Draft Final Report R&D Project 431

Emergency Sealing of Breaches - Phase 1

Sir William Halcrow & Partners Ltd

June 1993

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EMERGENCY SEALING OF BREACHES - PHASE 1

NRA R&D PROJECT 431

DRAFT FINAL REPORT

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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 guidelines 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 guidelines, 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.

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 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.

"6 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 has 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 and 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	6
	• 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	6	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.

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, 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, but 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. 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 PROFORMA

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

(i) Date of occurrence

(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, of particular importance being the successes and failures of the operation and any lessons learnt

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 few recorded uses of this method. 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.

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.

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 sued 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.

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 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.

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 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 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. As mentioned earlier there may be a need to stockpile materials before attempting to seal a breach. This could possibly lead to a greater volume of flooding and missing a low tide repair window. 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.

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. When planning the repair, account should be taken of the drainage from the flooded area and the possible need to provide a release through the defences. ARMCO pipes with flap gates have been referred to in some NRA areas, 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.

6 THE WAY FORWARD

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.

Not withstanding 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.

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.

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.

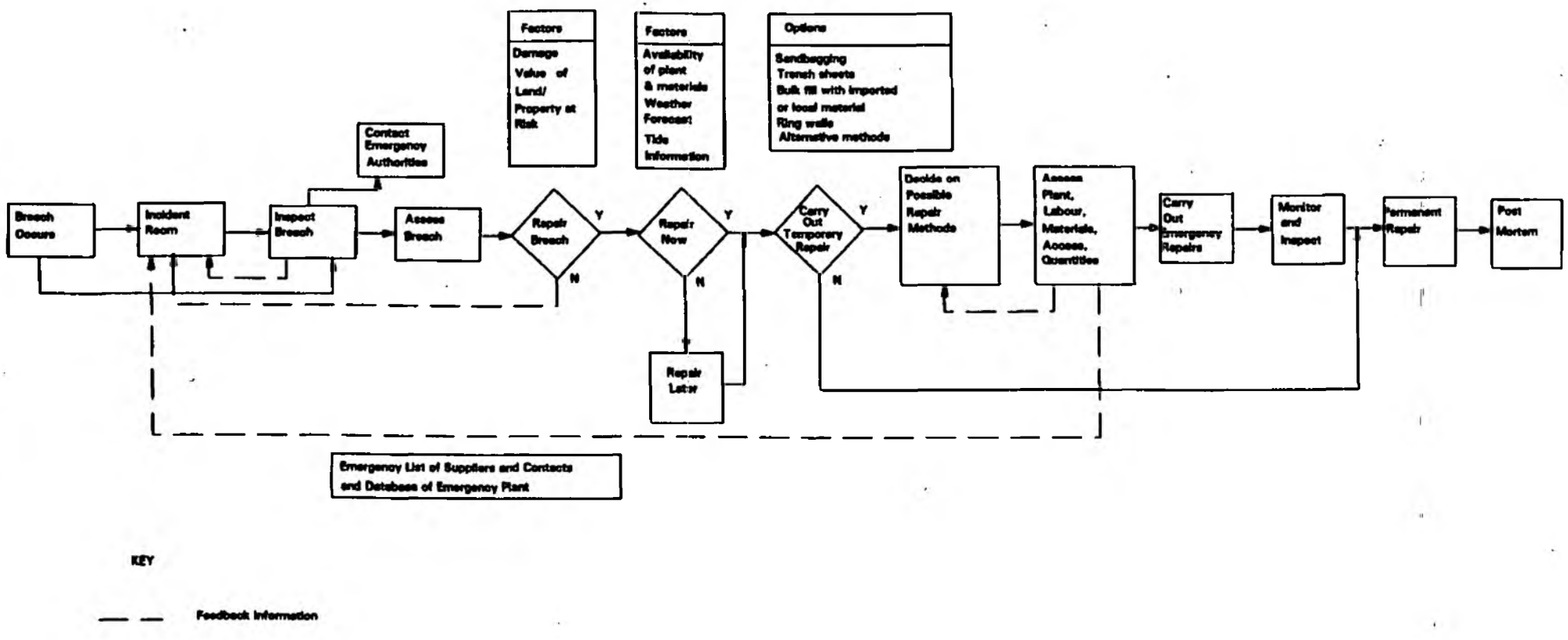

Figure 6.1 Flowchart Outlining Breach Sealing Methodology

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

Chapter 1	-	"To Repair or Not 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 "To Repair or Not 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. One idea is to use standards of service information and house equivalent figures 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.

(b) Chapter 2 Water Level/ Flow Conditions

The timing of repairs will almost certainly be influenced by consideration of water level/ flow conditions, whether the breach be 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.

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") developed a database of Emergency Plant and Vehicles - this should be kept up to date and referred to.

(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.

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) "To Repair or Not 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. Reach classification by house equivalents is one possibility which could be considered.

(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 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 RNA 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.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Some basic conclusions of the study are given below.

(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.

(k) No obvious R&D topics have come to light but there are some areas for possible further investigation.

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

QUESTIONNAIRE RESPONSE SUMMARY

APPENDIX B

REFERENCE MATERIAL

APPENDIX B - REFERENCE MATERIAL

Berkeley Thorn R, Roberts A G, (1981), 'Sea Defence and Coast Protection Works', Thomas Telford Ltd

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