NRA THAMES 274

KO

REAPPRAISAL OF THE RIVER LEE TO WHEATHAMPSTEAD MILL

Julie K Lee Stewart
Flood Hydrology
February 1994

REAPPRAISAL OF THE RIVER LEE TO WHEATHAMPSTEAD MILL

1.0 Introduction

To assess the frequency and extent of flooding, and the effectiveness of various alleviation options, the hydrological system of the River Lee to Wheathampstead was modelled in considerable detail. A hydrological model (RORB) was built in 1988 for Catchment Planning purposes and adapted at Waltham Cross to provided inflows to an ONDA model which extended from Luton Hoo Lakes to just downstream of Wheathampstead Mill. In September/October 1992 Brian Izzard requested that hydrographs for two events; 29 May 1992 and 22 September 1992 be run through the ONDA model to assess the peak flow and frequency of the flooding which occurred at Wheathampstead. Concern was expressed that there was a several cumec difference between flows recorded at Luton Hoo gauging station and those estimated by hydraulic models (based on calculations to achieve observed levels) at Wheathampstead Mill and this may influence the level of protection assumed in the design works prepared for the improvements at the Mill. Brian Izzard required confirmation that the flows and levels estimated in the proposed improvement design option 3 were still valid (see appendix 1 for a copy of table 2D which was originally presented in the report "Upper Lee Improvement Scheme. Bridge Mill Wheathampstead". Hydraulic Analysis. Flood Hydrology November 1992).

Hydrographs for these events were produced using the RORB model and taken from Luton Hoo gauging station and provided to the Hydraulic modelling group to be input into their hydraulic (ONDA) model. Further analysis was carried out. The general conclusions from this work illustrated that to match predicted with observed levels at Wheathampstead required higher flows than input into the model from the River Lee at Luton Hoo and the Sewerage Treatment Works (STW) at East Hyde and Harpenden. Since then various aspects of modelling have been reassessed and to summarise, the previous estimate of 10.9 cumecs is an underestimate of the 1 in 100 year return period upstream of Wheathampstead Mill. The improvement proposals at the Mill have been designed to accommodate a flow of 10.9 cumecs (the 100 year flow from the RORB model). But with an allowable freeboard, 12.6 cumecs should be accommodated (Improvement Scheme Design Option 3 see appendix 1). From the limited but best information available this flow has approximately a 1 in 50 year return period. It is recommended that the frequency of this estimate is confirmed by carrying out the following :-

- Collection of real data from temporary level recorders and frequent flow gauging especially during high flows to establish a rating curve and produce flow hydrographs

- Flow gauging in the bypass channel if possible

- Revise the structure of the hydrological model and recalibrate with flow data from Wheathampstead Mill

- Confirm the hydraulic analysis using measured flow and level data

The investigations carried out to arrive at this conclusion have been summarised below under the following headings

- Hydraulic Analysis
- Hydrological Modelling

The hydraulic analysis will be discussed first, as it is the flows estimated from the hydraulic models which firstly highlighted there were problems with RORB model and secondly have been used to adjust the hydrology.

2.0 Hydraulic Analysis.

2.1 Modelling work carried out by the Reading Hydraulic Modelling Team

Considerable work was carried out by the Hydraulic Modelling group in Reading, examining the operation of the hydraulic control structures at the Mill and the sensitivity of levels and flows to various coefficient options. For the River Lee immediately upstream of the Mill complex, several rating curves were derived. The gauging which was carried out on the 3 February 1994 (see appendix 2 for details) at Leasey Bridge estimated a flow of 3.65 cumecs. This flow and the observed level on the logger upstream of the Mill represents a point which lies spot on the favoured rating curve. (Although several gaugings would be required to verify the rating curve). Working with this rating curve (see figure 1) the estimated flows for the May and September 1992 events which caused flooding are 8.31 and 8.02 cumecs respectively. See table 1 for details.

However, this rating does not take into account the extent of spillage over a flood wall approximately 50 to 100 m upstream of the Mill. The Hydraulic Modelling Team have expressed their concern that the level of the top of the flood defence wall (assumed as 80.2 m AOD) is very close to the levels reached in both the May and September flood events by a matter of centimetres and whether the wall level is constant along its length is unknown. With the assumptions made in the ONDA model at present the estimate of the total flow in the two events are 10.26 and 9.53 cumecs respectively.

As the top level of this wall is so critical, Roger Pethick (Senior Hydraulic Modeller) has recommended that a survey at very close intervals be run along the top of the wall. This would highlight whether the wall level was constant along its 50 metre length.

2.2 Modelling work carried out by Mr Vairavamoorthy, Flood Hydrology in London.

As presented in a detailed report, Mr Vairavamoorthy from the Flood Hydrology Team in London has done extensive hydraulic analysis using his backwater program, of the Wheathampstead Mill complex. From this work a rating curve was produced for upstream of the Mill as illustrated on figure 1. Similarly the gauging carried out on the 3 February 1994 lies exactly on this rating curve (see figure 1). As clearly shown this rating curve is very similar to the curve produce by the alternative hydraulic analysis for flows up to approximately 6 cumecs. But for higher flow this rating rises less steeply and therefore estimates a higher flow for the observed levels in May and September 1992.

The spill over the flood defence wall 50 to 100 m upstream of the mill was not modelled.

In conversation with Mr Vairavamoorthy, he commented that the estimated losses in the bypass channel may have been on the conservative side due to the lack of observed data. But incorporating the flow and levels observed on the 3 February 1994 (see appendix 2 for details of flow gauging), the losses should be slightly lower. As a result the side channel may be able to take more flow than originally estimated.

The discrepancies between the two hydraulic studies can only be resolved by comparing both models in great detail, and measuring flows and levels at the mill to get the best estimates of the critical coefficient values used.

Despite these differences in the hydraulic analyses, the collective evidence seems to suggest that the original flows assumed at Wheathampstead were underestimated by the RORB model. Therefore the original hydrological analysis was reexamined in more detail.

3.0 Investigation of the hydrological model of the River Lee to Wheathampstead.

The flow estimates derived by running the ONDA model for the May and September 1992 events to match the observed flow levels using reasonable hydraulic coefficient values at the Mill (upstream of the flood defences wall) are 10.26 and 9.53 cumecs respectively. If this is correct the peak flows increased between Luton Hoo gauging station and Wheathampstead by 4.2 to 4.8 cumecs in the May and September 1992 events respectively.

The RORB model, calibrated using both Luton Hoo and Waterhall gauging station had indicated that there was little increase in peak flow between Luton hoo and Wheathampstead. this seemed reasonable since the catchment area increase is relatively small, with a long channel giving plenty of opportunity for attenuation of flow peaks.

Although it is a very broad assumption, with such limited information available, it was assumed that flows at Wheathampstead could be estimated by adding a constant 4.0 cumecs to Luton Hoo flows through out the range of return periods. This can be partly justified as these two events have different return periods but the difference in flow is very small. The return period for the May and September 1992 events ranged from 10 to 25 years and 5 to 10 respectively. In addition the increase in flows seems to be reducing with increased return period. This may reflect a tailing off of flow increase once the maximum discharge from the STW has been reached (due to physical limitations of the sewer system and the works) and it is contributing a constant input into the river.

The figure of 4 cumecs is very crude, being totally dependent on the amount of spillage over the flood wall.

The flows at Luton Hoo gauging station were estimated from 33 years of annual maxima data. The Generalised Extreme Value (GEV) distribution using the method of probability-weighted moments (PWM) was used to estimate flows of different return periods. The figures and flood frequency curve plot are presented in table 2 and figure 2 respectively. Superimposing the flood frequency curve for Wheathampstead (derived by adding 4.0 cumecs to flows at Luton Hoo) onto figure 2, a flow of 12.6 cumecs (the critical design flow for the improvement works) has a return period of approximately 50 years.

In addition it was examined whether or not it would be feasible to derive 4.0 cumecs as input to the River Lee, from the area between Luton Hoo and Wheathampstead. This was investigated further by considering the following :-

- Original assumptions made in both the hydrological and hydraulic modelling about the contributing catchment between Luton and Wheathampstead.
- RORB modelling details
- Reliability of Luton Hoo gauging station to measure flows.
- Size and frequency of the discharges from East Hyde and Harpenden Sewage Treatment Works (STWs)

Original assumptions made in both the hydrological and hydraulic modelling about the contributing catchment between Luton and Wheathampstead.

3.1 Rural Catchment

In the original ONDA modelling there was no allowance for any inflows from either the rural catchment or Harpenden. Presumably this is because the RORB model showed no increase in peak flows from Luton Hoo to Wheathampstead. The RORB model had two small rural subarea inputs between the two sites. Unfortunately there is very limited information on the original modelling work and assumptions made. One possible reason may be that it was assumed this area was not an important contribution to flow as a reflection of the RORB model results and the catchment soil types.

3.1.1 RORB Model Results

In the RORB model, flows are significantly attenuated between Luton Hoo and Wheathampstead with no increase in the peak flow between the two sites. The RORB model could only be calibrated at Luton Hoo and Waterhall gauging stations and not at any central sites in the catchment such as Wheathampstead due to the lack of any observed data. It was assumed that the model was representative of the whole catchment. Only very recently with the detailed hydraulic analysis and flow measurement has any doubt been place on the RORB flow estimates at Wheathampstead. However there is still insufficient data available to revise the model reliably.

3.1.2 Catchment Soil Type

The contribution assumed from the area between Luton Hoo and Wheathampstead was minimal because a very low percentage runoff was assumed in the RORB model which reflected the underlying chalk and possibly the Flood Studies Report (FSR) WRAP (winter rainfall acceptance potential) soil classification of a type 1 (ie very permeable). But on closer inspection of the 1:250 000 Soil Map of England and Wales (Soil Survey of England and Wales 1983) it can be seen that this area is covered with quite variable soils ranging from fine silty over clayey, and fine loamy over clayey soils with slowly permeable subsoils and slightly seasonal waterlogging. Therefore the percentage runoff from this area should be significantly higher than assumed in the RORB model.

3.2 Contribution to the River Lee from Harpenden

In the RORB model there is no allowance for any direct runoff from Harpenden into the River Lee. This may have been assumed because the town does not have a surface water system but operates on soakaways. Therefore in theory there is no contribution to the River Lee from surface water. However when the Drainage Department of the City and District of St Albans were consulted further on the drainage of this area they highlighted some interesting problems.

It was confirmed that Harpenden is on soakaways but they do not operate as designed because the town is on a pocket of clay. In addition highway drainage from both Harpenden and Batford (including the Lower Luton Road A6129) discharges direct into the River Lee but there are problems of backing up in the network due to high levels in the river. This combination of problems cause surface flooding. In the last two years there have been several relatively small events which have resulted in flooding with the firebrigade called out to relieve the problem by pumping. The Drainage Department commented that during the drought years the flooding problem was much more infrequent. The original modelling study was also carried out during this period and therefore any drainage problem may not have been apparent.

The original RORB model made no allowance for the contribution from this area. However it might be expected that flows from Harpenden might arrive at Wheathampstead in advance of the upstream hydrograph, and therefore not affect the peak flow greatly.

3.3 RORB Model Structure

In the RORB model the rural catchment area between Luton Hoo and Wheathampstead is divided into two subareas which are built into the network ie they were not two separate tributaries feeding into the River Lee. As a result it is not possible to get separate hydrographs from these areas without major changes to the model. Although a minor point this may have been one reason why these areas were ignored as inputs to the ONDA model. As an experiment each of the two nodes were hypothetically relocated in the model as a tributary input with an increased percentage runoff, to allow a flow to be estimated for both the May and September 1992 events. For the former event peaks up to 1.9 cumecs were derived while up to 1.4 cumecs were estimated for the latter event for the two nodes. Although it must be stressed that the timing of these hydrographs will be not coincide with the peak on the Lee at Luton Hoo. This exercise does give some feel for the size of flow from these areas.

3.4 Reliability of Luton Hoo Gauging Station

It was hypothesised that Luton may be contributing more to the River Lee than is observed at the Luton Hoo gauging station due to problems of bypassing.

The River Lee is gauged at Luton Hoo just downstream of Luton, on the overflow structure from the Luton Hoo Lakes. The structure is composed of several weirs which operate at different levels. The gauge measures low and medium flows relatively well, ie up to approximately 6 - 6.5 cumecs. Above that the structures are bypassed through overtopping on the right-hand bank of the lake upstream of the gauging station. It has been assumed that the scale of the bypassing is not very significant because it has very rarely been observed or measured. Therefore it seems unlikely that the flow discrepancy between Luton Hoo and Wheathampstead is the result of bypassing the gauging station. Flows in both the May and September 1992 event were at or below 6 - 6.5 cumecs.

3.5 Discharges from East Hyde and Harpenden STWs

There is very limited detailed information on the discharges from East Hyde and Harpenden STW's. No flow is measured at Harpenden STW. Only the daily average inflow to East Hyde STW is measured using a flume structure. This flume gets flooded regularly therefore it was suggested by Thames Water Utilities (TWU) that these figures may be slightly overestimates rather than underestimates. From the total daily flows the maximum average discharge is 0.5 - 0.6 cumecs. The works can cope with six times the dry weather flow which represents 35000-40000 m^3/day. The volume consent is 44418 m^3/day. There are five storm tanks each with a volume of 2500m^3. These tanks fill sequentially and once the 12500m^3 volume has been reached any excess flow discharges into the River Lee. Prior to October 1993 the treatment works was suffering from a problem of limited capacity, and therefore the tanks were being used on a very regular basis to store water prior to treatment. In the event of heavy rain these tanks had to be prematurely emptied into the River Lee. Since October 1993 work at the STW's has alleviated this problem and in the opinion of the site manager the tanks will now be used fairly infrequently. On the 13 October 1993 a particularly high flow of 118552 m^3/day (an average of 1.37 cumecs) was measured going into the works. This is an average of 1.37 cumecs, presumably the outflow peak could have been very much higher. It may be possible that these higher flows are occurring more frequently than measured and assumed. The only way to resolve this uncertainty would be to install a logger device on the outlet structure to measure flows.

4.0 Conclusions and Recommendations

Due to the discrepancy between flow estimates derived from the hydrological model and those predicted by the hydraulic analysis of the Wheathampstead Mill weir complex further analysis was carried out. The general conclusions from this work illustrated that to match predicted with observed levels at Wheathampstead required higher flows than input into the model from the River Lee Luton Hoo and the Sewerage Treatment Works (STW) at East Hyde and Harpenden. Since then various aspects of modelling have been reassessed and to summarise, the previous estimate of 10.9 cumecs is an underestimate of the 1 in 100 year return period just upstream of Wheathampstead Mill. The improvement proposals at the Mill have been designed to accommodate a flow of 10.9 cumecs (the 100 year flow from the RORB model). But with an allowable freeboard, 12.6 cumecs should be accommodated (Improvement Scheme Design Option 3 see appendix 1). From the limited but best information available this flow has approximately a 1 in 50 year return period. It is recommended that the frequency of this estimate is confirmed by carrying out the following :-

- Collection of real data from temporary level recorders and frequent flow gauging especially during high flows to establish a rating curve and produce flow hydrographs
- Flow gauging in the bypass channel if possible
- Revise the structure of the hydrological model and recalibrate with flow data from Wheathampstead Mill
- Confirm the hydraulic analysis using measured flow and level data

cc Roger Pethick, RBH8
Mr Vairavamoorthy, Wah Kwong House, London

FIGURE 1 UPPER LEE HYDRAULIC MODEL. RATING CURVES FOR UPSTREAM OF WHEATHAMPSTEAD MILL (ONDA NODE L22) DERIVED FROM ONDA AND HYDRAULIC ANALYSIS CARRIED OUT BY VAIRAVAMOORTHY.

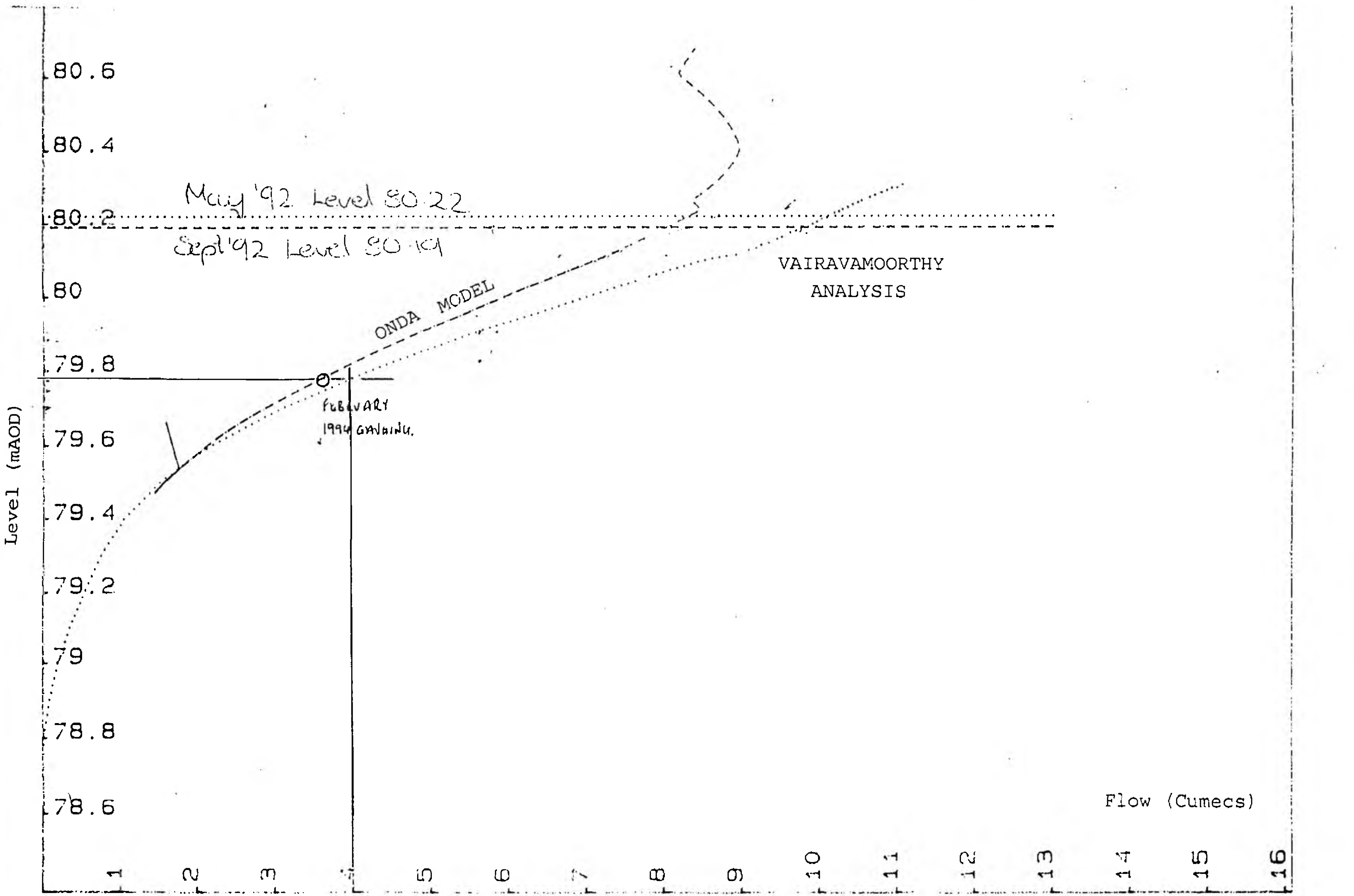

FIGURE 2 FLOOD FREQUENCY CURVES FOR THE RIVER LEE TO LUTON HOO AND WHEATHAMPSTEAD.

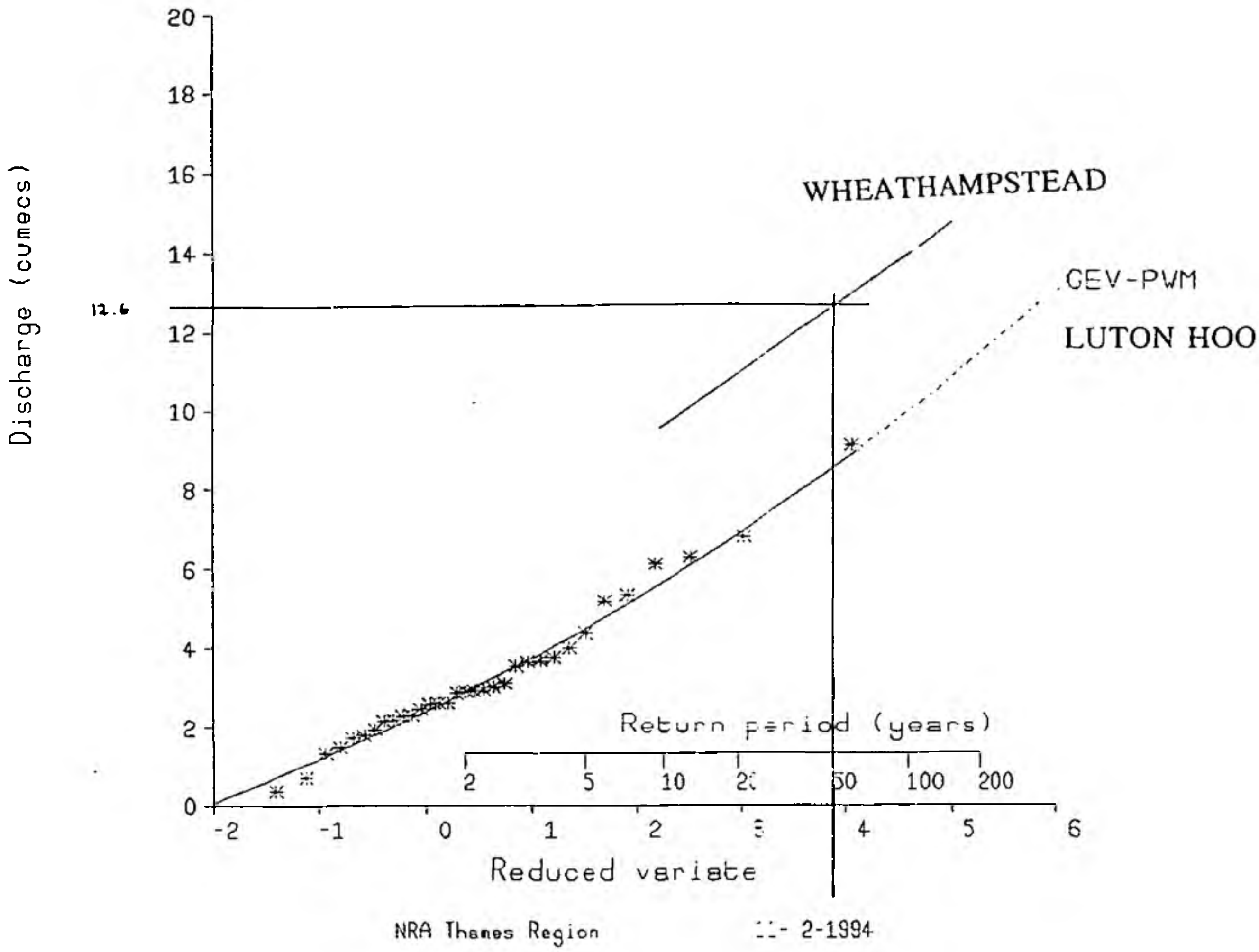

Table 1 **Flows at Wheathampstead and Luton Hoo for the May and September 1992 flood events.**

Date of Flood Event	Flow at The Mill (ONDA node L22)	Flow upstream of Mill & Flood Wall (ONDA node L23U)	Flow at Luton Hoo Gauging station
29 May 1993	8.31	10.26	6.12
22 Sept 1993	8.02	9.53	4.77

NB All flows in cumecs

SEE APPENDIX 3 FOR AN ONDA NODE MAP

TABLE 2 **Flows the River Lee at Luton Hoo Gauging Station and Wheathampstead Mill**

Return period (years)	Flow at Luton Hoo derived from GEV-PWM[1]	Flow at Wheathampstead by adjusting Luton Hoo flows[2]
2	2.87	6.87
5	4.48	8.48
10	5.65	9.65
25	7.27	11.27
50	8.57	12.57
100	9.97	13.97
200	11.47	15.47

NB All flows in cumecs.

[1] Generalised Extreme Value distribution using probability-weighted moments
[2] The adjustment is a simple addition of 4 cumecs to the River Lee flows at Luton Hoo

APPENDICES

1. Table 2D from "Upper Lee Improvement Scheme. Bridge Mill Wheathampstead. Hydraulic Analysis Flood Hydrology November 1992"

2. Details of the flow gauging carried out at Leasey Bridge (TL 162145) on 3 February 1994

3. ONDA node map around Wheathampstead Mill

APPENDIX 1 Table 2D taken from "Upper Lee Improvement Scheme. Bridge Mill Hydraulic Analysis". Flood Hydrology, November 1992.

FLOW OVER THE WEIRS FOR VARIOUS WATER LEVELS.

TABLE 2D:- Improvement Scheme Option 3.

LEVEL (m AOD)	TOT. FLOW (cumecs)	FLOW s.w.sharp (W1)	FLOW s.w.broad (W2)	FLOW m.w.sharp (W3)	FLOW m.w.broad (W4)
79.15	0.1	0.0	0.0	0.1	0.0
79.20	0.2	0.0	0.0	0.2	0.0
79.25	0.3	0.0	0.0	0.2	0.0
79.30	0.4	0.1	0.0	0.3	0.0
79.35	0.5	0.1	0.0	0.4	0.0
79.40	0.7	0.2	0.0	0.5	0.0
79.45	0.9	0.3	0.1	0.6	0.1
79.50	1.3	0.3	0.1	0.7	0.2
79.55	1.8	0.4	0.2	0.8	0.4
79.60	2.4	0.5	0.4	0.9	0.6
79.65	3.0	0.6	0.5	1.1	0.8
79.70	3.7	0.7	0.7	1.2	1.1
79.75	4.5	0.9	0.9	1.3	1.4
79.80	5.4 -	1.0	1.1	1.5	1.8
79.85	6.3	1.1	1.4	1.6	2.2
79.90	7.3	1.3	1.6	1.8	2.6
79.95	8.3	1.4	1.9	2.0	3.0
80.00	9.3	1.4	2.2	2.1	3.6
80.05	9.9	1.5	2.3	2.1	4.1
80.10	10.6	1.5	2.5	2.2	4.5
80.15	11.1	1.5	2.6	2.2	4.8
80.20	11.7	1.6	2.7	2.3	5.2
80.25	12.2	1.6	2.8	2.3	5.5
80.30	12.6	1.6	2.9	2.4	5.8

APPENDIX 2 DETAILS OF THE FLOW GAUGING CARRIED OUT AT LEASEY BRIDGE (TL 162145) ON 3 FEBRUARY 1994.

Time of Gauging	Observed Level upstream of Wheathampstead (mAOD)	Gauged Flow (cumecs)
16.05-16.30	79.78	3.65
16.45-17.15	79.78	3.56

From model 79.78 → 3.35 cumecs.

Levels at Wheathampstead Mill 3/2/94
16.00hrs – 17.15hrs from logger data

	u/s	d/s
16.00	79.782	78.153
15	.777	78.163
30	.776	.155
45	.778	.165
00	.781	.169
15	.781	.170

Data from Julie Lee

These levels coincide with the gauging about 1km upstream at Leasey Bridge of 3.6 cumecs.

APPENDIX 3 ONDA NODE MAP AROUND WHEATHAMPSTEAD MILL