Emergency Sealing of Breaches - Phase 1

Sir William Halcrow and Partners Ltd

Project Report 431/3/A

NRA

National Rivers Authority

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Emergency Sealing of Breaches - Phase 1

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EMERGENCY SEALING OF BREACHES - PHASE 1

PROJECT RECORD

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Statement of Use
This document contains a review and recommendations to the Authority on the issues of the sealing of breaches in sea, tidal and fluvial flood defences. It is provided to establish the current practice and experience within the Authority of such issues to Authority staff and sets out appropriate courses of action for further work.

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SUMMARY

This report covers Phase 1 of research into the Emergency Sealing of Breaches. A description of the work included is a state-of-the-art review of sealing of breaches in sea, tidal and fluvial flood defences for the production of an operational manual. The production of the manual is to be undertaken in Phase 2.

The work carried out and reported herein has included a review of emergency procedures within the NRA regions, together with an assessment of the state of preparedness to respond to an emergency. Defence forms, breach occurrence and historical response are reviewed, based on data collected from a questionnaire survey of the NRA regions and a limited number of meetings. Methods of sealing breaches, both commonly applied techniques such as sandbagging, piling and bulk fill, and alternative methods such as gabions, large bags etc, and their applicability are discussed. In addition, ancillary considerations, such as the timing of repairs, site access and logistical support are covered.

A recommendation is made for the preparation of an operational guideline report, rather than a manual. The term manual implies a precise document giving rigorous guidance which is not considered appropriate for the subject under review. A suggested contents list is given for the guideline, as are some ideas to be considered in the content of each chapter. Finally some ideas are suggested for future R&D topics, none of which are considered to be high priority.

KEYWORDS

Sea defences
Tidal flood defences
Fluvial flood defences
Breaches
Emergencies
Repairs
Maintenance

1. INTRODUCTION

1.1 Objectives

This project is classed under NRA R&D Commission "C-Flood Defence" and within the Topic "C08-Response to Emergencies". Its purpose is to undertake a state-of-the-art review of sealing of breaches in sea, tidal and fluvial flood defences for the production of an operational manual.

The project has been set up in two phases, the specific objectives of which are:

(a) Phase 1

- to investigate existing methods of sealing breaches in sea, tidal or fluvial flood defences both within the NRA and externally;
- to investigate possible future methods of sealing breaches using new technology and materials;
- to assess and propose the requirements for the production of an operational guidance manual, which will detail the various methods of emergency sealing of breaches in defences and advise on best option/practice;
- to suggest possible areas for further R&D, and
- to produce a final report which collates the above information and proposes objectives and a strategy for Phase 2 to achieve the Overall Project Objective.

(b) Phase 2

- to undertake R&D proposed in the Project Record from Phase 1, and
- to produce an operational manual for the emergency sealing of breaches.

This report is prepared at the end of Phase 1. It covers the findings of the investigations carried out and makes recommendations for the work to be undertaken in Phase 2.

1.2 Background

The background to the project, as defined in Section 6 of the R&D Project Investment Appraisal, is given below.

"Background

Due to major flood defence improvement works as a result of the floods in 1947 and 1953, etc, breaches only occur in flood defences infrequently. This situation results in any one Region having limited experience of dealing with breaches due to changes in staff. The issue of relevant experience for present staff is further compounded by a lack of documentation on previous breaches in many instances.

Reductions in the NRA's own manual labour-force have resulted in a loss of expertise in dealing with breaches. The resultant increased use of external contractors will necessitate the Authority to be assured of contractor performance. A manual will be of major significance in this respect.

New technology and materials will present possible scope for improving and extending the methods which can be employed to deal with the sealing of breaches".

(a) Context

This project has some links with other emergency R&D projects, but essentially it is a stand alone project.

There will be links to the "Dam Break Analysis" project which is being developed and "flood maps" (not produced in every Region) which are likely to be one of the recommendations coming out of the "Emergency Response Levels of Service" project in defining the risks of relating to breaches in defences.

Documentation (as a possible reference manual) is timely due to:

- loss of expertise;
- infrequent nature of events, and
- greater contracting out in the future.

(b) Do-nothing option

The NRA will not have an overall review of the methods of sealing of breaches and may miss the opportunity to evaluate and use new technology/ materials.

Expertise is being lost as staff with previous experience of breaches are retiring and their expertise is not documented. The change towards the use of external contractors may result in uncertain performance in emergency breach sealing situations. The Authority may not be able to provide a consistent level of service with respect to emergency sealing of flood defence breaches without the outputs proposed from this project".

2. METHODOLOGY

The emphasis of the study is towards practical methods of sealing breaches and not on emergency procedures. However, the need to refer to such procedures is accepted as being necessary to assess the state of preparedness to act when necessary. This chapter describes briefly the methods used to obtain data for analysis, namely a questionnaire, site visits and other sources of data.

2.1 Questionnaire

In preparing the questionnaire for distribution to NRA offices, the over-riding concern was to keep the form as concise and simple as possible while at the same time addressing the wide range of procedural and operational matters of interest. A copy of the questionnaire is included as Appendix A and it is in two parts, the first covering general information and procedures for the region/area/district, and the second part being a breach repair proforma to be completed for each breach of which staff have experience.

After agreeing the questionnaire format and content with the Project leader, five copies were sent to each region of the NRA via the contact officer for flood defence R&D projects. Thereafter, the questionnaires were distributed to area/district offices for completion, and return to the Consultants in due course. The response was mixed as indicated below:

NRA Region	No of returns
Anglian	4
Northumbrian and Yorkshire	5
North West	3
Severn-Trent	0
Southern	1
South West	0
Thames	6
Welsh	0
Wessex	3

Although no questionnaires were returned from the Severn-Trent Region they verbally advised that they had no experience of breaches to report. They did also provide copies of reports on breaches which occurred in 1947.

The findings of the questionnaire survey are discussed further in Chapter 3.

2.2 Site Visits

In addition to the questionnaire survey, a number of visits were made to NRA offices to discuss their experience of breach closure. At the inception meeting five NRA regions: Anglian, North West, Severn-Trent, Wessex and Yorkshire, were identified as those likely to have a range of defences and breach closure experience. However, telephone enquiries following distribution of the questionnaires revealed a distinct lack of recent experience and it was concluded that visits to all five regions were not justified. The offices visited were as follows:

NRA Region	Office
Anglian	Northern Area, Manby
Anglian	North Essex District, Kelvedon
North West	Central Area, Preston
Wessex	Avon & Dorset Area, Blandford Forum
Wessex	Regional Office, Bridgwater

When visiting the Manby District a meeting was arranged at a nearby sea defence site office for discussions with an ex NRA Area Engineer with relevant experience. Also in Bridgwater a meeting was held with a retired Divisional Engineer from the Somerset River Authority.

Notes of the discussions have been made and are available if required, but they are not included in this report. Usually the discussions covered the current emergency procedures for the particular office and their specific experience of dealing with breaches. The findings arising from the meetings are discussed in Chapters 3, 4 and 5.

2.3 Literature/ Data Review

During the course of the study to date, several sources of data have been identified. These can be broadly classified under the following categories:

- NRA;
- Halcrow;
- Industry, and

- Others.

A listing of the reference material is given in Appendix B.

2.3.1 NRA Data

The principal source of data from the NRA has been via the responses to the questionnaire sent out to the NRA regions, as discussed in Section 2.1. The questionnaire returns have been sorted onto a database providing information regarding the recipient of the questionnaire and the extent of data provided. A copy of the database is included in Appendix A. Site visits and interviews with key NRA personnel have also provided an insight into the problems concerned with breach management, highlighting key concerns and outlining historic events. The site visits have also provided an opportunity to gain access to regional NRA records, references and documentation on historical events which have helped to supplement the study.

At the request of Halcrow, the NRA have provided several reports on topics including emergency communications, the viability of emergency plant and vehicles, and river flood forecasting. Although not directly related to the study, these reports have provided an insight into how prepared and capable the NRA could be in the event of a serious breach.

2.3.2 Halcrow Data

The main thrust of the Halcrow data review has been via an extensive literature search. Papers published by bodies including ICE, ASCE, Rijkswaterstaat and Kyoto University have been obtained which document various aspects of breach occurrence and sealing for coastal and fluvial structures, dykes and dams.

The Halcrow library has also been able to supply information regarding manufacturers of products which have an appreciation or potential application in the field of breach sealing or breach prevention.

Several other departments within Halcrow have been contacted for their experience in the field of breach sealing or possible breach prevention. The geotechnical unit has been able to suggest slope strengthening methods, the dams unit has considerable experience in the inspection and maintenance of existing structures and the coastal department have been able to provide expertise on all aspects of coastal protection.

2.3.3 Industry Data

A review of industrial manufacturers who supply products with present or potential breach sealing applications has been undertaken. Suppliers and current trade literature have been consulted as a result of a search of the Halcrow library and on the recommendation of Halcrow staff. The review revealed few manufacturers who supply products specifically for breach sealing, but products with a potential use in the field of breach sealing have been identified.

2.3.4 Other Data Sources

The other data sources contacted for information are bodies with either extensive or recent experience in the field of breach sealing. To date, these external data sources include British Waterways Board (BWB), British Rail and Tayside Water Services. Questionnaires have been sent to personnel with these bodies, but the response has been limited. Some regions of BWB have responded and these have been included in the database (Appendix A). British Rail proved very difficult to contact and reluctant to assist. Tayside Water Services failed to return their questionnaire.

3. PROCEDURES

3.1 Analysis of the Questionnaire Responses

It is accepted that the main emphasis of this study is towards the practical aspects of breach repair. Nevertheless it is almost impossible to ignore procedural aspects in the context of the work and, if nothing else, they do give some indication of the degree of preparedness in any area or region.

The first part of the questionnaire sent out to the NRA regions covered general information and procedures relating to breach repair. The returns and the discussions held in a number of NRA offices indicate wide variations between regions and sometimes within regions. A summary of the questionnaire responses is given in Table 3.1 and some findings from an analysis of them are given below.

When considering the responses it is important to realise that the answers to the questions posed are on a yes/no basis. In many cases the correct answer may lie somewhere between the two extremes and the opinion of the respondent has been given. The discussions during site visits has confirmed the scope for interpretation. Nevertheless it is felt that the summary of the responses provides a reasonable basis on which to assess the state of preparedness within the NRA regions, and some findings from an analysis of the responses are given in this Chapter.

3.2 Documentation

From the responses it can be concluded that in all regions there exist emergency procedures in some form. These vary from complete emergency standing orders, which include detailed regional and local information, to a document containing a limited amount of general information. In some cases there are procedures prepared at a regional level, often criticised for being prepared without reference to operations staff, backed up by individually held local data, such as lists of contractors and material suppliers.

Without the benefit of discussion it is difficult to ascertain the completeness of the contingency plans in a particular office. Of the offices visited the emergency procedures held in the Manby office of the Anglian Region (Northern Area) are by far the most comprehensive. In addition to communications information and responsibilities, there is detailed information on all defences which are split into lengths and classified by type and defence level. Normal access is defined but it is accepted that in flood conditions this may not be usable. The document

EMERGENCY SEALING OF BREACHES

Summary of Questionnaire Responses

	NRA REGION	THAMES						WESSEX			ANGLIAN				NORTHUMBRIA & YORKSHIRE					STH	NORTH WEST			TOTALS	
	QUESTIONNAIRE NO.	1	2	3	4	5	6	8	9	10	7	13	17	19	14	15	23	24	25	16	20	21	22	Y	N
2.	Does your region/area have contingency plans for dealing with emergencies ? Yes/No	Y	Y		-	Y	Y	Y	Y	Y	Y	Y	Y	Y?	Y	Y	Y	Y	Y	some	Y	?	Y	18	0
2.1	If yes do they include :																								
	• Specific procedures for																								
	- coastal defences Yes/No	N	-		-	N	N	Y	Y	-	Y	Y	Y	N	Y	Y	Y	Y	Y	some	Y	N	N	11	6
	- tidal defences Yes/No	Y	N		-	Y	Y	Y	Y	-	Y	Y	Y	N	Y	Y	Y	Y	Y	some	Y	N	Y	15	3
	- fluvial defences Yes/No	Y	N		-	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	some	Y	N	Y	16	2
	• Appraisal of damage Yes/No	N	N		-	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	N	-	Y	N	N	N	Y	11	8
	• Plant hire contractors Yes/No	Y	Y		-	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	-	Y	some	Y	N	Y	15	3
	• Materials suppliers Yes/No	Y	Y		-	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	-	Y	some	N	N	Y	12	6
	• Responsibilities (who does what and when) Yes/No	Y	N		-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	17	3
	• Budget availability/control Yes/No	Y	N		-	Y	Y	Y	Y	Y	Y	Y	Y	-	Y	Y	N	-	Y	N	Y	?	Y	15	3
	• Incident report format Yes/No	Y	N		-	Y	Y	N	Y	Y	Y	Y	Y	N	N	N	-	-	Y	Y	Y	Y	Y	11	5
	• Duty rotas and telephone nos Yes/No	Y	N		-	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	18	2
	• External contacts (police, councils etc) Yes/No	Y	N		-	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	18	2
	• Evacuation procedures - general/regional Yes/No	?	Y		-	Y	N	N	Y	-	-	-	-	-	N	N	N	-	N	N	-	N	-		
	- site specific Yes/No	Y	Y		-	Y	N	N	Y	-	-	-	-	-	N	N	N	-	N	N	-	N	-		
	• Site specific access information Yes/No	Y	Y		-	Y	N	N	N	Y	Y	Y	Y	Y?	N	Y	N	-	Y	N	N	N	Y	11	8
2.2	Have you been trained to deal with emergencies, such as breaches of flood defences? Yes/No	N	Y		-	N	Y	N	Y	Y	N	Y	Y	Y	N	Y	N	N	N	N	N	N	N	8	12
3.	Are there historical records of defences in your area																								
	- as built drawings Yes/No	Y	some		some	-	Y	N	some	Y	Y	Y	Y	Y	some	Y	Y	Y	some	some	N	N	Y	10	3
	- maintenance manuals Yes/No	Y	some		some	-	Y	N	some	Y	Y	N	Y	N	N	N	Y	Y	some	some	N	N	N	7	8
	- maintenance/rehabilitation reports Yes/No	Y/N	some		some	-	Y?	N	Y/N	Y	Y	N	Y	N	N	?	N	-	N	some	N	N	N	5	10
	- inspection reports Yes/No	N	some		Y	-	Y	N	Y	Y	Y	Y	Y	Y	N	Y	N	N	some	some	N	N	N	9	8
4.	Are the defences in your area regularly inspected? Yes/No	Y	N		Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	some	N	N	N	15	4
4.1	If so, are inspection reports prepared? Yes/No	N	some		Y	-	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	excp	N	N	N	9	9
5.	Do you have a system for classification of breaches and their repair? Yes/No	N	Y		-	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	1	18

▨ Questionnaire Not Completed

Table 3.1

also contains flood warning information, based on the national colour coding system, the details of which have been put together by the local office.

In all areas there is a rota of duty officers. If there is an emergency or the area is on flood or surge tide alert it is normal to open up the local office incident room, usually manned by the District Engineer, and to get other operations staff out patrolling the defences at risk, particularly those that are historically problem spots.

Most, but not all, areas claim to have a format for reporting incidents. Although not included in the questionnaire, the information from site visits indicates that there is generally an information post-mortem after an emergency but the lessons learnt from the operation will not usually be written up for future reference.

The availability of historical records of defences is patchy with "as built" drawings and inspection reports being better provided than maintenance information. Whether it would be a realistic proposition to consult such records in the event of an emergency is questionable. Nevertheless good practice suggests that basic data on the defences and their history should be recorded and be available if required.

3.3 Training and Liaison

Less than half of the questionnaire respondents claim to have had some training in how to deal with emergencies, and this is consistent with the information gathered during site visits. Training can take many forms from workshops to discuss or review procedures to full scale field exercises, sometimes involving outside organisations. Field exercises are expensive but they can be very effective if they are relevant and targeted at the correct staff group.

In the event of an emergency, local councils, the police and sometimes other emergency services will be involved. Certainly it appears that it is the responsibility of the police to order evacuation of properties but they can only do this effectively if they are liaising closely with the NRA. This points to a need for periodic coordination between all parties so that each one is able to perform when an emergency occurs. From the limited sample of site visits the practice varies from regular meetings at regional level to annual meetings at district level and informal local contact.

3.4 Inspection

The apparent decrease in occurrence of breaches is generally attributed to strengthening of defences over the years by raising and/or improved construction and equipment availability. Thereafter inspection and maintenance are extremely important to keep defences in good condition. No attempt has been made to study maintenance regimes but questions have been asked about inspection procedures.

From the questionnaires returned, regular inspection of defences is carried out in over 75% of areas. The information gained during site visits indicates that coastal defences are inspected much more frequently than fluvial defences. Inspection is usually twice a year, before and after winter, and again after an event. In a few areas sea defences are also checked for level and cross section twice a year, however this varies greatly since defences in areas where active erosion is a problem, can be monitored on a monthly basis, while in others no surveys are carried out.

In only a few areas are fluvial defences inspected regularly, although operations staff observe them during maintenance work and report any problems. In the North West Region the visit to the Central Area revealed that a vermin operative inspects embankments twice a year and reports on any visible problem areas.

One point relating to maintenance, which has come out in most of the discussions, is the need for regular cutting of grass on embankments which are not grazed. Cut grass leads to clean growth, which binds and protects the bank. A general minimum requirement is that the tops and backs of banks be cut annually. Also if the grass is not cut you cannot inspect effectively and will not identify potentially troublesome vermin/rabbit holes or other problems. Another point is that bushes on banks attract animals and it is better to keep banks clear.

3.5 Degree of Preparedness

The responses received from the NRA regions and the preceding sections indicate the variability in the state of preparedness to respond to breaches in defences. This will not necessarily reflect the performance in the event of an emergency but may have some bearing on aspects of it. Notwithstanding this there should be contingency plans for dealing with emergency events.

To be effective a plan must be clear and concise and easy to follow such that any participant can clearly identify his role and the action expected

of him. Such plans should probably include both regional and local (area) information and will inevitably be closely related to flood warning procedures. They should include inter-alia:

- duty rotas;
- responsibility (who does what and when);
- telephone numbers of NRA staff and external contacts (police and other emergency services, local council etc);
- contact details for emergency contractors, plant hire contractors, material suppliers;
- location/availability of stocks of emergency materials;
- access details and landowner information;
- areas at risk maps (if available);
- incident report format and breach repair proforma, and
- budget approval procedure (if applicable).

It is recommended that at least basic procedures, as indicated above should be available in all areas. The need for emergency response to be documented is important and a possible format for a breach repair proforma is given as Figure 3.1. It is based on the proforma used in the questionnaire survey with some modifications.

The availability of procedures and/or contingency plans will only be successful if the people involved know what to do. It is important therefore that such procedures are introduced to all staff, possibly through local workshops, or in association with periodic training exercises. These exercises should involve all levels of staff and, if possible, practical applications in the field. Such exercises are expensive and therefore need to be carefully planned and implemented to be cost effective.

FIGURE 3.1

EMERGENCY SEALING OF BREACHES - PHASE I

BREACH REPAIR POST MORTEM

If you have recently been involved inthe sealing of breach you are requested to complete this form.

Name:

Position:

(i) Date of breach

(ii) Type of defence coastal/tidal/fluvial

(iii) Type of construction earth embankment/ sheet piled wall/ concrete wall/other (specify.....)

(iv) Antecedent conditions (weather/river flow/tide etc)

(v) Reasons for the breach (design or maintenance problems?)

(vi) Repair procedure (temporary or permanent works, type of construction, etc)

(vii) Type of plant used

(viii) Materials used and were they available from stockpiles

(ix) Site access (permanent/temporary, landside/waterside etc)

(x) Consideration of environmental or conservation aspects in repairs

(xi) Involvement of other parties (local councils etc)

Continued overleaf

(xii) Approximate extent of property/people flooded

(xiii) Property/people evacuated if any

(xiv) Other comments

(xv) Please include a location sketch in the space below to show extent of breach, access routes and areas flooded.

4. HISTORICAL REVIEW OF BREACHES

4.1 General

Flood defences come in many forms, mostly earth embankments with or without revetment, but including rock bunds, concrete walls, piled walls and more naturally occurring shingle ridges. The need for hard defences or heavily revetted embankments applies to coastal, and to a lesser extent, to tidal defences. Except in urban areas, fluvial defences are invariably earth embankments, usually with no more than grass protection. Breaches have occurred as a result of:

- overtopping and erosion of the back face;
- attack of weak spots or cavities, possibly caused by vermin or root growth;
- toe and/or face erosion, and
- slip failure.

The first two of these are the most commonly reported causes.

There are numerous possible ways of sealing a breach. Each situation will be unique in its timing, location and severity. The actual method adopted to seal the breach will be dependent upon several factors amongst which are the location of the breach, its magnitude, consideration of what is at risk and how urgently the breach needs to be sealed, and also what resources are available to carry out the repair. Decisions as to how to seal the breach are often taken on the spur of the moment, assisted by experience and local knowledge. Whatever decisions are made, the basic principle is to stem the flow of water through the breach and this is often achieved by whatever means are available at the time. In general breaches are unexpected, occur with little warning and the sealing operation often inevitably reflects reaction without sufficient time for planning and coordination.

By considering historical accounts of breaches and questionnaire returns general trends for sealing methodologies can be obtained. Research to date has found records of breaches going back to the eighteenth century with detailed accounts of breach sealing dating from the 1930's. Since this time the availability of hydraulic plant has significantly changed the approach to the emergency sealing of breaches. Improved construction methods and design have reduced the occurrence of breaches while

changes in the approach to inspection and maintenance have also had an impact on the number and severity of incidents.

4.2 Coastal Defences

Coastal defences have traditionally been embankments erected on saltings and set well back from the sea. In storm conditions the saltings acted to alleviate wave energy reaching the embankments. As foreshores have receded the energy alleviation provided by the saltings has reduced and the defences have come under increased attack. This has, to some degree, been remedied by improved defences and maintenance.

Since saltings and mudflats have such a strong influence on the severity of wave attack experienced by the sea defences, they can be considered as an integral part of the defence and as such will require their own maintenance and protection. It is essential that, where present, the saltings are preserved (although most are eroding, CIRIA 1986) and their erosion limited by protection at the seaward edge.

Sea defence structures are often protected from erosion and wave action by a revetment system of which there are four principal types of construction based on rock, concrete, bitumen and grass. The type of revetment selected will depend on many factors including the degree of attack anticipated, the cost of providing the revetment and the type of materials that are available locally. In terms of maintenance, a flexible type of revetment is preferred since it will accommodate settlement, prevent scour of the embankment itself and provide an external visual sign that remedial works are required.

The revetment along with the embankment and the foreshore form a complete coastal defence, with each part requiring maintenance for the whole structure to remain effective.

Historically maintenance has been carried out by compact teams on a small scale and regular basis to prevent deterioration of defences. These small teams have been considered economically unviable and maintenance has tended to shift towards reactive emergency repair which is either curative or carried out to prevent rapid deterioration of the defence. An acceptable approach to maintenance, as practised by some NRA regions, is to carry out a rolling programme of maintenance and inspections.

Probably the most memorable and catastrophic floods of this century were the 1953 East Coast floods during which 300 people died, 24,500 houses were damaged and 30,000 people evacuated. These floods occurred under

an extraordinary combination of tide, atmospheric pressure and wind which the coastal and tidal defences were unable to deal with, resulting in numerous breaches. Many of these defences were constructed from concrete or earth embankments with revetment protection and failure occurred primarily due to overtopping and back scour during the exceptionally high tide and heavy seas. At that time, with little heavy hydraulic plant and difficult access, breach sealing was a labour intensive operation relying heavily on sandbagging as a first response.

Since 1953 the East Coast defences have been improved considerably, through massive capital investment, and few breaches of coastal defences have been experienced recently. In cases where breaches have occurred a temporary sealing method has been to fill the breach with chalk and face it with concrete. In other cases imported stone has been used and there is a report of helicopters being used to lift in large bags filled with sand or earth. Observance of the tide cycle and the need to complete the filling operation to high tide level before the next high tide is frequently a most important consideration.

A method of breach sealing employed with success during the 1953 breaches was the construction of ring walls on the landward or seaward side of the breach. Since 1953 there have been only a few recorded uses of this method although the reasons for this lack of use are not apparent. Research in Japan has yielded no examples of the use of ring walls since 1917 (Fujita, 1987).

In some areas sea defences take the form of shingle ridges, an example being Chesil Beach in Dorset. There have been several recorded incidents of overtopping and lowering of the ridge crest. During heavy seas, such as those experienced in February 1979, the ridge profile becomes flattened, increasing the likelihood of overtopping. Severe flooding is also caused by percolation through the shingle structure. Although no actual breaches occurred in 1979, it is likely that continued denudation and overtopping would have led to a breach. In such incidents the repair method is to wait until the storm subsides and use heavy plant to reshape the ridge with material from the beach or nearby areas in which the eroded material has been deposited.

4.3 Fluvial Defences

The majority of fluvial defences reported are earth embankments. Failures of these embankments generally occur during periods of high river flow and are caused either by overtopping leading to back erosion or by percolation through the embankment leading to a piping type of failure.

Most failures are avoidable either by design and/or inspection but cost consideration often precludes such measures being taken. In some NRA regions embankments have been raised and the rear face of defences protected against overtopping. Dependent on the value of the land behind the embankment, it is becoming preferable (and cheaper) to protect the rear face and allow overtopping rather than to raise the embankment.

Animal burrows in embankments are considered a major problem in many NRA regions and have, on several occasions, been attributed as the cause of embankment failures during high river flows. Vermin operatives are employed in some NRA regions to inspect earth embankments and reduce the likelihood of piping type failures via animal burrows.

In natural channels both erosion and deposition can contribute to bank failure and breaching, as recorded by Wessex and Northumbrian NRA regions. Erosion can undercut river banks causing failure while deposition can raise bed levels effectively reducing the embankment height and increasing the risk of overtopping. Regular maintenance, inspection and dredging are therefore important issues.

Notable fluvial breaches occurred in Lincolnshire in April 1981 on the Rivers Ancholme, Bain and Barling's Eau. Here several methods were employed to seal breaches including sandbagging, trench sheets and timbers and filling with local or imported material. During the floods on the River Trent in 1947 several breaches occurred and in one situation barges were sunk in the breach to help stem the flow.

The method employed is dependent upon the magnitude and severity of the breach, location and availability of plant and materials. Generally speaking, and with the exception of sandbags, there are very few stockpiled materials specifically held for breaches. Sandbags are often used as a first response to a breach, however vast numbers may be required to facilitate an effective breach seal. Sandbags are also used to temporarily raise embankments during high flows to prevent overtopping. A more effective method of breach sealing uses sandbags in conjunction with fence stakes or trench sheets. Materials are ideally available locally and there are several recorded incidents of embankments being rebuilt with alluvial material deposited during floods. If not available, then local materials suppliers such as quarries or nearby construction sites need to be contacted. Invariably heavy plant is not immediately available and in many cases local plant hire firms have to be contacted.

4.4 Tidal Defences

Many tidal defences are earth embankments and hence failure mechanisms are similar to those for fluvial defences with the causes invariably being surge tides and rough weather combined with high river flows in some situations. During the 1953 storms many tidal defence embankments failed due to overtopping, erosion and percolation in the extreme conditions. There are also several recent accounts of breaches in concrete tidal defences due to non-maintenance or interference from land owners. The earth embankments have been sealed using methods as discussed for fluvial events however the concrete defences have utilised methods such as concrete filled sandbags and compacted clay to effect a seal.

As with coastal defences, the sealing of tidal breaches should preferably be undertaken at periods of low tide and hence the timing of operations is crucial involving substantial planning of resources to repair the breach and limit any flooding to the region. There is sometimes a need to stockpile materials on site ready for filling during the next low tide cycle.

With tidal, or in fact coastal or fluvial defences there is often a difference in level between the ground on either side of the defence. If a breach occurs this can also lead to a scour hole beneath the line of defence, which requires a large volume of material to fill it. Emergency repairs should consider a temporary bund around the edge of the scour hole tied in to the main defence on either side of the breach.

5. BREACH SEALING

5.1 Common Breach Sealing Methods

From the preceding discussion chapter commonly used breach sealing methods can be identified. A summary of these is presented in Table 5.1.

5.1.1 Sandbagging

Sandbags are one of the few materials applicable for breach sealing that are kept in large quantities by the NRA. Although of little use for large scale breaches due to the vast numbers required, sandbags can be an effective breach sealing method for small scale events. Irrespective of the breach magnitude, sandbags offer a flexible first line response and most emergency personnel will be familiar with their usage. Normally hessian sandbags are used since they have good bonding qualities but without treatment they are liable to rot. Plastic bags do not have this problem but they do not bond well. The bags are generally taken to site empty and then filled with whatever material is locally available (eg silt, sand or clay). There are reports of stocks of sandbags being filled in readiness for emergency response.

Some regions possess machines to fill sandbags. These machines are generally kept in a fixed location and are therefore best used to prepare a stack of filled sandbags for distribution by the NRA in times of emergency. The machines have limitations in that they are only able to use sand and moreover only particular grades of sand.

5.1.2 Sheet Piles

Sheet piling is a breach sealing method more applicable to permanent repair when conditions have improved, rather than as a rapid response emergency repair method. Only one case of its use in emergency has been reported from the NRA regions.

Large scale specialist equipment is required to perform a sheet piling operation and such equipment is unlikely to be available and close enough to the emergency. The scale of the equipment coupled with the likelihood of restricted temporary access to site and the probable requirement to work on narrow and unstable embankments also preclude the use of sheet piles in emergency situations. However, when planning permanent repairs at a later date, sheet piling can be considered as a viable method.

5.1.3 Trench Sheets/ Fence Stakes/ Posts

A more convenient alternative to sheet piling is to use materials such as trench sheets, fence stakes or posts. These kinds of materials are usually available somewhere near to the breach occurrence and have the advantage that they are readily transportable to site. They can be driven easily into a vertical position using the bucket of a hydraulic excavator and reinforced with timber walings if necessary. The resultant structure normally forms the basis of a temporary repair and is reinforced, to add extra strength and staunch flow through the breach, with other materials such as bulk fill, concrete or sandbags.

5.1.4 Bulk Fill

An often convenient and rapid method of staunching flow through a breach is to use bulk fill. Bulk fill is ideally locally won from borrow pits or, as recorded in several fluvial events, the alluvial material deposited on the land following a flood. In tidal and coastal breach situations there is generally adequate locally available material from the foreshore or nearby breaches. If bulk fill material is not locally available then it will require importing. Local construction sites and quarries are a good source of bulk fill material.

Materials and transportation are often expensive, particularly stone, and therefore a realistic estimate of quantities required will need to be made. When estimating the quantity required due allowance must be made for any scour hole beneath the breached defences.

Plant requirements for bulk fill operations should be available locally and typically include excavators, dump trucks and bulldozers.

When placing the fill care must be taken to ensure that the material placed has sufficient weight to withstand the erosive forces in the breach or is placed in sufficient quantities that the main portion is not carried away by the current. If feasible, consolidation of the placed material by heavy plant can assist the bulk fill in resisting erosive forces. As mentioned previously when using bulk fill in emergency situations it may be necessary to miss a low tide window or wait until water levels subside in order to allow adequate stockpiles of material to be amassed. If a sufficient volume of material is not available to staunch the flow then any material placed in the fast flowing current could be washed away and render the operation useless.

A further consideration when using stone is that water will flow through the voids between the blocks. A sealing layer such as a clay core or plastic sheeting is therefore necessary for an effective repair.

5.1.5 Mass Concrete

Mass concrete has been used to fill sandbags and repair tidal and coastal defences. Although a viable means of breach sealing, concrete is expensive and its availability cannot always be guaranteed, either because of access problems or the need for large quantities at short notice.

5.2 Alternative Breach Sealing Methods

Several potential methods of beach sealing have been researched during the course of this study, although only large bags can be foreseen as having any widespread use. It has to be appreciated that most repair situations are unique and there is unlikely to be the market demand to justify a manufacturer committing funds to product development.

5.2.1 Stone Filled Gabions

Although there are no records of them being used to seal breaches in the UK, stone filled wire mesh gabions such as those produced by Maccaferri have been used to seal breaches in embankments and river training works on the River Po in Italy. Cylindrical shaped gabion baskets were filled with stone on site, with each completed gabion weighing 900kg. The gabions were loaded onto a barge and then dropped into place to seal the breach. 50,000 gabions were used to seal a 400m long breach.

On the River Po the stone filled gabions were used as a permanent repair. It would however, be feasible for emergency repairs to be carried out using this method if the gabion baskets and stone are readily available.

Another use of stone filled gabions is for placing of the toe of embankments to prevent slumping and potential failure. Cases involving gabions used in this context have been recorded by NRA North West region.

Major problems exist when considering the use of gabions. Firstly sufficient stone of suitable quality and specification is required to fill the baskets. This stone may not be available on site and will require importing, which in itself could prove difficult both in location and transportation to inaccessible areas. Once filled with stone the gabions

require lifting into position. This will invariably require heavy plant which may not be able to gain access to the site.

An alternative method of placing the filled gabions is to lift them in using a helicopter. Generally military helicopters are used in emergency situations. Successful trials utilising military helicopters and Maccaferri gabions in a simulated emergency were performed by the Joint Air Transport Establishment and Wessex Water Authority in 1984 (Wessex Water Authority 1984). Helicopter use has the advantage that the gabions can be formed off-site at a stone stockpile and lifted directly into position. The disadvantage is the considerable expense in carrying out such an operation (recent experience by Anglian NRA in Suffolk quoted a cost of £1800 per hour), although in some circumstances the cost may be borne by the military. Other considerations when using helicopters include the available lifting capacity and flight time from the gabion source.

The base area of a gabion basket is at least 2m x 1m and ideally they should be placed on a prepared bed such that they can be stacked together in an orderly form. With breached defences these conditions do not exist. Also, as with bulk stone fill, gabions require a sealing layer to form an effective barrier to water.

5.2.2 Large Bags

Large sand bags have a potential in emergency breach sealing. Large fertiliser type bags filled on site and weighing 1/1½t have been used in some breach instances in the UK. However the criticism that they do not bond well has often been made. Their availability, from local farmers etc, is not usually a problem, but when full, they do require plant on site to handle them.

Shoreline Erosion Arrestor Bags (SEA bags) are semi porous polypropylene containers designed to be filled with a sand and water slurry via a self sealing valve. The permeable fabric allows the water to escape leaving the sand in the bag. When filled these bags weigh approximately 3t. The bags have been used in the USA as a form of beach erosion protection but it is possible that they could be applicable for use as an emergency sealing method.

Nicobags, marketed by MMG Civil Engineering Systems Ltd (MMG) are a synthetic type of sandbag. Various sized bags are available and they are filled and stitched up on site. It is probably unrealistic to expect large stocks of different size bags to be kept and, because of the limited demand, their availability in emergency cannot be guaranteed.

Another product marketed by MMG is the Geocontainer which is a large sized geotextile bag. The bag is placed into a barge, filled with granular material, sealed and then dropped into place where required. The size of the bag is variable and has many potential uses including the emergency sealing of breaches.

Flexible transportable bulk bags are available from FPT Industries. These bags are intended to be lashed onto a trailer and filled with liquid via a valve. The bags can be tailor made and are very durable. Such bags filled with water could have a potential use in breach sealing.

5.2.3 Emergency Boxes

Some NRA regions have considered the use of emergency boxes built from ply wood in a steel frame. The boxes, sized 2.4m x 1.2m x 1.2m are intended to be positioned in a breach and filled with any material on site. It is anticipated that these boxes could form the core of a permanent repair. The idea behind these boxes is a development of the gabion basket concept but doing away with the need for stone fill.

There are however potential problems with this system which have not been addressed. Firstly it must be considered that these boxes are very large and bulky and therefore not easy to transport to an emergency site. Producing boxes in a flat packed format with rapid, simple and robust assembly would overcome this problem.

The boxes have a rigid shape, which, although being very useful for stacking onto each other, makes them very difficult to place on an uneven bed. There is therefore some preparation required to form a flat base for the first layer of boxes to sit on. This preparation could prove to be very difficult in a remote location, with limited plant and in a fast flowing current.

5.2.4 Flood Prevention Booms

Allen Plastics Limited are proposing to manufacture a flood prevention boom from heavy duty PVC. The boom would be collapsible for transport to site, similar to a large fireman's hose, and once on site it would be unreeled and filled with water via a supply pump. The dimensions of the boom when full of water would be 30m long and 1500mm high, however it is anticipated that these booms would be used with a flood level of up to 500mm. The boom needs to be secured to the flood defence via a cleating system. Several booms can be connected together via anchor plates at each end to form any required length of defence.

Ideally the booms would provide a rapid response to prevent the overtopping of embankments (hence preventing scour and failure) in the event of rising water levels. This solution would hopefully be quicker to effect and less labour intensive than the traditional method of sandbagging to raise embankments.

A major drawback with the Flood Prevention Booms is that they are not yet in production and hence untested. An important issue that would require resolving before production is the provision of adequate durability and storage life. The effectiveness of the seal between the boom and embankment is also a matter of concern.

The booms are probably not applicable as an emergency means of breach sealing owing to the fact that they would be difficult to fill and secure in a fast flowing breach situation, and there would probably be insufficient protection height for the breach to be sealed. However, in areas prone to tidal or fluvial flooding and where adequate advance warning of high water levels is available, the booms could be brought in to location in the event of rising water levels. The rapid installation and filling would make the booms highly suitable in such emergency situations.

Inflatable rubber dams have been used in river control structures, but they are made to measure for a specific situation. Also they need a hard base to which to be anchored and are not considered to be suitable for sealing breaches.

5.2.5 Slope Stabilisation

Although not strictly a breach sealing method, slope stabilisation by methods such as soil nailing represents a means of preventing the occurrence of breaches. Soil nailing involves driving rigid rods into a slope to improve the strength of the soil mass hence making it less likely to fail.

The rods are driven into the embankment using a compressed air gun mounted on the boom of a standard caterpillar tracked vehicle. This is the only specialist plant required for the operation although a support vehicle is necessary to carry the nails which can be up to 6m long and 38mm in diameter.

The system is primarily aimed at strengthening existing embankments which show signs of impending failure.However other potential uses have been identified such as the temporary or permanent repair of failed slopes, improving the stability of an existing flood embankment so that it can be

Attributes \ Available Methods	Historic Methods					Possible Methods							
							Large Bags						
	Sandbags	Sheetpiles	Trench sheets Fence stakes Posts	Bulkfill	Mass Concrete	Gabions	SEA	Nicobag	Geocontainer	FPT	Emergency Boxes	Flood Prevention Booms	Slope Stabilisation
Suitable for large scale breaches	no	yes	yes	yes	no	yes	no	no	yes	no	no	n/a	n/a
Suitable for small scale breaches	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	n/a	n/a
Suitable for coastal breaches	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	n/a	n/a
Suitable for tidal breaches	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	n/a	n/a
Suitable for fluvial breaches	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	n/a	n/a
Specialist plant required	no	yes	no	yes	yes	yes	no	no	yes	no	no	no	yes
Applicable as permanent repair	no	yes	no	yes	yes	yes	no	no	yes	no	no	no	yes
Applicable as temporary repair	yes	no	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	no
Suitable for rapid response													
– materials kept in stock	yes	no	yes	no	no	no	no	no	no	no	no	no	no
– materials readily transportable	yes	no	yes	yes	no	no	no	no	no	no	no	no	no
– materials available at short notice	yes	yes	yes	yes	yes	no	yes	yes	no	yes	no	yes	no
Suitable as a preventative measure													
– toe protection	no	yes	no	no	no	yes	yes	no	no	no	no	no	no
– crest raising	yes	no	no	no	no	no	yes	yes	no	no	no	yes	no
Sealing layer required	no	no	yes	yes	no	yes	no	no	no	no	no	no	n/a
Preparation of breach required	no	no	no	no	yes	yes	no	no	no	no	yes	no	n/a
Ability to use in fast currents	yes	yes	yes	no	no	yes	yes	yes	yes	yes	no	n/a	n/a
Ability to stem breach rapidly	no	yes	yes	yes	no	yes	yes	no	yes	yes	yes	n/a	n/a

note : responses yes/no are only indicative; they will vary by region/area and need to be assessed by potential users prior to application in an emergency situation

Figure 5.1 Summary of Breach Sealing Methods

raised and still maintain an adequate factor of safety against failure, and anchoring of revetments and surface treatments to embankments.

It is not considered that soil nailing would be applicable in an emergency breach situation as it will do little to stem the flow of water through a breach. However, coupled with a regular inspection and maintenance programme the technique could prove a very useful and cost effective means of preventing breaches occurring.

5.3 Breach Sealing Considerations

When undertaking a breach sealing operation there are many factors that need to be taken into account. These considerations are discussed below.

5.3.1 Timing of the Operation

In certain circumstances a breach sealing operation may need to be undertaken immediately. This scenario is likely to occur where the threat from flooding associated with the breach is high. High threat would indicate large volumes of flood water, and risk to life and property. Tidal and coastal breaches are generally more serious since the immense volume of flood water coupled with severe coastal conditions experienced during heavy seas and storms can be a serious threat to life. The nature of the saline water also has a far greater damage potential, particularly to agricultural land and property, than fluvial flood waters. There is also a greater sense of urgency with tidal flooding in that more floods are likely to occur at the next high tide if the breach is not repaired.

In several situations it may be necessary or prudent to delay the breach sealing operation on the grounds of insufficient material or adverse weather, flow or tidal conditions. In a tidal breach situation recorded by North West Region, no attempt was made at repair on the following high tide as it was predicted to be equally high as that which caused the breach. The interim time was spent preparing access to the site and stockpiling materials before repair was effected when tidal levels dropped. Problems with insufficient or inappropriate material were experienced in Anglian region when attempting to seal a breach in sea defences. Stone and concrete were dumped during low tide but were found not to be totally effective and some stone was washed out during the next high tide. The problem was eventually remedied by placing some surplus precast concrete step units which were available at the time. Delaying repair could possibly lead to a greater volume of flooding, however it would be inadvisable to attempt an operation with insufficient material.

During particularly heavy flooding and large breaches, the breach site may be inaccessible or the flow of water so severe that a breach sealing operation would be impractical and potentially dangerous. In such conditions it would be advisable to concentrate on evacuating those in danger, protecting properties at risk, preparing access to the breach location and making general plans for the breach repair operation. Safety considerations must always be overriding when deciding what action to take.

5.3.2 Drainage of Flood Water

There have been cases where flood water, trapped behind the defences, has had to be pumped out after the breach has been sealed. Such a situation and the high cost of pumping are to be avoided if at all possible. Incidents have also been recorded where floodwater trapped behind an embankment combined with a rapid draw-down of rivers levels have led to breaches occurring from the land to the river. When planning the repair, or when considering preventative measures, account should be taken of the drainage from the flooded area and the possible need to provide a release through the defences. In some past situations the defences have been deliberately breached to allow flood water to return to the river. ARMCO pipes with flap gates have been referred to in some NRA areas, as a means of relieving flood water, and should be easily obtainable if needed.

5.3.3 Site Access

Access is often extremely difficult when a breach sealing operation is required to be undertaken. Invariably, breaches occur in inaccessible locations, during foul weather and in the dark of night.

Nearly all sealing operations will require vehicular access and probably access for tracked plant in addition. Moving such plant to remote sites can itself be an immense problem and one that requires considerable planning and discussion with landowners beforehand. In most situations recorded, permanent access was not available and temporary access was required.

When dealing with coastal breaches, access to the site can be an acute problem since many defences were built using seaward access. In such cases an assessment of the foreshore conditions and the potential for access from them should be considered. Sandy beaches will be relatively easy to traverse while mud flats could be treacherous. In cases where potential access is difficult it may therefore be prudent to consider

providing permanent access to the rear of defences. The cost of permanent access may appear large, however it is worth considering that the costs of temporary access for the repair and reconstruction of revetments can be as high as 20% of the contract value (CIRIA 1986). Permanent access can also be useful for operation and maintenance.

A common method of gaining access to breach locations is to travel along the embankment. There are potential problems associated with this, however such as the limited width generally available and the possible unstable nature of a breached embankment. The North Essex area of Anglian NRA has overcome these problems to some extent by developing special frames that enable their equipment to work along and from the top of narrow embankments. The frames are carried and placed by the plant using them, usually a hydraulic excavator.

5.3.4 Temporary or Permanent Repair

Some NRA regions visited expressed the view that the temporary breach repairs are not preferable since they are wasteful of time and money. This is obviously dependent upon what is at risk from the breach. However, temporary repairs are often carried out in haste and are inadequate as long term solutions. Permanent repairs are therefore required at a later date and extra costs are incurred. Consideration therefore needs to be given as to whether a temporary repair is required and also if it is possible to incorporate any temporary works into the permanent structure.

5.3.5 Logistical Support

When planning and carrying out breach repairs the welfare and morale of the workforce has to be taken into consideration. The provision on site, or as close as possible, of a cabin or shelter and plenty of hot drinks and food is most important.

Arrangements must also be made for a relief workforce. It is accepted that long hours can be worked in emergency situations but there are limits and shift working may be necessary.

5.3.6 Safety

The NRA's responsibility for health and safety must be considered at all stages of a breach sealing operation. The whole operation is potentially very dangerous since the extent of damage and likelihood of further breaching is often very difficult to ascertain in the confusion of an incident.

When initially investigating breaches, extra caution need be exercised to avoid entering a situation that is impossible to exit. At this stage communications with a control centre are absolutely vital. After assessing the extent and nature of the breach it is quite conceivable that it is considered too dangerous to proceed with the repair.

If repair is to be carried out it may be necessary to carry out some preparatory works to stabilise the situation. These could include reinforcing a potentially weak embankment to aid access and prevent failure, or limiting the extent of the breach using trench sheets. When undertaking the repair it is essential that personnel, and indeed anybody else, are not put at risk and that the NRA are fully aware of their health and safety responsibilities.

6. PROPOSALS FOR FUTURE WORK

6.1 Operational Guidance Manual

6.1.1 Document Format

The objectives of the review include an assessment of and proposals for the requirements of an operational guidance manual, which will detail the various methods of sealing of breaches in emergency and advise on best options/practice. The production of the operational manual will be undertaken in Phase 2.

The term manual suggests an extensive document with precise and rigorous guidance on how to tackle the problem. Case histories and data reviewed during this study point to the uniqueness of events and their solution. Production of a manual in traditional form is therefore difficult, possibly misleading and probably inappropriate. The word manual could mislead an inexperienced person into thinking that, in isolation, the correct solution to any incident can be defined. This is not the case. An extensive document may be both inappropriate as a reference document during an emergency and off putting to operations staff expected to use it.

Notwithstanding the above there is scope for producing a potentially valuable document towards achieving the objective envisaged. In this case the title of "Guidelines" may be a better description than "Manual" but that is peripheral to the purpose. It will be a document based on flow charts or decision trees with pointers as to the direction to follow, and backed up by limited text on methods, materials, plant, logistics etc. A typical flowchart for a breach sealing methodology is given as Figure 6.1. Decisions within the flowchart could be expanded upon, as shown in Figures 6.2 and 6.3. However, it is stressed that these flowcharts are only preliminary and they need to be carefully considered and developed as part of the guidelines preparation.

It should be noted that the guidelines or manual will be separate from and in addition to the emergency procedures or contingency plan. There will inevitably be cross referencing between the two documents, and possibly to other flood warning procedures. The following sub-section gives ideas on chapter headings which could form the basis of a document to be worked up in Phase 2.

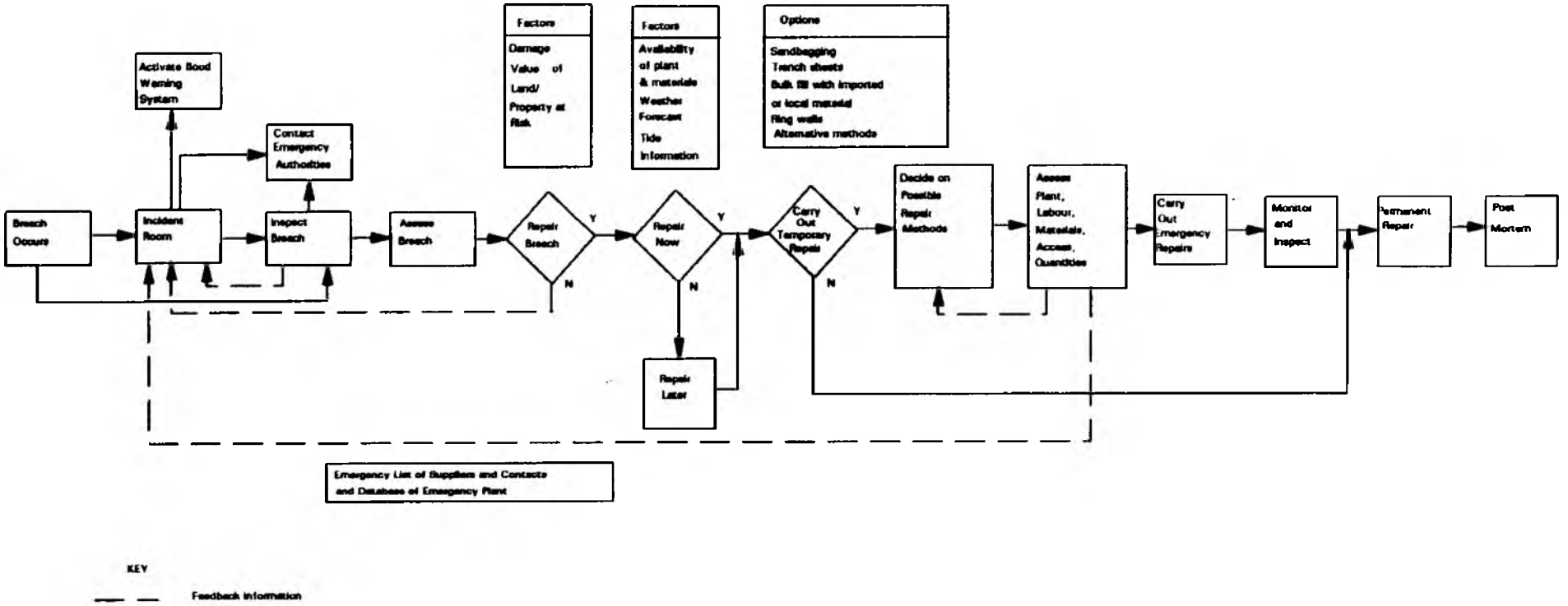

Figure 6.1 Flowchart Outlining Breach Sealing Methodology

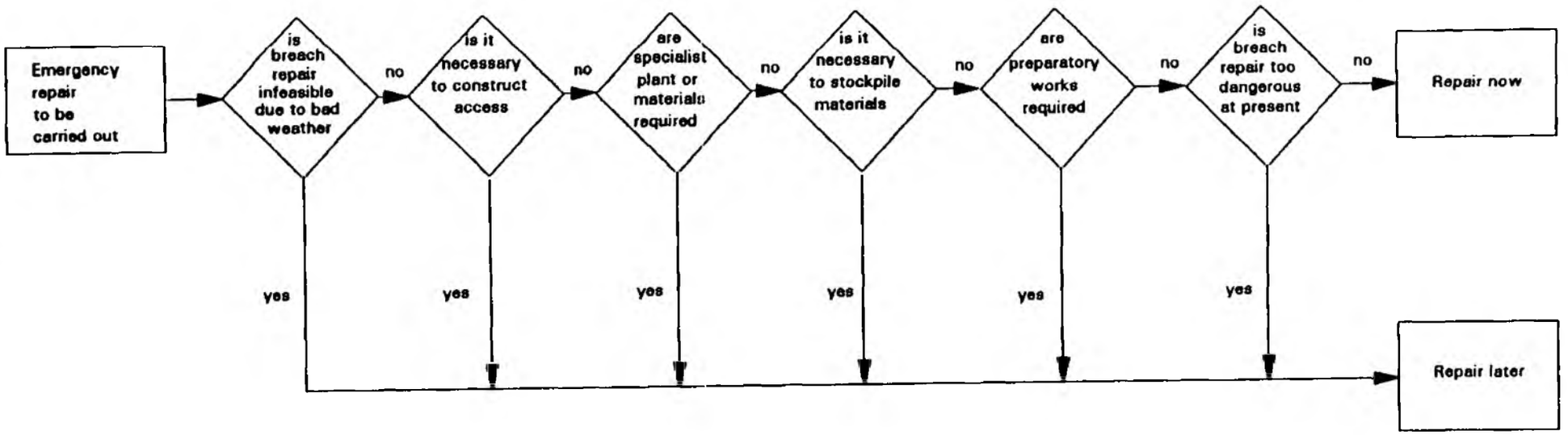

Figure 6.2 Flowchart Outlining Decision to Repair Now or Later

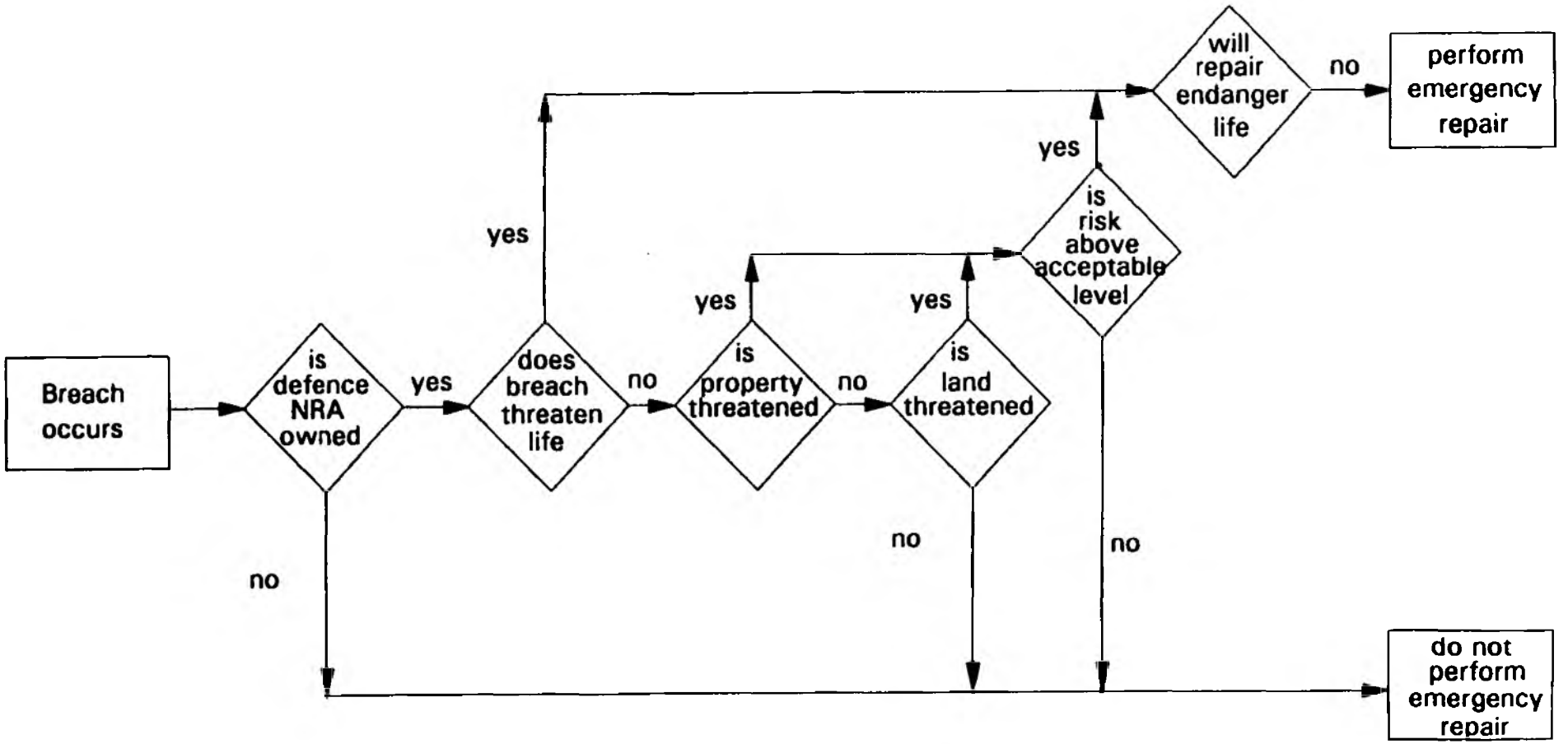

Figure 6.3 Flowchart Outlining Decision to Perform Emergency Repair or Not

6.1.2 Content

The guidelines will be aimed at the on site works following occurrence of a breach. They will assume that the area incident room has been set up and lines of communications have been established with other interested parties.

Possible chapter/ section headings for the guidelines are as follows:

Chapter 1 - Evaluating the Decision to Repair

Chapter 2 - Water Level/ Flow Conditions;

Chapter 3 - Method of Breach Repair;

Chapter 4 - Access;

Chapter 5 - Materials;

Chapter 6 - Plant;

Chapter 7 - Logistics, and

Chapter 8 - Post Repair Considerations.

Some initial comments on these are given below.

(a) Chapter 1 Evaluating the Decision to Repair

It must not be assumed that emergency repairs have to be carried out to all breaches. The decision should be based on what is at risk if repairs are not carried out. Obviously if developed areas are flooded or threatened then the likelihood is that an attempt should be made to seal the breach if possible, whereas that justification is not necessarily there in the case of undeveloped or farmland. The likelihood of the breach becoming worse must also be taken into account.

Some thought needs to be given to how this decision will be taken. The logical approach is to use standards of service information and land-use bands for a particular defence reach. This will require that reaches be kept small and that data are available for each, possibly as an appendix to the emergency procedures.

A further basic point is to establish that the breached defence belongs to the NRA, or that it is their responsibility to repair it. If other parties are involved they should be consulted and agreement reached on the distribution of costs etc. Notwithstanding this, the NRA always has permissive powers to carry out work to prevent flooding if it feels that this is necessary.

(b) Chapter 2 Water Level/ Flow Conditions

The timing of repairs will almost certainly be influenced by consideration of water level/ flow conditions, and whether the breach is in coastal, tidal or fluvial defences.

With coastal and/ or tidal defences reference should be made to the tide cycle and predictions of high tides for the next few days. If spring tides have passed so may have the risk and there could be up to two weeks in which to carry out repairs. However, if very high tides are expected to continue for the next day or two, and it has been decided that emergency repairs are necessary, then there is a need to act before the next high tide if possible.

With fluvial conditions an assessment is needed of the likely flow pattern in the river and whether or not the flood peak has passed. A receding river flow and level may obviate the need for emergency repairs or at least give better working conditions. Increasing flows and levels give no such respite.

The method of repair will also have to take into account the water level and flow conditions. If there is continuing flow through the breach, measures will have to be taken to stem the flow or any dumped material will have to be sufficiently heavy to withstand those forces.

(c) Chapter 3 Methods of Breach Repair

Chapter 5 has discussed methods of breach repair but guidance is required on which method to use. The decision on what to do will have to take into account the factors which are elaborated in other chapters of the guidelines: water level/ flow conditions, access, materials to use, and plant requirements. A table such as Figure 5.1 could form the basis of a decision regardig the applicability of methods.

Availability of materials and plant and the ability to get them to the breach site may be the determining factors in the decision. In other cases the need to stem the flow through the breach by some form of piled wall

or dumping of heavy material which will not be washed out may be the controlling factor. At the same time there is no point in considering steel sheet piling or dumped stone if access is not good enough to withstand heavy loading.

This chapter will require the development of a number of flowcharts or decision trees to guide the user towards an appropriate and achievable solution. They should lead towards the preparation of an action plan for the repairs.

(d) Chapter 4 Access

Case histories reported and reviewed often quote the problem of access to a breach site as being one of the main constraints to carrying out emergency repairs. Access should therefore be given relatively high priority in the decision making process.

The first question to answer is whether or not unrestricted access for all types of plant and transport is available. Only rarely will there be a positive answer to this and in most cases further questions will be posed:

- Is restricted access available?
- If yes, what are the restrictions on width and/or loading?
- If no, what is the shortest or most appropriate alignment for temporary access, such as along a flooded track or road etc?
- If necessary liaise with landowner and obtain agreement to construct temporary access.
- Decide on material type, eg hardcore, gravel, stone etc and determine approximate quantities and source for the temporary access road.
- Decide on a need for a filter under access road, if any, and type, amount and supply source.

(e) Chapter 5 Materials

This chapter should cover the type, quantity, source and method and rate of placing materials. It should include bulk fill materials, but also

sandbagging, piling in its widest sense, and any other ancillary requirements, such as gated drainage pipes, plastic sheeting, concrete etc.

The materials to be used will be decided at the Chapter 3 stage and be specified in the action plan. However, quantity and source of supply are important. If stone or rock is to be used quarry owners have to be contacted to arrange supply, whereas with earth fill somebody has to decide on the availability and suitability of material at the breach site. If this cannot be used another source has to be found and consideration should be given to local construction sites of quarries where spoil tips or borrow areas could be used.

The method and rate of placing of material will closely relate to the chapter on plant. There will be no use in having material on site which cannot be effectively placed in the breach, and this may determine the need for particular plant, ie long reach, lifting and/or driving capability.

A further important consideration, particularly when dealing with tidal conditions, is the possible need to stockpile materials on site before placing them in the breach. A partially completed repair which is over topped by the next high tide could be washed out and time and effort will have been wasted. In such cases breach filling should not start unless there is reasonable confidence that the stockpile of material on site or the rate of supply to site is not going to be a constraint to completing the operation before the next high tide.

(f) Chapter 6 Plant

Similarly, plant will also have been taken into account in the action plan but arrangements have to be made to ensure its availability and get it to site.

The NRA has its own plant resources which, if available, may be the most suitable for the work. This could include wide track/low pressure plant, small tracked dumpers, long reach hydraulic excavators etc. If the required plant is not available then it has to be obtained from a plant hire contractor. There will inevitably be cases where the limitations on what plant can be obtained will necessitate some re-thinking of the action plan.

A separate NRA project entitled "Viability of Emergency Plant and Vehicles" has already been undertaken. This project was carried out with the aim of assessing the viability of the NRA owning plant and machinery in order to respond to flood emergencies. Various types of flood emergency were identified including:

- localised breaches in embankments;
- repair of eroded or derived embankments;
- repair of under scour to sea defences through loss of beach material;
- repair of erosion to shingle ridges, and
- assisting other authorities in protecting the public or controlling the spread of water.

For each type of emergency, typical plant requirements were suggested although no details were provided on how to utilise the plant.

During the course of the Viability of Emergency Plant and Vehicles project a database of NRA owned emergency plant and vehicles was developed. If regularly and thoroughly updated, this database could prove a valuable tool for the NRA in the event of an incident.

(g) Chapter 7 Logistics

Although only peripheral to the main thrust of sealing a breach, good logistical support can ensure a successful operation. Items such as communications, shelter and messing facilities should be taken into account.

The use of car phones, pagers and two-way radio systems has considerably helped in communicating with isolated locations. A smooth and successful operation will require a link between the breach site and the area incident room.

High on the list of priorities should come the provision of shelter and facilities for providing hot food and drinks. If possible a cabin should be transported to the site or to a close location, otherwise a local community centre or school may be convenient and appropriate. The importance of this aspect in maintaining moral amongst the workforce subjected to inclement conditions on site should not be underestimated.

Small breaches could be repaired within 12 hours but if the operation is going to exceed this, arrangements will need to be made for a relief workforce. The responsibility for this should pass to the controller in the area incident room but the staff on site need to be reassured that the matter is under control.

The possible involvement of other parties should not be overlooked. There are many examples of land owners, local authorities and military helping in breach sealing operations.

(h) Chapter 8 Post Repair Considerations

Emergency procedures or contingency plans should include the format for the incident report. The need to hold a post mortem to review the successes and failures of the emergency action should also be specified.

Having carried out the post mortem, a procedure to collate and review the information at a national or regional level, needs to be implemented. The present thinking is that completed breach repair proforma will be kept by the Regional Flood Defence Manager, with copies being forwarded to a National Coordinator.

In addition operational aspects will need to be picked up to bring the operation to a successful close. Once repairs are complete there should be a procedure for the site staff to hand over responsibility for the site. Arrangements are required to maintain close inspection of the repairs for a period and also continued patrolling of the defences if they continue under threat. If repairs are temporary, the responsibility for assessing requirements for permanent repair has to be accepted by somebody.

Other points to consider are the clearing up of the site and the return of plant, equipment and surplus materials to their rightful home. There will be invoices to settle in due course for which approvals should be organised. Also workers timesheets will have to be completed, approved and forwarded to the appropriate office for payment.

6.2 Future R&D Topics

Identification of possible areas for further R&D is another of the objectives of Phase 1. It has to be said that no topics of obvious merit have come to light but some areas for possible consideration are given below:

(a) Evaluate the Decision to Repair

The first chapter of the emergency repair guidelines could have this title and further work is needed to identify the factors in the decision making and the responsibilities of the NRA in emergency situations. Risk assessment techniques could be used to aid decision making and establish acceptable levels of risk. Reach classification by standards of service land

use banding is one possible method that could be incorporated into a risk assessment to define the threat posed by a breach.

It is likely that this research will have links with the Standards of Service Studies currently being carried out by the NRA.

(b) The Need for Permanent Access

The problems caused by difficult access to breach sites is frequently referred to in this report. Section 5.3.2 makes reference to earlier work (CIRIA 1986) on the value of providing permanent access to facilities. This work could be reviewed, updated and developed with specific reference to flood defences.

(c) Appropriate Plant for Emergency Repairs

A separate NRA project (R&D note 51) has prepared a database of emergency plant and vehicles. This work could be expanded with a view to recommending most appropriate plant for breach sealing work.

(d) A Universal Breach Sealing Method

The uniqueness of breaches in terms of location, size, defence type, ground conditions etc means that it is most unlikely that a universal solution exists. Certainly there is not the market demand to justify a private manufacturing committing funds to this. Nevertheless the NRA may consider it worthwhile spending some money on further review and development.

(e) Effective Training in Emergency Response

It is rare that any training is wasted but it is often a costly exercise, especially if it involves practical work in the field. The preparation of recommended training programmes/exercises for dealing with emergency sealing of breaches would be a worthwhile exercise. Such training could consist of exercises, desk studies or videos.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The basic conclusions of the study are:

(a) There is a limited amount of recent experience in dealing with breach repair. This is generally attributed to raising and strengthening of defences, particularly since 1953, and to improved construction techniques and hydraulic equipment.

(b) Emergency procedures are available in some form in all NRA regions, but their coverage and level of detail vary considerably. There is a need to ensure that procedures or contingency plans, prepared to at least a minimum standard, are available in all regions.

(c) Inspection of coastal and tidal defences, usually twice a year, appears to be common practice, but less attention is paid to fluvial defences. The importance of maintenance, especially to grassed embankments, is widely accepted.

(d) Often the first decision to take in the event of a breach is whether or not to carry out emergency repairs or to wait until conditions improve and permanent repairs can be made. This will depend inter-alia on whether property is at risk, and possibly drainage from behind the defences.

(e) It is difficult to generalise about breach sealing methods. There is inevitably a need to treat each case on its merits, taking into account location, access, prevailing weather and tidal/water level conditions, and availability of materials and plant.

(f) When dealing with earth embankments, which constitute the majority of defences, and also shingle banks, the use of locally won material is the preferred practice. Imported clay or stone are sometimes used. With exposed coastal defences the use of dumped rock is more common.

(g) Sandbags are the only materials kept in stock for emergencies in all NRA regions. They have a use for sealing relatively small breaches, or temporary raising of defences to prevent overtopping. Large bags, either 1/1½t fertilizer bags or proprietary makes, are increasingly being used.

(h) Trench sheets have been used widely and effectively in combination with sand bags or earth fill, to seal breaches. Their advantages are availability, transportability and ease of driving. Fence posts or similar, which can be closely driven, can also be used. Steel sheet piles are generally not suitable for emergency breach sealing because of the need for specialised heavy plant.

(i) No new technology applicable to the emergency sealing of the breaches has been identified. The uniqueness of situations to be dealt with makes it unlikely any type of universal repair method will be developed.

(j) The term "manual" is probably inappropriate and unrealistic but there is scope for preparation of guidelines to assist with emergency breach repair.

7.2 Recommendations

On the basis of the studies carried out, as described in this report, it is recommended that further work be undertaken in the following fields:

- ensuring that emergency procedures or contingency plans are prepared for all NRA Regions/Areas, as indicated in Section 3.5;
- the preparation of guidelines for emergency sealing of breaches, as suggested in Section 6.1, and previously defined as Phase 2 of this R&D project;
- the database established in this project for recording details of breach incidents should be utilised and kept up to date, and
- consideration should be given to the relevance and potential value of the subjects listed in Section 6.2 as future R&D topics.

APPENDIX A

QUESTIONNAIRE AND RESPONSE SUMMARY

NATIONAL RIVERS AUTHORITY
NATIONAL R&D PROJECT C08(91)03

EMERGENCY SEALING OF BREACHES - PHASE I

QUESTIONNAIRE

You are requested to complete the attached questionnaire with general data about your area and one breach repair pro-forma for each incident of which you have knowledge or records. To enable us to progress the study and to plan any follow up meetings and/or site visits would you please return completed questionnaires to reach the address below by 19 April to:

John Palmer (Dept WH)
Sir William Halcrow & Partners Ltd
Burderop Park
Swindon
Wilts SN4 0QD

Tel: 0793 812479 (Ext 2681)
Fax: 0793 812089

If you have any questions or queries on the questionnaire please refer them to the above.

Details of the respondent:

Name
Position
Tel

1. Give approximate lengths (km) of flood defences in your area, defences being artificial construction to protect people and property from flooding:

Construction	Earth Embankment	Sheet Piled Wall	Concrete Wall	Other
Coastal				
Tidal				
Fluvial				

2. Does your region/area have contingency plans for dealing with emergencies? Yes/No

2.1 If yes do they include:

- specific procedures for
  - coastal defences Yes/No
  - tidal defences Yes/No
  - fluvial defences Yes/No
- appraisal of damage Yes/No
- plant hire contractors Yes/No
- materials suppliers Yes/No
- responsibilities (who does what and when) Yes/No
- budget availability/control Yes/No
- incident report format Yes/No
- duty rotas and telephone nos Yes/No
- external contacts (police, councils etc) Yes/No
- evacuation procedures - general/regional Yes/No
  - site specific Yes/No
- site specific access information Yes/No

2.2 Have you been trained to deal with emergencies, such as breaches of flood defences? Yes/No

3. Are there historical records of defences in your area

- as built drawings Yes/No
- maintenance manuals Yes/No
- maintenance/rehabilitation reports Yes/No
- inspection reports Yes/No

4. Are the defences in your area regularly inspected? Yes/No

4.1 If so, are inspection reports prepared? Yes/No

5. Do you have a system for classification of breaches and their repair? Yes/No

5.1 If so briefly describe or attach separate note

6. List any known/useful references related to breaches including: reports, periodicals, papers, memos etc.

EMERGENCY SEALING OF BREACHES - PHASE I

BREACH REPAIR PROFORMA

For any breach of which you have knowledge/experience please describe using the following headings as prompts, but not necessarily restricting your response to these:

(i) Date of occurrence 0-10, 10-20 or >20 years and year..... (if known)

(ii) Type of defence coastal/tidal/fluvial

(iii) Type of construction earth embankment/ sheet piled wall/ concrete wall/other (specify.....)

(iv) Antecedent conditions (weather/river flow/tide etc)

(v) Reasons for the breach (design or maintenance problems?)

(vi) Repair procedure (temporary or permanent works, type of construction, etc)

(vii) Type of plant used

(viii) Materials used and were they available from stockpiles

(ix) Site access (permanent/temporary, landside/waterside etc)

(x) Consideration of environmental or conservation aspects in repairs

(xi) Involvement of other parties (local councils etc)

(xii) Approximate extent of property/people flooded

(xiii) Property/people evacuated if any

(xiv) Other comments

QUES_NO	DATE_RECD	BODY	REGION	SUB_REGION	NAME	POSITION	COMMENT_1	COMMENT_2	COMMENT_3
1	20/04/93	NRA	THAMES		NIGEL BRAY	FD OPERATIONAL SERVICES MANAGER	NO BREACH DETAILS		
2	20/04/93	NRA	THAMES	NORTH EAST	M.J.DICKER	ACTING AREA MANAGER	1 TIDAL DEFENCE BREACH		
3	20/04/93	NRA	THAMES		ROGER POWLING	FD BUSINESS MANAGER	1 TIDAL DEFENCE BREACH		
4	20/04/93	NRA	THAMES	WALTHAM CROSS	JOHN MEEKINGS	PRINCIPAL PLANNING ENGINEER	VERY FEW DETAILS		
5	20/04/93	NRA	THAMES		T LEWIS	EMERGENCY PLANNING OFFICER	NO BREACHES		
6	20/04/93	NRA	THAMES	TIDAL THAMES AREA	G HAWES	OPERATIONS MANAGER	BREACH IN TIDAL DEFENCE		
7	14/04/93	NRA	ANGLIAN	SUFFOLK	COLIN BEAZLEY	DISTRICT ENGINEER	TYPICAL COASTAL BREACH REPAIR	TYPICAL TIDAL BREACH REPAIR	
8	/ /	NRA	WESSEX	BRISTOL AVON	KEN TATEN	AREA FLOOD DEFENCES ENGINEER	NO BREACH DETAILS		
9	21/04/93	NRA	WESSEX	SOMERSET	H.W.DJLWICH	ASSISTANT FLOOD DEFENCE ENGINEER	FLUVIAL BREACH REPORT INCLUDED		
10	21/04/93	NRA	WESSEX	AVON AND DORSET	L.A.MILES	ASST.AREA FLOOD DEFENCE ENGINEER	CHESIL BEACH EMBKT. OVERTOPIING	HISTORICAL ACCOUNT OF CHESIL FLOODS	
11	14/04/93	BWW	NORTH WEST		PETER BENTHAM	ENGINEERING MANAGER	NEGATIVE RESPONSE		
12	14/04/93	BWW	TECHNICAL SERVICES		BRIAN HASKINS	CHIEF CIVIL ENGINEER	CANAL BANK BREACH AND RECONSTRUCTION		
13	22/04/93	NRA	ANGLIAN	CENTRAL AREA	L.GRAY	ASSISTANT ENGINEER	1 COASTAL BREACH REPORT	1 FLUVIAL BREACH REPORT	
14	22/04/93	NRA	NORTHUMBRIAN	NORTHERN AREA	A.J.CLARKE	NORTHERN AREA ENGINEER	3 FLUVIAL BREACHES	1 TIDAL BREACH	
15	22/04/93	NRA	YORKSHIRE	SOUTHERN	K.G.BARTON	AREA ENGINEER	1 FLUVIAL BREACH		
0	/ /								
16	26/04/93	NRA	SOUTHERN		ADRIAN BIGGS	ACTING FLOOD DEFENCE OPS MANAGER	1 TIDAL EMBKT FAILURE LED TO BREACH	ALSO CONTACT ROY CROSSLAND	
17	26/04/93	NRA	ANGLIAN	MANBY	EDDIE MARKHAM	DISTRICT ENGINEER	35 BREACH REPORTS FROM 1795	REPORTS FROM 1938 GIVE REPAIR DETAILS	
18	29/04/93	BWW	NORTH EAST		P.J.BARNES	ENGINEERING MANAGER	2 CANAL BREACHES DESCRIBED	NO QUESTIONAIRRE RETURNED	
19	27/04/93	NRA	ANGLIAN	NORTH ESSEX	GARY COCKETT	ASST. DISTRICT ENGINEER	NO BREACHES		
20	04/05/93	NRA	NORTH WEST	NORTHERN AREA	G.VAUGHAN	ACTING DISTRICT MANAGER	1 FLUVIAL BREACH		
21	14/05/93	NRA	NORTH WEST	CHESHIRE	JOHN NORTON	DIST. MANAGER FLOOD DEFENCE	NO BREACHES		
22	14/05/93	NRA	NORTH WEST	MANCHESTER SOUTH	P.D.LEWIS	DIST. MANAGER FLOOD DEFENCE	1 FLUVIAL BREACH		
23	02/06/93	NRA	YORKSHIRE	NORTHERN AREA	M.J.DAVIES	SENIOR ENGINEER	1 TIDAL BREACH		
24	02/06/93	NRA	YORKSHIRE	NORTHERN AREA	J.D.FRANKISH	MAINTENANCE ENGINEER	1 TIDAL BREACH	2 FLUVIAL BREACH	
25	02/06/93	NRA	YORKSHIRE	NORTHERN AREA	IAN WARD	MAINTENANCE ENGINEER	TYPICAL FLUVIAL BREACHES		
0	/ /								
325									

APPENDIX B

DATABASE LISTING OF BREACH INCIDENTS

APPENDIX B - DATABASE LISTING OF BREACH INCIDENTS

Notes

1 Database information derived from questionnaires returned during study.

2 Field REF_1 refers to questionnaire number (see Appendix A).

3 Database fields are defined thus:

REF_1, REF_2, REF_3	Sources of information regarding event
YEAR	Year of event
DATE	Date of event
DEF_TYPE	Defence type
CONST_TYPE	Type of construction
ANTE_COND1, ANTE_COND2, ANTE_COND3	Antecedent conditions
REASON_1, REASON_2, REASON_3	Reported reason for breach
REP_PROC1, REP_PROC2, REP_PROC3	Repair procedure
PLANT_1, PLANT_2, PLANT_3	Plant used in repair
MATERIAL_1, MATERIAL_2, MATERIAL_3	Material used in repair
ACCESS_1, ACCESS_2	Comments regarding site access

ENV_ASPS		Environmental aspects considered in repair
OTHERS		Other parties involved in repair
PEOPLE_FL		Number of people affected by flooding
HOUSES_FL		Number of houses flooded
AREA_FL		Area of land flooded
COMMENT_1 COMMENT_2 COMMENT_3	)))	Additional comments regarding breach sealing operation

REF_1	Q002
REF_2	
REF_3	
YEAR	1987
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	CONCRETE WALL
ANTE_COND1	HIGH TIDE
ANTE_COND2	
ANTE_COND3	
REASON_1	NON MAINTENANCE
REASON_2	RIPARIAN OWNWER RESP
REASON_3	
REP_PROC1	CONC.FILLED SBAGS
REP_PROC2	
REP_PROC3	
PLANT_1	
PLANT_2	
PLANT_3	
MATERIAL_1	READY MIX CONCRETE
MATERIAL_2	HESSIAN SBAGS
MATERIAL_3	
ACCESS_1	PERMANENT
ACCESS_2	
ENV_ASPS	
OTHERS	RIPARIAN OWNER
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	SBAGS FROM STOCK
COMMENT_2	
COMMENT_3	

REF_1	Q003
REF_2	
REF_3	
YEAR	1980'S
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	EARTH EMKBKT.
ANTE_COND1	HIGH TIDE
ANTE_COND2	
ANTE_COND3	
REASON_1	MATERIAL EXCAVATED FOR NEARBY OPERATION PLACED ON EMBKT
REASON_2	EMBKT.SLIPPED
REASON_3	
REP_PROC1	RECONSTRUCT EMBKT.
REP_PROC2	CLAY CORE
REP_PROC3	GRAVEL SLOPES
PLANT_1	DUMPERS
PLANT_2	VIBRATING ROLLERS
PLANT_3	
MATERIAL_1	LONDON CLAY
MATERIAL_2	GRAVEL
MATERIAL_3	
ACCESS_1	PERMANENT
ACCESS_2	
ENV_ASPS	
OTHERS	ON SITE CONTRACTOR
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	APPROX. DAMAGE 50,000 POUNDS
COMMENT_2	CLAY BROUGHT IN FROM LONDON SITE
COMMENT_3	

REF_1	Q006
REF_2	
REF_3	
YEAR	1986
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	CONCRETE
ANTE_COND1	FINE
ANTE_COND2	
ANTE_COND3	
REASON_1	BREACH MADE BY OWNER TO GAIN FORESHORE ACCESS
REASON_2	
REASON_3	
REP_PROC1	TEMP. WITH CLAY
REP_PROC2	COMPACT CLAY
REP_PROC3	
PLANT_1	EXCAVATOR
PLANT_2	
PLANT_3	
MATERIAL_1	CLAY HOGGIN
MATERIAL_2	
MATERIAL_3	
ACCESS_1	NO PROBLEM
ACCESS_2	
ENV_ASPS	
OTHERS	CONTRACTOR LATER CALLED IN
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	OWNER MADE PERMANENT REPAIR
COMMENT_2	
COMMENT_3	

REF_1	Q007
REF_2	
REF_3	
YEAR	3/4 YR RI
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	SURGE TIDE
ANTE_COND2	ROUGH WEATHER
ANTE_COND3	
REASON_1	OVERTOPPING LEADING TO BACK EROSION
REASON_2	LOSS OF STABILITY
REASON_3	FAILURE
REP_PROC1	DEPENDS
REP_PROC2	
REP_PROC3	
PLANT_1	DEPENDS
PLANT_2	
PLANT_3	
MATERIAL_1	DEPENDS
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMP. FROM LAND
ACCESS_2	
ENV_ASPS	
OTHERS	POSS. POLICE
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	TYPICAL BREACH REPAIR
COMMENT_2	
COMMENT_3	

REF_1	Q007
REF_2	
REF_3	
YEAR	3/4 YR RI
DATE	/ /
DEF_TYPE	COASTAL
CONST_TYPE	SHINGLE BANK
ANTE_COND1	SURGE TIDE
ANTE_COND2	ROUGH WEATHER
ANTE_COND3	
REASON_1	OVERTOPPING
REASON_2	HIGH HEAD OF WATER ON DEFENCE
REASON_3	
REP_PROC1	BULLDOZE TO SHAPE
REP_PROC2	
REP_PROC3	
PLANT_1	BULLDOZERS/SCRAPERS
PLANT_2	EXCAVATORS
PLANT_3	DUMPERS
MATERIAL_1	LOCAL SHINGLE
MATERIAL_2	SHINGLE FROM NEARBY
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	
ENV_ASPS	SOURCE OF MATERIAL
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	TYPICAL BREACH REPAIR
COMMENT_2	
COMMENT_3	

REF_1	Q009
REF_2	WESSEX WATER REPORT
REF_3	BREACH AT BLACKBRIDGE LANGPORT
YEAR	1978
DATE	02/05/78
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	NORMAL
ANTE_COND2	
ANTE_COND3	
REASON_1	BREACH OCCURRED ON LINE OF NEWLY LAID PIPELINE
REASON_2	DISTURBED GROUND
REASON_3	
REP_PROC1	TRENCH SHEETS WITH TIMBER WALINGS
REP_PROC2	LOG SLOTS AND TIMBERS
REP_PROC3	
PLANT_1	HYDRAULIC EXCAVATOR
PLANT_2	
PLANT_3	
MATERIAL_1	TRENCH SHEETS
MATERIAL_2	TIMBERS
MATERIAL_3	
ACCESS_1	DIFFICULT
ACCESS_2	ALONG BANK TOP
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	GRASSLAND ONLY
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q010
REF_2	
REF_3	
YEAR	1979
DATE	/ /
DEF_TYPE	COASTAL
CONST_TYPE	SHINGLE
ANTE_COND1	HIGH TIDE
ANTE_COND2	HEAVY SWELL
ANTE_COND3	STORMS
REASON_1	OVERTOPPING
REASON_2	PERCOLATION
REASON_3	
REP_PROC1	PERMANENT REBUILD OF SHINGLE CREST
REP_PROC2	
REP_PROC3	
PLANT_1	BULLDOZERS D8 & D6
PLANT_2	955 BULLDOZER
PLANT_3	HYDRAULIC EXCAVATORS
MATERIAL_1	LOCAL SHINGLE
MATERIAL_2	
MATERIAL_3	
ACCESS_1	PERMANENT LANDSIDE
ACCESS_2	
ENV_ASPS	ENGLISH NATURE
OTHERS	DORSET CC,POLICE,WATER PLC'S
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	EXTENSIVE DAMAGE
COMMENT_2	
COMMENT_3	

REF_1	Q012
REF_2	
REF_3	
YEAR	1969
DATE	/ /
DEF_TYPE	CANAL BANK
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	NORMAL
ANTE_COND2	
ANTE_COND3	
REASON_1	SEEPAGE
REASON_2	PIPING
REASON_3	BANK SLIP
REP_PROC1	BANK RECONSTRUCTED
REP_PROC2	STONE WALL REBUILT
REP_PROC3	CANAL RELINED
PLANT_1	JCB
PLANT_2	DUMPERS
PLANT_3	MANUAL
MATERIAL_1	IMPORTED STONE
MATERIAL_2	PUDDLE CLAY
MATERIAL_3	
ACCESS_1	CANAL TOWPATH
ACCESS_2	
ENV_ASPS	LIKE FOR LIKE
OTHERS	POLICE,FIRE
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q014
REF_2	
REF_3	
YEAR	1981
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT
ANTE_COND1	50 YR RI FLOOD
ANTE_COND2	
ANTE_COND3	
REASON_1	FLOW EXCEEDED DESIGN PERFORMANCE
REASON_2	BED LEVEL RAISED BY GRAVEL DEPOSITION
REASON_3	PERCOLATION
REP_PROC1	TEMPORARY USING MAT'L WASHED ONTO LAND
REP_PROC2	PERMANENT USED DREDGING TO DEEPEN RIVER
REP_PROC3	DEREGED MAT'L TO WIDEN & RAISE BANK
PLANT_1	CAT 951
PLANT_2	DUMPERS
PLANT_3	
MATERIAL_1	RIVER SAND
MATERIAL_2	RIVER GRAVEL
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	20 Ha AGRICULTURAL
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q013
REF_2	
REF_3	
YEAR	1978
DATE	/ /
DEF_TYPE	COASTAL
CONST_TYPE	CONCRETE WALL
ANTE_COND1	HIGH WIND
ANTE_COND2	LOW PRESSURE
ANTE_COND3	TIDAL SURGE
REASON_1	OVERTOPPING
REASON_2	EROSION TO REAR
REASON_3	
REP_PROC1	FILL WITH CHALK
REP_PROC2	FACE WITH CONCRETE
REP_PROC3	LATER RECONSTRUCTED
PLANT_1	BULLDOZERS
PLANT_2	360 DEG EXCAVATORS
PLANT_3	LORRIES
MATERIAL_1	CHALK FROM QUARRY
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	WATERSIDE
OTHERS	
PEOPLE_FL	22
HOUSES_FL	150 HOUSES 1500 CARAVANS
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q013
REF_2	
REF_3	
YEAR	1978
DATE	/ /
DEF_TYPE	COASTAL
CONST_TYPE	SHINGLE BANK
ANTE_COND1	HIGH WIND
ANTE_COND2	LOW PRESSURE
ANTE_COND3	TIDAL SURGE
REASON_1	EROSION OF SEAWARD FACE
REASON_2	WASHOUT AT REAR FACE
REASON_3	OVERTOPPING
REP_PROC1	FILL WITH ADJACENT SAND/SHINGLE
REP_PROC2	
REP_PROC3	
PLANT_1	BULLDOZERS
PLANT_2	360 DEG EXCAVATORS
PLANT_3	LORRIES
MATERIAL_1	SHINGLE FROM BEACH
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	WATERSIDE
OTHERS	
PEOPLE_FL	22
HOUSES_FL	150 HOUSES 1500 CARAVANS
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q014
REF_2	
REF_3	
YEAR	1992
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	50 YR RI FLOOD
ANTE_COND2	
ANTE_COND3	
REASON_1	FLOW IN EXCESS OF DESIGN PERFORMANCE
REASON_2	
REASON_3	
REP_PROC1	REFORM BANK USING WASHED OUT MAT'L
REP_PROC2	
REP_PROC3	
PLANT_1	CAT 931
PLANT_2	DUMPERS
PLANT_3	
MATERIAL_1	ALLUVIAL MATERIAL
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	CONSERVATION INFORMED
PEOPLE_FL	
HOUSES_FL	
AREA_FL	10 Ha AGRICULTURAL
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q014
REF_2	
REF_3	
YEAR	1980
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HIGH TIDE
ANTE_COND2	
ANTE_COND3	
REASON_1	OVERTOPPING
REASON_2	POOR MAINTENANCE
REASON_3	
REP_PROC1	FILL WITH CONCRETE
REP_PROC2	OVERBUILD WITH CLAY
REP_PROC3	
PLANT_1	BULLDOZERS
PLANT_2	LORRIES
PLANT_3	
MATERIAL_1	CONCRETE FROM RMC
MATERIAL_2	CLAY FROM ROAD JOB
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	HIGHWAY DEPT & CONTRACTOR PROVIDED CLAY
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q014
REF_2	
REF_3	
YEAR	1991
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	VERY WET GROUND
ANTE_COND2	HIGH RIVER FLOW
ANTE_COND3	
REASON_1	GRASS GROWTH NOT COMPLETE
REASON_2	FARMER RELEASING FLOODWATER
REASON_3	OVERTOPPING
REP_PROC1	PERMANENT INFILL WITH CLAY
REP_PROC2	
REP_PROC3	
PLANT_1	BULLDOZERS
PLANT_2	360 DEG EXCAVATORS
PLANT_3	LORRIES
MATERIAL_1	CLAY FROM LOCAL AREA
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	ALONG BANKSIDE
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	100 ACRES
COMMENT_1	USED HIRED & OWNED PLANT
COMMENT_2	
COMMENT_3	

REF_1	Q015
REF_2	
REF_3	
YEAR	1970'S
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	RIVER HIGH
ANTE_COND2	FLOOD FLOW
ANTE_COND3	
REASON_1	CAVITY OCCURRED BETWEEN STONE HEADWALL & EARTH EMBKT.
REASON_2	
REASON_3	
REP_PROC1	TEMPORARY SANBAGGING
REP_PROC2	EARTHFILL
REP_PROC3	
PLANT_1	FRONT LOADING SHOVEL
PLANT_2	
PLANT_3	
MATERIAL_1	SANDBAGS
MATERIAL_2	
MATERIAL_3	
ACCESS_1	PERMANENT
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	WASHLAND ONLY
COMMENT_1	SANDBAGS FILLED ON SITE
COMMENT_2	SAND FROM ADJACENT BORROW PIT
COMMENT_3	

REF_1	Q016
REF_2	
REF_3	
YEAR	1990
DATE	27/02/90
DEF_TYPE	TID/FLU
CONST_TYPE	EARTH EMBKT.+REVET
ANTE_COND1	HIGH SPRING TIDE
ANTE_COND2	TIDAL SURGE
ANTE_COND3	PREVIOUS DRY SUMMER
REASON_1	LACK OF MAINTENANCE AND INSUFFICIENT CHALK REVETMENT
REASON_2	PREVIOUS DRY SUMMER CAUSED CRACKS
REASON_3	WEAK SOIL
REP_PROC1	REFORM WIDER EMBKT.
REP_PROC2	
REP_PROC3	
PLANT_1	CRANE+DRAGLINE
PLANT_2	BULLDOZERS
PLANT_3	360 DEG EXCAVATORS
MATERIAL_1	CLAY
MATERIAL_2	CHALK
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	1 HOUSE
AREA_FL	400 ACRES
COMMENT_1	MATERIALS WERE IMPORTED
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1938
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	EARTH EMBANKMENT
ANTE_COND1	HIGH TIDE
ANTE_COND2	
ANTE_COND3	
REASON_1	HIGH TIDE
REASON_2	
REASON_3	
REP_PROC1	STEEL SHEET PILES & TIMBERS
REP_PROC2	IMPORTED STONE & SOIL
REP_PROC3	
PLANT_1	HEAVY PLANT
PLANT_2	HAND LABOUR
PLANT_3	
MATERIAL_1	SANDBAGS
MATERIAL_2	STONE & SOIL
MATERIAL_3	STEEL SHEET & PILES
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	IDB'S, FARMERS AND WAR MINISTRY
PEOPLE_FL	
HOUSES_FL	
AREA_FL	AGRICULTURAL LAND
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1947
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	SNOW THAW
ANTE_COND2	HIGH RIVER LEVELS
ANTE_COND3	
REASON_1	RIVER CONDITIONS
REASON_2	
REASON_3	
REP_PROC1	SANDBAGGING
REP_PROC2	SANDBAGS REMOVED AS FLOW ABATED
REP_PROC3	
PLANT_1	
PLANT_2	
PLANT_3	
MATERIAL_1	
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	EMERGENCY PUMPS PROVIDED BY MILITARY
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1949
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HIGH TIDE
ANTE_COND2	
ANTE_COND3	
REASON_1	
REASON_2	
REASON_3	
REP_PROC1	LEFT OPEN FOR SOME TIME
REP_PROC2	AREA RECLAIMED BETWEEN 1ST & 2ND DEFENCE
REP_PROC3	
PLANT_1	
PLANT_2	
PLANT_3	
MATERIAL_1	
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	GOLF COURSE BETWEEN 1ST & 2ND DEFENCE
COMMENT_1	BENEFIT OF 2ND DEFENCE PROVED
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1958
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HIGH RIVER RECORDS
ANTE_COND2	
ANTE_COND3	
REASON_1	
REASON_2	
REASON_3	
REP_PROC1	STEEL SHEET PILING
REP_PROC2	FILL WITH STONE & SOIL
REP_PROC3	
PLANT_1	HEAVY CIVILS PLANT
PLANT_2	LIGHT RAILWAY
PLANT_3	BARGES
MATERIAL_1	STEEL SHEET PILES
MATERIAL_2	CLAY AND SOIL
MATERIAL_3	
ACCESS_1	TEMP APPROACH ROAD
ACCESS_2	BAILEY BRIDGE
ENV_ASPS	
OTHERS	BRITISH TRANSPORT RESPONSIBLE FOR BANK
PEOPLE_FL	
HOUSES_FL	
AREA_FL	SEVERAL HUNDRED ACRES
COMMENT_1	SOME DWELLINGS SANDBAGGED
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1959
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HARD FROST
ANTE_COND2	HEAVY RAIN
ANTE_COND3	RAPID THAW
REASON_1	
REASON_2	
REASON_3	
REP_PROC1	CULVERTS BLOCKED TO LIMIT FURTHER FLOODS
REP_PROC2	DRAGLINE USED
REP_PROC3	SANDBAGGING
PLANT_1	DRAGLINE
PLANT_2	
PLANT_3	
MATERIAL_1	SANDBAGS
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	SIPHONS UNDER RIVER INCREASED FLOODING
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1959
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HARD FROST
ANTE_COND2	HEAVY RAIN
ANTE_COND3	RAPID THAW
REASON_1	
REASON_2	
REASON_3	
REP_PROC1	SANDBAGGING
REP_PROC2	
REP_PROC3	
PLANT_1	LORRIES WITH SAND
PLANT_2	
PLANT_3	
MATERIAL_1	SAND
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	FARM LABOUR USED
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1960
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	INTENSE RAINFALL
ANTE_COND2	
ANTE_COND3	
REASON_1	FLOODS IN FIELDS BURST INTO RIVER
REASON_2	BANK FAILURES
REASON_3	
REP_PROC1	SANDBAGGING
REP_PROC2	MATERIAL IMPORTED
REP_PROC3	
PLANT_1	CIVILS PLANT
PLANT_2	HAND LABOUR
PLANT_3	
MATERIAL_1	SANDBAGS
MATERIAL_2	IMPORTED MATERIAL
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1960
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HIGH RIVER LEVELS
ANTE_COND2	
ANTE_COND3	
REASON_1	SETTLEMENT OF BANK TOP DUE TO UNDER FLOW
REASON_2	
REASON_3	
REP_PROC1	DAM ERECTED IN DRAIN BEHIND BANK
REP_PROC2	NEW SOKE DYKE EXCAVATED FURTHER AWAY
REP_PROC3	STEEL SHEET PILES DRIVEN & BANK REBUILT
PLANT_1	
PLANT_2	
PLANT_3	
MATERIAL_1	
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1960
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HIGH RIVER LEVELS
ANTE_COND2	
ANTE_COND3	
REASON_1	
REASON_2	
REASON_3	
REP_PROC1	FLOODING REDUCED BY POINTING DOZERS
REP_PROC2	RIVER LEVEL LOWERED BY WATER INTO FENS
REP_PROC3	MAT'L DOZED ACROSS CHANNEL INTO BREACH
PLANT_1	BULLDOZERS
PLANT_2	BARGES
PLANT_3	
MATERIAL_1	
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	FARMERS SUPPLIED LABOUR
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1978
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	BRICK FLOODWALL
ANTE_COND1	TIDAL SURGE
ANTE_COND2	
ANTE_COND3	
REASON_1	FLOOD WALL COLLAPSED
REASON_2	BUILT ON EARTH WITH NO FOUNDATIONS
REASON_3	
REP_PROC1	TEMPORARY SANDBAGS & TRENCHSHEETS
REP_PROC2	PERMANENT BRICK FACED CONCRETE FLOODWALL
REP_PROC3	
PLANT_1	CIVILS PLANT
PLANT_2	HAND LABOUR
PLANT_3	
MATERIAL_1	
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	FLOODWALL RECONST'
OTHERS	BOROUGH/CHURCH OWNED OLD WALL
PEOPLE_FL	
HOUSES_FL	180 HOUSES AND 30 BUSINESS PREMISES
AREA_FL	
COMMENT_1	FLOODING UPTO 1m.
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1981
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	EXTREME RAINFALL
ANTE_COND2	
ANTE_COND3	
REASON_1	
REASON_2	
REASON_3	
REP_PROC1	FILLED WITH IMPORTED STONE AND CLAY
REP_PROC2	
REP_PROC3	
PLANT_1	HYDRAULIC EXCAVATORS
PLANT_2	DUMPERS
PLANT_3	
MATERIAL_1	CLAY
MATERIAL_2	STONE FROM QUARRY
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	300 ACRES
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1981
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	EXTREME RAINFALL
ANTE_COND2	
ANTE_COND3	
REASON_1	
REASON_2	
REASON_3	
REP_PROC1	SOME BREACHES LEFT OPEN FOR DRAINAGE
REP_PROC2	STONE/SOIL USED TO SEAL BREACHES
REP_PROC3	
PLANT_1	HIRED PLANT
PLANT_2	
PLANT_3	
MATERIAL_1	STONE/SOIL
MATERIAL_2	
MATERIAL_3	
ACCESS_1	ALONG BANK TOP
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	1700 ACRES
COMMENT_1	FEN CULVERTS INCREASED FLOOD AREA
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1981
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	EXTREME RAINFALL
ANTE_COND2	
ANTE_COND3	
REASON_1	SCOUR ON LANDWARD FACE OF BANK RESULTING IN FAILURE
REASON_2	
REASON_3	
REP_PROC1	PERMANENT REPAIR USING IMPORTED CLAY
REP_PROC2	
REP_PROC3	
PLANT_1	360 DEG EXCAVATORS
PLANT_2	LORRIES
PLANT_3	
MATERIAL_1	CLAY IMPORTED
MATERIAL_2	
MATERIAL_3	
ACCESS_1	PERMANENT
ACCESS_2	BANK TOP
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	1 DOMESTIC PROPERTY + PIG FARM
AREA_FL	20 Ha AGRICULTURAL LAND
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q017
REF_2	
REF_3	
YEAR	1981
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	EXTREME RAINFALL
ANTE_COND2	
ANTE_COND3	
REASON_1	SEEPAGE THROUGH PEAT LAYER BELOW LAND LEVEL
REASON_2	BLOW OUT OF EMBANKMENT
REASON_3	
REP_PROC1	TEMPORARY SANDBAGS
REP_PROC2	TEMP. CLOSE BOARDED FENCE STAKES
REP_PROC3	REINSTATEMENT OF EMBKT. WITH LOCAL MAT'L
PLANT_1	LIGHT BOAT
PLANT_2	HYDRAULIC EXCAVATOR
PLANT_3	DUMP TRUCKS
MATERIAL_1	FENCE POSTS
MATERIAL_2	SANDBAGS
MATERIAL_3	
ACCESS_1	TEMP BY BOAT
ACCESS_2	PERM FROM LAND
ENV_ASPS	
OTHERS	LAND DRAINAGE BOARD SUPPLIED EXCAVATOR
PEOPLE_FL	
HOUSES_FL	
AREA_FL	100 Ha AGRICULTURAL LAND
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q018
REF_2	
REF_3	
YEAR	1979
DATE	/ /
DEF_TYPE	CANAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	NORMAL
ANTE_COND2	MAINTENANCE DREDGE
ANTE_COND3	
REASON_1	LEAKAGE THROUGH WASH WALL LED TO PIPING EROSION
REASON_2	
REASON_3	
REP_PROC1	FILL WITH IMPORTRED STEEL SLAG
REP_PROC2	
REP_PROC3	
PLANT_1	CAT D8
PLANT_2	
PLANT_3	
MATERIAL_1	STEEL SLAG
MATERIAL_2	
MATERIAL_3	
ACCESS_1	50m FROM ROAD
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	PERMANENT REPAIR USING SHEET PILES
COMMENT_2	
COMMENT_3	

REF_1	Q018
REF_2	
REF_3	
YEAR	1983
DATE	/ /
DEF_TYPE	CANAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	NORMAL
ANTE_COND2	
ANTE_COND3	
REASON_1	MASONRY WASH WALL REMOVED TO BE REPLACED BY SHEET PILES
REASON_2	SEEPAGE THROGH EMBANKMENT
REASON_3	
REP_PROC1	SHEET PILING FROM BOAT
REP_PROC2	
REP_PROC3	
PLANT_1	PILING BOAT
PLANT_2	
PLANT_3	
MATERIAL_1	SHEET PILES
MATERIAL_2	
MATERIAL_3	
ACCESS_1	
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q020
REF_2	
REF_3	
YEAR	1985
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HEAVY RAIN
ANTE_COND2	HIGH RIVER FLOWS
ANTE_COND3	
REASON_1	POOR DESIGN AND MAINTENANCE
REASON_2	
REASON_3	
REP_PROC1	REPLACE EARTH EMBKT.
REP_PROC2	
REP_PROC3	
PLANT_1	TRACKED EXCAVATOR
PLANT_2	
PLANT_3	
MATERIAL_1	SLIL/SPOIL
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	SOIL/SPOIL LOCAL BUT NOT STOCK PILED
COMMENT_2	
COMMENT_3	

REF_1	Q022
REF_2	
REF_3	
YEAR	1976
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HEAVY RAIN
ANTE_COND2	
ANTE_COND3	
REASON_1	MAINTENANCE PROBLEM - INFESTATION OF RABBIT BURROWS
REASON_2	
REASON_3	
REP_PROC1	TEMP. SANDBAGS
REP_PROC2	BAGS REINFORCED WITH TIMBER AND
REP_PROC3	FIR STAKE REVETMENTS
PLANT_1	
PLANT_2	
PLANT_3	
MATERIAL_1	TRENCH SHEETS
MATERIAL_2	FIR STAKES
MATERIAL_3	SANDBAGS
ACCESS_1	TEMPORARY
ACCESS_2	FARM TRACKS & FIELD
ENV_ASPS	FLOODWALL RECONST'
OTHERS	FARMERS ASSISTED
PEOPLE_FL	
HOUSES_FL	
AREA_FL	200 ACRES
COMMENT_1	PLANT & MATERIALS WITHIN 30 MILES
COMMENT_2	
COMMENT_3	

REF_1	Q023
REF_2	
REF_3	
YEAR	1947
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HEAVY RAIN
ANTE_COND2	SNOW MELT
ANTE_COND3	HIGH RIVER LEVELS
REASON_1	OLD EMANKMENT
REASON_2	
REASON_3	
REP_PROC1	TEMP. FILL WITH IMPORTED EARTH
REP_PROC2	
REP_PROC3	
PLANT_1	EXCAVATORS
PLANT_2	BARGES
PLANT_3	
MATERIAL_1	IMPORTED EARTH
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	
ENV_ASPS	
OTHERS	LOCAL AUTH. & ARMY
PEOPLE_FL	500 EVACUATED
HOUSES_FL	
AREA_FL	100 SQ. KM.
COMMENT_1	
COMMENT_2	
COMMENT_3	

REF_1	Q024
REF_2	
REF_3	
YEAR	1961
DATE	/ /
DEF_TYPE	TIDAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	HIGH RIVER FLOWS
ANTE_COND2	
ANTE_COND3	
REASON_1	BANK IN POOR CONDITION
REASON_2	
REASON_3	
REP_PROC1	CUT OFF BREACH WITH STONE FROM RIVER
REP_PROC2	BREACH SEALED WITH TIMBER PILING
REP_PROC3	BACKFILLED WITH EARTH
PLANT_1	BARGES FOR STONE
PLANT_2	EXCAVATORS
PLANT_3	PILING RIGS
MATERIAL_1	TIMBER
MATERIAL_2	STONE
MATERIAL_3	EARTH
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE & WATERSIDE
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	5000 ACRES
COMMENT_1	PERMANENT REPAIR
COMMENT_2	
COMMENT_3	

REF_1	Q024
REF_2	
REF_3	
YEAR	1979
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBANKMENT
ANTE_COND1	HIGH RIVER FLOWS
ANTE_COND2	
ANTE_COND3	
REASON_1	BANK IN POOR CONDITION
REASON_2	
REASON_3	
REP_PROC1	DIVERT WATERCOURSE
REP_PROC2	CONSTRUCT HARDROAD TO SITE
REP_PROC3	RECONSTRUCT EARTH EMBANKMENT
PLANT_1	TRACTORS + DOZERS
PLANT_2	EXCAVATORS
PLANT_3	DUMPERS
MATERIAL_1	IMPORTED EARTH
MATERIAL_2	IMPORTED STONE
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	300 ACRES
COMMENT_1	PERMANENT REPAIR
COMMENT_2	
COMMENT_3	

REF_1	Q024
REF_2	
REF_3	
YEAR	??
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBANKMENT
ANTE_COND1	HIGH RIVER FLOWS
ANTE_COND2	
ANTE_COND3	
REASON_1	BANK IN POOR CONDITION
REASON_2	
REASON_3	
REP_PROC1	WAIT FOR FLOW TO REDUCE
REP_PROC2	BUILD EARTHFILL STOCKPILE
REP_PROC3	PUSH IN EARTH & CONSOLIDATE
PLANT_1	DOZERS
PLANT_2	LOADING SHOVELS
PLANT_3	
MATERIAL_1	EARTHFILL FROM SITE
MATERIAL_2	
MATERIAL_3	
ACCESS_1	PERMANENT
ACCESS_2	
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	2000 ACRES
COMMENT_1	PERMANENT REPAIR
COMMENT_2	
COMMENT_3	

REF_1	Q025
REF_2	
REF_3	
YEAR	??
DATE	/ /
DEF_TYPE	FLUVIAL
CONST_TYPE	EARTH EMBKT.
ANTE_COND1	FLOOD FLOWS
ANTE_COND2	
ANTE_COND3	
REASON_1	FARMERS DIGGING OUT BACK OF BANK TO LET FLOOD WATER OUT
REASON_2	OVERTOPPING
REASON_3	RABBIT HOLES
REP_PROC1	PERMANENT BANK REPLACEMENT
REP_PROC2	
REP_PROC3	
PLANT_1	D4
PLANT_2	EXCAVATORS
PLANT_3	MOXY DUMPERS
MATERIAL_1	FROM FORESHORE
MATERIAL_2	
MATERIAL_3	
ACCESS_1	TEMPORARY
ACCESS_2	LANDSIDE
ENV_ASPS	
OTHERS	
PEOPLE_FL	
HOUSES_FL	
AREA_FL	
COMMENT_1	
COMMENT_2	
COMMENT_3	

APPENDIX C

REFERENCE MATERIAL

APPENDIX C - REFERENCE MATERIAL

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