

**Anglian Region: River Yare, River Wensum,
Woldgrift Drain**

Annex of R&D Note 456

Silsoe College, Cranfield University

R&D Project Record 317/19/ST

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NRA

National Rivers Authority

Anglian Region: River Yare, River Wensum, Woldgrift Drain

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This document describes methods, results and conclusions of a study to evaluate the impacts of alternative river maintenance strategies on the Rivers Yare and Wensum and the Woldgrift Drain in the Anglian Region. Its main purposes are to provide supporting information for R&D Note 456 'River Maintenance Evaluation' and to provide data which support routines for the prioritisation and programming of river maintenance.

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RIVER YARE

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ANGLIA RIVER YARE

1. BACKGROUND

1.1 Physical background

The River Yare is a spring fed river rising in a chalk aquifer. Its source is Black Water near Shipdham, Norfolk. The river is tidal in its lower reaches to the seaward side of Norwich. The fluvial Yare is 47 km in length. The catchment (232 square kilometres at Colney) is predominantly rural in character, the City of Norwich being the only major conurbation. The river flows through a variety of land uses including grassland, arable and gravel workings.

1.2 Study Reach

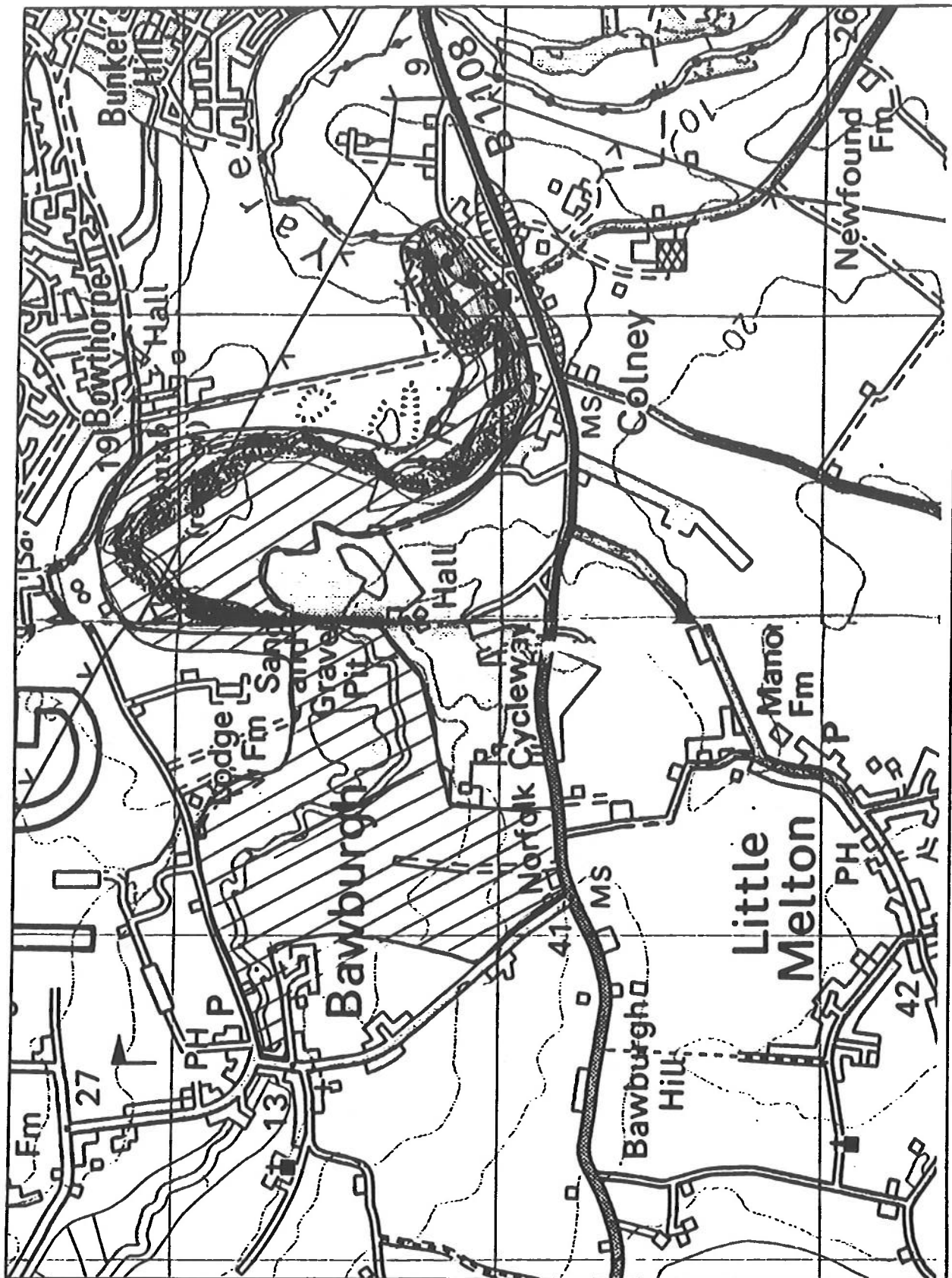
The section of the River Yare selected for study (Figure 1) runs for 3 km from Bawburgh (GR. 157 088) to Colney (GR. 183 083). This site is typical of main rivers in the area on which river maintenance in the form of weed clearance is performed. The area of land benefiting from river maintenance in terms of its effect on flooding and land drainage is estimated to be 100 ha (Figure 1). The benefit area encompasses gravel workings in addition to agricultural land and is divided into blocks according to land use, drainage condition and land management (Figure 2).

1.3 River Characteristics

The River Yare flows through a narrow floodplain at the upstream limit of the reach which widens out downstream. Within the study reach, channel width ranges from 1 m to 9 m. The average width is 5 m. For much of its length, the river is confined by gravel workings and artificially created lakes.

River freeboard is variable, ranging from 0.2 m to 1 m. The river banks consist of solid earth vegetated by grass and herbs. In the vicinity of the A47 road bridge which traverses the river, the banks consist of artificial stone and concrete revetments.

The flow of water is slow due to the shallow gradient and low lying nature of the land. Slack water predominates and is interspersed with short runs. Gravel and sands are the dominant bed substrates.



Legend :

Scale 1 : 9375



Benefit Area



Piped drainage

Figure 1 Location of the River Yare site, benefit area and land drainage

1.4 Land Drainage

High water levels in the River Yare are retained artificially for aesthetic purposes by a series of mills and weirs. Large lakes flank the river for much of its length, providing valuable storage for water in times of flood.

Within the study reach, five ditches discharge water into the River Yare. One is fed by an artificial lake (flooded gravel pit). The majority of land within the benefit area is drained naturally by gravity (88 %). Further details are presented in Figure 1 and Section 2.5.

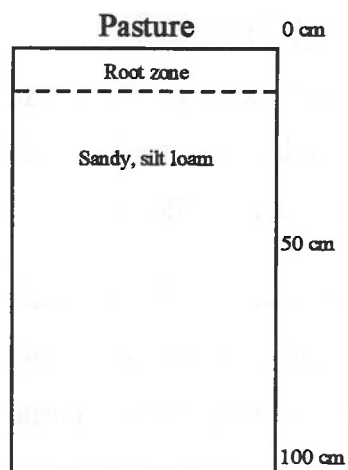
1.5 Geology, Soils and Land Capability

The River Yare flows over chalk bedrock which is overlain by chalky till, a glacial deposit. The till is locally more than 500 m in depth where it fills deep channels. Pebbles are abundant within the till and rounded fragments of chalk give it a characteristic spotted appearance.

The Isleham and Adventurers' soil series are to be found within the Yare valley. The Isleham series is a typical humic sandy gley soil with a peaty topsoil whilst the Adventurers' series consists of a well decomposed organic topsoil over a humified subsoil. Soil profiles taken within the reach are shown in Figure 3.

Both soil series are characteristically waterlogged within 40 cm of the surface for over 180 days in the year. The Soil Survey of England and Wales (SSEW) classify this soil wetness regime as Wetness Classification V (Hodge et al, 1984). The Agricultural Land Classification of the Ministry of Agriculture, Fisheries and Food (MAFF) classes the land as Grade 4. The crop range and yields are restricted. Grassland is the dominant land use due to the high watertables and risk of poaching (surface damage by livestock) and flooding. Some arable crops such as forage crops and cereals are also grown. According to data from the meteorological station at Morley St Botolph, the approximate mean annual rainfall is 637 mm.

Grid Reference	158 088
Soil Core Number	1
Soil Colour	Dark yellowish brown
Comments	Uniform profile, well drained



Grid Reference	182 082
Soil Core Number	2
Soil Colour	Dark yellowish brown
Comments	Uniform profile, well drained

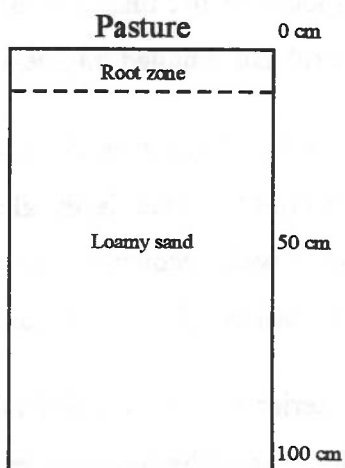


Figure 3 Soil profiles

1.6 Capital Works

No record of any capital works previously carried out on the River Yare was available at the time of this study. From the knowledge of the channel gained during this river maintenance study, it is speculated that the only capital works performed in recent times were the re-sectioning and realignment of the channel and protection of the banks with stone revetments following the construction of the A47 road bridge over the River Yare near Bawburgh.

1.7 River Maintenance

The River Yare is subject to a regular programme of maintenance for the benefit of land drainage and flood alleviation. Weed cutting using a Bradshaw Bucket on a hydraulic excavator or a weed boat takes place on an annual basis in the July/August. Between 50 % and 60 % of the vegetation cover is removed in a strip down the centre of the channel, leaving a fringe of vegetation down each margin.

Desilting is performed as required to remove accumulated shoals and sand residues; a product of the extensive gravel extraction. A programme of desilting in the River Yare between Colney and Bawburgh is scheduled for the future. The timing of this desilting however, remains uncertain. A plan to re-locate a section of the River Yare which runs through the gravel works is yet to be finalised. Once this plan has been confirmed and the re-location carried out, the desilting of the River Yare is likely to go ahead. This re-location has resulted in the postponement of the desilting works which were originally scheduled for 1992.

River maintenance on the River Yare is scheduled into part of a regular work programme based on the perceived need for maintenance, and custom and practice. All people with frontages on the watercourse are notified prior to maintenance taking place.

1.7.1 Farmers views on maintenance

During the farmer interviews the general opinion that maintenance is insufficient was expressed. The weed clearance programme was accepted as beneficial but the view that the channel requires desilting was expressed by many on several occasions. One farmer reported that 1 m of land was lost each year due to bank erosion caused by flooding and higher water levels because of a build up of silt in the channel.

1.7.2 Alternative maintenance strategies

Desilting of the channel was deemed necessary by four farmers within the benefit area. This would increase the freeboard of the river and improve the outfall for field drainage pipes. The straightening of the river to increase the flow of water and therefore to reduce flooding was suggested by one farmer as an appropriate alternative to the current maintenance regime which encourages desilting due to the vegetational fringe and a reduction in flow velocity. The fringe of vegetation left down each bank was accepted as beneficial for wildlife but is said to impede and prevent access to the river for drinking purposes by cattle. A cattle drink has been created by the farmer as a direct response to this problem.

1.8 Climate

The impact of river maintenance on watertable depth and river levels depends on the particular weather conditions, especially rainfall, which vary from season to season and year to year. The seasonal and yearly rainfall totals from the rainfall gauge at the Norwich Water Works (GR. 212 096) for the period of study are presented in Table 1.1.

Table 1.1 Rainfall totals

Period	Season	Actual Rainfall (mm)	Average * Rainfall (mm)	% Average Rainfall
1992	Spring	159.9	134.7	118.7
	Summer	208.8	154.0	135.6
	Autumn	218.9	170.5	128.4
1993	Spring	115.1	134.7	85.5
	Summer	151.0	154.0	98.0
	Autumn	233.9	170.5	137.2
1994	Spring	143.8	134.7	106.8
	Summer	126.1	154.0	81.9
	Autumn	264.4	170.5	155.0
1995	Spring	116.0	134.7	86.1
	1992	1284.9	1213.53	105.9
	1993	777.3	1213.53	64.1
	1994	693.3	1213.53	57.1

* Based on 33 year record from 1960 - 1993

Table 1.1 shows that 1992, the autumn of 1993 and spring and autumn of 1994 were wetter than average. This is supported by the wet field conditions reported by farmers.

The probability of a wet, dry and average season and year occurring (Table 1.2) has been determined through analysis of monthly rainfall records covering a 33 year period (Norwich Water Works GR. 212 096, station reference 208 389). The classification system of the Food and Agricultural Organisation (FAO) was used to determine the wet, dry and average rainfall bands. Dry and wet seasons/years are classed as those with less than 75 % of the average rainfall and more than 125 % of the average rainfall value respectively. Further details are presented in the R&D Note 456, Section 3.5.4.

Table 1.2 Probability of climatic conditions

Season	Dry *	Average *	Wet *
Spring	0.24	0.73	0.03
Summer	0.24	0.67	0.09
Autumn	0.27	0.64	0.09
Year	0.25	0.59	0.16

* Based on records 1960 - 1993

The R&D Note 456, Section 3.5.4 describes the process by which the financial benefits of maintenance are calculated according to the probability of each type of season and year occurring.

1.9 Aquatic Vegetation

Aquatic vegetation within the channel was identified prior to maintenance (Section 1.9.1 to 1.9.4). This vegetation has both hydraulic and environmental implications for the channel.

1.9.1 Floating vegetation

Potamogeton sp. (Pondweed) is the dominant floating plant found within the study reach. *Potamogeton* is a rooted plant with oval dark green leaves. Although it is classed as a floating broad-leaved aquatic plant it often has some submerged leaves. The pondweed reproduces through rhizomes and is therefore difficult to control through weed cutting alone. Desilting may be necessary in order to reduce or remove the seed bank of *Potamogeton* from the river bed.

The Yellow Water Lily (*Nymphaea lutea*) is a broad leaved plant with distinctive round leaves up to 30 cm in diameter which float on the surface. Veins within the leaf are arranged in a honeycomb pattern. The lily offers little resistance to flow as it has no submerged leaves. Its large leaves may serve to inhibit the growth of submerged vegetation as they restrict the amount of light able to penetrate the water.

1.9.2 Emergent vegetation

Reed Sweet-Grass (*Glyceria sp.*) is a narrow leaved emergent plant which is abundant within the River Yare. *Glyceria* may reach up to 2 m in height and grows in dense stands in slow moving water. It provides a strong resistance to flow and may present an impermeable barrier to the movement of water according to the stand density. It reproduces through a system of rhizomes so control through weed cutting is difficult. Desilting of the channel is necessary in order to remove the rhizomes from the river and to prevent regrowth.

Arrowhead (*Sagittaria sagittifolia*), can also be found. Its characteristic bright green arrow-shaped leaves may be emergent, submerged or floating in nature.

1.9.3 Algae

Filamentous algae is found within the River Yare. The long chains of this algae grow up from the hydrosol. It is difficult to control as it can be found anywhere and grows rapidly through simple fission by which each cell divides. Algae is common in nutrient rich waters and frequently invades areas where other aquatic plants have been controlled or eradicated.

2. FARM SURVEY

2.1 Introduction

Through structured interviews and informal discussions with farmers and a topographical survey, the area deriving benefit from the river maintenance work in terms of the impact on land drainage and flooding is estimated to be 100 ha. This area is classed as the benefit area (BA). The benefit area has been divided into separate blocks (Figure 2) according to land use, drainage condition and management practices. Forty seven percent of the benefit area is comprised of gravel workings and artificial lakes.

2.2 Farm Type, Size and Tenure

Four farms within the benefit area are classed as specialist cereal enterprises under the European Union (EU) classification system. One farm is classed as a dairy farm and two are small holdings. Gravel workings cover 47 % of the benefit area.

Farm size ranges from 1 to 324 ha, averaging 100 ha. The Standard Man Day (SMD) or Man-Work-Unit requirement ranges from 1 to 361 with an average of 182. This requirement may be used to assess the labour requirement of agricultural enterprises. In general, the higher the SMD value, the greater the amount of labour required.

Six farms are under sole proprietorship and one is run in a partnership. One farmer has two holdings but these are farmed as one under one holding number. All the land within the benefit area is owner occupied.

2.3 Livestock Enterprises

The dairy farm comprises a herd of Friesian cows. The milk yield is average being in the region of 5500 litres/cow/year. One farm within the benefit area has a beef herd consisting of seven beasts. They are finished off grass under an 18 months fattening system.

Sheep enterprises are followed on two farms. One, a small holding keeps four sheep and no system is followed. The other enterprise consists of 300 store lambs which are fattened off turnips and grass. They are bought in July and sold in November.

2.4 Arable Enterprises

Five farmers follow some arable enterprises which typically follow a four year rotation. Winter wheat, winter barley and sugar beet are the most common crops grown. Spring barley and combining peas are also grown although only winter wheat and horticulture are grown within the benefit area.

2.5 Land Use In The Benefit Area

Within the benefit area, the dominant land use is extensive grassland. This is characterised by low levels of nitrogenous fertiliser application ($< 50 \text{ kg N/ha}$), short grazing seasons and little grass conservation. A small area (1.8 ha) is cultivated for strawberries.

Further information on land use and drainage within the benefit area is provided in Table 2.1 and Figure 4. The horticulture enterprise makes use of higher land within the benefit area which is intensively drained and not under threat of frequent flooding.

Table 2.1 Land use in the benefit area

Land Use	Area (ha)	% of Benefit Area	% Land With Field Drains
Extensive grass	46.3	46	24
Grass/arable	4.6	5	0
Horticulture	1.8	2	100
Gravel workings	47.3	47	N/A

2.6 Turnout and Yarding Dates

Dates for the turnout and yarding of livestock follow a similar pattern throughout the benefit area. Livestock is turned out to graze following the first hay cut over the majority of the grassland area. Table 2.2 provides further information on turnout dates. All livestock are taken off the grassland and yarded in mid to late October

Table 2.2 Turnout dates

Turnout Date	% Grassland Area	% of Benefit Area
Mid/late April	24.4	11.3
Early/mid May	16.6	26.0
After hay cut	56.2	7.7
Not grazed	2.8	1.3

2.7 Grass Conservation

One cut of hay is taken over 70 % of the grassland area (32.3 ha). All hay is cut in June. Grassland under the grass/arable rotation is not cut for hay or silage.

2.8 Nitrogen Application

Nitrogen is applied to 17 % of the grassland area, excluding that under the grass/arable rotation. Both straight and compound NPK fertiliser in the ratio 20:10:10 are applied. Table 2.3 provides further information on application rates.

Table 2.3 Nitrogen application rates

Rate (kg N/ha)	Grassland Area (ha)	% Grassland Area
0	38.6	83.4
32.5	6.3	13.6
50	1.4	3.0

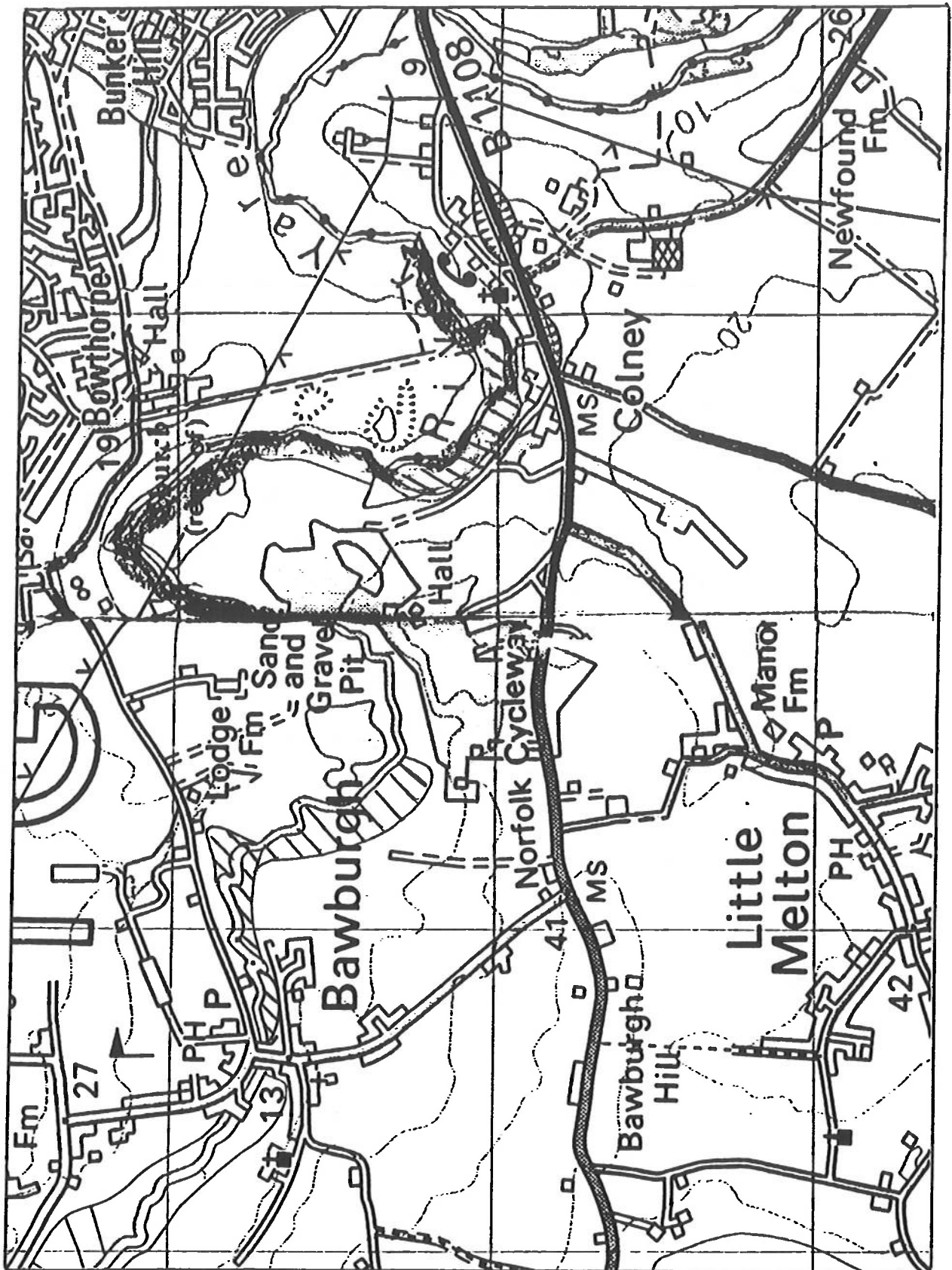
2.9 Flooding

As Table 2.4 shows, 22 % of the benefit area is prone to flooding. The majority of flooding occurs during the winter months. Duration of flooding ranges from 1 to 14 days. Land under horticultural enterprises is not prone to flooding. Areas which typically flood area are shown in Figure 5.

Table 2.4 Flooding

% Winter Flooding	Area Flooded (ha)	% of Area Flooded	% of Benefit Area Flooded
100	2.1	9.4	2.1
95	17.3	78.0	17.3
90	2.2	9.9	2.2
80	0.6	2.7	0.6

Farmers attribute flooding in the winter to excessive rainfall and high water levels in the river channel. Summer flooding is attributed to aquatic vegetation in the channel which keeps water levels artificially high. Litter and debris are the main penalties of the flooding.



Legend :

Scale 1 : 9375



Flooded areas

Figure 5 Areas prone to flooding

2.10 Waterlogging

Throughout the benefit area, the wetness condition of the land follows a similar pattern (Table 2.5). During the spring, 61 % of the benefit area is classed as being rarely wet. The remaining area is occasionally prone to wet conditions. Throughout the summer months the majority of land, 95 % is rarely wet. In the autumn, more land is prone to waterlogging and 25 % of the land is classed as permanently wet.

The wet condition of the land has been attributed to a variety of factors by the farmers. The low lying nature of the land and the fact that the land adjacent to the river is classed as old marsh meadow land which was originally allowed to flood and has low banks are the main causes of the wet conditions. Following the harvest, one farmer digs a 20 m long channel from the field centre to the river to allow flood and surface runoff to drain off the land into the river. This prevents the land from becoming permanently waterlogged.

Table 2.5 Farmer assessment of wetness condition

Season	Wetness Condition	Area (ha)	% Benefit Area (excluding area of gravel works)
Spring	Rarely wet	32.3	61.3
	Occasionally wet	20.4	38.7
	Often wet	0	0
	Permanently wet	0	0
Summer	Rarely wet	50.0	94.9
	Occasionally wet	2.7	5.1
	Often wet	0	0
	Permanently wet	0	0
Autumn	Rarely wet	32.3	61.3
	Occasionally wet	1.8	3.4
	Often wet	5.5	10.4
	Permanently wet	13.1	24.9

2.11 Statistical Analysis

It is apparent that land use, farming practice and drainage are interrelated. Statistical methods were used to determine whether these relationships occurred more frequently than might be expected by pure chance. Full details of this analysis in which the 12 sites were grouped

according to NRA Region, are presented in the Interim Report R&D 317/13/ST, presented to the NRA in December 1994.

The following observations can be made from the statistical analysis of fields in the benefit area of the River Yare maintenance programme:

- A strong relationship exists between land use and presence of field drainage. Extensive land use such as the grassland, is predominantly naturally drained whilst intensive land use (horticulture) is all drained by pipes. (Statistically, there is an 87 % chance of correctly predicting the presence of field drainage on the basis of land use).
- Land use and frequency of flooding are strongly related. Land which is prone to frequent flooding is under extensive enterprises. Land which does not flood is under horticulture. (Statistically, there is 97 % chance of correctly predicting the frequency of flooding on the basis of land use).
- A relationship exists between turnout dates for livestock and field wetness conditions in the spring. Turnout dates are later on the wetter land. A significant proportion of the wetter land is not grazed compared to 100 % of the well drained land (rarely wet) which is grazed (Statistically, there is a 94 % chance of correctly predicting turnout dates in the spring on the basis of field wetness conditions).
- Yarding dates for livestock are related to field wetness conditions. Land which is permanently wet in the autumn is not grazed and land which is often wet in the autumn is closed up for the winter earlier than land which is rarely wet. (Statistically, there is an 84 % chance of correctly predicting yarding dates for livestock on the basis of field wetness conditions in the autumn).

3. HYDRAULIC AND HYDROLOGICAL DATA

3.1 Introduction

Information on channel hydraulics and hydrological data has been used to determine the impact of maintenance on channel capacity and flood return periods.

3.2 Cross-section surveys

Cross-sectional surveys of the channel were completed at three points within the study reach at an average interval of 934 m (Figure 2). Channel capacity and freeboard were determined from these cross-sections. Channel dimensions were not altered during the process of river maintenance, therefore a post-maintenance cross sectional survey of the channel was not necessary.

Prior to river maintenance, an estimate of the roughness of the channel was expressed in the form of the Manning's n coefficient, using the methodology developed by Cowan (1956). This coefficient is calculated from the assessment of six parameters which include channel sinuosity, variations in channel cross-section and degree of vegetation growth. Further details of the methodology followed are presented in the R&D Note 456, Appendix IV. The same procedure was followed after maintenance in order to determine values of channel friction in a 'with' (post) and 'without' (pre) maintenance situation. Channel cross-section information including Manning's ' n ' values and stage/discharge curves are presented in Figure 6. Table 3.1 shows the bankfull channel capacities and associated flood return periods 'without' and 'with' maintenance at each cross-section location.

Table 3.1 Bankful capacity and flood return periods

Cross-section	Without Maintenance		With Maintenance	
	Bankful Capacity (m ³ /s)	Return period (years)	Bankful Capacity (m ³ /s)	Return Period (years)
1	7.0	0.9	11.7	3.5
2	7.4	1.0	11.8	3.8
3	7.5	1.0	15.1	11.0

(Source: modelled estimates)

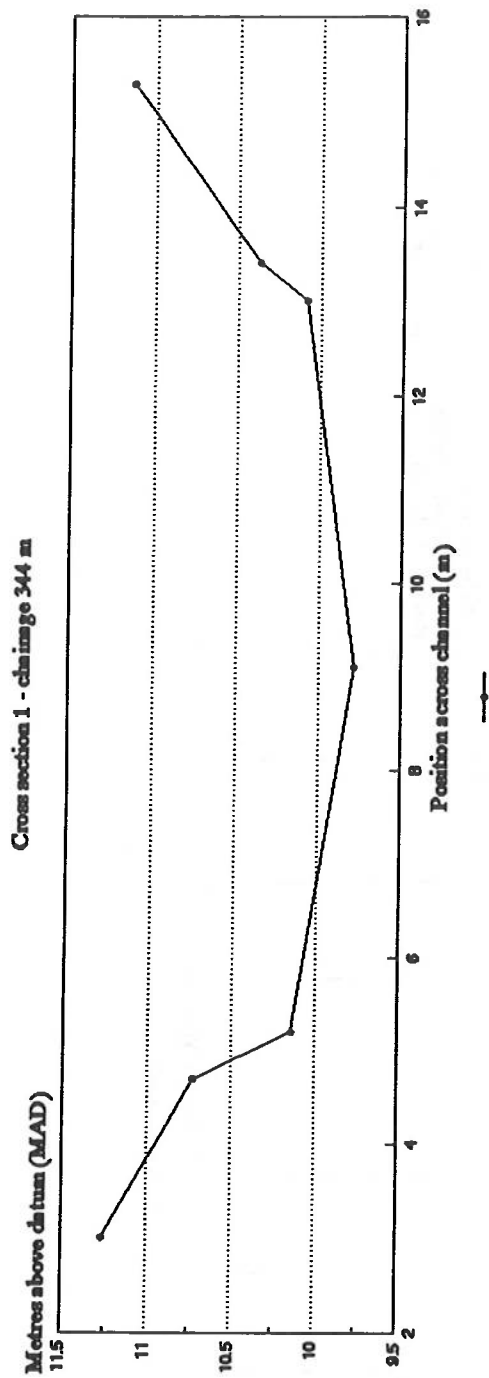
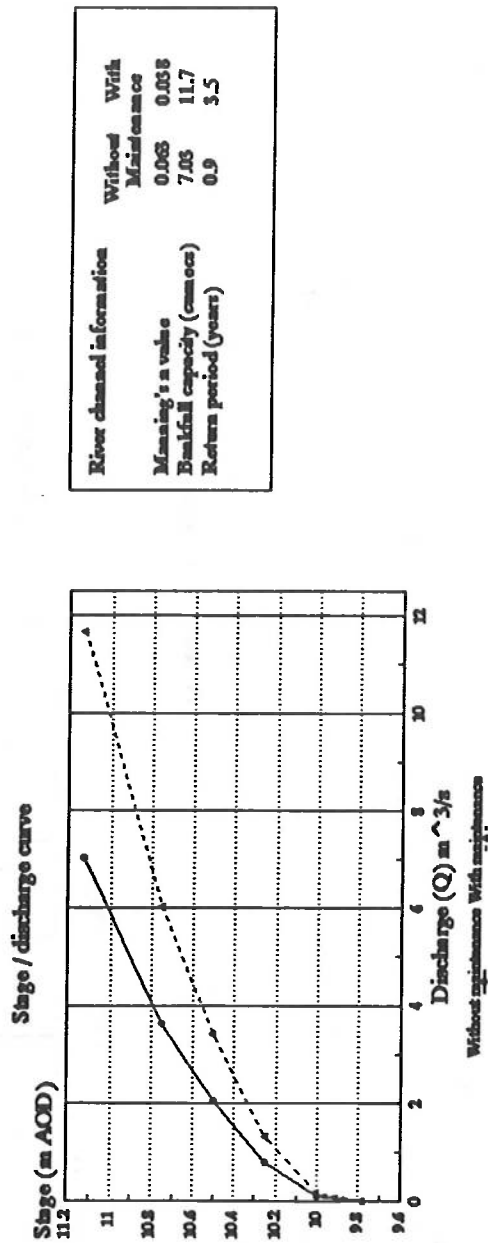
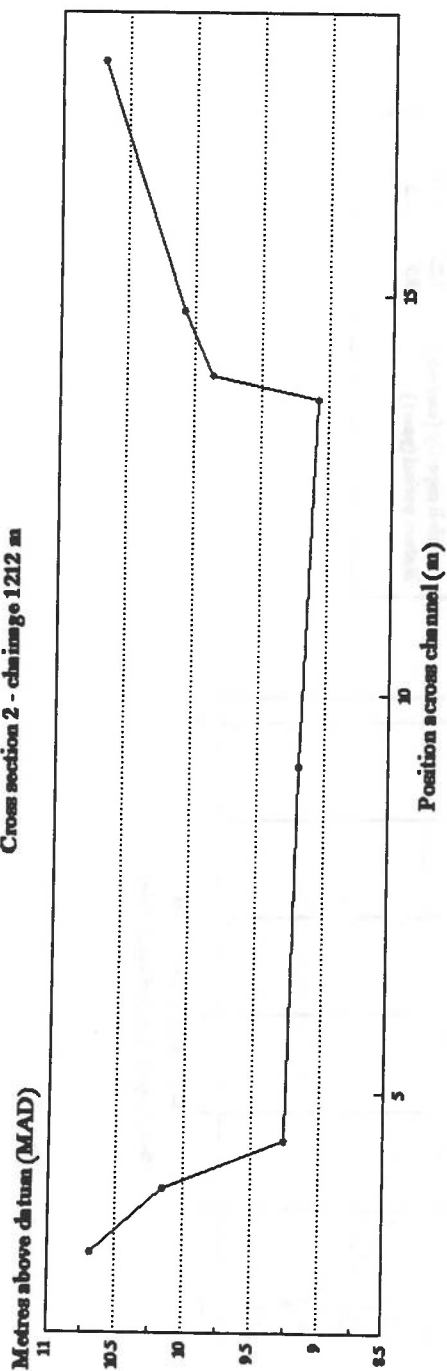
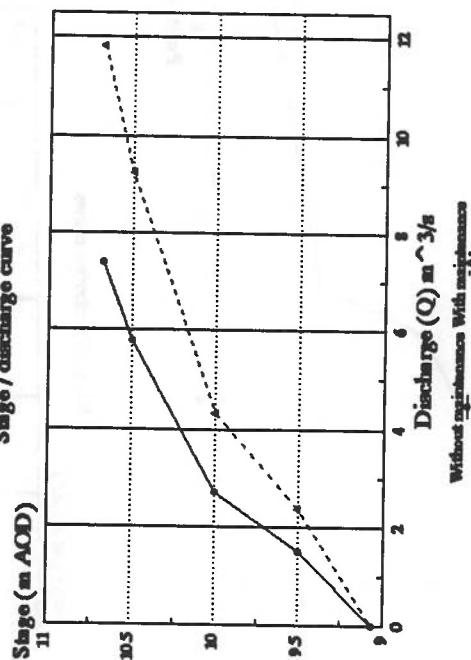


Figure 6 River Yare channel information

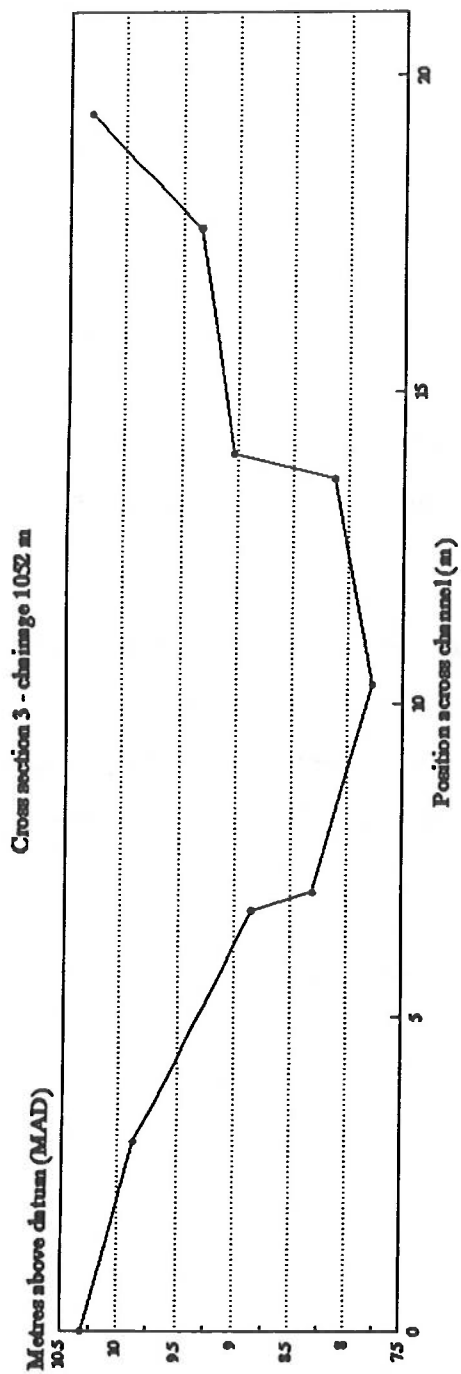
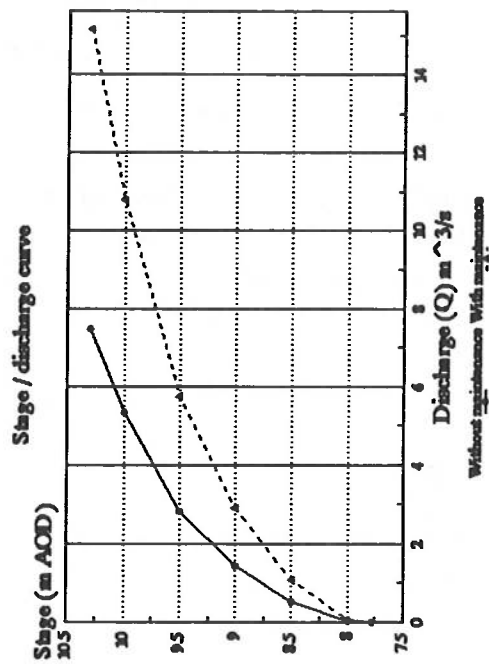
Cross section 2 - change 1212 m



Stage / discharge curve



River channel information	
Manning's n value	0.067
Bankfull capacity (cumecs)	7.4
Return period (years)	1.0
Without	With
Manning's n value	0.042
Bankfull capacity (cumecs)	11.8
Return period (years)	3.5



River channel information	
Manning's n value	0.067
Bankfull capacity (cumecs)	7.5
Return period (years)	1.01
Without maintenance	0.0331
With maintenance	15.1
	11.0

The bankfull capacity figures obtained from the cross-sections indicate an average increase in capacity attributable to maintenance of 43 % and an average increase in the interval between flood events of 79 %. The area affected by flooding is not expected to change in the absence of maintenance.

3.3 Flood return period

Throughout the period of the study, river water level information was collected on a regular basis from gauging stations within the study reach. Information relating to flood frequency and duration and flood flows were collected from NRA staff and local farmers. This information was used to compile a flood return period curve for the River Yare using the methodology contained within the Flood Studies Report (NERC, 1975). The frequency of floods of different magnitudes can be estimated by using this flood return period curve shown in Figure 7.

The flood return period for each block which floods and associated flooded areas are shown in Table 3.2. The 'without' maintenance return period is estimated by the farmer, the 'with' maintenance value is a modelled estimate using the cross-section information and Manning's n coefficient. It is assumed that the flooded area remains unchanged following maintenance.

Table 3.2 Flood return periods and flooded areas

Block No.	Block Size (ha)	Flooded Area (ha)	Flood Return Period (Years)	
			Without Maintenance	With Maintenance
101	1.4	0.42	0.5	3.0
201	1.8	0.61	1.0	3.0
202	2.8	0.58	0.3	3.0
301	26.0	4.42	0.5	3.5
401	6.3	0.80	1.0	3.0
501	11.3	6.78	0.4	5.0
701	1.3	0.40	3.0	3.5

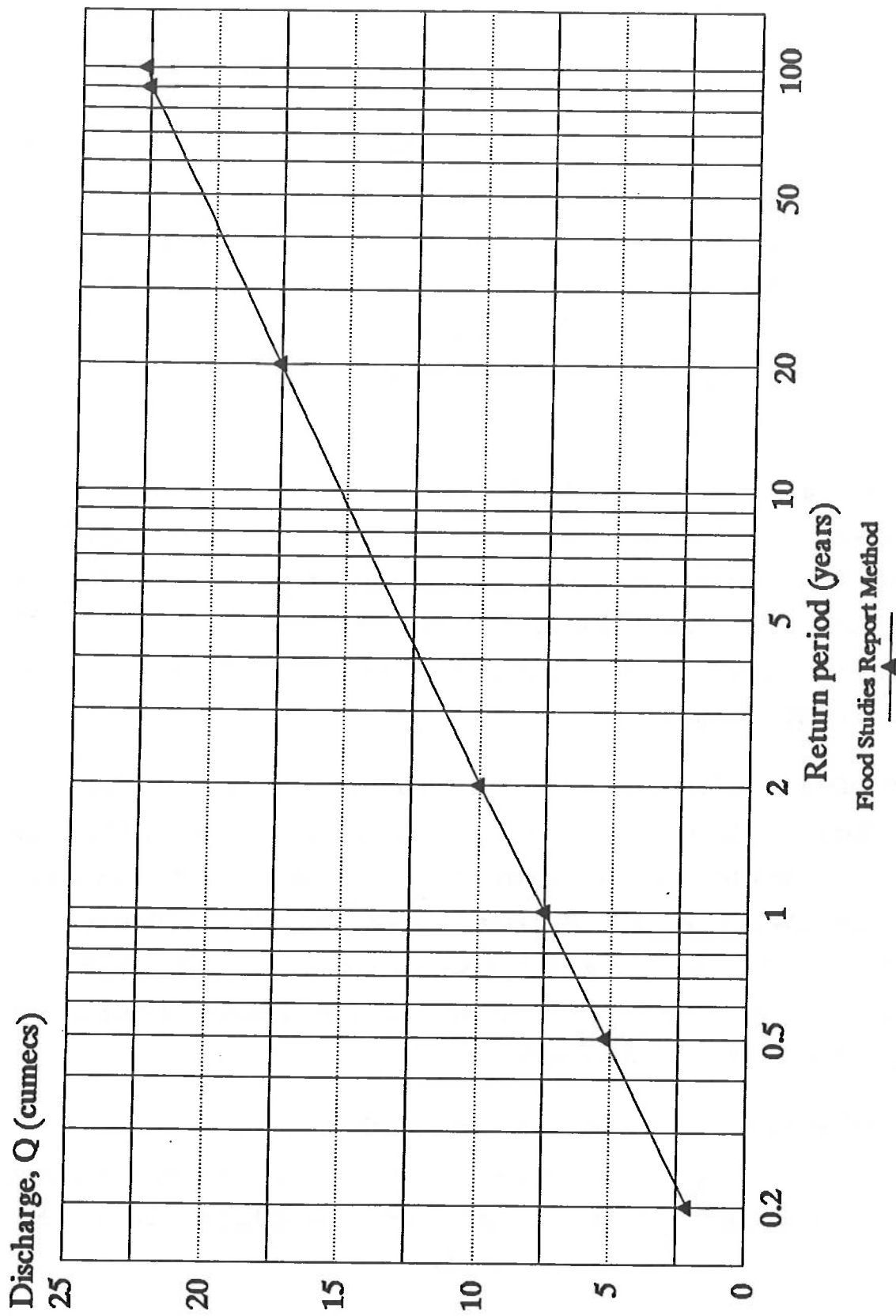


Figure 7 Flood return period curve

4. LAND DRAINAGE

4.1 Field Drainage Status

Through an extensive literature and farmer survey, the drainage status of land has been classified into three according to the watertable depth. These watertable bands have been identified as > 0.5 m from the surface, between 0.3 and 0.5 m of the surface and < 0.3 m from the surface. According to the time the watertable lies within these bands, the drainage status is classed as good (no restrictions on land use), bad (some restrictions on arable land use) or very bad (severe limitations to agriculture). Further details are presented in the R&D Note 456, Section 3.5.2.

The drainage status of land within the benefit area has been determined on a seasonal basis using a non-steady state watertable model which relates infield watertable levels (and hence drainage conditions) to observed water levels in the river and ditch system (see R&D Note 456 Section 3.5.2 for further details). The model has been run with river water levels for the 'with' and 'without' maintenance scenario and the same climatic data in order to isolate the impact of maintenance on drainage status.

The results of the watertable model and the assessment of drainage status made by farmers are shown in Table 4.1. In some cases, there is a change in the number of weeks that the watertable lies within the good, bad or very bad drainage bands following maintenance. However, these changes may not be of sufficient magnitude to change the drainage status classification. Where a change in drainage status has occurred due to maintenance, the changes appear in bold print in Table 4.1. Appendix I contains an example of the input and output data produced by the watertable model.

The output from the watertable model is consistent with the farmers assessment of drainage status under dry and average climatic conditions. Under wet conditions, there is agreement that drainage deteriorates but whereas farmers perceive much of the land as being under bad drainage the model predicts the drainage to be very bad.

In the 'without' maintenance situation, there is reasonable correlation between modelled and farmer assessment of drainage condition. Farmers generally identified the same areas as the watertable model which would deteriorate as a consequence of no maintenance.

Table 4.1 Drainage status for wet, average and dry seasons, without/with maintenance

Block No		Wet Season *		Average Season *		Dry Season *		Farmer Assessment			Without
		Without	With	Without	With	Without	With	Wet	Average	Dry	
101	N	VB	VB	G	G	G	G	<i>B</i>	G	G	B
201	N	VB	B	G	G	G	G	<i>B</i>	G	G	B
202	N	VB	VB	G	G	G	G	<i>B</i>	G	G	B
301	N	VB	VB	B	G	B	G	<i>VB</i>	<i>G</i>	G	B
401	N	B	G	G	G	G	G	G	G	G	G
501	Y	VB	B	G	G	G	G	<i>VB</i>	<i>B</i>	B	B
701	N	B	G	G	G	G	G	<i>B</i>	G	G	B
801	N	G	G	G	G	G	G	<i>B</i>	G	G	B

NB : * Modelled results, Y or N refers to the presence or absence of field drainage, bold type indicates a change in drainage status due to maintenance, italics indicate differences between farmer and modelled assessments

These assessments confirm that the 'with' maintenance drainage status in the benefit area is generally bad in wet climatic conditions and good in average and dry conditions. If maintenance were not performed, drainage conditions would deteriorate to very bad in some areas in a wet season and to bad under normal and dry conditions. River maintenance results in the prevention of a deterioration of drainage status on 4 blocks of land in a wet season and on 1 block in an average and dry season.

- In a wet season maintenance prevents deterioration from :
 B to VB over 13 ha (13 % of BA)
 G to B over 8 ha (8 % of BA)
- In an average and dry season maintenance prevents deterioration from :
 G to B over 26 ha (26 % of BA).

Under average weather conditions, farmer assessments suggest a deterioration of drainage condition from good to bad over 88 % of the agricultural land within the benefit area in the event of discontinuing weed maintenance.

5 SCHEME APPRAISAL

5.1 Maintenance Benefits

For each block of land, agricultural production scenarios were created which reflect different levels of field management under conditions of good, bad and very bad drainage (see R&D Note 456 Section 3.5.4). These scenarios are based on discussions with farmers in the benefit area over the period 1992-1994.

Changes in field drainage status as a result of maintenance under dry, average and wet climatic conditions have been identified. Changes in flood risk due to maintenance have also been determined. Estimates have been derived of the monetary value of changes in field management and productivity associated with changes in the standards of drainage service.

Two perspectives have been used to value agricultural performance. The first perspective is that of financial analysis which uses the prices paid and received by farmers to estimate the added-value associated with drainage. Financial analysis shows the benefits of maintenance to farmers in the benefit area.

The second perspective is that of economic analysis which modifies the financial analysis to make allowance for the direct and indirect subsidies paid to farmers by Government. In accordance with the MAFF Project Appraisal Guidance Notes on Flood Defence (PAGN, 1993), these modifications involve reductions in the financial value of output (including subsidies) by 10% in the case of cereals, oil seeds and grain legumes, 35% for beef and 25% for sheep. Commodities subject to quota such as potatoes, sugar beet and milk are treated as winter wheat. The set aside areas are also treated as wheat. The reasons for these adjustments are discussed in the R&D Note 456 Section 2.7.2.

Using the results of watertable modelling, Table 5.1 shows the financial net returns (1995/96 prices) for each block of land within the benefit area under conditions of good, bad and very bad drainage. Changes in net returns relating to a change in drainage status are also shown. Table 5.2 presents similar data using economic prices. Table 5.3 shows the flood costs for each block of land assuming with and without maintenance and specified field drainage

conditions. It is assumed that there is no difference between financial and economic values in the case of flood damage to standing crops.

Table 5.1 Financial net returns

Block	Area (ha)	Net Returns (£/ha)			Change in Net Returns		
		Good	Bad	Very Bad	Good to Bad	Good to Very Bad	Bad to Very Bad
101	1.40	409	325	259	84	150	66
201	1.80	424	356	233	68	191	123
202	2.80	424	356	233	68	191	123
301	26.00	90	68	57	22	33	11
401	6.30	385	313	259	72	126	54
501	11.30	227	198	166	29	61	32
601	47.30	Gravel pit					
701	1.30	155	129	98	26	57	31
801	1.80	1500	750	121	750	1379	629

Table 5.2 Economic net returns

Block	Area (ha)	Net Returns (£/ha)			Change in Net Returns		
		Good	Bad	Very Bad	Good to Bad	Good to Very Bad	Bad to Very Bad
101	1.40	32	19	8	13	23	10
201	1.80	362	294	166	68	196	128
202	2.80	362	294	166	68	196	128
301	26.00	-30	-33	-29	3	-2	-4
401	6.30	40	26	15	13	24	11
501	11.30	115	95	73	20	42	22
601	47.30	Gravel pit					
701	1.30	43	26	15	17	28	11
801	1.80	1500	750	166	750	1334	584

Table 5.3 Flood costs

Block Number	GOOD DRAINAGE				BAD DRAINAGE				VERY BAD DRAINAGE				CHANGE IN FLOOD COSTS			
	Without maintenance FRP	With maintenance FRP	Without maintenance flood cost	With maintenance flood cost	Without maintenance flood cost	With maintenance flood cost	Without maintenance flood cost	With maintenance flood cost	GOOD Without -with	BAD Without -with	VERY BAD Without -with	GOOD TO BAD Without -with	BAD TO VERY BAD Without -with	GOOD TO VERY BAD Without -with		
101	0.50	3.00	8.97	1.50	7.32	1.22	6.02	1.00	7.48	6.10	5.02	5.83	4.80	4.53		
201	1.00	3.00	15.89	5.30	13.92	4.64	11.64	3.88	10.59	9.28	7.76	8.62	7.00	6.34		
202	0.30	3.00	56.99	5.70	49.05	4.91	35.00	3.50	51.29	44.15	31.50	43.35	30.10	29.30		
301	0.50	3.50	3.01	0.43	2.55	0.36	2.15	0.31	2.58	2.19	1.84	2.12	1.79	1.72		
401	1.00	3.00	1.24	0.41	1.04	0.35	0.89	0.30	0.83	0.69	0.59	0.63	0.54	0.48		
501	0.40	5.00	9.50	0.76	8.75	0.70	7.91	0.63	8.74	8.05	7.28	7.99	7.21	7.15		
701	3.00	3.50	0.65	0.56	0.60	0.51	0.35	0.30	0.09	0.09	0.05	0.04	-0.16	-0.21		

Table 5.4 combines data on changes in drainage status, flood risk and financial performance to determine the financial benefits and change in financial net returns due to maintenance for wet, average and dry weather conditions for each block of land in the benefit area. These benefits are the avoidance of losses which would occur in the absence of maintenance. Benefits weighted by field size for wet, average and dry seasons are multiplied by the relative probability of the occurrence of the season to give an average expected annual benefit. These are summed for the benefit area as a whole.

Table 5.4 estimates a total expected annual benefit of £ 929 in 1995 financial prices, equivalent to about £ 18/ha per year. Table 5.5 shows the benefits attributable to maintenance using economic prices based on the current MAFF Project Appraisal Guidance Notes. Total average expected annual benefits are about £ 450 in economic prices for the benefit area, equivalent to £ 9/ha. On this basis, the benefit to the national economy is 50 % of the benefits which accrue to farmers. This difference reflects the adjustments required by MAFF to remove government subsidy from the assessment of benefits.

Table 5.4 Changes in net returns due to maintenance and climate, 1995/96 financial prices

Block	Area (ha)	Wet Season			Average Season			Dry Season			Total Change (£/yr)
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	
101	1.00	0	5.02	5	0	7.48	7	0	7.48	7	7
201	1.80	123	7.00	130	0	10.59	11	0	10.59	11	43
202	2.80	0	31.50	32	0	51.29	51	0	51.29	51	138
301	26.00	0	1.84	2	21	2.12	23	21	2.12	23	547
401	6.30	71	0.63	72	0	0.83	1	0	0.83	1	55
501	11.30	32	7.21	39	0	8.74	9	0	8.74	9	137
601	47.30	Gravel Workings									
701	1.3	26	0.04	26	0	0.09	0	0	0.09	0	4
801	1.80	0	0.00	0	0	0.00	0	0	0.00	0	0
Total	100								Total		929
Probability of :		Wet season			Average season			Dry season			Benefit (£/ha)
		0.07			0.68			0.25			
											18

Table 5.5 Changes in net returns due to maintenance and climate, 1995/96 economic prices

Block	Area (ha)	Wet Season			Average Season			Dry Season			Total Change (£/yr)
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	
101	1.00	0	5.02	5	0	7.48	7	0	7.48	7	7
201	1.80	128	7.00	135	0	10.59	11	0	10.59	11	44
202	2.80	0	31.50	32	0	51.29	51	0	51.29	51	138
301	26.00	0	1.84	2	3	2.12	5	3	2.12	5	120
401	6.30	13	0.63	14	0	0.83	1	0	0.83	1	14
501	11.30	22	7.21	29	0	8.74	9	0	8.74	9	124
601	47.30	Gravel Workings									
701	1.3	17	0.04	17	0	0.09	0	0	0.09	0	3
801	1.80	0	0.00	0	0	0.00	0	0	0.00	0	0
Total	100								Total		450
Probability of :		Wet season			Average season			Dry season			Benefit (£/ha)
		0.07			0.68			0.25			
											9

As an alternative estimate to that based on watertable modelling, Table 5.6 estimates the benefits due to maintenance which were perceived by farmers (earlier reported in Table 4.1) where they identified a change in drainage conditions between the 'with' and 'without' maintenance situations in an average, representative season. These estimates include the flood damage costs identified in Table 5.3, which were based on a combination of farmer and modelled data. Farmer assessment gave an average annual financial benefit of £ 2592 (£ 26/ha) and an economic benefit of £ 2105 (£ 21/ha).

Table 5.6 Farmer assessment of maintenance benefits

Block	Area (ha)	Average Season Financial Prices			Average Season Economic Prices		
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance
101	1.00	84	5.02	89	13	7.48	20
201	1.80	68	7.00	135	68	10.59	141
202	2.80	68	31.50	279	68	51.29	334
301	26.00	22	1.84	620	3	2.12	133
401	6.30	0	0.63	4	0	0.83	5
501	11.30	0	7.21	81	0	8.74	99
601	47.30	Gravel Workings					
701	1.3	26	0.04	34	17	0.09	22
801	1.80	750	0.00	1350	750	0.00	1350
Total	100	Total financial benefit (£)		2592	Total economic benefit (£)		2105
		Benefit (£/ha)		26	Benefit (£/ha)		21

According to the criteria used, these financial and economic benefit estimates show the limits which farmers and the nation respectively could justifiably spend on maintenance. These estimates require cautious interpretation as explained in the R&D Note 456 Section 2.7.2.

5.2 Maintenance Costs

Maintenance activities on the River Yare involved a programme of annual weed cutting. The unit cost according to NRA sources was £ 300/km in 1995 prices, equivalent to £ 900 for the study reach of 3 km, and £ 9/ha of benefit.

5.3 Scheme Appraisal

The estimated benefits attributable to maintenance can be compared with estimated costs to determine the justification for expenditure. Because the main maintenance activity is performed annually, the appraisal involves a simple comparison of annual benefits and costs.

Table 5.7 shows that the existing maintenance scheme is not viable in economic terms and is marginal in financial terms. The modelled results show that benefits to farmers and the economy do not appear to recover the costs of the scheme. Planned desilting was not carried out. This could deliver additional benefits, especially in wet seasons. The effect of this is likely to be small, however, and probably would not justify the additional cost.

Farmer assessment gave an average annual financial benefit of £ 2592 (£ 26/ha) and an economic benefit of £ 2105 (£ 21/ha) under average seasons. The scheme generates an annual benefit : cost ratio of 2.88 and 2.34 in financial and economic terms respectively.

Table 5.7 Maintenance scheme appraisal: River Yare

Average Annual Benefit (£)	Average Annual Benefits (£)	Average Annual Costs (£)	Benefit : Cost Ratio
<i>Modelled Estimates</i>			
Financial Prices	929	900	1.03
Economic Prices	450	900	0.50
<i>Farmer Estimates</i>			
Financial Prices	2592	900	2.88
Economic Prices	2105	900	2.34

These conclusions must be interpreted cautiously as discussed in the R&D Note 456 Section 2.7.2.

6 ENVIRONMENT

6.1 Introduction

REDS, a River Environmental Database is used within the Anglian Region of the NRA to store environmental information relating to each river. Details concerning flora and fauna of the river and its banks are supported by a river corridor survey. Additional information concerning the aquatic vegetation, habitat, fisheries and other features of environmental interest and importance are also recorded. Information from this database is drawn upon when preparing the river maintenance programme.

6.2 Norwich Countryside Fringe Management Project

The study reach of the River Yare falls within the Norwich Fringe Countryside Management Project. This is a joint venture between the Countryside Commission, Norwich City Council, Norfolk County Council, Broadland and South Norfolk District Councils and the Broads Authority. The outer boundary of the project area extends approximately 3.4 km beyond the built up area of Greater Norwich.

The aims and objectives of the scheme are:

- to improve opportunities for public access;
- to enable people to improve their environment;
- to increase awareness and appreciation of the area;
- to maintain and enhance the landscape; and,
- to protect and enhance areas of wildlife and archaeological value.

(Norwich Fringe Project Annual Report 1991-92, p5)

This Countryside Management Project provides a local service through which the interests of the residents and visitors to and managers of the countryside can be accommodated whilst conserving the landscape and environmental value of the area.

The project places no restrictions on maintenance of the River Yare although a margin of aquatic vegetation is left uncut along each bank in the interests of minimal disturbance to the ecological balance of the watercourse.

6.3 River Corridor Survey

Prior to the maintenance works of 1992, a river corridor survey was completed for the study reach of the River Yare. The methodology developed by the Nature Conservancy Council (NCC, now English Nature (EN)) was followed. Sketch maps and record cards were completed for each 500 m section of the reach. These are presented in Appendix II.

The corridor survey concentrated on the physical features of the river channel and adjacent land. Information relating to such features as bed substrate, channel dimensions and location of aquatic vegetation were recorded.

Following maintenance, it was not necessary to complete a second corridor survey as the channel dimensions and banks were not altered. A vegetational survey which concentrated on the location and percentage cover of channel vegetation was completed. This post-maintenance survey is presented in Appendix II.

6.4 Public Consultation

Prior to river maintenance, consultation takes place between the NRA and interested parties such as English Nature, the RSPB and Countryside Fringe Project. Details of the work programme are discussed and if necessary, modifications to the programme are made.

6.5 Farmer Assessment

During the interviews and discussions, farmers were asked to identify features of environmental interest which may be disturbed or damaged by river maintenance activities. Water lilies were the only feature of interest mentioned and these were not thought to be affected by maintenance works.

6.6 Water Quality

The quality of water in the River Yare, inferred from the National Water Classification (NWC) system is good being 1a. The water is suitable for potable supply abstractions and high class fisheries such as game fish. The amenity value of the river is high.

6.7 Channel and Bank Quality

The environmental quality of the river channel and banks has been determined by following the procedure outlined in the 'Guidelines for the Justification of River Maintenance' (R&D Note 511) produced within the framework of the NRA R&D Note 456 (River Maintenance Evaluation).

The quality of both the river channel and banks is classed as medium. Fringes of well developed vegetation border the banks and bed sediment varies between gravel and sand/silt. A few minor habitats are provided by submerged tree roots and overhanging bank vegetation. Small backwaters are provided by stands of emergent vegetation.

The banks are simple in form consisting of predominantly two or three vegetation types and lack areas of trees and scrub. Typically, the banks are 5 - 10 m in width. During the spring and summer, sections of the banks are rich in flowering herbs. The vegetational structure of the bank varies from short grazed grass to longer grass of the hay meadow.

7 CONCLUSIONS

7.1 Scheme Appraisal

The existing maintenance scheme of weed clearance is not viable in economic terms. The average annual economic benefit of maintenance in terms of its prevention in a deterioration in drainage status is £ 450. Average annual maintenance costs are approximately £ 900. The benefit : cost ratio is therefore 0.5. In financial prices, the benefit : cost ratio is 1.03.

7.2 Guidelines for River Maintenance

The 'Guidelines for the Justification of River Maintenance' (R&D Note 511), produced as a result of this River Maintenance Evaluation Study were used to provide an alternative method for justification of maintenance on the River Yare.

According to this method, the economic benefit : cost ratio is 2.6. This value is more than that derived from the detailed analysis; the results of which are summarised in Section 7.1. The differences in results may be due to the fact that average channel dimensions were taken for the whole study reach. If the study reach is divided up into sub-reaches, the benefit : cost ratio produced using the Guidelines is more comparable to that produced under detailed analysis.

7.3 Impact of Maintenance on Channel Vegetation

The types of vegetation found within the River Yare are discussed in Section 1.9. The impact of the submerged and emergent vegetation on channel capacity is also discussed. Different vegetation types respond to maintenance in different ways.

The Reed Sweet-grass (*Glyceria*) reproduce through a system of rhizomes (underground stems). *Potamogeton* (Pondweed) is a rooted plant. The current method of maintenance - regular cutting, actually stimulates regrowth of this vegetation. Desilting of the channel every few years is necessary in order to remove the rhizomes and the seed bank from the channel sediments.

7.4 Maintenance Best Practice

The preferred vegetation maintenance methods for the River Yare were determined using the 'Guidelines for the determination of preferred vegetation maintenance options' contained within R&D Note 511, and produced as a result of the Environmental Impact Assessment Study.

Channel

Best practice maintenance operations for emergent weed are identified as :

- Biennial cutting;
- Cutting on a 3 to 5 year rotation; and,
- Desilting / raking at an interval of 2 to 7 years.

Best practice maintenance operations for floating and submerged weed are identified as :

- Annual cutting in the autumn;
- Biennial cutting; and,
- Cutting on a 3 to 5 year rotation.

All these maintenance operations should be selective, concentrating on those areas which are particularly choked by vegetation or areas in which the weed is liable to cause an obstruction, hazard or restriction to flow.

The River Yare has been subject to an annual weed clearance programme throughout the study period. Approximately 60 % of the channel vegetation is removed in mid July. The vegetation is cut in a strip down the centre of the channel. Much of the emergent vegetation which grows at the channel fringes is left un-cut.

Selective desilting every seven years may be sufficient to remove silt and to provide sufficient capacity in the channel to provide the required standard of service even with partial vegetation removal. The River Yare is scheduled for desilting to remove accumulations of silt and debris.

This current maintenance practice is partially in accordance with the channel maintenance regime recommended as best practice in environmental terms. If the vegetation cutting was delayed until the autumn, this would enhance the environmental quality of the channel.

Bank

Although the banks of the River Yare are not cut as part of routine maintenance, if they were, given their medium quality, the following bank maintenance options would be preferred:

- Single bank mowing / flailing in spring / summer leaving a 1 m wide toe strip;
- Single bank mowing / flailing in autumn / winter leaving a toe strip > 0.25 m wide;
- Mowing / flailing every 3 - 5 years leaving a toe strip over 1 m wide or selective cutting (< 20 %); and,
- Light grazing.

From an environmental point of view, the preferred bank maintenance option is selective single bank mowing which leaves a toe strip of uncut vegetation. At present, the banks are not mown but the majority are grazed. Un-cut and un-grazed toe strips are therefore present at the foot of some of the banks. Additional bank maintenance in the form of selective mowing may enhance the environmental quality of the bank.

7.5 Recommendations

It is recommended that further research either through site monitoring or modelling examines:

- the impact of a reduced maintenance frequency on sections of the river (cutting every 2 years) on land drainage, flooding and sedimentation;
- the impact of reduced channel maintenance on channel environmental quality; and,
- the impact of desilting on channel capacity, flooding and land drainage.

7.6 Epilogue

This report has assessed the impacts of the current maintenance regime on the study reach. It has been used along with other study sites to formulate guidelines on the appraisal of maintenance works and best environmental practice. These draft guidelines are summarised in Chapter 5 of the R&D Note 456 and presented in full under separate covers.

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Map: Landranger 134, Norwich and the Broads. 1: 50 000 Ordnance Survey, Southampton.

APPENDIX I

Example of input and output data for the watertable model

River Yare

Block Number 201

Cross-section 1

Input Data		Output Data
River height (m AOD)		Watertable height (m AOD)
Week		
1992		
1	10.18	10.93
2	10.60	10.97
3	10.29	10.87
4	10.20	10.73
5	10.18	10.66
6	10.20	10.56
7	10.24	10.56
8	10.20	10.47
9	10.18	10.43
10	10.18	10.38
11	10.18	10.38
12	10.20	10.48
13	10.48	10.65
14	10.18	10.53
15	10.24	10.49
16	10.28	10.40
17	10.20	10.29
18	10.13	10.20
19	10.18	10.16
20	10.11	9.98
21	10.08	9.89
22	10.11	10.09
23	10.08	10.00
24	10.05	9.90
25	10.05	9.96
26	10.02	9.88
27	10.05	9.93
28	10.08	10.05
29	10.08	10.23

Example of drainage status classification, River Y are

With maintenance

Block 201

Watertable depth (m)	1992	Spring 1992	No. of weeks	Summer 1992	No. of weeks	Autumn 1992	No. of weeks
>0.5	36	10.50	11	10.50	13	10.50	10
0.3><0.5m	7	10.70	2	10.70	0	10.70	2
<0.3m	9	11.00	0	11.00	0	11.00	1

Drainage status classification, according to time watertable
is within the G, B, VB drainage bands

Good

Bad

Without maintenance

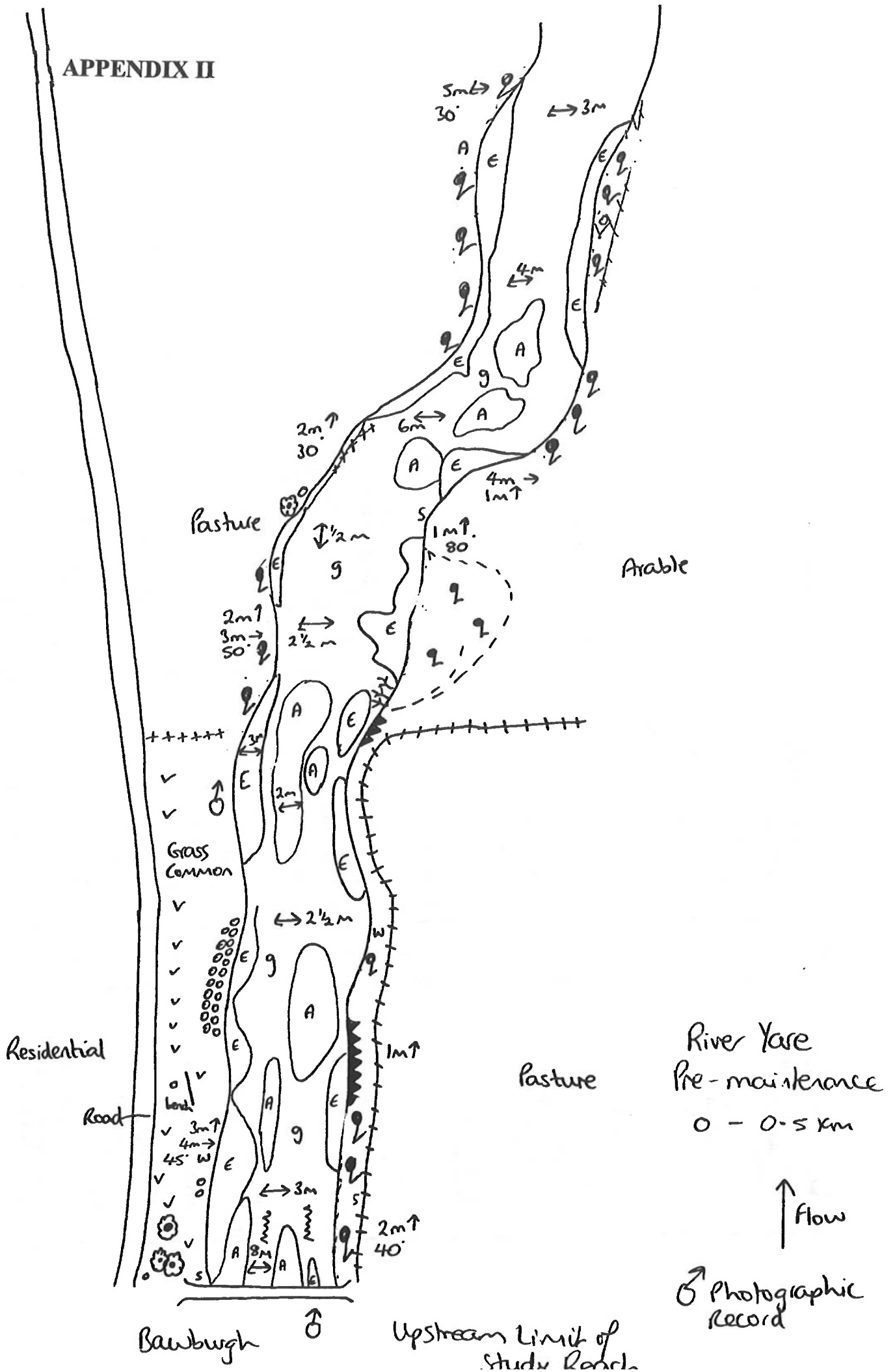
Watertable depth (m)	1992	Spring 1992	No. of weeks	Summer 1992	No. of weeks	Autumn 1992	No. of weeks
>0.5	32	10.50	9	10.50	13	10.50	10
0.3><0.5m	8	10.70	3	10.70	0	10.70	2
<0.3m	12	11.00	1	11.00	0	11.00	1

Drainage status classification, according to time watertable
is within the G, B, VB drainage bands

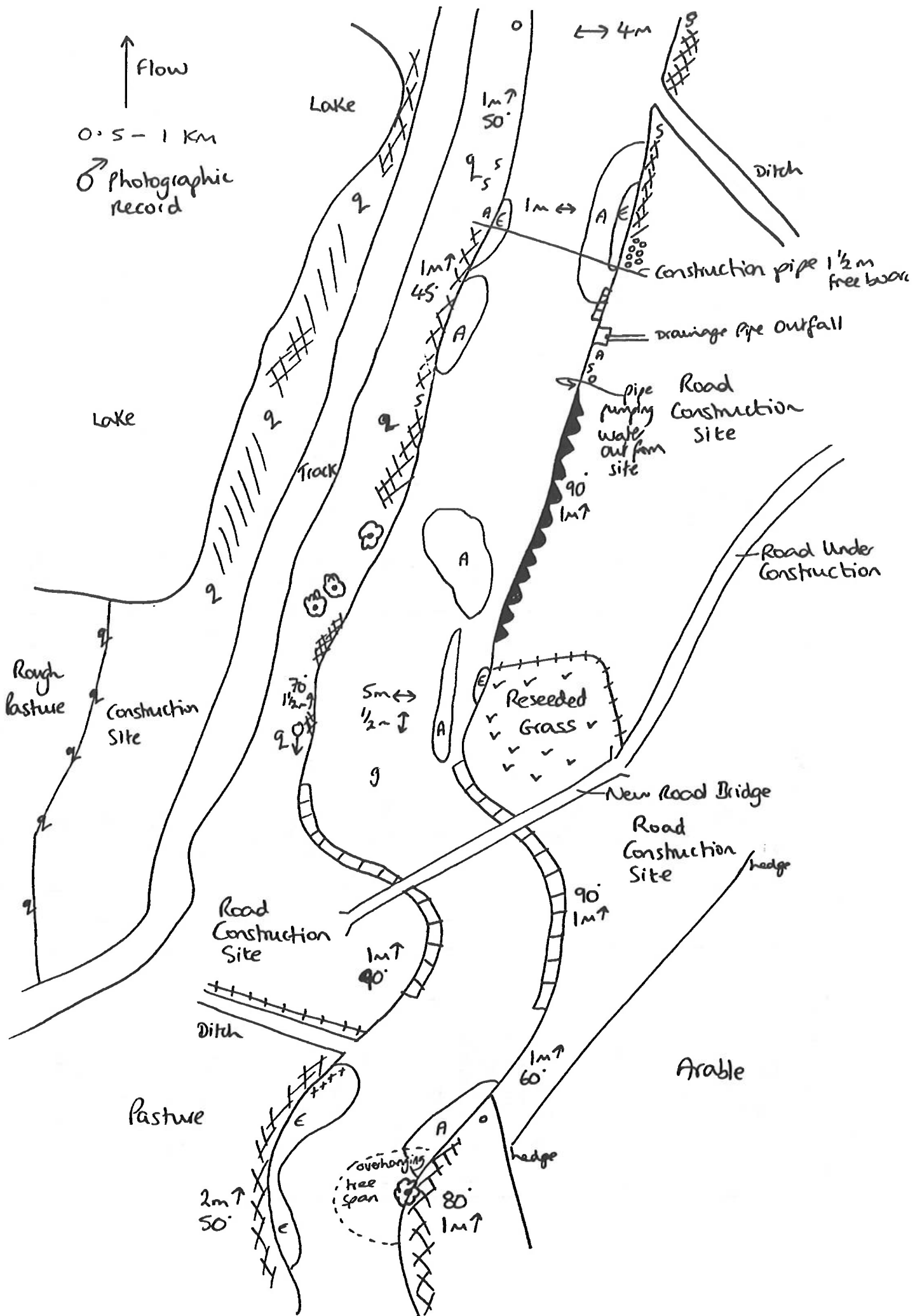
Good

Bad

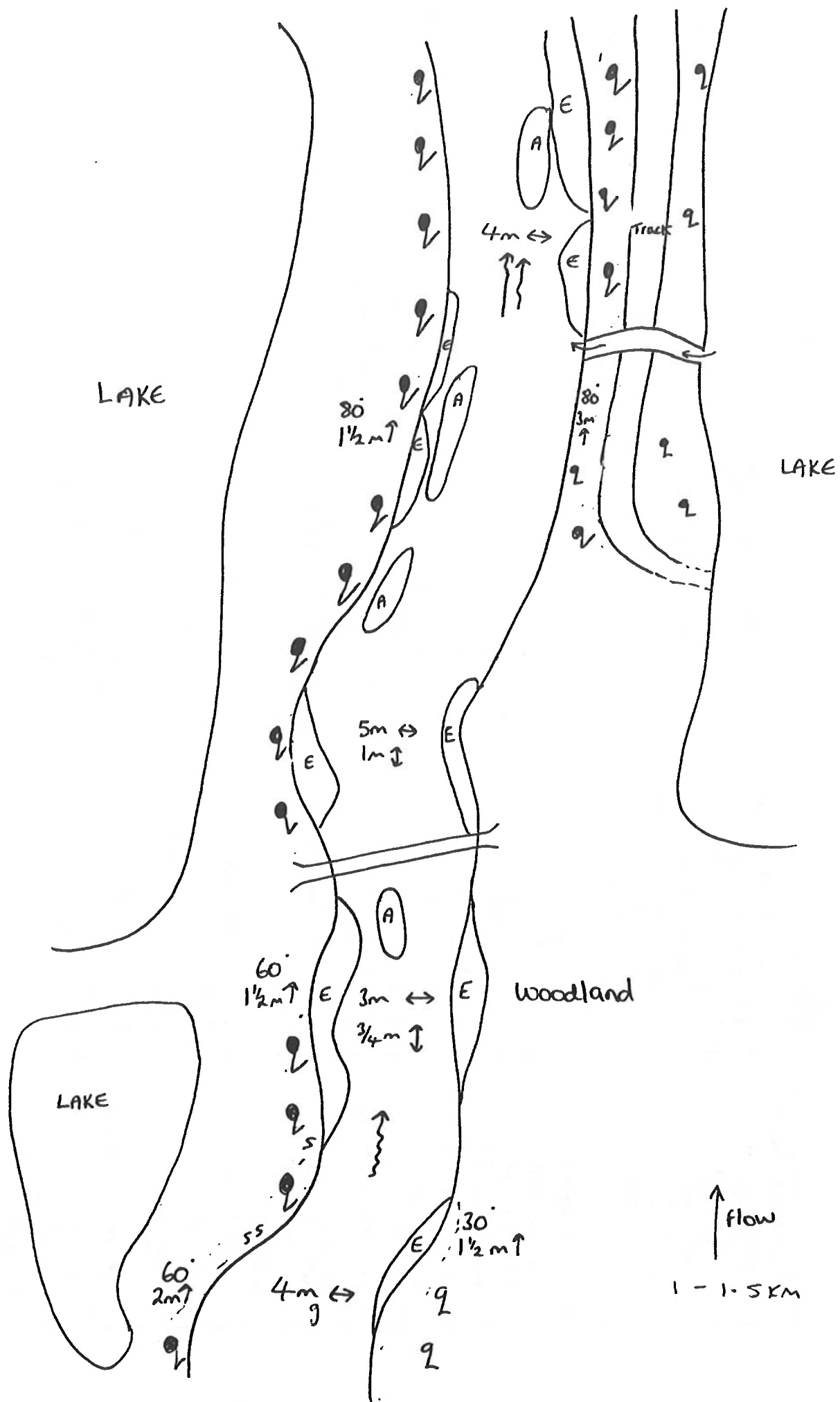
APPENDIX II



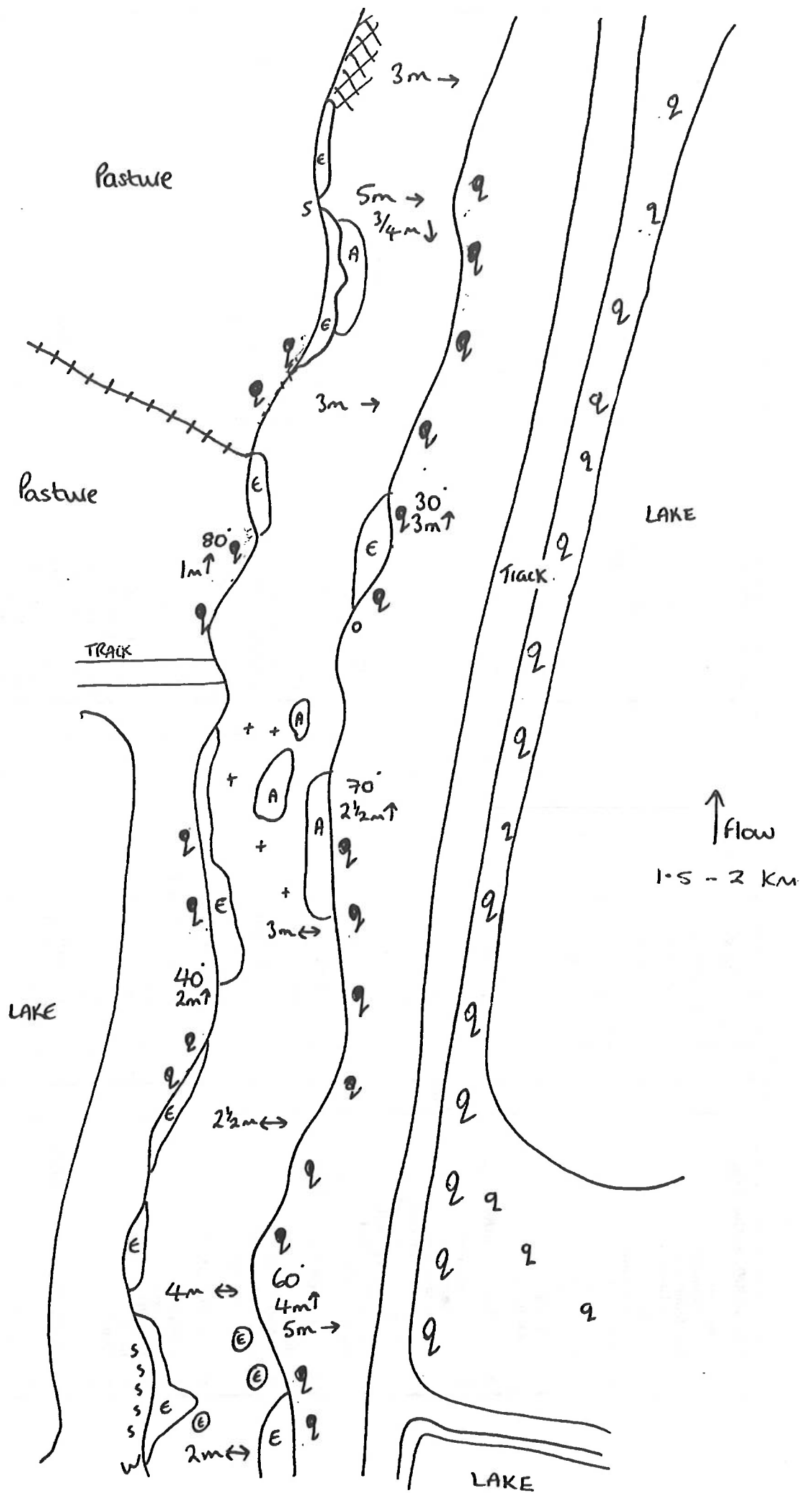
LG RB		RIVER		LB RB		RIVER			
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-natural plantation Scrub - dense Carr - alder willow Parkland Recently felled wood		RIVER YARE Run No. 0-0-5 Date 18/6/92 Surveyor JAD		BANK FEATURES % shill % solid earth cliff 1m ↑ } soft earth cliff >80 } rock cliff artificial flood bank ally flood bank set back levee Height ↑ Width → Slope ↗ 1-2m 2.5-5m <30° 30-45° 45-60° 60-90° >90° mud sand bare shingle vegetated shingle earth natural cobbles natural boulders BANK VEGETATION Gutter Oak, Ash, Sycamore Willow recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Herbs/Sedge % Dense open % Sparse open % Reseeded or mown % Exposed tree roots ISLANDS Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - mowing earth - with trees developed		RIVER HABITATS bridges/500m weirs/500m locks/500m inlets/500m Depth < 25m .25-0.5 0.5-1.0 >1.0m Width < 1 1-5 5-10 10-20 >20 Substrates bed rock boulders cobbles pebbles gravel sand silt/mud clay peat Habitats and Flow pool slack riffle rapids run waterfall protruding rocks Margins shingle ± bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total vegetated area bryophytes emergents submerged floating algae % of stretch		1 100 95 100 98 2 2 100 30 total 100%	
B. GRASSLAND & MARSH % 1. Acidic unimproved semi-improved Neutral unimproved semi-improved Calcareous unimproved semi-improved Improved/resuscitated Marsh/marshy grassland		G. OPEN WATER 1. Standing canal + ditch canal = dyke pond, pool, cut-off % lake % gravel pit % reservoir % flatness % stream < 1m wide 1-5m 5-10m >10		1. ROCK cliff scree limestone pavement cave other artificial/waste 2. MISCELLANEOUS arable amenity grassland ephemeral/short herb hedge + hedge = fence on bank fence set back wall building caravans fish farm silage clamp sewage works garden sick pit flood debris road railway disused used other		4 100 100 100 40 60 100 4 1 1 1 25 30 60 40 3 10			
C. TALL HERB & FERN % 1. Blacken 2. Upland ssp. rich veget. 3. Other - tall ruderal non ruderal D. HEATHLAND % 1. Dwarf scrub - dry wet 3. Lichen/bryophyte 4. Montane 5. Heath/grassland - dry wet E. MIRE, FLUSH AND SPRING % 1. Mires - bog Fen - reed sedge sweet-grass mixed 2. Bog flushes F. SWAMP/INUNDATION % 1. Swamp - single sp. down Tall mixed assemblage									



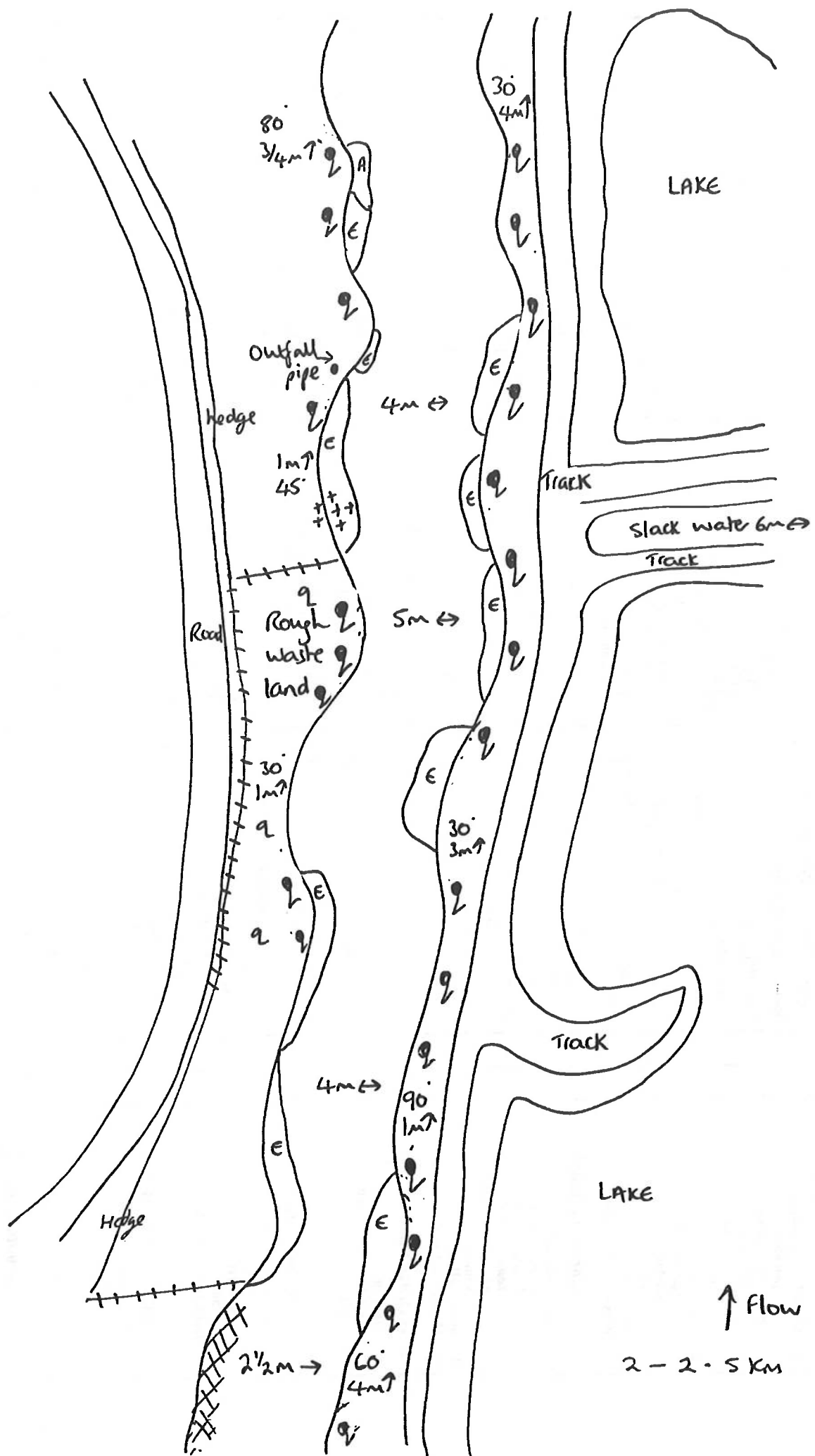
LG RB		RIVER YARE		LG RB		RIVER HABITATS		RIVER	
WOODLAND & SCRUB %		OPEN WATER		BANK FEATURES %		BANK VEGETATION		HABITATS AND FLOW	
1. Broad-leaved semi-nat. plantation		1. Standing canal + ditch	45	AAA solid earth cliff	20	HR bed rock	100	100	100
2. Coniferous semi-nat. plantation		2. pond, pool, cut-off %		AAA solid earth cliff	15	b boulders	100	100	100
3. Mixed semi-natural plantation		3. gravel pit %		AAA rock cliff	15	c cobbles	100	100	100
4. Scrub - dense		4. mature %		AAA rock cliff	15	d pebbles	100	100	100
5. Carr - alder		5. running stream < 1m wide		AAA rock cliff	15	e gravel	100	100	100
6. Parkland		6. 1.5m		AAA rock cliff	15	f sand	100	100	100
7. Recently felled wood		7. > 10		AAA rock cliff	15	g silt/mud	100	100	100
8. GRASSLAND & MARSH %		8. ROCK		AAA rock cliff	15	h clay	100	100	100
1. Acidic unimproved		1. chert		AAA rock cliff	15	i peat	100	100	100
2. semi-improved		2. scree		AAA rock cliff	15	j pool	100	100	100
3. Neutral unimproved		3. limestone pavement		AAA rock cliff	15	k slack	100	100	100
4. semi-improved		4. cave		AAA rock cliff	15	l mounds	100	100	100
5. Calcareous unimproved		5. other		AAA rock cliff	15	m rapids	100	100	100
6. improved/wooded		6. artificial/waste		AAA rock cliff	15	n run	100	100	100
7. Marsh/marshy grassland		7. MISCELLANEOUS		AAA rock cliff	15	o waterfall	100	100	100
8. TALL HERB & FERN %		8. arable		AAA rock cliff	15	p protruding rocks	100	100	100
1. Bracken		9. amenity grassland		AAA rock cliff	15	q margins	100	100	100
2. Upland spp. rich veg.		10. ephemeral/short herb		AAA rock cliff	15	r single 1 bare	100	100	100
3. Other - tall ruderal		11. hedge +		AAA rock cliff	15	s shingle, vegetated	100	100	100
4. non ruderal		12. hedge =		AAA rock cliff	15	t mud	100	100	100
5. HEATHLAND %		13. fence on bank		AAA rock cliff	15	u sand	100	100	100
1. Dwarf scrub - dry		14. wall		AAA rock cliff	15	v FLORA %	100	100	100
2. wet		15. building		AAA rock cliff	15	w emergent < 1m wide	100	100	100
3. Lichen/bryophyte		16. curavans		AAA rock cliff	15	x emergent 1-2m wide	100	100	100
4. Montane		17. silage clamp		AAA rock cliff	15	y emergent > 2m wide	100	100	100
5. Heath/grassland - dry		18. garden		AAA rock cliff	15	z total veg. area	100	100	100
6. wet		19. sick pile		AAA rock cliff	15	aa bryophytes	100	100	100
7. MIRE, FLUSH AND SPRING %		20. flood debris		AAA rock cliff	15	ab submerged	100	100	100
1. Mires - bog		21. road		AAA rock cliff	15	ac floating	100	100	100
2. Fen - reed		22. railway disused		AAA rock cliff	15	ad alyce % of stretch	100	100	100
3. Fen - sedge		23. other		AAA rock cliff	15		100	100	100
4. sweet-grass		24. road construction		AAA rock cliff	15		100	100	100
5. mixed				AAA rock cliff	15		100	100	100
6. Bog flushes				AAA rock cliff	15		100	100	100
7. SWAMP/INUNDATION %				AAA rock cliff	15		100	100	100
1. Swamp - single sp. dom.				AAA rock cliff	15		100	100	100
2. Tall mixed assemblage				AAA rock cliff	15		100	100	100



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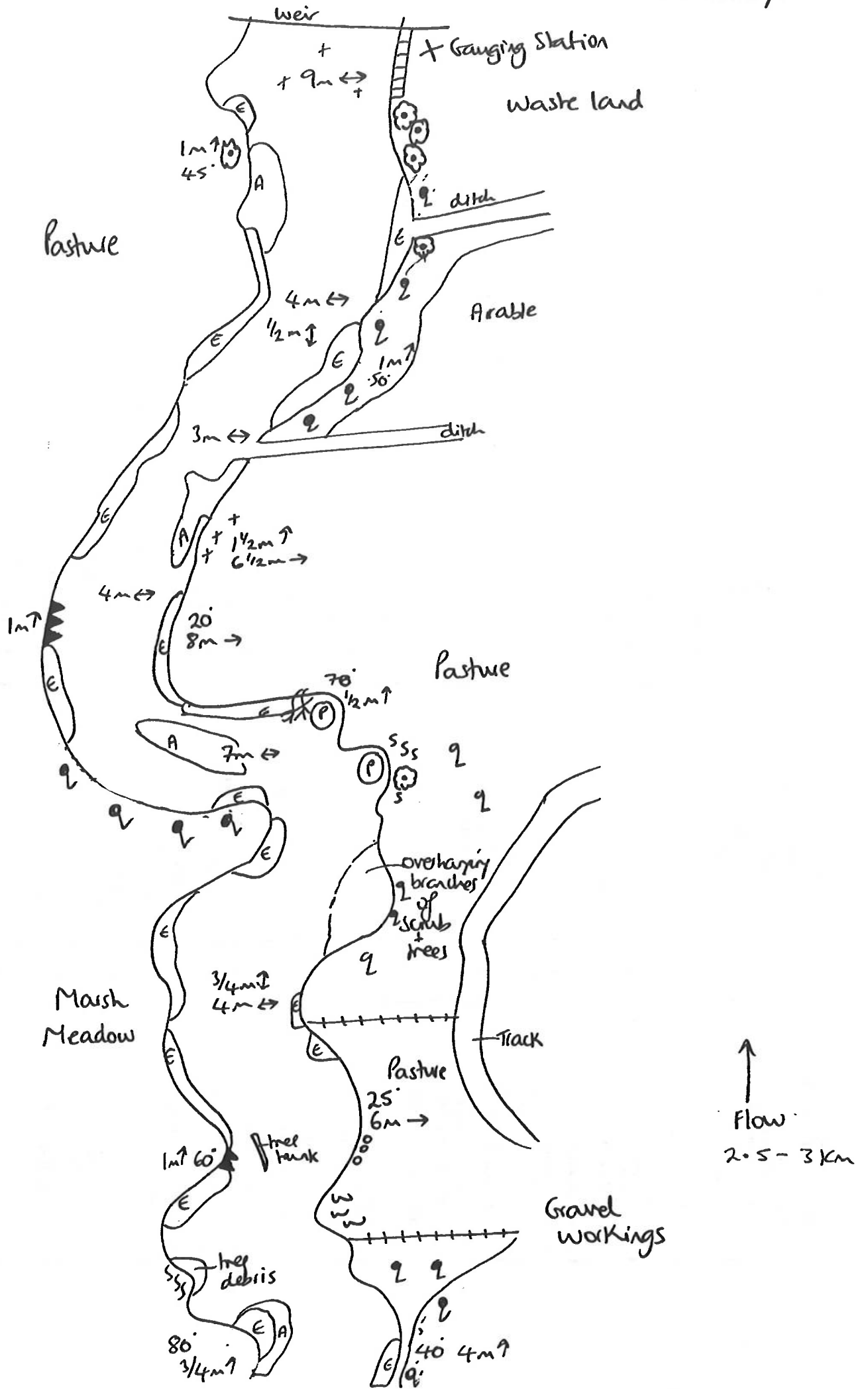


A. WOODLAND & SCRUB %		B. GRASSLAND & MARSH %		C. TALL HERB & FERN %		D. HEATHLAND %		E. MIRE, FLUSH AND SPRING %		F. SWAMP/INUNDATION %	
1. Broad-leaved semi-nat. plantation	100	1. Acidic unimproved	100	1. Blackon	100	1. Dwarf scrub - dry	100	1. Mires - bog	100	1. Swamp - single sp. dom.	100
2. Coniferous semi-nat. plantation	100	2. Neutral unimproved	100	2. Upland spp. rich veg.	100	2. Lichen/bryophyte	100	2. Fen - reed	100	2. Tall mixed assemblage	100
3. Mixed semi-nat. plantation	100	3. Semi-improved	100	3. Other - tall ruderal	100	3. Montane	100	3. Sweet-grass	100		100
4. Scrub - dense	100	4. Calcareous unimproved	100	4. Non ruderal	100	4. Heath/grassland - dry	100	4. Mixed	100		100
5. Carr - alder	100	5. Improved/rescued	100		100	5. Wet	100	5. Dog flushes	100		100
6. Parkland	100	6. Matis/marshy grassland	100		100		100		100		100
7. Recently felled wood	100		100		100		100		100		100

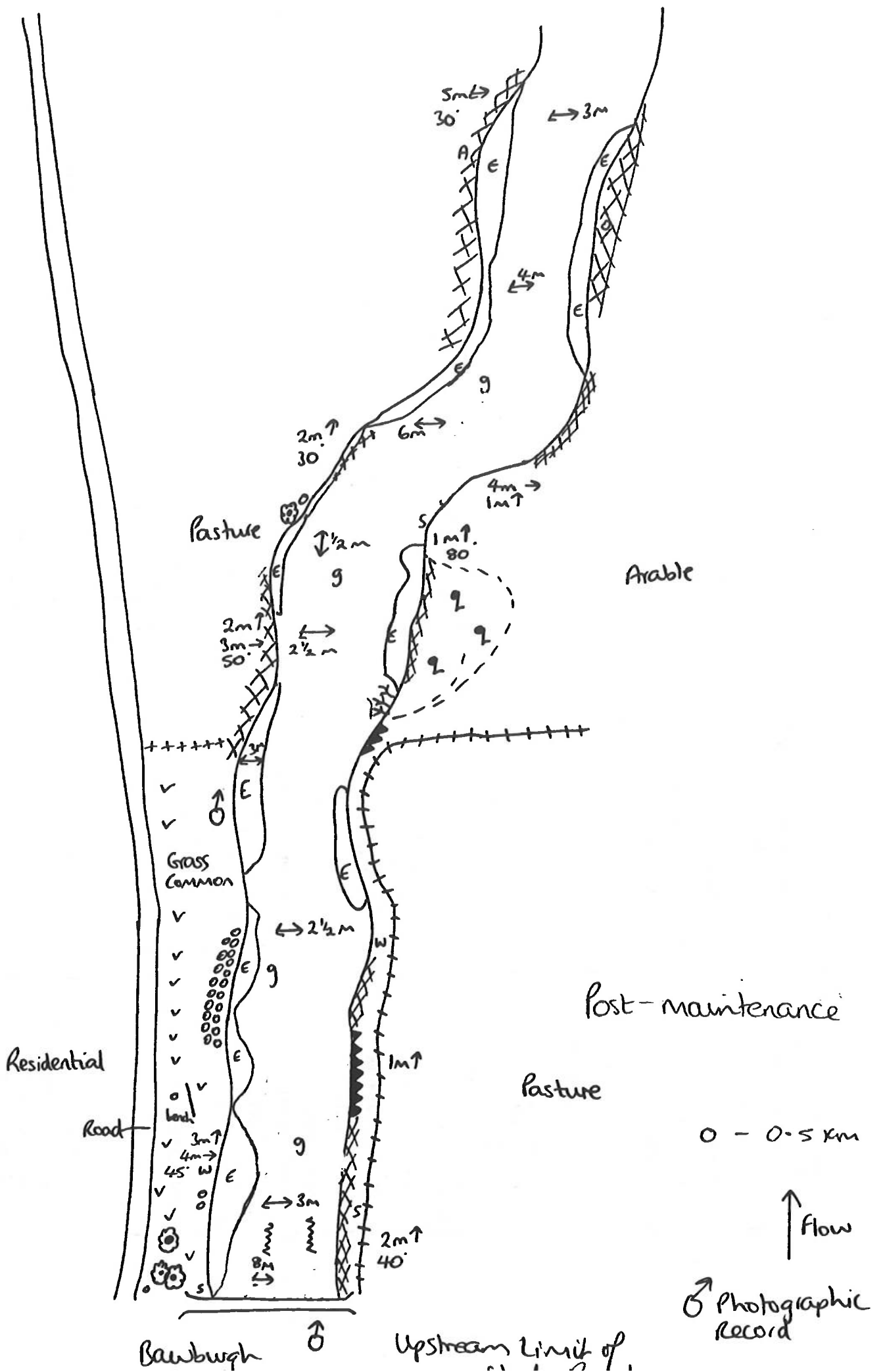


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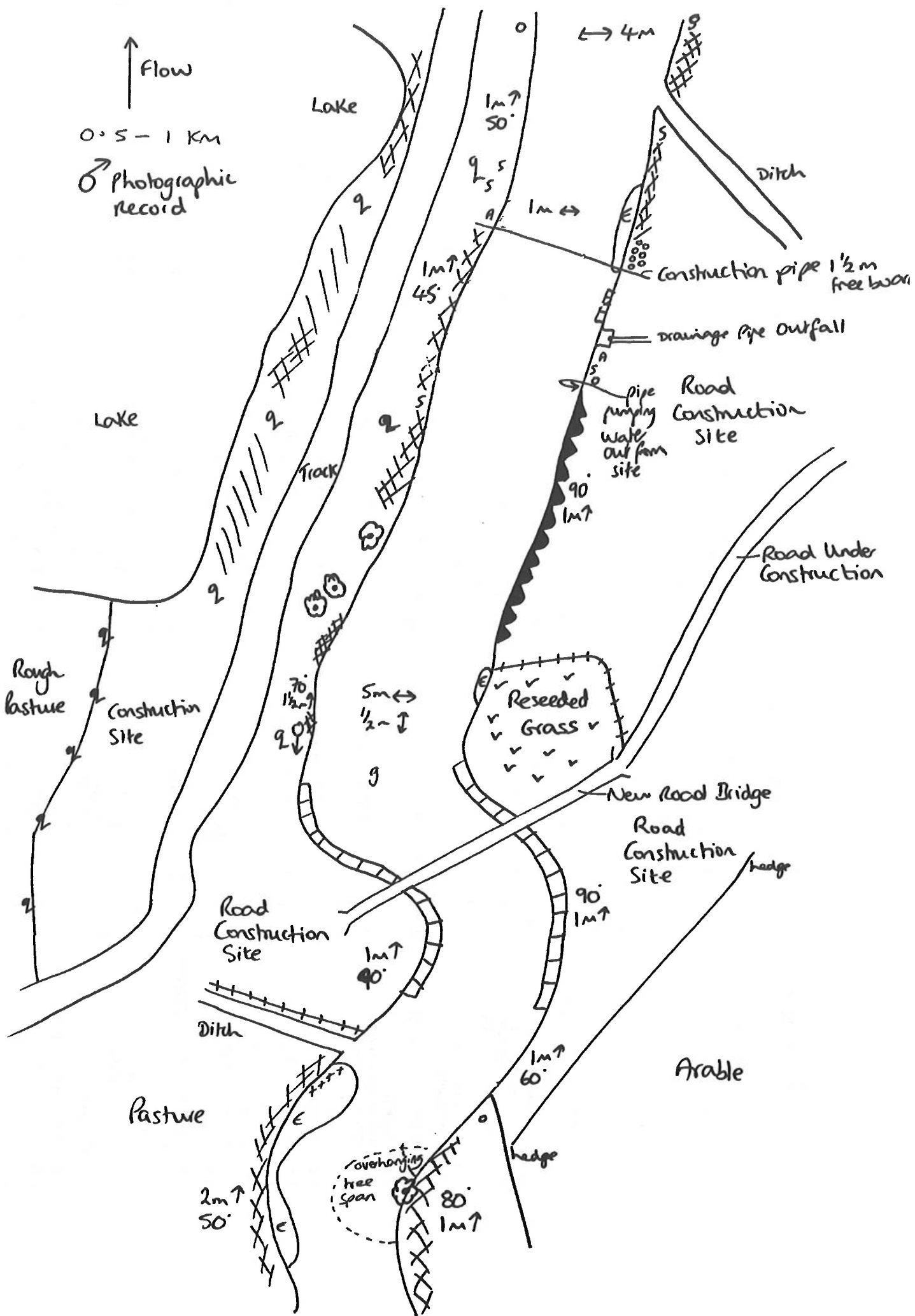
Downstream limit of reach
at Colney.

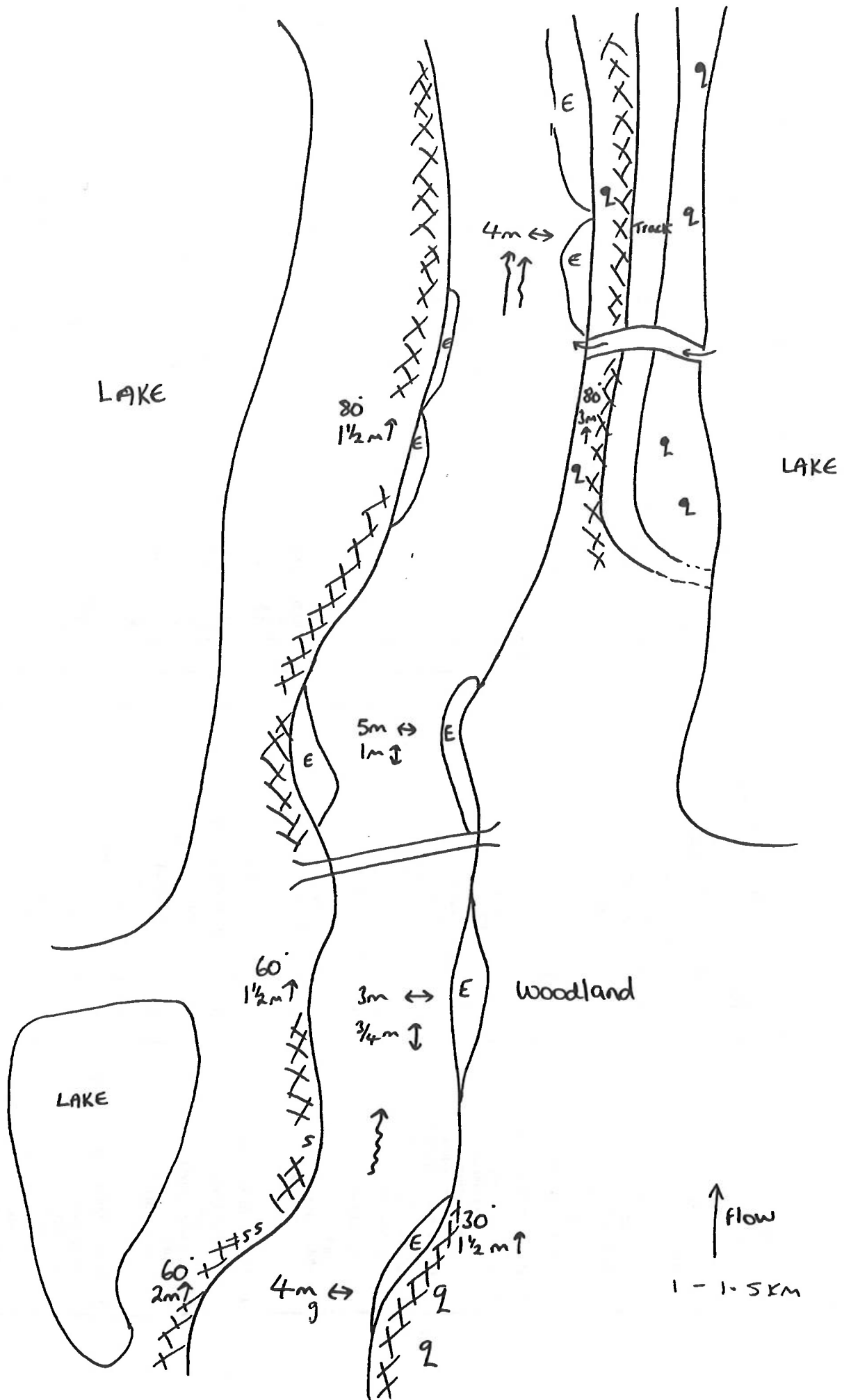


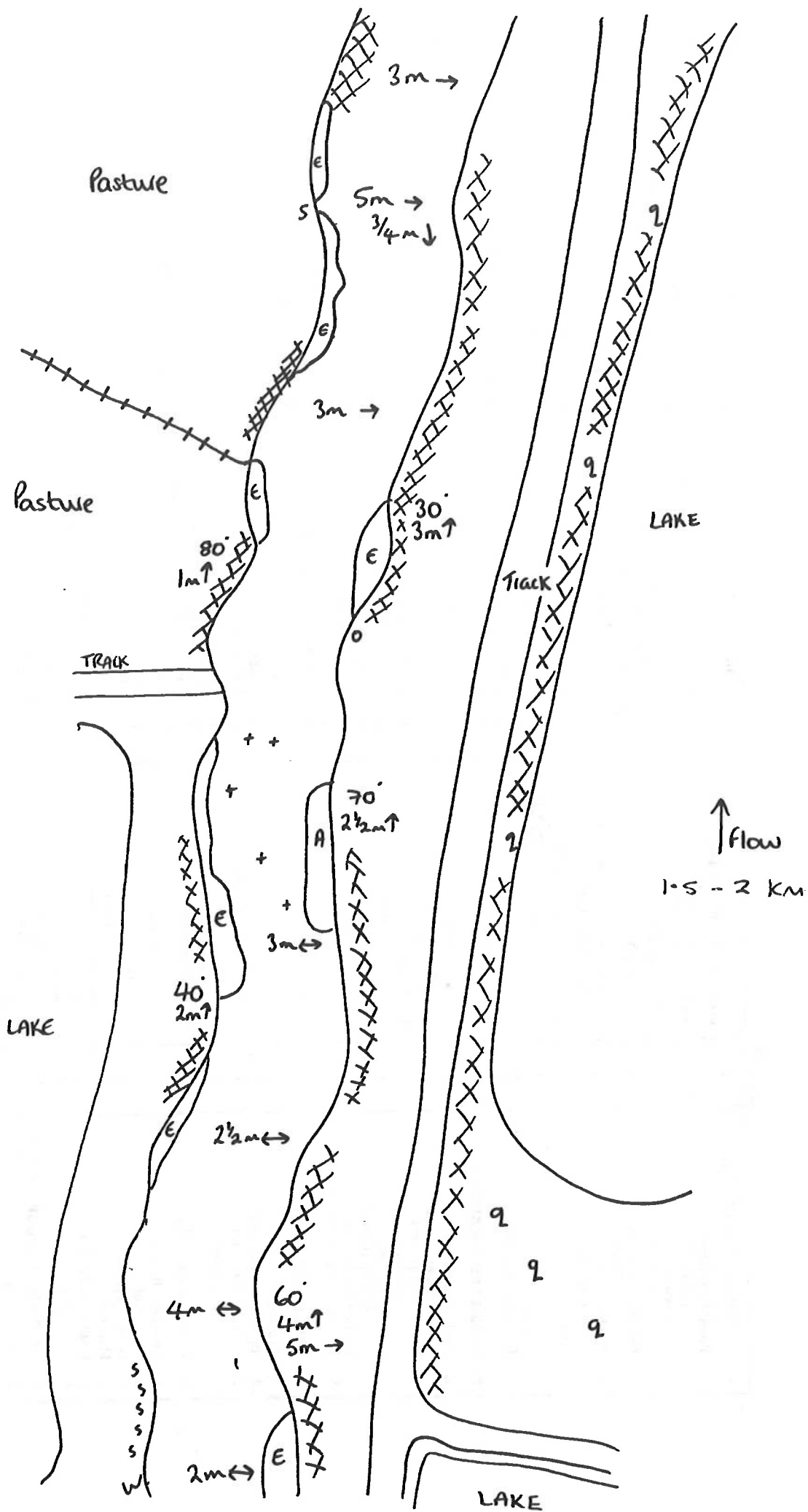
LG RB		LB RB		RIVER							
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation 2. Coniferous semi-nat. plantation 3. Mixed semi-nat. plantation 4. Scrub - dense 5. Carr - alder 6. Parkland 7. Recently felled wood		B. GRASSLAND & MARSH % 1. Acidic unimproved 2. Neutral unimproved 3. Semi-improved 4. Improved/conserved 5. Marsh/marshy grassland		C. TALL HERB & FERN % 1. Iracken 2. Upland sedge rich veget. 3. Other - tall ruderal 4. Dwarf scrub - dry 5. Lichen/bryophyte 6. Montane 7. Heath/grassland - dry 8. Mire, flush and spring 9. Mires - bog 10. Fen - reed 11. Dog flushes 12. Swamp/inundation 13. Swamp - single sp. dom. 14. Tall mixed assemblage		D. RIVER YARE Km No. 2.5 - 3 Date 19/6/92 Surveyor JALD G. OPEN WATER 1. Standing - canal + % of adj. reach stretch 2. ditch 3. pond, pool, cut-off % 4. lake % 5. reservoir % 6. marina % 7. stream < 1m wide 8. 1-5m 9. 5-10m 10. > 10m 1. ROCK 1. cliff 2. scree 3. limestone pavement 4. cave 5. other 6. artificial/waste MISCELLANEOUS 1. arable 2. amenity grassland 3. ephemeral/short herb 4. hedge + 5. hedge = 6. fence on bank 7. fence set back 8. wall 9. building 10. caravans 11. fish farm 12. sludge clamp 13. sewage works 14. garden 15. stick pile 16. flood debris 17. road 18. railway disused 19. used 20. other		E. BANK FEATURES % 1. shell % 2. solid earth cliff 1m↑ 3. soft earth cliff > 80↑ 4. rock cliff 5. artificial 6. flood bank only 7. flood bank set back 8. levee 9. Height < 1m 10. 1-2m 11. > 2m 12. Width < 1m 13. 1-2.5m 14. 2.5-5m 15. > 5m 16. Slope < 30° 17. 30-45° 18. 45-60° 19. > 60° 20. mud 21. sand 22. bare shingle 23. vegetated shingle 24. earth 25. natural cobbles 26. natural boulders BANK VEGETATION 27. Ginkgo 28. Oak, Ash, Sycamore 29. Willow - recent pollard 30. Willow old, not pollard 31. Standard willows 32. Alder 33. Other trees 34. Young trees 35. Thick Scrub/shrubs % 36. Sparse Scrub/shrubs % 37. River/Sedge % 38. Dense open % 39. Sparse open % 40. Recreated or mown % 41. Exposed tree trunks ISLANDS 42. Rocky, vegetated 43. rocky, 1 bare 44. shingle and rock 45. shingle, rock + veg 46. earth - maturing 47. earth - with trees 48. developed		F. RIVER HABITATS 1. bridges/500m 2. weirs/500m 3. locks/500m 4. inlets/500m 5. Depth < 25m 6. 25-50 7. 50-100 8. > 100m 9. Width < 1m 10. 1-5m 11. 5-10m 12. 10-20m 13. > 20m 14. Substrates 15. BR bed rock 16. boulders 17. cobbles 18. pebbles 19. gravel 20. sand 21. silty mud 22. clay 23. peat 24. Habitats and Flow 25. pool 26. slack 27. riffle 28. rapids 29. run 30. waterfall 31. protruding rocks 32. Margins 33. shingle 1 bare 34. shingle, vegetated 35. mud 36. sand 37. FLORA % 38. emergent veg < 1m wide 39. emergent 1-2m wide 40. emergent > 2m wide 41. total veg area 42. dryophytes 43. emergents 44. submerged 45. floating 46. algae % of stretch 47. total 100%	

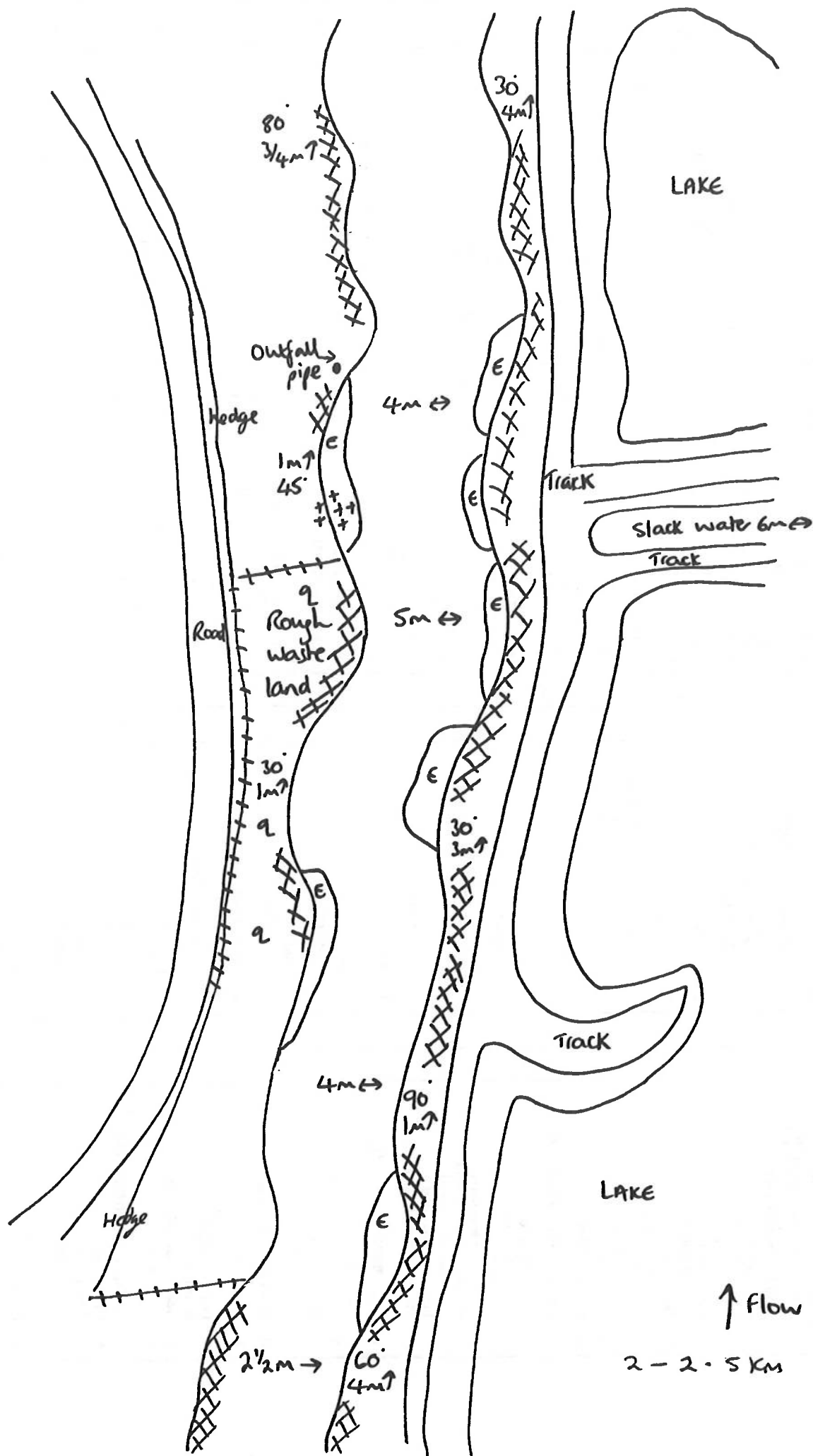


LG RB		RIVER		LG RB		RIVER		
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-natural plantation 2. Scrub - dense scattered Carr - alder willow 3. Parkland 4. Recently felled wood		RIVER YARE Item No. 0-0-5 Date 11/92 Surveyor JALD		BANK FEATURES % shell % solid earth cliff 1m ↑ soft earth cliff > 80° rock cliff artificial flood bank only flood bank set back levee Height Width Slope Shingle mud sand bare shingle vegetated shingle earth natural colluvies natural boulders BANK VEGETATION Cornifer Oak, Ash, Sycamore Willow recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Herbaceous % Dense open % Sparse open % Reseeded or mown % Exposed new rocks ISLANDS Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - mature earth - with trees developed		RIVER HABITATS bridge/500m weirs/500m locks/500m inlet/500m Depth Width Substrates RR b c p g s + sil/mud clay peat Habitats and Flow pool slack riffle rapids run waterfall protruding rocks Margins shingle + bare shingle, vegetated mud sand FLORA % emergent veg < 1m wide emergent 1-2m wide emergent > 2m wide tidal veget area bryophytes emergents submerged floating algae % of stretch		100 95 100 98 2 100 10 100
B. GRASSLAND & MARSH % 1. Acidic unimproved semi-improved Neutral unimproved semi-improved Cuckoos unimproved semi-improved Improved/marshy 5. Marsh/marshy grassland		G. OPEN WATER 1. Standing - canal + canal = ditch dyke pond, pool, cut-off % lake % gravel pit % reservoir % marina % 2. Running stream < 1m wide 1.5m 5.0m > 10		ROCK 1. cliff scree limestone pavement cave other 2. artificial/waste MISCELLANEOUS arable ancient grassland ephemeral/short herb hedge + hedge = fence on bank fence set back wall building caravans fish farm sludge clamp sewage works garden stick pile flood debris road railway disused used other		60 40 40 60 40 30 40 3		
C. TALL HERB & FERN % 1. Blacken 2. Upland spp. rich veg. 3. Other - tall ruderal non ruderal		D. HEATHLAND % 1. Dwarf scrub - dry wet 3. Lichen/bryophyte 4. Montane 5. Heath/grassland - dry wet		E. MIRE, FLUSH AND SPRING % 1. Mires - bog Fen - reed sedge sweet-grass mixed 2. Bog flushes		F. SWAMP/INUNDATION % 1. Swamp - single sp. dom. Tall mixed assemblage		100 98 2 100 10 100



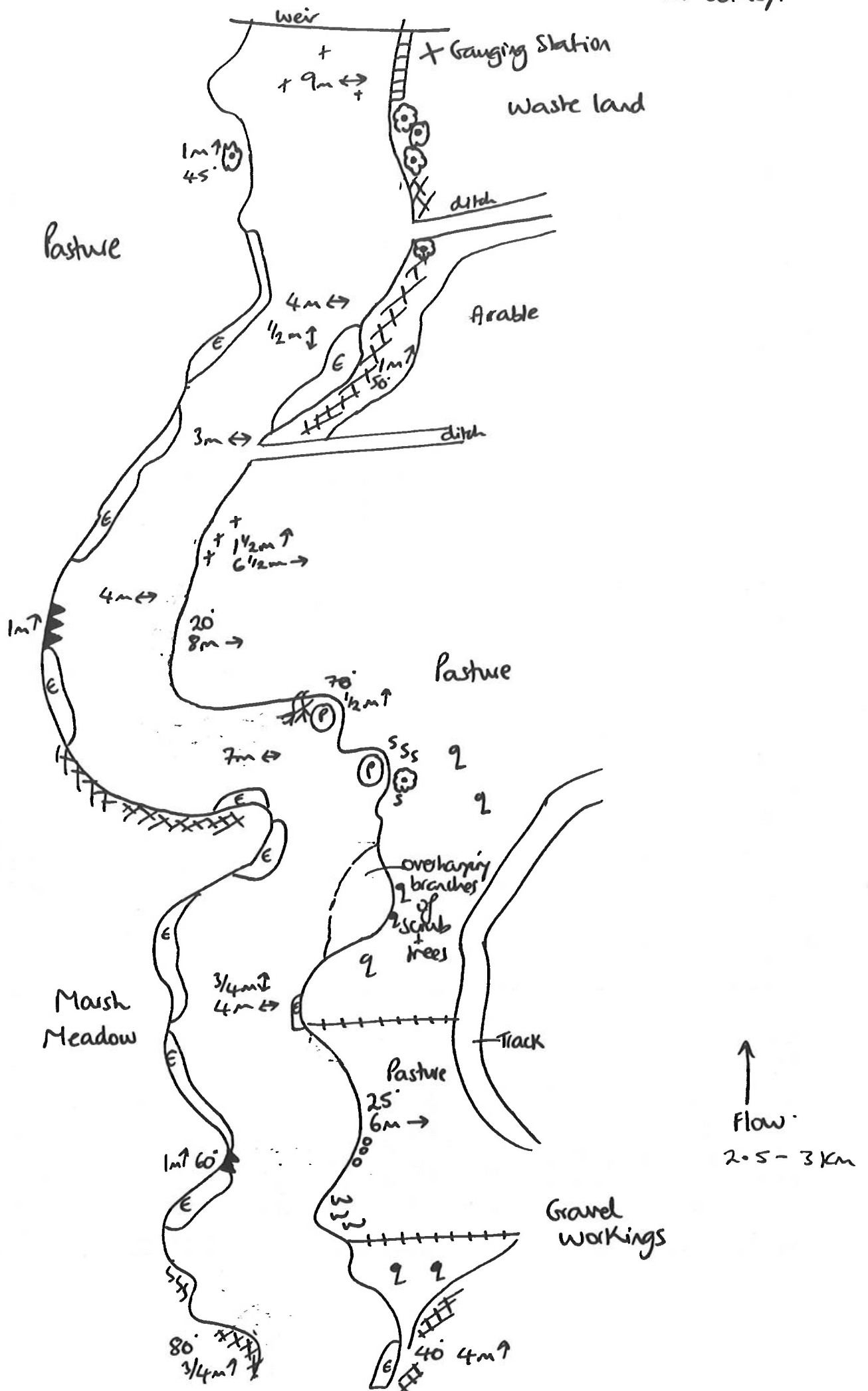


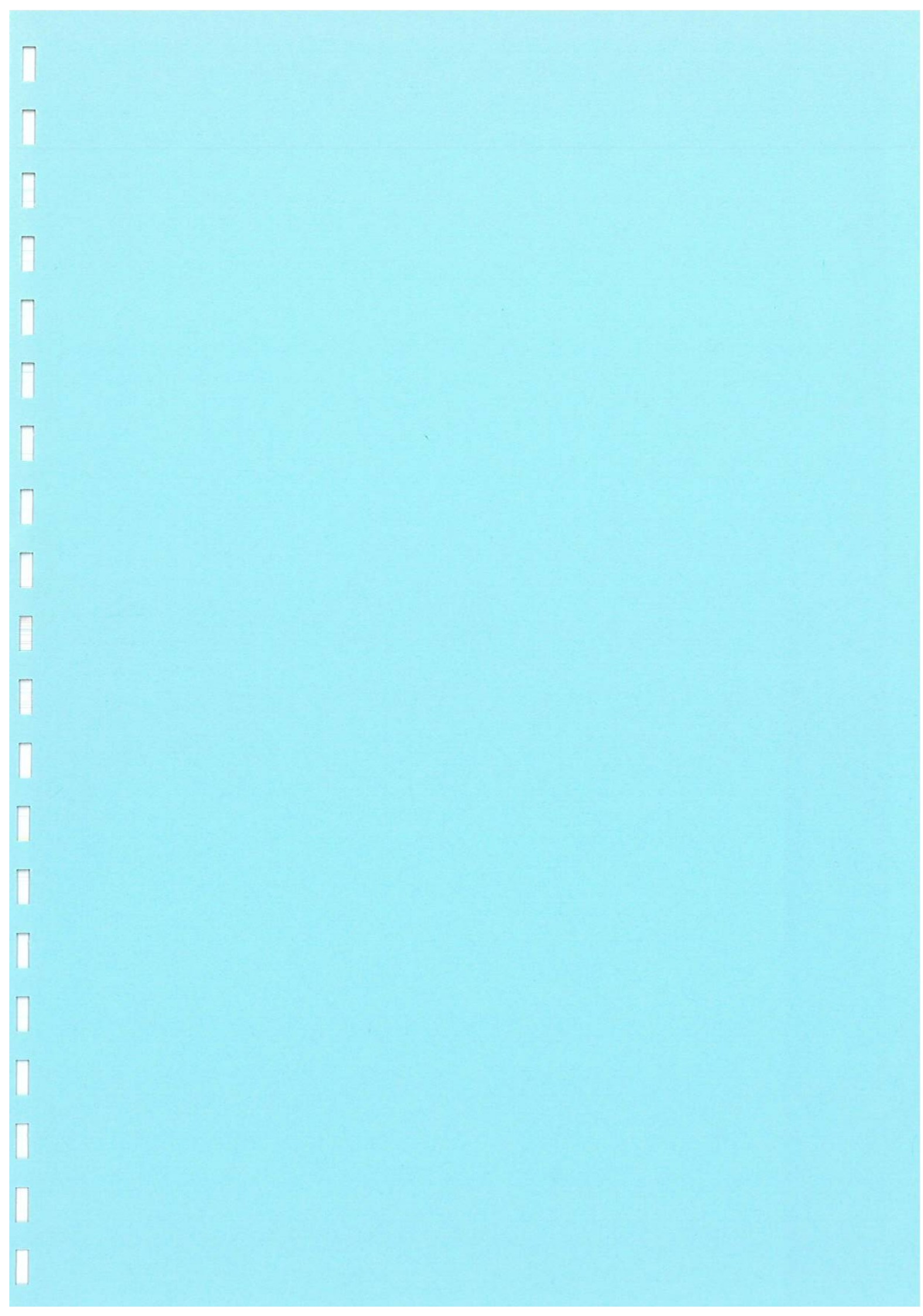




LG RB		RIVER YARE		LG RB		RIVER			
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-natural plantation 2. Scrub - dense scattered Carr - alder willow 3. Parkland 4. Recently felled wood		B. GRASSLAND & MARSH % 1. Acidic unimproved semi-improved Neutral unimproved semi-improved Calcareous unimproved semi-improved Improved/rosetted 2. Marsh/marshy grassland		C. TALL HERB & FERN % 1. Blacken 2. Upland spp. rich veget. 3. Other - tall ruderal non ruderal		D. HEATHLAND % 1. Dwarf scrub - dry wet 2. Lichen/eryophyte 3. Montane 4. Heath/grassland - dry wet 5. Mire, flush and spring % 6. Mires - bog Fen - reed 7. Bog flushes		E. SWAMP/INUNDATION % 1. Swamp - single sp. dom. Tall mixed assemblage	
RIVER Item No. 2 - 2.5 Date 11/192 Surveyor JALD		G. OPEN WATER 1. Standing canal + ditch 2. pond, pool, cut-off lake 3. gravel pit % reservoir % 4. running stream < 1m wide 5. 1.5m 5.0m > 10		H. BANK FEATURES % 1. cliff % 2. solid earth cliff 1-1.5 3. soft earth cliff > 80 4. rock cliff 5. artificial 6. flood bank only 7. flood bank set back 8. levee 9. Height < 1m 10. 1-2m > 2m 11. Width < 1m 12. 1-2.5m 2.5-5m > 5m 13. Slope < 30° 30-60° > 60° 14. mud sand bare shingle vegetated shingle 15. natural cutbanks 16. natural boulders 17. BANK VEGETATION 18. Oak, Ash, Sycamore 19. Willow recent pollard 20. Willow old not pollard 21. Standard willows 22. Alder 23. Other trees 24. Young trees 25. Thick Scrub/shrub % 26. Sparse Scrub/shrub % 27. Bare/shale % 28. Dense open % 29. Sparse open % 30. Reclaimed or mown % 31. Exposed tree roots 32. ISLANDS 33. Rocky, vegetated 34. rocky, 1 bare 35. shingle and rock 36. shingle, rock + veg 37. earth - maturing 38. earth - with trees developed		RIVER HABITATS 1. bridges/500m 2. weirs/500m 3. locks/500m 4. inlets/500m 5. Depth < 25m 6. 25-50 7. 50-100 8. > 100m 9. Width < 1 10. 1-5 11. 5-10 12. 10-20 13. > 20 14. Substrates 15. bed rock 16. boulders 17. cobbles 18. pebbles 19. gravel 20. sand 21. silt/mud 22. clay 23. peat 24. Habitats and Flow 25. pool 26. slack 27. riffle 28. rapids 29. run 30. waterfall 31. protruding rocks 32. Margins 33. shingle 1 bare 34. shingle, vegetated 35. mud 36. sand 37. FLORA % 38. emergent veg - 1m wide 39. emergent 1-2m wide 40. emergent > 2m wide 41. total veget area 42. bryophytes 43. unemerged 44. submerged 45. floating 46. algae % of stretch			

Downstream limit of reach
at Colney.





RIVER WENSUM

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RIVER WENSUM

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ANGLIA RIVER WENSUM

1. BACKGROUND

1.1 Physical Background

The River Wensum is a spring fed watercourse with sources at Syderstone Common, South Raynham and East Rudham, north east Norfolk. The river is a tributary of the River Yare; the confluence being on the eastern edge of Norwich. From its source to the confluence with the River Yare, the River Wensum is 55 km in length. The catchment of the River Wensum at the downstream limit of the study reach is 398 square km.

The river flows over a wide floodplain on which a variety of land uses exist including arable, pasture, urban and gravel workings.

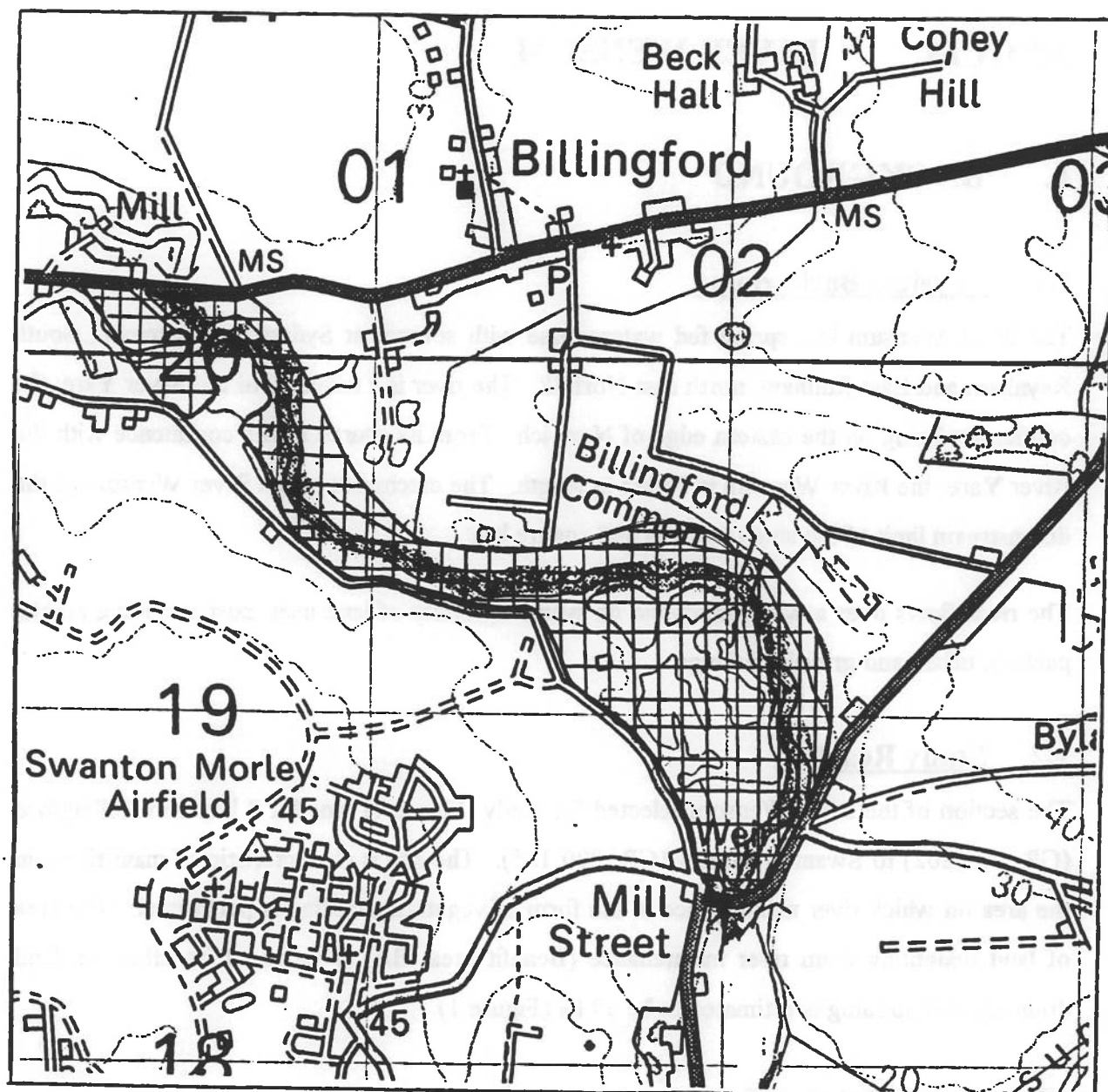
1.2 Study Reach

The section of the River Wensum selected for study (Figure 1) runs for 3 km from Billingford (GR. 005 202) to Swanton Morley (GR. 020 185). The site is characteristic of main rivers in the area on which river maintenance in the form of vegetation cutting is performed. The area of land benefiting from river maintenance (Benefit area, BA) in terms of its effect on land drainage and flooding is estimated to be 59 ha (Figure 1).

1.3 River Characteristics

The floodplain of the River Wensum is well defined within the study reach, bounded for much of its length by gravel workings and artificial lakes. Channel width ranges from 5 to 10 m with an average of 6 m. The freeboard is variable, ranging from 0.75 to 3 m, averaging 1 m. The river banks consist of earth, the majority of which are vegetated. Along short reaches, solid earth cliffs one metre in height predominate. Bank angles range from the 90 degree earth cliffs to 40 degrees vegetated banks.

The flow of water is slow due to the shallow gradient and low lying nature of the land. Slack water predominates interspersed with short runs and riffles. Bed substrates comprise gravels, sands and silty mud. Occasionally small boulders protrude above the water.



Legend :



Benefit Area

Scale 1 : 14833

Figure 1 Location of the River Wensum site and benefit area

1.4 Land Drainage

The majority of land within the benefit area is naturally drained (79 %, 46 ha, Figure 2). Four ditches discharge water into the River Wensum within the study reach. Two are fed with water from a lake created by the flooding of a gravel pit at Swanton Morley. Further information on land drainage is presented in Section 2.5.

The Black Water (sometimes known as Wadling Beck or White Water), a tributary of the River Wensum flows into the river at GR. 005 201, near the upstream limit of the study reach. At the confluence, the Black Water is comparable in size to the River Wensum.

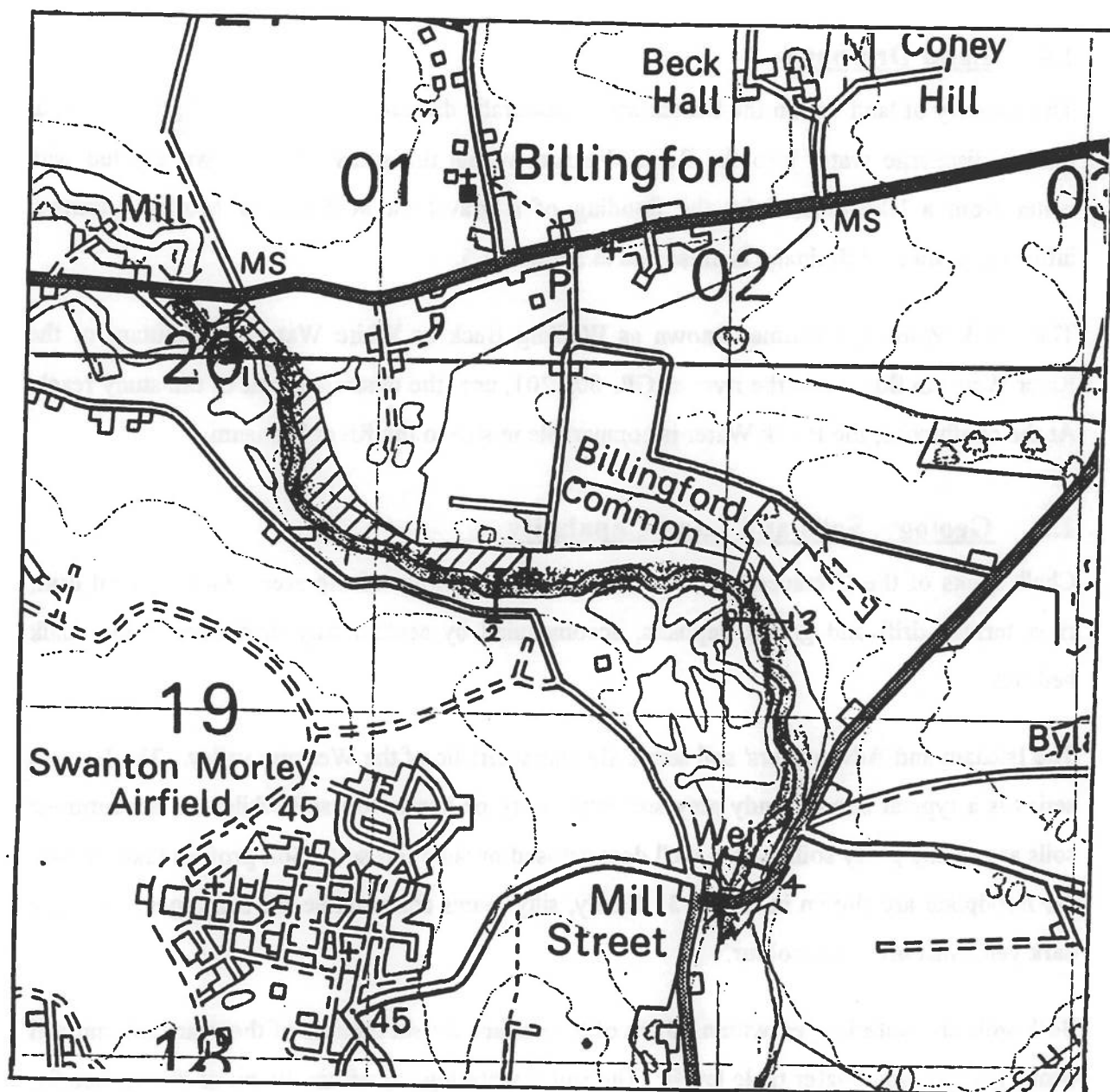
1.5 Geology, Soils and Land Capability

Chalk rocks of the Cretaceous period dominate the geology of the area. Glaciofluvial drift, river terrace drift and gravel deposits, accompanied by aeolian silty drift overlay the chalk bedrock.

The Isleham and Adventurers' soil series are characteristic of the Wensum valley. The Isleham series is a typical humic sandy gley soil with peaty or humic top soil whilst the adventurers' soils are earthy peaty soils with a well decomposed organic top soil. Soil profiles taken within the floodplain are shown in Figure 3. Sandy, silty loams characterise the soil types which are dark yellowish brown in colour.

Both soils are waterlogged within 40 cm of the surface for six months of the year (autumn and winter) due to high water table levels. The soil is waterlogged within 40 cm of the surface for over 50 % of the year (Hodge et al, 1984). Due to this level of waterlogging, the Isleham series is given a Wetness Class of V by the Soil Survey of England and Wales (SSEW).

According to rainfall data from the meteorological station at Tower Hill, the average annual rainfall is approximately 715 mm. Under the Agricultural Land Classification system of the Ministry of Agriculture, Fisheries and Food (MAFF), the land is classed as Grade 4. Permanent grassland is the dominant land use due to a high risk of poaching (surface damage by livestock) and flooding.



Legend :



Natural drainage



Piped drainage



Cross-section location

Scale 1 : 14833

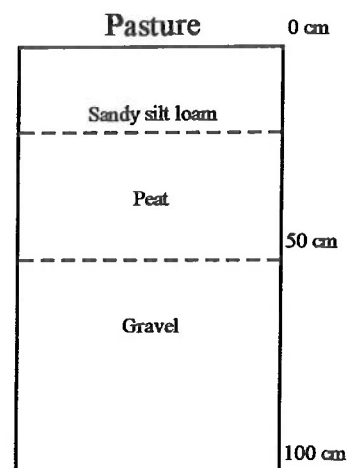
Figure 2 Land drainage and location of cross-sections

Grid Reference 022 186

Soil Core Number 1

Soil Colour Dark greyish brown

Comments Thin soil layer over gravel deposit

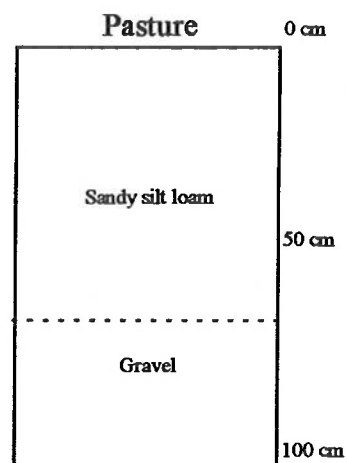


Grid Reference 009 194

Soil Core Number 2

Soil Colour Dark yellowish brown

Comments Thin soil layer over gravel deposit



Grid Reference 007 198

Soil Core Number 3

Soil Colour Dark yellowish brown

Comments Thin soil layer over gravel deposit

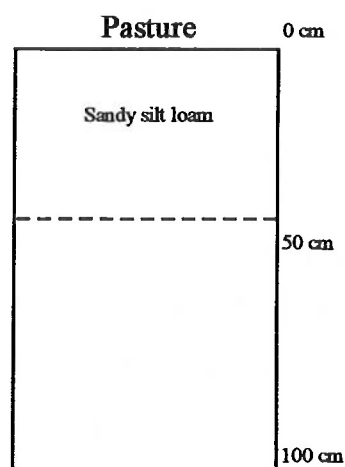


Figure 3 Soil profiles

1.6 Capital Works

No capital works have been performed on this section of the River Wensum in recent years. The river frontage was realigned and re-cut in the eighteenth century, following completion of the mill at Swanton Morley. Major dredging took place after the Second World War but no works which have altered the width or gradient of the channel have taken place since this time.

1.7 River Maintenance

Regular maintenance is performed on the River Wensum for the benefit of land drainage and flood alleviation. Weed cutting using a weed boat takes place on an annual basis in July/August. Sixty percent of the vegetation cover is cut in a central strip down the channel. A fringe of uncut vegetation is left along each bank. Fallen trees are removed as required and bushes are removed if they overhang the river. Desilting of specific high spots takes place as and when required.

Response to customer demand is the main reason for river maintenance on the River Wensum. Changes in river condition and inspections by NRA staff are listed as the secondary and tertiary reasons for performing maintenance. Criteria for the standard of service provided by the maintenance are determined through custom and practice and inspections by NRA supervisory staff.

Environmental factors influence the extent of the river maintenance. Prior to river maintenance activities, conservation bodies are notified of proposed works via a letter and frontages are visited. A meeting, to which those with a conservation interest are invited, is held annually to discuss the maintenance programme. Any objections may be raised and discussed. The maintenance programme may be modified as a result of this meeting.

1.7.1 Farmers views on maintenance

The general feeling of the farmers is that the current level of maintenance provides an adequate standard of service. However, mis-management of sluice gates at two privately owned mills (at Worthing and North Elmham) is blamed for some incidences of flooding. Reportedly the sluice gates are kept shut in order to maintain the river at a high level for aesthetic purposes. Farmers also state that these sluice gates are not opened in response to naturally high water

levels as soon as is necessary. When the gates are opened, a surge of water moves downstream which increases the risk and incidence of flooding.

1.7.2 Alternative maintenance strategies

The view was expressed that some flooding is the result of water from the Black Water backing up as it is unable to drain into the River Wensum due to the weeds growing in the Wensum channel. It was suggested by one farmer that if the confluence of the Black Water and River Wensum were kept free of weeds, this problem would not arise.

One farmer expressed the view that all the weeds in the channel should be cut. This would inhibit the development of stagnant water at the channel margins in which a 'scum' develops. This stagnant water is reported to hinder fishing on the river.

1.8 Climate

The impact of maintenance on watertable depth and river levels depends on the particular weather conditions, especially rainfall, which vary from season to season and year to year. Yearly and seasonal rainfall totals from the nearest meteorological station to the study site (North Elmham, station ref. 206 859) throughout the study period are presented in Table 1.1.

Table 1.1 Rainfall totals

Period	Season	Actual Rainfall (mm)	Average * Rainfall (mm)	% Average Rainfall
1992	Spring	171.3	151.0	113.5
	Summer	171.7	168.4	101.9
	Autumn	243.0	197.7	122.9
1993	Spring	130.0	151.0	86.1
	Summer	190.7	168.4	113.2
	Autumn	261.6	197.7	132.3
1994	Spring	193.7	151.0	128.3
	Summer	108.6	168.4	64.5
	Autumn	231.4	197.7	117.1
1995	Spring	133.2	151.0	88.2
	1992	1404.2	1364.6	102.9
	1993	825.2	1364.6	60.5
	1994	710.1	1364.6	52.0

* Based on 33 year record from 1961 - 1993

All seasons in 1992 were average when compared to the long term average rainfall totals. Autumn 1993 is classed as wet and the spring 1994 is classed as dry. The farmers within the benefit area confirm these results.

Monthly rainfall records from the Hope House rainfall gauge (station ref. 212 884) have been used to determine the probability of wet, average and dry seasons and years occurring according to the classification of the Food and Agricultural Organisation (FAO). Wet and dry seasons and years are classed as those with greater than 125 % and less than 75 % of the average rainfall respectively. Further details are presented in the R&D Note 456, Section 3.5.4.

The probability of each type of season/year occurring in the area of the River Wensum is shown in Table 1.2. Probabilities are based on monthly rainfall records from the meteorological station at Hope House over a 33 year period (station reference number 212 884).

Table 1.2 Probability of climatic conditions			
Season	Dry *	Average *	Wet *
Spring	0.15	0.73	0.12
Summer	0.22	0.75	0.03
Autumn	0.18	0.73	0.09
Year	0.16	0.69	0.15

* Based on records 1961 - 1993

The R&D Note 456, Section 3.5.4 describes the process by which the financial benefits of maintenance are calculated according to the probability of wet, average and dry seasons occurring.

1.9 Aquatic Vegetation

Aquatic vegetation within the channel was identified prior to maintenance (Section 1.9.1 to 1.9.4). This vegetation has both hydraulic and environmental implications for the channel.

1.9.1 Submerged vegetation

The *Elodea* sp. (Canadian pondweed) is a common species of aquatic weed within the study reach. Its preferred habitat is areas of sluggish to moderate waters such as drainage channels, ponds and lakes. The Canadian pondweed is a submerged aquatic plant characterised by branched stems which are streamlined in the direction of flow and can reach 3 m in length. The greater the discharge, the lower its resistance to flow. Weed cutting is an effective method of controlling the *Elodea*.

1.9.2 Floating vegetation

Ranunculus (Water-crowfoot) is found in the areas of faster flow. Its buttercup-shaped lobed leaves up to 3 cm wide float on the surface. Finely divided leaves remain submerged. A white buttercup-shaped flower up to 2 cm in diameter, usually with 5 petals can be seen between May and August.

Floating vegetation poses little resistance to flow as it has few if not any submerged leaves to act as a barrier to water movement.

1.9.3 Emergent vegetation

Glyceria (Reed Sweet-grass), *Juncus* (Rush) and *Carex* (Sedge) are abundant within the River Wensum. These tall emergent plants may reach up to 2 m in height and grow in dense stands in slow moving water. These plants provide greater resistance to flow than some submerged plants as they may provide a fairly impermeable barrier to the flow of water, depending on the density of the vegetation stand.

Control of *Glyceria* may be difficult as it reproduces through a system of rhizomes (underground stems) which are buried in the mud and silt of the channel bed. Any form of control which leaves these rhizomes intact will have only a short term benefit. Unless these are removed through desilting, *Glyceria* will regrow the following year.

1.9.4 Algae

Filamentous algae is found within the River Wensum. The long chains of this algae grow up from the hydrosol. Algae is difficult to control as it can be found anywhere and grows rapidly

through simple fission by which each cell divides. Algae is common in nutrient rich waters and frequently invades areas where other aquatic plants have been controlled or eradicated.

2. FARM SURVEY

2.1 Introduction

Following structured interviews and informal discussions with farmers and a topographical survey, the area deriving a benefit from the river maintenance work in terms of its impact on land drainage and flooding is estimated to be 59 ha. This area is classed as the benefit area (BA). Detailed interviews and discussions have been held with five farmers within the benefit area. The benefit area has been divided into separate blocks (Figure 4) according to drainage condition, land use and land management practices. Thirteen percent of the benefit area is comprised of gravel workings and artificial lakes.

2.2 Farm Type, Size and Tenure

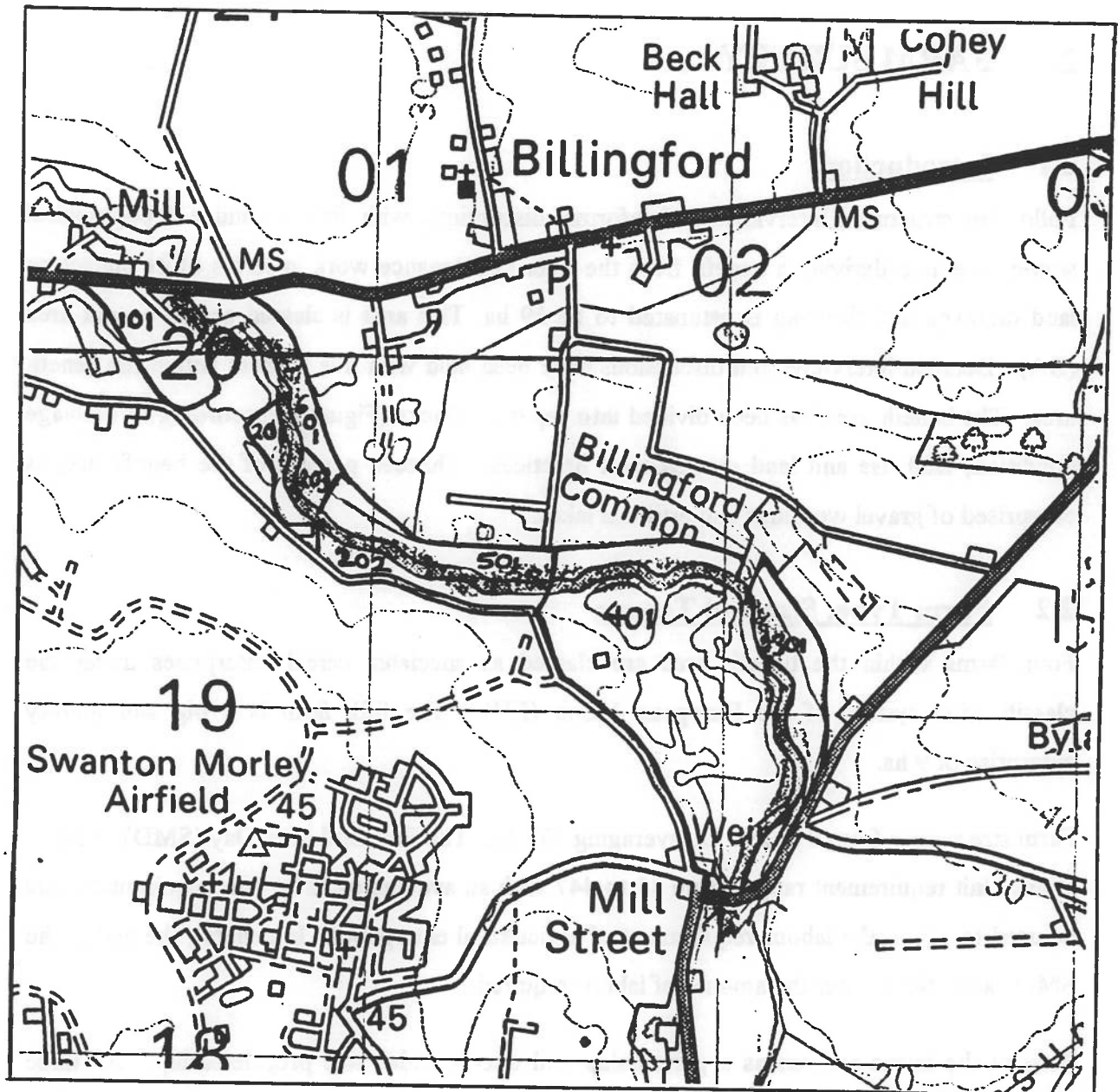
Four farms within the benefit area are classed as specialist cereal enterprises under the classification system of the European Union (EU). The fifth farm is a pig and poultry enterprise of 9 ha.

Farm size ranges from 9 to 291 ha, averaging 131 ha. The Standard Man Day (SMD) or Man-Work-Unit requirement ranges from 45 to 447 with an average of 221. This requirement may be used to assess the labour requirement of agricultural enterprises. In general, the higher the SMD value, the greater the amount of labour required.

Two of the farms are run as a partnership and one is under sole proprietorship. All three farmers have one holding. All the land within the benefit area is owner occupied.

2.3 Livestock Enterprises

A herd of 110 spring calving beef suckler cows are kept on one farm. The stocking rate is approximately 2.6 beasts/ha. Ten sows are kept on a different farm under a system of fattening outdoors. The same farm also keeps 50 store cattle which are fattened indoors. Areas of summer grazing are let for sheep.



Legend :

Scale 1 : 14833



Land blocks (Blocks are based on land use, land management, flooding and land drainage criteria)

Figure 4 Land blocks

2.4 Arable Enterprises

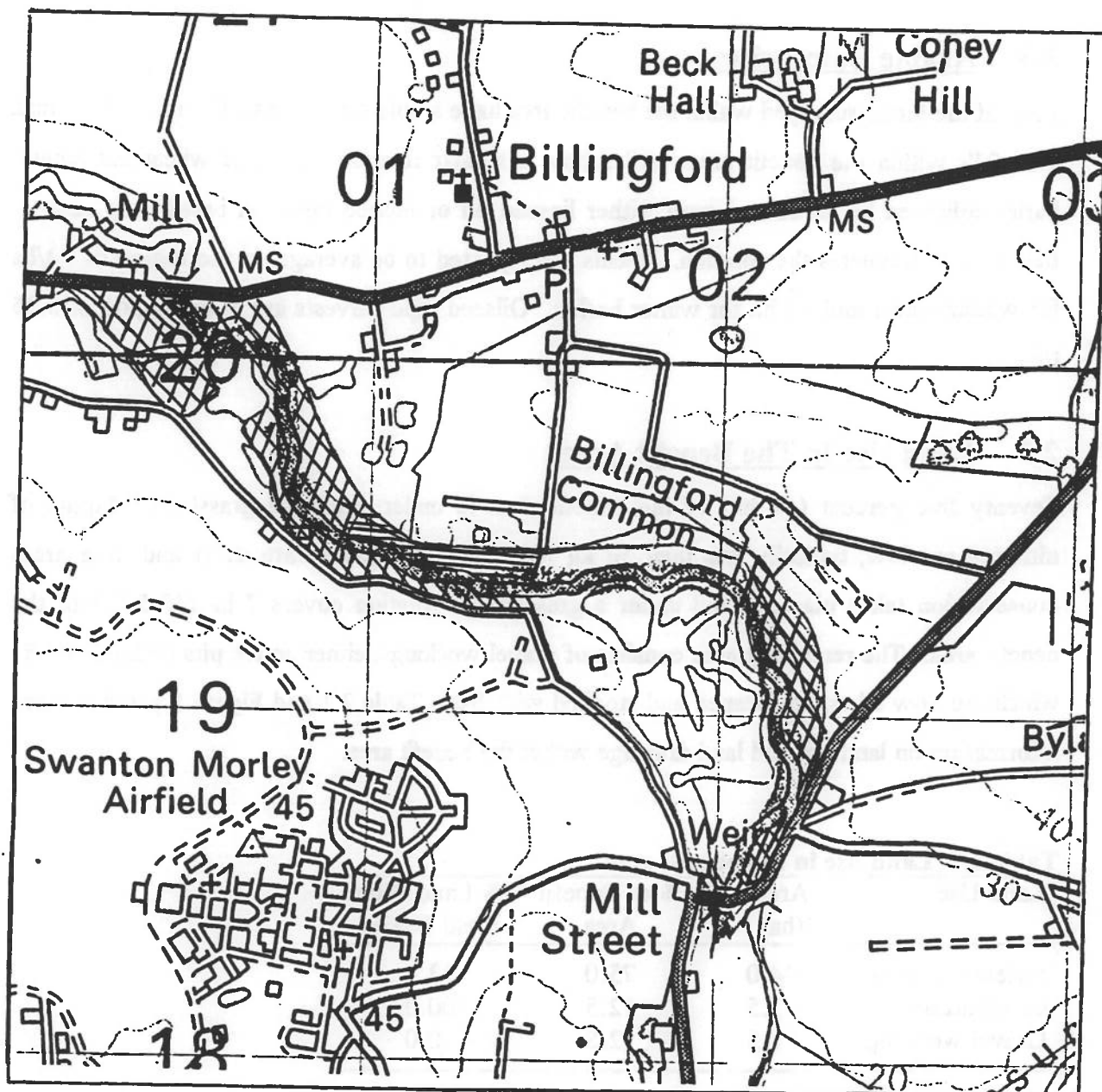
Four of the farms surveyed within the benefit area have arable enterprises although only a small area falls within the benefit area. All follow a similar rotation of winter wheat and winter barley followed by an oilseed crop; either linseed oil or oilseed rape. A break crop such as field beans completes the rotation. Yields are reported to be average; in the region of 7 t/ha for winter wheat and 6 t/ha for winter barley. Oilseed rape harvests are in the region of 3.25 t/ha.

2.5 Land Use In The Benefit Area

Seventy five percent (44 ha) of the benefit area is under extensive grassland. Inputs of nitrogen are low; typically less than 50 kg N/ha, grazing seasons are short and little grass conservation takes place. Land under a grass/arable rotation covers 7 ha (12.5 %) of the benefit area. The remaining area consists of gravel workings; either active pits or flooded pits which are now lakes, landscaped and stocked with fish. Table 2.1 and Figure 5 provide more information on land use and land drainage within the benefit area.

Table 2.1 Land use in the benefit area

Land Use	Area (ha)	% of Benefit Area	% Land With Field Drains
Extensive grass	44.0	75.0	13.4
Grass/arable	7.5	12.5	100.0
Gravel workings	7.5	12.5	0.0



Legend :



Extensive grass

Scale 1 : 14833



Grass / arable rotation



Gravel workings / flooded gravel pits

Figure 5 Land use in the benefit area

2.6 Turnout and Yarding Dates

Dates for the turnout and yarding of livestock stock follow a similar pattern over the benefit area (Tables 2.2 and 2.3). Livestock graze 29 % of the grassland area all year round. Stock are turned out in mid/late April over 29 % and after the first hay cut over 14 % of the grassland. Yarding dates for livestock are commonly mid to late October as Table 2.3 indicates. All figures for the grazing seasons of livestock relate to the extensive grassland and not to the land under grass/arable rotations. Throughout the survey, this grass/arable land was sown with crops.

Table 2.2 Turnout dates

Turnout Date	% Grassland Area	% of Benefit Area
Mid/late April	28.6	21.3
After 1st hay cut	14.3	10.7
Grazed all year	28.6	21.3
Not grazed	28.6	21.3

Table 2.3 Yarding dates

Yarding Date	% Grassland Area	% of Benefit Area
Mid/late October	42.8	31.9
Grazed all year	28.6	21.3
Not grazed	28.6	21.3

2.7 Grass Conservation

The majority of the extensive grassland within the benefit area is grazed only (57 %). One cut of hay is taken over 6 ha of grassland in mid/late June.

2.8 Nitrogen Application

Nitrogen is applied to 43 % of the grassland area. Application rates vary from 17 to 35 kg/ha as Table 2.4 shows. The compound NPK fertiliser in the ratio 20:10:10 is commonly applied. Application rates are limited due to the constraints imposed by the Environmentally Sensitive Area (ESA) designation of the valley.

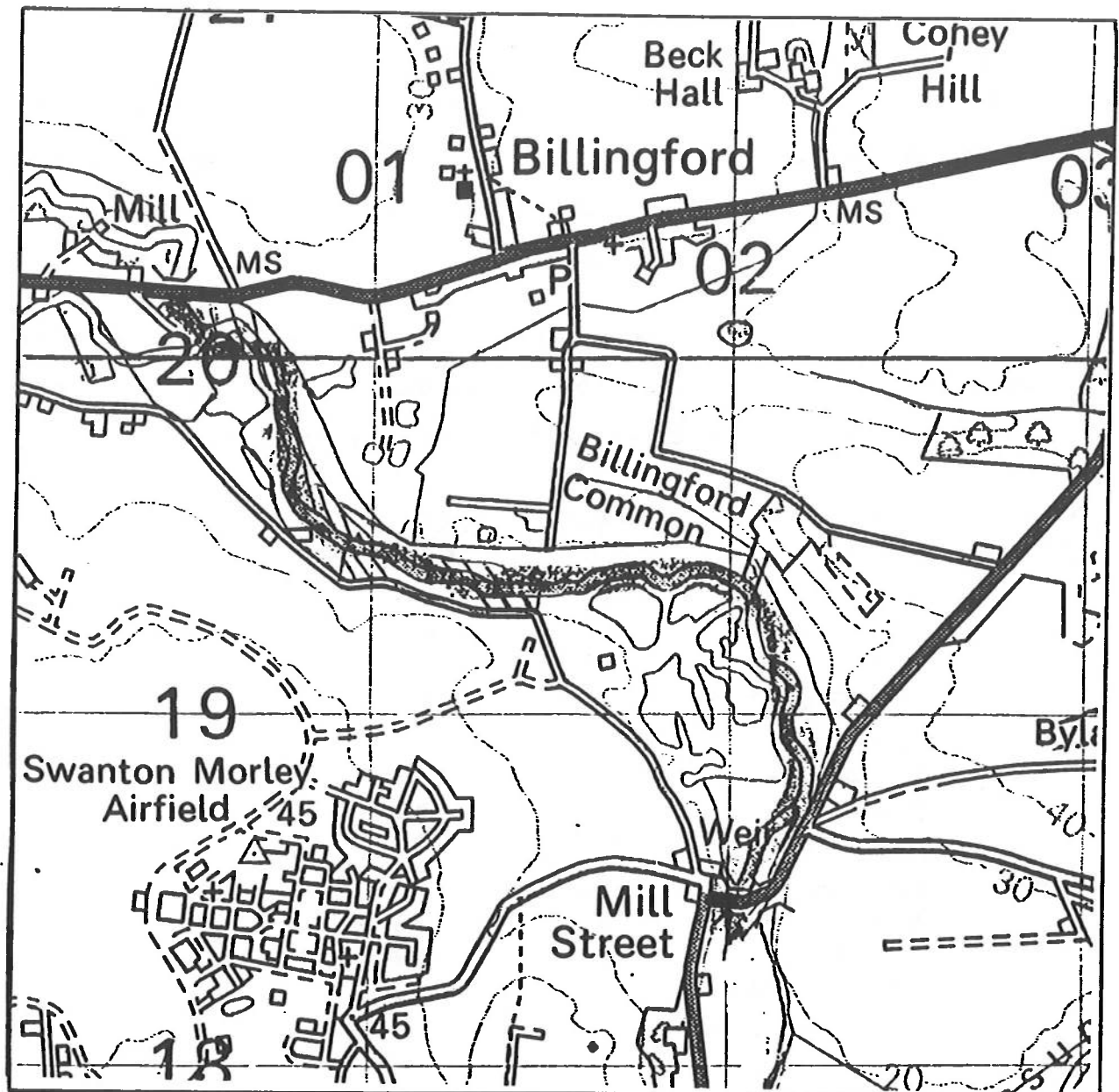
Table 2.4 Nitrogen application rates

Rate (kg N/ha)	Grassland Area (ha)	% Grassland Area
0.0	25.1	57.1
15 - 17	12.6	28.6
35.0	6.3	14.3

2.9 Flooding

A total of 37 % of the agricultural land within the benefit area is prone to flooding, 60 % of which occurs in the winter (Figure 6). The majority of flooding (84 % of the total flooded area) occurs on extensive grassland. The duration of flooding is reported to be 2 - 3 days.

The main factors reported to be responsible for the winter flooding are excessive rainfall and mis-management of the sluice gates on the Black Water. One of these gates is operated automatically but the others are said to be privately owned and it is these gates which are said by farmers to cause increased flooding within the benefit area. Farmers attribute summer flooding to aquatic weeds in the channel causing high water levels to be retained. The main consequence of flooding is said to be damage to fencing and bank structure.



Legend :

Scale 1 : 14833



Flooded areas

Figure 6 Areas prone to flooding

2.10 Waterlogging

Throughout the benefit area, the wetness condition of the land follows a similar pattern (Table 2.5). During the spring and summer months the land is reported to be well drained and rarely waterlogged. During the autumn, 17 ha remains rarely wet whilst 25 ha are often wet. No land is permanently waterlogged in the autumn.

Farmers attribute the wet conditions in the autumn to the weather, soil type and runoff from the adjacent road. The major factor said to contribute to flooding is high water levels in the river and the Black Water due to the presence of weeds and silt in the channel.

Table 2.5 Farmer assessment of field wetness condition

Season	Wetness Condition	Area (ha)	% Benefit Area
Spring	Rarely wet	42.1	71.4
	Occasionally wet	16.9	28.6
	Often wet	0.0	0.0
	Permanently wet	0.0	0.0
Summer	Rarely wet	59.0	100
	Occasionally wet	0.0	0.0
	Often wet	0.0	0.0
	Permanently wet	0.0	0.0
Autumn	Rarely wet	16.9	28.6
	Occasionally wet	16.9	28.6
	Often wet	25.2	42.9
	Permanently wet	0.0	0.0

2.11 Statistical Analysis

It is apparent that land use, farming practice, drainage and flooding are interrelated. Statistical methods were used to determine whether these relationships occurred more frequently than might be expected by pure chance. Full details of this analysis in which the 12 sites were grouped according to NRA Region, are presented in the Interim Report R&D 317/13/ST, presented to the NRA in December 1994.

The following observations can be made from the statistical analysis of fields in the benefit area of the River Wensum maintenance programme:

- A strong relationship exists between land use and the presence of field drainage. Land under the grass / arable system is more likely to be under-drained than the extensive grassland. (Statistically, there is a 92 % chance of correctly predicting the installation of field drainage on the basis of land use).
- Land use and flooding frequency are also strongly related. The greater the intensity of land use, the lower the intensity of flooding. (Statistically, there is a 77 % chance of correctly predicting the frequency of flooding on the basis of land use).
- A relationship exists between the yarding date of livestock field wetness conditions in the autumn. Livestock are overwintered on land which remains rarely wet and occasionally wet in the autumn and spring. Grazing on land which is often wet in the winter ends in October. (Statistically, there is a 56 % chance of correctly predicting livestock yarding dates on the basis of field wetness condition in the autumn).

3. HYDRAULIC AND HYDROLOGICAL DATA

3.1 Introduction

Information on channel hydraulics and hydrological data has been used to determine the impact of maintenance on channel capacity and flood return periods.

3.2 Cross-section Surveys

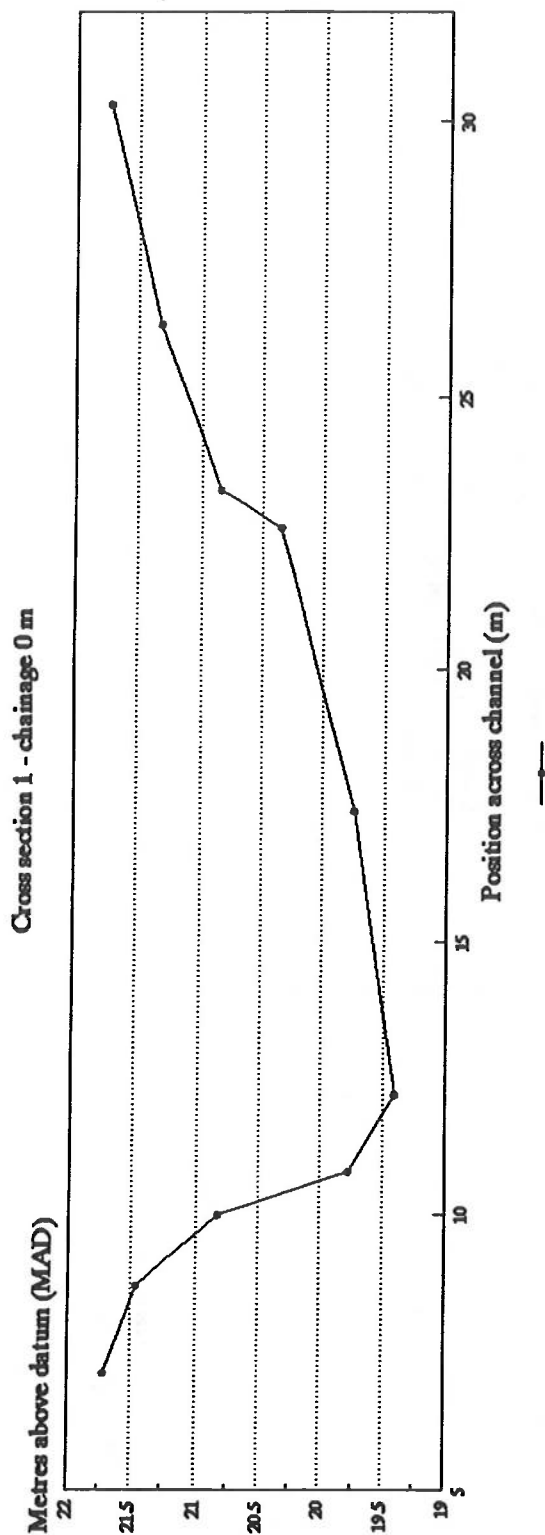
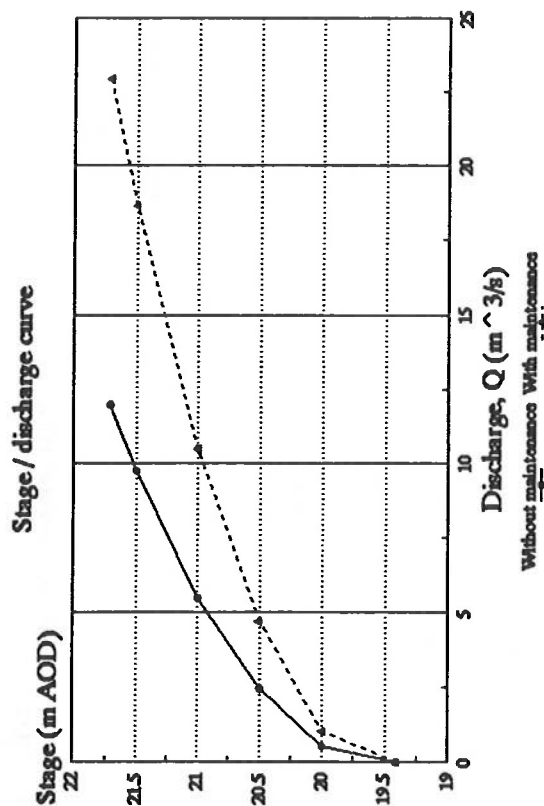
Cross-sectional surveys of the channel were completed at four points within the study reach at an average interval of 1087 m (Figure 2). Channel capacity and freeboard were determined from these cross-sections. Channel dimensions were not altered during the process of river maintenance, therefore a post-maintenance cross-sectional survey of the channel was not necessary.

Prior to river maintenance, channel roughness was expressed in the form of the Manning's n coefficient, using the methodology developed by Cowan (1956). This coefficient is composed of six parameters which include the predominant bed material, variations in channel cross-section and degree of vegetation growth. Further details of the methodology followed are presented in the R&D Note 456, Appendix IV. The same procedure was followed after maintenance in order to determine values of channel friction in a 'with' (post) and 'without' (pre) maintenance situation. Channel cross-section information including stage discharge curves and Manning's ' n ' values are presented in Figure 7. Table 3.1 shows the bankfull channel capacities and associated flood return periods 'without' and 'with' maintenance at each cross-section location.

Table 3.1 Bankfull capacity and flood return periods

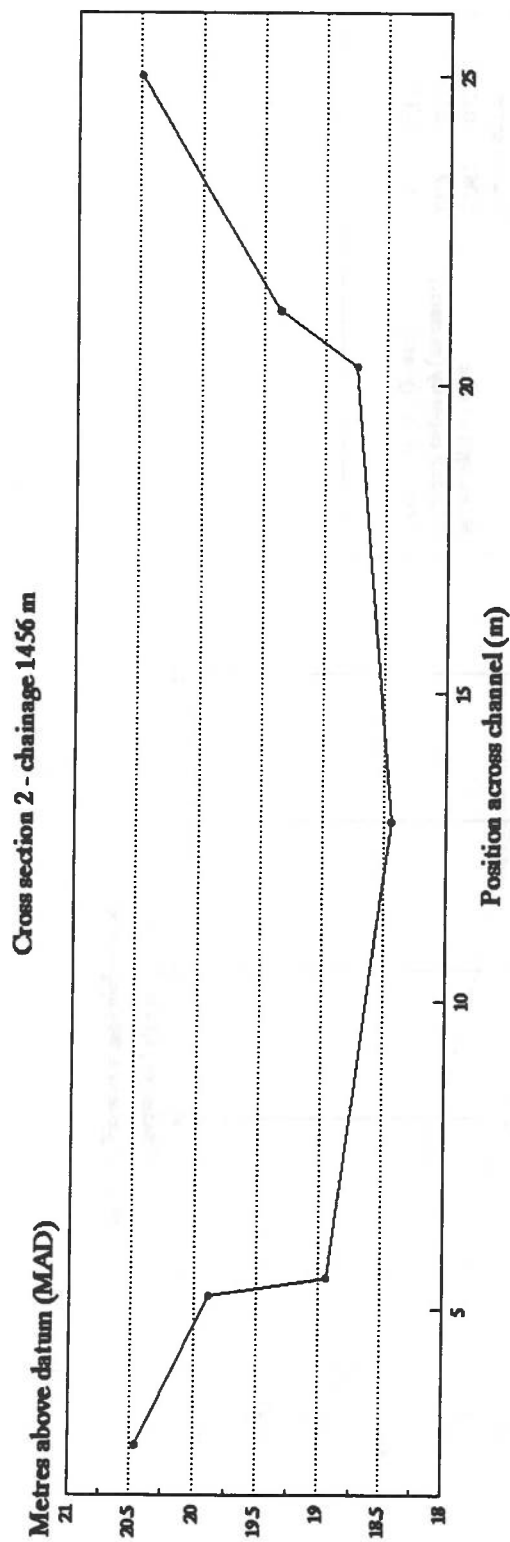
Cross-Section	Without Maintenance		With Maintenance	
	Bankfull Capacity (m ³ /s)	Return Period (years)	Bankfull Capacity (m ³ /s)	Return Period (years)
1	11.9	0.4	22.9	1.75
2	16.0	0.6	30.3	3.90
3	31.1	4.0	59.0	47.0
4	9.9	0.28	19.1	0.95

(Source: modelled estimates)

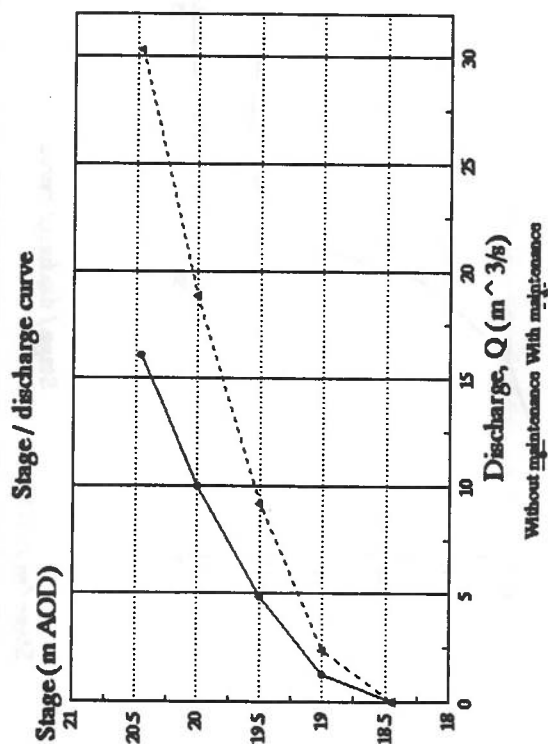


River channel information	
Manning's n value	0.067
Bankfull capacity (cumecs)	11.9
Return period (years)	0.4
Without Maintenance	0.035
With Maintenance	22.9
	1.75

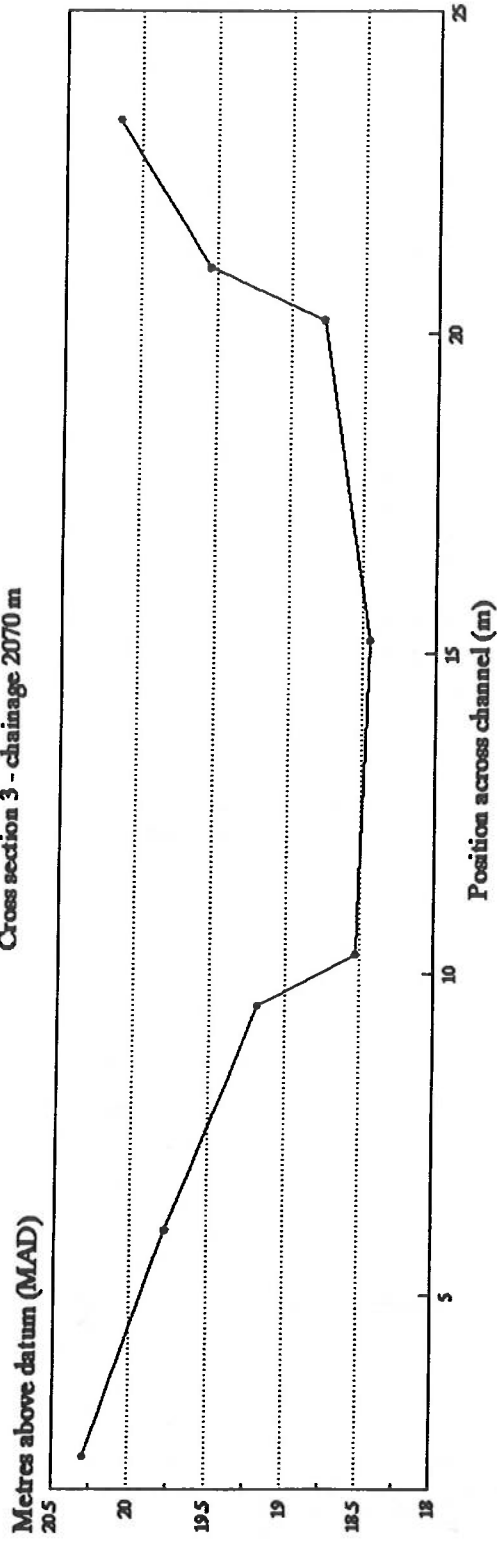
Figure 7 River Wensum channel information



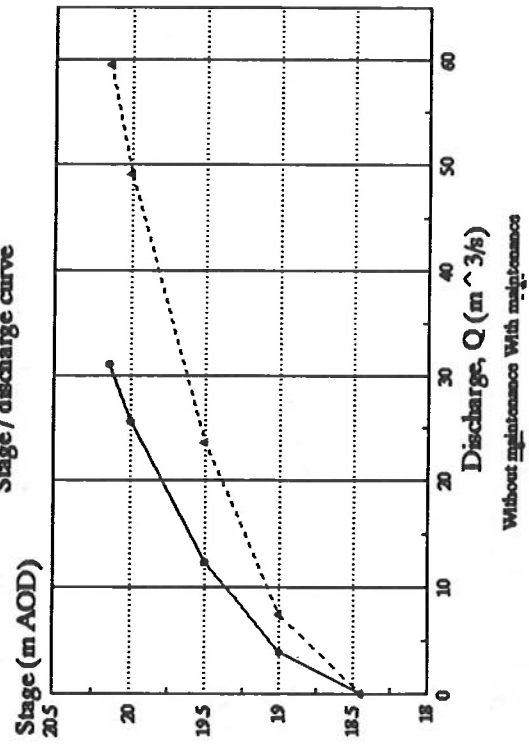
River channel information			
Manning's n value		Without Maintenance	With Maintenance
Bankfull capacity (cumecs)		0.066	0.035
Return period (years)		16.0	30.3
		0.6	3.9



Cross section 3 - chainage 2070 m

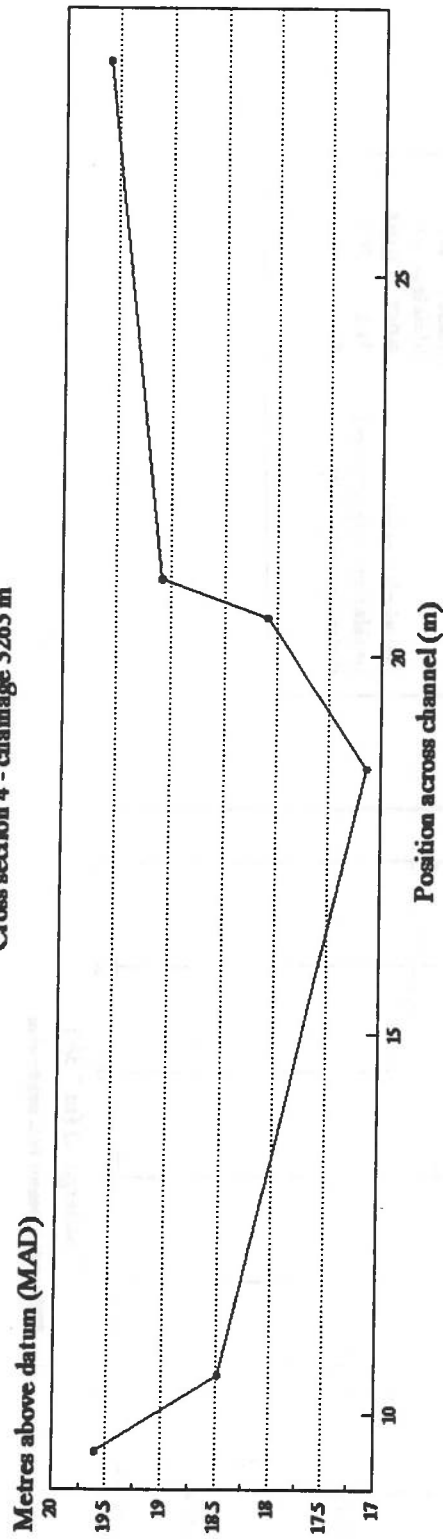


Stage / discharge curve

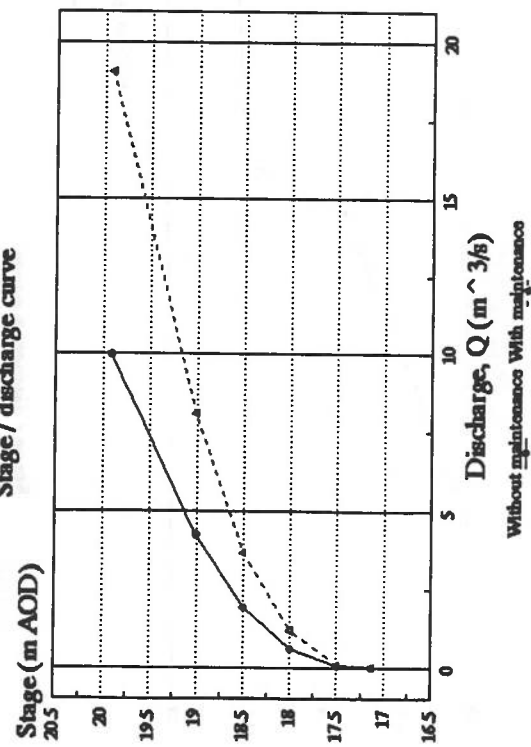


River channel information	
Manning's n value	Without Maintenance 0.067 With Maintenance 0.035
Bankfull capacity (cumecs)	Without Maintenance 31.1 With Maintenance 59.0
Return period (years)	Without Maintenance 4.0 With Maintenance 47.0

Cross section 4 - chainage 3263 m



Stage / discharge curve



River channel information		Without Maintenance	With Maintenance
Manning's n value		0.068	0.0356
Bankfull capacity (cumecs)		9.9	19.1
Return period (years)		0.28	0.95

The bankfull capacity figures obtained from the cross-sections indicate an average increase in capacity attributable to maintenance of 48 % and an average reduction in interval between flood events of 81 %.

3.3 Flood Return Period

Throughout the period of the study, river water level information was collected on a regular basis from a gauging station within the study reach. Information relating to flood frequency and duration and flood flows were collected from NRA staff and local farmers. This information was used to compile a flood return period curve for the River Wensum using the methodology contained within the Flood Studies Report (NERC, 1975). The frequency of floods of different magnitudes can be estimated by using this flood return period curve which is shown in Figure 8.

The flood return period for each block which floods and associated flooded areas, are shown in Table 3.2. The 'without' maintenance return period is estimated by the farmer, the 'with' maintenance value is a modelled estimate using the cross-section information and Manning's n coefficient. It is assumed that the flooded area remains unchanged following maintenance.

Table 3.2 **Flood return periods and flooded areas**

Block No.	Block Size (ha)	Area Flooded (ha)	Flood Return Period (Years)	
			Without Maintenance	With Maintenance
101	9.96	6.50	0.5	1.75
201	2.10	2.10	0.5	3.90
202	1.20	0.20	0.5	3.90
203	0.40	0.10	1.0	3.90
501	6.68	0.67	0.5	3.90
601	5.88	0.71	0.5	3.90

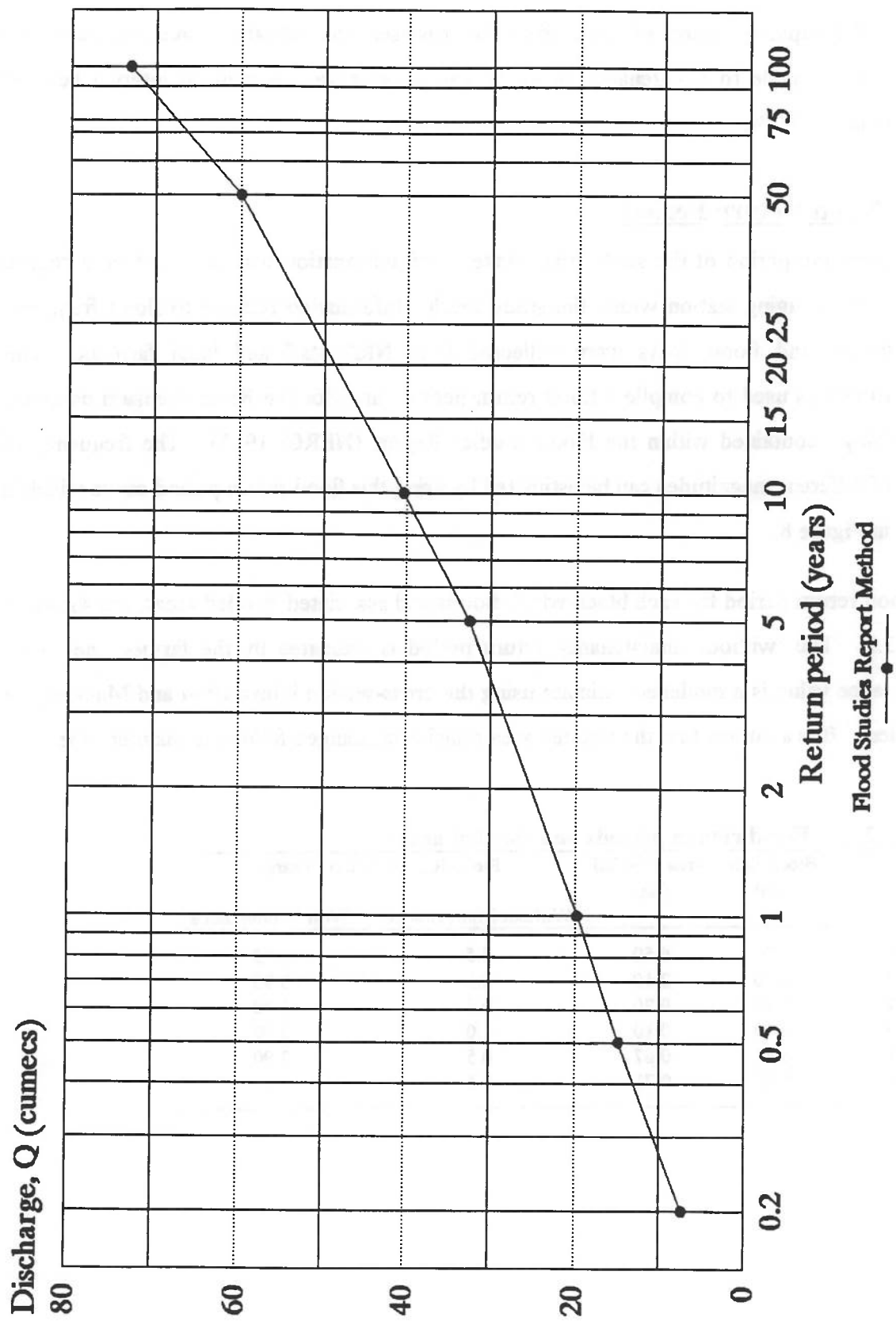


Figure 8 Flood return period curve

4. LAND DRAINAGE

4.1 Field Drainage Status

Through an extensive literature and farmer survey, the drainage status of land has been classified into three standards according to the watertable depth. Three watertable bands have been identified as : deeper than > 0.5 m from the surface, between 0.3 to 0.5 m of the surface and < 0.3 m from the surface. According to the time the watertable lies within these bands, the drainage status is classed as good (no limitation to land use), bad (some restrictions on land use) or very bad (severe limitations to agricultural production). Further details are presented in the R&D Note 456, Section 3.5.2.

The drainage status of land within the benefit area has been determined on a seasonal basis using a non-steady state watertable model which relates infield watertable levels (and hence drainage conditions) to observed water levels in the river and ditch system (see R&D Note 456, Section 3.5.2 for further details). The model has been run with river water levels for the 'with' and 'without' maintenance scenario using the same climatic data in order to isolate the impact of maintenance on drainage status. Appendix I contains an example of the input and output data produced by the watertable model. An example of the classification of the weeks of each season which are under conditions of good, bad and very bad drainage status is also given.

The results of the watertable model and the assessment of drainage status made by farmers are shown in Table 4.1. The watertable modelling identifies the difference in the number of weeks that the watertable lies within the good, bad and very bad drainage bands, with and without maintenance. However, these changes may not be of sufficient magnitude to change the drainage status classification. Where a change in drainage status has occurred due to maintenance, the changes appear in bold print in Table 4.1.

The output from the watertable model is consistent with the farmers assessment of drainage status under dry and average climatic conditions. For the 'with' maintenance situation there is 100 % agreement between the modelled and farmer assessment in a dry and average season. In a wet season, there is 86 % agreement. In the 'without' maintenance situation, there is 71

% agreement between modelled and farmer assessment of drainage condition under average weather conditions.

Table 4.1 Drainage status for wet, average and dry seasons, without/with maintenance

Block No		Wet Season *		Average Season *		Dry Season *		Farmer Assessment			Without
		Without	With	Without	With	Without	With	With Maintenance	Without		
								Wet	Average	Dry	
101	N	G	G	G	G	G	G	G	G	G	G
201	N	B	B	G	G	G	G	<i>G</i>	G	G	B
202	N	VB	B	B	G	G	G	B	G	G	B
203	N	VB	B	G	G	G	G	B	G	G	B
301	N	G	G	G	G	G	G	G	G	G	G
501	Y	B	B	B	G	B	G	B	G	G	B
601	Y	VB	B	B	G	B	G	B	G	G	B

NB: * Modelled results

Y or N refers to the presence of field drainage

Bold type indicates a change in drainage status due to maintenance

Italics indicate a difference in farmer and modelled assessment drainage with maintenance

With maintenance, drainage status in the benefit area is generally bad in wet climatic conditions and good in average and dry conditions. If maintenance were not performed, drainage conditions would deteriorate to very bad in some areas in a wet season and to bad under normal and dry conditions.

Current levels of river maintenance prevent a deterioration of drainage status on 3 blocks of land in a wet and average season and on one in a dry season. Maintenance prevents a deterioration in drainage status :

- In a wet season, from B to VB over 7.5 ha (22 % of BA, excluding area under gravel pits),
- In an average season, from G to B over 13.8 ha (40 % of BA, excluding area under gravel pits),
- In a dry season, from G to B over 5.9 ha (17 % of BA, excluding area under gravel pits).

The farmer assessment of field drainage conditions in an average season, suggest a deterioration in drainage condition from good to bad over 48 % (16 ha) of the agricultural land within the benefit area in the absence of maintenance.

5 SCHEME APPRAISAL

5.1 Maintenance Benefits

For each block of land, agricultural production scenarios were created which reflect different levels of field management under conditions of good, bad and very bad drainage (see R&D Note 456 Section 3.5.4). These scenarios are based on discussions with farmers in the benefit area over the period 1992-1994.

Changes in field drainage status as a result of maintenance under dry, average and wet climatic conditions have been identified. Changes in flood risk due to maintenance have also been determined. Estimates have been derived of the monetary value of changes in field management and productivity associated with changes in the standards of drainage service.

Two perspectives have been used to value agricultural performance. The first perspective is that of financial analysis which uses the prices paid and received by farmers to estimate the added-value associated with drainage. Financial analysis shows the benefits of maintenance to farmers in the benefit area.

The second perspective is that of economic analysis which modifies the financial analysis to make allowance for the direct and indirect subsidies paid to farmers by Government. In accordance with the MAFF Project Appraisal Guidance Notes on Flood Defence (PAGN, 1993), these modifications involve reductions in the financial value of output (including subsidies) by 10% in the case of cereals, oil seeds and grain legumes, 35% for beef and 25% for sheep. Commodities subject to quota such as potatoes, sugar beet and milk are treated as winter wheat. The set aside areas are also treated as wheat. The reasons for these adjustments are discussed in the R&D Note 456 Section 2.7.2.

Using the results of watertable modelling, Table 5.1 shows the financial net returns (1995/96 prices) for each block of land within the benefit area under conditions of good, bad and very bad drainage. Changes in net returns relating to a change in drainage status are also shown. Table 5.2 presents similar data using economic prices. Table 5.3 shows the flood costs for each block of land assuming with and without maintenance and specified field drainage

conditions. It is assumed that there is no difference between financial and economic values in the case of flood damage to standing crops.

Table 5.1 Financial net returns

Block	Area (ha)	Net Return (£/ha)			Change in Total Returns (£/ha)		
		Good	Bad	Very Bad	Good to Bad	Bad to Very Bad	Good to Very Bad
101	9.96	123	99	77	24	22	46
201	2.1	877	630	91	247	539	786
202	1.2	877	630	91	247	539	786
203	0.4	151	125	99	26	26	52
301	8.26	144	107	83	37	25	62
501	6.68	451	395	29	57	99	156
601	5.88	465	308	252	157	57	213

NB: Numbers have been subject to rounding

Table 5.2 Economic net returns

Block	Area (ha)	Net Return (£/ha)			Change in Total Returns (£/ha)		
		Good	Bad	Very Bad	Good to Bad	Bad to Very Bad	Good to Very Bad
101	9.96	-6	-14	-20	8	7	15
201	2.1	819	576	43	243	533	776
202	1.2	819	576	43	243	533	776
203	0.4	62	43	26	19	17	36
301	8.26	8	-7	-12	15	6	21
501	6.68	235	196	135	39	62	101
601	5.88	87	40	27	47	13	60

NB: Numbers have been subject to rounding

Table 5.3 Flood costs

Block Number	GOOD DRAINAGE				BAD DRAINAGE				VERY BAD DRAINAGE				CHANGE IN FLOOD COST							
	Without Maintenance		With Maintenance		Without Maintenance		With Maintenance		Without Maintenance		With Maintenance		VERY BAD		G to B		B to VB		G to VB	
	FRP	FRP	cost	flow	cost	flow	cost	flow	cost	flow	cost	flow	cost	flow	Without -with	Without -with	Without -with	Without -with	Without -with	Without -with
	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)	(£)
101	0.50	1.75	12.52	3.58	10.97	3.13	9.49	2.71	8.94	7.84	6.78	7.39	6.36	5.91						
201	0.50	3.90	9.53	1.22	8.86	1.14	8.02	1.03	8.31	7.72	6.99	7.64	6.88	6.80						
202	0.50	3.90	1.59	0.20	1.48	0.19	1.34	0.17	1.39	1.29	1.17	1.28	1.15	1.14						
203	1.00	3.90	1.10	0.28	1.02	0.26	0.91	0.23	0.82	0.76	0.68	0.74	0.65	0.63						
501	0.50	3.90	8.04	1.03	7.27	0.93	6.21	0.80	7.01	6.34	5.41	6.24	5.28	5.18						
601	0.50	3.90	1.84	0.24	1.36	0.17	1.17	0.15	1.60	1.19	1.02	1.12	1.00	0.93						

Table 5.4 Changes in net returns due to maintenance and climate, 1995/96 financial prices

Block	Area (ha)	Wet Season			Average Season			Dry Season			Total Change (£/yr)
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	
101	9.96	0	9	9	0	9	9	0	9	9	89
201	2.10	0	8	8	0	8	8	0	8	8	17
202	1.20	539	1	540	247	1	248	0	1	1	273
203	0.40	26	1	27	0	1	1	0	1	1	1
301	8.26	0	0	0	0	0	0	0	0	0	0
401	24.84	Gravel Workings									
501	6.68	0	6	6	57	7	64	0	6	6	327
601	5.88	57	1	58	157	1	158	157	1	158	884
Total	34.50										1591
Probability of :		Wet season			Average season			Dry season			Benefit (£/ha)
		0.08			0.74			0.18			46

Table 5.5 Changes in net returns due to maintenance and climate, 1995/96 economic prices

Block	Area (ha)	Wet Season			Average Season			Dry Season			Total Change (£/yr)
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	
101	9.96	0	9	9	0	9	9	0	9	9	89
201	2.10	0	8	8	0	8	8	0	8	8	17
202	1.20	533	1	534	243	1	244	0	1	1	268
203	0.40	17	1	18	0	1	1	0	1	1	1
301	8.26	0	0	0	0	0	0	0	0	0	0
401	24.84	Gravel Workings									
501	6.68	0	6	6	39	7	46	39	6	45	285
601	5.88	13	1	14	47	1	48	47	1	48	267
Total	34.50										927
Probability of :											
Wet season											
Average season											
Dry season											
Benefit (£/ha)											
27											

Table 5.4 combines data on changes in drainage status, flood risk and financial performance to determine the financial benefits and change in financial net returns due to maintenance for wet, average and dry weather conditions for each block of land in the benefit area. These benefits are the avoidance of losses which would occur in the absence of maintenance. Benefits weighted by field size for wet, average and dry seasons are multiplied by the relative probability of the occurrence of the season to give an average expected annual benefit. These are summed for the benefit area as a whole.

Table 5.4 estimates a total expected annual benefit of £ 1591 in 1995 financial prices, equivalent to about £ 46/ha per year. Table 5.5 shows the benefits attributable to maintenance using economic prices based on the current MAFF Project Appraisal Guidance Notes. Total average expected annual benefits are about £ 927 in economic prices for the benefit area, equivalent to £ 27/ha. On this basis, the benefit to the national economy is 58 % of the benefits which accrue to farmers. This difference reflects the adjustments required by MAFF to remove government subsidy from the assessment of benefits.

As an alternative estimate to that based on watertable modelling, Table 5.6 estimates the benefits due to maintenance which were perceived by farmers (earlier reported in Table 4.1) where they identified a change in drainage conditions between the 'with' and 'without' maintenance situations in an average, representative season. These estimates include the flood damage costs identified above (Table 5.3) which were based on a combination of farmer and modelled data. Farmer assessment gave an average annual financial benefit of £ 2287 (£ 66/ha) and an economic benefit of £ 1507 (£ 44/ha).

Table 5.6 Farmer assessment of maintenance benefits

Block	Area (ha)	Average Season Financial Prices			Average Season Economic Prices		
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance
101	9.96	0	9	89	0	9	89
201	2.10	247	8	535	243	8	528
202	1.20	247	1	298	243	1	293
203	0.40	26	1	11	19	1	8
301	8.26	0	0	0	0	0	0
401	24.84	Gravel Workings					
501	6.68	57	6	423	39	7	307
601	5.88	157	1	931	47	1	282
Total	34.50	Total financial benefit (£)		2287	Total economic benefit (£)		1507
		Benefit (£/ha)		66	Benefit (£/ha)		44

According to the criteria used, these financial and economic benefit estimates show the limits which farmers and the nation respectively could justifiably spend on maintenance. These estimates require cautious interpretation as explained in the R&D Note 456 Section 2.7.2.

5.2 Maintenance Costs

Maintenance activities on the Wensum involved a programme of annual weed cutting. The unit cost according to NRA sources was £ 290/km in 1995 prices, equivalent to £ 870 for the study reach of 3 km, and £ 25/ha.

5.3 Scheme Appraisal

The estimated benefits attributable to maintenance can be compared with estimated costs to determine the justification for expenditure. Because the main maintenance activity is performed annually, the appraisal involves a simple comparison of annual benefits and costs.

Table 5.7 Maintenance scheme appraisal: Wensum

Average Annual Benefit (£)	Average Annual Benefits (£)	Average Annual Costs (£)	Benefit: Cost Ratio
<i>Modelled Estimates</i>			
Financial Prices	1591	870	1.8
Economic Prices	927	870	1.1
<i>Farmer Estimates</i>			
Financial Prices	2287	870	2.6
Economic Prices	1507	870	1.7

The modelled results show that scheme is viable in financial and economic terms (Table 5.7). The modelled estimates generate annual benefit : cost ratios of 1.8 and 1.1 in financial and economic terms respectively.

The farmer based estimate shows that, based on benefits in an average year, the maintenance scheme is viable. The scheme generates an annual benefit : cost ratio of 2.6 and 1.7 in financial and economic prices respectively. These conclusions must be interpreted cautiously as discussed in the R&D Note 456 Section 2.7.2.

6 ENVIRONMENT

6.1 Introduction

A River Environmental Database (REDS) is used within the Anglian Region of the NRA to store environmental information relating to the rivers. A river corridor survey is supported by information detailing the flora and fauna of the corridor and fluvial hydrology. Additional information concerning for example, archaeological interests is also recorded as necessary. Information from this system is drawn upon when formulating maintenance programmes.

6.2 Environmentally Sensitive Area

The River Wensum Valley constitutes part of the Broads Environmentally Sensitive Area (ESA) which was designated in 1987 and covers an area of 29870 ha. The objectives of the ESA scheme within the Broads are :

- “to maintain and support traditional livestock grazing on permanent grassland;
- to conserve the landscape, wildlife, archaeological and other features which are responsible for the character of the traditional grazing marshes and meadows;
- to encourage the continuation of grassland farming; and,
- to extend the area covered by traditional grazing marshes on wet meadows by encouraging the adoption of traditional farming practices on land now managed more intensively” (MAFF 1989, 16).

Farmers entering into ESA agreements are required to maintain traditional grassland practices. Applications of fertilisers, pesticides and herbicides are restricted and limits are placed on the number of livestock units permitted per hectare.

6.3 River Corridor Survey

Prior to the maintenance works of 1992, a river corridor survey was completed for the study reach. The methodology developed by the Nature Conservancy Council (NCC, now English Nature (EN)). Sketch maps and record cards were completed for each 500 m section of the reach. These are presented in Appendix II.

The survey concentrated on the physical features of the river channel and adjacent land. Information relating to such features as bed substrate, channel dimensions and aquatic vegetation were recorded.

Following maintenance, it was not necessary to complete a second corridor survey as the channel dimensions and banks were not altered. The post-maintenance survey took the form of a vegetational survey which concentrated on the location and percentage cover of channel vegetation. The post-maintenance survey is presented in Appendix II.

6.4 Public Consultation

Prior to river maintenance activities being undertaken, consultation takes place between the NRA and organisations who have a direct interest in the river. Details of the maintenance programme are discussed and if necessary, modifications to the plans are made.

6.5 Farmer Assessment

Each farmer interviewed was asked to identify any features of environmental interest which may be disturbed or damaged by river maintenance. Kingfishers, coots, geese, chub and bream were highlighted as the main wildlife of interest. None were thought to be affected by river maintenance.

6.6 Channel and Bank Quality

The environmental quality of the river channel and banks has been determined by following the procedure outlined in the 'Guidelines for the Justification of River Maintenance' (R&D Note 511) produced within the framework of the NRA R&D Note 456 (River Maintenance Evaluation).

The channel of the River Wensum is of high quality. The marginal vegetation is well developed and consists of emergent and submerged plants and many forms of aquatic macrophyte can be found within a 500 m reach. At times of low flow, the transitional zone between the river and channel edge is well developed. Sediments are exposed and a band of wetland vegetation borders the river.

The banks of the River Wensum are deemed to be of moderate to high quality. They range from simple to complex in vegetational structure and are typically over 10 m in width. Areas of simple structure consist of predominantly two or three vegetation types with no areas of scrub. Complex vegetational stands are comprised of four or more vegetational types and banks are varied containing short and tall vegetation, herbs and grasses, scrub and trees. In the spring and early summer, a wide variety of flowering herbs are present (good botanical quality). Dense stands of single species vegetation such as nettle are also common (high bird quality). The varied structure of the banks in terms of different bank angles and the occasional earth cliff and some exposed roots provide mixed habitats for wildlife.

7 CONCLUSIONS

7.1 Scheme Appraisal

Using modelled results, the existing maintenance scheme of annual weed clearance is viable in financial terms and economic terms. The average annual economic benefit of maintenance in terms of its prevention in a deterioration in drainage status and increase in flooding is £ 927. Average annual maintenance costs are £ 870. The economic benefit : cost ratio is therefore 1.1.

7.2 Guidelines for River Maintenance

The 'Guidelines for the Justification of River Maintenance' (R&D Note 511), produced as a result of this River Maintenance Evaluation Study were used to provide an alternative method for justification of maintenance on the River Wensum.

According to this method, the economic benefit : cost ratio is 0.6. This value approximates to that derived from the detailed analysis; the results of which are summarised in Section 7.1.

7.3 Impact of Maintenance on Channel Vegetation

The types of vegetation found within the River Wensum are discussed in Section 1.9. The impact of the floating, submerged and emergent vegetation on channel capacity is also discussed. Different vegetation types respond to maintenance in different ways.

The sweet-grass (*Glyceria*) reproduces through a system of rhizomes (underground stems). The current method of maintenance - regular cutting, actually stimulates regrowth of this vegetation. Desilting of the channel every few years is necessary in order to remove the rhizomes from the channel bed.

The submerged *Elodea* and floating *Ranunculus*, are controlled by cutting. The sedges and rush (*Carex* and *Juncus*) are also controlled by cutting. However, regular cutting may stimulate regrowth at a faster rate than if the vegetation was not cut.

The current maintenance regime therefore is appropriate in controlling the majority of the channel vegetation. Desilting will be necessary every few years in order to effectively control the *Glyceria* and to remove the rhizomes from the channel bed.

7.4 Maintenance Best Practice

The preferred vegetation maintenance methods for the River Wensum were determined using the procedures presented in the 'Guidelines for the Justification of River Maintenance' (R&D Note 511), produced as a result of the Environmental Impact Assessment Study.

Channel

Best practice maintenance operations for emergent weed are identified as :

- Annual autumn cutting;
- Biennial cutting; and,
- Cutting on a 3 to 5 year rotation.

Best practice maintenance operations for floating and submerged weed are identified as :

- Multiple annual cutting in the summer / autumn;
- Biennial cutting; and,
- Cutting on a 3 to 5 year rotation.

All these maintenance operations should be selective, concentrating on those areas which are particularly choked by vegetation or areas in which the weed is liable to cause an obstruction, hazard or restriction to flow.

Since the beginning of this study, annual weed maintenance in mid summer has taken place. Approximately 60 % of the vegetation is removed. A strip of un-cut vegetation is left down each margin. According to the maintenance regimes recommended as best practice in environmental terms, the submerged and floating vegetation should be cut more than once a year.

Bank

Although the banks of the River Wensum are not cut as part of routine maintenance, if they were, given their moderate to high quality, the following bank maintenance options would be preferred:

- Single bank mowing / flailing in spring / summer leaving a toe strip 1 m wide;
- Single bank mowing / flailing in autumn / winter leaving a toe strip over 0.25 m wide;
- Mowing / flailing every 3 - 5 years leaving a toe strip over 1 m wide or selective cutting (< 20 %); and,
- Light grazing.

The banks are not flail mown. A lot of bank vegetation is trampled and grazed. If the bank maintenance regime recommended as best practice in environmental terms were implemented, the quality of the banks may improve and vegetation structure would change.

7.5 Recommendations

It is recommended that further research through site survey and modelling examines :-

- the impact of a reduced maintenance frequency on sections of the river on land drainage, flooding and sedimentation; and,
- the impact of reduced channel maintenance on channel environmental quality.

7.6 Epilogue

This report has assessed the impacts of the current maintenance regime on the study reach. It has been used along with other study sites to formulate guidelines on the appraisal of maintenance works and best environmental practice. These draft guidelines are summarised in Chapter 5 of the R&D Note 456 and presented in full under separate covers.

8. REFERENCES

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APPENDIX I

Example of input and output data for the watertable model

River Wensum

Block Number 203

Cross-section 2

Input Data		Output Data
River height (m AOD)		Watertable height (m AOD)
Week		
1994		
1	19.15	19.68
2	19.05	19.64
3	19.07	19.46
4	19.05	19.41
5	19.06	19.37
6	19.13	19.28
7	19.05	19.21
8	19.07	19.28
9	19.05	19.29
10	19.01	19.16
11	19.10	19.32
12	19.15	19.31
13	19.05	19.30
14	19.15	19.36
15	19.13	19.38
16	19.10	19.24
17	19.14	19.14
18	19.20	19.15
19	19.15	19.27
20	19.21	19.22
21	19.20	19.21
22	19.20	19.17
23	19.20	19.15
24	19.20	19.04
25	19.20	18.99
26	19.15	18.95
27	19.15	18.93
28	19.15	18.88
29	19.15	18.77

Example of drainage status classification, River Wensum

With maintenance

Block 203

Watertable depth (m)	Spring 1994	No. of weeks	Summer 1994	No. of weeks	Autumn 1994	No. of weeks
>0.5	19.3	13	19.3	13	19.3	13
0.3><0.5m	19.5	0	19.5	0	19.5	0
<0.3m	19.8	0	19.8	0	19.8	0

Drainage status classification, according to time watertable
is within the G, B, VB drainage bands

Good

Without maintenance

Watertable depth (m)	Spring 1994	No. of weeks	Summer 1994	No. of weeks	Autumn 1994	No. of weeks
>0.5	19.3	9	19.3	13	19.3	7
0.3><0.5m	19.5	4	19.5	0	19.5	5
<0.3m	19.8	0	19.8	0	19.8	1

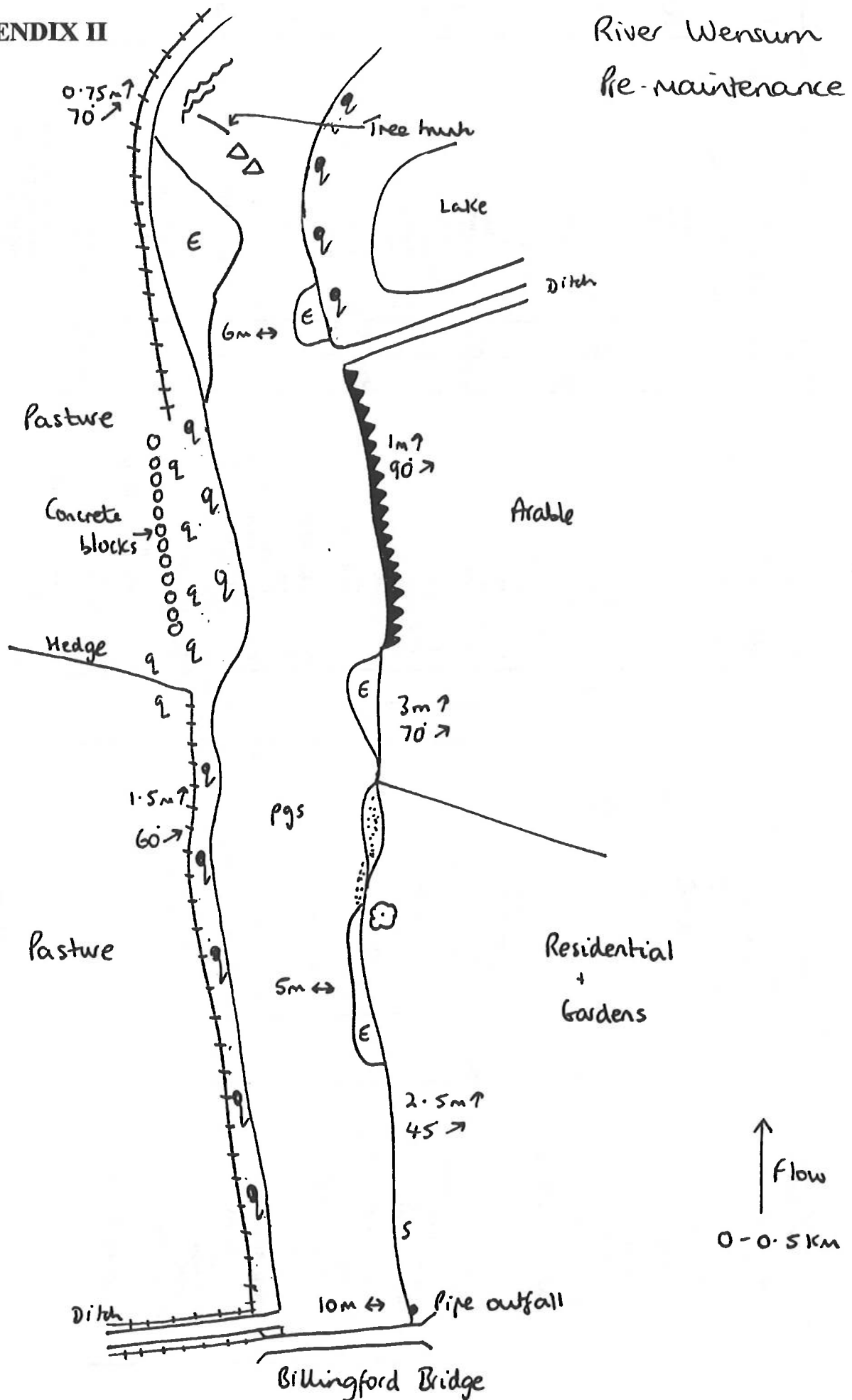
Drainage status classification, according to time watertable
is within the G, B, VB drainage bands

Good

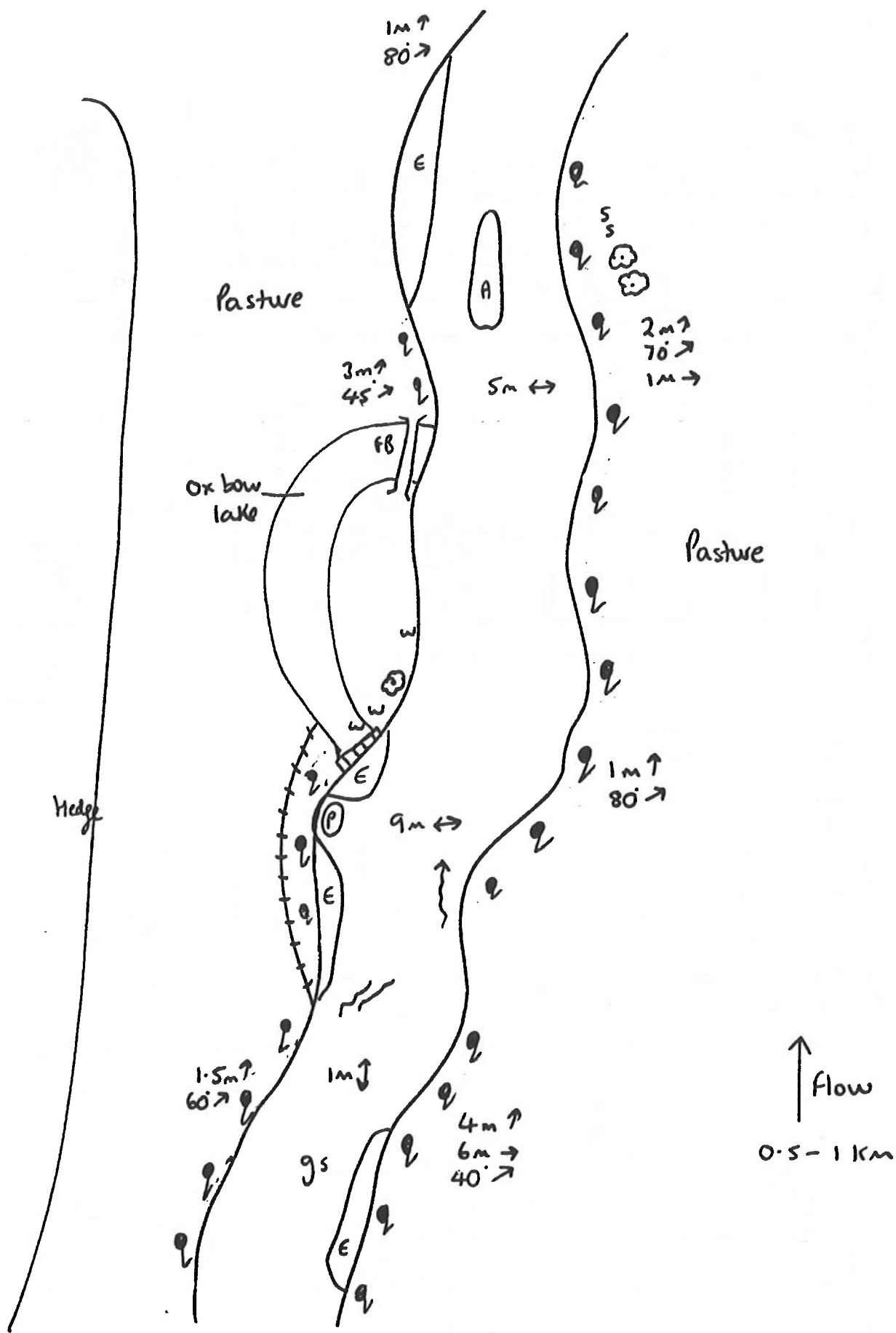
Bad

APPENDIX II

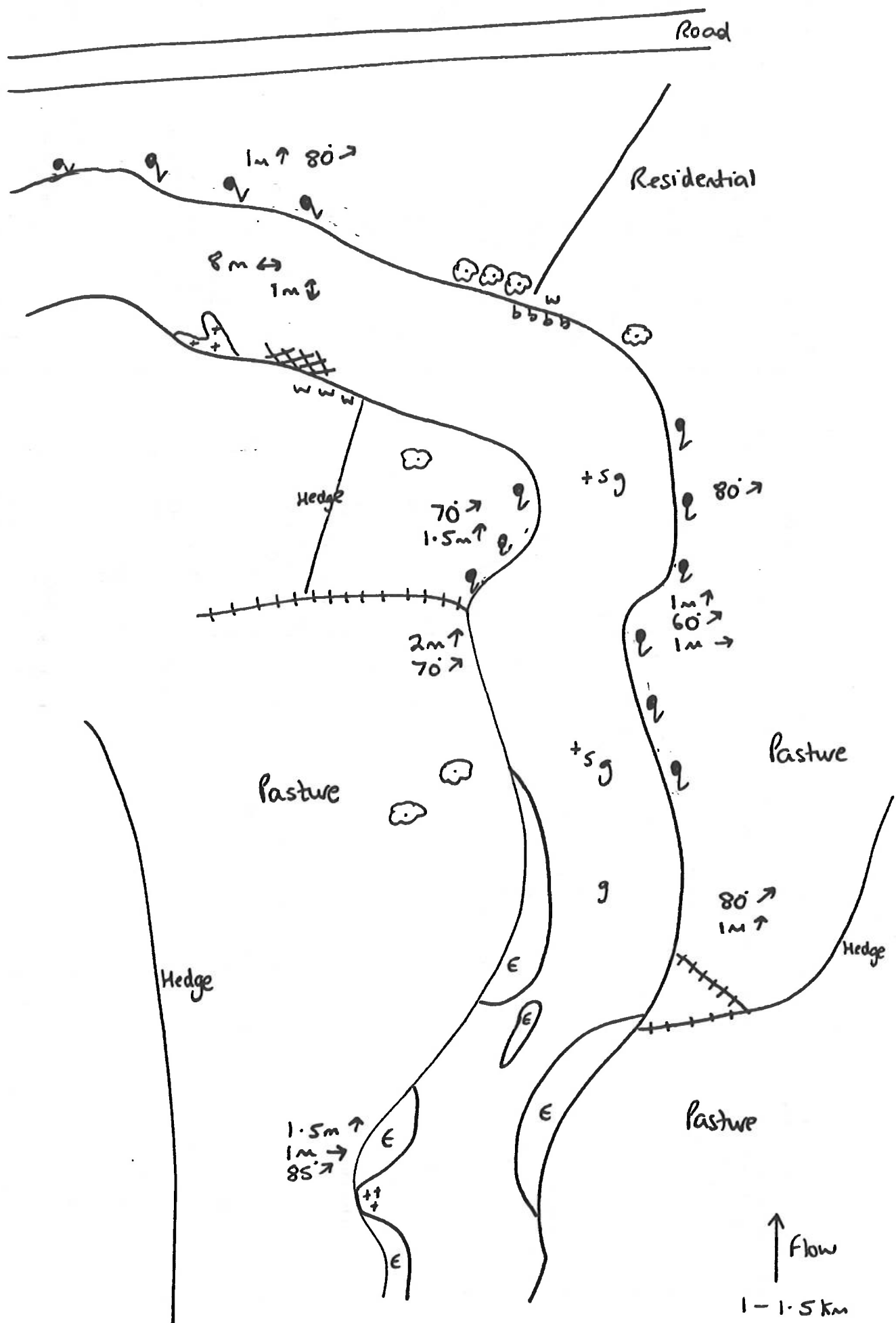
River Wensum Re-maintenance.



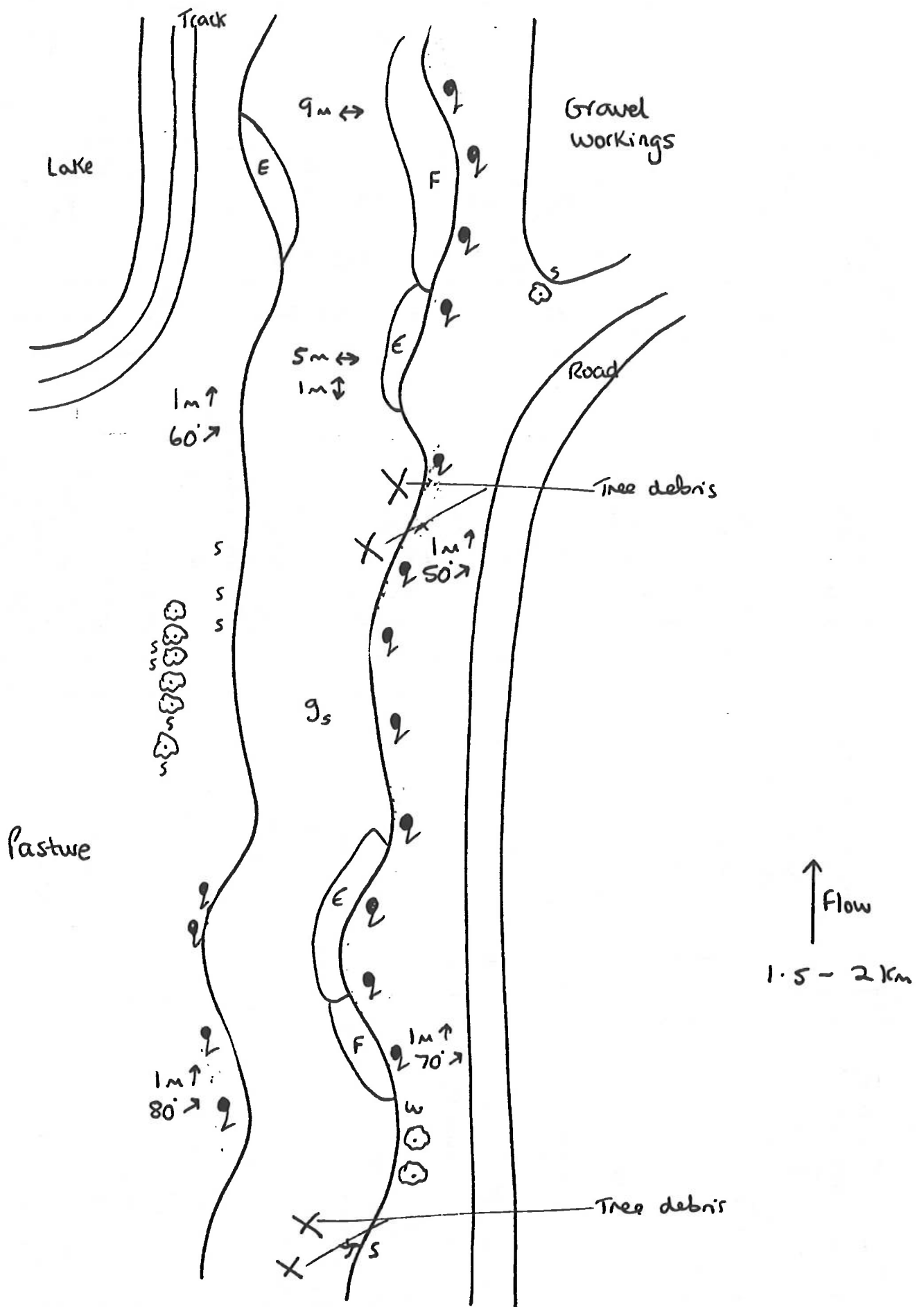
WOODLAND & SCRUB %		RIVER WENSUM		RIVER	
1. Broad-leaved semi-nat. plantation		River No. 0-0.5	LB	RB	LB
2. Coniferous semi-nat. plantation		Date 20/6/92			
3. Mixed semi-natural plantation		Surveyor JALD			
4. Scrub - dense					
5. Carr - alder					
6. Willow					
7. Parkland					
8. Recently felled wood					
GRASSLAND & MARSH %		G. OPEN WATER		RIVER HABITATS	
1. Acidic unimproved		1. Standing - canal		IR	bed rock
2. Semi-improved		2. ditch		b	boulders
3. Neutral unimproved		3. pond, pool, cut-off		c	cobbles
4. Semi-improved		4. lake %		p	pebbles
5. Calcareous unimproved		5. gravel pit %		g	gravel
6. Semi-improved		6. reservoir %		s	sand
7. Improved/seeded		7. mowing %		+	silts/clay
8. Marsh/marshy grassland		8. stream < 1m wide		@	peat
TALL HERB & REED %		1. ROCK		Habitats and Flow	
1. Bracken		1. cliff		Ⓟ	pool
2. Upland spp. rich veg.		2. screes		ss	slack
3. Other - tall ruderal		3. limestone pavement		tt	tillo
4. Other - tall ruderal		4. cave		rr	rapids
5. Other - tall ruderal		5. other		rrn	run
6. Other - tall ruderal		6. artificial/waste		rrn	waterfall
HEATHLAND %		1. MISCELLANEOUS		protruding rocks	
1. Dwarf scrub - dry		1. arable		Δ	Δ
2. Lichen/bryophyte		2. amenity grassland		Δ	Δ
3. Montane		3. ephemeral/short herb		Δ	Δ
4. Heath/grassland - dry		4. hedge		Δ	Δ
5. Wet		5. hedge =		Δ	Δ
6. Wet		6. fence on bank		Δ	Δ
MIRE, FLUSH AND SPRING %		1. MIRE, FLUSH AND SPRING %		FLORA %	
1. Mires - bog		1. Fen - reed		ss	ss
2. Bog flushes		2. sedge		ss	ss
3. Sweet-grass		3. mixed		ss	ss
4. Bog flushes		4. bog flushes		ss	ss
5. Swamp - single sp. dom.		5. Tall mixed assemblage		ss	ss
6. Tall mixed assemblage		6. other		ss	ss
SWAMP/INUNDATION %		ISLANDS		ISLANDS	
1. Swamp - single sp. dom.		1. Rocky, vegetated		ss	ss
2. Tall mixed assemblage		2. rocky, 1 bare		ss	ss
3. Shingle, rock + veg		3. shingle, rock + veg		ss	ss
4. earth - mature		4. earth - mature		ss	ss
5. earth - with trees		5. earth - with trees		ss	ss
6. developed		6. developed		ss	ss



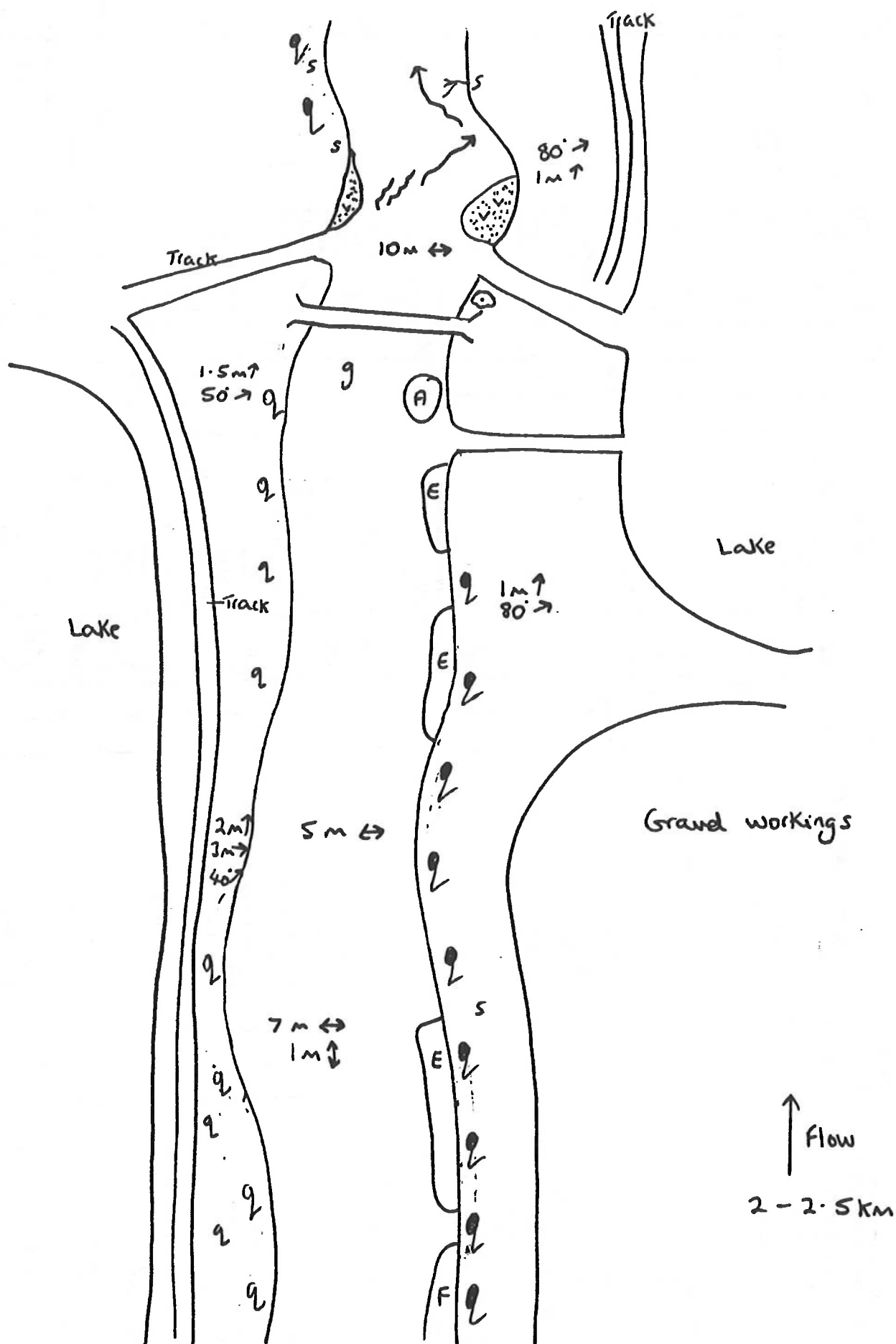
LG RB		LB RB		RIVER	
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-nat. plantation 2. Scrub - dense Carr - alder willow 3. Parkland 4. Recently felled wood		RIVER WENSUM Run No. 0-5-1 Date 20/6/92 Surveyor JALD		BANK FEATURES % 1. sh. 1 % solid earth cliff 1m ↑ solid earth cliff > 80° rock cliff artificial flood bank adj. flood bank set back levee Height < 1m 1 < 2m > 2m Width < 1m 1 < 2.5m 2.5 < 5m > 5m Slope < 30° 30 < 45° 45 < 60° > 60° mud sand bare shingle vegetated shingle earth natural cutbanks natural bankings BANK VEGETATION Caudex Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick scrub/shrub % Sparse scrub/shrub % River's edge % Dense open % Sparse open % Re-seeded or mown % Exposed tree roots ISLANDS Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed	
B. GRASSLAND & MARSH % 1. Acidic unimproved semi-improved Neutral unimproved semi-improved Calcareous unimproved semi-improved Improved/crosetted 4. Marsh/marshy grassland		G. OPEN WATER 1. Standing - canal + canal = ditch dyke pond, pool, cut-off % lake % gravel pit % reservoir % natural % flowing stream < 1m wide 1-5m 5-10m > 10		Substrates BR bed rock b boulders c cobbles p pebbles g gravel s sand + silty mud clay peat Habitats and Flow pool slack riffle rapids run waterfall protruding rocks	
C. TALL HERB & FERN % 1. Bracken 2. Upland sp. rich veget. 3. Other - tall ruderal non ruderal		100 100		100 100	
D. HEATHLAND % 1. Dwarf scrub - dry wet 3. Lichen/bryophyto 4. Montane 5. Heath/grassland - dry wet		20		90 5 5	
E. MIRE, FLUSH AND SPRING % 1. Mires - bog Fen - reed sedge sweet-grass mixed 2. Bog flushes		100		100	
F. SWAMP/INUNDATION % 1. Swamp - single sp. dom. Tall mixed assemblage		80 20		80 20	
				total 100%	



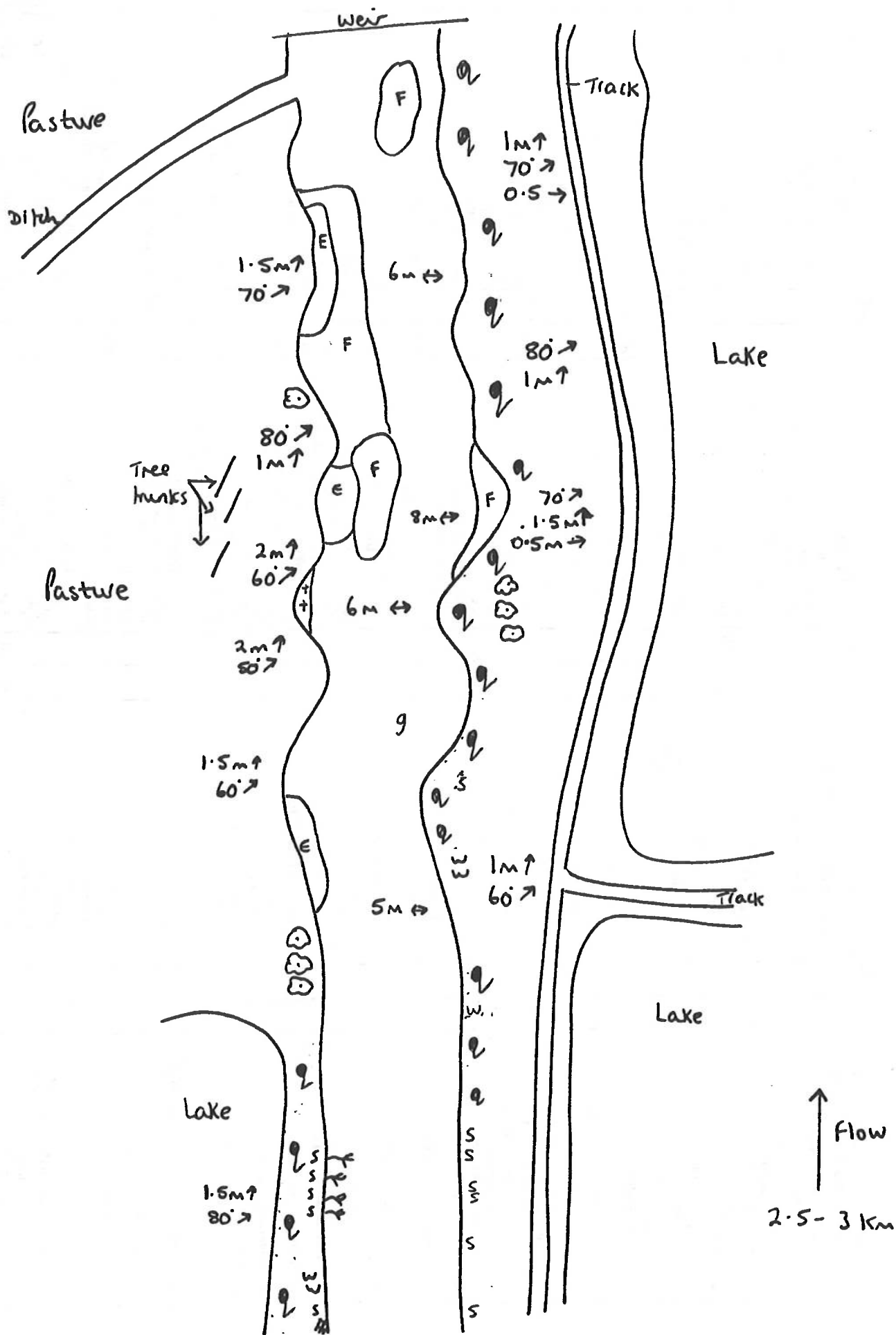
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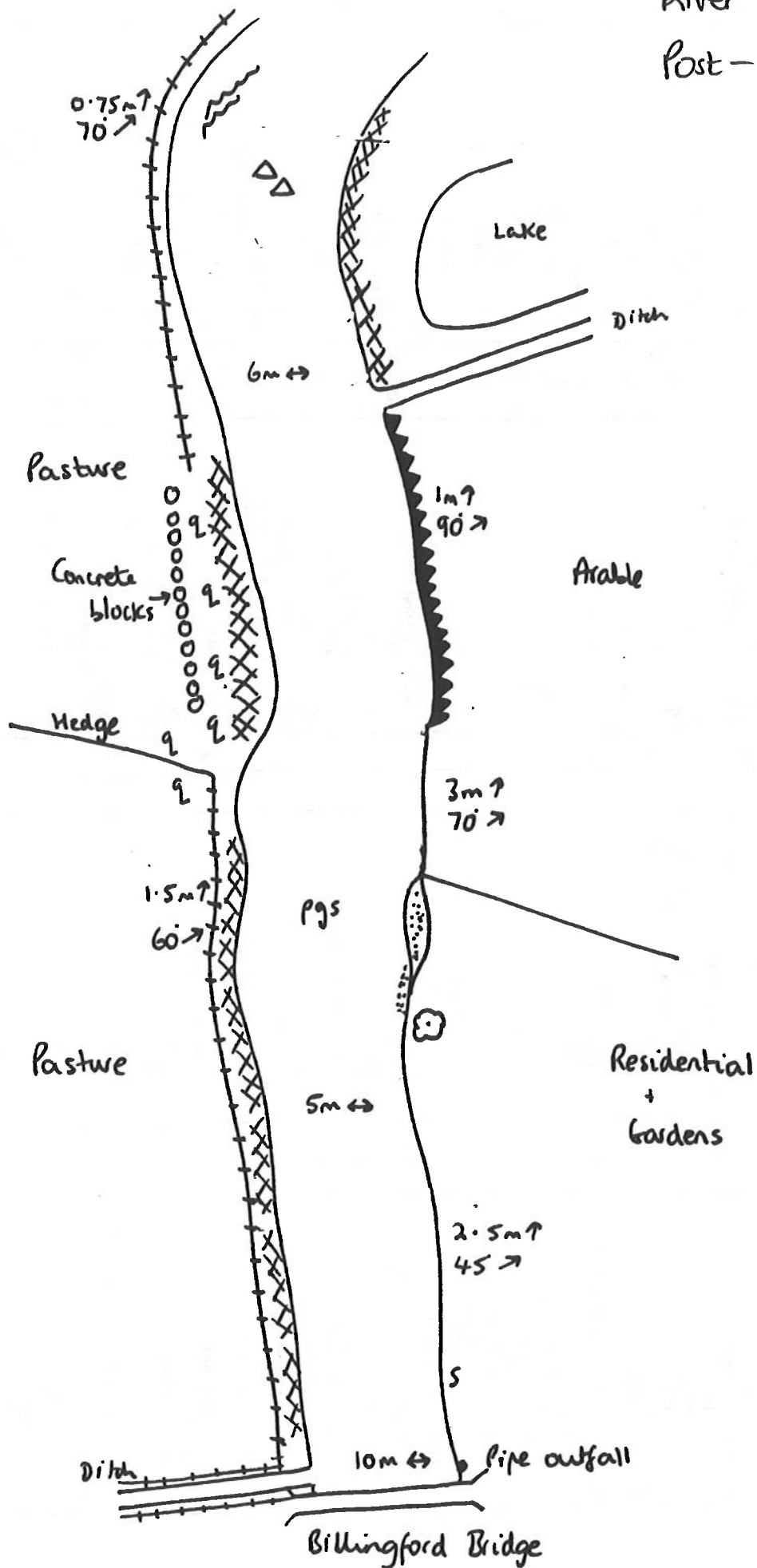
LG RB		LS RB		LB RB		RIVER	
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-natural plantation 2. Scrub - dense scattered Carr - alder willow 3. Parkland 4. Recently felled wood		RIVER WENSUM Km No. 1.5-2 Date 21/6/92 Surveyor JALD		BANK FEATURES % T- sh. 4% AAA solid earth cliff 1m ↑ AXX solid earth cliff > 80% (11) rock cliff (111) artificial (1111) flood bank ash (11111) flood bank soil back (111111) levee Height < 1m ↑ 1-2m > 2m Width < 1m → 1-2.5m 2.5-5m > 5m Slope < 30° 30-45° 45-60° > 60° 45-60° 60-75° 75-90° 90-100° 100-110° 110-120° 120-130° 130-140° 140-150° 150-160° 160-170° 170-180° 180-190° 190-200° 200-210° 210-220° 220-230° 230-240° 240-250° 250-260° 260-270° 270-280° 280-290° 290-300° 300-310° 310-320° 320-330° 330-340° 340-350° 350-360° 360-370° 370-380° 380-390° 390-400° 400-410° 410-420° 420-430° 430-440° 440-450° 450-460° 460-470° 470-480° 480-490° 490-500° 500-510° 510-520° 520-530° 530-540° 540-550° 550-560° 560-570° 570-580° 580-590° 590-600° 600-610° 610-620° 620-630° 630-640° 640-650° 650-660° 660-670° 670-680° 680-690° 690-700° 700-710° 710-720° 720-730° 730-740° 740-750° 750-760° 760-770° 770-780° 780-790° 790-800° 800-810° 810-820° 820-830° 830-840° 840-850° 850-860° 860-870° 870-880° 880-890° 890-900° 900-910° 910-920° 920-930° 930-940° 940-950° 950-960° 960-970° 970-980° 980-990° 990-1000° 1000-1010° 1010-1020° 1020-1030° 1030-1040° 1040-1050° 1050-1060° 1060-1070° 1070-1080° 1080-1090° 1090-1100° 1100-1110° 1110-1120° 1120-1130° 1130-1140° 1140-1150° 1150-1160° 1160-1170° 1170-1180° 1180-1190° 1190-1200° 1200-1210° 1210-1220° 1220-1230° 1230-1240° 1240-1250° 1250-1260° 1260-1270° 1270-1280° 1280-1290° 1290-1300° 1300-1310° 1310-1320° 1320-1330° 1330-1340° 1340-1350° 1350-1360° 1360-1370° 1370-1380° 1380-1390° 1390-1400° 1400-1410° 1410-1420° 1420-1430° 1430-1440° 1440-1450° 1450-1460° 1460-1470° 1470-1480° 1480-1490° 1490-1500° 1500-1510° 1510-1520° 1520-1530° 1530-1540° 1540-1550° 1550-1560° 1560-1570° 1570-1580° 1580-1590° 1590-1600° 1600-1610° 1610-1620° 1620-1630° 1630-1640° 1640-1650° 1650-1660° 1660-1670° 1670-1680° 1680-1690° 1690-1700° 1700-1710° 1710-1720° 1720-1730° 1730-1740° 1740-1750° 1750-1760° 1760-1770° 1770-1780° 1780-1790° 1790-1800° 1800-1810° 1810-1820° 1820-1830° 1830-1840° 1840-1850° 1850-1860° 1860-1870° 1870-1880° 1880-1890° 1890-1900° 1900-1910° 1910-1920° 1920-1930° 1930-1940° 1940-1950° 1950-1960° 1960-1970° 1970-1980° 1980-1990° 1990-2000° 2000-2010° 2010-2020° 2020-2030° 2030-2040° 2040-2050° 2050-2060° 2060-2070° 2070-2080° 2080-2090° 2090-2100° 2100-2110° 2110-2120° 2120-2130° 2130-2140° 2140-2150° 2150-2160° 2160-2170° 2170-2180° 2180-2190° 2190-2200° 2200-2210° 2210-2220° 2220-2230° 2230-2240° 2240-2250° 2250-2260° 2260-2270° 2270-2280° 2280-2290° 2290-2300° 2300-2310° 2310-2320° 2320-2330° 2330-2340° 2340-2350° 2350-2360° 2360-2370° 2370-2380° 2380-2390° 2390-2400° 2400-2410° 2410-2420° 2420-2430° 2430-2440° 2440-2450° 2450-2460° 2460-2470° 2470-2480° 2480-2490° 2490-2500° 2500-2510° 2510-2520° 2520-2530° 2530-2540° 2540-2550° 2550-2560° 2560-2570° 2570-2580° 2580-2590° 2590-2600° 2600-2610° 2610-2620° 2620-2630° 2630-2640° 2640-2650° 2650-2660° 2660-2670° 2670-2680° 2680-2690° 2690-2700° 2700-2710° 2710-2720° 2720-2730° 2730-2740° 2740-2750° 2750-2760° 2760-2770° 2770-2780° 2780-2790° 2790-2800° 2800-2810° 2810-2820° 2820-2830° 2830-2840° 2840-2850° 2850-2860° 2860-2870° 2870-2880° 2880-2890° 2890-2900° 2900-2910° 2910-2920° 2920-2930° 2930-2940° 2940-2950° 2950-2960° 2960-2970° 2970-2980° 2980-2990° 2990-3000° 3000-3010° 3010-3020° 3020-3030° 3030-3040° 3040-3050° 3050-3060° 3060-3070° 3070-3080° 3080-3090° 3090-3100° 3100-3110° 3110-3120° 3120-3130° 3130-3140° 3140-3150° 3150-3160° 3160-3170° 3170-3180° 3180-3190° 3190-3200° 3200-3210° 3210-3220° 3220-3230° 3230-3240° 3240-3250° 3250-3260° 3260-3270° 3270-3280° 3280-3290° 3290-3300° 3300-3310° 3310-3320° 3320-3330° 3330-3340° 3340-3350° 3350-3360° 3360-3370° 3370-3380° 3380-3390° 3390-3400° 3400-3410° 3410-3420° 3420-3430° 3430-3440° 3440-3450° 3450-3460° 3460-3470° 3470-3480° 3480-3490° 3490-3500° 3500-3510° 3510-3520° 3520-3530° 3530-3540° 3540-3550° 3550-3560° 3560-3570° 3570-3580° 3580-3590° 3590-3600° 3600-3610° 3610-3620° 3620-3630° 3630-3640° 3640-3650° 3650-3660° 3660-3670° 3670-3680° 3680-3690° 3690-3700° 3700-3710° 3710-3720° 3720-3730° 3730-3740° 3740-3750° 3750-3760° 3760-3770° 3770-3780° 3780-3790° 3790-3800° 3800-3810° 3810-3820° 3820-3830° 3830-3840° 3840-3850° 3850-3860° 3860-3870° 3870-3880° 3880-3890° 3890-3900° 3900-3910° 3910-3920° 3920-3930° 3930-3940° 3940-3950° 3950-3960° 3960-3970° 3970-3980° 3980-3990° 3990-4000° 4000-4010° 4010-4020° 4020-4030° 4030-4040° 4040-4050° 4050-4060° 4060-4070° 4070-4080° 4080-4090° 4090-4100° 4100-4110° 4110-4120° 4120-4130° 4130-4140° 4140-4150° 4150-4160° 4160-4170° 4170-4180° 4180-4190° 4190-4200° 4200-4210° 4210-4220° 4220-4230° 4230-4240° 4240-4250° 4250-4260° 4260-4270° 4270-4280° 4280-4290° 4290-4300° 4300-4310° 4310-4320° 4320-4330° 4330-4340° 4340-4350° 4350-4360° 4360-4370° 4370-4380° 4380-4390° 4390-4400° 4400-4410° 4410-4420° 4420-4430° 4430-4440° 4440-4450° 4450-4460° 4460-4470° 4470-4480° 4480-4490° 4490-4500° 4500-4510° 4510-4520° 4520-4530° 4530-4540° 4540-4550° 4550-4560° 4560-4570° 4570-4580° 4580-4590° 4590-4600° 4600-4610° 4610-4620° 4620-4630° 4630-4640° 4640-4650° 4650-4660° 4660-4670° 4670-4680° 4680-4690° 4690-4700° 4700-4710° 4710-4720° 4720-4730° 4730-4740° 4740-4750° 4750-4760° 4760-4770° 4770-4780° 4780-4790° 4790-4800° 4800-4810° 4810-4820° 4820-4830° 4830-4840° 4840-4850° 4850-4860° 4860-4870° 4870-4880° 4880-4890° 4890-4900° 4900-4910° 4910-4920° 4920-4930° 4930-4940° 4940-4950° 4950-4960° 4960-4970° 4970-4980° 4980-4990° 4990-5000° 5000-5010° 5010-5020° 5020-5030° 5030-5040° 5040-5050° 5050-5060° 5060-5070° 5070-5080° 5080-5090° 5090-5100° 5100-5110° 5110-5120° 5120-5130° 5130-5140° 5140-5150° 5150-5160° 5160-5170° 5170-5180° 5180-5190° 5190-5200° 5200-5210° 5210-5220° 5220-5230° 5230-5240° 5240-5250° 5250-5260° 5260-5270° 5270-5280° 5280-5290° 5290-5300° 5300-5310° 5310-5320° 5320-5330° 5330-5340° 5340-5350° 5350-5360° 5360-5370° 5370-5380° 5380-5390° 5390-5400° 5400-5410° 5410-5420° 5420-5430° 5430-5440° 5440-5450° 5450-5460° 5460-5470° 5470-5480° 5480-5490° 5490-5500° 5500-5510° 5510-5520° 5520-5530° 5530-5540° 5540-5550° 5550-5560° 5560-5570° 5570-5580° 5580-5590° 5590-5600° 5600-5610° 5610-5620° 5620-5630° 5630-5640° 5640-5650° 5650-5660° 5660-5670° 5670-5680° 5680-5690° 5690-5700° 5700-5710° 5710-5720° 5720-5730° 5730-5740° 5740-5750° 5750-5760° 5760-5770° 5770-5780° 5780-5790° 5790-5800° 5800-5810° 5810-5820° 5820-5830° 5830-5840° 5840-5850° 5850-5860° 5860-5870° 5870-5880° 5880-5890° 5890-5900° 5900-5910° 5910-5920° 5920-5930° 5930-5940° 5940-5950° 5950-5960° 5960-5970° 5970-5980° 5980-5990° 5990-6000° 6000-6010° 6010-6020° 6020-6030° 6030-6040° 6040-6050° 6050-6060° 6060-6070° 6070-6080° 6080-6090° 6090-6100° 6100-6110° 6110-6120° 6120-6130° 6130-6140° 6140-6150° 6150-6160° 6160-6170° 6170-6180° 6180-6190° 6190-6200° 6200-6210° 6210-6220° 6220-6230° 6230-6240° 6240-6250° 6250-6260° 6260-6270° 6270-6280° 6280-6290° 6290-6300° 6300-6310° 6310-6320° 6320-6330° 6330-6340° 6340-6350° 6350-6360° 6360-6370° 6370-6380° 6380-6390° 6390-6400° 6400-6410° 6410-6420° 6420-6430° 6430-6440° 6440-6450° 6450-6460° 6460-6470° 6470-6480° 6480-6490° 6490-6500° 6500-6510° 6510-6520° 6520-6530° 6530-6540° 6540-6550° 6550-6560° 6560-6570° 6570-6580° 6580-6590° 6590-6600° 6600-6610° 6610-6620° 6620-6630° 6630-6640° 6640-6650° 6650-6660° 6660-6670° 6670-6680° 6680-6690° 6690-6700° 6700-6710° 6710-6720° 6720-6730° 6730-6740° 6740-6750° 6750-6760° 6760-6770° 6770-6780° 6780-6790° 6790-6800° 6800-6810° 6810-6820° 6820-6830° 6830-6840° 6840-6850° 6850-6860° 6860-6870° 6870-6880° 6880-6890° 6890-6900° 6900-6910° 6910-6920° 6920-6930° 6930-6940° 6940-6950° 6950-6960° 6960-6970° 6970-6980° 6980-6990° 6990-7000° 7000-7010° 7010-7020° 7020-7030° 7030-7040° 7040-7050° 7050-7060° 7060-7070° 7070-7080° 7080-7090° 7090-7100° 7100-7110° 7110-7120° 7120-7130° 7130-7140° 7140-7150° 7150-7160° 7160-7170° 7170-7180° 7180-7190° 7190-7200° 7200-7210° 7210-7220° 7220-7230° 7230-7240° 7240-7250° 7250-7260° 7260-7270° 7270-7280° 7280-7290° 7290-7300° 7300-7310° 7310-7320° 7320-7330° 7330-7340° 7340-7350° 7350-7360° 7360-7370° 7370-7380° 7380-7390° 7390-7400° 7400-7410° 7410-7420° 7420-7430° 7430-7440° 7440-7450° 7450-7460° 7460-7470° 7470-7480° 7480-7490° 7490-7500° 7500-7510° 7510-7520° 7520-7530° 7530-7540° 7540-7550° 7550-7560° 7560-7570° 7570-7580° 7580-7590° 7590-7600° 76			



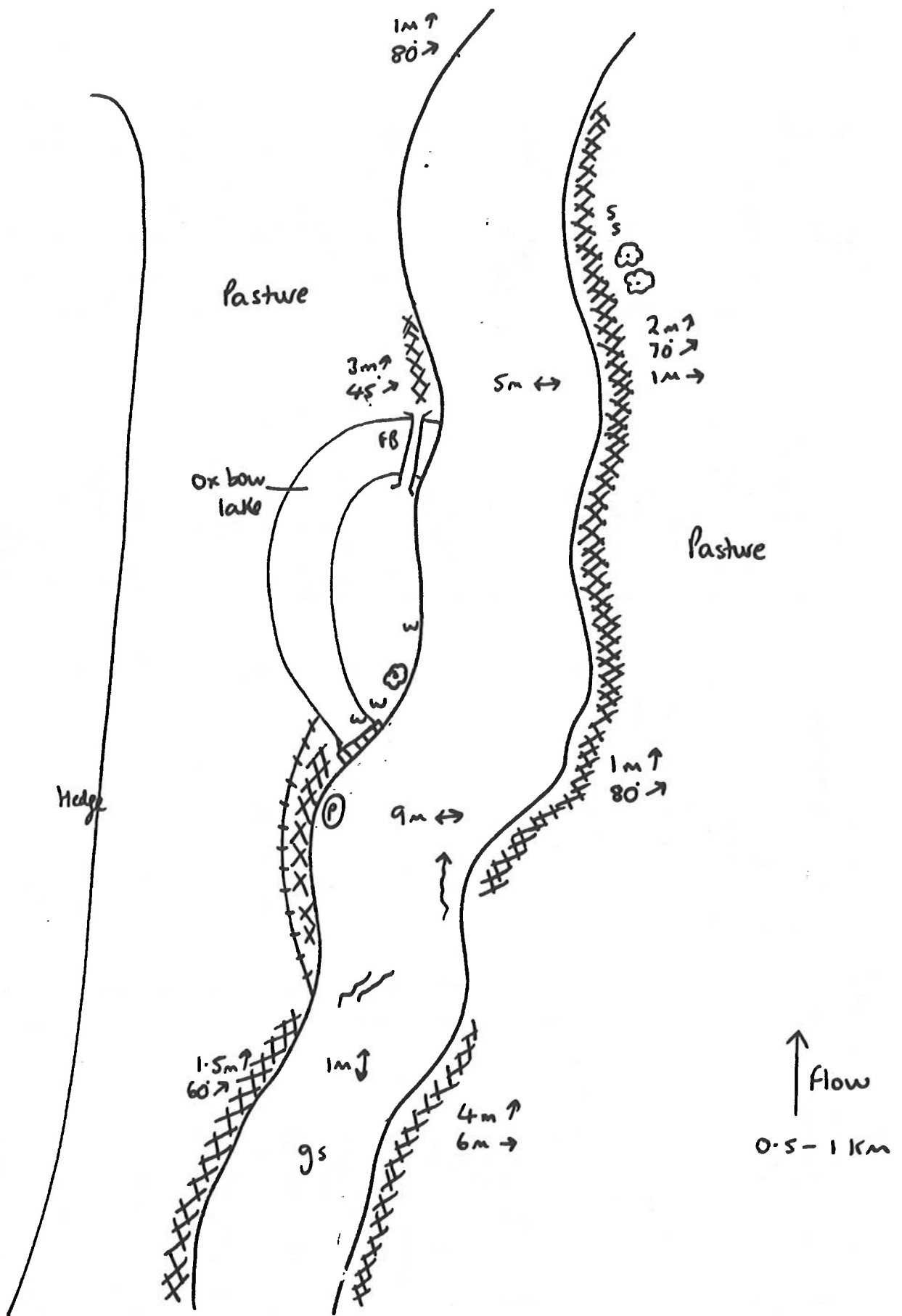
LG RB		RIVER		LB RB		RIVER			
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-natural plantation Scrub - dense Carr - alder Parkland Recently felled wood		RIVER WENSUM Km No. 2-2.5 Date 21/6/92 Surveyor JALD		BANK FEATURES % 1. sh. cliff % 2. solid earth cliff 1m 3. soil earth cliff > 80 4. rock cliff 5. artificial 6. flood bank only 7. flood bank soil back 8. levee		RIVER HABITATS 1. bridges/500m 2. weirs/500m 3. locks/500m 4. Intc/500m 5. Depth < 25m 6. 25- < 5 7. 0.5- < 1.0 8. > 1.0m 9. Width < 1 10. 1- < 5 11. 5- < 10 12. 10- < 20 13. > 20 14. Substrates 15. bed rock 16. boulders 17. cobbles 18. pebbles 19. gravel 20. sand 21. silt/mud 22. clay 23. peat 24. Habitats and Flow 25. pool 26. slack 27. riffle 28. rapids 29. run 30. waterfall 31. protruding rocks 32. Margins 33. shingle & bare 34. shingle, vegetated 35. mud 36. sand 37. FLOW % 38. emergent veg < 1m wide 39. emergent 1-2m wide 40. emergent > 2m wide 41. total veget area 42. bryophytes 43. emergents 44. submerged 45. floating 46. algae % of stretch 47. Total 100%			
B. GRASSLAND & MARSH % 1. Acidic unimproved 2. semi-improved 3. Neutral unimproved 4. semi-improved 5. Calcareous unimproved 6. semi-improved 7. unimproved/overseeded 8. Marsh/marshy grassland		G. OPEN WATER 1. Standing - canal + 2. canal = 3. ditch 4. dyke 5. pond, pool, cut-off % 6. lake % 7. gravel pit % 8. reservoir % 9. marsh % 10. running 11. stream < 1m wide 12. 1-5m 13. 5-10m 14. > 10		BANK VEGETATION 1. Canals 2. Oak, Ash, Sycamore 3. Willow - recent pollard 4. Willow old, not pollard 5. Standard willows 6. Alder 7. Other trees 8. Young trees 9. Thick scrub/shrubs % 10. Sparse scrub/shrubs % 11. Reeds/sedge % 12. Dense open % 13. Sparse open % 14. Reeds/sedge on mown % 15. Exposed tree roots 16. ISLANDS 17. Rocky, vegetated 18. rocky, 1 bare 19. shingle and rock 20. shingle, rock + veg 21. earth - maturing 22. earth - with trees 23. developed		HABITATS AND FLOW 1. pool 2. slack 3. riffle 4. rapids 5. run 6. waterfall 7. protruding rocks 8. Margins 9. shingle & bare 10. shingle, vegetated 11. mud 12. sand 13. FLOW % 14. emergent veg < 1m wide 15. emergent 1-2m wide 16. emergent > 2m wide 17. total veget area 18. bryophytes 19. emergents 20. submerged 21. floating 22. algae % of stretch 23. Total 100%			
C. TALL HERB & FERN % 1. Inacken 2. Upland ssp. rich veget. 3. Other - tall ruderal 4. non ruderal		I. ROCK 1. cliff 2. screes 3. limestone pavement 4. cave 5. other 6. artificial/waste		J. MISCELLANEOUS 1. arable 2. amenity grassland 3. ephemerals/short herb 4. hedge % 5. hedge = 6. fence on bank 7. fence set back 8. wall 9. building 10. caravans 11. fish farm 12. sludge clamp 13. sewage works 14. garden 15. stick pile 16. flood debris 17. road 18. railway disused 19. used 20. other		K. HEATHLAND % 1. Dwarf scrub - dry 2. wet 3. Lichen/bryophyte 4. Montane 5. Heath/grassland - dry 6. wet		L. MIRE, FLUSH AND SPRING % 1. Mires - bog 2. Fen - feed 3. sedge 4. sweet-grass 5. mixed 6. Dog flushes	
M. SWAMP/INUNDATION % 1. Swamp - single sp. dom. 2. Tall mixed assemblage		N. OTHER 1. other		O. TOTAL 1. Total 100%		P. TOTAL 1. Total 100%			



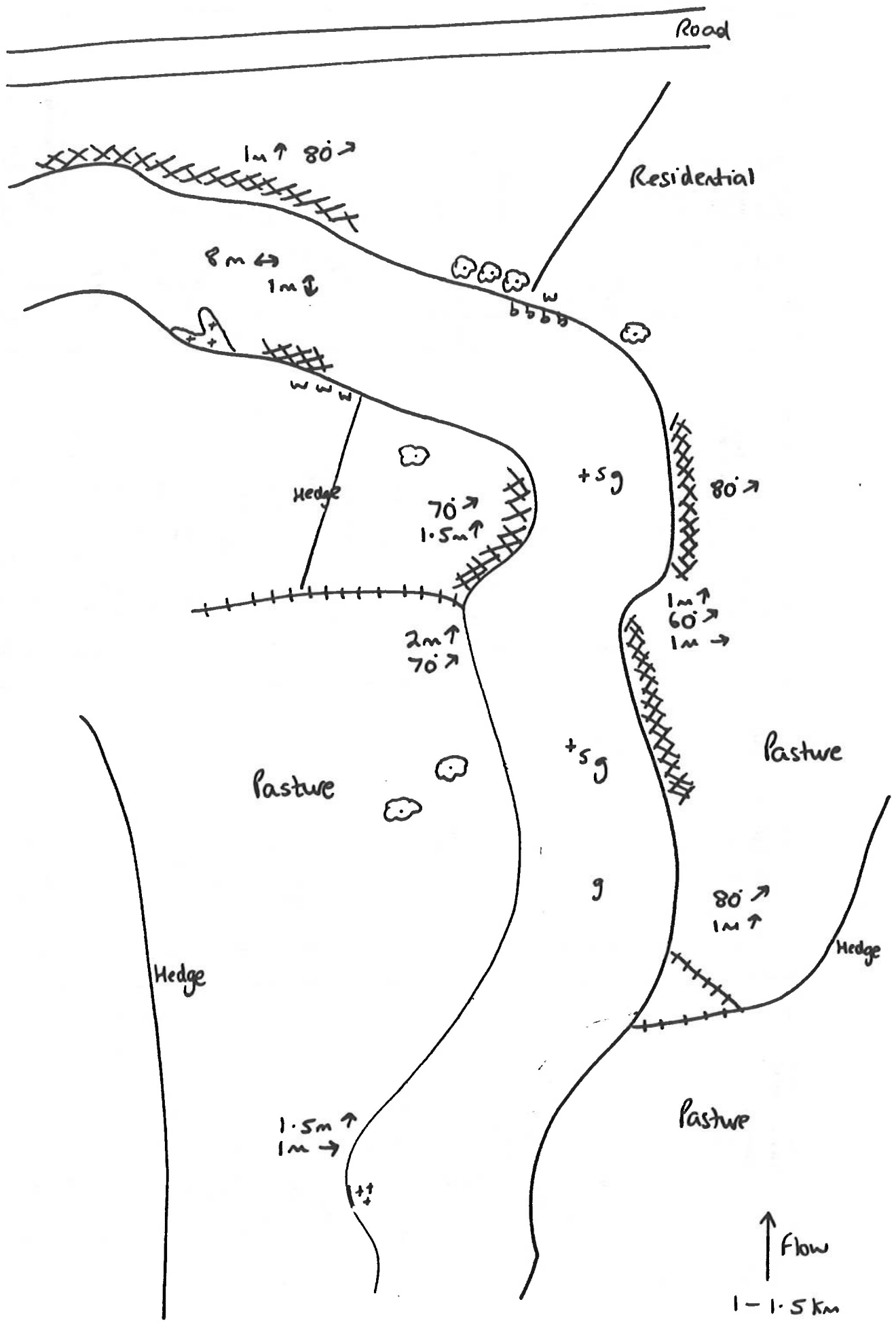
River Wensum Post-maintenance



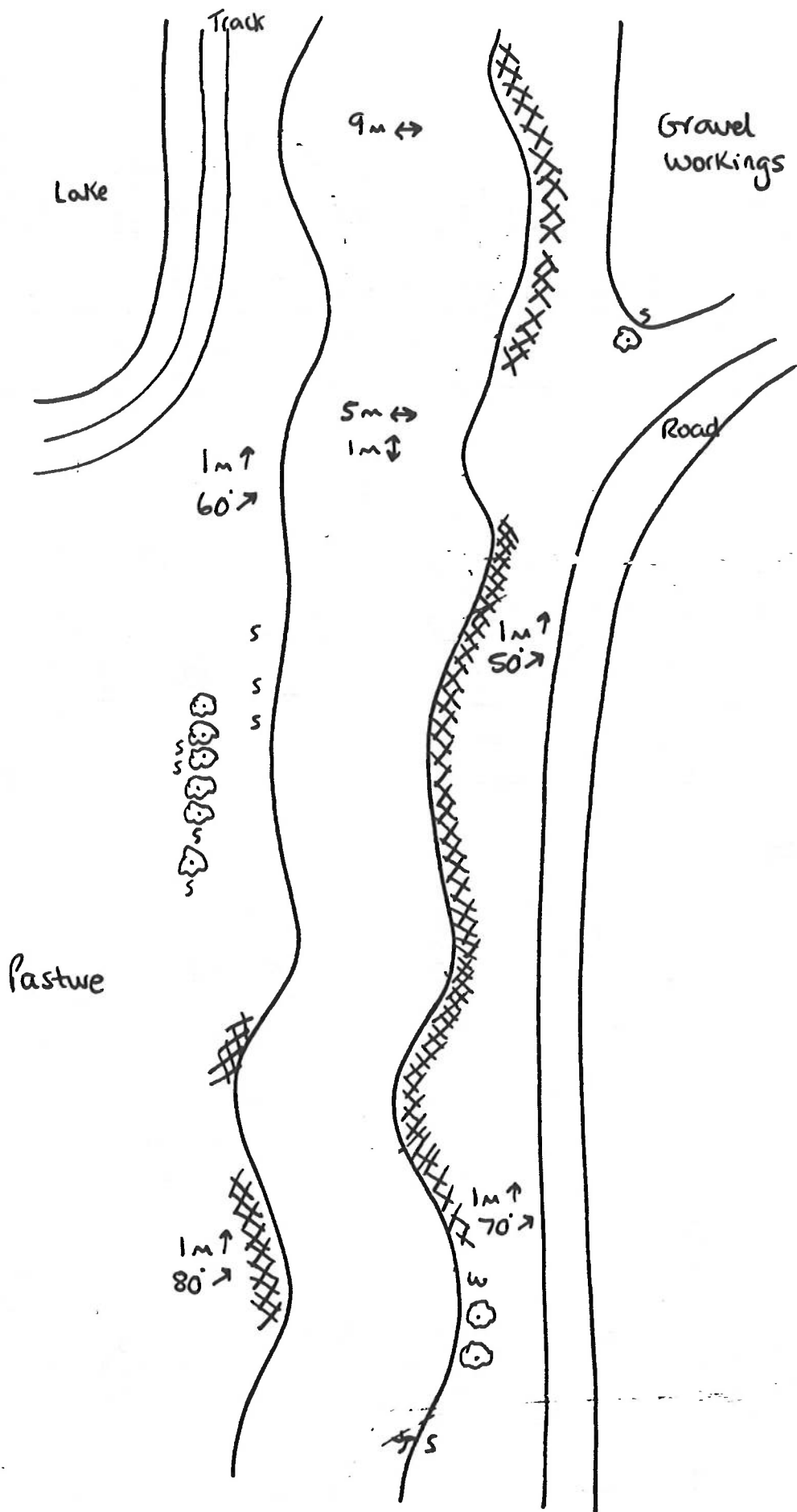
↑ Flow
0 - 0.5 km



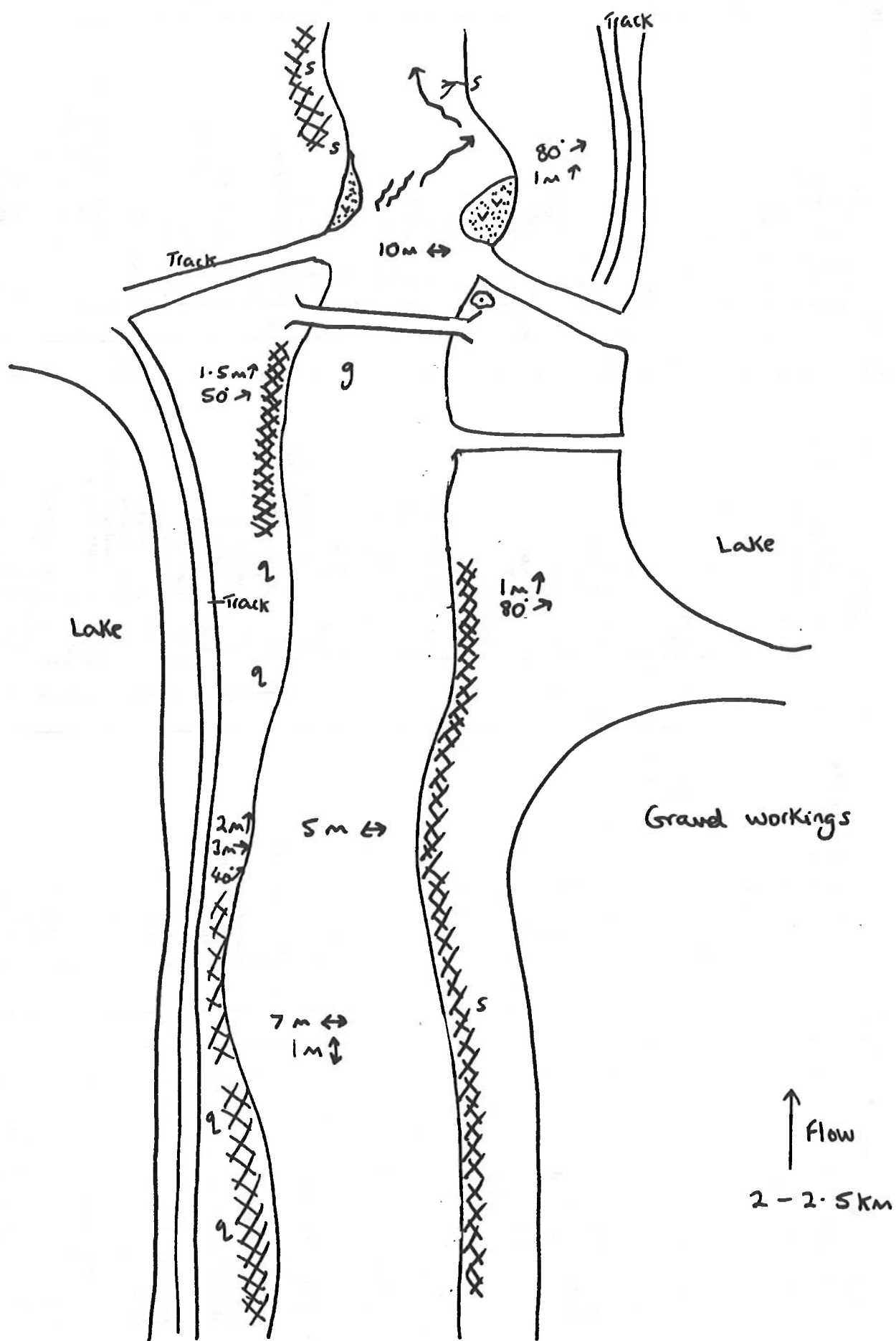
LG RG		LG RB		RIVER							
A. WOODLAND & SCRUB % 1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-natural plantation 2. Scrub - dense Carr - alder willow 3. Parkland 4. Recently felled wood		B. GRASSLAND & MARSH % 1. Acidic unimproved semi-improved Neutral unimproved semi-improved Calcareous unimproved semi-improved 4. Improved/wooded 5. Marsh/marshy grassland		C. TALL HERB & FERN % 1. Hacken 2. Upland spp. rich vegut. 3. Other - tall ruderal non ruderal		D. HEATHLAND % 1. Dwarf scrub - dry wet 3. Lichen/bryophyte 4. Montane 5. Heath/grassland - dry wet		E. MIRE, FLUSH AND SPRING % 1. Mires - bog Fen - reed sedge sweet-grass mixed 2. Bog flushes		F. SWAMP/INUNDATION % 1. Swamp - single sp. dom. Tall mixed assemblage	
RIVER WENSUM Km No. O-S-1 Date 10/92 Surveyor JALD		BANK FEATURES % 1. shell % AAA solid earth cliff 1m ↑ AAS soft earth cliff >80% (VV) rock cliff (VVVV) artificial (VV) flood bank only (VV) flood bank set back levee Height ↑ 1 < 1m 1 < 2m > 2m Width → 1 < 1m 1 < 2.5m 2.5 < 5m > 5m Slope: < 30° 30 < 45° (45 < 60°) > 60° mud sand bare shingle vegetated shingle earth natural cutbanks natural bankings BANK VEGETATION Canola Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick scrub/shrub % Sparse scrub/shrub % River/Willow % Dense open % Sparse open % Heavily cut on mown % Exposed bare rocks ISLANDS Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - mowing earth - with trees developed		RIVER HABITATS backpools/500m pools/500m locks/500m Intake/500m Depth < 25m ↑ .25 < .5 .5 < 1.0 > 1.0m Width < 1 1 < 5 5 < 10 10 < 20 > 20 Substrates b1 bed rock b2 boulders c cobbles p pebbles g gravel s sand t silt/mud clay peat Habitats and Flow pool slack riffle rapids run waterfall protruding rocks Margins shingle ± bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent > 2m wide total veg/100m layophytes emergent submerged floating algae % of stretch							
100		100		100		100		100			



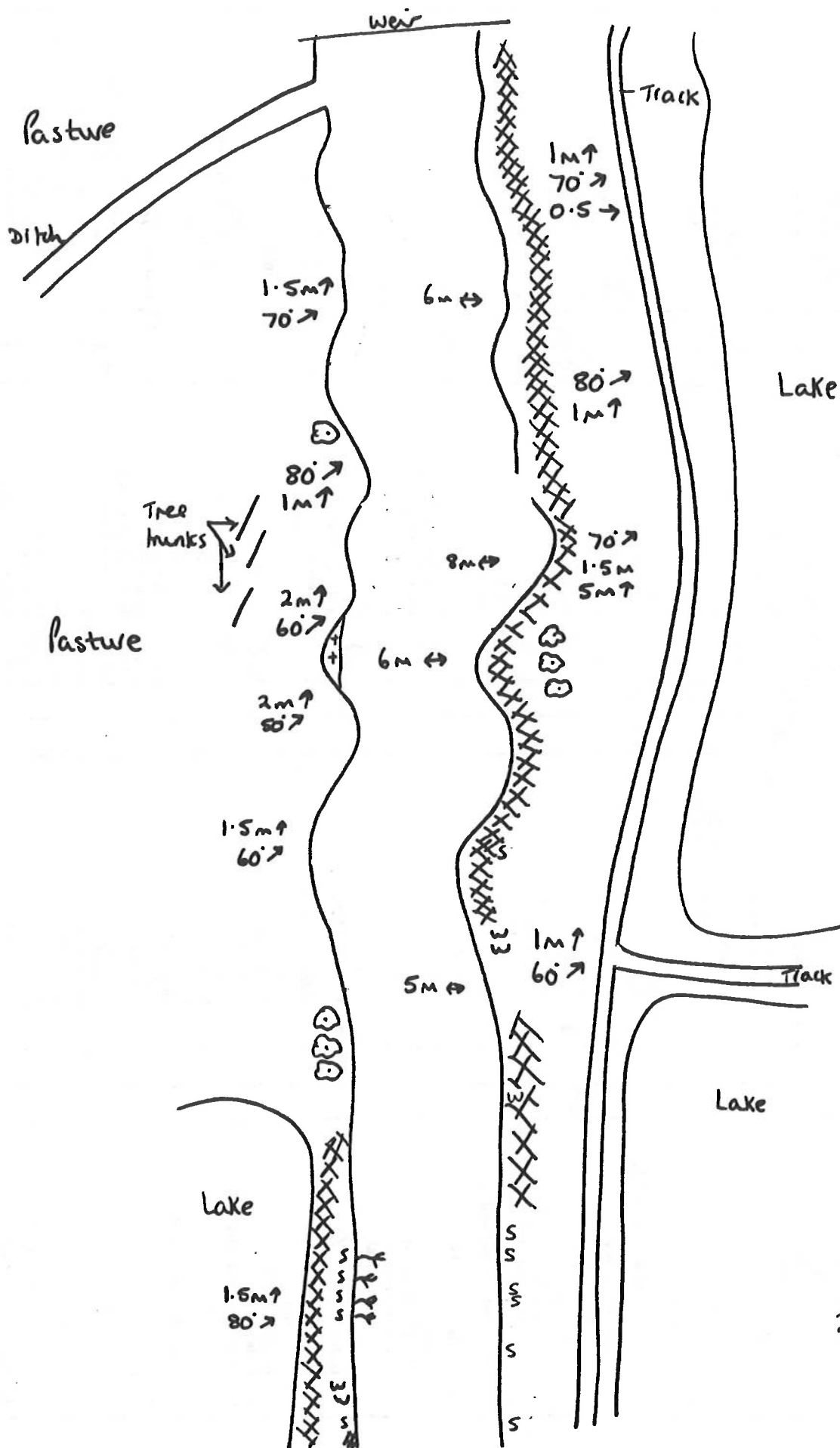
↑ Flow
1-1.5 km



↑ Flow
1.5 - 2 km

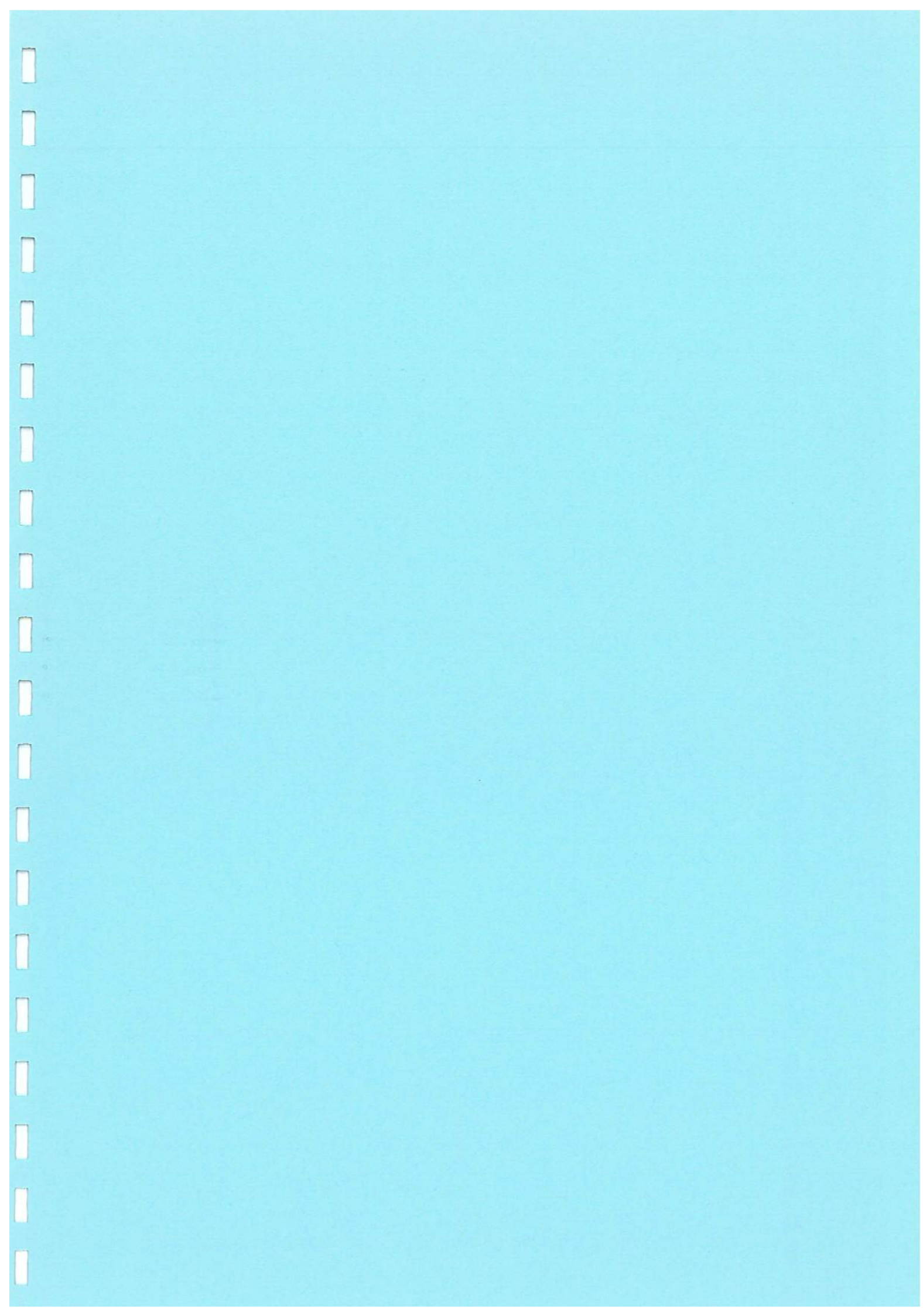


LG RB		LG RB		LG RB		LG RB		RIVER	
A. WOODLAND & SCRUB %		RIVER WENDSURY		BANK FEATURES %		RIVER HABITATS		1	
1. Broad-leaved semi-nat. plantation		River No. 2-2.5		shrub %		backlogs/500m			
Coniferous semi-nat. plantation		Date 10/92		solid earth cliff 1m↑		wens/500m			
Mixed semi-natural plantation		Surveyor JALD		solid earth cliff > 80°		locks/500m			
2. Scrub - dense				rock cliff		inlet/500m			
3. Carr - alder				artificial		Depth < 25m			
4. Parkland				flood bank only		25-45			
B. GRASSLAND & MARSH %				flood bank set back		0.5-1.0			
1. Acidic unimproved				levee		> 1.0m			
2. Neutral unimproved				Height < 1m		Width < 1			
3. Semi-improved				1-2m		1-5			
4. Improved				> 2m		5-10			
5. Marsh/marshy grassland				Width < 1m		10-20			
C. TALL HERB & FERN %				1-2.5m		> 20			
1. Blacken				2.5-5m					
2. Upland spp. rich veg.				> 5m					
3. Other - tall ruderal				Shores < 1m					
D. HEATHLAND %				30-40°					
1. Dwarf scrub - dry				60-90°					
2. Lichen/bryophyte				> 90°					
3. Montane				1-2m					
4. Heath/grassland - dry				SSS					
5. Wet				SSS					
E. MIRE, FLUSH AND SPRING %				SSS					
1. Mires - bog				SSS					
2. Fen - reed				SSS					
3. Dog flushes				SSS					
F. SWAMP/INUNDATION %				SSS					
1. Swamp - single sp. dom.				SSS					
2. Tall mixed assemblage				SSS					
G. OPEN WATER				SSS					
1. Standing - canal				SSS					
2. ditch				SSS					
3. dyke				SSS					
4. pond, pool, cut off %				SSS					
5. lake %				SSS					
6. gravel pit %				SSS					
7. reservoir %				SSS					
8. running %				SSS					
9. stream < 1m wide				SSS					
10. 1-5m				SSS					
11. 5-10m				SSS					
12. > 10				SSS					
H. ROCK				SSS					
1. cliff				SSS					
2. scree				SSS					
3. limestone pavement				SSS					
4. cave				SSS					
5. other				SSS					
6. artificial/waste				SSS					
I. MISCELLANEOUS				SSS					
1. arable				SSS					
2. amenity grassland				SSS					
3. ephemeral/silent herb				SSS					
4. hedge				SSS					
5. hedge =				SSS					
6. fence on bank				SSS					
7. fence set back				SSS					
8. wall				SSS					
9. building				SSS					
10. farm				SSS					
11. sewage works				SSS					
12. garden				SSS					
13. stock pile				SSS					
14. flood debris				SSS					
15. road				SSS					
16. railway				SSS					
17. disused				SSS					
18. other				SSS					
J. ISLANDS				SSS					
1. rocky, vegetated				SSS					
2. rocky, 1 bare				SSS					
3. simple and rock				SSS					
4. simple, rock + veg				SSS					
5. earth - natural				SSS					
6. earth - with trees				SSS					
7. developed				SSS					
K. FLORA %				SSS					
1. emergent veg ~ 1m wide				SSS					
2. emergent 1-2m wide				SSS					
3. emergent > 2m wide				SSS					
4. total veget area				SSS					
5. bryophytes				SSS					
6. emergent				SSS					
7. submerged				SSS					
8. floating				SSS					
9. algae % of stretch				SSS					



↑ Flow
2.5 - 3 km

LG RB		LB RB		RIVER	
A. WOODLAND & SCRUB %		RIVER WENSUM		RIVER HABITATS	
1. Broad-leaved semi-nat. plantation		Run No. 2-S-3		HWW	
Coniferous semi-nat. plantation		Date 10/92		DSS	
Mixed semi-natural plantation		Surveyor JALD		Depth < 25m	
2. Scrub - dense scattered		G. OPEN WATER		↑ ↓	
Carr - alder willow		1. Standing - canal + ditch dyke pond, pool, cut-off lake % gravel pit % reservoir % floating % stream < 1m wide 1 5m 5 10m > 10		Width < 1 1-5 5-10 10-20 > 20	
3. Parkland		2. Artificial/waste		Substrates	
4. Recently felled wood		1. cliff scree limestone pavement cave other		HWW	
B. GRASSLAND & MARSH %		2. artificial/waste		b boulders	
1. Acidic unimproved semi-improved		1. ROCK		c cobbles	
Neutral unimproved semi-improved		1. cliff scree limestone pavement cave other		p pebbles	
Calcareous unimproved semi-improved		2. MISCELLANEOUS		g gravel	
5. Improved/marshy grassland		1. arable ancient grassland ephemeral/short herb hedge + hedge = fence on bank fence set back wall building caravans fish farm silage clamp sewage works garden sick pile flood debris road railway disused used other		s sand	
6. Marsh/Marshy grassland		2. Artificial/waste		+ silt/mud	
C. TALL HERB & FERN %		1. ROCK		@ clay	
1. Bracken		1. cliff scree limestone pavement cave other		peat	
2. Upland spp. rich vegal.		2. MISCELLANEOUS		Habitats and Flow	
3. Other - tall ruderal iron ruderal		1. arable ancient grassland ephemeral/short herb hedge + hedge = fence on bank fence set back wall building caravans fish farm silage clamp sewage works garden sick pile flood debris road railway disused used other		pool	
D. HEATHLAND %		2. Artificial/waste		slack	
1. Dwarf scrub - dry wet		1. ROCK		riffle	
2. Lichen/bryophyte		1. cliff scree limestone pavement cave other		rapids	
3. Montane		2. MISCELLANEOUS		run	
4. Heath/grassland - dry wet		1. arable ancient grassland ephemeral/short herb hedge + hedge = fence on bank fence set back wall building caravans fish farm silage clamp sewage works garden sick pile flood debris road railway disused used other		waterfall	
5. Heath/grassland - dry wet		2. Artificial/waste		protruding rocks	
6. Wet		1. ROCK		Margins	
E. MIRE, FLUSH AND SPRING %		1. ROCK		shrubby 1 bank	
1. Mires - bog fen - reed sedge sweet-grass mixed		1. cliff scree limestone pavement cave other		shrubby, vegetated	
2. Bog flushes		2. MISCELLANEOUS		mud	
F. SWAMP/INUNDATION %		1. ROCK		SSS sand	
1. Swamp - single sp. dom. Tall mixed assemblage		1. cliff scree limestone pavement cave other		FLOORA %	
2. Swamp - single sp. dom. Tall mixed assemblage		2. MISCELLANEOUS		emergent veg ~ 1m wide	
3. Swamp - single sp. dom. Tall mixed assemblage		1. ROCK		emergent 1-2m wide	
4. Swamp - single sp. dom. Tall mixed assemblage		1. cliff scree limestone pavement cave other		emergent > 2m wide	
5. Swamp - single sp. dom. Tall mixed assemblage		2. MISCELLANEOUS		total vegal area	
6. Swamp - single sp. dom. Tall mixed assemblage		1. ROCK		bryophytes	
7. Swamp - single sp. dom. Tall mixed assemblage		1. cliff scree limestone pavement cave other		unimproved	
8. Swamp - single sp. dom. Tall mixed assemblage		2. MISCELLANEOUS		submerged	
9. Swamp - single sp. dom. Tall mixed assemblage		1. ROCK		floating	
10. Swamp - single sp. dom. Tall mixed assemblage		1. cliff scree limestone pavement cave other		algae % of stretch	



WOLDGRIFT DRAIN

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ANGLIA WOLDGRIFT DRAIN

1. BACKGROUND

1.1 Introduction

The Woldgrift Drain runs for 13.75 km from head of main river, an area of high land 1 km north of Saleby Woodhouse to its mouth through an outlet into the North Sea at Trusthorpe. The catchment area of the Woldgrift Drain is estimated to be 4015 ha. The catchment is mainly rural in character although the Woldgrift Drain is enclosed within a culvert through the market town of Alford. The major land use is intensive arable with a little temporary and permanent pasture providing a green belt area to the north of Alford.

1.2 Study Reach

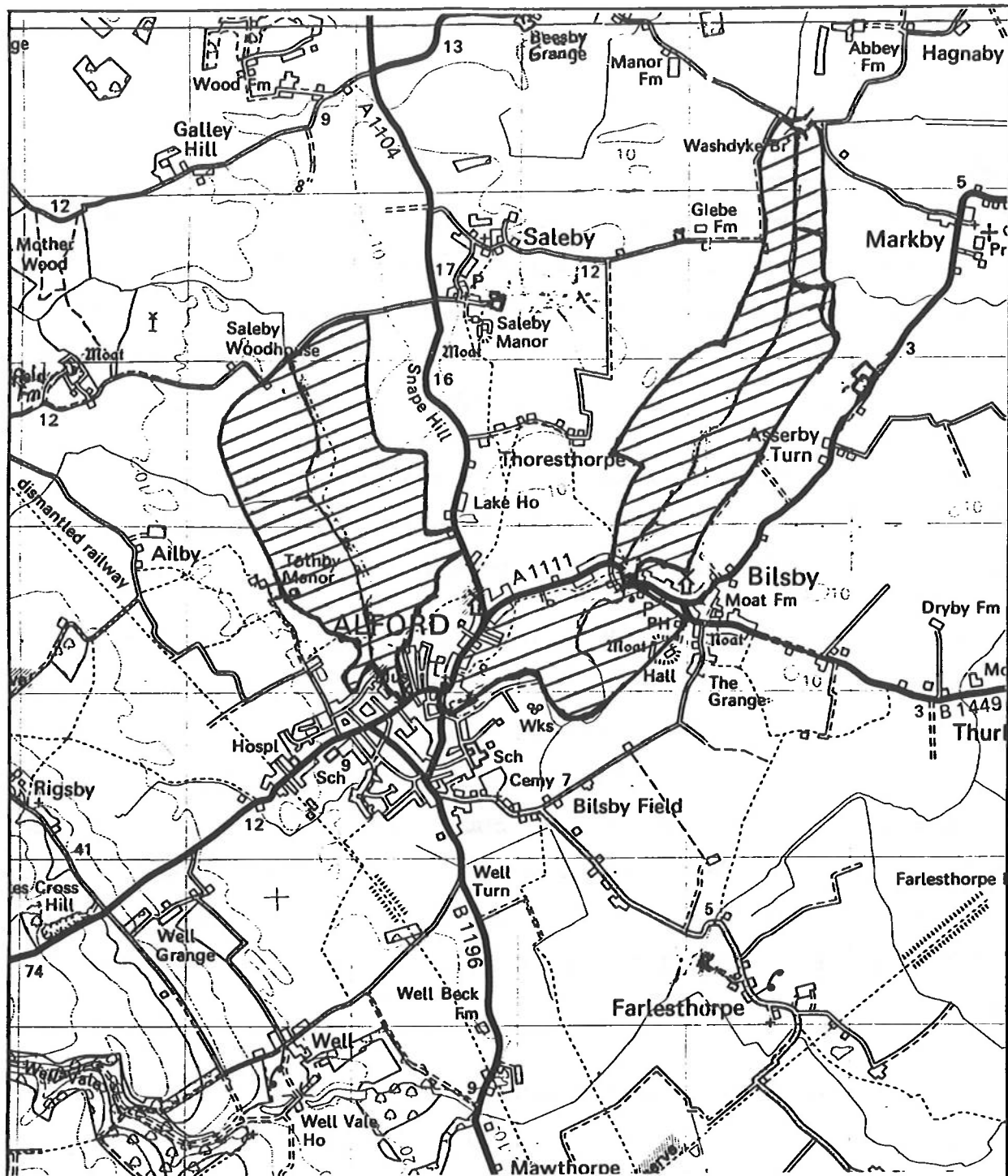
The section of the Woldgrift Drain selected for study (Figure 1) runs for 7 km between Greenfield Lane or Goose Field as it is sometimes known (GR. 780 446) and Washdyke Bridge (GR. 794 476). This site is typical of main rivers in the area on which river maintenance in the form of weed clearance is performed. The area of land benefiting from the river maintenance work in terms of its effect on flooding and land drainage is estimated to be 264 ha (Figure 1).

1.3 River Characteristics

The Woldgrift Drain is trapezoidal in shape, deep and fairly straight. It flows through an area of intensive arable land for much of its length.

The bank slope ranges from 45 to 90 degrees. The average slope is 70 degrees, although in localised sections such as through Alford the channel runs through a culvert. The freeboard is consistently high, averaging 2.5 m. At the upstream limit of the study reach (Greenfield Lane), the channel is 1 m in width, widening to 2.5 m at Washdyke Bridge. The gradient of the channel is slight, hence the slow flows which typically average 10 to 12 cumecs.

The dominant bed substrate is sand although the proportion of coarse sand and gravel increases with distance downstream. The Woldgrift Drain is tide-locked being unable to discharge into the sea until low tide due to its outfall being flapped.



Legend :



Benefit Area

Scale 1 : 32 500

Figure 1 **Location of the Woldgrift Drain site and benefit area**

1.4 Land Drainage

The Woldgrift Drain is a gravity flow drainage system. Its outfall through a tunnel in the sea defence into the North Sea at Trusthorpe, is shared with a pumped drainage system controlled by the Trusthorpe pumping station. A weir in the left bank of the Woldgrift Drain adjacent to the pumping station is set at 2 m AOD to allow for an overflow from the Woldgrift into the pumped drain. The catchment area of both these drainage systems is estimated to be 7973 ha.

The Woldgrift Drain serves the highland area upstream of Washdyke Bridge. Downstream of this bridge, the channel of the Woldgrift Drain runs over the lowland pumped scheme area but does not receive any additional water from land drainage.

Figure 2 shows the area of the benefit area which has field drainage pipes installed. Further information is provided in Section 2.5. Within the study reach twenty ditches run into the Woldgrift Drain from the right bank. Of these, 17 have flapped outfalls. On the left bank, 17 ditches discharge into the river; six of which have unflapped outfalls. The nature of one ditch on the left bank mid way between Washdyke Bridge and Bilsby was altered in 1994. The outfall of the ditch into the Woldgrift Drain (GR. 474 779) was sealed and the flow of water in the ditch reversed. This ditch is to serve as an overflow channel, allowing water to discharge from the Woldgrift Drain under high water levels once the level in the river exceeds a certain threshold.

1.5 Geology, Soils and Land Capability

The Woldgrift Drain flows over chalk bedrock which was deposited during the Cretaceous period. Alluvium deposits and chalky till overlay the chalk. The alluvium is a relic of the postglacial sea level rise which resulted in the deposition of silt and clay. The surface of the chalky till has flat crests and rounded slopes.

Soils of the Fladbury and Wallasea Association dominate the area. The Fladbury series is a pelo-alluvial gley soil which has a mottled subsoil. The Trent series (subsidiary series of the Fladbury Association) is in comparison, a loamy soil with no mottling within 40 cm of the surface. Both soils respond well to underdrainage and under this water regime they are given a value of IV under the Wetness Classification system (Hodge et al, 1984) of the Soil Survey of England and Wales (SSEW). However, waterlogging of low lying areas may occur during the

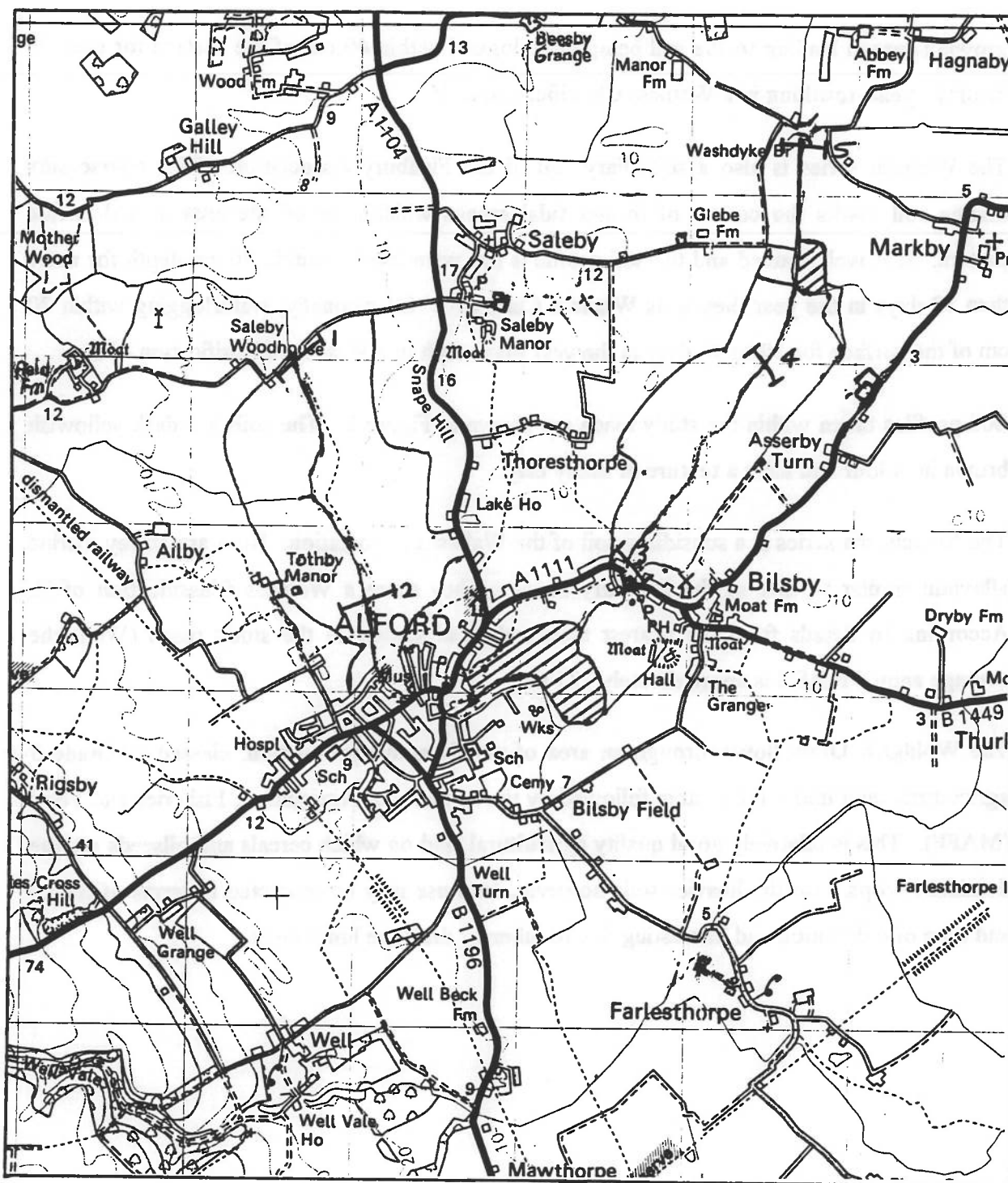
growing season leading to the soil being waterlogged within 40 cm of the surface for over 49 % of the year, resulting in a Wetness Classification of V.

The Wisbech series is also a subsidiary soil of the Fladbury Association. This coarse silty marine soil marks the course of former tidal creeks which crossed the area in a dendritic pattern. It is well drained and the soil profile is not waterlogged within 70 cm depth for more than 30 days in the year, hence its Wetness Class of I. Occasionally, waterlogging within 70 cm of the surface for 30 to 90 days in the year may result in a Wetness Classification of II.

Soil profiles taken within the study reach are shown in Figure 3. The soils are dark yellowish brown in colour and have a texture of sandy clay.

The Newchurch series is a subsidiary soil of the Wallasea Association. Both are clayey marine alluvium similar to that of the Fladbury series. They share a Wetness Classification of II. According to details from the nearest meteorological station to the study reach (Well) the average annual rainfall is approximately 721 mm.

The Woldgrift Drain flows through an area of mainly arable production, classed as Grade 3 agricultural land under the system followed by the Ministry of Agriculture, Fisheries and Food (MAFF). This is relatively good quality agricultural land on which cereals and oilseeds are the dominant crops. On the heavier soils however, land use may be restricted in terms of timing and type of cultivation and harvesting due to inherent drainage limitations.



Legend :



Piped drainage



Natural drainage



Cross-section location

Scale 1 : 32 500

Figure 2 Land drainage and location of cross-sections

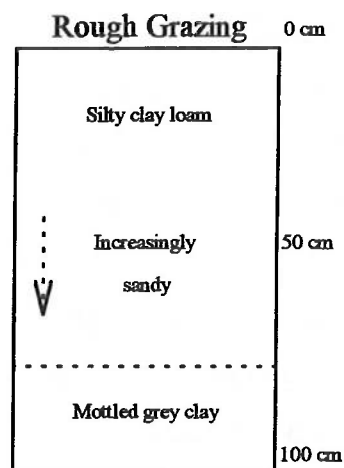
R&D 317/19/ST

Grid Reference 446 778

Soil Core Number 1

Soil Colour Dark yellowish brown

Comments Sandy clay loam

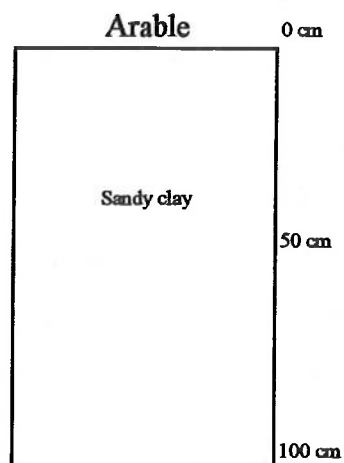


Grid Reference 467 766

Soil Core Number 2

Soil Colour Dark yellowish brown

Comments Sandy clay, friable texture, uniform profile



Grid Reference 476 793

Soil Core Number 3

Soil Colour Dark yellowish brown

Comments Well drained, uniform profile

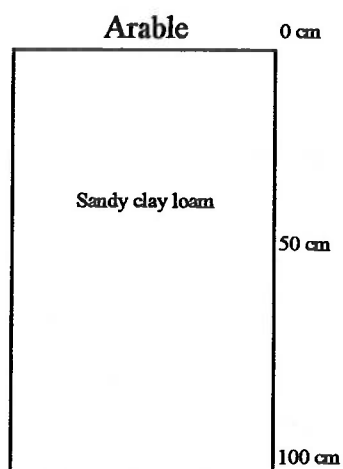


Figure 3 Soil profiles

1.6 Capital Works

During the 1950s the channel was dredged and new tidal doors were erected at the outfall at Trusthorpe. A gauging station was erected at Bilsby in the early 1980's. No other capital works have been carried out on the Woldgrift Drain in the last 30 years.

1.7 River Maintenance

The Woldgrift Drain is subjected to a regular maintenance programme to reduce flooding and for the benefit of land drainage.

Weed clearance takes place on an annual basis in August/September, using a VC 15 and a Bradshaw Bucket. A one metre fringe of vegetation is left down each channel margin. Both river banks are flail mown. Debris is removed by hand from the culvert under Alford on a regular basis. Repairs to the river banks are carried out as and when required.

Desilting of a small section downstream of Bilsby took place in June 1994. Due to scour and increased flow velocities following weed clearance, undercutting of the banks has been a problem in the past and bank slippage has resulted. The river banks were made shallower and the channel widened to increase channel capacity and bank stability and to reduce bank undercutting.

The main reason for river maintenance on the Woldgrift Drain is that it is part of a regular work programme. Response to customer demand and inspection by NRA engineers may also initiate maintenance.

The criteria for the standard of service provided by the weed cutting is based on custom and practice. The condition of the watercourse determines the method of maintenance. All people with frontages on the river are notified of pending maintenance work through a personal visit by an NRA representative.

1.7.1 Farmers views on maintenance

During interviews with farmers in the benefit area, all expressed satisfaction with the level and type of maintenance carried out within the Woldgrift Drain. One farmer questioned the necessity of removing most of the weeds from the channel but appreciated that if more were

left for aesthetic purposes, land holders upstream were likely to suffer land drainage problems and possible flooding in times of higher flow.

1.7.2 Alternative maintenance strategies

One comment was raised by several farmers - if the channel capacity was increased, the ability of the Woldgrift Drain to store more water during flood conditions would be increased. The view that the channel should be widened, deepened and pumped was expressed by one farmer. Several also thought that the culvert under Alford should be enlarged.

1.8 Climate

The impact of river maintenance on watertable depth and river levels depends on the particular weather conditions, especially rainfall, which vary between seasons and years. The seasonal and yearly rainfall totals (Well meteorological station, GR. 5448 3738) for the period of study are presented in Table 1.1.

Table 1.1 Rainfall totals

Period	Season	Actual Rainfall (mm)	Average * Rainfall (mm)	% Average Rainfall
1992	Spring	138.3	155.1	89.2
	Summer	204.8	162.6	126.0
	Autumn	235.9	170.4	138.4
1993	Spring	139.9	155.1	90.2
	Summer	149.3	162.6	91.8
	Autumn	307.2	170.4	180.3
1994	Spring	170.3	155.1	109.8
	Summer	82.8	162.6	50.9
	Autumn	205.5	170.4	126.6
1995	Spring	118.4	155.1	76.3
Year	1992	698.3	1984.5	35.1
	1993	761.9	1984.5	38.4
	1994	681.6	1984.5	34.3

* Based on 18 year record from 1976 - 1993

The summer of 1992, autumn of 1992, 1993 and 1994 were wet when compared to the long term average rainfall totals. This fact is confirmed by farmers who reported waterlogged soils

and flood conditions during the autumn and winter period. The remainder of the study period is classed as dry or average in terms of the rainfall received.

Monthly rainfall records (from Well met. station, GR. 5448 3738) covering a period of 18 years have been used to determine the probability of wet, average and dry seasons and years occurring (Table 1.2) in the immediate area round the Woldgrift Drain. The classification of seasons and years is based on that of the Food and Agricultural Organisation (FAO). Further details are contained in the R&D Note 456, Section 3.5.4. Dry and wet seasons and years are classed as those with < 75 % of the mean and > 125 % of the mean respectively.

Table 1.2 Probability of climatic conditions

Season	Dry *	Average *	Wet*
Spring	0.29	0.59	0.12
Summer	0.18	0.53	0.29
Autumn	0.24	0.58	0.18
Year	0.17	0.44	0.39

* Based on records since 1976

The R&D Note 456, Section 3.5.4 describes the process by which financial benefits of maintenance are calculated according to the probability of average, dry and wet seasons and years occurring.

1.9 Aquatic Vegetation

Aquatic vegetation within the channel was identified prior to maintenance (Section 1.9.1 to 1.9.3). This vegetation has both hydraulic and environmental implications for the channel.

1.9.1 Submerged vegetation

The *Elodea* sp. (Canadian pondweed) and *Potamogeton* sp. (Dogs Tongue or pondweed) are the dominant species of aquatic weed within the study reach. Their preferred habitats are areas of sluggish to moderate waters such as drainage channels, ponds and lakes.

The Canadian pondweed is a submerged aquatic plant characterised by branched stems which can reach 3 m in length. The pondweed is a rooted plant with submerged and emergent leaves but is classified as an emergent plant. Both types of plant are streamlined in the direction of flow. The greater the discharge, the lower their resistance to flow. As the *Potamogeton*

regenerates through rhizomes it is more difficult to control than *Elodea*. Desilting may be necessary at times in order to reduce or remove the 'seed bank' of *Potamogeton* from the river. Weed cutting is an effective method of controlling the *Elodea*.

1.9.2 Emergent vegetation

Glyceria (Reed Sweet-grass) is abundant within the Woldgrift Drain. This tall emergent grass may reach up to 2 m in height and grows in dense stands in slow moving water. This plant provides greater resistance to flow than some submerged plants as it may present a fairly impermeable barrier to the flow of water, depending on the density of the vegetation stand.

Control of *Glyceria* may be difficult as it reproduces through a system of rhizomes (underground stems) which are buried in the mud and silt of the channel bed. Any form of control which leaves these rhizomes intact will have only a short term benefit. Unless these are removed through desilting, *Glyceria* will regrow the following year.

Veronica (Brooklime and Speedwells) is also found within the Woldgrift Drain along the channel margins. It is commonly found singularly or in small clumps, has toothed edged leaves, round fleshy stem and grows to 30 cm in height. It poses little resistance to water movement as at high flows it becomes submerged and streamlined in the direction of flow.

1.9.3 Algae

Filamentous algae is found within the Woldgrift Drain. The long chains of this algae grow up from the hydrosol. This is difficult to control as it can be found anywhere and grows rapidly through simple fission by which each cell divides. Algae is common in nutrient rich waters and frequently invades areas where other aquatic plants have been controlled or eradicated.

2. FARM SURVEY

2.1 Introduction

Through structured interviews with farmers along the selected reach and through a topographical survey, the area deriving benefit from the river maintenance work in terms of impact on land drainage and flooding is estimated to be 264 ha. This area is termed the benefit area (BA). Detailed interviews and discussions have been held with ten farmers who farm within the benefit area. The benefit area is divided into separate blocks (Figure 4) according to land use, drainage condition and management practices.

2.2 Farm Type, Size and Tenure

Six of the nine farms surveyed within the benefit area are classed as general cropping enterprises, according to the European Union (EU) classification system. Two farms are specialised cereal farms and one is classified as being a pig and poultry enterprise.

Only three farms are under sole proprietorship. Four are run in a partnership and one by a farm manager. The largest farm (2913 ha) in the benefit area is run as a Limited Company. Five farmers have one holding whilst two farmers have two holdings. Two other farmers have three holdings. In each case all the holdings are farmed as one unit under the same holding number. One farm has 'several' holdings, also farmed as a single unit. The majority of land within the benefit area is owner occupied (98 %). The remaining land, two fields of extensive grassland covering 5 ha is rented under a full tenancy agreement. Information on farm size is presented in Table 2.1.

Table 2.1 Farm size by area

Size Class (ha)	No. of Farms
< 20	1
21 - 120	1
121 - 160	3
161 - 200	2
201 - 500	1
2001 - 2920	1

Standard Man Day (SMD) requirements of the farms range from 23 to 9455. The latter is for the farm which is a Limited Company. If this farm is excluded from the calculations, the average SMD requirement is 477. The SMD (Man - Work Units) is an approximate method for assessing the labour requirement of regular staff. It is assumed that each man provides 300 SMD annually.

2.3 Livestock Enterprises

Although none of the farms surveyed within the benefit area are classified as dairy farms, one farm does have a dairy herd of 500 Friesian cows and 250 followers which are over one year old. The milk yield averages 6500 litres/cow/year.

Three farms have beef herds. Two follow an 18 month grass/cereal system. Of these two, one is a suckler herd of 50 Belgian Blues with 75 beasts 6-12 months old and 25 under six months old. A system of finishing stores is followed on the third farm under which calves are bought in the spring at 150-175 kg and sold in the autumn around 275 kg, after being fattened off grass.

One farm has a flock of 130 ewes kept for breeding. The lambing rate of these cross-bred Leicestershire / Suffolk sheep is high being 1.8 lambs per ewes tupped.

Eight thousand hens are farmed under a battery system on one farm within the benefit area. The manure produced is used on the surrounding land as farm yard manure. The stocking rate for these birds is 62 birds/ha.

2.4 Arable Enterprises

Six farms are classified as general cropping farms. Two have no fixed rotation and grow a combination of winter and spring cereals with root crops and oilseeds. Two follow a four year rotation under which winter wheat is grown for two years followed by winter barley and then a break crop of oilseed rape or potatoes. The remaining 'general cropping' farms are under a six year rotation under which winter wheat, barley, beans and oilseed rape are grown.

The two specialist cereal farms follow a similar pattern of rotation. Winter wheat is commonly grown for two years followed by an oilseed crop, either oilseed rape or linseed and then winter barley or potatoes.

Actual yields for most crops in the benefit area during the study period were lower than expected. Expected yields for winter wheat ranged from 8.75 tonnes/ha to 9.3 tonnes/ha. The actual yields ranged from 7.5 to 8.1 tonnes/ha. The yields for oilseed rape followed a similar pattern. Actual yields were 0.4 tonnes/ha lower than the expected value of 3.5 tonnes/ha. Yields for sugar beet and winter barley averaged 40 and 6.25 tonnes/ha respectively.

All farmers harvesting lower crop yields than expected attributed the loss to weather conditions. A period of prolonged mildness throughout the growing season caused the crop to pass through each growth phase too quickly. The ears were thus not allowed enough time to fill before ripening. Prolonged rain prior to harvesting in 1992 and 1993 also resulted in an increase in pests, especially slugs and crop disease which further reduced yields.

2.5 Land Use In The Benefit Area

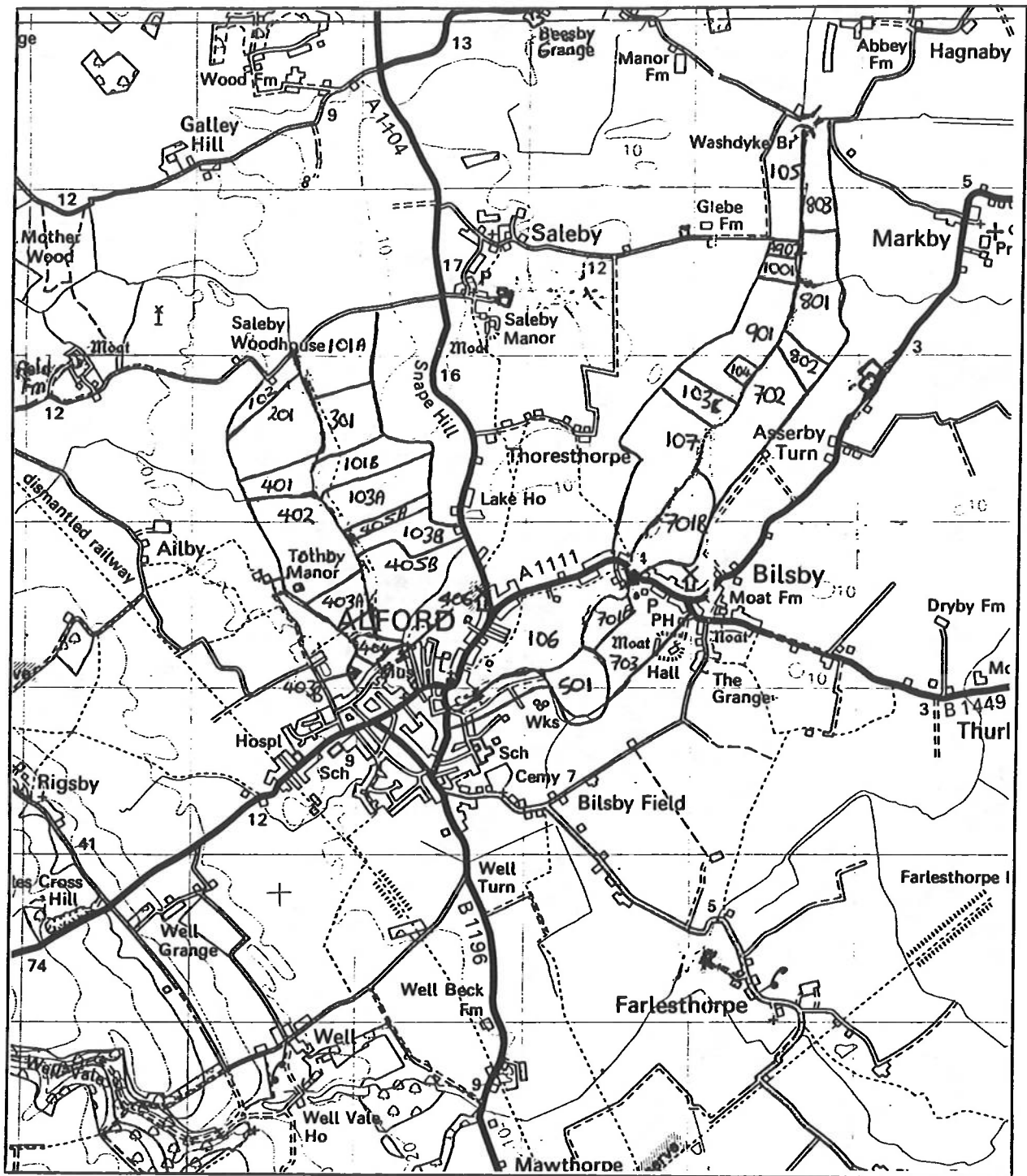
Figure 5 illustrates the breakdown of land use within the benefit area. The majority of the benefit area is cropped. Grassland, including that in a rotation, covers 28 % of the benefit area. Table 2.2 provides further information of the areas under different land uses.

Table 2.2 Land use within the benefit area

Land Use	Area (ha)	% Benefit Area	% Land With Field Drains
Cereal/oilseeds	139.9	56	99.6
Cereal/roots	85.6	16	100.0
Grass/arable	15.5	8	100.0
Intensive grass	8.4	4	100.0
Extensive grass	14.6	16	61.6

Extensive grassland is classified as that which receives little or no input of nitrogenous fertiliser (< 50 kg N/ha) and is subject to little or no grass conservation. If conservation is practised, hay rather than silage is usually cut. If extensive grassland is grazed, it is usually grazed by beef and sheep over short grazing seasons. Intensive grassland provides high quality grazing for long periods. The land is well drained and often grazed by dairy cattle. Levels of nitrogen application are high (180 - 200 kg N/ha) and multiple cuts of silage are usually taken.

The majority of the arable areas are intensively drained by a network of field pipes. All land under the intensive grassland system is drained and 62 % of extensive grassland is drained.



Legend :

Scale 1 : 32 500

101

Land blocks (Blocks are based on land use, land management, flooding and land drainage criteria)

Figure 4 Land blocks

2.6 Turnout and Yarding Dates

Over the whole benefit area the turnout and yarding dates for livestock fall into two distinct categories as Tables 2.3 and 2.4 illustrate. Generally, cattle graze from April to November.

Table 2.3 Turnout dates

Turnout Date	% Grassland Area	% of Benefit Area
Early/mid April	4	0.3
Mid/late April	8	0.7
After 1st hay cut	8	0.7
After 1st silage cut	4	0.3
Not grazed	76	6.6

Table 2.4 Yarding dates

Yarding Date	% Grassland Area	% of Benefit Area
Mid/late October	12	1.0
Mid/late November	8	0.7
Mid/late December	4	0.3
Not grazed	76	6.6

Of the grass under the grass/arable rotation, 9 ha is grazed by beef following the first silage cut. The stock is taken off this land in mid to late December.

2.7 Grass Conservation

Table 2.5 shows the areas over which various conservation practices take place. The majority of the extensive and intensive grassland within the benefit area which is conserved, is cut for hay.

Three cuts of silage and one cut of hay are taken off the grass in the grass/arable rotation. The first cut of silage is taken in mid to late May whilst the hay cut is made in early to mid June. The second and third cuts of silage are made at intervals of six weeks after the first cut.

Table 2.5 Grass conservation

Conservation System	Grassland Area (ha)	% Grassland Area
Grazed only	1.8	8
1 cut hay	5.5	24
1 cut silage	0.9	4
No conservation	14.8	64

2.8 Nitrogen Application

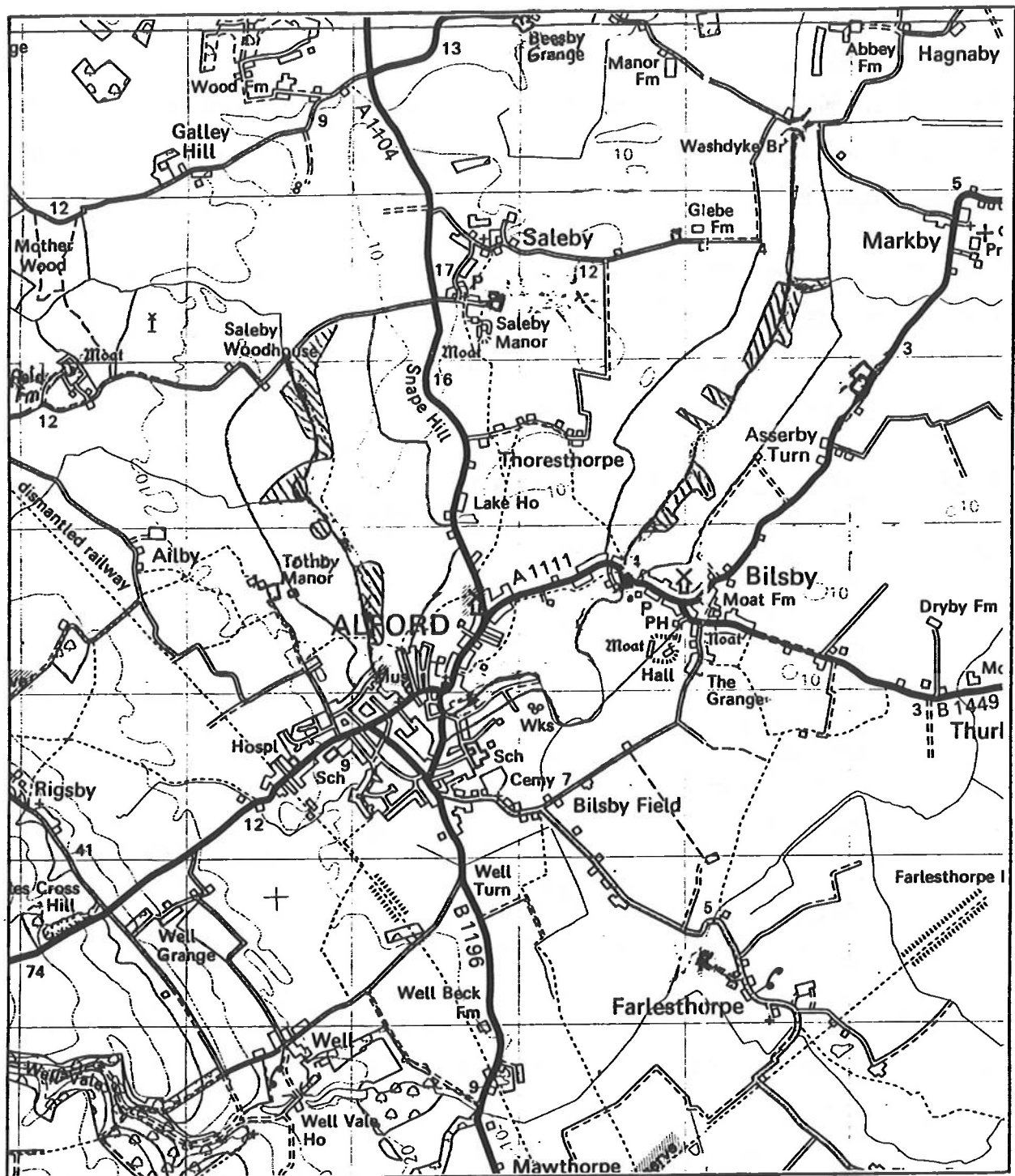
The majority of grassland within the benefit area receives no application of nitrogen fertiliser. A small area, 8.4 ha receives an application of 75 kg N/ha. All the grass within the grass/arable rotation receives 72 kg N/ha. Chicken manure is applied to 6.8 ha in variable quantities.

2.9 Flooding

Seven farmers within this reach report flooding to be a problem on their land. In each case, the factor said to be responsible for the flood is high water levels in the river. Surface runoff was not thought to be a contributory factor to the flooding.

The duration of flooding is reported to be between two to four days. The frequency of flooding over the last two years (1992 to 1994) has been two to three times a year. Consequences of flooding vary from litter and debris to reduced crop yields. Re-drilling of some crops following a flood has also been necessary and on occasions the wet condition of the land has delayed drilling operations and so spring crops rather than winter crops have had to be sown.

Ninety percent of the flooding occurs during the autumn and winter months. Twenty six percent of the benefit area (68 ha) suffers from flooding on a frequent basis. The areas which commonly flood are shown in Figure 6.



Legend :

Scale 1 : 32 500



Flooded areas

Figure 6 Areas prone to flooding

2.10 Waterlogging

Table 2.6 provides a breakdown of the wetness condition of the benefit area during the different seasons according to farmer assessment. Throughout the spring and summer the majority of land within the benefit area is well drained and not waterlogged.

Under the present river maintenance regime and under average weather conditions, 32 % of the benefit area experiences wetness problems (often and permanently wet) during the spring compared to 96 % in the autumn. In the spring, 64 % of the benefit area can be occasionally wet, showing sensitivity to weather conditions.

Table 2.6 Farmer assessment of wetness condition

Season	Wetness Condition	Area (ha)	% Benefit Area
Spring	Rarely wet	10.6	4
	Occasionally wet	168.9	64
	Often wet	84.5	32
	Permanently wet	0.0	0
Summer	Rarely wet	42.2	16
	Occasionally wet	221.8	84
	Often wet	0.0	0
	Permanently wet	0.0	0
Autumn	Rarely wet	0.0	0
	Occasionally wet	10.6	4
	Often wet	253.4	96
	Permanently wet	0.0	0

It is unusual for such a large extent of the benefit area to suffer problems of waterlogging in the autumn. These problems are attributed to the two wet autumns and winters experienced by the area in 1992/93 and 1993/94 when excessive rainfall was received. The wetter conditions on the land have been attributed to both flooding from the river channel, surface ponding and runoff. Two farmers stated that weeds in the channel caused the water level to rise thus preventing field drains from discharging freely into the river as their outfalls had become submerged.

2.11 Statistical Analysis

It is apparent that land use, farming practice, drainage and flooding are interrelated. Statistical methods were used to determine whether these relationships occurred more frequently than

might be expected by pure chance. Full details of this analysis in which the 12 sites were grouped according to NRA Region, are presented in the Interim Report R&D 317/13/ST, presented to the NRA in December 1994.

The following observations can be made from the statistical analysis of fields in the benefit area of the Woldgrift Drain maintenance programme:

- The dominant farming system influences land use within the benefit area. Typically it is an area of intensive arable production with only small areas devoted to livestock. The majority of farms are classed as specialist cereal or general cropping enterprises and therefore even if the land is liable to flood, land use reflects the dominant farming system; in this case arable.
- A strong relationship exists between land use and the presence of field drainage. Intensive arable land is drained by pipes and extensive grassland is not. This also reflects the fact that the dominant farming systems in the benefit area are intensive arable systems which by nature usually are intensively drained. (Statistically, there is an 85 % chance of correctly predicting the installation of field drainage on the basis of land use).
- A relationship exists between flooding and land use. Grassland areas are more prone to flooding than arable areas. Flood duration is greater on grassland areas. Areas under root crops are not prone to flooding. (Statistically, there is an 88 % chance of correctly predicting the incidence of flooding on the basis of land use).

3 HYDRAULIC AND HYDROLOGICAL INFORMATION

3.1 Introduction

Information on channel hydraulics and hydrological data has been used to determine the impact of maintenance on channel capacity and flood return periods.

3.2 Cross-section Surveys

Cross-sectional surveys of the river channel were taken at five points along the study reach at an average interval of 1700 m (Figure 2). Channel capacity and freeboard were determined from these cross-sections. The channel cross-section remained unchanged following the regular weed clearance programme and so a post-maintenance cross-sectional survey was not necessary. Following the widening of the channel downstream of Bilsby in 1994, a second cross-sectional survey was completed in order to determine the associated increase in channel capacity.

Prior to the weed clearance, the channel roughness was expressed in terms of the Manning's n coefficient, in accordance with the methodology developed by Cowan (1956). This coefficient is composed of six elements which include the degree of irregularity of the channel bed, level of vegetation growth and predominant bed material. Further details of this methodology are contained within the R&D Note 456, Appendix IV. The same procedure was followed post-maintenance in order to determine friction values for the 'with' and 'without' maintenance situation.

Stage/discharge curves for the 'with' and 'without' maintenance situation have been constructed for each cross-section using the different values of Manning's ' n '. The channel cross-section information, stage/discharge curves and channel information are presented in Figure 7. The bankfull channel capacities and associated return periods for the 'with' and 'without' maintenance scenario are presented in Table 3.1. Information for cross-section four and five relates to the channel following the widening in 1994.

The bankfull capacity figures obtained from the cross-sections indicate an average increase in capacity attributable to maintenance of 35 % and an average increase in interval between floods of 63 %.

Table 3.1 Bankfull capacity and return periods

Cross-Section	Without Maintenance		With Maintenance	
	Bankfull Capacity (m ³ /s)	Return Period (years)	Bankfull Capacity (m ³ /s)	Return Period (years)
1	2.4	0.3	5.3	0.6
2	15.7	3.5	24.4	17.0
3	7.3	0.8	11.3	1.8
4	15.2	3.5	20.1	8.0
5	31.1	50.0	41.6	251.0

(Source: modelled estimates)

3.3 Flood Return Period

Throughout the period of study (1992 to 1995) river water level information was collected on a regular basis through the reading of gauge boards and from gauging stations. Information regarding frequency, duration and magnitude of flood flows were collected from interviews with local farmers and NRA staff. A flood return period curve was compiled from this information, using the methodology contained within the Flood Studies Report (NERC, 1975). The frequency of floods of different magnitudes can be estimated from the flood return period curve (Figure 8).

The flood return period for each block which floods and associated flooded areas are shown in Table 3.2. The 'without' maintenance return period is estimated by the farmer, the 'with' maintenance value is a modelled estimate using the cross-section information and Manning's n coefficient. It is assumed that the flooded area remains unchanged following maintenance.

Table 3.2 Flood return periods and flooded areas, with and without maintenance

Block No. (Size, ha)	Flooded Area (ha)	Flood Return Period (Years)		Block No. (Size, ha)	Flooded Area (ha)	Flood Return Period (Years)	
		Without	With			Without	With
101 (21.4)	1.7	0.3	1.0	405 (16.1)	2.4	1.0	3.5
103 (12.1)	0.9	0.5	1.0	701 (39.2)	2.7	0.8	1.0
104 (8.4)	0.3	0.5	1.0	702 (29.6)	0.3	0.5	3.0
105 (9.1)	0.5	0.5	1.0	801 (10.2)	0.5	0.5	2.0
107 (6.4)	0.1	1.0	3.5	802 (5.6)	0.6	0.5	2.0
201 (10.7)	1.9	0.3	1.0	803 (5.5)	0.1	0.5	2.0
301 (6.0)	1.9	0.3	1.0	901 (13.4)	5.4	0.5	3.0
401 (13.4)	3.9	0.3	0.5				
402 (14.8)	1.9	1.0	3.5				
403 (7.4)	0.3	1.0	3.5				

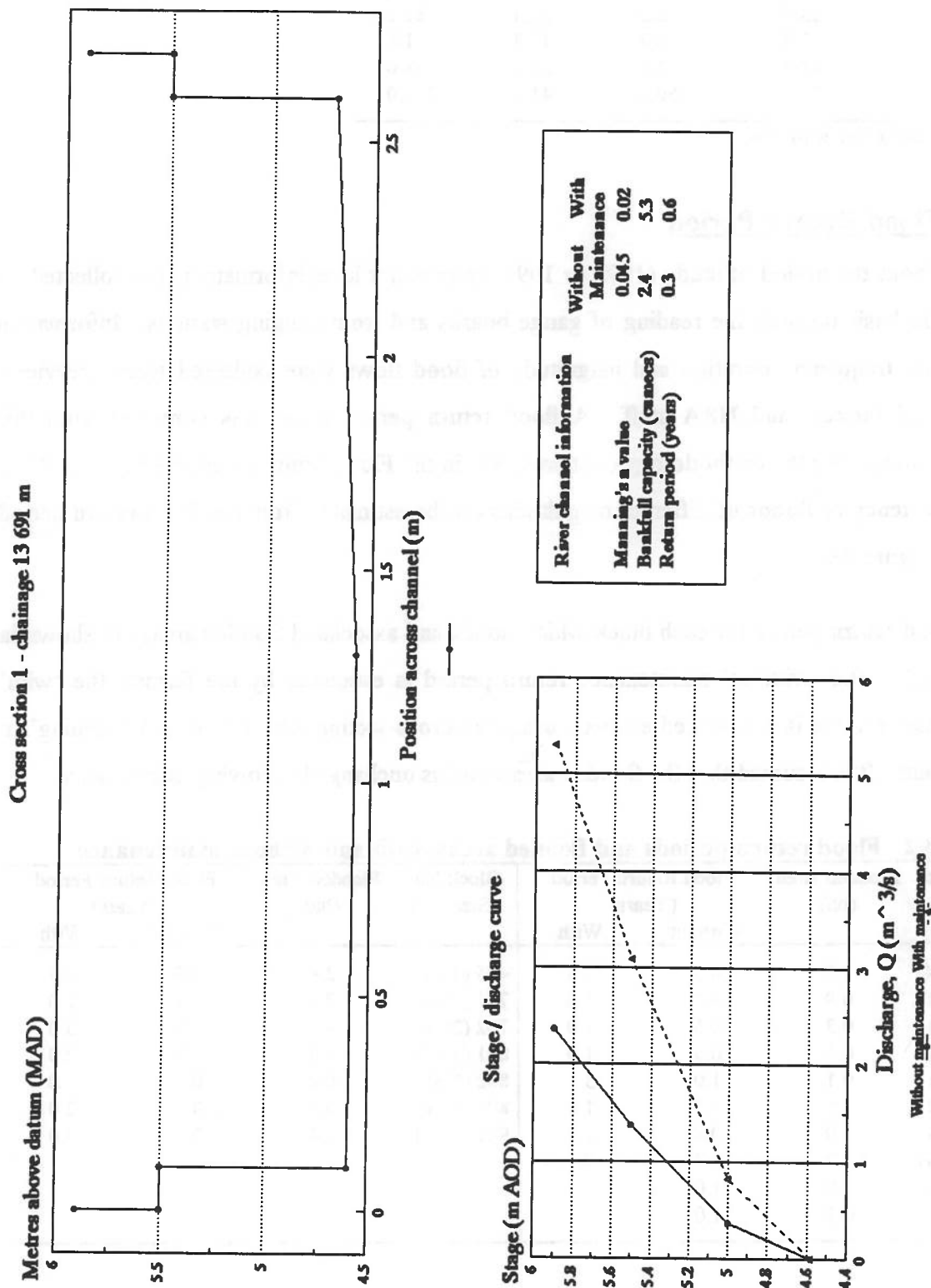
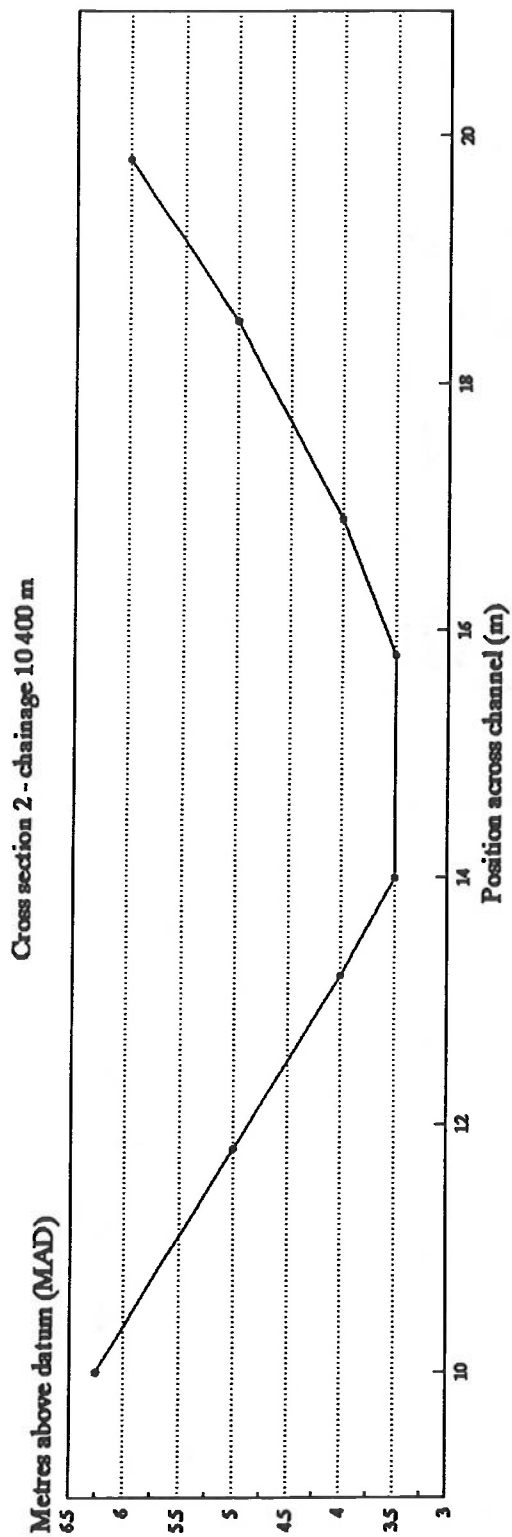
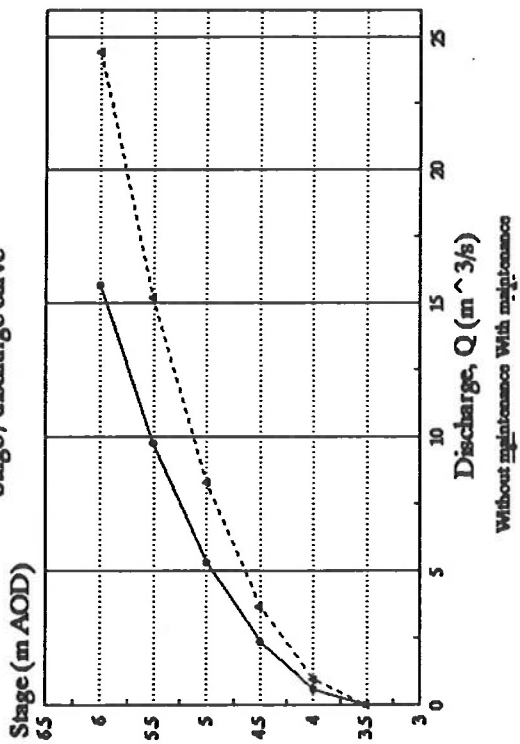


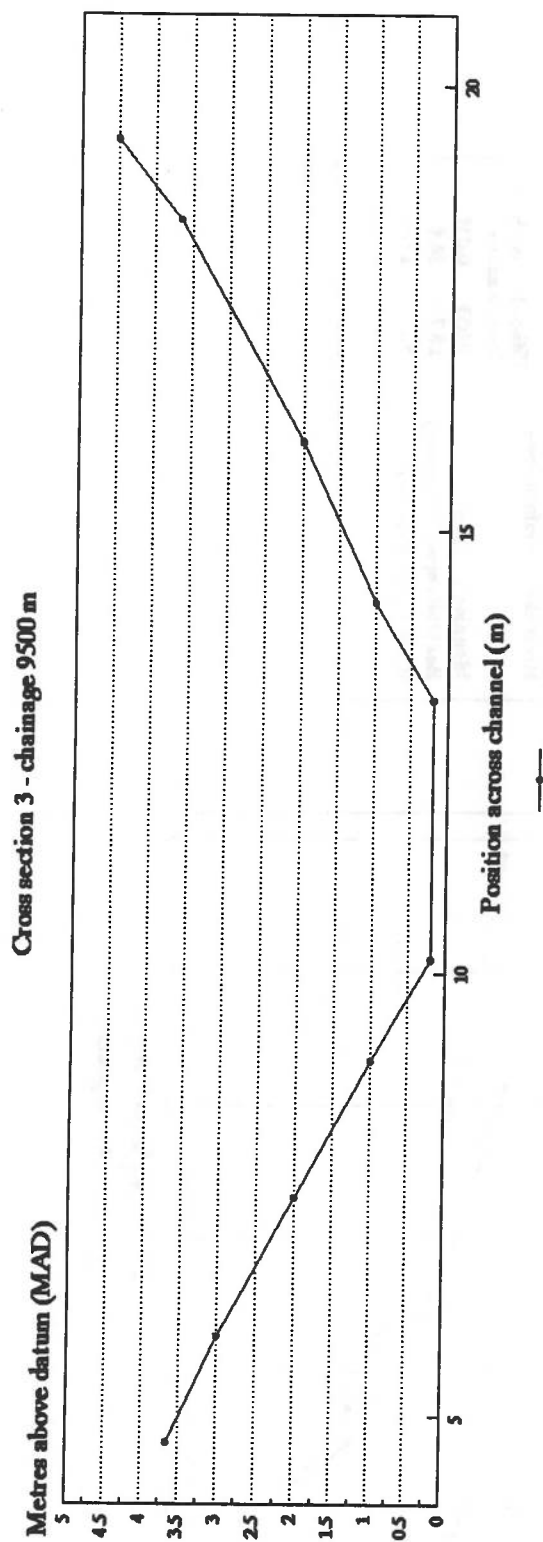
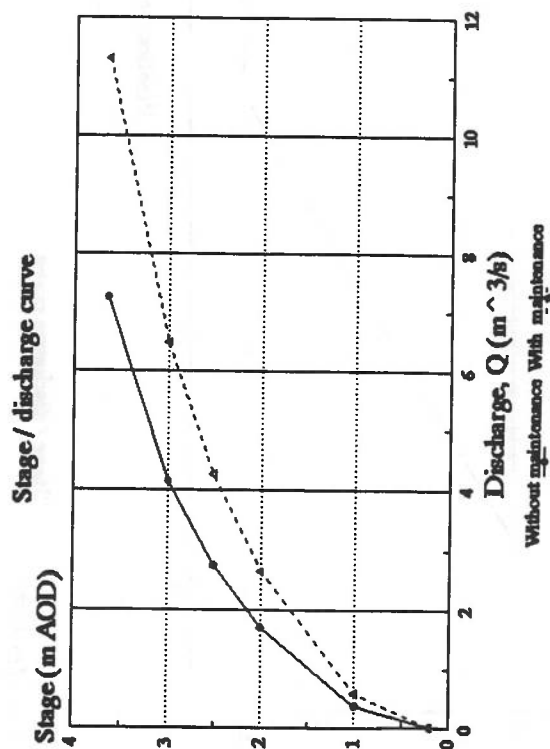
Figure 7 Woldgrift Drain channel information



Stage / discharge curve

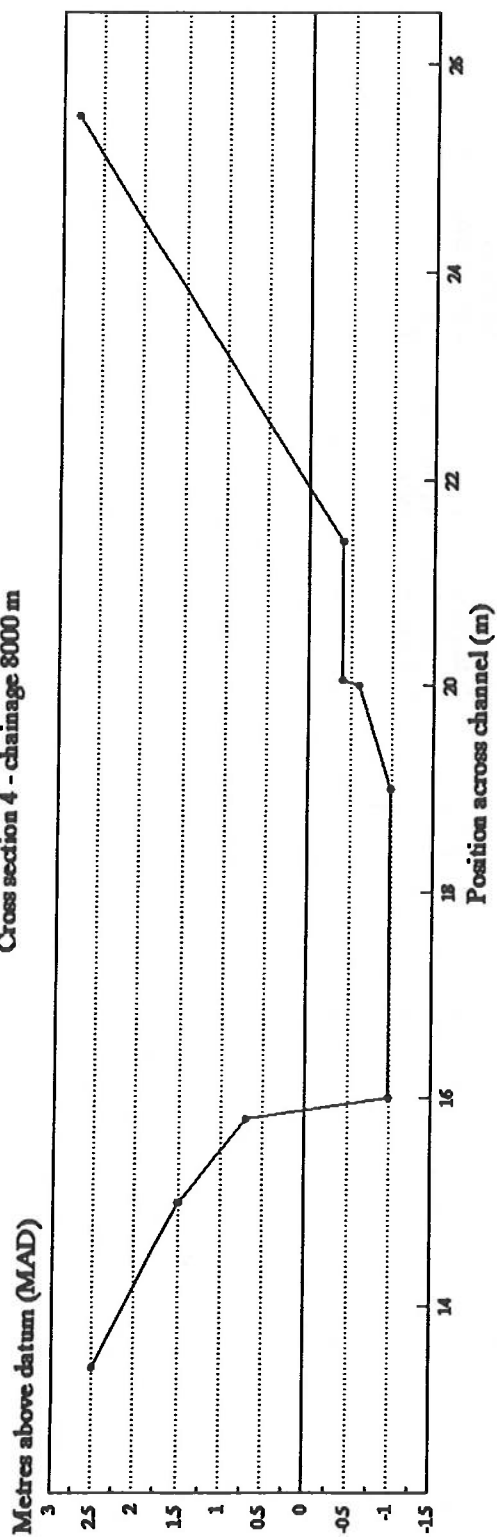


River channel information		Without Maintenance	With Maintenance
Manning's n value		0.053	0.034
Bankfull capacity (cumecs)		15.7	24.4
Return period (years)		3.5	17.0

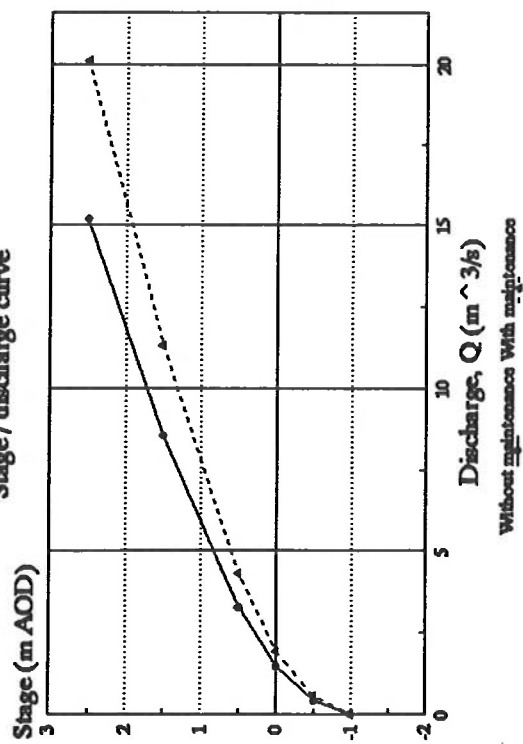


River channel information		Without Maintenance	With Maintenance
Manning's n value		0.053	0.034
Bankfull capacity (cumecs)		7.3	11.3
Return period (years)		0.8	1.8

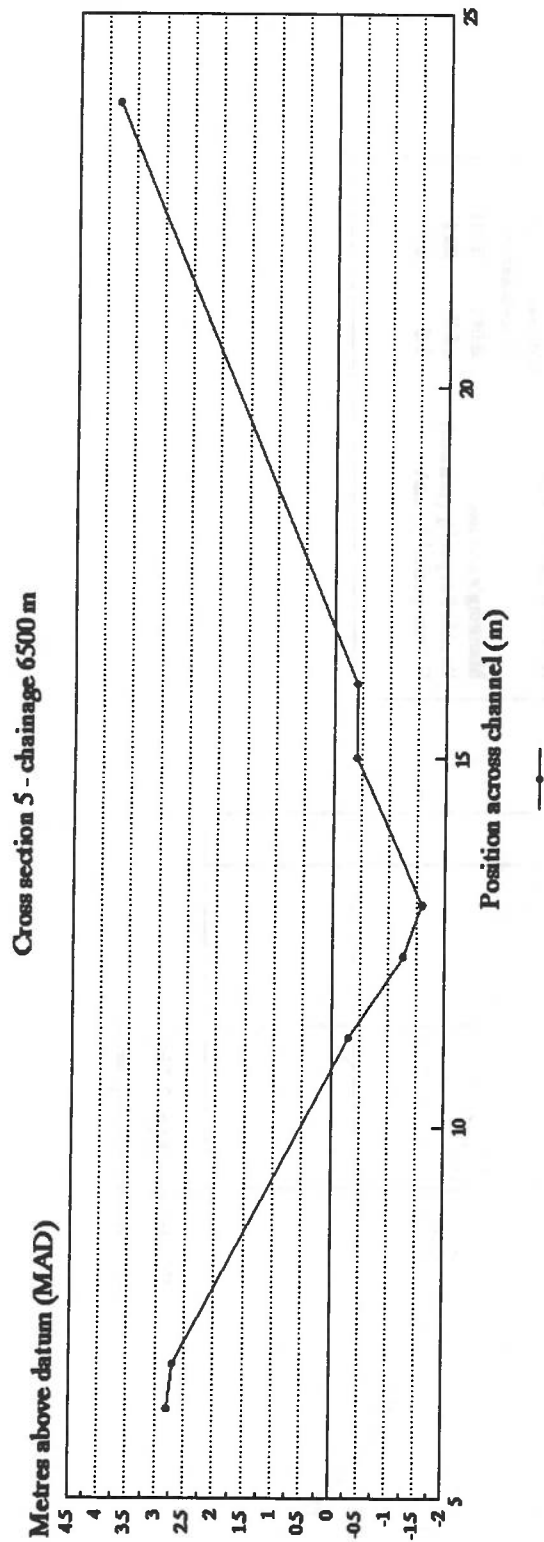
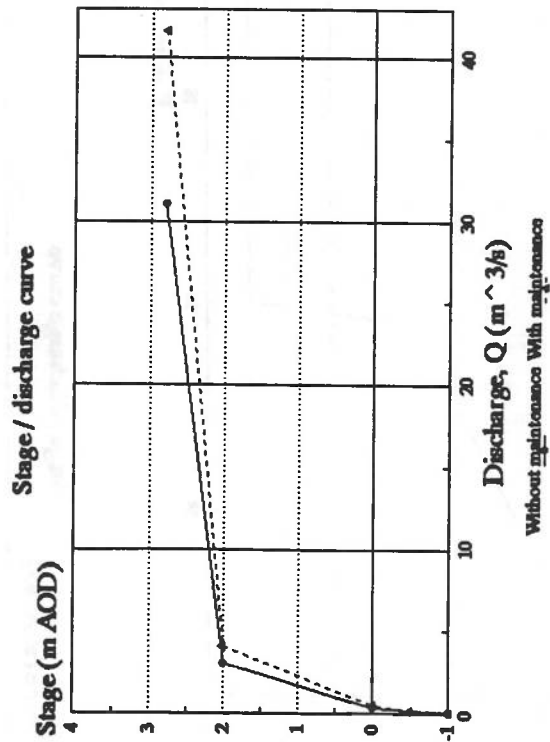
Cross section 4 - chainage 8000 m



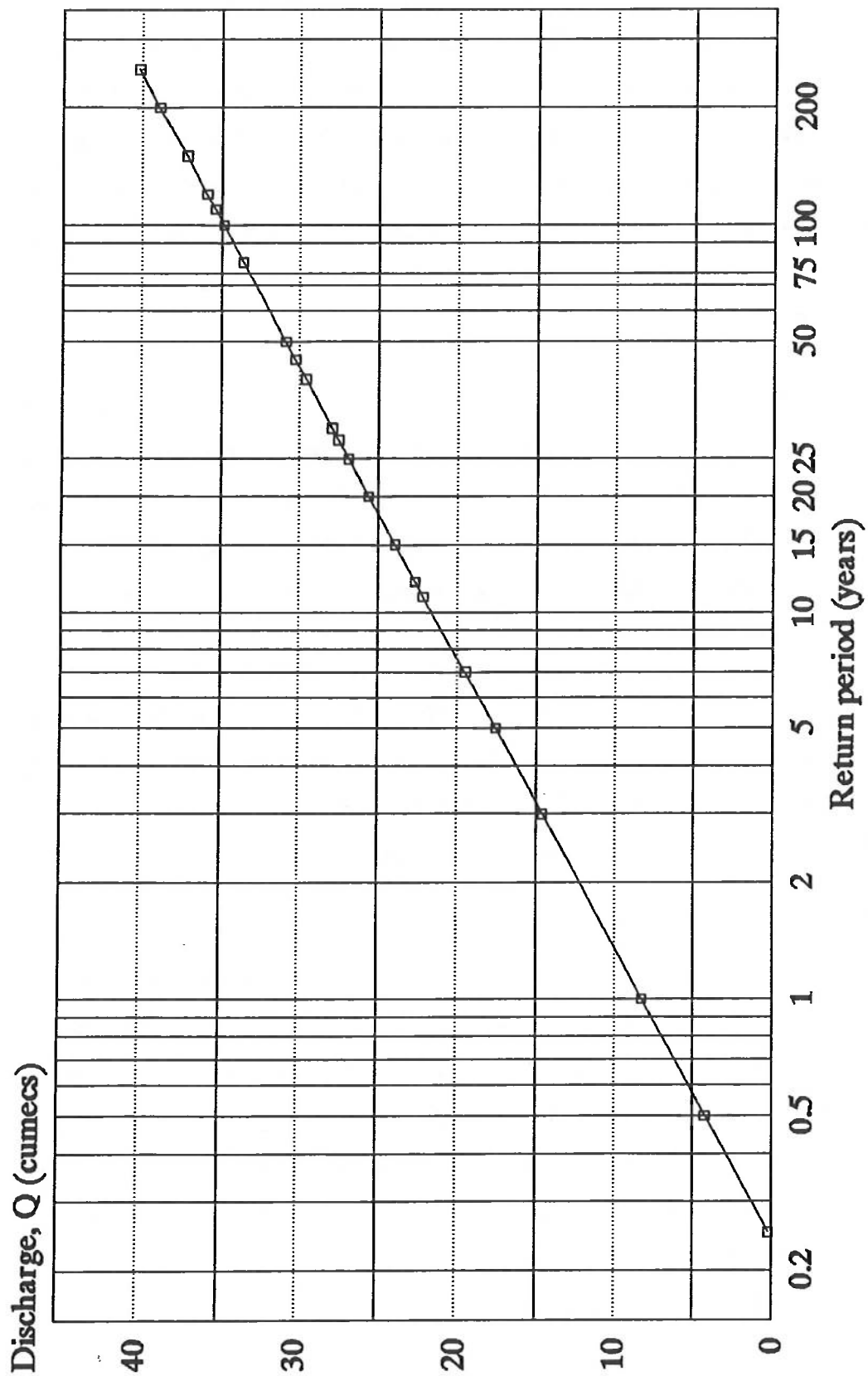
Stage / discharge curve



River channel information		Without Maintenance	With Maintenance
Manning's n value		0.041	0.031
Bankfull capacity (cumecs)		15.2	20.1
Return period (years)		3.5	8.0



River channel information	
Manning's n value	Without Maintenance
Bankfull capacity (cusecs)	With Maintenance
Return period (years)	



Flood Studies Report Method

Figure 8 Flood return period curve

4. LAND DRAINAGE

4.1 Field Drainage Status

The drainage status of land has been classified into three, according to watertable depth. An extensive literature review and farmer survey enabled three watertable bands to be identified:- > 0.5 m from the surface, between 0.3 and 0.5 m of the surface and < 0.3 m from the surface. According to the time the watertable lies within these bands, the drainage status is classed as good (G, no restrictions on land use), bad (B, some restrictions on agriculture) or very bad (VB, severe limitations to agricultural production). Further details are presented in the R&D Note 456, Section 3.5.2.

The drainage status of the land blocks within the benefit area has been determined on a seasonal basis using a non-steady state watertable model which relates infield watertable levels (and hence drainage conditions) to observed water levels in the river and ditch system (see R&D Note 456, Section 3.5.2 for further details). The model has been run with river water levels for the 'with' and 'without' maintenance situation using the same climatic data to enable the isolation of the impact of weed clearance on drainage status.

In some cases, there may be a change in the number of weeks that the watertable lies within the good, bad or very bad drainage bands following maintenance. However, these changes may not be of sufficient magnitude to change the drainage status classification. Where a change in drainage status has occurred due to maintenance, the changes appear in bold print in Table 4.1.

The results of the model and the assessment of drainage status made by farmers are shown in Table 4.1. A good correlation exists between the 'with' maintenance assessment of field drainage status predicted by the model and that assessed by farmers in average and dry seasons. The results from the watertable model are largely consistent with the farmer assessment of drainage condition under dry (100 % agreement), average (100 % agreement) and wet conditions (56 % agreement). In a wet season however, farmers often perceived the field drainage condition to be much worse than predicted by the watertable model. During wet seasons, farmers attribute much of the drainage problem to surface runoff and antecedent rainfall rather than to flooding from the river.

These assessments of watertable position in various seasons confirm that 'with' maintenance, drainage status in the benefit area is generally of a lower standard in wet climatic conditions than in average and dry seasons. In a wet season, drainage is likely to be impeded on many areas whether or not the watercourse is maintained. If no maintenance were performed however, a higher percentage of the benefit area would suffer bad drainage.

An example of the input and output of the watertable model, including the classification into the three drainage bands are is presented in Appendix I.

Table 4.1 Drainage status for wet, average and dry seasons, without/with maintenance

Block No		Wet Season *		Average Season *		Dry Season *		Farmer Assessment With Maintenance			Without
		Without	With	Without	With	Without	With	Wet	Average	Dry	
101	Y	B	B	B	G	G	G	B	G	G	B
102	Y	B	B	B	G	G	G	B	G	G	B
103	Y	B	B	B	G	G	G	B	G	G	B
104	Y	B	B	B	G	G	G	B	G	G	B
105	Y	B	B	B	G	G	G	B	G	G	B
106	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
107	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
201	Y	B	B	G	G	G	G	B	G	G	B
301	Y	B	B	G	G	G	G	B	G	G	B
401	Y	B	B	G	G	G	G	B	G	G	B
402	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
403	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
404	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
405	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
406	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
501	N	B	B	G	G	G	G	<i>G</i>	G	G	G
701	Y	G	G	G	G	G	G	G	G	G	B
702	Y	G	G	G	G	G	G	G	G	G	G
703	Y	G	G	G	G	G	G	G	G	G	G
801	Y	G	G	G	G	G	G	<i>VB</i>	G	G	B
802	Y	G	G	G	G	G	G	<i>VB</i>	G	G	B
803	Y	G	G	G	G	G	G	<i>B</i>	G	G	B
901	Y	G	G	G	G	G	G	G	G	G	G
902	N	B	G	G	G	G	G	G	G	G	B
1001	N	B	G	G	G	G	G	G	G	G	B

NB : * Modelled results

Y or N refers to the presence or absence of field drainage

Bold type indicates a change in drainage status due to maintenance

Italics indicate differences between farmer and modelled assessment of drainage with maintenance

According to modelled results, river maintenance results in the prevention of a deterioration of drainage status on 2 blocks of land in a wet season and on 5 blocks in an average season.

- In a wet season maintenance prevents deterioration from :
G to B over 5.6 ha (2 % of BA),
- In an average season maintenance prevents deterioration from :
G to B over 53.3 ha (20 % of BA).

The impact of annual weed cutting on the Woldgrift Drain is relatively small from the point of influence on watertable levels. This assumes that the channel capacity would not significantly deteriorate in the absence of weed cutting.

Farmer estimates suggest that in an average year, drainage would deteriorate from good to bad on 82 % of the benefit area as a consequence of lack of maintenance.

5 SCHEME APPRAISAL

5.1 Maintenance Benefits

For each block of land, agricultural production scenarios were created which reflect different levels of field management under conditions of good, bad and very bad drainage (see R&D Note 456 Section 3.5.4). These scenarios are based on discussions with farmers in the benefit area over the period 1992-1994.

Changes in field drainage status as a result of maintenance under dry, average and wet climatic conditions have been identified. Changes in flood risk due to maintenance have also been determined. Estimates have been derived of the monetary value of changes in field management and productivity associated with changes in the standards of drainage service.

Two perspectives have been used to value agricultural performance. The first perspective is that of financial analysis which uses the prices paid and received by farmers to estimate the added-value associated with drainage. Financial analysis shows the benefits of maintenance to farmers in the benefit area.

The second perspective is that of economic analysis which modifies the financial analysis to make allowance for the direct and indirect subsidies paid to farmers by Government. In accordance with the MAFF Project Appraisal Guidance Notes on Flood Defence (PAGN, 1993), these modifications involve reductions in the financial value of output (including subsidies) by 10% in the case of cereals, oil seeds and grain legumes, 35% for beef and 25% for sheep. Commodities subject to quota such as potatoes, sugar beet and milk are treated as winter wheat. The set aside areas are also treated as wheat. The reasons for these adjustments are discussed in the R&D Note 456 Section 2.7.2.

Using the results of watertable modelling, Table 5.1 shows the financial net returns (1995/96 prices) for each block of land within the benefit area under conditions of good, bad and very bad drainage. Changes in net returns relating to a change in drainage status are also shown. Table 5.2 presents similar data using economic prices. Table 5.3 shows the flood costs for each block of land assuming with and without maintenance and specified field drainage

conditions. It is assumed that there is no difference between financial and economic values in the case of flood damage to standing crops.

Table 5.4 combines data on changes in drainage status, flood risk and financial performance to determine the financial benefits and change in financial net returns due to maintenance for wet, average and dry weather conditions for each block of land in the benefit area. These benefits are the avoidance of losses which would occur in the absence of maintenance. Benefits weighted by field size for wet, average and dry seasons are multiplied by the relative probability of the occurrence of the season to give an average expected annual benefit. These are summed for the benefit area as a whole.

Table 5.4 estimates a total expected annual benefit of about £ 4000 in 1995 financial prices, equivalent to about £ 15/ha per year. Table 5.5 shows the benefits attributable to maintenance using economic prices based on the current MAFF Project Appraisal Guidance Notes. Total average expected annual benefits are about £ 3600 in economic prices for the benefit area, equivalent to £ 14/ha. On this basis, the benefit to the national economy is 88 % of the benefits which accrue to farmers. This difference reflects the adjustments required by MAFF to remove government subsidy from the assessment of benefits.

As an alternative estimate to that based on watertable modelling, Table 5.6 estimates the benefits due to maintenance which were perceived by farmers (earlier reported in Table 4.1) where they identified a change in drainage conditions between the 'with' and 'without' maintenance situations in an average, representative season. These estimates include the flood damage costs identified in Table 5.3, which were based on a combination of farmer and modelled data. Farmer assessment gave an average annual financial benefit of £ 31037 (£ 118/ha) and an economic benefit of £ 29490 (£ 112/ha).

Table 5.6 Farmer assessment of maintenance benefits

Block	Area (ha)	Average Season Financial Prices			Average Season Economic Prices		
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance
101	21.38	65	7.91	1559	67	7.41	1591
102	2.28	35	0.00	80	20	0.00	46
103	12.10	56	3.20	716	59	2.77	747
104	8.40	136	0.27	1145	44	0.37	373
105	9.12	46	1.66	435	44	1.39	414
106	13.60	116	0.00	1578	52	0.00	707
107	6.40	79	0.55	509	69	0.55	445
201	10.70	102	46.20	1586	93	18.01	1188
301	6.00	170	87.48	1545	180	36.21	1297
401	13.40	169	21.59	2554	177	25.43	2713
402	14.80	178	4.54	2702	184	4.54	2790
403	7.40	178	1.38	1327	185	1.38	1379
404	5.50	40	0.00	220	10	0.00	55
405	16.10	165	5.22	2741	185	5.22	3063
406	3.60	17	0.00	61	8	0.00	29
501	0.60	0	0.00	0	0	0.00	0
701	39.20	198	2.19	7847	202	2.19	8004
702	29.60	0	0.55	16	0	0.55	16
703	3.30	0	0.00	0	0	0.00	0
801	10.20	166	2.58	1720	187	2.58	1934
802	5.60	170	5.67	984	190	5.67	1096
803	5.50	187	0.12	1029	186	0.12	1024
901	13.40	0	39.48	529	0	39.48	529
902	1.40	24	0.00	34	12	0.00	17
1001	4.20	29	0.00	122	8	0.00	34
Total	264	Total financial benefit (£)		31037	Total economic benefit (£)		29490
		Benefit (£/ha)		118	Benefit (£/ha)		112

Farmer estimates exceed modelled estimates by a factor of about eight. It is likely that farmers have overestimated the benefit of maintenance in those periods when maintenance has little impact. Furthermore, they may not wish to encourage a reduction in the present level of maintenance activity.

According to the criteria used, these financial and economic benefit estimates show the limits which farmers and the nation respectively could justifiably spend on maintenance. These estimates require cautious interpretation as explained in the R&D Note 456 Section 2.7.2.

5.2 Maintenance Costs

Maintenance activities on the Woldgrift Drain involve annual weed clearance using a Bradshaw Bucket, some debris removal and flailing of banks. According to NRA sources, maintenance costs for the study reach were £ 2120 in 1992 and £ 4393 in 1993. On this basis the average annual cost in 1995 prices was £ 3464, equivalent to about £ 13/ha of benefit.

5.3 Scheme Appraisal

The estimated benefits attributable to maintenance can be compared with estimated costs to determine the justification for expenditure. Because the main maintenance activity is performed annually, the appraisal involves a simple comparison of annual benefits and costs.

Table 5.7 Maintenance scheme appraisal: Woldgrift Drain

Average Annual Benefit (£)	Average Annual Benefits (£)	Average Annual Costs (£)	Benefit : Cost Ratio
<i>Modelled Estimates</i>			
Financial Prices	4076	3464	1.18
Economic Prices	3627	3464	1.05
<i>Farmer Estimates</i>			
Financial Prices	31037	3464	8.9
Economic Prices	29490	3464	8.5

Table 5.7 shows that the existing maintenance scheme is viable in financial and economic terms. The modelled results show that benefits to farmers and the economy appear to recover the costs of the scheme.

Farmer assessment gave an average annual financial benefit of maintenance of £ 31037 (£ 118/ha) and an economic benefit of £ 29490 (£ 112/ha) under average seasons. The scheme generates an annual benefit : cost ratio of 8.9 and 8.5 in financial and economic terms respectively. These conclusions must be interpreted cautiously as discussed in the R&D Note 456 Section 2.7.2.

Table 5.1 Financial net returns

Block	Block size (ha)	Net Return (£/ha)			Change in Net Return (£/ha)		
		Good	Bad	Very Bad	Good to Bad	Good to Very Bad	Bad to Very Bad
101	21.38	471	406	304	65	167	102
102	2.28	435	400	281	35	153	119
103	12.10	455	399	309	56	146	90
104	8.40	571	435	332	136	240	104
105	9.12	429	383	267	46	162	116
106	13.60	485	369	209	116	277	161
107	6.40	435	356	223	79	213	133
201	10.70	467	366	257	102	210	108
301	6.00	456	391	286	170	65	105
401	13.40	487	414	318	169	73	96
402	14.80	491	414	314	178	77	100
403	7.4	491	416	314	178	75	103
404	5.5	191	170	151	40	21	20
405	16.1	479	435	314	165	44	121
406	3.6	176	159	140	17	35	18
501	0.6	456	400	307	149	56	93
701	39.2	441	368	244	198	73	125
702	29.6	383	328	249	134	55	79
703	3.3	546	228	-28	318	574	256
801	10.2	459	395	292	166	64	102
802	5.6	486	422	316	170	65	105
803	5.5	463	381	275	187	82	105
901	13.4	460	400	298	163	60	103
902	1.4	186	163	141	24	45	22
1001	4.2	253	223	200	29	52	23

Table 5.2 Economic net return

Block	Block size (ha)	Net Return (£/ha)			Change in Net Return (£/ha)		
		Good	Bad	Very Bad	Good to Bad	Good to Very Bad	Bad to Very Bad
101	21.38	408	341	232	67	176	110
102	2.28	174	154	345	20	-171	-191
103	12.10	394	335	236	59	158	99
104	8.40	134	90	55	44	79	35
105	9.12	276	232	147	44	129	85
106	13.60	276	224	126	52	150	98
107	6.40	275	206	108	69	167	98
201	10.70	395	301	193	93	202	108
301	6.00	397	330	218	180	68	112
401	13.40	430	291	253	177	139	38
402	14.80	434	355	249	184	79	106
403	7.4	434	357	249	185	76	108
404	5.5	71	62	62	10	10	0
405	16.1	434	381	249	185	53	132
406	3.6	63	55	47	8	16	8
501	0.6	395	337	236	160	58	101
701	39.2	380	307	178	202	73	130
702	29.6	219	176	108	110	43	68
703	3.3	353	287	159	66	194	128
801	10.2	400	334	214	187	66	121
802	5.6	424	355	235	190	70	120
803	5.5	397	319	210	186	77	109
901	13.4	398	333	227	172	65	107
902	1.4	66	54	42	12	24	11
1001	4.2	15	7	6	8	9	2

Table 5.3 Flood costs

Block Number	GOOD DRAINAGE						BAD DRAINAGE						VERY BAD DRAINAGE						CHANGE IN FLOOD COSTS					
	Without maintenance			With maintenance			Without maintenance			With maintenance			Without maintenance			With maintenance			GOOD		TO BAD		GOOD TO VERY BAD	
	FRP			FRP			flood cost			flood cost			flood cost			flood cost			Without -with		Without -with		Without -with	
	cost			cost			cost			cost			cost			cost								
101	0.30	1.00	12.97	3.89	11.30	3.39	14.57	4.37	9.08	7.91	10.20	7.41	11.18	10.68										
103	0.50	1.00	7.26	3.63	6.40	3.20	8.46	4.23	3.63	3.20	4.23	2.77	5.26	4.83										
104	0.50	1.00	0.34	0.17	0.54	0.27	0.44	0.22	0.17	0.27	0.22	0.37	0.17	0.27										
105	0.50	1.00	3.86	1.93	3.32	1.66	4.28	2.14	1.93	1.66	2.14	1.39	2.62	2.35										
107	1.00	3.50	0.77	0.22	0.66	0.19	0.81	0.23	0.55	0.47	0.58	0.44	0.62	0.59										
201	0.30	1.00	25.73	7.72	66.00	19.80	69.03	20.71	18.01	46.20	48.32	58.28	49.23	61.31										
301	0.30	1.00	51.73	15.52	124.97	37.49	146.13	43.84	36.21	87.48	102.29	109.45	108.64	130.61										
401	0.30	0.50	63.57	38.14	53.98	32.39	60.57	36.34	25.43	21.59	24.23	15.84	28.18	22.43										
402	1.00	3.50	6.36	1.82	15.08	4.31	17.06	4.87	4.54	10.77	12.19	13.26	12.75	15.24										
403	1.00	3.50	1.93	0.55	4.60	1.31	5.63	1.61	1.38	3.29	4.02	4.05	4.32	5.08										
404	1.00	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
405	1.00	3.50	7.31	2.09	18.21	5.20	21.27	6.08	5.22	13.01	15.19	16.12	16.07	19.18										
701	0.80	1.00	10.97	8.78	8.96	7.17	8.76	7.01	2.19	1.79	1.75	0.18	1.59	-0.02										
702	0.50	3.00	0.66	0.11	0.57	0.10	0.68	0.11	0.55	0.47	0.57	0.46	0.58	0.57										
801	0.50	2.00	3.44	0.86	3.04	0.76	4.32	1.08	2.58	2.28	3.24	2.18	3.56	3.46										
802	0.50	2.00	7.56	1.89	6.72	1.68	9.24	2.31	5.67	5.04	6.93	4.83	7.56	7.35										
803	0.50	2.00	0.16	0.04	0.12	0.03	0.20	0.05	0.12	0.09	0.15	0.08	0.17	0.16										
901	0.50	3.00	47.38	7.90	42.34	7.06	50.08	8.35	39.48	35.28	41.73	34.44	43.02	42.18										

Table 5.4 Changes in net returns due to maintenance and climate, 1995/96 financial prices

Block	Area (ha)	Wet Season			Average Season			Dry Season			Total Change (£/yr)
		Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	Benefit due to drainage (£/ha/yr)	Benefits of flood alleviation (£/ha)	Change in net return due to maintenance	
101	21.38	0	7.91	8	65	7.41	72	0	9.08	9	959
102	2.28	0	0.00	0	35	0.00	35	0	0.00	0	45
103	12.10	0	3.20	3	56	2.77	59	0	3.63	4	423
104	8.40	0	0.27	0	136	0.37	136	0	0.17	0	653
105	9.12	0	1.66	2	46	1.39	47	0	1.93	2	253
106	13.60	0	0.00	0	0	0.00	0	0	0.00	0	0
107	6.40	0	0.55	1	0	0.55	1	0	0.55	1	4
201	10.70	0	46.20	46	0	18.01	18	0	18.01	18	250
301	6.00	0	87.48	87	0	36.21	36	0	36.21	36	276
401	13.40	0	21.59	22	0	25.43	25	0	25.43	25	331
402	14.80	0	4.54	5	0	4.54	5	0	4.54	5	67
403	7.40	0	1.38	1	0	1.38	1	0	1.38	1	10
404	5.50	0	0.00	0	0	0.00	0	0	0.00	0	0
405	16.10	0	5.22	5	0	5.22	5	0	5.22	5	84
406	3.60	0	0.00	0	0	0.00	0	0	0.00	0	0
501	0.60	0	0.00	0	0	0.00	0	0	0.00	0	0
701	39.20	0	2.19	2	0	2.19	2	0	2.19	2	86
702	29.60	0	0.55	1	0	0.55	1	0	0.55	1	16
703	3.30	0	0.00	0	0	0.00	0	0	0.00	0	0
801	10.20	0	2.58	3	0	2.58	3	0	2.58	3	26
802	5.60	0	5.67	6	0	5.67	6	0	5.67	6	32
803	5.50	0	0.12	0	0	0.12	0	0	0.12	0	1
901	13.40	0	39.48	39	0	39.48	39	0	39.48	39	529
902	1.40	24	0.00	24	0	0.00	0	0	0.00	0	6
1001	4.20	29	0.00	29	0	0.00	0	0	0.00	0	24
Total	264										
Total											4076
Probability of :											
Wet season				0.19	Total				Benefit (£/ha)		
Average season				0.57					15		
Dry season				0.24							

6. ENVIRONMENT

6.1 Introduction

The River Environment Database (REDS) is a regional database containing river corridor surveys and environmental information on main rivers in the area. In 1988 a pilot river corridor survey was completed on the Woldgrift Drain. In 1990, a second survey was completed for inclusion within the REDS system. Information from REDS is utilised in the formulation of maintenance programmes within the area.

The environmental interest of the Woldgrift Drain study reach has been determined through a variety of methods.

6.2 River Corridor Survey

Prior to river maintenance in 1992, a river corridor survey was produced for the selected reach using the survey methodology developed by the Nature Conservancy Council (NCC, now English Nature (EN)). Sketch maps and record cards were produced for each 500 m section of the river. Both the record cards and maps can be found in Appendix II.

As river maintenance took the form of weed clearance and the channel dimensions were not changed, the post-maintenance survey took the form of a vegetational survey. This concentrated on the extent and surface cover of the aquatic vegetation. The post-maintenance survey is contained in Appendix II.

During 1994 when the downstream section of the channel was widened a second post-maintenance river corridor survey found that trees and bushes on the right bank in the vicinity of Washdyke Bridge had been removed. This section of the survey was repeated and the new survey is also presented in Appendix II.

6.3 Public Consultation

Before the maintenance programme is finalised, details of river maintenance work are given to the NRA Conservationists who survey the sections of the watercourse concerned. Best practices and techniques and opportunities for environmental enhancement which can be built

into the maintenance programme to enhance existing features or to create new areas of interest are identified.

A programme of maintenance work detailing what maintenance is to be performed in particular sections of each watercourse are circulated to various interested parties' such as EN on an annual basis. Interested parties are invited to walk the selected reaches with a representative of the NRA to discuss particular maintenance works. If necessary modifications to the maintenance programme can be made.

6.4 Farmer Assessment

Each farmer interviewed with land in the benefit area was asked to identify any environmental features along the river which may be affected by river maintenance. Three farmers thought the maintenance work may have environmental impacts. In each case the flora was thought to be affected, particularly yellow cowslips which are abundant along both banks of the Woldgrift Drain between Bilsby and Washdyke Bridge.

The majority of farmers were aware of wildlife within the Woldgrift Drain and its banks. Pike and ducks were said to be especially abundant.

6.5 Water Quality

The quality of water in the Woldgrift Drain is classed as 2 (fair), under the National Water Council (NWC) classification system. The water is suitable for potable supply after advanced treatment and is of moderate amenity value. The average pH value is 8.1, the water is slightly alkaline. The value of dissolved oxygen averages 12.7 mg/l and ammonia 0.262 mg/l.

6.6 Channel and Bank Quality

The environmental quality of the Woldgrift Drain channel and banks has been determined by following the procedure outlined in the 'Guidelines for the Justification of River Maintenance' (R&D Note 511), produced within the framework of the NRA R&D Note 456 (River Maintenance Evaluation).

The upper Woldgrift Drain channel and banks are of medium quality. The channel has bands of well developed vegetation at its margins and a variety of different macrophyte plant forms

growing within a 500 m reach. The banks are typically less than 2 m in width and are of simple format consisting of two or three vegetation types.

The lower Woldgrift Drain channel and banks are of low quality. The channel is uniform in structure and substrate and the transitional zone between river and channel edge during low flow is not well developed. The channel has been modified during maintenance works. The bank is typically less than 2 m wide and is of uniform structure with predominantly one vegetation type. Trees which used to line the bank at the downstream limit of the study reach were removed during maintenance in 1994.

7 CONCLUSIONS

7.1 Scheme Appraisal

The existing maintenance scheme of annual weed clearance is viable in financial and economic terms. The average annual economic benefit of maintenance in terms of its prevention in a deterioration in drainage status is £ 3627. Average annual maintenance costs are approximately £ 3464. The benefit : cost ratio is therefore 1.05. In financial prices, the benefit : cost ratio is 1.18.

7.2 Guidelines for River Maintenance

The 'Guidelines for the Justification of River Maintenance' (R&D Note 511), produced as a result of this River Maintenance Evaluation Study were used to provide an alternative method for justification of river maintenance on the Woldgrift Drain.

According to this method, the economic benefit : cost ratio is 7.1. This value is more than that derived from the detailed analysis; the results of which are summarised in Section 7.1. The difference in results may be due to the fact that average channel dimensions were taken for the whole study reach. The source of error may be in that the benefit area is large and relatively flat. The benefit area should be sub-divided into discrete areas for the purpose of using these maintenance guidelines.

7.3 Impact of Maintenance on Channel Vegetation

The types of vegetation found within the Woldgrift Drain are discussed in Section 1.9. The impact of the submerged and emergent vegetation on channel capacity is also discussed. Different vegetation types respond to maintenance in different ways.

The Canadian pondweed (*Elodea*) and Reed Sweet-grass (*Glyceria*) reproduce through a system of rhizomes (underground stems). *Potamogeton* (Pondweed) is a rooted plant. The current method of maintenance - regular cutting, actually stimulates regrowth of this vegetation. Desilting of the channel every few years is necessary in order to remove the rhizomes and the seed bank from the channel sediments.

The floating vegetation *Lemna* reproduces vegetatively and unless every fragment of this vegetation is removed from the channel, vegetative reproduction will occur and the weed will rapidly regrow. Chemical control is the most effective method of control in this case. However, *Lemna* does not affect channel capacity as it is a free-floating plant and offers no resistance to flow. It can however, reduce water quality.

The current maintenance regime is appropriate in controlling much of the channel vegetation. However, desilting is necessary in order to remove rhizomes from the channel sediments. Chemical control may be occasionally necessary to control *Lemna* if growth is excessive and affects water quality.

7.4 Maintenance Best Practice

The 'best practice' vegetation maintenance methods for the Woldgrift Drain were determined using the procedures outlined in the 'Guidelines for the Justification of River Maintenance' (R&D Note 511), produced as a result of the Environmental Impact Assessment Study.

Channel

Best practice maintenance operations for emergent weed are identified as :

- Annual autumn cutting;
- Biennial cutting; and,
- Cutting on a 3 to 5 year rotation.

Best practice maintenance operations for floating and submerged weed are identified as :

- Biennial cutting;
- Cutting on a 3 to 5 year rotation; and,
- Desilting / raking on a 2 to 7 year rotation.

All these maintenance operations should be selective, concentrating on those areas which are particularly choked by vegetation or areas in which the weed is liable to cause an obstruction, hazard or restriction to flow.

Since the beginning of this study, weed maintenance has been performed on an annual basis during the summer. All the channel vegetation is removed except for a 1 m fringe of

vegetation down each channel margin. Generally, in terms of the maintenance regimes recommended as best practice in environmental terms, the current maintenance frequency is too great. Cutting every two years rather than annually would enhance the environmental quality of the Woldgrift Drain.

Bank

Best practice maintenance operations for bank vegetation are identified as :

- Light grazing.

The majority of the banks in the grassland areas are lightly grazed and all banks are flail mown.

If the environmental guidelines were followed in this case, the banks would not be mown and would be grazed. Due to the nature of agriculture in this area being intensive arable with little grazing, in order for the environmental quality of banks to be improved the flail mowing regime could be adapted to simulate grazing.

7.5 Recommendations

It is recommended that further research examines :-

- the impact of a reduced maintenance frequency (cutting every 2 years) on land drainage and flooding within the benefit area; and,
- the impact of reduced channel maintenance on channel environmental quality.

7.6 Epilogue

This report has assessed the impacts of the current maintenance regime on the study reach. It has been used along with other study sites to formulate guidelines on the appraisal of maintenance works and best environmental practice. These draft guidelines are summarised in Chapter 5 of the R&D Note 456 and presented in full under separate covers.

8. REFERENCES

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APPENDIX I

Example of input and output data for the watertable model

Woldgrift Drain

Block Number 101

Cross-section 1

Input Data		Output Data
River height (m AOD)		Watertable height (m AOD)
Week		
1992		
1	5.15	6.00
2	5.25	5.91
3	5.10	5.75
4	5.10	5.68
5	5.64	5.67
6	5.12	5.56
7	5.10	5.49
8	5.10	5.37
9	5.06	5.34
10	5.06	5.27
11	5.10	5.30
12	5.10	5.41
13	5.12	5.56
14	5.14	5.44
15	5.10	5.39
16	5.13	5.33
17	5.06	5.29
18	5.13	5.28
19	5.06	5.32
20	5.03	5.22
21	5.03	5.20
22	5.03	5.36
23	5.06	5.44
24	5.03	5.28
25	5.03	5.21
26	5.13	5.27
27	5.13	5.72
28	5.13	5.70
29	5.13	5.68

Example of drainage status classification, Woldgrift Drain

With maintenance Block 101	No. of weeks		No. of weeks		No. of weeks	
	Watertable depth (m)	1992	Spring 1992	Summer 1992	Autumn 1992	No. of weeks
>0.5 0.3><0.5m <0.3m	5.7	42	5.7	5.7	5.7	10
	5.9	8	5.9	5.9	5.9	3
	6.2	2	6.2	6.2	6.2	0

Drainage status classification, according to time watertable is within the G, B, VB drainage bands

Good

Good

Bad

Without maintenance	No. of weeks		No. of weeks		No. of weeks	
	Watertable depth (m)	1992	Spring 1992	Summer 1992	Autumn 1992	No. of weeks
>0.5 0.3><0.5m <0.3m	5.7	8	5.7	5.7	5.7	7
	5.9	10	5.9	5.9	5.9	3
	6.2	34	6.2	6.2	6.2	3

Drainage status classification, according to time watertable is within the G, B, VB drainage bands

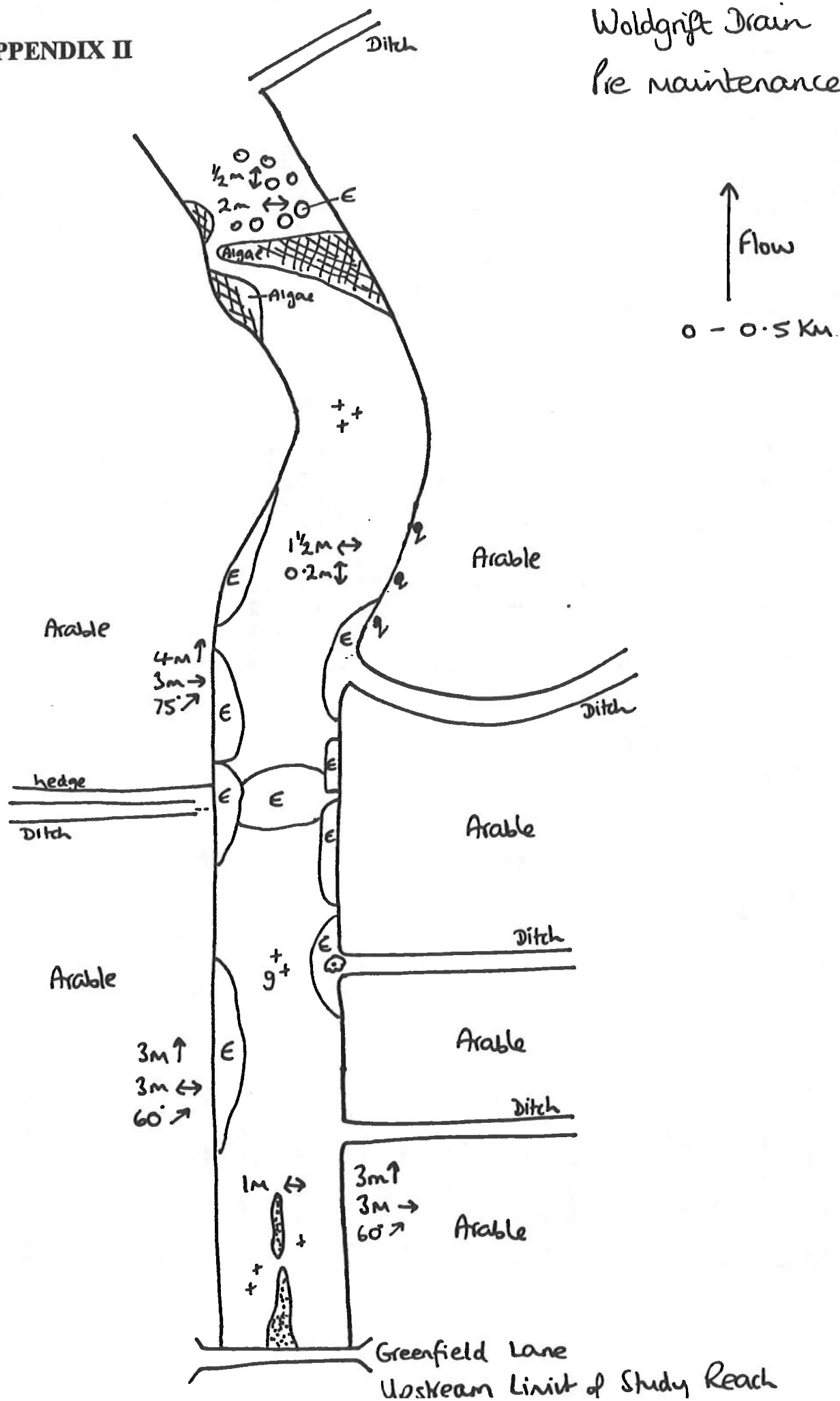
Good

Bad

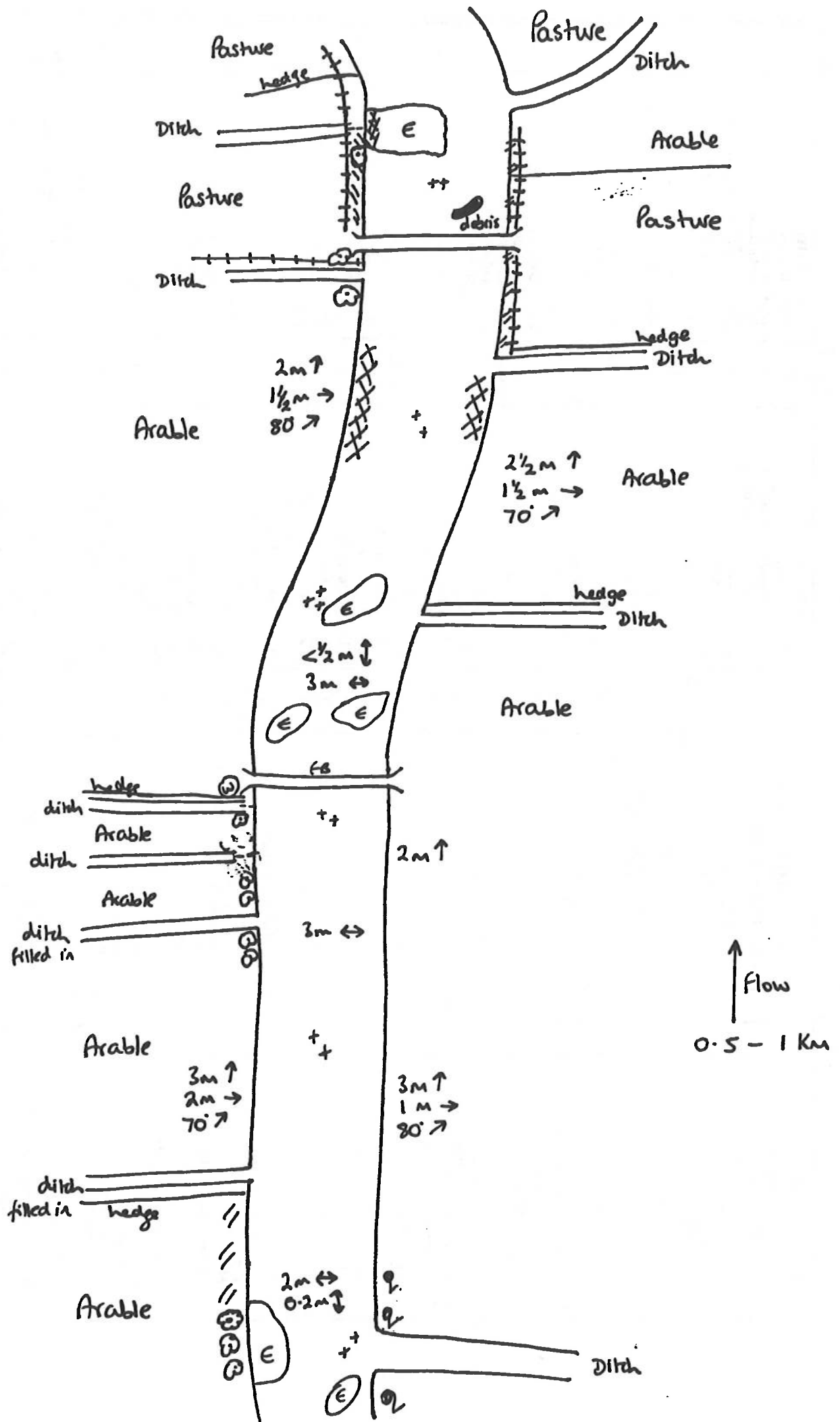
Bad

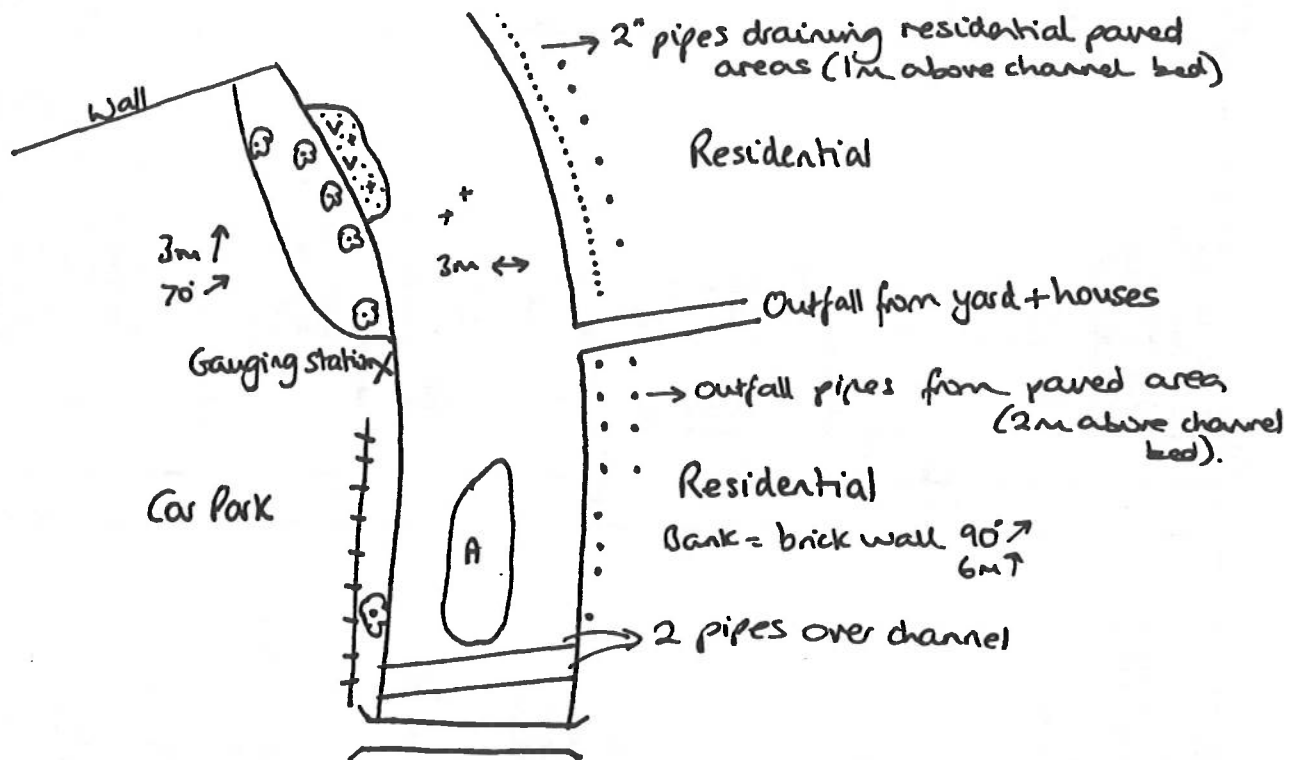
APPENDIX II

Woldgrift Drain
Pre maintenance

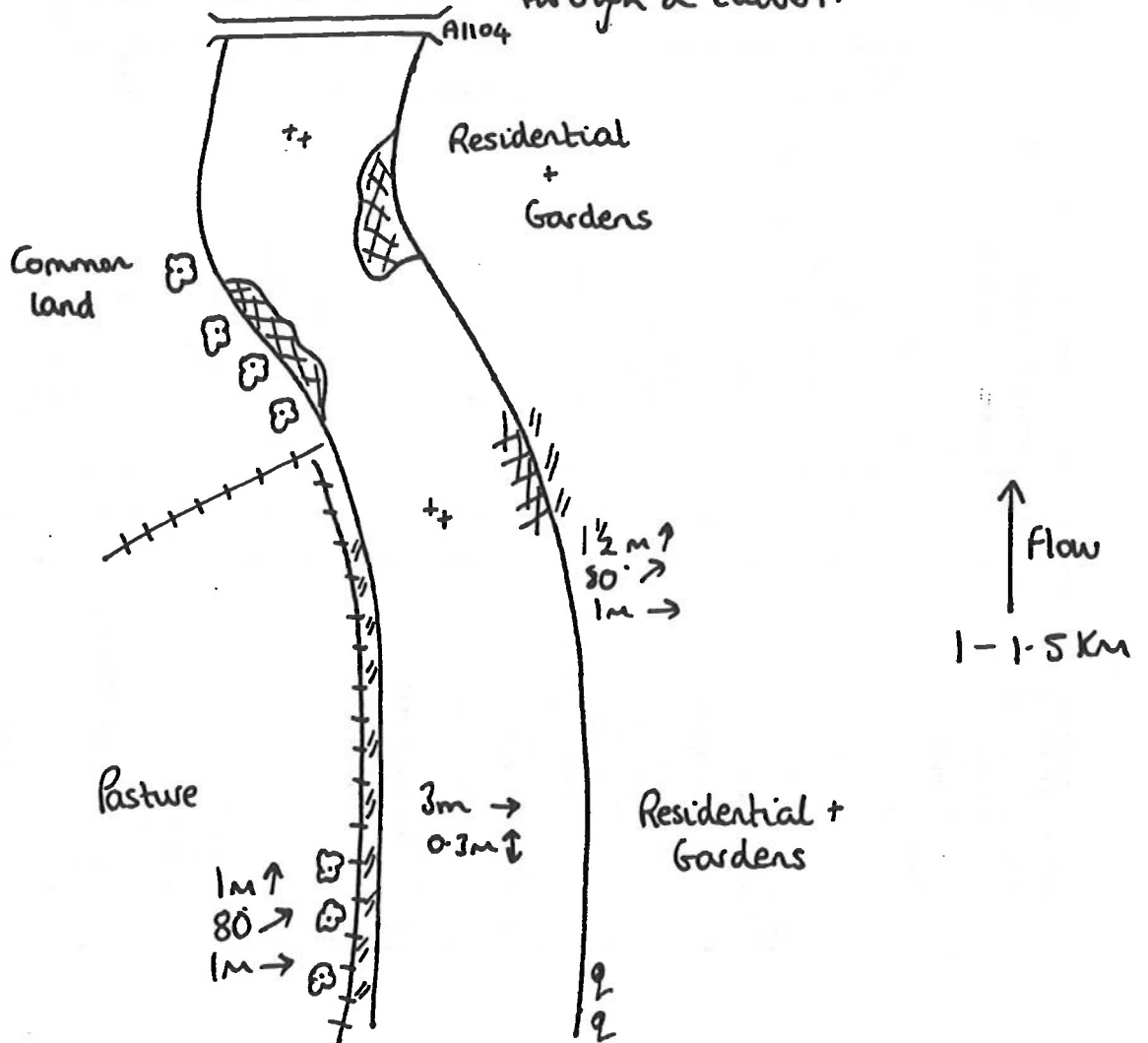


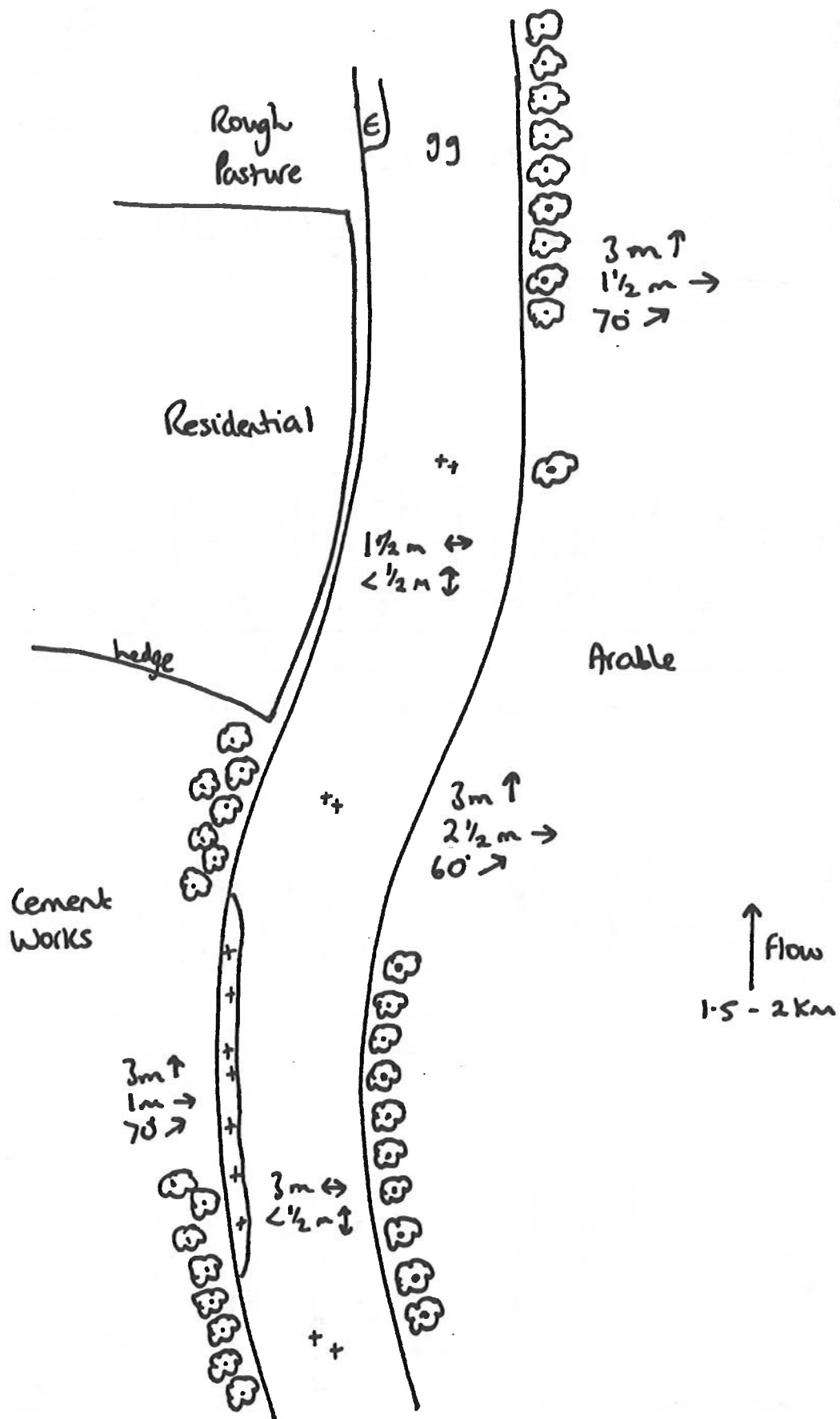
RIVER		BANK FEATURES %		RIVER HABITATS		RIVER	
W	S	W	S	W	S	W	S
RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD		BANK FEATURES % shill % solid earth cliff 1m f soft earth cliff 780 rock cliff artificial floral bank ash floral bank soil back levee Height 1-2m Width 1-2.5m 2.5-5m 5-10m Shilling 30-40" 60-80" 100" 1-2m 5-10m 15m 5-10m >10		RIVER HABITATS bridges/500m weirs/500m locks/500m inlets/500m Depth <25m 25-45 45-100 >100 Width <1 1-5 5-10 10-20 >20 Substrates DR boulders cobbles pebbles gravel sand silt/mud clay peat Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
G. OPEN WATER		BANK VEGETATION		Habitats and Flow		RIVER	
1. Standing - canal + canal = ditch dyke pond, pool, cut-off % lake % gravel pit % reservoir % marina % flunting stream <1m wide 1.5m 5.10m >10		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
1. ROCK		BANK VEGETATION		Habitats and Flow		RIVER	
1. cliff scree limestone pavement cave other 2. artificial/waste		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
1. MISCELLANEOUS		BANK VEGETATION		Habitats and Flow		RIVER	
arable amenity grassland ephemeral/short herb hedge + hedge = fence on bank fence soil back wall building cannons fish farm silage clamp sawage works garden stick pile flood debris road railway disused used other		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
1. WOODLAND & SCRUB %		BANK VEGETATION		Habitats and Flow		RIVER	
1. Broad-leaved semi-nat. plantation Coniferous semi-nat. plantation Mixed semi-natural plantations 2. Scrub - dense scattered Carr - alder willow 3. Parkland 4. Recently felled wood		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
B. GRASSLAND & MARSH %		BANK VEGETATION		Habitats and Flow		RIVER	
1. Acidic unimproved semi-improved Neutral unimproved semi-improved Calcareous unimproved semi-improved Improved/croqueted Marsh/marshy grassland		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
G. TALL HERB & FERN %		BANK VEGETATION		Habitats and Flow		RIVER	
1. Bracken 2. Upland spp rich veyol. 3. Other - tall ruderal non ruderal		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
D. HEATHLAND %		BANK VEGETATION		Habitats and Flow		RIVER	
1. Dwarf scrub - dry wet 2. Lichen/xyrophyte 3. Montane 4. Heath/grassland - dry wet		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
E. MIRE, FLUSH AND SPRING %		BANK VEGETATION		Habitats and Flow		RIVER	
1. Mires - bog Fen - reed sedge sweet grass mixed Bog flushes		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	
F. SWAMP/INUNDATION %		BANK VEGETATION		Habitats and Flow		RIVER	
1. Swamp - single sp. dom. Tall mixed assemblage		BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrubs % Sparse Scrub/shrubs % Rocks/Grass % Dense open % Sparse open % Re-sprouted or new % Exposed bare rocks Islands Rocky, vegetated rocky, 1 bare shingle and rock shingle, rock + veg earth - maturing earth - with trees developed		Habitats and Flow pool slack riffle rapids run run - water fall protruding rocks Margins shingle 1 bare shingle, vegetated mud sand FLORA % emergent veg ~ 1m wide emergent 1-2m wide emergent >2m wide total veget area biophytes emergents submerged floating algae % of stretch		RIVER Waldgrift Drain Km No. 0-0.5 km Date 5/5/92 Surveyor JAD	



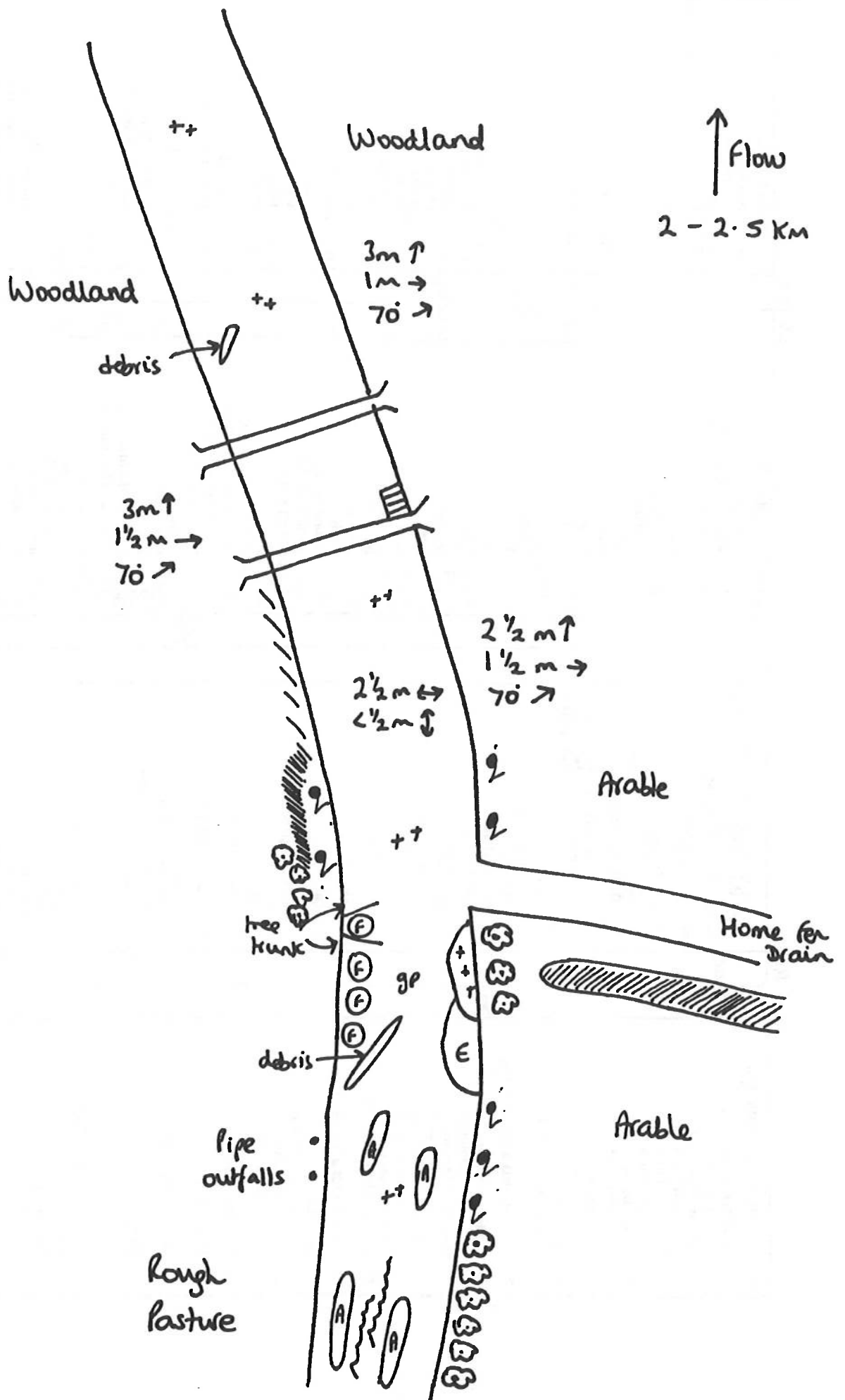


Alford
 Woldgrift Drain flows under town
 through a culvert.

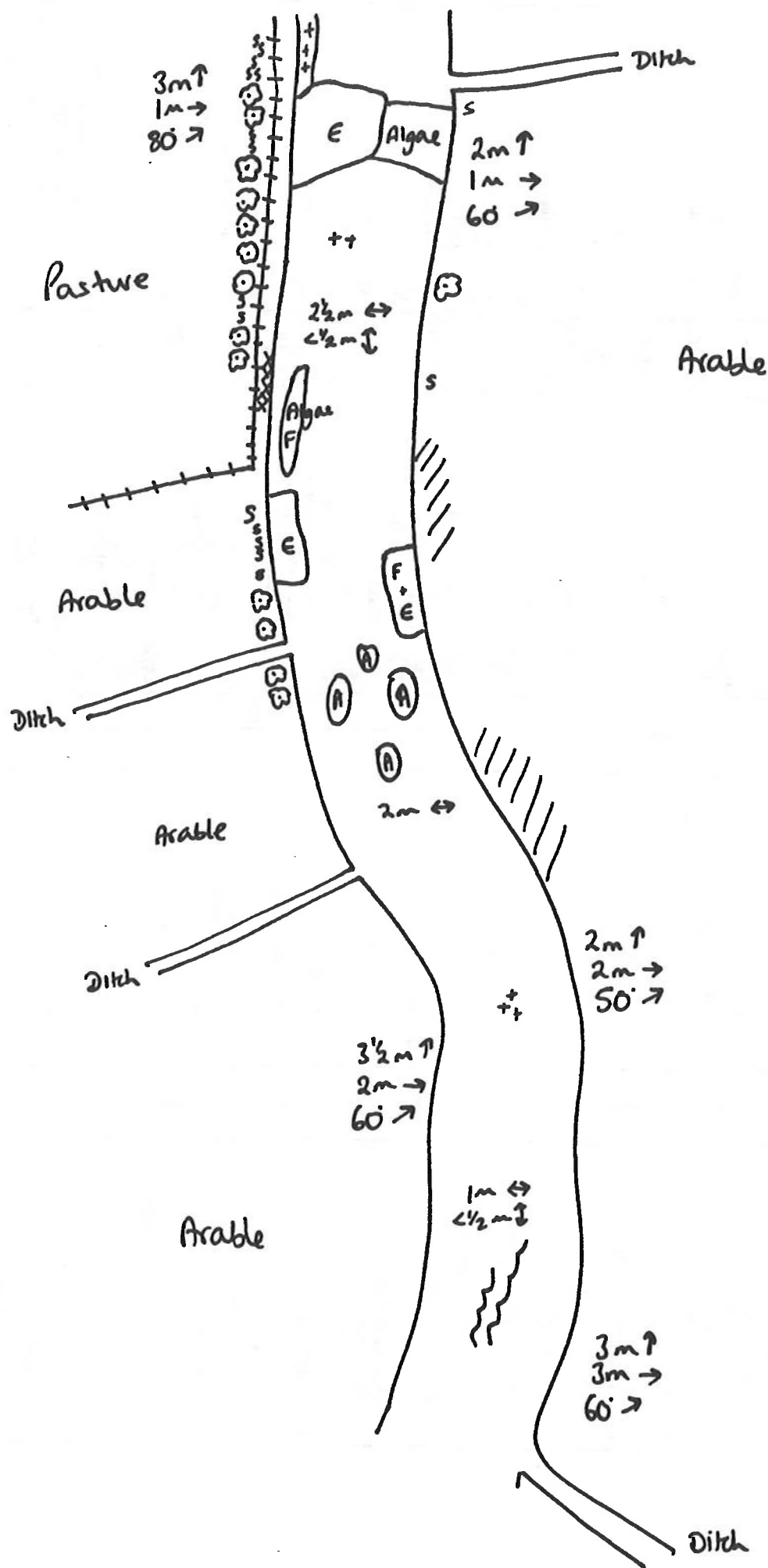




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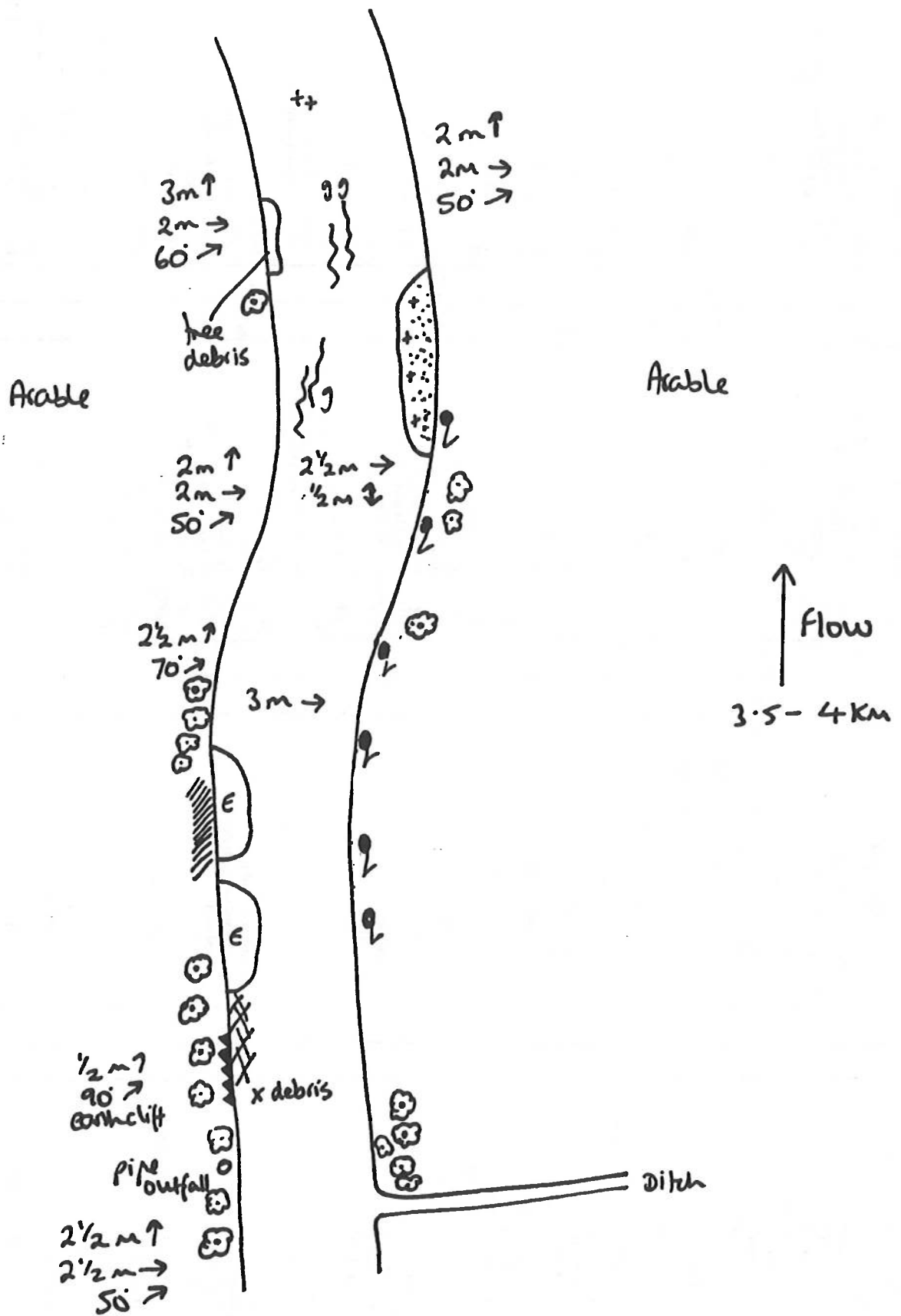


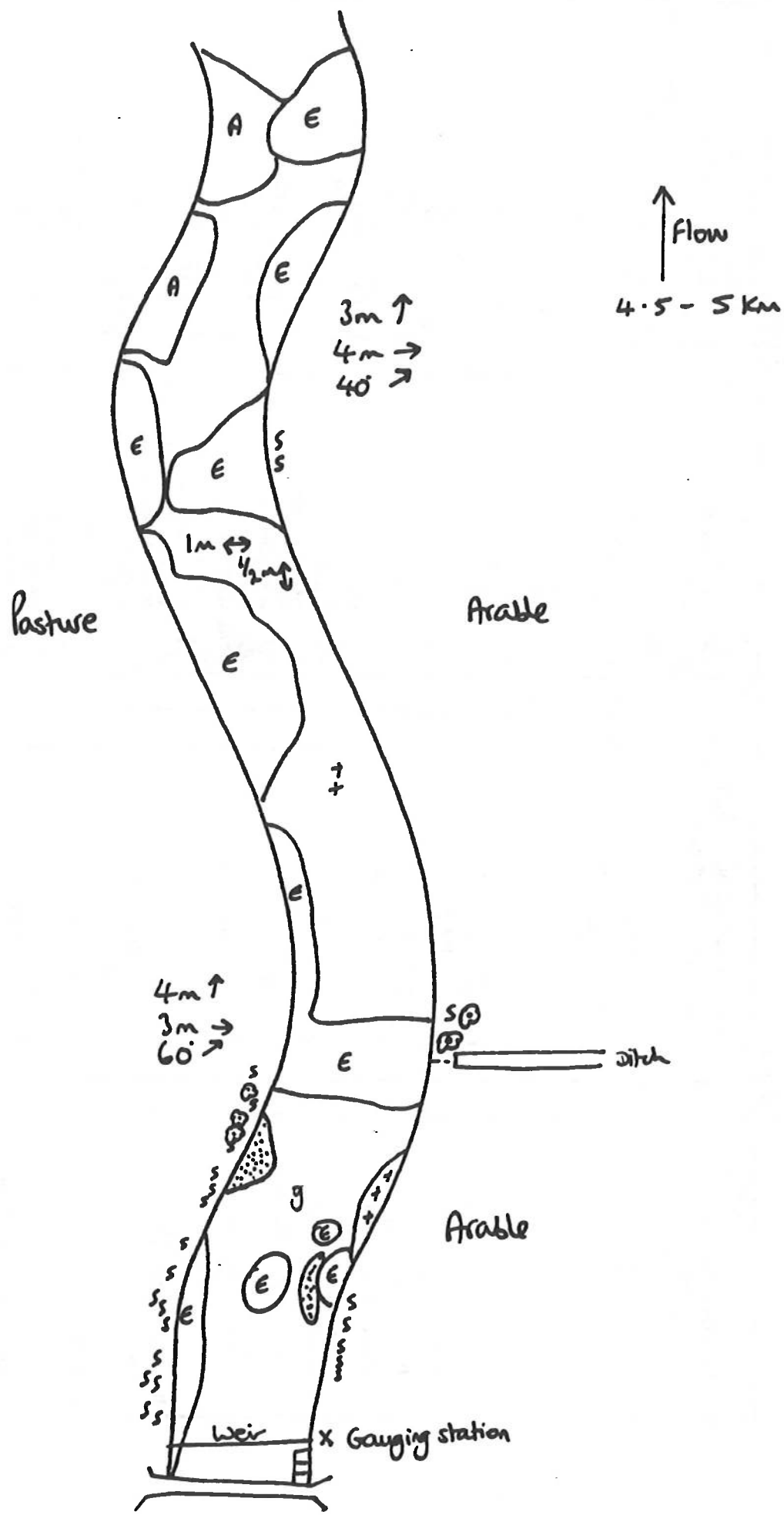
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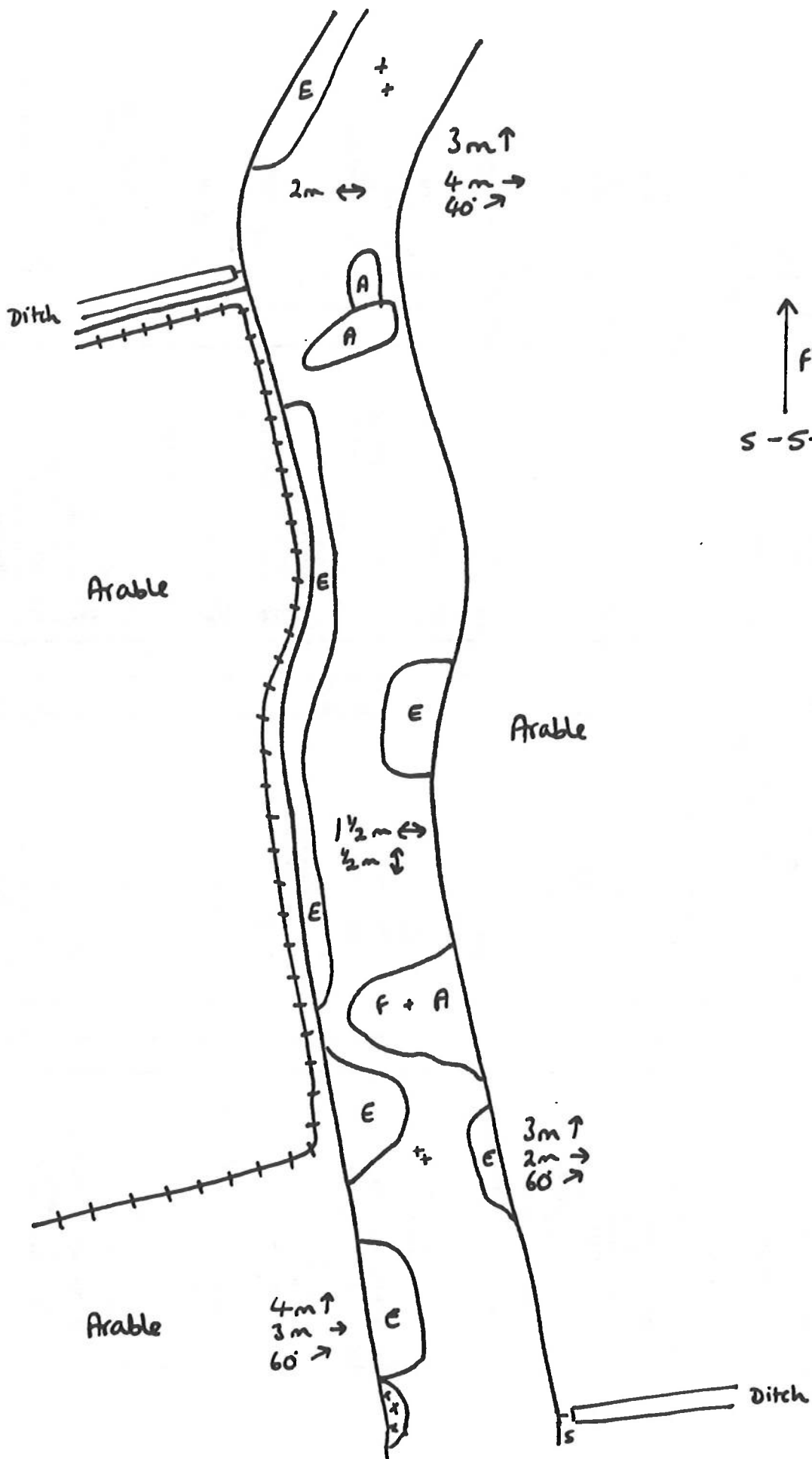
↑ Flow
3 - 3.5 km

[illegible]

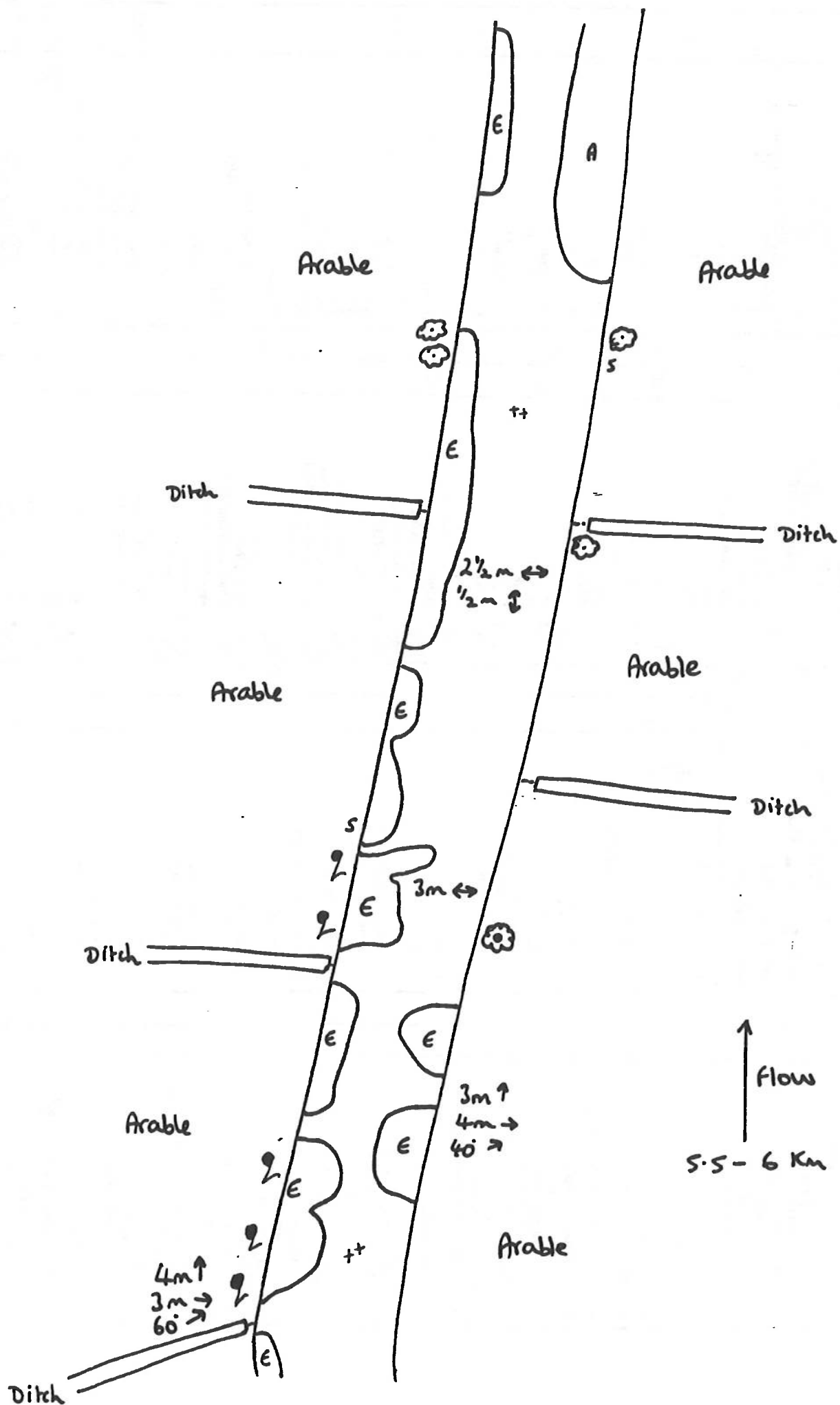


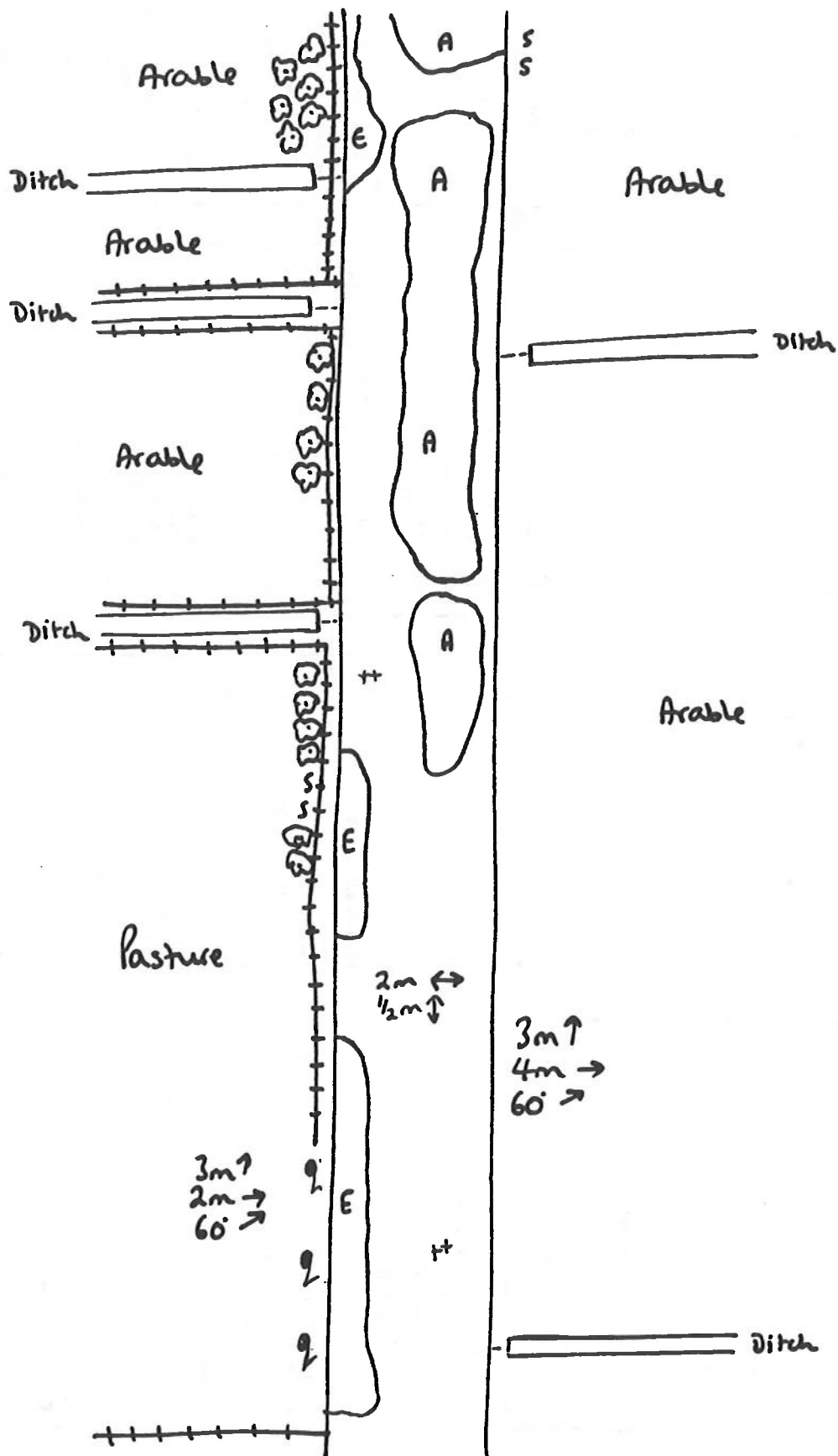


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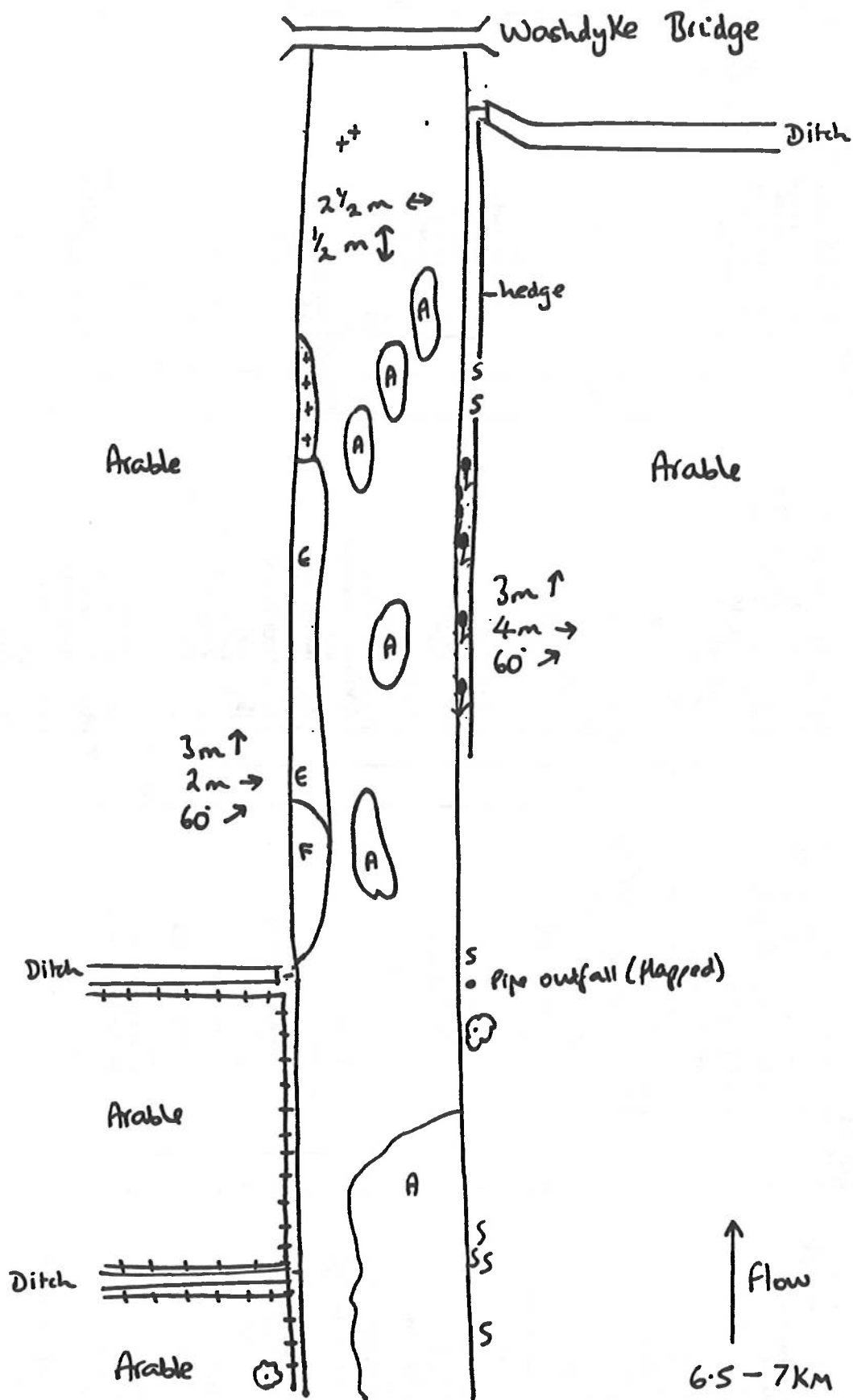


↑
flow
S - S.5 Km



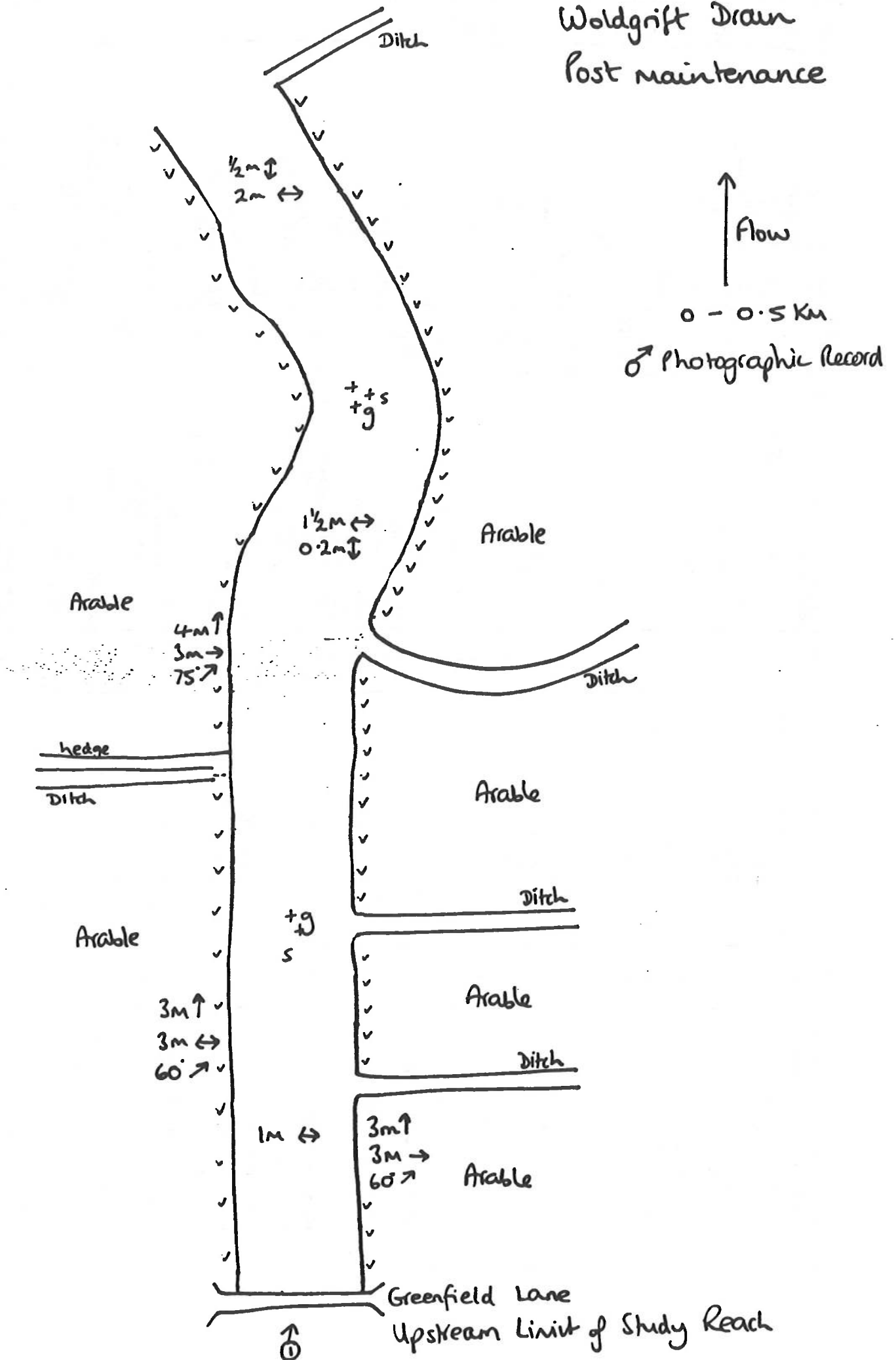


↑ Flow
6 - 6.5 Km

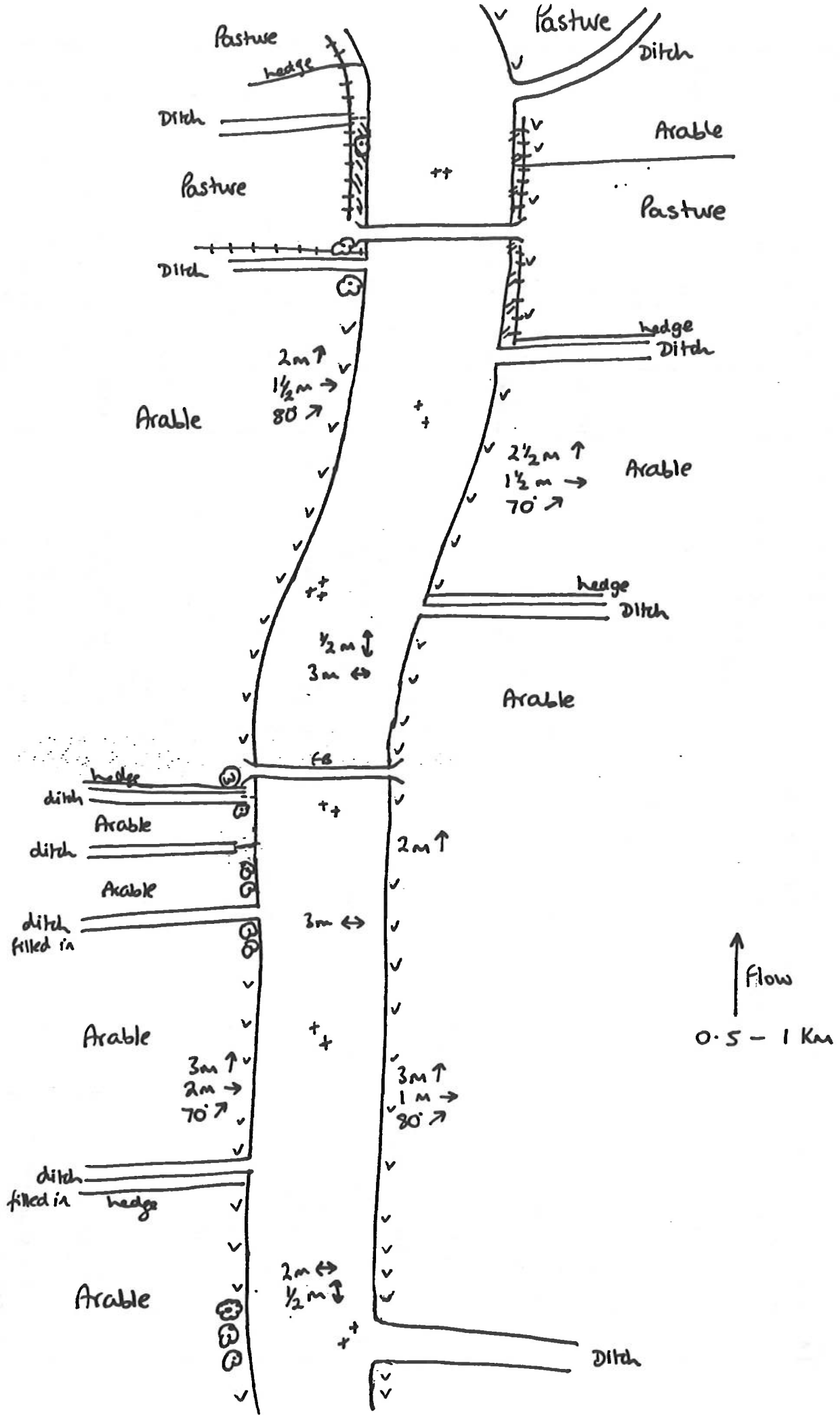


LG RB		LB RB		RIVER	
RIVER		BANK FEATURES %		RIVER HABITATS	
Woldgrift Drain Km No. 6-5 = 7 km. Date 6/5/92 Surveyor JAD.		shill % solid earth cliff 1m ↑ } soft earth cliff > 80 } rock cliff artificial flood bank only flood bank soil back levee Height < 1m 1-2m > 2m Width < 1m 1-2.5m 2.5-5m > 5m Skirt < 30° 30-45° 45-60° > 60° Top + mud sand bare slung/vexated vexated slung/vexated natural cutbanks natural boulders BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrub % Sparse Scrub/shrub % Bare/Salt % Dense open % Sparsely open % Exposed on mown % Exposed from roots ISLANDS Rocky, vegetated rocky, + bare slung/vexated and rock slung/vexated + veg earth - maturing earth - with trees developed		bridges/500m weirs/500m locks/500m inlet/500m Depth < 25m 25-5 5-10 10-20 > 20 Width < 1 1-5 5-10 10-20 > 20 Substrates bed rock boulders cobbles pebbles gravel sand silt/mud clay peat Habitats and Flow pool slack tillu rapids run waterfall protruding rocks Margins shingle + bare shingle, vegetated mud sand FLORA % emergent < 1m wide emergent 1-2m wide emergent > 2m wide total veget. area bryophytes emergents submerged floating algae % of stretch	
G. OPEN WATER		Height < 1m 1-2m > 2m Width < 1m 1-2.5m 2.5-5m > 5m Skirt < 30° 30-45° 45-60° > 60° Top + mud sand bare slung/vexated vexated slung/vexated natural cutbanks natural boulders BANK VEGETATION Oak, Ash, Sycamore Willow - recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick Scrub/shrub % Sparse Scrub/shrub % Bare/Salt % Dense open % Sparsely open % Exposed on mown % Exposed from roots ISLANDS Rocky, vegetated rocky, + bare slung/vexated and rock slung/vexated + veg earth - maturing earth - with trees developed		100 100	

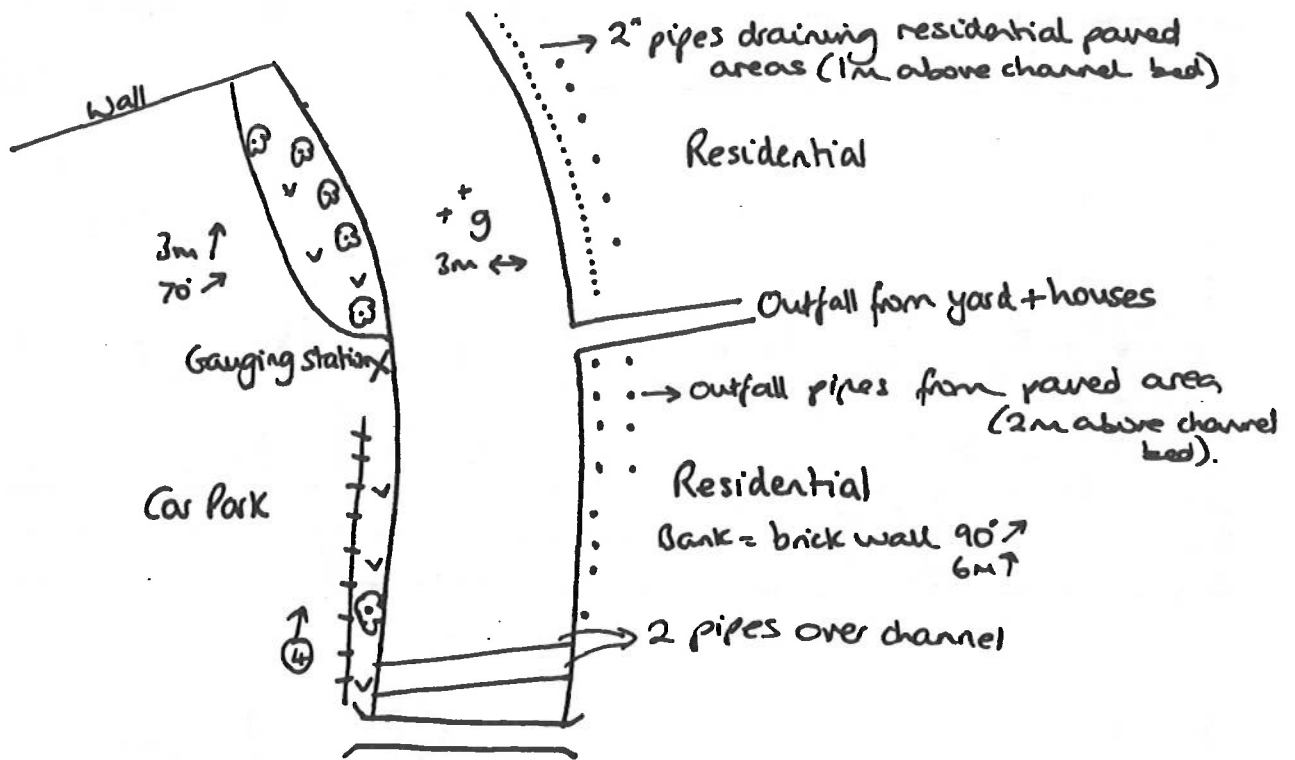
Woldgrift Drain Post maintenance



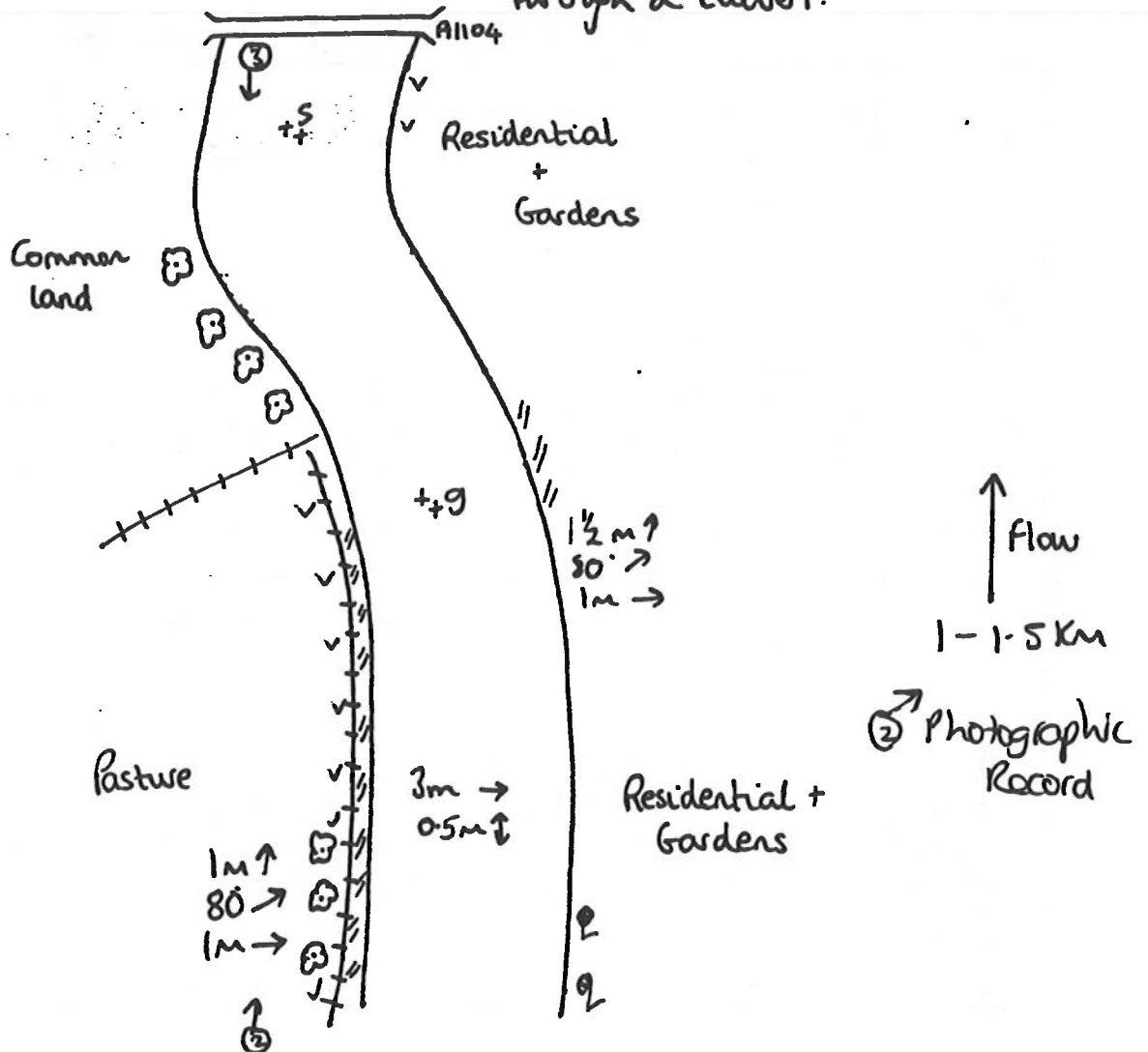
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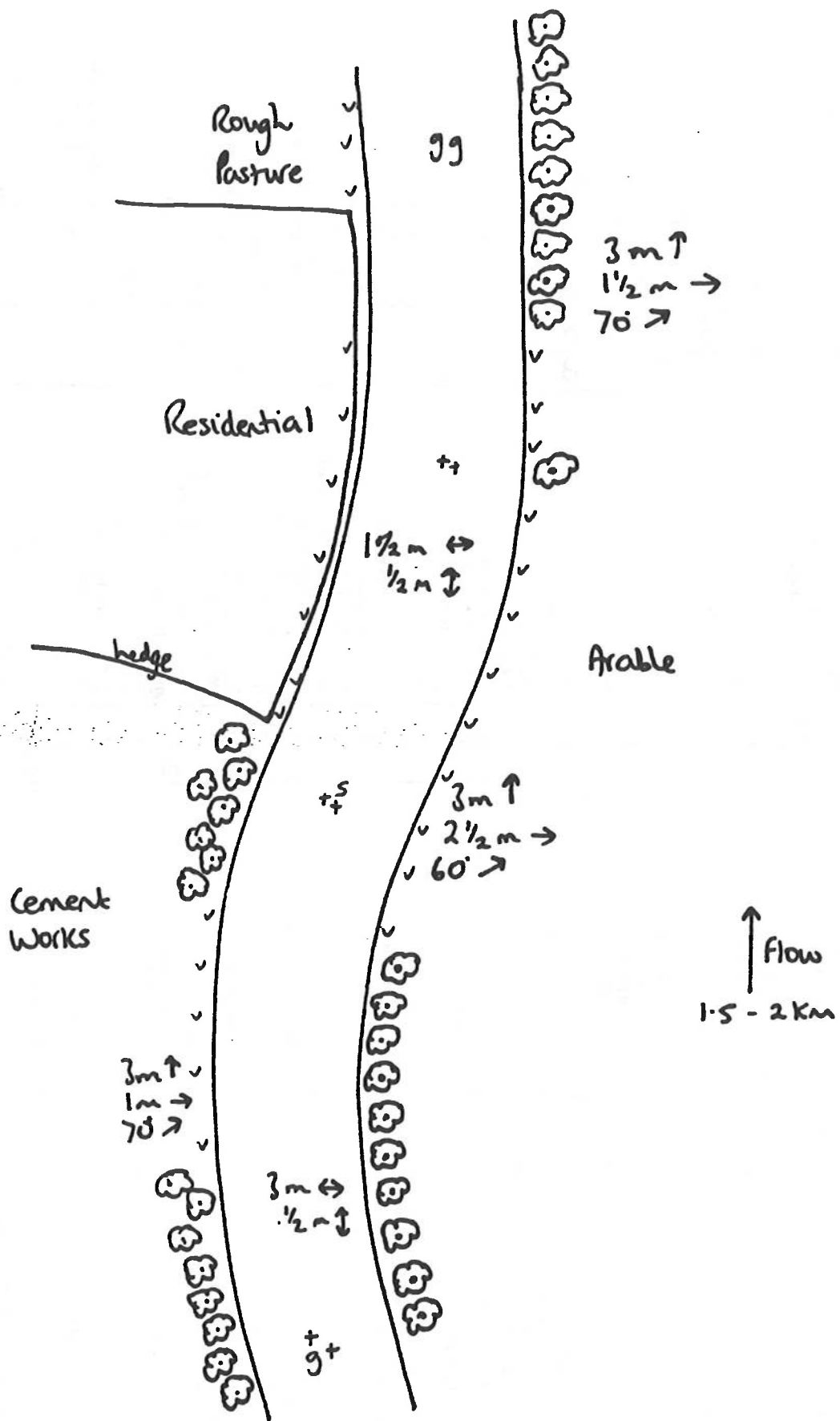
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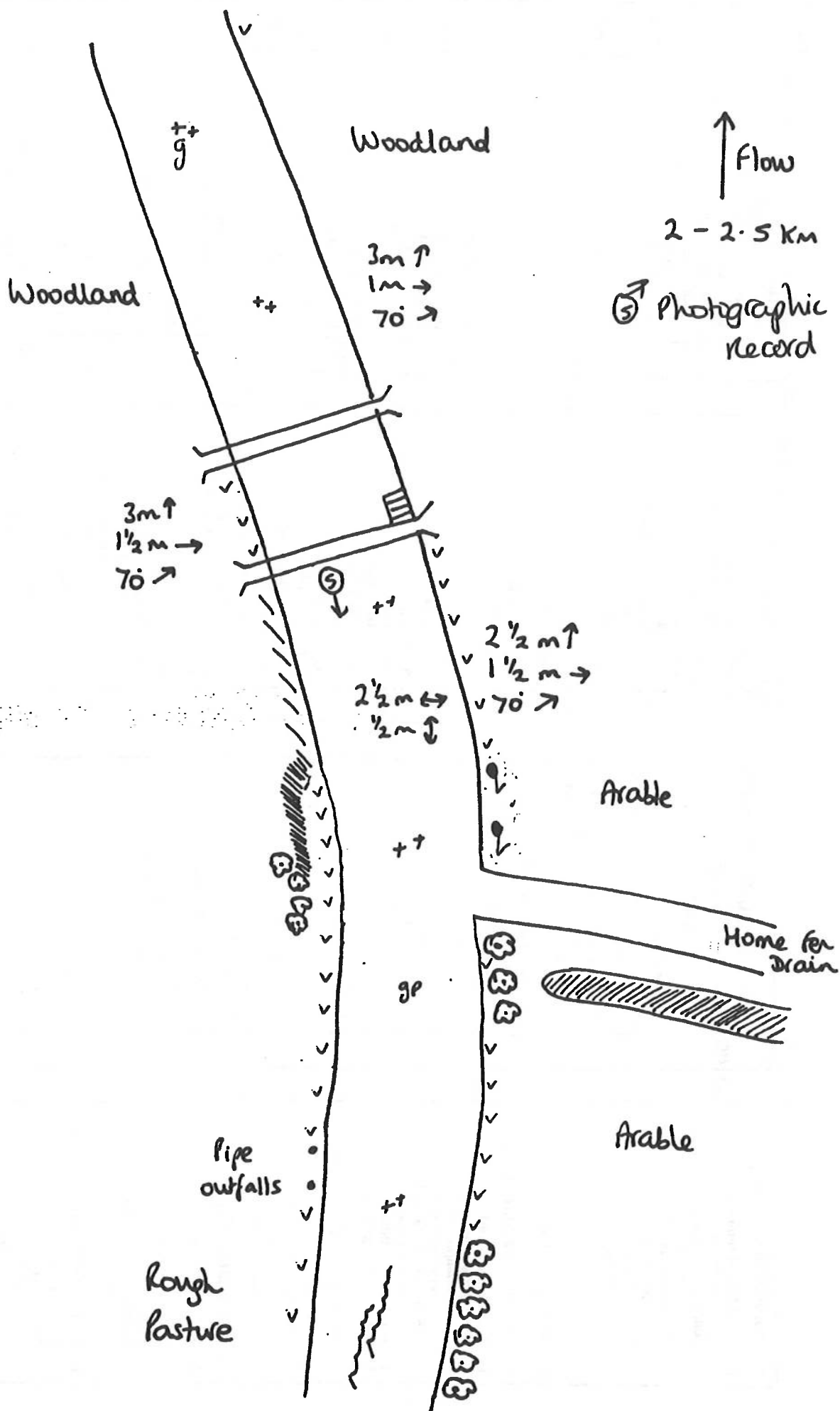
Alford
 Woldgriff Drain flows under town
 through a culvert.

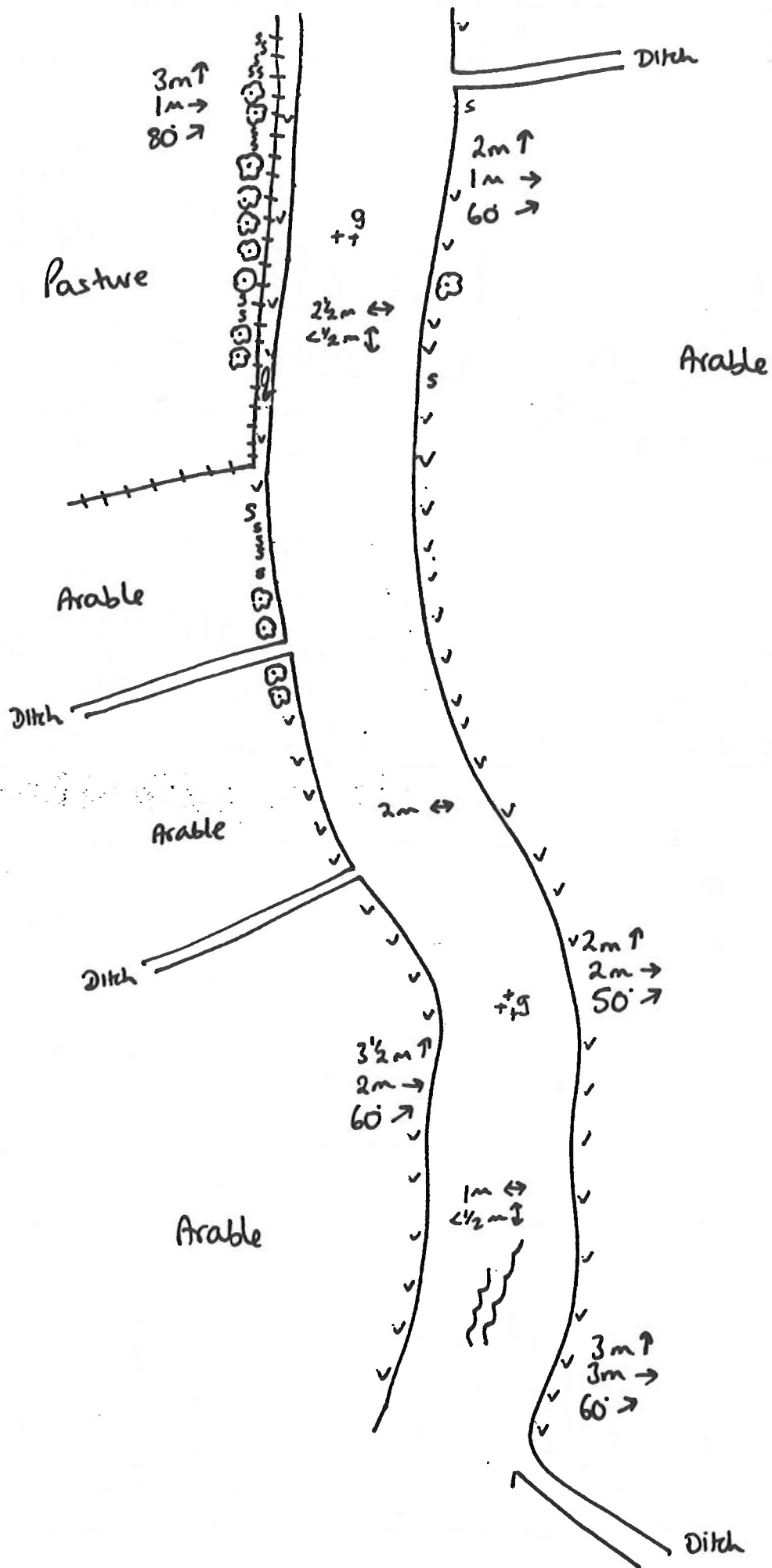


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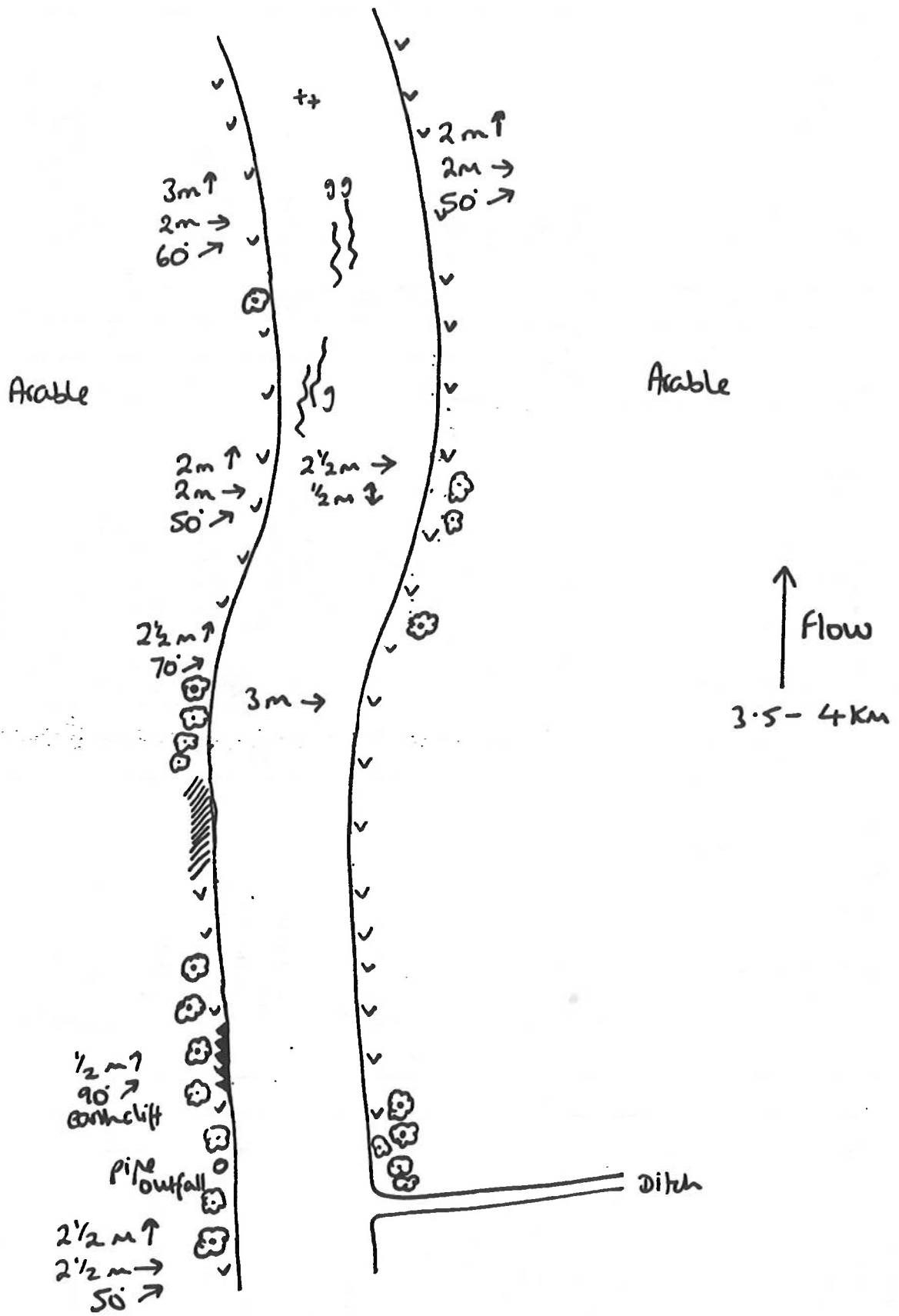
LG RB		LB RB		RB	
MIVER WOLDEGIFT BRAIN		BANK FEATURES %		RIVER HABITATS	
Run No. 1-5-2		shelf %		bridges > 500m	
Date 14/4/93		solid earth cliff 1m ⁺		weirs > 500m	
Surveyor JALD		soft earth cliff > 80°		locks > 500m	
		rock cliff		intake > 500m	
		artificial		Depth < 25m	
		flood bank only		25 < 5	
		flood bank set back		5 < 1.0	
		levee		> 1.0m	
		Height < 1m		Width < 1	
		1 < 2m		1 < 5	
		> 2m		5 < 10	
		Width < 1m		10 < 20	
		1 < 2.5m		> 20	
		2.5 < 5m		Substrates	
		> 5m		bed rock	
		Slope < 30°		boulders	
		30 < 45°		cobbles	
		45 < 60°		pebbles	
		> 60°		gravel	
		1-1-1 mud		sand	
		SSS sand		sil/mud	
		bare shingle		clay	
		vegetated shingle		peat	
		earth		Habitats and Flow	
		natural lakes		pool	
		natural features		slack	
		BANK VEGETATION		mill	
		Cambray		rapids	
		Oak, Ash, Sycamore		run	
		Willow, recent pollard		waterfall	
		Willow old, not pollard		protruding rocks	
		Standard willows		Margins	
		Alder		single 1 bare	
		Other trees		shingle, vegetated	
		Young trees		mud	
		Thick scrub/shrub %		sand	
		Sparse scrub/shrub %		FLORA %	
		Heavy scrub %		emergent veg < 1m wide	
		Dense open %		emergent 1-2m wide	
		Sparse open %		emergent > 2m wide	
		Regenerated on mown %		total veg. area	
		Exposed tree roots		by geophytes	
		ISLANDS		emergents	
		Rocky, vegetated		submerged	
		rocky, 1 bank		floating	
		shingle and rock		algae % of stretch	
		shingle, rock 1 veg			
		earth - maturing			
		earth - with trees			
		developed			

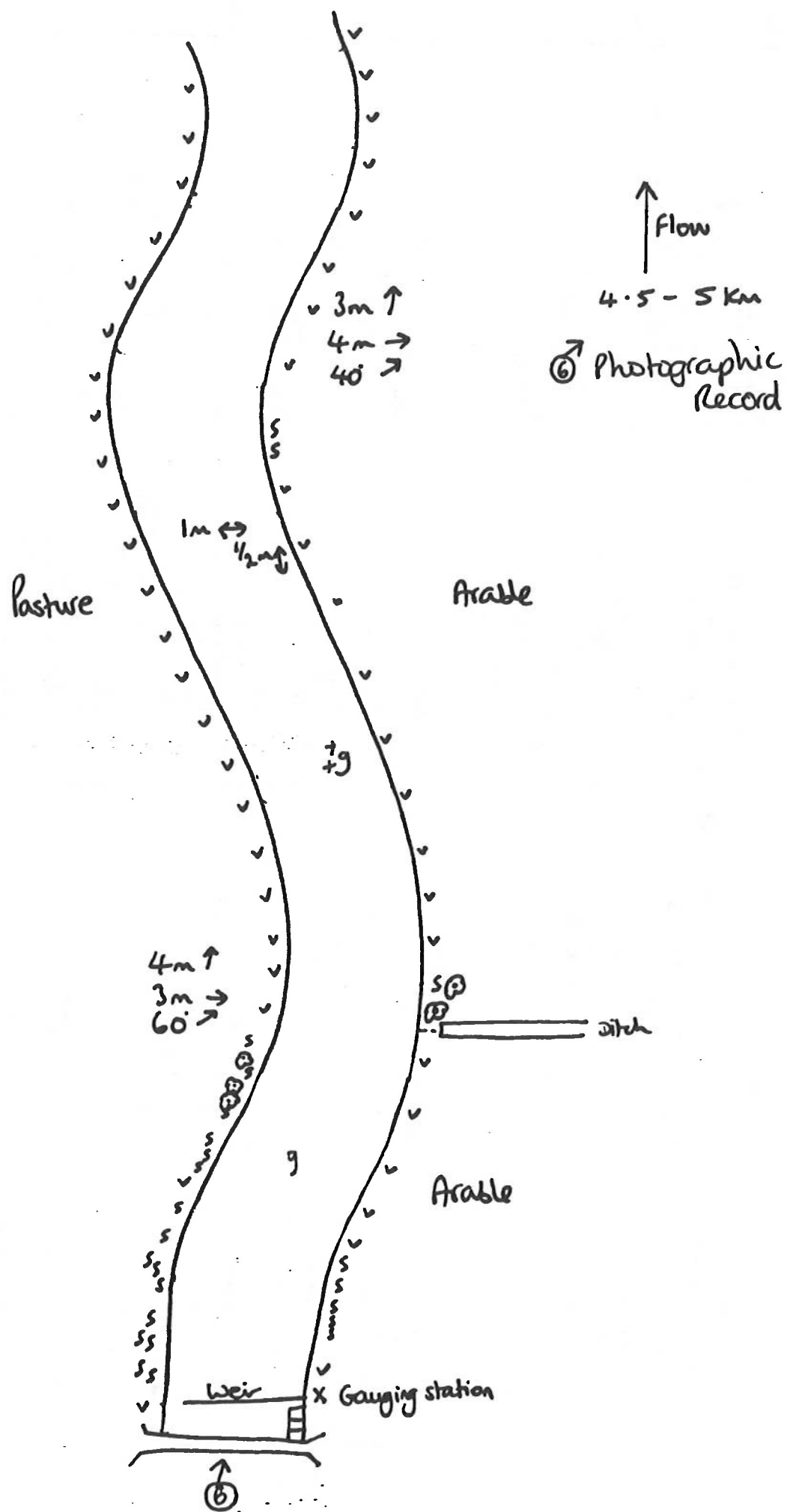


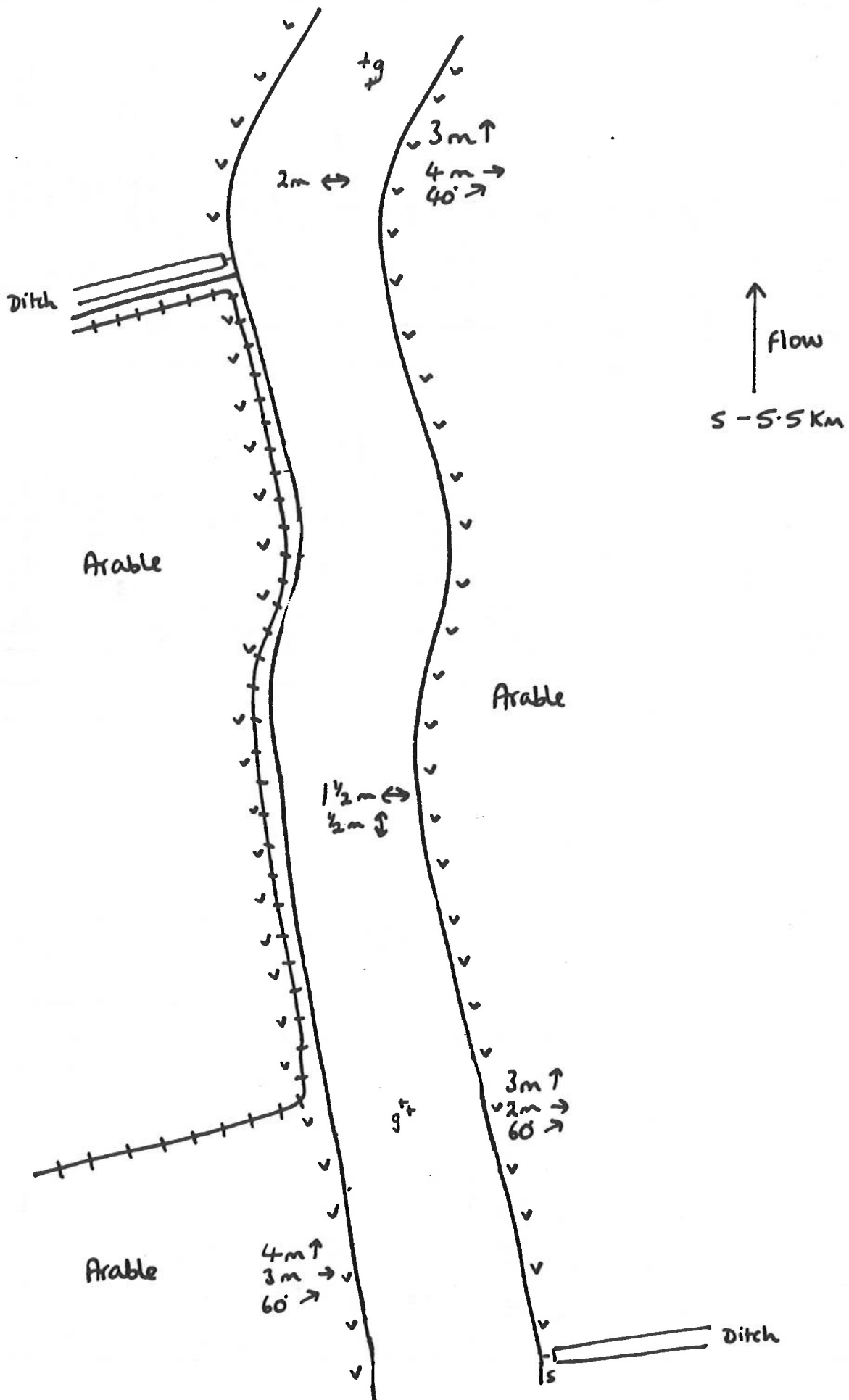


↑ Flow
3 - 3.5 km

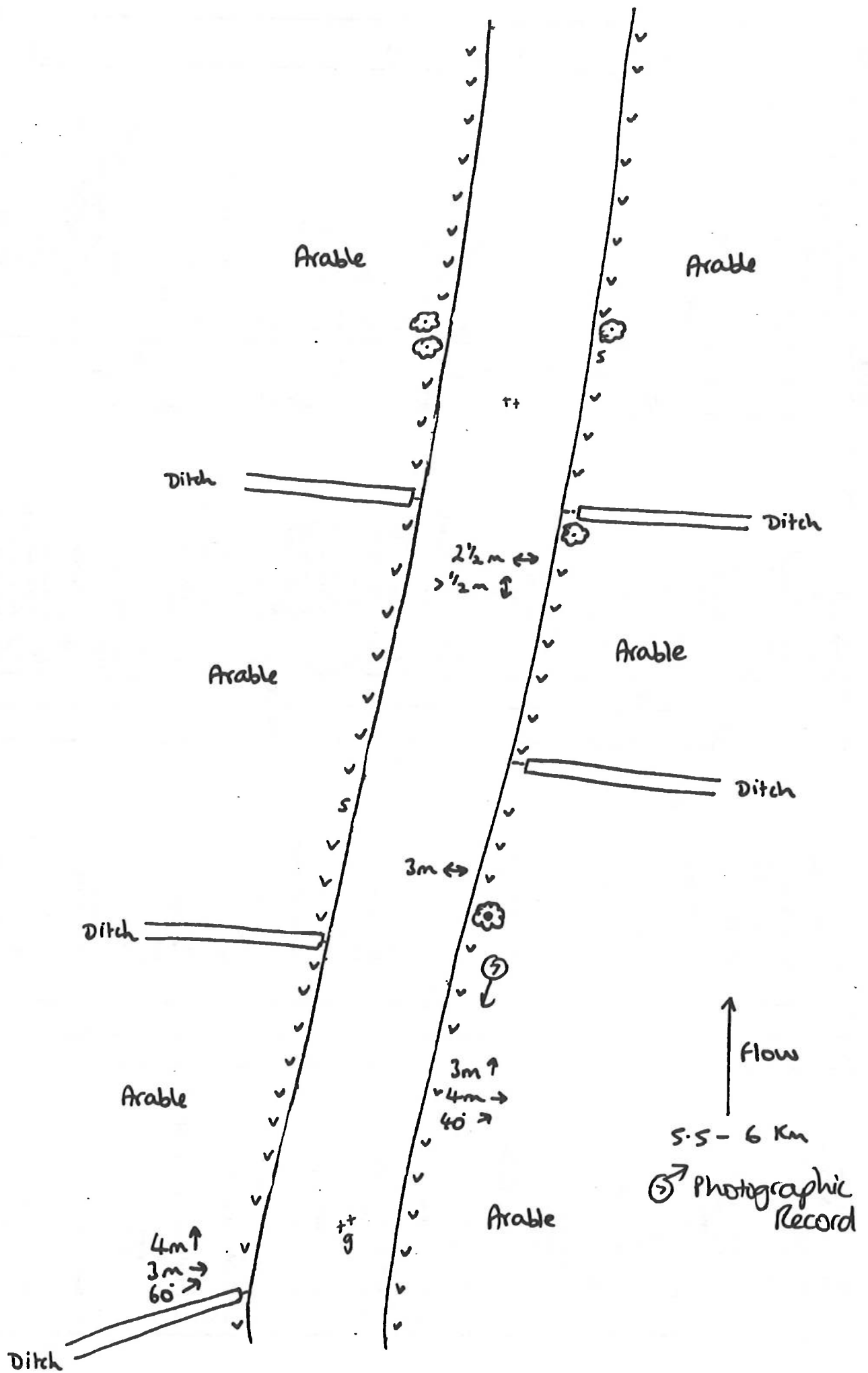
LG RB		LB RB		RB		RIVER	
RIVER WOODCRIFT DRAIN Item No. 3 - 3.5 Date 14/4/93 Surveyor JALD		BANK FEATURES % 1- solid % AAA solid earth cliff 1m ↑ AAA solid earth cliff > 80. ↑ UUU rock cliff UUU artificial UUU flood bank only UUU flood bank soil back UUU levee Height ↑ < 1m 1-2m > 2m Width → < 1m 1-2.5m 2.5-5m > 5m Slopes → < 30° 30-45° 45-60° > 60° 1-1m 1-2m 2-5m > 5m bare shrubs vegetated shrubs earth natural cutbanks natural bankiers BANK VEGETATION Caulies Oak, Ash, Sycamore Willow recent pollard Willow old, not pollard Standard willows Alder Other trees Young trees Thick scrub/shrubs % Sparse scrub/shrubs % Heavy Scrub % Decayed open % Sparse open % Recolonised or mown % Exposed tree roots ISLANDS Rocky, vegetated rocky, 1 bare shrub and rock shrub, rock 1 very earth - matting earth - with trees developed		RIVER HABITATS UUU bedrock/500m UUU wet/500m UUU lock/500m UUU inlet/500m Depth ↑ < 25m 25-50 50-100 > 100 Width → < 1 1-5 5-10 10-20 > 20 Substrates UUU bed rock UUU boulders UUU cobbles UUU pebbles UUU gravel UUU sand UUU silt/mud UUU clay UUU peat Habitats and Flow UUU pool UUU slack UUU tiller UUU rapids UUU run UUU waterfall UUU protruding rocks Margins UUU shrub UUU shrub, vegetated UUU mud UUU sand FLOORA % UUU emergent veg < 1m wide UUU emergent 1-2m wide UUU emergent > 2m wide UUU total veget. area UUU bryophytes UUU emergents UUU submerged UUU floating UUU algae % of stretch		100 100 30 70 98 2	



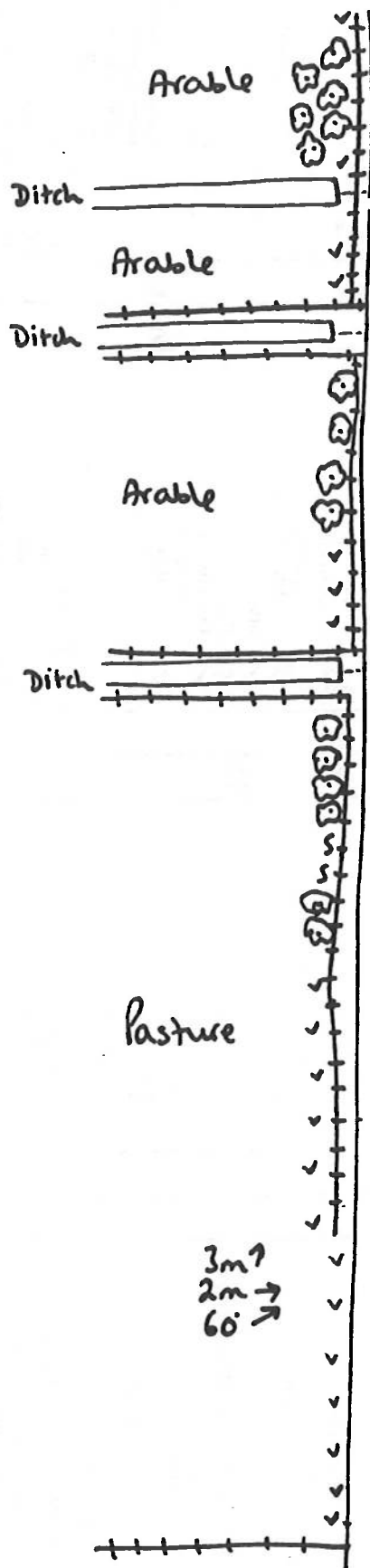
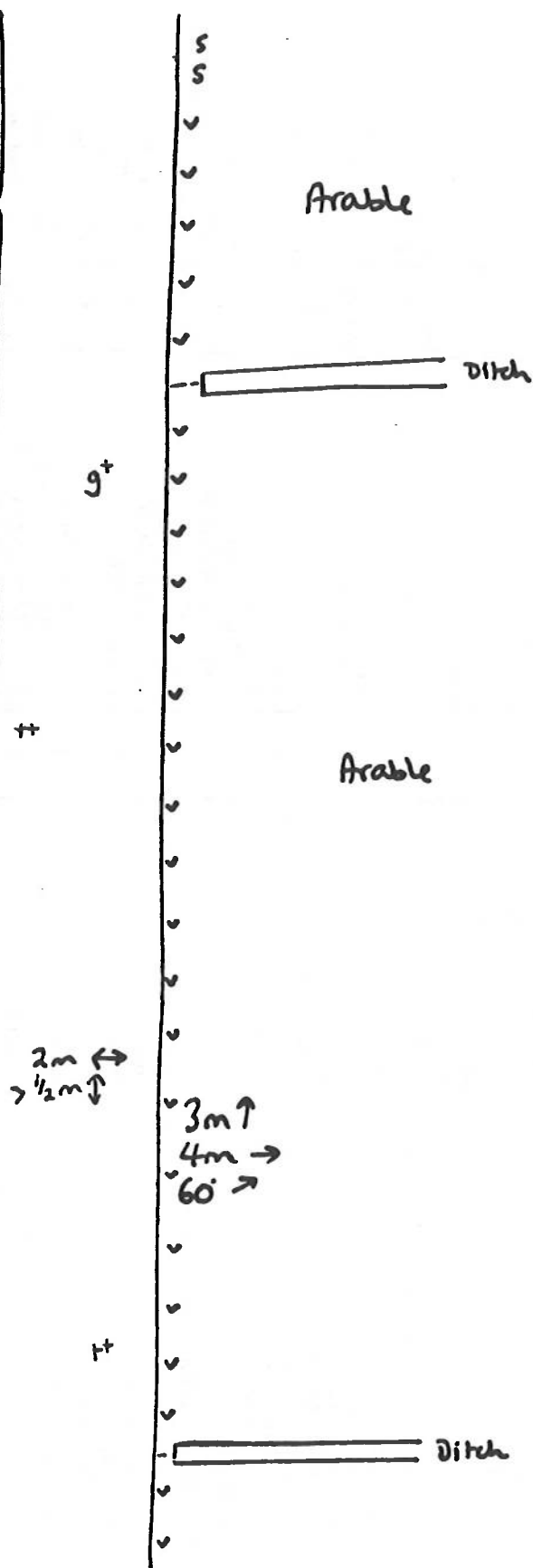




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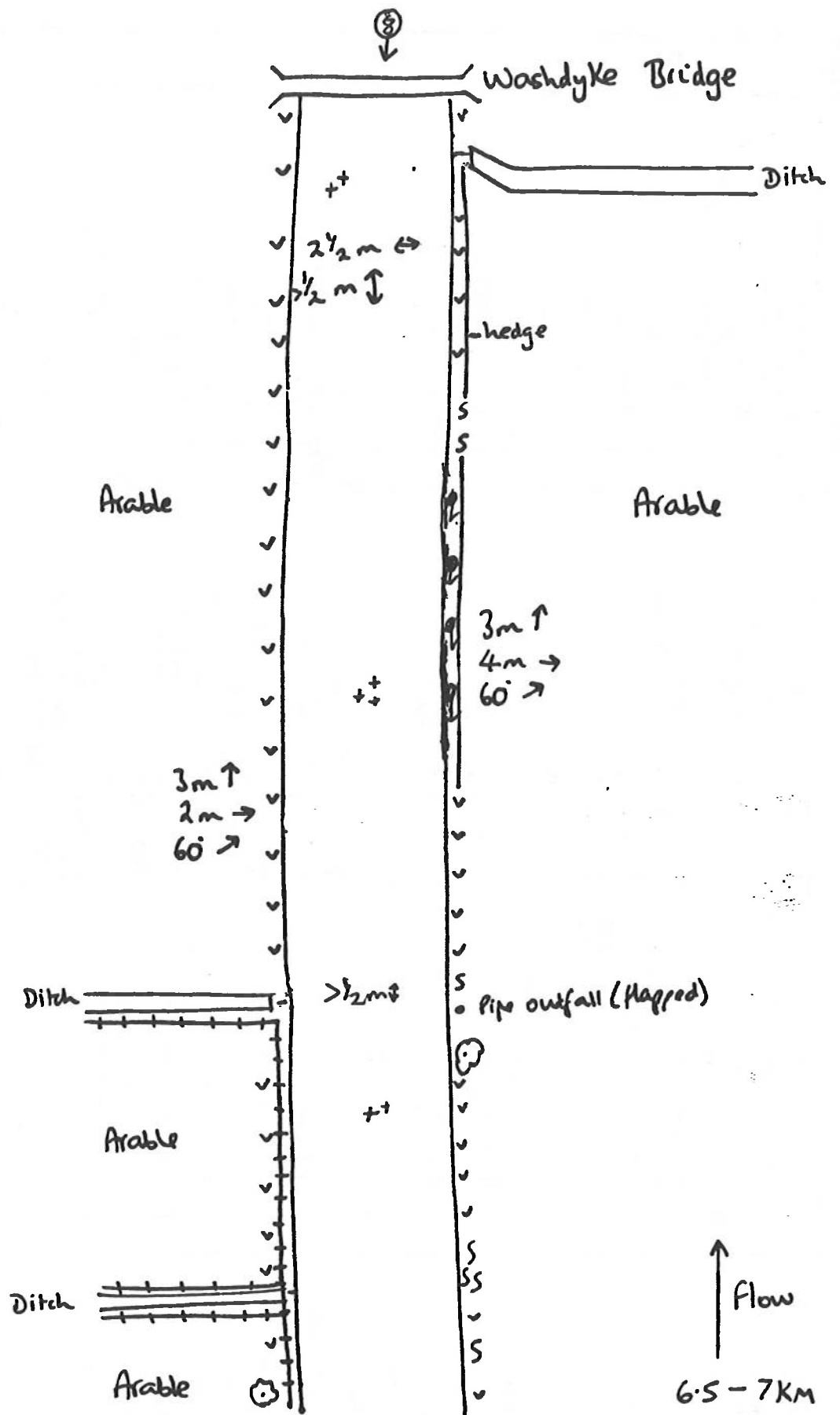


LG RB		LG RB		LG RB		RIVER	
A. WOODLAND & SCRUB %		RIVER WOULDGRIFT DRAIN		BANK FEATURES %		RIVER HABITATS	
1. Broad-leaved semi-nat. plantation		Rm No. 5-5-6		shrub %		bridges/500m	
Coniferous semi-nat. plantation		Date 15/4/93		solid earth cliff 1m↑		weirs/500m	
Mixed semi-natural plantation		Surveyor JALD		solid earth cliff > 80%		locks/500m	
2. Scrub - dense				rock cliff		inlets/500m	
3. Carr - alder				artificial		Depth < 25m	
4. Recently felled wood				flood bank only		25-50	
				flood bank set back		0.5-1.0	
				levees		> 1.0m	
B. GRASSLAND & MARSH %				Height		Width < 1	
1. Acidic unimproved				↑		1-5	
2. Semi-improved				Width		5-10	
Neutral unimproved				→		10-20	
Semi-improved				Shrub		> 20	
Calcareous unimproved				30-40%			
3. Improved/cossetled				40-50%			
4. Marsh/marshy grassland				> 50%			
C. TALL HERB & FERN %				Height			
1. Blacken				↑			
2. Upland spp. rich veget.				Width			
3. Other - tall ruderal				→			
4. Non ruderal				Shrub			
D. HEATHLAND %				30-40%			
1. Dwarf scrub - dry				40-50%			
2. Lichen/bryophyte				> 50%			
3. Montano				Height			
4. Heally/grassland - dry				↑			
5. Wet				Width			
6. Wet				→			
E. MIRE, FLUSH AND SPRING %				Shrub			
1. Mires - bog				30-40%			
2. Fen - reed				40-50%			
3. Sedge				> 50%			
4. Sweet-grass				Height			
5. mixed				↑			
6. Dog flushes				Width			
F. SWAMP/INUNDATION %				→			
1. Swamp - single sp. dom.				Shrub			
2. Tall mixed assemblage				30-40%			
				40-50%			
				> 50%			
				Height			
				↑			
				Width			
				→			
				Shrub			
				30-40%			
				40-50%			
				> 50%			
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				Height			
				↑			
				Width			
				→			
				Shrub			
				30-40%			
				40-50%			
				> 50%			
				Height			
				↑			
				Width			
				→			
				Shrub			
				30-40%			
				40-50%			
				> 50%			
				Height			
				↑			
				Width			
				→			
				Shrub			
				30-40%			
				40-50%			
				> 50%			
				Height			
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				Shrub			
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				Width			
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				Shrub			
				30-40%			
				40-50%			
				> 50%			
				Height			
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				Width			
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				Shrub</			



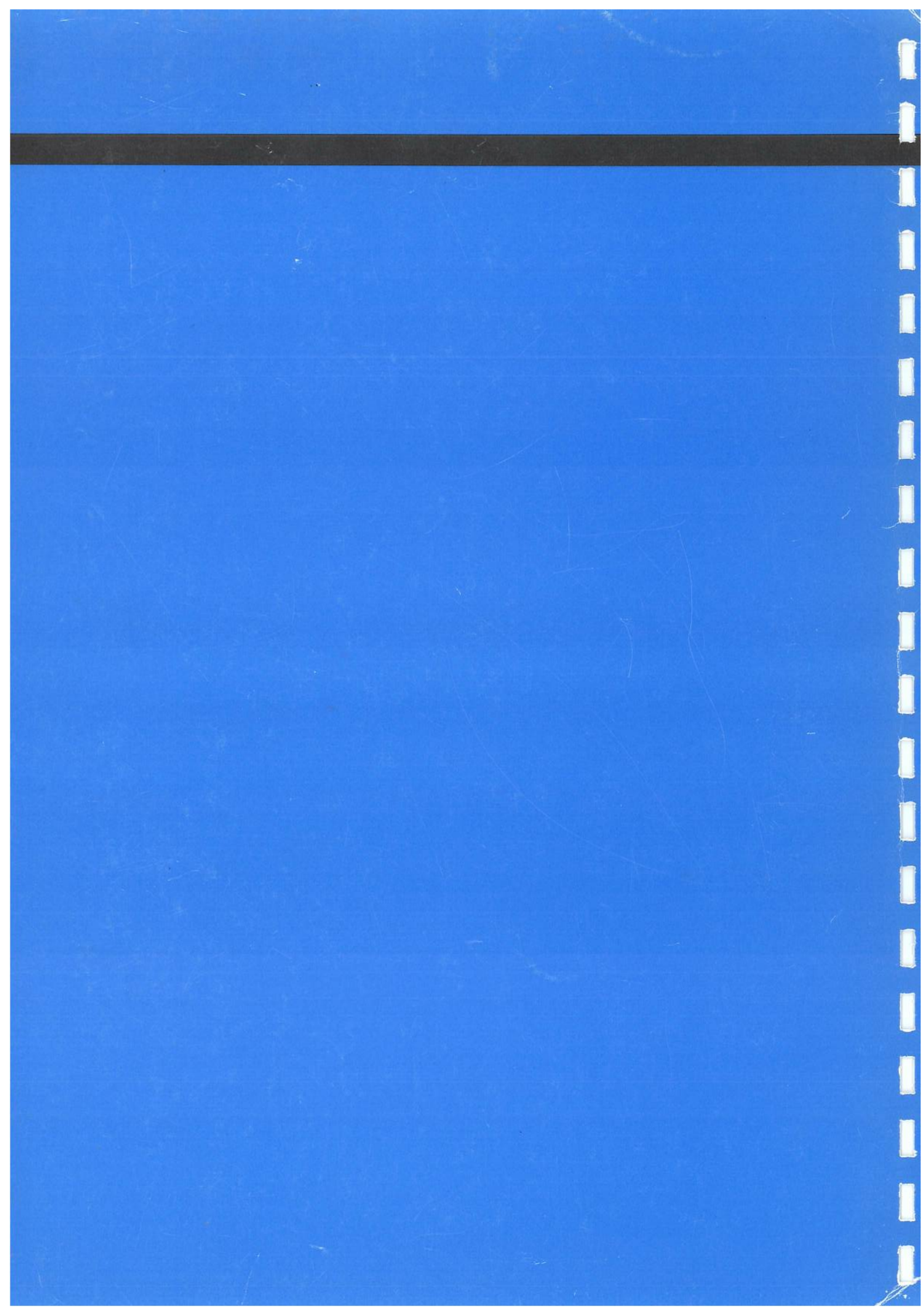
↑ Flow
6 - 6.5 Km

LG RB		LG RB		LG RB		LG RB		RIVER	
A. WOODLAND & SCRUB %		RIVER WOLDEGRIFF DRAIN		BANK FEATURES %		RIVER HABITATS			
1. Broad-leaved semi-nat. plantation		Run No. 6-6.5		shrub %		bridges 500m			
Coniferous semi-nat. plantation		Date 15/4/93		solid earth cliff 1m ↑		walls 500m			
Mixed semi-natural plantation		Surveyor JALD		rock cliff		locks 500m			
2. Scrub - dense				artificial		inlets 500m			
3. Carr - alder				flood bank only		Depth < 25m			
4. Recently felled wood				flood bank set back		↑			
B. GRASSLAND & MARSH %				levee		Width < 1			
1. Acidic unimproved				Height < 1m		1-5			
Neutral unimproved				↑		5-10			
Semi-improved				Width < 1m		10-20			
2. Calcareous unimproved				↑		> 20			
3. Improved/resuscitated				Shades		Substrates			
4. Marsh/marshy grassland				3M < 4M		bed rock			
C. TALL HERB & FERN %				6M < 8M		boulders			
1. Bracken				> 8M		cobbles			
2. Upland spp. rich veget.				↑		pebbles			
3. Other - tall ruderal				↑		gravel			
D. HEATHLAND %				↑		sand			
1. Dwarf scrub - dry				↑		siltsand			
2. Lichen/bryophyte				↑		clay			
3. Montane				↑		peat			
4. Heath/grassland - dry				↑		Habitats and Flow			
5. Wet				↑		pool			
E. MIRE, FLUSH AND SPRING %				↑		shrub			
1. Mires - bog				↑		shrub, vegetated			
2. Fen - reed				↑		reed			
3. Sedge				↑		sand			
4. Sweet grass				↑		FLORA %			
5. Mixed				↑		emergent veg ~ 1m wide			
6. Dog flushes				↑		emergent 1-2m wide			
F. SWAMP/INUNDATION %				↑		emergent > 2m wide			
1. Swamp - single sp. dom.				↑		total veget area			
2. Tall mixed assemblage				↑		bryophytes			
				↑		emergents			
				↑		submerged			
				↑		floating			
				↑		algae % of stretch			



⑤ Photographic Record

LG RB		US RB		LG RB		US RB		RIVER	
A. WOODLAND & SCRUB %		RIVER WOODGRIFT DRAIN		BANK FEATURES %		RIVER HABITATS		RIVER	
1. Broad-leaved semi-nat. plantation		Sta. No. 6-5-7		alt. %		Habitats		100	
Coniferous semi-nat. plantation		Date 15/4/93		solid earth cliff 1m ↑		Habitats		100	
Mixed semi-nat. plantation		Surveyor JALD		solid earth cliff > 80%		Habitats		100	
2. Scrub - dense				rock cliff		Habitats		100	
Catt - alder				flood bank only		Habitats		100	
Parkland				flood bank set back		Habitats		100	
4. Recently felled wood				levee		Habitats		100	
B. GRASSLAND & MARSH %				Height		Habitats		100	
1. Acidic unimproved				Width		Habitats		100	
Semi-improved				1-2.5m		Habitats		100	
Neutral unimproved				2.5-5m		Habitats		100	
Semi-improved				> 5m		Habitats		100	
Culcous unimproved				Slopes		Habitats		100	
Semi-improved				30-45°		Habitats		100	
Improved/Drainage				60-90°		Habitats		100	
5. Marsh/marshy grassland				> 90°		Habitats		100	
G. TALL HERB & FERN %				Height		Habitats		100	
1. Blacken				Width		Habitats		100	
2. Upland sp. rich veget.				1-2.5m		Habitats		100	
3. Other - tall ruderal				2.5-5m		Habitats		100	
non ruderal				> 5m		Habitats		100	
D. HEATHLAND %				Slopes		Habitats		100	
1. Dwarf scrub - dry				30-45°		Habitats		100	
wet				60-90°		Habitats		100	
2. Lichen/bryophyte				> 90°		Habitats		100	
4. Montano				Height		Habitats		100	
5. Heathy/grassland - dry				Width		Habitats		100	
wet				1-2.5m		Habitats		100	
6. MIRE, FLUSH AND SPRING %				2.5-5m		Habitats		100	
1. Mires - bog				> 5m		Habitats		100	
Fen - reed				Slopes		Habitats		100	
sedge				30-45°		Habitats		100	
sweet-grass				60-90°		Habitats		100	
mixed				> 90°		Habitats		100	
2. Bog flushes				Height		Habitats		100	
garden				Width		Habitats		100	
stick pile				1-2.5m		Habitats		100	
flood debris				2.5-5m		Habitats		100	
road				> 5m		Habitats		100	
railway drainage				Slopes		Habitats		100	
used				30-45°		Habitats		100	
other				60-90°		Habitats		100	
F. SWAMP/INUNDATION %				> 90°		Habitats		100	
1. Swamp - single sp. dom.				Height		Habitats		100	
Tall mixed assemblage				Width		Habitats		100	
				1-2.5m		Habitats		100	
				2.5-5m		Habitats		100	
				> 5m		Habitats		100	
				Slopes		Habitats		100	
				30-45°		Habitats		100	
				60-90°		Habitats		100	
				> 90°		Habitats		100	
				Height		Habitats		100	
				Width		Habitats		100	
				1-2.5m		Habitats		100	
				2.5-5m		Habitats		100	
				> 5m		Habitats		100	
				Slopes		Habitats		100	
				30-45°		Habitats		100	
				60-90°		Habitats		100	
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				> 5m		Habitats		100	
				Slopes		Habitats		100	
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				2.5-5m		Habitats		100	
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				2.5-5m		Habitats		100	
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				60-90°		Habitats		100	
				> 90°		Habitats		100	
				Height		Habitats		100	
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				2.5-5m		Habitats		100	
				> 5m		Habitats		100	
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				> 90°		Habitats		100	
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				2.5-5m		Habitats		100	
				> 5m		Habitats		100	
				Slopes		Habitats		100	
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				> 90°		Habitats		100	
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				Width		Habitats		100	
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				2.5-5m		Habitats		100	
				> 5m		Habitats			





DSPACE

<https://dspace.org/>

Anglian Region: River Yare, River Wensum, Woldgrift Drain

Dunderdale, J. A. L.; Morris, J.

1996

National Rivers Authority

<https://dspace.lib.cranfield.ac.uk/handle/1826/21272>

Dunderdale JAL, Morris J. (1996) Anglian Region: River Yare, River Wensum, Woldgrift Drain, Annex of R&D note 456, R&D project record 317/19/ST, produced for the National Rivers Authority 1996