Storm run-off from urban areas

M. V. KING

Mr D. K. McKenzie, late Chief Engineer, East Barnet UDC

Mr King's method is based on three unjustified assumptions.

36. In only a limited number of cases can the area/time diagram be considered to be a straight line. Both regularity and extreme narrowness of the impermeable area are necessary for such an assumption.

37. The development of a single storm to represent or approximate to Bilham's formula is a misrepresentatian of that formula which gives the frequency with which an amount of rain will fall in a given time. If the RRL formulae are considered to be reasonable approximations to Bilham, the Lloyd–Davies method (which logically includes the tangent application) is the only current method which correctly applies the Bilham formula.

38. Design by a combination of a storm with a pronounced peak and an assumption of uniform proportional depth is bound to result in excessive allowances for storage and underestimates of the peak run-off. Such design does not necessarily result in well tapered sewers. In any case, where two sewers meet having different times of concentration, the pipe below the junction has a capacity less than that of the two contributing pipes. The interval between the peak flows in the two pipes approximates to half the difference between the times of concentration. At no time would uniform proportional depth occur throughout the system.

39. In the Road Research Technical Paper No. 55,[1] particulars are given (pp. 52 and 53) of storms in two adjoining areas at Oxhey numbered 1 and 11 with times of concentration of 5·8 and 20 min respectively. A study of these pages indicates that:

(*a*) the interval between the peak flows in the two systems is about 7 minutes;
(*b*) when the peak flows occur at the outfall of No. 11, the flow in No. 1 is less than half the peak;
(*c*) the deficiencies recorded for the Lloyd–Davies method for Area No. 11 of 23% and 21% can be accounted for:
  (i) in the case of the storm of 5 November, 1955, because the effect of storm has a duration of 7 or 8 min, the peak flow occurring before the whole area is contributing (this illustrates Lloyd–Davies' insistence on a check being made of the effect of a storm of higher intensity on part of a drainage area, cutting off a part distant from the design point);
  (ii) in the case of the storm of 19 October, the deficiency is due to the fact that the storm as a whole has a much lower frequency than that part from which the run-off was calculated.

40. It is considered that a re-examination of the available evidence would justify the continued use of the procedure laid down in the first edition of the Standard Code of Practice.

Mr B. B. Willetts, Dept of Engineering, Marischal College, Aberdeen

By making a number of approximations which are good for well designed sewerage of an area of regular shape, the Author has been able to produce a mathematical

Paper published: *Proc. Instn civ. Engrs* 1967, 37 (May) 43–56.

solution for the run-off from an urban area. In the writer's opinion, this solution offers a design method which under some circumstances is likely to be preferable to the RRL method, to which it is closely related. The Author is to be congratulated. It is particularly interesting that this development comes from the same department as did the Lloyd–Davies method.

42. Does the Author propose his method for systems of the same range of size as has been found suitable for application of the RRL method? Perhaps using the approximation of § 29 for retention, this method may be fast and simple enough to replace that of Lloyd–Davies in the design of sewers too small for the RRL method to be viable. Has the Author examined its usefulness and reliability in this area?

43. In § 34 the Author considers that the labour involved in using this method 'would not be appreciably greater than that required for a computer program'. Since a library program would clearly be used for most problems of this type, perhaps the claim is that this method calls for little more work than the provision of data for an existing program?

44. It is disappointing that figures of run-off obtained using this method were compared only with figures calculated by the RRL method (presumably using the same storm profile). Are any measurements of run-off being made to provide data against which design predictions can be checked? Birmingham would appear a good place to do this because of its size and heterogeneous topography must contain a wide variety of drainage areas.

45. In §§ 26–31 the Author has presented a very simple procedure for the calculation of y_{max}. One can envisage such a method being used by many people who have not the ability or persistence to follow the careful argument by which on preceding pages it was developed and who, therefore, may apply it injudiciously. Comparison of Fig. 1 with Fig. 35 of Road Research Technical Paper 55 is sufficient to indicate the magnitude of the errors which are possible if this is done. Perhaps when the method is used by staff who are not professional engineers, a 'ready-reference' list of assumptions and approximations should be provided so that the advice of an engineer is sought in doubtful cases.

46. Has the Author anything to add to the controversy on the 'travelling storm'? A storm which travels down the drainage area in the direction of flow and at approximately the speed of flow in the sewer is held by some engineers to give rise to a greater peak flow than a storm which traverses the area transversely. Is it not true that the present method, and the RRL hydrograph method from which it derives, both calculate run-off for rainfall which varies with time, but at a given time has the same intensity everywhere in the drainage area. Delays in the sewer will produce from this circumstance a pattern of run-off broadly similar to that of a storm which moves transversely. It is considered that the calculation might predict too low a peak flow for an elongated area in which drainage is from SW to NE.

Mr M. V. King,

Some of the points raised refer to Road Research Technical Paper No. 55. Any views expressed in connexion with that Paper are my own interpretation of it.

48. Mr Mackenzie's first remark concerning the justifiability of assuming linearity of the area/time diagram seems to be rather over-generalized.

49. Essentially, the shape of an area/time diagram depends not only on the shape of the drainage area but on the size, layout and, in particular, on the gradients of the sewers also. The most common shape of drainage areas is that of a segment of a circle draining to the centre. If there are a sufficient number of radial sewers along which the rates of flow are constant, the area/time diagram will be a parabola inclining upwards. However, in reality, the rates of flow in the smaller, upstream sewers are generally lower than those in the larger, downstream sewers. This has the effect of flattening the parabola and producing the usual S-shape.

50. Again, this is probably carrying generalization too far. It is possible that the narrow drainage area mentioned would produce a linear area/time diagram but this is not necessarily so. Extreme variations in sewer gradients could produce diagrams of varying shapes. However, it is my experience that the great majority of these diagrams are very nearly linear even for areas of unusual shapes and with discontinuations.

51. With reference to Bilham's formula, whilst not attempting to detract in any way from the excellent work done by Bilham, the Meteorological Office storm profiles are not intended to represent his formula, although in fact as far as total rain falling in a specified time is concerned, there is good correlation. The Meteorological Office have discovered that high intensity storms can have a pronounced peak. If there are two storms of equal duration and delivering the same total rainfall, but one has a peak and the other is of uniform intensity, then the storm with the peak will give the greater peak run-off. Storm hydrographs represent a particular storm which occurred on average once in the specified time interval and contains the worst set of conditions for all times of concentration.

52. Mr Mackenzie is correct in his criticism of assuming uniform depth distribution for design with a storm profile. Clearly, when the peak of run-off is occurring at a downstream point with a long time of concentration, the peak has passed at upstream points and upstream sewers are not running full. The RRL method takes no account of this and therefore overestimates retention and consequently underestimates run-off but, in the Paper an attempt is made to modify retention as set out in §§ 26 and 27.

53. However, retention in the large valley sewers is very much greater than in smaller upstream sewers and so these errors are not as great as they may appear. The assumption of a linear flow-retention relationship is based upon uniform depth distribution but is also supported by recorded recession curves.

54. In order to incorporate into a computer program a modification for changing retention in upstream sewers, it would be necessary to introduce a facility for guessing the peak run-off time for the design point and then checking to find out if this time is in fact correct after taking account of the modified retention in upstream sewers. This would be an added complication to the already quite complex step-by-step program and would perhaps tax the ingenuity of even computer programmers.

55. With reference to the two storms at Area No. 11, Oxhey, mentioned in Road Research Technical Paper No. 55, the theoretical hydrographs, modified for retention, agree well with the recorded hydrographs. The unmodified hydrographs, which of course were not published, are in reality the Lloyd-Davies theory applied to an actual storm. The conclusion seems obvious.

56. Design by using a method incorporating a modification for retention as opposed to the Lloyd-Davies theory indicates that, for very flat systems with average gradients between 1/500 and 1/1000 there is considerable reduction in peak flow of perhaps 25%; for areas with gradients between 1/200 and 1/500 the reduction is of the order of 10%; and for areas with gradients of about 1/100 or steeper there is no reduction. This last case occurs because the retention is only sufficient to nullify the effect of using a storm profile with a peak as opposed to a uniform intensity storm. Such a situation probably causes some people to conclude philosophically that research 'goes in circles', perhaps because philosophising is a little easier than more thorough consideration.

57. I would like to thank Mr Willetts for his kind remarks and for his constructive comments.

58. The method has been produced mainly with large sewers in mind but is applicable to smaller sewers also. However, the reduction in flow entailed by modifying for retention very rarely produces a reduction in size of smaller sewers because the usual 3 in. size difference is too large in this range.

59. As far as completely new sewerage systems are concerned, the work involved is roughly the same as is required to provide the data for the RRL computer program. The difference is that the results are immediately available and that there is no delay. Also it seems very rare for a complete, detailed new system to be designed all at the same time. Generally, the valley sewers have to be designed and even built whilst architects, etc., are still deciding on the layout of buildings and roads. This means that it is perhaps more logical to use a less meticulous method.

60. When dealing with the existing systems, the RRL method requires a great deal of information, i.e. the size and gradients of all the sewers between every manhole. It is a fact that many local authorities have little or no information about their sewers, especially when these are old, and obtaining this information is a very lengthy and tedious business. Calculating the time of concentration and estimating the retention as described in § 29 is relatively easy.

61. Checking the method against actual recording is not considered necessary, as the general theory of modifying for retention has been checked, apparently conclusively, at the Road Research Laboratory. Also, the work involved in setting up and maintaining accurate rain meters cannot be undertaken by an overworked local government department.

62. Regarding the way in which various people may calculate y_{max}, the only problem is the calculation of retention at peak flow, and this is very largely a matter of commonsense and does not require a knowledge of the mathematics which produced the design Figs 6 and 7. A list of assumptions and approximations would be a good idea.

63. Speculation about 'travelling storms' would seem to be beyond the scope of the Engineer and of concern only to the Meteorological Office.

64. It is perhaps rather unlikely that a storm of sufficient intensity and duration to produce high flows will occur at the same time as those wind conditions which will produce movement in the right direction and at the right speed to produce higher flows than expected. The chance of such a combination must be rather remote. Furthermore, thunderstorms, which are the design storms for urban areas, do not generally seem to occur when the weather is particularly windy.