Review of Existing Practices for Fluvial Grass Management Throughout the NRA

CIRIA

R&D Project Record 213/1/Y

REVIEW OF EXISTING PRACTICES FOR FLUVIAL GRASS MANAGEMENT THROUGHOUT THE NRA

G Stephenson

Research Contrator
Construction Industry Research and Information Association
6 Storey's Gate
London SW1P 3AU

National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol BS12 4UD

Project Report 213/1/Y

Publisher

National Rivers Authority
Rivers House
Waterside Drive
Aztec West
Almondsbury
Bristol BS12 4UD

Tel: 0454 624400
Fax: 0454 624409

First Published 1992

Dissemination Status
Internal: Restricted
External: Restricted

Research Contractor
This document was produced under R&D Project 213 by:

Construction Industry Research and Information Association
6 Storey's Gate
London SW1P 3AU

Tel: 071 222 8891
Fax: 071 222 1708

NRA Project Leader
The NRA's Project Leader for R&D Project 213 was:

Mr Ken Barton - Yorkshire Region

Additional Copies
Additional copies of this document may be obtained from the Regional R&D Co-ordinator of NRA Yorkshire Region.

CONTENTS PAGE

List of Figures and Tables (ii)

EXECTIVE SUMMARY 1

1 INTRODUCTION 2

2 QUESTIONNAIRE SURVEY 3
2.1 Background 3
2.2 Results 3

3 LITERATURE REVIEW 26
3.1 Background 26
3.2 Main findings 26

4 DISCUSSION 35

5 CONCLUSIONS 48

6 RECOMMENDATIONS 49

Appendices

Appendix 1 Project objectives (as listed in the PIA) 51
Appendix 2 List of NRA people visited 53
Appendix 3 Questionnaire returns 54
Appendix 4 References for the literature review 55
Appendix 5 Grass mixes 67

LIST OF FIGURES

Figure 1 Grass sward structure as influenced by levels of management
Figure 2 Classic Hurley annual grass productivity curve
Figure 3 Number of times floodbanks cut related to rainfall, as a measure of grass growth

LIST OF TABLES

Table 1 Basic Regional Information
Table 2 Fluvial maintenance activities
Table 3 Methods of watercourse categorisation and management
Table 4 Fluvial maintenance costs
Table 5 Grass management
Table 6 Safety, training and equipment
Table 7 Maximum number of grass cuts per year
Table 8 Reasons given why grass is being cut
Table 9 a/b Grass cutting and subcontracting
Table 10 Seeding of banks
Table 11 Choosing machinery by Region - Reasons and influences
Table 12 Machinery for grass management
Table 13 Conservation
Table 14 Grass cutting times
Table 15 Length of grass-growing season

EXECUTIVE SUMMARY

This report presents the results of the first phase of a study who's overall objective is to produce guidance notes on the best practice for riverbank grass mowing throughout the NRA.

The objectives of this phase of the research were to produce interim guidance notes based on existing practices and to identify areas of further research.

The report concludes that because of the wide variation in current practices for grass mowing within the Regions and the diversity of recording systems it was impossible to produce interim guidance notes. However the present practices and reasons were recorded. A list of recommendations for further work was produced covering work specific to grass management and general recommendations to the NRA as a whole.

KEYWORDS: GRASSES, STREAMS (IN NATURAL CHANNELS), RIVER MANAGEMENT, MAINTENANCE MOWING

1. INTRODUCTION

Within the NRA the annual flood defence maintenance budget for 1989/90 was estimated to be approximately £45 million, and most of this was spent on fluvial maintenance. In this context maintenance can be considered to include all activities involved in keeping an asset (i.e. the watercourse) in an acceptable condition by routine/emergency repairs and monitoring. In their natural state, watercourses will achieve dynamic equilibrium. Where their cross-section will be influenced by, among other factors, the grass growth, supply of sediment, weed growth and frequency of discharge, these factors will, in turn, determine their carrying capacity. In the UK, however, many rivers, if left in a natural state, will not provide an adequate level of protection against flooding of property and land. Over the years many watercourses have had works carried out on them either within the channel or by bank protection to provide a higher level of protection against flooding. Usually these works have necessitated maintenance on a formal and/or ad hoc basis.

Within commission C Flood Defence of the R/D programme of the NRA topic C4, Operational Management, covers the development of a 'framework for the management of NRA flood defence maintenance so as to ensure that work programmes throughout the NRA are consistent, prioritised, adequately justified and cost effective and that the interests of other NRA functions are recognised'.

The overall purpose of this study, which is in two phases, is to produce guidance notes on best practice for riverbank grass management. The objective of Phase 1 is 'to produce interim guidance notes on best practice for riverbank grass management, based on existing practices within the NRA and to identify areas of further research'. The objective of Phase 2 is to implement the further research identified in Phase 1, carry out field trials, and produce guidance notes on best practice for riverbank grass management (Appendix 1).

2. QUESTIONNAIRE SURVEY

2.1 Background

At an early stage of the study a meeting was organised with the Steering Group to discuss the overall objectives of the study and the general availability of data, quality of the information and Regional variations. This meeting highlighted the need to visit each Region at least once if meaningful information was to be collected in a relatively short period of time.

A questionnaire was therefore prepared covering the information required from each Region and this was agreed with the NRA Steering Group prior to distribution. It contained data from NRA R/D project No. 200 entitled *Review of existing practices for fluvial maintenance operations throughout the NRA* and additional information on grass management. The questionnaire was sent to all ten Regions and formed the basis of meetings held with NRA representatives. These visits were undertaken by Ms K Buckley (ERAs Consultants of Grantham) under a subcontract to CIRIA. As part of the interviews, local site visits were also undertaken.

During each meeting (which normally lasted a full day) discussion with NRA staff highlighted the available data, their accuracy and any additional information. These discussions also revealed the fact that modifications were needed to the questionnaire because of the way different Regions manage their fluvial maintenance programmes. Following each visit, a copy of the meeting notes was sent to the Region to check for accuracy and the availability of further information. In many cases, however, the Regions were unable to provide additional data without the need for substantial efforts on their part.

A copy of the Questionnaire returns covering all of the visits was prepared as part of the study can be obtained from the NRA Project Leader.

In discussion with the NRA Steering Group it was agreed that no follow-up visits would be made to any of the Regions at this stage of the Study because of the lack of information or the effort needed by a Region to supply the information.

2.2 Results

The information gathered from the visits to the ten Regions and the questionnaire returns together with data from the previous R/D project (see above) can be analysed in a number of ways. This section, together with the Appendices, highlights the main findings and includes information supplied by the Region. The information contained in the Appendices, from the NRA Regions, is provided as examples only and should not be taken as specifically illustrating best practices. It should be noted that in some cases the information gathered was specific to the Area/Division/District etc. interviewed rather than to the Region as a whole.

Tables 1 to 6 inclusive contain information collected as part of the previous NRA project to review fluvial maintenance practices throughout the NRA while the rest of the information was collected at the time of the site visits. Table 1 outlines basic data on the ten Regions, including size, population and length of main river for flood defence purposes. Information

on maintenance costs is also included in Table 1, but these should be considered as giving only an indication due to the large variations in reporting methods used throughout the NRA (see notes to Table 1).

A breakdown of the basic criteria used by the ten Regions to define fluvial maintenance activities is given in Table 2, and Table 3 shows how each of the Regions has divided its watercourse into functional units and lists the various methods of data storage employed. Most of the systems appear to have evolved from bonus schemes, and obtaining information was noted to be particularly difficult in some of the Regions. Some store all information on computerised systems but at least one was running a paper-based system. Not only were variations between Regions noted but in at least two there appeared to be different methods used within the Regions.

For comparative purposes Table 4 gives a breakdown of the available information on fluvial maintenance costs for most of the maintenance activities identified in Table 2. In the majority of Regions some information on costs could be provided. Table 4 shows that in at least one Region, (North West) a breakdown by maintenance activity was not readily available. Table 5 indicates that for two Regions (North West and Anglian) there are no specific headings for grass management, and the activity is included within a broader category.

Table 6 illustrates the various methods of operator training and safety within the Regions and Table 6 (cont) shows the availability and range of equipment for grass management.

Table 1 Basic Regional Information

Region	Area (sq 1000 km)[19]	Pop (m)[19]	Length river maintained for flood def. km)[19]	Area of[17] flood plain (Ha)	Area of[17] land below sea level (Ha)	Total m'tence budget (£m)	Fluvial m'tence budget (£m)	Total labour m'tence (FTE)[2]	Labour fluvial m'tence (FTE)
Anglian	27.2	5.3	5812	470,000	200,000	9.5[5]	6.1	400	300[4]
N'brian	9.3	2.6	1643	14,100	1,100	0.75[5]	0.5	30	15
Nth West	14.5	7.0	6028	65,500	3,400	8.3[5]	8.3[18]	290	-[7]
Sv'n Trent	21.6	8.3	3673[14]	-	79,000	7.7[6]	7.7[8]	-[7]	-[7]
Southern	11.0	3.9[2]	2746	1,240	9,900	7.0[5]	3.5[9]	260	130
S'th West	11.0	1.5[1]	1400	-	-	0.64[10]	0.64[18]	61	30
Thames	12.9	11.6	5150[13]	69,500	-	16.5[5]	12.7[5]	300	-[7]
Welsh	21.3	3.1	5679	48,500	36,000	1.05[5,11]	1.05[5,11]	52[11]	52
Wessex	10.0	2.5	2355	93,900	57,600	2.9[12]	2.6[12]	85	55
Yorkshire	13.5	4.5	1741[15]	112,400	85,300	1.8[6]	1.8[18]	-[7]	35
TOTAL						56.14	44.89		

Notes: 1) Increases by app. 500,000/week during Summer
2) Resident population
3) Expressed as Full Time Equivalents (FTE)
4) Estimated figure
5) Excluding HQ costs and staff costs
6) Including staff costs and HQ costs
7) No figure available
8) £4.8 m for only operative costs + plant + materials
9) Includes some work for IDB's
10) Figure only covers part of Region
11) Figures only cover one of three Divisions
12) Includes area staff costs but not Regional HQ costs
13) 95% water course length is constructed flood defence
14) 840 km constructed flood defence
15) 990 km constructed flood defence
16) 1430 km embanked water courses
17) Approx. figures
18) Assuming fluvial maintenance budget is the same as the total maintenance budget where no figure is available.
19) Figures from NRA Corporate Plans

Table 2 Fluvial maintenance activities

ANGLIAN
All water courses in the Region use the following maintenance categories:-
Weed Control, obstructions and pioneer clearance; dredging; structures; channel and bank stabilisation; banks and embankments; flood storage reservoirs; other works; emergency works; pumping stations.
Note: Tree cutting where it is for obstruction/ removal is included in obstruction and pioneer clearance.
Grass management has *no* specific heading and is included in banks and embankments.

NORTHUMBRIAN
Watercourses are first divided into one of five headings (see Table 3) and then subdivided into the following maintenance categories:-

Inspection	-
River Channel	- spray/cut channel weed
	- cut weed on one bank
	- cut weed on both banks
	- brushing
Flood banks and walls	- cut grass
	- brushing
	- kill vermin
	- inspect and repair
Debris	- clear bridges, flaps
	- clear channel
Flaps/gates	- inspect and grease
	- paint and repair

Note: All watercourses are also allocated a frequency of inspection - e.g. once/year; spring/autumn; after floods/high tides; others.

NORTH WEST
All water courses use the following maintenance categories under general maintenance:-
Cut bank growth; pedestrian mower; flail mower; debris/refuse; hand cut weed; trees; cut weed boat; cut weed bradshaw bucket. For each activity there are a number of subdivisions relating to the specific task to be undertaken.
Note: Dredging is covered under heavy maintenance.

SEVERN TRENT
All watercourses use the following maintenance categories:-
Bank repair and vermin control; aquatic weed control; debris and blockage clearance; dredging and reinstatement; tree and bush; revetments; mowing; structures; patrolling and emergencies; pumping stations.

SOUTHERN
All watercourses use the following maintenance categories:-
Weed cutting (mechanical and hand); dredging; cut grass; removal of storm damage trees; removal of obstructions.
Note: Some of the categories are *not* used in all parts of the Region.

SOUTHWEST
This Region first divides maintenance between scheduled and non scheduled work and uses the following categories:-
Grass cutting; desilt/deweed (aquatic); dredging; shoal removal; timber handling; tree removal; grid maintenance/flap valves.

THAMES
This Region first divides maintenance between watercourses and structures and uses the following categories:-
Bank clearance; weed cutting; dredging; grass mowing; tree work; scavenging; gauge stations; obstructions.

WELSH
Maintenance works are first divided between scheme maintenance and watercourse maintenance and work is allocated between the following categories:-
Dredging; distilling; mowing and trashing; spraying; blockage and flood debris.

WESSEX
Maintenance works are first divided into preferred and non preferred activities the following categories are then used:
Vegetation control (hand, pedestrian mower, tractor flail, herbicides, weed launch, bradshaw bucket); blockage removal (trees, weed, debris, silt); dredging, (shoal removal and jetting); tree maintenance; fencing.

YORKSHIRE
All watercourses use the following maintenance categories:-
Repairs to flood bank; dredging; grass cutting; repairs to channel; aquatic weed control; clearance of debris; willow cutting/tree clearance; catch all emergency number; raking clearance from flood banks, general survey/routine patrol.

Table 3 Methods of watercourse categorisation and management

ANGLIA

Within the Region each water course has been divided into a number of specific river lengths and a unique number assigned to each length. The initial exercise to divide up the watercourses was based on local knowledge and the lengths vary in size.

In 1984 a formal 'Priority Based Budget' PBB exercise was carried out and each river length was categorised according to adjacent land use as being either urban or agricultural. The frequency with which the range of maintenance activities were undertaken was determined for each, based on past experience and perceived needs. Each maintenance activity (see table 2) on each river length was then assigned to one of five levels of service (see appendix F). Level one being the minimum amount of work that could be done, level three being the (then) current level of service and level five being a comprehensive/ idealistic level of service (levels two and four being intermediate levels of service).

The PBB exercise has been fully documented and is still in operation. An annual programme is drawn up each year for maintenance activities and forms the basis of the maintenance planning.

The system is mainly paper based at local level, but there is a degree of computerisation of the results by Regional HQ.

NORTHUMBRIAN

Within the Region each watercourse has been divided into specific lengths e.g. bridge to bridge, feature to feature based on local knowledge and a unique number assigned to each.
(See appendix E).

For each river length a frequency of inspection has been set (and written down) and the work needed has been assessed.

The system is paper based using local knowledge but is used to produce an annual programme of work.

NORTHWEST

The Region operates a formal written down system known as WIPPS, which is a computerised an annual system producing an annual maintenance programme and specific job cards for each length.

All water courses have been divided into section lengths and a unique number has been allocated to each. These lengths were taken from 1/2500 ordnance survey sheets and are based on identifiable features e.g. bridges. A maximum length of 1000m has been set for a section length, the average length being between 500-1000m.

For each section length an assessment of the maintenance works needed to maintain the asset to an acceptable standard has been made and written down. These works have been translated into standard hours and a programme can be generated for each length. Computerised job cards are produced for each length. The major draw-back to the system appears to be that information on specific maintenance activities is not easily available e.g. total spend on grass management (see Appendix D).

SEVERN TRENT

The Region operates a system called RIMS (Rivers Information and Maintenance System). Each river has been divided into reaches and sub reaches (1-4 km length), and given a unique reference number. An assessment of the work needed on each reach has been undertaken and an inspection programme assesses the work actually needed from which job cards are then produced. The system is fully computerised and can produce information relating all maintenance activities.

SOUTHERN

The Region has six Districts who appear operate independent fluvial maintenance systems. Each District has divided up all the water courses into individual length. Each length has been given a reference number but there seems to be some duplication of numbering. Each District produces an annual programme of the work needed on each river length in its area and HQ complies an overview of the total programme. The systems seems to be based on District needs and is operated on a paper based system.

Table 3 Continued

SOUTH WEST

The Region has divided all water courses into river elements or schemes and a unique number has been allocated to each. For each river element/scheme an assessment of the fluvial maintenance tasks needed to keep them to an acceptable standard has been made. Work study values have been allocated to each task and job cards can be produced for each task.

The system is fully computerised and an assessment of target times against actual times from time sheets can be made. The Region is at present installing a computerised planning package to maximise use of labour and plant throughout the year.

THAMES

This Region has divided all water courses into operational reaches (500m - 2 km in length) and each reach has been given a unique number. Structures, of which there are a large number, are identified separately and allocated a unique reference number.

An assessment has been made of the work needed to keep the assets i.e. operational reaches and structures to an acceptable standard. Prior to works been started a site inspection is undertaken by an Inspector who reports on the need or not to undertake the work. A job card is produced for each piece of work and passed to a supervisor who plans and undertakes the work.

The system is fully computerised.

It should be noted that this Region is unique in separating the functions of client and contractor. An inspector/flood defence engineer decide on the need for the works and undertake local planning, liaise with conservation groups etc. A separate supervisor /operations engineer carry out the work.

No other Region operates such as system.

WELSH

The Region is divided into three Divisions who seem to operate independently of each other. The comments in this section refer to the South East Division only.

The South East division has divided watercourses into schemes and non schemes. An adhoc system has been introduced to sub divide non schemes (i.e. watercourses) into specific lengths. An estimate of the maintenance works needed is made on an annual basis and job cards produced.

The system is paper based with HQ providing a co-ordinating role.

Note: The other two Divisions were not visited as part of the survey.

WESSEX

All watercourses in the Region have been given a unique reference number. In some cases because of the length of the watercourse or because of the high level of spending the watercourse some have been sub-divided. Some specific features e.g. culverts, pumping stations etc. have been identified separately.

The maintenance work needed on each 'piece' of watercourse has been assessed and is re-assessed prior to commencing the proposed work.

Job cards and monitoring of actual work against target times are all fully computerised. (See appendix K).

YORKSHIRE

All watercourses in the Region have been divided into river 'lengths' and a unique number has been allocated to each 'length'.

For each river 'length' an assessment of maintenance needs is made on an annual basis using local knowledge and local perceived needs. This activity is co-ordinated by Regional HQ. For each specific piece of work a job card is produced and local engineers/supervisors decide on when the work should be carried out.

The system is fully computerised and is part of the FMS.

Table 4 Fluvial maintenance costs

Region	Fluvial[1] M'ance £'000 budget	Grass management		Weed control		Tree management		Dredging		Debris/blockage clearance		Structures	
		£'000	% of total[2]	£'000	% of total[2]	£'000	% of total[2]	£'000	% of total[2]	£'000	% of total[2]	£'000	% of total[2]
Anglian	6100	–[4]		1341	22	–[4]		1357	22				
N'brian	500	71	10	26	5	15	3	129	26			97	19
N'th West	8300	No figure collected		No figure collected		No figure collected		No figure collected					
Sv'n Trent	4800[3]	592	12	395	8	657	14	447	9	589	12	400	8
Southern	3500	–[4]		2300	66	–[4]		300	9	175	5		
S'th West	640	–[4]		–[4]		–[4]		No work in Region					
Thames	12700	120	1	290	2	190	1.5	1300	10	900	7	4300	34
Welsh[5]	1050	172	16	No work in Region		45	4	174	17	110	10	300	29
Wessex[6]	2600	100	4	300	12	200	8	100	4				
Yorkshire	1800	222	12	160	9	277	9	210	12	165	9		

Notes

1. See Table 1 for details and notes
2. % of the total fluvial maintenance budget for the Region in question
3. Figure excluding HQ and staff costs (see Table 1)
4. No figures supplied
5. Covers only one of the Divisions
6. Figures are approximate and indicate an order of magnitude

Table 5 Grass management

Region	Is there a specific heading for grass management	If No – where is the work included	Measure	Cost £000/ year	Operatives FTE/Year	Contractors used (% work)	Written instructions on carrying out the work	Cuts/season	Written seeding policy
Anglian	No	Banks & embankments	N/A	N/A	6	Yes	Yes, basic guidance	1-3 depends on area	Yes?
N'bria	Yes	–	200 km	71.0	2/3	No	No[9]	No standard	No
N'th West	No	To a specific length	N/A	N/A	22[1]	No	No[9]	1 to 4	Yes (copy supplied)
Sv'n Trent	Yes	–	32.6 million m^2	592.0[2]	25	No	Yes, best-practice guide	4/5 flood banks, 1/2 channels	No
Southern	Yes	–	5.5 million m^2[3]	N/A	15/20	Yes(5%)	No[9]	1/2 but varies considerably	No
S'th West	Yes	–	N/A	N/A	3/4	No	No[9]	4 flood banks	No
Thames	Yes	–	N/A	N/A	10	No	No[9]	Nothing standard	Yes?
Welsh[5]	Yes[4]	–	N/A	172.0[6]	8[7]	No	No[9]	1/2 but varies	Yes?
Wessex	Yes	–	N/A	100	6/8	Yes(25%)	No[9]	1/2 but 6/8 along rural roads	No
Yorkshire	Yes	–	380 km[10]	222.0	8	No	No[9]	4 Southern 2 Northern	Yes (copy supplied)

Notes

(1) Figures for North Lancs and North Manchester only
(2) No adminstration, supervisory staff, Regional or HQ costs included
(3) Includes sea walls as no distinction is made between fluvial/coastal maintenance
(4) Includes TRASHING i.e. cutting undergrowth on small watercourses
(5) Figures only cover part of Region
(6) £100 k on trashing £72 k on grass mowing
(7) 6 FTE on trashing
(8) 'N/A' indicates no figures available
(9) Based on local knowledge, nothing written down (see Table 5)
(10) Estimate for 1991/92

Table 6 Safety, training and equipment

Region	Written Regional safety policy	Operative training[1]	Machine operative training[6,4]	Notes on training	Equipment owned/rented	M'ance of equipment	Notes
Anglian	Yes	Yes[5]	Yes (certification)	Cop for dredging. Specific guidance on tree cutting	Large % hired	In house	–
N'brian	Yes	Yes[5]	Yes (certification)	Guidance on tree cutting	Owned	33% in house 67% N'brian CC	–
N'th West	Yes	Yes[5]	Yes (certification)	Laid down policies if chemicals are used for weed control	Owned	100% NWW plc	–
Sv'n Trent	Yes	Yes[5]	Yes (CITB certification)	Guidance given to machine men who cut weeds but nothing written down	Owned	In-house/ STW plc	Lot of equipment is old and needs replacing – best practice guides
Southern	Yes	Yes[5]	Yes (certification)	Guidance on tree cutting	Owned	In house	–
S'th West	Yes	Yes[5]	Yes (certification)	Specific guidance only on tree cutting	Owned	In house	Policy to replace all equipment every 2.5 years
Thames[3]	Yes	Yes[5]	Yes (certification)	Specific instructions given to weed cutting operatives and tree cutting operatives	Owned	In house (90%)	Maintenance is based on local needs. Lots of equipment is old
Welsh[2]	Yes	Yes[5]	Yes (certification)	Guidance on tree cutting	Owned	In house	Lot of equipment is old
Wessex	Yes	Yes[5]	Yes (certification)	Guidance on tree cutting. Also specific training for weed-cutting operatives	Owned	In house	Try to replace all equipment every five years
Yorkshire	Yes	Yes[5]	Yes (CITB certification)	Guidance on tree cutting	Owned	In house	–

Notes

1. For fluvial maintenance
2. Covers only part of the Region
3. Thames operate a separate contractor and client policy for identifying work and undertaking the work even for their in house work force.
4. All Regions appear to give specific guidance on tree maintenance to their operatives. However, nothing is formally written down. There appears to be a wide difference in the specific instructions given. They are in general instructed to do as little as possible to make the tree safe and to remove only as a last resort.
5. On job only
6. All Regions operate systems whereby a machine operative has to be fully trained and hold a certificate before operating a machine.

Table 6 (cont) Safety, training and equipment[4]

Region	Grass management	Aquatic weed control	Tree management	Dredging
Anglian	50 Tractors with assorted side and rear-mounted flails, 4 AEBIs	Hydraulic excavators; RB10s; RB22s	Chain saws, tirfors, winches, tractors, Land Rovers, bush saws	38RB: 22 RB: 10 RB
N'bria	1 Tractor and flail, 1 mulag, 2 Allen scythes, 3 bradshaw cutters	3 Hydraulic excavators	Ditto	3 Hydraulic excavators
N'th West	Mulags, hand tools, tractor and flail, AEBIs	Hydraulic excavators, bradshaw buckets, weed boats, hand equipment	UC15, 22RB, hydraulic excavators	-[3]
Sv'n Trent	248 Pedestrian mowers, 16 Tractor mowers (gang and long arm), 6 Ride on-mowers	14 Excavators, 14 weed boats amphibian?	Ditto	18 Tracked excavators; 5 Wheeled excavators; 4 Draglines
Southern	-[3]	18 Hydraulic excavators (Mustang 120s or equiv.); 3-5 weed boats, 1 amphibian, hand equipment	Ditto	20 Excavators (VC15, Mustang 120); 4/5 Draglines (RB22), 1 dredging boat
S'th West	Tractor and flail (rear mounted and towed strimmers)	Some hydraulic excavators but mainly JCBs. Hand equipment	Ditto	-[3]
Thames	Mulags, hand tools, tractor and flail	Hydraulic excavators and bradshaw buckets, 2 amphibians, 5 weed boats, hand equipment	Ditto	Bucket dredger, floating grab dredgers, JCBs, hydraulic tracked excavators
Welsh[1]	1 Tractor and flail mower, 1 Hand mower	-	Ditto	Priestman VC15 Mustang 120, Cat 955
Wessex	13 Tractors and mowers, contractors[2]	9 '360' tracked and bradshaw/herder cutter, 2 wheeled excavators, RB22, 9 weed launches and contractors	Ditto	As for aquatic weed control (less weed launches) with additional RB22s one additional JCB 3c and Contractors
Yorkshire	Four-wheel drive tractors with double rear wheels and flail, mini tractors and flail (1m wide), chain harrow	12 Mustang 120s and bradshaw, 2 weed boats, VC15 - sometimes	Ditto	2 VC15, 2 No RB22, 6-8 No Mustang 120, 814, 818

Notes (1) Only covers part of Region (2) See separate list in appendix (3) No details supplied (4) Some equipment (e.g. hydraulic excavators) may be used for more than one operation

The following five subsections give specific information on the answers to the questionnaire (further details can be obtained from the Project Leader) and cover:

- Grass cutting
- Seeding
- Machinery
- General
- Conservation.

It is worth pointing out that the Regions were only asked to provide information that was readily to hand. In some cases it was stated that, with additional effort, the information requested could have been provided. In others it was felt that it would have been impossible to provide the data requested.

(a) Grass cutting

Questions 1,2 and 4: Why is grass cut? Do the reasons vary across the Region and what is the policy? (See Table 7)

It was noted that the change-over from hand-cutting to mechanical cutting in the Regions took place from 7 to 20 years ago. The traditional use of hand scythes for cutting grass (usually an annual cut) meant that material had to be raked and disposed of and required a large labour force. The introduction of small machines such as Allen scythes with a reciprocating cutter bar still involved the raking and disposal of the cut material, and it was not until flail mowers became widely available that cut material could be left to rot *in situ*.

A tractor and flail cuts grass faster, so fewer operatives were needed to manage the banks. More cuts could then be afforded and each Region, District or Area within a Region has settled on a 'standard' number of cuts for particular banks within their control to enable them to be inspected. The number of cuts each bank should receive has been established by local knowledge, and is largely dependent on the perceived threat should a bank fail and, in some cases, on the restrictions of the financial budget. Severn Trent Water carried out a 'best practice' exercise in 1985 which rationalised this ad hoc procedure and established standards for different banks.

Southern Area of Yorkshire has recently increased its standard from three to four cuts per year, Glamorgan is increasing from one to two cuts to keep Japanese Knotweed under control and two others interviewed said they would increase their standard if resources were available. Apart from Thames Region, which has decreased its cutting commitment, many Regions are increasing the lengths of bank to be managed each year by the building of new banks or by improving access to enable more banks to be cut. The cutting regimes have altered considerably with the introduction of mechanisation. Table 7 shows a breakdown of the maximum number of grass cuts per year undertaken by each of the Regions.

Table 7 Maximum number of grass cuts per year

Region	Floodbank		Channel Bank	Grass cut/year
	Urban	Rural		
Anglian	2-3	1-2	1	-(1)
Northumbria	2-3		1	200 km
North West	1-3	1-2		-(1)
Severn Trent (Trent Area) (Severn Area)	3-4	4-5(2) 1-2(3)	1-2	32 600 000 m^2
Southern	1-2	1-2		5,500 km(4)
South West	4	1-4(5)		
Thames	Little grass to cut (no standard)			-(1)
Welsh (Glamorgan)	1-2	1		-(1)
Wessex	2-3	1-2	1-2	-(1)
Yorkshire (N) Yorkshire (s)	3-4	2 3-4		139 km 90 km

Notes
(1) Information not available
(2) Floodbanks of tidal reaches have the highest number of cuts
(3) Floodbanks of non-tidal stretches
(4) Includes approximately 10% coastal grass banks
(5) Urban floodbanks × 4, estuarine floodbanks × 1
(6) Mainly amenity cutting (e.g. locks, etc.)

Question 3: How does cutting vary throughout the Region?

The 'standard' number of cuts set by the Regions was influenced less by the climate and length of grass-growing season than by the nature of the banks managed, perceived threat if the bank failed and the funds available for grass cutting.

Questions 5 and 6: What criteria are used for assessing need for cutting? (See Table 8)

In each Region the decision whether to carry out fewer than the 'standard' number of cuts or to make an additional cut is normally made by the local engineer or supervisor, usually by a personal visit but sometimes acting on information supplied by operatives or, as in the Somerset Area of Wessex, as a response to a complaint from the public. The decision is influenced by the grass growth in a particular season. Where the 'standard' number of cuts is low, then that standard is more likely to be kept to each year irrespective of poor grass-growing seasons.

Small channels, where the capacity is critical (e.g. within an urban area) will always be maintained to the standard or above. The banks of larger channels can be maintained to below standard but floodbanks will always be managed to standard, though this standard varies from place to place.

Questions 7 and 8: Staff for assessing cutting?

The Regions agreed that the loss of the local officer in charge would cause disruption but not to the extent of preventing work from being carried out. The work to be done is routine i.e. does not vary from year to year even though the order in which banks are cut may differ. The operatives tend to have been in the job for a long time and would get on with the work. Most Regions have a work programme that can be referred to with job sheets that can be generated for operatives (see Tables 2 and 3).

However, the importance of having local knowledge and contacts was frequently stressed. All those questioned either had a database that could be referred to or were in the process of setting one up. It was however seen as a help and not a replacement for local experience. Where a lot of the work is carried out on land not in the ownership of the NRA the loss of the personal knowledge of conditions and people was seen to be particularly disrupting.

Table 8 Reasons given why grass is being cut

Reason	Region									
	A	N	N W	ST	S	S W	T	W	Wx	Y
A. Maintain channel capacity and reduce rugosity	*	*	*	*	*	*	*	*	*	*
B. To allow for the visual inspection of the banks for condition and damage by vermin	*	*	*	*	*	*	*	*	*	*
C. Amenity and recreation	*	*		*	*	*	*	*	*	*
D. Discouraging the dumping of rubbish in urban areas by making the banks look 'cared for'				*						
E. Controlling weeds and scrub	*			*	*	*			*	
F. To promote denser grass growth		*			*				*	
G. Eliminate cover for vermin								*		

Notes

(1) On those channels that are cut, capacity is not an issue. In some Regions parts of the foreshore are sometimes left uncut for wildlife reasons.

(2) For all ten Regions A and B were always the main reasons, with A usually ahead of B.

Question 9: Vermin?

There were few observations on whether vermin increased or decreased with a reduced number of cuts, although cutting was widely used as a reason to enable banks to be checked for vermin damage.

However, vermin problems tend to be localised, such as rats in urban banks, or specific to an area of the country (e.g. badgers in raised banks on the Somerset levels). Rabbits are a particular problem in grazed channel banks in Northumbria and raised banks in Anglian; moles are a problem in raised banks in Glamorgan and by the River Severn. The presence of hedgerows close to the bank will influence whether a problem will arise from rabbits or badgers, as these form a site from which a population can spread out and provide routes for animal movement.

Questions 10-13: NRA and work for IDBs

In some Regions work is carried out for IDBs by the NRA and vice versa, but this tends to be channel works rather than grass cutting. In some Regions local authorities do work on contract for the NRA but usually as a result of competitive tendering. If grass is cut by the local authority it is generally to supplement the cutting already carried out by the NRA in urban areas. In some cases the NRA may carry out extra cuts under pressure from a local authority but not as part of a contract to them.

Question 14: Subcontracting out of grass cutting?

Tables 9a and 9b illustrate the variations in response to whether the grass cutting could be subcontracted.

Table 9 Grass cutting and sub contracting

Table 9a Could all or part of the work be subcontracted out?

	Region									
	A	N	N W	ST	S	SW	T	W	Wx	Y
Yes it would be possible	*	*	*	*		*	*	*	*	*
No it would not be possible					*					

Table 9b Reason given for the consequences of subcontracting out the work *or* why the NRA should do the work

	Region									
	A	N	N W	ST	S	S W	T	W	Wx	Y
High level of supervision would be required	*	*	*	*	*	*	*		*	*
Part only could be contracted out		*	*	*						
Is being *or* has been tried		*		*	*	*		*	*	
Would lose goodwill of landowners					*					
Not cost effective		*	*	*						
Needed to occupy operatives in summer months				*		*				
Done in combination with other jobs		*	*							
Wildlife/environment would lose out					*	*		*	*	*
Suitable contractors may not be available		*	*		*	*		*		*

(b) Seeding

Table 10 gives information on seeding. Further details can be found in Appendix 5.

Table 10 Seeding of banks

	Region									
Notes	A	N	NW	ST	S	S W	T	W	Wx	Y
All seeding done in-house										
Maintenance seeding done in-house for capital works, seeding mainly part of an external contract if it is a large area	*	*	*	*	*	*	*	*	*	*
May pay farmer to spread seed		*		*		*		*		
Very little seeding carried out, mainly re-instatement		*				*			*	
Low-maintenance mixture/wildflower mixture tried	*	*	*	*	*	*	*	*	*	*
Carrier of sand or barley meal tried			*							
In-house seeding more flexible							*	*		*
Repairs using turf tried		*	*	*		*				
Sowing done at end of job	*	*	*	*	*	*	*	*	*	*
Spring sowing preferred		*		*				*		
Autumn sowing preferred						*			*	*
Grass mix policy exists	*		*				*	*		*
Ad hoc grass mix policy		*		*	*	*			*	

(c) Machinery

Table 11 shows the answers given to Regional variations in choosing grass-cutting equipment and Table 12 the types of machines presently used.

Table 11 Choosing machinery by Region - reasons and influences

	Region									
Reasons	A	N	NW	ST	S	S W	T	W	Wx	Y
Suitable for main job it has to do		*	*					*	*	
Reach			*	*	*	*	*	*	*	*
Size (access versus performance)	*			*						
Versatility				*	*					*
Reliability/maintenance costs					*			*		*
Cost of purchase				*					*	*
Safety/operator fatigue						*				*
Influences										
Traditional practices	*	*	*				*			
Experience of the machine elsewhere *or* on trial	*	*	*	*	*	*	*	*		*
Opinion of operator who is to use it	*	*	*	*	*	*	*	*		*

Table 12 Machinery for grass management

	Region									
Notes	A	N	N W	ST	S	S W	T	W	Wx	Y
Handwork - scythes, strimmers, hand mowers (etc.)	*	*	*	*	*	*		*	*	*
Small tractors + mini-flail rotaries (e.g. kabato)					*					*
Tractor and rear-mounted long-arm flail		*	*	*	*	*		*	*	*
Tractor and side-mounted long-arm flail	*						*		*	
Tractor and mid-mounted long-arm flail									*	
Tractor-pulled flail				*						*
Mulag/AEBI type mowers	*		*	*	*	*	*			

Questions 3-7: Choice of machines for grass cutting?

The perception of the introduction of which machine (and mower) or mode of working has made the most impact on cutting varies from Region to Region, depending on how long term a view is put on it. Information from before the formation of the NRA was only available from peoples' personal experience. However, a common view was that the introduction of the flail cutter to replace hand scything and the raking up of cut material was probably the most notable event. Since then it was the production of the Turner 25S long-arm flail which enabled the easy changing of the flail head for cutting either side of the tractor and subsequently the production of the Mulag and the AEBI with their speed of cutting, greater safety on slopes and wider cutting head. These changes have resulted in fewer operatives being needed to carry out grass cutting. However more frequent cuts need to be made because of the cutting limitations of the equipment.

Very few people had experience of all three modes of mounting cutters (i.e. front, side and rear). The mounting used by any one area was generally what had been found to work well in the past, but interest was shown in others. No-one had experience of a front-mounted long-arm flail but Wessex had tried a mid-mounted (i.e. in front of the cab but central) on a Fendt Tractor, which was found to lose stability because it had no front-wheel drive.

The front-mounted cutters experienced by those interviewed were usually those on the AEBI and Mulag, which have wider cutter bars than a long-arm flail, and on an engineered bank with no obstacles will cut much faster and cost less per unit. However, the flail has been known to become fouled if used on overlong grass. A heavy-duty flail can cope with grass cut at longer intervals. Cutting immediately in front can also be dusty for the operatives in dry conditions. Both machines are easier to use on a slope than a tractor. Yorkshire regularly employs tractors on slopes, most Regions use them to cut from the bank top or from the base of the bank.

Side-mounted cutters enable the driver to see well but require to be counterbalanced by weights, and take the best part of a day to fit onto the tractor. The reach of the arm is generally 23 feet.

Rear-mounted long-arm cutters give poorer visibility and cause more operator fatigue. A recent accident has encouraged Wessex to consider side-mounted cutters as a safer alternative. Northumbria has had large mirrors fitted to overcome this. The cutter is quick to fit onto a tractor and the reach is generally longer at 25 feet. Originally, cutters would only cut on one side. The Turner 25S was a popular innovation, as it can work either side simply by changing a pin, and this saves an extra traverse. It is no longer available but Bomford has introduced an alternative.

Rear tractor-towed cutters have been tried by some but are only used regularly by Yorkshire and Trent Division of Severn Trent Region of those interviewed.

All Regions found flails to be superior to reciprocating cutters for the grass-cutting practices currently employed. Only where a hay cut was to be taken would the latter be used.

Most Regions felt that heavy-duty flails could cope with a single annual grass cut as long as the grass was not too lush, but a reciprocating blade would be more efficient. However, heavy-duty flails are generally used for cutting bramble etc. and the standard flails for grass cutting would have difficulty in dealing with a lush growth without fouling. The North West Region has experienced fouling with a Mulag when grass was left uncut for too long. Some concern was expressed over the mulch problem if the grass was left to get too long before being cut.

Questions 8-11: Grass cutting and weed control?

It was noted that it is possible to cut the grass on channel banks with a weed bucket as part of the operation of cutting channel weed but this is slow. It was only carried out regularly in areas with straight engineered banks and it may just be the base of the bank that is cut. In most areas where weed cutting was done the banks were cut using a long-arm flail or by hand before work began. Emergent bank-side growth and bank vegetation may be left for environmental reasons. Very little grass cutting was done in this way.

In some places the lowest part of the bank will be cut by a weed boat but again very little grass cutting is done in this way.

Questions 12, 13 and 15: Machine costs?

The cost of moving of machinery to where it is to work was not seen as being a factor in deciding where a machine was kept, but it may have been important when depots where originally set up, as most are central to the area they serve. Distances covered are relatively short, with an hour's travelling or less being typical. Tractors and flails in rural areas are often left in farmyards overnight for safe keeping, but are likely to be returned to the depots in urban areas, where vandalism is seen to be a major problem.

The decision as to whether extra machines should be purchased was based on whether there is sufficient work to keep the machine utilised rather than having machines local to the work to be done. The cost of getting a machine on site was seen as irrelevant compared to that of an extra machine.

Question 14: Large machines?

The question 'Has the use of larger machinery resulted in less machinery in total?' had a mixed response. Those Regions that had gone from hand working to mechanisation relatively recently saw a considerable reduction in the overall number of machines for grass cutting (e.g. both hand tools and ride-on mowers). Others who had been mechanised for longer saw it as a gradual progression and had either reached the limit of machine size because of poor access, had increased the area cut (so had not seen a reduction in the number of machines) or were still acquiring machines to further reduce the labour force.

Question 16: Replacement of vehicles?

Most Regions were feeling the effect of past policy changes. The old River Authorities tended to change plant and machinery relatively frequently but the Water Authorities that replaced them usually had the opposite policy. Since the formation of the NRA many areas have been able to start replacing old tractors with new models.

A policy on replacing vehicles is being developed by the NRA Headquarters and guidelines have been sent out. Generally, the oldest/less reliable machines have been replaced first and machinery will be kept for a shorter period in future, depending on their condition and the number of work hours they have done. Light plant such as strimmers are kept from 1 to 4 years. In Thames Region, because tractors travel on the public highway and require a road-fund licence, the policy is that they are not the responsibility of Flood Defence. (Note: since this Report was produced the law relating to this area has been altered.)

Questions 17-19: Hiring of equipment?

Machinery was not generally hired for grass cutting from outside the NRA. Occasionally, it was done where there was a machine breakdown. Yorkshire Region was able to hire tractors without drivers from dealers, taking tractors in part exchange from farmers. For some parts of the country such as Cumbria and Southern Region no grass-cutting machinery was available for hire. If machinery was hired its upkeep was the responsibility of the firm who owned it.

Question 20: Vandalism?

Vandalism was a problem to some extent in each Region. Hydraulic excavators tended to be more at risk than grass-cutting machinery, as they are less mobile and cannot be taken to a farmyard or depot overnight unless they are wheeled rather than tracked vehicles.

The problems were greater near centres of population rather than in rural areas, and work was often scheduled to avoid leaving vehicles in vulnerable sites over weekends and school holidays. Southern Region prefer tractor-mounted flails to a Mulag or AEBI, as they are more mobile.

The opportunist theft of equipment such as strimmers was not uncommon, but even large-scale theft of machinery from secure compounds at depots was not unknown.

(d) General

Question 1: Dumping?

Dumping was perceived to be a typically urban problem, causing few difficulties in rural areas. Sites that attracted dumping were usually alongside bridges or in the channel beneath the bridge, and less typically elsewhere on a channel such as picnic sites with car access.

The material dumped varies from supermarket trolleys to cars, carpets, builders' rubble to garden rubbish. There were known trouble spots and operatives would be aware of this. In some cases the operative would pick up the material before starting to cut or it may be noted during a pre-inspection visit and entered as a job under WIPPS. Southern Region owns a skip lorry and clear known problem areas before cutting. Some Regions use regular cutting as a means of deterring dumping by the psychological means of showing that an area is 'cared for'.

Question 2: 'Staff'?

Whether some posts could be peripatetic within a Region or the NRA attracted a variety of responses. Some posts were seen as being already peripatetic in that people such as the Conservation Officers and Safety Officers were centred on the Regional headquarters while being available to give advice to all the Districts and Areas. Severn Trent and Thames Regions have Landscape Architects available in the same way. Southern Region has members of the Management Services seconded to the Areas. River Inspectors are truly peripatetic as they have to issue licences, and Pest Control Operatives could be.

Some of those interviewed did not perceive a move in this direction but acknowledged that communication between disciplines was often poor despite induction courses. One officer remembered that in the River Authority it was standard procedure to second people to different departments, and at one time junior engineers were articled to engineers to enhance their practical skills.

Equipment was seen to be already peripatetic and inter-Regional demonstrations of grass-cutting equipment had proved useful.

(e) Conservation

Table 13 illustrates the range of answers relating to the question of conservation.

Table 13 Conservation

	Region									
Notes	A	N	N W	ST	S	S W	T	W	Wx	Y
Conservation policy (written/verbal) existing in Region	*	*	*	*	*	*	*	*	*	*
Operatives are given instructions on what to do for wildlife	*	*	*				*	*	*	*
Operatives allowed to take initiatives to protect wildlife	*			*	*	*	*	*	*	*
Cover left or created for otters		*	*	*		*	*	*	*	*
Local contact with County Wildlife Trust other than at regular meetings	*	*		*	*	*				*
Transplanting of species-rich turf tried										*

3. LITERATURE REVIEW

3.1 Background

A literature review was undertaken as part of the study. The first phase of this was a review of the data collected as part of the previously mentioned NRA research project No. 200 entitled *Review of existing practices for fluvial maintenance operations throughout the NRA - Volume III Literature Review* (see Section 2.1). The second was an in-depth look at a much wider range of sources and specific visits to a number of organisations involved with grass management, including grass-cutting equipment manufacturers (see Appendix 3).

The objective of the review was to ascertain what information was already available on the topic of floodbank grass management or relative topics. The review was carried out by Ms K. Buckley (ERAs Consultants of Grantham) under a subcontract to CIRIA.

3.2 Main findings

No externally published research was identified which comprehensively contained information specifically on either the creation or the management of grassland on raised floodbanks. The topic is discussed in general terms in a number of publications and internal research reports existing in the Severn Trent Region and there is on-going research in the Anglian and Yorkshire Regions (see Appendix 3).

While there have been 'best practice' reviews in Regions such as Severn Trent, it was generally the machinery that had been looked at in detail rather than the grass management regime itself. All Regions have taken decisions from time to time about the number of cuts banks should receive, but the reasoning behind these decisions were generally not documented. The main sources of published information on grass seeding and general grass management was therefore from research into amenity, nature conservation and agriculture.

Subsections 3.2.1 to 3.2.8 give more specific information from the literature review relating to grass management.

3.2.1 Plant and machinery for grass management

From the literature it can be seen that a great deal of expertise has been built up in the management of grassland in the water industry simply by experience, but this is generally not written down or is in the form of raw statistics listing what has been bought. Mechanisation has increased rapidly since the 1960s and has generally been *ad hoc* in response to an increase in the cost of labour and/or in the area of grass (mainly floodbanks) to be cut. Allen scythes or tractor-mounted reciprocating cutters were usually the first step up from hand scything, but still required the cut material to be raked up. It was not until the introduction of the flail mower that mechanisation could be considered to have had a serious impact on working practices.

Since flail mowers became a common tool for grass cutting there has been a plethora of small and large equipment coming onto the market. Tractors which were originally designed for farmers are now designed to take flail heads on an arm in various positions (rear- side- and mid-mounted). Flails can be towed and now specialist machines with front-mounted flails, low centres of gravity, with tracks or wide wheels have been designed for use on banks. There is no doubt that manufacturers see grass cutting as a lucrative industry and rely a great deal

on feedback from those operating them to identify needs for improvements (e.g. the Turner 25S flail was a market-led improvement).

Amenity works have produced the greatest amount of published material on machines, efficiency, costings, etc. A guide was issued to aid the costing of building features, earth moving, landscaping, etc. (Derek Lovejoy and Partners). Calculations have also been produced to indicate the time taken to cut different categories of turf a certain number of times with the appropriate machine as a guide to costing turf maintenance (*Turf-grass seeds handbook*, 1980) (see Table 14).

Table 14 Grass-cutting times

Turf	**Mowing**		**Area**	
Category	**Unit**	**Frequency**	**hr/yr/ha up to 0.5 ha**	**hr/yr/ha over 1 ha**
Rough grass	Tractor-mounted flail	4/year	20	17
			hr/yr 100 m^2	hr/yr 1000 m^2
Steep banks	Rotary (small)	1/month	8	50
			hr/yr/ha	Up to -ha /man/y
Rural roads	Tractor mounted flail	4/year	12 hr/km	80 km/man

From within the water industry internal reports on 'best practice' have been produced by Severn Trent Region. In 1985, *Land Drainage Tasks - Grass Cutting Best Practice* was produced. This includes a review of mowers and tractors fitted with flails and their capabilities, pedestrian and ride-on mowers and a review of the 'Principles to be adopted in quantifying annual savings on grass-cutting'. An analysis of the unit costs of different machines and modes of working in the form of tables gives a valuable ready-reference.

In 1986 the Severn Trent Water Authority produced *Management of Rivers Maintenance Work - Recommended Systems* which looked at reducing the unit costs of the work done by improved planning and management control of work. It recommended two systems in connection with plant and machinery:

a. Ensuring the provision of a satisfactory spare parts back-up for high cost items or those of strategic nature. Grass cutting machinery would fall into both categories. In the example given, an after sales clause was applied to the purchase of a Mulag: In the event of the goods being out of action for more than 48 hours due to spare parts not being available the Contractor shall forthwith provide the Authority with goods of a similar specification entirely free of charge, or alternatively pay the Authority the sum of £50.00 per day liquidated damages until such time as the goods can reasonably be restored to service. For the same reason, the plant manager (Technical Services Engineer) for Southern

Region prefers to purchase the make of tractor for which there is a back-up quickly available locally irrespective of the relative costs of equivalent machines.

b. The adoption of a centralised approach to plant so as to increase the degree of utilisation.

A table was produced in this document as an illustrative example of the amount of cutting that can be done by a tractor and 62-inch turbo-mower in metres squared when used by different operatives.

Another report, *Best working practice on tractors*, led to the production in 1988 of the *Tractor comparison report*. The aim of this was to enable the Water Authorities to take steps to rationalise the tractor fleet (approximately 300) in terms of make, model and size. Looking at four main makes of tractor (John Deere, Ford, Case International and Massey Ferguson), it compared the technical data of tractors in different horsepower ranges and their cost, and identified which make and model seemed best from this information alone. Such data are useful and can act as a valuable guide to what is available, especially if updated regularly and circulated to plant managers. However, the results of such an evaluation should not form the basis for a rigid instruction nationally for the following reasons:

- Machinery is being constantly developed for this market and improvements introduced
- Working conditions vary across the country and one piece of machinery is not universally applicable
- The importance of local back-up in the way of parts has been covered above
- Operatives develop their own ways of working and changes should be introduced gradually.

3.2.2 Bank engineering

A floodbank is designed according to established formulae to withstand the impact of water against it without breaching (Brandon, 1989). The design of the bank will be affected by how much land can be negotiated for it and what material is available for its construction. A good policy for planning banks is to keep the bank as far landward as possible, and this has three main benefits:

- It gives the greatest capacity for when the water leaves the channel
- It minimises the size of the bank needed to contain the highest flows before overtopping - this reduces the surface area receiving the impact and thus the opportunities for breaching as well as reducing initial construction costs and the area of bank grass requiring management
- It permits the dissipation of energy on the foreshore before reaching the bank, thus minimising the impact.

Factors that need to be considered include:

(a) *Design requirements*

In general, the design of a bank has to cover a number of factors, including:

- Required life
- Wave conditions
- Extreme high and low water levels
- Soil conditions
- Available foreshore
- Allowable overtopping discharge
- Design life.

As it may not be possible to satisfy every parameter the design will be a compromise. When developing the initial concept the principal aspects to be considered are:

- Location and plan shape of the bank
- Basic structure
- Planning for future maintenance.

(b) *Vegetation as part of bank design*

An engineer uses vegetation to protect new banks and to repair existing ones. Although it is generally more labour-intensive than 'hard' engineering solutions, vegetative methods of bank protection can be more readily integrated into the overall environmental planning considerations for a scheme (Brandon, 1989).

The use of vegetation is generally becoming more widely used in the UK. Its use in an engineering role (commonly termed 'bioengineering') differs from most other forms of engineering in two key respects:

- Bioengineering is more of an 'art' than a 'science' in that it requires considerable experience and judgement, as opposed to the application of quantitative design theory or rules

- Careful attention is required not only in the establishment of vegetation but also in its aftercare over the initial growing seasons.

Coppin and Richards (1990) have produced a comprehensive guide to the use of vegetation in civil engineering with sections on planning, design, construction, establishment, aftercare and management.

'Grass as an engineering material for bank protection is very efficient and widely used. Provided the sward is dense and well managed, grass will withstand considerable velocities. However, the presence of any bare patches or tussocks (which attract higher than average drag forces) can substantially reduce the ability of the bank to withstand erosion' (Brandon, 1989).

(c) *Functions of vegetation*

Vegetation can have a number of different engineering effects on a bank and performs some positive functions:

- It reduces local flow velocity and hence its erosion potential against the bank
- It shields the soil from being washed away
- The roots reinforce the bank at depth.

3.2.3 Grass species/mixtures for bank stabilisation and protection

Below are listed some basic facts about grass for bank stabilisation and protection:

- If left to grow unhindered in a typical, well-drained, fertile soil grass will have roots that spread and go down to a depth of up to 50 cm (20 in).
- The higher the watertable, the shorter the roots. That is why arable farmers drain their cornfields to encourage root depth.
- The further apart grass plants, the more their roots can spread laterally without competing with other plants and the more vigorous they will be.
- If left uncut, a sward will be seen to be made up of individual plants with soil visible between them under a tall top-growth. Flowers and seeds will be produced.
- If a grass plant is cut, the roots stop growing and food reserves held in the root are mobilised to replace the leaves as quickly as possible, so that photosynthetic production (making of plant food products from the sun) can be increased without delay and those food stores replaced.
- Grass that is cut regularly produces vegetative shoots called 'tillers' which increase the photosynthetic capacity of the plant, incidentally making the sward look 'greener', 'denser' and aesthetically 'neater'. The soil will not be visible between the plants and there will be no grass flowers or tall herbage. The roots will be shorter as the plant's efforts will be put into recovering its photosynthetic capacity. This is why in dry seasons, short turf suffers from drought and has a scorched appearance. (Conversely, long grass permits a higher evaporation rate and consequently a greater use of water over the year; water will be used to a deeper level.)
- The best turf develops when the soil has a slightly acidic reaction between pH 5.5 and 6.5 (pH 7 is neutral).

However, there is the added complication that there is more than one species of grass growth form and different levels of grass management can manipulate which species is favoured.

In the literature there is one school of thought that says that as grass floodbanks are susceptible to erosive forces then grass species that are rhizomatous (have creeping roots that can give rise to new plants) *or* are stoloniferous (have creeping stems that produce new plants) are the important ones to sow on banks because they give a dense turf. The standard

grass species sown on river banks has normally been Ryegrass, a species that is neither rhizomatous nor stoloniferous and gives an open turf when not cut or cut often. Its protective cover is normally greatest when it is cut once or possibly twice. Far from losing soil from the bank because of being unprotected by the poorly developed Ryegrass cover, a silt bank on the River Aire in South Yorkshire had no sign of scour after a recent flood, the fine particles of the silt apparently cementing together. Silt had been deposited in quantity on the foreshore, however, trapped by the leaves of the grass.

Ryegrass is a plant that has been bred to do a variety of jobs, e.g. strains have been developed to be highly productive and late flowering to give maximum leafiness in the summer for grazing or silage (agricultural) or to be short and leafy (amenity). All strains germinate and establish quickly on practically any soil, but require a high nutrient level and moisture to survive for more than a few seasons.

Grasses which are stoloniferous or rhizomatous are typically species that have been derived from stressed habitats such as frequently disturbed soils (arable), dry shallow soils (sands/chalk) or waterlogged/brackish conditions where the need for an alternative means of prolonging the survival of the species other than through producing seed is an advantage. These species tend to be stress- tolerant and produce a dense turf with a shallow matrix of roots but with some longer roots. They are highly competitive and can dominate a sward. It is these characteristics that make fescues highly desirable for golf greens and bowls greens and couch grass so undesirable in arable fields. This means that an ideal low-maintenance seed mix for a floodbank will combine two species of grass in particular:

- Ryegrass - preferably a sports-turf strain to act as a nurse crop giving the critical early cover to the ground

- Fescues - preferably a mixture of rhizomatous and tufted species and varieties.

The contents of a seed mix for a pasture area will usually be dictated by the farmer and will be a standard mix of high-yielding ryegrass strains. Appendix 5 includes details of standard and low- maintenance/conservation mixes used by various Regions.

3.2.4 Seeding methods

Seeding involves:

- Seed mixes - (see Section 3.2.3)
- Seeding methods
- Timing

The seeding method adopted will depend on the nature of the area being seeded, its size and the seed mixture it is being seeded with. The site could be:

- Dredgings or minor bank repair
- New flood or reservoir bank
- Amenity site.

The method will vary according to whether it involves:

- Reseeding of spread dredgings on pastures or seeding new banks with an agricultural mix for grazing
- Reseeding of spread dredgings on Sites of Special Scientific Interest (SSSI) and seeding of banks with low-maintenance/conservation mixes
- Hydroseeding
- Turfing.

The agricultural mixes used for reseeding/seeding areas to be grazed will always be based on one or more strains of high-yielding ryegrass and the size of the seeds is likely to be uniform. The usual method currently employed is to hand-broadcast seed with the quantity spread being fairly arbitrary, but as the cost of this seed is relatively low this is not a consideration while the need for a good take of grass is.

The mix used for reseeding of dredgings spread on an SSSI will be dictated by what is growing in the field at present, and advice on this will be received from the Government's statutory wildlife body, English Nature (formerly the Nature Conservancy Council). The mixture will be roughly equivalent to a low-maintenance mixture, with a variety of grass seeds and probably some broad-leaved herbs (wild flowers) as well. Because the seeds will be of various sizes and the higher cost of the mixture means that a more precise level of seeding is advisable (10g/m^2, 100 kg/ha being appropriate) then a carrier of sand or barley meal to mix with the seed is normally used. It can then be broadcast by hand or from a hopper. This will prevent seeds of different sizes settling out together and will show more clearly which areas have been seeded and which not.

The more complex the mixture, the more important the use of a carrier becomes. However, a simple grass mix with seeds of approximately the same size could be sown without one. This also pertains to seeding floodbanks with these mixes.

Hydroseeding is a technique usually used for seeding steep slopes or inaccessible areas of topsoil, raw subsoil and derelict land material but could be used wherever seeding was being carried out. It has been tried by the Yorkshire Region but it is unlikely to be a technique that would be needed on a regular basis. The larger the area to be seeded, the cheaper the cost of seeding, and as the machines do not run over the seeding but stay at a distance, there is less damage to the seedbed.

The technique involves mixing seed with fertiliser in water to form a slurry and spraying it on the site to be grassed over. Usually a mulch of some kind is either applied with the slurry or later over the top of the seed. Other additives such as soil bacteria can also be added. Results have been variable but the technique is being continually refined.

Turfing involves the transference of established pieces of turf to a site such as a bank where it is either laid on the levelled soil and left or pinned down with a fine mesh which can be left to become part of the turf if there are problems with rabbits etc. It can be removed after a few months if there is a possibility of fouling the flail heads.

3.2.5 Management by cutting

Some information has been obtained by the Severn Trent Region concerning the effect of cutting low- maintenance mixes at low frequencies. The findings are tentative at present but give some indication of what might be expected to happen.

Apart from this internal report, the published research work on cutting relevant to that carried out by the NRA has been done for amenity purposes.

The Sports Turf Research Association has been the main leader in this research in Britain and it is in its journal that most of the relevant work is published. However, the journal *Landscape Design* is a useful source of review papers.

3.2.6 Management by grazing

The desirability of having banks managed by grazing appears to depend on what stock is available for grazing, the steepness of the slopes and the availability of alternative dry standing in the winter. A considerable amount of damage can be caused by animal hooves, and while it is not always necessary to cut a grazed bank they have to be monitored carefully in case damage leads to a breach.

Sheep grazing produces the best sward, but if cattle or horses are used then grazing should be strictly limited to the April-October period. Cattle grazing apparently produces a better sward for giving cover to small mammals and thus gives better hunting territory for barn owls.

A cow eats by tearing off a length of grass held between the incisors of its lower jaw and the dental pad of the upper jaw, the tongue being used to help sweep in the 'bite'. A sward length of 10-15 cm is the optimum. The grass is then swallowed without mastication. Patches of grass fouled by excreta are avoided. Steep banks can be badly damaged by stock clambering up and down. Winter feeding on floodbanks to avoid damage to farmers' fields can also cause damage to the bank.

Sheep thrive better if they are grazed in association with cattle and the turf benefits by having surplus growth and tufts cleaned up. Sheep graze closer to the ground than any other stock. The incisor teeth of the lower jaw meet with the dental pad of the upper but without using the tongue, as in the cow. They are best suited to grazing on a short dense sward but fare satisfactorily on longer grass by progressively nibbling the tips of the grass. Raised banks can be used by lambs for basking and depressions can be enlarged and create a weakness in the bank.

A horse eats by peeling back its lips and nipping off the plants close to the base. A short dense sward will suit horses much better than an open sward exceeding 15 cm. Horses grazing without association with other livestock leave a patchy turf with some areas overgrazed to excess and others left with coarse-tufted vegetation. This method of grazing may be satisfactory for wildlife but is less so for keeping the turf in good condition if stocking rates are high. Shod horses can also severely poach the ground and expose the soil.

A pig can be used for grazing but it should always have a nose ring or it will root in the grass for beetles etc. and the turf will be damaged to the point of needing reseeding. Pigs are omnivores but will quite happily just graze, a short dense turf being preferred. Pigs used for grazing banks should not receive a supplementary feed as the droppings produced are very rich and can cause problems.

3.2.7 Wildlife conservation

Brandon (1989) includes chapters on the management of banks for nature conservation, and explanations are given as to the benefits to wildlife of cutting at lower frequencies on some banks, e.g.:

- Permits wild flowers to flower and seed
- Gives cover to small mammals (i.e. in biological terms this means mice, voles and shrews)
- The presence of small mammals provides a hunting ground for owls
- Provides nest sites for ground-nesting birds
- Provides food for seed-eating birds where the bank plants are allowed to flower and the seedheads are left uncut during the winter.

3.2.8 Amenity

An analysis of the water industry's impact on landscape and the opportunity it can present for public access and recreation is presented in a report by the Countryside Commission. Both reservoirs and watercourses are considered and advice is presented on land management, management agreements, design considerations, Environmental Impact Statements, buildings and artifacts.

Work on the amenity aspects of channels has been documented by the British Waterways Board (BWB). Provision is made for the management of towing paths as footpaths, picnic sites with good car access have been made and angling has been accommodated along with the needs of the boating industry.

4. DISCUSSION

In any review of this kind much information, both objective and subjective, is collected. The purpose of this section is to consider the information and its relevance to the specific objectives of this stage of the study (see Appendix 1).

It should, however, be pointed out at this stage in the discussion that the information from the Regions was collected as a snapshot in time and that only readily available data were sought. In a number of cases it was reported that, given more time and resources, it would have been possible to produce the required information. In others, however, it was accepted that the Region(s) did not collect such information. In Regions where no information was readily to hand or it was not collected in a suitable format a subjective assessment was made by the NRA staff. In a number of cases it was not even possible to make a subjective assessment in the given time scale and so a nil return was made.

At a Regional level general information on population, area and river length (see Table 1) seemed to be readily available from published data, which illustrated the wide variations in size between the ten Regions.

Information on the total maintenance budget (including coastal, fluvial and other activities) was available. At face value these figures conclude that approximately £56 million is spent per year on maintenance throughout the NRA. However, the actual costs included within the quoted figure vary considerably from Region to Region. For example, six of the figures exclude all staff and headquarters costs, two include staff and headquarters costs, two cover only part of a Region and one includes some staff costs but not Regional/National HQ costs, indicating a wide variation in methods of collecting basic information on costs.

In Tables 4 and 5 information on the budgets, by the various fluvial maintenance activities, shows that accurate figures on grass management were only available for six Regions. These figures show that for those six Regions approximately £1.1 million per year was spent, of which approximately £600,000 was spent by Severn Trent Region and £220,000 by Yorkshire. Those Regions who did not supply specific figures for grass management estimated that, between them, they spend approximately £1.8 million per year, giving a total of approximately £3 million per year. Table 5 gives an indication of the amount of grass cut and also illustrates the different methods of measure used throughout the Regions, which make comparisons almost impossible. It also shows that no information was available for a large number of the Regions.

All ten Regions of the NRA have adopted some subdivision of the fluvial maintenance budget to make it more manageable (see Table 2) but there is no universal system. It can be noted that some have a purely task-orientated system for all watercourses while others have divisions between asset types (e.g. watercourses and structures). In general, however, a number of basic maintenance activities can be identified for most of the Regions (e.g. grass cutting, weed control, dredging, tree management, debris, etc.). It should be noted that at least one Region (Anglian) has no specific heading for grass management and includes the task within bank and embankments.

All ten Regions have divided their watercourses into manageable lengths in some way and then assigned unique reference numbers within the Region (see Table 3). In two Regions (Southern and Welsh) there also appeared to be variations within the Region. The method of

dividing up the watercourses varied considerably from Region to Region, ranging from a few hundred metres to many kilometres.

In some Regions an assessment of the works to be carried out on each unique river length had been made. Most of these assessments were subjective, although some Regions (e.g. North West, Severn Trent, Anglian) have performed formal assessment exercises to establish the required work to maintain the asset to an acceptable standard. In many cases the acceptable standard (e.g. 'Level of Service') seemed to have been set at a local level, based on a subjective judgement of needs against local priorities. The systems vary from Region to Region and some are better documented than others.

When it comes to in-house workforce training all ten Regions (see Table 6) operate laid-down on-job training for manual workers and full certificated training for machine men. They all have written safety policies and provide safety training for all their operatives. There is, however, a general lack of specific written training material for maintenance tasks and there appear to be no formal Fluvial maintenance manuals in any of the Regions. This was surprising, given that the former Water Authorities had formal manuals for Sewerage Rehabilitation, Water Distribution Rehabilitation, Planning Policy, etc.

For grass cutting there seemed to be general agreement throughout the ten Regions as to why the grass was being cut (see Table 8), the main reasons being:

- Maintaining channel capacity and reducing rugosity
- To allow for visual inspection of the banks for condition and damage by vermin
- Amenity and recreation.

A number of secondary reasons were also given, including:

- To discourage dumping in urban areas
- Controlling weeds and scrub
- To promote denser growth
- Eliminate cover for vermin

Table 7 indicates that each Region has divided its floodbanks into different priorities, i.e. the number of cuts per year vary between different locations. The table also shows the wide variation in the number of cuts per year for similar types of asset (ranging from one to four cuts). In one case it was noted that two adjacent Regions seemed to have differing priorities for what essentially was the same floodbank. While accepting that some differences will occur because of geography and climate, not all of the anomalies could be accounted for.

It is a paradox that the literature notes that the hydraulic roughness of grass is least when the grass is long and the discharge intensity is high enough to flatten the grass, providing a relatively smooth surface, which seems to contradict the information in Tables 7 and 8. However, this situation has to be balanced against a possibly higher deposition of the watercourse's silt load when the grass is longer. In some cases this deposition of silt may result in an unacceptable cost and/or environmental damage (e.g. loss of wildlife habitats) if major works have to be carried out on the channel to bring it back to its original capacity.

Under a manual cutting regime with an annual cut or less, this would have been the bank's normal condition during some floods. When the grass was cut, it was raked and removed so there would have been no build-up of dead material to smother regrowth or loose material to

be swept downstream to block sluices etc. Using a flail enables the vegetation to be macerated and left *in situ* to rot, and dispenses with raking and disposal of grass. It also reduces the need for manual labour. When questioned, only the Yorkshire and Severn Trent Regions felt that a flail would have difficulty in dealing with a single cut a year (i.e. emulating the previous management regime) and no Region perceived that the plant material from a single flail cut would cause problems by physically smothering the turf. (This may be because it is outside their experience. However, when material is returned to rot down there is an enrichment factor which will encourage productivity and present opportunities for weed incursion.)

No-one suggested that there had been an inherent danger from flooding because the labour intensity of cutting by hand had prevented more frequent cuts, but an officer in South West Region remembered that breaches had occurred because weaknesses were not identified early enough due to banks not getting cut. It may be that the regular presence of operatives on the bank for cutting/pest control/inspection contributed to the identification of problems and thus prevented breaches occurring. The old system of 'Length Men' in the Somerset Levels, who lived locally and had responsibility for managing and monitoring a length of bank, was seen to be valuable for this reason. It was noted that all Regions had increased the number of grass cuts per year because of increased mechanisation.

Many Regions had had a 'notable' flood that had tested their banks and may have found them wanting. For the Lower Trent Division of the Severn Trent Region this was in 1947. In the 1950s there had been a number of occasions when banks were overtopped or had breached and the extensive capital works of the 1960s to restructure the banks had been carried out. This had increased the area of grass to be cut. It was also stated that the labour force was three times what it is today.

Some of the arguments directed against the contracting out of grass cutting could also be directed at why grass cutting should not stay at the same level as in the days of manual cutting (e.g. work done in combination with other jobs, effects on in-house work force, environmental damage). It was stated that the cost of cutting twice was less than twice the cost of cutting once, there was less strain on the machinery and there were benefits in cutting it more often. It was noticeable that a number of those Areas/Districts that cut only once or twice a year would like to increase the number of cuts per year, as this was perceived as desirable. Glamorgan, however, intended to increase the number of cuts to keep the Japanese Knotweed under control after an intense spraying programme had reduced but not eliminated it. Northumbria had no plans for increasing the number of cuts but had mechanised only recently, was still rationalising banks to give access for machinery and may do this later. Wessex reported that they may increase the number of cuts on some banks but were considering only cutting alternate banks in other places.

The cutting of banks to facilitate their inspection for weaknesses was noted as one of the most important functions of cutting, although the frequency varied considerably from Region to Region. In some small channels the rugosity factor was equally important. A shift of emphasis from cutting to inspection may need to be considered, given the above comments, if a suitable standard for inspection could be set.

At all levels of cutting frequency it is interesting to note that the reason for cutting was the same. While those Regions with a higher standard (see Table 7) would cut less if they felt they could get away with it or the season permitted it, all Regions felt they were managing to achieve a sufficient standard to protect the banks, even where they would like to increase

the number of cuts. The pattern of the number of cuts does not appear to correspond to rainfall or grass-growth patterns across the country. This suggests that factors other than engineering are more important in determining the 'standard' number of cuts and need to be investigated further. (See Figure 3 later.)

It was difficult from the information collected to ascertain whether the engineers who designed the floodbanks 20 or more years ago did so allowing for a maintenance regime of a single hand cut, which would supposedly require a higher design standard because of less channel capacity caused by the vegetation. It is interesting to consider whether design standards have altered in succeeding years. Alternatively, has there been such an increase in the amount of water runoff over the years as to make the higher standard of design sufficient for the purpose only because of the increased standard of management? These are pertinent questions if one is to justify cutting grass for channel capacity reasons.

It may also be relevant to ask whether, since the demise of the manual cutting regime, the annual inspection of the banks for condition and damage by vermin has been facilitated by a more frequent cutting regime. If so, is it merely a perceived improvement or one in fact? Given that the literature notes that short grass encourages rabbits, might there be reasons why longer grass may be more desirable in some areas?

A number of Regions have included as a subsidiary reason for cutting grass the need to promote denser grass growth. Yorkshire (S) manages the grass to a higher degree than other Regions and harrows it in those years when time permits.

The use of grass for engineering purposes ('bioengineering') is seen at present as an art rather than an exact science. However, some Regions then ignore the fact that even arts have rules, and what is demanded from grass often breaks those rules. For example, grass is expected to anchor the bank with its roots, and it is obvious that the deeper the roots, the better the anchorage is felt to be. At the same time, it is expected to prevent the soil from being washed away. Cutting is thought by some to encourage roots to grow, but it should be noted that root growth, far from being stimulated by cutting, is generally reduced with more cutting (see Figure 1).

Careful attention is also required not only in the establishment of vegetation (e.g. different cutting in the first year of growth, different cutting for wild flower mixes) but also in its aftercare.

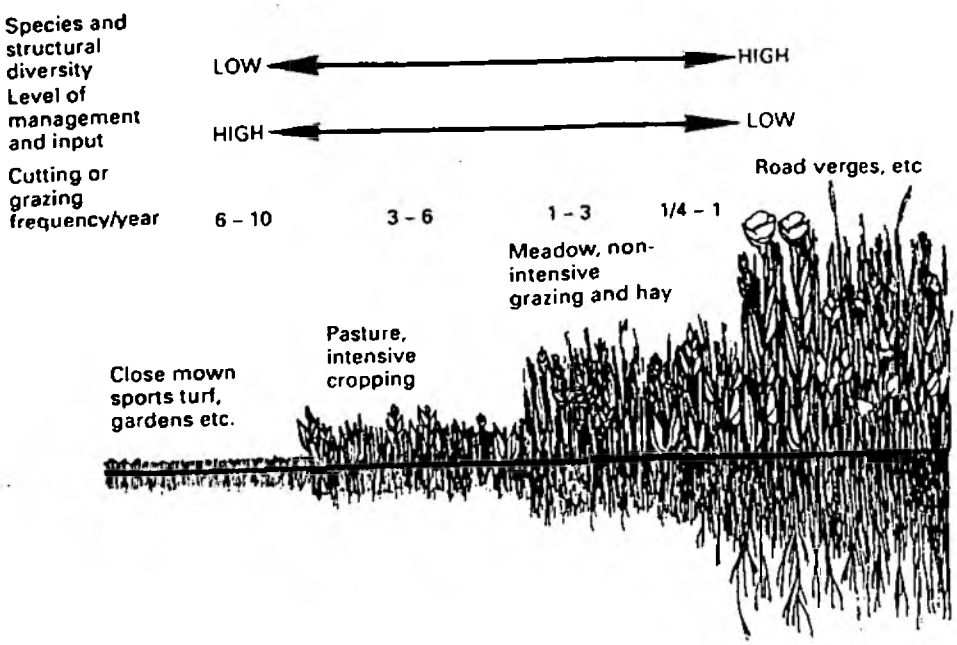

Figure 1 *Grass sward structure as influenced by levels of management*

Most Regions are currently replacing old equipment inherited from the Water Authorities. It was generally felt that Land Drainage (as Flood Defence was called then) was the poor relation within the WAs and was underfinanced accordingly. The creation of the NRA was seen to be the opportunity for replacing with modern equipment but the finances of some Regions still did not always permit this.

However, when interviewed, the Regions stressed that variations in the type of equipment used (see Table 12) usually reflected differences in the banks being cut. Some Regions had already tried a range of equipment and had settled on what currently worked best for their conditions and operatives, and others would like to try an alternative when funding allowed.

For instance, only those Regions which had large stretches of engineered banks seemed to benefit from using a Mulag or an AEBI. The speed of cut that they could achieve during the cutting season was seen by many as being sufficient compensation for their not having an alternative function in winter, as tractors could have. It was claimed that when compared to a tractor and flail an AEBI could put in an extra cut for the same cost. There was, however, little (if any) guidance regarding the need for the extra cut, and the fact that this extra and, at times, unnecessary cut reduced the cost per unit cutting price of the equipment seemed to be ignored when making comparisons between equipment (i.e. the equipment seems to be cheaper but only because unnecessary cuts are done).

Grass is cut in three main areas:

- Raised flood banks
- Channel banks
- Locks, gauging stations, reservoir banks and amenity areas.

(a) **Raised flood banks:** In all Regions these were perceived as the most critical banks to cut. The consequence of failure of one of these banks was seen in terms of the number of houses that would be flooded rather than in acreage of land affected. Banks protecting farmland were seen as slightly less critical and in some areas there are dual banks (e.g. on the River Aire in South Yorkshire) with a second bank set back a quarter to half a mile to contain any water that overtopped the main bank in extreme floods. Depending on the Region and their perception of the cutting needs of their floodbanks, they were cut at least once to a maximum of five times. (See Table 7.) Banks in urban areas may have additional cuts for aesthetic reasons, not just by the Region but also by the Local Council. In the Severn Trent Region an additional reason for cutting urban raised banks frequently was to engender respect for them in the public mind and so deter the dumping of rubbish.

(b) **Channel banks** The cutting of some channel banks was regarded as critical when the capacity of the channel was fixed due to its situation, such as in the middle of an urban area, and the predicted high flows were close to bankfull. Cutting was then done up to three times per year to maximise channel capacity and to reduce the rugosity of the banks. Handcutting was more likely to be carried out on these urban watercourses because of limited access. In some rural areas (Northern Area of Northumbria Region) channel banks were cut once to maintain capacity, particularly where water could back up the channel due to the outlet being affected by high tides. In Thames Region there was some cutting of two-stage channels. Channel banks may also be cut in urban areas for aesthetic reasons where a channel passes through an urban park or down the centre of a village (Severn Trent and Anglian).

(c) **Locks, gauging stations, reservoir banks and amenity areas** Apart from the reservoir banks, cutting for engineering reasons was noted as secondary to aesthetic and amenity at these sites. The area covered by such sites was small in proportion to the total grass cut but were relatively expensive to maintain because there were no economies of scale.

There was ongoing rationalisation of access to banks throughout the Regions for machinery to facilitate cutting. Some of these banks were customarily cut by hand or not cut at all, which led to an increase in the area of grass being managed. Thames Region was the exception, as the responsibility for many areas cut when part of the WA was that of Thames Water (e.g. New River, a potable water supply serving London).

Grass cutting was one of the main summer occupations of Flood Defence operatives. The start of the cutting season is dependent upon the spring weather and whether the grass has begun growing. This could be as early as the beginning of March or as late as the end of April. The start of the cutting season often requires fine judgement on behalf of the Supervisor or Area Engineer, as once growth starts it can produce a great deal of herbage in a short time. This can put a strain on machinery if there was a lush spring growth. Yorkshire Region benefits from the upper reaches of the watercourses that they cut being at a higher altitude, and grass growth there is delayed long enough for them to work upstream.

Many Regions employ their grass management operatives for more hours per week in the summer than in the winter to cope with the increased summer workload. Research has shown (Figure 2) that there is a spring and autumn grass growth peak. Increasing the number of hours worked in summer is a method of levelling out these peaks. Alternative strategies would be to move maintenance workers onto grass management to cope with the peak demand, which would require more equipment, or to hire extra men and machines at peak times. None of those interviewed hired extra grass-cutting machinery to overcome these peaks.

In farming, it is considered to be very important to know when grass is likely to begin to grow and when it will cease, as this determines the timing of certain activities (e.g. how soon cattle can be turned out in the spring, the optimum time for fertiliser to be applied, when fields should be rested, etc). A rough measure of the 'Grass Growing Days' can be worked out for different parts of the country using climatological data (Table 15). (Note: statistics for the 'Grazing Season' will be a few days shorter, as grass has to grow before there is sufficient 'bite' for the stock to graze and grazing ends before trampling damages the turf.)

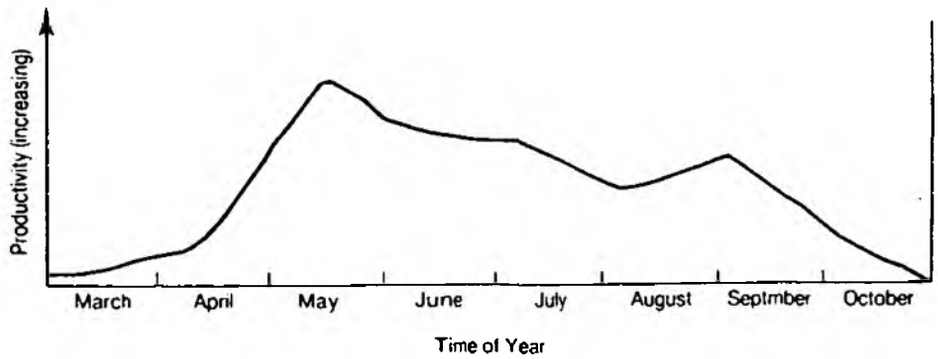

Figure 2 *Classic Hurley annual grass productivity curve (after Rappe, 1963)*

Table 15 Length of grass-growing season

Area	Growing season	GDs	CDs
East Devon	12 March - 18 Dec	281	215
Lower Severn Valley of Gloucestershire and Avon	19 March - 7 Dec	263	212
Sussex around Worthing	19 March - 12 Dec	268	219
South Glamorgan	19 March - 12 Dec	268	178
Cheshire Plain	24 March - 5 Dec	256	203
Lower Trent	29 March - 27 Nov	243	238
Vale of York	27 March - 27 Nov	245	226
Northumberland (inland)	21 April - 7 Nov	200	125
Northumberland coast south of Wooler	2 April - 26 Nov	238	203
GDs = Growing days; CDs = Grazing or cutting days			

It is not easy to define accurately the length of the grass-growing season in terms of meterological variables. There is no precise temperature level, in the air or in the soil, below which growth ceases. In general terms, 42° F (6° C) is regarded as the temperature when growth ceases but some grass species such as Ryegrass are more tolerant than others and may continue to grow. In some areas of the country, such as the extreme south-west of England, the soil temperature in winter is often at or above this level, and in mild winters this phenomenon will be extended around the country. In such seasons it will then be the amount of water or of sunlight available that becomes the limiting factor on the grass growth that occurs. Altitude, slope and aspect will also have an effect, so that there will be local variations (see data for Northumberland above). The turf on river banks in winter is likely to have more grass-growing days than adjacent grass fields; this is because of the microclimate a river creates, especially when embanked. The water tends to be warmer than the land, the air above it more humid and the water table much higher in the banks.

Research has shown that in sunny weather the rate of food production in a grass leaf (assimilation) is good but the leaf growth is poor; in cold, dull weather the assimilation is less but the leaf growth is better. Variations in temperature and light intensity, therefore, make less difference than might be expected. Seasonal variations in crop yield are probably determined more by the rainfall than by temperature (see Russell, 1932).

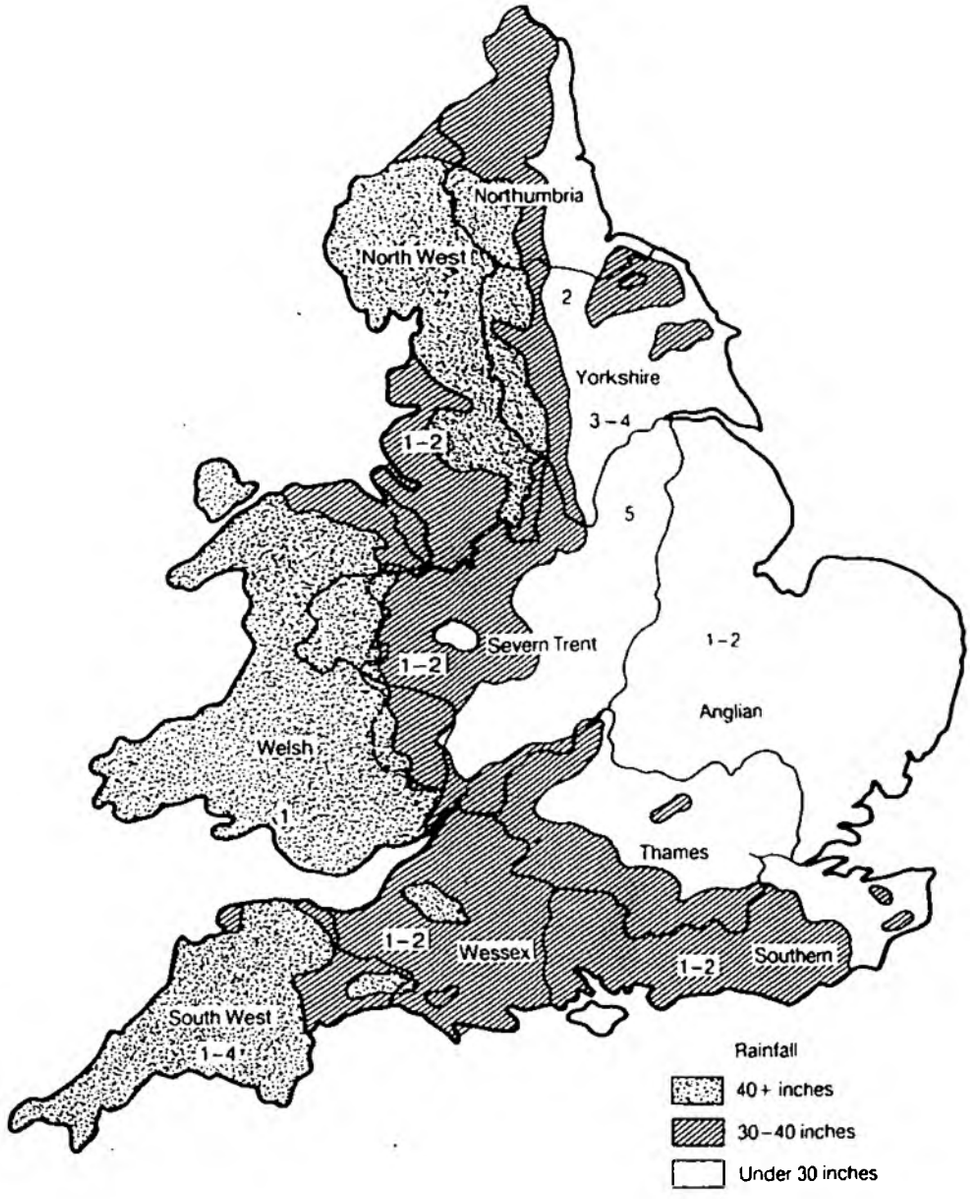

Figure 3 *Number of times floodbanks cut related to rainfall, as a measure of grass growth*

The information provided on what seed mixes were used in the past was sparse and mainly anecdotal. However, information on alternatives to agricultural mixes is a fairly recent phenomenon, and banks in the past were generally sown for the benefit of farmers using productive grass species, (always a Ryegrass, and probably with Timothy and Cock's-foot included). This was the standard agricultural mix for a permanent pasture and was widely used. On one River Trent floodbank Creeping Red Fescue had been used in isolation where it passed through the bottom of a series of gardens.

Conservation and low-maintenance mixes 20 years ago were very much a new idea, being tried by research workers at Monks Wood Experimental Station of the Nature Conservancy (subsequently renamed the Institute of Terrestrial Ecology). As experimental results were published and the idea became widespread and 'popular', more information and seed mixes have become available and all Regions have tried sowing such a mix (see Appendix 5). Anglian, Severn Trent and Yorkshire all have experimental trials using non-agricultural mixes.

Currently, there is still a widespread use of agricultural mixtures around the Regions (see Table 10 and Appendix 5). This was primarily for three reasons:

- The area to be reseeded may be part of a modern pasture and a grass mix similar to that already there is provided at the request of the farmer
- The seeding is being carried out by a contractor as part of a capital scheme
- The information available to those in charge of organising reseeding may be insufficient for them to opt for an alternative whose performance they have not experience of.

Some Regions have a recommended low-maintenance mixture such as North West and Severn Trent, but they are not used widely as yet. However, as some Regions are unable to find grazing tenants for banks or the banks have such steep faces that stock would damage them, cost saving in their management will only come from increased efficiency in cutting or having less vegetational growth.

With the forecast rise in sea levels it was reported that the NRA is studying the need to increase the height of floodbanks, and this would present an opportunity to reseed banks with low-maintenance mixtures. The initial cost of buying the seed and getting it established would be higher but the long-term savings in cutting may well offset this.

The seed mixtures that have been sown on banks by the Authority alter as weed grasses invade. The degree to which the mixture changes depends on how often the site was cut and whether there are other influences such as brackish (saline) water affecting the grass. Ryegrass has remained the main constituent of the mixtures over the years, although the strains used will have varied. However, it requires a high nutrient status and a high level of management to persist (see Section 3.2). Very few of the banks recorded in the spring of 1991 retained Ryegrass as a dominant constituent apart from those cut three to five times. For example, the banks in the Somerset levels are cut one to two times and are affected by brackish water, and Couchgrass dominated the swards there (Appendix 5).

A reduction in the number of cuts by itself may not be the answer to reducing costs, and combining it with the right seed mixture should be investigated.

The Flood Defence Department of Thames Region has what it calls a 'Trading Centre', i.e. a form of the Client/Contractor approach. The extent to which this approach is followed is unique to this Region, although North West has a similar approach to the funding of their conservation staff.

Work had been divided into two specific functions: identification of the work to be carried out as a client function and the carrying out of the work as a contractor function. These two activities are undertaken separately by different people within the Region. An Inspector acts for the client and is managed by the flood defence engineer, and they have no direct labour operatives, plant or materials. The contracting is managed by a supervisor, who reports to the operations engineer and all the operatives are under the control of the operating engineer. Both client and contractor staff report to the Area Manager. The effect of this approach is to delegate responsibility. Initially, the year's work is identified and costed and then staff are left to get on with it rather than working to a budget. Under this system the engineers have to justify everything they do.

The Water Industry has been given statutory responsibilities under various Acts towards wildlife and the environment, the latest of which is the 1989 Water Act:

> Section 8(1) of the Act imposes a duty to further conservation in respect of proposals relating to the NRA's functions, to protect sites of conservation interest and to take account of the effects that any proposals would have.
>
> Section 8(4) imposes a general duty to promote conservation to the extent that the NRA deems desirable.
>
> Section 10 contains a Code of Practice on Conservation, Access and Recreation in respect of the NRA's environmental duties.

The stated aim of the Authority in its Corporate Plan 1990/91 is 'To conserve and enhance wildlife, landscapes and archaeological features associated with waters under NRA control'.

All Regions exhibited a positive attitude towards wildlife and the environment. Each has at least one Conservation Officer/Ecologist, although this might be linked with a Fisheries responsibility (see Table 13). Some Regions have more than one permanent member of staff advising on conservation. North West funds its Ecologists by making their services chargeable. Yorkshire has River Corridor Surveyors as staff in the Areas as well as an ecologist at Headquarters. All officers had access to someone for advice, and major schemes would have an input from an ecologist, but there was rarely scope for fresh initiatives because of the workload of these staff members.

A pamphlet entitled *Conservation Guidelines for the Supervision of Flood Defence Operators involved in River Maintenance* has been produced by Southern Region and one on sowing low-maintenance grass mixes is being considered by Severn Trent. It was mentioned in all Regions that operatives recruited from the rural population had a knowledge and interest in wildlife and had been able to adapt to less stringent work practices that took conservation into account (e.g. cutting round trees and leaving patches or orchids).

Because most of the Authority's works are carried out by agreement with landowners and occupiers it has been considered essential to build up a relationship with the landholders along banks that are cut or channels being dredged. Where there are extensive areas of arable farming the changes in practice over the last 20 years have resulted in smaller 'windows of opportunity' for gaining access, and operatives may have to respond quickly when advised that access is possible. These factors have an influence on planning matters and make the present reliance on local knowledge possibly undesirable for a national organisation.

Efficiency and cost effectiveness in grass cutting has increased significantly in recent years as new machinery has become available. However, in some areas such as parts of Anglian Region it was stated that it has been impossible to purchase the machinery that would make a financial saving, due to the way they are funded.

It was noted that the efficiency of the Regions was also affected by the Local Planning Authority when permitting development adjacent to a watercourse. Hand work is not the most cost-effective way of cutting grass, but where access for machinery was not allowed for on some urban watercourses then this is the only means of management readily available. There may also be channels where the rugosity of the banks may be critical because of the limited capacity of the channel, necessitating an increased level of management.

An example of local planning involves a newly developed group of luxury houses by the River Arun in South Region, whose gardens include a grass strip behind the floodbank. The fences along the last 4-5m are liftable and the house deeds include an acknowledgement of the right of the NRA to remove these fences to gain access for work on the bank. Trees are not allowed to be planted or immoveable structures erected. While currently this may not present a problem, how does the NRA perform its duties in a few years, when the fences have rotted and been replaced with permanent ones, garden sheds have been erected and trees planted in contravention of the covenants?

5. CONCLUSIONS

A number of areas can be identified where no precise information has been forthcoming and which present unanswered questions. A lack of uniformity in systems used (e.g. terminology, units of measure, data storage etc.) was expected, given the history of the organisation, but it made comparative evaluation impossible at times.

It was observed that decisions were taken on a local *ad hoc* basis, using the experience of the people concerned. While there is a move to record and rationalise information connected with routine work, so that jobs done annually can be quickly identified for the year's work programme, much still depends on local knowledge and local contacts. There were no specific manuals on fluvial maintenance and very little other written information available on any aspect of the work beyond the 'best practice' reports prepared by Severn Trent Water and the recent management report by Anglian Region.

Only one Region had identified a standard maximum length to which grass should grow before cutting, and although each Region has identified to its own satisfaction why the grass is being cut, the *standard* to which the bank should be cut was not laid down, neither had any Region identified what constitutes a bank in 'good' condition. There is no uniformity in the units used for measuring the areas cut and some Regions could not quantify this or produce the cost of Grass Management. No Region had identified the consequences of failure for each bank or challenged their traditional perception of why they were cutting the banks.

While the Regions can identify, by a variety of systems, what work needs to be done and some have estimates of the time needed to do it (e.g. under the WIPPS system), no comparison appears to have been made between the work done internally and externally, or how similar work is carried out elsewhere and costed. The exact merits/demerits of contracting grass cutting has not been fully addressed except possibly under the Thames system. Apart from those Regions which still function under the WIPPS system there was often no audit system to check that work has been done.

The survey suggests that if there has been a measure of uniformity in the management of grass cutting across the Regions it has been as a result of the officers in charge having had similar training as engineers, which gives some standardisation of approach to the same problem.

6. RECOMMENDATIONS

Section 4 of this Report has considered the information available and the relevance of the literature review and has drawn certain conclusions which are listed in Section 5. Some of these relate specifically to grass management practices and some to the general management of the fluvial maintenance activity within the NRA. The purpose of this section is to provide recommendations for future work. These have, where possible, been divided into specific items relevant to the study in hand and general observations.

(a) Grass management

1. Investigate the differences in cutting standards presently used throughout the NRA and rationalise. Produce specific guidance on numbers of cuts per year, including length of grass bearing in mind Regional variations throughout the NRA, e.g. soil type, climate etc. The option to carry out more inspection of the floodbank and less cutting should be investigated.

2. Produce a document on the current 'best practice' on main equipment, linking it to the types of banks and conditions they are suitable for, including guidance on environmental issues, number of cuts per year and timing, costs, equipment limitations and advice on removal and disposal of material.

3. Investigate and produce guidance on the use of grass seed including the use of low-maintenance and conservation mixes (including choice of seed, planting, cutting in first year, long-term maintenance cost and practice).

4. Evaluate higher capital cost schemes (possibly with more land take) to produce floodbanks that require less maintenance and that may be more environmentally acceptable.

5. Employee training should be established for grass management.

6. Investigate and produce guidance on the use of grazing as an option for grass management

7. Assess the relevance of the foreign literature on grass management (e.g. Dutch experience) and translate as necessary.

8. Investigate and produce guidelines on weed control and the methods available (i.e. weeds on the grass bank).

9. Investigate the effect on silt deposition of varying the grass length and its effect on (1) above.

(b) General

1. Suitable data storage, handling and monitoring systems should be set up to implement the above recommendations both at national and Regional level, including standardisation on terminology, data collection, measurement units etc.

2. The use of better work-planning systems should be considered to optimise the use of labour and plant.

3. In order to reduce the reliance on local knowledge the use of electronic storage/retrieval systems, wider training and GIS should be evaluated.

4. Identify those areas where greater/clearer statutory powers would enable the NRA to work more efficiently and economically (e.g. having a right to have a working corridor for machinery left along watercourses in built-up areas, consider merits of purchasing banks).

5. Consideration should be given to more clearly defining the client contractor roles within the NRA, and implementing structures to reflect these ideas.

6. Investigate the effect of sea-level rise on floodbank maintenance.

Appendix 1 Project objectives (as listed in the PIA)

OBJECTIVES

Overall Project Objective

Phase 1

To produce interim guidance notes on best practice for riverbank grass management, based on existing practices within the NRA and to identify areas of further research.

Phase 2

To implement the further research identified in Phase 1, carry out field trials, and produce final guidance notes on best practice for riverbank grass management.

Specific Objectives, Phase 1

(a) To examine the efficiency and effectiveness of current grass management techniques across the NRA including environmental, amenity and economic factors.

(b) To assess the scope for improvements of grass management practice within the NRA.

(c) To identify and prioritise Research and Development needs in the field of grass management.

STRATEGY

Phase 1

Survey and desk study by external Research Contractor supervised by Project Leader with support from NRA Regions in provision of available data. Research Contractor chosen on basis of (a) appreciation of good practice and available literature on maintenance and (b) knowledge of flood defence operations.

(a) Agree data information requirements.
Produce and send out questionnaire to NRA Regions.

(b) Assess coverage of available literature (e.g. IWEM Manual on River Engineering; DoE/MAFF Code of Practice on Conservation, Access and Recreation; NCC/ADA Guide and Nature Conservation and Management of Drainage Channels).

(c) Assess data obtained from questionnaires.

(d) Visit each NRA Region to follow up questionnaire, obtain further data and assess practices.

(e) Establish appropriate contacts with external organisations and obtain data. In Phase 1 this will be by correspondence only.

(f) Develop basic framework for categorising maintenance activity; produce draft contents list for report on Phase 1.

(g) Broadly assess the scope for improvements in effectiveness of grass management practices.

(h) Identify and prioritise Research and Development needs for different grass management activities, in terms of (a) achieving best current practices and (b) developing desirable techniques and procedures.

(i) Complete draft Phase 1 project.

(j) Finalise Phase 1 project report following review by NRA.

Appendix 2 List of NRA people visited or contacted

ANGLIAN	-	Richard Kinsby; Alistair Spears; David Williamson
NORTHUMBRIAN	-	Peter Angus; Tony Clarke
NORTH WEST	-	Mark Diamond; Trevor Linford
SEVERN TRENT	-	Rick Lindow; Stewart Powers
SOUTHERN	-	John Donaldson; Ray Hurley
SOUTH WEST	-	Norman Grundy; Nigel Webber
THAMES	-	Nigel Bray
WELSH	-	Alan Abrams; Ken Hollaway
WESSEX	-	Simon Foyle
YORKSHIRE	-	Ken Barton; David Fullwood; Simon Keyes

Appendix 3 Questionnaire returns

A complete list of all responses to the questionnaires can, if necessary, be obtained from the project leader (Ken Barton).

Appendix 4 References for literature review

A further survey of published material was made to supplement that already undertaken by CIRIA as part of Project C89.1, *Review of existing practices for fluvial maintenance operators throughout the NRA*. Sources consulted include:

1. Personal research, books and papers on agricultural, amenity and nature conservation aspects of grass and grass management
2. Visit to the library of the Sports Turf Association
3. Nature Conservancy Council
4. Countryside Commission
5. British Waterways Board
6. Ministry of Agriculture, Fisheries and Food (ADAS)
7. AFRC Institute for Grassland and Animal Production, North Wyke Research Station (formerly the Grassland Research Institute)
8. Agricultural Research Centre at Jokioinen, Finland
9. Derelict Land Unit, University of Liverpool
10. CIRIA

An enquiry into the grass-cutting equipment available was made by visiting a major supplier of equipment: Maestenbrooks of Boston, Lincolnshire.

Information on what machinery is in general use (and why) has been derived from the information supplied by each Region of the NRA. Two plant managers were particularly chosen for an interview on the advice of Maestenbrooks.

TOPICS

This review included references to the following topics with synopses or the whole paper where pertinent:

1. Plant and machinery for grass management
2. Bank engineering
3. Grass species/mixtures for bank stabilisation and protection
4. Seeding methods
5. Management by cutting
6. Management by grazing
7. Wildlife conservation
8. Amenity

1 PLANT AND MACHINERY FOR GRASS MANAGEMENT

(i) DEREK LOVEJOY & PARNERS and
DAVIS LANGDON & EVEREST (updated yearly)
SPON's 1991 Landscape and external works price book
Chapman & Hall

Contains details of the law relating to wildlife, safety, contracts employees, wages etc. Mainly concerned with the costing of works involving earth moving, construction of hard and soft features but not maintenance after construction.

(ii) W W JOHNSON & SON Ltd (1980)
Turf-grass seeds handbook
W W Johnson & Son Ltd

Contains details on the time a machine should cut a type of grass sward appropriate to that machine.

(iii) NORTHUMBRIAN WATER AUTHORITY (1985)
Report by the Treatment and Safety Group:
Examination of existing and proposed ground maintenance methods in the Northumbrian Water Authority
NWA

This report gives a comparison between grass-cutting machines and methods, their advantages and disadvantages for use in a variety of situations and a comparison of their costs.

(iv) SEVERN TRENT WATER (1985)
Land drainage maintenance tasks - grass cutting best practice
0060R

Draft Introduction: The investigation of working practices in relation to rivers and land drainage operations is the third stage of a five-stage plan to improve the overall management of the land drainage service. The aim of this stage is to carry out a 'best practice' exercise, decide work method and frequency and establish targets.

(v) SEVERN TRENT WATER (1986)
Management of river maintenance work - recommended systems
0261R

Introduction: It is evident from the best practice investigations that unit costs could be reduced through improved planning and management control of work. The systems contained in this report all appear to have significant merit towards this end.

(vi) SEVERN TRENT WATER (1988)
Tractor comparison report

Introduction: The Severn Trent Water Authority utilises approximately 300 wheeled tractors and one of the main recommendations of the *Best Working Practice on Tractors* was that we should take steps to rationalise our tractor fleet in terms of make, model and size. (An appraisal follows.)

2 BANK ENGINEERING

(i) BRANDON, T. W. (ed.) (1989)
Water Practice Manual 8. River engineering - Part II Structures and coastal defence works
Institution of Water and Environmental Management

Guidance is given to engineers and contractors involved with the construction of river and coastal defence works, with reference to handbooks, codes of practice and British Standards. The manual discusses the wide range of maintenance and operation required to keep these structures, and plant and watercourses, operating efficiently. The high costs of capital works can be justified only if maintenance and operational standards ensure the designed life and performance of the structures.

(ii) COPPIN, N. J. and RICHARDS, I. G. (1990)
Use of vegetation in civil engineering
CIRIA

Vegetation, widely used in a landscape role in civil engineering, works as a way of reducing visual impact and can also serve an engineering function (for example, to protect and stabilise the ground surface, reducing erosion and mass instability). This practical book covers a wide range of applications of vegetation as an engineering material with which engineers are often not familiar. The specialised skill of bioengineering combines an understanding of engineering principles with a knowledge of vegetation and its interaction with soil, water and climate. The book explains the different functional engineering effects of vegetation and gives information on the selection, establishment and management of vegetation, to enable the engineer to interact effectively with the other disciplines involved.

3 GRASS SPECIES/MIXTURES FOR BANK STABILISATION AND PROTECTION

(i) CANAWAY, P M (1975)

Turf Wear: A literature review
J. Sports Turf Research Institute, No. 51

(ii) CAVE, L. W. (reproduced 1967)
Cave's guide to turf culture
Pelham Books Ltd (Reproduced by Gardeners Book Club_

(iii) BAUMANN, H. and KLAUS, M. -L. (1955)
Root building with a high soil water table
Z. Acker- u Pflbau, 99, 410 - 26

(iv) GARWOOD, E. A. (1967)
Seasonal variation in appearance and growth of grass roots.
British Grassland Society Journal, 121 - 30

(v) RUSSELL, E. J. (1932, 6th edn)
Soil conditions and plant growth
The Rothampsted Monograph on Agricultural Science
Longmans

(vi) SEVERN TRENT WATER (1986-91)
Trent Floodbanks
Research Reports

(vii) SPORTS TURF RESEARCH INSTITUTE (1991)
Turfgrass seed
STRI

Tabulated information on the strains of grasses currently on the market, giving their qualities for different functions (e.g. short growth, winter greenness, compactness and resistance to diseases).

(viii) TROUGHTON, A. (1957)
The underground organs of herbage grasses
Bulletin No. 44, Commonwealth Bureau of Pastures and
Field Crops, Hurley, Berkshire

(ix) WILLIAMS, E. D. (1984)
Changes during 3 years in the size and composition of the seed bank beneath a long-term pasture as influenced by defoliation and fertilizer regime
J. Applied Ecology, 21, 603 - 15

When the input of seed from grasses was prevented, grasses declined by 27% per annum but dicotyledonous species (wild flowers and weeds) by 16%. Many grass species, which made only a small contribution to the seed bank initially, virtually disappeared during the 3 years of the experiment.

4 SEEDING METHODS

(i) CAVE, L. W. (reproduced 1967)
Cave's guide to turf culture
Pelham Books Ltd (Reproduced by Gardeners Book Club)

(ii) COPPIN, N. J. and BRADSHAW, A. D. (1982)
A guide to quarry reclamation: a brief account of the establishment of vegetation in quarries and non-metal open pits
Mining Journal Books Ltd

(iii) COPPIN, N. J. and RICHARDS, I. G. (1990)
Use of vegetation in civil engineering
CIRIA

(iv) ROBERTS, D. and BRADSHAW, A. (1985)
Hydraulic seeding
Landscape Design, August

(v) ROBERTS, R. D. and BRADSHAW, A. D. (1985)
The technique of a hydraulic seeding technique for unstable sand slopes II. Field Evaluation
J. of Applied Ecology, 22, 978 - 94

Hydraulic seeding is used to establish vegetation in areas inaccessible to traditional agricultural machinery. This paper examines the results of trials on sand wastes produced by

the china clay industry. The success of hydraulic seeding is discussed in relation to the effects of mulching, substrate characteristics and climatic conditions on the availability of favourable microsites and natural seed burial processes.

(vi) SEVERN TRENT WATER (1986-91)
Trent Floodbanks
Research Reports

5 MANAGEMENT BY CUTTING

(i) BRANDON, T. W. (ed.) (1989)
Water Practice Manual 8. River engineering - Part II Structures and coastal defence works
Institution of Water and Environmental Management

Advice on cutting banks for wildlife is included.

(ii) COPPINS, N. J. and RICHARDS, I. G. (1990)
The use of vegetation in civil engineering
CIRIA

(iii) DICKINSON, N. M. and POLWART, A. (1982)
The effect of mowing regime on an amenity grassland ecosystem: above- and below- ground components
J. of Applied Ecology, 19, 569 - 77

The effects of mowing frequency and cessation of mowing on ecosytem structure in a semi-permanent grassland are examined, with particular application to amenity grasslands. Below-ground plant components are studied in detail as roots, rhizomes and a detached root fraction.

(iv) LEWIS, G. and WILLIAMS, G. (1984)
Rivers and Wildlife Handbook: A guide to practices which further the conservation of wildlife on rivers
RSPB/RSNC

Advice on cutting banks for wildlife is included.

(v) NEWBOLD, C., HONNOR, J. and BUCKLEY, K. (1989)
Nature conservation and the management of drainage channels
Nature Conservancy Council/Association of Drainage Authorities

Advice on cutting banks for wildlife is included.

(vi) PARR, T. W., COX, R. and PLANT, R. A. (1984)
The effects of cutting height on root distribution and water use of ryegrass (*Lolium perenne* L S23) turf
J. Sports Turf Res. Inst., 60, 45 - 52

The effects of three cutting heights (20 mm, 44 mm and uncut) on shoot growth, root growth and water use during the establishment of a spring-sown turf of *Lolium perenne* were compared. The 44 mm cut only reduced root biomass at soil depths below 15 cm whereas the 20 mm cut reduced roots at all depths and resulted in a 35% reduction in total root biomass. Total water use over the summer period was greatest in the uncut plots and least in the low-cut ones. Cutting also reduced the depth at which water was used from 90 cm to 65 cm. Although cutting reduced the total grass biomass, the root:total shoot ratio stayed the same indicating a direct relationship between root and shoot production.

(viii) WILLIAMS, E. D. (1984)
Changes during 3 years in the size and composition of the seed bank beneath a long-term pasture as influenced by defoliation and fertilizer regime
J. Applied Ecology, 21, 603 - 15

When the input of seed from grasses was prevented, grasses declined by 27% per annum but dicotyledonous species (wild flowers and weeds) by 16%. Many grass species, which made only a small contribution to the seed bank initially, virtually disappeared during the 3 years of the experiment.

6 MANAGEMENT BY GRAZING

(i) ANGLIAN REGION (1990)
Report of a working group on:
Environmentally sensitive management of watercourses in the Northern Area (The Market Harborough Declaration)
National Rivers Authority, Anglian Region

(ii) COPPINS, N. J. and RICHARDS, I. G. (1990)
The use of vegetation in civil engineering
CIRIA

(iii) THOMAS, J. E. H. (1949)
The grazing animal
Faber & Faber

7 WILDLIFE CONSERVATION

(i) ANGLIAN REGION (1990)
Report of a working group on:
Environmentally sensitive management of watercourses in the Northern Area ('The Market Harborough Declaration')
National Rivers Authority, Anglian Region

(ii) BRANDON, T. W. (ed.) (1989)
River engineering - Part II.
Structures and coastal defence works
Institution of Water and Environmental Management

Advice on the cutting of banks for wildlife, the creation of bankside habitat for otters etc is included.

(iii) COUNTRYSIDE COMMISSION (1988)
The water industry in the countryside
Countryside Commission CCP 239

Details of the protection of the high water table of a fenland NNR affected by agricultural drainage are included.

(iv) ERHARDT, A. (1985)
Diurnal lepidoptera: sensitive indicators of cultivated and abandoned grassland
J. Applied Ecology, 22, 849 - 61

In general, species richness of butterflies and moths is closely correlated with that of vascular plants (grasses and wild flowers). It is also high in traditionally lightly cultivated grassland (i.e. unfertilized, annually mown and lightly grazed meadows).

(v) LEWIS, G. and WILLIAMS, G. (1984)
Rivers and Wildlife Handbook: A guide to practices which further the conservation of wildlife on rivers
RSPB/RSNC

Advice on cutting banks for wildlife is included.

(vi) LUFF, M. L. (1966)
The abundance and diversity of the beetle fauna of grass tussocks
J. Animal Ecology, 35 189-208

This paper gives the results of work on the numbers of beetles occurring in tussocks and the life histories of selected common species.

(vii) MORRIS, M. G. (1979)
The responses of grassland invertebrates to management by cutting. I. Species diversity of Hemiptera
J. Applied Ecology, 16, 77 to 98

Rotational cutting is advocated to maintain species diversity of plant bugs.

(viii) MORRIS, M. G. (1979)
The responses of grassland invertebrates to management by cutting. II. Heteroptera
J. Applied Ecology, 16, 417 - 32

Grazing was found to be preferable to cutting to maintain populations of plant bugs.

(ix) NEWBOLD, C., HONNOR, J. and BUCKLEY, K. (1989)
Nature conservation and the management of drainage channels
Nature Conservancy Council/Association of Drainage Authorities

Advice on cutting banks for wildlife is included.

8 AMENITY

(i) BRITISH WATERWAYS BOARD (1981)
Vegetation control manual
BWB

(ii) BRITISH WATERWAYS BOARD (draft 1989)
Waterways Specifications
BWB

iii) COUNTRYSIDE COMMISSION (1988)
The water industry in the countryside
Countryside Commission CCP 239

The publication sets out to identify 'best practice' for all those currently working on aspects of water management and thus bringing the conservation and recreation activities of the industry up to a common high standard. It also intends to present innovative ideas and highlight future opportunities, while acknowledging the accomplishments of those people within the industry that have pioneered this type of work.

9 GENERAL

(i) ANGLIAN REGION (1990)
Report of a working group on:
Environmentally sensitive management of watercourses in the Northern Area
NRA, Anglian Region

(ii) COPPIN, N. J. and SMITH, I. G. (1990)
Use of vegetation in civil engineering
CIRIA

(iii) LEWIS, G. and WILLIAMS, G. (1984)
Rivers and Wildlife Handbook. A guide to practices which further the conservation of wildlife on rivers
RSPB/RSNC

(iv) NATIONAL RIVERS AUTHORITY
Corporate Plan 1990/91
NRA

(v) NORTHUMBRIAN WATER AUTHORITY (1985)
Report of the Treatment and Safety Group:
Examination of existing and proposed ground maintenance methods in the Northumbrian Water Authority
NWA

(vi) RAPPE, G. (1963)
A yearly rhythm in production capacity of graminaceous plants.
Oikos, 14, 44 - 83

(vii) REE, W. O. (1949)
Hydraulic characteristics of vegetation for vegetated waterways
Agricultural Engineer, April, 184 - 9

(viii) SEVERN TRENT WATER (1985)
Land drainage maintenance tasks - grass cutting best practice
0060R

(ix) WILLIAMS, E. D. (1984)
Changes during 3 years in the size and composition of the seed bank beneath a long-term pasture as influenced by defoliation and fertilizer regime
J. Applied Ecology, 21, 603-15

Appendix 5 Grass mixes

This appendix contains information on grass mixes used by the NRA (and others) together with information on plants currently growing on floodbanks in the NRA Regions.

1 GRASS MIXES

(a) ANGLIAN REGION

Standard deep-rooted bank mix - Ely District	**%**
Perennial Ryegrass 'Sisa'	33
Perennial Ryegrass 'Pergamo'	33
Perennial Ryegrass 'Phantoom'	33

Seeding rate: £16/25 kg

Ouse Washes SSSI, Barrier Banks Trial 1990

Standard WA seed mix used for *c.* 40 years (Mix 4)	**%**
Perennial Ryegrass 'Magella'	25
Perennial Ryegrass 'Parcour'	25
Timothy 'Motim'	15
Smooth-stalked meadow grass 'Ensema'	15
Slender Creeping Red Fescue 'Estica'	10
Browntop Bent 'Highland'	5
White Clover ' Kent Wild White'	5

Low-maintenance mix (Mix 1)	**%**
Crested Dog's-tail	15
Perennial Ryegrass 'Bravo'	10
Annual Ryegrass 'Westerworlds'	10
Smooth-stalked Meadow Grass 'Erte'	10
Creeping Bent-grass 'Emerald'	10
Creeping Red Fescue 'Tridano'	10
Timothy 'Motim'	10
Yorkshire Fog	5
Meadow Barley	5
Sweet Vernal Grass	5
White Clover 'Kent Wild White'	5
12 wild flowers	5

Low-maintenance mix (Mix 2)	**%**

Perennial Ryegrass 'Magella'	15
Perennial Ryegrass 'Parcour'	15
Annual Ryegrass 'Westerworlds'	10
Smooth-stalked Meadow Grass 'Erte'	10
Creeping Bent-grass 'Cobra'	10
Crested Dog's-tail	10
Creeping Red Fescue 'Tridano'	5
Browntop Bent 'Highland'	5
Yorkshire Fog	5
Timothy 'Motim'	5
White Clover 'Kent Wild White'	5

8 wild flowers

Low-maintenance mix (Mix 3) **%**

Perennial Ryegrass 'Magella'	15
Perennial Ryegrass 'Parcour'	15
Annual Ryegrass 'Westerworlds'	15
Smooth-stalked Meadow Grass 'Erte'	10
Creeping Bent-grass 'Cobra'	10
Crested Dog's-tail	10
Creeping Red Fescue 'Tridano'	5
Browntop Bent 'Highland'	5
Yorkshire Fog	5
Timothy 'Motim'	5
White Clover 'Kent Wild White'	5

No Wild Flowers

(b) NORTHUMBRIAN REGION

Provisional specification for low-maintenance grass mixtures 1985

Species	**%**
Smooth-stalked Meadow Grass	- (0-15)
Hard Fescue, Sheep's Fescue or Fine-leaved Sheep's Fescue	30 (10-40)
Chewings Fescue	20 (10-40)
Strong Creeping Red Fescue	40 (20-50)
Browntop Bent 'Highland'	10 (0-10)
White Clover	(0-10)

(unbracketed figures total 100%, bracketed figures denote acceptable modifications)
Seeding rate: 50-150 kg/ha (45-135 lb/acre)
Use high rates where full cover is wanted rapidly, or seedbed conditions are poor; low rates where establishment of other species are to be encouraged, or seedbed conditions are good.

(c) NORTH WEST REGION

This Region has a comprehensive table of advice entitled: 'Table 1 Grass Seed Mixes (choice by soil type of grass function)'. As the title suggests, it recommends grass mixes for a variety of soil types and functions with recommended seeding and fertiliser application rates. Advice on the number of cuts, cutting height and whether a wild flora mix recommended by the Landscape Architect might considered is also presented. However, dredged silt did not form one of the categories and information on how to seed and manage cricket fields and bowling greens may not be needed very often. Examples are set out below:

Mix C Heavy soils, clays, demolition and quarry-affected soils
Temporary sites and low maintenance
0-3 cuts/annum - April/July/September

	%
Creeping Red Fescue 'Boreal' (Strong)	40
Annual Meadow Grass 'Reptans'	15
Chewings Fescue 'Waldorf'	15
Crested Dog's-tail	15
Brown-top Bentgrass 'Highland'	10
White Clover 'S100'	5

Seeding rate: 100-140 kg/ha

Mix G Topsoil and reasonable subsoil
Very hard wearing, rapid germination
Requires regular cutting

	%
Perennial Ryegrass 'Sprinter'	40
Smooth-stalked Meadow Grass 'Julia'	20
Creeping Red Fescue 'Boreal' (Strong)	20
Chewings Fescue 'Waldorf'	15
Brown-top Bent 'Highland'	5

Seeding rate: 250-300 kg/ha

(d) SEVERN TRENT REGION

River Torne Improvements, started 1989 SE 6703

Low-maintenance mix specified	%
Slender Creeping Red Fescue 'Dawson'	25
Hard Fescue 'Biljart'	20
Annual Ryegrass	20
Chewings Fescue 'Koket'	15
Fine-leaved Sheep's Fescue 'Festalia'	15

Brown Bent 'Highland'	5

Seeding rate: 100 kg/ha

Low-maintenance mix as provided by seed merchant	**%**
Creeping Red Fescue 'Boreal'	25
Hard Fescue 'Valda'	20
Chewings Fescue 'Banner'	15
Hard Fescue 'Ridu'	15
Brown Top 'Highland'	5
Annual Ryegrass 'Elunaria Westerworlds'	20

Seeding rate: £52.50/25 kg

Horse Paddock mixture	**%**
Perennial Ryegrass 'Morgana' Intermediate heading	25
Perennial Ryegrass 'Lamora' Late heading	40
Strong Creeping Red Fescue 'Boreal'	15
Timothy 'Aberystwyth S48'	15
Wild White Clover 'Rivendel'	5

Seeding rate: £35.94/25 kg

Trent Floodbank Trials

1986 Trial - All included the same 19 wild flowers
All sown at a rate of 150 kg/ha

Mix 1 BSH Ass	**%**
Brown-top Bent 'Highland'	60
Slender Creeping Red Fescue 'Logro'	35
Perennial Ryegrass 'Lorina'	5

Mix 2	**%**
Hard Fescue 'Biljart'	50
Fine-leaved Sheep's Fescue 'Barok'	50

Mix 3	%
Chewings Fescue 'Barfalla'	30
Chewings Fescue 'Frida'	30
Chewings Fescue 'Waldorf'	30
Brown-top Bent 'Highland'	10

Mix 4	%
Slender Creeping Red Fescue	40
Slender Creeping Red Fescue	40
Common Bent 'Bardot'	20

Mix 5	%
Rough-stalked Meadow Grass 'Dasas'	45
Rough-stalked Meadow Grass 'Sabre'	40
Fine-leaved Sheep's Fescue 'Barok'	15

Mix 6 - Called 'Severn Trent Mix but its origins are sadly obscure despite growing very well	%
Perennial Ryegrass (excellent low-growing strain)	55
Timothy	25
Rough-stalked Meadow Grass	10
Red Rescue	5
Crested Dog's-tail	5

1989 Trial - All included the same 12 wild flowers
All sown at a seeding rate of 40 kg/ha plus 20 kg of a nurse Annual Ryegrass (Westerworlds) = 60 kg/ha

Mix 1	%
Perennial Ryegrass 'Arno'	40
Crested Dog's-tail	30
Sheep's Fescue	15
Rough-stalked Meadow Grass	10
Sweet Vernal Grass	5

Mix 2	%
Crested Dog's-tail	50
Slender Creeping Red Fescue 'Merlin'	20
Creeping Bent-grass	15
Rough-stalked Meadow Grass	10
Yellow Hair-grass	5

Mix 3	%
Sheep's Fescue	50
Slender Creeping Red Fescue 'Merlin'	40
Crested Dog's-tail	10

Mix 4	%
Sheep's Fescue	40
Slender Creeping Red Fescue 'Merlin'	15
Crested Dog's tail	15
Flattened Meadow-grass	15
Creeping Bent-grass	10
Sweet Vernal Grass	5

(e) SOUTHERN REGION

'Sussex' mix (agricultural type mix)	%
Perennial Ryegrass 'S23'	27
Meadow Fescue	4
Smooth or Rough-stalked Meadow Grass	4
Creeping Red Fescue	4
Perennial Ryegrass 'Kentish indigenous'	4
White Clover 'New Zealand'	4

Seeding rate: 0.2 oz/yd^2

Being considered: Low-flow/low-grow mix	%
Creeping Red Fescue 'Boreal'	50
Chewings Fescue 'Menuet'	45
Browntop Bent 'Highland'	5

Seeding rate: £52/25 kg

Being considered: High-flow/fast-grow mix	%
Perennial Ryegrass 'Taya'	18
Perennial Ryegrass 'Trimmer'	12
Creeping Red Fescue 'Boreal'	15
Creeping Red Fescue 'Suzette'	10
Chewings Fescue 'Scarlet'	20
Smooth-stalked Meadow Grass 'Trampas'	20
Browntop Bent 'Highland'	5

The level of Ryegrass is deliberately low so as not so swamp the finer grasses which are more salt tolerant.

Seeding rate: £49.75/25 kg

(f) WELSH REGION

Taffs Well, 1988

Long-term grazing ley for cattle and sheep	kg
Perennial Ryegrass 'Frances'	2.5
Perennial Ryegrass 'Talbot'	2.5
Perennial Ryegrass 'Melle'	3.0

Perennial Ryegrass 'contender'	3.0
Timothy 'Erecta RvP'	1.5
White Clover 'N.Z. Grasslands Huia'	1.0

Seeding rate: 13.5 kg/acre £14.00/acre

Shade mixture	**%**
Smooth-stalked Meadowgrass 'Ampellia'	20
Chewings Fescue 'Atlanta'	30
Creeping Red Rescue 'Boreal'	40
Browntop Bent 'Highland'	10

Seeding rate: £48.90/25 kg

Low-maintenance mixture	**%**
Perennial Ryegrass 'Elka'	60
Slender Creeping Red Fescue 'Recent'	35
Browntop Bent 'Highland'	5

Seeding rate: £42.30/25 kg

(g) WESSEX REGION

Ley mixture WR No. 1 mix	%
Italian (annual) Ryegrass	13
Perennial Ryegrass 'Liprior' (early flw)	30
Perennial Ryegrass 'Hercules' (late flw, pasture)	17
Meadow Fescue 'Rossa' (slow growing)	20
Timothy 'Goliath'	17
White Clover 'Huia'	3

Seeding rate: 15 kg/ha (NB the seeding rate for capital works is higher).

(h) YORKSHIRE REGION

General grass seed specification - Riccall Mix

Slopes and floodbanks	kg
Perennial Ryegrass 'Melle'	33.0
Creeping Red Fescue	11.0
Timothy 'S48'	6.5
White Clover 'Grasslands Huia'	4.5

Seeding rate: 55 kg/ha

Flat areas	kg
Perennial Ryegrass 'Melle'	22.5
Perennial Ryegrass 'Talbot'	11.0
Timothy 'S48'	4.5
White Clover 'Grasslands Huia'	2.0

Seeding rate: 40 kg/ha

Ea Beck near Doncaster

Mix for the inside of floodbanks	**%**
Creeping Red Fescue	30
Annual Ryegrass 'Westerworlds'	20
Smooth-stalked Meadow Grass	20
Bird's-foot Trefoil	19
Creeping Bent-grass	10
Wild White Clover	1

Seeding rate: 55 kg/ha £2.50/kg

Ea Beck near Doncaster

Mix for the outside of floodbanks	**%**
Chewings Fescue	25
Sheep's Fescue	20
Bird's-foot Trefoil	15
Smooth-stalked Meadow Grass	15
Annual Ryegrass	10
Creeping Bent-grass	5
Crested Dog's-tail	5
Meadow Foxtail	5

Seeding rate: 55 kg/ha £4.01/kg

Mix sown for a farmer at West Haddlesey, River Aire, SE5525, seeded autumn 1989	**kg**
Perennial Ryegrass 'Wendy'	20
Perennial Ryegrass 'Gran Cropper'	12
Perennial Ryegrass 'Parcuor'	12
Creeping Red Fescue 'Boreal'	8
Timothy 'Goliath'	4

Seeding rate: £1.39/kg

1 BRITISH WATERWAYS BOARD
Waterway Environment Handbook, BWB, 1984

Urban grass areas	**%**
Perennial Ryegrass	30
Creeping Red Fescue	30
Chewings Fescue	30
Brown-top 'Highland'	10

Sowing rate: 340 kg/ha

General low-maintenance mixes	**%**
Creeping Red Fescue	65
Smooth-stalked Meadow Grass	25
Brown-top 'Highland'	10
Chewings Fescue	40
Creeping Red Fescue	40
Brown-top 'Highland'	20

Sowing rates: 170 kg/ha

Steep slopes and embankments	**%**
Creeping Red Fescue	40
Smooth-stalked Meadow Grass	30
Perennial Ryegrass	20
Brown-top 'Highland'	10

Sowing rate: 170 kg/ha

2 ENVIRONMENTAL ADVISORY UNIT, UNIVERSITY OF LIVERPOOL
A Guide to Quarry Reclamation, 1982
N. J. Coppins and A. D. Bradshaw

Two general-purpose grass-legume seed mixes for erosion control and ground cover		1 %	2 %
Perennial Ryegrass	'Manhattan', 'Pelo', Melle', Stadion'	10	25
Common Bentgrass	'Holfior', Bardot', 'Highland'	10	10
Creeping Red Fescue	'S59', 'Dawson', 'Merling', 'Moncorde'	20	30
Fine-leaved Sheep's Fescue	Any	20	-
Smooth-stalked Meadow Grass	'Geronimo', 'Parade', Newport', 'Fylking'	20	15
Wild White Clover	'S184', 'N.Z. Grslnds', 'Huia', 'Kent Wild W.'	10	10
Alsike Clover		-	10
Bird's-foot Trefoil		10	-

Mixture 1: Infertile areas, uplands, or in tree plantations
Mixture 2: More fertile areas, heavy grazed or traffic, lowlands

3 EXISTING CONSTITUENTS OF BANK SWARDS:

Frequency: A = Abundant, D = Dominant, F = Frequent, LA = Locally Abundant, LF = Locally Frequent, O = Occasional, R = Rare

(a) ANGLIAN REGION

River Slea, North Lincs, SK 088485
Cut once a year - late cut

Species	Frequency
Creeping Bent-grass	F
False Oatgrass	F
Meadow Brome	F
Reed Canary Grass*	LA
Cow Parsley	O
Creeping Thistle	O
Goosegrass (Cleavers)	A
Hogweed	O
Sowthistle	F
Spear Thistle	O
Stinging Nettle	A

* Forming a fringe by the water's edge and at the top of the bank where dredged material had been deposited.

Billinghay Skirth, Linconshire SK 154544
Cut once a year

Species	Frequency
Couch Grass	D
False Oat-grass	F
Celandine	O
Goosegrass (cleavers)	A
Persian Speedwell	F
Stinging Nettle	A

(b) NORTH WEST REGION
Padgate Brook, Warrington, Cheshire
Established turf, cut two to three times a year

Species	Frequency
Cock's-foot Grass	F
Red Fescue	F
Cough Grass	A
Broad-leaved Dock	O
Common Sorrel	O
Cow Parsley	O
Creeping Buttercup	A
Hogweed	O
Ribwort Plantain	F
Stinging Nettle	LF
White Dead-nettle	O

(c) NORTHUMBRIAN REGION
Narrow floodbank by River Till, Northumberland
Seeded *c.* 40 years ago, river face not cut every year because of getting access across the crop for tractor, track face cut more often but may not be every year.

Species	Frequency
Cock's-foot Grass	F
False Oatgrass	D
Celandine	F
Common Sorrel	O
Hogweed	O
Stinging Nettles	LA

Extra species noted on trackside face:

Red Fescue	LF
Dandelion	O
Yarrow	O

The track face had a denser, more diverse, sward than the other.

(d) SEVERN TRENT REGION
Trent floodbank cut four to five times a year SK8090

Species	Frequency
Cock's-foot grass	F
Common Bent-grass	LF
Creeping Bent-grass	LF
Perennial Ryegrass	A
Smooth-stalked Meadow Grass	L
Yorkshire Fog	LA
Creeping Buttercup	A
Daisy	O
Dandelion	A
Field Woodrush	O
Ox-eye Daisy	O
Red Clover	O
Ribwort Plantain	F
Self-heal	LA
White Clover	O
Foreshore, additional species	
Broad-leaved Dock	LA
Lady's Smock	F

(e) SOUTHERN REGION

Low raised floodbank on River Arun, Arundel, below the A27 bridge. Cut once a year. Considerable trampling by walkers along bank top.

Species	Frequency
Cock's-foot Grass	O
False Oat-grass	O
Red Fescue	F
Perennial Ryegrass	A
Yorkshire Fog	F
Bramble	O
Cow Parsley	A
Dandelion	O
Soft Crane's-bill	O
Stinging Nettle	O
White Clover	F

White Dead Nettle	F
Yarrow	O

Large raised floodbank on River Arun by Arundel Castle. Central core of chalk. Relatively recent bank.

Species on landward face	Frequency
Cock's-foot	O
Couch Grass	O
Perennial Ryegrass x two productive agricultural strains	D
Rough-stalked Meadow Grass	O
Broad-leaved Dock	R
Cow Parsley	O
Creeping Buttercup	O
Hogweed	O
Soft Crane's-bill	O
White Clover	O

The seed mix on the landward face has taken very well, 100% cover and with a lush growth. The seed mix on the river face has hardly taken at all, and there are large bare patches with annual weeds. This likely to be the effect of the saline water washing against the bank at high tides. The berm is vegetated with a species of Couch, possibly *Elymus repens X pungens*, which is salt tolerant. It is unlikely to have been planted and may have arrived as a 'volunteer'.

(f) SOUTH WEST REGION
Floodbanks in Exeter City, Devon
Cut four times a year

This is also a recreational area, more like a park. The turf is almost entirely Ryegrass but as it is cut regularly and there are few plant propagules in the vicinity that could seed in, this is not surprising.

(g) WELSH REGION
River Taff at Treforest, Glamorgan
Cut twice a year

Species	Frequency
Cock's-foot Grass	O
Red Fescue	A
Tall Fescue	LF
Yorkshire Fog	F
Autumnal Hawkbit	F
Common Sorrel	O
Hairy Bittercress	F
Japanese Knotweed	LF
Mouse-ear Chickenweed	O
Ribwort Plantain	F
Soft Crane's-bill	O
Tufted Vetch	O
White Clover	O

River Ely, Pont y Clun, Glamorgan
Small raised floodbank cut once a year

Species	Frequency
Cock's-foot	A
Common Bent-grass	F
Perennial Ryegrass	O
Tufted Hairgrass	O
Yorkshire Fog	D
Celandine	A
Dandelion	O
Garlic Mustard	F
Ground Elder*	A
Japanese Knotweed	LF
Ragwort	O
Ribwort Plantain	F
White Clover	O

*Had grown under the shade of the Knotweed and remained after recent spraying programme had reduced Knotweed cover.

(h) WESSEX REGION
River Parratt adjacent to NRA office, Bridgewater
Bank affected by saline water. Cut once a year

Species	Frequency

Cock's-foot Grass	F
Common Bent-grass	O
Couch Grass	D
False Oat-grass	F
Tall Fescue	F
Celandine	O
Cow Parsley	O
Hogweed	O
Stinging Nettle	LF
White Clover	L

River Parrat near Burrowbridge, Somerset
Cut twice a year

Species	Frequency
Couch Grass	D
Reed Canary Grass*	LA
Broad-leaved Dock	A
Celandine	F
Mugwort	O

Stinging Nettle	LF

*Plants on top of bank rooted from those dredged from channel

(I) YORKSHIRE REGION

Raised floodbank of Yorkshire Ouse SE 7425
Cut three to four times a year

River face (northerly aspect): species	Frequency
Cock's-foot Grass	F
Perennial Ryegrass	A
Smooth-stalked Meadow Grass	O
Celandine	F
Cow Parsley	O
Creeping Buttercup	LF
Dandelion	O
Ribwort Plantain	F

Arable facing slope (southerly aspect)	Frequency
Cock's-foot Grass	F
Common Bent-grass	F
Perennial Ryegrass	A
Smooth-stalked Meadow Grass	O
Yorkshire Fog	F
Celandine	O
Cow Parsley	O
Creeping Buttercup	F
Dandelion	O
Hogweed	R
Mouse-eared Chickweed	O
Persian Speedwell	O
Ribwort Plantain	F
Selfheal	F
White Clover	O