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A SURVEY OF AQUATIC WEED CONTROL METHODS USED BY INTERNAL DRAINAGE BOARDS, 1973

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SUMMARY

Discussions on aquatic weed research in Britain identified a need for information on present methods of weed control used in different parts of the country as this information might be of value to others. A joint project to obtain the information was carried out by the Association of Drainage Authorities and the Weed Research Organization. A questionnaire was sent to 262 Internal Drainage Boards and replies were received from 245. Analysis of the information provided showed that hand weeding was the most widely used technique, followed by mechanical removal and chemical control in that order. Only very limited use of biological control methods was noted. Hand weeding was usually carried out with traditional tools but one interesting innovation, employing a V-shaped knife attached to a long rod, was reported.

Mechanical removal on banks was usually carried out with standard machinery but, in water, the recently developed weed cutting bucket has found rapid acceptance. Weed rakes attached to draglines are also popular. Equipment is described which has been developed for the removal of cut weed from the water.

Herbicides are now used extensively both on the banks and in the water. There is a need however for more advice on their use and on the Pesticides Safety Precautions Scheme to ensure that only cleared herbicides are applied and side effects are avoided. Some novel bank-operated and floating equipment for herbicide application has been developed.

An appendix describes and illustrates some of the more interesting modifications and developments of equipment by Internal Drainage Boards.

INTRODUCTION

A meeting was held at the Weed Research Organization (WRO) in January 1973 to discuss problems and progress of aquatic weed research in Britain. It was attended by research workers in official organizations and universities, river authority pollution and fisheries officers, land drainage and river authority engineers and members of relevant Government departments and Agricultural Research Council Headquarters. One of the topics raised by Captain P.H.E. Welby-Everard, Chairman of the Association of Drainage Authorities (ADA) Engineering Sub-Committee, was the need to discover how Internal Drainage Boards (IDBs) were tackling aquatic weed control. It was felt that much useful information is likely to have accrued within individual IDBs from years of practical experience and that this might be of value but may not be available to others facing similar problems. Captain Welby-Everard suggested that ADA and WRO should co-operate in a project to collect, report and disseminate this information. This suggestion was approved by the meeting. Following further detailed discussion the proposal was put firstly to the Executive Council of ADA and then to the ADA Annual Conference in June 1973, with a request for funds to support the project. The Conference approved the expenditure of up to £700 from ADA funds to cover the employment of a clerical assistant for 3 months, overheads, travelling and postage, printing and stationery costs while WRO would provide accommodation and scientific planning, supervision and the preparation of the final report.

It was agreed that a preliminary report should be given to the 1974 Aquatic Weed Research Meeting in January/February 1974 and this full report presented at the ADA Annual Conference in June the same year.

METHODS

A questionnaire was drawn up (Appendix I) and sent by the Secretary of ADA to all IDBs listed in the ADA records in October 1973. When completed these were sent to WRO.

The basic information (i.e. yes/no answers, herbicides used) for each IDB was then recorded on a separate punch card. Subject cards were also prepared for the different kinds of weed control operations. From each of these may be obtained a reference to all IDBs using that particular technique (herbicide, machine, etc). Because the object of this survey was to gather information on methods of weed control and bring to light any new or interesting techniques, improvisation or invention, only incidental attention was given to questions of cost, efficiency and the size of the pro lem. However, any future survey to investigate these topics in detail will be able to use the same record system by adding data to the existing IDB cards and creating additional subject cards as required.

Questionnaires were sent to 267 IDBs. The response was exceptionally good and 245 (approximately 92%) completed forms were returned. The amount of detail included in each reply varied as might be expected and 132 Boards were asked for further information to clarify certain points.

As far as possible the yes/no answer technique was used to standardise replies and reduce the number of expressions of opinion. It was not, however, possible to eliminate subjectivity completely because the reporter had to judge for himsel whether a technique was new, unique and worth including. As a result a number of methods were reported as new by some IDBs who had only recently introduced them and were omitted by others who had been using them for some years, e.g. the weed cutting bucket. A large number answered es' to a question about new or modified equipment but did not provide details and thus necessitated further clarification. This was obtained either b letter or telephone and those items judged to be new or uncommon were followed up by a visit from Mr. P. Barrett of WRO whose report is attached as Appendix II.

RESULTS

The numbers of IDBs using the different forms of weed control are given in Table 1. Most of them still find it necessary to use traditional hand methods against all groups of weeds and also use some form of mechanised weed cutting equipment. Sixty per cent use chemicals on the banks while almost 50% have tried them on submerged weeds. The comparatively low number attacking algae (blanket weed) with chemicals comp red with the numbers removing it by hand or machine perhaps indicates a need for a suitable, safe algicide.

All the 10 Boards reporting biological control of bank weeds use sheep intentionally to keep down the grass and the reeds.

The figures in Table 1 are simply the numbers of Boards using each kind of technique and do not necessarily reflect the amount of channel treated. This information was not requested in the questionnaire.

Table 1 The number and percentage of IDBs using the different methods of weed control

	Hand methods	Mechanical methods	Chemical	Biological
Total number of IDBs using each method	224 91%	191 78%	150 61%	
On banks/batters	211 86%	178 73%	146 60%	10 4%
On emergent weeds in channel	198 81%	176 72%		
On submerged and floating weeds	173 71%		117 48%	
On filamentous algae	166 68%	151 62%	60 25%	

METHODS OF WEED CONTROL

Hand methods

Fifteen IDBs reported new or modified hand tools. Most of them were minor modifications to traditional tools such as altering the angle between the blade and shaft of a scythe to make it easier to use on a slope.

One idea for scything submerged weeds from a boat is described in Appendix IIa. A similar tool with the V-shaped knife attached to a chain instead of the rigid rod has been used on the Continent and was available commercially some years ago.

Mechanical methods

The majority of improvements to the traditional manual methods of weed control have been aimed at reducing labour needs by mechanisation. Sometimes this has been done by using and adapting machinery developed for other situations e.g. motor mowers and draglines. In other cases, and

especially to deal with submerged weeds, it has been necessary to develop new machines.

The questionnaire sent out to IDBs was designed to obtain information on new equipment and modifications made by engineers to the standard machinery. It was not intended to collect full details of all the equipment used. As a result the judgement of whether a machine is of interest and worth reporting was left to the person filling in the form. This has led to unevenness between replies and it would be unreliable to extract statistics on numbers of IDBs using different machines. However, it is possible to list most of the specialised equipment below and describe some of the modifications in Appendix II.

Manufacturers of weed cutting machinery reported by Internal Drainage Boards

Flail, rotary and reciprocating mowing machines

Barfords of Belton Ltd.

Bomford Bros. Ltd.

Berky (Krinke & Krüger GMBH)

Hayter's Ltd.

Lupat Ltd.

Turner Engineering Ltd.

Weed cutting buckets

Bradshaw (Contractors) Ltd.

Herder (Krinke & Krüger GMBH)

F.W. McConnel Ltd.

Weed cutting boats

E^{rs} G. Gibeaux (Importer, Rolba Ltd.)

J. Wilder (Engineering) Ltd.

New or modified equipment

Machinery for weeds on banks

Much of the cutting on the banks is done by a rotary or flail mower on a hydraulic arm extension. In some instances a weed cutting bucket on the hydraulic jib of an excavator is used. It is only possible to use the tractor or excavator mounted equipment when the adjacent land is not being cropped and in arable areas this means limiting the operation to a period before sowing or after harvesting. This is a serious limitation to mechanical weed clearance because weeds need most attention while the crop is growing. The small specialist mowers from the Continent (Appendix II.2)

are an attempt to overcome this problem of access, but the few reports available on their performance in this country are not very favourable.

Of the 178 Boards using machinery on the banks 34 reported having new or modified equipment. Many of these were found, on further enquiry, to be standard commercial equipment comparatively recently introduced but well enough known not to be classed as new.

Machinery for weeds in water

a) Bank based

The most spectacular development in recent years has been the introduction of the weed cutting bucket. Originally introduced from the Netherlands it is now manufactured in this country in 3 sizes (12 ft, 9.5 ft and 6 ft). The most popular size at present is the 9.5 ft but some believe the larger 12 ft version will supersede it. Very few Boards are using the tractor-mounted 6 ft bucket and those that do find that its reach is often insufficient. A modification to the weed-cutting bucket to enable it to tip sufficiently to empty its contents close to the side of the excavator has been made and is referred to in Appendix II.3A.

Many Boards use a weed rake on a dragline. The River Ivel IDB has bolted a steel blade onto the tines of one of these rakes and finds it very efficient for cutting weeds and removing some silt as well (Appendix II.3B). It is more robust than the weed-cutting bucket but a version of the latter is being developed suitable for use with a dragline. The Gwynedd River Authority has built a rake to its own design (Appendix II.3C).

b) Weed cutting boats

Two weed cutting boats are available in this country. Each has its advantages and drawbacks and full specifications should be obtained from the distributors.

c) The removal of cut weeds from the water

Some weed cutting equipment e.g. the weed rakes and weed-cutting bucket, removes the weeds from the water after cutting them and some IDBs reported having equipment specifically designed for weed removal. The Witham Fourth IDB has a weed rake 10 ft wide with tines 2 ft long for use with a dragline and used primarily for dragging out blanket weed. Similar weed rakes are known to be used by other IDBs. The Trent River Authority has a floating weed elevator and mechanised rake on a screen at a pumping station (Appendix II.4).

The Welland and Deepings IDB have for some years been using a mobile crane for weed removal. This has certain advantages over draglines amongst which are its mobility and its versatility (e.g. it can be hired out as a crane when not needed for weed removal).

The Wilder boat now has a rake which can be attached to the hydraulic lift in place of the cutting blade and can sweep up the floating cut weed, lift it from the water and dump it on the bank.

Machinery for algae (blanket weed)

One hundred and fifty one IDBs use machinery for removing algae. Fifteen reported new or modified equipment, but when these were investigated it was found that most were either weed-cutting buckets or weed rakes. In fact the same equipment as is used for submerged weeds.

Chemical weed control

The use of herbicides was investigated in some detail. IDBs were asked to provide information on all the herbicides used by them on the three main groups of weeds (emergent, submerged and algae). They were asked for dose, method and time of application and their opinion of the result. As had been expected most of the replies referred to trade names and manufacturers' recommendations. Many, however, did not mention the formulation used and others gave unusual units of measurement (e.g. oz per chain). In order to standardise and group the treatments a large proportion of IDBs had to be contacted several times.

Of the IDBs who returned the questionnaire 95 (39%) do not use herbicides at all. More than half of the Boards spray the banks of channels and emergent weeds (60%), nearly half (48%) use herbicides regularly or have at least tried them to control submerged and floating weeds and a quarter have tried them on filamentous algae (Table 1). A list of the herbicides used and the numbers of IDBs using them is given in Table 2.

A number of interesting points emerge from this table. Although only eight herbicides have been officially cleared under the Pesticides Safety Precautions Scheme (PSPS) for use in or near water eighteen chemicals are included in the list. In Table 2 the herbicides and herbicide mixtures which were acceptable under PSPS in 1973 are marked with an asterisk and it will be seen that in the majority of cases (429) cleared herbicides were used.

Table 2 Number of IDBs using herbicides

	Emergent	Submerged	Algae
Asulam	6	-	-
Copper sulphate	-	-	14
*2,4-D	29	15	-
*Dalapon	99	3	2
*Dalapon/2,4-D	4	-	-
Dalapon/MCPA	2	-	-
*Dalapon/paraquat	22	-	-
*Dichlobenil	41 (10)	105 (4)	17 (1)
Dimanin	-	-	5 (5)
*Diquat	6	45	29
Diuron	-	1	17 (16)
MCPA	11	-	-
*Maleic hydrazide	1 (1)	-	-
*Maleic hydrazide + 2,4-D	12	-	-
*Maleic hydrazide + 2,4-D + chlorpropham	1 (1)	-	-
Maleic hydrazide + MCPA	2	-	-
Mecoprop	1	-	-
Paraquat	35 (1)	3	2
Picloram/2,4-D	7	-	-
Sodium chlorate	1	-	-
2,4,5-T	4	-	-
2,4,5-T + 2,4-D	6	-	-
Terbutryne	-	1 (1)	17 (17)
WL 63611	-	3 (3)	4 (4)

The numbers in brackets refer to experimental use, but they are included in the original total.

* Herbicides cleared under Pesticides Safety Precautions Scheme for use in or near water.

In the 142 instances when non-cleared herbicides were used 40 applications were experimental and probably on a very small scale. Most of these would also have received PSPS "trials clearance" through the commercial firm supplying the chemical. Of the others a number would have been foliar sprays on patches of brambles and other woody species on the bank (picloram/2,4-D, 2,4,5-T and 2,4,5-T/2,4-D) and applied to a portion of an area only. It is unlikely, therefore, that uncleared herbicides are used on anything but a

very small scale. However, that they are used at all indicates that the user either does not know of the Pesticides Safety Precautions Scheme or does not appreciate the risks involved. Information on this scheme is available from the Ministry of Agriculture, Fisheries and Food and is summarised in the Ministry's Bulletin 194 "The Control of Aquatic Weeds" (revised version October 1973).

One uncleared herbicide which must receive particular mention is picloram. This was used by 7 Boards administered by the same River Authority for the control of giant hogweed. It is one of the most active of all herbicides against broad leaved plants, is very soluble and persistent. There is, therefore, a great risk to susceptible irrigated crops even if only a very small amount is used and thus it should never be allowed near any water body.

Since this survey was completed terbutryne has received "provisional clearance". This adds an efficient algicide to the list of cleared herbicides. There are now suitable chemicals for all the main weed groups and there should be no need to use any uncleared products.

Another point of interest is that in some instances cleared herbicides have been used against weed groups for which they have not been recommended. Dalapon is only effective against certain reeds and yet it has been used on submerged weeds and algae; dichlobenil is not recommended as an algicide but 17 IDBs have tried it against blanket weed; and diquat is not normally used on emergent plants but 6 IDBs have done so. This again seems to stem from a lack of knowledge which could be overcome by reading the label on the container carefully and referring to Bulletin 194.

On the whole most IDBs attempted to use the herbicides at the doses recommended by the manufacturer. In practice it is difficult to ensure the exact dose but there were a few cases where it was intentionally increased or decreased by 50% or more. Herbicide recommendations on the label have been reached after a long period of research and development and it is, therefore, unlikely that performance can be improved within the limits set under the PSPS by changing the dose. This is particularly true of those products that have been approved under the Agricultural Chemicals Approvals Scheme, since this approval signifies official confirmation by the Ministry of Agriculture, Fisheries and Food of the recommendations on the label.

<u>Herbicide application equipment</u>

Thirty-three IDBs reported having built or modified application

equipment. In most cases this has meant adapting commercial motorised sprayers for operation from a Landrover or trailer with hand lances and/or long booms.

In Appendix II.5 details are given of some of the more novel modifications to tractor mounted equipment. These are concerned with designing a spray boom which will reach the weeds in a channel to the side of the tractor. Some are mounted on the fore-loader so that they can be raised or lowered as required. The booms are purpose built and may be long and straight for spraying long batters e.g. Burnt Fen IDB equipment or shaped to spray both sides and the bottom of a narrow ditch e.g. Witham Fourth IDB.

As with mechanical control spraying from the bank raises problems of access which are increased by the risk of accidental herbicide damage to the crops. Where there is sufficient water boats are used for spraying. There is no commercially produced boat for this purpose and as a result some IDBs have built their own equipment. A list of those concerned and details of some of the equipment are given in Appendix II.6. Another advantage of a boat mounted sprayer is that the water for the spray can be drawn directly from the channel saving space and time.

Some IDBs have arranged with a contractor to spray dalapon from a helicopter (Appendix II.7). An invert emulsion (i.e. water droplets formed in the oil instead of oil droplets in water and the viscosity is increased) has been used and the dose of dalapon reduced by about 50%. All but two of the IDBs (King Sedgmoor & Cary Valley and Curry Moor in Somerset) reported good results. The poor results may be due to the treatment of resistant species rather than to the method of application.

CONCLUSIONS

The very good response from IDBs to the request for information and their co-operation throughout the survey has provided very good data on present weed control practices. It has also indicated the interest in this subject amongst IDBs.

Although most Boards still find a need to use hand labour wherever possible cutting is being mechanised. Generally Boards appear to consider the equipment commercially available for cutting weeds and grass on the batters as adequate and little modification is attempted. However, there still appears to be a need for an efficient system of controlling weed growth on the batters during the cropping season. The availability and

efficiency of small specialist machines on the Continent should perhaps be investigated further and so should the possibility of safe growth retardant chemicals.

No modifications to weed cutting boats for submerged weeds were reported. The removal of cut weed however appears to present problems and some original ideas for overcoming them have been mentioned by some Boards.

Herbicides are now used extensively both on the banks and in the water. There appears to be a need for more advice on their use and more publicity for both the Pesticides Safety Precautions Scheme and the Agricultural Chemicals Approvals Scheme to ensure that only those herbicides cleared and approved under these schemes are used and that they are applied at recommended doses.

The correct use of herbicides presupposes the correct interpretation of the instructions on the herbicide label and this in turn the correct identification of the weeds concerned. A lack of this knowledge and an absence of biological advice probably contributed largely to the instances where herbicides were applied to the wrong group of plants and this may be responsible for a number of reports of chemicals not controlling "susceptible" weeds.

Herbicide spraying equipment provided the greatest need for modification. No specialised equipment for aquatic weeds is available commercially and agricultural sprayers, apart from knapsack sprayers, required some modification or improvisation if only in replacing the boom with hand lances. Considerable ingenuity has been shown by a number of Boards in their attempts to build efficient booms and to develop boat-mounted sprayers. Much useful information is thus available to others considering herbicide spraying.

The use of a helicopter has been limited to applying dalapon in an invert emulsion ("Biflon"). All the treatments were done by one firm centred in the fens. Aerial application has the advantage of speed, ease of access and a smaller herbicide dose but is usually expensive and the risk of spray drift increases the risk to adjacent crops. It is unlikely that aerial spraying will be used for any herbicide other than dalapon because the others are much more active and affect a wider range of crop plants.

Finally the data collected in this survey will form a useful

reference for future surveys and studies of weed control methods and the changes that take place over the years.

ACKNOWLEDGEMENTS

My thanks are due to the Association of Drainage Authorities for providing funds for this survey; to Captain P. Welby-Everard for suggesting and encouraging it; to Mr. H. Wells and Mr. D. Miles for active assistance with the preparation and distribution of the questionnaires and especially to all those officials of the IDBs who completed the questionnaires and patiently responded to our further enquiries and visits.

APPENDIX I

Association of Drainage Authorities

RESEARCH ON THE CONTROL OF AQUATIC WEEDS

Weed Research Organisation

Research on the control of aquatic weeds
Co-operation between A.D.A. and Weed Research Organisation
Methods of Water Weed Control

QUESTIONNAIRE

The questionnaire is in 3 parts.

Section A Is simply a record of who is reporting.

Section B Lists the main groups of weed control operations under the methods used and the 4 main groups of weeds. All that is needed here is a choice between 'yes' and 'no'. Whichever is not applicable should be crossed out.

Section C When the answer to a main question in Section B (i.e. one that is underlined) is 'yes' please give details and a description of equipment used under the appropriate heading in Section C.

To be of greatest assistance to other people the description and specifications of locally developed methods or equipment should be as full as possible to enable them to be copied.

Section A.

Questionnaire for collection of information on weed control operations.

Name of Person reporting

Name of I.D.B.(s)

Acreage Covered

Address Telephone No.

Date

Section B.

1. **Hand methods**

Do you use hand tools on

1.1. **Weeds on banks and batters** .....Yes/No 1.1.

If yes – are the methods you use

1.1.1. long established (i.e. been used more than 10 years) ..... Yes/No 1.1.1.

1.1.2. Modified by I.D.B..... Yes/No 1.1.2.

1.1.3. New (including developed by I.D.B. ....., Yes/No 1.1.3.

1.2. **Emergent weeds in channel**.....Yes/No 1.2.

If yes – are the methods you use

1.2.1. long established .....Yes/No 1.2.1.

1.2.2. Modified by I.D.B.....Yes/No 1.2.2.

1.2.3. New (including developed by I.D.B.).....Yes/No 1.2.3.

1.3. **Submerged and floating weeds**.....Yes/No 1.3.

If yes – are the methods you use

1.3.1. long established .....Yes/No 1.3.1.

1.3.2. modified by I.D.B. .....Yes/No 1.3.2.

1.3.3. new (including developed by I.D.B.) .....Yes/No 1.3.3.

1.4. **Filamentous algae (blanket weeds)**..... Yes/No 1.4.

If yes – are the methods you use

1.4.1. long established .....Yes/No 1.4.1.

1.4.2. modified by I.D.B. .....Yes/No 1.4.2.

1.4.3. New (including developed by I.D.B.).....Yes/No 1.4.3.

2. Mechanical Methods

Do you use machinery on

2.1. **The banks and batters**.....Yes/No 2.1.

If yes – do you have any unusual machines operating from

2.1.1. the bank .....Yes/No 2.1.1.

2.1.2. the water .....Yes/No 2.1.2.

2.2. **Weeds in the water**.....Yes/No 2.2.

If yes – do you have any unusual machines operating from

2.2.1. the bank .....Yes/No 2.2.1.

2.2.2. the water .....Yes/No 2.2.2.

2.3. **Algae (blanket weeds)**.....Yes/No 2.3.

If yes – do you have any unusual machines operating from

2.3.1. the banks.....Yes/No 2.3.1.

2.3.2. the water.....Yes/No 2.3.2.

3. Chemical Methods

Have you used chemicals to control

3.1. **Emergent and bank weeds** .....Yes/No 3.1.

If yes – please complete below

	Chemical	dose lb./ac. and vol/ac.	Method of application	Usual time of application	Result (good fair/poor)
3.1.1.					
3.1.2.					
3.1.3.					
3.1.4.					

3.2. **Submerged and floating weeds other than algae**..... Yes/No 3.2.

If yes – please complete below

	Chemical	dose	Method of application	Usual time of application	Result (good fair/poor)
3.2.1.					
3.2.2.					
3.2.3.					
3.2.4.					

3.3. **Algae** – (blanket weed) .....Yes/No 3.3.

If yes – please complete below

	Chemical	dose	Method of application	Usual time of application	Result (good fair/poor)
3.3.1.					
3.3.2.					
3.3.3.					
3.3.4.					

3.4. **Have you built or modified any herbicide application equipment** .....Yes/No 3.4.

4. Biological methods

Do you use any biological methods (e.g. herbivorous fish, sheep grazing etc. .....Yes/No 4.1.

4.1. **on the banks/batters**.....Yes/No 4.1.1.

4.2. **in the water**.....Yes/No 4.1.2.

Section C

Description of interesting and new methods of weed control.

Please give details of any equipment and method you find particularly useful. There is no need to list tools that are commonly used unless they have been improved in some way.

Please make each entry under the appropriate heading, on a separate piece of paper, as this will make it much quicker to handle and sort the information.

1.1. Hand tools on banks and batters.

1.2. Hand tools on emergent weeds (reeds etc.) in the channel.

1.3. Hand tools on submerged and floating weeds.

1.4. Hand tools on algae (blanket weed).

2.1. Machinery on banks and batters.

2.2. Machinery on weeds in the water.

2.3. Machinery on algae (blanket weed).

3.4. Application equipment for herbicides (e.g. sprayers, granule applicators).

4.1. Biological methods on banks (e.g. sheep).

4.2. Biological methods in water (e.g. herbivorous fish, ducks).

APPENDIX 2

EQUIPMENT BUILT OR MODIFIED BY INTERNAL DRAINAGE BOARDS

P.R.F. Barrett

This information was collected during the winter months when many IDBs were servicing and repairing machinery and it was therefore not possible to view all the equipment in working order.

Some of the equipment developed by IDBs has not been included. Where two or more pieces of machinery were found to involve the same basic design with only marginal differences in detail then a description of one has been omitted.

I would like to thank the engineers who showed me their equipment and took so much trouble preparing it in advance of the season.

1. Hand cutting of submerged weeds from a boat

Two scythe blades have been bolted together giving an arrow shaped cutting face. The point of the arrow is attached to steel conduit 10-16 ft long and the other end of the conduit is connected to a handle bar held by the operator standing in a boat. Another operator controls the boat with an outboard motor. The actual cutting is done by a series of jerking motions of the arms. The angle of the blades is adjustable depending on the thickness of weed as is the length of conduit for different depths of water.

The technique is in use by Selby, Selby Dam, Lower Aire, etc Internal Drainage Boards.

2. Berky slopemower

The slopemower is a 2 wheeled mowing machine with a 4 ft reciprocating cutter bar. The cutter bar extends on one side of the machine and a long bar with the throttle control attached to it extends on the other side so that the operator steers the mower from higher up the bank. It can operate on slopes of 1.5:1 and is used in areas inaccessible to larger machines or where small areas require cutting. The machine is satisfactory where the banks are reasonably firm but is difficult to operate on a loose or uneven surface. The Middle Level Commissioners use this machine.

3. Machinery for weeds in water

A) The Upper Axe and Upper Brue IDB has modified the head of the Bradshaw

weed bucket by moving the linkage points so that it can be emptied close to the tracks of the excavator. This reduces the need for slewing and keeps the cut weed close to the bank and parallel to it instead of being spread in a wide path away from the bank. The modification was carried out by Messrs. Bradshaw (Contractors) Ltd.

B) The River Ivel IDB has attached a cutting blade to the tines of a Priestman rake, Plate 1. This cuts the larger weeds and is robust enough to allow the rake to be used for cutting through silt so that roots and silt are removed with the cut weed.

C) Plate 2 shows a weed rake made by Gwynedd River Authority. The rake is used on ditches in the Internal Drainage District where the weed needs clearing but where the ditches are already deep enough and therefore do not require dredging.

4. <u>The removal of cut weeds</u>

The Trent River Authority have a farm elevator mounted on floats, or on a platform in the bank. It is necessary to arrange floating booms to bring the weeds exactly to the pick up point. Two or three men are needed to operate and clear the tip etc. but the heavy lifting is much reduced. This equipment has been set up by the Trent River Authority workshops, and none appears to be available from manufacturers.

The Trent River Authority also have a fixed screen with mechanical rake installed at the pumping station at Dirtness. It replaces one third of the width of the original 30 ft wide screen. The rakes are fixed to an endless belt and are carried upwards through the screen, the material collected being forced off the tines at the top of the downward travel, depositing the weed onto the platform at the rear. A conveyor belt or a tub on rails etc. can be arranged to collect and remove the weed. The rake is driven by a 10 h.p. electric motor and is arranged to operate when the pumps are started so that the station is automatic. This machine has been developed by Messrs. Longwood Engineering Co. Ltd. of Huddersfield, the makers of Parkwood screens.

5. <u>Land based spraying equipment</u>

A number of IDBs reported that they had modified agricultural spraying equipment for use with Landrovers, tractors or trailers using hand lances and spray booms. Since these were mostly constructed of commercially available agricultural equipment and the modifications were fairly minor they are not described here in detail.

Three machines which incorporated novel ideas are described below.

A) Tractor mounted bank sprayer. A 21 ft boom is mounted on the fore-loader of a tractor so that the height can be controlled by the driver using the hydraulics of the tractor (Plate 3). The spray unit is a standard Dorman sprayer working off the tractor power take-off. The boom is divided into 3 sections for spraying so that individual sections can be switched on and off as required. For transport the boom swings parallel to the tractor. This machine is used mainly for spraying reeds and broad-leaved weeds on the banks and has been used for 4 years by Burnt Fen IDB.

B) Tractor mounted ditch sprayer. The spraying rig consists of a V-shaped boom suspended from a hydraulic jib mounted laterally on a tractor. (Plate 4). The two halves of the boom, each 5½ ft long, which are adjustable for width and angle are suspended from the jib so that they spray both banks of the ditch while a small 1½ ft boom with 3 nozzles sprays the bottom of the ditch. A granule spreader is mounted above this small boom so that the bottom of the ditch may be treated with dichlobenil at the same time. The granule spreader has a screen to prevent the granules from going on the ditch banks. There are 2 operators, one controlling the tractor while the other operates the sprayer and controls the extension and height of the jib. This has a maximum reach of 14 ft and can be swung into a vertical position for transporting. The spraying rig is used mainly for maleic hydrazide and 2,4-D on grasses and broadleaved weeds on the banks and dichlobenil for total weed control in the ditch bottom. It has been in use for 7 years by Witham Fourth IDB.

C) Combined flail mower and bank sprayer. A system combining a flail mower with a short spray boom has been developed by the Upper Medway Internal Drainage Board. (Plate 5). The Board has attached an Allman spray unit with a 4 ft boom to a Lupat flail mower. The spray boom is mounted on the rear of the flail mower and the hydraulic arm is used to position the spray boom as required. The system can, therefore, be used for mowing or spraying, though not in a single operation.

6. Boat mounted sprayers

IDBs using boat mounted sprayers:

Black Sluice

Burnt Fen

(Middle Fen of Mere

(Waterbeach Level

Middle Level Commissioners
(South Welland
(South Holland
(South Welland Embankment
(Holland Elloc
(Sutton Bridge
Welland and Deepings
Witham Fourth District

A) Witham Fourth IDB have a small flat bottomed boat propelled by a single paddle wheel driven by a petrol engine and steered by twin rudders linked astern of the paddle. (Plate 6). An 8 ft off-set boom is mounted in front of the operator and is adjustable for angle, height and position. The boat carries a small tank of herbicide concentrate which is mixed with water from the river in the correct proportions by a small petrol driven pump. The mixture goes to the boom and is sprayed immediately.

The boat is used mainly for spraying maleic hydrazide and 2,4-D onto the grass banks but has also been used for spraying reeds with dalapon and spreading dichlobenil. It has been used for about 10 years.

B) Welland and Deepings Internal Drainage Board have mounted a 12 ft spray boom laterally on a flat bottomed boat. The boat is propelled by an outboard motor. The spraying system is a Visgol 50 gal unit normally fitted to a tractor but, in this case, powered by a 3 h.p. four stroke engine.

The boom is set at the necessary angle to the bank before spraying commences and the boat is steered close along the bank with the outboard motor. It has been in use for 3 years and is used mainly for spraying dalapon on reeds.

C) A Howard and Dennis boat has been converted for bank spraying by replacing the cutting bar with an 8 ft spray boom. (Plate 7). All controls including the spray pump are powered by the hydraulic system from the motor. The spray tank holds 20 gals. The boom has a reach of 10 ft, can operate on either side of the boat and its angle and height may be adjusted as spraying is in progress.

The boat has been used by Burnt Fen IDB for 3 years mainly for spraying reeds and broadleaved weeds on the banks.

D) The Middle Level Commissioners have built a twin hulled spraying boat with a 24 ft boom. (Plate 8). One man steers the boat and controls the angle of the boom while another operates the spray system. The boom is

divided into 3 sections so that any part can be turned on or off during spraying when a wider or narrower swath is required. There are 2 x 60 gal spray tanks each with a separate pump. One tank is filled from the river while the other is spraying. The boom can be swung in to the side of the boat to allow it to pass under bridges etc and since the boat does not need to stop for any of these operations it is possible to spray up to 30 miles in one day.

The catamaran hull produces little wash and this is important when spraying water-lilies. The system has been in use for 5 years for spraying bank weeds, reeds and water-lilies.

7. IDBs using helicopters for spraying dalapon as an invert emulsion

(King Sedgmoor & Cary Valley
(Curry Moor
Benwick
Middle Level Commissioners
(Ramsey First District
(Ramsey Second District
(Ramsey Fourth District
(Ramsey Fifth District
(Ramsey Upwood and Great Rarely
(Whittlesey and Farcet
(Grassmoor and Mereside
(Whittlesey and Kingsland
(Holmewood and Stilton
(Feldale

Plate 1. A cutting blade attached to the tines of a Priestman rake by the River Ivel IDB

Plate 2. Weed rake made by the Gwynedd River Authority

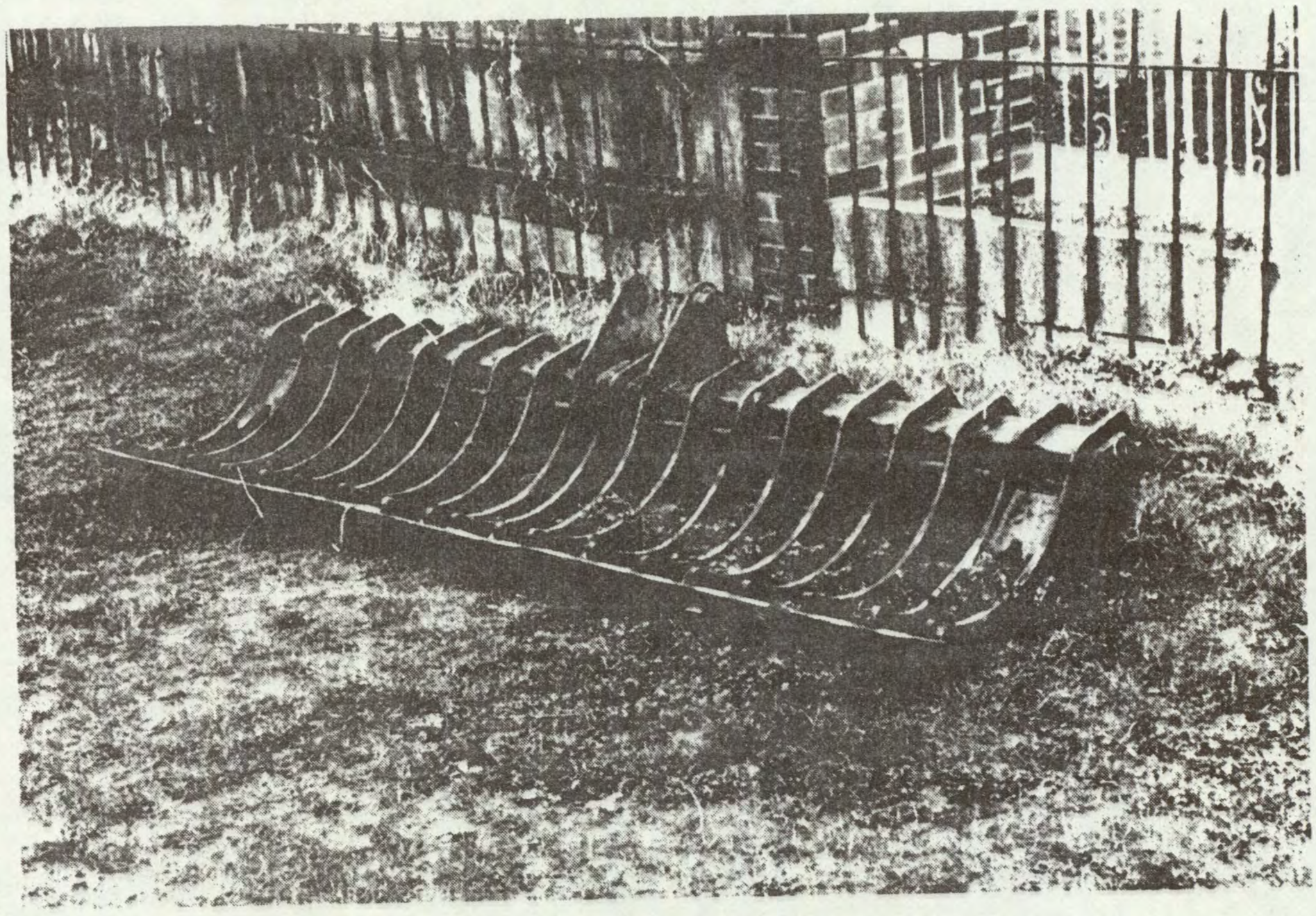

Plate 1

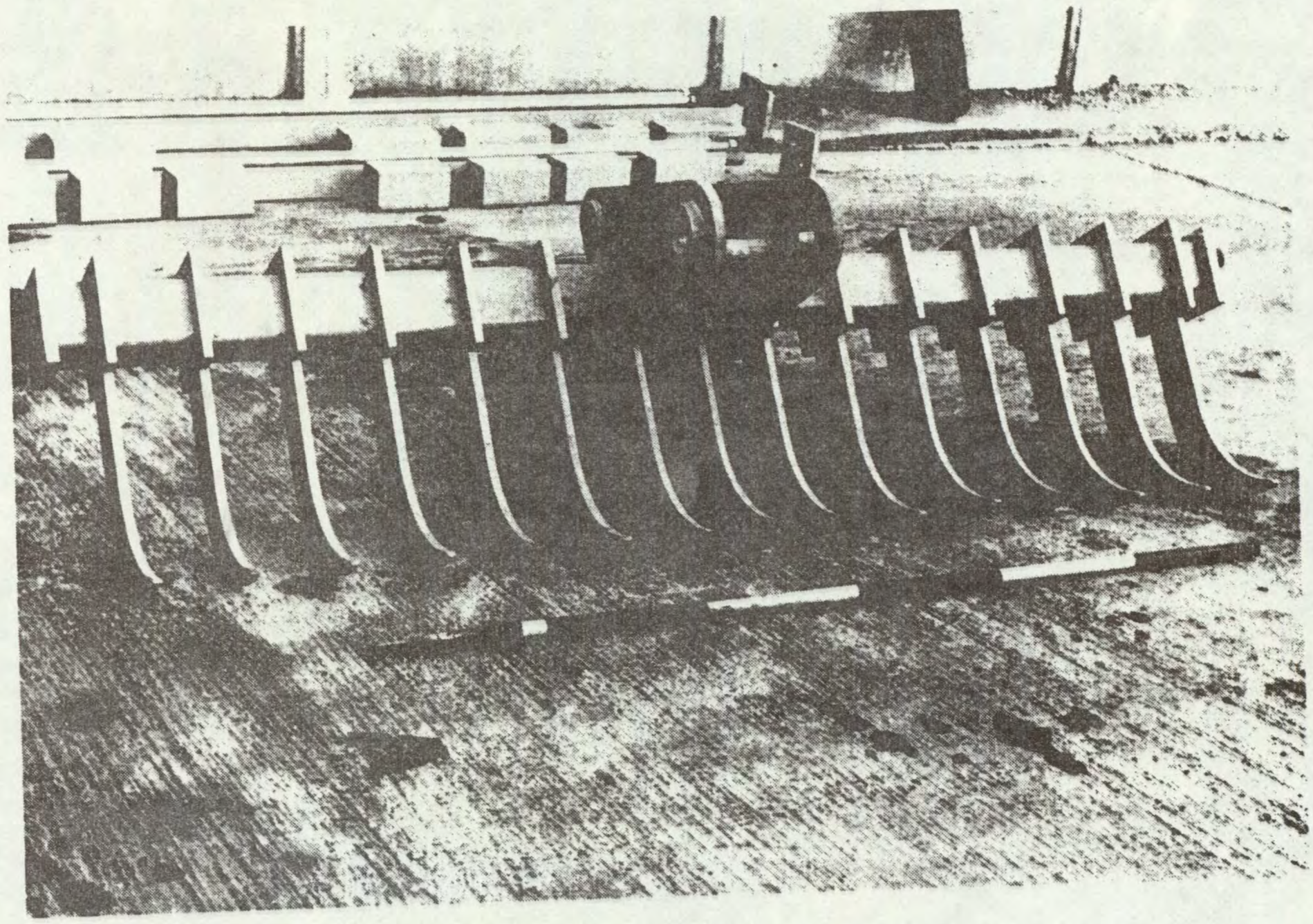

Plate 2

Plate 3. A 21 ft boom mounted on the foreloader of a tractor by the Burnt Fen IDB

Plate 4. V shaped spray boom and granule spreader built by the Witham Fourth IDB

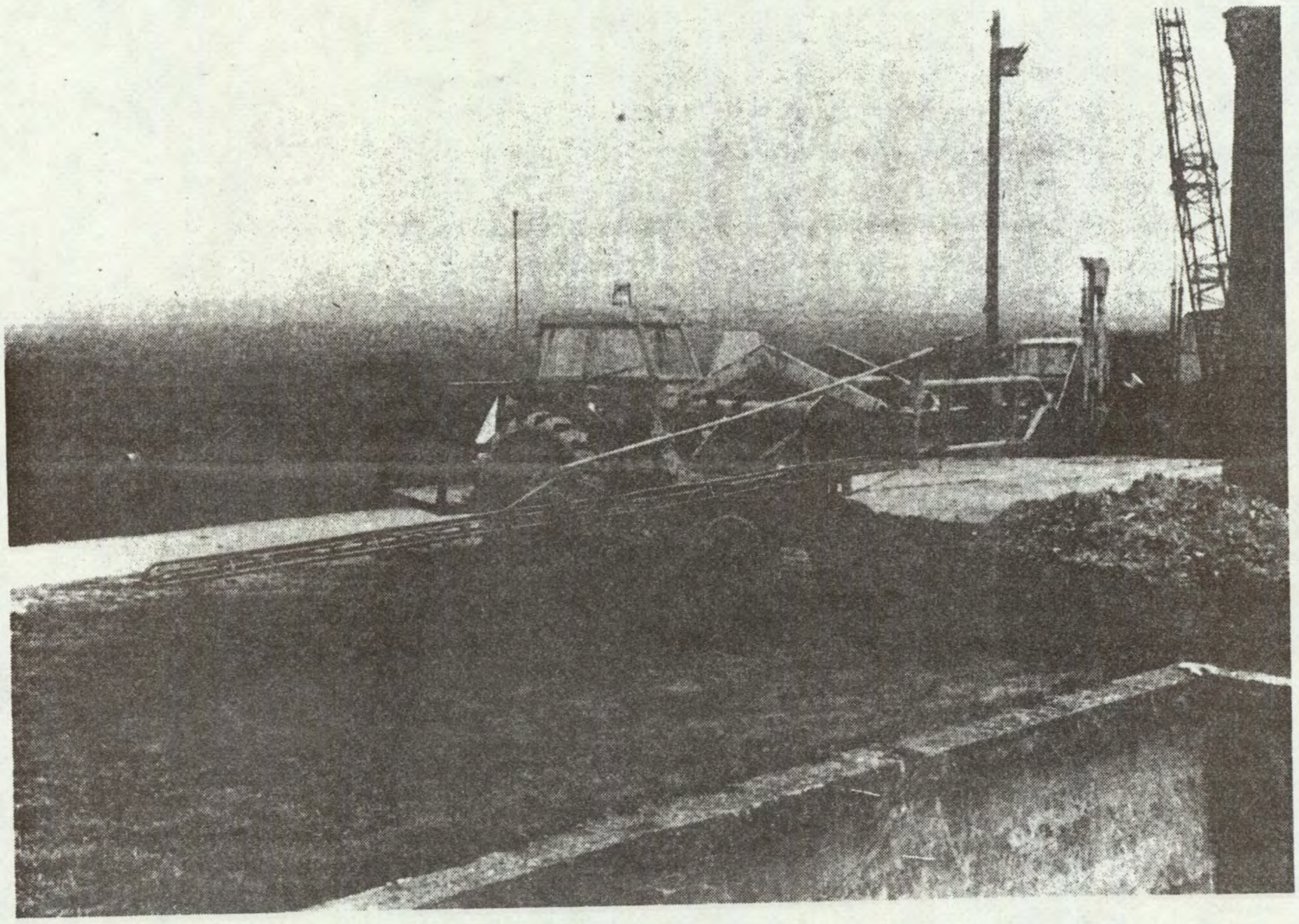

Plate 3

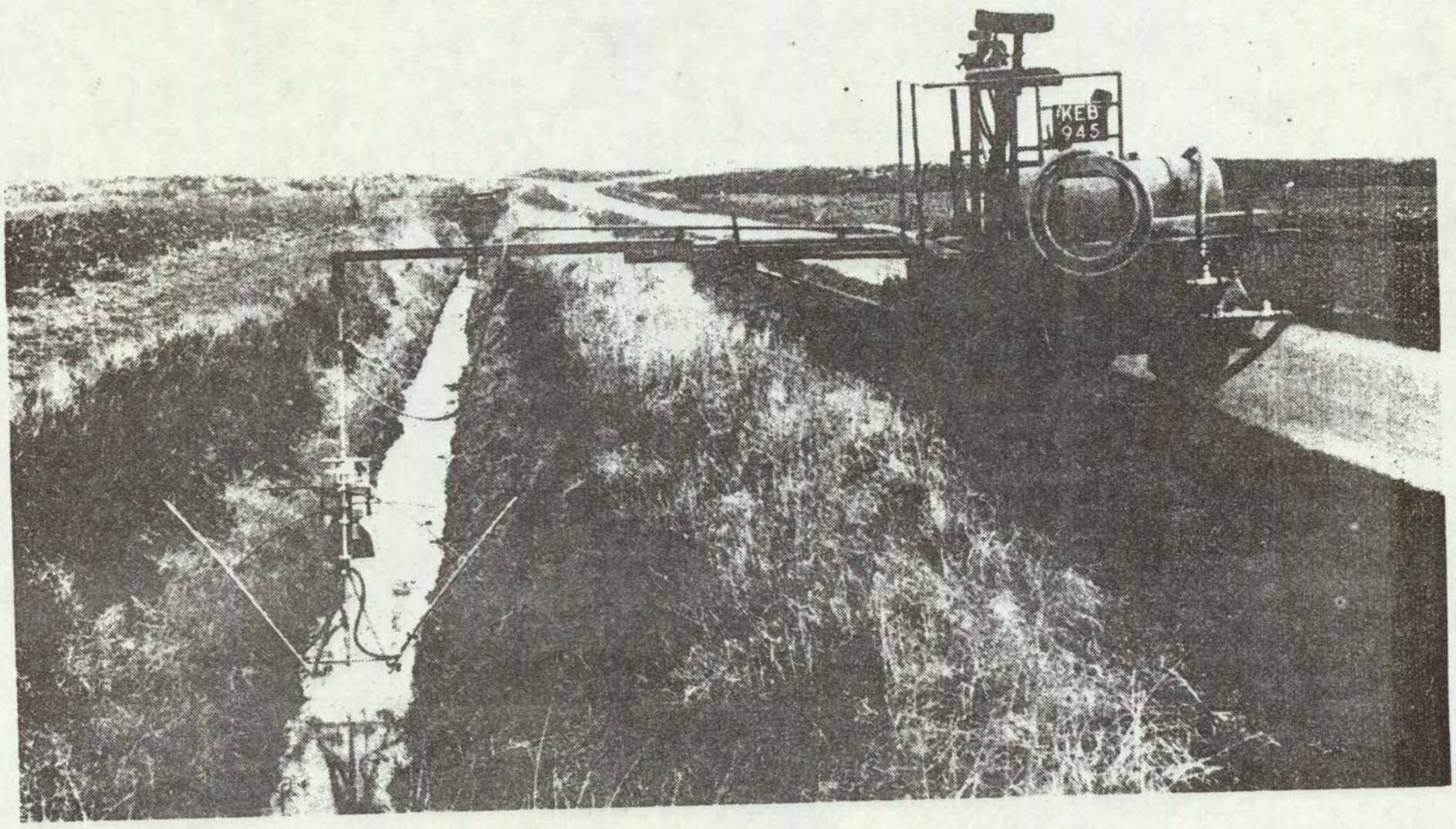

Plate 4

Plate 5. A spray boom attached to a flail mower by the Upper Medway IDB

Plate 6. A flat bottomed spraying boat driven by a single paddle wheel built by the Witham Fourth IDB

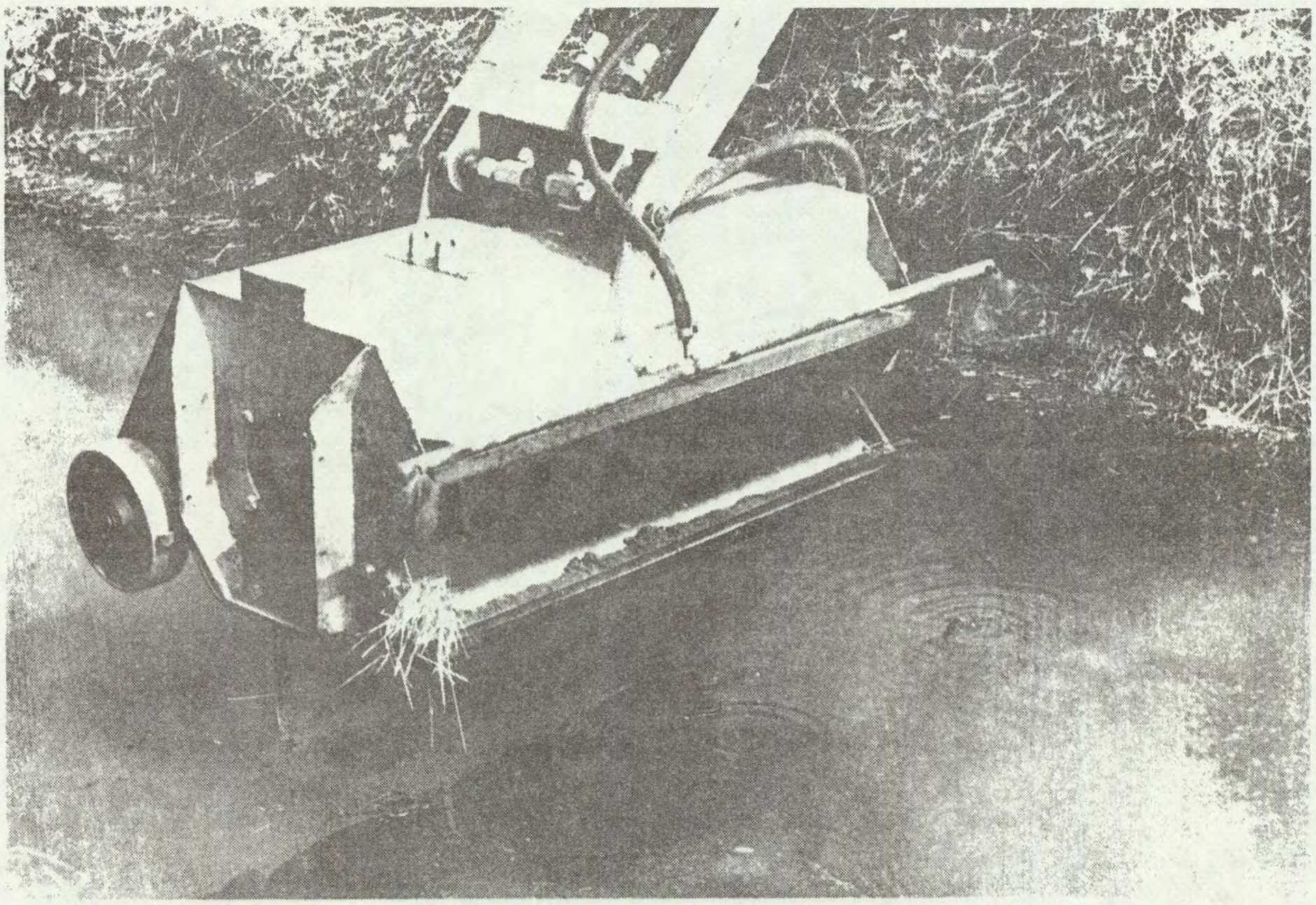

Plate 5

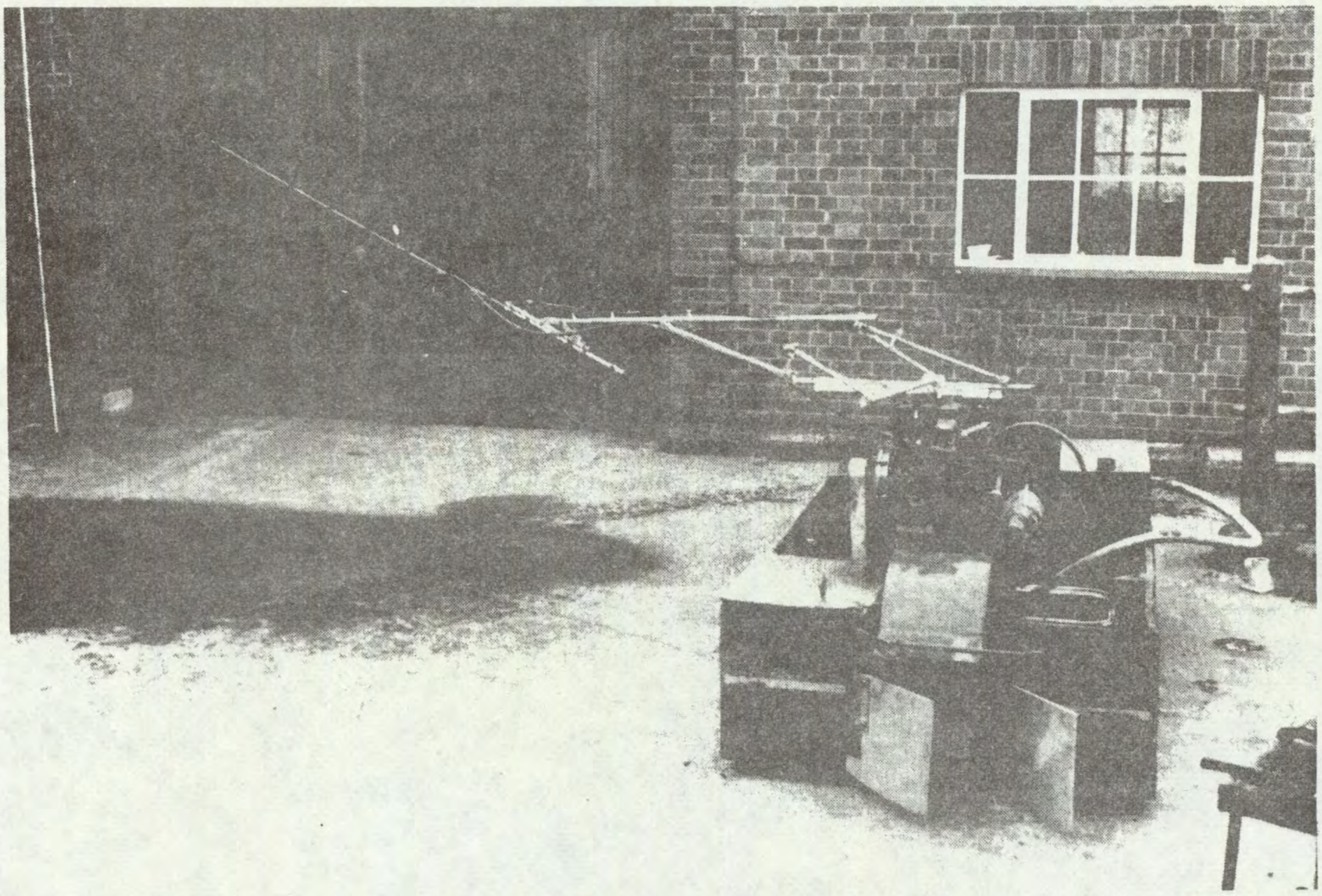

Plate 6

Plate 7. The replacement of the cutting bar with a spray boom on a weed cutting boat (Burnt Fen IDB)

Plate 8. Twin hulled spraying boat built by the Middle Level Commissioners

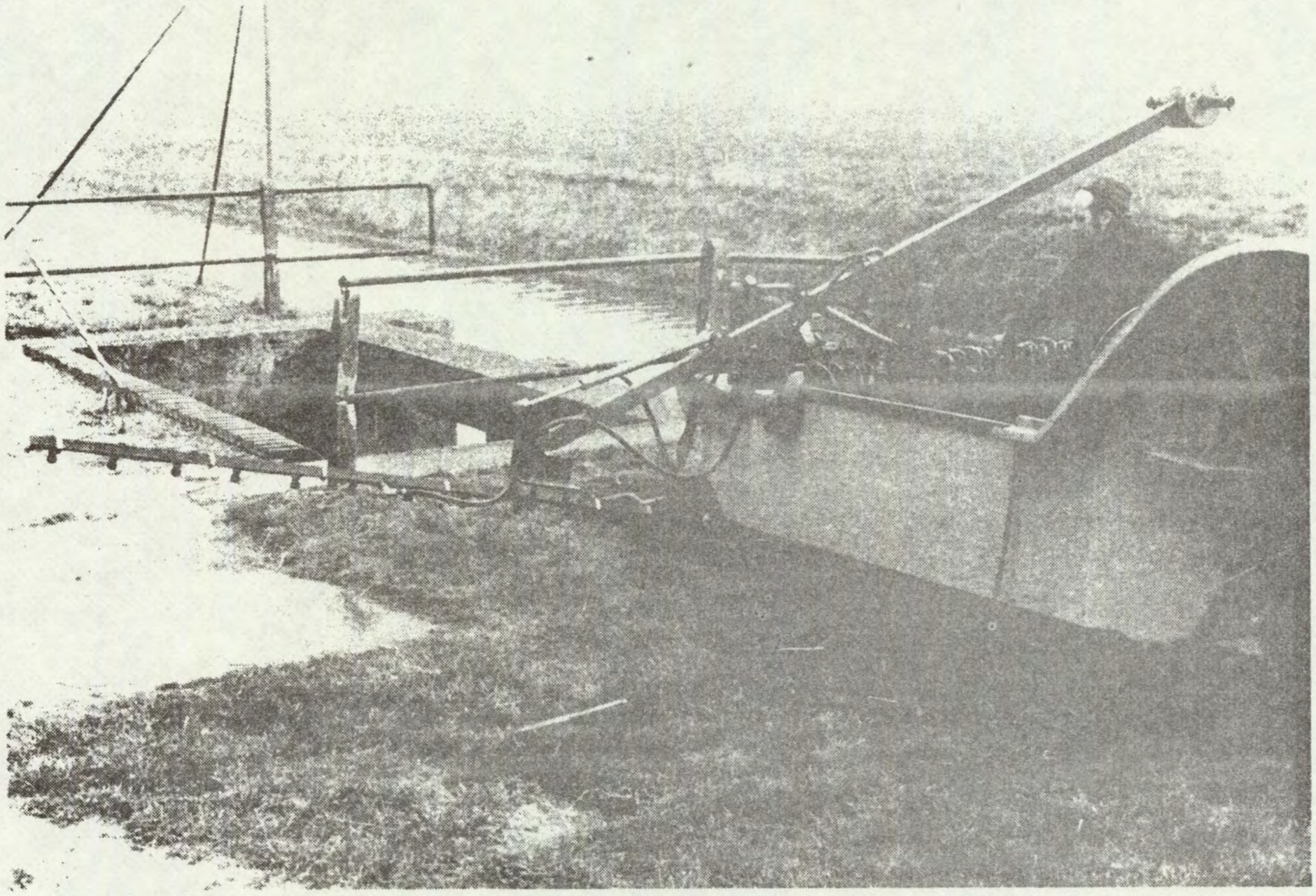

Plate 7

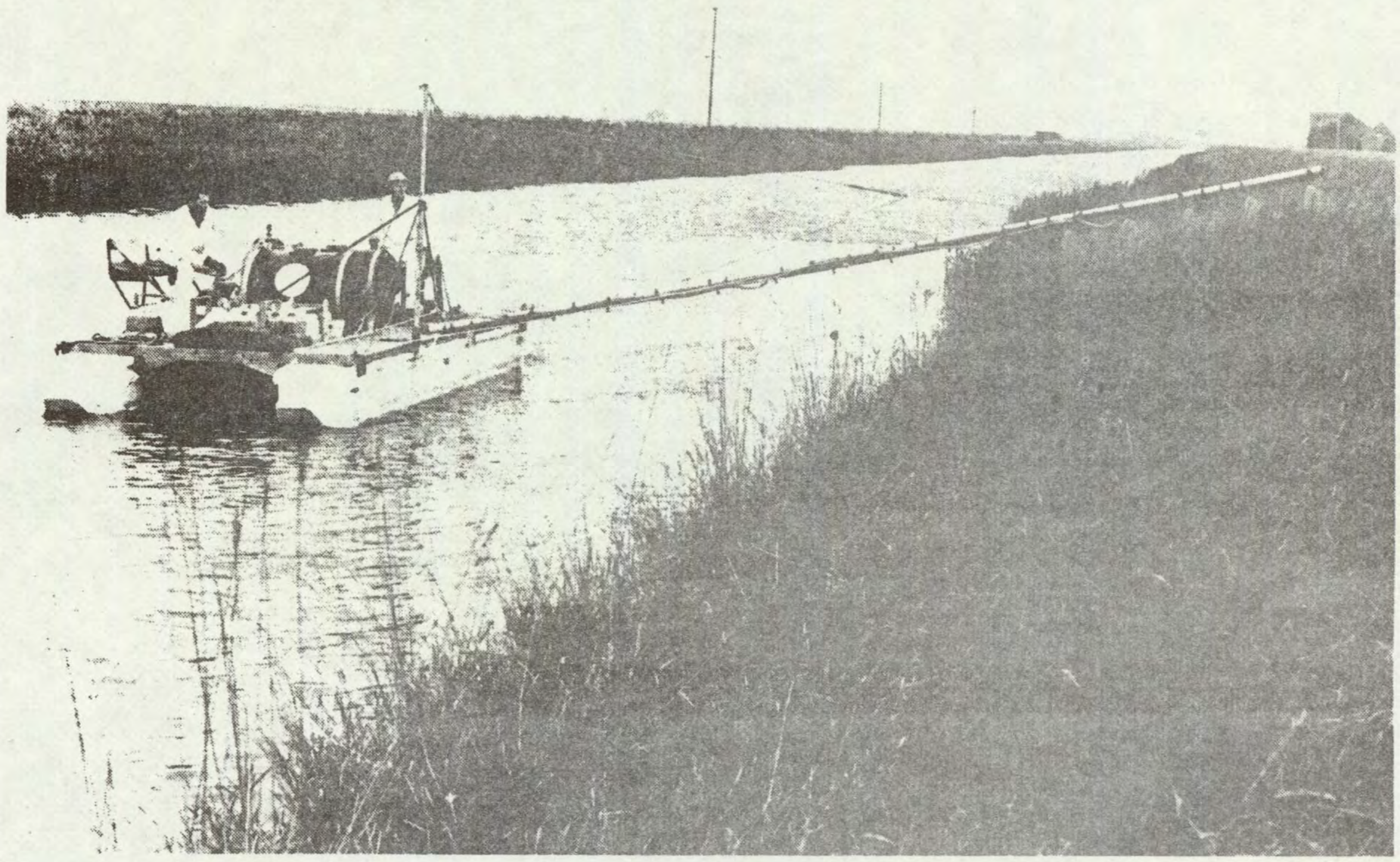

Plate 8

ABBREVIATIONS

ångström	Å
Abstract	Abs.
acid equivalent*	a.e.
acre	ac
active ingredient*	a.i.
approximately equal to*	≃
aqueous concentrate	a.c.
bibliography	bibl.
boiling point	b.p.
bushel	bu
centigrade	C
centimetre*	cm
concentrated	concd
concentration	concn
concentration × time product	ct
concentration required to kill 50% test animals	LC50
cubic centimetre*	cm^3
cubic foot*	ft^3
cubic inch*	in^3
cubic metre*	m^3
cubic yard*	yd^3
cultivar(s)	cv.
curie*	Ci
degree Celsius*	^oC
degree centigrade*	^oC
degree Fahrenheit*	^oF
diameter	diam.
diameter at breast height	d.b.h.
divided by*	÷ or /
dry matter	d.m.
emulsifiable concentrate	e.c.
equal to*	=
fluid	fl.
foot	ft
freezing point	f.p.
from summary	F.s.
gallon	gal
gallons per hour	gal/h
gallons per acre	gal/ac
gas liquid chromatography	GLC
gramme	g
hectare	ha
hectokilogram	hkg
high volume	HV
horse power	hp
hour	h
hundredweight*	cwt
hydrogen ion concentration*	pH
inch	in.
infra red	i.r.
kilogramme	kg
kilo ($\times 10^3$)	k
less than	<
litre	l.
low volume	LV
maximum	max.
median lethal dose	LD50
medium volume	MV
melting point	m.p.
metre	m
micro ($\times 10^{-6}$)	µ
microgramme*	µg
micromicro (pico: $\times 10^{-12}$)*	µµ
micrometre (micron)*	µm (or µ)
micron (micrometre)*[×]	µm (or µ)
miles per hour*	mile/h
milli ($\times 10^{-3}$)	m
milliequivalent*	m.equiv.
milligramme*	mg
millilitre	ml

[×] The name micrometre is preferred to micron and µm is preferred to µ.

millimetre*	mm
millimicro* (nano: $\times 10^{-9}$)	n or mμ
minimum	min.
minus	-
minute	min
molar concentration*	M (small cap)
molecule, molecular	mol.
more than	>
multiplied by*	×
normal concentration*	N (small cap)
not dated	n.d.
oil miscible concentrate	o.m.c. (tables only)
organic matter	o.m.
ounce	oz
ounces per gallon	oz/gal
page	p.
pages	pp.
parts per million*	ppm
parts per million by volume*	ppmv
parts per million by weight*	ppmw
percent(age)*	%
pico (micromicro: $\times 10^{-12}$)	p or μμ
pint	pint
pints per acre	pints/ac
plus or minus*	±
post-emergence	post-em.
pound	lb
pound per acre*	lb/ac
pounds per minute	lb/min
pound per square inch*	lb/in^2
powder for dry application	p. (tables only)
power take off	p.t.o.
precipitate (noun)	ppt.
pre-emergence	pre-em.
quart	quart
relative humidity	r.h.
revolution per minute*	rev/min
second	s
soluble concentrate	s.c.
soluble powder	s.p.
solution	soln
species (singular)	sp.
species (plural)	spp.
specific gravity	sp. gr.
square foot*	ft^2
square inch*	in^2
square metre*	m^2
square root of*	$\sqrt{}$
sub-species*	ssp.
summary	s.
temperature	temp.
ton	ton
tonne	t
ultra-low volume	ULV
ultra violet	u.v.
vapour density	v.d.
vapour pressure	v.p.
varietas	var.
volt	V
volume	vol.
volume per volume	v/v
water soluble powder	w.s.p. (tables only)
watt	W
weight	wt
weight per volume*	w/v
weight per weight*	w/w
wettable powder	w.p.
yard	yd
yards per minute	yd/min

* Those marked * should normally be used in the text as well as in tables, etc.

Technical reports available

5. A survey of the problem of aquatic weed control in England and Wales. October, 1967. T.O. Robson. Price - £0.25.

6. The botany, ecology, agronomy and control of Poa trivialis L. rough-stalked meadow-grass. November 1966. G.P. Allen. Price - £0.25.

7. Flame cultivation experiments 1965. October, 1966. G.W. Ivens. Price - £0.25.

8. The development of selective herbicides for kale in the United Kingdom. 2. The methylthiotriazines. Price - £0.25.

9. The post-emergence selectivity of some newly developed herbicides (NC 6627, NC 4780, NC 4762, BH 584, BH 1455). December, 1967. K. Holly and Mrs. A.K. Wilson. Price - U.K. and overseas surface mail - £0.25; overseas airmail - £0.50.

10. The liverwort, Marchantia polymorpha L. as a weed problem in horticulture; its extent and control. July, 1968. I.E. Henson. Price - £0.25.

11. Raising plants for herbicide evaluation; a comparison of compost types. July, 1968. I.E. Henson. Price - £0.25.

12. Studies on the regeneration of perennial weeds in the glasshouse; I. Temperate species. May, 1969. I.E. Henson. Price - £0.25.

13. Changes in the germination capacity of three Polygonum species following low temperature moist storage. June, 1969. I.E. Henson. Price - £0.25.

14. Studies on the regeneration of perennial weeds in the glasshouse. II. Tropical species. May, 1970. I.E. Henson. Price - U.K. and overseas surface mail - £0.25; overseas airmail - £0.50.

15. Methods of analysis for herbicide residues in use at the Weed Research Organization. December, 1970. R.J. Hance and C.E. McKone. Price - U.K. and overseas surface mail - £0.25; overseas airmail - £0.50.

16. Report on a joint survey of the presence of wild oat seeds in cereal seed drills in the United Kingdom during Spring 1970. November, 1970. J.G. Elliott and P.J. Attwood. Price - £0.25.

17. The pre-emergence selectivity of some newly developed herbicides, Orga 3045 (in comparison with dalapon), haloxydine (PP 493), HZ 52.112, pronamide (RH 315) and R 12001. January, 1971. W.G. Richardson, C. Parker and K. Holly. Price - U.K. and overseas surface mail - £0.25; overseas airmail - £0.50.

18. A survey from the roadside of the state of post-harvest operations in Oxfordshire in 1971. November, 1971. A. Phillipson. Price - U.K. and overseas surface mail - £0.12; overseas airmail - £0.34.

19. The pre-emergence selectivity of some recently developed herbicides in jute, kenaf and sesamum, and their activity against Oxalis latifolia. December 1971. M.L. Dean and C. Parker. Price - U.K. and overseas surface mail - £0.25; overseas airmail - £0.45.

20. A survey of cereal husbandry and weed control in three regions of England. July 1972. A. Phillipson, T.W. Cox and J.G. Elliott. Price - U.K. and overseas surface mail - £0.35; overseas airmail - £0.75.

21. An automatic punching counter. November 1972. R.C. Simmons. Price - U.K. and overseas surface mail - £0.30; overseas airmail - £0.50.

22. The pre-emergence selectivity of some newly developed herbicides: bentazon, BAS 3730H, metflurazone, SAN 9789, HER 52.123, U 27,267. December 1972. W.G. Richardson and M.L. Dean. Price - U.K. and overseas surface mail - £0.25; overseas airmail - £0.45.

23. A survey of the presence of wild oats and blackgrass in parts of the United Kingdom during summer 1972. A. Phillipson. Price - U.K. and overseas surface mail - £0.25; overseas airmail - £0.45.

24. The conduct of field experiments at the Weed Research Organization. February 1973. J.G. Elliott, J. Holroyd and T.O. Robson. Price - U.K. and overseas surface mail - £1.25; overseas airmail - £1.47.

25. The pre-emergence selectivity of some recently developed herbicides: lenacil, RU 12068, metribuzin, cyprazine, EMD-IT 5914 and benthiocarb. August 1973. W.G. Richardson and M.L. Dean. Price - U.K. and overseas surface mail - £1.75; overseas airmail - £2.20.

26. The post-emergence selectivity of some recently developed herbicides: bentazon, EMD-IT 6412, cyprazine, metribuzin, chlornitrofen, glyphosate, MC 4379, chlorfenprop-methyl. October 1973. W.G. Richardson and M.L. Dean. Price - U.K. and overseas surface mail - £3.31; overseas airmail - £3.56.

27. Selectivity of benzene sulphonyl carbamate herbicides between various pasture grasses and clover. October 1973. A.M. Blair. Price - U.K. and overseas surface mail - £1.05; overseas airmail - £1.30.

28. The post-emergence selectivity of eight herbicides between pasture grasses: RP 17623, HOE 701, BAS 3790, metoxuron, RU 12068, cyprazine, MC 4379, metribuzin. October 1973. A.M. Blair. Price - U.K. and overseas surface mail - £1.00; overseas airmail - £1.25.

29. The pre-emergence selectivity between pasture grasses of twelve herbicides: haloxydine, pronamide, NC 8438, Orga 3045, chlortoluron, metoxuron, dicamba, isopropalin, carbetamide, MC 4379, MBR 8251 and EMD-IT 5914. November 1973. A.M. Blair. Price - U.K. and overseas surface mail - £1.30; overseas airmail - £1.50.

30. Herbicides for the control of the broad-leaved dock (Rumex obtusifolius L.). November 1973. A.M. Blair and J. Holroyd. Price - U.K. and overseas surface mail - £1.06; overseas airmail - £1.30.

31. Factors affecting the selectivity of six soil acting herbicides against Cyperus rotundus. February 1974. M.L. Dean and C. Parker. Price - U.K. and overseas surface mail - £1.10; overseas airmail - £1.35.

32. The activity and post-emergence selectivity of some recently developed herbicides: oxadiazone, U-29,722, U-27,658, metflurazone, norflurazone, AC 50-191, AC 84,777 and iprymidan. June 1974. W.G. Richardson and M.L. Dean. Price - U.K. and overseas surface mail £3.62; overseas airmail - £3.88.

33. A permanent automatic weather station using digital integrators. September 1974. R.C. Simmons. Price - U.K. and overseas surface mail - £0.63; overseas airmail - £0.88.

34. The activity and pre-emergence selectivity of some recently developed herbicides: trifluralin, isopropalin, oryzalin, dinitramine, bifenox and perfluidone. November 1974. W.G. Richardson and M.L. Dean. Price U.K. and overseas surface mail - £2.50; overseas airmail - £2.76.

35. A survey of aquatic weed control methods used by Internal Drainage Boards, 1973. January 1975. T.O. Robson. Price - U.K. and overseas surface mail - £1.39; overseas airmail - £1.64.