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The Evaluation of River Maintenance

Silsoe College

Project Report



NRA

National Rivers Authority

NATIONAL RIVERS AUTHORITY

SEVERN TRENT REGION

THE EVALUATION OF RIVER MAINTENANCE

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LIST OF ABBREVIATIONS AND ACRONYMS

NCC	Nature Conservancy Council (now English Nature)
NRA	National Rivers Authority
NRA (ST)	National Rivers Authority (Severn Trent Region)
RIMS	Rivers Information and Maintenance System
RSPB	Royal Society for the Protection of Birds
SCADE	Silsoe College Agricultural Drainage Evaluation
STWA	Severn Trent Water Authority

cms	centimetres
d/s	downstream
ha	hectares
kg	kilograms
km	kilometres
m	metres
m^3/s	cubic metres per second
m AOD	metres Above Ordinance Datum
MJ	Mega Joules
mm	millimetres
SMD	Standard Man Days
t	tonnes
u/s	upstream
yr	year

EXECUTIVE SUMMARY

Background

Rivers serve a variety of interests including those of water supply, drainage, environmental quality, and recreation. One of the main functions of managed rivers is to dispose of surplus water from urban and rural areas. In the case of rural areas this drainage function relates to the control, within acceptable limits, of flooding and water table levels on riparian, mainly agricultural land.

The purpose of river maintenance is to sustain a particular standard of drainage service. In the case of agricultural land, there are, therefore, no extra benefits to be set against maintenance costs, but rather the avoidance of losses which would be associated with a decline in agricultural productivity due to a deterioration in drainage standards.

During the mid 1980s, Severn Trent region of National Rivers Authority (NRA) (and its predecessor Severn Trent Water Authority (STWA)) began to apply objective management criteria to the appraisal of its river maintenance programmes. In January 1989, NRA commissioned Silsoe College to undertake an evaluation of river maintenance activities on selected sites with Severn Trent region.

Study Aim

The broad aim of the study was to develop and verify a database and methodology for the appraisal of river maintenance in rural, mainly agricultural catchments. In this respect the concern of the study was more with methods of appraisal than the evaluation of particular maintenance schemes.

Study Approach and Methods

The principal maintenance operations involve dredging and/or desilting, weed cutting and clearance, tree and bush maintenance, bank and flood bank protection and grass cutting, debris and obstruction removal, and repair of structures.

These river maintenance activities affect levels of service to riparian land users through the impact on channel dimension and roughness. Maintenance influences the relationship between flows and levels in the river and drainage system. In this way, maintenance affects the ability of the river to retain flows of a given magnitude, and thereby the risk of

flooding. Similarly, maintenance affects water levels in the river and tributary ditch system and the outfall for field drainage, whether by natural movement of water through soils or assisted by underground pipes. Maintenance also affects environmental qualities, either directly through its impact on conditions within the channel, or indirectly through its impact on soil water regimes in the adjacent floodplain.

The impact of river maintenance was assessed by comparing "with" and "without" maintenance conditions in the watercourse, and the effects on land-use, land users and environmental features in the floodplain. Site monitoring, farmer interview and review of research literature were used to assess: the effect of maintenance on river channel conditions; the effect of the latter on flood risk and watertable heights in the floodplain; the link between these drainage conditions and agricultural productivity; and, in the case of major maintenance activities such as desilting, the likely longevity of the works. These methods enabled the study findings to be extrapolated beyond the period of study and to provide databases and routines for maintenance programming and prioritization.

With respect to the influence of channel maintenance on flooding, channel dimensions were taken and estimates of channel friction made for with and without maintenance. These data were combined with flow data to estimate flood risk associated with different maintenance standards.

A model, developed at Silsoe College, was used to determine the influence of river and ditch water levels, and hence river maintenance, on field drainage conditions, taking into account local rainfall, evapotranspiration, soil type and the intensity of artificial field drainage. The model predicts water table heights in the surrounding floodplain against time for given conditions. These watertable heights are then compared with those required for crop growth and trafficability of soils.

Recognising that the impact of river maintenance is likely to vary according to the frequency of rainfall and river flows, the model was used to show the effect of different standards of maintenance on water table heights for different weather conditions. For this purpose, historical rainfall data was used to classify and determine the relative frequency of wet, mean and dry years.

With respect to drainage standards for agriculture, a review of literature revealed that watertable levels at or greater than 0.5m depth do not impede yields or farming practice. Water tables between 0.3m and 0.5m from the surface can depress yields and limit field access by machines and animals. Watertables persistently within 0.3m of the surface,

however, lead to severe restrictions on land use. These agricultural drainage categories were labelled "good", "bad" and "very bad", respectively. Drainage status was then defined in terms of the proportion of the time that the watertable lay within these critical boundaries. A season with 80% of weeks with water tables deeper than 0.5m was described as one of good drainage status. A season with at least 50% of weeks with water tables deeper than 0.3m was described as one of bad drainage, a season with at least 50% of weeks with water tables within 0.3m of the surface was described as one of very bad drainage. From a land-use viewpoint, the main concern in Britain is with field drainage status during the spring and autumn periods, especially as this influences the timeliness of field operations.

Information was derived from the farm survey and the literature to compile farming productivity scenarios which described the input-output relationships and resultant financial performance of land use and farming practice under the categories of drainage status previously described. The estimates of benefits associated with the different productivity classes were used to determine the benefits attributable to the maintenance of standards of drainage service, and thereby, the benefits of river maintenance. For instance, if a good drainage status on a particular land use generates a benefit of £460/ha/year and a bad drainage status generates a benefit of £340/ha/year, the net benefit of river maintenance which prevents a decline from good to bad drainage conditions is £120/ha/year.

Using the methods described above, the drainage status and related benefits of land in the benefit areas of schemes were estimated for wet, mean and dry rainfall conditions and for with and without river maintenance. The benefits of maintenance were thereby identified by the change, if any, in drainage status for given climatic conditions. Drawing on historical weather data, the benefits were then weighted by the relative frequency of the three types of weather conditions to derive an average, expected annual benefit.

A similar approach was adopted to estimate the benefits of flood alleviation associated with a change in maintenance standards. Estimates were derived of the cost of single or multiple flood events occurring on given land use (and productivity class) at different times of year and the change in flood risk associated with channel maintenance. For example, if deteriorating maintenance standards result in a decrease in the interval between floods of, say, 3 to 2 years for which the average annual costs of damage are £9/ha and £6/ha respectively, the flood alleviation benefits attributable to maintenance is £3/ha over the area of flood risk.

The benefits of flood alleviation were added to the benefits of drainage status (weighted by the probability of types of weather year) to determine total benefits attributable to maintenance. These benefits were aggregated within the benefit area of a scheme and set against the cost of providing the maintenance service to determine the overall value-added. The discounting procedure was used for this purpose.

Analysis and Results

The above methods were developed and applied in the context of six river sites located within the Severn Trent region. These sites, chosen from a list of 23 possible sites, were selected for study using the criteria of river characteristics, floodplain features and type of maintenance operations.

The study sites covered a variety of river and flood plain types. They ranged from 3 to 30 cumecs mean annual flow, with flood plains which varied in width, shape and slope. Soils were mostly alluvial, silty or sandy clays on mainly grade 3, and to a lesser extent, grade 2 agricultural land. The average reach studied was about 4 km, with a benefit area of about 120 ha.

With respect to farm type and land use, the benefit areas accommodated a range of farm types, reflecting locally dominant farming systems: arable in the east, livestock in the west. Average farm size was 103 ha, with an average of about 20% of their total areas lying within the benefit area of a scheme. Forty-four per cent of land was down to continuous grass, 38% was continuous arable, and the remaining 18% involved grass/arable rotations.

Maintenance activities included desilting, weed cutting and tree and bush work. The cost of works range from about £600/km (£21/ha of benefit) for annual weed cutting to over £11,000/km (£372/ha of benefit) for a 15 year desilting operation. Obtaining reliable cost estimates of work carried out was not always easy, either because costs were insufficiently segregated between different activities, or because costs were based on predicted works at standard rates rather than on actual works at actual costs. Cost were higher where environmental protection or enhancement works were also carried out within the maintenance programme.

River engineers responsible for managing the maintenance function were interviewed regarding management practices. Most maintenance work was part of a routine programme which followed river inspection in order to confirm the need to do work. All of the work examined was justified in terms of land drainage and flood alleviation. Custom and

practice were given as the main criteria for determining maintenance frequency, standards and methods. Maintenance schemes increasingly incorporated conservation protection and enhancement measures. Landowners were always contacted before commencement of works, but, in most cases there was no post operation follow-up.

With respect to the effect of river maintenance on flood risk and field drainage status, farmers reported that maintenance was associated with lower flood risk: maintenance prevented flooding on 10% of the area, and reduced its incidence on a further 17% of the total area. These estimates accorded well with the results of hydraulic modelling.

Analysis showed that the estimates of drainage status obtained by farmer interview and by groundwater modelling were closely related. In a mean rainfall year, the percentages of the combined benefit areas classified as good, bad and very bad drainage were 45%, 36% and 19% respectively in the absence of maintenance. With maintenance, these percentages were 55%, 35% and 10% respectively. By comparison, in wet years, drainage status was generally poorer and maintenance had a greater beneficial effect. The study observed that the sensitivity of drainage status to river maintenance is influenced by the presence or absence of field drainage or intensive ditch systems, the hydraulic conductivity and drainable porosity of soils, and the degree to which river and ditch levels change as a consequence of doing, or not doing, maintenance.

The benefits of maintenance were aggregated at scheme level and set against the costs of carrying out the works in order to determine the economic value of maintenance activities. Annual benefits per hectare varied considerably amongst schemes from about £4 to £30, reflecting the standard of service provided and the sensitivity of farming to such provision. Generally, the more intensive was the land use, the better was the standard of field drainage (either due to light soils or piped underdrainage), and the greater was the sensitivity to standards of river maintenance.

Maintenance benefits exceeded maintenance costs at the Treasury's 6% test discount rate on four of the six sites that were studied. Of the other two schemes, one was prejudiced by higher than anticipated costs, and the other by very low benefits. This analysis requires cautious interpretation, not least because the analysis looked at selected reaches of river in isolation of the larger catchment, and within the time frame of the study, it was not possible to assess the long term consequences for the river, and related levels of service, of not carrying out the maintenance works.

With respect to the environmental impact of river works, maintenance did not appear to result in negative, long term, irreversible changes in the river environment. In some cases, maintenance works were accompanied by environmental enhancement activities, such as berm creation and tree planting.

Conclusions and Recommendations

The study concluded that it was possible to formulate guidelines for the objective appraisal of river maintenance works in rural areas. The main components of appraisal for which data and assessment methods are required are those which relate to the maintenance activity, the physical and hydrological characteristics of the river and floodplain, land use and farming systems, and environmental qualities.

The study developed new methods for maintenance appraisal which provide the basis for practical guidelines for assisting the management of the river maintenance function.

The study made recommendations regarding the practical application of the methods developed and the need for further research. It recommended:

- action to test the practical application of the appraisal methods in the Severn Trent region of NRA;
- extension of the study in order to further refine the appraisal methods and apply them in other regions of the NRA;
- further research in order to determine the long term implications of not carrying out maintenance work, either for commercial farming or environmental interests;
- a detailed assessment of the environmental impacts of river maintenance in order to identify, and incorporate into river maintenance, appropriate environmental enhancement and protection measures.

Some of these recommendations are currently being acted upon.

CHAPTER ONE - INTRODUCTION

1.1 BACKGROUND

Organisations charged with the responsibility for maintaining rivers are increasingly asked to justify their activities in financial terms. In addition, limited maintenance budgets require that river maintenance work should be ranked in order of priority. For some years, methods have been available for the evaluation of land drainage improvement schemes. This involves estimating the increase in productivity of agricultural land resulting from the alleviation of land drainage constraints. Methods for the evaluation of river and land drainage maintenance have been less well developed. The purpose of river maintenance is to maintain a given standard of service for land drainage, in terms of both waterlogging and flood risk. There are, therefore, no extra benefits to be set against maintenance costs, but rather the avoidance of losses which would be associated with the reduction in agricultural productivity resulting from a decline in drainage standards.

During the mid 1980's, Severn Trent region of National Rivers Authority (NRA) (and its predecessor Severn Trent Water Authority (STWA)) began to apply objective management criteria to the appraisal of its river maintenance programmes. Drawing on experience obtained in the appraisal of capital works, STWA developed methods for the programming and prioritization of river maintenance. These were incorporated into a computer based procedure known as River Information and Management System (RIMS). Silsoe College assisted STWA in the formulation of methods for the appraisal of agricultural benefits attributable to river maintenance.

In January 1989, NRA commissioned Silsoe College to undertake an evaluation of river maintenance activities on selected sites with Severn Trent region. This document reports on the aims, methods, and results of the study which was carried out over the period January 1989 to March 1992.

1.2 AIMS AND OBJECTIVES

The broad aim of the study is to further develop and verify a database and methodology for the appraisal of river maintenance, in order to assess the benefits associated with alternative river maintenance strategies in differing, mainly agricultural catchments.

Specific objectives of the study are as follows:

- to examine by site monitoring the effect of different maintenance strategies (operations and frequencies) on channel characteristics, particularly freeboard and channel capacity, and resultant impacts on land use, including agricultural, conservation and recreation interests;
- to consider the relationship between river maintenance benefits and land use, farming practice and farming circumstances;
- to design practical procedures for monitoring and evaluating river maintenance works in rural areas.

1.3 PHASING OF THE STUDY

The study comprised three phases, as follows:

- Phase I, completed in December 1989, involved study formulation, set-up, and the Baseline Survey. The Baseline Survey report was presented in January 1990;
- Phase II consisted of on-going monitoring and evaluation of the study sites through repeated site visits; analysis of maintenance impacts and benefits for agriculture, conservation and recreation. Water table modelling and impact assessment techniques were developed during Phases I and II. A report was presented in January 1991 which covered the first Phase II surveys and provided some early results. Phase II was completed in December 1991;
- Phase III involved the analysis of the survey results in order to meet the study objectives given in 1.2 above. The topics studied in Phase III included: the formulation of guidelines and procedures for rural data collection and RIMS operation; methods for relating maintenance works to changes in water table level and flood risk; agricultural benefit assessment data and methods; and environmental impact assessment.

1.4 REPORT STRUCTURE

This report summarises the objectives, methods, results and conclusions to the whole study. Reference is made in the report to supporting Appendices which provide further information on data collection methods and to Annexes which provide detailed information on the individual study sites.

Chapter Two defines the study topic and the context of river maintenance evaluation. Chapter Three describes the study methods including: the procedure for site selection; the sites selected; the data needs, sources and collection methods for the study; and methods of maintenance evaluation. Chapter Four presents the summary results for all the schemes included in the survey (detailed site reports are included in the Annexes). The conclusions and recommendations of the study are presented in Chapter Five.

CHAPTER TWO - CONTEXT OF RIVER MAINTENANCE EVALUATION

This Chapter defines the nature and purpose of river maintenance in rural, mainly agricultural areas and identifies the need for evaluating maintenance activities. It examines the objectives, methods and benefits of drainage for agriculture. The Chapter also examines ways in which the impact and justification for river maintenance can be assessed.

2.1 RIVER MAINTENANCE MANAGEMENT

Rivers serve a variety of interests including those of water supply, drainage, environmental quality, and recreation. One of the main functions of managed rivers is to dispose of surplus water from urban and rural areas. In the case of rural areas this drainage function relates to the control, within acceptable limits, of flooding and water table levels on riparian land. Until recently, agricultural land-use took priority, and drainage needs were defined in terms of agricultural requirements. More attention is now being given to conservation and recreational land-uses.

2.1.1 Purpose and Practice

The purpose of river maintenance is to sustain a particular standard of drainage service. Where rivers have been the subject of a capital improvement scheme, maintenance involves retention of the design standard of the scheme. In the absence of capital schemes, maintenance involves the provision of a notional 'satisfactory' standard of service. Satisfactory here refers to a standard of maintenance which provides a channel capacity and freeboard sufficient for adequate drainage of riparian land. Satisfactory standards of service involve judgements based on policy objectives and priorities, public and professional perceptions, and resources at any given point in time. These judgements are guided by criteria such as economic performance or environmental quality.

The management of river maintenance seeks to establish the need and justification for maintenance, and that the maintenance activities are executed in 'the most economic way'. The most economic way (ie in terms of economic costs and benefits) is qualified by the need to meet the requirements of land drainage and good river management (STWA, 1980).

River maintenance has often been subordinate to the principal preoccupation of capital works. However, there has been an increasing awareness of the important role of river maintenance and the need to assess this objectively. This is due to a number of factors.

New technology, whether mechanical or chemical, has increased the capacity to undertake maintenance work. Organisational changes, such as the greater use of contractors, have in some cases converted maintenance from an overhead to a direct, avoidable cost. Simultaneously, maintenance benefits for agriculture have fallen in real terms due to the relative decline in agricultural produce, prices and profitability.

As a consequence, there has been a reduced emphasis on drainage for agriculture, and a concomitant concern with environmental protection and enhancement. This has questioned previous activities, both with respect to the frequency and type of maintenance.

As a consequence of these factors, river maintenance, previously based on custom and practice, has become much more of a management variable. River maintenance management aims to establish acceptable procedures to achieve effective maintenance.

The principal maintenance operations (Table 2.1) involve dredging and/or desilting, weed clearance, tree/bush maintenance, bank and flood bank protection, grass cutting, debris and obstruction removal, and repair of structures. The methods and tools selected for each operation usually depend upon channel size, dimensions and accessibility and the scale of work to be completed.

Table 2.1: Maintenance Operations and Methods

Operation	Method	
Dredging/desilting	- Dredger	
	- Dragline excavator	
	- Hydraulic excavator	- Ditching bucket
		- 4 in 1 bucket
Weed clearance	- By hand (sickles, scythes, etc.)	
	- Weed boat	
	- Bradshaw Bucket	
	- Tractor flail	
	- Herbicides	
Tree/bush maintenance	- Clearance of fallen trees	
	- Felling	
	- Pollarding	
	- Root/stump removal	
Grass cutting	- By hand	
	- Mechanical	- Pedestrian controlled
		- Tractor mounted
Bank and floodbank protection		
Debris and obstruction removal		
Repairs to structures		

2.1.2 Need for Maintenance Evaluation

The land drainage function within the NRA operates in a financial system where a fixed annual budget is used to support a large number of maintenance operations which compete for funds. In order that required standards of service can be assessed and work can be prioritised, some form of maintenance evaluation is required.

The role of maintenance evaluation is to consider the relevant variables, such as land and water use, flood return periods and drainage constraints on farming systems, which describe a particular stretch of river. These variables can be used to determine the necessary standard of service to satisfactorily maintain the river and its related features. The need for maintenance on one stretch of river can be compared to that on other rivers and a maintenance programme drawn up according to need and priority.

2.2 AGRICULTURAL LAND DRAINAGE

2.2.1 Purpose of Drainage

Water is essential for agriculture, but too much of it can limit crop growth and cropping activities. The basic aim of agricultural drainage is to alleviate or prevent the problems caused by excess water in order to facilitate more productive agriculture.

The agricultural drainage problem may be due to coastal or fluvial flooding, and/or the presence of seasonal or permanent high water table levels. Poor drainage due to flood inundation often calls for river re-channelling and embankment works. Where poor drainage is due to waterlogging, the pre-occupation is with improving arterial watercourses, installing piped under-drainage, and other measures such as subsoiling, which improve the movement of water in the soil.

Figure 2.1 summarises the principal benefits of improved drainage for grass and arable enterprises. These can be generalised in terms of improvements in the soil/plant/water growing environment and in the trafficability of soils, which allow more timely access for field activities, together with a reduction in crop damage caused by inundation.

A review of relevant agricultural drainage literature is given elsewhere (Morris, 1990). Much research into crop response to drainage has measured soil wetness in terms of depth to water table, and has related yields to this parameter. Experimental results show a wide difference in the tolerance of crops to the timing and duration of waterlogging or inundation. Recent UK research has examined the yield effects of waterlogging at different

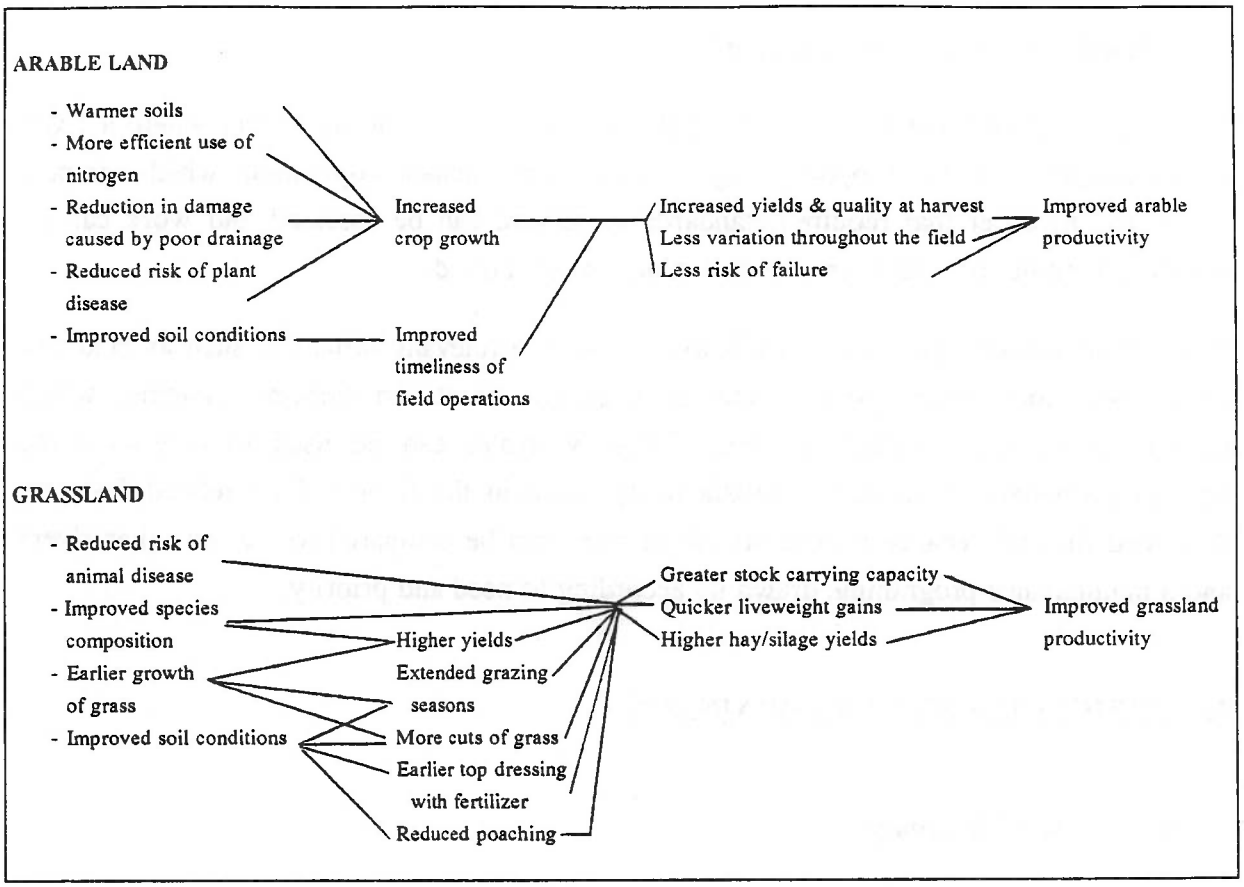


Figure 2.1: Benefits of Improved Drainage for Arable and Grassland Uses

stages of crop development, concluding that water table control to 0.5 m is adequate provided that incursions above this level are brief.

With respect to field trafficability and work-day probability, soil strength and load bearing capacity vary inversely with water content and water table height. Better drainage reduces the risk of untimeliness yield penalties for critical operations such as seed-bed preparation or fertilising. In many respects requirements for trafficability and workability may impose stricter conditions than the crop itself.

In grassland systems, improved drainage can: reduce the risk of surface damage or 'poaching'; allow earlier access for grazing stock; allow the timely application of nitrogen fertilizer; and, facilitate a move to more intensive and predictable silage making systems.

A major purpose of river and arterial drainage maintenance is to sustain the benefits of agricultural land drainage. Inadequate maintenance results in a decline in agricultural productivity and consequent 'disbenefits'.

2.2.2 Drainage Methods

The purpose of drainage design is to control the level of the water table and reduce the risk of flooding according to the limits required for agricultural production. River, arterial and field drainage in the agricultural catchment must be considered as a whole.

Field drainage, which remains at the discretion of the individual farmer, is mainly a traditional art based on experience of soil type location and conditions. Open ditches may adequately serve soils which are free draining; otherwise, tube drains or unlined mole drains may be required, with or without permeable stone fill. The scientific approach to drainage design attempts to control the water table by finding suitable drain spacing and depth for the expected rainfall and hydraulic characteristics of the soil, using mathematical equations and modelling. Agronomic trials provide guidelines for preferred water table heights, which for most crops average 500 mm below the surface. Tube drains are often laid at 0.8-1.5 m from the soil surface depending on soil type and field conditions with about 0.15 m clearance between pipe and ditch or river level at the outfall. Mole drains are placed at about 0.5-0.6 m depth.

With respect to flood risk, practice has provided criteria for arterial designs to give minimum acceptable 'whole year' flood frequencies. This is 1-in-2 to 1-in-5 for most field crops, and 1-in-10 years for high-value horticultural crops. Desired standards for flood risk during the April-October period are more stringent.

The design standards of the drainage system dictate the standards of maintenance. The more intensive or closely managed is the drainage system, the more intensive in the land-use, and the greater the need and justification for drainage maintenance.

2.3 BENEFITS OF DRAINAGE

The benefits of drainage manifest themselves in a number of ways at farm level, namely:

- drainage may allow the reclamation of land previously unsuited to commercial agriculture;
- improved drainage could allow the intensification of existing enterprises, especially from the use of yield increasing inputs;
- better drainage could facilitate land-use change and a switch to new, more profitable enterprises, such as a move from permanent pasture to an arable/ley rotation;
- reduced production costs could result from better working conditions.

Where drainage incorporates a significant part of the farm, there may be benefits for activities on other parts of the farm. For example, where increased stocking on lowland pastures releases higher land for arable production whilst maintaining herd size.

Figure 2.2 provides a basic framework for agricultural drainage benefit assessment. Improved land drainage offers a degree of flood alleviation and/or an improvement in outfall levels in the arterial drainage system. The extra value of intensifying existing, or moving to new, farming systems, can be expressed in terms of changes in enterprise gross margins and farm-level fixed costs.

In the event of a deterioration of drainage standards as a result of, say, reduced maintenance these types of benefits may be lost. They become 'disbenefit scenarios' which describe the consequences of lower maintenance and drainage standards. It must be remembered that river maintenance is not a means of achieving extra agricultural benefits over and above those normally obtained. Maintenance should not be seen as a substitute for capital works. The latter provide potential for drainage improvement which may or may not be taken up by farmers. Uptake of benefits is inconsistent with the concept of maintenance.

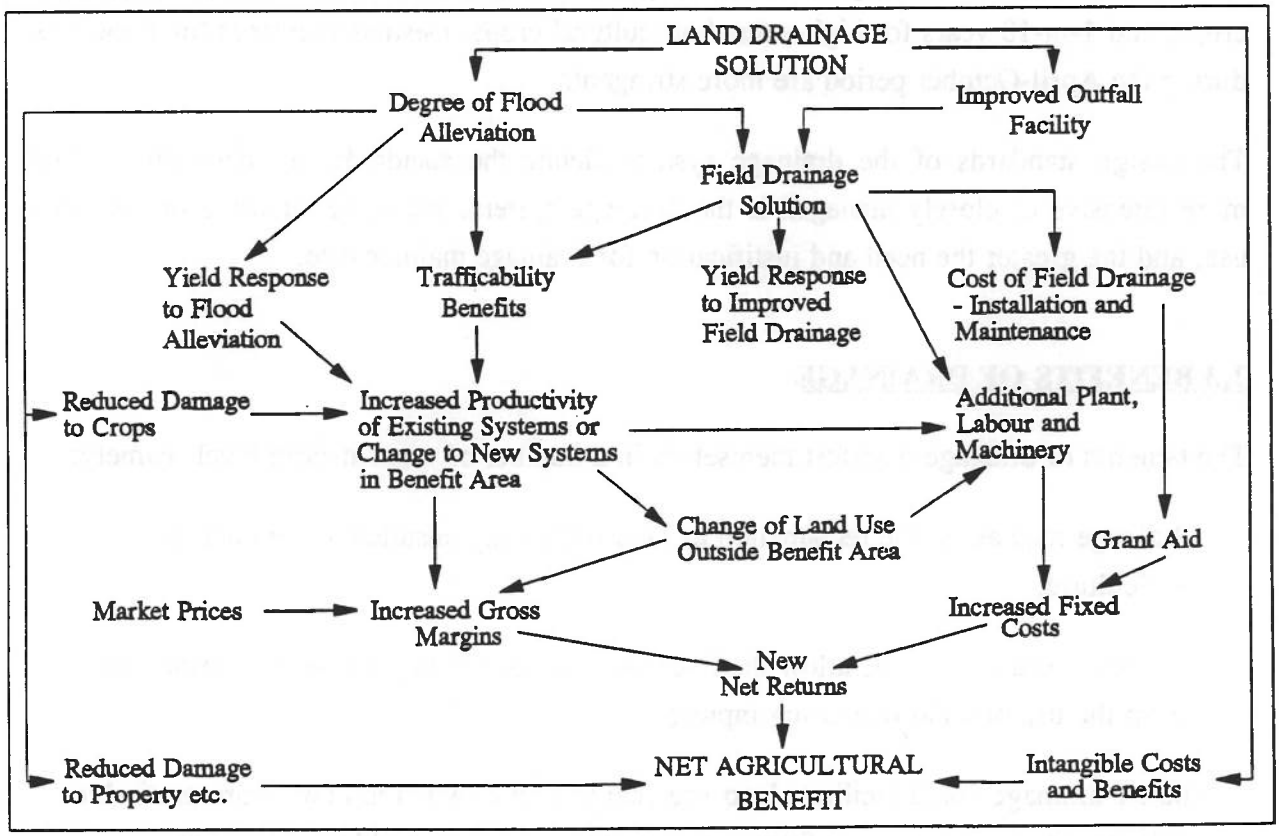


Figure 2.2: Determination of Drainage Benefits at Farm Level

2.4 DRAINAGE BENEFIT ASSESSMENT METHODS

The general approach to assessing the agricultural effects of a change in land drainage involves comparing the value-added from agriculture under different drainage conditions. The area affected by river improvement or maintenance works is referred to as the 'benefit area'. For each block of land under study, the extra net benefit (value-added) attributable to drainage is the difference between net returns 'before' and 'after' change. The latter are defined in terms of enterprise gross margins, farm fixed costs, flood damage costs, and 'extras' such as the value of grazing days.

This approach is incorporated in the Silsoe College Drainage Evaluation (SCADE) Model which can be used to assess the agricultural benefits associated with a given standard of, or change in, drainage conditions (Hess and Morris, 1985). The model combines input data which describes farming practice and drainage conditions with a database containing relevant agricultural economic and management data. The model can be used to formulate the benefit scenarios referred to previously. It can be adapted to simulate the impact of maintenance related changes in drainage.

Within the SCADE model, a distinction is made between the benefits of reduced waterlogging and reduced flooding. With respect to estimating benefits of reduced waterlogging, arable enterprise yields can be obtained from farm survey or from regional statistics adjusted for drainage status based on research findings. The assessment of grassland productivity on a given site requires data of a kind not available on most farms (eg. livestock turnout dates and liveweight, liveweight gain, or milk yield at grass). To overcome this, a physical model was developed drawing on the work at the Grassland Research Institute (Morrison et al, 1980; Doyle, 1982). This estimates the productivity of grass in terms of energy value on the basis of soil type, rainfall, drainage status, fertilizer use, and grass conservation method. Energy from grass converts to stocking rates for given stock types (eg. dairy cows per hectare) at standard grass energy needs per head. Stocking rates convert to gross margins and fixed costs per hectare at standard rates, with adjustment for the value of extra grazing days and forage production costs. The model allows that extra energy from grass can either be used to increase stocking rates and stock numbers, substitute for purchased feeds, or allow the release of land for other purposes.

Flood damage costs include the loss of output due to inundation plus the cost of remedial work. Loss of output depends on frequency, duration, and the timing of flooding with respect to crop growth stages and critical operations. Analysis of STWA data showed that large catchments exhibit predominantly winter flooding, whereas small and urban catchments have a greater degree of summer flooding. The model incorporates a seasonal probability distribution for flooding based on catchment characteristics which combines

with flood return period estimates to determine monthly flood probabilities. The latter are combined with the estimated costs of a flood occurring in a given crop in a given month, to give an average annual expected flood damage cost (Morris and Hess, 1988). The effect of flooding on arable crop yield is based largely on experimental data. Where relevant, allowance has been made for reseeding costs, and the savings in harvest costs where crops are lost. For grassland, flood damage is assessed in terms of the costs of replacing energy losses with alternative feed, emergency stock housing, net of savings in harvesting costs if forage crops are lost. The model also considers the impact of multiple flood events.

Estimates of net agricultural benefits are very sensitive to assumptions regarding the need for additional farm expenditure on regular labour, power and machinery, buildings, storage and drying, and the use of contractors. These so-called fixed costs are often equivalent to 70-80% of total farm gross margins. The model distinguishes between the need for extra recurrent expenditure on these items (eg. machinery running costs) and extra capital expenditure (eg. machinery depreciation). Relevant charges per hectare or per livestock are made at standard rates according to farm circumstances, and any net increase in fixed costs 'before' and 'after' change in drainage conditions is identified.

The model can run with financial or economic prices for agricultural output commodities. The former are those received by the farmers. The latter adjust for the cost of Government intervention. The Ministry of Agriculture in 1985 required the use of reduction factors (20% on cereals, and 20 to 50% on beef and sheep depending on the level of price support) to convert financial to economic gross margins for the appraisal of drainage improvement schemes. The use of economic prices for the most part reduces the value of agricultural drainage benefits and the value of capital or maintenance expenditure. The 1985 guidelines are currently under review and their validity for present circumstances is questionable. They do not apply to non-grant aided maintenance.

2.5 MAINTENANCE EVALUATION METHODS

Maintenance activities are carried out in the context of given river and flood plain characteristics in order to sustain standards of flood protection and water table management (Figure 2.3).

River maintenance affects the profile and roughness of the watercourse. This in turn determines the channel capacity and flood risk, and through its affect on river water levels, the drainage facility offered to adjacent land.

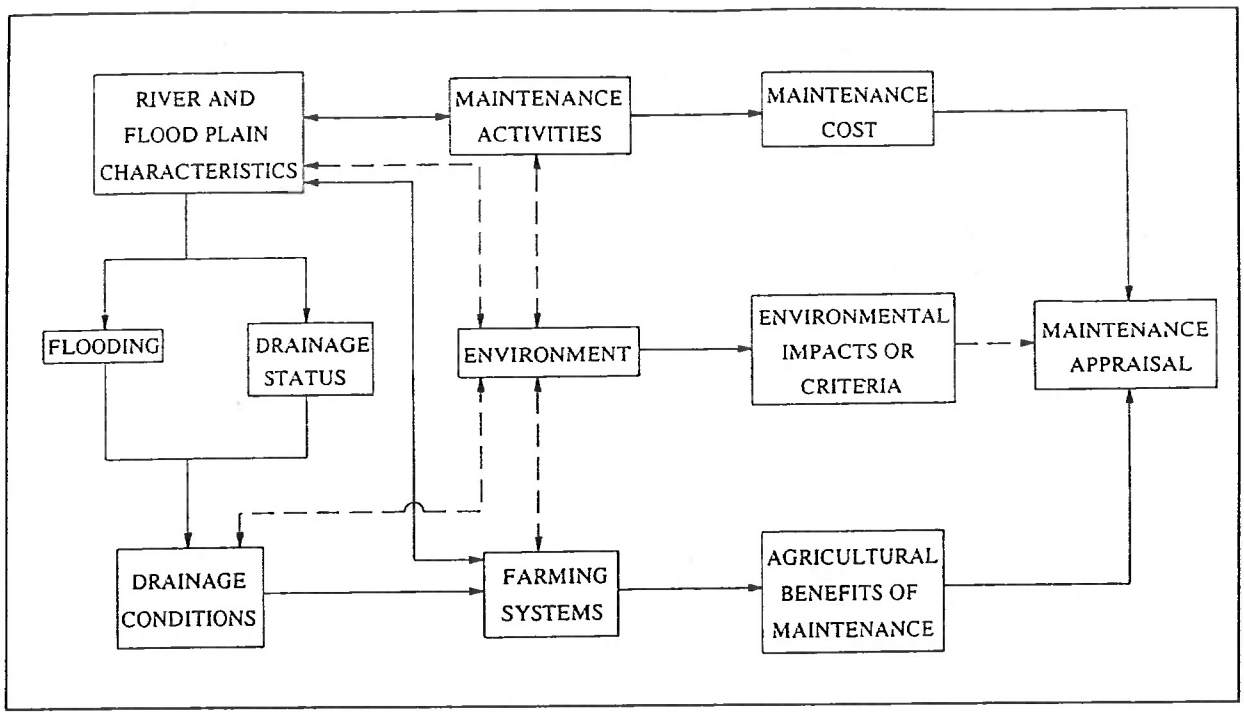


Figure 2.3: River Maintenance Activities in Context

An early attempt at evaluating maintenance standards of service developed a simple model which combined basic data on agro-climate, soil types, topographical and catchment characteristics, field drainage, flood risk and land-use, to identify arterial drainage design parameters (Figure 2.4) (Hess et al, 1989). Drawing on research evidence and field observations, drainage productivity classes were defined in terms of water table depths during the critical spring period. Water tables between the surface and 300 mm depth indicate a 'breakdown' productivity situation, between 300 mm and 500 mm a 'low' productivity class, and greater than 500 mm a 'normal' productivity situation unimpeded by drainage. The method estimates field water table depth on the basis of freeboard in the adjacent water course for specified hydraulic conductivity and flood plain topography (Figure 2.5).

Where the water table is controlled by underdrainage, the desired freeboard is determined by drain depth in the field as influenced by soil type, drainage problem, and pipe-run and gradient. Productivity class is normal provided that freeboard is sufficient to avoid submergence of outfalls. Otherwise productivity classes could be low or breakdown.

Where sites drain naturally to the river, drainage equations can relate water table height to freeboard (hydraulic head), seepage rate (hydraulic conductivity), land slope, and rainfall. For specific local conditions, freeboard is used to estimate water table height and thereby a drainage productivity class.

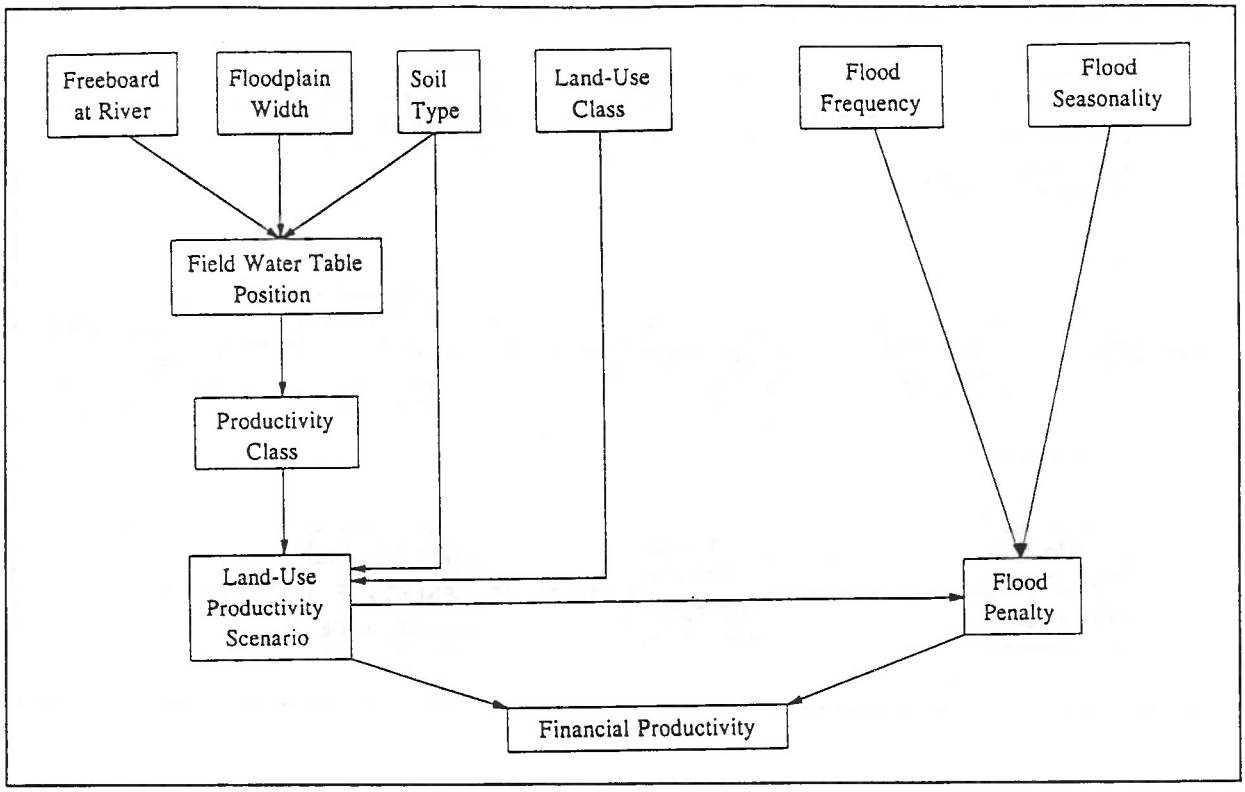


Figure 2.4: An Approach to River Maintenance for Agriculture

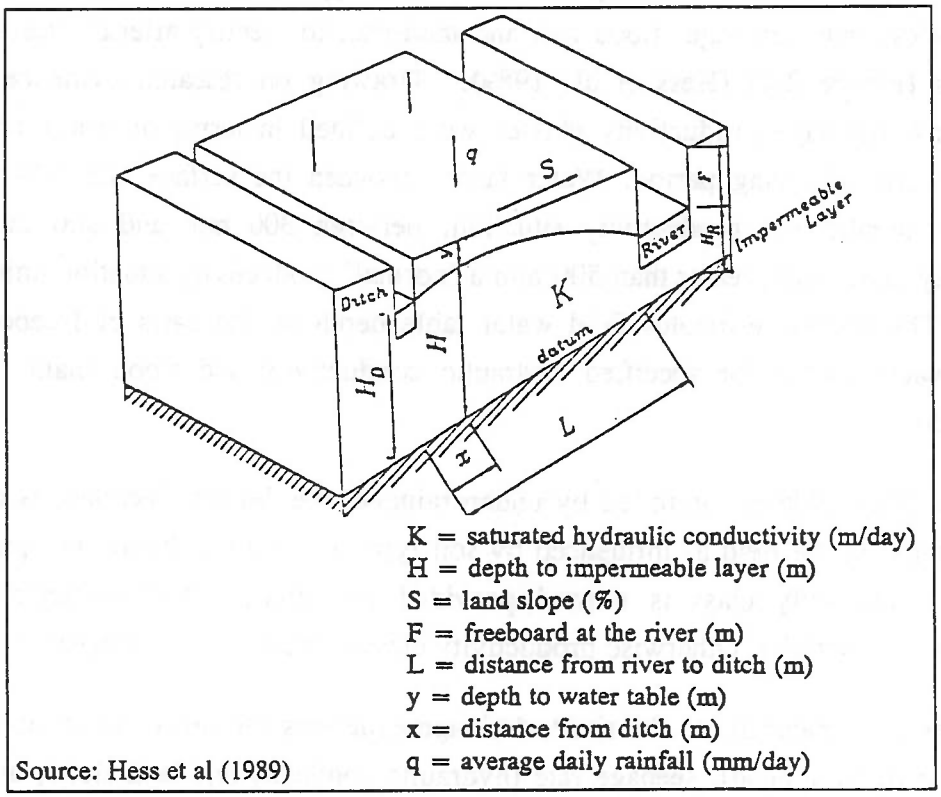


Figure 2.5: Steady State Water Table Model

Surveys in the catchment area can be used to compile scenarios for each land-use class/ productivity level combination. Each is described in terms of financial performance, reflecting the impact of waterlogging. Table 2.2 shows examples, in 1991 prices, of net returns (gross margins less semi-fixed costs) associated with given land-uses and productivity classes on clay soils in the Midlands. Drawing on estimates of changes in flood risk associated with changes in channel capacity, the approach can be used to assess the change in flood costs associated with different maintenance standards on different land-uses and productivity classes.

Table 2.2: Examples of Net Returns for Given Land-Uses and Productivity Classes (For Clay Soils in the Midlands - 1991 Prices)

	Permanent Grass	Temporary Grass	Arable
Productivity Class	£/ha	£/ha	£/ha
Normal	350	390	390
Low	160	175	260
Breakdown	70	80	140

The scenarios are then used to show the benefit associated with maintaining a given level of service, the likely 'disbenefit' associated with lower standards, and the justification for maintenance expenditure.

This simple model has been more recently refined into a non-steady state model (Youngs et al, 1989; Youngs et al, 1991) to allow for variable rainfall and evapotranspiration conditions, and variable floodplain characteristics and ditch configurations. The refined model estimates water table depth for given locations within the floodplain (eg. 20 m or 150 m from the river) and for a given shape of drainage network (eg. rectangle, triangle, rhombus, parallelogram, ellipse, etc.). The model also takes into account daily meteorological and hydrological information. The model recognises both the influence of weather conditions (eg. short term variations in rainfall and seasonal changes in evapotranspiration) and river water levels upon water table height. For example, low rainfall and high evapotranspiration in the summer may result in the water table lying below the river bed, whatever the river water levels. The model may be run repeatedly, in order to identify the impacts of changes in weather and river water level on water table depth.

2.6 ENVIRONMENTAL IMPACT OF LAND DRAINAGE

Land drainage may have a number of environmental consequences for natural vegetation, wildlife, groundwater levels and quality, and catchment hydrology. Concern about the impact of land drainage on the environment has focused on the permanent loss of wetland sites and the effect of changes in agricultural practices following drainage.

Natural vegetation can be affected in two main ways: (a) where the expansion of agricultural production displaces natural plant communities, and (b) where lower water tables result in a change in species composition in previously wetland sites. Wildlife resident in, or directly dependent on, wetlands can be depleted by the drainage, change of use and consequent loss of habitat. Depending on local conditions, land drainage may divert water into rivers, thereby reducing the recharge of the aquifer, and may cause a lowering of groundwater levels. This can result in the drying up of ponds, reduced summer stream flows, and peat shrinkage.

In addition, changes in land-use associated with field and arterial drainage may lead to modifications in the hydrological cycle. Whereas field drainage, by quickly drying out soils, tends to increase soil water storage capacity and reduce runoff and flood risk during heavy storms, improved arterial drains tend to create earlier peak flows in the main channels and thereby increase flood risk.

River works, including regular maintenance, can disrupt the hydrological and biological balance of the river, with consequences for fish and other aquatic creatures.

The alteration of the landscape and ecology of a site can have a major impact on its use for recreation and amenity. Anglers, bird watchers, outdoor sports-persons, and those in pursuit of rural tranquillity may be affected because of land drainage.

In response to environmental concerns, design and operational guidelines have been drawn up for capital works and river maintenance (examples in CIRIA, 1986). It is now common practice to take environmental audits and notify special interest groups before the design and start of works. Maintenance activities are increasingly executed in an environmentally sensitive manner, combined with environmental enhancement activities such as berm or pool creation.

These factors have implications for the choice, timing, frequency and cost of maintenance activities. They may also influence the hydraulic performance of the channel, though this may not necessarily be detrimental, as in the case of conservation lagoons, or widened two-stage channels (Newbold et al, 1989).

The growth in concern with environmental quality requires that environmental impacts be explicitly considered in the design and implementation of river maintenance.

2.7 MAINTENANCE SCHEME APPRAISAL

For the purpose of appraising expenditure on maintenance, the benefits of maintenance are compared with the costs of maintenance, discounted to present values at the test discount rate, currently 6%. Prices should be adjusted to a constant price base.

Figure 2.6 (i) shows the general case, assuming a linear rate of deterioration. Benefits decline with time (from a to c) until the without maintenance condition is reinstated. For frequent maintenance activities, such as annual weed maintenance, there may be little or no post-maintenance deterioration, hence the benefits remain constant (a to d). In the latter case, total benefits are represented by the area 'abcd'.

For long interval operations, such as desilting, there may be an advantage in scheduling repeat operations before the full deterioration of maintenance standards, or undertaking intermediate river maintenance activities to reduce the rate of deterioration. The best strategy will depend on the shape of the deterioration curve, the relative sizes of maintenance benefits and costs, and the discount rate used.

Figure 2.6 (ii) shows the pattern of with and without maintenance benefits assuming a linear deterioration rate and repeat maintenance in order to reinstate standards after a 50% decline from the design standard. For the initial maintenance expenditure, total benefits are represented by the area 'abc'. For the next maintenance activity, the additional benefits are represented by the area 'deci'; the area 'efc' has already been included in the benefits of the initial maintenance expenditure. This is the same as the area 'dfcg', the total area of benefit between maintenance intervals.

Figure 2.6 (iii) shows the case for a 75% decline from the initial standard before maintenance is carried out again. The definition of benefits is similar to that for Figure 2.6 (ii) and for each maintenance interval given by the area 'dfig'. For some maintenance activities such as desilting, the deterioration may be more rapid in the early years (Figure 2.6 (iv)). In such cases a reduced interval, or additional annual maintenance to reduce the rate of deterioration, may be justifiable depending on local circumstances.

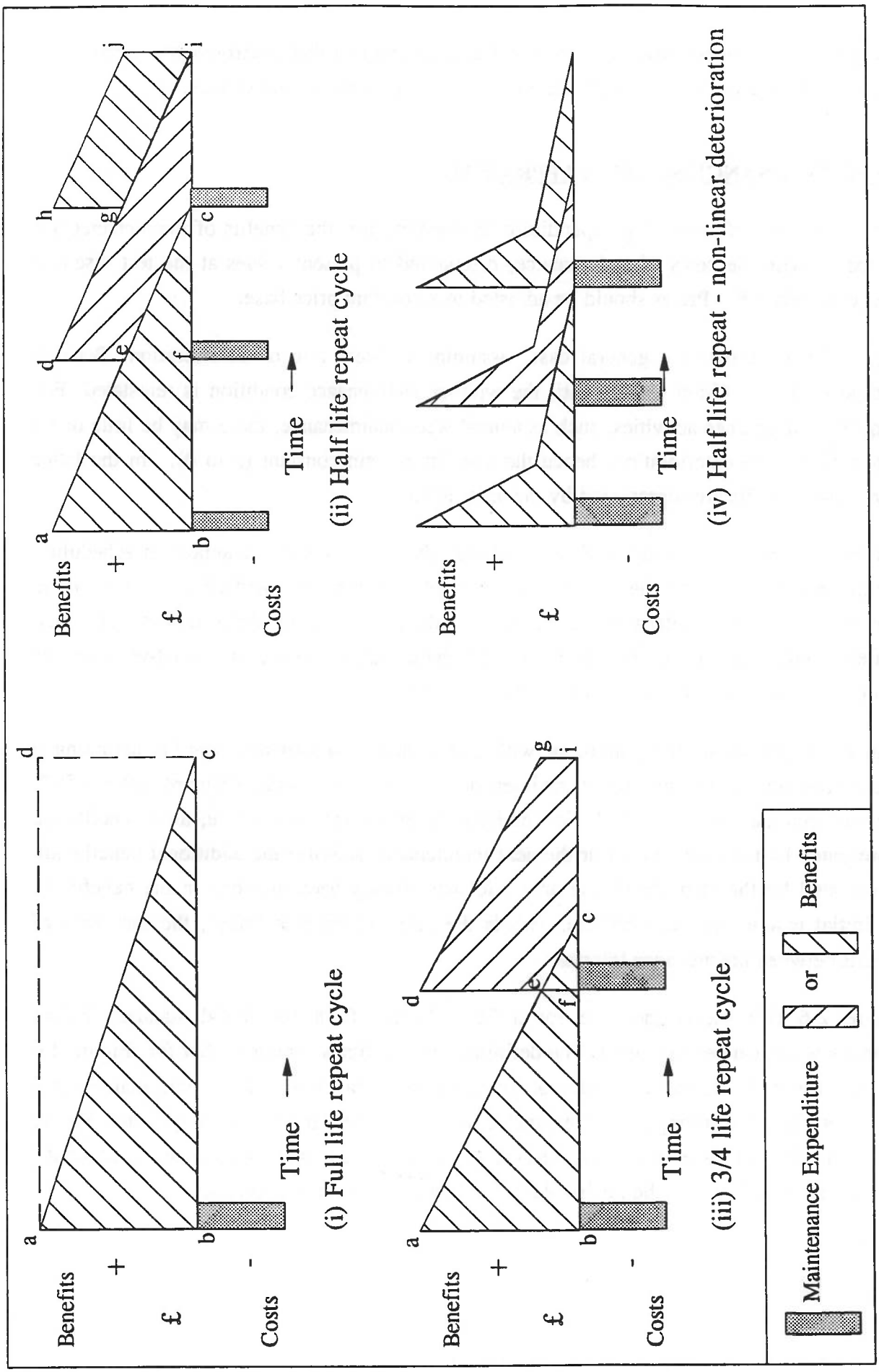


Figure 2.6: Maintenance Scheme Appraisal

2.8 RIVERS INFORMATION AND MAINTENANCE SYSTEM (RIMS)

RIMS is a system developed by NRA Severn Trent Region to manage river maintenance activities. The system incorporates many of the features and concepts highlighted above in order to appraise and justify maintenance on 'main' rivers in the region (Fitzsimmons and Pimberton, 1990).

Originally developed as a main-frame system, RIMS now runs on a minicomputer and is known as RIMS II. The system enables Flood Defence staff to calculate the benefits and costs of river maintenance operations, and to assess the impact of such operations on the river environment.

RIMS II comprises four main sections:

- **General watercourse enquiries** which contains information on reaches, subreaches, land use features and access;
- **Contacts enquiries** which contains information on riparian land owners and groups with interests in the river;
- **Operational enquiries** which includes information on the maintenance operations within a watercourse and enables the calculation of maintenance costs and 'disbenefits' associated with non-maintenance;
- The **update procedures** allow data revision.

One of the main reasons for undertaking this study was to provide data and methods for inclusion in RIMS.

2.9 SUMMARY

This Chapter has discussed the issues behind the rationale for maintenance and provided a critique of the methods used in identifying drainage benefits and maintenance scheme appraisal. Appendix 1 includes a brief summary of agricultural and environmental policy which has been introduced in the last few years and which may influence some of the decisions of farmers in the region in the near future.

CHAPTER THREE - METHODS

3.1 INTRODUCTION

The aim of the study is to assess the benefits attributable to river maintenance and to develop techniques for the monitoring and evaluation of river maintenance works. This Chapter describes the methods used in pursuit of this aim, with particular reference to site selection, data needs and collection methods, and the assessment of maintenance impacts, benefits and costs.

3.2 SITE SELECTION

Twenty three sites were selected by NRA (Severn-Trent) from the four administrative areas (Upper and Lower Trent and Upper and Lower Severn) where maintenance had been scheduled for 1989. From the twenty three sites, eight were selected by Silsoe College and NRA (Severn-Trent), two from each area. The sites were selected on the following criteria:

- river characteristics (size, shape, features, function);
- floodplain characteristics (land use, soil type, area of benefit, environmental features);
- proposed maintenance operations (desilting, weed clearance, tree maintenance).

The schemes were required to be separately identifiable projects to which benefits and costs could be attributed, though not necessarily justified purely in terms of agricultural benefits.

Although eight sites were initially selected for study, objections from conservation bodies to desilting on two of the rivers (the Blythe in Staffordshire and the River Morda in Shropshire) led to the postponement of maintenance indefinitely on these two sites. The Blythe was replaced by the Hilton Brook (Derbyshire), a river of similar characteristics. The tree maintenance on the Laughern Brook near Worcester was postponed and this river was removed from the study. Table 3.1 shows the final selection of sites, the features of which are described in Chapter 4 below.

Table 3.1: Sites included in RIMS Evaluation Study

Site	Area
River Anker	Upper Trent
Hilton Brook	Upper Trent
River Sence	Lower Trent
Oldcoates Dyke	Lower Trent
River Roden	Upper Severn
River Swilgate/Dean Brook	Lower Severn

3.3 DATA NEEDS AND COLLECTION METHODS

The data required for the study included agricultural, hydrological, hydraulic, meteorological and environmental data.

3.3.1 Agricultural Data

Agricultural data were gathered from primary (farm survey) and secondary (Regional Farm Management Surveys) sources. The data concerned farming systems, farm inputs and outputs, field management, and farmers' views on the relationship between river maintenance, drainage status and field management. Table 3.2 shows the main categories of data collected. This data was collected during the Baseline Survey, which examined the pre-maintenance drainage conditions, farming practice and performance, and during subsequent repeat farm visits (Phase II) which examined post-maintenance conditions and related issues. The questionnaires used in the Baseline and Phase II surveys are shown in Appendices 2 and 3.

3.3.2 Hydraulic and Hydrological Data

Hydraulic and hydrological data requirements included channel dimensions before and after maintenance, flow data and information on drainage systems for the study sites. The channel dimensions were measured by cross-section surveys carried out by contractors appointed by Severn-Trent NRA before and after maintenance where desilting was done, and before maintenance only where weed maintenance was done.

Flow data were made available by the Hydrology Department of Severn-Trent NRA. The data were in the form of peak flows (to calculate flood return periods) and average monthly flows (to calculate river water levels for the survey sites). Gauging data were not available for the River Swilgate/Dean Brook or the Hilton Brook. Level recorders were installed on

Table 3.2: Major Elements of Farm Data Collection

Category	Data Collected
Farming systems	- Farm size and enterprise type - Management status - Cropping patterns - Livestock enterprises
Farming inputs	- Nitrogen application rates - Field drainage installation
Farming outputs	- Crop yields (and influences upon) - Dairy yields
Field management	- Turnout and yarding dates for livestock and reasons for dates stated - Grass conservation (and influences upon)
Drainage status	- Wetness condition of soil in spring, summer and autumn - Major influences upon wetness condition - Influence of drainage status upon land management - Changes due to and since last maintenance
Flooding	- Flooding sources, frequency, time of year, area affected, duration, damage incurred - Changes due to and since last maintenance
Environmental data	- Farmers' assessment of environmental quality

the Swilgate and Dean Brook to monitor water levels and NRA (ST) provided flooding data in the form of Flood Studies Report Data (NERC, 1975). A level recorder was not installed on the Hilton Brook. However, basic flow and flooding data were supplied by NRA (ST).

On the two sites where weed maintenance was carried out (the Anker and Oldcoates Dyke), gauging boards were installed at several points along the site in order to assess the impact of weed maintenance on water levels. These boards were read by NRA staff; once a week on the Oldcoates Dyke, and once a month on the River Anker.

Information on the drainage systems on the study sites, including ditch networks, field drainage installation and areas of drainage influence of the river was collected through site surveys and farmer interviews.

3.3.3 Meteorological Data

Rainfall data were provided by the NRA in the form of long term monthly totals (20 to 30 years) and daily totals since 1988. The long term monthly data were used to assess the probability of wet, average and dry seasons. The daily rainfall data since 1988 data were collated into a weekly format for the purpose of water table modelling. Mean regional evapotranspiration data were provided on a monthly basis and converted to weekly estimates for the purpose of water table modelling.

3.3.4 Environmental Data

The terms of reference for this study required a habitat based approach to environmental assessment rather than a detailed species based approach. The Nature Conservancy Council's River Corridor Survey Draft Methodology (NCC, 1985) was selected for this purpose. A full survey was carried out on the sites before and after maintenance for desilting sites. On weed maintenance sites, a full survey was carried out before maintenance and in-channel observations only were made following maintenance. An example of the River Corridor Survey output is shown in Appendix 4.

3.4 IMPACT ASSESSMENT METHODS

Methods have been developed and used for assessing the flooding, groundwater, agricultural, and environmental impacts of river maintenance activities on selected sites, and for carrying out benefit assessments. In addition, methods developed by Hydraulics Research Ltd to estimate siltation and erosion rates on rivers were used to assess the recovery rates of a river following maintenance, i.e. the number of years before the river reinstates itself. These were used on the River Sence to assess their suitability for river maintenance evaluation.

The following sections describe the impact assessment methods used in the study.

3.4.1 Flood Risk

Channel dimensions were obtained before and after maintenance by cross-section surveys. The data from the cross-section survey were entered on a spreadsheet, so that graphical reconstructions of the channel form could be drawn. The use of spreadsheets also allowed for the use of mathematical formulae. Manning's equation for calculating channel capacity was applied to the data. Table 3.3 shows the recorded data and calculations of channel capacity for a sample cross-section.

Table 3.3 : Cross-section Data and Channel Capacity Calculation - Example

1. (5) @ Ch 1285 m (315 m u/s Railway Bridge)
(Datum = 60 m AOD; Right bank floods first)

Point	MAD	Relative height	Chainage	Area	Perimeter
	m	m	m	m^2	m
1	62.793	0	12.20	0.33	1.15
2	61.965	0.828	13.00	0.98	1.04
3	61.665	1.128	14.00	1.23	1.02
4	61.465	1.328	15.00	1.68	1.22
5	60.765	2.028	16.00	2.03	1.00
6	60.765	2.028	17.00	2.05	1.00
7	60.715	2.078	18.00	2.08	1.00
8	60.715	2.078	19.00	2.05	1.00
9	60.765	2.028	20.00	1.95	1.01
10	60.915	1.878	21.00	1.75	1.03
11	61.165	1.628	22.00	1.53	1.02
12	61.365	1.428	23.00	1.33	1.02
13	61.565	1.228	24.00	1.11	1.34
14	62.165	0.628	25.20	0.46	0.81
15	62.270	0.523	26.00	0.49	1.00
16	62.330	0.463	27.00	0.43	1.00
17	62.386	0.407	28.00	0.20	1.08
18	62.793	0	29.00		
Totals:				21.69	17.75

Hydraulic radius:	1.22
Water level at 1860m:	62.549
Water level at 1285m:	62.165
Slope (%):	0.000656
Manning's 'n':	0.0452
Channel capacity flow according to Manning's 'n':	14.04

Estimates of channel friction before and after maintenance were obtained by site survey and the use of Manning's roughness coefficient (Cowan, 1956). This takes into account the influence upon Manning's 'n' of river bed material, the extent of meandering, obstructions and variations in channel cross-section, and aquatic and bankside vegetation. These criteria are defined in Box 3.1. Information on channel dimensions and roughness were combined to calculate bankfull flows before and after maintenance, which were then read off flow/return period graphs to estimate changes in flood risk attributable to river maintenance. The flow frequency data were compiled either from historical flow data where gauging information was available, or by means of the Flood Studies Report method (NERC 1975).

Box 3.1: Computation of Manning's Roughness Coefficient Using Cowan's Method

Manning's 'n' = $(n_0+n_1+n_2+n_3+n_4)\, m_5$, where:

n_0 = material involved n_1 = degree of irregularity n_2 = variations of channel cross-sections
n_3 = relative effect of obstructions n_4 = vegetation m_5 = degree of meandering

(range of values in parentheses)

Material involved

This simply reflects the predominant bed material - earth (.02) to coarse gravel (.028)

Degree of irregularity

The degree of irregularity is considered smooth (.000) for surfaces comparable to the best attainable for the materials involved; minor (.005) for good dredged channels; moderate (.010) for fair to poorly dredged channels, moderately sloughed or eroded side slopes of canals or drainage channels; and severe (.020) for badly sloughed banks of natural streams, badly eroded or sloughed sides of canals or drainage channels and unshaped, jagged, and irregular surfaces of channels excavated in rock.

Variations of channel cross-sections

The character of variations in size and shape of cross-sections is considered gradual when the change in size or shape occurs gradually, altering occasionally when large and small sections alternate occasionally or when sharp changes cause occasional shifting of main flow from side to side, and alternating frequently when large and small sections alternate frequently or when sharp changes cause frequent shifting of main flow from side to side.

Relative effect of obstructions

This value is based on the presence and characteristics of obstructions such as debris deposits, stumps, exposed roots, boulders, and fallen and lodged logs. Conditions considered in other steps must not be re-evaluated or double-counted in this selection. In judging the relative effect of obstructions, the following should be considered: the extent to which the obstructions occupy or reduce the average water area, the character of obstructions (sharp-edged or angular objects induce greater turbulence than curved, smooth-faced objects), and the position and spacing of obstructions transversely and longitudinally in the reach under consideration. Values range from negligible (0.00) to severe (0.04-0.06).

Vegetation

Values for vegetation range from 0.005-0.01 for low vegetation growth to 0.05-0.1 for very high vegetation growth. Vegetation includes in-channel and bankside growth. The value is also influenced by the size and shape of the channel which can influence the effect that vegetation has on channel roughness.

Degree of meandering

Values range from 1 for minor to 1.3 for severe meandering.

3.4.2 Groundwater and Drainage Status

A non-steady state model was developed at Silsoe College (Hess et al, 1989; Youngs et al, 1989) and was modified to suit the requirements of the study. This estimates water table height in the floodplain throughout the year, taking into account rainfall, evapotranspiration, water levels in the ditch/river, soil characteristics, and field drainage system whether natural or piped.

The data requirements of the water table model are shown in Table 3.4. The model calculates field water table position against time for given local conditions. The input data for rainfall, evapotranspiration and river water levels and the output data for water table depths are presented on a weekly basis.

Table 3.4: Input Data for the Water Table Model

Ditch spacing (m) .
Depth to impermeable layer (m) .
Geometrical factor for ditch system .
Initial water table depth (m) .
Hydraulic conductivity of the topsoil (m/day) .
Hydraulic conductivity of the subsoil (m/day) .
Soil boundary depth (m) .
Specific yield (topsoil) (m/m) .
Specific yield (subsoil) (m/m) .
Unsaturated hydraulic conductivity exponent .
Surface elevation (m AOD) .
Ditch base elevation (m AOD) .
Set water ditch base levels? Yes = 1, No = 0 .
Is there irrigation? Yes = 1, No = 0 .
Draw ditch water levels? Yes = 1, No = 0 .
Weekly water level data (m AOD)
Weekly rainfall data (mm)
Weekly evapotranspiration data (mm)

The drainage status of agricultural land is determined on a seasonal timescale (spring, summer and autumn) and is defined in terms of the number of weeks that the water table depth is between the surface and 0.3 m depth, between 0.3 m and 0.5 m, and greater than 0.5 m from the surface. These classes were based on a review of the research literature which examined the link between crop yields and water table height, and water table height and soil bearing strength. Table 3.5 shows the method used for classifying drainage status of land in the benefit area. Water tables at or below 50 cms from the surface are not considered to impose restrictions on farming practice; water table levels in the 30-50 cm range can directly depress crop yields and restrict access to the land by machines or

animals, thereby limiting grazing seasons and timely field operations; where water tables are persistently between 0-30 cms below the surface, poor drainage is likely to impose severe constraints on the land use. These three agricultural productivity classifications were defined as 'good', 'low' and 'breakdown'. Agriculture in the UK is particularly sensitive to spring and autumn field wetness conditions, although on some soils overdrainage could cause droughtiness problems in the summer.

Table 3.5: Classification of Drainage Status from Water-Table Model Output

For a given time period, for example Spring, Summer or Autumn, if:
- at least 80% of weeks are > 0.5m, then 'Good' drainage
- at least 50% of weeks are > 0.3m, then 'Bad' drainage
- at least 50% of weeks are < 0.3m, then 'Very Bad' drainage

The impact of maintenance on flood risk and water table height varies according to prevailing weather conditions, especially the amount of rainfall in a given period.

Agriculture in Britain is particularly sensitive to field wetness conditions, especially in the spring. Daily and monthly rainfall records from weather stations adjacent to the study sites suggested a normal distribution of rainfall frequency (Figure 3.1) when classified by year

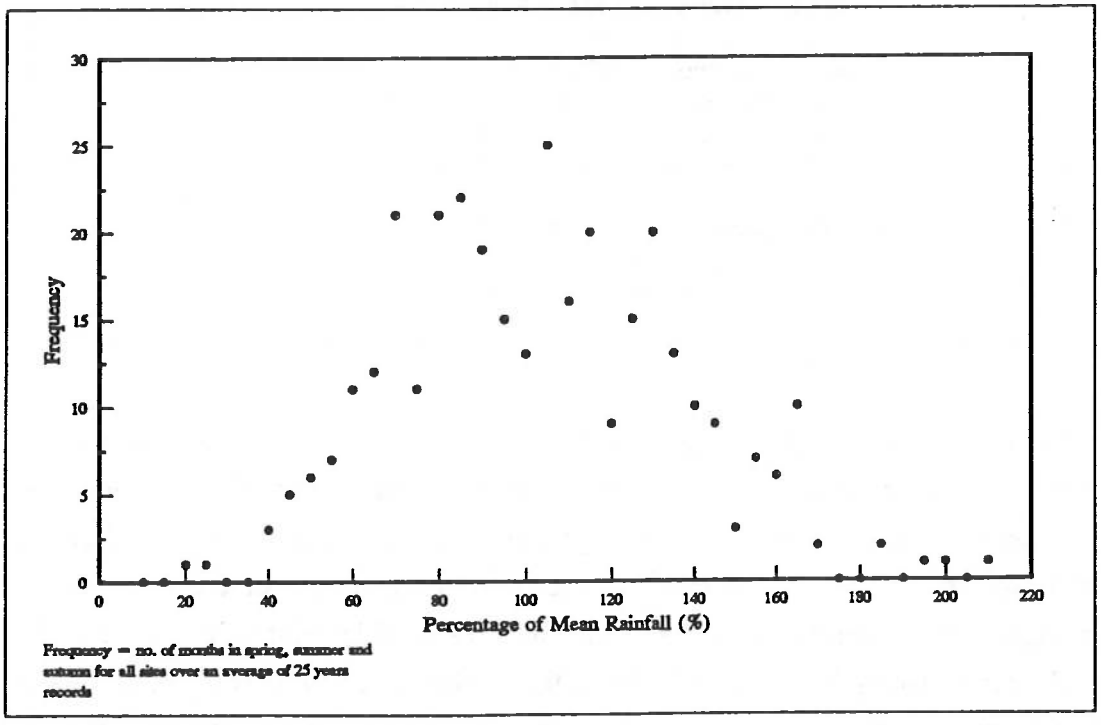


Figure 3.1: Distribution of Monthly Rainfall Totals about the Mean for all Sites in Spring, Summer and Autumn

and season. Seasons (spring, summer and autumn) were classified by rainfall. A mean season was taken to be that which contained rainfall +/- 10% of the mean. Dry and wet seasons were classed as those with less than 90% of the mean and more than 110% of the mean respectively. These ranges were set to reflect the perceived sensitivity of drainage conditions to variations in rainfall about the mean. The sensitivity of maintenance benefit estimates to this assumption is considered later in the results chapter.

For each site, the water table model was run for 'with' and 'without' maintenance river water levels for given weather conditions (wet, mean, dry) in order to identify the impact of maintenance on water table levels and hence on drainage status. Estimates of weekly water table heights within wet, mean and dry seasons were derived in order to classify seasonal drainage status using the criteria in Table 3.5 above. These drainage conditions were linked with estimates of agricultural productivity to determine the benefits attributable to maintenance for given weather conditions.

3.4.3 Agricultural impacts

The farmers were visited regularly during the study, once before maintenance was carried out and three or four times after maintenance. The Baseline Survey concentrated on the drainage conditions and management of the land in the benefit area prior to the maintenance activity. The farm surveys post-maintenance mainly considered the relationship between drainage status, river maintenance, and field management and performance. Farm interviews also assessed the variation in field management under different drainage standards, i.e. how the farmer did, or would, manage the land under good, bad and very bad drainage conditions and the likely consequences for farm inputs and outputs. This enabled agricultural production scenarios to be created for each block of land for different drainage conditions.

3.4.4 Agricultural Benefit Assessment

Information was drawn from the farm survey and literature review to determine productivity scenarios for each block of land in the benefit areas of the maintenance schemes. These scenarios showed the input-output relationships and resultant financial performance of land-use and farming practice under different drainage conditions, namely good, bad and very bad. These drainage conditions were defined in terms of the water table height classifications previously described.

A general statement on the formulation of these scenarios is given in Table 3.6. Data describing input-output performance for each land block under good, bad and very bad

drainage conditions was processed using the SCADE Model. Table 3.7 shows an example of the input data for a selected block and Table 3.8 summarises the estimates of financial returns associated with the three drainage categories. Constant 1991 financial prices were used throughout the analysis.

The estimates of financial returns associated with the different productivity scenarios provide the basis for estimating the benefits attributable to river and land drainage maintenance. The difference in financial returns between good, bad and very bad drainage conditions shows the extra benefits associated with maintaining drainage status at a given level and avoiding the losses associated with a deteriorating drainage condition. In the example in Table 3.8 the benefits of maintaining a good drainage status are £117/ha (ie £459-£342) if, in the absence of maintenance, drainage status deteriorates to a bad classification.

Table 3.6: Common Farming Practices and Performance by Field Drainage Status

	Drainage Status		
	Good	**Bad**	**Very Bad**
Land Use			
Grassland			
- nitrogen application % of application on 'good' category	100%	70%	50%
- grass conservation	2 cut	1 cut	1 cut hay
- grazing season penalty days c.f. 'good' category:			
Spring	0	-14	-28
Autumn	0	-14	-28
Arable			
- yield as % of 'good' category			
Winter wheat and barley	100	80	50
Spring wheat and barley	100	90	80
Oil Seed Rape	100	90	80
Potatoes, Peas, and Sugar Beet	100	60	40*

* not grown if persistently very bad

Table 3.7: An Example of Input Data for Different Field Drainage Conditions

		Drainage Status		
		Good	Bad	Very Bad
Crop Type	**Winter Wheat**			
Crop Yield (t/Ha)		6.75	5.4	3.4
Fixed Costs (Labour)	Semi			
Fixed Costs (Buildings)	Semi			
Recurrent Extras (£/Ha/Yr)	0			
Winter Wheat				
No. of Years in Rotation		2	2	2
Fixed Costs	Semi			
One-Off Extras (total) £/Ha	0			
Crop Type	**Winter Barley**			
Crop Yield (t/Ha)		6.3	4.6	2.9
Fixed Costs (Labour)	Semi			
Fixed Costs (Buildings)	Semi			
Recurrent Extras (£/Ha/Yr)	0			
Winter Barley				
No. of Years in Rotation		2	2	2
Fixed Costs	Semi			
One-Off Extras (total) £/Ha	0			
Crop Type	**Grass**			
No. Cuts		2	1	0
Fixed Costs (Pasture)	Semi			
Grass Type	Temporary			
Stock Type	Fat Lamb			
Stock Type	Dairy Cows			
Stock Type	24 Month Beef			
Fixed Costs (Labour)	Semi			
Fixed Costs (Buildings)	Semi			
Start of Grazing		After Cut	After Cut	Early May
Recurrent Extras (£/Ha/Yr)	0			
Grass				
No. of Years in Rotation		2	2	2
Nitrogen Level (Kg/Ha)		200	130	100
Conservation System		Silage	Silage	Graze
Fixed Costs (Conservation)	Semi			
Ley Length (years)		2	2	2
Weighting Factor - Lambs %	50			
Weighting Factor - Dairy %	30			
Weighting Factor - Beef %	20			
Fixed Costs	Semi			
End of Grazing		Early Nov.	Mid Oct.	Late Sept.
One-Off Extras (total) £/Ha	0	0	0	0

Data Source : Farm Survey

Fixed Costs Assumptions = Semi denotes changes in operating costs only with no change in investment costs for buildings, equipment.

Table 3.8: Estimates of Financial Returns for a Sample Block of Land

	Drainage Status		
	Good	**Bad**	**Very Bad**
Wheat			
Yield (t/ha)	6.75	5.4	3.4
Gross Margin	562	427	209
Crop Fixed Cost	142	135	126
Extras +/-	-	-	-
Net Returns (£/ha)	421	291	83
Barley			
Yield (t/ha)	6.3	4.6	2.9
Gross Margin	517	350	163
Crop Fixed Costs	122	115	106
Extras +/-	-	-	-
Net Returns (£/ha)	395	235	56
Grass - Mixed Stock			
Yield (MJ/ha)	74800	62400	49500
Gross Margin	1283	1078	850
Forage Variable Cost	160	119	94
Grass Fixed Costs	214	166	140
Stock Fixed Costs	354	291	230
Extras +/-	+12	-	-18
Net Returns (£/ha)	563	502	368
Average for Rotation (£/ha) (2 Wheat, 2 Barley, 2 Grass)	459	342	169
(1991 prices)			

In formulating scenarios for individual blocks of land, care was taken to ensure that improved drainage due to maintenance did not assume increases in input levels, such as additional fertilizer on grass, beyond that regarded by the farmer as normal practice. The benefits of maintenance were confined to the avoidance of losses and those automatic benefits associated with higher yields and longer grazing seasons. In other words, 'uptake' of benefits was not used to justify higher levels of maintenance.

Using the methods previously described, the drainage status of each block in the benefit area was assessed for dry, normal and wet weather conditions for 'with' and 'without' river maintenance. The benefits of maintenance as determined by a change, if any, in drainage status were thus identified for given weather conditions. These benefits were then weighted by the relative probabilities of the three types of weather condition in order to derive an expected annual benefit. The procedure is shown in Table 3.9

Table 3.9: Estimation of Benefits of Drainage Status Attributable to River Maintenance

	Weather Conditions		
	Wet	Mean	Dry
Drainage status without maintenance £/ha	VB (£169)	B (£342)	G (£459)
Drainage status with maintenance £/ha	B (£342)	G (£459)	G (£459)
Difference due to maintenance: £/ha	173	117	0
Probability of weather conditions	0.4	0.2	0.4
Expected benefits: £/ha	69.2	23.4	0
Average expected benefits per year: £92.6/ha : for a 5 ha field = £463/yr			

(a) Flood Damage Costs

River maintenance often influences the capacity of a water course to contain flows of a given magnitude, and thereby the frequency of flooding. Flood damage costs were assessed for each block of land for each productivity scenario both with and without maintenance. Changes in flood costs attributable to maintenance were thus identified taking into account any changes in productivity associated with drainage status.

Table 3.10 shows for an example field that, where maintenance prevents drainage status from falling from good to bad and reduces the interval between flooding from 0.4 years to 1.4 years, the average annual benefit is £7/ha (i.e. £10-£3). These flood alleviation benefits were then weighted by the probability of the weather conditions to give an expected average annual value. This approach assumes that flood return period is independent of type of weather year. Within the limits of available data, this seems reasonable.

(b) Scheme justification

The justification for river maintenance was assessed by comparing the present value of the expected future benefits and costs of maintenance over the economic life of the works. The latter was assumed to be the longest interval between repeat maintenance activities in a given benefit area, such as ten years in the case of desilting. All benefits and costs were

Table 3.10: Estimated Benefits of Flood Alleviation Attributable to Maintenance

Example : per ha. (Drainage status in parentheses)	Flood return period	Wet weather	Mean weather	Dry weather
Flooding costs without maintenance £/ha	0.4	(VB) 5.7	(B) 10.0	(G) 11.0
Flooding costs with maintenance £/ha	1.4	(B) 2.0	(G) 3.0	(G) 3.0
Difference due to maintenance £/ha		3.7	7.0	8.0
Probability of weather conditions		.4	.2	.4
Expected flood alleviation benefit £/ha subject to flooding			6.08	

expressed in 1991 prices using the RPI in the case of maintenance costs (1989 = 86.5; 1990 = 94.5; 1991 = 100).

By way of example, Table 3.11 shows the average annual benefits per block of land on the River Sence. Table 3.12 compares the present value of these benefits with the present value of the costs of the desilting operation. The maintenance programme breaks even over its planned life of 20 years at the 6% test discount rate. An examination of sedimentation rates in the river suggested, however, that additional annual weed cutting may be required to achieve this life expectancy, though the cost of this could prejudice programme feasibility. The desilting maintenance programme would not be worthwhile if the works need to be repeated after a ten year interval.

For the purpose of the present analysis, the basic assumption is that annual benefits remain constant over scheme life. This may not be so in reality for infrequent maintenance which experiences a decline in service over time. However, the without maintenance situation is also likely to be one of continued deterioration. In this respect the decline in with and without maintenance benefits are likely to cancel each other out as the river reinstates its natural condition. The influence of rates of post-maintenance deterioration of the financial performance of maintenance schemes is considered in the sensitivity analysis. The issue of post-maintenance sedimentation and erosion has been identified for further study.

Table 3.11: Average Annual and Total Benefits Attributable to Maintenance of the River Sence

Block number	Block size (ha)	Wet (£/ha/yr)	Mean (£/ha/yr)	Dry (£/ha/yr)	Total change (£/yr)
101	20.8	30.88	0.71	0.71	266
102	6.8	30.88	0.25	0.25	85
103	3.1	30.88	0.26	0.26	39
201	8.6	0.48	0.52	0.52	4
301	10.4	30.2	4.11	33.57	274
302	13.4	4.11	8.05	23.00	167
401	4.3	49.97	13.58	28.85	147
402	9.9	57.11	6.33	71.54	522
501	9.0	24.50	24.50	3.96	147
601	8.8	5.46	5.46	5.46	48
602	7.5	0	0	0	0
603	12.0	2.70	3.67	3.67	39
604	5.6	176.7	124.0	8.0	553
605	4.9	146.00	43.44	43.44	414
701	9.1	14.85	14.85	14.85	135
901	11.0	31.77	39.00	39.00	397
Total:	145.2				3237

Total benefits over 20 years: £37130

Probability of:		
	Wet conditions	0.4
	Normal conditions	0.2
	Dry conditions	0.4

Table 3.12: Scheme Appraisal - River Sence (1991 Price Base)

Appraisal Method	Present Value Costs (£)	Present Value Benefits (£)	Net Present Value (£)	Internal Rate of Return
Full life repeat cycle (20 yrs)				
- anticipated costs	24 950	37 130	12 180	12.4%
- actual costs	31 940	37 130	5 190	8.2%
Half life repeat cycle (10 yrs)				
- anticipated costs	24 950	23 825	-1 125	4.8%
- actual costs	31 940	23 825	-8 115	-1.0%

3.4.5 Environmental Impacts

The NCC River Corridor Surveys were carried out before and after maintenance at each 500m section of the study sites. Conservation data, along with the results of discussions on environmental impacts with the farmers and various NRA conservation and fisheries staff, were analysed so that the nature and scale of the impacts of maintenance, if any, upon the conservation features of the study sites could be identified.

In some instances, costs of environmental protection and enhancement are incurred during maintenance activities. Environmental protection costs such as the costs of executing the works in an environmentally sensitive manner (such as on the River Sence) have been charged to the scheme and need to be covered by the non-environmental benefits. Environmental enhancement costs, such as the creation of a lagoon habitat on the Swilgate, have not been charged because the resultant environmental benefits have not been valued for inclusion in the analysis.

3.5 GENERAL IMPACT ASSESSMENT

The results of the site surveys have been summarised in the form of an impact assessment matrix, the outline of which is shown in Appendix 5. The impact assessment matrix shows the nature and scale of the impacts of maintenance on hydrological, agricultural and environmental features. The matrix is designed to provide summary information for the site as a whole in both quantitative and qualitative terms. The impacts are also classified according to whether they are negative or positive, short term or long term, direct or indirect and reversible or irreversible.

3.6 SUMMARY

This Chapter has identified the site selection criteria, the sites selected, data requirements and methods of collection and the methods of impact assessment adopted during the study. The results of the study are presented in the next Chapter.

CHAPTER FOUR - RESULTS

Chapter Four provides a summary of the results from the six sites included in the study. These include scheme characteristics, river engineers survey results, farm survey results, results from the modelling procedures used in the study and scheme appraisal results.

4.1 INTRODUCTION

Eight sites were included in the study originally but two were subsequently excluded. The original list of sites was:

River Blythe (Staffs) and River Anker - Upper Trent;

River Sence and River Ryton - Lower Trent;

River Roden and River Morda - Upper Severn;

River Swilgate/Dean Brook and Laughern Brook- Lower Severn.

The River Blythe, River Morda and Laughern Brook were included in the Baseline Survey but were dropped from the Study during Phase II because the maintenance work was not carried out as originally intended. In the cases of the Blythe and Morda this was due to objections from the Royal Society for the Protection of Birds (RSPB) and Otter Trust respectively. In the case of the Laughern Brook the tree maintenance was delayed for local management reasons. Maintenance on the Brook has since been completed and has been included in another study being carried out by Silsoe College on behalf of Severn-Trent NRA as part of a Tree and Bush Maintenance Best Practice Review (Spring 1992). The River Blythe was replaced by the Hilton Brook, a similar watercourse in the same Area. The Morda and Laughern Brook were not replaced because the decision to not perform maintenance was taken too late to give time for the selection of other sites.

The River Ryton was excluded because when the Baseline Survey was due to be carried out, it was revealed that maintenance had already been completed. The Oldcoates Dyke was identified by the Lower Trent Area and accepted for study.

4.2 SCHEME CHARACTERISTICS

4.2.1 River and Floodplain Characteristics

The six sites included in the study cover a variety of river and floodplain types. The size of the rivers ranges from 2.7 m^3/s (Dean Brook) to 30 m^3/s (River Anker). The rivers include those which: are fast flowing (eg. Hilton Brook); are wide and slow moving (eg. River Anker); meander considerably across the floodplain (eg. River Swilgate); and are relatively straight (eg. River Roden).

The floodplains vary in width, shape and steepness from the wide flat floodplain on the Oldcoates Dyke to the narrow steep floodplain on much of the River Roden. Most of the soils in the floodplains are alluvial clays, silty clays or sandy clays. The Agricultural Land Classification of the benefit areas contains Grade 2, Grade 3 and Grade 4 land. Grade 3 land is most common, followed by Grade 2 and Grade 4 land. The variation between areas is considerable. For example, all of the land in the Hilton Brook benefit area is Grade 4 land and 90% of the land in the River Sence benefit is Grade 2 land. A summary of the river and floodplain characteristics is shown in Table 4.1. Plates 4.1 to 4.8 show representative sections of each of the watercourses included in the Study.

4.2.2 Maintenance Activities

The schemes included in the Baseline survey involved three types of maintenance: desilting, weed maintenance and tree and bush maintenance. The scheme which was scheduled for tree and bush maintenance, the Laughern Brook, was rescheduled and dropped from the study. Of the six sites, four involved desilting and two involved weed maintainance.

The desilting work on the Swilgate/Dean Brook and River Sence included conservation protection and enhancement measures as part of the maintenance works, including pond creation, submerged berm construction and small stone weir creation (see Scheme Annexes for details). Weed maintenance on the Oldcoates Dyke involved a weed cutting boat. Weeds on the River Anker were cleared using two methods. One section was cleared using a Bradshaw Bucket on a hydraulic excavator and another section was 'slubbed out' with a dragline excavator. A section was also left untouched to act as a control. Marker boards were installed to monitor water levels following maintenance. The analysis of the relative impact of maintenance activities in the three sections is included in the River Anker Annex.

Table 4.2 shows a summary of the sites, maintenance activities and benefit areas.

Table 4.1: River and Floodplain Characteristics

River	Mean Annual Flood (m^3/s)	Channel Features	River Function	Floodplain Features	Soils
Roden	19	50% relatively shallow, wide, mainly cobble substrates, fast flow. 50% relatively wide, deep, slow, and straight, silt substrates.	Agricultural flood alleviation and land drainage, conservation, especially fisheries.	Variable width (0-200m) and slope (0.01-45%). Agricultural Land Classification: 20% Grade 2, 75% Grade 3, 5% Grade 4	Newport 80% Clifton 15% Crannymore 5%
Swilgate/ Dean Brook	6.5 2.7	Steep sided, narrow channels Silt and clay substrates. Fast flowing stream. Dean Brook straight, Swilgate tightly meandering.	Agricultural land drainage and upstream urban flood relief.	Generally uniform width Gently sloping 95% Grade 3, 5% Grade 4	Evesham 100%
Anker	50	Wide, deep channel shape. Heavy weed growth. Variety of substrates. Gently winding watercourse.	Agricultural flood alleviation and land drainage.	Variable width from flat wide (upstream end) to steep narrow (down stream end). 10% Grade 2, 90% Grade 3.	Compton 50% Wick 50%
Hilton Brook	12	Wide, shallow cross-section. Fast flowing, tight meanders. Substrates mainly cobbles.	Agricultural flood alleviation	Narrow on one bank. Wide and flat on other bank to parallel watercourse. 100% Grade 4.	Compton 100%
Sence	20	Mainly deep narrow cross-section. Meandering, medium fast flowing. Various substrates.	Agricultural flood alleviation and land drainage. Conservation and recreation.	Narrow on side by canal, wide on other bank. Gently sloping. 90% Grade 2, 10% Grade 3.	Fladbury 90% Ragdale 10%
Oldcoates Dyke	12	Upstream end shallow and wide. Downstream narrower and deeper. Upstream meanders, downstream straighter.	Agricultural flood alleviation and land drainage.	Narrow and gently sloping one one bank, wide and flat on the other side. 40% Grade 2, 50% Grade 3, 10% Grade 4.	Enborne 100%



Plate 4.1: River Sence (Lower Trent) - Pre-maintenance (April 1989)



Plate 4.2: River Sence (Lower Trent) - Post-maintenance (April 1991)

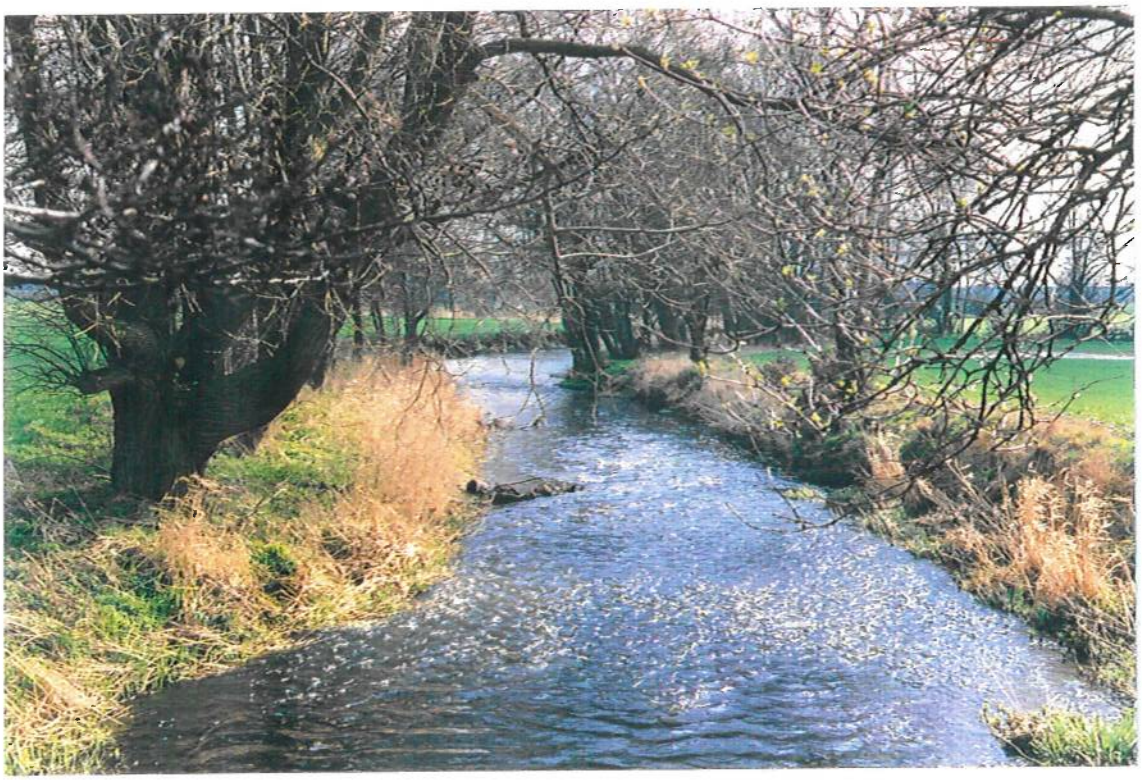


Plate 4.3: Hilton Brook (Upper Trent - March 1991)



Plate 4.4: River Anker (Upper Trent - November 1991)



Plate 4.5: Oldcoates Dyke (Lower Trent - October 1991)



Plate 4.6: River Roden (Upper Severn - March 1989)



Plate 4.7: Dean Brook (Lower Severn - May 1991)



Plate 4.8: River Swilgate (Lower Severn - May 1991)

Table 4.2: Summary of Site Characteristics

Area	Watercourse	Length (km)	Maintenance Activities	Area of Benefit (ha)	Date Completed	Current Cost (£)	Current Cost (£/km)	Current Cost (£/ha)
Upper Severn	River Roden	4	Desilting	107	.5 Spring 90 .5 Spring 91	3470 4880 (8350)	2090	78
Lower Severn	River Swilgate/ Dean Brook	5	Desilting	192	Spring 1990	16730	3350	87
Upper Trent	River Anker	3	Weedcutting - Bradshaw Bucket - Dragline - None	92	Summer 1989	6050	2015	66
Upper Trent	Hilton Brook	3	Desilting	94	Spring 1990	35000	11700	372
Lower Trent	River Sence	4.5	Desilting	145	Spring 1990	32000 *	7100	220
Lower Trent	Oldcoates Dyke	5	Weedcutting - Weed boat	145	Annual	89 - 2624 90 - 3805 91 - 2782	614 (average)	21 (average)

Current cost = Cost at out-turn prices

4.3 RIVER ENGINEERS SURVEY

Selected river engineers engaged in the management of the rivers under study were interviewed by NRA (ST) Flood Deference Operations staff using a questionnaire designed at Silsoe College. The questionnaire covered issues relating to the decision to perform maintenance; criteria for standards of service; criteria for methods of maintenance; pre-maintenance communication; post-maintenance evaluation; post-maintenance contact with affected groups. The results were analysed and presented in the Phase II report.

During the last phase of the study, informal discussions were conducted with the river engineers to reconsider some of the issues raised in the questionnaire, especially regarding post-maintenance procedures.

(a) Reasons for decision to perform maintenance

The main reasons given for the decision to perform maintenance were that it was part of their regular work schedule and followed inspection of the river, ie conditions in the watercourse confirmed to the inspector that maintenance was required. These reasons were mentioned by all of the engineers.

The maintenance schemes were justified in a variety of ways. All of the schemes were justified on the basis of land drainage and flood protection. In addition, one scheme, the Swilgate/Dean Brook was justified because of the increased threat of flooding within the benefit area due to large scale urban development upstream in a steep, flashy catchment.

(b) Criteria for selecting standards of maintenance

Custom and previous practice were mentioned as major criteria in determining the frequency and standard of service and the methods used. Desilting schemes were preceded by supervisors' inspection and engineers' survey and appraisal. In most cases pre-maintenance cross-section surveys were carried out in order to assess the volume of desilting required. For weed maintenance the main criteria was custom and practice.

Further discussions showed that RIMS was increasingly being used in order to determine the standard of service. Maintenance schemes were increasingly taking into account conservation protection and enhancement measures.

(c) Criteria for methods of maintenance

The criteria mentioned most often for selecting the methods of maintenance were proven suitability, characteristics of the watercourse, cost effectiveness, environmental factors and

the availability of skills/machines. The watercourse type and conditions in the watercourse were particularly important variables in the selection of weed maintenance methods.

(d) Pre-maintenance communication

The landowners were contacted in all cases before maintenance was carried out, although the method of contact varied, including letters to the landowners, personal contact from the sub-area operations engineer or supervisor, or notice of entry. The regional conservation officer was also contacted in all cases either through a meeting to discuss the particular site scheduled for maintenance or on an annual basis when the whole scheduled programme of maintenance for that year would be discussed. The number of outside organisations contacted by the NRA engineers was greater for desilting activities than it was for weed maintenance or tree and bush work. These organisations included public utilities, statutory bodies and particular interest groups.

(e) Post-project evaluation and communication

The main, and almost only method of post-project evaluation was visual inspection. The inspections were by means of single or periodical walks along the maintained reach during which the results were compared to the plans. In some cases, site meetings were held with engineers, conservation staff and, occasionally, farmers who had special interests. Only one divisional engineer reported that post-project evaluation took the form of taking channel levels to confirm that the work conformed to the plans.

Post-project communication with the landowners was reported to be informal and not a regular feature. The main contact was through farmers phoning the NRA to register complaints. In some areas the response from the NRA was immediate and to the landowners satisfaction. In other cases there was no response, much to the annoyance of some farmers. Site meetings between engineers and conservation/fisheries staff were more regular and formal when the work was likely to have environmental impacts.

4.4 FARM SURVEY

This section includes the results of the farmer surveys carried out over the three year study. The farmers were visited once before maintenance was carried out and twice a year following maintenance. The section is divided into two parts: farm information and land use information. The data for farm classification includes the data for the three sites included in the Baseline Survey but which were subsequently excluded. The data for both farm classification and field management includes the results from capital works post-

project appraisal work carried out by Silsoe College (Morris et al, 1984). The data for the 1984 study have been included for comparison purposes.

4.4.1 Farm Information

(a) Farm Classification

The main classifications of farms included farm size, type, percentage within the benefit area, and tenure. The information is summarised in Table 4.3. The mean farm size varied considerably from site to site, the smallest was 69 ha for the Hilton Brook and the largest was 182 ha for the Oldcoates Dyke. The mean farm size for this study of 103 ha was similar to the mean size (105 ha) for the STWA capital works study completed in 1984.

The most common farm types covered in the survey were, in descending order, general cropping, specialist dairy, livestock rearing and fattening, and specialist cereals. This is a wider selection of farm types than those identified in the 1984 study, where 46% of farms were dairy farms.

The percentage of the total area of farms which lie within the benefit areas varied from 15% on the Roden, which had a narrow benefit area in many places, to 25% on the River Swilgate/Dean Brook which had a wide benefit area and which also included several small farms which were almost entirely within the benefit area.

The large majority of fields in the benefit areas were farmed by the owners. In some cases the farmers were tenants or managers of other farms but had bought less intensively farmed land by the rivers in order to carry out their own low input/output smallholder farming. In addition some of the farmers who owned the land in the benefit areas were farming part-time and had other business interests.

(b) Farm Diversification

In the early period of study (1989), very few of the farmers expressed any interest in, or plans for, extensification or diversification. However, during the latest site visits (1992), some of the specialist cereals farmers were beginning to consider voluntary 'set aside'. This was due mainly to the fall in cereal prices. One of the farmers had turned some of the farm buildings into an arts and crafts centre and two other farmers had begun extensive outdoor pig enterprises. Many of the farmers were beginning to look at ways in which grants for conservation, such as the Farm Woodland Scheme and the Countryside Commission Scheme, would fit into future farm management plans.

Table 4.3: Sampled Farms by Scheme , Farm Type, Size and Tenure

Scheme	Area surveyed (ha)	Number of farms in benefit area	Mean farm size (ha)	Mean SMD requirement	Type of farm: % of farms							Mean % of farms in benefit area	Field tenure: % farm area			
					Dairy	Livestock	General cropping	Specialist cereals	Pigs and poultry	Other	No data		Owned	Tenanted	Summer let	Other
Roden	107	7	120	900	29	-	43	14	14	-	-	15	94	6	-	-
Swilgate/ Dean Brook	192	10	84	384	10	30	20	30	-	10	-	25	93	7	-	-
Anker	92	5	84	582	20	20	40	20	-	-	-	20	100	-	-	-
Hilton Brook	94	5	69	510	40	20	-	40	-	-	-	26	100	-	-	-
Sence	145	8	97	800	38	38	24	-	-	-	-	19	86	14	-	-
Oldcoates Dyke	145	5	182	1021	-	-	100	-	-	-	-	17	84	16	-	-
Total	775	40	103	658	22	20	35	17	3	3	-	19	92	8	-	-
Morda	213	10	89	719	90	-	-	-	-	-	-	32	78	5	11	6
Laughern Brook	115	4	153	760	25	50	25	-	-	-	-	21	100	-	-	-
Blythe	204	18	72	800	61	28	-	-	-	11	-	18	100	-	-	-
Total	1307	72	96	708	42	21	21	10	2	4	-	19	91	6	2	1
STWA Study - 1984	5417	170	105	926	46	18	22	-	-	5	9	42	56	34	1	9

4.4.2 Land use

The information on land use and field drainage installation for the six sites and for the 1984 capital works study is shown in Table 4.4.

The average distribution of land use for all of the benefit areas included in this study is 38% for permanent pasture, 38% for all-arable rotations, 18% for grass/arable rotations and 6% for temporary grass. All of the temporary grassland belonged to one dairy farm in the River Swilgate benefit area. The temporary grassland was intensively farmed with high levels of nitrogen application, two to three cuts of silage, and subsequently grazed by dairy cattle until December.

Table 4.4: Land Use and Field Drainage Installation

Scheme	Permanent grassland		Temporary grassland		Arable/grass rotation		All arable rotation	
	Area (ha)	Field drains %	Area (ha)	Field drains %	Area (ha)	Field drains %	Area (ha)	Field drains %
River Roden	64	70	-	-	-	-	43	100
River Swilgate/ Dean Brook	55	73	49	100	64	95	24	60
River Anker	22	100	-	-	7	100	63	83
Hilton Brook	44	38	-	-	17	28	33	88
River Sence	97	44	-	-	48	59	-	-
Oldcoates Dyke	12	20	-	-	-	-	124	87
Total	294	57	49	100	136	74	287	86
(% area)	(38)		(6)		(18)		(38)	
STWA Study 1984 (% area)								
Pre-scheme	77		5		6		12	
Post-scheme	48		7		13		32	

There are considerable variations in the distribution of land use between the study sites. For example, over 90% of the Oldcoates Dyke benefit area in Nottinghamshire is down to all arable rotations whilst over 60% of the River Roden benefit area in Shropshire is down to permanent pasture. This reflects the regional variations in land use.

The data shows that, with the exception of temporary grassland were only one sample was available, the more intensive is the land use, the higher is the percentage of the land which has field drainage installed. The percentage of total area with field drainage by land-use type ranged from 57% of permanent pasture to 86% of all-arable land. Statistical analysis

of the data, through the use of the Chi-square test, confirmed that there was a significant relationship between land use and the installation of field drainage (Chi-square value 8.4, significance level 0.015).

The detailed information on field management is shown in the Scheme Annexes.

4.5 FLOOD RISK

The impact of maintenance on flood risk has been analysed by two methods. One is through reported changes in flood risk from interviews with farmers and the other is through analysing the changes in cross-section and Manning's 'n' and using Manning's equation to calculate the change in channel capacity and, hence, change in flood return period. The changes in flood risk relate to changes in flood frequency rather than changes in area. The changes in flood risk as determined by farmer reports and modelling are shown in Table 4.5.

Table 4.5: With and Without Maintenance Flood Risk - Reported and from Cross-section Analysis

Site		% Area Affected - Reported				% Area Affected - Modelled			
		No flooding	Infrequent flooding	Once a year	> once a year	No flooding	Infrequent flooding	Once a year	> once a year
Roden	Without	86	3	11	-	86	-	-	14
	With	90	-	10	-	86	10	-	4
Swilgate/	Without	96	2	2	-	96	2	2	-
Dean Brook	With	100	-	-	-	100	-	-	-
Anker	Without	25	-	15	70	25	-	-	75
	With	25	-	50	25	25	-	15	60
Hilton	Without	48	-	-	52	48	-	-	52
Brook	With	90	-	10	-	48	-	32	20
Sence	Without	43	-	22	35	43	-	-	57
	With	65	-	35	-	43	-	23	34
Oldcoates	Without	98	-	2	-	85	5	-	10
Dyke	With	98	-	2	-	85	5	-	10
Total	**Without**	**71**	**1**	**8**	**20**	**69**	**1**	**-**	**30**
Total	**With**	**81**	**-**	**16**	**3**	**69**	**1**	**10**	**20**

The rivers which were particularly affected by flooding before maintenance were the Anker, Hilton Brook and the Sence. The Oldcoates Dyke and the Swilgate/Dean Brook experienced very little flooding before the maintenance was carried out. Flooding in the River Roden was restricted to a small area because of the narrow steep sided floodplain characteristics.

According to farmer estimates, the percentage of the total area on all six sites flooding more frequently than once a year reduced from 20% to 3% due to maintenance. Most of the rest of the area which was flooded more than once a year without maintenance has subsequently flooded once a year on average. The area of the benefit area which has not flooded at all has increased from 71% before maintenance to 81% after maintenance. The sites where the greatest improvement in flood risk was reported were the Hilton Brook and the River Sence. The smallest impact on flood risk was reported on the Swilgate, where flooding was not a major problem before maintenance and maintenance was carried out as a preventative measure, and the Oldcoates Dyke where flooding was not reported to be a problem with or without maintenance.

These results need to be treated with caution because of the unusually dry conditions which have occurred since the completion of maintenance activities, and the limited period of observation.

The analysis of the cross-sections (Table 4.5) suggests that there has been no change in the no-flooding area, and that one third of the area which flooded more than once a year without maintenance (10% of the total area) floods once a year on average following maintenance. The largest changes in flood risk according to the modelled data are on the Hilton Brook and the River Sence.

In some cases the change has been more dramatic than is shown in Table 4.5. For example, the Hilton Brook flooded between five and ten times each winter without maintenance and with maintenance the flood risk fell to once a year or not at all. The River Sence flooded three or four times a year in places without maintenance, but subsequently this was reduced to once a year.

It should be repeated that these results are for a period of exceptionally dry weather conditions. This fact is reflected in a comparison of the farmers' estimates (actual change) and the cross-section analysis (predicted change). Farmers estimated that the area which does not flood at all has increased from 71% to 81%. However, analysis of the cross-sections suggests that the area which does not flood at all is the same with and without maintenance. In addition, whilst farmers estimated that the area which floods more than

once a year has dropped from 20% to 3%, analysis of the cross-sections suggests that the drop is from 30% to 20%.

In situations where river maintenance has little effect on drainage status in the benefit area (e.g. on heavy soils without field drainage), flood alleviation is the main benefit derived from river maintenance. However, under these conditions, flood damage costs, and therefore maintenance benefits, are likely to be modest. Flood alleviation benefits are likely to be greatest where land also derives under-drainage benefits from maintenance.

4.6 DRAINAGE STATUS

The classification of drainage status varied significantly between benefit areas from the mainly very bad drainage status of the Hilton Brook to the generally good drainage status of the Swilgate/Dean Brook. The drainage status was classified using a non-steady state water table model (see section 3.4.2) and the estimates compared statistically with the farmers' appraisal of drainage status. The Chi-square test showed that the relationship between the modelled drainage status under mean climatic conditions and the farmers assessment of normal drainage status was highly significant (Chi-square value 37.6, significance level 0.00).

The drainage status was assessed for without and with maintenance river water levels for wet, mean and dry weather conditions, see Table 4.6. The water table depths were analysed for wet, mean and dry weather conditions in order to assess under which particular weather conditions the impact of maintenance on drainage status was especially significant. The agricultural benefits attributable to maintenance were then weighted according to the probability of the particular weather conditions occurring.

Table 4.6 shows a variety of responses amongst sites in terms of the change in water table depths due to maintenance under different weather conditions. For example, on the River Swilgate and Dean Brook, there has been very little change in drainage status as a result of maintenance under wet and dry weather conditions, but under mean conditions there has been a significant difference. Without maintenance in a mean year only 50% of the benefit area was classified as good drainage status but with maintenance this has increased to 100% of the benefit area. However, on the Oldcoates Dyke, there has been no change in drainage status in wet and mean weather conditions as a result of weed maintenance. Under dry weather conditions, there has been a change from bad to good on a small area of the benefit area (8%) where the freeboard is less than elsewhere in the reach.

The main factors which affect the degree to which drainage status has changed as a result of maintenance are soil type, freeboard without and with maintenance, and the presence or absence of field drainage. For example, the soils beside the Hilton Brook are heavy clays. The freeboard was very limited without maintenance, remained limited with maintenance, and less than half of the benefit area has field drainage. The drainage status is very bad in wet weather conditions, both without and with maintenance, and either bad or very bad in mean conditions. In relatively dry conditions the drainage status is still very bad or bad for almost 70% of the benefit area without maintenance. With maintenance the drainage status in dry weather has improved, but 40% of the benefit area is still classed as bad drainage status. These areas are mainly down to grass. It should be taken into account, however, that in very dry summers these pastures may exhibit the benefits of retained water for grass production compared to other drought prone pastures.

Table 4.6: Without and With Maintenance Drainage Status in Wet, Mean and Dry Weather Conditions

Scheme	Maintenance Situation	% Area								
		Wet Weather Conditions			Mean Weather Conditions			Dry Weather Conditions		
		VB	B	G	VB	B	G	VB	B	G
River Roden	Without	21	43	36	19	15	66	-	23	77
	With	13	31	56	13	8	79	-	21	79
River Swilgate/ Dean Brook	Without	2	98	-	-	51	49	-	-	100
	With	-	96	4	-	-	100	-	-	100
River Anker	Without	61	39	-	33	67	-	-	11	89
	With	31	69	-	-	88	12	-	-	100
Hilton Brook	Without	100	-	-	77	23	-	7	62	31
	With	100	-	-	41	59	-	-	41	59
River Sence	Without	67	21	12	-	84	16	-	78	22
	With	31	38	31	-	67	33	-	40	60
Oldcoates Dyke	Without	31	19	50	17	20	63	-	24	76
	With	31	19	50	17	20	63	-	17	84
Total	Without	41	43	16	19	36	45	1	31	68
Total	With	29	47	24	10	35	55	-	19	81

On the River Swilgate, where the soils are silty or sandy clays, where freeboard is in excess of 1.5 m, and where field drainage has been installed, the drainage status is bad

under wet weather conditions and good under mean or dry weather conditions, both without and with maintenance. However, on sections of the Swilgate and Dean Brook, where the freeboard was limited without maintenance and has been significantly increased as a result of desilting, the drainage status is bad under wet and mean conditions without maintenance but is good with maintenance. The responsiveness of these fields to changes in river water levels as a result of maintenance was greater on those fields with field drainage than those without.

On watercourses such as the Oldcoates Dyke where freeboard is in excess of 1.5m for the majority of the reach, where most fields are drained and where maintenance activities do not significantly change the river water levels, the impact of maintenance on drainage status is less significant.

In general, the sensitivity of drainage status to maintenance activities and, hence, the level of maintenance benefits is influenced by:

- the presence or absence of field drainage or intensive ditch systems. Better drained sites are usually intensively farmed and are particularly sensitive to river maintenance;

- the hydraulic conductivity and drainable porosity of the soils. The lighter are the soils the more easily does water move through them, and the more sensitive they are to river maintenance;

- the initial river water levels and the degree to which river water levels change as a result of maintenance activities, or as a result of not performing maintenance.

4.7 RELATIONSHIPS BETWEEN LAND USE AND DRAINAGE STATUS

Statistical analysis of the data collected for the six sites indicate that the relationship between modelled drainage status under mean weather conditions and farmer classification of normal drainage status is highly significant (Chi-square 37.6, significance 0.00). Because farmers have not been able to assess the impact of maintenance due to the exceptionally dry conditions, the water table model has been used to classify the changes in drainage status as a result of maintenance for given weather conditions as shown in section 4.6 above.

The relationship between piped/natural drainage systems and the farmers' assessment of drainage status is also significant (Chi-square value of 11.3, significance 0.0035). Improved drainage status was associated with the installation of field drains. In almost all

cases where field drainage was installed the drainage status was either good or bad (under wet weather conditions). However, in almost all cases where field drainage was not installed the drainage status was bad or very bad.

The relationship between land use and field drainage installation was also significant (Chi-square value 8.4, significance 0.015). Over 80% of land under all-arable rotation or grass/arable rotation had field drainage installed, whereas only 50% of permanent grassland had field drains. However, the relationship between land use and the farmers' assessment of normal drainage status was not strong enough to be statistically significant (Chi-square value 3.57, significance 0.47).

4.8 BENEFIT ASSESSMENT AND SCHEME EVALUATION

4.8.1 Benefits at Scheme Level

The benefits for each scheme take into account the change in drainage status without and with maintenance for wet, mean and dry conditions and the relative probability of wet, normal and dry conditions. Where a change in drainage status results from maintenance, the changes in financial returns resulting from the change in field management have been calculated. The benefit assessment results are shown in Table 4.7 on an annual and scheme life basis. Assumptions regarding scheme life are based on estimates by river engineers of the anticipated return frequencies of maintenance.

Table 4.7: Maintenance Benefit Assessment

Site	Benefit area (ha)	Annual Benefits(£)	Annual Benefits per ha (£)	Scheme Life (years)	Total Benefits (£) (Present value at 6%)
Roden	107	1890	17.7	10	13 900
Swilgate/Dean Brook	192	2450	12.7	15	23 800
Anker	92	2370	25.7	3	6 340
Hilton Brook	94	2770	29.5	10	20 400
Sence	145	3240	22.3	20	37 130
Oldcoates Dyke	136	510	3.8	1	510
Average/ha			17.3		

The results vary considerably between the sites. The Oldcoates Dyke shows the lowest annual benefit per hectare at £3.80 per hectare. On this site annual weed maintenance was carried out by weed cutting boat and the measured changes in water level as a result of weed maintenance were small (less than 100 mm). The freeboard along most of the site is

in excess of 1.5 m. The detrimental effect of not doing weed maintenance on such a site is likely to be the gradual and long term effect on siltation. Further research is being done at Silsoe College in cooperation with Hydraulics Research Ltd to look into the longer term effect of weed growth, with and without maintenance, and its impact on siltation rates.

Those sites which show the greatest financial benefits per hectare, such as the Hilton Brook and the River Anker, are sites where there has been a significant change in freeboard during the late spring/early summer and where the without maintenance freeboard was limited. For example, on the River Anker, where the observed changes in river water level as a result of maintenance were considerable (in excess of 0.4 m during the late spring and summer). These changes, along with a freeboard of between 1 m and 1.5 m meant that the changes had a significant impact on water table depth, especially where field drainage was installed and had outfalls at about 1 m below the ground surface. The benefit area was also narrow and a high percentage of the area lies within the zone of maximum watertable response to river water levels.

The benefits of maintenance on the Roden were relatively low. Land use and field operations were not significantly constrained before desilting was carried out. On the Swilgate the freeboard was between 1.75 m and 2.0 m before maintenance and a further increase of about 200 mm to 300 mm did not have a major impact on water table depths.

Several factors influence the levels of benefit attributable to maintenance including those which influence the responsiveness of the watertable to changes in river water level (see section 4.6 above) and the type of land use. The analysis confirms that land uses involving high value arable crops and intensive grassland are more sensitive to maintenance standards of service than extensively grazed permanent pasture.

4.8.2 Scheme Evaluation

The scheme evaluation results are shown in Table 4.8. The estimates show that of the six sites included in the study four (River Roden, River Swilgate, River Anker and River Sence) are justified in terms of agricultural benefits generating internal rates of return greater than the 6% test discount rate. The economic performance of desilting schemes is, however, sensitive to assumptions regarding the rate of siltation and the interval for repeat maintenance. Two schemes (Hilton Brook and Oldcoates Dyke) do not appear to be justified by agricultural benefits alone. The Hilton Brook was prejudiced by higher than anticipated costs. Weed cutting on the Oldcoates Dyke appeared to be more than necessary to maintain the required standard of service.

The results indicate that there are three variables which influence the justification of schemes: benefits per hectare; size of the benefit area; and costs of maintenance. In particular, the size of the benefit area and the costs of maintenance have influenced the justification/non-justification of schemes included in this study. For example, the Hilton Brook has the highest level of benefits per hectare derived from maintenance activities. However, the floodplain characteristics are such that the benefit area is relatively small at 94 ha. This, combined with the comparatively expensive maintenance costs, means that maintenance is not fully jusitified in terms of agricultural benefits alone. However, on the Swilgate, the per hectare benefits were considerably less than those for the Hilton Brook but the benefit area was more than double the size. This, combined with relatively low maintenance costs (Swilgate maintenance costs were half the costs on the Hilton Brook), meant that the scheme was justified.

Table 4.8: Maintenance Scheme Evaluation (1991 Price Base)

Site	Present Value Costs (£) *	Present Value Benefits (£) *	Net Present Value (£) *	Internal Rate of Return
River Roden	8 070	13 900	5 830	24.4%
River Swilgate/Dean Brook	16 700	23 800	7 100	13.3%
River Anker	6 040	6 340	300	11.5%
Hilton Brook	34 950	26 900	-8 050	1.7%
River Sence	31 940	37 130	5 190	8.2%
Oldcoates Dyke (average annual costs)	2 895	485	-2 410	-

* net present value at 6% discount rate

The results for each scheme are analysed in detail in the Annexes to this report. The results of the scheme evaluation, however, need cautious interpretation. The analysis considered the maintenance of discrete sections of rivers in isolation of upstream and downstream impacts. In practice, a river or catchment system perspective is required. Within the resources available, it has not been possible to reliably assess the long term consequences for the river, and related standards of service not carrying out maintenance. For instance, the long term impact of not carrying out annual weed maintenance on channel capacity, and the condition to which the river and drainage systems would revert in the complete absence of maintenance, are topics which require further assessment before a more confident appraisal of maintenance is possible.

4.8.3 Critique of the Method

The method relies on a combination of results from site observation, farmer interview, and computer modelling. A fundamental criticism is that the method reduces very varied and complex realities into simple classifications, such as drainage status (good, bad, very bad) and agricultural productivity (normal, low, breakdown). These are discrete classifications which are attractive for decision making but dangerous because they give the impression of precision and confidence.

Using the classification of weather condition as an example, a redefinition of an average rainfall year to +/- 20% of the mean annual rainfall (rather than +/- 10%) has a significant effect on estimates scheme benefits and net present value (Table 4.9). The direction of this effect varies between schemes; positive in the case of the River Anker and negative in the case of the River Sence, for example. This reflects differences in local

Table 4.9: Effects of Changes in Weather Classification on Annual Returns and Scheme Appraisal (Indices)

SITE	ANNUAL RETURNS			NET PRESENT VALUE		
	Average conditions = 10% either side of mean rainfall	Average conditions = 15% either side of mean rainfall	Average conditions = 20% either side of mean rainfall	Average conditions = 10% either side of mean rainfall	Average conditions = 15% either side of mean rainfall	Average conditions = 20% either side of mean rainfall
Anker	100	111	119	100	227	314
Hilton Brook	100	107	117	100	110	122
Sence	100	96	93	100	87	77
Roden	100	99	93	100	98	83
Swilgate/ Dean Brook	100	142	175	100	355	557
Oldcoates Dyke	100	101	104	-	-	-

weather and differences in soil types and their sensitivity to river water levels under given weather conditions. It may, therefore, be appropriate to define weather year according to local drainage conditions rather than some general classification. Alternatively, if weather data are available, it may be possible to estimate drainage conditions in each year over, say, a thirty year period, in order to derive some weighted average climatic condition. These and other options for dealing with classification variables could not be pursued within the resources available, but they have been identified for future work.

4.9 ENVIRONMENTAL IMPACTS

The assessment of the impact of river maintenance environmental quality was confined to qualitative assessment using habitat-based criteria. For the most part, maintenance did not result in negative, long-term irreversible changes in environmental quality. But of course, the cessation of frequent maintenance such as weed cutting would probably lead to different qualities than those currently in place. A summary of the environmental impacts on river maintenance work on each watercourse is presented in the Annexes.

Weed cutting and clearance activities did not appear to result in major impacts in environmental quality in the case of the Oldcoates Dyke and the River Anker. For example, environmental impacts were direct, of short duration and reversible through natural regeneration of the river. In terms of the effect on fish and in-channel vegetation, impacts were positive on the River Anker but negative on the Oldcoates Dyke, although bed substrates were largely undisturbed on both watercourses.

Desilting operations appeared to have a greater impact than weed clearance on the riverine environment. Negative impacts were recorded at desilted sites in terms of the effect on channel characteristics (substrates, pools and runs). The gravel/cobble substrate of the River Roden, for example, changed to a more sandy/silty composition following maintenance. This may be detrimental to fish populations which require a coarse bed for breeding. River banks were untouched during desilting operations, but in areas of bank instability, such as on the Rivers Sence, Swilgate and Dean Brook, slippage resulted in the development of soft earth cliffs. These have been left unprotected by revetments and are potentially important habitats for kingfishers and sand martins.

From the recreational point of view, where fish were present in the river prior to maintenance, they returned following desilting operations or were replaced by restocking. Access for fishing was improved on the River Anker. Tree planting on the river banks was an integral part of maintenance on three of the sites. Environmental enhancements were carried out on some of the rivers, including excavation of small berms on the River Swilgate and the excavation of a small pond on the Dean Brook.

4.10 SUMMARY

This Chapter has reported the results from the survey of the six Study Sites. The methods of analysis developed by the Study were used to evaluate the impacts of and justification for river maintenance. The next Chapter uses these results to draw conclusions and identify priorities for further research.

CHAPTER FIVE - CONCLUSIONS AND RECOMMENDATIONS

This Chapter summarises the aims and results of the Study, draws a number of conclusions, and makes recommendations for the application and further development of procedures for the evaluation of river maintenance.

5.1 SUMMARY

The broad aim of the Study was to develop methods for the appraisal of river maintenance in rural, mainly agricultural catchments. For this purpose, six river and floodplain sites were selected for Study. Maintenance activities were mainly desilting and weed cutting. Pre and post-maintenance surveys were carried out which included:

- farmer surveys using a structured questionnaire which covered farming systems, field management, drainage status and flood risk assessment and views on the role and impact of maintenance;
- drainage surveys which identified the ditch and field drainage systems in the benefit areas;
- soil surveys which identified the texture and hydraulic conductivity of the soils in the benefit area;
- river corridor surveys which identified the environmental features and maintenance impacts;
- river cross-section surveys before maintenance and, where maintenance activities changed the channel size, after maintenance;
- a river engineers' survey which examined the decision-making processes and current rationale for river maintenance.

Routines for data collection and analysis were developed which link maintenance standards in river and arterial drainage systems with waterlogging and flood risk, and hence agricultural productivity in the adjacent benefit area. These methods were used to evaluate the extra financial benefits attributable to river maintenance and to set these against the costs of the maintenance work. Four of the six sites studied appeared worthwhile at the 6% test discount rate. The Study generated databases and methods for general application in river maintenance programming and prioritization.

At the end of the project, a training workshop was held at Silsoe College to inform NRA (ST) river engineers currently engaged in maintenance management about the study, its findings, and the methods of maintenance appraisal.

5.2 CONCLUSIONS

The conclusions presented here refer to the study and its findings as a whole. Those conclusions relating specifically to the sites can be found in the individual scheme Annexes.

5.2.1 General Conclusions

The main components of river maintenance evaluation are the maintenance activity; physical characteristics of the river and floodplain; flooding and waterlogging conditions; land-use and farming systems; and environmental criteria. It is possible to combine these to produce objective guidelines on the programming and prioritisation of river maintenance standards of service.

5.2.2 Research Project Management

- Site selection and scheduling of maintenance work and site surveys were critical factors.
- Close collaboration between the NRA and the research contractor were essential. Briefing and debriefing workshops were very beneficial.

5.2.3 Assessment Methods

- Data on flood risk and drainage status pre- and post maintenance should be derived from multiple sources.
- Farmers' views tend to be subjective, relying on recall with respect to pre-maintenance conditions. They are also influenced by prevailing weather conditions.
- Flood routing and water table modelling provide more objective assessments than farmer recall but they require additional data especially regarding river and floodplain profiles, hydrological and weather data and information on soil types;
- A good positive correlation was shown between drainage assessments derived from farmer sources and model output.

- Using data from farm survey it was possible to compile estimates of agricultural benefits associated with different standards of drainage service afforded by maintenance.

- The methods recognised that maintenance benefits vary according to the type of weather-year. It was possible to derive estimates of expected average annual benefits attributable to maintenance. These estimates allowed for the relative frequency of wet, mean and dry weather conditions. However, estimates of benefits are sensitive to the classification of drainage and wetness categories.

- Pre and post maintenance environmental impact assessment is an important element of maintenance design, monitoring and evaluation. The physical habitat assessment method is adequate for most purposes, especially with the use of mapping and video techniques, but this needs to be supported by a better understanding of the impacts of maintenance on particular environmental qualities such as aquatic invertebrates and fish.

- The evaluation methods used in the study are too detailed for general application but they can provide standard data and simplified routines for river maintenance justification and prioritisation.

- There are different ways of achieving the same standards of service. Maintenance activities are inter-related: heavy maintenance, such as desilting, may not be beneficial without subsequent annual weed maintenance, but annual weed maintenance may reduce the need for desilting.

5.2.4 Maintenance Benefits and Scheme Evaluation Results

- Agricultural benefits do not necessarily reflect the level of expenditure on maintenance.The results show that a comparatively expensive desilting operation which increases channel capacity and lowers river water levels does not necessarily produce greater benefits than less expensive weed maintenance activities.

- On none of the sites included in the study did all of the floodplain benefit area achieve benefits from maintenance. The percentage of designated benefit areas which did benefit from maintenance ranged from 8% on the Oldcoates Dyke to 50% on the Swilgate/Dean Brook.

Those factors which have an influence on the scale of the benefits include:

- **river characteristics,** including pre-maintenance freeboard levels and the extent to which the freeboard is changed as a result of maintenance.

The degree to which the water levels are changed as a result of maintenance activities is partly a function of type of maintenance. For example, river water levels are changed more by desilting than by tree and bush maintenance. However, as on the River Anker for example, weed cutting activities can increase the freeboard at crucial times of the year (late spring, early autumn) by the same amount as would have been achieved through desilting activities.

- **floodplain characteristics**, floodplain width, soil types and drainage system.

The width of the flood plain (or benefit area) and the distance of land from the river has an impact on the degree to which maintenance activities have an impact on drainage status. The changes in river water level have a more pronounced impact on water table levels nearer to the river itself. However, this needs to be treated with caution as other factors such as soil properties and drainage intensity also influence the degree to which changes in river water level affect water table depth.

The soil characteristics in the benefit area affect the responsiveness of water table depth to changes in river water level. In particular, the hydraulic conductivity and drainable porosity (specific yield) of the soils influence the speed and extent of movement of water through the soil.

The drainage system in the benefit area is also shown to influence the extent to which water table depth responds to changes in river water level. The water table in an intensively drained system (either intensive ditch system or field drainage) is more sensitive to changes in river water levels than a less intensive drainage system.

- **farming systems characteristics**, including intensity of land use, responsiveness of land use to changes in drainage status and farmers' perceptions of drainage constraints on field management.

Drainage status is not always the dominant factor in determining field management. Land use and farming practices are likely to be influenced by the type of management on the farm as a whole.

In general terms, river maintenance is more beneficial and worthwhile where the adjacent land is well drained, whether this be due to light, naturally free draining soils or due to intensive artificial field drainage. Intensive grassland and arable farming require good drainage, whether this be natural or artificial. These areas are likely to be sensitive to maintenance standards in the river and arterial system. Extensive grassland, however, can accommodate poor drainage, and is usually associated with heavier, undrained soils. Here, standards of river maintenance have limited impact on infield

drainage conditions and land use, and therefore have lower benefits and justification. Thus, existing land use is the key indicator for likely river maintenance benefits.

Obtaining reliable estimates of actual maintenance costs proved difficult, particularly where direct labour was engaged to undertake the maintenance as part of a larger programme of works. Costs per km varied considerably, usually in proportion to the amount of material removed, but in some cases the reasons for variation in costs between sites was difficult to ascertain.

In the context of managed rivers examined in this Study, river maintenance did not appear to result in major undesirable, long term, irreversible environmental impacts. In some cases, maintenance was accompanied by environmental enhancements such as tree planting and berm creation.

5.3 RECOMMENDATIONS

The recommendations refer to: further research into important issues; the application of the results and conclusions of this study to river maintenance in general; and the further development of monitoring and evaluation methods for river maintenance management. Specific recommendations for each individual site concerning management and monitoring can be found in the individual scheme Annexes.

5.3.1 Special Issues

- The study sites did not include tree and bush maintenance. This maintenance activity should be examined.

- Future research should examine the implications of not carrying out maintenance so that the without maintenance consequences can be assessed in terms of future without maintenance conditions and rates of deterioration. This is important for defining optimum intervals between maintenance activities.

- Weed management in channels serving intensively farmed areas should be examined in more detail, particularly as it affects the overall performance of the drainage system.

- Maintenance to avoid saline intrusion or inundation was not examined in the study sites, but it is important in some tidal and coastal areas. Consideration should be given to this.

- More attention needs to be given to the definition of variables such as drainage status, weather conditions, and agricultural productivity classification, and the sensitivity of maintenance benefit assessments to these variables.

- The study of the environmental impacts of river maintenance identified the need for further research. Changes in bed substrate and bank characteristics as a consequence of maintenance may affect flora and fauna living within and adjacent to the river system. A study of aquatic invertebrates and fish populations is needed both prior to and following maintenance activities to determine impacts on habitats and species. River maintenance often involves the mowing of banks, alteration of bank angle and spreading of aquatic vegetation and accompanying silt on adjacent land. It is not known how these activities effect the composition of bank side and adjacent, in-field natural vegetation. Likewise, the effect of habitat disturbance on birds, mammals and insects which depend upon the riverine ecosystem needs to be determined in order to incorporate appropriate environmental protection and enhancement measures into river maintenance.

5.3.2 Developing Methods and Guidelines

- The study identified new methods for maintenance evaluation. Further work is required to incorporate these into practical methods for assisting maintenance management.

- A classification system should be drawn up to generalise maintenance requirements and best practices according to local circumstances. This implies the development of locally relevant databases and strategies. In this way guidelines on the need for and return frequency of maintenance activities such as desilting, weed cutting and tree and bush work can be formulated.

- Guidelines should be drawn up for the monitoring and evaluation of river maintenance activities, especially regarding data requirements, sources, collection methods, data logging, retrieval and analysis. The monitoring of maintenance costs is very important.

- The study identified the need for greater consistency in approach to maintenance among engineers, but one which incorporated local needs and professional judgement. It is recommended that the information and training needs of engineers be identified and provision made accordingly.

- Further analysis should be carried out of the water table model, especially regarding the classification of drainage and weather conditions, and the derivation of probabilities for predictive purposes.

5.3.3 Ongoing Research

Writing in March 1993, Silsoe College have been sponsored by NRA to extend the evaluation of river maintenance to a total of 12 sites in 5 NRA regions. Where possible, the lessons learned and the recommendations made following the study reported here have been incorporated in ongoing research.

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Appendix 1: Literature Review - Environmental Issues

1. Agricultural Policy

(a) General Agreement on Tariffs and Trade (GATT) - Uruguay Round

The Uruguay Round of GATT negotiations which are intended to liberalize world trade for all commodities have still not been concluded. The chairman of GATT, Mr Arthur Dunkel has set the deadline as Easter 1992. The main area of conflict concerns agricultural trade policy.The latest proposals for discussion have been put forward by Mr Dunkel and these include (i) commit all governments to cut by 20%, before 1999, the amount of trade-distorting aid they arrange for their farmers; (ii) the promise to take the many forms of protectionism, convert them into tariffs and reduce these by 36% by 1999; and (iii) the volume of each country's subsidised exports would have to fall by 20% and the amount of money spent buying crops expensively at home to dump cheaply abroad would have to fall by 36%. These proposals are meeting with much opposition at the moment but commentators feel that the final treaty will contain elements similar to these.

(b) European Economic Community (EEC)

The EEC Member States are in the process of completing economic integration. In 1987 the Member Countries signed the Single European Act and in February 1988 agreed to remove all physical, technical and fiscal barriers to free trade by the end of 1992. Rules, regulations and standards will need to be harmonised to enable internal EC borders to be eliminated. Agriculture amongst other industries will be affected.The ultimate removal of subsidies and monetary compensatory amounts (MCA's) accompanied by the elimination of border taxes may result in true common farm prices with greater reliance placed on comparative advantage production within the EC. The 1992 programme is providing the legal framework and EC-wide institutions for environmental groups and governments to address environmental issues related to agriculture. It is estimated that production in ten years time will be significantly lower because of the increased focus on environmental issues.

2. Agriculture and Environmental Policy

The UK Government and European EC are working to integrate agricultural and environmental objectives across the whole range of their policies throughout the 1990's:

- MAFF's **'set aside'**, a voluntary scheme designed to reduce surpluses of arable crops by paying compensation for land taken out of production;

- **Countryside Premium Scheme**, administered by the Countryside Commission to enhance five main environmental features - woodland margin, meadowland, wildlife fallow, Brent Geese pasture, habitat restoration;

- **20 year set aside scheme** planned by the EC;

- **Farm Extensification Scheme** designed to compensate farmers to retain the same land use but at a lower intensity of production;

- **Woodland Grant Scheme** where grants are available for planting areas of woodland on farms ;

- **Countryside Stewardship Scheme**, administered by the Countryside Commission, which aims to support management practices which conserve, re-create and enhance particularly valued landscape and wildlife habitats;

- **Environmentally Sensitive Areas**, designated areas where incentive payments are made to farmers to manage their land in a way that preserves the traditional environment;

- **Nitrate Sensitive Areas**, a voluntary scheme in 10 designated areas where farmers are paid grants to substantially reduce the levels of input application. These Areas are likely to be replaced in the future by Water Protection Zones which seek to prevent the contamination of groundwater by pesticides and fertilizers;

- **Nitrate Buffer Zones**, there is likely to be a scheme in the near future to encourage farmers to take strips of land close to the river and to plant natural vegetation designed to filter out nitrates before they reach the river;

- **Linking Environment and Farming** (LEAF), a new initiative designed to promote the concept of Integrated Crop Management which gives equal consideration to ecological and economic goals;

- **Farm Diversification Scheme**, which is an alternative to 'set aside' and provides grants for the setting up of a variety of alternative rural enterprises.

Appendix 2: Baseline Survey - Farmers' Questionnaire

SILSOE COLLEGE RIVER MAINTENANCE EVALUATION QUESTIONNAIRE

Scheme interviewer:

Farm interviewee:

Division code:
Scheme code:
Farm code:

SECTION A: FARM AND FARMER DETAILS

1. How many holdings do you farm? _____

   If more than one, please briefly describe the relationship with other holdings:

   The following questions refer to the holding(s) which include land within the benefit area.

2. **Farm size** (ha/acres)

   Total farm: _____

   Area owned: _____

   Area tenanted:

   - Full _____
   - 364 day _____
   - Summer grazing _____

3. **Number of workers**

   Family _____

   Regular hired _____

   Casual (no. weeks) _____

4. **Management status**

   1. Sole proprietor
   2. Manager
   3. Partner
   4. Other (please specify) _____

5. For how many years have you farmed this holding? _____

6. Cropping pattern

	Ha/acres	SMD
Winter sown cereals (wheat/barley)	_____	____
Spring sown cereals (wheat/barley)	_____	____
Potatoes (early/maincrop)	_____	____
Sugar beet	_____	____
Forage crops	_____	____
Field vegetables	_____	____
Leys + temporary grass	_____	____
Permanent pasture	_____	____
Rough grazing	_____	____
Woodland	_____	____
Unused	_____	____
Other (please state)	_____	____

7. How often do you reseed:

(i) Temporary grass/ley _____

(ii) Permanent grass _____

(iii) Rough grazing _____

Mixture used:

8. Dairy enterprises

	No.	L.U.'s	SMD
No. of dairy cows:	_____	_____	_____
No. of followers:			
- Over one year old	_____	_____	_____
- Less than one year old	_____	_____	_____

Milk yield per cow (litres or gallons):

9. Beef enterprises

	No.	L.U.'s	SMD
No. of beef cattle			
- less than 6 months	_____	_____	_____
- 6 to 12 months	_____	_____	_____
- 1 to 2 years	_____	_____	_____
- over 2 years	_____	_____	_____
Suckler herd (no. of cows)	_____	_____	_____

System:

10. Sheep enterprises

	No.	L.U.'s	SMD
No. ewes	_____	_____	_____
No. lambs reared per ewe tupped	_____	_____	_____

Breed(s):

System:

11. Pig enterprises

	No.	(SMD)
No. of sows	_____	_____
No. of weaners	_____	_____

System:

- Breeding
- Fattening

12. Poultry enterprises

	No.	(SMD)
Total no. of poultry	_____	_____

SECTION B: FIELD LEVEL INFORMATION

Identify on the map your fields whose drainage condition is influenced by the 'main river'. (Where possible, group fields together that are similar in terms of drainage, land use and soil type). Please number each field or group of fields for future identification.

1. Field description

Field no.	Fragmentation	Distance from farmstead	Tenure Status	Years farmed	Drainage		
					Natural/ piped	Gravity/ pumped	Into ditch /river

If you have piped pump drainage installed, what is the age of the installation?

---------- years

2. Present land use for each field

Field Nos.	ARABLE				GRASS	
	Crop type	No. yrs in rotation	Yield	Perm/ temp	Stock Type	Rel. weight

Field Nos.	GRAZING				
	Average Weight	Nitrogen Rate	Overwintering at grass	Turnout date	Yarding date

Field Nos.	CONSERVATION		
	Date of close-up	Date of first cut	Date of second cut

3. Farmer knowledge of maintenance on river

As far as you are aware, have any of the operations below been performed on the 'main river'? If your answer is YES, please state the approximate date of the operation.

	Yes/No	Date last done
Dredging/desilting		
Repairs to riverbanks		
Repairs to structures		
Tree felling/removal		
Bush clearence		
Debris removal		

4. Farmer maintenance of farmer drainage systems

Have you carried out any of the functions below? If yes, please state in which fields this was performed and the approximate dates.

	Yes/No	Fields	Date last done
Ditching/ditch clearance			
Weeding			
Subsoiling			
Pumping		Regular/Intermittent	

5. Drainage status for each field

In what way does the river condition influence drainage conditions in the field?

	YES	NO
Flooding	Field nos.	Field nos.
Waterlogging	Field nos.	Field nos.

5.1 Flooding

Flood description	**Field no:**					
Source of flood water	- river - rain - upland water					
Frequency						
Date of last flood						
Time of year (%)	- winter - summer					
Duration (days)						
Area flooded						
Associated river condition	- normal - silted - breach - blockage - weedy					
Consequence of flooding						
Damage to standing crop	- loss of yield - reseeding					
Loss of livestock (head)						
Damage to fencing						
Damage to buildings						
Litter and debris						
Erosion						
Pollution						

5.1 (cont)

Field no:

Change in flood risk

Since the last major river maintenanceoperation, has there beein a noticable change in flooding? If yes:
Time of year
Duration
Source
Frequency
Area

5.2 Waterlogging

Wetness condition of field:

Spring (how often wet)
- rarely
- occasionally
- often
- permanently

Summer (how often wet)
- rarely
- occasionally
- often
- permanently

Autumn (how often wet)
- rarely
- occasionally
- often
- permanently

In your opinion, what factor is most associated with the wet condition?

- soil type
- lack of field drainage
- limited outfalls into ditch/river
- submerged outfalls into ditch/river

5.2 (cont)	Field no:					
Have you noticed any changes in wetness conditions since the last major river maintenance operation? If so what was the previous condition?						
Spring (how often wet)	- rarely - occasionally - often - permanently					
Summer (how often wet)	- rarely - occasionally - often - permanently					
Autumn (how often wet)	- rarely - occasionally - often - permanently					

5.3 Impact of changes in field drainage conditions

In what ways have changes in field drainage conditions affected land use productivity?

- no change
- change in productivity
- change in land use

If there has been a change in productivity or land use, please indicate the previous situation

Previous situation:

(see next page)

Previous situation:

Field Nos.	ARABLE				GRASS	
	Crop type	No. yrs in rotation	Yield	Perm/ temp	Stock Type	Rel. weight

Field Nos.	GRAZING				
	Average Weight	Nitrogen Rate	Overwintering at grass	Turnout date	Yarding date

Field Nos.	CONSERVATION		
	Date of close-up	Date of first cut	Date of second cut

Have changes in field drainage conditions resulted in a change in costs? If so, which of the below have been altered?

- machinery costs
- labour costs
- bought feeds
- contractor costs
- stock yarding/agistment
- other

6. Environmental aspects

Are there, in your view, non-agricultural features on any of your fields which are affected by 'main' river maintenance?

		Yes/No	Important?	+ve or -ve impact
- Fisheries				
- Wildlife habitats	- birds			
	- flora			
	- fauna			
- Landscape				
- Archeological				
- Recreational				

Have you taken any measures to protect or enhance non-agricultural features? Y/N

Is 'set aside' likely to be an attractive option for land use in the area concerned? Y/N
If so, do you have any plans in mind?

THANK YOU FOR YOUR COOPERATION

Appendix 3: Phase II Survey - Farmers' Questionnaire

SILSOE COLLEGE RIVER MAINTENANCE EVALUATION QUESTIONNAIRE FOR 1990/91 SITE VISITS

SECTION A: FARM AND FARMER DETAILS

Since last years visit, have there been any changes in any of the following:

1.	No. of holdings farmed		1990:	1991:
2.	Farm size:		1990:	1991:
3.	Farm tenure:		1990:	1991:
4.	Management status:		1990:	1991:
5.	Cropping pattern:		1990:	1991:
6.	Dairy:	No. cows:	1990:	1991:
		No. followers:	1990:	1991:
		Milk yield:	1990:	1991:
7.	Beef:	System:	1990:	1991:
		No. beef and ages:	1990:	
			1991:	
		No. sucklers:	1990:	1991:
8.	Sheep:	No. ewes:	1990:	1991:
		Lambing rate:	1990:	1991:
		Breeds:	1990:	1991:
9.	Pigs:	No. sows:	1990:	1991:
10.	Poultry:	No. birds:	1990:	1991:

SECTION B: FIELD LEVEL INFORMATION

Changes in land tenure: 1990: 1991:

1. Land Use

a) Arable crops

1990: Crops in field: Other crops in rotation:

Years in rotation:

Anticipated yield:

Actual yield for 1989 crops in field:

1991: Crop in field: Anticipated yield:

b) Grassland

1989/1990 management: Actual turnout dates:

Actual yarding dates:

Nitrogen rate for the year:

Date of close up:

Type, nos., dates, and yield of cuts:

Stock types:

1991 management: Actual turnout dates:

State of land at time of turnout:

Reason for turnout date:

State of land
Shortage of feed
Earliest possible time
Traditional date

Policy in 1991 regarding:

i) Conservation:

ii) Nitrogen rate: Reason: Climate
Conservation
Soil type
Set policy

Who determines rate? Yourself
ADAS adviser
Manufacturer's adviser

2. River maintenance

Reaction to maintenance: Unnecessary
Too severe
About right
No sufficient

Do you feel alternative measures could have been taken?

What are your feelings regarding the consequences of maintenance activities? (ie. machinery on land, spoil loss of land, etc.)

Strongly opposed
Accepted as part of the job

Do you feel alternative measures could have been taken?

How quickly and how much has the river recovered from the maintenance activities?

3. Drainage installation

Since the last visit, have you:

i) Installed any new field drains? If so, where?

ii) Cleaned any ditches. If so, where?

iii) Done any moling or subsoiling? If so, where?

Was any of the above done in response to river maintenance?

4. Flooding

Since the last visit:

i) How many flood events have occurred?

ii) When were the floods?

iii) Duration of the events?

iv) Areas affected:

v) Damage incurred:

How does this compare with the same period in previous recent years?

How much is due to climate and how much due to river maintenance?

5. Waterlogging

	March	April	May
Wetness condition of the fields this Spring:			
Climate this Spring:			

Has there been any improvement which you can attribute to the river maintenance? If so, what?

Has there been any change in land use as a result of river maintenance?

6. Environmental consequence

Have you noticed any impacts on the following as a consequence of river maintenance?

Fisheries:

Wildlife - birds

- fauna

- flora

Landscape:

Archeology:

Recreation:

Have you introduced any new conservation measures?

What are your current views on **set aside?**

Appendix 4: NCC River Corridor Survey Methodology - Output

Example of a River Corridor Map

① Upstream of Gwendon Bridge

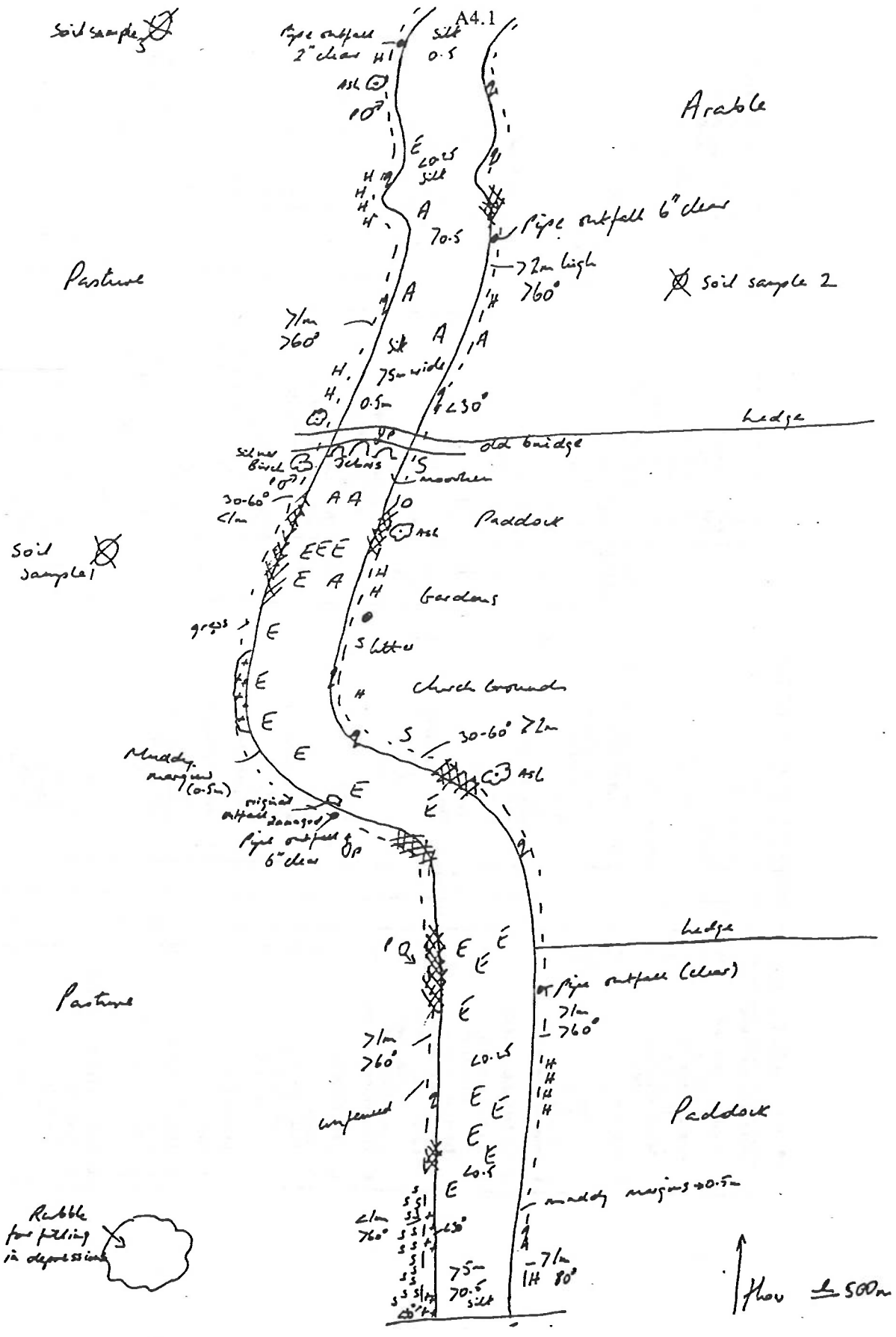
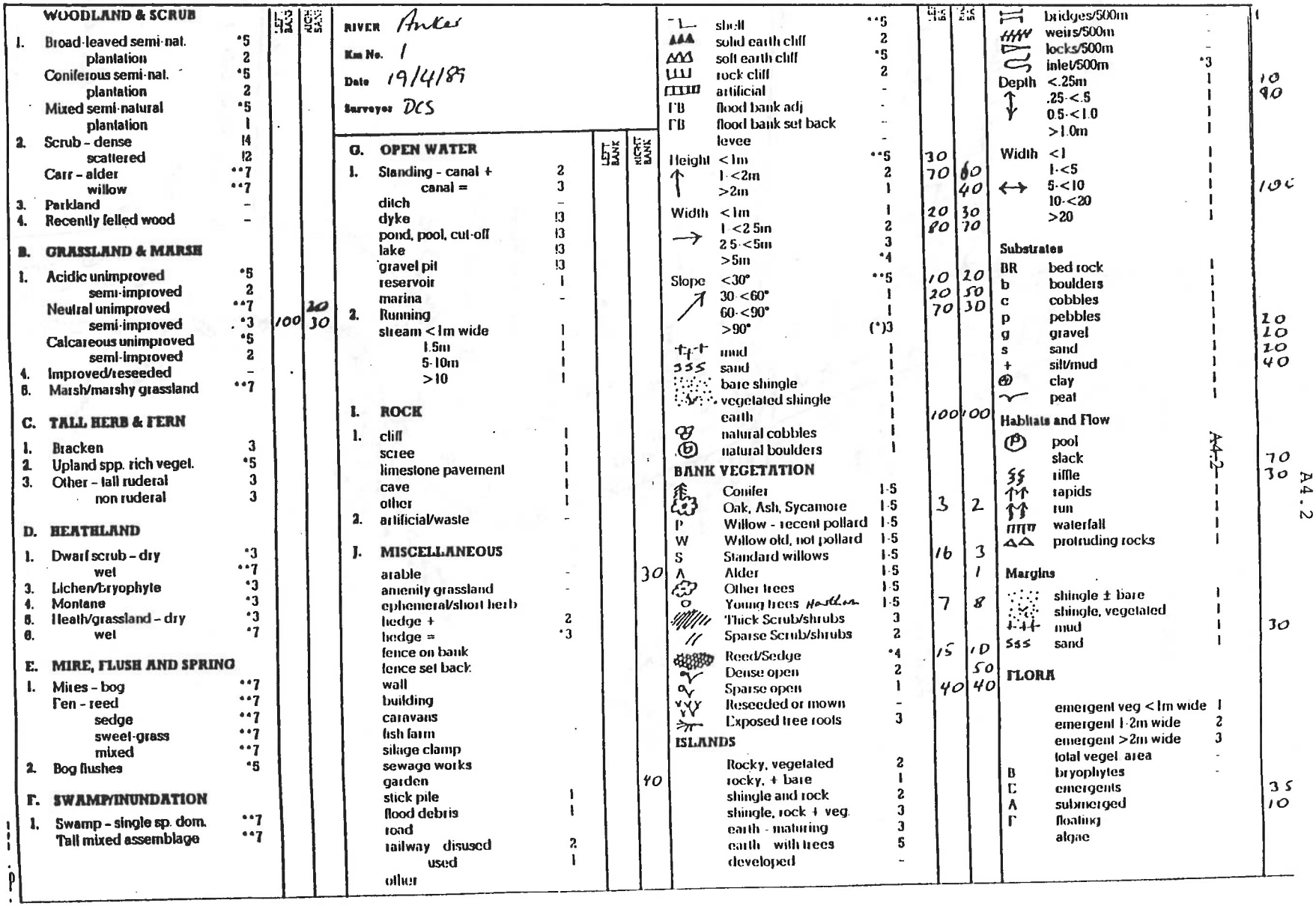


Table A4.1: River Corridor Checklist



RIVER Ankes
Km No. 1
Date 19/4/89
Surveyor DCS

			LEFT BANK	RIGHT BANK
A. WOODLAND & SCRUB				
1.	Broad-leaved semi-nat.	*5		
	plantation	2		
	Coniferous semi-nat.	*5		
	plantation	2		
	Mixed semi-natural	*5		
	plantation	1		
2.	Scrub – dense	14		
	scattered	12		
	Carr – alder	**7		
	willow	**7		
3.	Parkland	–		
4.	Recently felled wood	–		
B. GRASSLAND & MARSH				
1.	Acidic unimproved	*5		
	semi-improved	2		
	Neutral unimproved	**7		20
	semi-improved	*3	100	30
	Calcareous unimproved	*5		
	semi-improved	2		
4.	Improved/reseeded	–		
6.	Marsh/marshy grassland	**7		
C. TALL HERB & FERN				
1.	Bracken	3		
2.	Upland spp. rich veget.	*5		
3.	Other – tall ruderal	3		
	non ruderal	3		
D. HEATHLAND				
1.	Dwarf scrub – dry	*3		
	wet	**7		
3.	Lichen/bryophyte	*3		
4.	Montane	*3		
6.	Heath/grassland – dry	*3		
6.	wet	*7		
E. MIRE, FLUSH AND SPRING				
1.	Mires – bog	**7		
	Fen – reed	**7		
	sedge	**7		
	sweet-grass	**7		
	mixed	**7		
2.	Bog flushes	*5		
F. SWAMP/INUNDATION				
1.	Swamp – single sp. dom.	**7		
	Tall mixed assemblage	**7		

			LEFT BANK	RIGHT BANK
G. OPEN WATER				
1.	Standing – canal +	2		
	canal =	3		
	ditch	–		
	dyke	13		
	pond, pool, cut-off	13		
	lake	13		
	gravel pit	13		
	reservoir	1		
	marina	–		
2.	Running			
	stream < 1m wide	1		
	1-5m	1		
	5-10m	1		
	>10	1		
I. ROCK				
1.	cliff	1		
	scree	1		
	limestone pavement	1		
	cave	1		
	other	1		
2.	artificial/waste	–		
J. MISCELLANEOUS				
	arable	–		30
	amenity grassland	–		
	ephemeral/short herb			
	hedge +	2		
	hedge =	*3		
	fence on bank			
	fence set back			
	wall			
	building			
	caravans			
	fish farm			
	silage clamp			
	sewage works			
	garden			40
	stick pile	1		
	flood debris	1		
	road			
	railway disused	2		
	used	1		
	other			

			LEFT BANK	RIGHT BANK
	shelf	**5		
	solid earth cliff	2		
	soft earth cliff	*5		
	rock cliff	2		
	artificial	–		
FB	flood bank adj	–		
FB	flood bank set back	–		
	levee	–		
Height	<1m	**5	30	
	1-<2m	2	70	60
	>2m	1		40
Width	<1m	1	20	30
	1-<2.5m	2	80	70
	2.5-<5m	3		
	>5m	*4		
Slope	<30°	**5	10	20
	30-<60°	1	20	50
	60-<90°	1	70	30
	>90°	(*)3		
	mud	1		
	sand	1		
	bare shingle	1		
	vegetated shingle	1		
	earth	1	100	100
	natural cobbles	1		
	natural boulders	1		
BANK VEGETATION				
	Conifer	1-5		
	Oak, Ash, Sycamore	1-5	3	2
P	Willow - recent pollard	1-5		
W	Willow old, not pollard	1-5		
S	Standard willows	1-5	16	3
A	Alder	1-5		1
	Other trees	1-5		
O	Young trees Hawthorn	1-5	7	8
	Thick Scrub/shrubs	3		
	Sparse Scrub/shrubs	2		
	Reed/Sedge	*4	15	10
	Dense open	2		50
	Sparse open	1	40	40
	Reseeded or mown	–		
	Exposed tree roots	3		
ISLANDS				
	Rocky, vegetated	2		
	rocky, + bare	1		
	shingle and rock	2		
	shingle, rock + veg.	3		
	earth - maturing	3		
	earth with trees	5		
	developed	–		

	bridges/500m		1
	weirs/500m		
	locks/500m		
	inlet/500m	*3	
Depth	<.25m	1	10
	.25-<.5	1	90
	0.5-<1.0	1	
	>1.0m	1	
Width	<1	1	
	1-<5	1	
	5-<10	1	100
	10-<20	1	
	>20	1	
Substrates			
BR	bed rock	1	
b	boulders	1	
c	cobbles	1	
p	pebbles	1	20
g	gravel	1	20
s	sand	1	20
+	silt/mud	1	40
	clay	1	
	peat	1	
Habitats and Flow			
P	pool	A4.2	
	slack		70
	riffle		30
	rapids		
	run		
	waterfall		
	protruding rocks		
Margins			
	shingle ± bare	1	
	shingle, vegetated	1	
	mud	1	30
sss	sand	1	
FLORA			
	emergent veg < 1m wide	1	
	emergent 1-2m wide	2	
	emergent >2m wide	3	
	total vegel area	-	
B	bryophytes	-	
E	emergents		35
A	submerged		10
F	floating		
	algae		

Appendix 5: Impact Assessment Matrix

A5.1

IMPACT ASSESSMENT MATRIX

AVERAGE IMPACT ALONG WHOLE REACH

River: **Maintenance Operation:**
Length maintained: **Cost:**

1. HYDROLOGICAL

Features	**Impacts**				
	P/N	**S/L**	**D/I**	**R/I**	**Comments**
Channel capacity					
- water levels					
- channel depth					
- channel width					
- bed width					
Bank height					
Bank slope					
Bank stability					
Bank vegetation					
Channel slope					
Channel straightness					
Channel roughness					
- obstructions					
River Flow					
Freeboard					
- pipe outfalls					
- ditch outfalls					
Flooding					
- frequency					
- timing (winter/summer)					
- area					
- duration					

Drainage status	Wet	Normal	Dry	Climatic conditions
	VB - B %	VB - B %	VB - G %	
	B - G %	B - G %	B - G %	

NB: P/N = positive/negative impacts
S/L = short/long term impacts
D/I = direct/indirect impacts
I/R = irreversible/reversible impacts
- = no impact

2. AGRICULTURAL

Features	Impacts				
	P/N	S/L	D/I	R/I	Comments
Land use change					
Management:					
- turnout dates					
- yarding dates					
- grass conservation					
- nitrogen					
- stock type					
- stock rate					
Productivity:					
- crop yields					
% change due to:					
- maintenance					
- climate					
Land impact:					
- spoil					
- bank subsidence					
- machinery					

NB: P/N = positive/negative impacts
S/L = short/long term impacts
D/I = direct/indirect impacts
I/R = irreversible/reversible impacts
- = no impact

3. ENVIRONMENTAL

Features	Impacts				
	P/N	S/L	D/I	R/I	Comments
River:					
- substrates					
- pools, runs, etc					
- submerged vegetation					
- emergent vegetation					
- floating vegetation					
Banks:					
- structure					
- stability					
- steepness					
- bank vegetation					
- trees					
- scrub					
- carr					
Wildlife:					
- invertebrates					
- fish					
- birds					
- fauna					
Recreation/ Landscape:					
- woodland					
- footpaths					
- ponds					

NB: P/N = positive/negative impacts
S/L = short/long term impacts
D/I = direct/indirect impacts
I/R = irreversible/reversible impacts
- = no impact



https://dspace.org/

The evaluation of river maintenance

Morris, J.; Sutherland, D. C.

1993-05
Cranfield University
https://dspace.lib.cranfield.ac.uk/handle/1826/21260
Morris J, Sutherland DC. (1993) The evaluation of river maintenance, report for the National Rivers Authority, May 1993

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