The township is, broadly speaking, a residential district, and the population is not likely to be dense. Forty persons per acre, using 80 gals. of water per day, with half of this drawn off in 8 hours, gives a flow per acre of something less than one-hundredth of a cubic foot per second. One hundredth c.f.s. was taken as the figure for sewage. It was possible to design a scheme dealing with sewage alone with comparatively small pipes, and at first sight this would seem the obvious plan for the township in its early stages of development. One difficulty which confronted us was the flat gradients required to get out of the valleys sloping towards the city.

It was necessary, in some cases, to take the trunk sewers through the ridge dividing watersheds at, of course, great depths. Though small diameter sewers would carry the sewage on reasonable gradients, when working against the disadvantages mentioned, much larger diameters were necessary, with the consequent increase in cost. These disproportionately large sewers would have too low velocities and would likely cause much trouble by prolonging the time the sewage must remain in the sewer. These considerations caused us eventually to abandon the idea of a separate system of sewers for most of the scheme.

In the separate system no allowance is made for rain water from roofs of houses, so unless the householders have

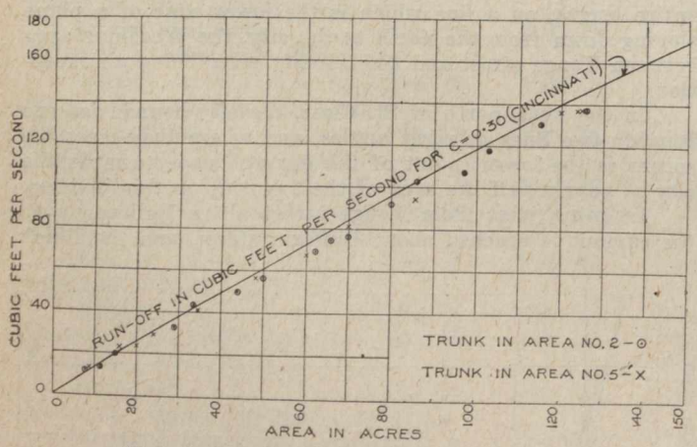

FIG. 3—STORM WATER RUN-OFF CURVE
Cincinnati Rainfall Intensity, $I = 16/(t)^{\frac{1}{2}}$;
York Township Rainfall Intensity, $I = 13.2/(t)^{\frac{1}{2}}$.

rain water cisterns and take advantage of this supply of soft water, flooding will occur on the lawns and yards.

If water is admitted to the sewers from the down pipes, the conditions are naturally changed. The sewers would receive benefit from the flushing caused by the increased quantity of water during rainstorms, which would be of assistance where the grades are flat, but on the other hand, the sewers would have to be much larger.

Investigation showed that six or seven houses was a fair average per acre, and the area of house-roofs would then be 0.075 of the total area. With a rainfall intensity of 1.6 ins. per hour, the run-off from roofs would be 0.12 cu. ft. per second per acre; that is, twelve times the dry weather flow. This "roofwater and sewage" in the same sewer looks like a pretty good scheme for the developing district, but like the "sewage only" scheme, it is not a final solution. There is still the storm water to deal with, from roads, lawns and backyards.

As a district gets built up, sidewalks are laid, pavement put down, and the proportion of land which will absorb rain as it falls becomes less. In time, every heavy rainfall will mean flooded ground. How is this to be dealt with? The trunk sewers of the system might be parallelled by additional trunks or relief sewers which would receive from the original trunks, by overflows, such excess rainfall which they could not carry, but the lateral sewers in each individual street would not be large enough to deal with the rainfall were connections to be made to them from the catch-pits, etc. So, to deal with the storm in addition to the sewage and roof water, it would be necessary to have a second sewer in each street.

These storm sewers might be laid in shallower trenches, and so be less costly, also their installation might be delayed for a good many years and so keep down the initial capital charges but on the other hand pavements would be cut up by them, and house connections already in might, in crossing, coincide with the adopted grade of the storm sewer and cause much trouble. There is also the danger of house drains being connected to the wrong sewer.

Where a district slopes towards a stream into which storm water can be discharged at many points on its course, that is to say, where nearly every street running towards the river could deliver its storm water into it, probably a separate system would be the least costly, both in the developing stage and ultimately. In York township the conditions are not very favorable to this system, for in most cases the outfall for storm water would be into the city area, into which it now flows from the land.

Rainfall and Run-off

In the district east of the Woodbine heights, in the Black creek area and in the Swansea district, it is possible to keep down the size of the main trunks by overflows at certain points. Short relief sewers taken from these overflow to the stream.

In the lower Black creek area immediately adjoining the creek, and in the lowest parts of Swansea where the lack of fall compel the use of pumps, sewage only is dealt with in the present proposal, as these areas lend themselves to the separate system, and short storm sewers could deal later with any part likely to be flooded.

A few reasons have been given for the adoption of the combined system and now it is necessary to ascertain what we may expect in the way of rainfall and run-off. The volume of storm water will be so large as compared with the sewage flow that it is, in most cases, unnecessary to consider sewage except from one angle, namely that of fixing gradients so as to make the sewers self-cleansing with dry weather flow.

Until comparatively recent times, rainfall gauges simply recorded the total fall, and if they were examined daily the record taken was that of the precipitation for each day, usually stated in inches.

This information is very useful in estimating the monthly or yearly yield of a catchment area for water supply or power development, but it is not of much use in sewer design. The object of a combined system is to get rid of the surface water as soon as possible and so prevent flooding.

Land in a natural state, with a fair slope, permits the falling rain to flow off in a film over the surface to the streams, and it also absorbs a great quantity which percolates directly into the soil, but with paved areas, etc., as in a city, less absorption takes place, the surface film is barred by artificial objects, and the result is that roads are converted into rivulets and flooding takes place in numerous localities before the water can reach the natural outlet in the stream.

Rainfall in Short Periods

The point, then, is not what is the total rainfall in a day but rather what happens every five minutes. Many cities now have self-recording rain gauges which give rainfall over short periods. From these we find that some storms may be so intense that ½ in. falls in one particular five minutes; that is, at the rate of 6 ins. per hour. A total precipitation of 6 ins. in 24 hours is a very severe storm.

Taking these short period gaugings, maximum rates have been found for 5 minutes, 10 minutes, etc., and so on over a period of years. The highest rainfall occurring in each year, or period of years, has also been found, and from this information it is possible to say, for instance, that every five years there may be a storm intensity of 4.7 ins. per hour lasting for a period of 5 minutes.

Fig. 1 is for rainfall in the city of Buffalo. The Toronto records so far as they go correspond very closely with