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“Daily Fluctuation in Sewage-Flows.”

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It is important for the engineer engaged upon the design of sewerage works for a town or district to have some knowledge of the probable fluctuation in the rate of daily flow of sewage discharged at the outfall or the sewage-disposal works. As it is not always possible to have gaugings taken for plotting the curves of actual flow, reference has to be made to records taken from districts under as nearly as possible similar conditions. The curves shown herein have accordingly been selected from a number of actual gaugings of the rate of discharge, which were made in various districts in recent years, being plotted from measurements taken every 30 minutes, in all cases over 24 hours continuously.

For convenience of reference the curves have all been brought to a common basis, and plotted to a uniform scale; the maximum rate of discharge during the 24 hours has been taken as 100, and all other gaugings are worked out to a percentage of the maximum flow. By this means the fluctuation in the flow of a small district can be conveniently compared with those of a large district.

The districts of which the Figures give the curves of discharge are described in the Appendix.

Curves taken from rural districts are shown in *Fig. 1*. In these the fluctuation in flow where the population is scattered very much resembles what would be effected by a long outfall-sewer draining an urban district.

In curves (*a*) and (*b*) the districts are almost similar, but (*a*) has about 14 miles of collecting sewers and $1\frac{1}{2}$ mile of outfall sewer to the point of discharge; while district (*b*) has not much more than $\frac{1}{2}$ mile of outfall sewer and about 5 miles of collecting sewers laid.

In (*a*) the minimum flow is 40 per cent. of the maximum, while in (*b*) it falls to 30 per cent. In the former again the maximum flow occurs about the usual time, namely 11 a.m., whereas in the latter case this is delayed until about 2 p.m.

The period during which the flow exceeds 60 per cent. of the maximum rate of flow is in both cases about 14 hours out of the 24.

In curve (c) the circumstances are exceptional. This curve is taken from a district largely rural, with approximately 15 miles of collecting sewers laid. There are a few points where small villages are connected to the system, but the bulk of the sewage-flow is received at the extreme end of the district, about 3 miles from the outfall and point of discharge.

In addition to this, the leakage of subsoil water into the sewers is abnormally high, reaching from 30 to 50 per cent. of the total daily flow, according to the season of the year and the rainfall.

In this case the minimum flow is about 73 per cent. of the maximum flow, but it occurs between 8 and 11 a.m., while the maximum flow

Fig. 1.

RURAL DISTRICTS.

does not come on until about 3 p.m., and continues later into the evening than usual.

Curves showing fluctuations of flow of the most usual character are given in *Fig. 2*. These are from districts where, in addition to a closely populated central area, there is a suburban area of villa residences and cottages surrounded with garden ground. The gradients of the collecting sewers are moderately good, and the length of outfall sewer between the border of the built-on area and the outfall works is not unusually long.

In all three examples the subsoil is more or less of a similar nature, and the amount of leakage is not excessive.

In such cases there is only one period of maximum or rather high flow, usually occurring between 9 a.m. and noon. The minimum rate of flow during the night will be between 30 and 50 per cent. of the maximum rate of flow, depending largely upon the distance of the built-on area from the point of discharge, the length

of the outfall sewer, and to a certain degree upon the amount of subsoil leakage into the sewers.

In curve 2*b*, the outfall sewer has a length of 1 mile, and part of the district having considerable elevation the gradients are good, with the result that the contrast between the minimum flow at night and the maximum in the day is more marked than in curve 2*c*, where the outfall sewer is over 2 miles in length, and the whole of the gradients of the district are flat. In the former curve the period of maximum flow comes on between 9 and 10 a.m., earlier than in the other, where the maximum rate of flow is not reached until about 11 a.m.

The whole curve, however, of (c) as compared with (b) is flattened out, due largely to the equalizing effect of the longer outfall sewer and the flatter gradients of the collecting sewers.

Fig. 2.

COMBINED URBAN AND SUBURBAN DISTRICTS.

In the districts represented by *Fig. 2*, the rate of flow usually exceeds 60 per cent. of the maximum rate of flow over a period of 14 hours out of the 24.

Curves from districts of a different character are shown in *Fig. 3*, and represent the case of a provincial town or urban district with a fairly closely built-upon central area, surrounded by a villa district. The difference in elevation of parts of the district is considerable, with the consequence that the gradients of all sewers are good and in some places steep.

The subsoil is clay, and there is consequently no leakage of subsoil water into the sewers. In addition, the points of discharge are situated close up to the built-on areas, so that there are no considerable lengths of outfall sewers between the collecting sewers and the point of discharge.

In this case the curves show a marked difference when compared

with those before described. The fluctuations in the rates of flow are much more pronounced, and the gaugings taken at the outfalls are much more subject to rapid variation. The difference between the minimum at night and the maximum during the day in this

Fig. 3.

instance varies between 10 and 30 per cent. of the maximum rate of flow, and the maximum rate of flow is higher than it would be from such districts as are represented by *Fig. 2*, owing to the quicker run-off of the sewage to the outfall. This has the effect of making two periods of high flow: one in the morning, and one in the afternoon.

Fig. 4.

In some cases the morning and in some cases the afternoon flow is the maximum, but both are usually quite pronounced.

The absence of a long outfall sewer or flat gradients in the drainage system has its effect upon the length of the period during which the high flow continues, and generally speaking in such cases

the period during which the rate of flow exceeds 60 per cent. of the maximum rate is not more than 10 hours out of the 24.

If curve (a) in *Fig. 3* had been from a district with moderately flat sewers and with a considerable length of outfall sewer, the minimum flow at night would in all probability have risen, while the curve of the two high flows would have combined, flattened down, and continued fuller, with a gradual fall, during the afternoon.

In *Fig. 4* the curves are taken from sub-districts of the areas represented by curves 2a and 2b.

Curves 4a and 4b are practically the same so far as leakage and nature of district are concerned, but in the former the sewers are laid with very flat gradients, particularly the main collecting sewer which passes through the district for about 2 miles. In the case of the latter, the gradients of the collecting sewers are fairly good.

Fig. 5.

The minimum rate of flow in (a), therefore, is about 65 per cent. of the maximum, while in (b) it is only about 33 per cent.

Curve 4 (c) is taken from a small sub-district very closely built upon, and one in which there are several public works and laundries. Due to these special circumstances, the curve does not follow the more usual lines of the other two.

The curve in *Fig. 5* has been drawn from the information contained in the Institution Proceedings,¹ and is comparable with the curves in *Fig. 2*.

The minimum rate of flow is about 37 per cent. of the maximum rate, and the curve is more equal and regular than any of those before mentioned; an effect due to the equalizing effects of the longer length of sewers and of the larger area drained.

¹ Minutes of Proceedings Inst. C.E., vol. clxxxi, p. 268.

From the foregoing remarks it would appear that, while the quantity of subsoil water finding access to a system of sewers has a certain effect, still, if not excessive, it does not materially alter the fluctuation in flow. This fluctuation is directly proportional to the length of outfall sewer and the ruling gradients of the sewers of the district. The flatter the gradients and the longer the outfall sewer the higher will be the percentage of night flow, and the more equal will be the flow during the 24 hours, the difference between the minimum and maximum rates of flow being reduced.

In a rural district where the points of contribution are widely scattered, the night flow may not fall below 50 per cent. of the maximum rate of flow.

Generally speaking, in an urban district with no exceptional length of outfall sewer and fair gradients in the collecting sewers, the night flow will be about one-third of the maximum rate of flow.

The Paper is accompanied by a tracing, from which the Figures in the text have been prepared, and by the following Appendix.

APPENDIX.

Fig. 1a.—Population : 3,500.

Water-supply : Say, 15 gallons per head.

Outfall sewer : $1\frac{1}{2}$ mile long.

District : Rural. Small class of houses and scattered. About 14 miles of collecting sewers, with considerable amount of leakage of subsoil water into the sewers, and trade waste from a brewery.

Subsoil : Sand and gravel.

Fig. 1b.—Population : 3,600.

Water-supply : 15 gallons per head.

Outfall sewer : Not more than $\frac{1}{2}$ mile in length. Built-on area more compact than *1a*.

Remarks : Same as *1a*, but district in part more of an urban character.

Fig. 1c.—Population : 6,100.

Water-supply : Say, 12 gallons per head.

Outfall sewer : There are about 15 miles of collecting sewers draining a rural district, at the extremity of which, some 3 miles distant from the point of outfall, there is a closely built-on area, chiefly small houses, which contribute the bulk of the sewage. The sewers are laid in water-logged ground, and a very large quantity of subsoil water finds access into them, the quantity of subsoil water varying, with the season, from 30 to 50 per cent. of the total flow.

Fig. 2a.—Population : 65,000.

Water-supply : 30 gallons per head.

Outfall : 1 mile from the main contributing areas.

District : Urban. Central portions closely built on, with a few public works, and surrounded by an area of suburban villa character.

Subsoil : Sand, gravel and clay.

Fig. 2b.—Population : 33,000 (sub-district).

Water-supply : 31 gallons per head.

Outfall sewer : About 1 mile from the boundary of the contributing area. Collecting sewers have good gradients.

District : Urban. Central portion closely built upon, a few public works, a brewery and dyeworks ; the greater portion of area is of the suburban villa character.

Subsoil : Clay and gravel.

Fig. 2c.—Population : 30,000 (sub-district).

Water-supply : 28 gallons per head.

Outfall sewer : About 2 miles from centre of the district, which is flat. Collecting sewers have flat gradients.

District : Urban, closely built upon. Chiefly small class suburban property. Few public works.

Subsoil : Sand and gravel.

Fig. 3a.—Population : 11,000.

Water-supply : 25 gallons per head.

Outfall : Close up to built-on area, and no long length of outfall sewer.

District : Urban, with few public works. Old-established and closely built on, surrounded by villa area.

Subsoil : Clay.

Figs. 3b-d.—Sub-districts. Particulars as in *Fig. 3a*.

(*b*) Population : 650.

This outfall drains a closely-built-upon part of the district, with a resident population employed in the town.

(*c*) Population : 7,000.

(*d*) Population : 2,500.

These outfalls drain areas more of a villa character, where a large portion of the population is non-resident throughout the day.

In all three cases the outfall sewer does not exceed $\frac{1}{2}$ mile in length ; the sewage disposal works being situated almost on the borders of the built-on areas.

Fig. 4a.—Urban district, portion of *2a*, with a population of about 12,000, taken at the boundary of the contributing area where the outfall sewer begins. The gradients are flat, and a considerable amount of subsoil water finds access to the sewers.

Fig. 4b.—Urban district, a contributory area of *2c*, with a population of 4,000 ; but in this case the sewers have much better gradients than district *2a*, and the amount of leakage is comparatively small.

Fig. 4c.—Urban district, a small contributory area of district *2a*, with a population of 900, and has practically no leakage ; closely built on ; small class of house, laundries, and works.

Fig. 5.—Population : 950,000.

Manufacturing City, with adjacent suburbs. Plotted from information given in the Institution Proceedings.