Thames Water

Tidal Thames Defence Levels

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Preliminary Report on River Lee Flows and Levels

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Sir William Halcrow & Partners Ltd
Institute of Hydrology

PRELIMINARY RIVER LEE ANALYSIS

CONTENTS

TABLES

GLOSSARY

AM	annual maximum flood peak series
AREA	catchment area (km^2)
CWI	catchment wetness index
EVI	extreme value Type I distribution
FSR	Flood Studies Report (NERC, 1975)
GEV	general extreme value distribution
I	instantaneous flood peak (m^3/s)
MAF	mean of AM instantaneous flood series (m^3/s)
MAFD	mean of annual maximum mean daily flood series (m^3/s)
MAFr	MAF for rural catchment (m^3/s)
MAFu	MAF for catchment including urban development (m^3/s)
MD	mean daily flood peak (m^3/s)
N	length of record (years)
POT	peaks-over-threshold flood peak series
PRr	percentage runoff from rural catchment
PRu	percentage runoff from catchment including urban development
Q50r	50-year flood from rural catchment (m^3/s)
Q50u	50-year flood from catchment including urban development (m^3/s)
SAAR	standard (1916-50) annual average rainfall (mm)
SOIL	soil index (FSR)
STMFRQ	stream frequency (junctions/km^2)
S1085	10-85% stream slope (m/km)
URBAN	fraction of catchment in urban development

SUMMARY

In this study, the frequencies have been estimated of Thames high tidal water levels at the Lee/Thames confluence, and of flood peaks in the Lower Lee. A summary of these results is presented in Tables A and B. These water level and flood frequencies represent the preliminary inputs needed for the Thames Tidal Model. However, at this stage the water level frequencies are based only on historic records, and modifications are being carried out to take proper account of the effects of the Thames Barrier on future water level frequencies.

The historic water level frequencies shown in Table A for the Lee/Thames confluence have been derived from an interpolation between the frequencies indicated by the long-term water level gauging stations at North Woolwich (5.7 km downstream), and Tower Pier (10.6 km upstream). Also shown for comparison are the water level frequencies at long-term stations Southend and Tilbury, and frequencies at Brunswick Wharf, where 30 years of Thames water level records exist for a former recording station 0.5 km upstream of the Lee/Thames confluence. The effects of the linear upward trend in tidal water levels at these stations were computed and compared in the course of the study, and this trend has been taken into account in the water level frequencies shown in Table A so that they represent 1986 conditions.

Flood frequencies have been computed for both of the Lee channels which discharge into the tidal reach near the Lee/Thames confluence.

The eastern channel, the Flood Relief Channel, carries flood runoff from the great bulk of the 1370km^2 catchment, including most of the rural catchment. Its flood frequencies are based on the short record of floods recorded at the lower end of the Flood Relief Channel at Low Hall, using the long-term record upstream at Feildes Weir for verification.

The western channel of the Lower Lee is the Lee Navigation Channel. This channel carries flood flows from a number of tributaries draining 116.5 km^2 of highly urbanised land in the N and NE regions of London. No river gauging station records floods on this channel, and so floods have been estimated from an analysis of flood records for a number of Lower Lee tributaries. Flood frequencies for these Lower Lee tributaries, which were derived in the course of the study, are also presented. Although the area drained by Lee Navigation Channel is relatively small, because of the highly urbanised nature of its catchment and its steepness, its flashy instantaneous flood peaks are quite high in comparison with the much flatter and the much more voluminous flood peaks of the Flood Relief Channel.

It should be noted that the presented flood peaks in the two channels for any particular return period would not normally be expected to coincide, though with the right combination of storm rainfall sequence and movement it is possible on rare occasions.

Flood data analysed in the course of deriving these flood frequencies indicate generally upward trends, reflecting the increasing urbanisation of their catchments. Data periods are too short to take meaningful account of the trends in flood frequencies in this study, but further investigation into the historic rates of urbanisation within Lee sub-catchments may enable refinements to be made in this context.

TABLE A FREQUENCIES OF TIDAL THAMES HIGH WATER LEVELS

RETURN PERIOD	THAMES/LEE CONFLUENCE	STATION				
		SOUTHEND	TILBURY	NORTH WOOLWICH	BRUNSWICK WHARF	TOWER PIER
2	4.52	3.66	4.05	4.44	4.56	4.67
5	4.75	3.90	4.31	4.67	4.79	4.90
10	4.91	4.07	4.49	4.84	4.94	5.05
25	5.13	4.31	4.71	5.07	5.12	5.24
50	5.29	4.50	4.89	5.24	5.25	5.37
100	5.45	4.70	5.06	5.43	5.38	5.50

NOTES : 1. QUANTILES FOR LEE/THAMES CONFLUENCE AND THAMES TIDAL STATIONS SHOWN AS M AOD

2. WATER LEVELS HAVE BEEN UPDATED TO 1986 USING LOCAL TREND

TABLE B FLOOD FREQUENCIES FOR THE LOWER LEE CHANNELS

RETURN PERIOD YEARS	FLOOD RELIEF CHANNEL M3/S	NAVIGATION CHANNEL M3/S
2	59	53
5	82	68
10	97	78
25	124	89
50	157	95
100	190	107
200	220	115

Preliminary River Lee Analysis

1 INTRODUCTION

1.1 Objectives

The objectives of this preliminary study are to ascertain the frequencies of floods entering the tidal reach of the Lower Lee and the frequency of peak water levels in the Thames at the Lee confluence. The lower Lee reaches in question are the tidal sections of this river system up to Lee Bridge on the Navigation Channel and nearly up to the Flood Relief Channel river gauging station at Low Hall and, for flood frequencies, the non-tidal reaches immediately upstream of tidal range.

The water level and flood frequencies are required for a range of return periods up to 200 years. They have been presented for 2, 5, 10, 25, 50, 100 and 200 year return periods. In the course of the analyses flood frequencies have been computed for gauging stations on tributaries of the Lower Lee, and these results have also been presented in detail.

1.2 The Lower River Lee System

The Lee river system is very complex in its lower reaches downstream of Feildes Weir (see Figure 1.1). Upstream of Feildes Weir the Lee has a predominantly rural and chalk catchment and generally consists of natural channels, though significant offtakes exist which supply various water undertakings. At Feildes Weir the Lee is regulated through two channels flanking its flood plain, the western channel supplying and later becoming the Lee Navigation Channel, and the eastern channel being the Lee Flood Relief Channel. Upstream of the Pymme's Brook confluence, relatively steady flows are maintained within the Navigation Channel so far as possible by diverting flood flows eastward through several channels to the Flood Relief Channel. A number of large raw water storage and service reservoirs exist within the flood plain between the two main channels, and are linked with the latter by a number of additional channels to effect supply and to accommodate spillage. The complex network of channels and regulating structures, and the numerous alternative operating procedures, make the accurate prediction of floods within specific channels difficult.

As the Lee channels pass southwards from Feildes Weir, the catchments of incoming tributaries from east and west are progressively more urbanised, the lowest such as Dagenham Brook and The Moselle being almost entirely built-up. The degree of urbanisation in the Lower Lee tributaries has increased significantly in recent decades, and this influence would be expected to increase flood peaks unless balancing pond development has kept pace.

1.3 Data Availability

Water levels have been recorded at a number of stations along the tidal Thames from Teddington to Southend. The nearest Thames water level recording station to the mouth of the River Lee is at Brunswick Wharf, which is 0.5 km upstream of the confluence. This station ceased to operate in 1983 when the Thames Barrier was commissioned, but its effectively continuous record provides an annual series of water level peaks of 30 years. Upstream of the Thames confluence but within the tidal reach of the River Lee, the Bow Locks water level recording station offers a data set of 27 years of annual peak water levels since its start in 1934 until its data were affected by the commissioning of the Lee Barrier in 1972. This data series includes the exceptionally severe events of 1953 and 1949. The nearest Thames long term water level recording stations upstream and downstream of the Lee confluence are at Tower Pier and N Woolwich (Gallions). Data for the latter stations extend back to 1912 and 1915 respectively. Trends are also detectable in the tidal water level records. However, the major influence on Lee confluence water level frequencies is now the Thames Barrier, the precise effects of which have not been estimated in the course of this preliminary study.

Floods on the main River Lee are measured at Feildes Weir and at Low Hall on the Flood Relief Channel. No river gauging station exists on the Navigation Channel, which acts as the flood collecting channel for tributaries south of the Turkey Brook confluence. Direct estimates are therefore possible of flood frequencies on the Flood Relief Channel using the short Low Hall record supplemented by the Feildes Weir longer record. However, flood frequencies on the lower Navigation Channel must be deduced from flood and catchment characteristics of local gauged tributaries. Flood trends and their effects on flood frequencies are also important considerations.

2 DATA COLLECTION

2.1 Tidal Water Level Data

Water level records relating to the Thames/Lee and tidal lower Lee have been collected from Thames Water for Brunswick Wharf, Bow Locks and the Lee Barrier. These data are in the form of microfilm, and their grid references and data periods are presented in Table 2.1 below. Annual maximum peaks and the dates of these peaks have been extracted and are presented in Table 2.2. Further tidal Thames water level data for other stations upstream and downstream of the Thames/Lee confluence have been presented in the Preliminary Report on River Crane Flows and Levels.

2.2 Flood Data for the Lower Lee and Tributaries

Flood peaks, generally in the form of annual maximum (AM) series and sometimes peak-over-threshold (POT) series, have been extracted from the records of usable river gauging station data for the Lower Lee and tributaries. In the course of extracting these data, certain data sets have been rejected as being of too poor quality. Table 2.3 lists the details of all used and rejected data series. The extracted annual maximum floods are listed in Table 2.4.

2.3 Sub-Catchment Areas

For the purposes of estimating flood frequencies in the Lower Lee, it has been necessary to measure catchment areas contributing to the two main channels as well as those relating to individual river gauging stations. Sub-catchment areas in the Lower Lee are listed in Table 2.5, and the sub-catchments are shown diagrammatically in Figure 1.1. The areas quoted here relate to the catchment boundaries ascertained by Thames Water, whose staff have walked stretches of boundary where uncertainty existed (usually urban areas).

It can be seen in Table 2.5 that the catchment area to Feildes Weir is 1036 km^2, while the whole Lee catchment area down to the Thames confluence is 1412 km^2. Of this additional 376 km^2 downstream of Feildes Weir, 272 km^2 drains to the Navigation Channel under conditions of normal runoff, and the remaining 103 km^2 drains into the Flood Relief Channel. For the purposes of this study, flood frequencies are required effectively at Lee Bridge on the Navigation Channel and Low Hall on the Flood Relief Channel. For these two locations, direct catchment areas are 116.3 km^2 and 1243 km^2 respectively.

2.4 Urban Areas

The degree of urbanisation is of fundamental importance in FSR procedures for computing growth factors for the prediction of floods with return periods longer than twice the available data period. The same parameter is also needed for the FSR method of computing MAF where a catchment is ungauged. The effects of urbanisation, particularly where drains are installed which greatly speed up runoff, can be far-reaching. This effect is certainly demonstrated by the very large floods from 0.66 urbanised Pymme's Brook where mean annual floods from 43 km^2 are about 50% of those from the almost entirely rural 1036 km^2 catchment at Feildes Weir.

In this preliminary study it has not been possible to ascertain the history of development within the study area and therefore to define the rate of urbanisation. Urbanisation is of particular significance in the estimation of floods for the Navigation Channel. Upward trends are visible in the flood data for urbanised Lower Lee tributaries which reflect the urbanisation that has occurred.

For this study, urbanised areas have been measured for the entire area (URBAN = 0.63), mainly North-East London, which drains exclusively through the Lee Navigation Channel, and for catchment areas of individual gauging stations of the Lower Lee tributaries. These urban areas have been taken from 1:25000 scale OS maps following standard FSR procedures, and they are presented in Table 2.5. The maps used were, from south to north:

Sheet TQ 28/38, Second Series, dated 1971 (revisions 1968)
Sheet TQ 29/39, Pathfinder Series (Second Series), dated 1978 (revisions 1977)
Sheet TL 20/30, Pathfinder Series (Second Series), dated 1982 (revisions 1981)

For the past 20 year period during which nearly all of the flood data used in this study were collected, the degree of urbanisation shown on TQ 28/38 has changed very little since this part of London was heavily built up many years ago and park land has remained protected from development. Over the same period, the increase in development has been much more significant in TW 29/39, which embraces the urban/rural interface. The latter affects Salmon's Brook and Turkey Brook in particular, but Pymme's Brook catchment urbanisation has remained fairly constant apart from some development in the Hadley Wood vicinity. Sheet TL 20/30 includes part of the Turkey Brook catchment but none of the area from which floods drain into the lower section of the Lee Navigation Channel.

Hence the urban percentages computed for sub-catchments relate to particular points in time, and where genuine trends exist as a result of urbanisation, these points in time must be interpreted in the course of defining flood frequencies.

3 TREND ANALYSES

3.1 Water Level Trends

There is an upward trend in tidal water levels in the Thames estuary, and this effect is indicated in the Brunswick Wharf data. A simple linear correlation and regression with time shown on Table 3.1 quantifies this trend and Table 4.2 shows the resultant quantile estimates updating the annual maximum levels using the locally determined trend.

3.2 Flood Trends

Trends in floods would be expected to occur as increased urbanisation results in greater impermeability and as the installation of drains speeds up runoff. In order to detect genuine trends in flood peaks, however, it is necessary to have a very long and reliable data set. For all data sets available for the Lower Lee and its tributaries, data periods are too short for very meaningful evaluation of trends, the longest being 33 years for the Pymme's Brook, but the remainder being for 20 years or less. Clearly for such short data sets, any trend analysis may be heavily biased by the chance timing of maximum and minimum events, whereas in very long data series such effects would be much less significant.

For Feildes Weir, a very long data series of 109 annual maxima exists for mean daily flood peaks (or 114 annual maxima if the even less certain 1851-56 data are included). However, mean daily flood peaks would not be expected to change very significantly (if at all) as a result of increased urbanisation, which affects instantaneous peaks much more dramatically than runoff volumes.

It is with these provisos that the results of linear trend analyses on annual maxima are presented in Table 2.3 and Figure 3.1. The numerical results show that Feildes Weir mean daily flow has actually tended to decrease very slightly (by 0.3% of MAF annually) over its entire span although inspection of the Figure 3.1A time series reveals reasonable stability post 1920. The 20 recent years instantaneous flood peaks show an opposite upward trend of 1.5 $m^3/s/year$, or 3.1% of MAF, although this impression is much enhanced by the location of two particularly high maxima in 1978 and 1982. Turkey Brook and Lee FRC at Low Hall, which have data periods of 15 and 10 annual maxima respectively, show implied downward trends of 1.0% and 4.4% of MAF annually. For the remaining 3 gauging stations with enough annual maxima to carry out tentative analyses of trends, upward trends were indicated, these being for Intercepting Drain, Pymme's Brook and Dagenham Brook respectively rates of 2.2%, 0.3% and 9.3% of MAF annually. Clearly the Pymme's Brook trend, based on 33 years, is the most meaningful, and its very low rate of flood peak increase presumably reflects the modest degree of development over the period of observation. The Dagenham Brook catchment, with 11 years of data during which very little if any increase occurred in urbanised area, is unlikely to have a genuine 9.3% annual increase in MAF, and these data show the potential for spurious trends to be indicated by too-short data periods.

Overall, it may be concluded that a slight upward trend is generally indicated in accordance with the increasing urbanisation of the Lee basin.

4 FREQUENCY ANALYSES OF TIDAL WATER LEVELS

4.1 Frequency of Tidal Water Levels

Peak tide levels at Brunswick Wharf are, as would be expected consistently lower than those in the Lee 4.3 km upstream at Bow Locks. However, because an erratic relationship appears to exist between Bow Locks and Brunswick Wharf, concurrent annual maximum peak levels at the former were not further considered. Water levels recorded at the Lee Barrier gauge were also not used since only 11 years of data are available.

Table 4.1 shows estuary levels corresponding to particular return periods based upon revised data obtained from PLA stations and the Brunswick Wharf data of Table 2.2. The effect of the linear trend (Table 3.1) in the data has been removed in Table 4.2. As in the Crane report these values do not allow for the effect of Barrier closure and so are now of mainly historical interest above 5 year return period. The Thames Barrier is currently operated with the aim of keeping water levels at Tower Pier below 4.85 m AOD. Assuming all barrier closure events are reduced to low levels at this location, Table 4.1 indicates that, with the current operating rules, levels at Brunswick Wharf could not be expected to rise substantially above 4.75 m AOD. However, the definitive estimate for the post-barrier condition is the subject of continuing work.

4.2 Adjustment to Lee Mouth

Brunswick Wharf data can in principle be regarded as representing Lee Mouth levels without further adjustment. However its record is short by comparison with the PLA gauges and the question of choice of estimator arises. Brunswick Wharf is 5.7 km upstream of North Woolwich and 10.2 km downstream of Tower Pier and on this criterion the values for return periods below 10 years appear to be some 4 cm too high by comparison with the much longer recording PLA gauges. However the overall trend of the data does suggest that a linear interpolation between North Woolwich and Tower Pier may reasonably be adopted.

5 FLOOD FREQUENCIES AT RIVER GAUGING STATIONS ON THE LOWER LEE

5.1 General Approach

The approach to be taken here was dictated (i) by the requirement for separate flood frequencies for the easterly channel represented by Low Hall, and the westerly channel represented by Lea Bridge, and (ii) by the disposition of the discharge measurement sites. The usefully sited gauge at Low Hall has a record length too short for high return period estimation but is backed up by the very long Fieldes Weir station. In this area local data procedures can be used directly to enhance flood frequency estimation. The approach taken for the western channel is rather different as the only gauging stations are on tributaries. In this case the tributary information has been used to develop a local regional estimate of the mean annual flood from which higher return period floods have been derived using standard regional multipliers.

5.2 Flood Frequencies Based on Flood Data Analyses

Gumbel (EVI) analyses, using method of moments fitting, have been carried out on AM series for the data of Table 2.4 except for the Salmon's Brook at Edmonton, where less than 10 years of data are available and so a peak-over-threshold (POT) analysis has been carried out to determine flood frequencies.

The results of these analyses of recorded flood peaks are presented in Table 5.1. The long return periods presented in Table 5.1 are, in all cases except Feildes Weir mean daily peaks (109 years), too long for realistic predictions based on the short data sets. Hence Table 5.1 is presented for comparison purposes only.

Included in Table 5.1 are flood frequencies for the River Lee at Feildes Weir based on long and short records of mean daily flows. They relate to a particularly long period of record (109 years), and a relationship derived between concurrent mean daily flows (discrete days, not 24 hour maximum) and instantaneous peaks enables additional understanding of Lee flood characteristics to be obtained. A regression between concurrent instantaneous and mean daily maximum flood peaks over a period of 20 years (Figure 5.1) shows a good relationship between the two (coefficient of correlation = 0.93):

$$I = (1.12 \times MD + 6.1)\ m^3/s$$

The Feildes Weir record contains an exceptionally high flood in 1857 which has not been used in the derivation of the mean daily flood frequencies presented in Table 5.1. This instantaneous value of 280 m^3/s was gauged by Beardmore (1872) and is more than twice as high as any flood recorded since. On the basis of the frequency analysis of instantaneous Feildes Weir flood peaks for the recent 20 years, such a flood would have a return period of more than 1000 years (240 m^3/s). Incorporation of the extra data point in a maximum likelihood analysis has been shown to modify the fitted distribution at high return periods considerably, and so the accuracy and significance of this event should be further investigated.

5.3 Flood Frequencies Using FSR Procedures

Under FSR standard procedures, frequency analyses of observed data should be used for return periods up to 2 x N, where N is the number of annual maximum flood peaks used in the analysis, and for estimation of the mean annual flood. To predict floods for return periods of 5 x N or more, FSR regional growth curves, suitably modified for degree of urbanisation, must be applied directly to MAF's based on observed floods. For the range between 2 x N and 5 x N, a smoothed transition is recommended in FSR procedures.

Flood frequencies for Lower Lee and tributary gauging stations resulting from these standard FSR procedures are presented in Tables 5.2 and 5.3. Figure 5.2 shows plots of the two sets of flood frequencies, based on data analysis only (Table 5.1) and based on MAF and growth factors only (Table 5.2), plus the transitions between 2N and 5N (Table 5.3).

Generalised curves have been developed following the method of FSSR for obtaining growth factors for various degrees of urbanisation and for a range of return periods up to 500 years. These curves are presented in Figures 5.3 and 5.4 and details of computations are presented in Table 5.4. The resulting urbanised growth factors, together with relevant catchment parameters, are shown in Table 5.5.

Beyond 50 years return periods the FSR methodology for computing urbanised growth factors is based on very few data and so is tentative. However an updated analysis of stations with over 50% urbanisation in the London area gives some basis for confidence in the method at longer return periods. A number of Lower Lee tributaries, such as the Dagenham Brook and the Moselle, have urbanisation levels higher than 75% and in some cases reach 95%. Because this is beyond the level considered in FSSR5 and because the above review suggested the adjustment was conservative, the 75% urbanised factors have been used for all such cases.

5.4 Proposed Flood Frequencies for Gauging Stations

The comparisons, as shown in Figure 5.2(A), of flood frequencies based firstly on data analyses and secondly based on MAF with growth factors, indicate that on the main Lee at Feildes Weir and Low Hall, the longer return period floods are substantially higher for the FSR approach. At the 200 year return period, these differences are 46% and 38% respectively. However, the reported 1857 flood of 280 m^3/s still exceeds the 1000 year flood by 40 m^3/s using the FSR approach. Overall the FSR standard procedure of transition from data analysis values at 2 x N to MAF with growth factors at 5 x N appears to be appropriate for the main Lee.

In the case of the Turkey Brook and Pymme's Brook frequency plots shown in Figure 5.2(b), the data analysis and FSR standard procedures result in flood frequencies which are very close to each other, and the FSR procedure therefore appears eminently suitable. For Salmon's Brook in the same Figure, only the MAF and growth factors approach has been possible since meaningful definition of flood frequencies is not possible based on only 7 years of data. The divergence of the tentative POT analysis line and the MAF/growth factor line is therefore not significant.

Figure 5.2(C) shows flood frequencies for the Intercepting Drain and Dagenham Brook based on data and MAF/growth factor approach. In the case of Intercepting Drain (71% urbanised), the difference between the two methods is not great, the FSR values being somewhat higher. In the case of Dagenham Brook, analysis of data results in subtantially higher floods at long return periods than the FSR approach. It is noticeable that the highest recorded flood (14.1 m^3/s) in the 11 year Dagenham Brook record is equal to the FSR 500 year flood. However, its catchment area is very highly built up in the order of URBAN = 0.95, and this is beyond the range of FSR data base. Although the data period is much too short for such long extrapolations, it seems more appropriate in this case to accept the data analysis values, and the latter are presented in Table 5.3 as the proposed flood frequencies.

6 FLOOD FREQUENCIES IN LOWER LEE CHANNELS

6.1 Flood Frequencies in Lee Flood Relief Channel

For the lower reaches of the Flood Relief Channel, a direct measure of floods is provided by the river gauging station at Low Hall. The Low Hall record is not a long one - only 10 years. However, since this is a Crump weir gauging station, its rating is considered to be suitably accurate. Furthermore floods are recorded upstream at Feildes Weir where there is a 20 year record of instantaneous flood peaks and a much longer record (114 years) of annual mean daily peaks (MAFD), and comparisons between Low Hall and Feildes Weir flood characteristics enable the Low Hall data to be used with more confidence.

Low Hall flows are not entirely natural in that part of the Lee floods bypass this station via the Navigation Channel to the east. However, the great bulk of Lee floods passes along the Flood Relief Channel, and so it is considered as a working hypothesis that Low Hall gauge measures the floods of the entire Feildes Weir catchment plus all left bank tributaries plus the right bank tributaries to Small River Lee and Turkey Brook.

At Feildes Weir, Lee flows are divided between the Navigation Channel and Flood Relief Channel. For the Navigation Channel, a steady and, relative to flood flows, fairly low flow is aimed at in the course of Feildes Weir operation. When floods occur, the surplus flows over Navigation Channel requirements are passed down the Flood Relief Channel. Further downstream, additional inflows pass into the Flood Relief Channel from the eastern tributaries of the Lee, including Cobbins Brook and the Ching, and from further flood overflow channels from the Navigation Channel. The overflows from the Navigation Channel include inflows from all western tributaries downstream of Feildes Weir as far as (and including) Turkey Brook. Even further downstream at Chalk Bridge, a small part of the Flood Relief Channel flow is directed back towards the Navigation Channel, but during floods this diversion is only small.

Figure 6.1 shows concurrent flood peaks at Feildes Weir and Low Hall for the data period 1978/87 common to the two stations. Substantial flood storage exists, in particular between Hoddesdon and Waltham Abbey, and for this reason Feildes Weir flood peaks are usually attenuated before arriving at Low Hall. However, if high storm rainfall occurs over the highly urbanised residual area, peaks may be higher at Low Hall, particularly if the timing of this storm rainfall is such that it enables slow drainage from the main Lee to coincide with the much swifter downstream drainage from the urbanised tributaries. The close coincidence of MAFs displayed on Table 6.1 for the two sites over their common period suggests that this is of sufficiently frequent occurrence to balance approximately the attenuation effect. As is to be expected, mean daily flows at Feildes Weir are exceeded by Low Hall attenuated peaks (except in one marginal case). Overall it may be concluded that tentative use may be made of the Feildes Weir data in augmenting the information contained in the Low Hall flood record.

Ideally one would like to extend directly the short Low Hall record using the very long Feildes Weir MAFD record. However within the scope of a preliminary analysis this is not considered to be possible because of uncertainty in the relationship between peak and daily mean discharge and also variable flood peak attenuation. Nevertheless Feildes Weir remains a valuable indicator of the representativeness of the short period record. Table 6.1 shows the necessary comparisons of MAFs.

It is very apparent from Table 6.1 and from Figure 3.1(A) that there were fewer high annual maxima recorded at Feildes Weir between 1965 and 1976 than subsequently. Something of this same bias is visible in the MAFD record although less marked. If this same distortion were present at Low Hall it could lead to overestimation of the design flood. Pending a more detailed analysis in following stages of the study it is recommended that no reduction be made to the Table 5.3 flood frequency estimates. This conservative decision is taken in the light of (i) a brief scrutiny of other long term records in the Upper Lee catchment above Feildes Weir which did not reveal such a sizeable jump between the two periods; and (ii) a surprisingly greater difference in the ratio of peak and MAFD values in recent years than hitherto. Both these matters should be clarified in follow-up studies.

6.2 Flood Frequencies in the Lee Navigation Channel

No direct estimation of flood frequencies is possible for the Lee Navigation Channel since no river gauging station records floods on this branch of the Lee. It is therefore necessary to estimate flood frequencies on this branch indirectly by use of the Floods Study Report (FSR), catchment characteristics and observed flood records of contributing catchments to the Lower Lee.

Catchment parameters relevant to FSR procedures are presented in Table 5.5 for river gauging stations on the Lower Lee and tributaries. These consist of area (AREA), standard average annual rainfall (SAAR), percentage urbanised (URBAN) and soil type (SOIL). The percentage urbanised values relate effectively to the 1978 versions of OS 1:25,000 scale maps, which show revisions up to the year 1977. No estimate has been made in this preliminary study of the rate at which urbanisation has increased in recent decades or how this would be expected to affect future flood frequency. For the two gauged catchments most critically affected by urban change, Turkey Brook and Salmon's Brook, where flood peak records are available since 1972 and 1980 respectively, the year 1977 is not representative for the mid-point of the data sets, and significant urbanisation may perhaps have occurred since that year. However no allowance has been made for this aspect in this study, and slight refinement may be found to be necessary after further investigation.

Flood frequencies at river gauging stations on the Lower Lee and relevant tributaries are discussed in Section 5 and are presented in Tables 5.1 to 5.3. They show that in all cases but the Dagenham Brook, the slopes of EV1 probability lines and the growth curves as presented in FSR result in broadly consistent flood peaks. Furthermore Dagenham Brook is very highly urbanised (URBAN = 0.95) and this is beyond the range of the FSR data base. The characteristics indicated on the Lower Lee and tributaries are therefore considered to confirm that standard FSR growth factors are appropriate for the Lee Navigation Channel catchment, which has an area of 116.5 km^2 and an urbanisation equivalent to URBAN = 0.63. These growth factors are presented in Table 5.5.

More difficult, however, is the estimation of an appropriate MAF for the Lee Navigation Channel, which is not a standard natural catchment. Inflows to this channel consist of right bank tributaries downstream of Turkey Brook plus the residual flows from further upstream which have not spilled eastwards through the various flood overflow channels to the Flood Relief Channel. The right bank tributaries have varying degrees of urbanisation from URBAN = 0.22 to URBAN = 0.95, and catchment areas, shapes and times of concentration range widely. Clearly MAF's for individual tributaries cannot be added together since date and time to peak would not generally coincide, though it may be deduced that the MAF upper and lower limits would be, excluding the contribution from Turkey Brook and upstream, the sum of MAF's for individual tributaries, and the highest individual tributary MAF (= 25.0 m^3/s on Pymme's Brook) respectively.

The normal FSR procedure is to compute MAF from catchment characteristics using in this case FSSR No 5 for urban areas, taking due account of MAF's observed either upstream or downstream on the same river, or on nearby and similar rivers. However this method is not readily applicable for the computation of floods in a channel which is being contributed to by a series of tributaries of varying sizes.

Tables 6.2 and 6.3 show the computation of MAF's for 4 of the gauged tributaries of the Lower Lee with comparisons, from which it can be seen that observed MAF's are higher in all cases. The degree of overestimation is very significant for Pymme's Brook (64%) which would be expected to be the predominant influence on the Navigation Channel floods. This substantial difference at Pymme's Brook and also the high observed specific MAF for Pymme's Brook may in part be explained by the use of the modular rating for events during which the weir is drowned. This is known to have occurred during the 1979 flood and subsequent study will reveal its overall influence.

For the remaining tributaries, the Intercepting Drain, Saddlers Mill Stream, The Moselle, it has not been possible to compute the FSR synthetic MAF because the stream frequency cannot be determined in this heavily urban area. If a stream frequency equal to the weighted average (0.4) of Salmon's Brook and Pymme's Brook is applied to the entire 116.5 km^2 contributing to the Navigation Channel, then the MAF for the latter is computed to be 22 m^3/s. This is less than the Pymme's Brook alone, and so a revision of the standard FSR approach was sought.

The procedure adopted used a local correlation of "ruralised" observed MAFs with catchment area. The resulting relationship has been used to estimate first the "ruralised" MAF for the Navigation Channel, which has then been converted to a MAF for 63% urbanisation. The correlation of ruralised specific MAF with area is presented in Figure 6.2. The resulting regression equation, with a correlation coefficient of 0.95, is:

$$MAF_r = 0.33 - 0.092 \text{ (Log AREA)}$$

Hence for 116.5 km^2, $MAF_r = 0.140\ m^3/s/km^2 = 16.3\ m^3/s$. For 63% urbanisation, $MAF_u = 2.77 \times MAF_r = 45.2\ m^3/s$. On the basis of this MAF, flood frequencies for the Lee Navigation Channel are presented in Table 6.4. In addition to these direct contributions from the tributaries downstream of Turkey Brook, an allowance ranging from 8 m^3/s at MAF to 10 m^3/s at 200 years return period has been made in Table 6.4 for the unspilled flows entering this reach from upstream via the Lee Navigation Channel. This results in MAF and 200 year floods in the Navigation Channel of 53 and 115 m^3/s respectively, which, at 71% and 52% of the corresponding floods for the Lee Flood Relief Channel as shown in Table 5.3, represent a significant proportion of the entire floods in the Lower Lee. However it should be noted that although peaks from this urban catchment are relatively high, flood volumes are very much smaller than those passing from the great bulk of the catchment through the Flood Relief Channel.

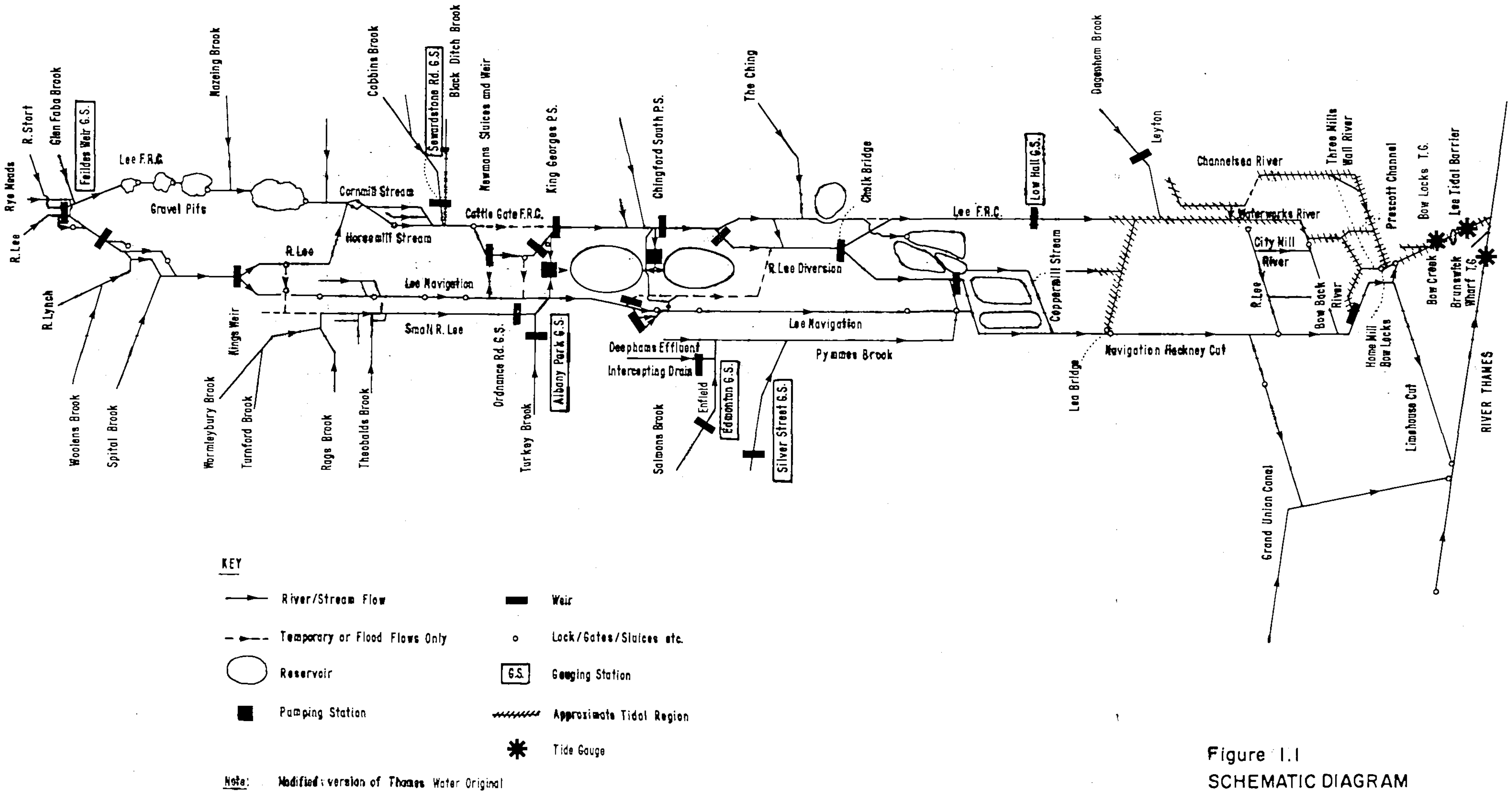


Figure 1.1
SCHEMATIC DIAGRAM
OF THE LOWER LEE SYSTEM

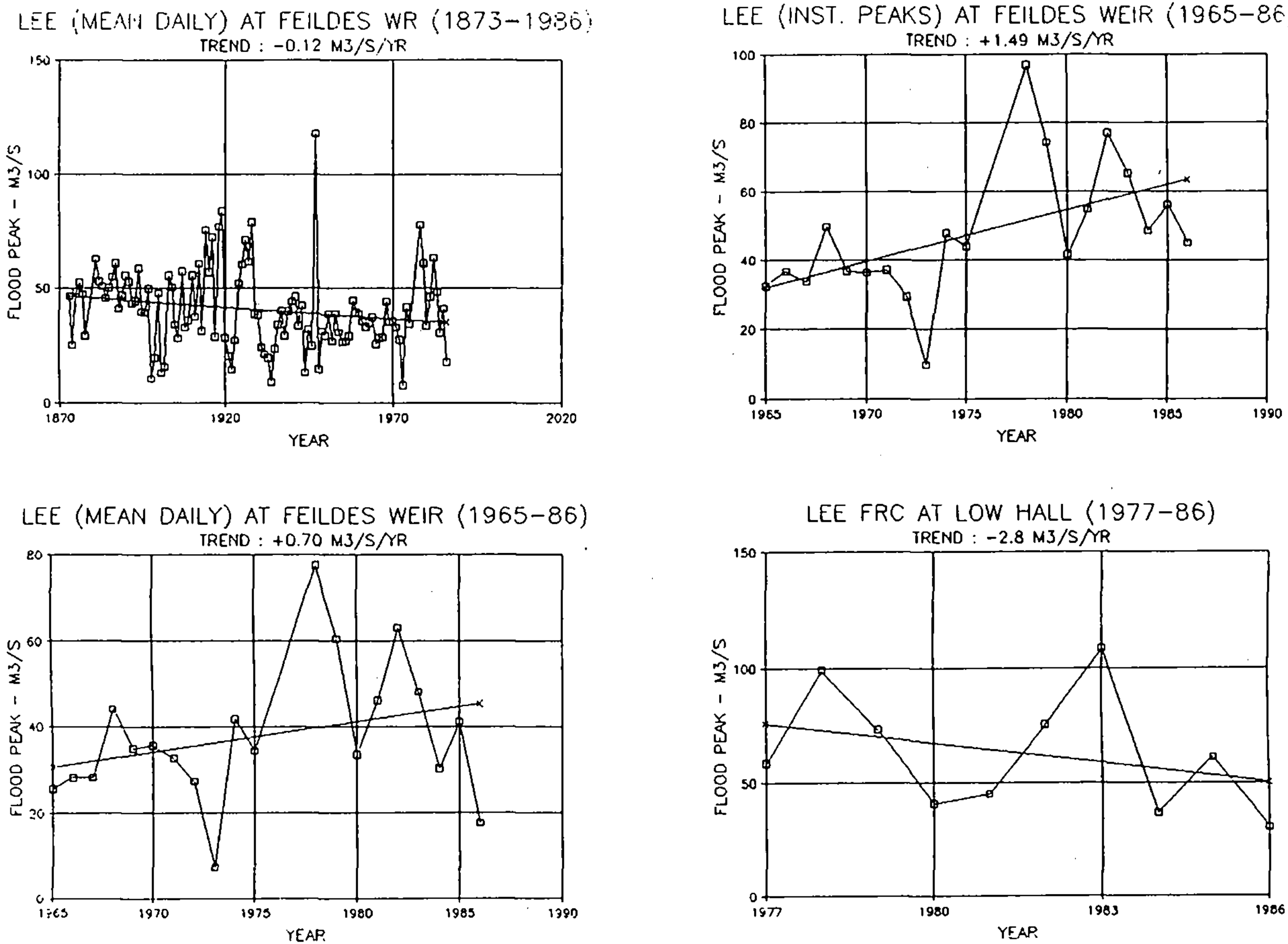

LEE (MEAN DAILY) AT FEILDES WR (1873–1986)
TREND : -0.12 M3/S/YR
FLOOD PEAK - M3/S
YEAR
LEE (INST. PEAKS) AT FEILDES WEIR (1965–86)
TREND : +1.49 M3/S/YR
FLOOD PEAK - M3/S
YEAR
LEE (MEAN DAILY) AT FEILDES WEIR (1965–86)
TREND : +0.70 M3/S/YR
FLOOD PEAK - M3/S
YEAR
LEE FRC AT LOW HALL (1977–86)
TREND : -2.8 M3/S/YR
FLOOD PEAK - M3/S
YEAR

FIGURE 3.1 (A)

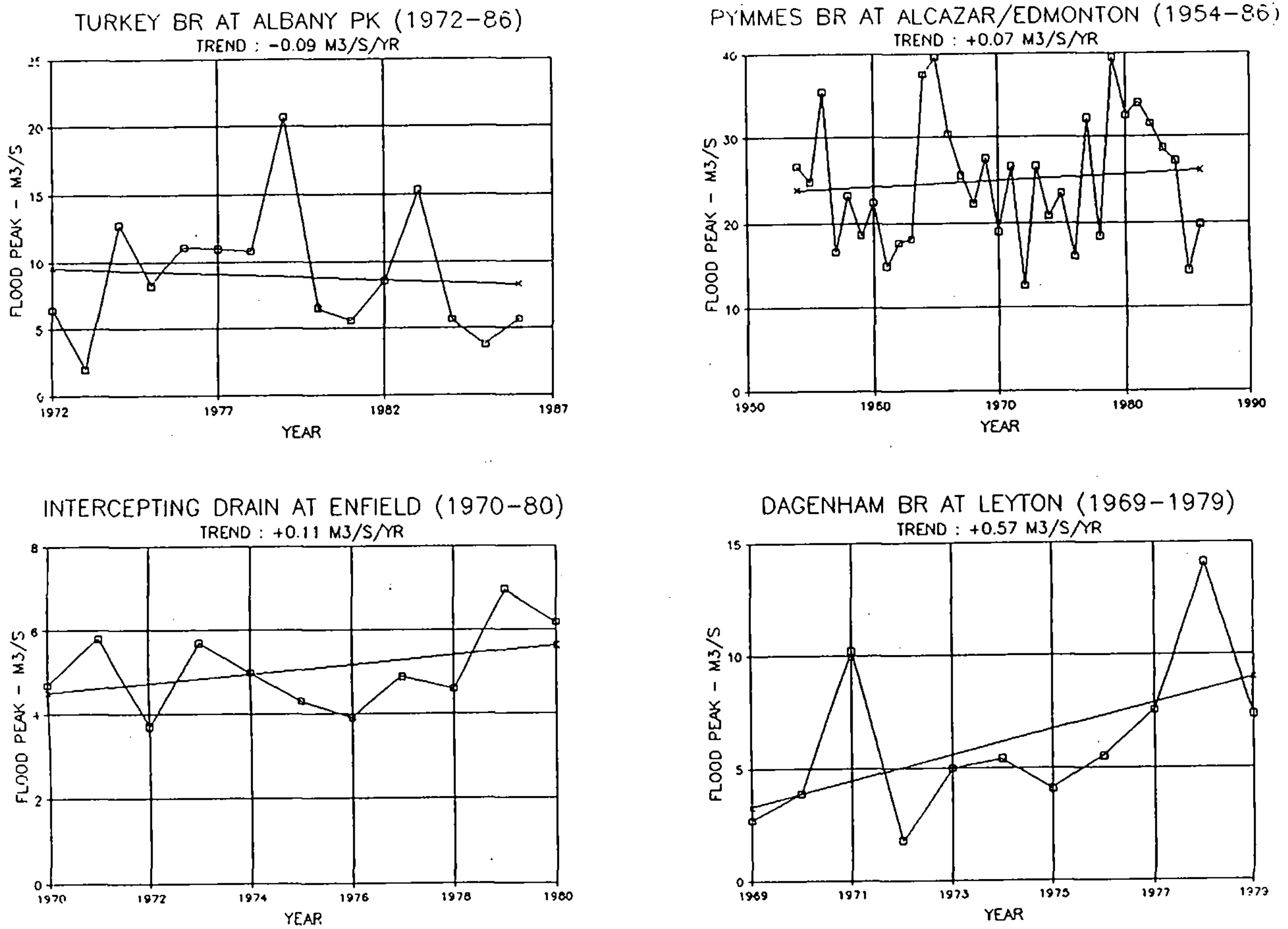

TURKEY BR AT ALBANY PK (1972-86)
TREND : -0.09 M3/S/YR
FLOOD PEAK - M3/S
YEAR
0
5
10
15
20
1972
1977
1982
1987
PYMMES BR AT ALCAZAR/EDMONTON (1954-86)
TREND : +0.07 M3/S/YR
FLOOD PEAK - M3/S
YEAR
0
10
20
30
40
1950
1960
1970
1980
1990
INTERCEPTING DRAIN AT ENFIELD (1970-80)
TREND : +0.11 M3/S/YR
FLOOD PEAK - M3/S
YEAR
0
2
4
6
8
1970
1972
1974
1976
1978
1980
DAGENHAM BR AT LEYTON (1969-1979)
TREND : +0.57 M3/S/YR
FLOOD PEAK - M3/S
YEAR
0
5
10
15
1969
1971
1973
1975
1977

FIGURE 3.1 (B)

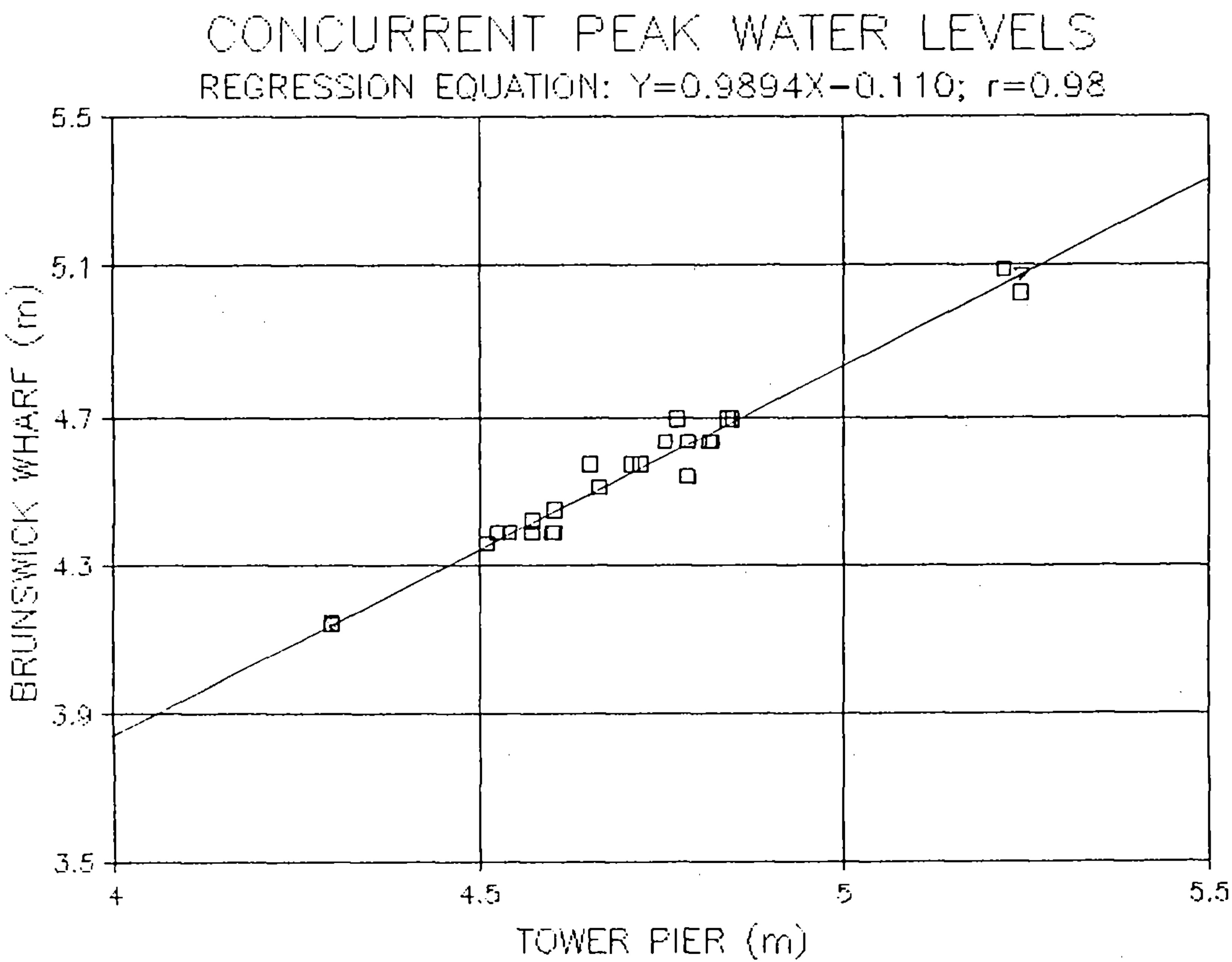

CONCURRENT PEAK WATER LEVELS
REGRESSION EQUATION: Y=0.9894X-0.110; r=0.98
5.5
5.1
4.7
4.3
3.9
3.5
BRUNSWICK WHARF (m)
4
4.5
5
5.5
TOWER PIER (m)

FIGURE 4.1

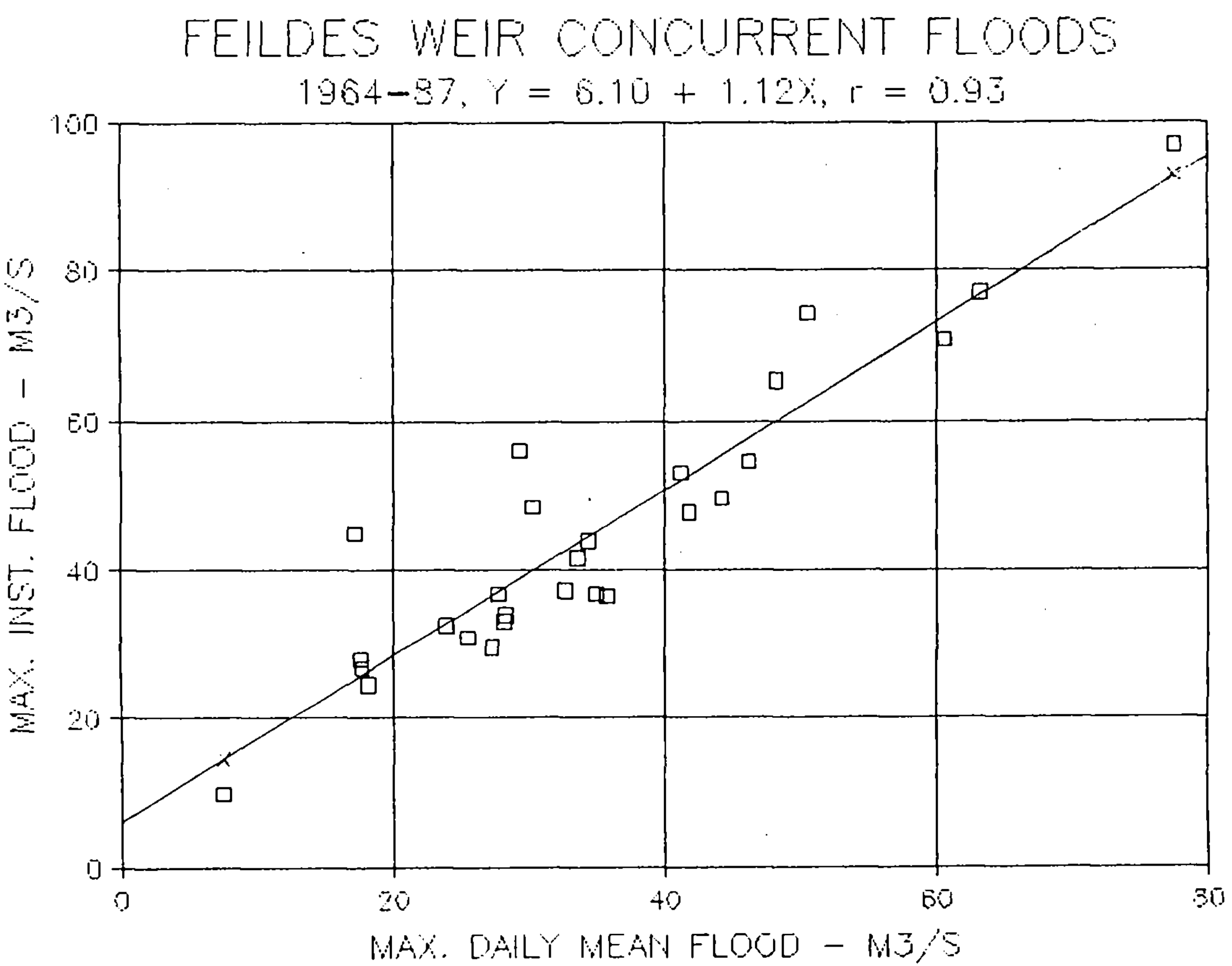
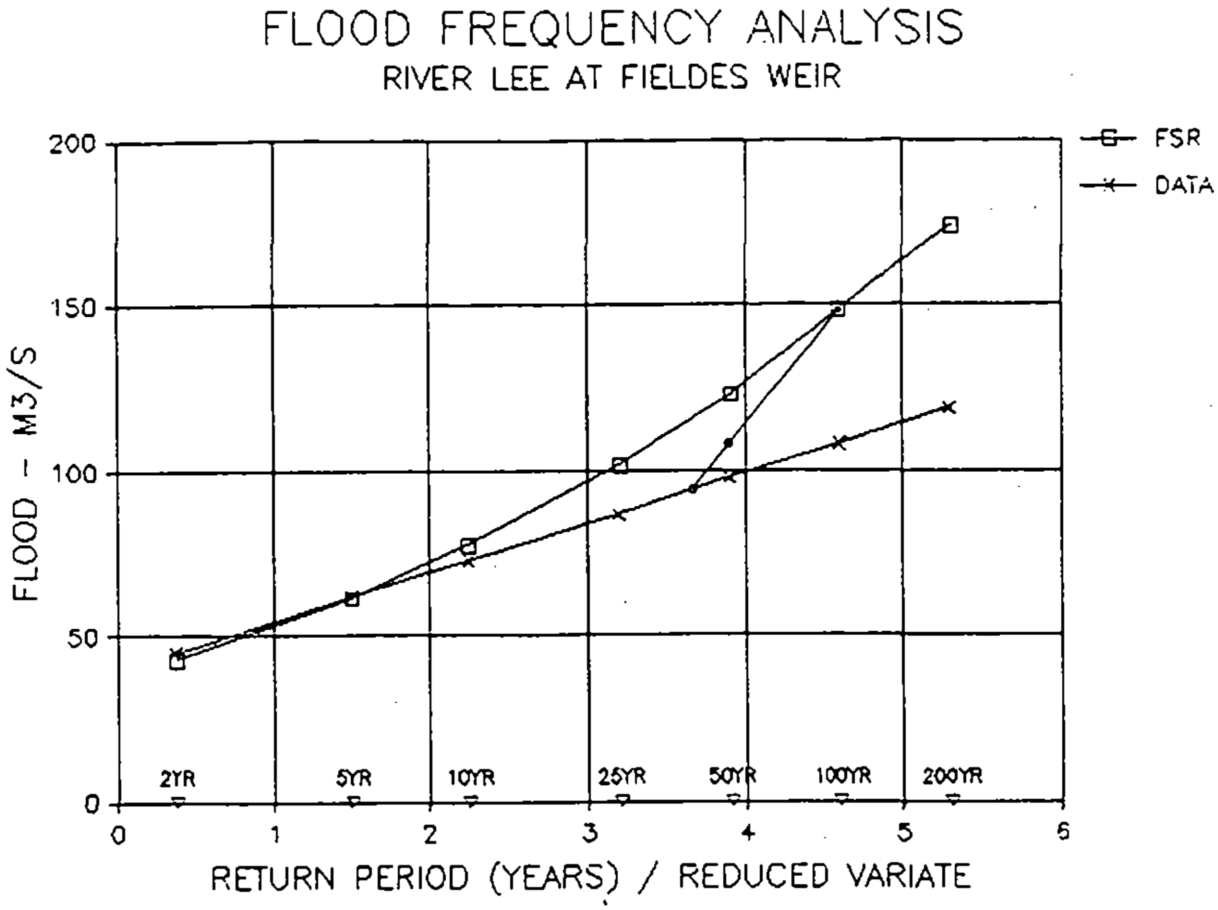

FEILDES WEIR CONCURRENT FLOODS
1964-87, Y = 6.10 + 1.12X, r = 0.93
MAX. INST. FLOOD - M3/S
MAX. DAILY MEAN FLOOD - M3/S
0
20
40
60
80
100

FIGURE 5.1


FLOOD FREQUENCY ANALYSIS
RIVER LEE AT FIELDES WEIR
FSR
DATA
FLOOD - M3/S
RETURN PERIOD (YEARS) / REDUCED VARIATE
200
150
100
50
0
0
1
2
3
4
5
6
2YR
5YR
10YR
25YR
50YR
100YR
200YR

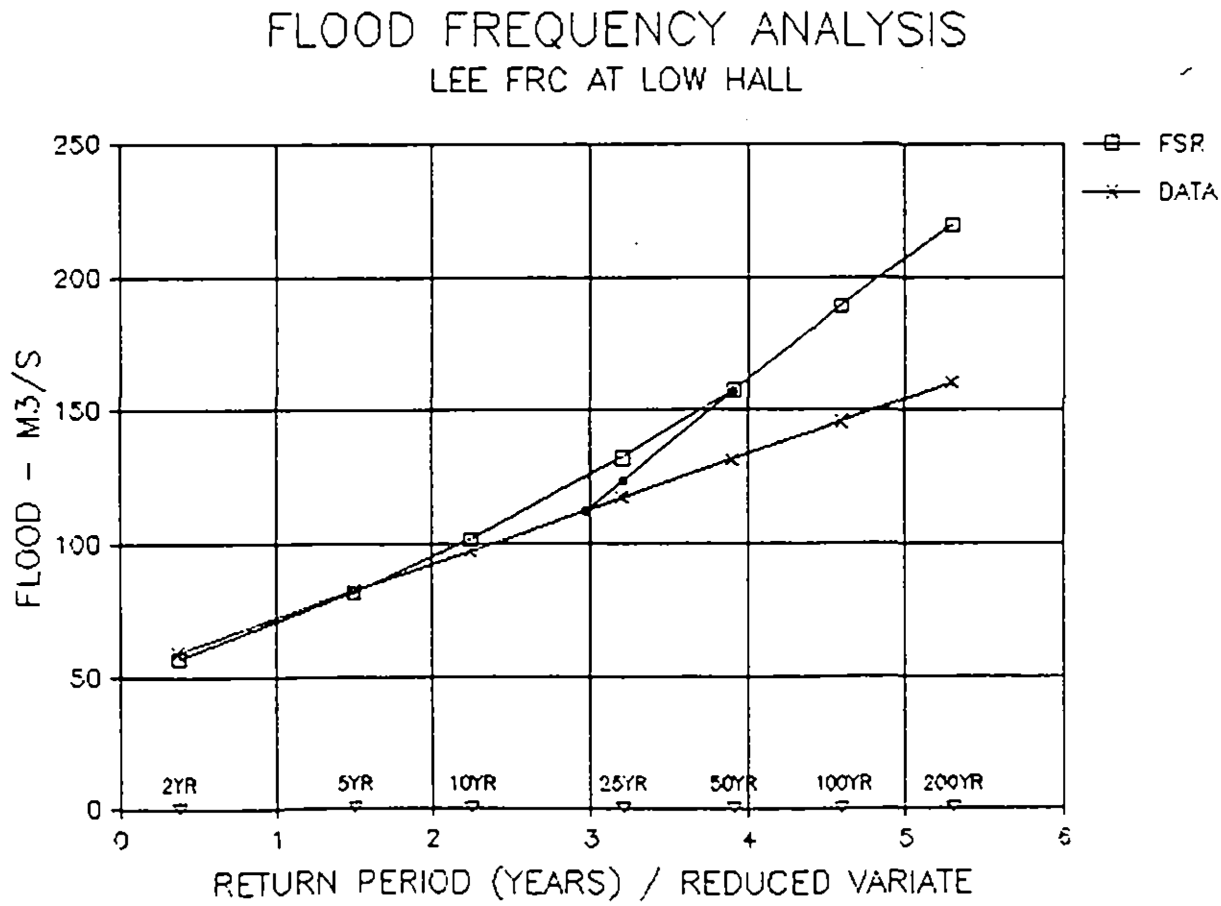
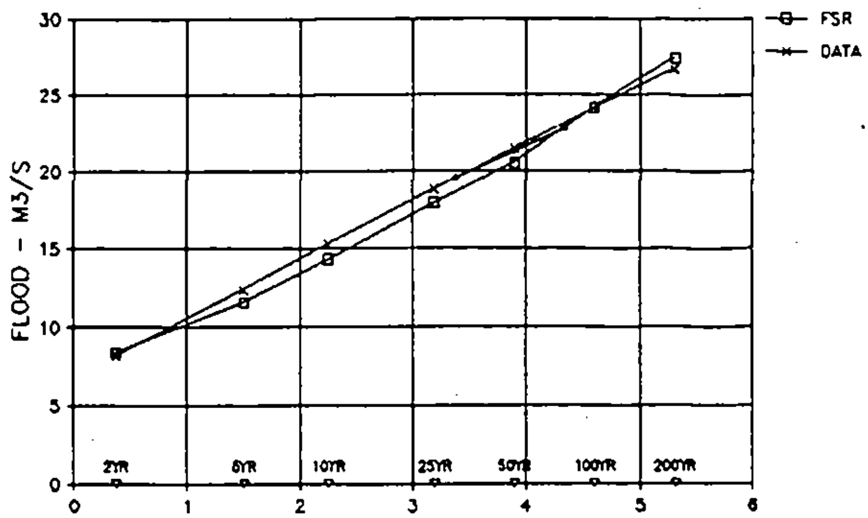
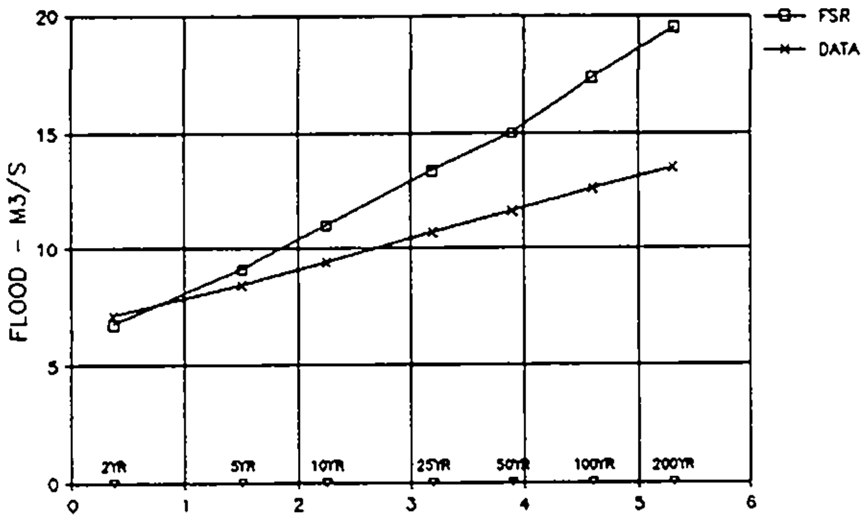

FLOOD FREQUENCY ANALYSIS
LEE FRC AT LOW HALL
FSR
DATA
FLOOD - M3/S
RETURN PERIOD (YEARS) / REDUCED VARIATE
250
200
150
100
50
0
0
1
2
3
4
5
6
2YR
5YR
10YR
25YR
50YR
100YR
200YR

FIGURE 5.2 (A)

FLOOD FREQUENCY ANALYSIS
TURKEY BROOK AT ALBANY PARK



FLOOD FREQUENCY ANALYSIS
SALMON BROOK AT EDMONTON



FLOOD FREQUENCY ANALYSIS
PYMMES BROOK AT ALCAZAR/EDMONTON

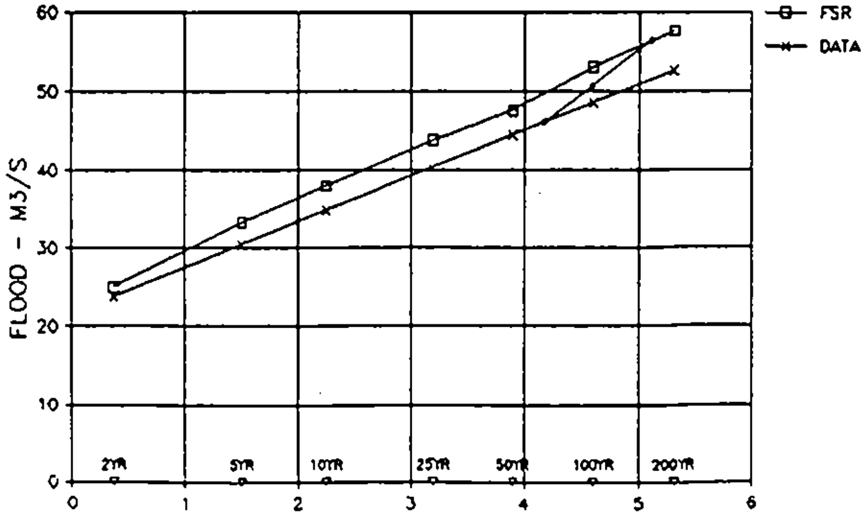
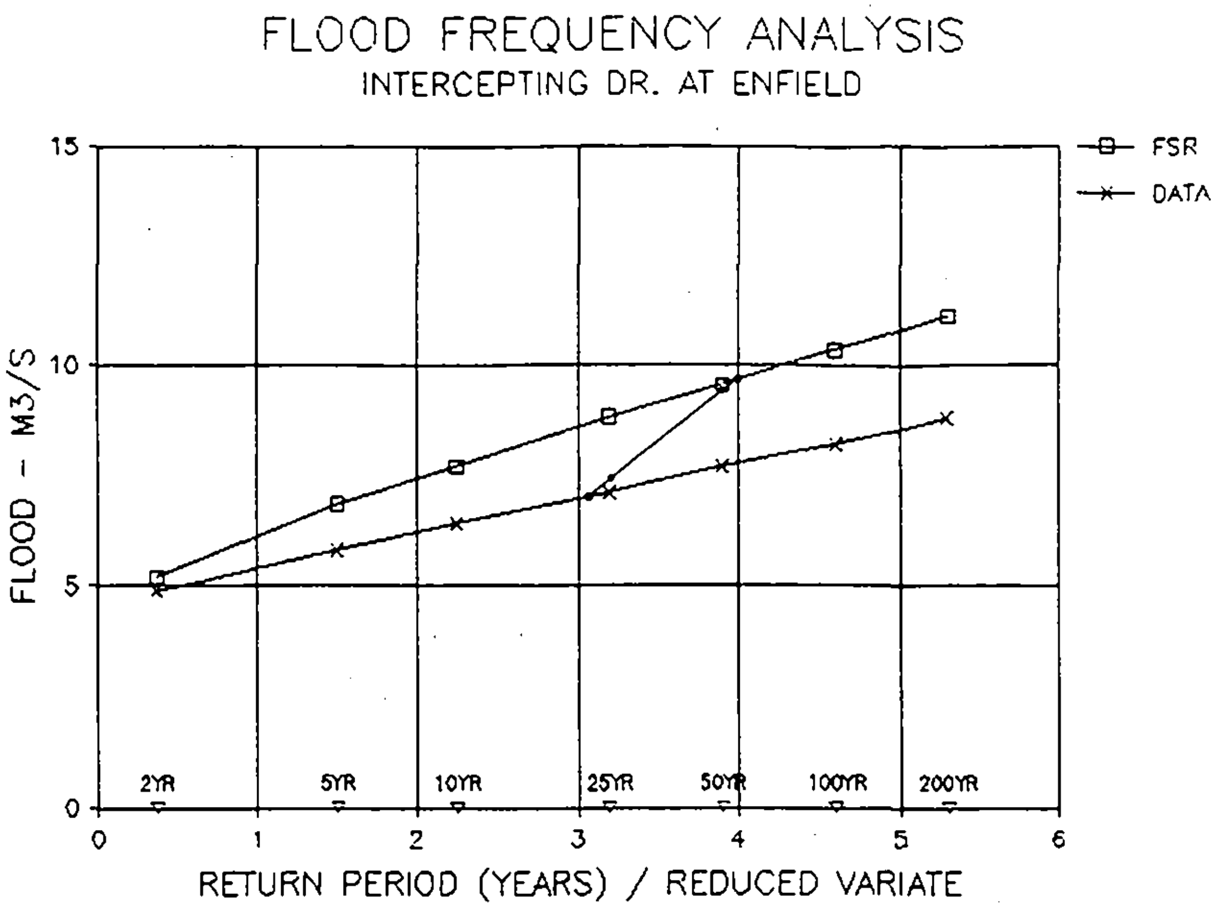


FIGURE 5.2 (B)


FLOOD FREQUENCY ANALYSIS
INTERCEPTING DR. AT ENFIELD
FLOOD - M3/S
RETURN PERIOD (YEARS) / REDUCED VARIATE
FSR
DATA
2YR
5YR
10YR
25YR
50YR
100YR
200YR
0
5
10
15
0
1
2
3
4
5
6

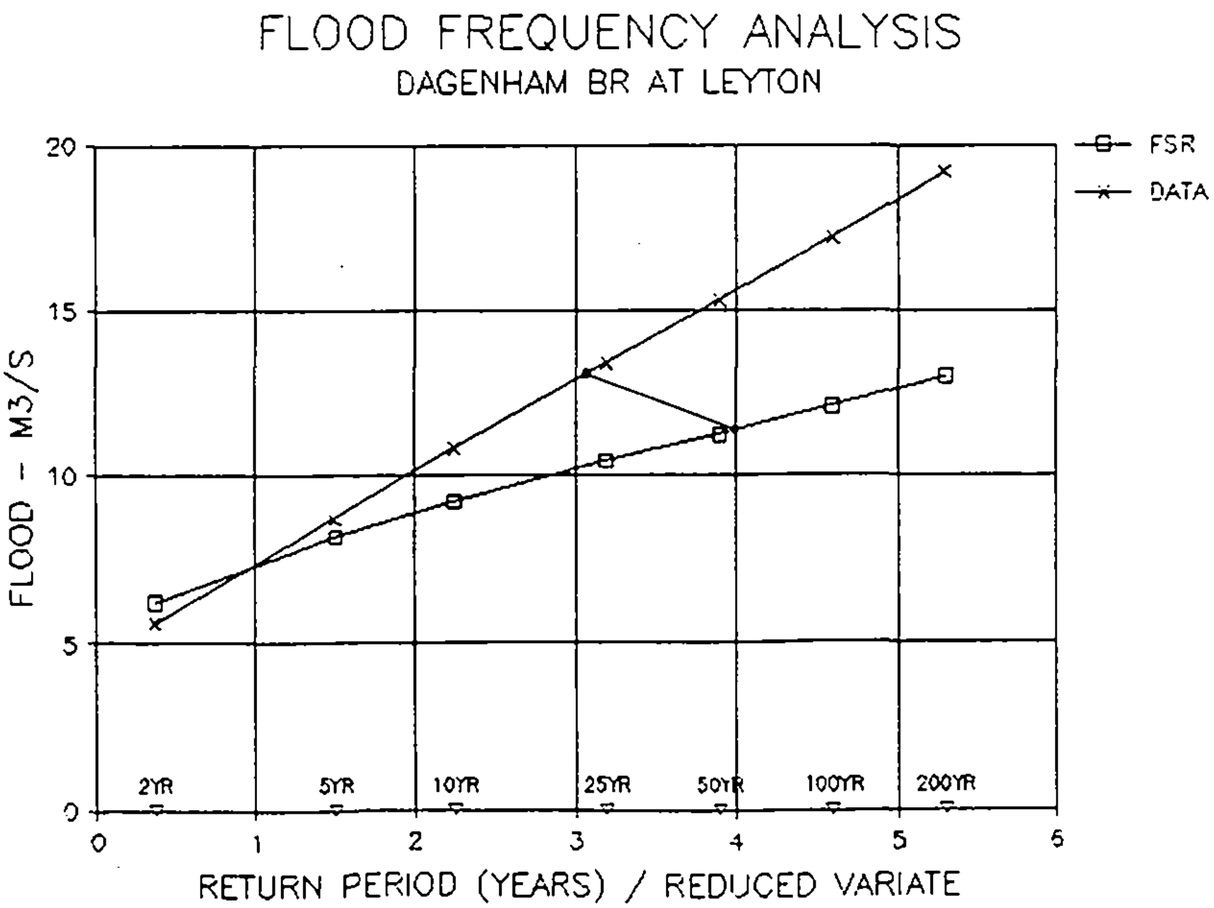
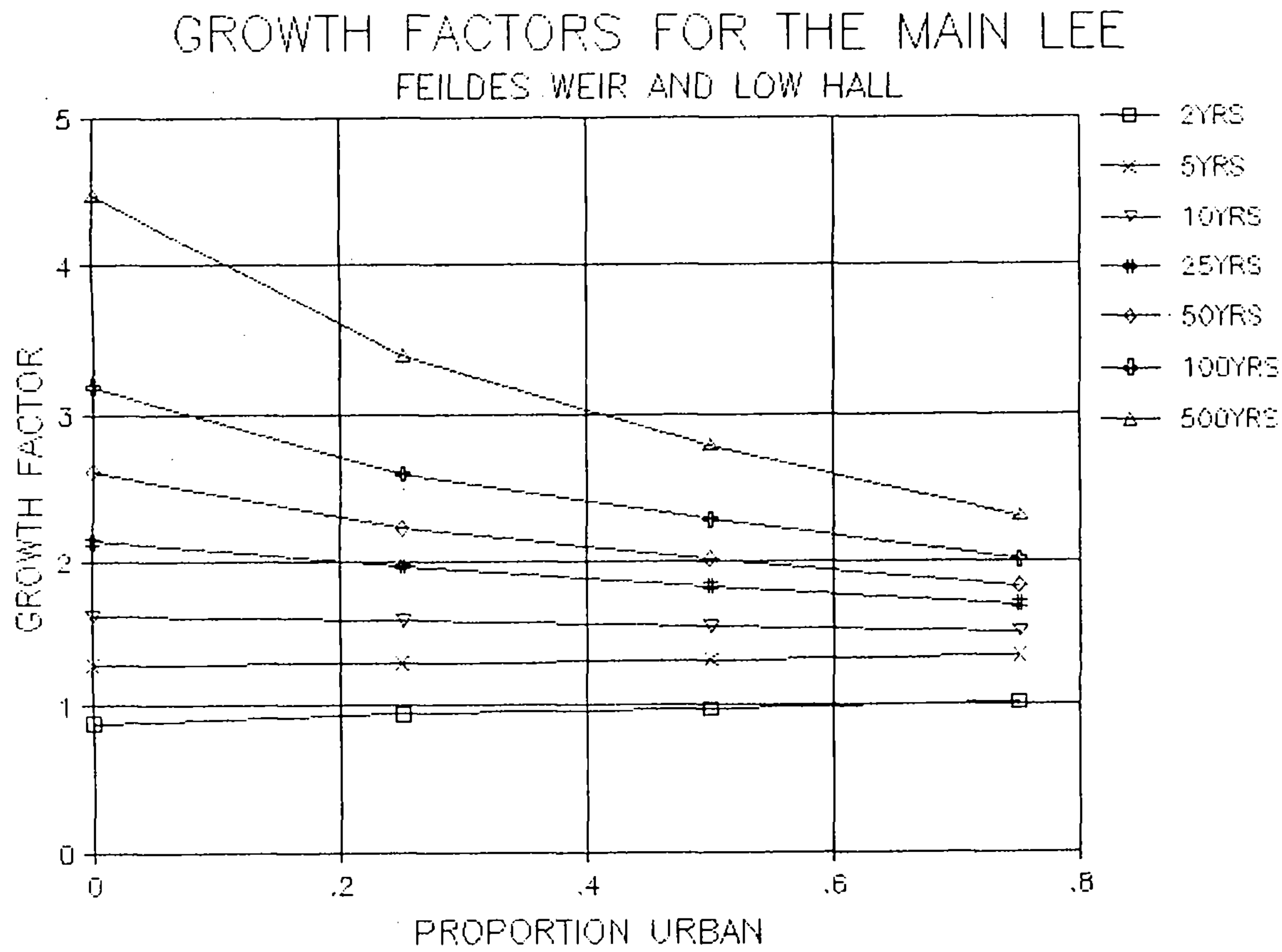

FLOOD FREQUENCY ANALYSIS
DAGENHAM BR AT LEYTON
FLOOD - M3/S
RETURN PERIOD (YEARS) / REDUCED VARIATE
FSR
DATA
2YR
5YR
10YR
25YR
50YR
100YR
200YR
0
5
10
15
20
0
1
2
3
4
5
6

FIGURE 5.2 (C)



GROWTH FACTORS FOR THE MAIN LEE
FEILDES WEIR AND LOW HALL
GROWTH FACTOR
PROPORTION URBAN
0
1
2
3
4
5
0
.2
.4
.6
.8
2YRS
5YRS
10YRS
25YRS
50YRS
100YRS
500YRS

FIGURE 5.3

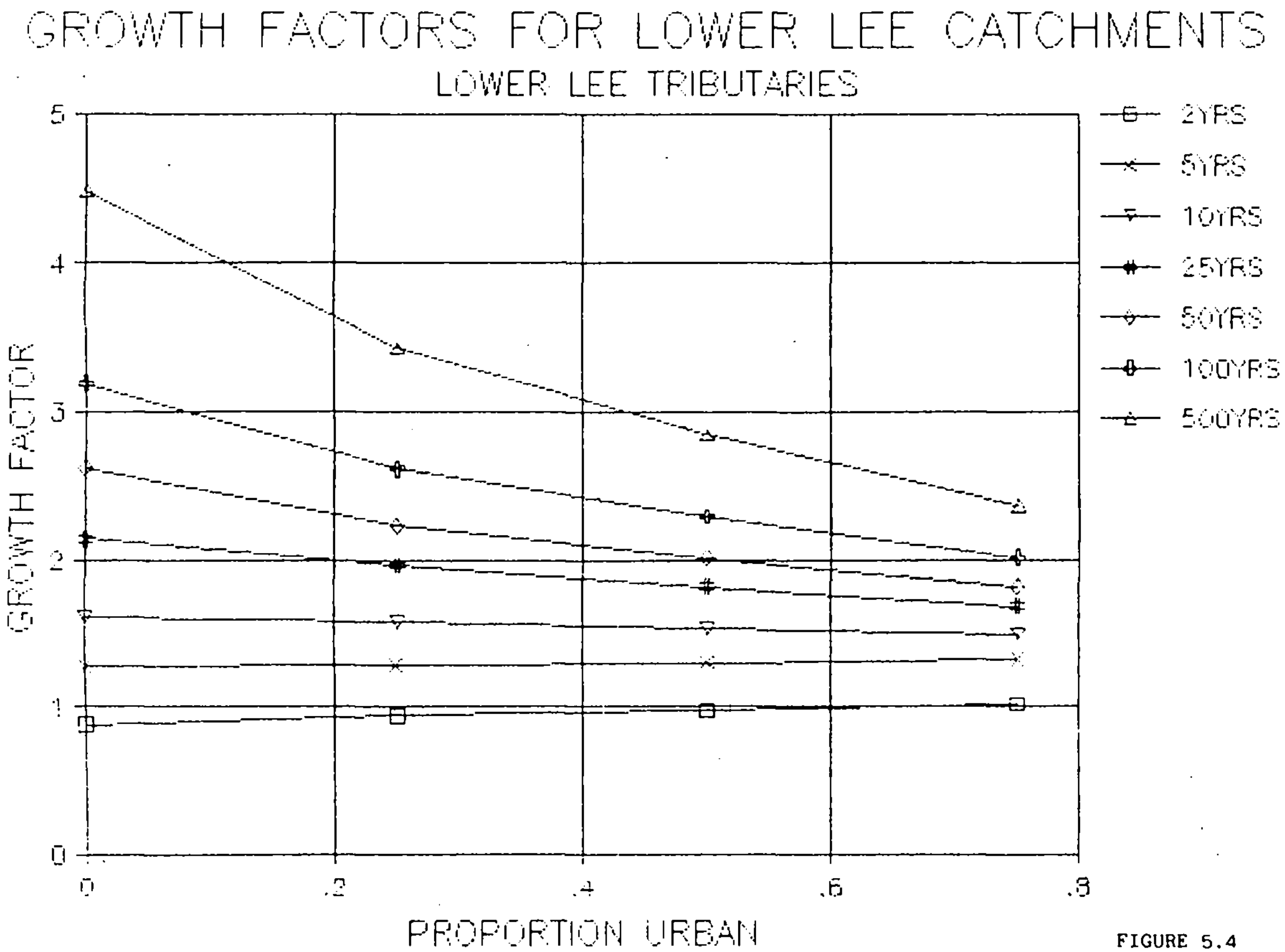

GROWTH FACTORS FOR LOWER LEE CATCHMENTS
LOWER LEE TRIBUTARIES
GROWTH FACTOR
PROPORTION URBAN
0
1
2
3
4
5
0
.2
.4
.6
.8
2YRS
5YRS
10YRS
25YRS
50YRS
100YRS
500YRS

FIGURE 5.4

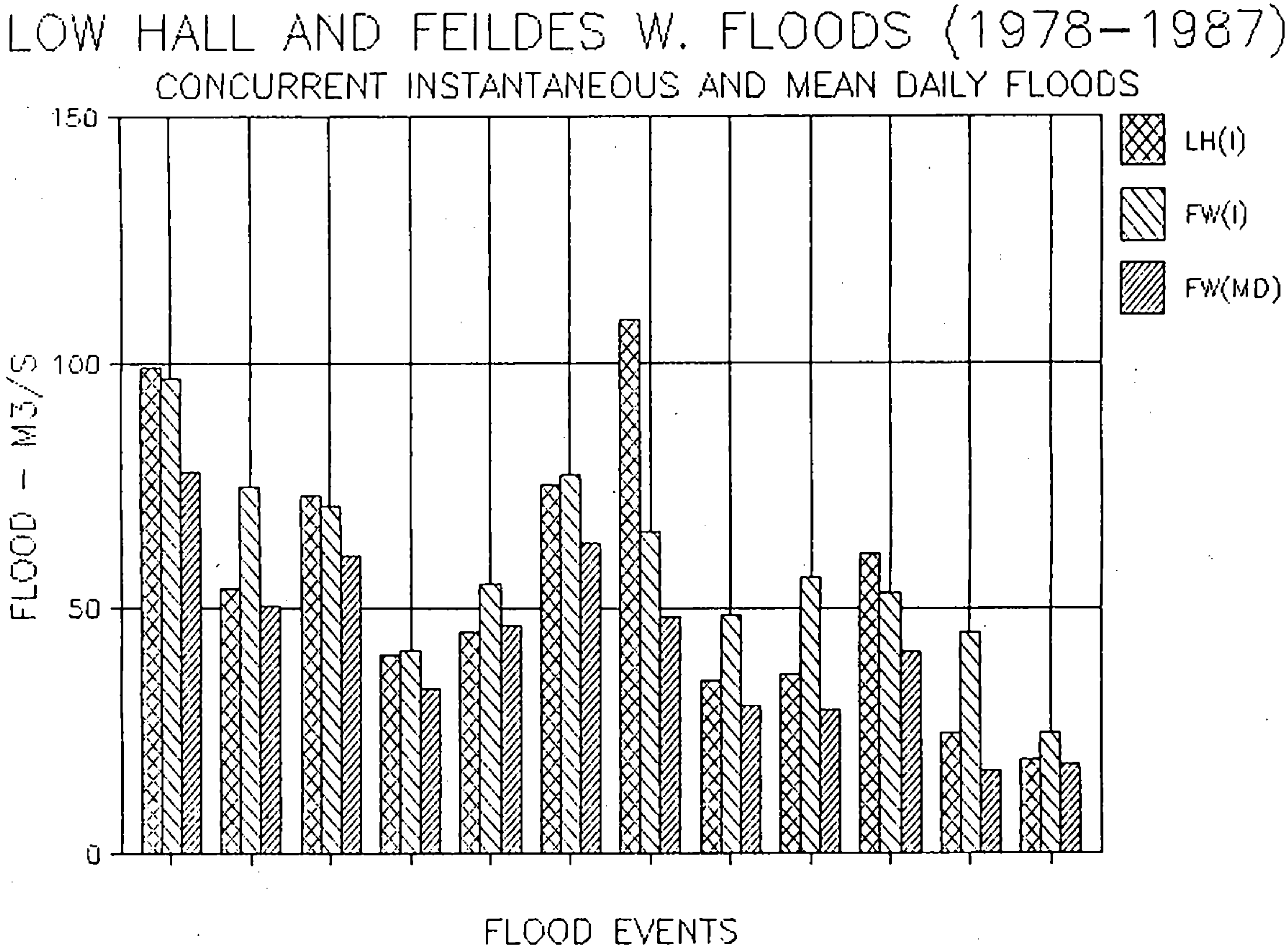

LOW HALL AND FEILDES W. FLOODS (1978-1987)
CONCURRENT INSTANTANEOUS AND MEAN DAILY FLOODS
150
100
50
0
FLOOD - M3/S
FLOOD EVENTS
LH(I)
FW(I)
FW(MD)

FIGURE 6.1

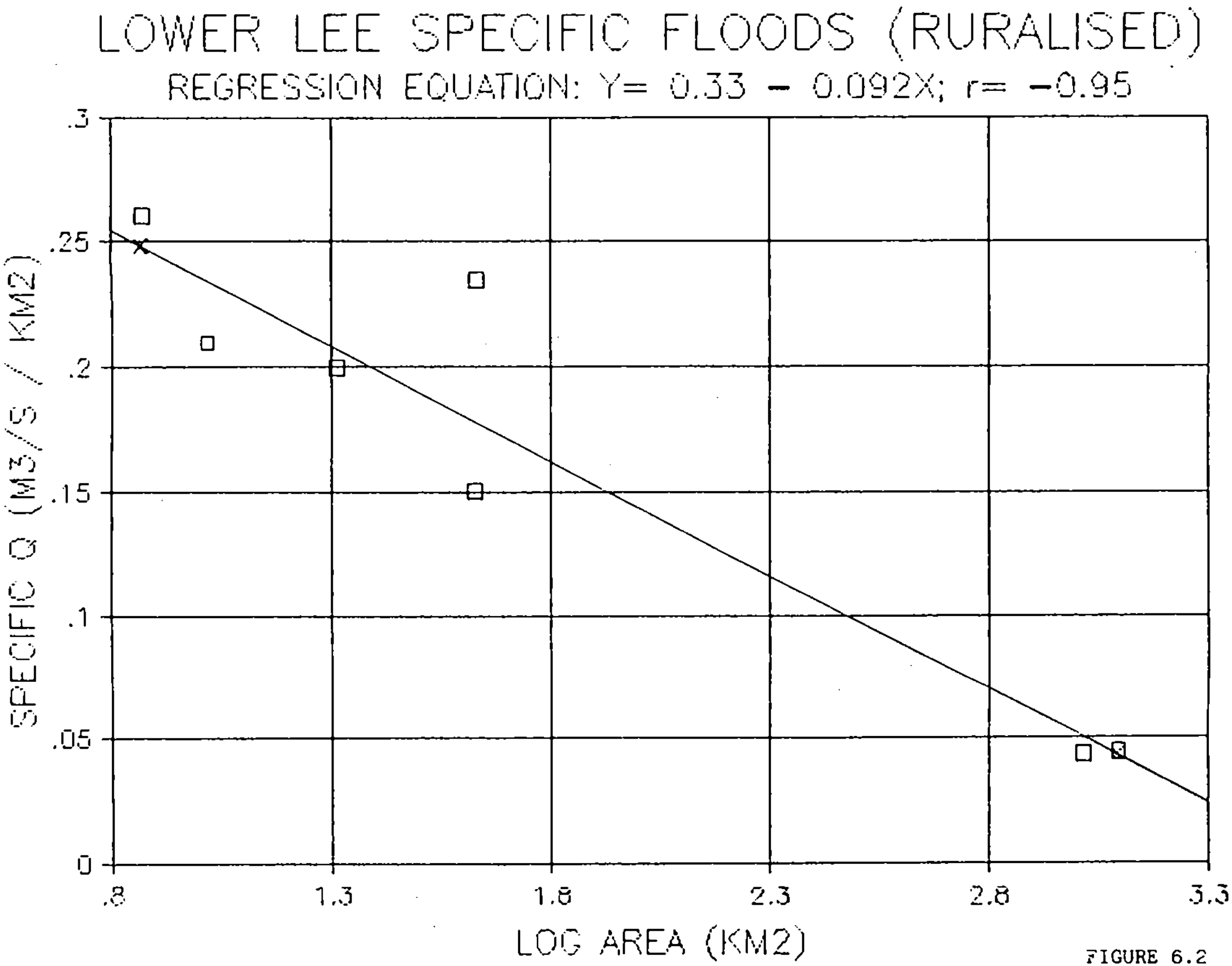

LOWER LEE SPECIFIC FLOODS (RURALISED)
REGRESSION EQUATION: Y= 0.33 - 0.092X; r= -0.95
SPECIFIC Q (M3/S / KM2)
0
.05
.1
.15
.2
.25
.3
.8
1.3
1.8
2.3
2.8
3.3
LOG AREA (KM2)

FIGURE 6.2

TABLE 2.1 AVAILABILITY OF ANNUAL MAXIMUM TIDAL RIVER LEVELS

RIVER	STATION	GRID REF	PERIOD OF DATA
THAMES	TOWER PIER	TQ334805	1912-86
THAMES	BRUNSWICK WHARF	TQ390807	1954-83
THAMES	NORTH WOOLWICH	TQ444804	1915-86
LEE	BOW LOCKS	TQ383823	1935-72
LEE	LEE BARRIER	TQ394812	1972-82

TABLE 2.2 ANNUAL MAXIMUM TIDAL WATER LEVELS

YEAR	THAMES BRUNSWICK WHARF	LEE (BOW CREEK) BOW LOCKS
1935		4.93
1936		4.88
1937		
1938		5.11
1939		
1940		
1941		
1942		
1943		5.01
1944		4.63
1945		
1946		
1947		4.71
1948		
1949		5.44
1950		4.72
1951		
1952		4.89
1953		5.72
1954	4.51	4.48
1955	4.54	4.45
1956	4.18	4.33
1957	4.63	4.60
1958	4.51	4.60
1959	4.39	4.42
1960	4.39	4.42
1961	4.70	4.72
1962	4.45	4.33
1963	4.39	
1964	4.36	
1965	5.03	5.15
1966	4.63	4.66
1967	4.63	4.63
1968	4.57	4.63
1969	4.39	4.48
1970	4.42	4.63
1971	4.39	4.42
1972	4.39	4.42
1973	4.70	
1974	4.39	
1975	4.70	
1976	4.57	
1977	4.63	
1978	5.09	
1979	4.45	
1980	4.57	
1981	4.60	
1982	4.40	
1983	4.40	
1984		
1985		
1986		

TABLE 2.3 FLOOD DATA AVAILABILITY ON LOWER LEE AND TRIBUTARIES

RIVER	STATION	NO.	GRID REF	AREA KM2	DATES OF RECORD	YEARS OF RECORD	ANALYSIS +	MAF M3/S	MAX REC Q M3/S	TREND M3/S/YR	TREND % MAF
LEE	FEILDES WEIR	038001	TL390092	1036	1873-1986	109	AMD	40	118	-0.12	-.3
"	" "	"	"	1036	1965-86	20	AMD	38	78	+0.70	1.8
"	" "	"	"	1036	1965-86	20	AM	48	97	+1.50	3.1
TURKEY BR	ALBANY PK	038021	TQ359985	42.2	1972-86	15	AM	9.0	20.7	-0.09	-1.0
LEE	CHALK BR	038908	TQ356913	1240	-	-	R	-	-	-	-
SALMON'S BR	EDMONTON	038014	TQ343937	20.5	1980-86	7	POT	7.0	8.2	-	-
	MONTAGUE RD	038919	TQ354932	33.9	-	-	R	-	-	-	-
INTERCEPT. DR	ENFIELD	038015	TQ355932	7.4	1969-80	11	AM	5.1	7	+0.11	2.2
PYMME'S BR	ALCAZAR/	038925	TQ340925	41.4	1954-86	33	AM	25	40	+0.07	.3
	EDMONTON	038022	TQ343937	42.6							
LEE FLOOD RC	LOW HALL	038023	TQ356880	1243	1977-86	10	AM	63	109	-2.80	-4.4
					1977-86	10	POT	63	109		
DAGENHAM BR	LEYTON	038910	TQ374864	10.4	1969-79	11	AM	6.1	14.1	+0.57	9.3

\+ AMD = Annual maximum series, mean daily peaks
AM = Annual maximum series
POT = 'Peaks - over - threshold' series
R = Rejected data series

TABLE 2.4 ANNUAL MAXIMUM INSTANTANEOUS FLOOD PEAK DATA

YEAR	LEE FEILDES WEIR	TURKEY BR ALBANY PARK	SALMON'S BR EDMONTON	INT'CEPT DR ENFIELD	PYMME'S BR ALCAZAR/ EDMONTON	LEE FL RC LOW HALL	DAGENHAM BR LEYTON
1954					26.6		
1955					24.8		
1956					35.4		
1957					16.6		
1958					23.3		
1959					18.6		
1960					22.4		
1961					14.9		
1962					17.6		
1963					18.1		
1964					37.5		
1965	32.6				39.7		
1966	36.8				30.4		
1967	34.0				25.6		
1968	49.6				22.3		
1969	36.8				27.6		2.7
1970	36.5			4.7	19.0		3.9
1971	37.2			5.8	26.6		10.2
1972	29.6	6.5		3.7	12.6		1.8
1973	9.9	2.0		5.7	26.6		5.0
1974	47.7	12.8		5.0	20.8		5.4
1975	44.0	8.3		4.3	23.5		4.1
1976		11.1		3.9	16.0		5.5
1977		11.0		4.9	32.2	58.4	7.5
1978	96.9	10.8		4.6	18.4	99.3	14.1
1979	74.3	20.7		7.0	39.5	72.9	7.3
1980	41.6	6.6	7.8	6.2	32.5	40.9	
1981	54.7	5.6	6.9		34.0	45.2	
1982	77.0	8.6	8.2		31.6	75.1	
1983	65.3	15.3	6.8		28.7	108.7	
1984	48.5	5.7	6.5		27.2	36.9	
1985	56.1	3.8	4.3		14.3	60.8	
1986	45.0	5.7	4.4		19.8	30.7	

NOTE : ALL FLOWS IN M3/S

TABLE 2.5 CATCHMENT AREAS AND URBAN PERCENTAGES

(A) RIVER GAUGING STATIONS ON LOWER LEE AND TRIBUTARIES

RIVER	STATION	AREA KM2	URBAN %
LEE	FEILDES WEIR	1036	4*
TURKEY BR	ALBANY PK	42.2	22
SALMON'S BR	EDMONTON	20.5	35
INTERCEPT. DR	ENFIELD	7.4	71
PYMME'S BR	ALCAZAR/	41.4	66
	EDMONTON	42.6	66
LEE FLOOD RC	LOW HALL	1243	8*
DAGENHAM BR	LEYTON	10.4	95*

* approximate

(B) LEE NAVIGATION CHANNEL SUB-CATCHMENTS AND URBAN AREAS

SUB-CATCHMENT	AREA KM2	URBAN %
SADDLER'S MILL ST	10.6	75
INTERCEPTING DR	7.4	71
BRIMSDOWN DR	0.5	88
ENFIELD DR	1.9	50
SALMON'S BR	24.8	35
PYMME'S BR	45.6	67
REMAINDER **	25.7	78
TOTAL	116.5	63

** remainder consists of remaining area fully drained by navigation channel down to Lea Bridge.

TABLE 3.1 CORRELATION AND RISE IN ANNUAL MAXIMUM LEVEL

	SOUTHEND	TILBURY	NORTH WOOLWICH	BRUNSWICK WHARF	TOWER PIER	RICHMOND
CORRELATION COEFFICIENT	.27	.29	.26	.17	.17	.34
RATE OF RISE MM/YR	3.28	3.47	2.82	3.59	1.84	2.53

TABLE 4.1 QUANTILES FOR THAMES TIDAL STATIONS (M AOD)

RETURN PERIOD	STATION				
	SOUTHEND	TILBURY	NORTH WOOLWICH	BRUNSWICK WHARF	TOWER PIER
2	3.54	3.94	4.36	4.49	4.60
5	3.79	4.19	4.61	4.73	4.84
10	3.97	4.37	4.77	4.88	4.99
25	4.20	4.60	4.98	5.06	5.16
50	4.39	4.78	5.13	5.20	5.28
100	4.57	4.96	5.28	5.33	5.40

TABLE 4.2 QUANTILES FOR THAMES TIDAL STATIONS (M AOD)
(UPDATED TO 1986 USING LOCAL TREND)

RETURN PERIOD	STATION				
	SOUTHEND	TILBURY	NORTH WOOLWICH	BRUNSWICK WHARF	TOWER PIER
2	3.66	4.05	4.44	4.56	4.67
5	3.90	4.31	4.67	4.79	4.90
10	4.07	4.49	4.84	4.94	5.05
25	4.31	4.71	5.07	5.12	5.24
50	4.50	4.89	5.24	5.25	5.37
100	4.70	5.06	5.43	5.38	5.50

TABLE 5.1 FLOOD FREQUENCIES ON THE LOWER LEE AND TRIBUTARIES, BASED ON DATA ANALYSES

RIVER	STATION	AREA KM2	DATES OF RECORD	YEARS OF RECORD	DATA *	MAF M3/S	REDUCED VARIATE / RETURN PERIOD (YRS) .367 / 2	1.5 / 5	2.25 / 10	3.199 / 25	3.902 / 50	4.6 / 100	5.296 / 200
							FLOOD PEAK - M3/S						
LEE	FEILDES WEIR	1036	1873-1986	109	AMD	40	37	53	63	76	86	95	105
"	" "	1036	1965-86	20	AMD	38	35	49	59	71	79	88	97
"	" "	1036	1965-86	20	AM	48	45	62	73	87	98	108	119
TURKEY BR	ALBANY PK	42.2	1972-86	15	AM	9.0	8.2	12.4	15.3	18.8	21.5	24.1	26.7
SALMON'S BR	EDMONTON	20.5	1980-86	7	POT	7.0	7.1	8.4	9.4	10.7	11.6	12.6	13.5
INTERCEPT DR	ENFIELD	7.4	1969-80	11	AM	5.1	4.9	5.8	6.4	7.1	7.7	8.2	8.8
PYMME'S BR	ALCAZAR/ EDMONTON	41.4 42.6	1954-86	33	AM	25.0	23.8	30.4	34.8	40.3	44.4	48.5	52.5
LEE FLOOD R C	LOW HALL	1243	1977-86	10	AM	63	59	82	97	117	131	145	160
DAGENHAM BR	LEYTON	10.4	1969-79	11	AM	6.1	5.6	8.7	10.8	13.4	15.3	17.2	19.2

* AMD = annual maximum series of mean daily floods
AM = annual maximum series
POT = peaks-over-threshold series

TABLE 5.2 FLOOD FREQUENCIES USING MAF AND FSR GROWTH FACTORS ONLY

RIVER	STATION	AREA KM2	MAF M3/S	REDUCED VARIATE / RETURN PERIOD (YRS) .367 2	1.5 5	2.25 10	3.199 25	3.902 50	4.6 100	5.296 200
				FLOOD PEAK - M3/S						
LEE	FEILDES WEIR	1036	48	43	61	78	102	123	149	173
TURKEY BR	ALBANY PK	42.2	9.0	8.4	11.6	14.3	17.9	20.5	24.1	27.5
SALMON'S BR	EDMONTON	20.5	7.0	6.7	9.1	11.0	13.4	15.0	17.4	19.5
INTERCEPT. DR	ENFIELD	7.4	5.1	5.2	6.8	7.7	8.7	9.4	10.4	11.2
PYMME'S BR	ALCAZAR	41.4	25	25.0	33.3	38.0	43.8	47.5	53.0	57.5
	EDMONTON	42.6								
LEE FLOOD R C	LOW HALL	1243	63	57	81	101	132	157	190	220
DAGENHAM BR	LEYTON	10.4	6.1	6.2	8.2	9.2	10.4	11.2	12.3	13.2

NOTE : Based on MAF's from Table 5.1 and growth factors from Table 5.5

TABLE 5.3 PROPOSED FLOOD FREQUENCIES FOR GAUGING STATIONS ON LOWER LEE AND TRIBUTARIES

RIVER	STATION	YEARS OF RECORD (N)		REDUCED VARIATE / RETURN PERIOD (YRS) .367 / 2	1.500 / 5	2.250 / 10	3.199 / 25	3.902 / 50	4.600 / 100	5.296 / 200
LEE	FEILDES WEIR	109*	Q (M3/S)	37	53	63	76	86	95	105
			NOTE	1	1	1	1	1	1	1
LEE	FEILDES WEIR	20*	Q (M3/S)	35	49	59	71	-	-	-
			NOTE	1	1	1	1	-	-	-
LEE	FEILDES WEIR	20	Q (M3/S)	45	62	73	87	109	149	173
			NOTE	1	1	1	1	2	3	3
TURKEY BR	ALBANY PK	15	Q (M3/S)	8.2	12.4	15.3	18.8	21.3	24.1	27.5
			NOTE	1	1	1	1	2	3	3
SALMON'S BR	EDMONTON	7	Q (M3/S)	6.7	9.1	11.0	13.4	15.0	17.4	19.5
			NOTE	3	3	3	3	3	3	3
INTERCEPT. DR	ENFIELD	11	Q (M3/S)	4.9	5.8	6.4	7.4	9.4	10.4	11.2
			NOTE	1	1	1	2	2	3	3
PYMME'S BR	ALCAZAR/ EDMONTON	33	Q (M3/S)	23.8	30.4	34.8	40.3	44.4	50.7	57.5
			NOTE	1	1	1	1	1	2	3
LEE FLOOD RC	LOW HALL	10	Q (M3/S)	59	82	97	124	157	190	220
			NOTE	1	1	1	2	3	3	3
DAGENHAM BR	LEYTON	11	Q (M3/S)	5.6	8.7	10.8	13.4	15.3	17.2	19.2
			NOTE	**1	**1	**1	**1	**1	**1	**1

* mean daily flows
** substantially higher data analysis values are preferred for this highly urban catchment (beyond FSR range)

NOTE 1 : data frequency analysis
2 : transition line between 2N and 5N
3 : MAF with FSR growth factors

TABLE 5.4(A) GROWTH FACTORS FOR THE MAIN LEE

FEILDES WEIR AND LOW HALL

1 CATCHMENT RAINFALL SAAR
(A) SAAR = 650

2 CWI
(A) CWI = 95

3 SOIL (AV FOR FW AND LH)
SOIL = .33

4 PRr
(A) PRr = 102.4 SOIL + .28(CWI-125)
PRr = 25.392

5 URBAN
(A) URBAN VALUES 0 .25 .5 .75

6 GROWTH FACTORS UP TO 50 YEARS RETURN PERIOD

RET PER YRS	URBAN = 0	.25	.5	.75
		GROWTH	FACTORS	
2	.88	.94	.98	1.02
5	1.28	1.3	1.32	1.34
10	1.62	1.59	1.55	1.51
25	2.14	1.97	1.83	1.7
50	2.62	2.23	2.02	1.83

(REF: FSSR NO 5,TABLES 1 & 2; FSSR NO 14,TABLE 1)

7 GROWTH FACTORS FOR 100 YEARS RETURN PERIOD AND LONGER
(REF: FSSR NO 5)

$$MAFu/MAFr = (1 + URBAN)^{1.5} \; (1.0 + 0.3URBAN\ (70/PRr - 1))$$

$$QTu/QTr = 1 + Be^{-ky}$$

$$k = .48(\ln(MAFu/MAFr - 1) - \ln(Q50u/Q50r - 1))$$

$$B = (Q50u/Q50r - 1)e^{3.9k}$$

URBAN =	0	.25	.5	.75
MAFu/MAFr	1	1.582	2.321	3.230
Q50u/Q50r	1	1.346	1.790	2.256
k	0	.249	.247	.276
B	0	.914	2.070	3.679

RET PER YRS		GROWTH	FACTORS	
100	3.19	2.60	2.29	2.01
500	4.49	3.39	2.80	2.31

TABLE 5.5 : CATCHMENT PARAMETERS AND URBANISED GROWTH FACTORS (SE AND 6/7 REGIONS)

RIVER	LOCATION	AREA KM2	SAAR MM	CURRENT URBAN	SOIL	FSR GROWTH FACTORS 2YR	5YR	10YR	25YR	50YR	100YR	200YR
LEE	FEILDES WEIR	1036	650	.04	.32	.89	1.28	1.62	2.12	2.57	3.11	3.61
TURKEY BR	ALBANY PK	42.2	645	.22	.45	.93	1.29	1.59	1.99	2.28	2.68	3.05
SALMON'S BR	EDMONTON	20.5	625	.35	.45	.96	1.3	1.57	1.91	2.14	2.48	2.78
INTERCEPT. DR	ENFIELD	7.4	615	.71	.45	1.01	1.34	1.51	1.71	1.85	2.03	2.2
PYMME'S BR	ALCAZAR EDMONTON	41.4 42.6	660	.66	.45	1	1.33	1.52	1.75	1.9	2.12	2.3
LEE FLOOD R C	LOW HALL	1243	650	.08	.33	.9	1.29	1.61	2.09	2.5	3.02	3.5
DAGENHAM BR	LEYTON	10.4	610	.95	.45	1.02	1.34	1.51	1.7	1.83	2.02	2.17
LEE NAVIG CH	LEA BRIDGE	116.5	650	.63	.45	1	1.33	1.52	1.76	1.91	2.14	2.33

NOTES : 1. 6/7 Region curves used for all catchments.
2. Where URBAN exceeds the FSSR No 5 upper limit of 0.75, growth curves for URBAN = 0.75 have been adopted.
3. For Feildes Weir and Low Hall, SAAR and URBAN are only approximate in this table.
4. For all stations, SAAR = 650mm has been adopted since the range 610-660mm results in effectively the same growth factors.

TABLE 6.1 FEILDES WEIR AND LOW HALL OBSERVED MAF'S

STATION	DATA FORMAT	PERIOD 1873-1986 MAF	N	1965-1986 MAF	N	1977-1986 MAF	N
FEILDES WEIR	MEAN DAILY	40	109	38	20	46	9
FEILDES WEIR	INSTANTANEOUS	-	-	48	20	62	9
LOW HALL	INSTANTANEOUS	-	-	-	-	63	9
LOW HALL	INSTANTANEOUS	-	-	-	-	63	10

NOTE : MAF = mean of annual maximum flood series (m3/s)

N = number of years of available data

TABLE 6.2 MEAN ANNUAL FLOODS USING FSR UNGAUGED CATCHMENT PROCEDURE

RIVER	STATION	AREA KM2	STMFRQ	URBAN	MAF M3/S
TURKEY BR	ALBANY PK	42.2	.98	.22	8.3
SALMON'S BR	EDMONTON	20.5	.65	.35	5.2
INTERCEP.DR	ENFIELD	7.4	-	.71	-
PYMME'S BR	EDMONTON	42.6	.26	.66	9.1
DAGENHAM BR	LEYTON	10.4	.21	.95	4.5
LEE NAV CH	LEA BR	116.5	.4	.63	22

NOTES : 1. $MAF = .373\ AREA^{0.70}\ STMFRQ^{0.52}\ (1+URBAN)^{2.5}$, where STMFRQ = stream frequency (junctions/km2) (REF : FSSR5 for Essex, Lee and Thames Region)

2. Lee Navigation Channel computed MAF is not proposed as definitive, but is presented only for comparison.

3. STMFRQ shown for Lee Navigation Channel is the weighted average for Salmon's Br and Pymme's Br.

TABLE 6.3 OBSERVED AND COMPUTED MEAN ANNUAL FLOODS

RIVER	STATION	AREA KM2	URBAN	MAFu (OBS) M3/S	MAFu (FSSR5) M3/S	MAFu/ MAFr (FSSR5)	MAFr M3/S	SPECIFIC MAFr M3/S/KM2
LEE	FEILDES WEIR	1036	.04*	48	-	1.08	45	.043
TURKEY BR	ALBANY PK	42.2	.22	9	8.3	1.42	6.3	.150
SALMON'S BR	EDMONTON	20.5	.35	7	5.2	1.71	4.1	.200
INTERCEPT. DR	ENFIELD	7.4	.71	5.1	-	2.65	1.9	.260
PYMME'S BR	ALCAZAR/ EDMONTON	42.6	.66	25	9.1	2.5	10	.235
LEE FRC	LOW HALL	1243	.08*	63	-	1.15	55	.044
DAGENHAM BR	LEYTON	10.4	.95	6.1	4.5	2.8	2.2	.209

* approximate only

NOTE : "Ruralisation" based on FSSR5 methodology

TABLE 6.4 PROPOSED FLOOD FREQUENCIES FOR THE LEE NAVIGATION CHANNEL

RETURN PERIOD YEARS	GROWTH FACTOR	TRIBS.FLOOD M3/S	CHANNEL FLOOD M3/S	TOTAL FLOOD M3/S
MAF	-	45.2	8	53.2
2	1.00	45	8	53
5	1.33	60	8	68
10	1.52	69	9	78
25	1.76	80	9	89
50	1.91	86	9	95
100	2.14	97	10	107
200	2.33	105	10	115

NOTE : Channel flood is approximation to contribution from upstream of Turkey Br