SEWAGE DISPOSAL

CITY OF BRADFORD
CENTENARY YEAR
1947

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SEWAGE DISPOSAL

THE LORD MAYOR, ALDERMAN T. I. CLOUGH, J.P.

CITY OF BRADFORD

SEWAGE DISPOSAL

1870-1947

FOURTH AND REVISED EDITION

CENTENARY YEAR

1947

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Fourth Edition (Revised and Enlarged) 1947

FOREWORD

As Chairman of the Sewage Committee, I am privileged to introduce this new and revised account of the Works of Sewage Disposal undertaken by the Corporation.

The development of this important municipal service has been an outstanding achievement and the Works constructed and the methods and processes adopted for the purification of sewage and the recovery of valuable by-products are without parallel in this country or, in fact, throughout the world.

The primary object of this service is the preservation of the health of the citizens, but in addition a huge industry and business has been developed in the recovery and sale of matters removed during the purification of the wastes from the city's dwellings and industries which has made a unique contribution to the finances of the Corporation.

This has been achieved by the bold, fore-sighted policy of the City Council, who have not hesitated to support, with encouragement and material resources, the work of the Sewage Committee described in this book.

I commend the careful perusal of its pages to all, particularly to the citizens of our great city.

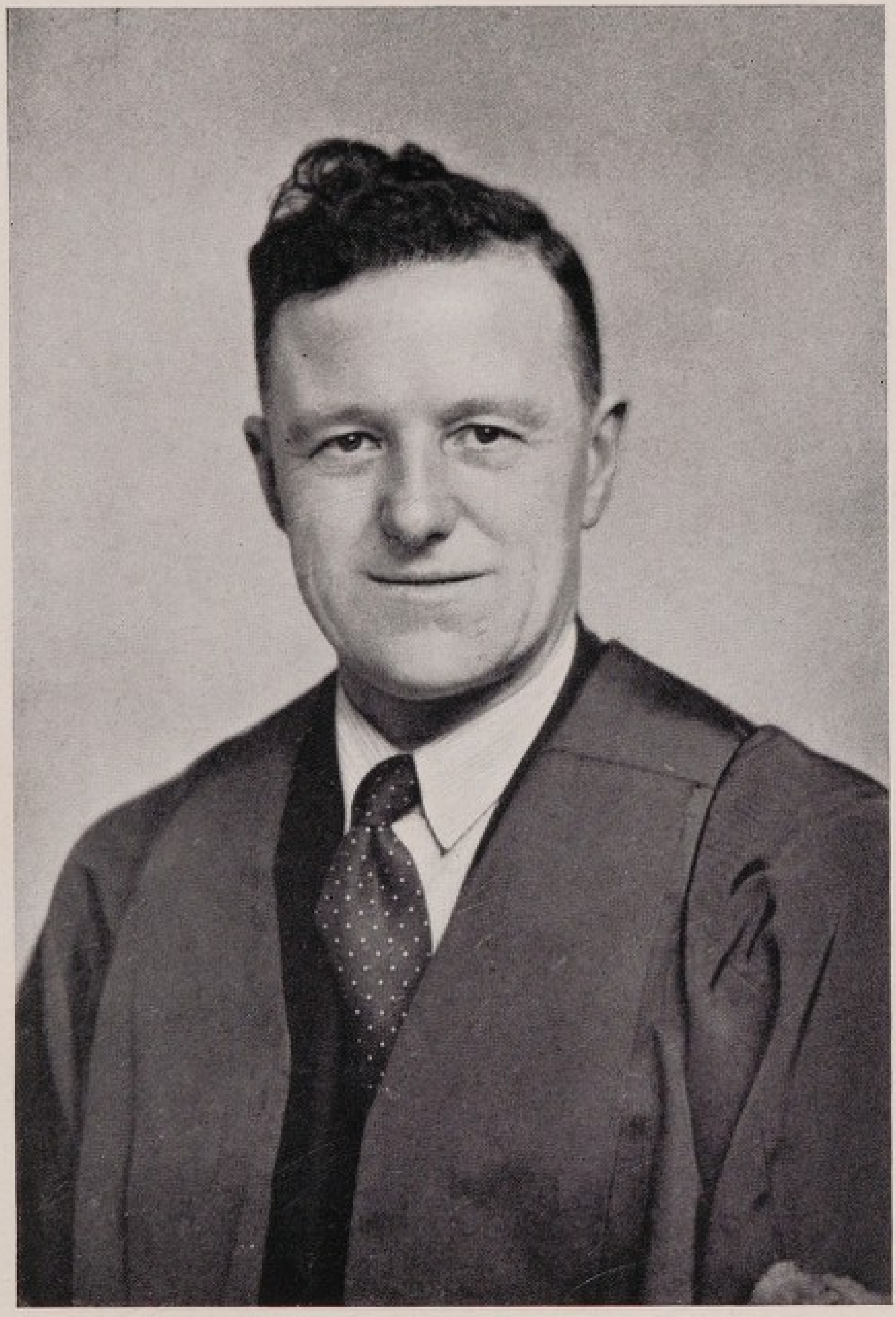
G. T. Meggison.

CONTENTS

ILLUSTRATIONS

PLANS, TABLES, Etc.

COUNCILLOR G. T. MEGGISON,
CHAIRMAN



COUNCILLOR S. SCOTT,
DEPUTY CHAIRMAN

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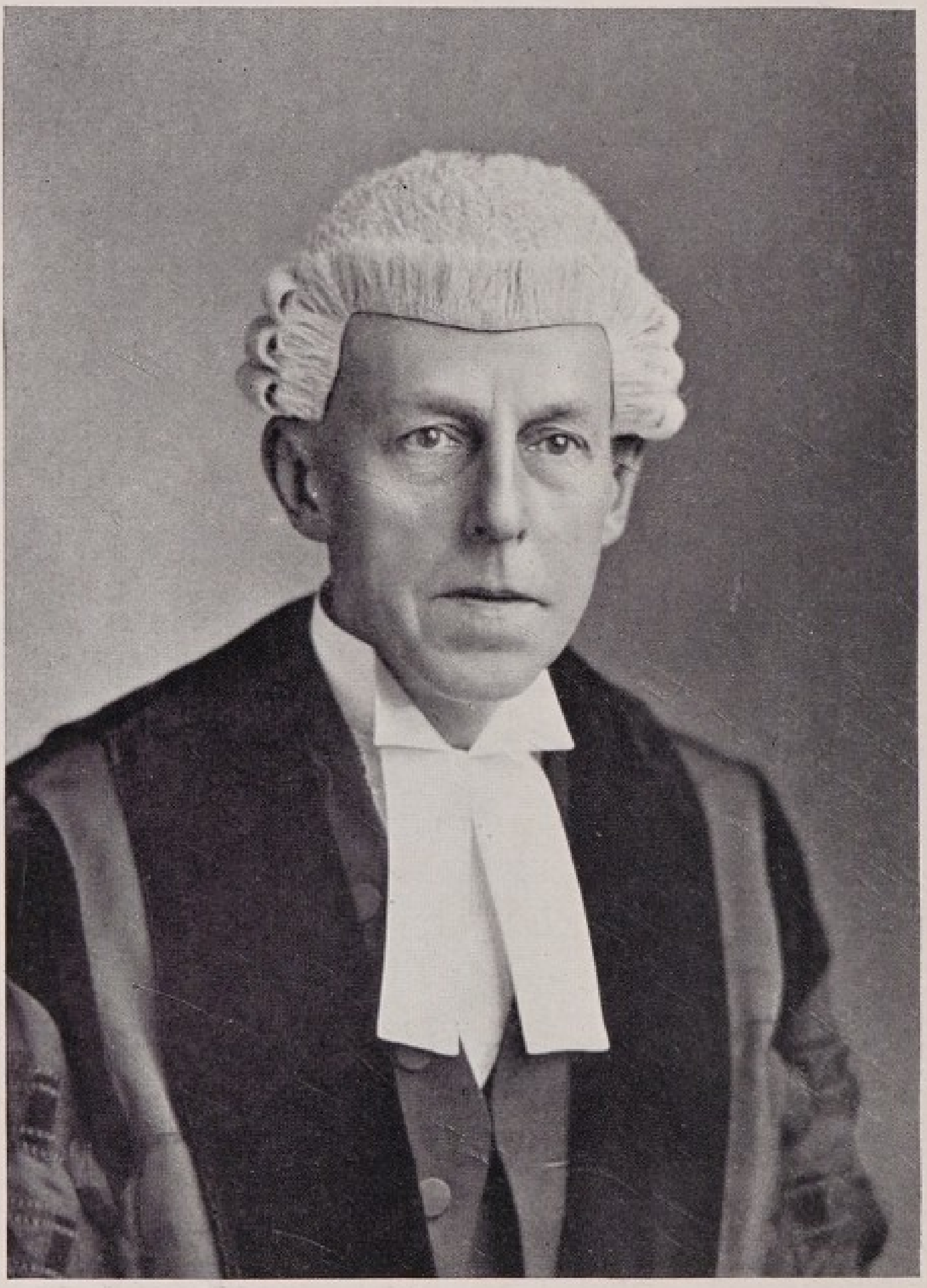


W. H. LEATHEM, LL.B.,
TOWN CLERK

B. R. SINKINSON, F.S.A.A.,
CITY TREASURER

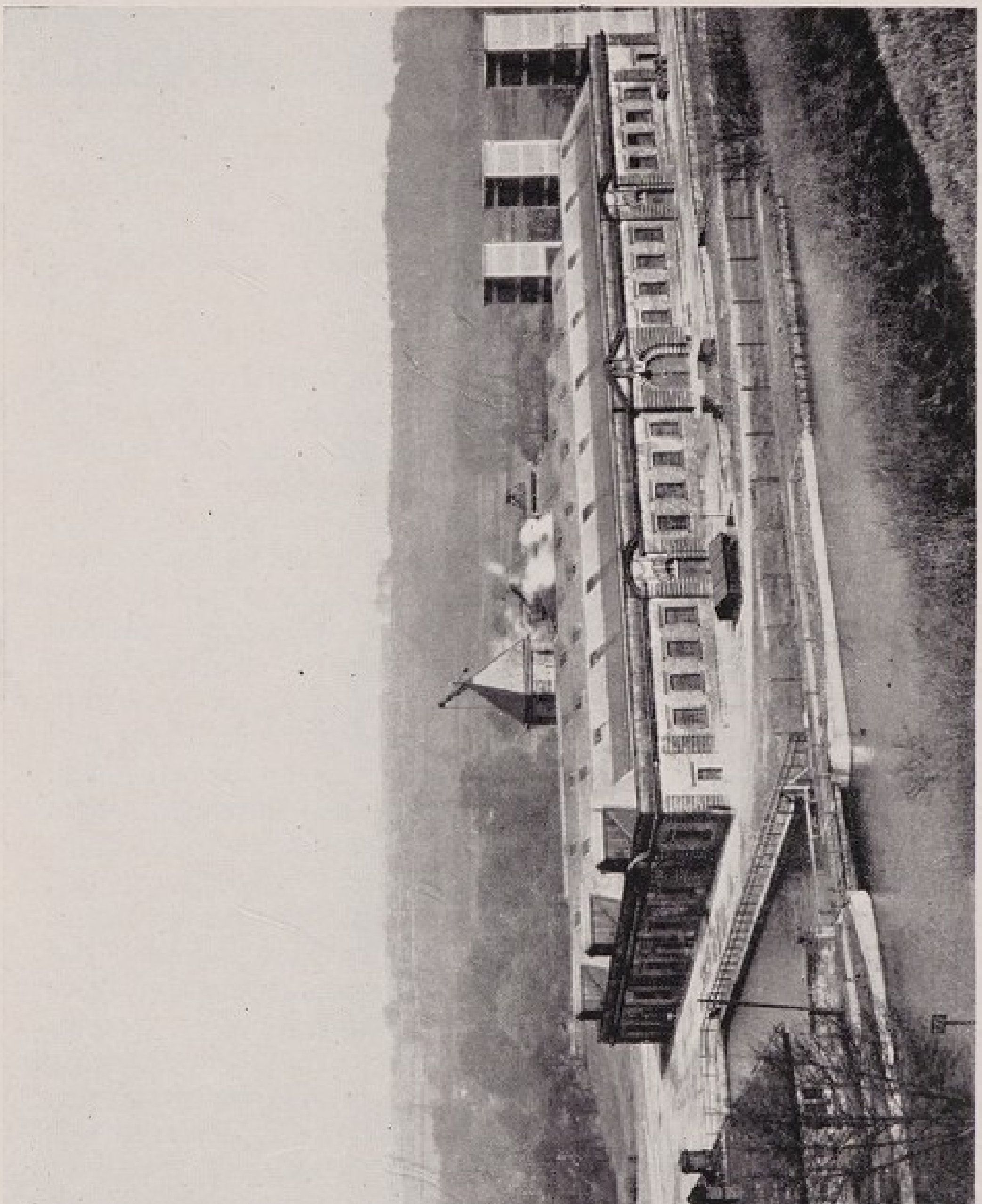
Chapter I

EARLY DIFFICULTIES

The Esholt scheme is the culmination of many years of effort by the citizens of Bradford to deal with the problem of sewage disposal. The situation of the city, the history of its development, and the character of the industries in which a large proportion of its population is engaged are all factors which have combined to give to the local sewage problem almost unique complexity.

Up to the closing years of the eighteenth century Bradford still remained much as it had been from medieval times, a tiny market town of two or three thousand inhabitants, with some traditional interest in the textile trade but mainly engaged on agricultural pursuits. With the opening of the nineteenth century a new order of things began. The development of the steam engine and of the factory system meant the beginning of a new life for the inhabitants. From its long repose in the bosom of its peaceful valleys, the town shot upwards and outwards with suddenness, and from the dimensions of a miniature country town it assumed the size and importance of a great manufacturing centre. Tall chimneys, huge factories, costly warehouses and shops, and innumerable streets of houses sprang up in all directions. For a long time, however, the social, intellectual, and municipal wants of the town failed to keep pace with its increasing wealth and commercial importance. The streets, mostly unpaved and without footpaths, were miserably lighted, and many of the dwellings of the poorer classes were unfit for human habitation. In those early days no provision was made for dealing with the sewage and waste liquors discharged from the ever-growing number of houses and industrial premises. Sewage was turned direct into the Bradford Beck and its tributaries, changing them from limpid trout streams into what were little better than open sewers. The community was not prepared for the rapidity of this industrial expansion. The principles of public health had yet to be evolved; municipal bodies were without adequate powers; they did not appreciate their vast opportunities, and they found the daily growing burden of their duties paralysing rather than stimulating.

So until far into the nineteenth century the sanitary condition of Bradford was deplorable. An experienced government officer, who was engaged during some years in collating the material which resulted in the Public Health Act of 1848, came to Yorkshire in 1843, and he declared in his report that, bad as were many industrial communities, Bradford was "the most filthy town I visited." There was not a public sewer in the town; antiquated private drains served the houses in the



PRESS HOUSE AND WORKS YARD

principal streets, whilst the sewage of the inferior streets ran into open channels. The chief commercial advantage of the town, its canal, added to the insanitation. In the middle of the eighteenth century a branch of the Leeds and Liverpool Canal had been carried up the Bradford valley and had its terminal basin partly upon the site of what is now Forster Square. Here sluice-gates intercepted the water of the Bradford Beck. The consequence was that the stagnant pool became the receptacle for vast quantities of sewage. Recurrent fever epidemics were the natural outcome of these intolerable conditions.

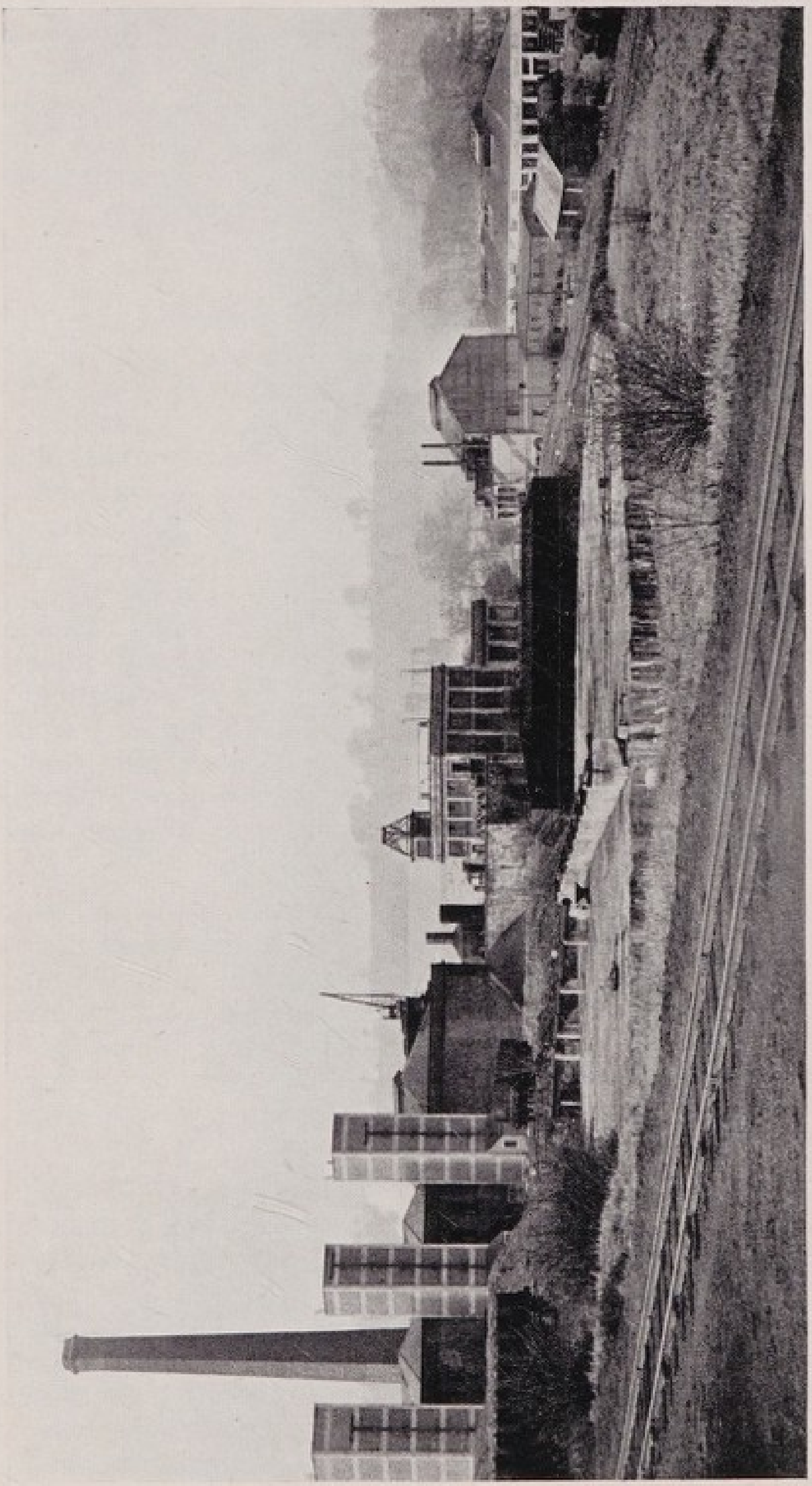
A Sanitary Awakening

A charter of municipal incorporation had been secured in 1847, and shortly afterwards an outbreak of cholera brought home to the new Town Council the necessity for radical sanitation measures. In 1853 the Borough Surveyor, Mr. Charles Gott, M.Inst.C.E., laid down the line for the first main sewer, although it was not until 1862 that construction actually began. By 1870 thirty miles of main sewer had been completed, and since then, as the city has extended, the work of sewering has never ceased. Besides this the Corporation undertook the covering in of the Beck where it passed through the town, and in 1866 it dealt with that festering plague spot, the canal basin. Action was taken in Chancery to prevent the Canal Company utilizing the sewage-charged waters of the Beck to feed their navigation water. For a while this involved the closing of the canal to traffic, but eventually pumping stations were established, which enabled the higher reaches of the canal to be fed with pure river water. Following the passing of the Bradford Canal (Abandonment) Act of 1922, the canal was emptied and its course has now been filled in.

But all these sanitary measures proceeded upon the primitive principle that the river was the natural place into which the sewage should be poured, and the more efficient the drainage of the town, the worse became the condition of the Beck and of the River Aire into which it flowed. That condition, of course, being intensified by the fact that other industrial communities on the banks of the Aire were rapidly rising and were also utilizing the river for sewage disposal.

The Local Difficulties

The woolcombing industry which developed with extraordinary rapidity in the town in the middle of the nineteenth century added peculiar difficulties. Wool and hair were, and still are, brought to Bradford from all parts of the world in the crude state in which they are clipped from the backs of the animals. Before being combed the wool is washed, and in that process it loses in many cases as much as 60 per cent of its weight, that 60 per cent consisting partly of the natural fat and partly of the dirt and manure clinging to the fleeces. As a consequence the waste water from the woolcombing process is extremely "rich" in organic materials and it is also very offensive. It is indicative of the magnitude of the problem which this trade creates



WORKS BUILDINGS, SHOWING PRESS HOUSE, SOLVENT PLANT, SOAP PLANT, AND GREASE HOUSE that no less than one-fifth of the wool produced in the whole world, or four-fifths of the quantity grown in and imported into England, is washed and dealt with in the area of this single municipality.

As the wool trade increased in Bradford protest was made by the residents on the river banks against the growing nuisance. In 1868 Mr. William Rookes Crompton Stansfield, the owner of Esholt Hall and estate about five miles from Bradford, took legal action in the Court of Chancery. The Corporation presented to the Court a view of the difficulties in which they found themselves. All schemes of precipitation or deodorization of sewage at that time invented had proved unworkable on a large scale. The Rivers Pollution Commission which had been severe on Bradford's sanitary condition had been appealed to for useful advice and aid, but "the Royal Commissioners were at a loss how such cases should be dealt with," and it was argued "if the most able officers whom the Government can select are thus embarrassed it may readily be believed that Local Boards are in equal difficulty." The Court first attempted to set a limit to the nuisance by prohibiting the opening of any additional sewers, but this order was annulled on the Corporation's giving an undertaking to take practical steps before 11th January 1872 to treat the sewage before discharging it into the river.

Bradford entered upon an era of experiments in sewage treatment. These experiments were made at Frizinghall, the lowest point within the borough. Here eleven acres of land were purchased and certain works were constructed. The first effort was a private venture. In 1871 a company undertook the treatment of the sewage free of cost. The Corporation undertook to construct works and provide them rent free, and a lease was granted to the company for twenty-one years. Their advisers proposed to filter the liquid through peat charcoal, and they calculated upon a handsome profit by the sale to the farmers of the residual as manure. But after losing £30,000 in their experiments the company came to grief. The Corporation then in 1874 took the works into their own hands, and appointed a manager to superintend the purification processes. The works were completed at considerable cost, and for some years the system worked quite satisfactorily.

The Problem of Wool Fat

If the exceptional strength of the Bradford sewage in the common organic elements had been its only peculiar quality the task of sewage treatment would still have been difficult. But, besides the dirt, there was taken from the fleeces in wool-washing an immense quantity of wool fat, known in the refined state as Lanolin. At one stage of the commercial development of the borough it paid the woolcomber to extract part of the fat from his effluent, but as the quantity of wool dealt with increased, the price of the residual fat or grease declined, and eventually nearly all the effluent was passed entirely untreated into the sewers, and the sewage works became inadequate to deal with the difficulty. The estimated quantity of this grease thus poured into the Beck was, in 1889, stated at twenty-five tons a day when the wool trade was suffering a bad time, and fifty tons a day or more in prosperous times. In addition, of course, vast quantities of soap and alkali were used in its removal from the wool.

One more difficulty arose from the presence in Bradford of many dyeworks, which also poured their effluents into the sewers, so that the sewage at one time ran acid, and at another strongly alkaline.

After many experiments the method adopted was to precipitate the solids with lime and the effluent then underwent a final purification by filtration through coke-breeze. The works were so operated for many years. Only a portion of the sewage could be dealt with, however, and meanwhile the town was growing rapidly.

Subsequently the use of lime as a precipitant of the sewage was abandoned, and ferric sulphate was used. But this proving very expensive, sulphuric acid was substituted in January 1901 and treatment by this chemical has been continued to the present time. After precipitation difficulties were conquered, it became necessary to dispose of the sludge, and experiments proved that this could be effected by means of filter presses. Through this treatment the grease is extracted and is marketable, as is also the dried sludge-cake. Since 1903 this process has been gradually expanded.

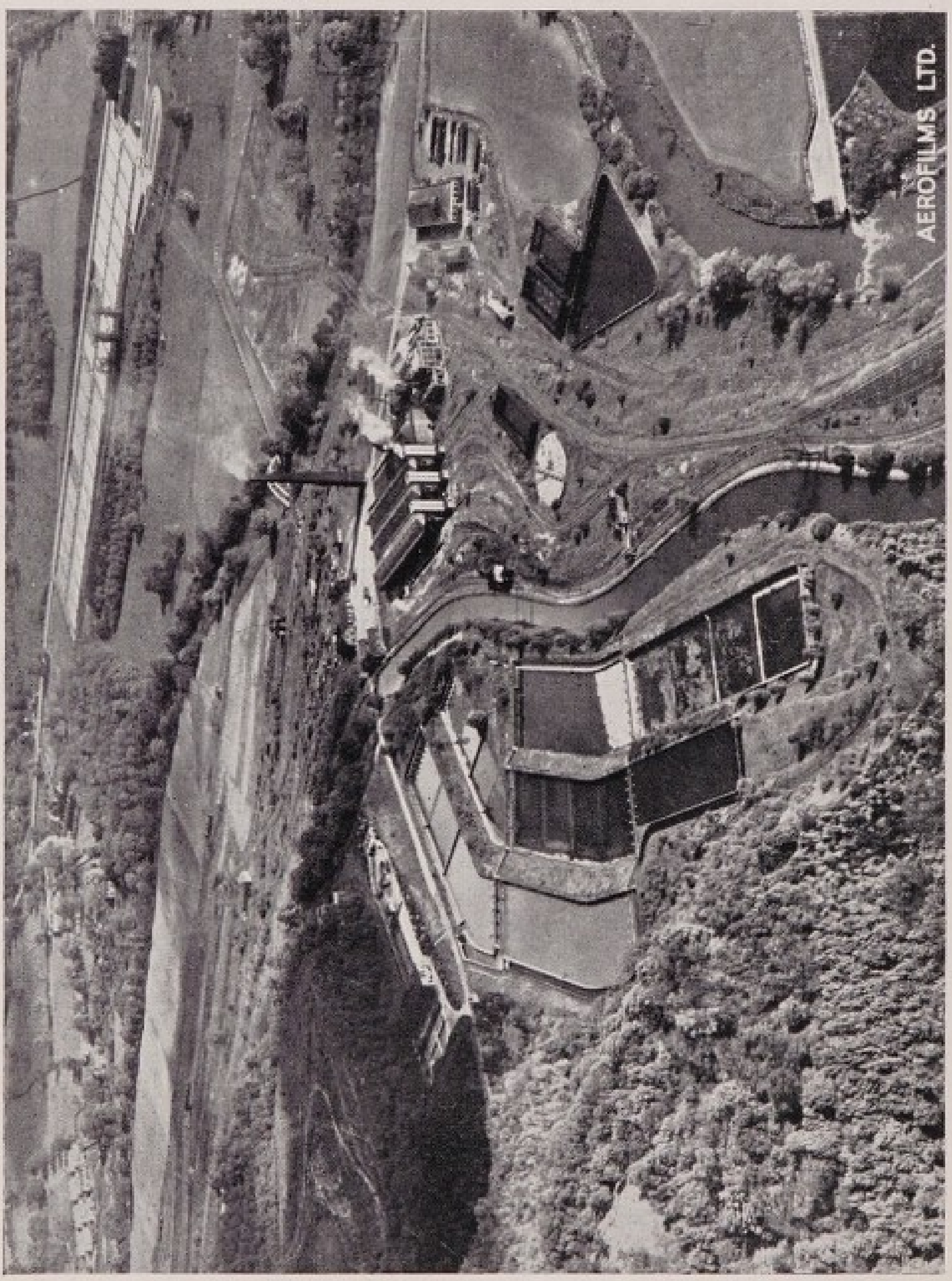
The condition of the Aire improved but slowly under the early experiments, and the West Riding of Yorkshire Rivers Board, which was formed in 1893, almost immediately brought pressure to bear on the Bradford Corporation to improve the effluent discharged from their works. The Corporation accordingly decided in 1894 to extend the Frizinghall works, and the consent of the Local Government Board was given to the scheme with the express intimation that it was accepted "very reluctantly," the Board evidently feeling that though it was the best devisable, any scheme of treatment in so limited an area, some 38 acres, as was at the utmost available at Frizinghall, was necessarily far from satisfactory. Beck and road improvements were carried out, but before the new purification works at Frizinghall were commenced the scheme for the extension of the boundaries of the borough arose. In the course of the Local Government Board's Inquiry into that proposal the sewage disposal of Bradford was a good deal criticized, and eventually, when the extension was sanctioned, there was inserted, in the Extension Order of 1899, a stipulation that Bradford should proceed with a proper sewage disposal scheme within twelve months.

The Esholt Scheme Conceived

Meanwhile the feeling was growing that it was necessary to remove the works to the main valley of the Aire, and the only site there available seemed to be at Esholt on the estate of the successors of the gentleman whose legal proceedings first emphasized the gravity of the problem. Before they proceeded with an undertaking of such magnitude as the acquisition of the Esholt Estate, two alternative policies were considered by the Sewage Committee. One was that trade effluents should be conveyed to Frizinghall by an entirely separate system of sewers to be constructed at the expense of the traders; the other was that powers should be sought to compel the woolcombers to remove the grease from the effluent before it passed from their works. Both these suggestions were dropped, however, and the Corporation embarked on the scheme for acquiring the necessary land at Esholt and constructing suitable works. But ten further years of protracted negotiations were to ensue before any work could be put in hand.

In 1898 the Corporation decided to apply for compulsory powers for the acquisition of the Esholt Estate. A provisional order was granted empowering the Corporation to purchase 529 acres out of the total estate area of 1700 acres; but this order was opposed by the owners, the Misses Stansfield, and a select committee of the House of Commons refused to confirm the order. The Corporation was still, however, under compulsion to proceed with a complete sewage disposal scheme, and again applied to Parliament in 1901. This time powers were granted to acquire an area of 310 acres, 210 belonging to the Esholt Estate. This order too was rejected by a select committee on the grounds that the area was insufficient for the required purpose. The Bradford Corporation Act, 1901, meanwhile had given the Corporation until 31st December 1902 to carry out its sewage disposal obligations, this date being subsequently extended to 31st December 1904. The Rivers Board was still pressing the Corporation to take action, and in 1902 the owners of the estate were again approached. Ultimately, in February 1904 they made an offer to sell the whole estate to the Corporation. The price of £239,742 was settled by arbitration, and on the 2nd February 1906 the estate became the property of the citizens of Bradford.

A detailed scheme for the utilization of the estate was submitted to the Council by the then Chairman of the Sewage Committee (the late Councillor E. J. Smith) in December 1906. It was finally approved in March 1907, the cost of the scheme then being estimated at £955,000. It was not until 23rd April 1909, however, that the Local Government Board gave permission for the work to be proceeded with.



AERIAL VIEW SHOWING STORM WATER TANKS, WORKS BUILDINGS, AND PRECIPITATION TANKS

Chapter II

THE CONSTRUCTION OF THE ESHOLT WORKS

The works first undertaken, apart from the canal basin and a branch line of railway from the London, Midland, and Scottish system, were those in connection with the disposal of sludge because it was thought that by this means effect could be given to improvement in the river in the shortest possible time. The construction of the press-house was therefore commenced at the Esholt Works in the year 1910, and completed and brought into use in the year 1912, thereby allowing the sludge to be drawn from the precipitation tanks at the old Frizinghall Works in sufficient quantities and thus reducing the amount of sludge finding its way into the Bradford Beck and thence to the River Aire. The sludge was forced by compressed air a distance of over four miles along an 8-in. diameter main and this method was continued until the spring of the year 1926, when the Main Outfall Sewer came into operation for the passage of the crude sewage into the new Esholt Works.

The Works Buildings

The buildings are substantially built of sandstone with brick internal facings and have a handsome appearance. The general elevations will be seen in the illustration on page 2. Care was taken in laying out these works to provide for every contingency with regard to transport; and canal, standard-gauge railway, and road are available at the works in order to provide the cheapest possible transport. A large amount of excavation was necessary on the site as a hill known as Strangford Hill had to be removed. The main building covers an area of $1\frac{1}{4}$ acres and comprises the press-house (237 ft. × 92 ft.), the sludge-heating house (237 ft. × 50 ft.), the engine house and fitters' shop (115 ft. by 40 ft.), and the boiler house (80 ft. × 68 ft.). A basement extends under the press-house for the accommodation of the railway trucks which receive the press-cake from the presses. The grease vats and storage tanks were originally housed in the same building as the sludge-heating vats, but a new grease house (190 ft. × 62 ft.) accommodating thirty vats was built in 1939 on a site between the main building and the river. This is a modern single story building in reinforced concrete. The removal of the grease vats from the old grease house has made space available for an additional row of filter presses. The chimney (8 ft. square inside dimension by 200 ft. high) is detached from the main building and placed on a solid rock foundation 78 yards distant.

The flue laid outside from the boiler-house to the chimney is 5 ft. wide by 8 ft. 6 in. high. Since the erection of the main building other units have been added to complete the works. A chemical laboratory, mess room, and lavatories for the workpeople, constructed in 1914, which can be seen in the foreground of the illustration on page 2; a block of workshops accommodating blacksmiths, joiners, electricians, and stores to the left of the picture; also the main electrical transformer station which transforms the current (alternating, 3 phase, 50 cycles) from 6600 volts to 400 volts for power purposes and 230 volts for lighting.

Towards the end of the first World War, when the demand for grease was high, a solvent plant was erected near the existing buildings for the purpose of extracting the residual grease from the press cake. The process was later found to be uneconomic and since 1938 the solvent plant building has been used for the production of several of the Department's specialized by-products, which are described in a later chapter. Further extensions to this part of the works have been made as the by-products side has expanded, the most recent being the Soap plant which was erected in 1938.

The Main Outfall Sewer

In the year 1913 a commencement was made with the construction of the main outfall sewer in tunnel. It should be mentioned that the construction of this tunnel was decided upon because only by taking the shortest route could full use be made of the lands available at Esholt by gravitation. With a total fall of only 12 feet, it was found possible whilst providing self-cleansing velocities to pass the sewage from the Frizinghall district of the City by way of the tunnel and across the Aire valley, a distance of more than three miles, to the only natural site available for the precipitation tanks, on the north side of the valley, and thus permit the use of 800 acres of land for works by gravitation. The work of constructing the tunnel was first let to a contractor for the sum of £113,971 who commenced the preliminary works necessary before the driving of the actual tunnel commenced. However, this contractor was unfortunate and became bankrupt after very little of the work had been done. Borings had previously been sunk on the line of the tunnel but the Committee decided that before they let a further contract they would sink two shafts with a view to investigating more closely the geology of the site. This work was carried out by administration and was completed in 1914. A new contract for £121,616 was let the same year, but this contractor was soon in difficulties on account of war-time restrictions on the supply of labour and materials. He was glad when the Corporation, in consequence of Treasury restrictions upon borrowing, decided to shut down the works in 1916. This contractor was afterwards paid off and his plant and materials sold, nothing further being done until after the War. In the year 1919 the Corporation resolved to undertake the work by direct labour.

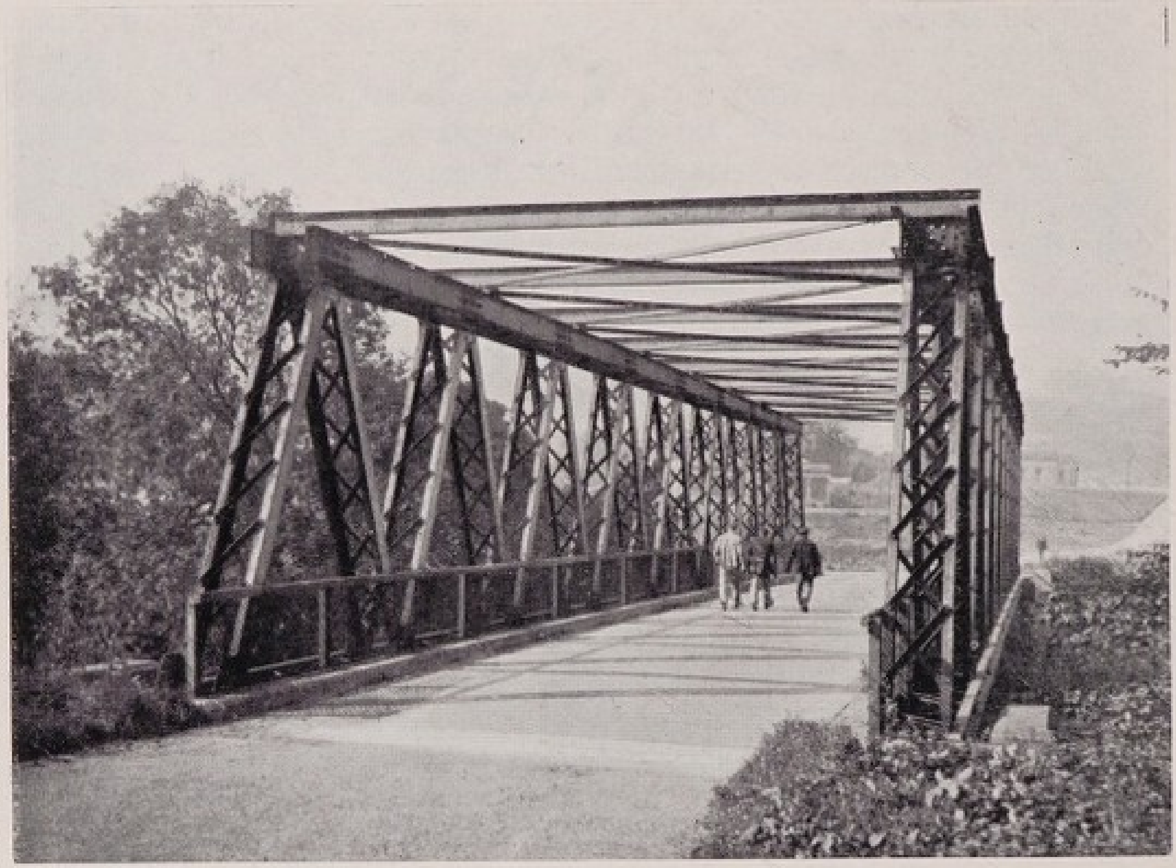
In the autumn of 1919 a bottom heading about 7 ft. by 7 ft. was started from both the Frizinghall and the Esholt ends, and these being well advanced in November 1920, arrangements were made to open up the full-sized tunnel. For ease in construction the arch and side walls of the tunnel were concreted first throughout the whole length. When this was done the completion of the circular section was proceeded with from the centre of the tunnel simultaneously outwards to each end. This operation consisted of laying the concrete invert and at the same time building a lining ring of blue brickwork, $4\frac{1}{2}$ in. thick, to complete the section with an internal diameter of 10 ft. The method worked admirably, and as the bricklayers worked themselves out, the finished tunnel was left clean and swept behind them. The whole tunnel was driven without any appreciable error in alignment or level and, when completed, was found to be thoroughly sound and watertight throughout its length.

The tunnel workings passed through the lower coal measures and great care had to be exercised in excavating the ground. Coal seams were encountered, and at one section near the Frizinghall end old workings were met which caused the Corporation considerable expense in providing special foundations. The tunnel passed also through ironstone which was only bored with difficulty, through treacherous shales, and through many faults, one of them more than 100 feet wide consisting of mud and water. The Corporation were fortunate in not tapping the large quantities of water known to be overhead in the old abandoned stone mines on Idle Moor. Progress was made by means of compressed air drills and the use of explosives. The excavation and bricklaying was let to mining sub-contractors on a piece work basis and the amount of work done was extraordinarily good and increased as the men got more used to the work, the average weekly progress rising from 25 ft. in 1920 to nearly 100 ft. in 1923. The tunnel was finally completed in 1924. It is two and three-quarter miles in length, has a gradient throughout of 1 in 2000, and has a discharging capacity of 180,000,000 gallons per day.

The Eccleshill and Idle Sewer

The intercepting sewer from the Eccleshill and Idle districts of Bradford was commenced in August 1909 and completed in June 1910. The sewer, for a length of 2092 yards, is egg-shaped, 2 ft. 4 in. wide by 3 ft. 6 in. high with a gradient of 1 in 630 and has a discharging capacity of 12,000,000 gallons per day. This section of the sewer is in tunnel for one-third of a mile. The total length is 3000 yards, the upper end consisting of 24-in. stoneware pipe sewers together with manholes, storm water overflow chamber, and sewer connections.

As soon as the work of lining the main tunnel was launched in 1920–21, the Corporation had to seriously consider the question of proceeding with other important sections of the work, namely the detritus and storm water tanks on the south side of the valley and the precipitation tanks and the filters on the north side of the valley. The



ROAD BRIDGE ACROSS THE RIVER AIRE

STORAGE AND DRYING GROUND FOR PRESS CAKE

Minister of Health, in March 1921, urged upon the Corporation "the importance of proceeding as rapidly as practicable with the construction of the Aire valley aqueduct, precipitation tanks, and bacterial filters, and of having the aqueduct, tanks, and at least 30 acres of filters constructed in time to be brought into use concurrently with the tunnel outfall sewer." Thus followed the commencement of the precipitation tanks in the year 1921, the filters in 1922, and the detritus and storm water tanks in 1923.

Detritus Pit and Tanks and Storm Water Tanks

The detritus pit measures 55 ft. × 83 ft. 9 in. and is 11 ft. deep. The detritus tanks are two in number each 150 ft. long by 40 ft. wide and have, together, a capacity of 1,000,000 gallons. These works are substantially built with blue brick facings.

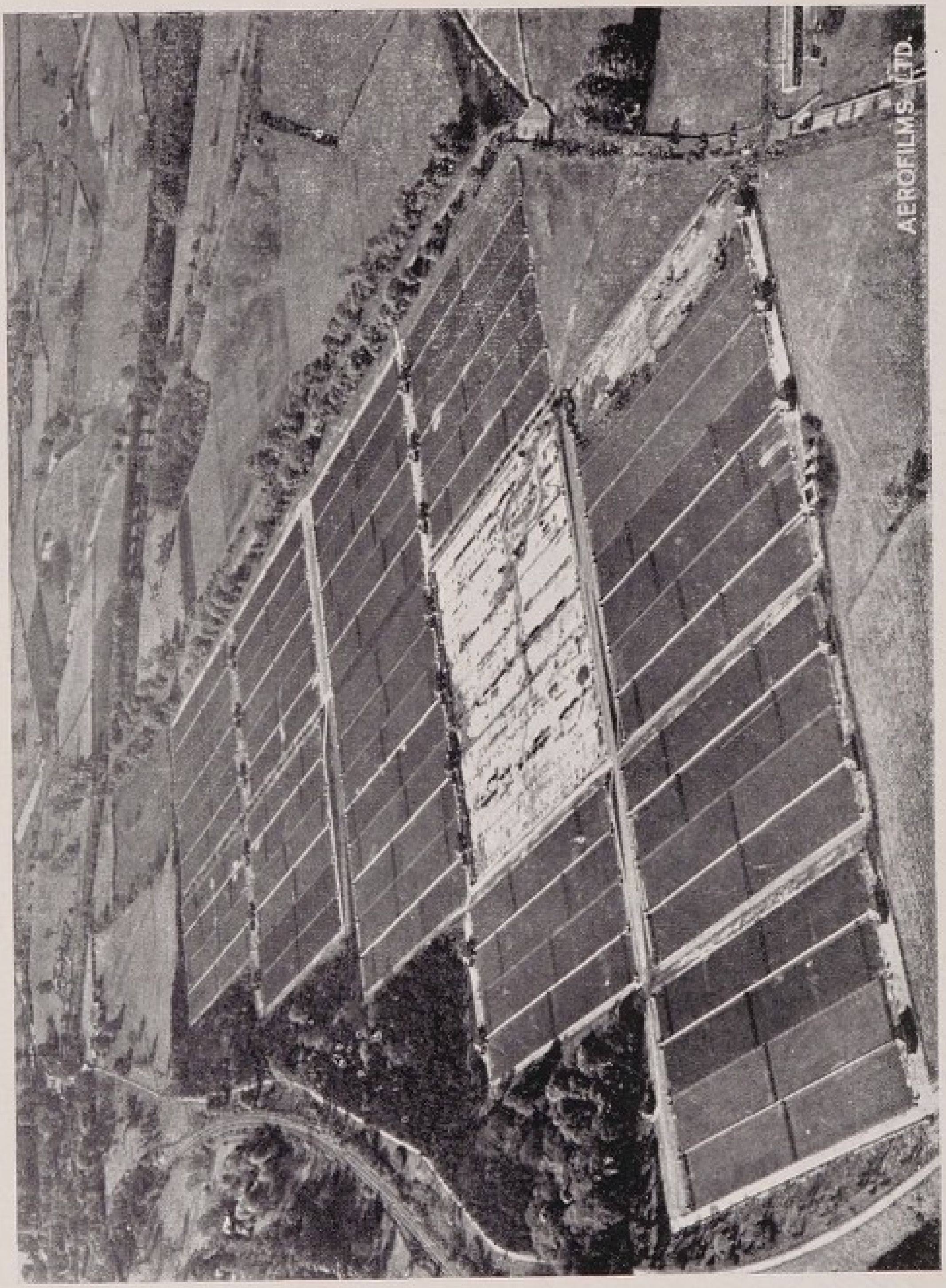
The storm water tanks are of various sizes, seven in number, and cover 6 acres. The average depth is 6 ft. 6 in., the walls being built of concrete finished with a blue brick coping. The sludges from the detritus tanks and the storm water tanks pass in sealed mains under gravity to the sludge-screening house and, after mixing with other sludges, are discharged to the press-house.

The Aire Valley Syphons

The low level syphons were constructed partly in tunnel and partly in cutting whilst a portion of the pipe lines rest on piers above ground level. In passing (in tunnel) underneath the Leeds and Liverpool Canal considerable difficulty was met with as the roof of the heading was within 4 feet of the canal bottom. Special C.I. segments were designed for the work and progress was slow as it was necessary to bogee with lime each section, 2 feet in length, as the work progressed. In spite of the greatest care, the water burst in on one occasion but the men escaped. Precautions had been taken against risks of emptying the canal. Although the three syphon headings were only completed with the greatest difficulty, another tunnel under the canal only 170 yards away and of 11 feet internal diameter and equally near the canal bottom, constructed for the purpose of accommodating various pipes, was completed without any trouble, although the risk was great. Two of the pipe lines were completed in March 1926, and a third pipe line was completed in November 1929. The net cost of this section of the work totalled £41,000, against the cost of the proposed overhead aqueduct estimated to cost, before the War, £75,000, and which would certainly have cost, after the War, more than double that amount. The pipes are 4 feet in internal diameter, 700 yards long, and each can convey about 30,000,000 gallons of sewage per twenty-four hours. The vertical depth of the syphon is 68 feet.

Precipitation Tanks

The precipitation tanks were completed in 1926. The primary tanks are 140 ft. long by 60 ft. wide with an average depth of 7 ft. 4 in. and contain 7,500,000 gallons in twenty tanks and the secondary tanks are



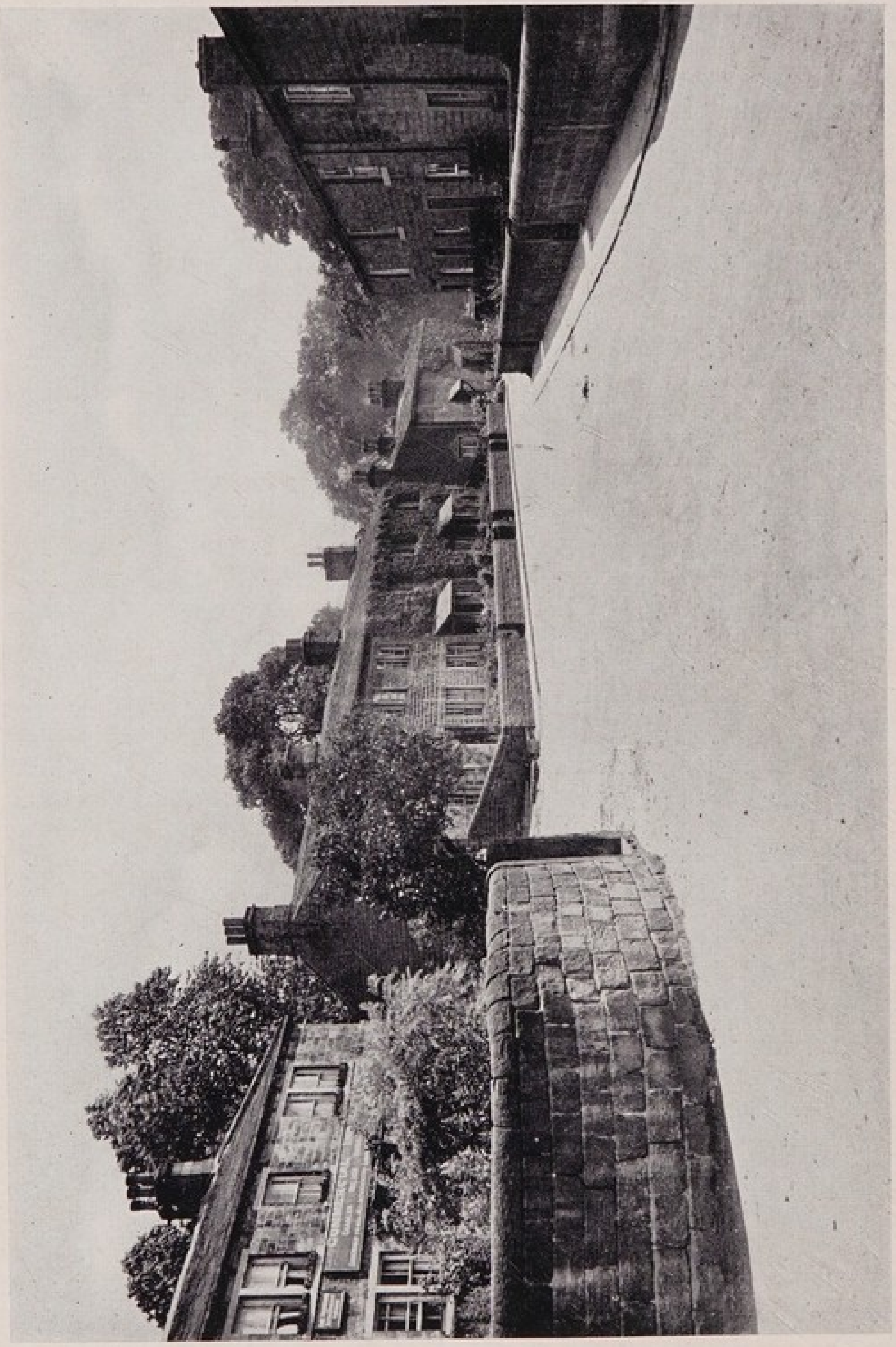
AERIAL VIEW SHOWING BIOLOGICAL FILTERS WITH COAL REMOVAL IN PROGRESS

140 ft. long by 65 ft. wide with an average depth of 10 ft. 2 in., and contain 11,500,000 gallons, making the total volume 19,000,000 gallons, which is rather more than a day's dry weather flow. The walls are built with blue brick facings, one row of headers to three rows of stretchers with a concrete hearting, whilst the channel walls are of red faced with blue brickwork. The walls have been well preserved and the action of the very dilute acid has not affected the brickwork or the cement joints appreciably. The reason for this is that a greasy scum forms on the walls, acting as an excellent protection.

Biological Filters

The construction of the filters was completed in 1931. The beds cover an area of 53½ acres and comprise one of the largest filter installations in the world. The floor is of concrete 6 in. thick, and drainage channels 18 in. wide, covered with reinforced concrete slabs, are provided. The beds are uniformly 6 ft. deep, a depth chosen after tests on experimental beds, 10 ft. and 15 ft. deep, had proved that the deeper bed did not produce an appreciably better effluent. The filtering material is coal of a size from ¾ in. to about 1½ in., known in the trade as washed singles and doubles. The hard Yorkshire coal has proved to be a satisfactory filtering material for the type of sewage which has to be dealt with at these works. Moreover, it is extremely valuable as a business asset, having always a potential value which has on more than one occasion come to the community's aid during an emergency. During the general strike in the year 1926, the whole of the gas and electrical services of Bradford were maintained at full output by means of this coal, by far the greater part of which had not been brought into use for sewage treatment. In addition, factories in Yorkshire and Lancashire, and also householders in the City were supplied. In this way 200,000 tons were sold and afterwards replaced. Again, in the early days of 1947 the Sewage Committee decided to release further stocks of coal from the beds in order to help in the national fuel crisis. This necessitated modifications in the operation of the filters, and the approval of the West Riding of Yorkshire Rivers Board had to be obtained. A total of twelve acres, representing about 60,000 tons, has been cleared, some of the coal going into Bradford to help keep the mills running. Naturally, the Department's public health obligations to purify the sewage before it enters the river are of paramount importance, and only a limited acreage can be laid off at any one time. But plans are already in hand to refill the empty beds, using broken stone from the Committee's quarries on the works, however, instead of coal as media. It has been decided to replace with stone, as supplies of coal cannot be obtained for this purpose. Stone will, however, make an equally satisfactory filtering media, and exhaustive tests have been made on this material. It is interesting to note that the calorific value of the coal has been in no way impaired during its use as filter media.

On the completion of the filter installation in 1931, the work of constructing the humus tanks and clarification lakes was put in hand. These were completed in the following year.



ESHOLT VILLAGE—WORKMEN'S COTTAGES

Bridges

Attention might also be drawn to the river and canal crossings, there being four very fine bridges of 130 feet span and over. One bridge is of reinforced concrete carrying the three syphon pipe lines, two railway bridges of steel construction, and one road bridge of similar construction seen in the illustration on page 12. Some 25 miles of standard gauge railway cover the works and enable material to be unloaded at the necessary points. Private sidings connect to the L.M.S. main line.

Constructional Problems

These notes on the construction of the works would be incomplete without some reference to the enormous amount of work undertaken which is not now apparent. Taking excavation alone, some 1⅓ million cubic yards had to be moved and for this purpose five steam diggers were at work, two being Ruston Hornsby machines on rails with 2½ cubic yard buckets, and three of a smaller type. There were six standard gauge steam and one petrol locomotive in use, and four electric and three petrol 2-ft. gauge locomotives. Also thirteen steam cranes capable of lifting 5 tons and under, with and without grabs, and nine machine concrete mixers. Altogether some £96,000 was expended on plant with which to carry out the works. The Corporation's own sandstone quarry has provided all the stone for building as well as broken stone and sand for concrete. Altogether some 300,000 tons of stone have been used in these works.

After standing idle for some sixteen years, this quarry will probably once again soon become a scene of activity. As previously stated preparations are in hand to utilise the stone as filter media in place of the coal which was removed from the filter beds early in 1947.

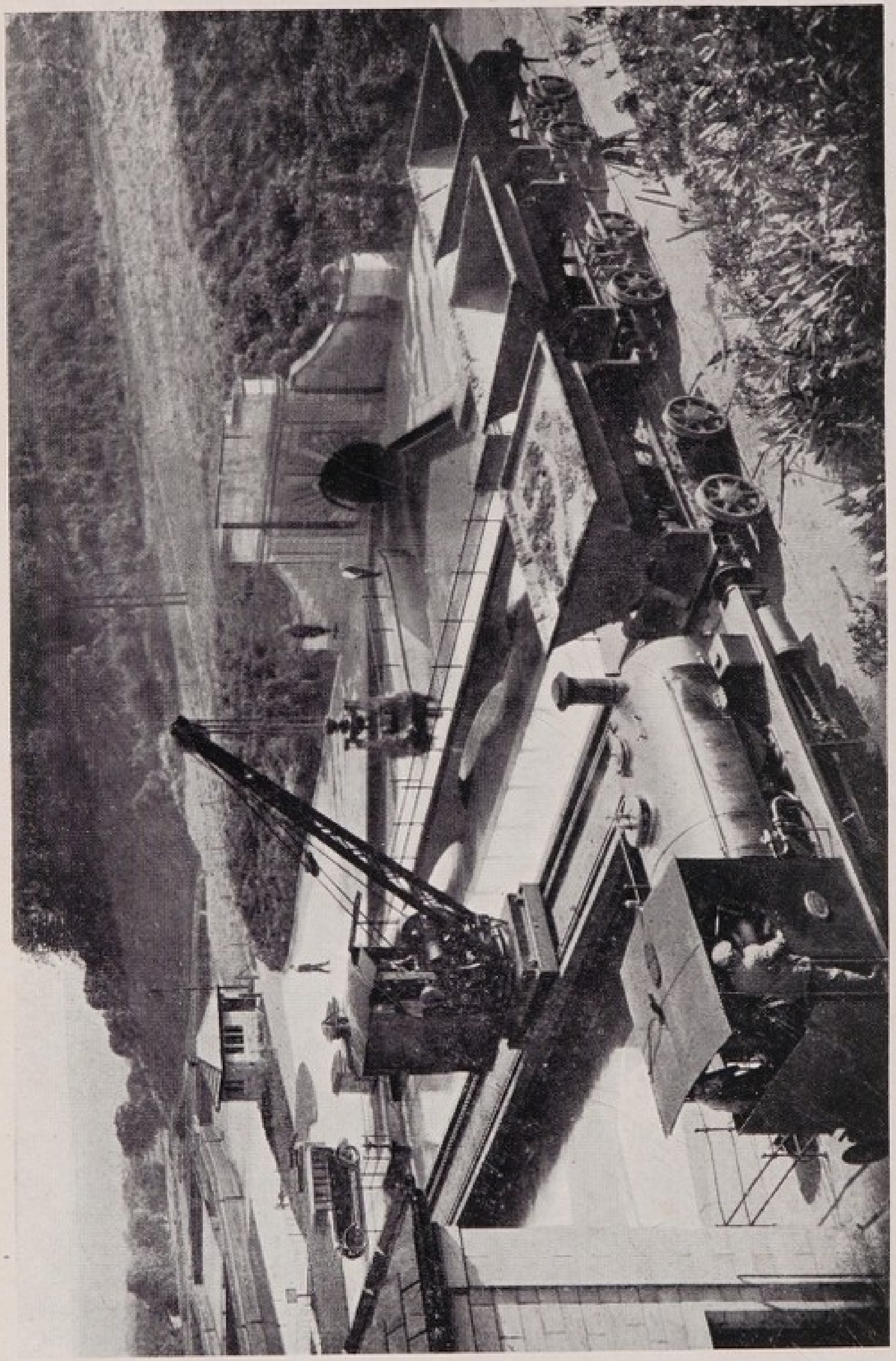
Housing

Many of the workmen are accommodated on the Corporation's own estate either in Esholt village, an illustration of which appears on page 16, or in the houses built on the lands around. The Corporation have 146 workmen's dwellings on the estate of which 34 were built after the First World War.

The Cost of the Works

The capital cost of the Esholt scheme has amounted to about £2,500,000, of which the land cost about £240,000. The original estimate for the cost of the works was £955,000, but the increased sum is largely accounted for by the rise in the cost of labour and materials in the years following the First World War, when, for a period, labour was three and a half times and materials from three to four times pre-war prices.

The capital cost of the Esholt Works and the costs for treating the sewage are very heavy owing to the particular trade wastes discharged



TUNNEL OUTFALL AND DETRITUS PIT

by the industries in the City. The sewage is one of the most difficult in this country to treat, and the works that have been constructed and the processes adopted are world renowned.

Up to the end of the last century the Bradford sewage had been regarded as untreatable, but, largely owing to the pioneer work and imaginitive foresight of the late Mr. Joseph Garfield, M.I.C.E., the first Sewage Works Engineer, the present works were designed, and construction commenced. Mr. Garfield died in 1925 and his successor, Mr. H. Wontner-Smith, M.I.C.E., who retired in 1945, completed the construction of the works.

TABLE I

GENERAL STATISTICS

Area of City..	25,504 acres
Population (est. 1945)	262,660
Total Rateable Value	£2,199,033
Product of 1d. Rate	£8,500
Sewage Disposal Rate (1947–48)	6·434d.
Income from Sale of By-Products (1946–47)	£291,670
Total Income from Sale of By-Products since 1902 ..	£3,100,000

ESHOLT DRAINAGE AREA

	Area—acres	Population
City of Bradford (part draining to Esholt) ..	21,972	239,000
Baildon	1,350	7,500
Aireborough U.D.C.:		
Yeadon District	700	9,000
Guiseley District	1,500	7,000
Totals ..	25,522	262,500

The Corporation has also entered into an agreement with the Shipley Urban District Council to treat the whole of the sewage from Shipley at Esholt. This agreement will be put into effect as soon as the necessary works for conveying the sewage to Esholt have been constructed.

NORTH BIERLEY DRAINAGE AREA

The southern part of the City falling within the River Calder watershed is drained to the Corporation's North Bierley Sewage Works. The area drained is 3,532 acres with a population of 23,500, and the daily Dry Weather Flow is about 1¼ million gallons. See Chapter VII.

Chapter III

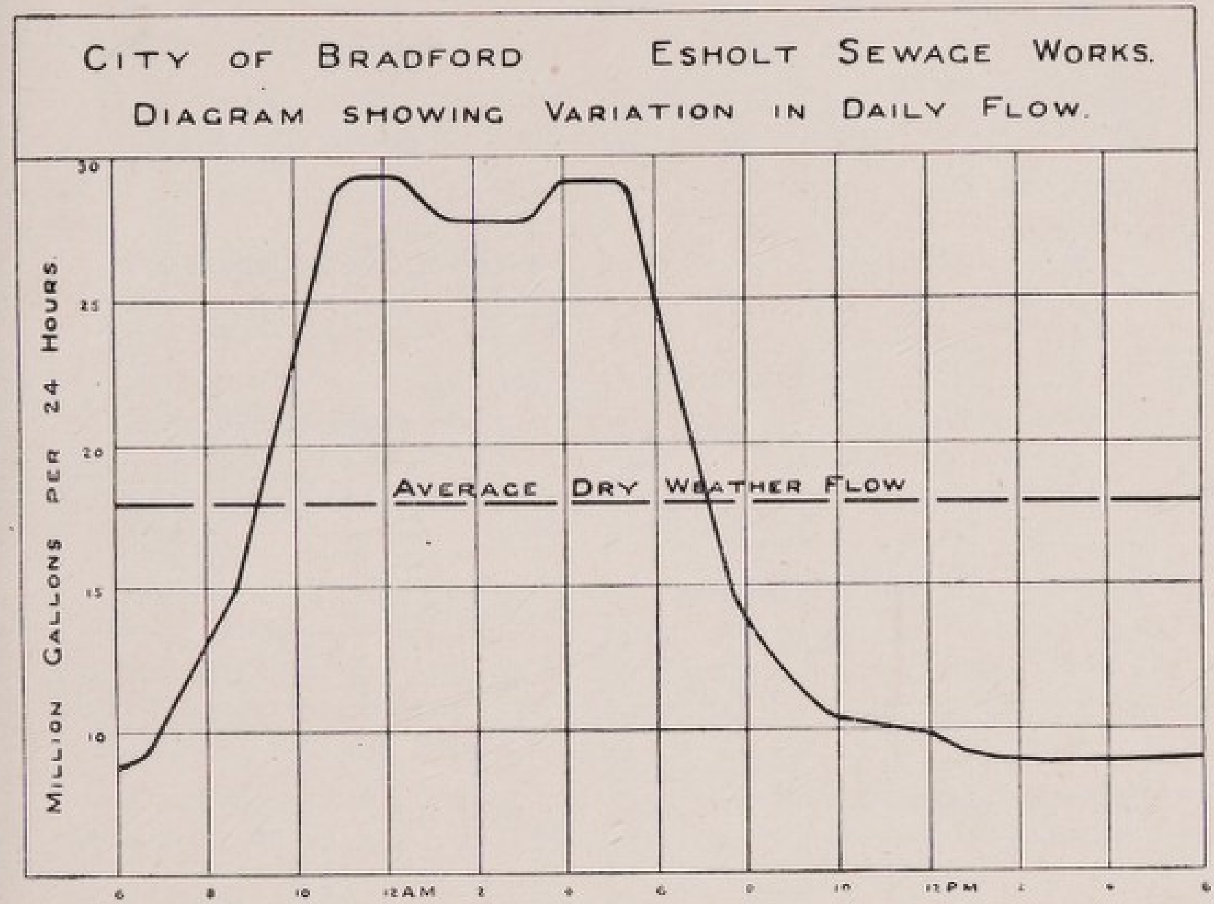
SEWAGE PURIFICATION

The area of the City of Bradford is 25,504 acres. Of this area 21,972 acres drain to the Esholt Works situated in the Aire valley, whilst most of the remainder drains to the North Bierley Works of the Corporation in the Calder valey. There are, however, one or two very small areas of the City which drain, as a matter of convenience, to outside authorities. In addition to the area in Bradford draining to the Esholt Works, there are also some 2,200 acres in the Aireborough U.D.C. area, and 1,350 acres in the Baildon U.D.C. area, which also drain to the Works, these Councils having entered into agreements with the Corporation whereby the latter undertakes to receive and treat their sewage.

The population of the City of Bradford according to an estimate made in 1945 is 262,660, of which the population draining to the Esholt Works is taken to be 239,000, added to which is a population of about 16,000 from the townships of Yeadon and Guiseley in the Aireborough U.D.C. area, and 7,500 from the township of Baildon, making a total of 262,500 people. The average dry weather flow of sewage flowing to the Esholt Works is shown by gaugings to be approximately as follows:

	Million Gallons per day
From Bradford via the Main Outfall Sewer ..	14·5
From Bradford via the Idle and Eccleshill Sewer	1·0
From Baildon U.D.C.	·5
From Yeadon (Aireborough U.D.C.)	1·0
From Guiseley (Aireborough U.D.C.)	1·0
Total ..	18·0

Thus the dry weather flow of sewage amounts to 67 gallons per head per day of the population served, and is of a quality later described. The volume of sewage in wet weather, which is liable to flow to the Esholt Works, is at the rate of over 100 million gallons per day, which figure has been reached on many occasions. The average flow treated throughout the year (taking 1946–47 as an example) amounts to 24 million gallons daily, the total flow for that year being 8,824 million gallons. One of the features of the Bradford flow is the high rate maintained during the working hours of the day as is shown by the following diagram:



This is due mainly to the emptying of wash-bowls and vats at the various wool-washing and dyeing plants in the City.

The sewage entering the Esholt Works is composed of approximately half domestic and half trade waste. The latter consists mainly of textile wastes, such as crude wool scouring effluents, seak tank effluents from wool scouring treatment plants, and various dye liquors. In addition, there are, of course, the usual trade effluents from a large city, such as brewery wastes, pickling wastes, chromium plating wastes and effluents from various engineering and chemical works.

Typical analyses of wool scouring liquors are as follows:

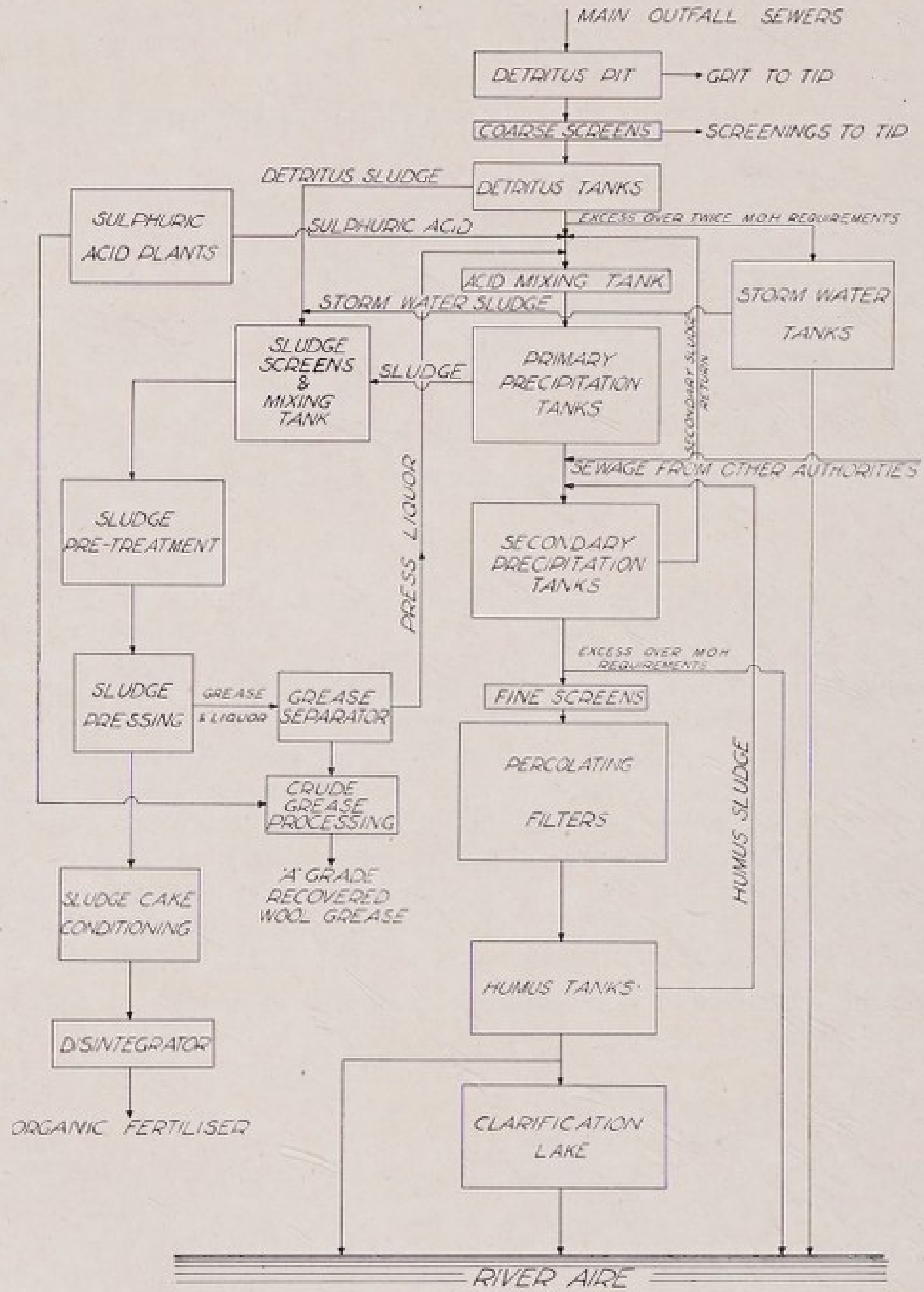
Wool Scouring Effluent

Grease	2,220·0 parts per 100,000
Suspended matter	3,030·0 ,, ,, ,,
Oxygenabsorbed(4hours@80°F.)	234·0 ,, ,, ,,
Alkalinity (to methyl orange) ..	612·5 ,, ,, ,,

Treated Wool Scouring (Seak Tank) Effluent

Grease	144·0 parts per 100,000
Suspended matter	315·0 ,, ,, ,,
Oxygenabsorbed(4hours@80°F.)	117·9 ,, ,, ,,
Acidity	102·9 ,, ,, ,,

The dye liquors are too varied in character to enable separate analyses to be given, some being acid and some strongly alkaline, according to whether they are from the wool, cotton, silk, or rayon industries.



ESHOLT SEWAGE WORKS—FLOW DIAGRAM

Quality of Sewage

The strength of the sewage of Bradford arriving at the works may be illustrated by giving the following average analysis over 12 months:

	Parts per 100,000
Oxygen absorbed (4 hours @ 80°F.)	22·8
Alkalinity (to methyl orange)	68·6
pH	7·6
Nitrogen as—	
Free Ammonia	4·6
Albuminoid Ammonia	2·5
Suspended Solids	120·0
Grease	64·0

These figures do not measure the difficulty of the treatment problem, however, owing to the emulsified state of the grease. It should be emphasised, also, that during the daily period when the discharge of wool scouring waste is at a maximum the above figures for average strength may be more than doubled.

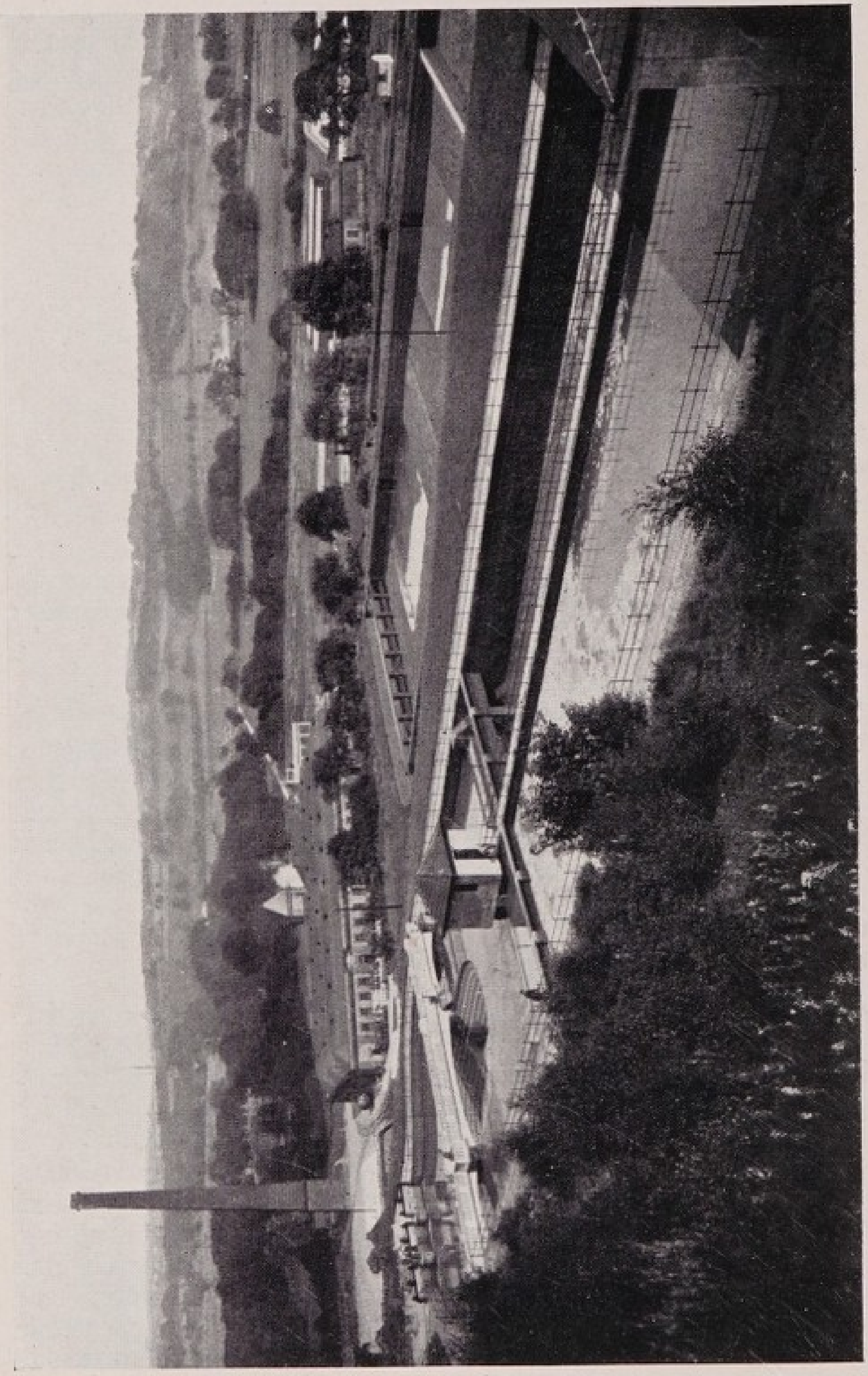
The Flow Diagram on page 22 indicates the course of the sewage through the works, and shows the relationship of the various processes.

Outfall Sewers

The greater part of the sewage reaches the works by way of the main 10-ft. diameter tunnel sewer, which has a discharging capacity of about 180 million gallons per day. This capacity is expected to serve the needs of the City for at least 100 years. The Idle and Eccleshill Intercepting Sewer has a capacity of 12 million gallons per day, and the two sewers discharge into the inlet bay where the process of sewage purification begins.

Detritus Pits and Tanks

The illustration on page 18 shows the inlet bay at the mouth of the tunnel sewer. Here the sewage flow is spread over the whole width of the detritus pit and the velocity so reduced that the coarser grit brought down with the sewage is deposited. This material is dredged out by the grab seen in the photograph and, together with the rags and other fibrous matter collected on the coarse bar screens, is conveyed by railway wagons to a tip on the site. About 7,500 tons of dredgings are collected annually and, after some years maturing, the material breaks down into a quite valuable manure which has been successfully applied to the Department's own agricultural land and to that of nearby farmers. This dredging is, however, kept within very narrow limits, the object being to allow as much of the fine sand as possible to go forward to the main detritus tanks. The gritty sludge produced in these tanks is valuable as one of the component parts of the sludge pressing compound. For a similar reason not only is



DETRITUS TANKS AND STORM WATER BAY

the fine sand required, but all the paper and fibrous floating matter is found to be so helpful that the battery of fine screens, which was installed as part of the process following the detritus pit, is not now used. It is found that if the floating matters are allowed to go forward through the detritus tanks, which will be seen on the illustration on page 24, these matters become entangled in the scum which collects behind the scum-boards guarding the outlets to these tanks. Thus they go down and become part of the sludge when the supernatant water is pumped off from these tanks. As no precipitant is used on this side of the valley it is necessary to operate the detritus tanks at frequent intervals for the removal of the sludge, in order to minimise smell in the subsequent hot sludge disposal process. The procedure is that the two detritus tanks are cleaned alternately and the sludge removed from each within seven days, and rather oftener in the hot summer months. The tanks are fitted with floating arms placed beyond the scum boards, the water content of each tank being pumped from one to the other as required, leaving the sludge exposed for removal to the press-house. Each of these tanks contains half a million gallons of liquid, the velocity of sewage through the tanks being such as to cause the settling-out of the heavier suspended matter which might otherwise tend to deposit in the syphon pipes. The sludge from here gravitates to the sludge screening house for mixture with the greasy sludge from the precipitation tanks and other sludges.

Measurement of Sewage Flow

Before going forward to the storm water bay all the sewage in passing over two weirs each 33 feet long, is gauged by means of Lea Recorders. A third recorder measures the volume of storm water before it passes down the cascade over an elliptical weir 160 feet long. By this means a continual record can be kept of the sewage going for full treatment, and also that being passed through the storm tanks when these are in operation. The recording house is shown in the illustration on page 24.

Storm Water

All the sewage (including storm water) passes forward to the storm water bay, which will be seen in the same picture, where the excess water flows over the storm water weir to the storm water tanks, one of which can be seen behind the detritus tanks in the foreground. The sewage undergoing full treatment flows from the storm water bay to the syphon head, which is controlled by penstocks seen in the picture.

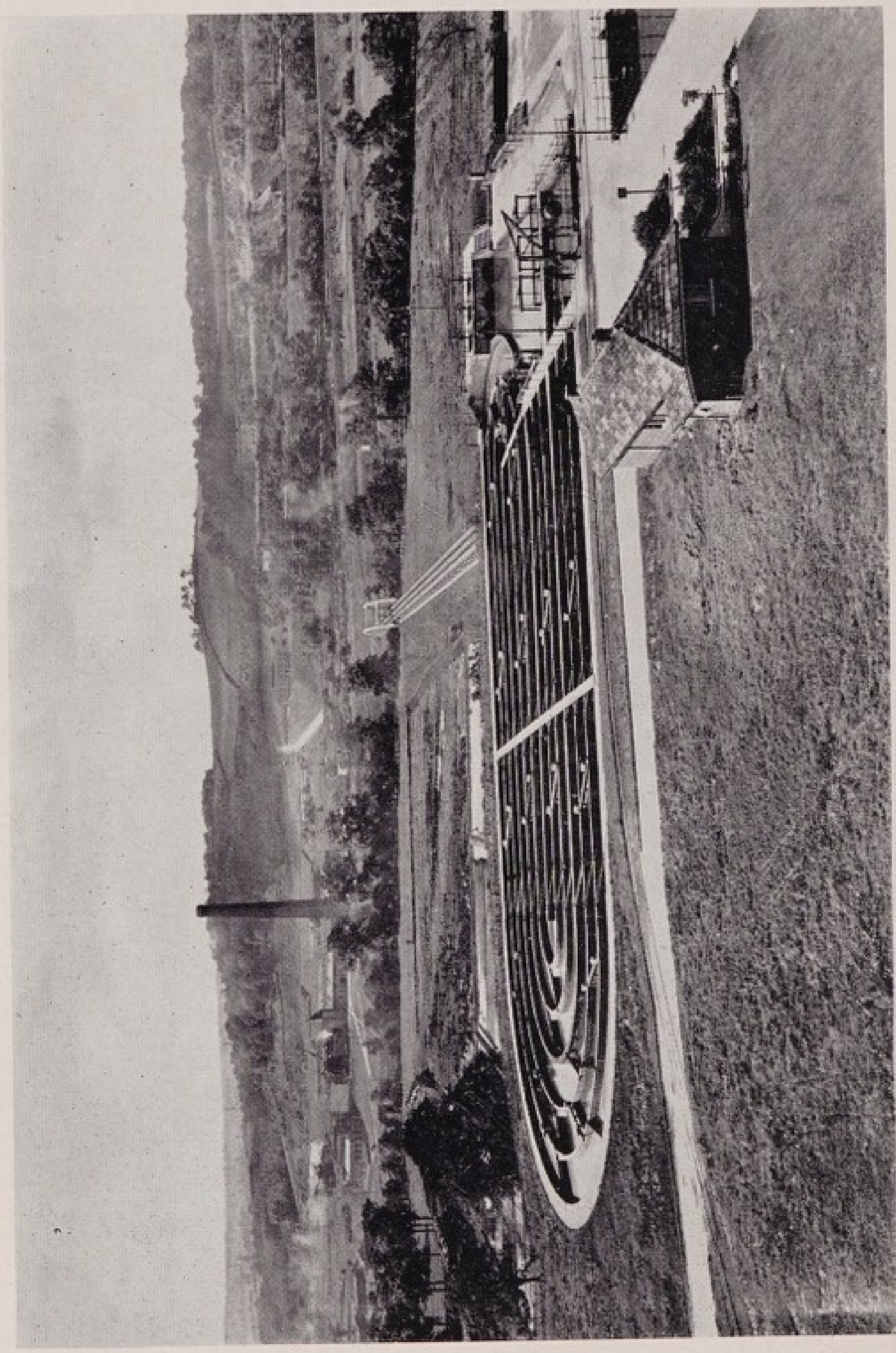
Ministry of Health "requirements" allow flows in excess of three times the domestic flow, plus one and one-tenth the trade wastes to be passed to the storm tanks. But owing to the fact that storm flows based on this proportion still contain a certain amount of grease the weir has been set to pass twice the required flow forward for full treatment. The storm tanks are seven in number and have a total

REINFORCED CONCRETE BRIDGE CARRYING SYPHON PIPE LINES capacity of 11 million gallons. Excess storm water during heavy rain, after tank treatment, passes to the river through a 4 feet diameter culvert. The sludge from the storm water tanks is passed by gravity to the sludge screening plant in a fresh condition, it being very necessary to see that it is not allowed to lie in the tanks for more than a few days.

Syphons crossing Aire Valley

The sewage flows across the Aire Valley in three lines of 48-inch diameter pipes constructed in the form of inverted syphons, each of the three pipe lines being capable of passing 30 million gallons per day. Two of these pipe lines are in constant use and one is kept in reserve. Reference to the illustration on page 26 will show the pipe lines crossing the valley to the north side where the precipitation tanks and other plant are situate.

The crossing of the Aire Valley by means of inverted syphons was a matter concerning which there was a great deal of discussion. This method was only adopted ultimately because of the heavy expense of erecting the overhead aqueduct which before the war was the accepted design. Owing to the high cost of materials and labour after the war the committee decided that they must, even at some risk, reduce the cost of this portion of the undertaking. Thus it was agreed that syphons should be provided subject to safeguards against blockage. This is the more necessary because the velocity through these pipes owing to the restricted head often falls below two feet per second. To guard this position three lines of defence were adopted. (1) The operation of a wooden ball on the lines of that seen working in the syphons under the Seine during the visit to Paris by a deputation from the Committee in 1923. The ball at Bradford consists of a solid wooden sphere, in four segments bolted together, of home-grown timber and weighing 15 cwts. (See illustration on page 32.) This ball floats low and just about displaces its own weight of water. By this means it is found that without any help, except guidance to the particular line of pipes it is intended to clean, the flow of water draws the ball down the vertical leg of 68 feet deep at the head of the syphon, after which the ball passes along the pipe line on a slightly ascending gradient with finally a sharp gradient at the delivery end. The retardation of the ball, which is 3 in. less in diameter than the pipe through which it passes, owing to friction in rubbing along the top (intrados) of the pipe, causes a great increase in the velocity of the liquid underneath the ball and therefore all the sediment is stirred up and moved forward. The ball travels the distance across the valley of 712 yards in 7 minutes under normal conditions. Each pipe line in use is thus cleaned once a week. Although this work has been in operation now for twenty years the mains are free from deposit. (2) The syphons were arranged to cross above the river on a reinforced concrete bridge which will be seen in the illustration on the opposite page (although very much fore-shortened in appearance, this bridge being 130 feet span). This made it possible to arrange wash-out pipes



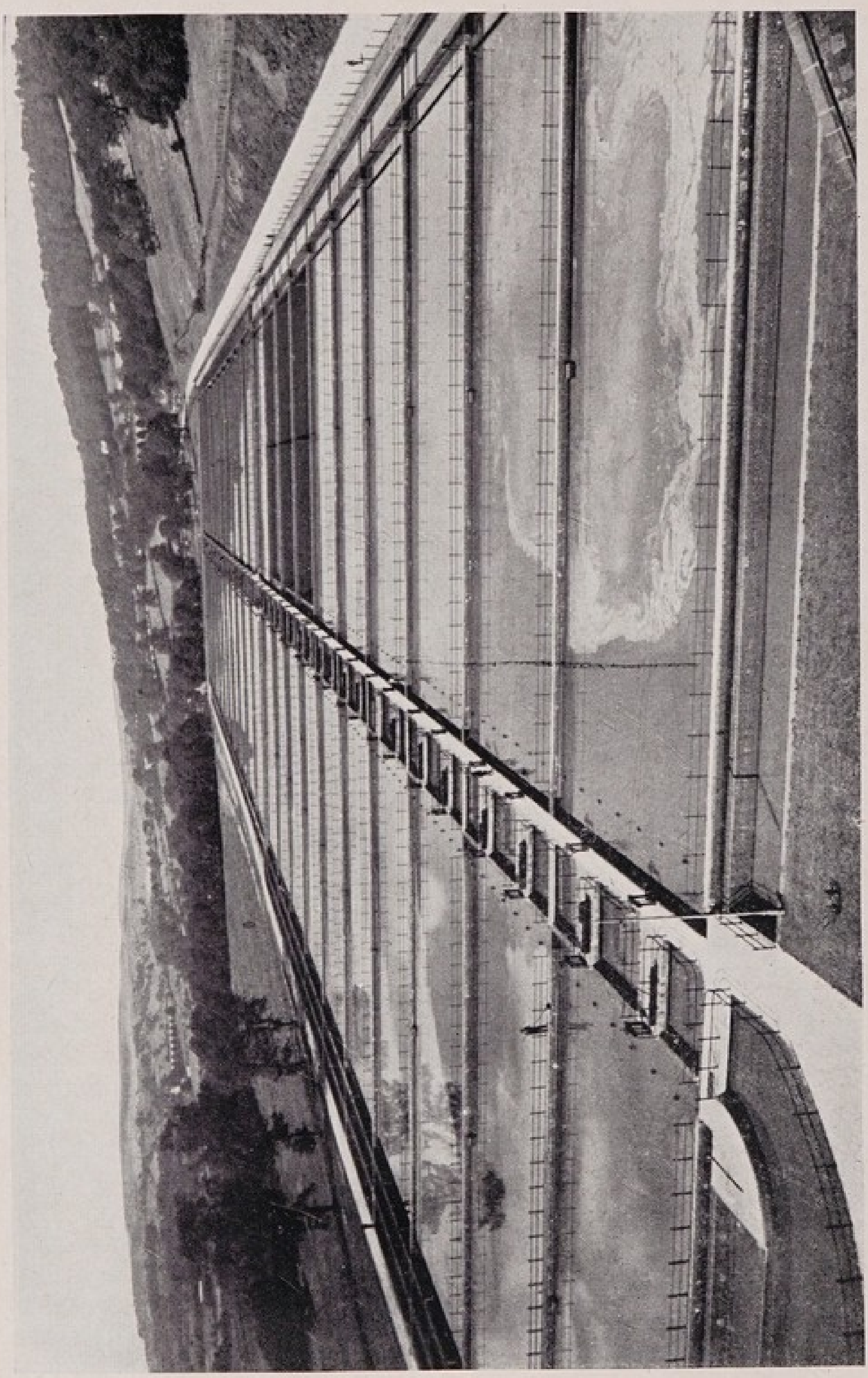
MIXING TANK

into the river in order that, in case of necessity, the pipe lines could be emptied. (3) Lastly, cast iron access doors (hatch boxes) were arranged in each pipe line at suitable points so that, in case of necessity, workmen could get into the pipes and dig them clear after the water had been removed. This has never been necessary.

Mixing Tank and Precipitation Tanks

After discharging from the tail end of the syphons on the north side of the valley the sewage is treated with sulphuric acid (B.O.V.) with the object of cracking out the soaps in the sewage and precipitating a good deal of the dissolved organic matter, the wool waxes and the suspended matter being also carried down in the process. The acidified sewage passes through a specially designed mixing tank of 445,000 gallons capacity, illustrated on page 28, where the precipitate is well mixed with the sewage, being gently turned over by means of baffle boards suitably placed across the natural flow. An improved cracking of the soaps and a reduction of the colloidal content is thus obtained. As a matter of fact, the visible effect in comparing the crude sewage before cracking with acid and the same after passing through the mixing tanks, where there is a delay period of half an hour, is very pronounced. This improvement measured in terms of oxygen absorbed from potassium permanganate in 4 hours at 80° F. represents a 14 per cent purification. Laboratory experiments, however, indicate that this is not the maximum improvement possible. An increase of suspended solids in the liquor still further improves the effluent and for this reason the sludge from the secondary precipitation tanks is pumped back to be mixed with the incoming sewage at times when the strongest wool suds are arriving at the works.

The quantity of acid required varies throughout the day and is ruled by the alkalinity of the incoming sewage. The process is controlled by an assistant who takes samples frequently (about every quarter of an hour) and regulates the amount of acid in order to produce a sewage which is about 10 parts per 100,000 acid, using methyl orange as an indicator. It was the custom originally to acidify the sewage during the whole of the 24 hours and when this was done the amount of acid used by the Department in twelve months amounted to some 20,000 tons. This was not only a great expense but it was found that the filtration of an acid sewage had limits, and that probably considerable sums of money could be saved and better final results obtained if the grease could be precipitated by the use of less quantities of acid. After exhaustive experiments it was found that the best results in filtration were obtained when the pH value of the secondary precipitation tank effluent was about 6, and therefore with this in view a reduction of the amount of acid used has been standardised without prejudicing the amount of grease collected. It is now the custom to use acid only when actual wool suds are arriving at the works. This means that at certain periods during the night, on Saturday afternoons, Sundays, on Monday mornings, and during very wet weather practically



PRECIPITATION TANKS

no acid is added. The effect of this is, that instead of using 20,000 tons of acid per annum, 12,000 to 13,000 tons is sufficient. This alone has saved the department a considerable sum of money. Moreover, the average acidity of the primary tanks is reduced to a much lower figure. Having achieved this the second series of twenty tanks, which were designed either for primary or secondary use as might be required, are now used for secondary precipitation and advantage is taken of discharging to them alkaline sewage from Yeadon and Guiseley in the Aireborough U.D.C. area, and from Baildon.

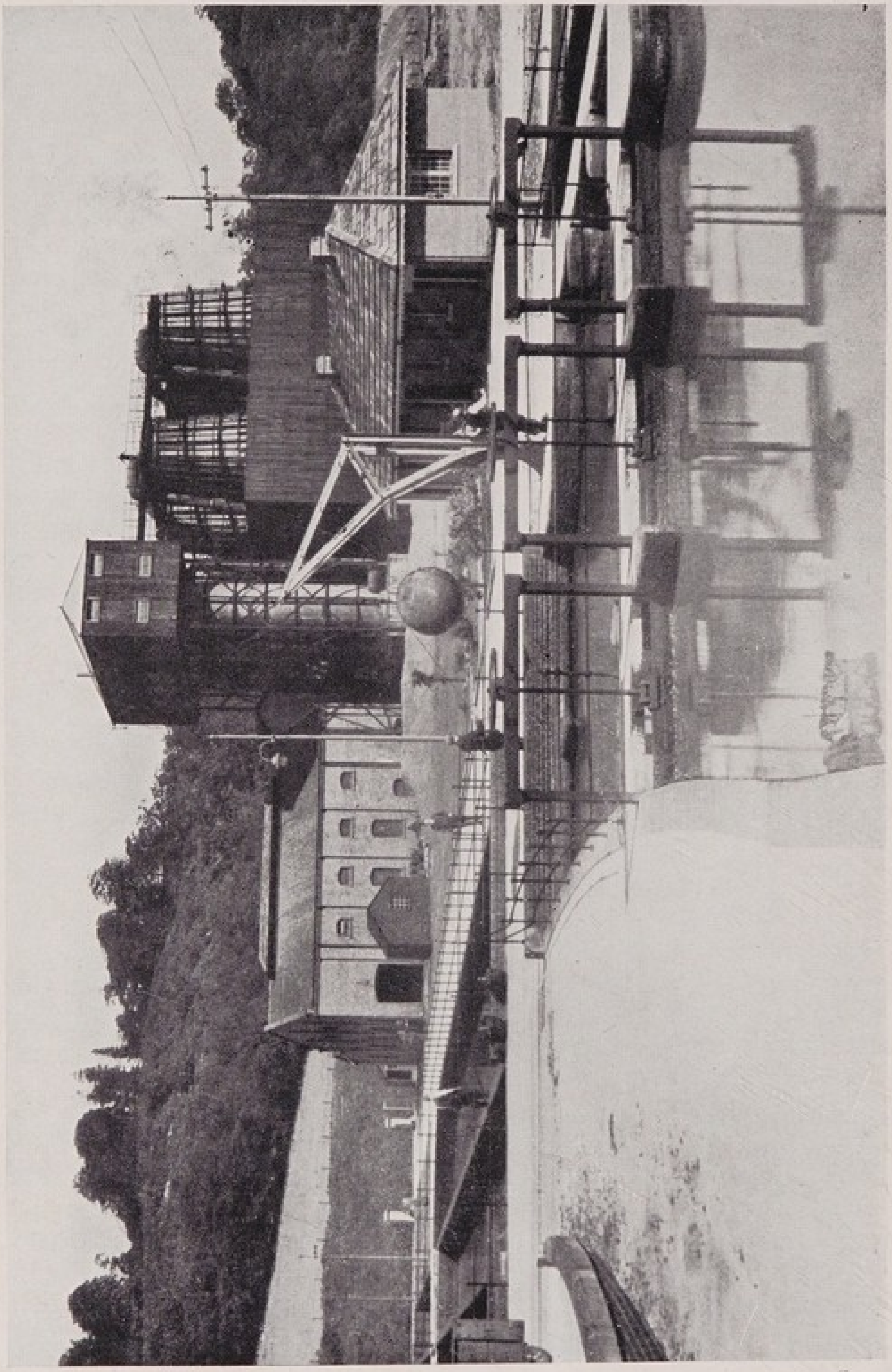
The design of the precipitation tanks at Esholt is an extremely satisfactory one for the purposes required. They are so designed that they may be worked either in parallel or in series. Inlet and outlet weirs the full width of the tanks are arranged so that the film of water flowing into and out of the tanks is very regularly and quietly governed throughout the whole length of flow. One of the values of the acid cracking process is the preservation of the sludge collected in the tanks which secures entire freedom from smell and enables dense sludge to be collected. This is a very great asset when dealing with sludges because, whilst Bradford works up a sludge in the neighbourhood of 80 per cent water, most other towns are unable, owing to the necessity for frequent emptying, to produce a sludge of less than 90 per cent. Thus, in the case of Bradford, the bulk of sludge to be handled is halved, the value of this being obvious. The sludge is drawn from the tanks and passed through the press-house as required, an average of approximately 75 tons of cake being produced daily, having a percentage of moisture of about 26. It should be remembered that in order to provide an 80 per cent sludge, it must be built up over a period and thus three months commonly passes before the sludge arrives at the press-house. This position can be faced without danger of smells arising; in fact the sludge has been kept for much longer periods without offence.

The processes by which the sludge from the detritus tanks and the precipitation tanks is dealt with at the press-house and treated for the extraction of grease and fertiliser are fully described in Chapter IV, dealing with the recovery of by-products.

Sulphuric Acid Plant

The Sulphuric Acid used in the Department is practically all made by the Corporation. It is obtained from two sources, first from the plant at Esholt and secondly from the Department's Chemical Works at Frizinghall which produces 4,000 tons of B.O.V. per annum using a by-product of gas manufacture, viz., spent oxide, as the raw material.

The installation at Esholt is a Mills-Packard Chamber process plant of modern design capable of producing equivalent to 9,000 tons of 140° Twaddle Sulphuric Acid (77·17 per cent H_2SO_4) per annum. About 5,000 tons of Iron Sulphide (in the form of imported pyrites)



RECEIVING BAY TO PRECIPITATION TANKS AND SULPHURIC ACID PLANT is roasted in mechanically-operated furnaces. The sulphur content of the raw material averages 48–49 per cent of which 46–47 per cent is available for acid making.

The plant is situated in a convenient position near the precipitation tanks, the acid being delivered direct from the plant to storage tanks by gravitation. Compactness and economical working are two big features of the plant and since its erection large savings have been effected owing to the Committee's policy of being self-suppliers.

Tank Effluent

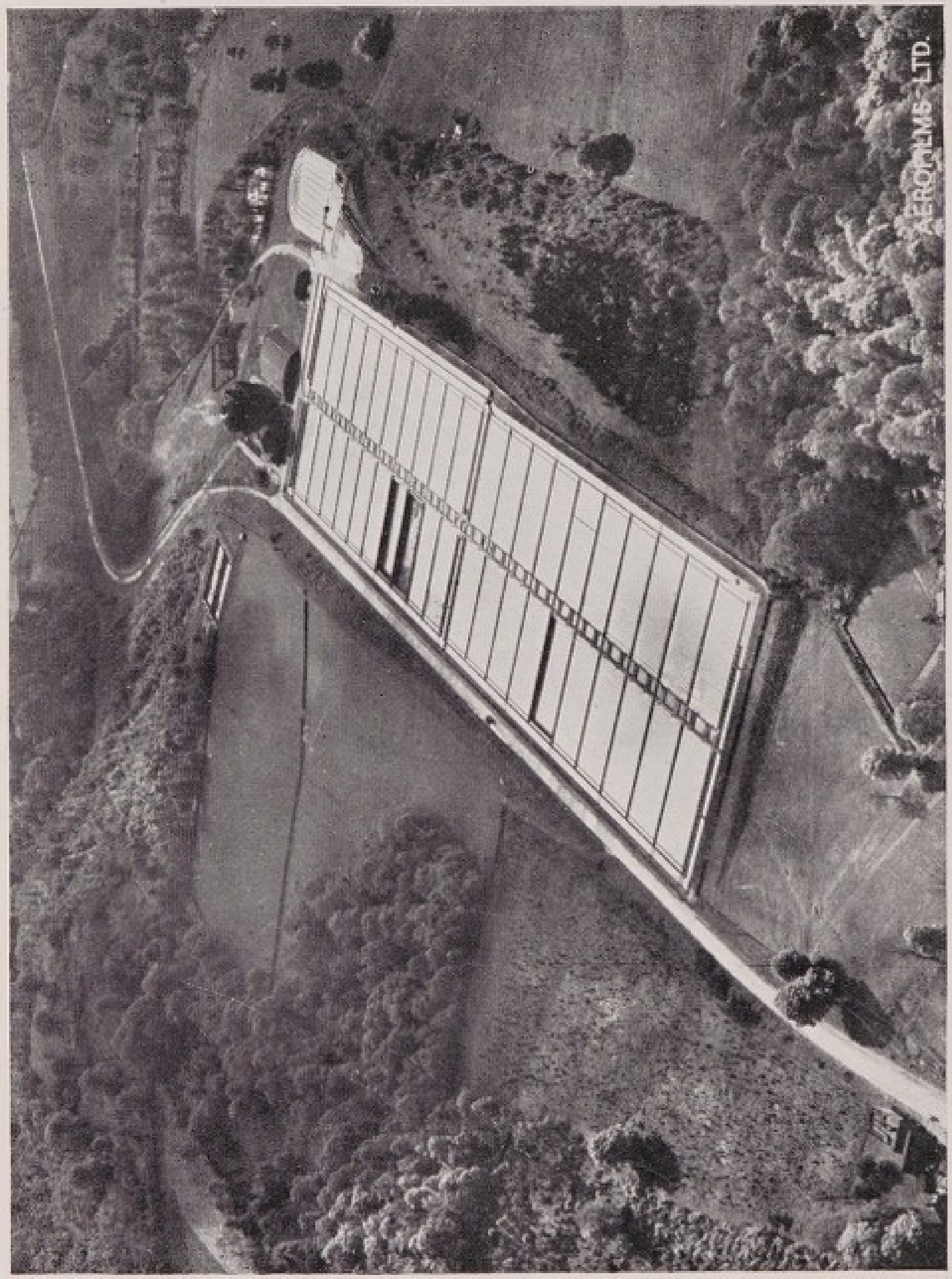
The tank effluent passing by the way of the main eastern conduit to the filters, a distance of 920 lineal yards, has an average analysis as follows:

	Parts per 100,000
Oxygen absorbed (4 hours @ 80° F.)	11·6
Alkalinity (to methyl orange)	3·9
pH	5·5–6·0
Nitrogen as—	
Free Ammonia	2·5
Albuminoid Ammonia	0·8
Bio-chemical Oxygen demand	28·4
Suspended Solids	11·2
Grease	5·6

One of the difficulties encountered at this stage is the growth of certain fungi, which appear to be much encouraged by the mineral acid used for precipitation. It may be said, however, that the amount of fungus has much decreased since the pH value of the effiuent was increased. The fungi (*fusarium aqueductum* and others) are more pronounced in winter and thrive particularly on the length of the underground conduit leading to the filters. It is necessary, therefore, to pass the tank effluent through a series of three fine screens in order to eliminate as far as possible the fungoid growths which have broken away from the walls and floors of the channels. The screens are also of use in preventing leaves and any other extraneous matter passing on to the filters.

Biological Filters

The filters cover an area of 53½ acres and they deal with a dry weather flow of 18 million gallons per day which is equivalent to 340,000 gallons per acre, 70 gallons per square yard or 35 gallons per cubic yard, the filters being 6 feet deep. Owing to the high flow,

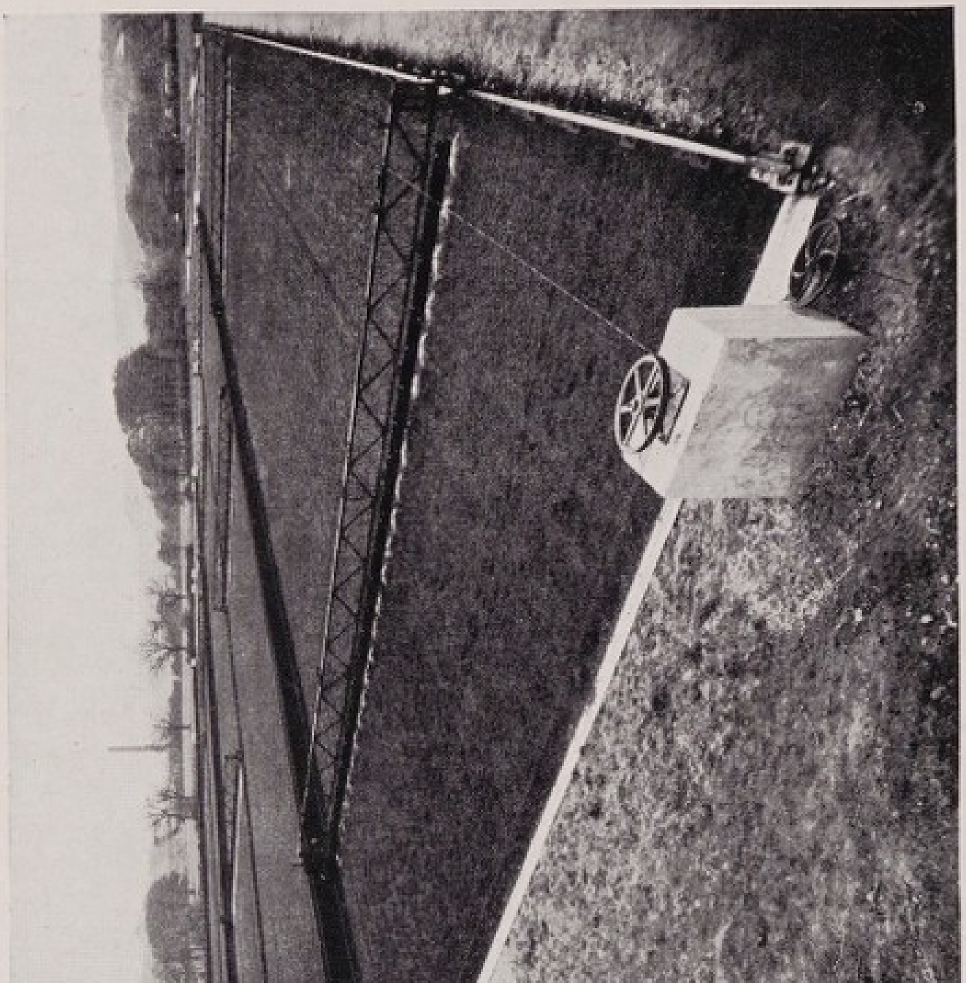


AERIAL VIEW SHOWING PRECIPITATION TANKS, MIXING TANK, AND SULPHURIC ACID PLANT however, for ten hours during the working day, the filters are then called upon to function at a considerably greater rate. It is not uncommon for the flow during the day to be maintained at the rate of about 30 million gallons for long periods, this being equivalent to an average of 560,000 gallons per acre, 116 gallons per square yard or 58 gallons per cubic yard, while for short periods certain beds have to be worked at the maximum rate of 70 gallons per cubic yard. The filtering material up to the present time has been hard Yorkshire coal, which has given satisfactory service. As explained earlier, however, in view of the stringency of the present national fuel position, it is probable that the coal will gradually give place to broken stone or some other suitable alternative.

The rectangular type of distribution, although more expensive in first cost, was adopted throughout the works, after comparative tests with circular distributors had proved its superiority. This was chiefly because the larger jets and lower frequency of dosing of the rectangular type were better suited to deal with the difficult tank effluent. As the object throughout the design of the work has been to make the greatest use of the natural forces provided, advantage has been taken of the head of water available, owing to the difference in level between the screening house and the filter-beds, to obtain power. Thus the sewage operating overshot water-wheels provides all the power, free of cost, before going forward itself for purification on the beds. The illustrations on pages 36 and 38 show the general and detail designs and it will be noted that the distributors are run in pairs, balanced as well as drawn along, by wire ropes. This is a very important feature as it secures uniformity of wind pressure. The distributors have simple automatic reversing gear and need very little attention. The troughs conveying the sewage across the beds are made of cast iron. These rest on the top of the coal without any solid support except that at the leading end of each trough when laid, two wooden pit props of the correct length were driven with a mallet into the coal and rest on the concrete bottom of the bed. The rails are laid on sleepers in accordance with ordinary railway practice. The nozzles discharging on the bed being large ($\frac{7}{8}$-in. diameter) tend to prevent choking from fungus or any other obstruction, and the fact that the jet of water impinges on a porcelain plate causes an excellent umbrella spray which has been found to be most satisfactory. It is necessary, however, to see that the distance from the porcelain plate to the coal is not too great, about 5 inches being the practice.

Humus Tanks and Clarification Lake

The effluent from the filters passes by way of the main effluent culvert, 10 feet wide by $6\frac{3}{4}$ feet high, to the humus tanks. These are four in number and cover an area of three acres. They have a combined capacity of $4\frac{1}{2}$ million gallons, averaging 450 feet long and 5 feet deep. Three tanks are normally in operation at one time, each tank being



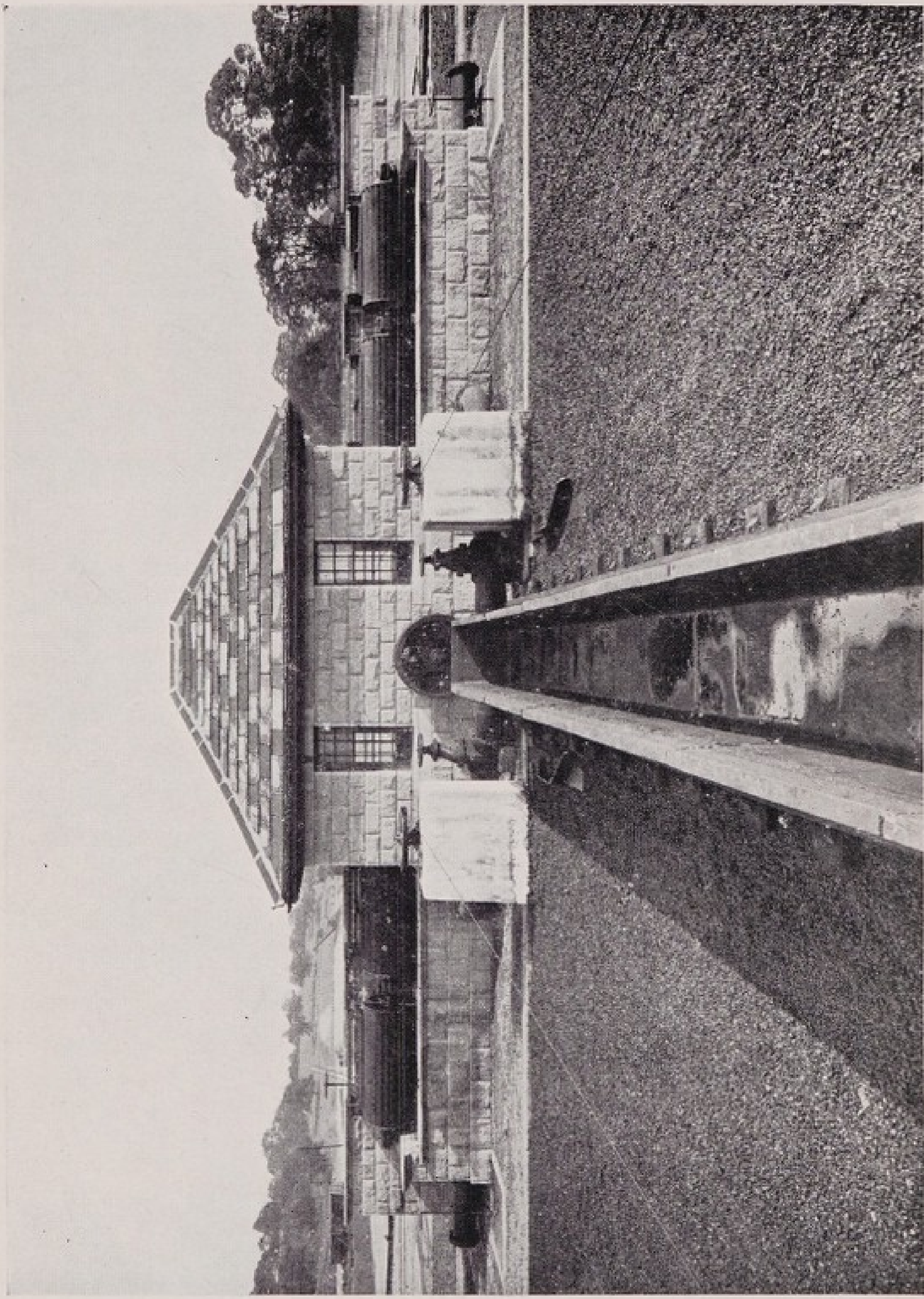
BIOLOGICAL FILTERS

sludged every fourth day. The humus sludge is lifted by centrifugal pumps through an 8 inch diameter rising main to the suction well of the Baildon and Thackley Pumping Station, described later, whence it is lifted to the secondary precipitation tanks and mixed with the incoming primary tank effluent. Here the humus sludge is settled and, after being re-circulated with the incoming acid-treated sewage is deposited in the primary tanks and forms part of the sludge compound which is dealt with in the press-house. The peculiar structure of the humus sludge is largely broken down and cost of disposal is relatively small.

The provision of a lake intended for the final purification and brightening of the effluent is a notable feature of the Esholt Works. It was constructed in its present form after considerable experiment and the results of its working have been most instructive. It has demonstrated the feasibility of operating a healthy lake fed only by humus tank effluent, without recourse to dilution by river or other water, and of maintaining a sufficiency of dissolved oxygen even for the support of fish life.

The lake was constructed by the simple means of raising low earth embankments upon the alluvial area bordering the river. The area of the lake is $14\frac{1}{2}$ acres, and it contains $10\frac{1}{2}$ million gallons of effluent; the depth nowhere exceeds 4 feet. The original mat of old vegetation was broken up by ploughing the surface, and the bed of the lake consists of alluvial deposits. From the sills of the humus tanks the water passes through the lake to a semi-circular weir, which in turn directs the flow on to a concrete apron from which it discharges over a white tiled weir, 100 yards long, into the main effluent culvert leading to the river. The cascading curtain of clear effluent provides a striking contrast with the appearance of the crude sewage arriving at the works. The lake, however, is not sufficiently large for the whole volume of effluent to be passed through it and a certain proportion is allowed to flow direct from the humus tanks by means of a covered culvert to the outlet bay.

The oxygen content of the lake is sufficient to promote the growth of animal life of many kinds, such as crustacea, water-beetles, water boatmen and the like. Perhaps the most remarkable feature has been the enormous number of cyclops and daphnia which swarm in all parts of the lake. These voracious scavengers appear as white clouds in the water, and play a considerable part in the purification process. The crustacea provide abundant food for the fish which have been successfully introduced into the water. The margins of the lake have been planted with aquatic plants of various kinds, and help to give the lake its attractive and natural appearance, which is further enhanced by the varieties of bird life which frequent its surface and the surrounding banks.



BIOLOGICAL FILTERS—POWER UNIT

A typical analysis of the effluent passing over the weir is given below:

	Parts per 100,000
Oxygen absorbed (4 hours @ 80° F.)	2·57
Alkalinity (to methyl orange)	2·4
pH	6·4
Nitrogen as—	
Free Ammonia	2·6
Albuminoid Ammonia	0·36
Nitric Nitrogen from Nitrates	0·8
Bio-chemical Oxygen demand	2·2
Suspended Solids	3·2
Putrescibility always negative.	

During the recent war years the lake was drained, and it was only during the autumn of 1946 that certain necessary repairs were effected and the lake once again refilled. The building up of life in an artificial lake of this kind is a slow process, but already tests have shown that the lake is once again performing its function.

Research in Sewage Purification

The unique and complex operations carried on at the Esholt Works have been developed to their present state only after a large amount of preliminary research work. From the first attempt to recover the grease, which was the chief source of pollution to the rivers, each step towards success has entailed much experimental work, first in the laboratory and then on a small plant scale, before finally the design of the full scale works could be undertaken.

Precipitation with sulphuric acid both alone and also in conjunction with other chemicals, has provided a special field of research at Bradford. Much detailed work has also been done on the biological filtration of liquors after acid treatment, and the methods evolved and now adopted have resulted in a considerable saving to the Department, both in the cost of acid and also in that of alkali for neutralising excess acid. In the final purification of the sewage many problems have arisen which have been tackled by research work, and mention might be made of the decision to construct the clarification lake for the final treatment of the effluent, a process which has no counterpart in this country.

As various developments in sewage purification have come to the fore, researches have been conducted with a view to exploring their possible application to Bradford's special problems. In addition to laboratory experiments, these tests have always been conducted on plant of moderately large scale, and much interesting information obtained. For instance, large scale experiments were carried out in connection with the activated sludge process, both by diffused air and also by paddles. Valuable results were obtained, but the method was not incorporated into the works processes, largely because it was found more economical to recover the grease rather than break it down into simpler substances.

Extensive experiments, too, were made on the digestion of sludge which, although here again the grease is largely decomposed, might possibly have been found to be more economical than the present process. It was demonstrated, however, that the sludge, after the necessary acid precipitation, did not lend itself to the digestion process.

In concluding these notes, it may be said that research on sewage purification problems is now receiving renewed attention, and a sewage research chemist was appointed this year. Every effort is being made to produce a still better final effluent and to run the plant ever more efficiently and economically. The Department's successful efforts to produce new and valuable by-products from the City's sewage, and the researches which have led to this achievement are described in the following chapter.

Chapter IV

THE RECOVERY OF BY-PRODUCTS

The Department's statutory obligations are fulfilled with the discharge of a purified effluent into the River Aire, but the purification processes form only part of the operations carried out at the Esholt Works. Almost of equal importance and, because they are unique, probably of greater interest, are the means adopted for recovering valuable by-products from the City's sewage. The basis of these recovery processes lies in the treatment of the sludge, and the methods now in use are the culmination of over half a century's persistent experiment.

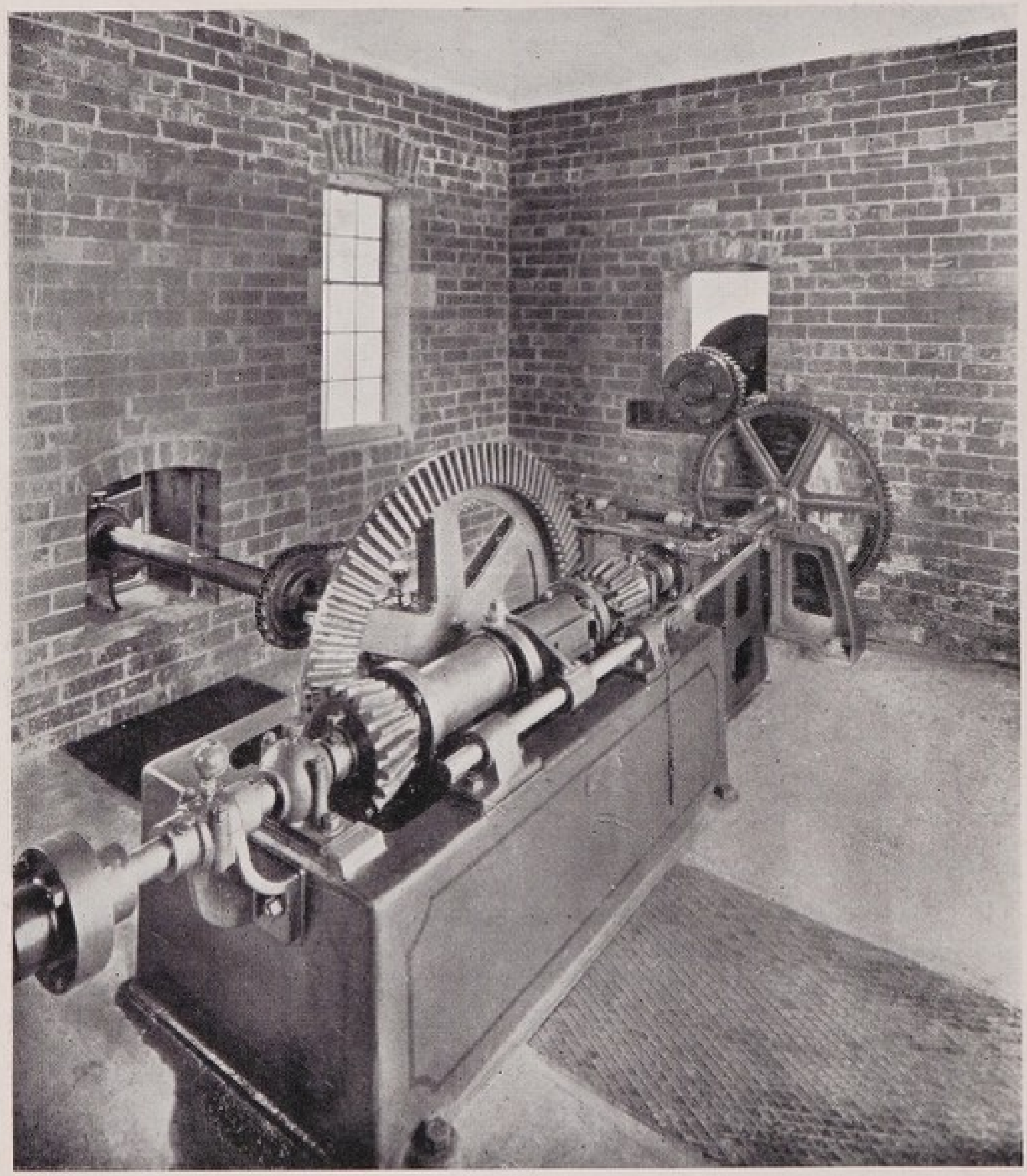
Steam Plant and Engine House

Heat-processing plays an essential part in these operations, the heat being supplied by steam generated in the boiler house, which is sited adjacent to the press house. There are four Stirling water tube boilers each capable of evaporating 15,000 lb. of water per hour, three being in service at one time. They are fired automatically by chain grate stokers fed from coal hoppers above the boiler house roof. Coal is the fuel normally used but the boilers are adapted for making use of grease or sludge cake as fuel if necessary. The annual consumption of coal is about 10,000 tons. Steam is generated at 120 lb. per sq. in., the greater part of it being used for process work. The engine house contains three steam-driven compressor units. A high-speed Belliss and Morcom machine develops about 250 h.p. and compresses 1000 cubic feet of free air per minute. Two low-speed Robey compressors, each of 175 h.p., can compress a total of 1500 cu.ft. of free air per minute. Air is compressed to 100 lb. per sq. in., but for sludge pressing the pressure is reduced by suitable valves to about 60 lb. per sq. inch.

Sludge Treatment

The greater part of the grease brought down in the sewage is deposited with the sludge in the precipitation tanks, and the method adopted for liberating the grease involves pre-treatment by heating with sulphuric acid, followed by hot-pressing. Sludge from the detritus tanks, storm water tanks, and precipitation tanks (which inludes humus sludge), gravitates to a common collecting chamber, centrally placed alongside the works yard. The mixed sludge, with a moisture content of about 85 per cent, is passed through mechanical screens before discharge into two hand-operated pneumatic rams, each of 30 tons capacity, from which it is lifted into the sludge-heating vats. To promote good pressing, the gritty detritus sludge is added to the greasy precipitation sludge in the proportion of one to four. The eight 7-ton capacity sludge-heating vats are lined with blue brick and provided with open steam pipes for heating.

Sulphuric acid is added to the sludge as it is discharged into the vats and the sludge is raised to a temperature of 180° to 200° F., a process which takes about forty minutes. With a very gelatinous sludge and when a relatively high proportion of humus sludge is present in the precipitation sludge, a longer time is necessary and the sludge is even boiled. The rate of heating the sludge is limited by the frothing which is apt to take place. The vats are hooded, and the gases are led away



FILTER DISTRIBUTOR DRIVING GEAR

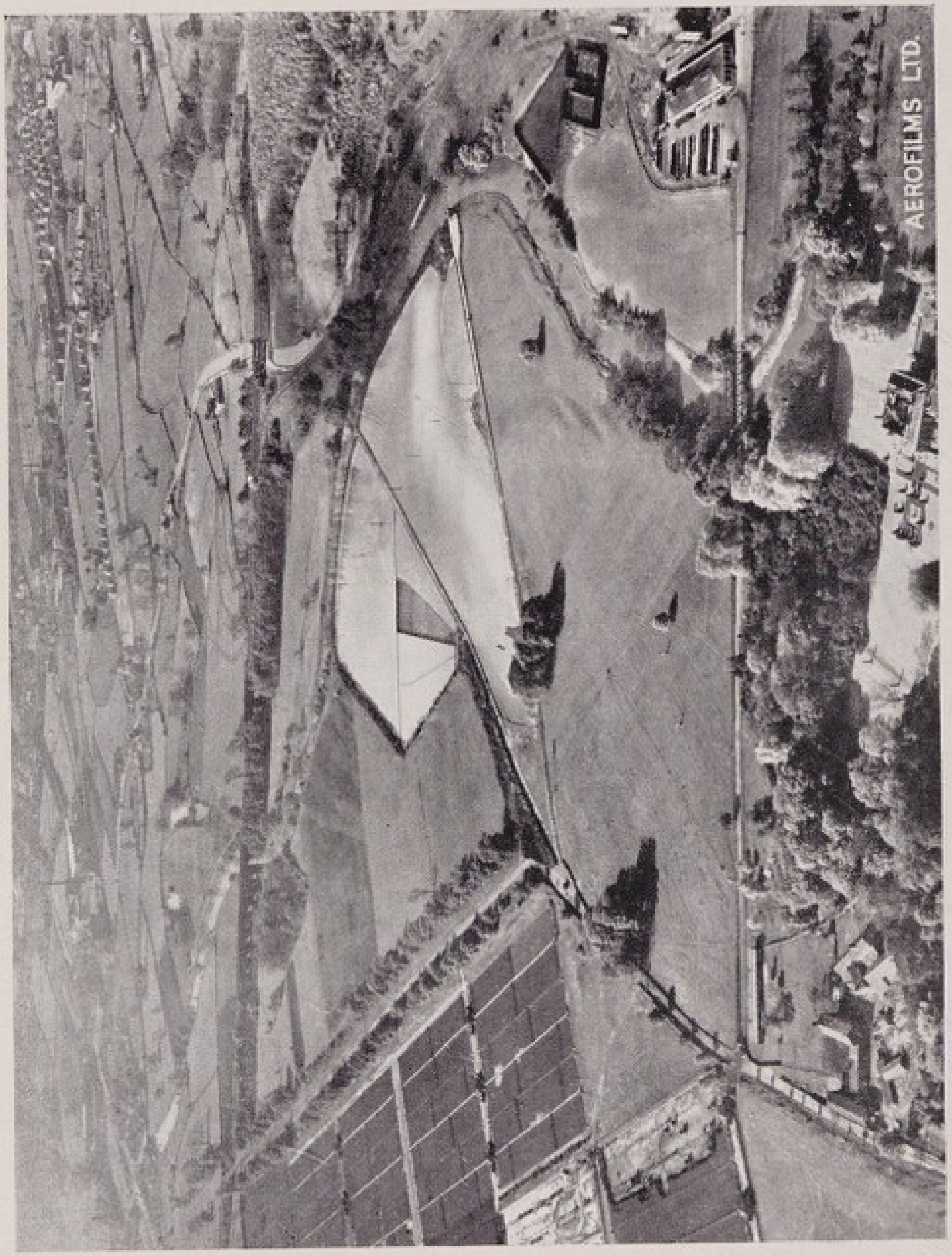
through a system of stainless-steel ducting to a fume tower outside the main building. Here the gases are forced by means of a fan through a counter current of chlorine and soda ash in solution, which effectively removes any offensive smell before discharge to the atmosphere.

After this pre-treatment, the sludge is in a fit condition to be passed to the filter presses for removal of the greater part of the water and grease. The hot sludge from the vats gravitates to eight 7-ton capacity pneumatic rams in the basement, from which it is forced forward into the presses which have been previously heated by superheated steam. There are 128 presses in four rows of thirty-two, each press containing forty-six plates measuring 36 in. square. Pressing begins at a very low pressure, about 8 lb. per square inch, but this is gradually built up during the first twenty-four hours to about 40 lb. During the second day's operation the pressure is further increased to about 55 lb. per square inch. The presses operate on three hours' sludging alternating with one hour's steaming to keep up the temperature. Water and grease are forced through the cotton filter cloths which clothe the plates. About 40,000 of these cloths are used annually, their average life being six to eight weeks. The sludge cake remaining behind after forty-eight hours' pressing usually contains about 26 per cent of moisture. When the presses are opened the cake drops into trucks in the press house basement and is conveyed by rail to open tips on a 9-acre site where the cake is left to mature for six to twelve months.

Since the earliest days of this system of sludge treatment, research work has continued with a view to improving the process, particularly with the object of removing more water and grease from the sludge, and thus producing a drier press cake for subsequent grinding into a powdered fertilizer. Investigations into the factors governing the breaking down of the sludge structure, have resulted in the present method of pre-treatment which, by using a minimum quantity of acid and steam, has resulted in a considerable saving in the cost of press cloths. The press cloths themselves have also been the subject of continuous research, every new development in materials or cloth structure being at once tried out with a view to increased efficiency and greater economy in working.

Organic Fertilizer

The cake is in a hot condition when tipped and is little affected by weather conditions. It contains at the outset about 16 per cent of grease calculated on the dry solids, but the "heating" that takes place causes some of the grease to sink into the lower part of the heaps. Some grease also is broken down into simpler substances by a chemical action largely bound up with the growth of moulds. The heaps are turned over by grab from time to time and finally the material is passed to the disintegrator plant where it is ground into powder and loaded into wagons. This powdered organic fertilizer is entirely free from seeds and is effectively sterilized. When fully matured it contains about



AERIAL VIEW OF CLARIFICATION LAKE, SHOWING ESHOLT HALL IN FOREGROUND

15 per cent of moisture, and the small amount of grease and water present makes it convenient to handle and free from light dust. The inorganic matter (about 45 per cent) is mostly fine sand that has been washed from raw wool, and this has a lightening effect on heavy soils. Between 20,000 and 30,000 tons of powdered organic fertilizer is produced annually and finds a ready market, chiefly as a base for compounded fertilizers.

Recovered Wool Grease

Reference was made earlier to the grease and water which is forced through the filter cloths during the sludge pressing process. This liquid is collected from the presses and conducted by a system of timber troughs to tanks where the grease is separated from the water by means of flotation. The water is fed to two pneumatic ejectors, each of 250 gallons capacity, which force it through an 8-in. diameter rising main to the acid mixing tank where it is added to the incoming sewage. The volume of this "press liquor" varies according to the amount of sludge dealt with but is approximately 100,000 gallons per day.

After separation, the grease is pumped into the grease house, where it is clarified and processed. The grease house, a large single-story building, constructed in reinforced concrete and shown in the illustrations on pages 56 and 58, contains thirty lead-lined steel vats, each of 7-ton capacity and each vat is fitted with two draw-off valves for filling grease into drums or barrels, and a run-off valve in the base for the discharge of acid liquor. The vats are elevated above floor level and are arranged in three groups, each of ten vats. Below each group of vats is a grease storage tank of 30 tons capacity sunk in the floor, into which the clarified grease may be run from the vats and stored prior to pumping into road or rail tank wagons. The acid liquor, which is highly corrosive, is collected in a sump and pumped into a lead-lined tanker wagon. The full wagon is drawn by locomotive to the acid-mixing tank, where the liquor is discharged into the sewage.

Two groups of vats are used for the clarification of the crude separated grease, whilst the third group is employed in the production of further grease products. Clarification of the crude grease is effected by adding sulphuric acid (about 5 per cent by weight) and boiling by means of live steam for about three hours. On standing, the acid water and a finely divided sludge settle out, leaving the clarified grease ready for drumming or pumping as may be required. This recovered grease, styled "A" grease, consists mainly, about 70 per cent, of wool grease, the remainder being largely of domestic origin. It is rather dark brown in colour and possesses a somewhat unpleasant smell. Its composition is remarkably uniform and a considerable industry—that of wool grease distillation—has been built up using this material largely as its raw material. The grease is somewhat similar to the "Yorkshire Brown Grease" made by woolcombers having their own grease extraction plants, but it has a higher free fatty acid content due to the domestic soaps and fats and other fatty oils discharged from the City's industries.

Grease Research

In spite of its high content of wool fat, the recovered grease has not in the past found markets sufficient to absorb the whole of the works production. This has been mainly due to the high free fatty acid content and to the dark colour and smell. Between the wars large accumulations of grease were stored on the works, and were added to year by year. Little success resulted from efforts to find new markets, and a relatively serious situation was created. The Corporation decided in 1935 that the best way to deal with the problem was to appoint their own specialist grease research chemist, whose task would be to try to produce new derivatives from the grease. It was hoped in this way to open up new markets which would dispose of the grease not sold directly in the form of "A" grease. That this policy was the right one has been justified by the success which so far has followed these research efforts.

Table II, below, gives a complete list of the various by-products which so far have been produced on a commercial scale from Bradford's recovered wool grease. It is beyond the scope of this descriptive account to give in detail the processes by which these different materials are evolved, but the following notes as to their manufacture and use will be of interest.

TABLE II

LIST OF WOOL GREASE PRODUCTS

RECOVERED WOOL GREASE:	"A" Grade. "B" Grade—deodorized. "C" Grade—deodorized and bleached.
NEUTRALIZED WOOL GREASE:	Rust preventative in three types: Hard, Medium, and Soft.
CRUJOL:	Crude Soda Ribboned Soap.
CRUJOL FATTY ACIDS:	Crude Soda Ribboned Soap split with acid.
SCROJOL:	Purified Anhydrous Powdered Soap.
SCROJOL FATTY ACIDS:	Purified Anhydrous Powdered Soap split with acid.
VARWOLAX:	Unsaponifiable Drying Oil.
LANALOID:	Fusible Semi-mastic Compound in lump or powdered form.
LANALOSE:	Oil Paint Vehicle, in solid or liquid form.

The plant for manufacturing Crujol occupies a compact building conveniently situated between the solvent plant and the grease house. The first floor contains the heating vats, the ground floor is occupied by the furnaces and the cooling conveyors, while the ribboning machines are housed in the basement. The plant is duplicated throughout and can turn out 9 tons of Crujol per working day which, in turn, would yield 6 tons 6 cwt. of extracted dry soap powder and 2 tons 14 cwt. of the viscous unsaponifiables, described later.

Scrojol and Varwolax

Crujol contains about 32 per cent of unsaponifiable matter, and the next stage in by-products manufacture is to separate this from the pure soap. This operation is carried out in the Solvent Plant, where the unsaponifiable matter is removed by a solvent process employing ethylene dichloride and acetone. Special extraction vessels are used in which the Crujol is treated with the mixed solvent, the unsaponifiables being recovered as a viscous brown oil called Varwolax and the extracted soap material being discharged as a light brown, almost dry, powdered soap, to which the name of Scrojol has been given. The photograph on page 60 shows the extractors with a batch of Scrojol discharging on to the floor. The capacity of the plant is approximately 25 tons of Crujol throughout per week, which yields $17\frac{1}{2}$ tons of Scrojol and $7\frac{1}{2}$ tons of Varwolax. The Scrojol, in addition to its use as a powdered soap, is also used in the production of "Scrojol (pure) Fatty Acids" by splitting with sulphuric acid.

As mentioned in an earlier chapter, the solvent plant occupies the building which was constructed for the extraction of the residual grease from the sludge cake. Much of the original installation was made use of when the plant was turned over to the manufacture of by-products in 1938. In this building is also housed the old grease research laboratory which will shortly be supplemented by the new laboratory now being equipped in one of the outbuildings of Esholt Hall.

Paint Products

It was at first intended to apply the extracted Varwolax to lubrication purposes, but a more interesting development was opened up when this viscous oil was found to possess "drying" properties, and it has now found special uses in the paint trade. Following a successful collaboration with Dr. L. A. Jordan, D.SC., A.R.C.SC., F.R.I.C., M.I.CHEM.E., of the Paint Research Station at Teddington, a very successful water paint was developed which made use of Varwolax in a solution of Crujol to which is added an ordinary finely divided pigment such as lithopone. The resultant water paint dries rapidly, soon becoming quite water-resistant and washable. The entrance hall and several of the rooms at Esholt Hall have been decorated with paint of this type.

Lanaloid is the name given to a brittle synthetic wax, obtained by the substitution of a magnesium soap for the soda soap present in Crujol.

This wax does not give fluid solutions in solvents, but it was found that the addition of further Varwolax under suitable conditions had the effect of producing fluidity. The name of Lanalose has been given to the resultant material, which has the properties of an oil paint vehicle. It is sold either in the solid form, as it is after cooling, or in a solution of white spirit, in which form it is readily pourable at all normal temperatures. While Lanalose can be used to produce a paint entirely without linseed oil, in practice it is more usually blended with a linseed oil varnish medium, thus conserving equivalent quantities of linseed oil now, of course, in very short supply. Lanalose-based oil paints are being successfully used by the Corporation on its own housing estates and it is used on the exterior decoration of Esholt Hall and other buildings of the estate. At present the whole output of this material is being taken up by the paint trade.

By-Products and Future Research

As mentioned earlier, the Department's primary concern is to purify the sewage received at the works and so ensure that a satisfactory effluent is turned into the River Aire. The necessary treatment is particularly expensive in Bradford because of the nature and large volume of trade wastes present and, irrespective of the state of the grease market, a large proportion of the grease in the sewage must be removed before biological treatment can be effectively given. Grease recovery must, therefore, continue so long as Bradford is the centre of the wool-scouring and washing industry; and efforts to market the fertilizer, grease and other by-products must be maintained and intensified if sound economy is to be secured.

Business in the powdered organic fertilizer, although subject to price variations according to the state of the market for organic and artificial fertilizers, has been sound for many years, and in view of the national revival in agriculture, the demand is likely to exceed production for many years to come.

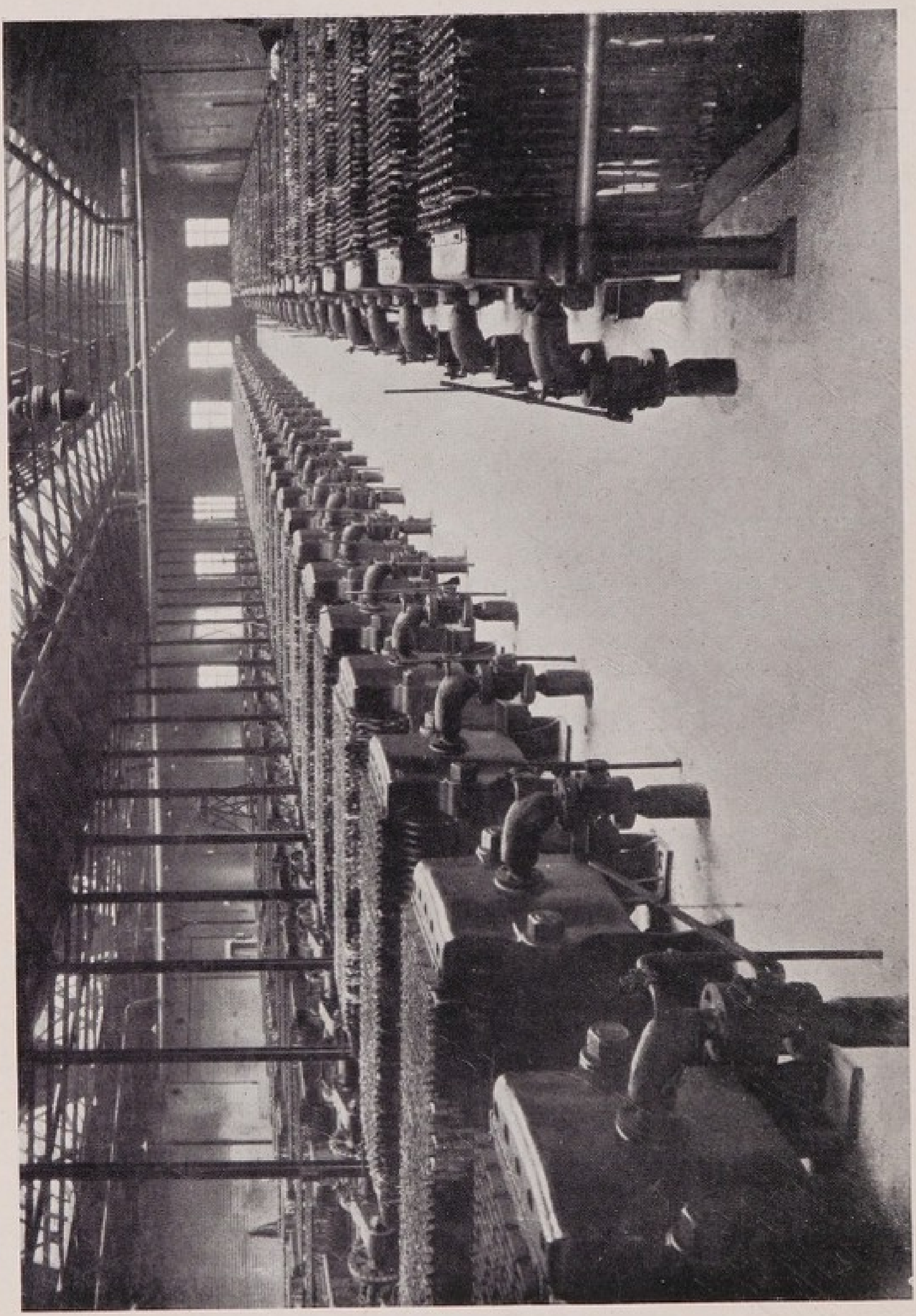
The Committee has recently set up a small Agricultural Research Station on the Department's Estate, with the object of studying more closely the behaviour of the organic fertilizer when actually applied to the land. Four half-acre plots are being cultivated with the same crop under controlled conditions, varying quantities of fertilizer being employed in order to determine the optimum effect on crop yield. These experiments have been planned to extend over several years, and it is hoped that some useful and illuminating results may be obtained. It is also intended to carry out a series of experiments in composting, making use of the organic fertilizer, and also sludge cake from the North Bierley Works, in conjunction with various organic wastes such as screenings, straw, garden refuse, and so on.

The Department, too, is actively engaged on further research with the object of improving the present grease by-products as well as evolving new ones. The products already described in this chapter are in steady production and have found definite markets, but they by no means exhaust the list of new materials evolved in the grease research laboratory.

Research at present in progress is aimed primarily at improving the specialized paint materials, Varwolax and Lanalose. In this investigation a pilot plant, especially designed to eliminate the less desirable constituents of these products has been in operation for some time and has given promising results. Precise details of processing are now being worked out, together with further research on the properties of the paint films produced.

To intensify research on wool grease derivatives an assistant grease research chemist was appointed last year and a new research laboratory is now being equipped on the most up-to-date lines.

Bradford may be considered to be in a favoured position for the recovery of by-products but these have been evolved and developed only after much original investigation in the laboratories and the subsequent overcoming of the many practical difficulties involved in the large scale application.



PRESS HOUSE CONTAINING 128 SLUDGE PRESSES

Chapter V

THE BUSINESS SIDE OF THE UNDERTAKING

From the outset of sewage treatment in Bradford, it appears, efforts have been made to produce some commercial asset. Clauses were inserted in the Bradford Corporation Gas and Improvement Act, 1871, *re* the defœcation of sewage, and Clause 46 states "The Corporation may upon such terms and conditions as may be fixed by agreement with the owners or occupiers of any lands contiguous to sewage works of the Corporation supply to such owners or occupiers respectively sewage for the fertilization of such lands."

In 1873 when the first sewage works in Bradford was completed it was handed over by the Corporation to the Peat Engineering and Sewage Filtration Co. Their idea was to strain the sewage through peat in order to purify the effluent and extract its manurial properties at one and the same time, afterwards drying the peat under cover, and recovering the cost of the process by selling the product as a manure for agricultural purposes. This, like many admirable theories, broke down utterly in practice. Various other processes were tried by companies and persons, but with no greater success. Consequently, in 1874, the Corporation took over the works and commenced treatment themselves, with some success, by means of lime and subsequent filtration.

The cost of treatment was reduced from £6276 in 1876 to £4000 in 1880. At this period there was little or no complaint in regard to the effluent, but from this time on, the population and trade increased to such a degree that the works soon became totally inadequate. Large quantities of lime sludge were produced, the disposal of which proved difficult. This state of things obtained until the year 1899. Experiments and remedies were tried by companies and individuals but were either too costly or deemed unsatisfactory.

Fertilizer Sales

In the year 1902, when the method of pressing the sludge after precipitation by sulphuric acid commenced, many difficulties had to be overcome. By constant experiment and attention to detail, however, these difficulties were gradually dispelled, and eventually a cake was produced with about 30 per cent of moisture but containing some 20 per cent grease. It was thought at the time that on account of the grease the cake had little or no manurial value. The cake was tipped at Frizinghall, the amount varying from 40 to 80 tons per day, and early in the year 1904 about 12,000 tons of cake had been disposed of in this manner. It became the cause for general complaint from people passing along the road. In consequence it was decided to install a Wilton Patent Furnace, fitted to the Lancashire boiler. By means of this furnace a large portion of the sludge cake then being made was burnt, and a saving of coal effected.

Also in 1904 the Committee decided after much experiment to engage Dr. Grossmann to prepare plans and specifications for a process of distillation to recover the remaining grease and produce a saleable manure.

Sales of the dried sludge did fructify, amounting to approximately £30 for each of the first two years. After working for a period this plant, not proving wholly satisfactory, was abandoned to make room for press-house extensions in 1908.

However, a start had been made in selling the dried sludge. A local firm, who specialized in the degreasing of woolcombers' sud cake, commenced taking deliveries of sludge cake for the same purpose, but the quantities were only small. Compounders of artificial manures were taking small quantities of cake to grind up as a base for the more expensive chemical fertilizers. With the resulting demand for a ground sludge, a pan grinding machine was installed. Grinding the cake was a difficult operation as the material containing both grease and moisture had a more or less plastic composition. However, it was found by exposing to the atmosphere and air drying, it could be ground more readily, and a steady increase in the demand for this powder developed. Experiments in grinding finally decided in favour of a "bar disintegrator" comprising two cages of different sizes, the smaller revolving inside the larger, the two travelling in opposite directions, as being the most practical. This type is still in use to-day.

With the advent of the new press-house at Frizinghall, and an increased production of cake, experiments were made with a "Mason's Gas Producer," burning the cake by slow combustion and making a producer gas to fire a Babcock and Wilcox boiler. Steam was raised in this manner for the sludge pressing plant for a period, but as there were considerable troubles from clinkering, firing, etc., it was abandoned.

About this time, early in the year 1908, a more insistent demand for a dried sludge led to experiments with the installation on trial of a mechanical drying machine, but this after many tests did not meet requirements.

However, in spite of the difficulties of finding a standard material, the demand was steadily increasing. In the year 1909 an order for ground sludge, packed in bags, for export to France was booked. Undoubtedly a milestone in progress when one considers the cost of freight.

In 1910 a "Ruggles Cole" rotary kiln drying machine was erected at Frizinghall. Immediately an order was received for 700 tons of the "machine dried and ground cake." This was followed up by an order for a further 2000 tons, the result being that the £1000 mark in sales of sludge per annum was reached. The year 1912 found the sales were more than doubled, £2259 being realized. Efforts were being made at this time to find further outlets, and two Ovoid Briquetting machines were put into operation at Esholt. The briquettes were about the size of small soap tablets, and were used as boiler fuel on the chain grate stokers in conjunction with coal. In December 1913 an order was booked for 10,000 tons of the briquetted sludge. Sales were now increasing year by year. The period of the First World War saw the closing down of the rotary kiln dryer and the briquette machines, but the substitution of natural drying in the open did not cause any diminution in demand. The sales for the year 1915 amounted to £3825, being a five-fold increase in five years, while the year 1921 realized no less than £13,655, a record figure up to that time. The demand had been stimulated by the war-time shortage of artificial chemical manures; but even during the inter-war years, when prices were falling and artificial fertilizers abundant, the demand was steadily maintained and almost the whole production was regularly sold.

No opportunity was wasted in further extending the scope of usefulness of the fertilizer and extending the area of distribution. It was exported to the U.S.A., to France, and other European countries. In connection with the sales to America, the fertilizer had to satisfy the very stringent import regulations for fertilizers, and a certificate as to its sterility and freedom from weed seeds was given by the Chemical Inspector to the American Legation.

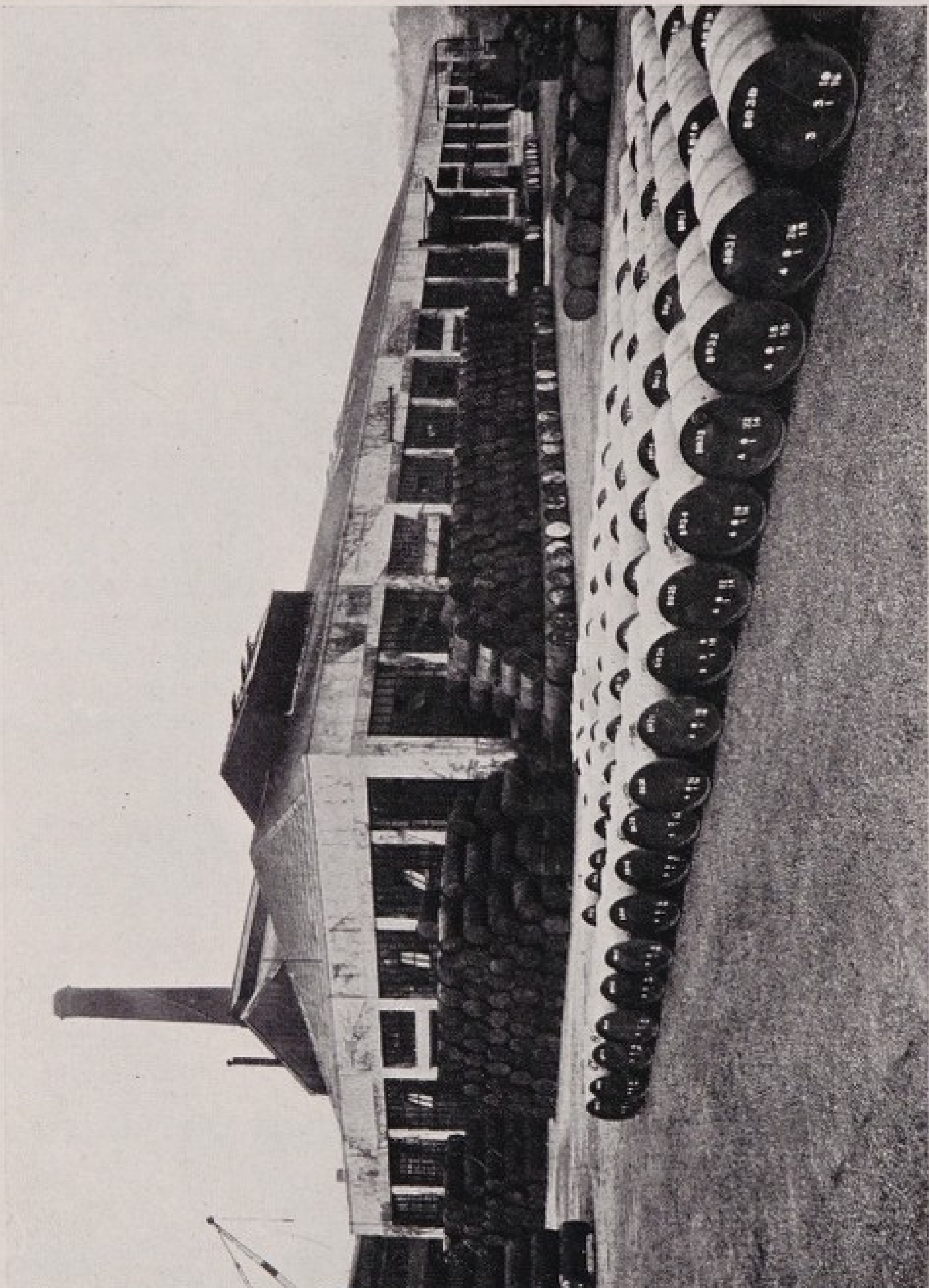
Recently, samples of press cake and powdered fertilizer have been tested by the City and County Analyst for sterility and his certificate states:

"The cake, as produced, is practically sterile apart from mould spores (which develop in the total count at 20–22° C.). After grinding and weathering considerable bacterial development takes place, but these are airborne organisms such as would normally be found in soil.

"The Coli Aerogenes group is absent in both samples, indicating a freedom from organisms of fæcal origin.

"We think that the cake may, from a health point of view, be regarded as sterilized, and the ground up material should therefore be the same, providing it is not contaminated in storage."

At the present time about three-quarters of the fertilizer sold is taken by large compounding firms, who mix it with other organic materials and with artificials in order to produce complete fertilizers with guaranteed percentages of nitrogen, potash, and phosphorus for various agricultural purposes. The remainder is sold to a large number



GREASE HOUSE

of smaller customers, either for compounding or for direct use. Amongst these are included farmers' organizations, golf, cricket, and other sports clubs. For direct application to grass, the organic fertilizer has been recommended by the Golf Research Association, and the lawns at Esholt Hall bear witness to its efficacy.

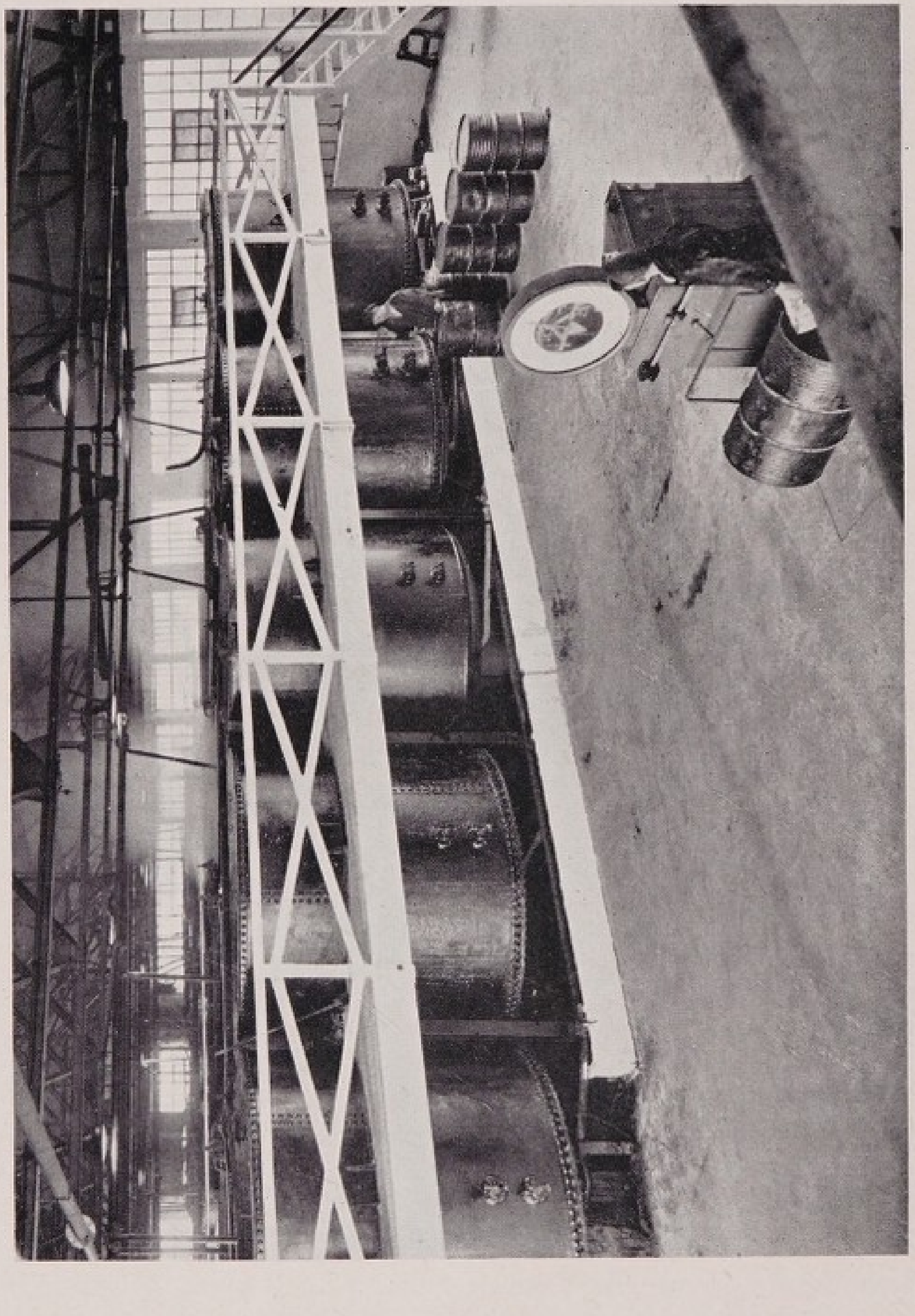
The conditions created by the last war once again saw an increased demand for the fertilizer, the sales figure, which was £4092 in 1939, reaching the record total of £28,156 in 1943. The total sales of fertilizer up to 1947 amounted to £296,179.

As will be seen from the statement of yearly income given in Table III on page 64, business in this organic fertilizer over the past years has been subject to variations, according to the state of the market for organic and artificial manures. But a steady demand has now been created and it is thought likely that, in view of the national revival in agriculture, and of the need to reduce imports of artificial fertilizers, the production will be fully absorbed by demand for many years to come. Another factor which may affect future demand for this organic fertilizer is the growing realization among the agricultural community of the part played by organic wastes in maintaining the humus content and fertility of the soil. The views, strongly advocated by Sir Albert Howard, C.I.E., M.A., the eminent authority on organic fertilizers, that artificial chemical fertilizers are unable to maintain a healthy soil, are likely to lead to still greater attention being focused on the necessity for recovering and making use of organic fertilizers made from the wastes of our great cities.

Grease Sales

In the year 1901 at the old Frizinghall Works the change to sulphuric acid precipitation took place, and in October 1902 the method of sludge disposal by filter pressing was put into operation. This process which, although improved during the intervening years, is still in operation to-day, was the beginning of an era of commercial enterprise. From October 1902 to the end of March 1903 grease to the value of £222 had been sold. The following year this had increased to £2371. In the years 1908–9 a second press-house was erected, doubling the number of presses to sixty-four, which gave a subsequent increase in production and the sales had passed the £20,000 per annum mark. Prior to the First World War nearly £200,000 had been obtained from the sale of grease alone. In 1912 the new press-house at Esholt was opened, having double the capacity of that at the Frizinghall Works, the presses from the latter place being transferred to the new works.

In the year 1918 the sale of grease reached the then unprecedented figure of £126,658 due to the record high price obtained for the grease. This was the result of abnormal circumstances, but the sales for the three years 1918–19–20 contributed to relieving the rates to the extent of £81,453.



INTERIOR OF GREASE HOUSE, SHOWING GREASE-BOILING VATS

In the first twelve years of the inter-war period, the sales produced over half a million pounds sterling, but the unsettled market conditions culminating in the slump in the early 'thirties restricted the demand and large stocks began to accumulate. As described in the previous chapter, a strong drive to develop new outlets for the grease was started in 1936 and from that time sales have steadily increased. The economic position caused by the Second World War still further stimulated the demand for grease and grease products, sales reaching a figure exceeding a quarter of a million pounds per annum.

Before the First World War practically the whole of the grease was sold to the grease distillation trade, which had developed on this raw material and which to-day still remains the largest consumer. The products of wool grease distillation are well defined and have become recognized in most parts of the industrial world. The most valuable material produced is wool grease stearine, which is used for high-grade lubricants and in the preparation of metal-polishing compounds. Other products of distillation are wool grease oleine, used in the production of "shoddy," and wool pitch, which has been found useful for the insulation of electric cables and in the manufacture of lubricants for very hot bearings.

Substantial quantities of "A" grade grease are supplied direct to manufacturers of lubricating greases who neutralize the free fatty acids with caustic soda to make grease blocks for hot-neck lubrication. Fairly large quantities of this grease were shipped to France in 1939 and 1940.

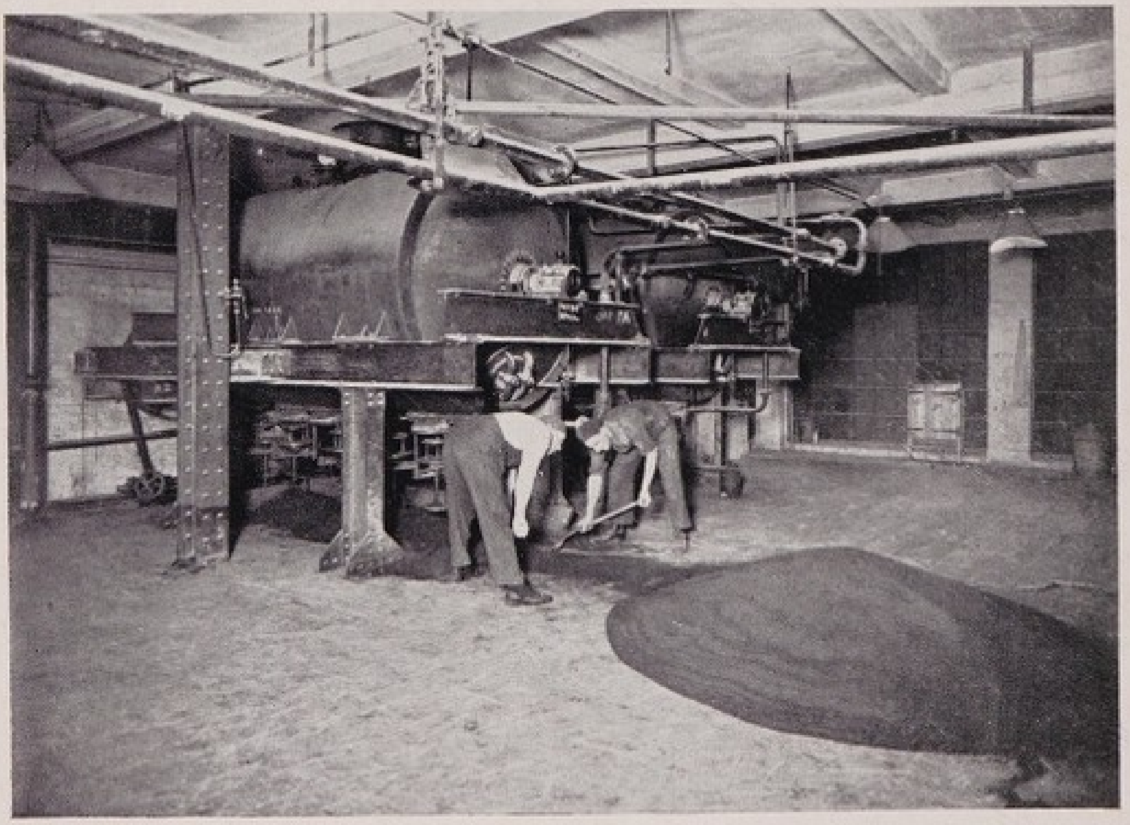
In 1941 a fresh and very important development took place in the utilization of "A" grease for the manufacture of railway axle grease for wagon axle boxes. Up to that time, about 1000 tons a year of good tallow and palm oil had been used for the production of a special grease for this purpose; and obviously, in time of war, such usage of high-quality oils and fats could not continue if any alternative were available. On the basis of the Corporation's Axle Grease formula, a solidified emulsion of recovered grease in Crujol solution, a bulk quantity was made up by the L.M.S. Railway and given a comparative trial run on the axles of a goods train. On the success of this experiment it was decided at a meeting of the Railway Companies' chemists at Euston in July 1940, that Bradford Corporation recovered grease should be used by all the British Railway Companies for all their axle grease requirements. Since that time the adopted formula of the Corporation has been exclusively used, calling for over 1000 tons per annum of "A" grease and its crude soda soap (Crujol).

During the war very large quantities of grease were used in the manufacture of camouflage paints.

"B" and "C" Grade Greases

The Grade "B" grease, which has been deodorized, finds many uses in connection with the preparation of leather. It is used as a dressing

SOAP PLANT SHOWING RIBBONING MACHINES



SOLVENT PLANT SHOWING EXTRACTION VESSELS compound and, together with wax, is used to make dark "stuffing" grease. It is also used as a valuable plasticizer, by small additions to hard bitumen. There are numerous minor uses for this grease, such as in the manufacture of carbon copying paper, printing inks, and so on.

Grade "C" grease, the best available quality of bleached and deodorized grease, was shipped to France in large quantities up to 1940, mainly for use in the jute industry as a batching (or softening) oil when mixed with spindle oil.

Neutralized Greases

These neutralized greases are excellent rust preventatives for iron and steel, and the "hard" quality in white spirit solution was much used for protecting military equipment for service in the Far East during the last war. Government laboratory tests showed neutralized grease to be one of the next best products to lanolin itself. Specifications were drawn up by the Ministries of Supply and Aircraft Production for the use of this material in various rust preventative formulations.

Considerable quantities of the "Medium" quality were used by Naval Stores and various steel users for direct application, and large quantities were sold for the manufacture of dubbin, which contained 60 per cent of the grease, mainly for greasing Army boots.

Since the end of the Japanese War, when Government contracts for rust preventative solutions were cancelled, there has been a large drop in the sales of these greases and an advertising campaign is now being pursued to place the merits of the materials before the appropriate trades.

Crujol

Apart from the consumption of Crujol in the works solvent extraction process, the chief outlet for this crude soda soap ribbon is to the railway companies for the manufacture of wagon axle grease, about 400 tons being sold annually for this purpose. Considerable quantities also are sold, together with Varwolax, for water paint manufacture. When split with sulphuric acid into Crujol Fatty Acids it finds a sale to manufacturers, distillers, and others.

Scrojol

This is the already saponified (i.e. soap) content of Crujol and normally contains under 3 per cent of unsaponifiable material. It possesses very good detergent properties and before the advent of soap rationing, found a sale as a soap powder. Some difficulty is now experienced in marketing it, however, as it would have to be taken at the expense of normal rationed soap fats if employed for general use. At present the bulk of the Scrojol produced is split with acid into "Scrojol (Pure) Fatty Acids" and sold to the grease distillation trade for the production of stearine.

Varwolax

This is the unsaponifiable portion extracted from Crujol and its outlet is mainly to the paint trade for water paint manufacture, in which it is used together with Crujol. The demand for Varwolax is much greater than the production capacity, although continuous working, Monday to Saturday, has been in operation for many months, and a rationing scheme has had to be introduced. It is also used in the manufacture of Lanalose.

Lanaloid

This product is a very good acid-resistant flooring material, somewhat similar to bitumen. Its high melting point (about 100° C.) necessitates a high temperature in laying, and a very hot trowel. So far, sales progress in this direction has been limited, but small steady business is in hand in connection with its use as a constituent of crayons and of floor, leather, and furniture polishes. It is also used in the making of carbon copying paper.

Lanalose

This oil paint vehicle is in great demand at present, particularly in the 40 per cent solution form with white spirit. Production is at the rate of 15 tons of the solid form and 25 tons of the solution per month. Work is in hand on the enlargement of the solution plant.

Packages and Transport

The methods in use for packing the by-products for transport and shipment have been worked out to suit the requirements of the various trades concerned. The organic fertilizer, for instance, is sold in bulk, f.o.r., in minimum 6-ton wagon loads. "A" grease is supplied to the railway companies in rail tank wagons from 6 to 10 tons capacity, and the large distillers take delivery in their own road tank wagons of from 3 to 5 tons capacity. To other customers the grease products are sold in lightweight steel drums of 40–45 gallons capacity, while, of the other specialized products, Crujol and Scrojol are marketed in four-ply paper sacks, and Lanaloid is packed in hessian sacks.

Methods of Marketing

In general, the Corporation sells direct to the customer and gives technical advice on the use of the various products. For the "straight" products such as organic fertilizer and recovered grease in the three grades, all business is conducted direct, solely by the Corporation. In the case of certain of the specialized by-products, however, where successful marketing is largely dependent on personal contact with a wide circle of customers and prospective customers at home and abroad, the Corporation has appointed a firm of high standing in the paint and allied trades to act as its agents on a commission basis. As with all up-to-date concerns, advertising plays an important part, and such costs are shared with the agents. Several articles have been written by officers of the Department for publication in suitable trade journals with a view to placing before potential customers authoritative technical information.

Close liaison is maintained with the Ministry of Food, Oils and Fats Division, and allocations of grease and grease products are made quarterly in collaboration with this Ministry. It is pleasant to place on record that the officers of the Ministry have always been most helpful and appreciative of the Corporation's particular problems.

Income from Sales

Reference was made earlier in this chapter to the fluctuating revenue derived year by year from the sale of by-products. To bring the record up to date it is interesting to note that the sales of grease and grease products during the year ending 31st March 1947 amounted to no less than £270,623. Not only is the current production of grease being readily absorbed, but the large stocks accumulated in the years between the two wars have also been almost completely disposed of. Present-day demand for grease and by-products is far in excess of total production, and it has become necessary to ration the Department's customers. Every effort is being made to take advantage of the present situation to place the materials made at the Esholt Works in as many markets and trades as possible, with the object in view of steady business being maintained when more normal conditions ultimately return.

Table III, on page 64, shows a summary of the Department's expenditure and income year by year from 1930 to 1946. From this table it will be clearly seen that in each of the last five years for which complete figures are available the income received from the sale of by-products has more than met the total cost of running the works and has also gone some way towards covering interest and sinking fund charges.

As has been emphasized earlier, the cost of sewage purification in Bradford is unusually high owing to the particularly difficult type of sewage, both the capital cost and the running expenses being very considerably greater than would be the case in a town of comparable size having a more "normal" sewage. The primary object in the production of by-products is to offset as far as possible the heavy cost of sewage treatment. That this aim has been largely realized will be seen from the fact that the sewage disposal rate levied for the year 1947–8 has been reduced to the phenomenally low figure of 6·434d. in the £.

Tribute has been paid in an earlier chapter to the work of the late Mr. Joseph Garfield and Mr. H. Wontner-Smith in connection with the design and construction of the Esholt Works.

The recovery and sale of fertilizer and grease, initiated and developed by the late Mr. Joseph Garfield, was extended and elaborated by Mr. H. Wontner-Smith, and the present satisfactory position is due in no small measure to his energy and ability.

Table III

BRADFORD CORPORATION SEWAGE DEPARTMENT

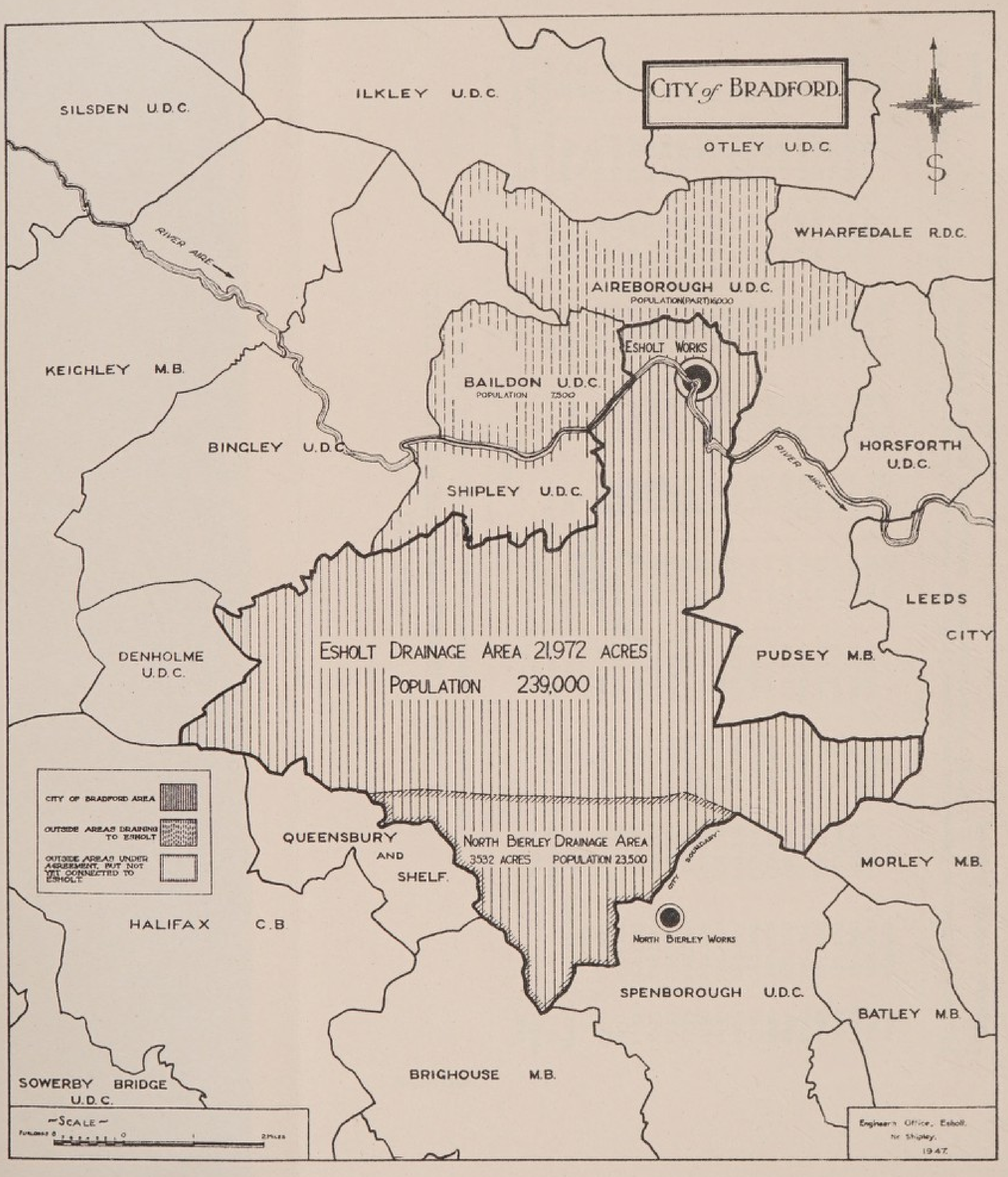
Summary of Expenditure and Income—Years 1930 to 1946

Year ending 31st March	Population*	Works Expenditure £	Loan Charges £	Total Expenditure £	Income: Grease and Products £	Income: Fertilizer £	Income: Other £	Income: Total Income £	Net Expenditure £	Equivalent Rate Poundage Pence in £	Cost per head of Population s.	d.
1930	289,200	103,076	136,664	239,740	43,720	4,509	26,371	74,600	165,140	16·207	11	5
1931	298,041†	140,770	89,451	230,221	33,221	4,105	22,761	60,087	170,134	20·568	11	5
1932	300,900	96,588	147,423	244,011	32,648	1,968	30,490	65,106	178,905	22·746	11	11
1933	298,600	82,555	150,671	233,226	13,360	2,792	13,685	29,837	203,389	26,116	13	8
1934	295,700	96,542	145,999	242,541	4,920	4,008	16,251	25,179	217,362	27·816	14	8
1935	293,650	96,325	144,063	240,388	22,890	6,324	17,650	46,864	193,524	24·281	13	2
1936	292,200	100,807	140,611	241,418	40,597	6,151	17,244	63,992	177,426	22·805	12	1
1937	290,500	108,702	136,276	244,979	49,850	4,355	16,778	70,983	173,996	21·828	12	0
1938	289,510	114,219	135,964	250,183	41,527	5,716	17,438	64,681	185,502	22·874	12	9
1939	288,700	112,260	134,340	246,600	33,091	4,092	15,263	52,446	194,154	23·763	13	5
1940	287,500	132,391	134,468	266,859	90,115	5,128	19,295	114,538	152,321	18·480	10	7
1941	271,700	140,253	136,119	276,372	100,298	10,580	22,572	133,450	142,922	17·284	10	6
1942	271,700	157,833	163,962	321,795	152,007	17,590	23,808	193,405	128,390	15·419	9	5
1943	271,700	159,296	210,639	369,935	222,165	28,156	24,553	274,874	95,061	11·567	7	0
1944	271,700	159,424	203,734	363,158	167,728	24,943	26,422	219,093	144,065	16·821	10	7
1945	261,890	153,109	144,232	297,341	157,328	23,496	28,795	209,619	87,722	10·380	6	8
1946	262,660	198,125	147,962	346,087	180,531	21,363	52,318	254,212	91,875	10·861	7	0
1947	262,660	—	—	—	270,623	21,047	51,416	343,086	—	—	—	

The complete figures of Expenditure and Income for the year ended 31st March 1947 are not yet available but the rate levied for Sewage requirements for the financial year 1947–8 is 6·434 pence.

* Registrar General's Estimate.

† Census.


CITY of BRADFORD.
SILSDEN U.D.C.
ILKLEY U.D.C.
OTLEY U.D.C.
WHARFEDALE R.D.C.
RIVER AIRE
AIREBOROUGH U.D.C.
POPULATION (PART) 16,000
ESHOLT WORKS
KEIGHLEY M.B.
BAILDON U.D.C.
POPULATION 7,500
BINGLEY U.D.C.
HORSFORTH U.D.C.
SHIPLEY U.D.C.
LEEDS CITY
DENHOLME U.D.C.
ESHOLT DRAINAGE AREA 21,972 ACRES
POPULATION 239,000
PUDSEY M.B.
CITY OF BRADFORD AREA
OUTSIDE AREAS DRAINING TO ESHOLT
OUTSIDE AREAS UNDER AGREEMENT, BUT NOT YET CONNECTED TO ESHOLT
QUEENSBURY AND SHELF.
NORTH BIERLEY DRAINAGE AREA
3532 ACRES POPULATION 23,500
CITY BOUNDARY
MORLEY M.B.
HALIFAX C.B.
NORTH BIERLEY WORKS
SPENBOROUGH U.D.C.
BATLEY M.B.
SOWERBY BRIDGE U.D.C.
BRIGHOUSE M.B.
SCALE
0
1
2 MILES
1947.

Chapter VI

HOW ESHOLT SERVES AREAS OUTSIDE THE CITY

The Esholt Works provide a striking example of the benefits of centralization in sewage disposal practice. Not only have those areas within the City, formerly served by small isolated works, been drained to Esholt but, in addition, several districts outside the City have taken advantage of the facilities offered by these works. The Esholt Works have, in fact, irrespective of administrative boundaries, become the regional sewage disposal works for this section of the Aire valley drainage area.

In the 'seventies of the last century, when the Frizinghall works were opened, the Bradford boundary enclosed a far smaller area than it does to-day, and the neighbouring parishes and townships, which have since been incorporated in the City, each had their own small sewage works. The closing down of these small and often inefficient works was one of the many benefits conferred on these areas by amalgamation with their larger neighbour. So long, however, as Frizinghall remained the City's main sewage works, many of these areas, owing to their geographical position, had of necessity to retain their old works. It was only with the opening of the Esholt works that a wholesale reduction in the number of these small plants became possible.

The Urban Districts of Eccleshill and Idle had, for instance, been absorbed into the City in 1899, but it was not until 1912, when the Idle and Eccleshill intercepting sewer was constructed, that the sewage of these areas could be diverted to Esholt and the old works at Idle, Eccleshill, and Greengates abandoned. In 1930 the Urban District of Clayton was added to the City, and in the same year the old works at Clayton were closed down and the sewage diverted. To the inhabitants of these areas the benefits of incorporation, from the sewage disposal angle, became at once apparent. The sites of the former small works were released for housing or other purposes; the smells and nuisances were forgotten; the sludge disposal problem—always particularly acute on a small works—was solved; the local becks ran with pure water once again; and finally, the people had the satisfaction of knowing that their sewage, both domestic and industrial, was being treated fully and by the most scientific methods and that their rates were being assisted by the production of valuable by-products, which only a large works with its great resources is able to extract from the sewage.

Yeadon

The first area outside the City boundary to take advantage of the Esholt scheme was the former Urban District of Yeadon, which now forms part of the Aireborough Urban District. The old Yeadon works were situated off Gill Lane, the effluent being discharged into the Yeadon Gill Beck about half a mile above its junction with the Guiseley Beck in the gardens of Esholt Hall. The works were thus favourably situated for linking up with the main precipitation tanks of the Esholt works. So long ago as 1901 the Urban District Council had started negotiations with the Corporation, and in 1908 a thirty years' agreement was concluded, under which the Corporation undertook to treat the Yeadon sewage at an agreed rate. Certain constructional works were necessary before the agreement could be implemented. A balancing tank of 250,000 gallons capacity preceded by a detritus tank was installed. During very heavy storm flows the balancing tank can overflow storm water to the beck after first depositing any settleable solids in the tanks. The main outfall sewer to the Esholt works is 1110 yards in length, 12 in. to 15 in. diameter, and enters the works at the main secondary precipitation tanks. A recorder is provided to give an automatic record of the flow. The average daily dry weather flow from Yeadon amounts to a little over 1,000,000 gallons per day, nearly 80 per cent of which is trade wastes, chiefly from dye-works and woollen mills. The sewage is generally alkaline and helps to correct any excess acidity in the effluent leaving the primary precipitation tanks.

The original agreement with Yeadon lapsed in 1938, and a new one on similar terms for a further thirty years, commencing on 3rd January 1940, was concluded with the Aireborough Urban District Council.

Guiseley

An agreement has also been entered into with the Aireborough Urban District Council for the treatment of sewage from the Guiseley area. In the years before the last war this area was developing rapidly and the old works situated just outside the City boundary and discharging to the Guiseley Beck were found to be incapable of dealing effectively with the increasing flow. The plant could not treat the whole of the normal dry weather flow, the filter beds being capable of dealing with only about 60 per cent of the flow, the excess during the daily peak periods passing to the storm tanks. The old Guiseley Urban District Council, faced with the prospect of reconstructing and extending their works on a very inadequate site, had started negotiations with the Corporation with a view to diverting the sewage to Esholt, and an agreement to last for thirty years was finally concluded in April 1938.

Under the provisions of the agreement the Corporation undertook to construct and maintain the necessary new works, while the U.D.C. was to pay for the treatment of their sewage with an agreed minimum of 550,000 gallons per day. The population draining to the Guiseley works is about 7000, and the area served is 4040 acres, although a large part of this area, particularly around Hawksworth, is at present undeveloped. The normal dry weather flow is about 900,000 gallons per day, the peak flow being about 2,225,000 gallons. About two-thirds of the flow is trade wastes, chiefly from dye and textile works.

The new outfall sewer to link up the old works with Esholt is 1400 yards in length and was constructed in difficult and heavily-wooded country. It varies in size from a cast iron pipe sewer 15 in. diameter to a brick and concrete egg-shaped sewer 2 ft. wide by 3 ft. high. The sewer terminates on the high ground just north of the Sulphuric Acid Plant. The sewage passes through a screening chamber to a measuring flume which operates a recorder. This is followed by two detritus tanks each of 5000 gallons capacity, after which the sewage flows to two balancing tanks, totalling 524,000 gallons in capacity, and thence to the main secondary precipitation tanks where it mixes with the effluent from the primary tanks.

Baildon

In 1928 the Baildon Urban District Council approached the Corporation with a request to examine the possibility of receiving the Baildon sewage at Esholt. The old Baildon works in Esholt Lane were becoming obsolete, and the necessary extensions would have been difficult and expensive. Meetings between the Authorities resulted in an agreement being reached to last for thirty years from May 1931. The scheme necessitated the construction of a new aqueduct bridge across the River Aire opposite the old works and the provision of a new outfall sewer to Esholt, running parallel with the river on the south bank. The Corporation took advantage of this opportunity to improve the sewerage of the Thackley area of the City; the old works at Thackley, occupying some 12½ acres of riverside land, were in a poor condition and inadequate to meet the growing needs of the district. It was convenient to link up these old works with the new Baildon sewer. The agreement, therefore, provided for the capital cost of the works to be shared proportionately between Baildon and Bradford, and fixed unit charges were agreed for treating the sewage received from Baildon.

The works were constructed in 1932 and the scheme came into full operation the following year. From the old Thackley sewage lands a pipe sewer 870 yards in length leads to a recorder house at the Bradford side of the river crossing from Baildon. Here the flows are automatically recorded and the combined sewage continues through an egg-shaped sewer 2 ft. wide by 3 ft. high and 1213 yards in length to the Esholt works. The sewage discharges to detritus tanks provided in duplicate, afterwards being pumped through an 18-in. diameter rising main to mix with the effluent from the primary precipitation tanks before passing forward to the secondary tanks. The pumps are of the electrically driven centrifugal type, three being provided—a small one for dealing with the low night flow and two larger pumps for day and storm flow. The pumps are automatically operated by float control.

The average dry weather flow from Thackley amounts to some 100,000 gallons per day, while that from Baildon is about 500,000 gallons, the greater part of this being sewage of domestic origin.

Shipley

The most recent neighbouring authority to conclude an agreement with Bradford for the treatment of its sewage at Esholt is the Shipley Urban District Council. Negotiations between the two authorities reached a successful conclusion in October 1940 when a thirty years' agreement was signed. Unfortunately war-time conditions have made it impossible to implement the scheme, but it is hoped that the work will be begun in the near future. The sewage reaching the Shipley works is very similar in composition to that from Bradford, having a high grease content from the numerous wool-scouring mills in the area. The present Shipley works have been overtaxed for many years and, unlike the Esholt works, are not equipped for dealing with this very difficult type of sewage. Last year the Shipley Urban District Council approached the Corporation with the request that the Department be permitted to undertake the management and administration of these works for the Council. The Corporation agreed, and this arrangement will continue until the completion of the new scheme.

To bring the Shipley sewage to Esholt will mean the provision of pumping plant, a rising main, and an outfall sewer which will follow the contours of the valley as far as the main detritus tanks, where the Shipley sewage will mix with the incoming sewage from Bradford. Most of the site at present occupied by the works at Shipley will thus be freed for industrial or other development, and the condition of the River Aire should be vastly improved. It is expected that the opportunity will be taken at the same time to improve the sewerage of the western part of Baildon and convey the sewage to Esholt. Negotiations, too, have been in progress with the Bingley Urban District Council which may result in that district agreeing to participate in a joint scheme with their neighbours, Baildon and Shipley.

The areas, both inside and outside the City boundary, now served by the Esholt works are shown on the map facing page 65. It will be seen that nearly all those districts, which geographically form part of the area naturally draining towards Esholt, either have already concluded agreements with the Corporation or are known to be considering the matter. The benefits of centralization in sewage disposal, both from a local and a national viewpoint, are now becoming more fully appreciated, and the smaller authorities increasingly aware of the advantages to be gained by entrusting their sewage purification obligations to a larger authority possessing the necessary resources to cope with the many difficulties of the problem.

Chapter VII

NORTH BIERLEY SEWAGE WORKS

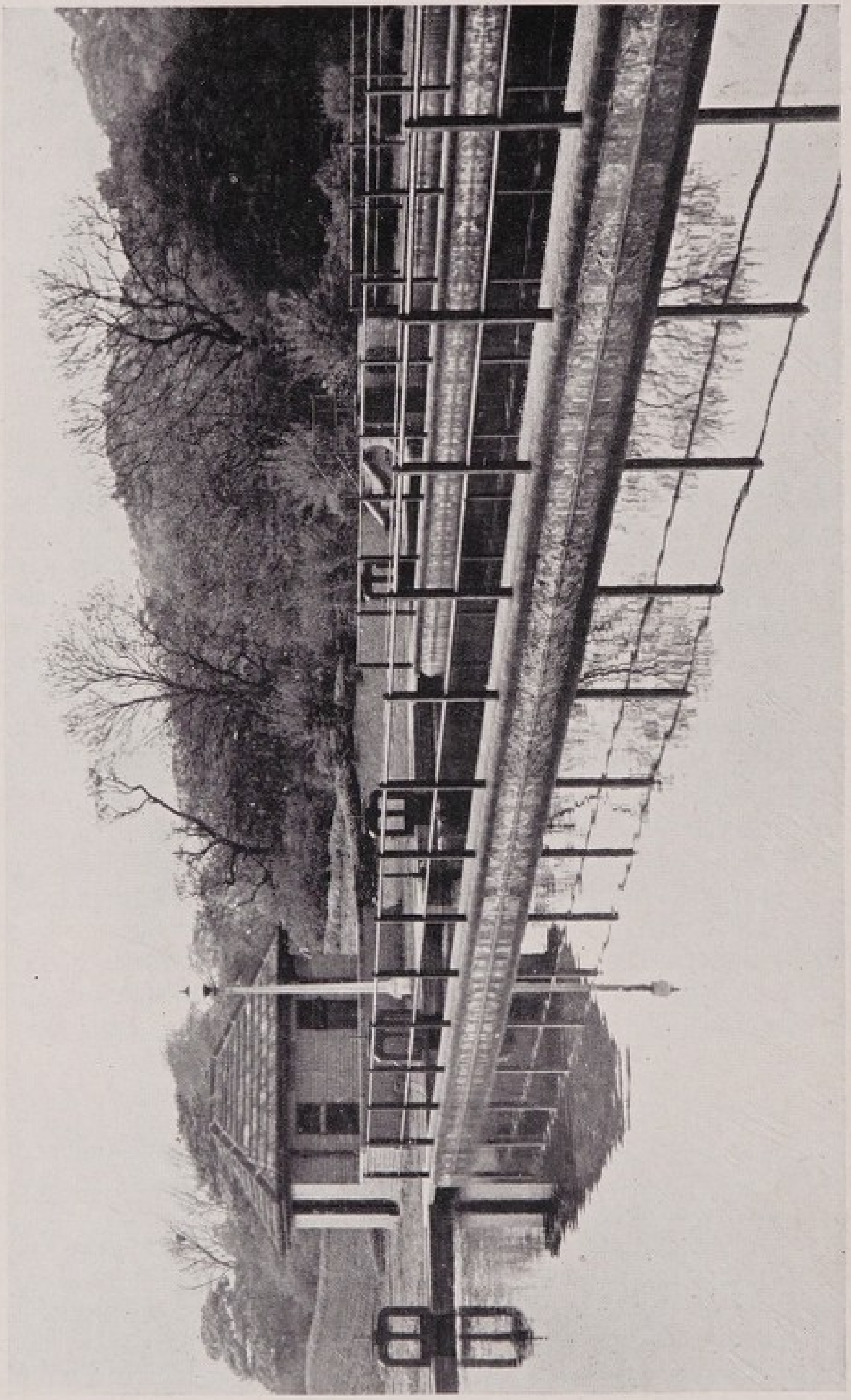
These works deal with the sewage from that part of the City to the south of the ridge of hills running through Rooley Lane and Odsal Top, which naturally drains to the Hunsworth Beck, a tributary of the River Calder. The area draining to the works is 3532 acres, with an estimated population of 23,500. The works are wholly outside the City boundary, being situated within the Spenborough Urban District area.

The original works were founded about the year 1880, and passed from the old North Bierley Local Board to the Bradford Corporation in 1899. The Corporation partly reconstructed the works in 1903 at a cost of some £5000, which included the provision of new settling tanks. These tanks remain to-day in good order and are of ample capacity for the present flow of sewage. The old works served their purpose well and turned out a satisfactory effluent until about 1930 when, owing to the increasing amount of trade waste arriving at the works, it was found that parts of the plant were incapable of treating the full volume. The position was that, while the dry weather flow was adequately dealt with, the additional storm water flow received only tank treatment, and a certain amount of pollution reached the Hunsworth Beck.

In 1934 the Corporation decided to reconstruct and extend the works in accordance with a scheme drawn up by the Sewage Works Engineer. Sanction to borrow money for this purpose was given by the Ministry of Health, and the work was undertaken by direct administration. The work was completed in 1936 at a total cost of about £43,000.

Volume and Strength of Sewage

The works cover an area of about 28 acres, and are approached by an outfall sewer capable of discharging 12,500,000 gallons of sewage per 24 hours. The length of sewer between the City boundary and the works is 335 yards. The average dry weather flow of sewage amounts to about 1,200,000 gallons per day, which represents a total water consumption of about 41 gallons per day per head of the population served. From daily gaugings taken on an automatic recorder at the works, the average rate of dry weather flow during the normal working hours of industry is 1,750,000 gallons, with a maximum rate of 2,000,000 gallons per 24 hours. The maximum wet weather flow is at the rate of 7,250,000 gallons per 24 hours. An overflow weir is set so



NORTH BIERLEY SEWAGE WORKS—HUMUS TANKS

that full treatment is given to 2,460,000 gallons, which equals three times the domestic flow and $1\frac{1}{10}$ the trade flow. Storm flow in excess of this amount is passed to the storm water tanks.

The sewage is classed as of "medium" strength and consists of approximately one-third of domestic sewage and two-thirds trade wastes. The latter is derived chiefly from one firm of dyers who have concentrated several of their works in this area; in addition, effluent is received from a large wire works and from other miscellaneous industries. The sewage varies somewhat in composition according to the time of day and of the industrial processes being carried on, but an average analysis is as follows:

	Parts per 100,000
Oxygen absorbed (4 hours @ 80° F.)	10·4
Nitrogen:	
Free Ammonia	3·0
Albuminoid Ammonia	0·65
Suspended Solids	32·0
Alkalinity, Caustic	1·96
„ , Total	33·32
pH	8·1

A sewage of this strength does not call for the elaborate and costly type of plant that has been provided at Esholt, and the North Bierley works therefore possess few unusual features. They do, however, offer a good example of a small and efficient works of orthodox design, and merit a brief description.

Detritus Tanks and Precipitation Tanks

The process of purification employed is settlement followed by biological treatment on percolating filters. The sewage on arrival at the works passes through an inlet channel to two detritus tanks, which are constructed in parallel and are designed to work alternately. Each tank is 59 ft. 6 in. long by 13 ft. 6 in. wide by 7 ft. deep, the combined capacity being 66,000 gallons. The detritus is discharged via a 10 in. diameter main to a sludge ram, from which it is lifted by compressed air to the sludge storage tanks. Deep scum boards are provided in the detritus tanks to intercept floating matter, and the sewage finally passes over weirs to a 4 ft. wide outlet channel. Here the sewage flows over an 8 ft. wide gauging weir where the flow is automatically recorded.

The precipitation tanks were constructed in 1903. They are in good order and are of ample capacity for present-day needs. The six tanks are each 90 ft. long by 50 ft. wide by 6 ft. average depth, and have a total capacity of 1,012,500 gallons, equal to about 20 hours' dry weather flow. Floating arms are provided for drawing off the supernatant water when the tanks are to be sludged. The water and sludge are passed through a 9-in. diameter main to an electrically-operated pumping plant where the supernatant water is pumped back into one of the other precipitation tanks, while the sludge is pumped to the sludge storage tanks. The effluent from the precipitation tanks is passed on to the biological filters.

Storm Water

The storm water overflow weir, 82 ft. 7 in. long, is situated on the east side of the 4 ft. wide channel between the detritus tanks and the precipitation tanks. The diverted storm water flows through 24-in. diameter concrete pipes to the two storm water tanks. These each measure 94 ft. 6 in. long by 50 ft. wide by 5 ft. 2 in. average depth, with a capacity of 152,500 gallons, or 6 hours dry weather flow. The tanks are worked in parallel; weirs the full width of the tanks are provided at both the inlet and outlet ends, scum boards being fixed to protect the outlets. The effluent passes to the Hunsworth Beck by way of a 15-in. diameter pipe, and supernatant water is drawn off by means of floating arms, to be pumped back to the precipitation tanks. The sludge gravitates to the pumping station already mentioned.

Biological Filters

The effluent from the precipitation tanks is given final purification treatment on biological filters. The new filter units constructed in 1936 cover two acres and are fitted with rectangular distributors similar to those employed on the Esholt works. The distributors are balanced to give even distribution whatever the direction of the wind, and the power is supplied by the sewage itself, operating overshot waterwheels. The sewage is fed to the beds in cast iron troughs from which it is syphoned to the distributors and discharged through nozzles $\frac{7}{8}$ in. diameter fitted with circular porcelain dashplates. The filtering media is hard coal of a size varying from 1 in. to 2 in. and the depth of media is 5ft. 6 in. During periods of dry weather flow, the rate of distribution on these beds averages 67 gallons per day per cubic yard of media.

At times of high peak flows and during storm time, the old filter beds are brought into use to supplement the new ones. These beds cover $5\frac{1}{3}$ acres and distribution is effected by means of fixed sprays from cast iron distributor pipes arranged on the surface of the beds. The filtering media consists of broken colliery shale 6 ft. in depth. These beds, although old-fashioned in design, give a fairly satisfactory effluent so long as they are not worked too often. The beds are divided into six sections and are fed from three dosing chambers which operate automatically as soon as the prescribed flow to the new filters is exceeded.

Humus Tanks

The filter effluent both from the coal and the shale beds passes by way of a 24-in. concrete pipe to the humus tanks, which are shown in the illustration on page 70. These are rectangular continuous flow tanks, three in number, and are worked in parallel; they have a total capacity of 210,000 gallons equal to a little over 4 hours' dry weather flow. Weirs extend the full width of the tanks, both at the inlet and outlet ends, and scum boards are fixed to protect the outlet weir against the passage of scum. Floating arms are provided to draw off the supernatant water from each tank when cleaning and the sludge is discharged to the suction well of the pumping station alongside the tanks. Two 4-in. centrifugal pumps are provided, each driven by an 18 b.h.p. electric motor. The supernatant water is lifted back to the humus tanks, whilst the humus sludge is pumped through an 8-in. rising main, 725 yards long, to the precipitation tanks.

The final effluent flows through a 27-in. diameter cast iron pipe to the centre of a circular basin, 24 ft. diameter, constructed in red brickwork, the circular weir being provided with a white-tiled coping. From this point the final effluent discharges into the Hunsworth Beck. The volume of effluent often exceeds the quantity of water coming down the beck, but its quality is consistently good as is illustrated by the following average analysis:

	Parts per 100,000
Oxygen absorbed (4 hours @ 80° F.)	1·43
Nitrogen:	
Free Ammonia	0·95
Albuminoid Ammonia	0·20
Suspended Solids	2·8
Alkalinity	18·62
pH	7·4
Bio-chemical Oxygen demand	0·85

Sludge Disposal

The amount of sludge to be dealt with from the detritus tanks, the precipitation tanks, and the storm tanks, amounts to some 13,000 tons per annum at 95 per cent moisture. Before the works were reconstructed the sludge had been discharged to lagoons on the site, but a more efficient means of disposal was sought, and in 1934 a series of experiments was carried out to find the method best suited to this particular sludge. The best results were obtained by cold filter pressing following the addition of 1½ to 2 per cent of lime to the sludge. By this means the annual production of 13,000 tons of wet sludge can be reduced by pressing to 2000 tons at 68 per cent moisture, which will again dry down on storage to about 1000 tons of cake at 35 per cent moisture.

Three presses are installed in the pressing shed. These are generally similar to the ones in use in the press-house at Esholt, each press having forty-seven cast iron plates with a filtering surface 36 in. square on each face, the space between the plates yielding a cake 1½ in. thick. The capacity of each press is 10 tons of wet sludge which is reduced to 32 cwt. of press cake after pressing for a period of from two to three hours according to the condition of the sludge. The wet sludge is pressed when cold, the lime solution being fed into the ram at the same time as the sludge from the storage tanks. The lime is mixed into a slurry in a 200-gallon mixing tank and chlorine in the form of bleaching powder is added as an additional filter aid.

Compressed air is supplied from a compressor driven by a 40 b.h.p. electric motor having an output of 200 cubic feet of free air per minute at a maximum pressure of 60 lb. per sq. in.

The sludge cake is removed in steel tipping wagons and hauled by a petrol locomotive over a 2-ft. gauge track to the land set aside for drying out and storage. Part of the mature press cake finds a ready market as a fertilizer with local farmers, but, on account of its being produced by a cold process, it cannot, in contrast with the Esholt fertilizer, be guaranteed sterile or free from weed seeds.

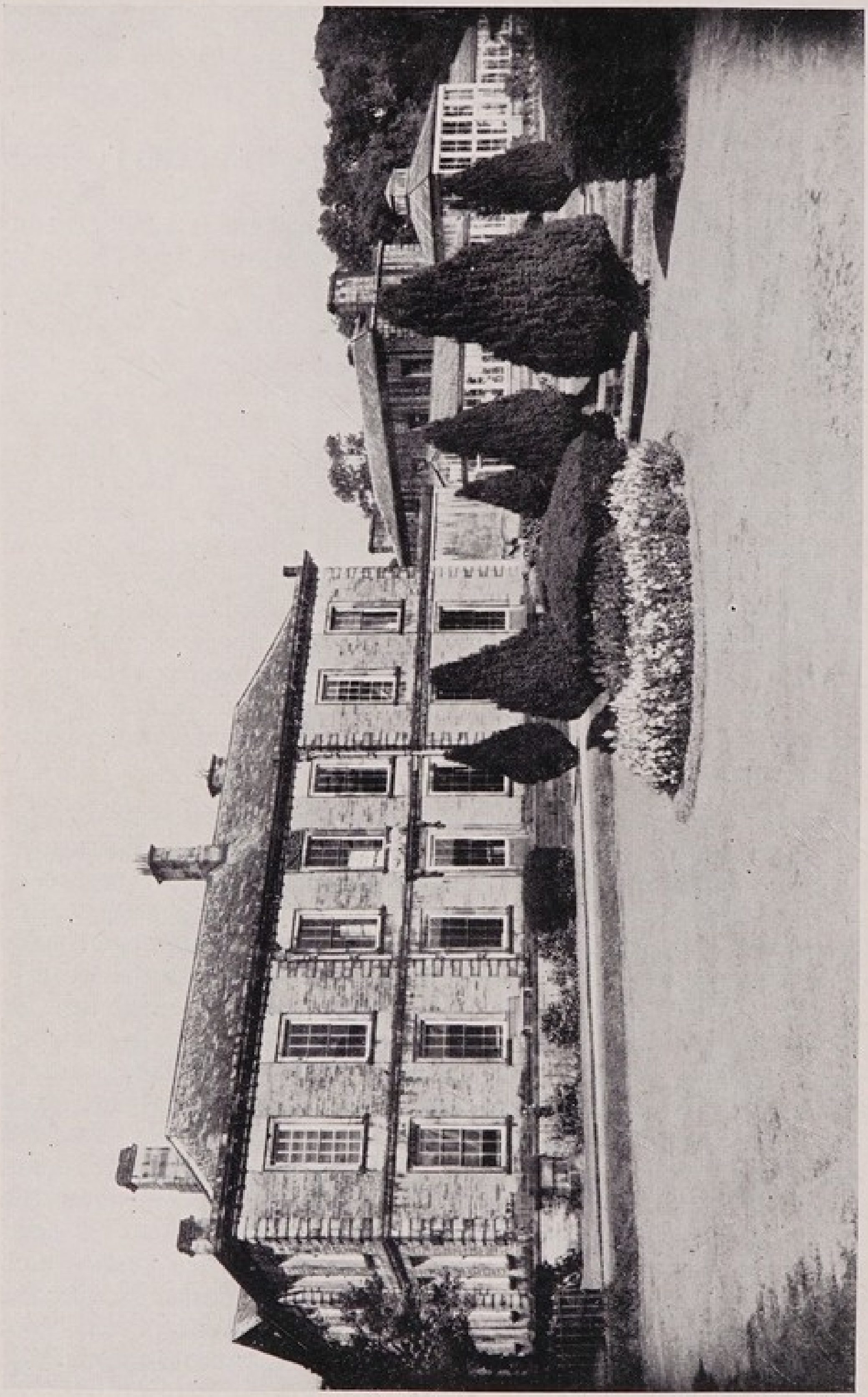
At the present time the North Bierley works are dealing very efficiently with the sewage of the southern part of the City, but there is not a large reserve capacity in the purification plant. The works serve an area which is not fully developed and, should an extensive building programme be undertaken in the future, it will probably be necessary to lay down additional filtration units to meet the increased load.

Chapter VIII

HISTORY OF THE ESHOLT ESTATE

The estate of Esholt possesses no little historic interest. The name of the place implies "Ashwood," and that name in itself curiously links the past with the present. Ash trees are not very common upon the Coal Measure rocks which prevail in Mid-Airedale. The native woodland, the primeval jungle which clothed the hillsides of Aire and its tributaries before man cut into them a multitude of "royds," was of oak. Ash trees flourish only upon soil well supplied with lime, and if such trees were in this little bend of the Aire valley so numerous as to attract the special notice of the early settlers, we may find the reason in the circumstance that in the Great Ice Age a glacier from the mountains at the head of Airedale brought down from the Craven crags by Settle abundant limestone debris. In the river valley itself few limestone boulders remain. For centuries they were collected and burnt for lime for building and for the fertilization of peaty land, but in the boulder clay which lies up on the northern flank tracing the line of the lateral moraine of the glacier, there is still much limestone, and ash trees find the conditions suitable, so that the Esholt woods have many fine specimens.

Esholt is not mentioned by name in that first and greatest of national records, Domesday Book, the taxing assessment made by William the Conqueror's orders in 1086. But there were in the wide manor of Otley two different subordinate manors (berweicks) both called "Hawksworth." One of these, it is fairly evident, must have been really Esholt. But Domesday tells us much of interest relative to the locality. The estate which the Bradford Corporation now owns extends far beyond the border of the township of Esholt into Hawksworth (proper), Guiseley, Yeadon, Baildon, and Rawdon. All those places, except Rawdon, lay in the lordship of the Archbishop of York, and their dues had before the Conquest contributed to the upkeep of the splendour and the civilizing influence of the Northumbrian see. But at the dread coming of William the Conqueror to wreak vengeance upon the inhabitants of this hill-country for their fierce opposition to his arms the district had been utterly devastated. In the eighteen years which had elapsed between William's awful campaign in Yorkshire and the Domesday survey, a few poor farmers and their labourers had crept back to their ruined homesteads and had rebuilt them, but most of the locality still lay desolate. It was indeed the very limit of cultivation, for the Sheriff of Yorkshire did not, when the survey was drawn up, discover a living soul from Bradford to the mountains.



ESHOLT HALL, THE OFFICES OF THE DEPARTMENT

Rawdon had perhaps even more interesting ownership than that of the Archbishop, for it was the property of Robert Bruce, to adopt the modern spelling, the ancestor of his famous namesake, the unfortunate King of Scotland, whose constancy in a struggle against a sea of troubles has been the admiration of ages. It is curious to link up great romantic figures like the Bruces with this busy industrial district, and to look upon them as a Yorkshire family. But so they were before Scotland knew them, for they had their castle at Skelton, to the north of Whitby, and the old priory at Guisborough which they founded, and the abbeys of St. Mary at York and Whitby, to the riches of which they largely contributed, testify to their local patriotism and devotion. Airedale must, consequently, have shared with Cleveland a curious interest in the scraps of news which came through of the great doings in Scotland in the early fourteenth century.

Esholt itself comes into history under that name in 1172, when Sir Simon Warde, of Guiseley, gave some of his land beside the Aire to the Syningthwaite Priory, a little Cistercian nunnery which had been founded a dozen years or so earlier in the fertile plain between Wetherby and York. The Wardes seem to have been a family of some interest, but in early days of no great wealth locally. They were good friends, however, to the Cistercians, then establishing their hold of the Yorkshire Dales, and they gave many gifts to Fountains Abbey and some to Kirkstall Abbey.

A Cistercian Nunnery

How long the Syningthwaite nuns retained their Esholt interest and how they lost it no one knows, but just before Richard I ("Richard Yea and Nay") commenced his erratic course through Europe a nunnery at Esholt is found in existence. One, Galfred Haget, of whom there is nothing to say, and the Wardes were honoured as founders. The early interest of the latter family was continued thenceforth. As successive generations of Wardes grew in wealth they gave rich gifts to the little nunnery, and several members of the family directed that they should be buried there, and one at least of the prioresses bore the name of Warde.

After its establishment the little convent enjoyed for three and a half centuries the happiness which is asserted to belong to the community without history. Nearly all we know of its affairs consists of the names of a few of those who proved themselves benefactors, and a hardly less imperfect list of the prioresses who ruled within the walls of the little establishment. The stirring events of the times passed this little retreat by. But some ripples must have been raised in the pool in passing. The place was the refuge for, among the others, the daughters of a good many of the important local families, viz., the Wardes, Calverleys, Chellerys, Woodhalls, Pudseys, Plumptons, and, austere as was the Cistercian rule, the nuns canno have gone unmoved when brothers and cousins lost their estates in the Magna Carta campaign of the Barons against King John, as did the Wardes temporarily, or were captured or fell fighting at Bannockburn or Flodden.

The Cistercians were no literary order. They wrote no chronicles, and took no care to transcribe and preserve the ancient classics. But they were splendid farmers, and their great abbeys of Fountains, Kirkstall, and Rievaulx, gave to Yorkshire a farming tone which it has never lost. The nuns of Esholt took their share in this agricultural work as supervisors and directors of their retinue of servants, and among the few documents which have survived is a bundle of farmers' and foresters' accounts in the Public Record Office, which shows with how much care, a care excelling that of most modern farmers, the bailiffs accounted for their receipts and payments and the foresters recorded the dates of their various plantings. There is some hint, however, that Esholt suffered the decay which overcame monasticism generally in the fifteenth century. It probably had at the height of its prosperity eighteen nuns, that being the number of the nuns' stalls in the church, but it had only six when Henry VIII's commissioners travelled here to demand and receive the surrender of the little community of their home and property, and to dissolve the house.

We get a glimpse of the convent as it stood in its latter days through a description made by a surveyor of the Exchequer immediately after the Suppression. The writer was interested only in recording the saleable building materials, such as lead, timber, stone, and slate. He cared nothing for archæology, and it was somebody else's business to take account of the plate, valuable reliquaries, and so forth, so that the description does not answer all the questions one would like to have settled. But through all the confusion of this description we get hints which enable us to form a pretty clear conception of the little house. Let us start with its situation:

"Item the seid monastery is sett vpon a Ryuer callid Heyer. And she is lady of the same water vpon bothe sydes, that is to sey by the space of iij quarters of a myle vpon the north syde and half a mile vpon the southe syde. And ther is ouer that Ryuer a ffayre brigge, which the lady must maynteyn in reparacon.

"Item she may fishe in the said Ryuer at her pleasure from the lorship of West Essholt vnto Apperley Brigge, which is by the space of half a myle or more."

The Convent Buildings

The conventual buildings themselves evidently followed generally the ordinary Cistercian plan, but the smallness of the house involved a reduction of the number of apartments usual in larger houses like Kirkstall. The church was quite small, being but 72 feet long and 18 feet broad. It was divided into two equal parts by a rood loft. The choir contained eighteen stalls for the nuns, and the nave beyond the rood, which was allotted to the servants of the convent, was also provided with seats, a somewhat rare furnishing. The window above the High Altar was of three lights with "viij other partes of glass aboue," from which we may infer that it was of Geometrical or Decorated design. This may possibly indicate the rebuilding of the choir in the fourteenth century, since the other windows of the choir were also of three lights each. The nave was lighted only by six little windows each 2 feet in height and half a foot broad, proportions which suggest the Early English style, so that the nave probably belonged to the original building. We are not told whether the church had aisles, possibly not, nor whether it had transepts, which is probable. Upon the church was a "stepulle of litle thack bordes couer'yd with slate." This must have been a bell turret such as was once common, but to find an existing example of which we must go to Hubberholme Church in Wharfedale.

From the church one passes to the cloister, in the eastern walk of which was the chapter house, the business council chamber of the little community. This was a room 15 feet square. Next to it was a little chamber the purpose of which is not known, though in some big abbeys it is supposed to have been used as a mortuary-chapel. Then came a passage-way to the eastward. This led out into the orchard, for there was not at Esholt such a suite of infirmary buildings as occupies the ground eastward of the cloister court of Kirkstall and Fountains. These two apartments and passage being all that touched the eastern wing of the cloister, there must have been plenty of room for the existence of a south transept.

Over this eastern range of rooms was, of course, the dormitory of the nuns, which was 15 feet broad and 40 feet long. It did not retain its primitive simplicity, but had been divided into seven cells. At the south end of the dorter were three little rooms "callid the ladyes parlers." Two of these rooms had fireplaces and all had windows looking across the river to the wooded hills of Idle and Thackley, a very fair prospect. One of the parlours had a "litle kychyn," so that this may have been used for the eating of flesh meat on the occasions when, through ill-health, a nun was permitted to add to her diet meat, a luxury not admitted to the monastic kitchen proper. These comfortable apartments would obviously belong to a period when the austerity of the rule was becoming a little relaxed, and they would undoubtedly utilize the space saved in the dormitory when the number of nuns was reduced.

In the south walk of the cloister, and at the eastern corner was the door of the great parlour, the one room in the building which in early severe days had a fire in the winter, and in which was relaxed the rule of absolute silence prevailing elsewhere. This room had a "ffayr chimney of stone" 6 feet wide. Looking into the orchard was a bay-window "glasid." Next in the south aisle was the refectory, the "hall" as it is called here, a building of 35 feet by 20 feet. This stood with its long axis north and south, as at Fountains and Rievaulx. On the west side towards the north end was a "fayre bay window" with an upright window above it. Within this bay window doubtless stood the pulpit from which during meals a book was read to the diners, according to the custom of the Order. The bay window may be compared with those at Rievaulx and Fountains. On the opposite side of the room was a large wood and plaster fireplace.

The pantry and buttery seem to have been at the south end of this hall with the customary screens fitted with two sliding doors and one "shutting door." Close by was a "kychyn of the olde ffasshyon" with a louvre roof. Those who have seen the kitchen of Glastonbury Abbey will recognize the "old fashion," the custom of the Benedictines, for the position of the kitchen usual with the Cistercians, adjoining the south walk of the cloister, was at Esholt impossible because of the smallness of the cloister court. In this detached kitchen which may have been octagonal, was a fire-range 12 feet in width, very ample proportions, and two "fair ovens," in one of which could be baked two stones of bread, and in the other one stone. Adjoining the south end of the "hall" was a pantry (for the bread), a buttery (for the drink), a larder, a malt-house, and a brew-house.

There was also an "old hall" occupied in the latter days of the convent by a man and his wife who were in effect lodgers, the right of food and lodging having been conferred upon them either by the patron of the house, or by the nuns as a benevolence or for payment. To purchase of a convent such a "corrody" as that right was called, was a favourite way of providing a refuge for old age.

On the west side of the cloister were a wood-house, a coal-house, a garner, and three "fair chambers" probably used as workshops, for the convent was self-supporting in everything, even spinning and weaving its own habit cloths. Over this range was the dormitory for the servants, who would probably be twice as numerous as the nuns.

Outside this compact little block of buildings was a yard, and beyond it a considerable range of farm-buildings, a limekiln, and a mill. There was also a "gate howse over the gate, wherein there ys a prati lodgynge." The imagination will seek aid in picturing the place from the gatehouse of Kirklees, famous in tradition as the place of the death of Robin Hood, and the comparison will be appropriate, for the Esholt gateway, like that at Kirklees, had a lower story of stone and the upper story half-timbered in panels. A good many of the other subsidiary buildings at Esholt were also in this manner of building.

It has been inferred that the place suffered abject poverty, the recorded income in money at the Dissolution being only £35 18s. 11d. a year. But this must have been equal to at least £2500 of the money of our time, and it has to be remembered that nearly all the needs of the place could be met by the products of the farm-lands and the river.

A Soldier's Home

After the Dissolution the place lay for some years ruined and deserted. Then the site was granted to one of the officials of the royal court, one Henry Thompson, gen d'armes to the King. Thompson had displayed considerable gallantry at the siege of Boulogne in 1544. For this he was rewarded with the confiscated property of an ancient hospital, the Maison Dieu in Dover. In the last months of the King's life an arrangement was made for an exchange by which the Dover hospital reverted to the Crown and Thompson took the lands of the nunnery at Esholt. Airedale thenceforward became his residence. Possibly for a time his family continued to reside in the monastic buildings. There are in the cellars of the existing hall considerable portions of the outer walls and windows of a building which, though it has been supposed to have been a part of the priory, cannot, judging from the debased character of the architecture, date farther back than about 1600, and this probably formed a part of the Thompsons' home.

For about 150 years the estate remained in the ownership of the Thompsons, but it passed through vicissitudes during the ownership of a grandson and namesake of the first grantee. One of his servants drew his sword in a street quarrel in York and struck "one Mr. Blackiston unto the brains, so that he was hardly saved alive." Some sort of "employer's liability" seems to have been proved, and Thompson was ordered to pay £1000. To evade payment he made his estate over to his father-in-law, Walter Stanhope, of Horsforth, and disappeared into Cumberland, but when in some legal way not quite clear the verdict was set aside, Thompson was "sore put to it to get his estate again from Stanhope, and was not quite loosed till later end of Mr. Calverley's time, after Stanhopes had gotten vast sums out of it." This at least is one gossip's account of the matter.

The Erection of the Hall

This Henry Thompson left his estate to an only daughter, Frances, who married Walter Calverley, of Calverley, and it was their son Walter who erected the existing hall. A very interesting Memorandum Book kept by the latter Walter, and now in the British Museum, was edited by Mr. Samuel Margerison some years ago for the Surtees Society. This gives us much interesting material for a picture of the local life of the early eighteenth century. In 1700 Walter's mother, then a widow, made the property over to him, and in 1706, when Walter was 33 years of age, he set about building a new hall on the site of the nunnery. The old buildings had been much lower than the existing ground level and had apparently been subject to floods. The level was consequently raised very considerably, a circumstance which would probably account for the fact that so few relics of the nunnery have been turned up in the gardens, and encourages the expectation that considerable remains lie awaiting some day the spade of the antiquarian excavator, beneath the lawns and shrubberies. It is interesting to notice that Walter Calverley did not engage the services of an architect, a profession then growing into general recognition, but followed the medieval plan of committing the work of his new house to a "chief mason," who in this case was one Joseph Pape, of Farnley.

The Renaissance style, which was only just then in West Yorkshire overcoming the traditional debased Gothic, was followed.

In the first week of May, 1706, the foundations of the new house were laid, and a few weeks later Walter, as his note-book shows, "went towards Newcastle" with the task of seeking the hand of Mistress Julia Blackett, the eldest daughter of the late Sir William Blackett, Bart., of Wallington, Northumberland, a wealthy benefactor of the borough of Newcastle. The note-book gives us curious details of the "labyrinth of difficultyes" which beset the matrimonial arrangements, arising partly out of "my lady's (Blackett's) greatness and magnificence," but mainly out of questions of settlement. In the following January the marriage took place, but it was not till September 1707 that Walter Calverley made entertainment to "all the neighbouring gentlemen and their ladyes" and two days later to "my tenants and neighbours and wives" "upon the account of my wife's coming to Esholt." So that probably that date marks the completion of the house.

Thoresby, the Leeds antiquary and historian, came over to Esholt, or, as it was then called, "New Calverley," in September 1711 and noted in his diary "the noble and beautiful house lately erected, to which Mr. Walter Calverley is adding gardens and waterworks, etc." Thoresby, of course, searched for relics of the monastery but was too late. "He could hear of none save Elizabeth Pudsey, the last prioress." A stone bearing that lady's name and some insignia still exists and is built into the wall of the laundry at the back of the hall. Towards the end of that same year 1711, Walter Calverley was made a baronet. For the rest his memoranda are mainly records of hospitality offered at Esholt to the great folk of the time, Ferdinando Lord Halifax (in the old building), Dr. Richard Richardson, the botanist and antiquary of Bierley Hall, Dr. Sharp, Archbishop of York, the heads of the families of Fawkes, Arthington, Dyneley, Hawkesworth, and others.

The only stirring passage in the history was the visit in disguise of Sir William Blackett, brother of Lady Calverley, in 1715. It was the time of the Jacobite rising, and the incident shows us the difficulties of the times. Sir William was "pursued by Mr. Forster and a great many Northumberland gentlemen who were then in arms against King George," readers of Sir Walter Besant's *Dorothy Forster* will remember the part which the Forsters played in this trouble. Their design was to force Sir William to join them, but "he was as much pursued by the King's forces, who suspected him to be in the rebels' interest." "He told me," says Sir William Calverley, "he was no ways concerned nor under any obligations to them, but was not willing to be taken for fear of being committed to prison." Calverley too seems to have been suspected of Jacobite tendencies, for on one or two occasions he was pointedly challenged to drink "A confusion to the Pretender, and all his adherents, and to all his open and secret friends," and on one occasion Esholt Hall was searched by the King's officers. It was unsafe ground, and Sir William Blackett was hurried off to security in London in the disguise of a countryman. He tramped across to Wyke, but was so tired when he got there that he bought a horse and took the risk such a possession carried with it.

The Blackett interests in Northumberland, which came by the marriage of Sir Walter into the Calverley family, so greatly exceeded in importance the Airedale interest that the son of the diarist became wholly a Northumbrian. He adopted his mother's surname and even sold his Yorkshire estates. The Calverley properties, including the ancient home of the family which had been the scene of the terrible happenings of the pseudo-Shakespearian drama *A Yorkshire Tragedy*, were sold to Thomas Thornhill, of Fixby, near Huddersfield.

Purchase by the Stansfields

For the Esholt estate he found, in 1755, a purchaser in Mr. Robert Stansfield, the youthful son and heir of a then very well-known and lately deceased Bradford drysalter, who for some years had been a keen competitor of Sir Walter Calverley in the acquisition of Idle and Thackley properties coming into the market. Robert Stansfield had previously been the owner of the Paper Hall, in High Street, Barkerend, but this he sold upon entering upon the more imposing home at Esholt. He died without issue, and the Esholt estate passed to a sister Anne, wife of William Rookes, of Royds Hall, and from them to a daughter Anna Maria, who married Joshua Crompton, of Derby. Their son, William Rookes Crompton, took the surname of Stansfield, but he had no children and at his death in 1871 it passed to a nephew, General William Henry Crompton Stansfield, whose daughters were the vendors of the estate to the Corporation.

It is rarely that a century-and-a-half of the history of a great landed estate sees so many descents by the female line. The circumstances are peculiarly interesting because of the old superstition, recorded by the antiquary Spelman, that the possessors of the properties of the dissolved monasteries were commonly "cursed" by the failure to continue their family through the male line. It is a superstition which has not sustained statistical examination, but such a line of descent as that shown by the lands of the Esholt nunnery is the sort of case to make the lover of the old fables fancy "there may be something in it after all." At all events, it may be hoped that the "curse" will not continue to operate in the case of the present owners, the citizens of Bradford.

The fine old oak staircase and the oak panelling "carved by a master hand" which were formerly in the hall are said to be now at Barrowby, Kirkby Overblow.

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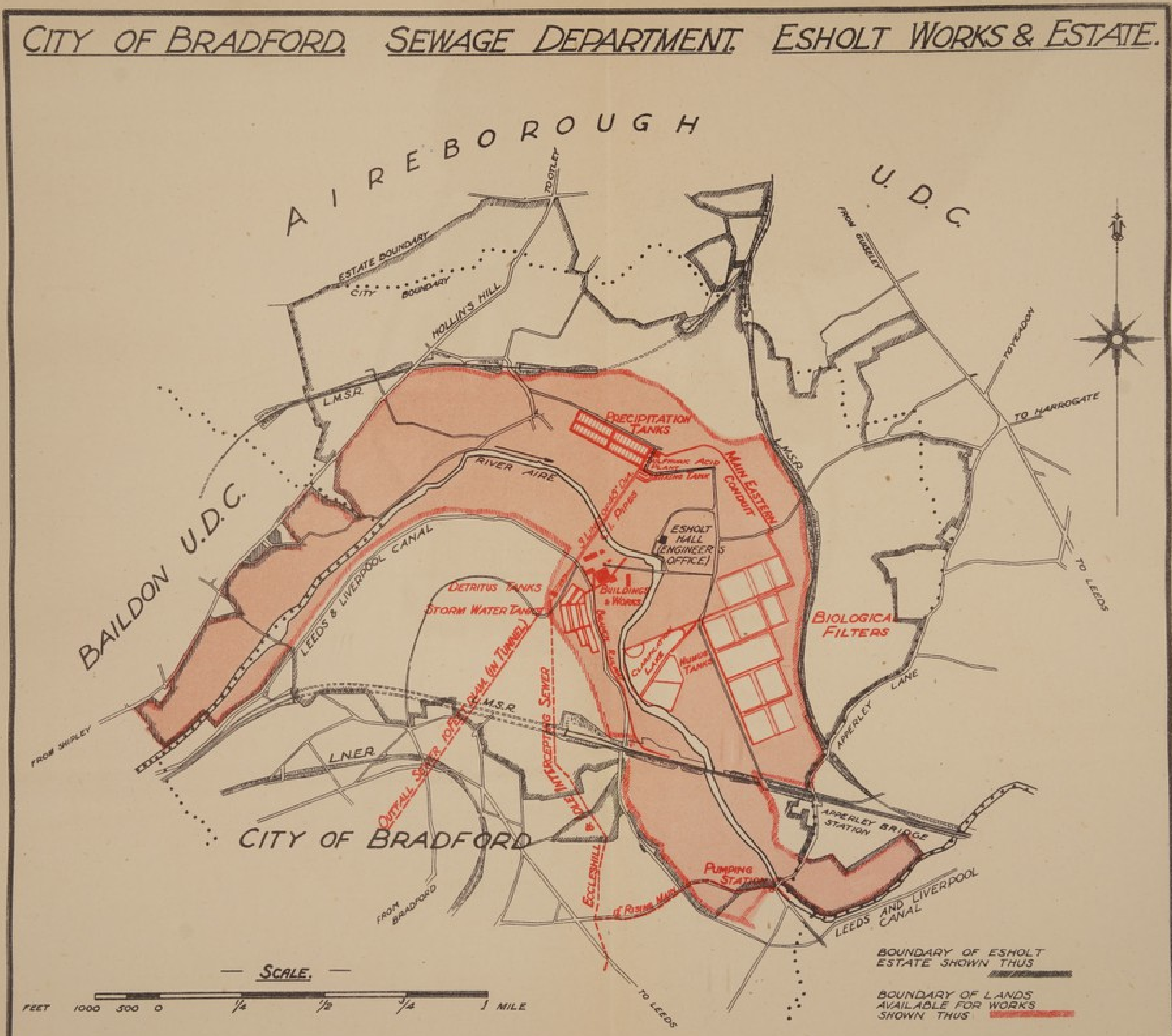
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FROM GUISELEY
TO YEADON
TO HARROGATE
TO LEEDS
L.M.S.R.
L.N.E.R.
RIVER AIRE
LEEDS & LIVERPOOL CANAL
PRECIPITATION TANKS
MAIN EASTERN CONDUIT
ESHOLT HALL (ENGINEER'S OFFICE)
DETRITUS TANKS
STORM WATER TANKS
BUILDINGS & WORKS
BIOLOGICAL FILTERS
CLARIFICATION LAKE
HUMUS TANKS
OUTFALL SEWER 10 FEET DIAM. (IN TUNNEL)
IDLE INTERCEPTING SEWER
ECCLESHILL
PUMPING STATION
APPERLEY LANE
APPERLEY BRIDGE STATION
LEEDS AND LIVERPOOL CANAL
FROM SHIPLEY
FROM BRADFORD
TO LEEDS
SCALE.
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BOUNDARY OF LANDS AVAILABLE FOR WORKS SHOWN THUS