtain cleansing facilities by using flush tanks. Where an unreasonably large pipe would be required in order

to obtain cleansing velocities due to lack of fall, it was found more economical to install smaller pipe augmented by the use of flush tanks.

Flush tanks were employed in two instances to aid the functioning of inverted siphons. Five inverted siphons were used in the Collecting System. Adequate fall and sufficient sewage were available in three cases to operate the siphons satisfactorily. Insufficient sewage was available to operate the Binghamtown siphon, and a flush tank was installed above the influent end of the siphon. Lack of available fall necessitated the use of a flush tank on the East Main in order to obtain a permissible velocity.

Standard Design #4 Miller Siphon Flush Tanks manufactured by the Pacific Flush Tank Company were used. This type of flush tank has an average rate of discharge of 0.35 cubic feet per second.

Siphons employed on the project are of the multiple pipe line type. The siphons consist of two manholes of different elevations connected by two cast iron pipes that sag under the obstructions. The difference in head between the two manholes operates the siphon. The siphon pipes are arranged in the

influent manhole so that the elevation of the crown of the smaller pipe is the same as the invert elevation of the larger pipe. The smaller of the two lines is in operation continually and the larger pipe is thrown into action with increase in discharge of sewage. The discharge openings of the siphon pipes in the effluent manhole are at the same invert elevation. The siphons are of simple construction and contain no moving parts. Changes in direction of flow were made as slight as practicable.

A typical siphon problem follows:-

Length of siphon	= 100 feet
Available fall	= 1.15 feet
Maximum siphon sag	= 8 feet
Gravity sewers connected by siphon	= 10" V.P.

Rate of flow:-

Minimum	= 0.4 cu. ft. per second
Maximum	= Capacity of 10" line
Assumed inlet loss	= 0.3 feet
Net available fall	= 0.85 feet
Approximate available slope	= $\frac{0.85}{100} = 0.0085$

From hydraulic charts based on Kutter's formula using

$n = 0.013$ (cast iron pipe)

Slope = 0.0085

A 6" pipe will have

$v = 2.4$ feet per second

$Q = 0.45$ cu. feet per second

An 8" pipe will have

$v = 2.95$ feet per second

$Q = 1.0$ cu. feet per second

The above pipes having met the requirements of the problem were therefore selected.

In several instances it was found necessary to construct sewers across depressed basins placing the sewers above the natural ground elevations. Cast iron sewers were used in such cases, supporting the cast iron pipe on reinforced concrete piers. These piers did not exceed 6 feet in height and were of standard design, consisting of rectangular concrete footings supporting the pedestals. Piers were placed behind the bell of each twelve-foot joint of pipe where no fill over the pipe was encountered.

Where a fill was proposed, piers were placed on six-foot centers.

Specifications for the Collecting System and Treatment Plant were written under the supervision of the consulting engineer. The design of the Treatment Plant and the Pumping Station was made under the supervision of the consulting engineer.

CHAPTER 9
CONSTRUCTION
OF
COLLECTING SYSTEM

Construction of the Collecting System was divided into two parts, Contract 1-A amounting to approximately \$39,000.00, and Contract 1-B amounting to approximately \$183,000.00.

Bids were opened on Contract 1-A at 10:00 A.M., Central Standard Time, on December 28, 1938; and the Contract was awarded to G. M. Ferris, Contractor, of Athens, Tennessee.

Contract 1-A was approved for construction on January 26, 1939, and construction started on February 13, 1939. Immediately were encountered unfavorable ground conditions, which had been caused by a flood occurring February 3, 1939. The low flat areas of the city were inundated by flood waters and the elevation of the ground water table was raised to an average depth of two feet below the natural ground line.

The following is a list of the contractor's equipment:

1-Air Compressor manufactured by Chicago Pneumatic Tool Company.

2-2" Centrifugal pumps manufactured by Gorman Ruff, Mansfield, Ohio.

2-1½" Centrifugal pumps manufactured by Construction Machine Company, Waterloo, Iowa.

1-3/4 yard Backdigging Shovel manufactured by Northwest, Chicago, Illinois.

1-Austin Ditching Machine Style #900 manufactured by Austin Machinery Corporation, Muskegon, Michigan.

1-Allis-Chalmers Angle Dozer Model S.O. Blade manufactured by Gar Wood Indentrees, Detroit, Michigan.

Work proceeded slowly at first because of wet trench conditions. Deep sump holes were cut adjacent to each bell and pumped continually so that the asphaltic joints were poured in dry conditions.

Asphaltic joints were used throughout both contracts. Production on the smaller sizes of pipe was increased considerably by pouring approximately fifty per cent. of the joints at the top of the trench. These double lengths were then lowered in place with a

stiffener so that the made joints were protected.

The contractor elected to build all sewer lines before starting on house connection and manhole construction. As a consequence, this contract was not completed until September 6, 1939.

Inspection was rigid throughout the duration of this contract, and no serious deviations from the Specifications and Contract Documents were permitted.

Bids were opened on Contract 1-B at 10:00 A. M. June 1, 1939 and the contract was awarded to the Smith-Pew Construction Company of Atlanta, Georgia.

Construction on Contract 1-B started June 27, 1939 and was completed June 1, 1940. Unusually favorable weather conditions were encountered throughout the time sewers were being constructed under this contract. A maximum of (7) seven major trench openings was reached and maintained during the summer months. The following is a list of the Contractor's equipment used:

1-1 R Paving Breaker CC45 Serial #30272

1-2" Nova Diaphragm pump Serial #P7895

1-Aerol Kerosene Burner for heating G. K.

1-Tractor & Angle Dozer M 5158
 1-2" Centrifugal Jaeger Pump No. 5840
 1-2" Centrifugal Jaeger Pump No. 4375
 1-3" Centrifugal Jaeger Pump No. 3519
 1-JA 45 IR Jackhammer No. 464714
 1-JA 45 IR Jackhammer No. 454510
 1-JA 45 IR Jackhammer No. 454321
 1-JA 45 IR Jackhammer No. 449368
 1-IR Sheeting Head No. 5446
 1-Chicago Pneumatic Sheeting
 Head No. 5953
 1-Jaeger 3" Diaphram Pump No. 13773
 1-Jaeger Mixer No. 66869
 1-Jaeger Mixer No. 66903
 1-Caterpillar Terracer No. 9B 704
 1-Black Diamond Trailer (Serial # E 8506-2 Ton
 Wt. 4040)
 1-Set Fairbanks Wheelbarrow
 Scales No. 5634 C
 1-10 S Jaeger Concrete Mixer No. 60466
 1-Rex 4" Diaphram Pump No. M 375
 1-Chicago Pneumatic Paving
 Breaker No. 852
 1-Worthington Compressor two
 wheel rubber tire No. 4098

1-IR Clay Spade	No. A 4264
1-Worthington Compressor	No. 1656 (Four Wheel)
1-Lima Shovel # 807 with pull shovel, and clam-shell attachment.	
1-160 Buckeye Trenching Machine	No. 3989
1-120 Buckeye Trenching Machine	No. 3969
1-Model "D" Backfiller	No. 3767
1-Model "D" Backfiller	No. 3104
1-White Truck Motor #60,562-1½ Tons model 15-1920 Model.	
1-Chevrolet Truck Motor #2,209,730-1½ Ton Model 1939.	
1-International Dump Truck Motor #7137 1½ ton-1937 Model.	
1-Dodge Pickup Truck	
12-Rubber tired wheel barrows	
50-Dozen Jackbits	
100-Feet drill steel (different lengths)	
500-Feet sewer rods complete	
6-Hand pumps	
2-Small lead pots complete	
1-Large lead pot complete	

Each foreman with a trenching machine was expected

to lay 1000 feet of pipe per day. Bell holes were dug for each joint, and care was taken to secure a firm foundation for the pipes. Good jointing was assured on pipe 12" and larger by cracking the joint-runner away from the bell at the crown and pouring the asphaltic compound in such a manner that it flowed around and over the pipe. All pipe joints were visually inspected by the inspectors at the trench openings.

Four inspectors were employed on the Collecting System. The duties of three of these men were essentially the same. The inspectors visually inspected all sewer pipe for conformance with specifications. All pipe was tested for cracks by the hammer-tap method. Records of each opening were kept by the inspectors in regard to pipe laid, specials installed, and all extra pay quantities. The fourth inspector had charge of manhole and house connection inspection. The inspection of these two operations required the full time of one inspector. All four inspectors reported daily to the resident engineer who acted as chief inspector in addition to his regular supervisory duties. It was found necessary to discharge only

one foreman for disregarding instructions and not accomplishing satisfactory results.

An instrumentman and a survey party were employed to reestablish line and grade stakes that had been disturbed. Less than four per cent of the original sewer locations were changed and the work of the survey crew was generally a matter of rerunning the original lines.

Due to unusually favorable weather conditions, relatively few of the trenches were wet. However, all bell and spigot ends of the vitrified pipe were painted with an asphalt cut-back as an aid to bonding where moisture was encountered in the trenches.

In the low flat areas of the city the trench conditions changed frequently. In one instance the following formations occurred in a distance of 200 feet along the trench: yellow clay, running sand, solid rock, coal, gray sandy clay and soapstone. As the ground conditions changed, construction methods were also changed in order to assure good foundation for the pipe. Quakey trench bottoms were stabilized with 2000# concrete cradle. Where there was danger of crushing the sewer pipe due to live loads in case of shallowness, or dead

loads in case of extreme depth, the sewer pipe was encased in 2000# concrete. Soft trench bottoms were stabilized by placing 2" X 10" oak timbers longitudinally in the trench supplemented by a crushed stone cradle placed between the timbers and the pipe. In such cases every precaution was taken to obtain an even bearing cradle for the pipe. Where quicksand varying in depth from 3" to 12" was encountered, overlying a stratum of hardpan, the quicksand was removed and a refill of crushed stone was employed to furnish a solid foundation. Where greater depths of quicksand were encountered, pin piling was used to an advantage.

The pin pile method of supporting pipe consists of the following: 4" X 4" oak piles are driven below grade to a firm foundation. Two piles are placed behind each pipe bell and capped with a 4" X 4" cap. 2" X 10" stringers are nailed to the caps and 2" X 8" blocks are nailed to the stringer on each side of the pipe bells. The sewer pipe is then placed to line and grade; wedges nailed to the blocks prevent any movement.

(See Sketch)

Various types of sheeting were used depending

on the depth of cut, trench section, ground conditions, and proximity of buildings. Open trenches in hard clay and rock frequently needed no sheeting whatever. Skeleton bracing was used in deep cuts through hard clay and rock. Horizontal box sheeting was used in wide trenches with soft bottoms. Where quicksand was encountered, solid vertical sheeting was used. Voids between the sheeting timbers were caulked with oakum or hay to prevent sand boils. Sheeting and bracing were left in place where conditions warranted such action.

As construction progressed, various situations arose which required immediate consideration and special treatment. The grades of unrecorded existing sewers and water lines conflicted numerous times with the grades of the proposed sanitary sewers. It was required that these existing lines be kept in service. In some instances the existing sewers were siphoned under the new sanitary sewers, care being taken to reduce the size of pipe in the siphons to obtain cleansing velocities. It was found feasible in other cases to install extra manholes in the sanitary lines and change either the alignment or gradient in order to avoid conflict with the grades of the existing sewers or water lines. Most of the existing

sewers were small in size, and separation of grades was accomplished at minimum costs.

One of the most interesting problems on the project arose when the alignment of the Winchester Outfall Sewer was changed between 19th Street and 20th Street. The line was originally proposed along the center-line of a 20-foot alley at a depth of ten feet. This particular location is in the heart of the commercial district. In the interest of business, the merchants involved requested that this line be shifted from the alley to the canal bank which is parallel to the alley. As a result of this change, the Winchester Outfall Sewer was placed above the ground line and approximately ten feet in front of the discharge end of a 4' X 5' concrete storm sewer. This necessitated the use of cast iron pipe on concrete pedestals. The size of the Winchester Outfall Sewer at this point is 18". The invert of the 18" line is approximately 8" above the flow line of the concrete storm sewer which discharges into the canal at this point. Pressure varying in intensity would be exerted against the 18" sewer, depending on the relative elevations of water in the canal and the storm sewer. The maximum pressure would be exerted when the canal flow is low

and the storm sewer is flowing full under pressure.

A reinforced concrete flume was designed providing adequate waterway to take the average low flow of the storm sewer under the Winchester Outfall Sewer. (See illustration.) The top of the flume was extended toward the outlet of the storm sewer and culminated in a 3" lip. From the top of this 3" lip, a weir was formed over the 18" cast iron pipe in the shape of a reverse curve. During periods of average flow in the storm sewer, the discharge flows through the flume under the Winchester Outfall Sewer. As the discharge from the storm sewer increases, water rises in the flume until its capacity is reached. At this point the water begins to rise over the 3" lip and when sufficient head is developed, the surplus discharge leaps along the reverse curve and leaps over the 18" cast iron sewer.

By constructing the flume-weir, the total area subjected to pressure was reduced from 960 square inches to 144 square inches. The pressure against the 18" cast iron sewer subsequently was reduced approximately 85 per cent.

Velocity of flow through the flume will reach

scouring intensity each time the discharge of the storm sewer exceeds low flow of the canal. The flume-weir is constructed of 3000 pound concrete reinforced for temperature stresses.

CHAPTER 10
CONSTRUCTION OF TREATMENT PLANT
AND
PUMPING STATION

Bids were opened on Contract 2 at 10:00 A. M., Central Standard Time, on June 1, 1939. Contract 2 was awarded to the Central Contracting Company of Atlanta, Georgia, and amounted to approximately \$141,000.00.

The work included under Contract 2 consisted of the following:

- (a) All piping, Valves and gates at the Treatment Plant and Pumping Station.
- (b) Pumping Station
- (c) Head House
- (d) Control Chamber
- (e) Flocculator Basin
- (f) Primary Settling Basin
- (g) Secondary Settling Basin
- (h) Trickling Filters
- (i) Sludge Digester
- (j) Sludge Drying Beds
- (k) Tannery Waste Retention Basin
- (l) Acid Handling System

- (m) Bridge
- (n) Mechanical and Pumping Equipment
- (o) Electrical
- (p) General
- (q) Fences
- (r) Roads and Walkways
- (s) Excavation and Grading
- (t) Starting Plant in Operation
- (u) Guarantee of Equipment

The pumping station was constructed of reinforced concrete and is rectangular in shape. The floor of the pit is well below the bottom of Yellow Creek, but no foundation difficulties were encountered. All motors at the pumping station are considerably above all previous high water levels. All main valves have extension stems so that they may be operated from the main floor level.

The head house is a reinforced concrete and brick building that houses the main electrical control board, temperature control equipment, chemical dry feed machine, integrator, chlorinator and scales, hot water boiler and circulating pump, primary sludge pump and centrifugal pump. A chemical laboratory is loca-

ted on the second floor of the Head House.

The control chamber is a reinforced concrete structure containing 2 sets of baffles and a bronze weir. The baffles serve to quiet the incoming sewage and decrease the velocity of approach of the weir.

The flocculator basin is of reinforced concrete and contains a slow mixing paddle apparatus motivated by a horizontal type, four speed, geared weather-proof motor. The mixing equipment is driven by means of a chain and sprocket.

The primary settling basin is a reinforced concrete circular tank with a conical bottom. Overall diameter of the primary is 60'-8". The clarifier mechanism consists essentially of a central driving mechanism which rotates and supports a center cage with two rake arms. Attached to the rake arms are scraping blades arranged to scrape the sludge from the tank bottom to the central well or sludge pocket.

The secondary settling basin is similar to the primary but is 41'-4" in overall diameter. The clarifier mechanism is similar to that described above. A control pit adjacent to the secondary

contains a return sludge pump for pumping the sludge from the secondary back to the control chamber. Overload alarms are provided on both the primary and secondary basins.

There are two circular trickling filters 138'-8" in overall diameter. The filters are of reinforced concrete design and utilize double walls. Filter bed blocks cover the entire inside base of each filter and support 8' of broken limestone filter material.

The sludge digester is a circular double-walled structure. The inside wall, which will be exposed to sludge, is reinforced concrete. The outside wall is brick masonry. The sludge digester has a floating cover which will rise and fall with the increase and decrease of the volume of sludge and gas. 2" standard black steel pipe heating coils were installed around the inside circumference of the digester.

The sludge drying beds are of reinforced concrete construction. Total area of drying bed surface is 7700 sq. ft. A minimum of 6" of crushed limestone covers the drying beds. The top layer of filter material on the drying beds is composed of 6" of

Torpedo Sand. An underdrain system of tile was installed under the drying beds.

A straight sided cylindrical, open top tank of approximately 104,000 gal. capacity was constructed to serve as the tannery waste retention basin. This tank was constructed of Tide Water Red Cypress wood and is supported by a creosoted wood structure and mud sills. Cypress baffles and braces were installed inside the tank together with a slow rotating paddle agitator. The agitator prevents the tannery wastes from settling.

The acid handling system included an 8,000 Gal. steel, horizontal, cylindrical tank, a constant orifice feed system, pump, and tank car unloading line. The steel tank is equipped with an 18" diameter manhole. The shell thickness of the tank is not less than $\frac{1}{4}$ ". The tank was fabricated by welding and all joints were butt joints. The constant orifice box is formed of $\frac{1}{4}$ " steel plate and lined with $\frac{1}{4}$ " chemical lead.

A six-span wood bridge was constructed across Yellow Creek as part of Contract 2. Select Southern Yellow Pine was used in the bridge. All timber was creosoted by the full cell process. The bridge piles

were driven to refusal.

A traffic bound macadam road was constructed through the plant site in order to provide ingress to and egress from all structures, particularly the sludge drying beds. Walkways lead from the road to the primary and secondary settling basins, control chamber, flocculator, acid tank, and trickling filters.

The plant site was graded so that open trenches drain the entire plant area and discharge directly into Yellow Creek.

No difficulty was encountered in the construction of the treatment plant with the exception of a foundation problem revealed when excavation for the secondary settling basin was completed. Upon investigation it was revealed that the secondary settling basin was located in an old creek bed. The sub-base was found to consist largely of a stratum of running sand. This unfavorable condition was overcome by removing the running sand and tamping crushed limestone into the sub-base. Approximately 67 tons of limestone were used to stabilize the base of the secondary basin.

DESCRIPTION OF SEWAGE TREATMENT

The sewage discharged by the gravity collecting system enters the first phase of treatment upon arrival at the Pumping Station. At this point the sewage passes through a mechanical shredder consisting of a by-pass bar screen and a comminutor. The bar screen is constructed of $\frac{1}{4}$ " x 2" wrought iron bars spaced 1" clear and welded to a top and bottom plate. The bar screen is set at an angle of 45 degrees with the vertical to facilitate cleaning.

The comminutor consists of a motor driven revolving slotted drum screen. Sewage passes into the drum through its slots and out of its bottom. Material too large to pass through the slots is cut by stellited cutters on the drum into pieces small enough to pass through the slots.

After the sewage has been shredded, it is pumped to the treatment plant. The operation of the pumping station is automatic and the pumps are arranged to operate in accordance with predetermined water levels in the pump house. The pumping equipment at the Pumping Station consists of three pumps: a 300 G. P. M., a 500 G. P. M., and a 700 G. P. M. Space has

been provided for a future pump of 15 H. P. At a predetermined water level the 300 G. P. M. pump will function. If the 300 G. P. M. pump is unable to carry the load and the water continues to rise, the 500 G. P. M. will cut in and the 300 G. P. M. pump will shut down. If the 500 G. P. M. pump overloads, the 700 G. P. M. pump will cut in and the 500 G. P. M. pump will shut down. If the 700 G. P. M. pump will not carry the load and the water continues to rise, the 300 G. P. M. pump will cut in to assist the 700 G. P. M. pump. If the water continues to rise, the 500 G. P. M. pump will cut in to assist the combination. The capacity of the combined pumping unit is 2,160,000 G. P. D. As the water level falls, the 500 G. P. M. and 300 G. P. M. pumps will cut out at predetermined levels leaving only one pump to carry the load.

The shredded sewage leaves the pumping station and is pumped to the control chamber. The control chamber serves to control the flow of both domestic sewage and tannery wastes which are admitted at the control chamber. Sulphuric acid and other chemicals are added to the sewage at this point to correct the high pH value of the tannery waste, in order that a

sludge may be obtained which can be digested.

After chemical dosing, the sewage passes from the control chamber to the flocculator basin and is retained for a period of approximately 15 minutes. Slow revolving paddles in the flocculator serve to mix the sewage with the acid and other chemicals. This action tends to build up the small particles as an aid to coagulation.

The sewage then passes from the flocculator to the primary settling basin where it is retained for a period of from 2 to 3 hours, depending on the rate of flow. During this retention period the greater per cent. of the solids settle out and are swept to a receiving well by rotary paddles. The solid matter or sludge is pumped to the sludge digester. The effluent from the primary settling basin, which still contains a small per cent. of the finer solids together with some dissolved solids, is then passed to the rotary distributors on the trickling filters.

These rotary distributors are designed for continuous operation and spread the sewage by means of flat jets over the area of the trickling filter beds. The trickling filters are of the circular,

double-walled, base filter-block type, which insures maximum aeration and oxidation. In passing through the trickling filters the sewage is further purified through the action of oxidizing bacteria.

The effluent is then passed from the trickling filters to the secondary settling basin. Before reaching the secondary clarifier the effluent is chlorinated to destroy B-Coli and / or any other harmful bacteria that may be present. Here the effluent is further clarified by the removal of particles of bacteria sludge that may have sloughed off from the trickling filters.

The effluent from the secondary basin is then carried through vitrified pipe to Yellow Creek.

Both the primary and secondary settling basins are equipped with a clarifier or sludge concentrating mechanism that drags the sludge from the floor of the basin to a central well. From the primary basin the sludge is pumped to the sludge digester where it is retained until it is properly ripened and free from odor. The sludge from the secondary basin is pumped back to the control chamber from which point it repeats the treatment cycle. This return sludge assists

in keeping down odors in the incoming sewage.

The sludge from the primary basin is pumped to the floating cover sludge digester where digestion is brought about by anerobic bacteria. The digestion of the sludge produces a combustible gas which is chemically similar to natural gas except that it contains hydrogen sulphide and some carbon dioxide. The gas is drawn away from the sludge digester and is burned in a hot water boiler. The heat thus obtained is used to maintain a temperature of between 90 degrees and 100 degrees in the digester since digestion takes place most rapidly within this range of temperature.

The heat from the hot water boiler is also used to heat the Head House during the winter season.

After the sludge has been digested to a point that it is not offensive, it is drawn off to the sludge drying beds where the moisture content is reduced sufficiently so that it can be handled satisfactorily. This dried sludge is a very good fertilizer for farm crops, since it contains from 1 to 3½ per cent of nitrogen, from 1 to 3 per cent of phosphoric acid, from 0.1 to 0.3 per cent of potash and 25 to 35 per cent of humus.

The resident engineer arrived in Middlesborough on January 7, 1939. All contracts were substantially complete by May 17, 1940.

CHAPTER 11

CONCLUSIONS

It is extremely unfortunate that it was impossible for the writer to spend a reasonable length of time observing the operation of the Treatment Plant. Since this was not done, no conclusions have been reached regarding the operation of this particular type of treatment plant. However, certain opinions may be expressed at this time.

It occurs to the writer that a very practical treatment plant has been built in Middlesborough in regard to the original cost and the theoretical operating cost. In addition to reasonable costs, it is the writer's opinion that a very satisfactory type of sewage treatment will be obtained at Middlesborough. The plant itself conforms to the very latest standards of present day sewage treatment. Certain refinements were added to the Middlesborough Treatment Plant that are not always included in such a project.

For example, the double walls around the trickling filters are a refinement not to be found in cheaper and less efficient plants. The cost of constructing an additional wall is not great, yet a much higher degree of aeration in the filters can be obtained by so doing.

At some treatment plants no effort is made to recover the gas evolved in the sludge digester. At Middlesborough, however, this gas is utilized in heating the sludge, thereby aiding the digestion process.

The writer observed the entire collecting system in operation and found that all sewer lines operated satisfactorily. It is the writer's opinion that the location work would have been facilitated if a contour map of the city had been made. Lack of time prevented this method of procedure.

From observations made, it is the writer's opinion that Middlesborough now has one of the most efficient and complete sewer systems and treatment plants in this section of the country.

ILLUSTRATION #1

SANITARY SEWER SYSTEM
MIDDLEBROUGH - KENTUCKY
PLAN & PROFILE - MANCHESTER LYNWOOD E. SIDE
J. S. WATKINS, CONSULTING ENGINEER
LEXINGTON, KENTUCKY
Scale 1" = 100'
Date MAY 11 1939
Job MED
Sheet 49-70

SEE SHEET NO 4

SEE SHEET NO 3

SEE SHEET NO 7

ILLUSTRATION #2

SANITARY SEWER SYSTEM
MIDDLESBOROUGH, KENTUCKY
PART PLAN

J. S. WATKINS CONSULTING ENGINEER
LEXINGTON, KENTUCKY

Scale 1" = 200'
May 13, 39
M.E.D.
130

C-70

ILLUSTRATION #3

PLOT PLAN

MIDDLESBOROUGH, KENTUCKY
SEWAGE TREATMENT PLANT

FRONT ELEVATION
Scale: 1" = 10'

PLAN
Scale: 1" = 2'

SIDE ELEVATION
Scale: 1" = 10'

Flow line ex. Sewer

NOTE: Reinforce both Upper and Lower Slabs and Vertical Walls with 1/2" #4 at 12" O.C. both ways.

MIDDELSBORO SEWER SYSTEM
J.S. Watkins Consulting Eng.
LEXINGTON, KENTUCKY. Nov 20, 1939

PIN PILE METHOD FOR SUPPORTING PIPE WHERE QUICKSAND WAS ENCOUNTERED

ILLUSTRATION #6.

ILLUSTRATION #7

ILLUSTRATION #10

ILLUSTRATION #13

ILLUSTRATION #14

ILLUSTRATION #15

ILLUSTRATION #16

ILLUSTRATION #17

ILLUSTRATION #18

ILLUSTRATION #19

ILLUSTRATION #20

ILLUSTRATION #21

ILLUSTRATION #22

ILLUSTRATION #23

ILLUSTRATION #24

ILLUSTRATION #25

ILLUSTRATION #26

ILLUSTRATION #27

ILLUSTRATION #28

ILLUSTRATION #29

ILLUSTRATION #30