

Oxford University Computing Laboratory

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ICL 1900 Civil Engineering and Building
General
Storm Sewer Design and Analysis
3rd Edition 1972

4289

CIVIL ENGINEERING & BUILDING

General.

Storm Sewer Design & Analysis 3rd Ed. 1972

1900

MANUAL (NOTICE NO.)

21/6/72

4289

STORM SEWER DESIGN AND ANALYSIS (1)

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NEW VERSIONS

New versions of the Storm Sewer Design and Analysis program will be issued as follows:

Magnetic tape version *E.D.S. version*

#X3C1/15	#X3B1/7
#X3C2/15	#X3B2/7
#X3C3/15	#X3B3/7
#X3C4/15	#X3B4/7

These programs correct the errors described in the Software Notices 1900/54, item 95 and 1900/55 item 96.

The program will print the highest peak of an input hydrograph as the peak flow of the subarea. The calculation will no longer fail when the dimension of the pipe exceeds 2896 mms.

The programs have been amended so that a system of pipes can now be numbered 1.0, 1.1, 1.2 etc., or 1.00, 1.01, 1.02 etc., or 1.000, 1.001, 1.002 etc., as described on page 8 of the manual.

ERRORS IN THE MANUAL

Certain errors have been discovered in the manual, as detailed below.

Page 8

The list of pipe numbers at the end of the first paragraph should read:

1.00, 1.01...1.09, 1.10, 1.11... or
1.000, 1.001...

The paragraph following the heading *Determining pipe dimensions* does not give an adequate description of the action of the program in analysis mode. When a pipe is overloaded, the program prints the existing size of the pipe and the *surcharge*, which is defined as the ratio of the capacity of the original pipe to the capacity of its size increased to remove surcharge. Calculations for downstream pipes are based on the assumption that the surcharged pipe has been enlarged sufficiently to cope with the surcharge.

If the user wishes to analyse an existing system and does not want surcharge to be passed downstream as described in the previous paragraph, then he should specify maximum pipe dimensions and gradients (see the section *Maximum pipe dimensions and gradients*, page 9) for all pipes and run the package in redesign mode. In particular, if the maximum pipe dimensions and gradients specified are the same as those of the existing system, then any pipe size increase or gradient change will be prohibited. The program will assume that any surcharge will be cleared by the water overflowing at the upstream end of the pipe and leaving the system.

Pages 14 and 22

Maximum dimensions and gradients may be specified only in redesign mode, not design mode as implied by the first paragraph of page 14 and the second line of page 22.

Page 25 and 27

In the sections *Use of peripherals*, TY0 should be specified as being used by all programs other than #X3x3. Its use is optional for #X3x2. (x is B or C, as appropriate.)

Page 43

The reference to Figure 6 in the third and fourth paragraphs are inaccurate. The hydrograph for pipe 1.10 is stored during calculations of branches 4, 5 and 6. The combined hydrograph of branches 1 and 4 is then stored during calculation of branches 7 and 8. If the simple branch 6 were numbered as branch 4 and the more complex branch ending at pipe 4.2 had been numbered as branches 5 and 6, the number of hydrographs to be stored would have been increased by one.

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STORM SEWER DESIGN AND ANALYSIS (2)

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Some users of the package have experienced difficulties in deciding on the order of numbering of branches within pipe systems. The following points should be noted in conjunction with the account of pipe numbering given on page 6 of the manual. The branch number is defined as that part of the pipe number preceding the decimal point.

- 1 At any point in the system, no two inlet pipes may have the same branch number, but the outlet pipe must have the same branch number as the lower branch-numbered inlet pipe.
- 2 If two branches join a given branch, then the junction with the lower numbered branch must be at the same point as, or preceding, that with the higher numbered branch.
- 3 If two branches with non-consecutive branch numbers join at a point, then water from any branches with intervening branch numbers must flow directly or indirectly to that same point.

When a sub-area is to be analysed or redesigned, the Time of Concentration specified in the sub-area must be greater than or equal to its associated Time of Entry.

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STORM SEWER DESIGN AND ANALYSIS (3)

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USE OF INPUT HYDROGRAPHS

During the calculations, the program examines each calculated hydrograph to check that the flow of water is large enough to be significant. If the rate of flow is less than 10^7 cusecs (or cu. ms/sec) throughout the first 50 minutes from the start of the rainfall, then the flow from that pipe will be ignored.

Under normal circumstances, this situation only occurs when either the permeable area associated with the pipe and all upstream pipes is negligible or the time of entry is very large.

Difficulties may arise with pipes downstream of a subarea for which a hydrograph is being input, under the following circumstances:

- 1 An approximate version of the hydrograph is input, giving values near the peak accurately and values near the ends as zero, and the first non-zero value input is for a time later than 50 minutes.
- 2 The pipe immediately downstream from the subarea (and any other pipes upstream of that pipe) has a zero permeable area.

Under these circumstances, the hydrograph calculated for the downstream pipe will also have zero flow for the first 50 minutes and so the entire flow from the pipe will be ignored by the program.

To ensure that such a situation does not occur, input hydrographs should include a value greater than 10^7 cusecs (or cu. ms/sec) at or before the time 50 minutes.

ORDER OF PIPES IN INPUT DATA

The last pipe input to the program must be the outfall pipe of the sewer network; otherwise an execution error will occur in the calculation program.

ERRORS IN MANUAL

The *surcharge* of a pipe, as output by the program, was wrongly defined in User Notice (1). The surcharge is the ratio of the capacity of the original pipe to the corrected maximum rate of run-off (peak rate of flow) for a pipe of adequate size to remove the surcharge.

Certain items listed in the section *Results output for each pipe*, page 21, may be amplified as follows:

- 1 The time of concentration (first line, item 3) and the cumulative pipe volume (second line, item 2) are as input for a non-surcharged subarea; for other cases, the calculated value is related to the pipe size which is sufficient to accommodate the inflow.
- 2 The peak rate of flow (first line, item 7) is for the pipe size large enough to allow all the inflow to be passed downstream.



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STORM SEWER DESIGN AND ANALYSIS (4)

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NEW ISSUES

New versions of the Storm Sewer Design and Analysis program will be issued as follows:

Magnetic tape version *E.D.S. version*

#X3C1/16	#X3B1/8
#X3C2/16	#X3B2/8
#X3C3/16	#X3B3/8
#X3C4/16	#X3B4/8

These programs have been amended to correct an error described in the Software Notice 1900/OTHER ENGINEERING APPLICATIONS AND MISCELLANEOUS/64, item 108.

Due to the incorrect data input unit conversions, this error produces an incorrect result when the units of any 18th pipe input (from the first onwards) are different from those of the first pipe.

ERROR IN THE MANUAL

The rainfall formulae, based on metric units, given on page 1 and 2 are incorrect.

The rainfall during the first t hours of a storm of frequency N should be calculated by the Bilham formula as follows:

$$\frac{10}{N} = 1.25 t \left(\frac{r}{25.4} + 0.1 \right)^{-3.55}$$

in which r is the rainfall in millimetres.

Hence, where $r_{15}(N)$ is the rainfall during the first 15 minutes of the storm of frequency N ,

$$r_{15}(N) = (3033.9N)^{0.2817} - 2.54$$

and

$$k = \frac{(3033.9N)^{0.2817} - 2.54}{(3.033.9)^{0.2817} - 2.54}$$

or

$$k = ((3033.9N)^{0.2817} - 2.54) / 7.0285$$

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STORM SEWER DESIGN AND ANALYSIS (5)

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NEW ISSUES

New versions of the Storm Sewer Design and Analysis program will be issued as follows:

Magnetic tape version

E.D.S. version

#X3C1/17
#X3C2/17
#X3C3/17
#X3C4/17

#X3B1/9
#X3B2/9
#X3B3/9
#X3B4/9

Four modifications have been made to the programs:

- 1 The error which causes the calculation programs (#X3C2 and #X3B2) to loop has been corrected.

Software Notice 1900/69, item 113 is now cancelled

- 2 If the time of entry plus the time of flow in a pipe exceeds 80 units of incremental time, the following message will be printed on the console.

"TIME OF ENTRY PLUS TIME OF FLOW IN PIPE
(n) EXCEED 80 INTERVALS PROG.HALT"

This pipe will then be treated as a pipe which exceeds the time limitation taken to reach the peak flow. The calculation programs will be terminated with the results detailed on page 22 of the manual.

- 3 The peak flow which an egg-shaped pipe can carry has been increased.
- 4 The error published in Software Notice 1900/72, item 116 has been corrected.

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STORM SEWER DESIGN AND ANALYSIS (6)

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Some users of the package have experienced difficulties in analysing the output values of a surcharged sub-area. The following points should be noted.

- 1 The time of entry is known as the time delay when the whole impermeable catchment is contributing to the flow in the pipe.

The impermeable area contribution to the flow is assumed to increase linearly with time from the onset of the storm until after the lapse of a time known as the concentration (when the entire catchment area is contributing to the outfall of that particular pipe). If there is no change in the time of entry for the particular pipe and its upstream pipes, the time of concentration is equal to the time of entry plus the longest possible time of flow through the pipe network to the outfall of the pipe under consideration.

- 2 The calculations carried out by the program in the case of a sub-area are as follows:

- (a) Compute (initial) full bore velocity for pipe size specified in data
- (b) Compute (initial) time of flow in pipe being considered = specified time of concentration less the time of entry
- (c) Compute equivalent pipe length = (initial) time of flow times (initial) full bore velocity.

If surcharge is present and excess water is not to be overflowed, the following additional calculations are carried out:

- (d) Either the size or the gradient of the pipe is increased according to the user's requirement
- (e) The new cross-sectional area or the hydraulic gradient parameter is computed
- (f) The new full bore velocity is computed.
- (g) The new time of flow is computed from the equivalent pipe length divided by the new full bore velocity
- (h) If the size of the pipe is increased the new volume is computed from the new cross-sectional area times the equivalent pipe length.
- (i) Items (d) to (h) are repeated until the surcharge is cleared.

The effect is that the input cumulative pipe volume need not be altered for a non-surcharged sub-area. If the size of a surcharged pipe is being enlarged, the volume of the pipe should be recalculated. The new pipe dimensions and its computed equivalent pipe length are used in the calculation of the new pipe volume which bears no relation to the input value.

- 3 The time of concentration of a surcharged sub-area is different from the input value, and the reason is as follows:

the equivalent pipe length

= initial time of flow through pipe times initial size full-bore velocity
= final time of flow through pipe times final size full-bore velocity.

Since the size or the gradient is being increased for a surcharged pipe, the velocity will increase. As a result, at constant length, the time of flow and hence the time of concentration will be decreased.

- 4 When using a sub-area, the following approximation is made. The outfall from the sub-area is assumed to come from a single pipe draining the whole impermeable area.

In practice a sub-area may be a subsidiary network containing a number of pipes of different sizes and lengths. The catchment areas contribute to the water flow in the outfall pipe of this subsidiary network in stages and at different velocities. A particular size of the outfall pipe may be big enough to accommodate the water flow when the subsidiary network is individually examined. However, treating the sub-area flow as coming from a single pipe may cause surcharge for the same particular size of outfall pipe.

If a hydrograph is specified as the input data for a sub-area, it gives the correct flow pattern of the subsidiary network.

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AMENDMENT TO THE MANUAL

Page 25

The job description on running under GEORGE 1 or 2 should read as follows:

JOB SEWNAL,24617,ANALYSER

1 DATA MT(PROGRAM X3ZC)

2 DATA CR0/0(NETWDATA)

IN 1

LOAD #X3C4

SWITCH ON 1

(Delete this line if the data is in Metric
units)

IN 2

ENTER

AT DELETED FI, GO TO 3

AT OTHER HALTED, END

3 IN 1

LOAD #

SWITCH ON 2

(Delete this line if Console typewriter output
for every tenth pipe is not required)

SWITCH ON 3

(Delete this line if Console typewriter output
for every pipe is not required)

ENTER

AT DELETED FI, GO TO 4

AT OTHER HALTED, END

4 IN 1

LOAD #

RESUME

END

DOCUMENT NETWDATA

...

...

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STORM SEWER DESIGN AND ANALYSIS (8)

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AMENDMENT TO THE MANUAL

Start of pipe data, page 12

The following should be added to the end of this section:

A blank line is not allowed in the data when the input is on punched cards.
If a blank card is included in the pipe data, the calculation program
#X3B2 will halt with execution error 50.

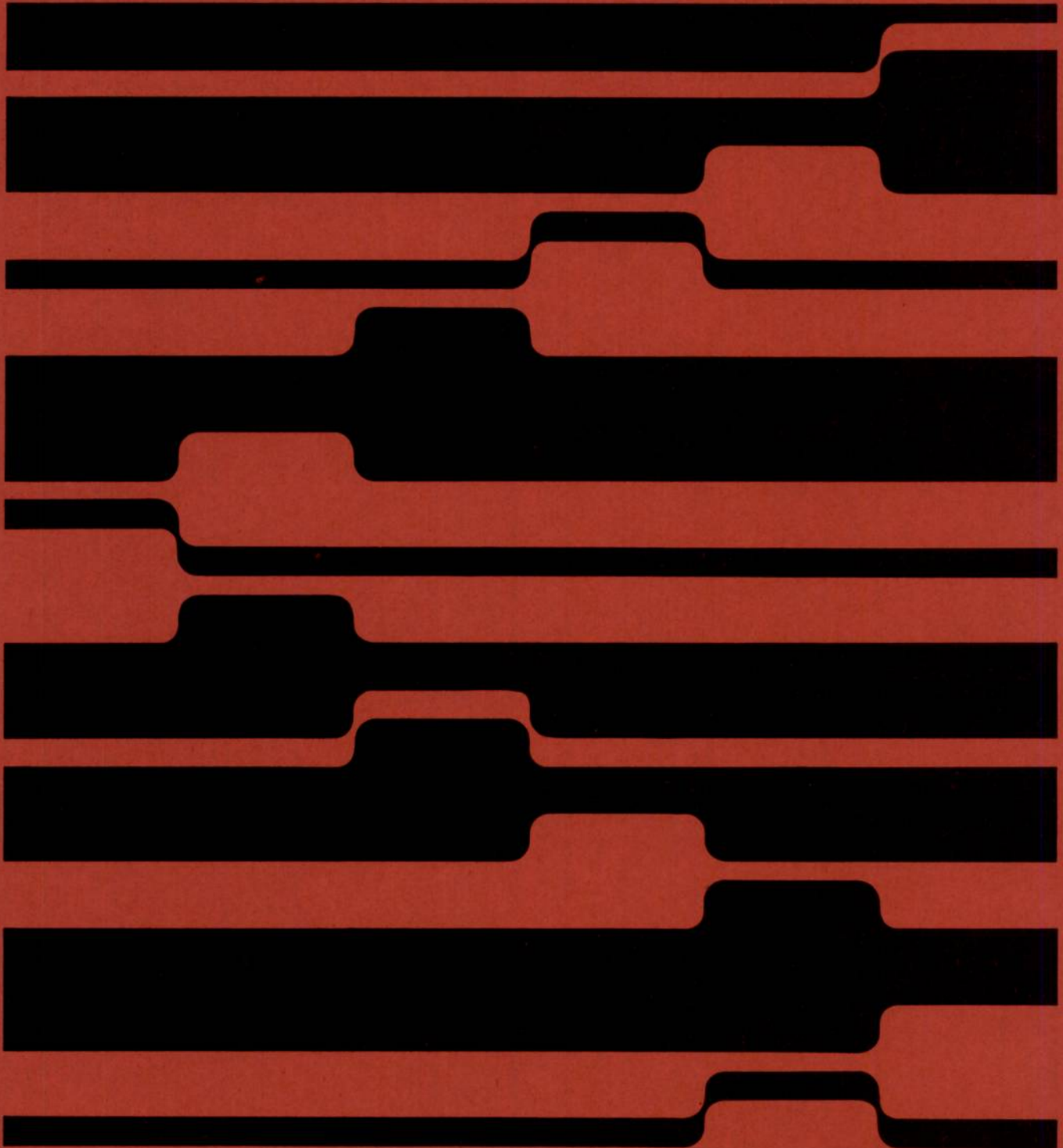
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1900 Series

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Preface

OXFORD UNIVERSITY COMPUTING LABORATORY
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The manual describes the ICL 1900 Series Storm Sewer Design and Analysis package, which contains facilities for analysing or redesigning an existing sewer network and for designing a new network which may, if required, incorporate existing pipes. Data input to the program may be in British or metric units.

The minimum computer configuration required to use this package is as follows:

- 1900 Series central processor with at least 16K words of core store
- 1 card reader or 1 paper tape reader
- 4 magnetic tape decks or 1 E.D.S. transport
- 1 line printer

The terminology used in this manual and the facilities available in the package are described in Chapter 1 of this manual. Chapter 2 describes the input required to use the package, and Chapter 3 describes the output which will be obtained. Chapter 4 gives the operating instructions required to use the package and other information which is primarily of interest to the computer operator and installation manager. Chapter 5 gives examples of input to and output from the package. Some supplementary information is given in Appendices.

ICL would like to acknowledge that the methods used in this program are fundamentally based on work carried out by the Road Research Laboratory and is grateful for the assistance of L.H. Watkins and C.P. Young of the Climate and Environment Section of R.R.L.

The following papers, referred to in this manual, may be of interest to users of the package:

The Design of Urban Sewer Systems Road Research Technical Paper No. 55 (S.O. Code 47-110-55)

Road Note No. 35 Road Research Laboratory (S.O. Code 47-141-35)

Hydraulic Research Paper No. 1 (S.O. Code 47-201-1)

Walton J.H. *A note on metrication and modular co-ordination of pipe dimensions* Clay Pipe Development Association Limited, November 1969.

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Chapter 1 Basic concepts

In urban areas, where the ground surface is generally paved, a network of sewers must be constructed in order to remove rain water from the surface and reduce the frequency of flooding. The package described in this manual will design a sewer network to limit flooding to an average frequency specified by the user.

The package may be used in one of three modes, as follows:

- 1 A proposed new system can be designed. Given the configuration and requirements of the network, the program will calculate the dimensions of each pipe. Existing pipes may be included in the system if required.
- 2 An existing system can be analysed. The program will indicate which pipes are overloaded and give a measure of the surcharge.
- 3 An existing system can be redesigned. The program will analyse the system, and for any overloaded pipes it will indicate the surcharge and calculate the correct size for that pipe by adding small increments to the cross-sectional area.

STORM FREQUENCY AND RAINFALL PROFILE

The two major parameters of a storm are its *duration* and its *magnitude*, the amount of rain that falls in the period of time taken as the duration of the storm. For any geographical region, the *frequency* of a storm of a given duration and magnitude is the amount of time that elapses, on average, between two periods of time (equal to the duration) during which the rainfalls observed are greater than or equal to the given magnitude. The *rainfall profile* of a storm specifies the variation of the rate of rainfall over the duration of the storm. In the design of a storm sewer network, the rainfall profile determines the changing rate of inflow to the various pipes.

The package described in this manual will design a sewer network to cope with the amount of rain corresponding to a given rainfall profile, and thus to a given storm frequency. Flooding is defined as occurring when the sewer network is unable to remove the peak run-off from its catchment area for any period of time. This will occur when the rainfall magnitude exceeds that corresponding to the rainfall profile of a given frequency used in designing the network, and thus the frequency of flooding is equal to the storm frequency for that magnitude.

Assumptions of the package

It is assumed that the rainfall measured at any point within the catchment area is representative of the rainfall over the entire area. A storm duration of two hours is assumed; this is long enough to cover all major rainfall events in the British Isles and in most other areas.

The package contains a standard rainfall profile. The values, obtained by the Meteorological Office, are based on measurements in Britain and correspond to a storm frequency of one year. This profile is given in Appendix 2, page 45. This profile will be used in analysing or designing the system unless the user specifies an alternative rainfall profile or an alternative storm frequency.

If the package is to be used for another part of the world, an equivalent rainfall profile for a storm frequency of one year should be input. However, the package can only be used when the only significant part of the rainfall is contained within the standard duration of two hours.

If a flooding frequency of one year is considered unacceptable another storm frequency, M , can be specified. In this case the values of the rate of rainfall for either the standard profile given in Appendix 2 or any other profile that has been specified are multiplied by a factor K given by:

$$K = \frac{r_{15}(M)}{r_{15}(1)}$$

where $r_{15}(N)$ is the rainfall during the first 15 minutes of a storm of frequency N as calculated by the Bilham formula:

$$\frac{10}{N} = 1.25t(25.4t + 0.1)^{-3.55}$$

in which r is the rainfall in mms. during the first t hours of the storm.

Hence:

$$r_{15}(N) = \left\{ \left(\frac{1.25N}{40} \right)^{0.2817} - 0.1 \right\} / 25.4$$

and

$$K = \left\{ \left(\frac{1.25M}{40} \right)^{0.2817} - 0.1 \right\} / \left\{ \left(\frac{1.25}{40} \right)^{0.2817} - 0.1 \right\}$$

or

$$K = \left\{ (0.03125M)^{0.2817} - 0.1 \right\} / 0.2767$$

STORM SEWER NETWORKS

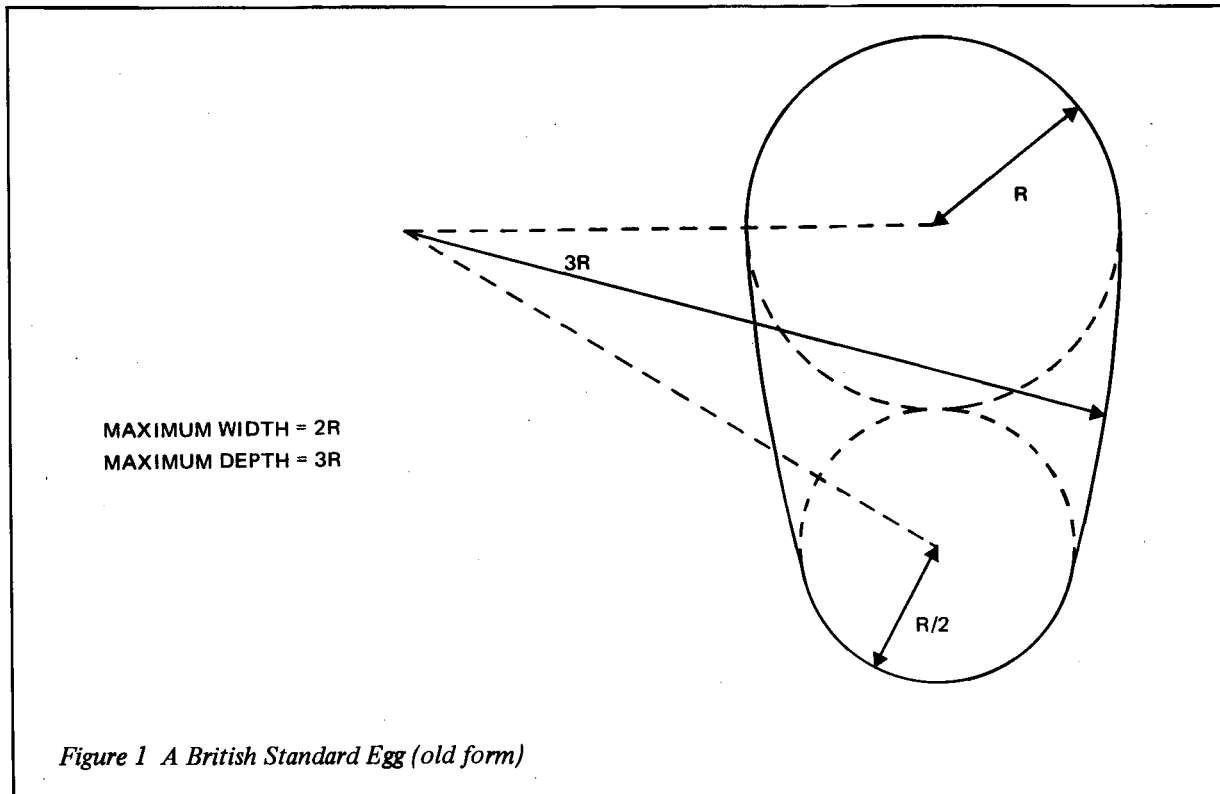
The network to be analysed by the package must be a tree structure except that any pipe may end in an overflow chamber which allows excess water to leave the pipe network. Thus loops and bifurcations in a pipe are not allowed: water entering a pipe must either leave it via one down stream pipe or else must leave the system from an overflow chamber.

Each pipe is associated with a catchment area: that is, the area of paved or impermeable surface draining directly into that pipe. Unpaved surfaces can, in general, be considered to be completely pervious and hence not to require storm sewer drainage. The outfall from any pipe is thus the sum of the outfalls of all pipes draining into that pipe and of the water reaching the pipe from its catchment area less any overflow from an overflow chamber.

Parameters associated with the pipes in a network

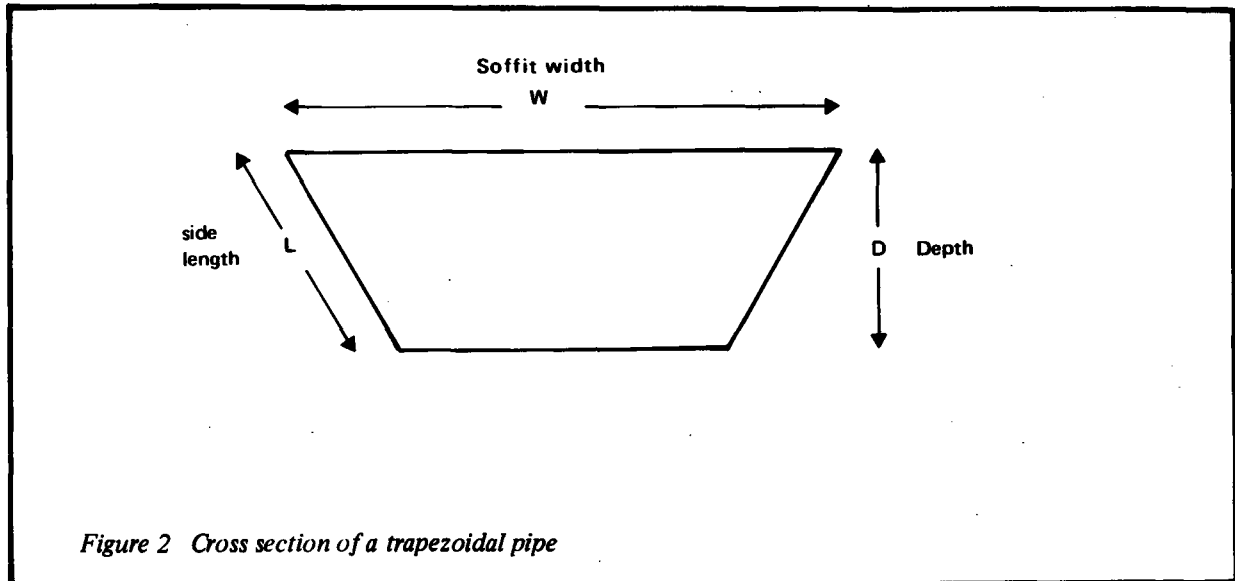
THE PIPE DIMENSIONS

If the user is analysing or redesigning an existing system, the pipes specified may be circular, trapezoidal or egg shaped. If he is designing a new system, the pipes may be specified as circular, rectangular or egg shaped. The dimensions of existing pipes are input to the package as data.



The cross-sections of all egg-shaped pipes are assumed to be of the shape given by the British Standard Egg (old form) shown in Figure 1. If the user specifies a non-standard egg shaped pipe, the program will accept the width given and approximate the depth to the nearest standard egg.

All trapezoidal pipes are assumed to be symmetrical about the vertical axis, and the dimensions to be input by the user are shown in Figure 2, below. The width given in the data is taken as that of the soffit level (i.e. the upper surface of the pipe) and the invert level (i.e. the water carrying surface) is taken to be narrower than the soffit level.



For each pipe in the system, the user must specify the pipe length, gradient and roughness coefficient; the time of flow in the pipe is determined from the full bore velocity calculated by the Colebrook-White formula given in *Hydraulics Research Paper No. 1* (S.O. Code 47-201-1).

THE CATCHMENT AREA

The user must specify the (horizontal) catchment area that is assumed to contribute to each pipe and the time of entry for the pipe. The whole impermeable catchment area is assumed to be contributing to the flow in the pipe after a time delay, equal to the time of entry, which allows for the time required for the water to reach the inlet from roofs, gutters, etc. The determination of the catchment area is discussed in *Road Note No. 35* Road Research Laboratory (S.O. Code 47-141-35).

THE PIPE HYDROGRAPHS

The program commences the analysis or design of a sewer system by considering one of the outermost pipes and calculating its uncorrected hydrograph: a graph of inflow to the pipe in cubic metres/second or cusecs. against time from the start of the rainfall in minutes. Allowance is made in this calculation for the dry weather flow in the pipe, and the area contributing to the flow is assumed to increase linearly with time so that the full area is contributing after the time of entry has elapsed.

The corrected hydrograph for this pipe can then be calculated by making allowance for the temporary retention of water in the pipe. A more detailed discussion of this point and of the other general principles used in the program is given in *The Design of Urban Sewer Systems* Road Research Technical Paper No. 55 (S.O. Code 47-110-55). The relationship between the two hydrographs is shown in Figure 3, page 4.

The program then examines the pipe to check that its capacity is sufficient to cope with the maximum flow expressed by the corrected hydrograph. If an existing system is being analysed, any overloading is recorded; if an existing system is being redesigned or if a new system is being designed, the size of the pipe will be increased in fixed increments until its capacity is adequate (see also the section *Determining pipe dimensions*, page 8).

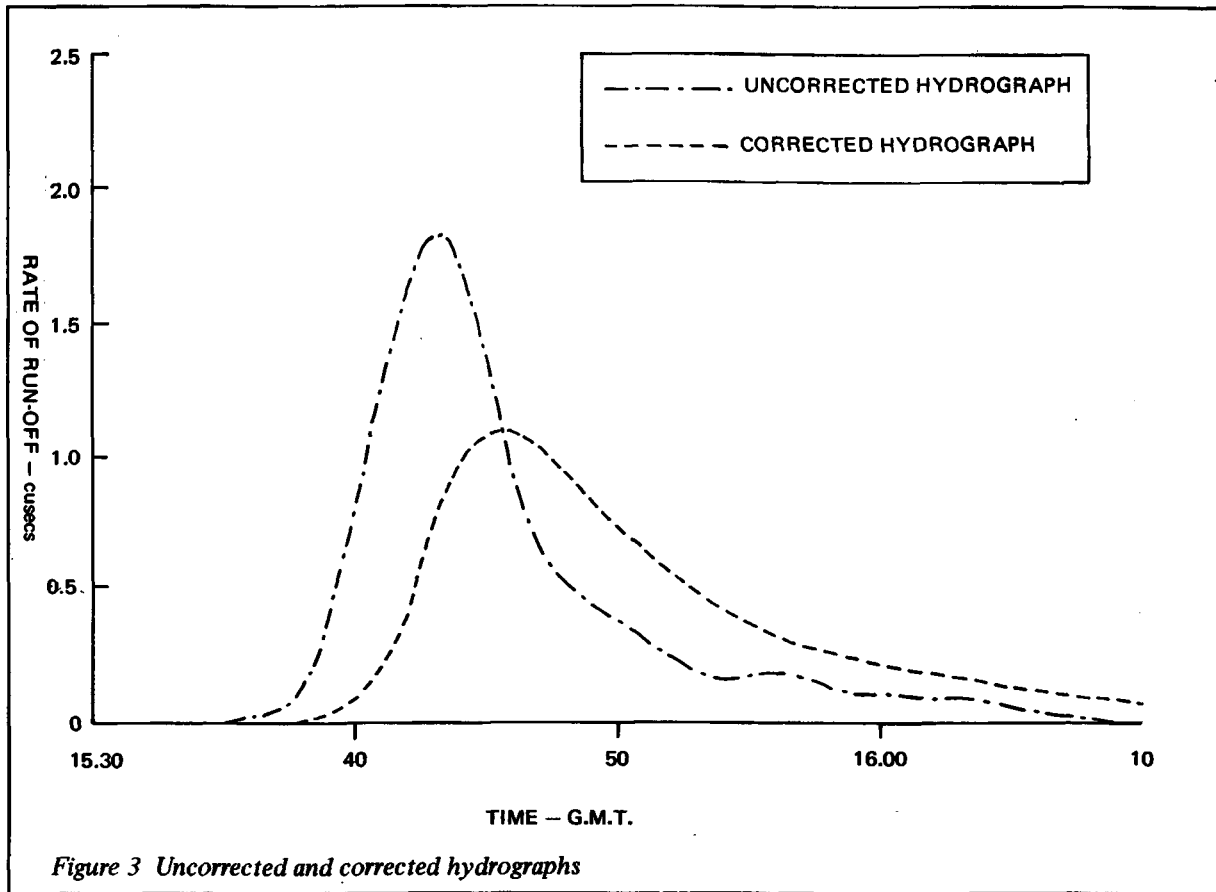


Figure 3 Uncorrected and corrected hydrographs

If the pipe ends with an overflow chamber the user must specify the maximum rate of outflow, Q , to the downstream pipe. If the maximum flow of the corrected hydrograph exceeds this value it is truncated as shown in Figure 4, below. The maximum overflow is the difference between the peak value of the corrected hydrograph and the value Q . No storage correction is made in the overflow chamber.

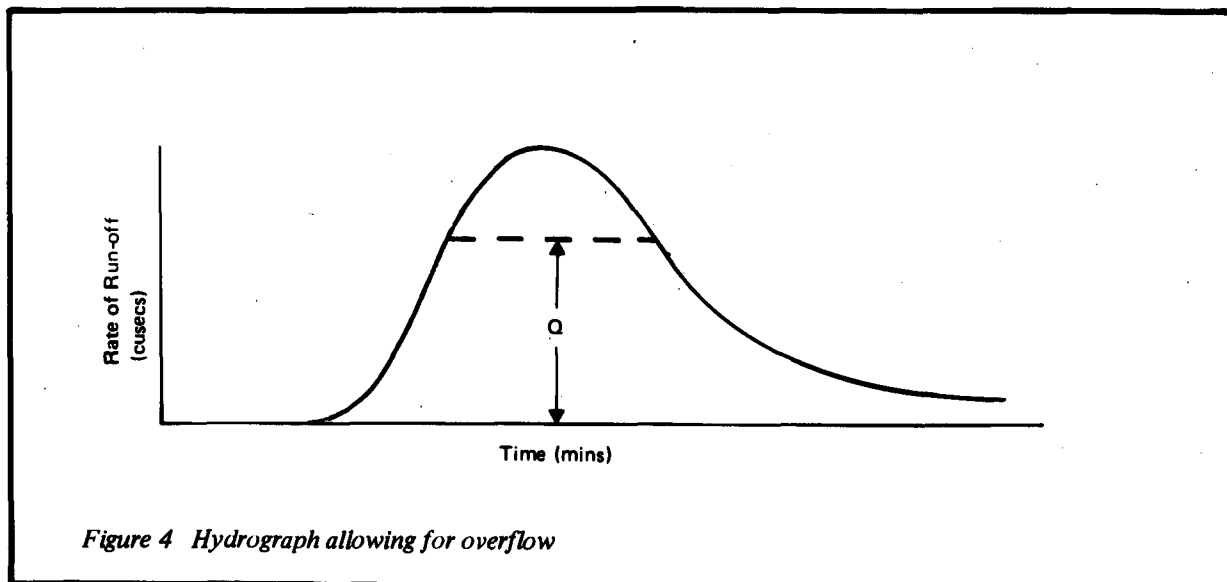


Figure 4 Hydrograph allowing for overflow

The calculations for the first pipe having been completed, the program then proceeds to compute the corrected hydrograph for the next pipe in the system. The order in which pipes are examined corresponds to the order in which they are specified (see the section *Specification of pipes and sub-areas*, page 6) and is such that the inflow pipes for any pipe are all considered before that pipe is itself examined.

If the second pipe considered is the outfall pipe for the first pipe, the outfall hydrograph for that pipe will contribute to the inflow. When the corrected hydrograph of the second pipe is known, the pipe capacity is checked as above.

The program proceeds through the sewer network in this way, computing the uncorrected and corrected outfall hydrographs for each pipe and checking the pipe's capacity, until the final outfall is reached.

The ordinates of the corrected hydrograph at specified time intervals may be output for any pipe in the network; if water is allowed to overflow from an overflow chamber both the hydrograph entering the overflow chamber and that leaving the chamber are output.

THE AREA-TIME DIAGRAM AND THE TIME OF CONCENTRATION

The total impermeable area contributing to the flow at any point in the network increases with time until, after the lapse of a time known as the time of concentration, all the catchment areas upstream of that point are contributing.

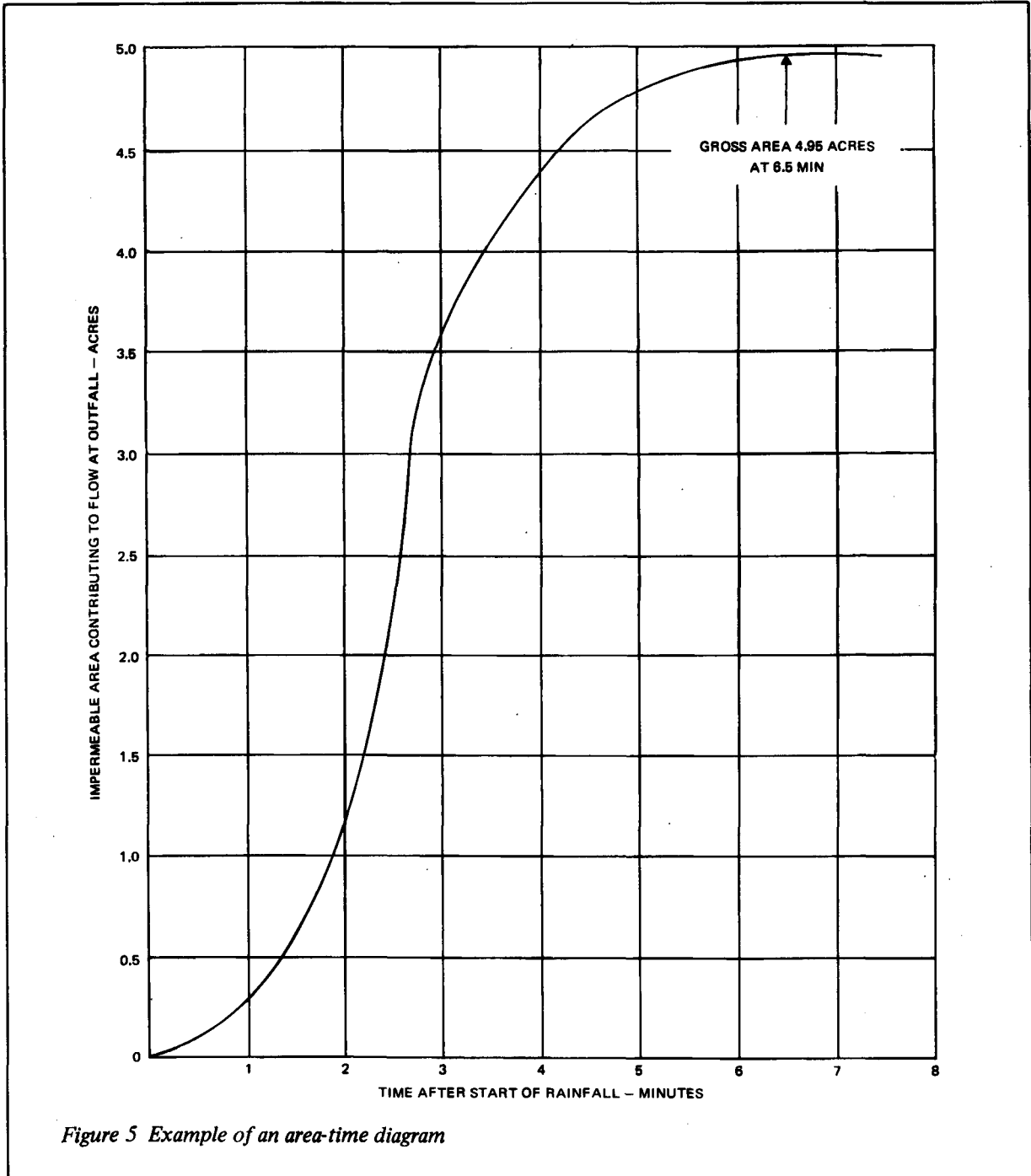


Figure 5 Example of an area-time diagram

The graph of the change in area with time is known as an area-time diagram; an example of an area-time diagram for an experimental area at Blackpool, quoted in Road Research Laboratory Technical Paper Number 55, is shown in Figure 5. The time of concentration, which in this example was 6.5 minutes, is dependent on the times of flow and of entry in the upstream pipes.

The ordinates of the area-time diagram at specified time intervals may be output for any pipe in the network; the time of concentration is always output.

For a pipe not at the upstream end of a branch in the network, the area-time diagrams for the upstream pipes are first added together to form an area-time diagram for the inflow point. The origin of this composite diagram is then moved by the time of flow in the pipe, to allow for the time taken for the water to pass from the inlet to the outfall; this is done by linear interpolation between the points of the diagram and has the effect of slightly increasing the apparent time of concentration. To the corrected diagram is added the diagram for the catchment area associated with the pipe, and the ordinates of this composite diagram are then printed.

THE CUMULATIVE VOLUME

This is defined as the total volume of the pipes upstream of a given point in the network, and is output for every pipe.

Sub-areas

When an existing sewer network is being analysed, small subsidiary networks may be represented as sub-areas. The user must specify the shape, gradient and dimensions of the outfall pipe, the dry weather flow in that pipe, and the time of concentration and cumulative volume for the pipe. The catchment area should be given as the whole sub-area. The outfall from the sub-area is then treated as the outfall from a single pipe and is included in the hydrograph for the downstream pipe in the usual way.

Existing water courses

If water from an existing water course enters the sewer system, its hydrograph can be input to the program (see the section *Hydrograph input* on page 13). Such an input hydrograph is processed by the program as though it were the outfall hydrograph from a sub-area, and the water course must be specified (see below) as if it were a sub-area.

Specification of pipes and sub-areas

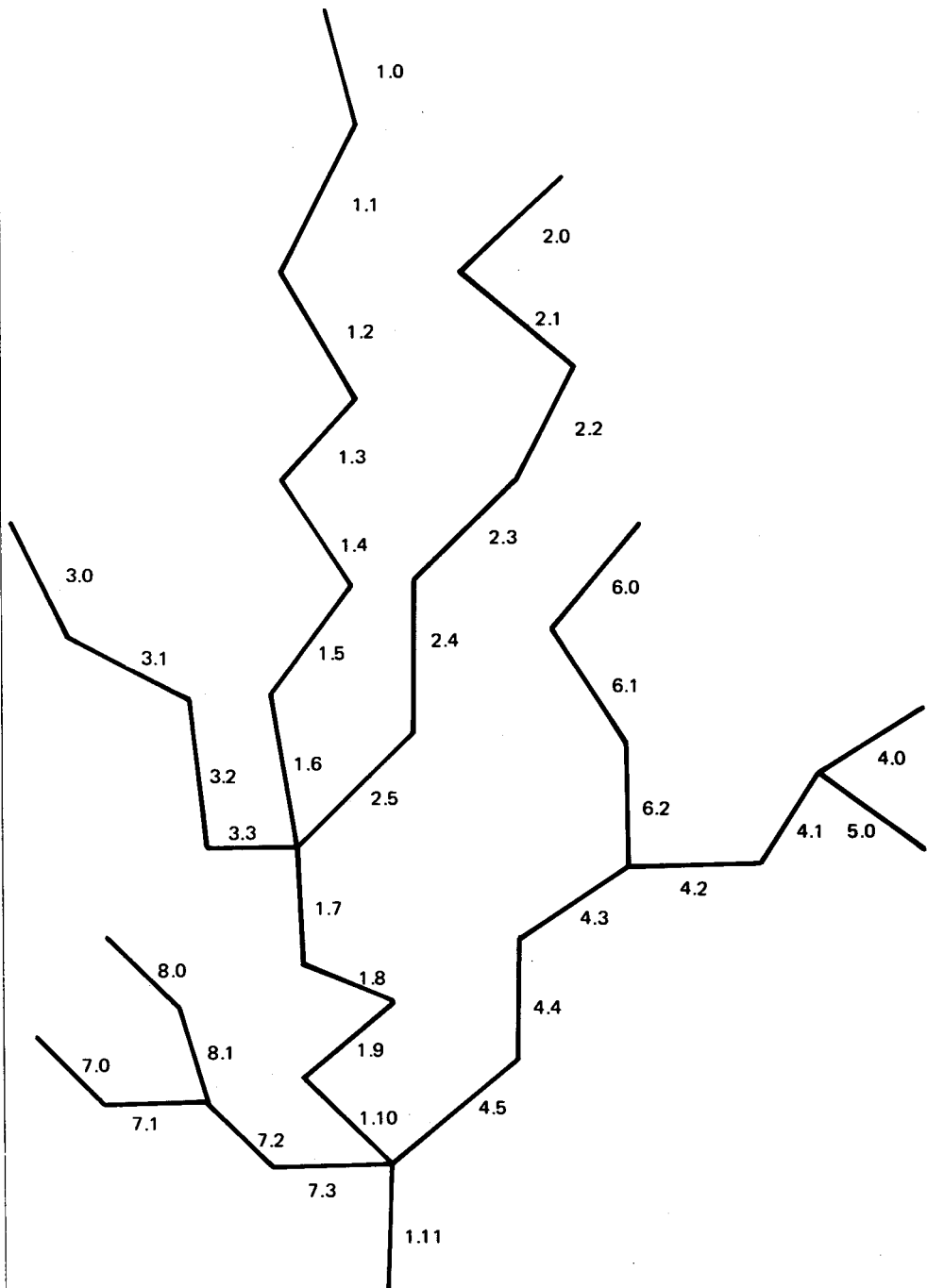
Each pipe and each sub-area in the network to be analysed is identified by means of a decimal number. A key plan of the network, such as that in Figure 6, page 7, should be used, and the pipes and sub-areas are numbered as follows:

- 1 The upstream pipe or sub-area of one of the furthest branches from the outfall is numbered 1.0, and the pipes downstream of this are numbered 1.1, 1.2, 1.3, . . . 1.9, 1.10, 1.11 . . . and so on up to and including the final outfall pipe
- 2 The furthest upstream point at which a second branch joins branch 1 is selected and the longest branch to this point is numbered 2. If this branch is a sub-area, it is numbered 2.0. If the branch contains one or more pipes, these are numbered 2.0, 2.1, 2.2, . . . and so on from the upstream pipe to the point where the branch joins branch 1
- 3 The furthest upstream point at which a branch joins branch 2 is selected and the longest branch to this point is numbered 3; sub-areas and pipes are then numbered following the scheme above
- 4 Numbering of branches, sub-areas and pipes continues in this way, all branches to a given branch being considered in turn, until all pipes and sub-areas have been numbered.

An example of a numbering system is shown in Figure 6; it should be noted that there are program limitations, discussed in Appendix 1, page 43, which restrict the complexity of the network that may be analysed.

The specification of the pipes and sub-areas on the data sheets, from which the data input to the program on punched cards or paper tape is prepared, is discussed in Chapter 2, page 12. It is important to note that the data for a pipe can only be entered when data for all pipes upstream of it has been entered. Thus the entries should begin with 1.0 and then proceed with 1.1, 1.2, etc. until the junction with branch 2 is reached; the order is then 2.0, 2.1, etc. until the junction with branch 1 or branch 3 is reached, and so forth. The whole network must be entered in this order, and it is clear that any numbering errors will result in the wrong network being designed or analysed or in a data error being reported.

ORDER IN WHICH THE PIPES AND
SUB-AREAS MUST BE SPECIFIED
ON THE DATA SHEET



- 1.0
- 1.1
- 1.2
- 1.3
- 1.4
- 1.5
- 1.6
- 2.0
- 2.1
- 2.2
- 2.3
- 2.4
- 2.5
- 3.0
- 3.1
- 3.2
- 3.3
- 1.7
- 1.8
- 1.9
- 1.10
- 4.0
- 4.1
- 4.2
- 6.0
- 6.1
- 6.2
- 6.0
- 6.1
- 6.2
- 4.3
- 4.4
- 4.5
- 7.0
- 7.1
- 8.0
- 8.1
- 7.2
- 7.3
- 1.11

Figure 6 Plan of a sewer network

Note: In the printout produced by the program, the pipe numbers are zero-filled to three places after the decimal point. Thus, for example, pipe 1.1 will appear on the printout as 1.100. A pipe numbered on input as 1.10 would also appear on the printout as 1.100. This will not affect the correct running of the program, but might lead to users becoming confused when examining the output. When there will be more than ten pipes in a branch, this problem could be overcome by numbering the pipes as, for example, 1.01, 1.02 . . . 1.09, 1.10, 1.11 . . . or 1.001, 1.002 . . .

UNITS

The ICL 1900 Series Storm Sewer Design and Analysis package can be used with data in metric units, British units or a mixture of the two. The program initially assumes that the data is in metric units unless a switch is set at run-time (see *Running under Executive alone*, pages 26 and 28) in which case the program assumes the data to be in British units. The user may also change the units in which the data is read at any stage of the input, as often as required, by punching the appropriate directives in the pipe data (see *Changing the units of input*, page 12). The two sets of units are listed in the table below:

<i>Quantity</i>	<i>Metric units</i>	<i>British units</i>
pipe length	metres	feet
pipe dimensions	mms.	inches
rainfall	mms./hour	inches/hour
area	hectares	acres
volume	cu. ms	cu. feet
flow at run-off	cu. ms/second	cusecs.
velocity	ms/second	feet/second
roughness coefficient	metres	feet

Nominal pipe sizes

Nominal pipe diameters for circular clay pipes defined by the British Standards Institution start at 75mms. (or 3 inches) and increase in steps of 75mms. to 900mms. (or 36 inches). The difference between the standard metric and British diameters mentioned above is approximately 1.6%, but this difference is within the tolerance allowed by the British Standards Institution. Further information on this and related matters is given in Walton J.H. *A note on metrication and modular co-ordination of pipe dimensions* Clay Pipe Development Association Limited, November 1969.

DETERMINING PIPE DIMENSIONS

As specified on page 1, the package can be run in design, analysis or redesign mode. Analysis mode does not require the package to output suitable pipe dimensions. In the design and redesign cases, if a pipe is overloaded, the pipe size is increased gradually until either the pipe is large enough to take the required flow or until a user-specified maximum size is reached (see the section *Maximum pipe dimensions and gradients*, page 9). In the latter case the pipe gradient may be altered from the initial gradient specified by the user.

Design of a new system

When a new system is being designed, all pipes at the upstream end of a branch are considered to have the following dimensions:

<i>Cross-section</i>	<i>Dimensions</i>	
	<i>Metric units</i>	<i>British units</i>
Circular	150 mms.	6 ins. (diameter)
Rectangular	150 mms. X 225 mms.	6 ins. X 9 ins. (depth X width)
Egg-shaped	225 mms. X 150 mms.	9 ins. X 6 ins. (depth X width)

The increments that are added to the cross-section of any surcharged pipe are as follows:

<i>Cross-section</i>	<i>Dimensions</i>
Circular	75 mms. or 3 inches to the diameter
Rectangular	75 mms. or 3 inches to the width and to the depth
Egg-shaped	50 mms. or 2 inches to the width and 75 mms, or 3 inches to the depth.

The cross-section of the pipe will be incremented in this way until it is large enough to accommodate the flow.

If a pipe is not at the head of a branch, it is initially assumed to be the same size as the preceding pipe in its branch: thus a new pipe will never be smaller than a pipe immediately upstream of it. This restriction has been incorporated into the program in order to save computing time. The width of a rectangular pipe is taken as 75 mms. or 3 inches greater than the depth. If a reduction in pipe size is desirable, for example when a pipe of steep gradient follows a pipe of shallow gradient, the analysis should be re-run in redesign mode with the network and the dimensions of the pipe specified as smaller than the estimated value: the optimum pipe size will then be obtained.

If a rectangular pipe of a particular shape (width to depth ratio) is required, minimum dimensions should be specified and the pipe redesigned (see below). The given ratio of dimensions will then be retained.

Redesign of an existing system

The increments which are added to the dimensions of a pipe which is surcharged and is to be redesigned are as follows:

<i>Cross-section</i>	<i>Dimensions</i>
Circular	75 mms. or 3 inches to the diameter
Trapezoidal	75 mms. or 3 inches to the width; the depth and side length are increased in proportion so that the shape is unchanged
Egg-shaped	50 mms. or 2 inches to the width and 75 mms. or 3 inches to the depth

Rectangular pipes in an existing system are treated simply as a special case of trapezoidal pipes.

Maximum pipe dimensions and gradients

For a redesign run of the package the user may specify maximum dimensions for any pipe in the system. For a circular pipe a maximum diameter is given, and for an egg shaped pipe a maximum width. A maximum soffit width and depth may be specified for trapezoidal and rectangular pipes.

In the case of a circular or egg shaped pipe the pipe will be expanded until either the size is sufficient to take the required water flow or the maximum size specified is reached. In the case of a rectangular or trapezoidal pipe the pipe is expanded in such a way as to maintain its original shape until either the size is sufficient to take the required water flow or one of the dimensions reaches the maximum specified size; if the pipe has reached its maximum depth but not its maximum width, the width is then expanded until it reaches its specified maximum (or until the required size is reached), and the depth and side length remain constant.

If a pipe reaches its specified maximum cross section and its capacity is still not sufficient to take the required flow of water, and if the specified maximum gradient is steeper than the initial gradient, the program will gradually increase the gradient of the pipe from the existing initial value. The user may specify the size of successive increments. If the maximum gradient is reached and the pipe still cannot cope with the required flow of water, water is assumed to overflow at the upper end of the pipe.

Chapter 2 Input

Data may be input to the package punched on either 80-column punched cards or eight track paper tape. The data begins with general data, described below, which includes a job title and such parameters as the design storm frequency, and continues with data for each pipe or sub-area (see the section *pipe data* on page 12) in the order described in the section *Specification of pipes and sub-areas*, page 6.

In order to assist the user in preparing his data for punching, suggested data sheets are portrayed for card input (pages 15 to 17) and paper tape input (pages 18 to 20). The input data format corresponds as far as possible to that described in the Road Research Laboratory's *Road Note No. 35* (S.O. Code 47-141-35), but some changes have been made with the intention of reducing the possibility of error.

Some numbers in the data must be entered as integers; all others must contain a decimal point. The requirement for each quantity is given on the data sheet. Numbers should be entered right-justified in the boxes on the data sheet.

Within the general data, data must be given consistently in either British or metric units. The system of units may subsequently be changed in the course of the pipe data. When the package is run, the operator should be informed of the initial system of units (see Chapter 4).

GENERAL DATA

The general data should be entered on data sheet A (see page 15) for card input or on data sheet D (see page 18) for paper tape input.

Job title

The job title may contain up to 96 characters from the ICL 1900 Series line printer character set which is given in Appendix 3, page 47.

CARD INPUT

The first card input to the package must contain the character N in the first character position and one of the characters 1 or 2 in the fifth character position; this indicates the number of cards to be used for the job title and if 1 is entered, the third line of the data sheet should be deleted. The next card may contain up to eighty characters, and the third card, if present, may contain characters in the first sixteen positions.

PAPER TAPE INPUT

The first line of paper tape input to the package must start with the character N and finish with a newline character; it may contain up to 96 characters in all.

Instruction for surcharged pipes

The next card or paper tape line must contain D if the package is to be run in redesign mode; that is if the sizes of surcharged pipes are to be incremented until they are adequate to cope with the flow. This arises if an existing system is to be redesigned; if an existing system is being analysed the box on the data sheet should be deleted.

Time of entry and roughness coefficient

The time of entry (in minutes) and the roughness coefficient (in metres or feet) are specified in the general data; the values may be changed in the course of the pipe data. Both these parameters are entered as decimal numbers and are mandatory.

Storm frequency

The design storm frequency must be entered in the next box as an integer number of years.

Time increment

If output of hydrographs and area-time diagrams is to be requested in the pipe data, or if input hydrographs for any sub-areas are to be provided, the time increment to be used should be entered as a decimal number of minutes. If none of these input or output facilities are to be used, this line should be deleted from the data sheet.

Rainfall profile

If the user wishes to use a rainfall profile which differs from the standard profile given in Appendix 2, page 43, the profile should be input as part of the general data. If the roughness coefficient was given in metres, the rainfall values must be given in millimetres per hour; if the roughness was given in feet, the rainfall values must be given in inches per hour. One hundred and twenty values must be given in order at one minute intervals, thus specifying the profile over a two hour period.

CARD INPUT

The rainfall profile input is introduced by a card containing the character F in the first character position. The twelve subsequent cards must each contain ten decimal values; each value must be separated by at least one space from neighbouring values, but spaces must not be left between the characters of any value. If the standard rainfall profile is to be used, the line containing the character F and the twelve subsequent lines must be deleted from the data sheet.

PAPER TAPE INPUT

The rainfall profile input is introduced by the character F followed by a newline character. The twelve subsequent lines each contain ten decimal values separated by either spaces or newline characters. If the standard rainfall profile is to be used, the line containing the character F and the twelve subsequent lines must be deleted from the data sheet.

Start of pipe data

The character P in the first character position of a card or a line of paper tape signifies that the end of the general data has been reached, and that subsequent data will be for pipes or sub-areas.

PIPE DATA

Data for pipes and sub-areas begins immediately after the character P specified above; input for the package ends with the character Z in the first character position of a card or line of paper tape. The line containing this character should be deleted from all data sheets used other than the last. Data for each pipe or sub-area is entered on a new data sheet B (page 16) for card input, or on a new data sheet E (page 19) for paper tape input. If an input hydrograph (see the section *Hydrograph input* on page 13) is to be supplied for a sub-area, a data sheet C (see page 17) should be used in addition to a data sheet B for card input, or a data sheet F (see page 20) should be used in addition to a data sheet E for paper tape input.

The order in which pipes and sub-areas must be given is discussed in the section *Specification of pipes and sub-areas* on page 6.

Changing the units of input

The first line of data sheets B and E allows for the system of units used for input to be changed. If previous input was in metric units and subsequent input is to be in British units, the character B should be entered in the box provided. If previous input was in British units and subsequent input is to be in metric units, the character M should be entered in the box provided. If the system of units is not to be changed, this line of the data sheet should be deleted.

Data input for each pipe of sub-area

At least one card or paper tape line must be supplied for each pipe or sub-area. This must be supplied in the format of the second line on data sheets B or E.

Column 1 of the line is N if a new pipe is being specified, S if a sub-area is being specified, and blank in all other cases. Column 2 is B if a pipe is being specified and it is rectangular or trapezoidal, E if the pipe is egg-shaped, and blank if the pipe is circular; if a sub-area is being specified the code in this column defines the shape of the outfall pipe for the sub-area.

The next information to be entered is the decimal number of the pipe or sub-area (see also *Specification of pipes and sub-areas*, page 6).

The next box contains the dry weather flow in the pipe (or in the outfall pipe in the case of a sub-area) in cu. ms./sec. or cusecs.; if the value is zero, 0.0 should be entered.

The next box is only used if a pipe is being specified; it contains the length of the pipe as an integer number of metres or feet. If a sub-area is being specified, this box should be left blank.

It is followed by the gradient of the pipe (or of the outfall pipe in the case of a sub-area). If, for example, the pipe gradient is 1 in 50, the number 50 should be entered on the data sheet.

The area contributing to the flow in the pipe section (or the area of the sub-area) should be entered in the next box as a decimal number of hectares or acres.

ANALYSIS OR REDESIGN OF AN EXISTING SYSTEM

The rest of the line is only used when an existing system is being analysed or redesigned. The next three boxes specify the dimensions of the pipe (or of the outfall pipe of the sub-area), entered as integer numbers of mms. or inches.

The first of these contains the pipe diameter (circular pipes) or the pipe width (egg-shaped, rectangular or trapezoidal pipes).

The next box is left blank in the case of a circular pipe; in other cases it contains the depth of the pipe. The final box in this group is left blank for both circular and egg-shaped pipes, but in other cases contains the length of side of the pipe; it should be noted that a rectangular pipe is treated as a special case of the trapezoidal pipe, and hence identical values should be entered for the depth and the side length.

Sub-areas

The last two boxes are only used if a sub-area is being specified, and contain an estimate of the time of concentration of the outfall pipe (as a decimal number of minutes) and the total volume of the pipes in the sub-area (as an integer number of cu. metres or cu. feet).

Hydrograph input

If the second line of a data sheet B or E contains details of a sub-area for which an outflow hydrograph is to be specified by input data (see the section *Existing water courses* on page 6), the remaining lines of the data sheet should be deleted, and hydrograph details filled in on a data sheet C or F. The full data of the sub-area must be given. The outflow hydrograph of the sub-area includes the dry weather flow and the rain contributed by the impermeable area for that sub-area, but the program still requires to know these quantities in order to calculate the total dry weather flow, area-time diagrams and total pipe volumes of downstream pipes.

The sub-area data should be followed by the character G in the first character position of a new card or paper tape line. This is followed by one or more lines or cards giving co-ordinates of the input hydrograph in the same units as were used for the dry weather flow in the data for the sub-area. Co-ordinates are given at time intervals equal to the time increment specified on data sheet A or D. The number of co-ordinates which the program expects to read is given by the formula

$$N = 10 \times \text{integer part of } (0.5 + 20.0/T)$$

where T is the time increment in minutes. Ten co-ordinates must be given as decimal numbers on each card or on each paper tape line. At least one space must be left between each number, but no spaces should be left between the characters of a number.

Hydrograph data must be input immediately after the sub-area data. Thus if any of the remaining functions of data sheet B or E described below are required for that sub-area, these must be entered on a new data sheet following the hydrograph data with the first two lines deleted.

Overflows

If a pipe ends with an overflow chamber, the value of Q , the maximum rate of run-off into the downstream pipe must be entered on the line of data sheet B or E which starts with the character Q in the first character position. The value is entered as a decimal number in the same units as were used for the dry weather flow of the same pipe. If overflow is not required this box should be deleted from the data sheet.

Maximum dimensions and gradients

If the sewer system is being designed or redesigned and the user wishes to specify maximum values for the dimensions or gradient of a pipe, he should do so on the line of data sheet B or E which starts with the character W in the first character position.

The first two values to be filled in allow the user to specify gradient increments and a maximum gradient to be used if the capacity of the pipe is not sufficient when the specified maximum dimensions are reached. If the gradient is not to be increased from that specified as the initial gradient for the pipe, the value zero should be entered in the first box and a number equal to the original gradient in the second. Otherwise the maximum gradient should be entered in the appropriate box as an integer in the same way as the initial gradient. If the gradient is to be increased by successive increments of 5%, a zero or negative value or the value 5 should be entered in the incremental gradient box. Otherwise the required value should be entered. For example if the value 3 is entered in this box, the gradient will be increased in steps of 3% of the initial gradient.

The maximum width box should contain either the maximum allowable width (or diameter, for a circular pipe) as an integer number of millimetres or inches, or, if the width is not to be limited, the value zero. If the pipe is not allowed to expand, the value entered should be that of its initial width.

The maximum depth box should contain the maximum depth for a trapezoidal, rectangular or egg-shaped pipe or the maximum diameter for a circular pipe as an integer number of millimetres or inches. If the pipe is not allowed to expand, the value entered should be that of its initial depth. Thus, for a circular pipe, two identical values will be entered.

If the size of the pipe is not to be limited, this line should be deleted from the data sheet. Under these circumstances the program will never increase the gradient.

Output options

In addition to the standard output, two optional items of output may be requested for the outfall of any pipe in the network; these options are identified by the following codes:

Ordinates of area-time diagram:	A
Ordinates of corrected hydrograph:	H

For card input one or both of the codes may be entered in either order on the box provided on data sheet B. For paper tape input the boxes corresponding to any forms of output which are not required should be deleted from data sheet E.

Time of entry and roughness coefficient

The time of entry (in minutes) or the roughness coefficient (in metres or feet) or both may be re-specified in the course of the pipe data by use of the boxes shown on the data sheets. The new value(s) will apply to all subsequent pipes until again altered by use of another card or paper tape line.

End of input

If the program reads a card or paper tape line starting with the character Z it assumes that the end of the input has been reached. Thus this line should be deleted from all data sheets B or E except for the sheet submitted for the last pipe.



Data processing

1900 Series storm sewer design and analysis paper tape input

Punch date encircled by heavy lines only
 Punch spaces only where indicated by
 (a) ▽ characters
 (b) blanks in boxes with character positions marked thus
 (Trailing spaces need not be punched)
 Tab characters → New lines ↓

Data sheet D

Reference

Page number

N											
↓	Job title										
↓	Instructions for surcharged pipes (delete if nothing is entered)										
T	↓	Time of entry in minutes (decimal)									
K	↓	Roughness coefficient in metres or feet (decimal)									
R	↓	Storm frequency in years (integer)									
I	↓	Time increment of hydrographs and area-time diagrams in minutes (decimal); delete if no value is entered									
F	↓	Rainfall profile: ten decimal values per line; delete this line and the next twelve lines if the standard profile is to be used									
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ICL Data processing

1900 Series storm sewer design and analysis paper tape input

Punch data encircled by heavy lines only
 Punch spaces only where indicated by ∇
 Tabulate characters →
 New lines ↓

Data sheet E

Reference

Page number

→ ↓ If units are to change enter B or M; otherwise delete the box

Sub-area or new pipe	Pipe shape	Pipe number (decimal)	Dry weather flow (decimal)	Length (integer)	Gradient 1 in ... (integer)	Impermeable area (decimal)	Existing sewer dimensions			Time of concentration (decimal)	Volume (integer)	
							Dia. or width (integer)	Depth (integer)	Length of side (integer)			
		→	∇	∇	∇	∇	∇	∇	∇	∇	∇	↓

If this is a sub-area for which a hydrograph is to be input, delete the remainder of this sheet and continue on a data sheet F

← ↓ If overflow is to be specified enter the maximum outflow value here; otherwise delete this line (decimal value)

Incremental gradient % (integer)	Maximum gradient 1 in ... (integer)	Maximum width (integer)	Maximum depth (integer)	
W →	∇	∇	∇	↓

Delete this line if this system is being analysed only, or if the dimensions of the pipe are not to be limited.

→ ↓ → ↓ Output options: delete any boxes not required

→ ↓ Time of entry (decimal): delete if unchanged

→ ↓ Roughness coefficient (decimal): delete if unchanged

→ ↓ Delete except on the last data sheet and continue on a new data sheet E

Chapter 3 Output

The data is checked for errors on input and if any errors are found an error message is printed on the line printer. The messages are listed in the section *Error diagnostics*, page 23. If errors are found the run of the package is halted; otherwise the message INPUT DATA CORRECT is printed on the console typewriter; the network is then analysed and the results output. The principal output is printed on a line printer, but other output possibilities are also described in this Chapter.

RESULTS

The results are output in the following order:

- 1 The title and general data for the system as a whole.
- 2 Results as detailed below for each pipe in the system.
- 3 Ordinates of area-time diagrams for any pipes for which these were requested.
- 4 Ordinates of the corrected hydrograph for any pipes for which these were requested. If the pipe ends with an overflow chamber the hydrograph adjusted for overflow is also output. The adjusted inflow hydrograph is also printed if excess water overflows at the upstream end of a pipe whose dimensions have been restricted.

If the input is entirely in British units or entirely in metric units, then the output will be in the same units as the input. If the input is in a mixture of units then the output will be in metric units.

Results output for each pipe

The results output for each pipe are tabulated with two lines of output for each pipe. The first line contains the following values:

- 1 The pipe number.
- 2 The impermeable area draining directly into that pipe (as input).
- 3 The time of concentration.
- 4 The existing dimensions of the pipe (as input) or the dimensions of a new pipe being designed: up to three values depending on the shape of pipe.
- 5 The full-bore velocity.
- 6 The full-bore rate of flow.
- 7 The peak rate of flow.
- 8 If the pipe is overloaded, one of the following:
 - (a) The ratio of items 7 and 6 if the system is being analysed.
 - (b) The new dimensions if the system is being redesigned.

The second line contains the following values:

- 1 The cumulative impermeable area of this pipe and those draining into it.
- 2 The cumulative pipe volume.
- 3 The pipe length (as input).
- 4 The pipe gradient (as input).
- 5 The dry weather flow originating in this pipe.
- 6 The cumulative dry weather flow of this pipe and those draining into it.

- 7 The adjusted peak flow (allowing for overflow where this occurs).
- 8 The new gradient (if the system is being designed or redesigned and the gradient is allowed to alter).

When an existing system is being analysed, the full bore velocity and rate of flow are calculated for the pipe size as specified in the input data. In other cases the values are calculated for the corrected size or the redesigned pipe. In cases where there is an entry for the adjusted peak flow (item 7 of the second line), the maximum rate of overflow can be found by subtracting this value from the peak flow (item 7 of the first line). If an adjustment has to be made to the inflow to a pipe whose dimensions have been restricted, the amount of overflow at the upstream end of the pipe is the difference between the accumulated peak outflow to all pipes immediately upstream of the pipe under consideration and the capacity (item 6 of the first line of output) of the restricted pipe.

The programs allow for the fact that the maximum flow in a closed pipe occurs when the pipe is not quite full; in other words, the full-bore flow does not represent the maximum flow which the pipe will carry. Thus surcharge is not indicated in some cases when the peak flow is marginally higher than the corresponding full-bore flow.

If the pipe is new or being redesigned, this higher maximum flow may allow the pipe to be a size smaller.

Output if program limitations are exceeded

If for any pipe *x.x* in the sewer network, the limitation on the time taken to reach peak flow is exceeded (see also Appendix 1, page 43), the program will halt with the following output:

- 1 The results, including any optional items, for all pipes up to and including the pipe at which the program halted; the peak flow for the pipe will be set equal to 0.0.
- 2 The ordinates of the area-time diagram and of the corrected hydrograph for the pipe at which the program halted; the time interval for these ordinates will be taken as one minute.
- 3 The following message:

HALTED AT PIPE NUMBER, *x.x*. THE PEAK FLOW FOR THIS PIPE HAD NOT BEEN REACHED
AFTER 200 MINUTES

CONSOLE TYPEWRITER OUTPUT

Under normal operation of the package, line printer output is not produced until all calculations for all pipes in the network have been completed. If the user wishes to check on the progress of the calculation during the running of the program he may arrange to have a message output to the console typewriter either after calculations have been completed for every tenth pipe or before each calculation of the hydrograph.

Output after every tenth pipe, which is obtained by setting switch 2 (see the section *Running under Executive alone* on page 26) takes the form:

PIPE (*number*), WIDTH = *value*, PEAK = *value*

Output before each calculation of the hydrograph, which is obtained by setting switch 3 (see the section *Running under Executive alone* on page 26) takes the form:

PIPE *number*, WIDTH = *value*, GRAD. = *value*

This type of output is only useful if the user's installation is running under an operator's Executive environment as under these circumstances the console message is displayed at run time and the user could arrange for the operator to abandon the run if unexpected results appear. If the installation is running under GEORGE 1 or 2 these considerations are not applicable.

DUMP AND RESTART FACILITY

As the calculations involved in the package may take a long time if a large sewer system is being analysed, a facility is included to allow the current state of the program to be output on to a file on disc: this process is known as *dumping*. A dump is principally a safeguard against any failure of the computer hardware. If such failure occurs after a dump has been made, the program can be restarted from the state preserved in the latest dump instead of from the beginning. Under these circumstances the program would continue the calculations after each dump has been made. The operator could be instructed to make dumps at regular intervals during the program run.

It is also possible for the operator to arrange for the program run to be terminated after a dump has been made. This facility could be useful in conjunction with the console typewriter output mentioned in the previous section. If the console typewriter output was such as to indicate that something was going wrong, a dump could be made and the program halted. If after examining the console messages further the user wished the run to continue he could do so by using the dump.

Full details of the use of the dump and restart facility are given in Chapter 4, page 27.

ERROR DIAGNOSTICS

The following error messages may be output on the line printer when the general data on data sheets A or D is read:

<i>Message</i>	<i>Reason</i>
STORM SEWER DESIGN PROGRAM: NO TITLE	The first character input is not N, and the title is not recognized
ERROR : T NOT SPECIFIED	The time of entry, roughness coefficient or storm frequency has not been introduced by the appropriate identifying letter and is not recognized.
ERROR : K NOT SPECIFIED	
ERROR : R NOT SPECIFIED	
ERROR : ILLEGAL CHARACTER IN DATA. <i>x</i>	An unspecified alphabetic character <i>x</i> has been punched following the title.

The following error messages may be output on the line printer when the pipe data on data sheets B or E is read; where appropriate, each message includes the number, *n*, of the paper tape line or punched card in which the error occurs.

<i>Message</i>	<i>Reason</i>
ERROR LINE <i>n</i> : ILLEGAL CHARACTER. <i>x</i>	An unspecified character <i>x</i> has been punched in the pipe data.
ERROR LINE <i>n</i> : CHANGE OF PARAMETER WITH DATA	T or K appears on the same line or card as S,N,E or B.
ERROR LINE <i>n</i> : S WITH N IMPERMISSIBLE	S and N appear on the same line or card; the program does not allow for new sub areas so this line or card is not valid.
ERROR : TOO MANY PIPES BETWEEN <i>x.x</i> AND NEXT DOWNSTREAM PIPE	The pipe data contains data for more than 252 pipes between one pipe, <i>x.x</i> , and the pipe immediately downstream of it (see also Appendix 1, page 43).
ERROR : INSUFFICIENT STORE FOR PIPE <i>x.x</i>	The topology of the network requires more than 8 hydrographs to be held in store when that for pipe <i>x.x</i> has been found (see also Appendix 1, page 43). It may be possible to correct this error by renumbering the system; alternatively the section containing pipe <i>x.x</i> can be specified as a separate system and then treated as a sub-area of the main system.

The following error messages may be output on the line printer when the hydrograph data on data sheets C or F is read.

<i>Message</i>	<i>Reason</i>
ERROR IN PIPE DATA : INPUT HYDROGRAPH NOT ASSOCIATED WITH S IMPERMISSIBLE	The directive G which introduces the co-ordinates of an input hydrograph is not preceded by the data for a sub-area.
MORE THAN 10 INPUT HYDROGRAPHS WITHIN 20 CONSECUTIVE PIPES INPUT IMPERMISSIBLE	Too many input hydrographs have been specified.

The following error messages may be output on the line printer when the maximum gradients and dimensions on data sheet B or E are read:

ERROR : INPUT MAXIMUM DEPTH SMALLER THAN EXISTING DEPTH IMPERMISSIBLE.

ERROR : INPUT MAXIMUM GRADIENT SMALLER THAN EXISTING GRADIENT IMPERMISSIBLE.

ERROR : INPUT MAXIMUM WIDTH SMALLER THAN EXISTING WIDTH IMPERMISSIBLE.

The following error message may be output if input is on paper tape.

<i>Message</i>	<i>Reason</i>
ERROR LINE <i>n</i> : TAB NOT PUNCHED	The numeric data has not been preceded by a tab character.

If errors are found in the data, the input program will halt with the message:

STORM SEWER DESIGN PROGRAM HALTED : DATA HAS ERRORS

The errors should be corrected and the job re-run.

FORTTRAN object time halts

The programs may be halted by one of the checks built into them during compilation by the 1900 series FORTRAN compiler. This will occur, for example, if a decimal point occurs in integer data. A message is output on the console typewriter and the operator should delete the program; the messages that may occur are described in the ICL 1900 series manuals *FORTTRAN : Magnetic Tape Compiler (TP 4159)* and *FORTTRAN : 32K Disc Compiler (TP 4149)*.

When program halts of this type cannot be traced to errors in the data, they may be due to software errors. If a software error is suspected, the user should send a listing of the input data, together with any line printer and console typewriter output, to:

Software Errors Section,
International Computers Limited,
Lovelace Road,
BRACKNELL,
Berkshire.

Chapter 4 Operating

Two versions of the package are available: a version using magnetic tape, which is described below, and a version using E.D.S., which is described on page

MAGNETIC TAPE VERSION

Description of the package

The magnetic tape version of the ICL 1900 Series Storm Sewer Design and Analysis package consists of the following four programs:

- 1 #X3C1 (paper tape input) or #X3C4 (card input). These programs read and check the data and write to three magnetic tapes with file names SSD1, SSD2 and SSD3
- 2 #X3C2 This designs and analyses the sewer network and writes the results to the magnetic tape with file name SSD3
- 3 #X3C3 This prints the results and calculates and outputs any area-time diagrams requested

The programs required by the user must be copied to a magnetic tape library file named PROGRAMVX3ZC, the first program on which must be a search program named #X3ZC. The file should be created using the library maintenance program #XPMV (see the ICL 1900 Series manual *Compiling Systems* TP 4241).

Operating instructions

EXECUTIVE PRIORITY

The programs as supplied have an Executive priority of 50.

USE OF PERIPHERALS

<i>Peripheral</i>	<i>Use</i>	<i>Assignment and release</i>
CR0 or TR0	Input data	Used by #X3C4 only Used by #X3C1 only
MT1	SSD1	Used by all programs other than #X3C3
MT2	SSD2	Used by all programs other than #X3C3
MT3	SSD3	Used throughout the run
LP0	Output and diagnostics	Used by all programs other than #X3C2
TY0	Console output (optional)	Used by #X3C2 only

RUNNING UNDER GEORGE

The following is an example of a job description to be input on punched cards to control a run of the package with card input under GEORGE 1 or GEORGE 2.

```
JOB SEWNAL, 24617, ANALYSER
1 DATA MT (PROGRAM X3ZC)
2 DATA CR0/0 (NETWDATA)
IN 1
LOAD #X3C4
IN 2
```

ENTER
 AT DELETED FI, GO TO 3
 AT OTHER HALTED, END
 3 IN 1
 LOAD #
 ENTER
 AT DELETED FI, GO TO 4
 AT OTHER HALTED, END
 4 IN 1
 LOAD #
 RESUME
 END

 DOCUMENT NETWDATA
 ...
 ... *storm sewer design and analysis data* ...

RUNNING UNDER EXECUTIVE ALONE

<i>Narrative</i>	<i>Console message</i>
1 Load three magnetic tape decks with the tapes SSD1, SSD2 and SSD3 fitted with write-permit rings	
2 If the data is on punched cards, type:	FI #X3C4 #X3ZC
If the data is on paper tape, type:	FI #X3C1 #X3ZC
3 If the data is in British units, type:	ON #X3Cx 1
where <i>x</i> is 1 or 4 as appropriate	
4 Type:	GO #X3Cx 20
5 Place the data in the reader allocated and fix the reader as requested	
6 The input program will be executed and, if no data errors have been found, the calculation program #X3C2 will be loaded automatically with the messages	INPUT DATA CORRECT #X3Cx; DLTD:- FI #X3C2 #X3ZC #X3C2: HALTED:- LD
7 If console typewriter output is required for every tenth pipe, type:	ON #X3C2 2
8 If console typewriter output is required for every pipe, type:	ON #X3C2 3
9 Type:	GO #X3C2 20
10 On request from the user, console typewriter output for every pipe may be suppressed by typing:	OFF #X3C2 3
and restarted by typing:	ON #X3C2 3

Narrative

Console message

- 11 At the completion of all calculations, the output program will be loaded and entered automatically with the message:
and subsequently deleted with the message:
- 12 When the job has been completed, the magnetic tapes will be rewound but not unloaded. A further copy of the output can be obtained by typing:

#X3C2: DLTD-FI #X3C3 #X3ZC

#X3C3: DLTD

FI #X3C3 #X3ZC

System failures

In the event of a hardware failure the job can be restarted by the operator typing the last FIND message appearing on the console typewriter output.

When very small networks are being analysed and the machine times required are short, the package may output an unsuccessful FIND message on the console typewriter: Executive will then reply with a message #X3Cx NOT FOUND. This means that the library tape is still rewinding; when the tape is closed the operator should retype the last FIND message.

E.D.S. VERSION

Description of the package

The E.D.S. version of the ICL 1900 Series Storm Sewer Design and Analysis package consists of the following four programs:

- 1 #X3B1 (paper tape input) or #X3B4 (card input). These programs read and check the data and write to three E.D.S. work files (see *Setting up the work files*, page 28) called SSD1, SSD2, and SSD3.
- 2 #X3B2 This designs and analyses the sewer network and writes the results to the file SSD3
- 3 #X3B3 This prints the results and calculates and outputs any area-time diagrams requested

The programs required by the user must be copied to an E.D.S. library file named PROGRAMVX3ZC using the library maintenance program #XPEU which is described in the ICL 1900 Series manual *Compiling Systems* (TP 4241).

If the dump and restart facility is to be used a further E.D.S. file will be required called PROGRAMVDUMP with file generation number 0. An area of at least 160 blocks with bucket size 1 must be allocated to this file to hold one dump. The dumps are cyclically rewritten and hence only the last n dumps are available for restarting, where n is the maximum number of dumps that can be held on the file.

Operating instructions

EXECUTIVE PRIORITY

The programs as supplied have Executive priorities of 50.

USE OF PERIPHERALS

<i>Peripheral</i>	<i>Use</i>	<i>Assignment and release</i>
CR0 or TR0	Input data	Used by #X3B4 only Used by #X3B1 only
ED1	SSD1	Used by all programs other than #X3B3
ED2	SSD2	Used by all programs other than #X3B3
ED3	SSD3	Used throughout the run
ED4	Dump (optional)	Used by #X3B2 only
LP0	Output and diagnostics	Used by all programs other than #X3B2
TY0	Console output (optional)	Used by #X3B2 only

Setting up the work files

The package requires the use of three work files, names SSD1, SSD2 and SSD3, and before the package can be run these must be allocated on one or more E.D.S. cartridges using the file allocator program #XJEC. The files should be allocated one cylinder each, and will be extended automatically by the package as necessary. An example set of parameters for #XJEC is given below, indicating the integrity code and bucket size required:

XJEC1,1,727001,SSD1,0,0,3,1,1,E,727001,10,10,0,79,*

Use of these parameters would result in cylinder 10 of cartridge 727001 being allocated to the file SSD1.

A similar parameter would be required to set up the dump file if one is to be used.

#XJEC is described in the 1900 Series manual *Direct access utilities* (TP 4190)..

RUNNING UNDER GEORGE

The following is an example of a job description to be input on paper tape to control a run of the package with paper tape input under GEORGE 1 or GEORGE 2. The dump and restart facility is not used.

```
JOB SEWNAL1, 24618, ANALYSER
1 DATA ED (PROGRAM X3ZC)
2 DATA TR0/0 (NETWDATA)
IN 1
LOAD #X3B1
IN 2
ENTER
AT DELETED FI, GO TO 3
AT OTHER HALTED, END
3 IN 1
LOAD#
ENTER
AT DELETED FI, GO TO 4
AT OTHER HALTED, END
4 IN 1
LOAD #
RESUME
END
****
DOCUMENT NETWDATA
...
...          storm sewer design and analysis data
****
```

RUNNING UNDER EXECUTIVE ALONE

Narrative

Console message

- | | | |
|---|---|----------------|
| 1 | Load the E.D.S. cartridge(s) containing the files SSD1, SSD2, SSD3 and PROGRAMVDUMP if a dump file is to be used. | |
| 2 | If the data is on punched cards, type: | FI #X3B4 #X3ZC |
| | If the data is on paper tape, type: | FI #X3B1 #X3ZC |

Narrative

Console message

- | | | |
|----|--|---|
| 3 | If the data is in British units, type:
where <i>x</i> is 1 or 4 as appropriate. | ON #X3Bx 1 |
| 4 | Type: | GO #X3Bx 20 |
| 5 | Place the data on the reader allocated and
fix the reader as requested. | |
| 6 | The input program will be executed and, if no
data errors have been found, the calculations
program #X3B2 will be loaded automatically with
the message: | INPUT DATA CORRECT
#X3Bx; DLTD:- FI #X3B2 #X3ZC
#X3B2; HALTED:- LD |
| 7 | If console typewriter output is required for every
tenth pipe, type: | ON #X3B2 2 |
| 8 | If console typewriter output is required for every
pipe, type: | ON #X3B2 3 |
| 9 | Type: | GO #X3B2 20 |
| 10 | On request from the user, console typewriter
output for every pipe may be suppressed by
typing:

and restarted by typing: | OFF #X3B2 3

ON #X3B2 3 |
| 11 | If the dump and restart facility is to be used,
each time a dump is required and execution is
to continue, type:

When the dump is completed the message:

is output where <i>nn</i> is the dump number and <i>m</i>
the pipe currently being calculated. If execution
is to be abandoned after a dump, type:

The dump number message will be output
followed by | SU #X3B2
ON #X3B2 5
GO #X3B2

DUMP NO. <i>nn</i> MADE AT PIPE <i>m</i> ON EDS.

SU #X3B2
ON #X3B2 4 5
GO #X3B2

#X3B2; DLTD |
| 12 | At the completion of all calculations, the output
program will be loaded and entered automatically
with the message:

and subsequently deleted with the message: | #X3B2; DLTD; FI #X3B3 #X3ZC

#X3B3; DLTD |
| 13 | When the job has been completed the cartridges
are not unloaded, and a further copy of the
output can be obtained by typing: | FI #X3B3 #X3ZC |
| 14 | To restart execution from a dumped version
of #X3B2 load the E.D.S. cartridges containing
all files including the dump file. Type:

where <i>nn</i> is the number of the dump to be used
(normally the last dump). The specified dump is
reloaded and renamed #X3B2 and execution
continues. | FI #XFnn #DUMP |

System failures

In the event of a hardware failure when a dump is not available, the job can be restarted by the operator typing the last FIND message appearing on the console typewriter output.

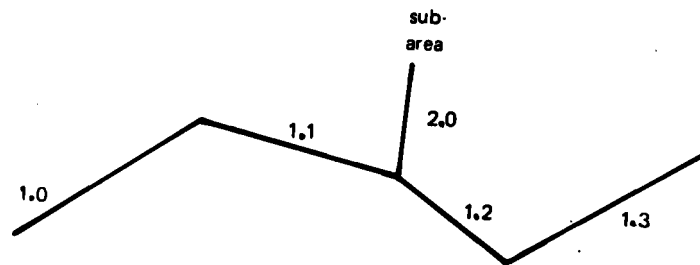
Exception conditions

<i>Message</i>	<i>Reason</i>	<i>Action</i>
FILE 'PROGRAMVDUMP' TOO SHORT: RUN ABANDONED	A dump has been unsuccessful for the stated reason	Make a longer PROGRAMVDUMP file available and restart the run of #X3B2 from the beginning.

Chapter 5 Examples

This Chapter gives examples of input and output formats for the package and falls into three unrelated parts:

- 1 pages 32 to 39 contain examples of completed data sheets for card input for the design of a very small sewer network whose plan is shown below. A non-standard rainfall profile is specified. Existing pipes are to be used for pipes 1.0 and 1.1, and maximum dimensions are specified for 1.1. 2.0 is a sub-area with a different roughness coefficient for which an input hydrograph is to be specified and pipes 1.2 and 1.3 are new pipes, of which the former is to have an overflow chamber. Both forms of optional output are required for 2.0 and 1.3, and the ordinates of the area-time diagram are required for all other pipes.
- 2 page 40 contains an example of normal output for the redesign of a small system.
- 3 pages 41 and 42 contain examples of the output format of the optional output: area-time diagrams and hydrographs.





Data processing

1900 Series storm sewer design and analysis card input

Punch data encircled by heavy lines only
Punch characters in the card positions shown
Punch each line on a separate card
∇ indicates space

Data sheet A

Reference

Page number 1 of 8

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

N ∇ ∇ ∇ ∇ |

EXAMPLE OF INPUT

Job title (delete the second line if it is not required)

Instructions for surcharged pipes (delete if nothing is entered)

T ∇ ∇ ∇ | 11.0 Time of entry in minutes (decimal)

K ∇ ∇ ∇ ∇ | 0.000610 Roughness coefficient in metres or feet (decimal)

R | 1 Storm frequency in years (right justified integer)

I ∇ ∇ ∇ ∇ | 2.00 Time increment of hydrographs and area-time diagrams in minutes (decimal): delete if no value is entered

F Rainfall profile: ten decimal values per line separated by one space; delete this line and the next twelve lines if the standard profile is to be used

0.508 0.508 0.508 0.508 0.508 0.508 0.508 0.508 0.508 0.508

0.508 0.508 0.508 0.508 0.508 0.508 0.508 0.762 0.762 0.762

0.762 1.016 1.016 1.27 1.27 1.524 1.524 1.778 1.778 1.778

1.778 1.778 1.778 2.032 2.032 2.686 2.686 2.686 2.686 2.794

3.048 3.556 4.064 4.318 4.572 5.08 5.588 6.096 7.112 7.874

9.144 10.668 12.192 13.97 16.002 19.05 23.114 28.702 37.592 49.276

50.038 39.878 32.258 27.432 23.622 20.574 18.034 15.748 13.716 12.192

10.922 9.906 9.398 8.89 8.382 7.874 7.112 6.604 6.096 5.588

5.08 4.826 4.572 4.318 4.064 3.556 3.048 3.048 2.794 2.54

2.54 2.286 2.286 2.032 1.778 1.778 1.524 1.27 1.27 1.016

1.016 0.762 0.762 0.762 0.762 0.508 0.508 0.508 0.508 0.254

0.254 0.254 0.254 0.254 0.254 0.0 0.0 0.0 0.0 0.0

P Beginning of pipe data: continue on a data sheet B

ICL Data processing

1900 Series storm sewer design and analysis card input

Punch each line on a separate card
 Punch data in the column positions indicated
 Punch data encircled by heavy lines only

Data sheet B

Reference

Page number 2 of 8

If input units are to change enter B or M; otherwise delete the box

sub area to be analysed	Pipe number (decimal)	Dry weather flow (decimal)	Length (integer)	Gradient 1 in ... (integer)	Impermeable area (decimal)	Existing sewer dimensions			Time of concentration (decimal)	Volume (integer)
						Dia. or width (integer)	Depth (integer)	Length of side (integer)		
	1.0	0.0186	94	135	5.46	6.00				

If this is a sub-area for which a hydrograph is to be input, delete the remainder of this sheet and continue on a data sheet C

Outflow (decimal)															

if overflow is to be specified enter the maximum outflow value here; otherwise delete this line

Incremental gradient % (integer)	Maximum gradient 1 in (integer)	Maximum width (integer)	Maximum depth (integer)

Delete this line if the system is being analysed only, or if the dimensions of the pipe are not to be limited.

Output options (delete if no optional output is required)															
<input type="checkbox"/>	Time of entry (decimal). Delete if unchanged														
<input type="checkbox"/>	Roughness coefficient (decimal) Delete if unchanged														
<input type="checkbox"/>	Delete except on the last data sheet and continue on a new data sheet B														

ICL Data processing

1900 Series storm sewer design and analysis card input

Punch each line on a separate card
 Punch data in the column positions indicated
 Punch data encircled by heavy lines only

Data sheet B

Reference

Page number 3 of 8

If input units are to change enter B or M; otherwise delete the box

sub area or new pipe Pipe shape	Pipe number (decimal)	Dry weather flow (decimal)	Length (integer)	Gradient 1 in ... (integer)	Impermeable area (decimal)	Existing sewer dimensions			Time of concentration (decimal)	Volume (integer)
						Dia. or width (integer)	Depth (integer)	Length of side (integer)		
	1.1	0.079	83	150	1.48	600				

If this is a sub-area for which a hydrograph is to be input, delete the remainder of this sheet and continue on a data sheet C

Outflow (decimal)															
0															

If overflow is to be specified enter the maximum outflow value here; otherwise delete this line

Incremental gradient % (integer)	Maximum gradient 1 in (integer)	Maximum width (integer)	Maximum depth (integer)
0	150	675	675

Delete this line if the system is being analysed only, or if the dimensions of the pipe are not to be limited.

A	Output options (delete if no optional output is required)														
T		Time of entry (decimal). Delete if unchanged													
K	0.0001524	Roughness coefficient (decimal) Delete if unchanged													

Delete except on the last data sheet and continue on a new data sheet B

ICL Data processing

1900 Series storm sewer design and analysis card input

Punch each line on a separate card
 Punch data in the column positions indicated
 Punch data encircled by heavy lines only

Data sheet B

Reference

Page number 6 of 8

If input units are to change enter B or M; otherwise delete the box

sub area or new pipe Pipe shape	Pipe number (decimal)	Dry weather flow (decimal)	Length (integer)	Gradient 1 in ... (integer)	Impermeable area (decimal)	Existing sewer dimensions			Time of concentration (decimal)	Volume (integer)
						Dia. or width (integer)	Depth (integer)	Length of side (integer)		

If this is a sub-area for which a hydrograph is to be input, delete the remainder of this sheet and continue on a data sheet C

Outflow (decimal)										
1	2	3	4	5	6	7	8	9	10	11
0										

If overflow is to be specified enter the maximum outflow value here; otherwise delete this line

Incremental gradient % (integer)	Maximum gradient 1 in (integer)	Maximum width (integer)	Maximum depth (integer)

Delete this line if the system is being analysed only, or if the dimensions of the pipe are not to be limited.

A	H	Output options (delete if no optional output is required)
T		Time of entry (decimal). Delete if unchanged
K	0.00061	Roughness coefficient (decimal) Delete if unchanged
Z		Delete except on the last data sheet and continue on a new data sheet B

ICL

Data processing

1900 Series storm sewer design and analysis card input

Punch each line on a separate card
 Punch data in the column positions indicated
 Punch data encircled by heavy lines only

Data sheet B

Reference

Page number 7 of 8

If input units are to change enter B or M; otherwise delete the box

sub area or new pipe Pipe shape	Pipe number (decimal)	Dry weather flow (decimal)	Length (integer)	Gradient 1 in ... (integer)	Impermeable area (decimal)	Existing sewer dimensions			Time of concentration (decimal)	Volume (integer)
						Dia. or width (integer)	Depth (integer)	Length of side (integer)		
N	1.2	0.0326	373	22.0	0.66					

If this is a sub-area for which a hydrograph is to be input, delete the remainder of this sheet and continue on a data sheet C

Outflow (decimal)															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Q															

If overflow is to be specified enter the maximum outflow value here; otherwise delete this line

Incremental gradient % (integer)	Maximum gradient 1 in (integer)	Maximum width (integer)	Maximum depth (integer)

Delete this line if the system is being analysed only, or if the dimensions of the pipe are not to be limited.

A	Output options (delete if no optional output is required)														
T	Time of entry (decimal). Delete if unchanged														
K	Roughness coefficient (decimal) Delete if unchanged														
Z	Delete except on the last data sheet and continue on a new data sheet B														

ICL

Data processing

1900 Series storm sewer design and analysis card input

Punch each line on a separate card
Punch data in the column positions indicated
Punch data encircled by heavy lines only

Data sheet B

Reference

Page number 8 of 8

If input units are to change enter B or M; otherwise delete the box

sub area or new pipe Pipe shape sew gns	Pipe number (decimal)	Dry weather flow (decimal)	Length (integer)	Gradient 1 in ... (integer)	Impermeable area (decimal)	Existing sewer dimensions			Time of concentration (decimal)	Volume (integer)
						Dia. or width (integer)	Depth (integer)	Length of side (integer)		
N	1.3	0.0326	373	220	0.66					

If this is a sub-area for which a hydrograph is to be input, delete the remainder of this sheet and continue on a data sheet C

Outflow (decimal)															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Q															

If overflow is to be specified enter the maximum outflow value here; otherwise delete this line

Incremental gradient % (integer)	Maximum gradient 1 in (integer)	Maximum width (integer)	Maximum depth (integer)
1	2	3	4
W			

Delete this line if the system is being analysed only, or if the dimensions of the pipe are not to be limited.

Output options (delete if no optional output is required)															
A, H															
T															
K															
Z															

Delete except on the last data sheet and continue on a new data sheet B

1900 STORM SEWER DESIGN AND ANALYSIS PROGRAM.

TEST STORM OVERFLOW AND RESTRICTION ON DIMENSIONS

TIME OF ENTRY(MINS) 3.0000
 ROUGHNESS COEFF.(FT) 0.500000
 STORM FREQUENCY(YEARS) 1
 TIME INC.OF HYDROGRAPHS(MINS) 1.00

PIPE NUMBER	IMPERMEABLE AREA ACRES	TIME OF CONCENTRATION MINS.	EXIST DIMENSIONS INS.			FULL-BODP VELOCITY FT/SEC	FULL-BODP FLOW CUSECS	PEAK FLOW CUSECS	SURCHARGED PIPE NEW DIMENSIONS INS.		
			WIDTH	DEPTH	STOE LENGTH				WIDTH	DEPTH	STOE LENGTH
CUMULATIVE IMPERMEABLE AREA ACRES		CUMULATIVE PIPE VOLUME CU.FEET	LENGTH FEET	EXIST GRADIENT 1 IN-		DRY WEATHER FLOW CUSECS	CUM.DRY WEAT.FLOW CUSECS	ADJUSTED PEAK FLOW CUSECS	NEW GRADIENT 1 IN-		
1.000	0.40	7.28	138	46	61	7.79	243.64	5.27			
	0.40	62571.17	2000	113		0.00	0.00				
1.100	0.10	7.33	24			4.62	14.51	5.32			
	4.50	42618.30	15	113		0.00	0.00				
1.200	0.10	8.27	130	36	46	7.11	180.08	5.17			
	6.60	72754.72	400	113		0.00	0.00				
2.000	13.50	11.75	21			4.00	21.68	17.12	S	24	
	13.50	973.89	310	135		0.66	0.66				
2.100	3.66	12.40	24			7.04	28.01	21.79	S	27	
	17.16	2063.34	274	150		0.28	0.94				
2.200	0.00	14.26	27			8.51	33.84	21.45			
	17.16	5852.54	953	103		0.00	0.94				
2.300	2.80	16.85	27			8.43	33.51	23.17			
	19.96	11049.27	1307	105		0.04	0.98				
2.400	24.55	16.96	33			9.12	34.18	48.75			
	46.51	11423.46	63	115		1.01	1.99	20.12			
2.500	3.25	18.96	33			9.12	34.18	24.07			
	49.76	17927.29	1095	115		0.22	2.21				
1.300	0.10	19.56	24			4.96	35.03	20.01	S	36	
	56.46	91926.08	176	172		0.00	2.21				

AREA-TIME DIAGRAMS. CALCULATED AT TIME INTERVAL 1.0 MINS.

PIPE NUMBER 1.500

2.54	5.89	10.07	14.76	19.87	25.48	29.50	32.45
34.85	36.83	38.41	39.45	39.93	40.06	40.08	40.08
40.08	40.08	40.08	40.08	40.08	40.08	40.08	40.08
40.08	40.08	40.08	40.08	40.08	40.08	40.08	40.08
40.08	40.08	40.08	40.08	40.08	40.08	40.08	40.08

PIPE NUMBER 1.600

2.58	5.16	8.35	13.67	19.80	26.68	34.06	41.24
46.46	50.22	53.03	55.33	57.21	58.66	59.57	59.96
60.07	60.08	60.08	60.08	60.08	60.08	60.08	60.08
60.08	60.08	60.08	60.08	60.08	60.08	60.08	60.08
60.08	60.08	60.08	60.08	60.08	60.08	60.08	60.08

PIPE NUMBER 2.400

1.27	3.92	8.18	13.65	19.51	25.39	29.89	32.79
35.06	36.71	37.46	37.63	37.64	37.64	37.64	37.64
37.64	37.64	37.64	37.64	37.64	37.64	37.64	37.64
37.64	37.64	37.64	37.64	37.64	37.64	37.64	37.64
37.64	37.64	37.64	37.64	37.64	37.64	37.64	37.64

PIPE NUMBER 2.500

0.79	1.58	2.36	3.15	4.35	6.84	10.79	16.23
22.61	29.01	34.45	38.44	41.14	43.22	44.58	45.14
45.26	45.27	45.27	45.27	45.27	45.27	45.27	45.27
45.27	45.27	45.27	45.27	45.27	45.27	45.27	45.27
45.27	45.27	45.27	45.27	45.27	45.27	45.27	45.27

PIPE NUMBER 1.700

2.04	4.08	9.56	15.99	23.33	32.83	43.84	55.10
67.55	80.74	92.88	103.40	112.01	118.66	123.55	127.27
129.76	130.96	131.32	131.38	131.38	131.38	131.38	131.38
131.38	131.38	131.38	131.38	131.38	131.38	131.38	131.38
131.38	131.38	131.38	131.38	131.38	131.38	131.38	131.38

PIPE NUMBER 1.800

1.84	3.68	6.34	10.23	15.49	23.19	31.83	41.14
51.24	62.35	74.09	86.84	99.60	111.10	120.85	128.68
134.62	139.04	142.27	144.25	145.11	145.34	145.38	145.38
145.38	145.38	145.38	145.38	145.38	145.38	145.38	145.38
145.38	145.38	145.38	145.38	145.38	145.38	145.38	145.38

PIPE NUMBER 1.600

VALUES CALCULATED FOR PIPE OF WIDTH 39 INS.

TIME OF CONCENTRATION 15.02 MINS.

CUMULATIVE VOLUME 22206.63 CU.FT.

HYDROGRAPH.

0.00	0.01	0.01	0.02	0.03	0.05	0.08	0.12	0.16	0.21
0.27	0.32	0.38	0.44	0.49	0.55	0.60	0.65	0.70	0.75
0.80	0.85	0.91	0.98	1.06	1.16	1.26	1.38	1.52	1.69
1.86	2.04	2.21	2.39	2.57	2.74	2.91	3.08	3.24	3.43
3.64	3.86	4.11	4.39	4.70	5.05	5.46	5.92	6.50	7.15
7.87	8.68	9.66	10.83	12.17	13.78	15.74	18.13	21.17	25.08
29.92	35.36	41.06	46.87	52.49	57.44	61.21	63.46	64.11	63.50
61.79	59.36	56.48	53.50	50.51	47.61	44.77	41.96	39.17	36.40
33.67	31.03	28.52	26.18	24.02	22.03	20.27	18.66	17.20	15.92
14.75	13.67	12.69	11.82	11.01	10.25	9.56	8.93	8.37	7.82
7.30	6.80	6.33	5.87	5.49	5.12	4.75	4.40	4.08	33.77
3.49	3.23	3.02	2.81	2.61	2.42	2.23	2.04	1.87	1.71
1.55	1.41	1.29	1.18	1.08	0.98	0.89	0.82	0.75	0.69
0.64	0.58	0.53	0.49	0.45	0.42	0.39	0.36	0.34	0.31
0.29	0.27	0.25	0.23	0.21	0.20	0.19	0.18	0.17	0.16
0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08
0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.04
0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

PIPE NUMBER 1.110

VALUES CALCULATED FOR PIPE OF WIDTH 78 INS.

TIME OF CONCENTRATION 25.32 MINS.

CUMULATIVE VOLUME 211474.69 CU.FT.

HYDROGRAPH.

0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.04	0.05
0.07	0.09	0.12	0.16	0.23	0.34	0.45	0.59	0.74	0.95
1.16	1.38	1.59	1.79	2.01	2.24	2.46	2.68	2.92	3.18
3.48	3.83	4.22	4.65	5.14	5.73	6.38	7.05	7.73	8.42
9.12	9.82	10.53	11.25	12.01	12.91	13.91	14.98	16.18	17.56
19.11	20.87	22.96	25.44	28.22	31.40	35.13	39.66	44.89	51.26
59.07	68.58	80.23	94.50	111.41	130.81	151.77	172.68	191.63	207.08
218.32	225.11	228.07	227.55	224.36	219.58	214.14	208.97	204.68	201.35
198.84	196.93	195.36	193.83	192.09	189.91	187.15	183.71	179.53	174.58
168.94	162.67	155.83	148.55	140.96	133.29	125.59	118.01	110.67	103.54
96.82	90.50	84.50	78.95	73.80	68.91	64.30	60.18	56.28	52.60
49.17	46.11	43.28	40.58	38.02	35.61	33.40	31.46	29.58	27.78
26.07	24.44	22.90	21.51	20.30	19.13	17.99	16.90	15.85	14.85
13.90	13.02	12.22	11.59	10.97	10.38	9.80	9.25	8.71	8.20
7.71	7.24	6.30	6.38	5.98	5.62	5.30	5.03	4.78	4.53
4.29	4.07	3.85	3.65	3.45	3.29	3.13	2.99	2.84	2.70
2.57	2.44	2.32	2.21	2.10	2.00	1.91	1.83	1.76	1.69
1.62	1.56	1.49	1.43	1.37	1.31	1.26	1.20	1.15	1.10
1.06	1.01	0.97	0.93	0.90	0.86	0.83	0.80	0.77	0.75
0.73	0.71	0.69	0.67	0.65	0.63	0.61	0.59	0.57	0.55

Appendix 1 Limitation on the package

LIMITATIONS ON THE NETWORK TOPOLOGY

There is a limit of 252 on the number of pipes that may be specified in the pipe data between any one pipe and the pipe immediately downstream of it; effectively this means that, in general, no branch may contain more than 252 pipes. This limitation will rarely affect the analysis of actual sewer networks; it may in any case often be avoided by use of the sub-area facility.

The inflow hydrograph for any pipe is composed of the run-off hydrograph for its catchment area and the outflow hydrographs for any pipe or sub-area immediately upstream of the pipe. It follows that, when a complex network is being analysed, a number of hydrographs may have to be held in store simultaneously. This number is limited to eight. Hydrographs are calculated in the order in which the pipes are input, and each time a branch is encountered the hydrograph for one arm of the branch must be stored until that of the other is calculated and can be added to it.

For example, in the network shown in Figure 6, page 7, the hydrograph calculated for pipe 1.10 must be stored throughout the calculations involving branches 4, 5, 6, 7 and 8; that of branch 7.1 must be stored while that of branch 8 is calculated, and so on.

More complex branches should be given in data before simpler branches to minimize the number of hydrographs that have to be stored. Thus in the above example, if pipe 5.0 had been given after branches 7 and 8 the number of hydrographs to be stored would be increased by one.

The limitation on the number of stored hydrographs can sometimes be overcome by optimizing the numbering system and the order of presentation of data; alternatively the sub-area facility may be used.

LIMITATION ON THE TIME REQUIRED FOR THE FLOW TO PEAK

For each pipe in the sewer network, the ordinates of the corrected hydrograph are calculated over a period of 200 minutes from the start of rainfall. If the peak flow for any pipe has not been reached before this period has elapsed, the calculations program will halt and the results detailed on page 22 will be output.

This condition should only arise when very large networks are being analysed or when the network contains pipes with very long times of entry.

LIMITATION ON INPUT HYDROGRAPHS

Not more than ten input hydrographs are allowed within twenty consecutive sub-areas and pipes.

Appendix 2 The rainfall profile

The table below shows the rainfall profile used by the package for a storm of a frequency of one year; the correction of the profile to deal with other frequencies is discussed under *Storm frequency and rainfall profile*, page 1. These values were obtained from the Meteorological Office and are based on measurements made in Britain. For other countries, provided that the two-hour duration is acceptable, various storms can be obtained by specifying an appropriate frequency in the data.

Time (mins.)	Rainfall		Time (mins.)	Rainfall	
	mms./hr.	ins./hr.		mms./hr.	ins./hr.
1	0.51	0.02	61	50.03	1.97
2	0.51	0.02	62	39.87	1.57
3	0.51	0.02	63	32.26	1.27
4	0.51	0.02	64	27.43	1.08
5	0.51	0.02	65	23.62	0.93
6	0.51	0.02	66	20.57	0.81
7	0.76	0.03	67	18.03	0.71
8	0.51	0.02	68	15.75	0.62
9	0.51	0.02	69	13.72	0.54
10	0.51	0.02	70	12.19	0.48
11	0.51	0.02	71	10.92	0.43
12	0.51	0.02	72	9.91	0.39
13	0.51	0.02	73	9.40	0.37
14	0.51	0.02	74	8.89	0.35
15	0.51	0.02	75	8.38	0.33
16	0.51	0.02	76	7.87	0.31
17	0.51	0.02	77	7.11	0.28
18	0.76	0.03	78	6.60	0.26
19	0.76	0.03	79	6.10	0.24
20	0.76	0.03	80	5.59	0.22
21	0.76	0.03	81	5.08	0.20
22	1.02	0.04	82	4.83	0.19
23	1.02	0.04	83	4.57	0.18
24	1.27	0.05	84	4.32	0.17
25	1.27	0.05	85	4.06	0.16
26	1.52	0.06	86	3.56	0.14
27	1.52	0.06	87	3.05	0.12
28	1.78	0.07	88	3.05	0.12

<i>Time (mins.)</i>	<i>Rainfall</i>		<i>Time (mins.)</i>	<i>Rainfall</i>	
	<i>mms./hr.</i>	<i>ins./hr.</i>		<i>mms./hr.</i>	<i>ins./hr.</i>
29	1.78	0.07	89	2.79	0.11
30	1.78	0.07	90	2.54	0.10
31	1.78	0.07	91	2.54	0.10
32	1.78	0.07	92	2.29	0.09
33	1.78	0.07	93	2.29	0.09
34	2.03	0.08	94	2.03	0.08
35	2.03	0.08	95	1.78	0.07
36	2.29	0.09	96	1.78	0.07
37	2.29	0.09	97	1.52	0.06
38	2.29	0.09	98	1.27	0.05
39	2.29	0.09	99	1.27	0.05
40	2.79	0.11	100	1.02	0.04
41	3.05	0.12	101	1.02	0.04
42	3.56	0.14	102	0.76	0.03
43	4.06	0.16	103	0.76	0.03
44	4.32	0.17	104	0.76	0.03
45	4.57	0.18	105	0.76	0.03
46	5.08	0.20	106	0.51	0.02
47	5.59	0.22	107	0.51	0.02
48	6.10	0.24	108	0.51	0.02
49	7.11	0.28	109	0.51	0.02
50	7.87	0.31	110	0.25	0.01
51	9.14	0.36	111	0.25	0.01
52	10.67	0.42	112	0.25	0.01
53	12.19	0.48	113	0.25	0.01
54	13.97	0.55	114	0.25	0.01
55	16.00	0.63	115	0.25	0.01
56	19.05	0.75	116	0.00	0.00
57	23.11	0.91	117	0.00	0.00
58	28.70	1.13	118	0.00	0.00
59	37.59	1.48	119	0.00	0.00
60	49.27	1.94	120	0.00	0.00

Appendix 3 Character set

This Appendix lists the 1900 Series line printer character set. Any characters from this set may be used in the job title (see page 11 of Chapter 2).

0]	P	;
1	A	Q	:
2	B	R	!
3	C	S	!
4	D	T	[
5	E	U	\$
6	F	V	*
7	G	W	>
8	H	X	<
9	I	Y	↑
(space)	J	Z	£
&	K	-	,
#	L	"	%
@	M	/	?
(N	+	=
)	O	.	←

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