MASTER

NRA

National Rivers Authority
(Anglian Region)

Lodes - Granta Groundwater Development Scheme
River Regulation Trials - River Bourn

Final Report

April 1991

Mott MacDonald

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

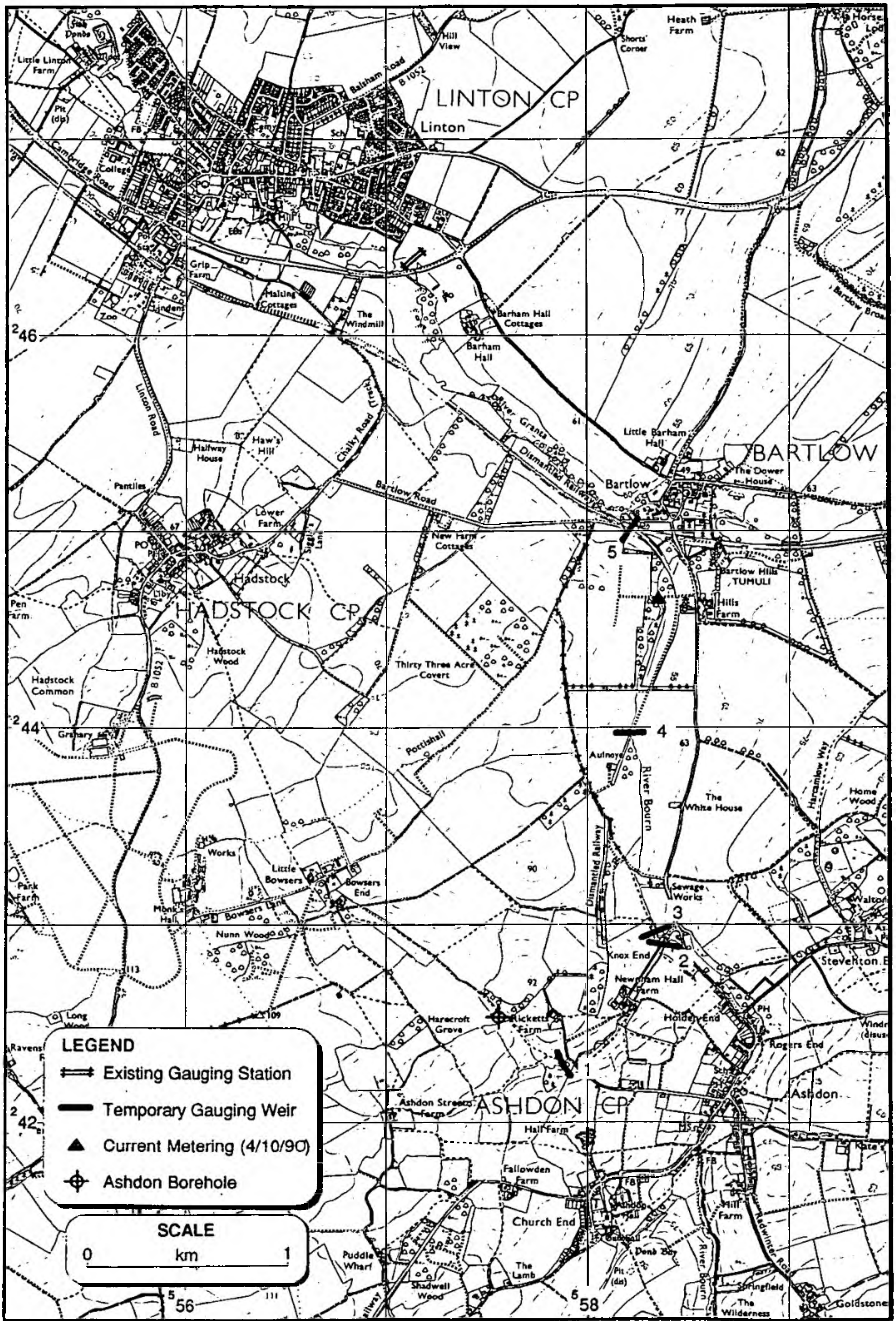
Groundwater abstraction from the Upper Granta catchment in Cambridgeshire and Essex has caused a reduction in the amount of baseflow within the river system. River support is necessary to maintain summer flows in the River Granta and this is to be achieved by pumping groundwater from a Chalk borehole near Ashdon to the river. The water is to be added to the river about 200 m above the gauging station at Linton. Locations are shown in Figure 1.

The 132 m deep Chalk borehole, numbered TL 54/121 and drilled at 610 mm diameter in 1981, is located near Ricketts Farm at Ashdon (grid reference TL 576425). It is close to a tributary of the River Bourn which, with the River Bourn itself, might be used as a conduit for some river support water. Field trials were therefore conducted on the River Bourn and tributary between the borehole and Bartlow to determine the extent of any streambed infiltration. Streambed infiltration along the River Granta between the Linton gauging station and Bartlow had been assessed previously. Extension of the trials down to the gauging station was not therefore required.

The field trials were carried out at a time of very low groundwater levels from late September to early October 1990. This report summarises the findings.

Figure 1

Location Map



CHAPTER 2

METHODOLOGY

2.1 Field Reconnaissance

In order to determine the extent and distribution of any streambed infiltration losses during the field trials, temporary gauging sites were required between the borehole and Bartlow. A field reconnaissance was carried out in late April 1990 to identify potential gauging sites. Flows in the river were estimated by eye during the visit.

The borehole is located close to a tributary channel of the River Bourn as shown in Figure 1. The tributary joins the main river at Knox End. At the time of the reconnaissance there were very minor flows, probably less than 0.5 l/s, in both the channel adjacent to the borehole and the channel draining from the vicinity of Ashdon Street Farm. At the confluence with the River Bourn at Knox End, the tributary had a flow estimated to be less than 1 l/s whilst the main River Bourn was flowing at about 5 l/s. At Bartlow, just above the confluence with the River Granta, the Bourn had an estimated flow of 5 to 10 l/s. The discharge point for the sewage works, about 300 m downstream from Knox End, was also noted during the reconnaissance. Discharge from the works was seen to be intermittent.

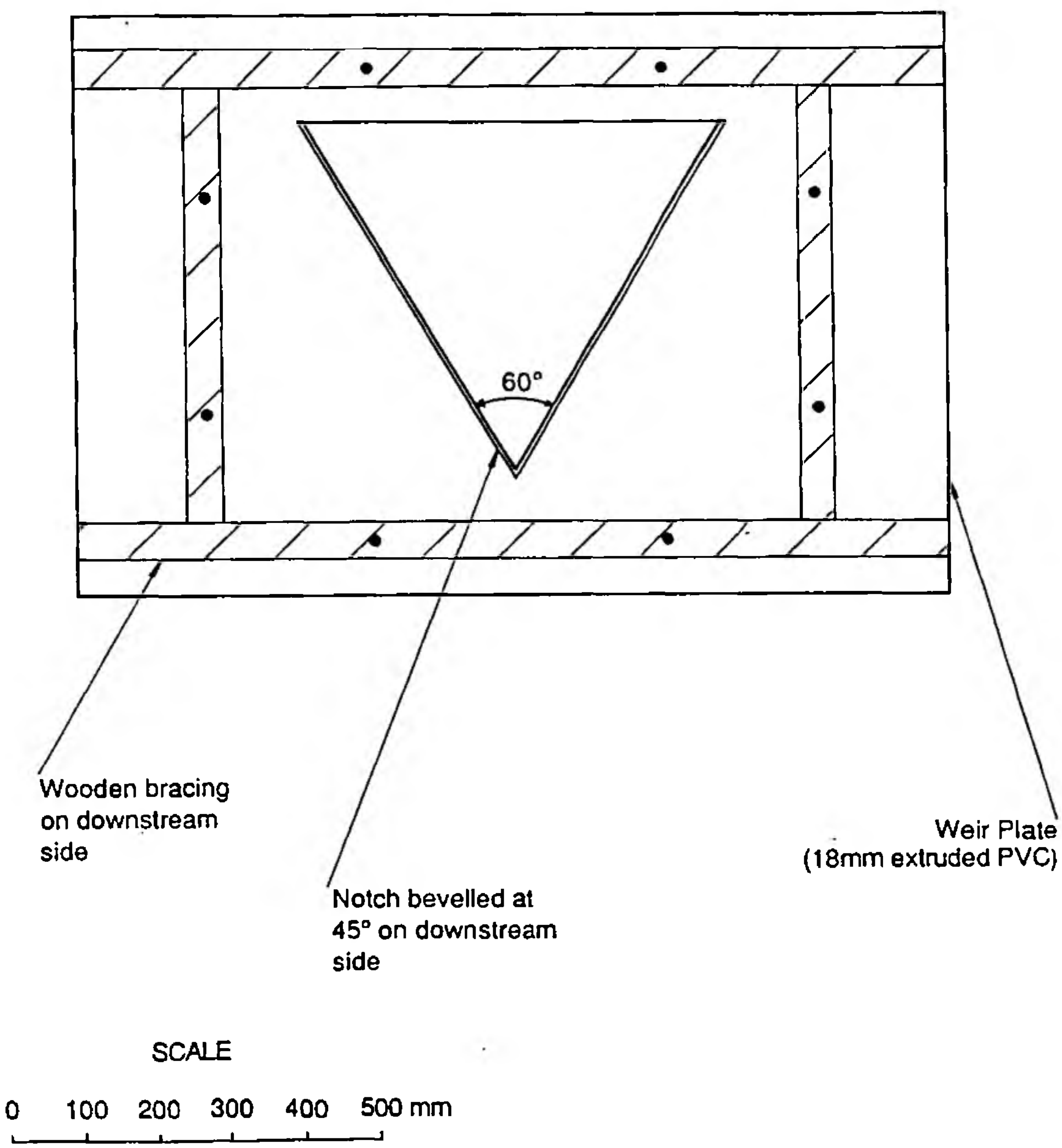
2.2 Planning

On the basis of the reconnaissance, installation of five temporary weirs at locations shown in Figure 1 was planned. The intention was to gauge at approximately equal intervals of one kilometre along the length of the channel. Weirs 2 and 3 were sited up and downstream of the confluence of the tributary with the main River Bourn in order to determine any contribution from the Bourn upstream of Knox End. It was found that no records were kept of discharge from the sewage works. If necessary, however, bucket measurements of discharge were planned to assess the contribution to river flow.

V-notch weir plates for installation at gauging sites were fabricated to a design based upon BS 3680, as shown in Figure 2. The field trials were planned for a period of three weeks in late summer/autumn when ground conditions would be dry and the Chalk groundwater table would be at a low level. Any streambed losses should be clearly evident at this time. Maximum discharge was required to be about 35 l/s.

Figure 2

V-notch Weir Design



2.3 Implementation

A contract was let to Contract Drilling Limited of Newmarket for borehole pump installation, V-notch weir installation and operation of equipment and flow gauging during the trials. V-notch weir plates were installed in early September 1990. They were firmly secured with timber into channel banks and sand-bagged where necessary to minimise leakage. Upstream and downstream measuring points were established on stakes driven firmly into the streambed at each weir site. Measuring points were approximately one metre either side of the plate.

Pumping from the Ashdon borehole commenced at 0900 hours on 18 September 1990 and continued for 21 days to 9 October 1990. Well discharge was measured using a cumulative meter and a V-notch tank and channelled into the tributary located about 10 m from the borehole via a field boundary ditch. The discharge was adjusted over the first six hours of the test to approximately 90% of full bore rate. Thereafter, it was maintained within 5% of the average test discharge of 28.8 l/s through adjustment of a gate valve.

Prior to the trials, the tributary above Knox End was dry apart from a flow estimated to be only a few litres per minute in the channel draining from Ashdon Street Farm. This flow was lost through streambed seepage upstream of weir 1. The main River Bourn was dry at Knox End. Discharge from the sewage works was ponding and infiltrating entirely over a stream length of about 100 m and therefore no measurement of sewage works discharge was considered necessary. Otherwise the River Bourn was completely dry from Knox End to the confluence with the River Granta at Bartlow.

Each weir was visited at two hour intervals or more regularly during the first day of the trials, and water level measurement started once well discharge had reached the site. Thereafter, visits were made at six hour intervals. Once the well pump had been stopped on 9 October, visits were continued until flow at each weir had ceased.

During installation, V-notch weir plates were located so that the lower horizontal wooden bracing was at about bed level. The plates were designed with a low 'V' in order to minimise any unnatural water losses through channel side walls just upstream of the weirs. The low level of the 'V', combined with irregularities in channel bed gradients, caused weirs to be partially submerged at three of the sites with downstream water levels above the 'V' of the weir. Water level measurements were therefore recorded upstream and downstream of the weirs. The effect of submergence could then be taken into account in discharge calculation. During the trials two downstream measuring points had to be relocated to one side of the main water flow. This minimised the effect of ripples in preventing accurate water level readings.

The period of the trials was predominantly dry. Weather conditions were recorded in a site diary. Showers and some rain were noted on 8 days. Heavy rain was noted on two days (22 and 30 September).

2.4 Calculation of Flows

Flows over the weirs were calculated using the standard equation for a 60° V-notch weir as follows:

$$Q_o = 789\ h_u^{5/2}$$

where Q_o is the discharge for a free-flowing weir in litres/second and hu is the height of the water surface (in metres) above the point of the 'V' just upstream of the weir.

Where there was downstream submergence of the weir, the actual discharge was derived from Q_o by application of the Villemont formula, as follows:

$$Q = Q_o \left[1 - \left(\frac{h_d}{h_u}\right)^{2.5}\right]^{0.385}$$

where Q is the actual discharge for a partially submerged weir and h_d is height of the water surface above the point of the 'V' just downstream of the weir.

CHAPTER 3

RESULTS AND ANALYSIS

3.1 Borehole Discharge and Drawdown

The cumulative discharge from the Ashdon borehole during the field trials is shown in Figure 3, together with average daily drawdown in the borehole due to pumping.

Just prior to the start of the test the static water level in the well was at a depth of 26.85 m below ground level. A complete set of drawdown readings, including those taken during the first day at time intervals appropriate to the start of a borehole constant discharge test, are given in Appendix A. Discharges were varied in the first 12 hours in order to determine the maximum yield which could be reliably maintained at a constant rate throughout the trials. The drawdown data for the first day cannot be analysed in detail to give an accurate value for local aquifer transmissivity.

Figure 3 confirms that borehole discharge was effectively constant throughout the trials. Variations at days 2, 3 and 11 were probably caused by readings being taken at the time of change for a meter dial with large unit value. Incorrect readings have lead to under-measurement of cumulative flow on these days. The under measurements are corrected by valid readings on subsequent days. Little adjustment to the discharge was required after the first day. This was mainly because subsequent drawdown changes were small compared to the total depth to pumping water level, and therefore the total lift required by the pump. The average discharge metered at the borehole was 28.8 l/s. This was about 12% higher than the measurement of 25.5 l/s from readings taken in the V-notch tank also located close to the borehole. As a flow averaging 27.5 l/s was obtained at weir 1 once discharge had built up to a maximum after three days, it is considered that the meter readings should be taken as the more accurate gauge for borehole discharge.

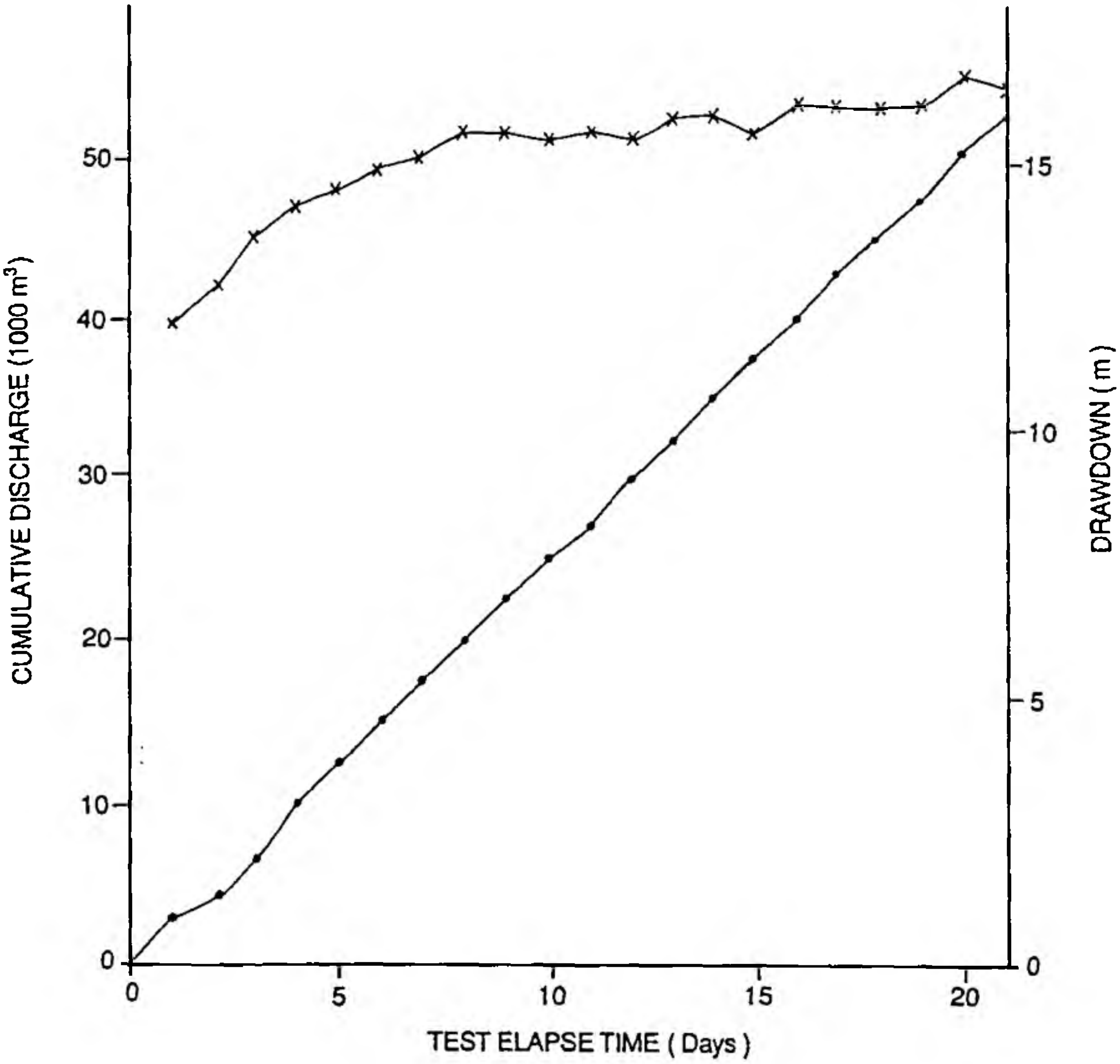
3.2 Weir Flows

Discharges derived from water level measurements at the weirs are shown in Figure 4. The time taken for flow to reach each weir is shown in Table 1. At weir 1, the flow had already built up to 20 l/s 50 minutes after well pumping had commenced. It then took several hours for the water level to rise sufficiently in a culvert about 100 m long just downstream of the weir before flow could continue on towards weir 2.

Some discharge eventually arrived at weir 5 at the beginning of the fourth day of the trials (Figure 4). Prior to this time, it took about two days for a culvert beneath the dismantled railway line just upstream of weir 5 to fill sufficiently for flow to continue on to the weir. Flow at the weir then occurred over a period of 4 to 5 days, with a peak of about 3 l/s. In the latter half of the period, flow declined steadily to zero at weir 5. There was no further flow at the weir during the trials.

Figure 3

Well Discharge and Drawdown



LEGEND

• · Cumulative Discharge

X Drawdown (daily average)

Figure 4

Gauged Streamflow

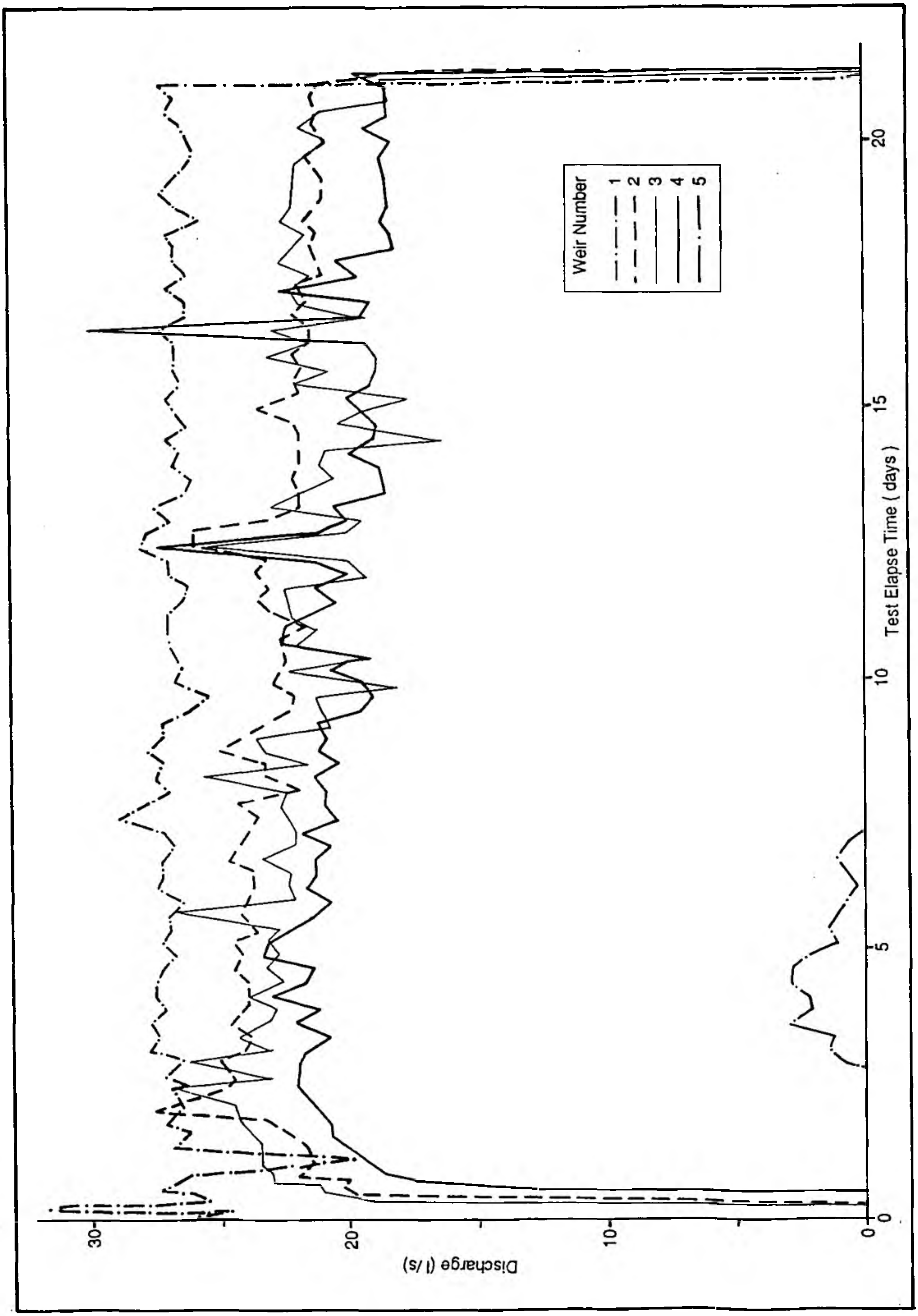


TABLE 1

Flow Arrival and Weir Submergence

Weir Nr	Estimated time of travel from borehole (hours)	Weir submergence (h_d/h_u) at maximum discharge (%)	Q/Q_o from Villemont Equation (%)
1	<0.8	0	100
2	8-9	43	95
3	8-9	95	44
4	15	67	84
5	75	0	100

At weirs 1 to 4, flow took up to three days from the start of the trials to reach peak values. Weir submergence at peak flow, and the effect of submergence upon discharge calculation, are indicated in Table 1. It can be seen that submergence has to reach about 50% before it has a significant effect on discharge.

After building up to a peak, measurements at weirs 1, 2 and 4 show a gentle steadily declining trend in flow to the end of the trials. At a flow of 25 l/s with zero submergence, a water level measurement accuracy of 5 mm would lead to a 5% variation in calculated flow. A measuring error of this order would account for the variation about the generally declining trend in flow, apparent for weir 1.

Some anomalous peaks and troughs can be seen in the data presented in Figure 4. The peak at all weirs on day 12 (30 September) probably resulted from heavy rainfall recorded that day giving rise to minor run-off. The reading of 19.5 l/s at weir 1 on day 2 of the test could have resulted from a temporary short-term shut down of borehole discharge. The large peak at weir 4 on day 17 is probably a misreading of the upstream level. The weir had moderately high submergence, but the downstream level remained as for other readings on the same day, whilst a much higher upstream level was recorded.

The most variable discharges were calculated for weir 3. Up to day 14 of the test, discharge at weir 3 has the same trend as at weir 2, but at about 1 l/s less flow overall. Following erratically low readings over a further two day period, readings were re-established at a level giving discharges which were very close to those for weir 2. Variability in flows for weir 3 is attributable to difficulty in taking measurements, with deep water caused by high submergence present in a narrow, steep-sided channel section. The change in flow levels in the period from day 14 to day 16 could have resulted either from a slight change in measuring practice or possibly from a physical change in the short length of channel (approximately 30 m) between weirs 2 and 3.

The intention in siting weir 3 just below the confluence with the upper River Bourn was to gauge any flow contribution from the upper main river. As no flow was noted at any time in the upper main river, weir 3 provides little additional data to that obtained from weir 2. Readings are also less reliable than for weir 2. Data for weir 3 has therefore been excluded from further analysis.

3.3 Streambed Infiltration Losses

Weir discharges and streambed infiltration losses are summarised in Table 2. As already indicated, no flow reached weir 5 over much of the period of the trials.

TABLE 2

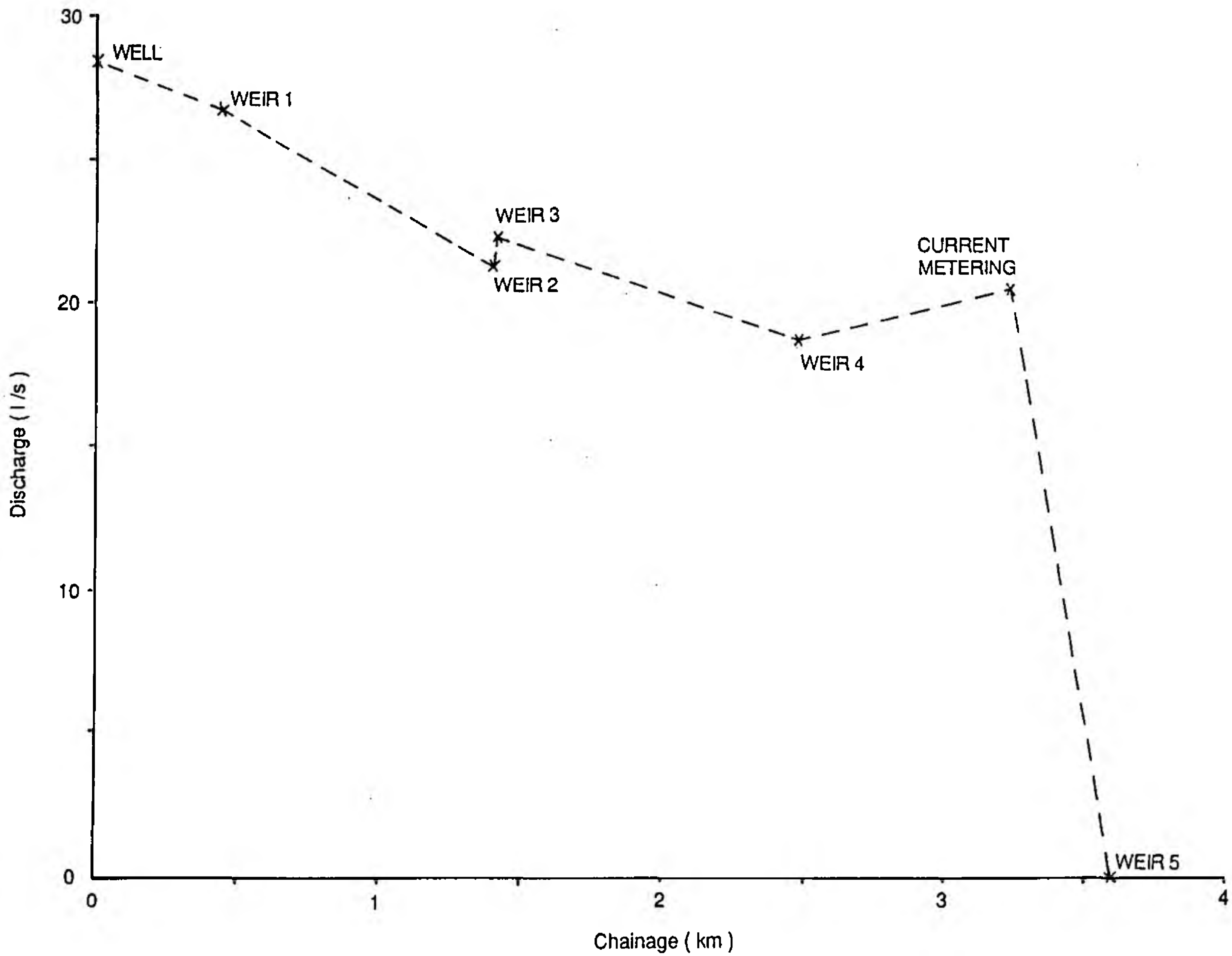
Discharge Summary

Weir Nr	Discharge (l/s)		Loss in reach above weir			
	after 4 days	after 21 days	after 4 days (l/s)	after 21 days (l/s)	after 21 days as % of well discharge	after 21 days as l/s per km channel length
1	27.3	26.5	1.5	2.3	8	5.2
2	24.2	20.8	3.1	5.7	20	6.0
4	21.7	18.3	2.5	2.5	9	2.3
5	2.3	0.0	19.4	18.3	63	16.6

The main losses occurred in the reach between weirs 4 and 5 (63% of borehole discharge on the last day of the trials). However, significant losses also occurred further up the channel, particularly above weir 2 (28% of borehole discharge). A further 9% of borehole discharge was lost between weirs 2 and 4 .

An increase in streambed losses is apparent for the tributary above weir 2 as the trials proceeded. Increasing losses could have occurred as a result of removal by the borehole discharge of silt or decayed vegetation forming a partial seal to the streambed. The decrease in flow in the tributary would have been a contributing factor resulting in the decline of flows over weir 5 to zero after flow had established at the weir.

The losses downstream of weir 4 were investigated on 4 October, the seventeenth day of the trial. Current metering was carried out at a site near Hills Farm shown on Figure 1. The discharge profile for 4 October is shown in Figure 5.



Discharge Profile : 4 October 1990

Figure 5

Current metering indicates that there was little if any loss over the reach extending 750 m downstream of weir 4 (the higher flow obtained from current metering as compared to the gauged discharge at weir 4 reflects the level of accuracy obtainable from current metering rather than any real increase in flow). Below the current metering site the streambed was heavily overgrown. Most of the loss through infiltration appeared to occur in an area just upstream of the culvert above weir 5. A pond about 100 m long had formed behind sand and gravel banks. Infiltration was occurring through sand and gravel lining the streambed. Removal of silt or decayed vegetation in the streambed below weir 4 (in addition to streambed changes above weir 2) could have given rise to additional infiltration losses over the period of the trials which resulted in all the borehole discharge seeping away above weir 5.

An assessment of streambed losses for the reach of the River Bourn from about 250 m downstream of weir 4 to Bartlow was also made by Anglian Water Authority (1981) during testing at the Ashdon borehole. Copies of relevant sections of the report are given in Appendix B. Flows were measured by current metering, and indicated a loss of only 5 l/s in the reach towards the end of the test, with flow at the upstream end of 30 l/s. The test was conducted in October and November 1981.

The test report indicates that groundwater levels at the time were about one metre below streambed level in the vicinity of Hills Farm. There were also natural runoff events during the test with 167 l/s measured in the upper River Bourn at one stage. In contrast, conditions prior to and during the trials in 1990 were generally dry. Water table conditions were comparable with, or possibly lower than, those in the autumn of 1976. For 1976, the Institute of Geological Sciences (1981) indicate that groundwater levels were about four metres below streambed level close to Hills Farm.

In 1981, it is possible that infiltration from natural run-off and/or borehole discharge saturated the formation down to the water table in the immediate vicinity of the river. This resulted in average losses of only 17% of the 30 l/s inflow to the reach over a five day period at the end of the test. In 1990, streambed losses in the reach would have contributed to the Chalk aquifer without producing saturation of the greater depth of dry formation below the streambed. Losses therefore continued at a very high rate throughout the 1990 trials.

During the 1990 trial, losses were undoubtedly increased by the presence of sand and gravel banks in the streambed upstream of the culvert between weirs 4 and 5. Losses would be reduced by grading and smoothing the streambed. Presumably, however, irregularities in the streambed have formed under natural runoff conditions. Unless maintained, the streambed would be expected to revert to an irregular profile with the potential for high infiltration losses from any discharge in dry periods.

Finally, infiltration losses upstream of weir 4 should not be overlooked. Although less than the losses downstream of weir 4, they amounted to 37% of total borehole discharge.

3.4 Field Trials Completion

Once the well pump was stopped on 9 October 1990, weir readings were continued, to monitor decline in levels. Flow had ceased at weir 1 two hours after pump shutdown. Six hours after shutdown, flow had decreased at weir 2 to about ½ l/s and at weir 4 to about 8 l/s. Flow at all weirs had ceased at the next visit 20 hours after pumping had been stopped. Temporary weirs were then removed.

CHAPTER 4

CONCLUSIONS

Field trials conducted on the lower River Bourn and tributary below Ashdon borehole, indicated a total loss by streambed infiltration of the 29 l/s discharged from the borehole for most of the 21 day period of discharge. Some reduction in losses might be achieved by streambed grading at one location. However, the streambed would be expected to revert to an irregular profile under natural runoff conditions, with the potential for total loss of discharge as experienced in the field trials.

Use of the River Bourn and tributary would not therefore be an efficient means of conveying groundwater for river support to the River Granta at Linton. Efficiency would be at its lowest in dry summers with low water table conditions. These are the periods when effective river support is needed most.

REFERENCES

Anglian Water Authority - Great Ouse River Division	1981	Aquifer and Well Test Report - Ashdon
Institute of Geological Sciences and Anglian Water Authority	1981	Hydrogeological Map of Southern East Anglia

APPENDICES

APPENDIX A

Borehole Drawdown

DATE	TIME	WATER LEVEL BELOW DATUM (m)	DRAWDOWN (m)
18-9-90	9.00	26.85	0.00
	9.01	28.02	1.17
	9.02	29.21	2.36
	9.03	30.11	3.26
	9.04	30.73	3.88
	9.05	31.27	4.42
	9.06	31.52	4.67
	9.07	31.80	4.95
	9.08	32.00	5.15
	9.09	32.22	5.37
	9.10	32.41	5.56
	9.15	33.01	6.16
	9.20	33.44	6.59
	9.25	33.76	6.91
	9.30	33.85	7.00
	9.35	34.00	7.15
	9.40	34.20	7.35
	9.45	34.45	7.60
	9.50	34.61	7.76
	9.55	34.68	7.83
	10.00	34.78	7.93
	10.10	34.92	8.07
	10.20	35.08	8.23
	10.30	35.29	8.44
	10.40	35.45	8.60
	10.50	35.53	8.68
	11.00	35.62	8.77
	11.15	35.75	8.90
	11.30	35.56	8.71
	11.45	35.07	8.22
	12.00	35.00	8.15
	12.15	35.05	8.20
	12.30	35.10	8.25
	12.45	35.13	8.28
	13.00	35.19	8.34
	14.30	35.45	8.60
	15.00	39.21	12.36
	15.30	39.49	12.64
	16.00	39.65	12.80
	16.30	39.79	12.94
	18.30	37.86	11.01
	20.30	38.06	11.21
	22.30	38.26	11.41
19-9-90	0.30	38.42	11.57
	2.30	38.57	11.72
	4.30	38.70	11.85
	6.30	38.82	11.97
	8.30	38.91	12.06
	10.30	39.04	12.19
20-9-90	13.30	38.57	11.72
	3.30	38.86	12.01
	5.30	38.98	12.13
	7.30	39.44	12.59
	9.30	39.58	12.73
	11.30	39.61	12.76
	13.30	39.69	12.84
	15.30	39.78	12.93
	17.30	39.90	13.05

DATE	TIME	WATER LEVEL BELOW DATUM (m)	DRAWDOWN (m)
20-9-90	19.30	39.90	13.05
	21.30	39.98	13.13
	23.30	40.04	13.19
21-9-90	1.30	40.15	13.30
	3.30	40.25	13.40
	7.30	40.53	13.68
	12.00	40.93	14.08
	18.00	40.95	14.10
22-9-90	0.00	41.02	14.17
	6.00	41.07	14.22
	12.00	41.12	14.27
	18.00	41.26	14.41
23-9-90	0.00	41.45	14.60
	6.00	41.42	14.57
	12.00	41.45	14.60
	18.00	41.60	14.75
24-9-90	0.00	41.61	14.76
	6.00	41.75	14.90
	12.00	41.77	14.92
	18.00	41.87	15.02
25-9-90	0.00	41.81	14.96
	6.00	41.94	15.09
	12.00	42.05	15.20
	18.00	42.29	15.44
26-9-90	0.00	42.32	15.47
	6.00	42.41	15.56
	12.00	42.42	15.57
	18.00	42.40	15.55
27-9-90	0.00	42.39	15.54
	6.00	42.41	15.56
	12.00	42.43	15.58
	18.00	42.42	15.57
28-9-90	0.00	42.34	15.49
	6.00	42.26	15.41
	12.00	42.18	15.33
	18.00	42.46	15.61
29-9-90	0.00	42.37	15.52
	6.00	42.41	15.56
	12.00	42.49	15.64
	18.00	42.49	15.64
30-9-90	0.00	42.44	15.59
	6.00	42.48	15.63
	12.00	42.44	15.59
	18.00	42.53	15.68
1-10-90	0.00	42.50	15.65
	6.00	42.65	15.80
	12.00	42.69	15.84
	18.00	42.72	15.87
2-10-90	0.00	42.81	15.96
	6.00	42.73	15.88
	12.00	42.69	15.84
	18.00	42.74	15.89
3-10-90	0.00	42.64	15.79
	6.00	42.39	15.54
	12.00	42.93	16.08
	18.00	42.96	16.11
4-10-90	0.00	43.06	16.21

DATE	TIME	WATER LEVEL BELOW DATUM (m)	DRAWDOWN (m)
4-10-90	6.00	42.98	16.13
	12.00	43.03	16.16
	18.00	42.99	16.14
5-10-90	0.00	42.89	16.04
	6.00	42.89	16.04
	12.00	42.97	16.12
	18.00	42.91	16.06
6-10-90	0.00	42.78	15.93
	6.00	42.85	16.00
	12.00	42.72	15.67
	18.00	42.79	15.94
7-10-90	0.00	42.82	15.97
	6.00	42.88	16.03
	12.00	43.00	16.15
	18.00	43.37	16.52
8-10-90	0.00	43.54	16.69
	6.00	43.46	16.61
	12.00	43.45	16.60
	18.00	43.42	16.57
9-10-90	0.00	43.29	16.44
	6.00	43.23	16.38
	9.00	43.40	16.55

APPENDIX B

Extracts from Report giving Results of Current Metering in 1981

ANGLIAN WATER AUTHORITY

GREAT OUSE RIVER DIVISION

AQUIFER AND WELL TEST REPORT

ASHDON

1981

CONTENTS

1. INTRODUCTION

This report presents the results of an investigation carried out by the Great Ouse River Division of the Anglian Water Authority within the Granta Basin near Ricketts Farm, Ashdon (NGR TL 576 425). The aim was to determine the hydrological and hydrogeological significance of an underground abstraction on ground water levels in the area and bed losses along the River Bourn between Ashdon and Bartlow. The latter assessment provides vital information relating to future injection points in the event of the test pumped borehole being used for river support purposes. Field investigations included the monitoring of ground water levels, natural and artificial river bed losses, geophysical flows and formation logging.

At a later stage in the Granta Basin Investigation, when additional data referring to surface flows between Bartlow and Stapleford had been assessed, the hydrogeological and hydrological information obtained from investigations at Marks Grove, Horseheath; Westoe Farm, Bartlow, and the present investigation will be collated and interpreted in terms of the available ground water resource and its allocation for either public water supply or river support purposes. The additional surface water data is required to fix target flows for the Granta, a watercourse complicated due to varying degrees of hydraulic connection with the underlying chalk aquifer and bordering alluvium and undifferentiated gravels.

9. RIVER AQUIFER INTERACTIONS.

In the attempt to assess river bed losses along the Bourn between the discharge point (NGR TL 5800 4303) and the Barlow Flood Station four sites were prepared for current metering.

CM1	Barlow Flood Station	TL 5824 4506
CM2		TL 5827 4421
CM3	Near Thicko Cottage (Pump Discharge)	TL 5819 4334
CM4	Ashdon Sewage Treatment Works	TL 5826 4328

Table 12 lists the river flow recorded at these four current metering sites prior to the commencement of constant rate testing. Flows recorded at CM4 and CM3 are combined, the tribuataries joining at TL 5829 4342. This feature is not shown on the current Ordnance Survey maps as the course was altered during abstraction of sands and gravels in the Bourn Valley. CM3 remained dry throughout most of this period even during the first three steps. These losses are attributable to the saturation of the previously dry alluvium bordering the minor tributary. A rainfall even on the 19th October accounts for the high flows recorded during step testing and with the varying inputs from pumping masks any natural recession along the Bourn until the period between 24th October and the start of constant rate testing (Figure 29). Analyses of flows in terms of stream bed losses becomes meaningful only after 6/7th November when the effects of rainfall and initial instability due to pumping have disappeared.

The flows recorded during the constant rate test are listed in Table 13 where initial losses between the abstraction borehole and CM1 are due to continual saturation of the bordering alluvium. During the period of stability (6th November to 11th November) an average loss of 23% occurs between the abstraction borehole and CM2 and 36% between the abstraction borehole and CM1. These losses are attributable to natural seepage into the materials bordering the Bourn channel and are not artificially induced by pumping at Ricketts Farm, Ashdon. Borehole TL 54/23 is situated only ten metres from the Bourn and levels rise in response to stream flows, the ground water levels prior to testing being approximately one metre below the base of the Bourn at this point. The input into the chalk aquifer by vertical drainage may eventually contribute to the baseflow component of Granta discharge between Bartlow and Stapleford.

The influent river condition inferred along the length of the Bourn refers specifically to the ground water levels prevailing during the testing period. Previous investigations have shown the Granta becomes effluent at or above Bartlow Flood Station during periods of high ground water levels. Similar conditions could be envisaged along the lower reaches of the Bourn near CM1 and in this event pumping at Ricketts Farm would induce stream bed seepage.

DATE	BOREHOLE TL 54/121 DISCHARGE (l/sec)	FLOW CM3 (l/sec)	FLOW CM4 (l/sec)	CM3 + CM4 (l/sec)	FLOW CM2 (l/sec)	LOSSES BETWEEN CM3 + CM4 AND CM2 %	FLOW CM1 (l/sec)	LOSSES BETWEEN CM2 AND CM1 %	LOSSES BETWEEN CM3 + CM4 AND CM1 %
30-9-81		DRY	9.4	9.4	7.9	16.0	DRY	100	100
2-10-81		"	21.1	21.1	18.4	12.8	10.8	41.3	48.8
7-10-81		"	167.4	167.4	165.7	1.0	265.0	GAIN	GAIN
9-10-81		"	46.7	46.7	39.3	19.6	31.6	19.6	32.3
12-10-81		"	12.8	12.8	5.9	53.9	DRY	100	100
14-10-81		"	DRY	DRY	DRY		"		
16-10-81	8	"	8.0	8.0	"	100	"		100
19-10-81	18	"	DRY	DRY	"		"		
21-10-81	32	"	134.4	134.4	146.1	GAIN	161.9	GAIN	GAIN
23-10-81	40	31.8	36.8	68.60	23.2	66.2	27.2	GAIN	60.3
24-10-81		DRY	28.5	28.50	21.7	23.9	18.3	15.7	35.8
26-10-81	44	31.4	19.2	50.6	17.8	35.2	12.1	32.0	76.1

TABLE 12. RIVER BOURN FLOWS (30-9-81 to 26-10-81).

DATE	BOREHOLE TL 54/121 DISCHARGE (l/sec)	FLOW CM3 (l/sec)	FLOW CM4 (l/sec)	CM3 + CM4 (l/sec)	FLOW CM2 (l/sec)	LOSSES BETWEEN CM3 + CM4 AND CM2 %	FLOW CM1 (l/sec)	LOSSES BETWEEN CM2&CM1 %	LOSSES BETWEEN CM3+4 & CM1	LOSSES BETWEEN BOREHOLE AND CM1 l/sec	%
28-10-81	45.4	DRY	16.9	16.9	12.5	26	7.8	37.6	53.8	37.6	82.8
29-10-81	42.6	39.9	15.6	55.5	11.1	80	6.7	39.6	87.9	35.9	84.3
30-10-81	41.7	38.3	15.8	54.1	12.1	77.6	4.6	62.0	91.5	37.1	89.0
31-10-81	41.9	33.6	15.6	49.2	18.6	62.2	14.5	22.0	90.5	27.4	65.4
1-11-81	40.5	NR	NR	NR	NR	NR	NR	NR	nr		
2-11-81	40.5	NR	NR	NR	NR	NR	NR	NR	NR		
3-11-81	40.7	27.9	9.5	37.4	36.2	3.2	34.2	5.5	8.6	6.5	16.0
4-11-81	40.2	25.2	8.1	33.3	34.1	21.2	31.4	7.9	5.7	9.8	21.9
5-11-81	40.2	31.4	7.5	38.9	33.8	13.1	27.1	19.8	30.3	13.1	32.6
6-11-81	39.9	NR	NR	NR	NR	NR	NR	NR	NR		
7-11-81	39.9	26.5	6.4	32.9	31.1	5.5	28.5	8.4	13.4	11.4	28.6
8-11-81	40.0	26.6	5.8	32.4	30.1	7.1	26.5	12	18.2	13.5	33.8
9-11-81	38.3	26.6	6.0	32.6	29.9	8.3	24.5	18.1	24.8	13.8	36.0
10-11-81	37.6	27.0	5.9	32.9	29.9	9.1	25.3	15.4	23.1	12.3	32.7
11-11-81	38.7	24.2	8.5	32.7	29.2	10.7	20.8	28.8	36.4	17.9	46.25

TABLE [illegible]

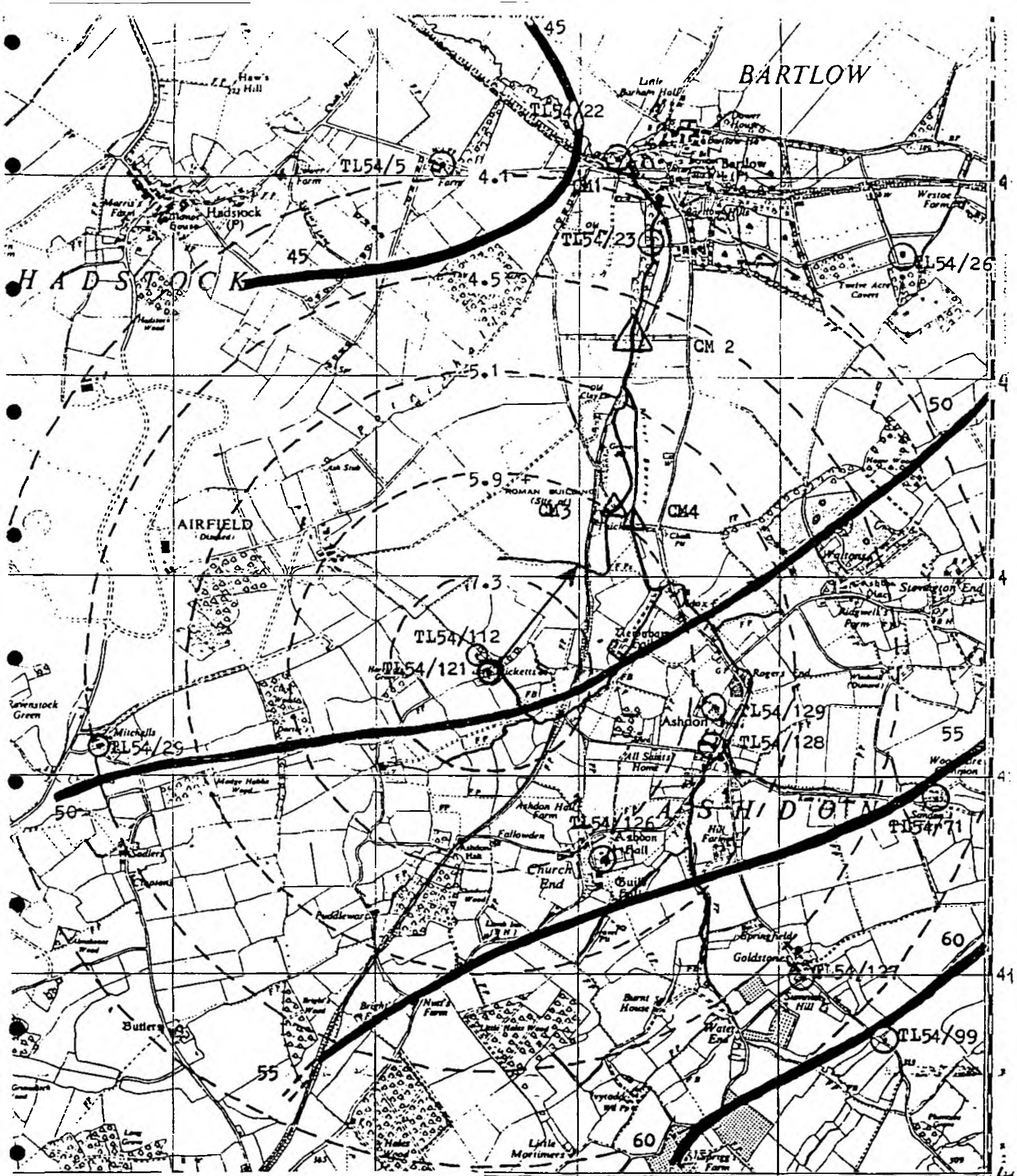


Figure 4. Ground Water Contour Map (12/10/81)
(Scale: 4cms to 1km)

▬▬▬	Ground water contour (mAOD)
— — —	Theoretical drawdown (m)
◯ TL54/112	Observation borehole
△ CM2	Current metering site

7000 8000 9000 Yards

Made and published by the Director General of the Ordnance Survey, Southampton, 1956. Reprinted with the addition of new major roads 1969.

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